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Effects of change in temperature on reference crop evapotranspiration (ETo) in the northwest region of Bangladesh

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ABSTRACT: Bangladesh is one of the most climate vulnerable countries in the world and will become even more as a result of climate change. Increased temperature, floods, droughts, extreme events and changes in precipitation pose additional risks for developing countries like ours who is striving to achieve sustainable development. At present, climate is thought to be putting extra stress on agricultural productivity because climate change may lead to changes in reference crop evapotranspiration (ETo). Climatic variables like temperature, relative humidity, sunshine hour, wind speed and rainfall are important parameters for the agricultural and regional water resources planning. Data have been collected from five meteorological stations of northwest regions namely Bogra, Rangpur, Dinajpur, Rajshahi and Ishwardi. Monthly average data analysis has been used as it closely resembles agricultural and water resources planning activities in Bangladesh. The Penman- Monteith method is used for reference crop evapotranspiration (ETo) computation. Both the Parametric and non- parametric methods are used for testing the statistical significance of trends in maximum and minimum temperature. Results indicate that average maximum temperature has decreasing trends in Rangpur and Dinajpur. Average minimum temperature shows increasing trends except Rajshahi station. Comparison between predicted trends from regression analysis and PRECIS model's output show that maximum deviation is expected during the monsoon period in both the future year 2030 and 2050. Changes in reference crop evapotranspiration (ETo) based on temperature is determined without and with climate change condition. Rajshahi station shows an increase in ETo about 1.14% by 2030 and about 2.0 % by 2050 for raising temperature due to climate change. As a result of increasing ETo rate, Rajshahi station will require more irrigation

1 INTRODUCTON

Climate is typically described by the statistics of a set of atmospheric and surface variables, such as temperature, precipitation, wind, humidity, cloudiness, soil moisture, sea surface temperature, concentration and thickness of sea-ice. Natural hazards that come from increased rainfall, rising sea levels and tropical cyclones are expected to increase as climate change, each seriously affecting agriculture, water and food security, human health and shelter. It is believed that in the coming decades the rising sea level alone will create more than 25 million climate refugees (bccsap, 2008). The northwest region of Bangladesh, where many believe desertification process is in active course, has been undertaken for the present investigation to study any discernible trends up or down prevailing. The main objective of this study is to characterize that variability of the maximum and minimum temperature.

The evapotranspiration rate from a reference surface, not short of water, is called the reference crop evapotranspiration or reference evapotranspiration and is denoted as ETo. The Northwest region of Bangladesh which is basically a drought prone area and determination of ETo is essential to estimate the effects of climate change for this region. ETo is a climatic parameter and can be computed from weather data (Allen et al., 1998). To effectively manage the Nation's water resources, water managers need to understand the significance of evapotranspiration in the hydrologic budget. In order to determine the effects of climate change on reference crop evapotranspiration, this study would suggest what will be the ETo rate in some of the predicted years of 21st century and how it will affect the climate change pattern.

The study areas are the five climatic stations of Bangladesh Meteorological Department (BMD), situated in the northwest region of Bangladesh. The required data's are collected from BMD for the stations – Dinajpur (25˚39'N, 88˚41'E), Rangpur (25˚44'N, 88˚14'E), Rajshahi (24˚22'N, 88˚42'E), Bogra (24˚51'N, 89˚22'E) and Ishurdi (24˚8'N, 89˚3'E).

2 METHODOLOGY

There are two methods of trend analysis-one is parametric method and the other is the non-parametric method.

2.1 *Parametric test method*

In the parametric method, 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 has the equation of the following form:

$$Y = a_o + b_o * X \qquad (1)$$

Where a_0 and b_0 are the estimated intercept and slope of the line, respectively.

