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Climatic Variability and Impact of Climate Change on Rice and Wheat in the Eastern Plain Zone of Uttar Pradesh, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

In this research climate variability and impact of climate change on major crop i.e. rice and wheat in the Eastern plain zone were investigated. For this study temperature (maximum & Minimum) and rainfall were collected from different sources such as India meteorological Department, Lucknow and Banaras Hindu University, Department of agronomy, Institute of agriculture science Varanasi, Yield data of crop was collected from Directorate of Economics and statistics, Ministry of agriculture. Historical data (2000-2020) on different meteorological parameters of Eastern Plain Zone of Uttar Pradesh (Azamgarh, Ayodhya, Ghazipur) were analyzed. Seasonal as well as annual variability for maximum & minimum temperature, rainfall of Eastern Plain Zone of Uttar Pradesh for the period of 2000-2020 were computed. From the analysis it was found that, the average temperature of Eastern Plain Zone of Uttar Pradesh has been 31.6℃. The highest average temperature was 32.5℃ in the year 2009 while the lowest temperature was 30.4℃ in the year 2014. Over the year from 2000 to 2020 there has been sharp/significant increase in the temperature, which is approximately between 31.6℃ to 32.5℃.

Even in the year 2009 there was an increase of approximately 0.9℃ in average temperature. Understanding trend in rainfall is one of the crucial parameters for various sectors. Furthermore average rainfall was decreasing by 0.53mm every year during 2000-2020.

Keywords: Climate variability; trend; maximum & minimum temperature; rainfall; rice and wheat yield.

1. INTRODUCTION

Climate change will very likely affect future crop growth and consequently crop management. In detail, there are many climatic factors affecting agro ecosystems and thereby influencing crop yield indifferent ways. Climate change poses a substantial challenge to agriculture by altering the timing of crop development, reducing photosynthetic efficiency and biomass production in the summer and creating a reliance on irrigation due to changes in rainfall patterns [1]. Reported that the Country-wide annual surface air temperature has increased by 0.4°C/100 years in 20th century but the rate of increase slowed down in the recent three decades. The monsoon seasonal rainfall was in decreasing trend over east Madhya Pradesh and adjoining areas, North-east India and parts of Gujarat and Kerala [2]. Climate change is a global phenomenon with widespread impact on natural ecosystems. Increasing concentration of GHGs is contributing to rise in the temperature of earth surface which has already increased by 0.85°C over the period 1880 to 2012 (IPCC, 2014). Lal et al. [3] expected an increase in annual mean surface air temperature of 1°C over Indian subcontinent in 2040s over 1980s. Unpredictable weather events such as floods, droughts, amplified rainfall intensity; frosting, temperature fluctuations etc. are some of the factors affecting the natural systems. High mountain areas such as Himalayas are likely to get most disrupted from the climate change and thus present an ideal site to study the impact of climate change [4-6]. North Western Himalayas have warmed at a rate higher than the global average during the last century [7]. High mountainous region, minimum temperature has increased at an elevated pace, whereas in North Western Himalayas the rise in air temperature is primarily due to rapid increase in both the maximum and minimum temperatures, with former increasing more rapidly [8]. Rainfall in recent years was declining. However, the monsoon rainfall was excess in 2007 and unusual summer rains were received much ahead in 2008. 1987, 2002 and 2008 were typical monsoon years during which rainfall distribution was different when compared to the normal monsoon behavior. The distribution of rainfall is such that it may lead to frequent floods during monsoon or drought during summer. This phenomenon appears to be more frequent and it can be attributed to global warming due to man-made interventions. It will result in severe consequences on various sectors and it is more so in agricultural sector including food security and food prices. Keeping the above in view, an attempt was made to analyze rainfall trends, climate shifts and shifts in cropping systems over Kerala. Rice and wheat are the major cereal crops of India. Therefore, primary food security concerns are focused on improving and sustaining their productivity. These two crops occupy a significant area in the IGP of South Asia, which extends from Pakistan in the west to Bangladesh in the east. Wheat is an important Rabi cereal crop of Punjab. It was grown on 3.3 million ha area with production of 160.07lakh tones during 2015-16 (India state,

