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Research Article

Statistical Analysis of Projected Climate Data under Diverse Scenarios for *Kandi* Region of Punjab

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ABSTRACT

The temperature and rainfall data from HadGEM2-ES model under different climate change scenarios (RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5) for *kandi* region of Punjab (Ballowal Saunkri) was obtained from the Marksim weather generator. Due to biases in the projected and actual climatic data, the actual climate data recorded and the baseline data derived from Marksim weather generator for the period 2010-13 was used for deriving the correction factor. The projected weather data by the end of 21st century was corrected by using this correction factor. Then the corrected data were analyzed on annual and seasonal basis to quantify the changes in maximum temperature, minimum temperature and rainfall for *kandi* region of Punjab. The projected data showed increase in maximum temperature from the baseline period (1984-2018) at Ballowal Saunkhri during the period 2020-2050, 2051-70 and 2071-2095 under all the climate scenarios. The annual maximum temperature at Ballowal Saunkhri may change from 0.5-4.6, 1.5-5.2 and 2.5-5.4 °C during 2021-2050, 2051-70 and 2071-2095, respectively. The *kharif* maximum temperature is projected to increase by 0.5-6.3, 1.3-7.0 and 2.2-7.3 °C; *rabi* maximum temperature by 0.7-3.0, 0.9-2.6 °C during 2021-2050, 2051-70 and 2071-2095, respectively. The annual, *kharif* and *rabi* minimum temperature has been projected to rise by 0.6-1.1, 0.9-2.7 and 0.9-4.4 °C; 0.5-6.3, 1.0-3.0 and 1.1-4.7 °C in different scenarios under study during 2021-2050, 2051-70 and 2071-2095, respectively. The increase in minimum temperature as compared to baseline minimum temperature has been observed to be more under RCP 8.5 scenario as compared to other scenarios. Similarly, the annual rainfall has also been projected to increase over the annual rainfall of baseline period and this increase would be higher under RCP 8.5 followed by RCP 4.5, 6.0 and 2.6 scenario. The projections indicate that during the years 2020-2050, an increase in annual rainfall by 27.8-33.9, 27-49 and 25-52 percent from normal may occur under different scenarios by 2021-2050, 2051-70 and 2071-2095, respectively. Similarly, the change in *kharif* and *rabi* season rainfall expected is by 28.7-39.2, 31.1-56.8 and 32.1-63.9 percent, respectively; and by -6.3-23.1, -12.7-7.9 and -15.6 to -7.1 percent, respectively during 2020-2050, 2051-70 and 2071-2095. The projections indicate that there would be continuous warming during the 21st century along with occurrence of higher rainfall in the *kandi* region.

Key words: Temperature, Rainfall, RCP 2.6, 4.5, 6.0 and 8.5 scenario

Introduction

The livelihood of people is greatly affected by climate change and variability. The frequently occurring extreme events such as cold and heat waves, droughts and floods, forest fires, landslips etc. are of major concern among the scientists and human beings. The natural disasters such as volcanic eruptions, earthquakes etc. alter the

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chemical composition of the atmosphere. Some anthropogenic activities such as burning fossil fuels, deforestation etc are also responsible for the alleviation of temperature at the global and regional scales which in turn result in to the reduction in rainfall amount and number of rainy days, more extreme precipitation events, shifts in onset/withdrawl of monsoon etc (Gautam *et al*., 2013). Changes in climate system have been observed at global, regional, and local levels (Fitzpatric *et al*., 2008, Choudhary *et al*., 2019) which have been simulated to impact precipitation and temperature patterns to varying degrees in different parts of the world (Root *et al*., 2005; William *et al*., 2007). The projected climate change studies predict on an increase in mean temperature over India between 3.3 and 5.8 degrees Celsius (^{o}C) under RCP 8.5 scenario by 2100 (Chaturvedi *et al*., 2012) which would have severe impacts on the earth's hydrological system, ecosystems, sea level, crop production and related processes. The impact would be particularly severe in the tropical areas, which mainly consist of developing countries, including India (Balasubramanian and Birundha 2012). Changes in temperature could yield similarly disruptive impacts such as increased droughts as a result of higher temperatures (Sheffield and Wood, 2008).