2.2 *Non parametric test method*

Nonparametric Mann-Kendall (MK) test method is another process of conducting trend analysis. This test has been widely used for hydrological data analysis. For this test method, Mann (1945) first suggested using the test for significance of Kendall's tau, τ where the X variable is the time (T) as test for trend.
A two-sided test for correlation will evaluate the following equivalent statements for the null hypothesis H_0, as compared to the alternate hypothesis H_1:
H_0: a) no correlation exists between X and Y ($\tau = 0$), or
b) X and Y are independent, or
c) The distribution of Y does not depend on X, or
d) Prob ($Y_i < Y_j$ for $i<j$) = ½
H_1: a) X and Y are correlated ($\tau \neq 0$), or
b) X and Y are dependent, or
c) The distribution of Y (percentiles, etc) depends on X, or
d) Prob ($Y_i < Y_j$ for $i<j$) ≠ ½

2.3 *Prediction and Comparison of Climatic Parameters Based on Trend*

In order to predict reference crop evapotranspiration for future climate change scenarios, it is necessary to determine the predicted trend of temperature because the immediate impact of temperature rise will be on reference crop evapotranspiration. Prediction can be done by either Global Climate Model (GCM) or by observed data analysis. It is difficult to estimate the increase in reference crop evapotranspiration (ETo) from GCM projected temperature rise figures since the maximum (day) and minimum (night) temperatures, and not the average temperatures, are required inputs for ETo computation. Five possible realistic combinations of daytime and nighttime temperatures may be hypothesized and five different ETo increase scenarios may be developed. It is better to use long-term average data for reference crop evapotranspiration estimation rather than using a single year data to get reliable values. Finally ETo values in different months for both without and with climate change conditions may be obtained where without climate change condition indicates the trend obtained from observed data and with climate change condition indicates the trend predicted for future years with respect to a base year data. In this study, the year 2000 has taken as the base year.

2.4 *Estimation of reference crop evapotranspiration*

To estimate evapotranspiration from different climatic parameters, four such methods were presented to calculate the reference crop evapotranspiration (ET_0) are: the Blaney-Criddle, radiation, pan evaporation and modified Penman methods. The Penman-Monteith method (Allen et al., 1998) is the method by which the reference crop evapotranspiration (ET_0) can be unambiguously determined and the method provides consistent ET_0 values in all regions and climates.

The FAO Penman-Monteith equation:

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (2)$$

3 RESULTS & DISCUSSIONS

3.1 *Monthly average maximum temperature*

In order to determine the significance level of the both correlation coefficients, Pearson's r and Kendall's τ, the trends of temperature in the study area have been observed. At first, the trends in monthly average maximum temperature at five climatic stations (Bogra, Rajshahi, Rangpur, Dinajpur and Ishurdi) for twelve months of a year have been determined. The trend of average maximum temperature for April at five stations is shown in Figure 1.

