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Temperature Trends and their impact on rabi crops in changing climatic scenario of Bihar

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Abstract: Climate is perceived to be changing worldwide and there has been growing concern towards the direction and magnitude of these changes. Greenhouse gases are responsible for maintaining earth's surface temperature suitable for sustaining life, but excess emission of GHGs increase the earth's surface temperature and causing global warming. Globally, over the past several decades, about 80 percent of human-induced carbon dioxide emissions came from the burning of fossil fuels, while about 20 percent from deforestation and associated agricultural practices. Climate change associated variables like CO_2, temperature and rainfall etc. affect food production through direct impact on growth and yield of food crops. These variables may also affect yield of crops indirectly through hydrological changes, soil erosion, organic matter, pest and disease incidence etc. To cope with the adverse impacts of increasing GHGs and associated global warming adaptation and mitigation approaches are the need of hour.
Keywords: Bihar, Climate change, Rabi crops, Temperature

INTRODUCTION

Food and energy security of India are crucially dependent on favourable weather and the timely availability of adequate amount of water. Air temperature and precipitation are principle elements of weather systems, so for the prediction of future climate conditions, level of variability of these two weather elements must be examined. Analyses of climate trends indicate that the global mean surface temperature has increased by about 0.3 to 0.68°C since the late 19th century and by about 0.2 to 0.38°C over the last 40 years [1]. Climate model simulations predict an increase in average surface air temperature of about 2.5°C by the year 2100 [2]. According to the estimates by IPCC (2007) earth's linearly averaged surface temperature has increased by 0.74°C during the period 1901-2005 [3]. Pant and Kumar, 1997 [4] reported that there is a significant warming trend of 0.57°C per 100 years. Bhutiyani et al., 2007 [5] found increasing trend in maximum mean and diurnal temperature range over the northwestern Himalayan region during the 20th century. Increasing trends of rainfall and minimum temperature in Gangetic plains of Bihar was observed [6]. Weather generators can be used to generate long term weather data wherever data is not available for impact studies. One such generator is LARSWG which was used and produced similar observations of rainfall and temperature as actual weather data for Bihar in eastern India [7]. Temperature practically trendless in winter and pre-monsoon season and increased in the monsoon and post-monsoon seasons over NE India observed [8]. Maximum temperature showed significant rising trend of 0.008°C/yr during monsoon season; 0.014°C/yr during post-monsoon season and 0.008°C/yr in the annual maximum temperature during the period 1914–2003 for Central Northeast India [9].

Although increase in CO_2 is likely to be beneficial for crops, yet associated temperature and rainfall variability may change the food production situation. Simulation studies are useful in predicting future climate scenario based on changing trends in temperature, CO_2 and rainfall etc [10, 11]. Wheat yield in Patna and Ranchi showed a declining trend due to increased temperature (thermal stress) coinciding with grain filling stage of crop [12]. Simulation studies showed that long duration rice varieties are more prone to yield decline under future climate scenarios [13-15].A study conducted at Indian Agriculture Research Institute indicated the possibility of 4-5 million tonnes loss in wheat yield with 1°C rise in temperature. Similar results were also observed by other researchers also [16- 18]. In north India, chickpea grain yield decreased by 53 kg ha–1 in Uttar Pradesh and 301 kg ha–1 in Haryana per degree increase in seasonal temperature [19]. Most chickpea genotypes do not set pods when temperatures reach >35°C [20].

Assessment of the impact of temperature on rabi crops might help adopt suitable farming techniques to maximize crop production. Simulation studies are useful in predicting future climate scenario based on changing trends in temperature, CO_2 and rainfall etc. Thus, understanding the variations in temperature both spatially and temporally and improving the ability of forecasting rainfall may help in planning crop calendar, selection of varieties matching water availability as well as in designing water storages for flood and drought mitigation etc.