The knowledge of natural and anthropogenic factors affecting emissions and responses by climate system to these factors is of utmost importance. The changes in extremes of temperature and precipitation, decrease in snow cover and sea level rise are expected to occur but their expected rate of change is uncertain (Karl and Trenberth, 2003). The global climate models have been widely used by researchers to assess potential climate impacts in a variety of areas (Zhang *et al*., 2018, Zhao *et al*., 2019). Developing high resolution models on a global scale is not only expensive for climate change simulations, but also suffers from errors due to inadequate representation of climate processes worldwide (Zampieri *et al*., 2019). These models simulate variations in different climatic parameters under different set of scenarios. CMIP5 is global climate model (GCM) which has been widely used for simulating the climate under different climate change scenarios. Intergovernmental Panel on Climate Change (IPCC) has given different set of RCP scenarios which aim to represent possible changes in future anthropogenic greenhouse gas (GHG) emissions and their atmospheric concentrations. RCP 2.6 assumes that global annual GHG emissions (measured in CO_2-equivalents) peak between 2010–2020, with emissions declining substantially thereafter. Emissions in RCP 4.5 peak around 2040, then decline. In RCP 6, emissions peak around 2080, then decline. In RCP 8.5, emissions continue (IPCC, 2014) to rise throughout the 21st century. Rupakumar *et al.* (2006) simulated the regional climate of India by using PRECIS for the baseline 1961–1990 as well as 2071-2100 under the SRES scenarios A2 and B2. Krishnakumar *et al.* (2011) also used PRECIS model for India for the period 1961-2098 using SRES scenario A1B. Bal *et al*. (2015) also showed increase in maximum, minimum temperature and high rainfall events during mid and end of 21st century. Kaur and Kaur (2019) projected increase in maximum and minimum temperature in the central region of Punjab.

In the present study, RCP scenarios i.e. RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5 in kandi region of Punjab state were analyzed. The regional scale analyses are necessary to identify the range of changes that may occur in different areas with respect to temperature and precipitation. Also, while multiple climate change-related studies have been performed at the global and national scale, the literature for the regional scale is more limited. Therefore, we planned to analyze the simulated changes in the temperature and precipitation using RCP scenarios for precipitation and temperature for mid and end of the 21st century for *kandi* region of Punjab.

Material and Methods

Study area

The lower *Shivalik* region of Punjab, commonly called *kandi* region, constitute about 7.8% in the North Eastern of Punjab and covers five districts namely Pathankot, Hoshiarpur, SBS

Nagar, Rupnagar and SAS Nagar. This region is different from rest of Punjab in many ways because of lack of irrigation facilities resulting in low agricultural productivity. Although, the annual rainfall of this region is about 1.6 times more than the average annual rainfall of Punjab yet the crop failures and low crop yields are common phenomenon in the region which may be due to the uneven distribution and erratic nature of rainfall. Therefore, the scenarios of possible changes expected in future need to be studied for this region. Ballowal Saunkhri situated at 31°6′5″ N, 76°23′26″ E and 357m was selected for the study. The daily climatic data projections for HadGEM2-ES model from CMIP5 model under different climate change scenarios (RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5) was obtained from Marksim weather generator for the Ballowal Saunkhri located in north eastern region (*kandi* region) of Punjab (Fig 1).