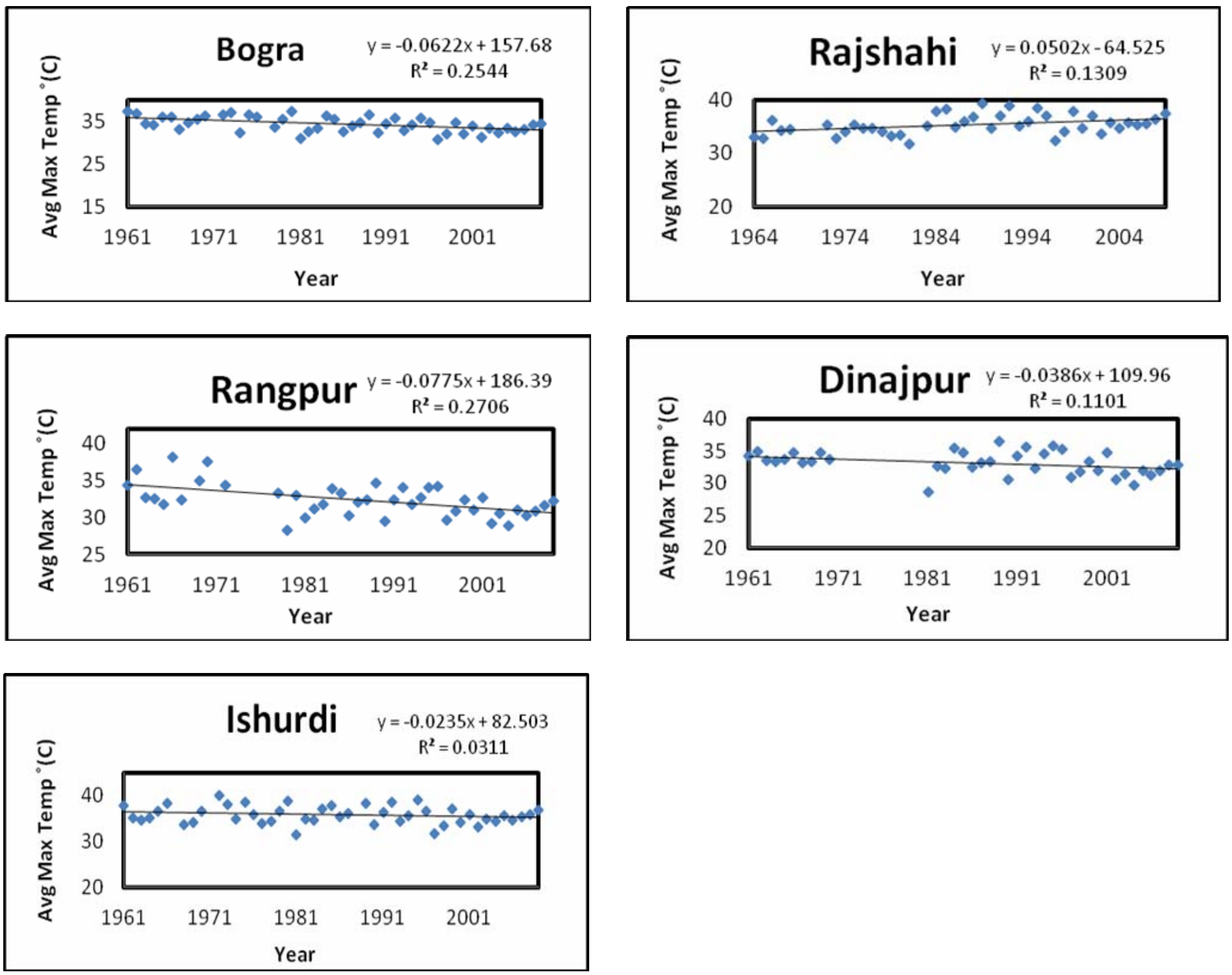

Figure 1. Trend of Monthly Average Maximum Temperature (˚C) for April at selected stations

The slope value of the trends is tabulated on Table 1. It is seen from the table that average maximum temperature has increasing trends in three stations except the Rangpur and Dinajpur stations. The average increasing trends of maximum temperature from 1961 to 2009 for Bogra, Rajshahi and Ishurdi are 0.01˚C, 0.017˚C and 0.01˚C, respectively. The average decreasing trends of maximum temperature for Rangpur and Dinajpur are .02˚C and .01˚C, respectively. Rangpur, which is located mainly in the Teesta Floodplain shows decreasing trend in summer (March-May) average maximum temperature and both Rangpur and Dinajpur are irrigation intensive area which may be a possible reason for decrease in maximum temperature.

