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Long Term Analysis of Rainfall and Temperature Under Different Climate Change Scenarios in Southern Telangana State

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ABSTRACT

The understanding of long term variability in Rainfall and Temperature is the key for enhancing agricultural productivity in the semi arid tropical region. A 30 year base period (1984-2014) data of rainfall and temperature in Rangareddy district of South Telangana, were analysed to compare with trends in various climate change scenarios. Two climate change scenarios of representative concentration pathway (RCP) of 4.5 and 8.5 were selected with ensembled data for the time periods of 2025, 2050 and 2090. The annual, seasonal, weekly rainfall, rainy days and temperatures were analysed. The results indicated that, the mean annual and seasonal rainfall (MAR, MSR) predicted in 2025, 2050 and 2090 are (MAR: 916.20; 939.98; 982.60 mm & MSR: 721.84; 744.87; 731.36 mm) and (MAR: 953.36; 942.29; 1045.82 mm & MSR: 758.29; 744.34; 874.76 mm) under RCP 4.5 & RCP 8.5 respectively. The numbers of annual & seasonal rainy days are decreased by 47.95, 43.87 & 42.85 % and 44.89, 40.81 and 39.79 % under RCP 4.5 & 8.5 during 2025, 2050 and 2090 over the base period. The seasonal average temperature is increased by 10.04 & 11.71 % (2025); 14.04 & 15.69 % (2050) and 14.33 & 19.69 % (2090) under RCP 4.5 and 8.5 respectively as compared to the base period. These results would help to farming community, policy makers and academicians for adopting climate resilient technologies in southern Telangana state.

Keywords: *Base period, Climate change, Extreme events, RCPs, Rainy days, Temperature, Weather parameters*

INTRODUCTION

Telangana is India's youngest state, relying on seasonal rainfall for crop production, particularly in rainfed systems, with 55 percent of net sown area (50 lakh ha) and crop productivity of around 1.0 t/ha [28]. Millets, maize, oil seeds, pulses, and cotton are the major rainfed crops grown in the region in soils with an average depth of 30 to 50 cm, low organic carbon (0.5 percent) and poor water holding capacity, resulting in low productivity [27]. Cotton accounts for 3.7 lakh ha of the 17.05 lakh ha cultivated in South Telangana during the *kharif* season [27]. These crops are more vulnerable to variations in rainfall and temperature over time and space [30]. The change in air temperatures (maximum and minimum) as well as rainfall variability of 30 to 60 % had an impact on the yield and profitability of major crops under rainfed farming in the state [6]. Future air temperature analysis is crucial because it affects crop evapotranspiration (ET), yield, and quality. According to reports, raising the temperature adds 10.83 percent to the ET of wheat, maize, and cotton [34]. Climate change in future weather parameters of rainfall, quantity, and distribution during crop growth period is regarded as the most significant challenge for crop production of major crops in southern districts such as Rangareddy in Telangana [28].

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Under future climate change, the analysis of critical weather parameters such as rainfall and air temperature would provide valuable information for water resource planning and management, crop planning and management [35]. Temperature changes will influence crop evapotranspiration, which has a direct impact on crop yield [8]. The maximum temperature in southern Telangana is expected to rise by 1 to 1.53% and 2.5% between 2030 and 2060 [3]. Many studies have found that increasing the temperature raises the ET of maize, wheat, and cotton by 7.9 percent, 10.83 percent, and 8.4 percent, respectively, in various parts of the country [26]. The average annual rainfall in southern Telangana deviated from normal by 5.16 percent in 2030 and 9.5 percent in 2060, and 5 to 25 percent excess rainfall is forecast for parts of peninsular India [20]. Climate change impacts, particularly on rainfall and temperature, must be studied in order to develop future strategies for judicious use of water resources and crop planning, particularly in rainfed areas [16] [27]. To create future plans for effective water and agricultural planning in rainfed areas, long-term climate data analysis is needed, with a focus on temperature and rainfall. The hydrologic impact models can directly use this data for long-term productivity analysis [1].