The correction factor was derived from the actual and simulated data for maximum temperature, minimum temperature and rainfall using difference method and it was used for minimizing the biases between model and actual data correction / validating the model data. In this method, the daily differences of the model (X_{model}) and observed (X_{obs}) value of weather parameter was computed for each Julian day (365 days) form historical data. This was considered as daily correction factor. The daily correction factor was subtracted from the modeled uncorrected (Xmodel $_{uncorr}$) value so that the corrected (Xmodel $_{corr}$) values are closer to the observed ones.

$$\text{Xmodel}_{corr} = \text{Xmodel}_{uncorr} - (X_{model} - X_{obs})$$

Thereafter the simulated weather data for the 2021-50, 2051-70 and 2071-95 was corrected by applying correction factor in order to minimize the biases in the modelled data. Then the corrected futuristic daily weather data was analyzed on annual, *kharif* season (May-October), and *rabi* season (November-April) basis using averages of long term data to quantify the changes in maximum temperature (°C), minimum temperature (°C) and rainfall (mm) from the baseline period. The trend analysis of the baseline and simulated data were done by calculating their respective annual linear average which were then regressed against time to obtain their regression coefficients. The F values (observed) were calculated using the formula as given below:

$$F = \frac{R^2}{1-R^2}\frac{n-p-1}{p}$$

Where, R^2 is coefficient of determination, n is number of observations, p is the number of independent variable whose value for linear

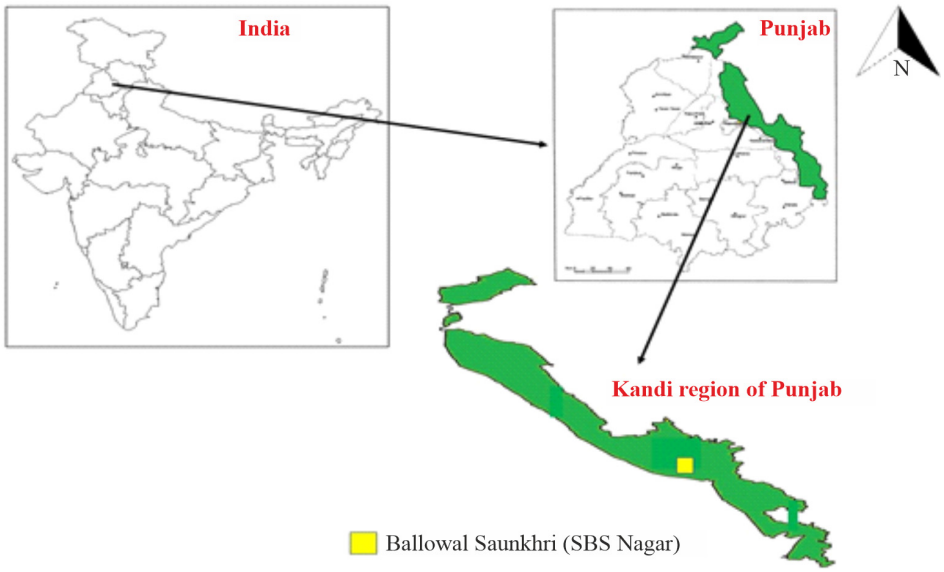

Fig. 1. Location of Ballowal Saunkhri (*kandi* region) of Punjab

regression is one. This calculated value of F was compared with tabulated value of $F_{(p, n-p-1)}$ at 1% level of significance to test the significance of the regression coefficient.

Results and Discussion

Changes in temperature and rainfall in the during the 21st century (2021-95)

The temperature and rainfall projections for the 21st century based on RCP scenarios represent a strong warming over the 21st century. The differences in maximum temperature, minimum temperature and rainfall from their baseline during 21st century under different scenarios averaged over the *kandi* region of Punjab have been given in Table 1. The data shows that the annual, *kharif* and *rabi* season maximum temperature in the *kandi* region of Punjab may increase by 1.4 to 5.0°C, 1.3 to 6.8°C and 1.7 to 4.4°C, respectively as compared to their respective baselines 30.1, 34.5 and 25.5°C. Similarly, the annual, *kharif* and *rabi* season minimum temperature in this region of Punjab has been projected to increase under different climate change scenarios by 0.8 to 2.6°C, 0.9 to 2.8°C and 0.7 to 2.4°C, respectively as compared to their respective baselines 16.3, 22.5 and 10.0°C. The increase in minimum temperature is greatest under the RCP 8.5 and lowest under RCP 2.6 scenario. In case of rainfall, the annual, *kharif* and *rabi* rainfall is expected to increase respectively, by the 300 to 400 mm, 300 to 410 mm and 140 to 180 mm as compared to their respective baselines 1051.0, 888.0 and 160.9 mm (Table 1).