Table 1. Trends in monthly average maximum temperature (˚C) per year at five climatic stations

Month	Bogra	Rajshahi	Rangpur	Dinajpur	Ishurdi
January	-0.019	-0.033	-0.05	-0.06	-0.022
February	-0.015	-0.005	-0.025	-0.02	-0.007
March	-0.047	-0.002	-0.039	-0.027	-0.017
April	-0.062	0.05	-0.077	-0.038	-0.023
May	-0.001	0.039	-0.028	0.003	-0.002
June	0.033	0.046	-0.006	0.007	0.021
July	0.03	0.024	0.00	0.013	0.021
August	0.041	0.039	0.003	0.027	0.038
September	0.022	0.017	-0.009	0.008	0.017
October	0.03	0.012	-0.008	0.012	0.034
November	0.041	0.015	0.002	0.01	0.03
December	0.019	0.001	-0.012	-0.003	0.021
Average	0.01	0.017	-0.02	-0.01	0.01

The significant level for both parametric and non-parametric correlations between monthly average maximum temperatures and time (years in this case) were estimated using the SPSS software. The correlations between monthly average maximum temperatures and time (years) for Bogra station are given in Table 2. It is seen from the table that the maximum temperature has statistically significant increasing trends in the months of June, July, August, September, October and November at the 5% level of significance (significant level being less than or equal to 0.05). So, the probability of occurrence of rising trend in maximum temperature by chance is less than or equal to 5%. It means that there is at least 95% probability that such trends may occur. There are statistically non-significant increasing trends only in December. But in the month of January, February and May have the statistically non-significant decreasing trends. March and April have the decreasing trends which is statistically significant at 5% level. It thus appears that the overall trends in maximum temperature for Bogra station are more significant for both correlation coefficients.

Table 2. The correlation coefficient between monthly average maximum temperature (˚C) and time (years) and its significance level at Bogra station

Month	Kendall's Tau_ b	Significance Level	Pearson's r	Significance Level
January	-0.149	0.135	-0.261	0.073
February	-0.118	0.244	-0.159	0.286
March	-0.337	0.001	-0.478	0.001
April	-0.336	0.001	-0.504	0.000
May	-0.035	0.733	-0.013	0.929
June	0.339	0.001	0.487	0.001
July	0.368	0.000	0.544	0.000
August	0.532	0.000	0.693	0.000
September	0.245	0.013	0.428	0.002
October	0.351	0.000	0.502	0.000
November	0.401	0.000	0.623	0.000
December	0.15	0.137	0.291	0.047

3.2 *Monthly average minimum temperature*

The trends in monthly average minimum temperature at five climatic stations (Bogra, Rajshahi, Rangpur, Dinajpur and Ishurdi) for twelve months of a year have been observed. The trend of average minimum temperature for the month of February at five stations is shown in Figure 2.