2016). [9] reported a reduction in crop duration due to increased temperature and predicted a possible increase in rice yields under rainfed conditions under changing climatic scenario in Kerala. Climatic variables which affect crop growth and development are temperature, precipitation, radiation and humidity. Climate change and variability can affect yield of Rabi and Kharif crops through their direct as well as indirect effects such as weather induced changes in incidence of insect pests and diseases [10]. The Climate change is a particular environmental concern for the region, as these have numerous direct and indirect links to agricultural production. Elevated CO_2 increases yields of important crop of the region such as wheat and rice, but the degree of change is modulated by changes in temperature and rainfall. Often, these interactions may result in production decline. The increased incidence of weather extremes such as onset of rainfall, and duration and frequencies of drought and floods will also have major effects, and preliminary reports indicate that the recent declines in yields of rice and wheat in the region could have been partly due to changes in weather extremes [11]. Recent studies on the impacts of possible future climate over this region indicate spatio-temporal variations in impacts on rice and wheat crops in India [12]. Assessment of the vulnerability of crops requires spatial and temporal scenarios of future climate.

2. MATERIALS AND METHODS

Temperature and rainfall data from the past 21 years (2000-2020) for Eastern Plain Zone, Uttar Pradesh, were collected and analyzed to observe trends in rainfall and temperature. Eastern Plain Zone is located at 26°05' N latitude, 79°05' E longitude. It falls under the Eastern Uttar Pradesh. This zone comprises 8 districts: Azamgarh, Mau, Ballia, Ayodhya, Ghazipur, Jaunpur, Sant Ravidas Nagar, & Varanasi.

2.1 Meteorological Data used

The daily and monthly weather data of maximum and minimum temperature and rainfall of Eastern Uttar Pradesh collected for the period of 2000 - 2020 to study the climatic variability, trend analysis and determining normal values of weather variables for this location.

2.2 Temperature

It is the measure of hotness or coldness of a body. The terms hot cold which anyone feels are terms used to denote a comparison between a higher or lower temperature. Since temperature can be high or low, we use instruments to measure at what point they are at any given point. We use thermometers to help us put temperature in perspective. Thermometers give us a scale in which to compare higher or lower temperature.

2.3 Average Temperature

$$\frac{Tmax.+Tmini.}{2}$$

2.4 Mean Total Rainfall

The mean weekly, seasonal and annual rainfall is worked out to study the rainfall climatology of that area. The formula is given below:

$$P = \frac{1}{n}\sum_{i=1}^{n} Pi$$

Where,

Pi, is the rainfall at single station
i and n, is the no. of station
P, Mean total rainfall (mm)

2.5 Yield Data

The yield data of Rice and Wheat crop for Eastern Uttar Pradesh were taken from DACNET (Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare) for 20 years (2000-2020)

2.6 Variability and Trend Analysis

The long-term trend in maximum, minimum temperature and rainfall has been calculated on seasonal and annual for Eastern Plain Zone. Trend was studied in 21 years period seasonal trend was observed for four seasons *i.e.* winter season/ cold weather (December, January and February) Summer season/Hot Weather season/ (March, April and May) South-West Monsoon/Monsoon (June, July, August and September) Post- monsoon season (October and November) by using liner trend analysis. The mean, standard deviation (SD) and coefficient of variation (CV) of rainfall and temperatures have been calculated to analyses [13].

Table 1. Geographical locations of selected districts Eastern Plain Zone

Station	Latitude	Longitude	Altitude
Azamgarh	26° 03' N	83° 13' E	83.69 m
Ayodhya	26° 48' N	82° 14' E	97 m
Ghazipur	25° 54′ N	83° 58' E	67.50m

2.7 Trend Analysis

A trend is a significant change over time exhibited by a random variable. In general, the magnitude of trend in a time series is determined either using regression analysis (parametric test) or Mann–Kendall's test (non-parametric method). Both these methods assume a linear trend in the time series. In this particular study, both the linear regression and Mann-Kendall' tests were employed.