Changes in maximum temperature under different scenarios during different periods of end century

The projected annual and seasonal maximum temperature at *kandi* region of Punjab during the baseline period, mid and end 21st century have been presented in Table 2. The annual and seasonal maximum temperature is expected to increase by the mid and end of 21st century at *kandi* region of Punjab. The annual maximum temperature may rise as compared to the baseline temperature (30.1°C) by 0.5 to 4.6°C, 1.5 to 5.2°C and 2.5 to 5.4°C, respectively, during 2021-50, 2051-70 and 2071-95 under different RCP

Table 1. Projected changes in maximum temperature, minimum temperature and rainfall by the end century under different scenarios and their deviation from baseline period in Punjab

Season	Annual	*Kharif*	*Rabi*
	Maximum temperature (°C)		
Baseline	30.1	34.5	25.5
RCP 2.6	35.1 (+5.0)	41.3 (+6.8)	28.9 (+4.4)
RCP 4.5	32.1 (+2.1)	36.4 (+1.9)	27.7 (+2.2)
RCP 6.0	31.5 (+1.4)	35.8 (+1.3)	27.2 (+1.7)
RCP 8.5	32.5 (+2.4)	36.7 (+2.2)	28.2 (+2.7)
	Minimum temperature (°C)		
Baseline	16.3	22.5	10.0
RCP 2.6	17.1 (+0.8)	23.4 (+0.9)	10.7 (+0.7)
RCP 4.5	17.8 (+1.5)	24.4 (+1.9)	11.1 (+1.1)
RCP 6.0	17.8 (+1.5)	24.3 (+1.8)	11.3 (+1.3)
RCP 8.5	18.9 (+2.6)	25.3 (+2.8)	12.4 (+2.4)
	Rainfall (mm)		
Baseline	1051.0	888.0	160.9
RCP 2.6	1362.3 (+311.3)	1197.3 (+309.3)	165.4 (+4.5)
RCP 4.5	1389.2 (+338.2)	1221.5 (+333.5)	167.8 (+2.4)
RCP 6.0	1427.4 (+376.4))	1252.3 (+364.3)	175.8 (+14.9)
RCP 8.5	1444.8 (+393.8)	1298.2 (+410.2)	146.4 (+14.5)

Table 2. Projected changes in maximum temperature during the mid and end century under different scenarios and their deviation from baseline period in Punjab

Season	Baseline	2021-50	2051-70	2071-95
		RCP 2.6		
Annual	30.1	34.7(+4.6)	35.3(+5.2)	35.5(+5.4)
Kharif	34.5	40.8(+6.3)	41.5(+7.0)	41.8(+7.3)
Rabi	25.5	28.5(+3.0)	28.1(+2.6)	29.2(+2.7)
		RCP 4.5		
Annual	30.1	31.0(+0.9)	32.5(+2.4)	33.2(+3.1)
Kharif	34.5	35.4(+0.9)	36.7(+2.2)	37.5(+3.0)
Rabi	25.5	26.6(+1.0)	27.2(+1.7)	28.8(+3.3)
		RCP 6.0		
Annual	30.1	30.6(+0.5)	31.6(+1.5)	32.6(+2.5)
Kharif	34.5	35.0(+0.5)	35.8(+1.3)	36.7(+2.2)
Rabi	25.5	26.2(+0.7)	26.4(+0.9)	28.4(+2.9)
		RCP 8.5		
Annual	30.1	31.0(+0.9)	32.6(+2.5)	34.4(+4.3)
Kharif	34.5	35.3(+0.8)	36.8(+2.3)	38.5(+4.0)
Rabi	25.5	26.5(+1.0)	27.3(+1.8)	30.2(+4.7)