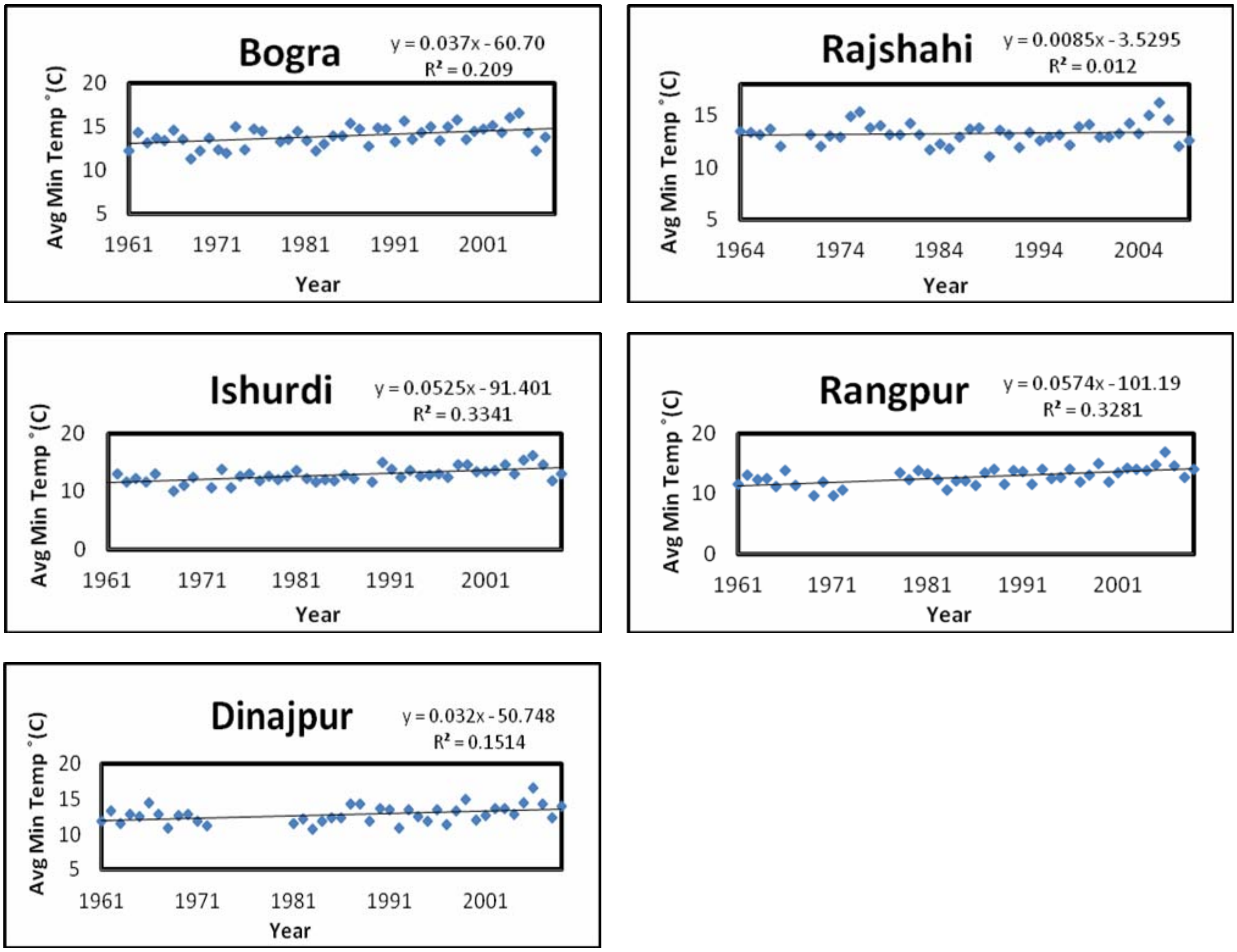

Figure 2. Trend of Monthly Average Minimum Temperature (˚C) for February at selected stations

The slope values of the estimated trends in average minimum temperature at five climatic stations (Bogra, Rajshahi, Rangpur, Dinajpur and Ishurdi) are tabulated in Table 3. It is seen from the table that most of the months show increasing trend in average minimum temperature except the Rajshahi station. Rajshahi shows mainly decreasing trends in winter (December-February) average minimum temperature. The average increasing trends of minimum temperature from 1961 to 2009 for Bogra, Rangpur, Dinajpur and Ishurdi are 0.011˚C, 0.03˚C, .012˚C and 0.02˚C, respectively. The average decreasing trends of minimum temperature for Rajshahi is .002˚C, respectively as it is located mainly in the upper part of Barind Tract and in Ganges River Floodplains.

The correlation coefficient and corresponding significance level at Rangpur station are given in Table 4. There are statistically significant increasing trends for January, February, March, April, May, October, November and December at 5% level of significance. There are statistically non-significant increasing trends in June, July, August and September. It appears that the overall trends in minimum temperature for Rangpur station have significantly increasing trends in February, March and December for both correlation coefficients.