2.8 Correlation Analysis

Correlation is a term that refers to the strength of a relationship between two variables. A strong or high correlation means that two or more variables have a strong relationship with is other, while a weak or low correlation means that the variables are hardly related. The correlation coefficients between different meteorological parameters and Rice and wheat yield (2000 to 2020) were worked out using EXCEL.

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

3. RESULTS AND DISCUSSION

From the seasonal and annual variability of temperature following results were found.

3.1 Seasonal and Annual Temperatures (Maximum & Minimum)

Seasonal and annual mean, standard deviation (SD) and coefficient of variation (CV) were computed for temperature and rainfall. Data related to seasonal and annual temperatures (maximum & minimum) variability of Eastern Plain Zone have been presented in Table 1. It can be observed from the data analyzed over last 21 years (2000-2020) that seasonal variation of maximum mean temperature was 35.9℃ in summer season, 33.9℃ in SW Monsoon, 30.4℃ in post monsoon and 23.6℃ in winter season. Maximum mean temperature 32.5℃ was found in year of 2009. Seasonal variation of minimum mean temperature 19.8℃ in summer season, 24.8℃ in South West Monsoon (SW), 16.4℃ in post monsoon and 8.9℃ in winter season. Minimum mean temperature 17.2℃ was found in year of 2002 at Eastern Plain Zone. The SD for maximum temperature 0.74 in summer season, 1.41 in SW monsoon, 0.53 in post monsoon and 0.26 in winter monsoon. Maximum SD 1.18 was found in year of 2020. Standard deviation for minimum temperature 1.20 in summer season, 1.52 in SW monsoon, 0.93 in post monsoon and 1.13 in winter monsoon. Minimum SD 0.42 was found in the year 2018. The Coefficient of variation for maximum temperature in summer season 2.05%, SW monsoon 1.41%, post monsoon 1.74% and winter monsoon 1.14%. The Coefficient of variation for maximum temperature for Eastern Plain Zone is highest in the Year of 2020 and it is observed as 3.78 %. The CV for minimum temperature 6.04% in summer season, 6.11% in SW monsoon, 5.68% in post monsoon and 12.58 in winter monsoon. Lowest CV was found 2.23 were found in 2018.