*Figures in the parenthesis denote deviation from the baseline value

scenarios. The expected increase in *kharif* maximum temperature as compared to the baseline temperature (34.5°C) may be in the range of 0.5 to 6.3°C, 1.3 to 7.0°C and 2.2 to 7.3°C, respectively, during 2021-50, 2051-70 and 2071-95 under different RCP scenarios. Similarly, during 2021-50, 2051-70 and 2071-95, the *rabi* season maximum temperature may increase than baseline temperature (25.5°C) by 0.7 to 3.0°C, 0.9 to 2.6°C and 2.7 to 4.7°C, respectively, respectively, under different RCP scenarios (Table 2). A mean annual and seasonal temperature rise within range of 2.9-4.1°C for India under B2 and A2 scenario during 2080's relative to 1970's was reported by Rupakumar *et al.* (2011). Similarly, an annual warming of 3.5-4.3°C over the same period for A1B scenario has been reported by Krishankumar *et al.* (2011).

The regression equations as a result of trend analysis of maximum temperature revealed that by the end of 21st century, the annual, *kharif* and *rabi* maximum temperature has been predicted to increase at the rate of 0.02 to 0.07°C/year, 0.02 to 0.06°C/year and about 0.03 °C/year respectively under the different climate change scenarios (Table 5). The trend analysis of projections indicate that changes in temperature for the *kharif* season are significant than *rabi* season (Table 5). Also the historical data analysis using three yearly moving averages of the temperature for the region shows not much increase during *rabi* season. The global warming and climate change are going to affect the climate system resulting in the shifts in the temperature and precipitation patterns. The rising temperature have been predicted by the end of century under all the scenarios, whether this increase is more or less in the different scenarios. The reason behind this increase may be the changes in land uses resulting in the less carbon sequestration and more radiative forcing by the greenhouse gases.

Changes in minimum temperature under different scenarios during different periods of end century

The temperature data for *kandi* region shows warming trends. The annual and seasonal minimum temperature at different locations of Punjab during the baseline period, mid and end 21st century have been presented in Table 3. The analysis of data reveals overall increasing trend in the minimum temperature in North western

zone of Punjab state under different climate change scenarios. At Ballowal Saunkhri, representing the *kandi* region, the minimum temperature during the 2021-50 is expected to increase by 0.6 to 1.1°C annually, 0.6 to 1.2°C for the *kharif* season and 0.6 to 0.9°C for the *rabi* season than the baselines of 16.7, 22.6 and 10.8°C, respectively. By 2051-70, the minimum temperature on annual, *kharif* and *rabi* basis may rise from 0.9 to 2.7°C, 1.0 to 3.0°C and 0.5 to 2.1°C, respectively, under different climate change scenarios. During the period 2071-95, the deviation from the baseline in minimum temperature on annual, *kharif* and *rabi* basis is expected to be 0.9 to 4.4°C, 1.1 to 4.7°C and 0.7 to 4.1°C, respectively under different scenarios (Table 3).

The regression equations as a result of trend analysis of minimum temperature revealed that by the end of 21st century, the annual, *kharif* and *rabi* minimum temperature has been predicted to increase at the rate of 0.01 to 0.06°C/year, 0.01 to 0.07°C/year and about 0.01 to 0.04 °C/year respectively under the different climate change scenarios (Table 5).

Changes in rainfall under different scenarios during different periods of end century

The annual and seasonal rainfall at different locations of Punjab during the baseline period, mid and end 21st century have been presented in Table 4. The model predictions for the rainfall indicate that during 2021-50 to 2071-95, rainfall over the *kandi* region may increase and extreme rainfall events would rise sharply. The annual, *kharif* and *rabi* rainfall over the *kandi* region during 2021-50 is expected to change by about 27-34%, 28-39% and -6 to 25%, respectively as compared to the baseline (1051, 888.0 and 160.9 mm, respectively, for annual, *kharif* and *rabi*). During 2051-70, the deviation in rainfall from the baseline on annual, *kharif* and *rabi* basis is expected to be 27 to 50%, 31 to 57% and -12 to 8%, respectively under different climate change scenarios. By the end of the century (2071-95), this change in rain as compared to the baseline may range from 25 to 52%, 32 to 64% and -12 to -7% on annual, *kharif* and *rabi* season basis, respectively. The highest increase is expected under RCP 8.5 scenario during the end century period. Rajendran and Kitoh, (2008) also