Table 3. Trends in monthly average minimum temperature (˚C) per year at five climatic stations

Month	Bogra	Rajshahi	Rangpur	Dinajpur	Ishurdi
January	-0.002	-0.031	0.038	0.002	0.019
February	0.037	0.008	0.057	0.032	0.052
March	0.028	0.008	0.061	0.023	0.042
April	-0.001	0.001	0.042	0.005	0.015
May	0.001	0.001	0.039	0.006	0.008
June	0.005	0.001	0.028	0.006	0.01
July	0.007	0.005	0.014	0.012	0.009
August	0.011	0.008	0.001	0.008	0.011
September	0.004	-0.002	0.003	0	0.001
October	0.006	-0.01	0.016	-0.001	0.005
November	0.019	-0.011	0.03	0.023	0.022
December	0.022	-0.001	0.051	0.027	0.036
Average	0.011	-0.002	0.03	0.012	0.02

Table 4. The correlation coefficient between monthly average minimum temperature (˚C) and time (years) and its significance level at Rangpur station

Month	Kendall's Tau_ b	Significance Level	Pearson's r	Significance Level
January	0.366	0.001	0.509	0.001
February	0.418	0.000	0.573	0.000
March	0.394	0.000	0.579	0.000
April	0.32	0.003	0.384	0.012
May	0.313	0.004	0.362	0.018
June	0.091	0.407	0.275	0.078
July	0.17	0.127	0.247	0.119
August	0.056	0.618	0.036	0.826
September	0.004	0.974	0.072	0.652
October	0.237	0.028	0.302	0.049
November	0.349	0.001	0.448	0.003
December	0.467	0.000	0.647	0.000

3.3 *Comparison between observed trends from regression analysis and PRECIS model's trends:*

The output results from PRECIS (Providing Regional climates for Impact studies), developed by Hadly Centre, UK and the observed trend at five climatic stations for average mean temperature for the year 2000 is plotted in this study. The model outputs were provided in a 50km*50km grid format and the model were used to project rainfall and temperature in future years in Bangladesh using ECHAM4 SRES A2 emission scenarios as model output. A graphical plot of average mean temperature (˚C) between the observed trend for Rajshahi station and the PRECIS model output trends for the year 2000 is given in Figure 3.

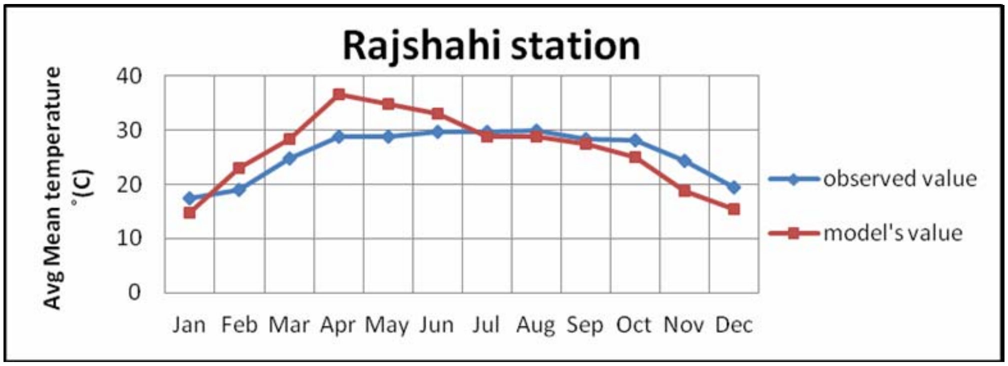

Figure 3. Comparison graph of average mean temperature at Rajshahi station for 2000.

In the above figure, it is found that the observed trend is flatter than the model trend and these patterns are followed generally in the northwest region of Bangladesh. Though the pattern is in observed trend is quite similar to the PRECIS model trends, there is a bit of deviation is found for the pre-monsoon (March-May) period in between two trends. The observed trend is plotted from the secondary data information collected by BMD, as well there were many missing data in monthly mean temperature at Rajshahi station which deviate the observed trend from the real value. As a natural phenomena, in the pre-monsoon season there occur a drastically change in weather pattern which may not be considered in PRECIS model. Moreover, PRECIS model works with six scenario (A1F1, A1T, A1B, A2, B1, and B2) groups whose results are vary from one another. The above model trend is based on SRES A1B scenario. Special Report on Emissions Scenarios (SRES) A1B scenario assumes a balanced mix of technologies and supply sources, with technology improvements and resource assumptions such that no single source of energy is overly dominant. The implications of these alternative development paths for future GHG emissions are challenging: the emissions vary from the carbon-intensive to decarburization paths by at least as much as the variation of all the other driving forces across the other SRES scenarios and so the trend from PRECIS model might not be quite realistic.