METHODOLOGY

Study area

Bihar is located in eastern India in Middle Gangetic Plain Zone (zone 4) based on agroclimatic zones/regions and is divided into three agroclimatic zones viz. North West alluvial plains (Zone 1), North East alluvial plains (Zone 1I), South Bihar alluvial plains (Zone III) which is further divided into Zone IIIA and IIIB. On an average, the plain region of Bihar records a mean annual total rainfall of 1297 mm which is distributed in the monsoon, post monsoon, winter and summer seasons as 1039, 32, 110 and 58 mm, respectively. Average maximum temperature is highest for zone III (37.1°C), while average minimum temperature is highest in zone II (8.8°C). One district from each zone was selected for study viz. Samastipur (Zone I), Madhepura (Zone II), Bhagalpur (Zone IIIA) and Patna (Zone IIIB) respectively.

Temperature data analysis

Temperature (maximum and minimum) was investigated in selected districts of three agro climatic zones using 51 years of monthly data record (1950-2000) taken from Indian Meteorological Department site. Rabi season and annual temperature (tmax and tmin.) time series is analyzed by linear regression method for detecting climate variability over time and space and the rate of change in temperature as well as rainfall.

RESULTS AND DISCUSSION

Mean maximum temperature remained highest (40.46°C) during the month of May in Patna district followed by Samastipur (Zone I) with temperature value 39.01°C and so during summer season Patna (Zone IIIB) was hottest with 37.35°C maximum temperature among all the four districts.

For Samastipur district, slope of linear trend in maximum temperature showed upward trend (0.02°C/year) for post-monsoon and downward (-0.009°C/year and -0.02°C/year) for winter and pre-monsoon seasons. Minimum temperature showed variation of 0.028°C/year for post-monsoon and 0.014°C/year for winter seasons respectively. However pre-monsoon season showed negative trend (-0.003°C/year).

For Madhepura district (Zone II), slope of linear trend in maximum temperature showed upward trend (0.018°C/year) for post-monsoon and downward (-0.008°C/year and -0.021°C/year) for winter and pre-monsoon seasons. An upward trend in minimum temperature was observed during post-monsoon and winter to the tune of 0.026 and 0.017°C/year respectively. Pre-monsoon season temperature showed decreasing tendency at the rate of -0.001°C/year.
For Bhagalpur district (Zone IIIA), slope of linear trend in maximum temperature showed upward trend (0.021°C/year) for post-monsoon and downward (-0.009°C/year and -0.025°C/year) for winter and pre-monsoon seasons.

Positive trend in minimum temperature for Bhagalpur (0.030°C/year) and Patna (0.031°C/year) was observed for post-monsoon. During winter season 0.019°C/year and 0.014°C/year a slope in minimum temperature was observed. Pre-monsoon season showed negative trend to the tune of -0.002 and -0.005°C/year for Bhagalpur and Patna respectively.

Table 1. Monthly and seasonal temperature variation in Samastipur district

Zone	District	Month/Season	Maximum Temperature (°C)	Minimum Temperature (°C)
I	Samastipur	October	31.95	22.28
		November	28.84	15.41
		December	24.73	10.89
		January	23.54	9.94
		February	26.71	12.44
		March	32.90	17.45
		April	37.89	22.78
		May	39.01	25.85
		ON (October-November)	30.40	18.84
		DJF(December-January-February)	24.99	11.09
		MAM (March- April- May)	36.60	22.02

Table 2. Monthly and seasonal temperature variation in Madhepura district

Zone	District	Month/Season	Maximum Temperature (°C)	Minimum Temperature (°C)
II	Madhepura	October	31.60	21.68
		November	28.71	15.10
		December	24.86	10.69
		January	23.63	9.39
		February	26.57	11.74
		March	32.32	16.40
		April	36.60	21.45
		May	37.00	24.15
		ON (October-November)	30.15	18.39
		DJF(December-January-February)	25.02	10.61
		MAM (March- April- May)	35.30	20.67