Table 3. Projected changes in minimum temperature during the mid and end century under different scenarios and their deviation from baseline period in Punjab

Season	Baseline	2021-50	2051-70	2071-95
		RCP 2.6		
Annual	16.3	16.9(+0.6)	17.2(+0.9)	17.2(+0.9)
Kharif	22.5	23.1(+0.6)	23.5(+1.0)	23.6(+1.1)
Rabi	10.0	10.7(+0.7)	10.5(+0.5)	10.7(+0.7)
		RCP 4.5		
Annual	16.3	17.2(+0.9)	18.0(+1.7)	18.5(+2.2)
Kharif	22.5	23.7(+1.2)	24.7(+2.2)	25.3(+2.8)
Rabi	10.0	10.7(+0.7)	10.9(+0.9)	11.7(+1.7)
		RCP 6.0		
Annual	16.3	17.0(+0.7)	17.9(+1.6)	18.8(+2.5)
Kharif	22.5	23.4(+0.9)	24.4(+1.9)	25.3(+2.8)
Rabi	10.0	10.6(+0.6)	11.0(+1.0)	12.2(+2.2)
		RCP 8.5		
Annual	16.3	17.4(+1.1)	19.0(+2.7)	20.7(+4.4)
Kharif	22.5	23.7(+1.2)	25.5(+3.0)	27.2(+4.7)
Rabi	10.0	10.9(+0.9)	12.1(+2.1)	14.1(+4.1)

Table 4. Projected changes in rainfall during the mid and end century under different scenarios and their deviation from baseline period in Punjab

Season	Baseline	2021-50	2051-70	2071-95
		RCP 2.6		
Annual	1051.0	1407.0(+356.0)	1337.7(+286.7)	1322.8(+271.8)
Kharif	888.0	1235.7(+347.7)	1163.9(+275.9)	1173.2(+285.2)
Rabi	160.9	172.4(+11.5)	166.3(+5.4)	149.4(-11.5)
		RCP 4.5		
Annual	1051.0	1349.2(+298.2)	1440.1(+389.1)	1401.2(+350.2)
Kharif	888.0	1152.1(+264.1)	1291.0(+403.0)	1257.3(+369.3)
Rabi	160.9	198.1(+37.2)	142.1(-18.8)	143.8(-17.1)
		RCP 6.0		
Annual	1051.0	1342.7(+291.7)	1575.0(+524.0)	1421.3(+370.3)
Kharif	888.0	1142.6(+254.6)	1392.3(+504.7)	1285.1(+397.1)
Rabi	160.9	201.5(+40.6)	173.6(+12.7)	135.9(+25.0)
		RCP 8.5		
Annual	1051.0	1355.6(+304.6)	1402.2(+351.2)	1596.9(+545.9)
Kharif	888.0	1204.4(+316.4)	1255.7(+367.7)	1455.8(+567.8)
Rabi	160.9	150.8(-10.1)	140.5(-20.4)	140.2(-20.7)

*Figures in the parenthesis denote deviation from the baseline value

Table 5. Results of trend analysis in maximum temperature, minimum temperature and rainfall for the mid and end century under different scenarios