3.2 Rainfall Variability Eastern Plain Zone of U.P.

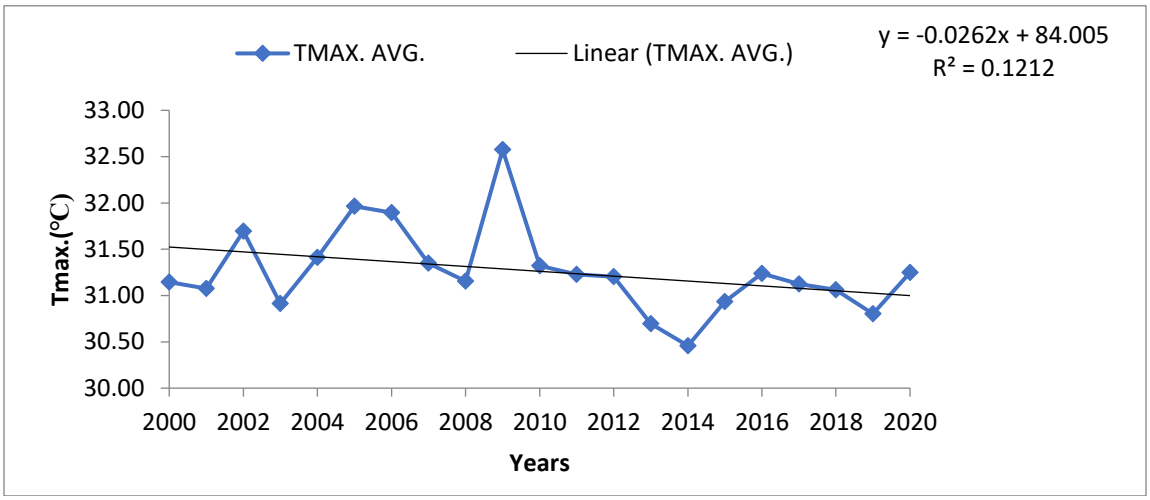
Data related to seasonal and annual rainfall variability of Eastern Plain Zone have been presented in Table 2 Seasonal rainfall 43.18 mm in summer season, 792.91 mm in SW Monsoon, 35.39 mm in post monsoon and 28.87 in winter season. Maximum rainfall was found 1160.3 mm in year of 2003. Seasonal CV of rainfall 5.58, 0.77, 19.32, and 38.72% during summer season, South-West monsoon, post monsoon and winter respectively. Highest CV of rainfall was 40.0% in 2016. Standard deviation of rainfall was observed 4.13, 37.84, 6.84 and 11.18 during summer season, SW monsoon, post monsoon and winter monsoon. Highest standard deviation of rainfall was 411.0 in 2016 for Eastern Plain Zone.

3.3 Trend Analysis of Eastern Plain Zone of Uttar Pradesh during 2000-2020

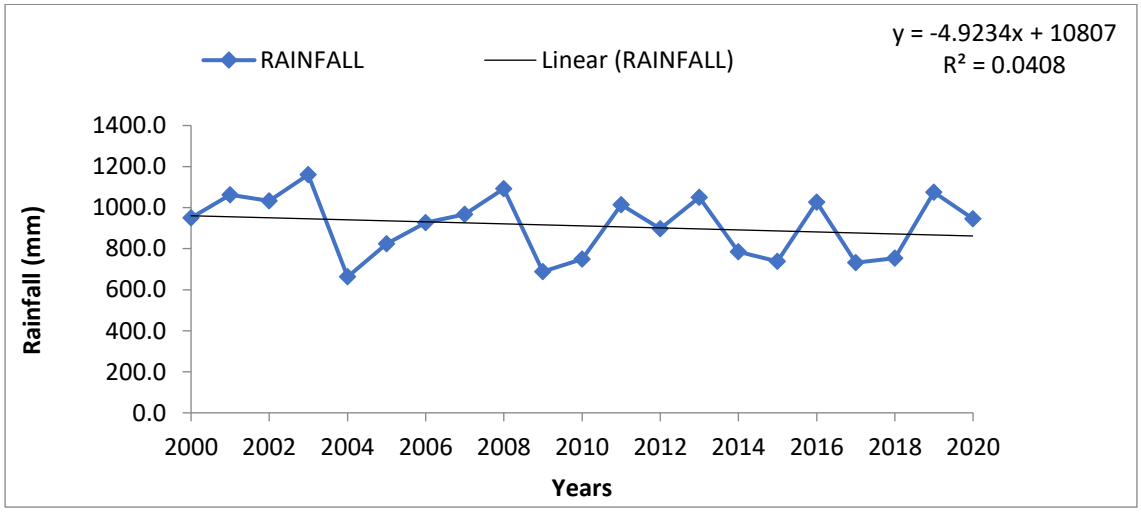
The results of trend analysis in Graphs 1, 2 & 3 analyses of maximum temperature and rainfall showed that decreasing trend& minimum temperature showed that increasing trend.