There are two methods for predicting or estimating future climate variables such as rainfall and air temperatures. One method is to use ClimGen or LARS-WG to forecast autoregression models based on long-term historical data [22]. Another option is to use GCM ensemble data for climate change scenarios with RCPs ranging from 2.5 to 8.5 as defined in the IPCC 5th Assessment Report (AR5) [9]. Many scientists have reported that RCP 4.5 and RCP 8.5 are appropriate for the Indian subcontinent [5] [33]. Similar projections for different agroclimatic conditions were also made for Central and North India in order to study future climate changes and their impact on agriculture [14]. Under the RCP 8.5 scenario, the relative increase by the period 2071-2100 over the control period 1871-1900 ranges from 13 to 50% [21]. Under RCP 4.5 and 8.5, all-India rainfall is projected to increase by 4 to 5% by the 2030s and by 6 to 14% by the end of the century (2080s) when compared to the 1961-1990 baselines [32]. Under highest emission scenario (RCP 8.5), most models predict an increase in extremely heavy rainfall [25]. Under RCP 6.5 (medium stabilisation scenario), mean temperature in India is expected to rise by 1.7 to 2°C by 2030, 3.3 to 4.8°C by 2080, and very high under RCP 8.5 [19]. They also reported that the summer mean air temperature projections for central and peninsular India show the greatest spread in the far future time slice. Such projections, however, are not available for South India, particularly for southern Telangana, where rainfall is the primary water resource for crop production. It is desirable to analyse and predict the change in critical climatic variables, such as temperature and rainfall, which will provide valuable reference for future water resources planning and management in the region. The current study sought to comprehend historic rainfall and temperature trends in southern Telangana from ensembled downscaled climate data time-series under selected RCP scenarios and the base period.

MATERIALS & METHODS

Gunegal Research Farm (GRF), ICAR-Central Research Institute for Dryland Agriculture (CRIDA), Rangareddy district of Telangana, is located at 78° 40 18 N and 17°2 5 E, with a mean sea level of 621 m. The CRIDA weather station at GRF was used to collect daily climate data such as rainfall, maximum and minimum temperatures. The study area's annual and seasonal rainfall averages were 702 and 479 mm, respectively. The average temperature in the study area was 25.5°C, with average minimum and maximum temperatures of 8.94 and 42.06°C, respectively.

2.1 Baseline data

Thirty years of daily meteorological data from 1985 to 2014 were collected from the Gunegal research farm of the ICAR-CRIDA weather station and used as a baseline for comparing future climate projections under various climate change scenarios. The data (daily rainfall, minimum and maximum temperatures) were subjected to quality control checks such as missing values, typographical errors, and extreme values.

2.2 Climate change scenarios

The IPCC report's RCP 4.5 represents the world's moderate warming scenario. According to RCP 4.5, GHG and total radiative force will be around 650 ppm CO_2 equivalent and 4.5 Wm^{-2} by 2100. RCP 8.5 is the most extreme warming scenario, with GHG and total radiative force reaching 1370 ppm CO_2 equivalent and 8.5 Wm^{-2}, respectively [11]. We used RCP 4.5 and RCP 8.5 scenarios in this study because they represent moderate and highest warming scenarios, respectively, that are suitable for the Indian subcontinen [24]. Table 01 shows the details of four representative concentration pathways (RCP) with time periods. As a result, downscaled climate data for RCP 4.5 and 8.5 are downloaded from the website http://gismap.ciat.cgiar.org/MarkSimGCM/ (Climate Change on Agriculture and Food Security) and used in the current study of rainfall and temperature analysis for South Telangana, with Ranagreddy district serving as a representative for the region with similar agro-climatic conditions.

2.3 Climate data analysis

The collected rainfall data is analysed for weekly, monthly, seasonal, and annual rainfall, as well as variability in mean, maximum, and minimum air temperatures from 2010 to 2100, and is compared to a base period of 1985 to 2014. Three time scenarios were developed based on the variability/changes in rainfall and air temperatures: near century (2010-2040), mid century (2041-2070), and end century (2071-2100), which represent the years 2025, 2050, and 2090, respectively. Statistical parameters such as standard deviation (SD) and co-efficient of variation (CV) were estimated using standard formulas for all climatic variables across all time scenarios [28].

$$\sigma = \left[\frac{E\left(x_i - x_{avg}\right)^2}{(n-1)}\right]^{1/2} \text{ ----------(01)}$$

Where, x_i Rainfall magnitude in mm, i=1, 2 to n, n is the total number of years.

$$C_v = \left(\frac{\sigma}{x_{avg}}\right) \times 100 \text{ -------- (02)}$$

Where, C_v is the co-efficient of variation & standard deviation.