3.4 *Comparison between predicted trends from regression analysis and PRECIS model's trends:*

For predicted year, 2030:

In this part of the study, a predicted trend of average mean temperature for the year 2030 at Rajshahi station is determined using linear regression trend with respect to the base year 2000. The year from which the data were available for a certain station was considered as the base year. A graphical plot of average mean temperature (˚C) between the predicted trend from regression analysis for Rajshahi station and the PRECIS model output trends for the year 2030 is given in figure 4.

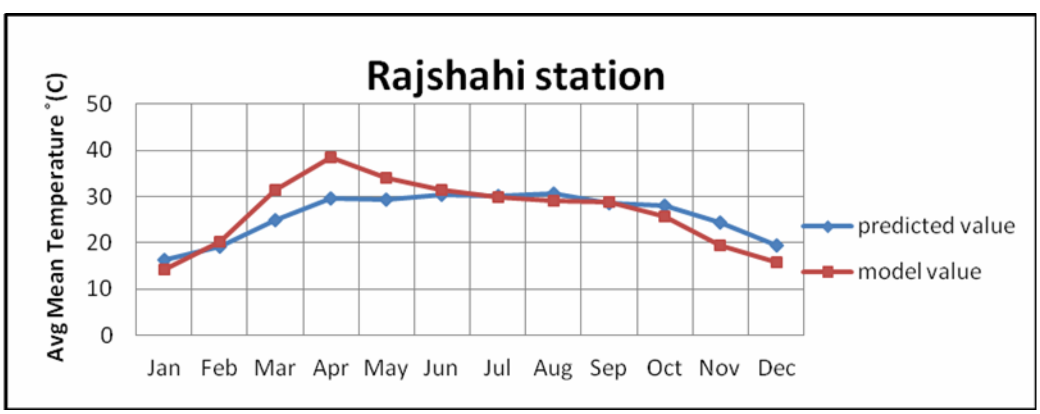

Figure 4. Comparison graph of average mean temperature at Rajshahi station for 2030.

The predicted trend of average mean temperature from linear regression for 2030 shows the maximum temperature for the month of June and second highest temperature for August, whereas the model shows the maximum temperature for April. So, the predicted trend from regression line is quite deviated from the model trends. The predicted trend is quite anonymous with the model trends for monsoon (June-September) period. Rajshahi shows significant fluctuation of day and night temperature in winter season and climatic parameters play the dominant factors as it is the most vulnerable rice growing region (Bashak, 2009). So, the predicted trend results do not show similarity with the model trends as well as the model has some limitations.

For predicted year, 2050:

A predicted trend of average mean temperature for the year 2050 at Rajshahi station is determined using linear regression trend with respect to the base year 2000. A graphical plot of average mean temperature (˚C) between the predicted trend from regression analysis for Rajshahi station and the PRECIS model output trends for the year 2050 is given in Figure 5.