Seasons	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
		Maximum temperature (°C)		
Annual	Y = 0.017X + 0.16 R^2 = 0.91	Y = 0.0454X - 61.17 R^2 = 0.97	Y = 0.0393X - 49.38 R^2 = 0.99	Y = 0.0682X - 107.74 R^2 = 0.99
Kharif	Y = 0.0201X - 0.04 R^2 = 0.93	Y = 0.0441X - 54.26 R^2 = 0.99	Y = 0.0336X - 33.43 R^2 = 0.99	Y = 0.0631X - 93.01 R^2 = 0.99
Rabi	Y = -0.0161X + 28.82 R^2 = 0.01	Y = 0.0195X + 26.32 R^2 = 0.01	Y = 0.0043X + 26.15 R^2 = 0.001	Y = 0.0251X + 26.20 R^2 = 0.02
		Minimum temperature (°C)		
Annual	Y = 0.0061X + 4.53 R^2 = 0.62	Y = 0.0273X - 38.34 R^2 = 0.98	Y = 0.0362X - 56.68 R^2 = 0.99	Y = 0.0666X - 118.1 R^2 = 0.99
Kharif	Y = 0.0093X + 4.20 R^2 = 0.85	Y = 0.0332X - 43.75 R^2 = 0.98	Y = 0.0396X - 57.14 R^2 = 0.99	Y = 0.0693X - 117.18 R^2 = 0.99
Rabi	Y = -0.0066X + 10.76 R^2 = 0.01	Y = 0.0091X + 10.52 R^2 = 0.02	Y = 0.0136X + 10.41 R^2 = 0.04	Y = 0.0423X + 10.27 R^2 = 0.22
		Rainfall (mm)		
Annual	Y = -1.7849X + 50 R^2 = 0.51	Y = 1.9667X - 2655.3 R^2 = 0.13	Y = 2.8068X - 4344.7 R^2 = 0.19	Y = 4.8037X - 8434 R^2 = 0.64
Kharif	Y = -1.4167X + 4110.7 R^2 = 0.35	Y = 2.9022X - 4746.8 R^2 = 0.26	Y = 3.7941X - 6550.2 R^2 = 0.38	Y = 5.0186X - 9022.7 R^2 = 0.65
Rabi	Y = -0.38X + 180.02 R^2 = 0.06	Y = -1.5184X + 216.9 R^2 = 0.39	Y = -0.548X + 204.76 R^2 = 0.04	Y = -0.3778X + 157.23 R^2 = 0.09

simulated high rainfall events by the end of century. The trends of heavy or in some places reduced precipitation have also been observed in some other studies(Palmer *et al*., 2002; Goswami *et al*., 2006; Kitoh *et al*., 2008). An increase in precipitation by 4 to 5% during 2030's and 6 to 14% towards end of century (2080's has also been simulated by Chaturvedi *et al*. (2012).

The result of trend analysis of rainfall showed that the annual, *kharif* and *rabi* rainfall has been predicted to decrease by the end of 21st century at the rate of -1.7 to 4.8 mm/year, -1.4 to 5.0 mm/year and -0.4 to 1.5 mm/year respectively under the different climate change scenarios (Table 5).

More increase during the *kharif* season as compared to *rabi* season which may increase the evaporative demand of the crops resulting in high water requirement and effect on the crop production. An increase in *kharif* and decrease in *rabi* season rainfall has been expected in the future. This might be due to a significant increase in temperature during *kharif* as compared to *rabi* season, which must be responsible for increasing moisture content in the atmosphere leading to heavy rainfall events. These events would affect runoff and soil erosion in these areas.

Conclusions

The results of the present study indicate more increase in minimum temperature as compared to increase in both maximum and minimum temperature during the 21st century under the RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5 scenarioin *kandi* region of Punjab. An increase in maximum temperature would affect water requirement of crop, whereas, the rising minimum temperature would affect the respiration rate of the plants leading to reduced yield as a result of degradation of photosynthates. This means that growth, development and yield of crops would be affected with the rise in both day and night temperature. The rainfall amount has also been predicted to increase in future in the study area. Both the intensity and area affected by high rainfall events have been projected to increase over this region which means increase in rate of erosion and runoff will be there in future. These simulated changes may have implications for agricultural production in the region also. As rising temperatures and reducing rainfall increase the evaporative demand of atmosphere, therefore rainfed regions have more profound effects from changes in rainfall than the irrigated areas due to non-availability of irrigation facilities. The excess water in these areas may be harvested so as to use during the dry spells. Therefore, actions are needed to be taken in order to limit the magnitude of future climate change and adapt to its impacts. Micro-irrigation, protected cultivation, afforestation, agroforestry, in situ moisture conservation, shifting sowing dates etc. can be the measures to cope with the changing climate.

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