Table 3. Monthly and seasonal temperature variation in Bhagalpur district

Zone	District	Month/Season	Maximum Temperature (°C)	Minimum Temperature (°C)
IIIA	Bhagalpur	October	31.25	21.08
		November	28.33	14.62
		December	24.87	10.26
		January	23.92	9.28
		February	27.04	11.95
		March	32.75	16.65
		April	36.97	21.62
		May	37.31	24.10
		ON (October-November)	29.79	17.85
		DJF(December-January-February)	25.28	10.50
		MAM (March- April- May)	35.68	20.79

Table 4. Monthly and seasonal temperature variation in Patna district

Zone	District	Month/Season	Maximum Temperature (°C)	Minimum Temperature (°C)
III B	Patna	October	31.97	21.36
		November	28.79	14.77
		December	24.69	10.09
		January	23.70	9.29
		February	26.95	11.89
		March	33.05	16.72
		April	38.54	22.43
		May	40.46	26.07
		ON (October-November)	30.38	18.06
		DJF(December-January-February)	25.11	10.42
		MAM (March- April- May)	37.35	21.74

Impact of temperature on rabi crops

Wheat

Simulation studies performed for different time periods using HADCM3 factors at four centres located in three different agroecological zones showed that simulated yield of wheat may decline in future time periods. Simulated yield of wheat (HUW 468) decreased from the baseline in 2050 and 2080 to 3.6% and 14.1% respectively for Samastipur. At Madhepura, decline in yield from the baseline was by 5% during 2020 and 13% and 21% for 2050 and 2080 respectively. Patna and Bhagalpur showed decrease in simulated yield around 40% for 2080s [21].

Winter Maize

Simulated yield of winter maize showed an increase from the baseline. For Samastipur, this increase was 10.7, 18.7 and 37.4% for 2020, 2050 and 2080 respectively. Maximum increase was observed in Bhagalpur viz. 18.2, 25.4 and 76.7% for all the three time-periods respectively. For Madhepura maize yield increase ranged from 8.8 to 23.6% from 2020 to 2080 time period. Increase in simulated maize yield was 8.4, 14.1 and 28.5 % respectively for 2020, 2050 and 2080 in Patna district [21].

Chickpea

Generally, chickpea adapts to high temperatures, however, heat stress during reproductive phase can cause significant yield loss. At Pusa, sowing of chickpea on 22nd November showed an increase of simulated yield from the baseline upto 23.9, 17.5 and 6.7 % for 2020, 2050 and 2080 time periods. In case of Patna, 22nd November sowing of chickpea showed an increase in simulated yield from the baseline to 3.4% for 2020 only, whereas during 2050 and 2080, yield is declined to the tune of 12.2 and 29.9 % respectively [22].

Predicted increase in temperature for future time periods may prove to be detrimental in future time periods for rabi crops, however, crop like winter maize may be benefitted due to increase in temperature upto some extent, i.e. there is possibility of substituting wheat to winter maize in Bihar.

Mitigation strategies to combat impact of climate change

The reduction in concentration of CO_2 in the atmosphere can be achieved by enhancing the rates of removal of the atmospheric CO_2 through carbon sequestration. Mitigating climate change by reducing fossil fuel emissions improves quality of soil and water resources and enhances agronomic productivity [23]. Agriculture conservation practices like use of different cropping and plant residue management and organic management can enhance soil carbon storage. Practices like increase soil carbon are direct seeding, perennial forage crops, windbreaks, and proper straw management. Using high yielding varieties and maximizing yield potential can also increase soil carbon. The overall benefits of soil carbon sequestration need to be viewed as an opportunity to improve soil quality as well as the environment. Diversifying the production system by including agroforestry may reduce the risks associated with climatic variability in synergy with climate change mitigation. The interactions of the different components of agroforestry systems can help absorb and sequester carbon dioxide and other greenhouse gasses from the atmosphere [24].

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