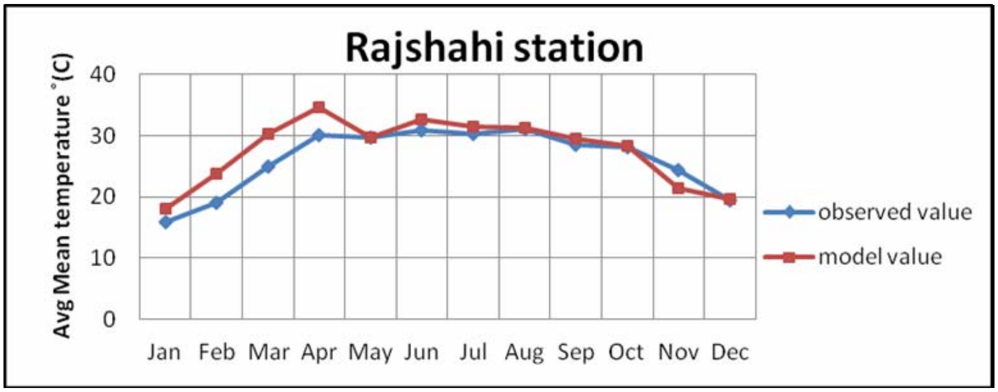

Figure 5. Comparison graph of average mean temperature at Rajshahi station for 2050

The predicted trend of average mean temperature from linear regression for 2050 shows the maximum temperature for the month of June and second highest temperature for August, whereas the model shows the maximum temperature for April. But, there is also a dropdown point of temperature is found for May. The predicted trend is quite anonymous with the model trends for later monsoon (July-September) and beginning of post monsoon period (October-November) period. So, the predicted trend from the model shows fluctuation in pattern for year 2050 than from 2030. But, the predicted trend obtained from regression analysis show quite similarity with the model trends in this case.

3.5 *Changes in reference crop evapotranspiration (ETo) for predicted years:*

Relative observed seasonal changes between maximum and minimum temperatures may provide some insight as to how GCM predicted regional average warming may be broken up into daytime and nighttime temperatures. In order to determine the effect of temperature on reference crop evapotranspiration (ETo) for the predicted years, ETo values are calculated using the CROPWAT software with respect to the base year 2000. Here only the effect of temperature is considered by remaining the effect of other climatic parameters such as relative humidity, wind speed, sunshine hour constant. ETo (mm/day) values for different months at Rajshahi for both without climate change conditions and with climate change conditions are given in Table 5.

The results from the table indicate that an increase in ETo of about 1.14% by 2030 and about 2.0% by 2050 due to climate change at Rajshahi station. Though we found about 2% increase in ETo due to increase in temperature, the level of increase may partly be offset by reduced crop water use in a CO_2-enriched atmosphere (IPCC, 1990b). The size of the openings in plant leaves (stomata), through which plants breathe, reduces in CO_2-enriched environment resulting in a reduction in transpiration rate (Brammer et al., 1996). Furthermore, due to increased rate of evaporation from ocean, river, water bodies, etc. in a warmer climate, cloud cover and number of cloudy days may increase. This may decrease sunshine hours and increase in relative humidity- both of which would reduce evapotranspiration. Rangpur station shows a decrease in ETo of about 0.9% by 2030 and about 1.18% by 2050 as in decrease in temperature due to climate change.

Table 5. Reference crop evapotranspiration ET_o (mm/day) for Rajshahi station

Month	Without climate (2000)	With climate (2030)	With climate (2050)
January	2.11	2.05	2.0
February	2.5	2.48	2.47
March	3.93	3.91	3.91
April	5.05	5.18	5.28
May	4.31	4.4	4.46
June	4.21	4.32	4.39
July	4.03	4.08	4.11
August	3.73	3.81	3.86
September	3.41	3.45	3.48
October	3.53	3.54	3.55
November	2.98	2.99	3
December	2.37	2.39	2.4
Average	3.51	3.55	3.58

4 RECOMMENDATIONS

The climatic data (temperature) collected for the study can be used in model like PRECIS to determine reference crop evapotranspiration (ETo) and the simulated ETo can be compared with this study. The effect of CO_2 concentration in the atmosphere on reference crop evapotranspiration (ETo) was not taken into consideration in this study and future study should consider this. To determine the ETo values from CROPWAT software for future years, the effect of only temperature was only considered. Other climatic parameters like wind speed, relative humidity and sunshine hours should consider in future studies.

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