Table 2. Seasonal and annual mean value standard deviation coefficient of variation of maximum and minimum temperature, and rainfall at EPZ of U.P. during 2000 to 2020

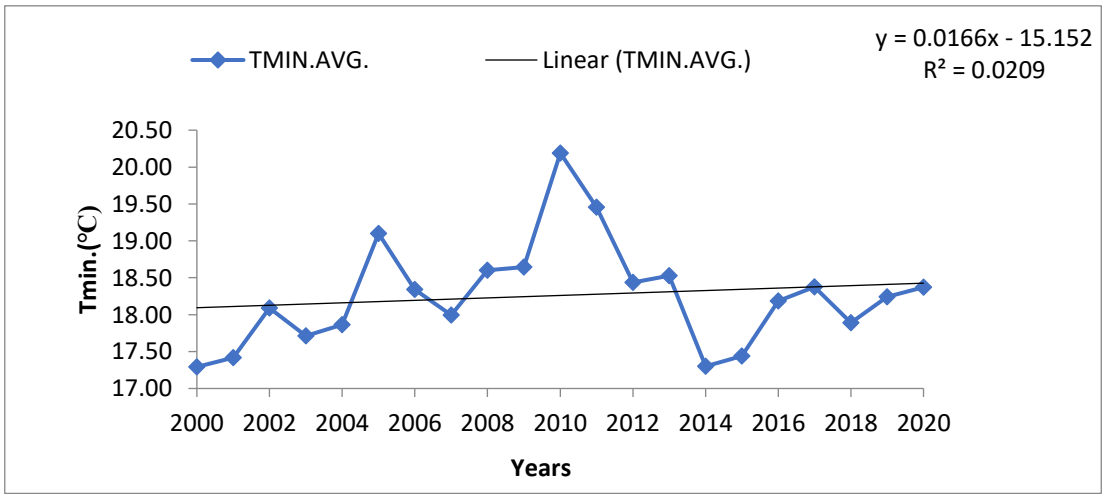
Period Temperature(℃)							Rainfall(mm)		
Season	Tmax			Tmin			Mean	SD	CV (%)
	Mean	SD	CV (%)	Mean	SD	CV (%)			
Summer (March to May)	35.9	0.74	2.05	19.8	1.20	6.04	43.18	4.13	9.58
SW. Monsoon (June to Sep.)	33.9	0.48	1.41	24.8	1.52	6.11	792.91	37.84	0.77
Post Monsoon (Oct. to Nov.)	30.4	0.53	1.74	16.4	0.93	5.68	35.39	6.84	19.32
Winter Monsoon (Dec. to Feb.)	23.6	0.26	1.14	8.9	1.13	12.58	28.87	11.18	38.72
Annual									
2000	31.1	0.21	0.66	17.2	1.53	8.84	950.1	77.1	8.1
2001	31.0	0.19	0.62	17.4	1.54	8.83	1061.8	188.2	17.7
2002	31.7	0.17	0.54	18.0	1.59	8.77	1032.7	165.6	16.0
2003	30.9	0.28	0.92	17.7	1.55	8.77	1160.3	141.8	12.2
2004	31.4	0.51	1.61	17.8	1.79	10.05	662.8	131.9	19.9
2005	31.9	0.48	1.49	19.1	1.30	6.79	823.2	58.6	7.1
2006	31.9	0.27	0.85	18.3	0.84	4.58	927.4	82.9	8.9
2007	31.3	0.29	0.93	17.9	0.78	4.34	967.4	241.0	24.9
2008	31.1	0.53	1.69	18.6	0.91	4.91	1092.1	298.1	27.3
2009	32.5	0.70	2.16	18.6	1.12	6.03	688.7	210.9	30.6
2010	31.3	0.36	1.15	20.1	1.09	5.40	749.6	31.5	4.2
2011	31.2	0.62	1.99	19.4	0.86	4.43	1014.5	146.5	14.4
2012	31.2	0.32	1.03	18.4	0.97	5.25	897.6	139.0	15.5
2013	30.7	0.50	1.64	18.5	1.38	7.44	1050.6	83.7	8.0
2014	30.4	0.11	0.36	17.3	2.10	12.13	784.4	140.6	17.9
2015	30.9	0.29	0.94	17.4	2.49	14.26	737.3	159.7	21.7
2016	31.2	0.44	1.41	18.1	1.53	8.40	1027.0	411.0	40.0
2017	31.1	0.14	0.43	18.3	1.02	5.55	732.6	101.3	13.8
2018	31.0	0.23	0.74	17.8	0.42	2.36	753.2	39.9	5.3
2019	30.8	0.38	1.23	18.2	0.47	2.60	1075.1	126.7	11.8
2020	31.2	1.18	3.78	18.3	1.24	6.74	945.0	148.1	15.7



Graph 1. Trend analysis (temperature maximum) of Eastern Plain Zone of Uttar Pradesh during 2000-2020



Graph 2. Trend analysis (rainfall) of Eastern Plain Zone of Uttar Pradesh during 2000-2020



Graph 3. Trend analysis (temperature minimum) of Eastern Plain Zone of Uttar Pradesh during 2000-2020

Table 3. Correlation between yield of rice & weather parameters at Eastern plain zone of U.P. during 2000-2020

Parameters	Yield(t/h)	Tmax.	Tmin	Rainfall
Yield(t/h)	1			
Tmax.	-0.330	1		
Tmin	-0.278	-0.130	1	
Rainfall	0.401	-0.329	-0.116	1

** Significance of r<0.444 at 5%, **significance of r<0.561 at 1%*

Table 4. Correlation between yield of wheat & weather parameters at Eastern plain zone of U.P. during 2000-2020

Parameters	Yield(t/h)	Tmax.	Tmin	Rainfall
Yield(t/h)	1			
Tmax.	-0.811**	1		
Tmin	-0.023	0.021	1	
Rainfall	0.214	-0.244	-0.084	1

** Significance of r<0.444 at 5%, **significance of r<0.561 at 1%.*

3.4 Impact of Weather Parameters on Major Crops (Rice & Wheat) of Eastern Plain Zone

The Yield of rice& wheat was considered as dependent variables and weather parameters viz., maximum temperature, minimum temperature, and rainfall were considered as independent variables. Further statistical analysis carried out using correlation coefficient analysis to know the effect of above selected weather parameters on the yield of rice& wheat

3.5 Correlation between Yield of Rice & Weather Parameters at Eastern Plain Zone of U.P. during 2000-2020

The correlation data with respect yield of rice with meteorological parameters are presented in Table 3. At Rainfall (0.401) positively correlated with yield of rice and maximum temperature (-0.330), minimum temperature (-0.278) negative correlated with yield of rice at Eastern Plain Zone of U.P. during 2000-2020. The study revealed that there was significant impact of different weather parameters (Tmax. & Tmin) on yield of rice.

3.6 Correlation Between Yield of Wheat & Weather Parameters at Eastern Plain Zone of U.P. during 2000-2020

The correlation data with respect yield of wheat with meteorological parameters are presented in Table 4 at minimum temperature (0.158) positively correlated with yield of wheat and maximum temperature (-0.352), rainfall (-0.353) negative correlated with yield of wheat at EPZ of Eastern U.P. during 2000-2020. The study revealed that there was significant impact of different weather parameters (Tmax. & Rainfall) on yield of wheat.

The productivity of rice, maize, sorghum, and ragi crops negatively influenced with increase in actual average maximum temperature. Productivity of barley, rice, maize, and ragi crops decline due to excessive rain [14].

4. CONCLUSION

In this study the climatic variability and effect of weather parameters on yield of rice and wheat crop were studied. From the trend analysis result, it was found that maximum temperature and rainfall showed decreasing trend & minimum temperature showed increasing trend. Weather parameters play an important role in rice and wheat yield in Eastern Plain Zone during 2000-2020.Rainfallpositively correlated and maximum temperature, minimum temperature negatively correlated with yield of rice and minimum temperature positively correlated and maximum temperature, rainfall negative correlated with yield of wheat at Eastern Plain Zone.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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