RESULTS AND DISCUSSION

Baseline Data (1985-2014)

During the baseline period, the meteorological station at Gunegal Research Farm (GRF), ICAR-CRIDA, recorded daily maximum and minimum air temperature and rainfall. Figures 01–05 show the trends in mean daily rainfall depth, maximum and minimum temperature for the base period. Tables 02–04 present an analysis of mean weekly rainfall, seasonal, annual, and rainy days. In the study area, the mean seasonal and annual rainfall during the base period was 479 mm and 702 mm, respectively. The average monthly rainfall showed that the most rainfall (131.50 mm) was received in July and the least in February (06.37 mm). The weekly rainfall ranged from 15.6 to 42 mm, with the lowest at 23 weeks and the highest at 39 weeks. The monthly rainfall from June to September accounted for 68.12% of the total mean annual rainfall. When compared to other weeks, the standard weeks (SW) from 22 to 44 received the most rainfall. The highest and lowest mean annual temperatures were 27.70 and 23.50 degrees Celsius, respectively. The maximum and minimum seasonal mean temperatures were 28.0 and 25.35 degrees Celsius, respectively.

Rainfall and temperature analysis under climate change scenarios and time periods

Table 02 shows that, the wet weeks (>20 mm) during crop season (June to September) are 11, 10 & 9 and 11, 10 & 10 weeks in 2025, 2050, and 2090 under RCP 4.5 and RCP 8.5, respectively, as compared to the base period seasonal wet weeks of 14, out of total seasonal weeks (19 SW). Furthermore, under RCP 4.5 and 8.5, dry weeks (20 mm) increased by 03 weeks in 2025 to 05 weeks in 2090. It was also discovered that, the weekly maximum rainfall increased by 194.13 and 266.92 percent, 169.17 and 208.89 percent, 195.65 and 207.31 percent, respectively, under RCP 4.5 and 8.5 during 2025, 2050, and 2090 (42.95 mm). The coefficient of variation in weekly rainfall indicates that, the variability in weekly rainfall is greater between 2025 and 2090 under both RCP 4.5 and 8.5 as compared to the base period, which is important for crop

planning and sowing date advice to farmers in south Telangana.
The expected changes in monthly rainfall for each time period ranges between RCP 4.5 and 8.5, as shown in Table 03. The monthly rainfall shows an increase in rainfall during seasonal months under both RCP 4.5 and 8.5 during the 2025, 2050, and 2090 years when compared to the base period. However, the number of rainy days in the corresponding month has decreased when compared to the baseline period (1985-2014). Over the base period, the mean monthly number of rainy days decreased by 58.72 to 35.13 percent under RCP 4.5 and 8.5. The coefficient of variation in monthly rainfall indicates that there was more variability under both RCP 4.5 and 8.5 in all years when compared to the base period.
Table 04 shows seasonal and annual rainfall projections under RCP 4.5 and 8.5 for 2025, 2050, and 2090. The average seasonal (June to September) and annual rainfall of the base period were 479 mm and 702 mm, respectively, with standard deviations of 130 mm and 88 mm and coefficients of variation of 18.52 and 18.40 percent. The synthetic long-term series data for average annual rainfall under RCP 4.5 in 2025, 2050, and 2090 are 916.20, 939.98, and 982.6mm, respectively, with standard deviations of 176.40, 189.35, and 201.01 mm and coefficients of variation of 19.25, 20.14, and 20.45 percent. Under RCP 8.5, the average annual rainfall increased to 953.36 942.29 and 1045.82 mm with standard deviations of 182.40, 183.12, and 210.10 mm and coefficients of variation of 19.13, 19.43, and 20.08 percent in the time periods of 2025, 2050, and 2090, respectively. The average seasonal rainfall in three time steps of 2025, 2050, and 2090 was 721.84, 744.87, and 731.36 mm, with standard deviations of 134, 140.01, and 145 mm and coefficients of variation of 18.56, 18.76, and 19.82 percent under RCP 4.5. However, under RCP 8.5, seasonal rainfall increased to 758.29, 744.34, and 874.76 mm with standard deviations of 140.2, 145.24 and 165.10 mm and coefficients of variation of 18.48, 19.51 and 18.87 percent, respectively. The analysis clearly showed that average annual rainfall (mm) increased by 30.53, 33.92 and 40% under RCP 4.5 and 35.83, 34.25 and 49% under RCP 8.5 during the 2025, 2050 and 2090 years respectively, over the base period (1985-2014). When compared to the base period seasonal rainfall, the average seasonal rainfall (mm) increased to 51, 55.87 and 52.98 percent under RCP 4.5 and 58.52, 55.70 and 82.98 percent under RCP 8.5 in three time scenarios of 2025, 2050 and 2090 years respectively. The number of rainy days during seasonal and annual rainfall series were estimated and compared to base data under RCP 4.5 and 8.5. Figures 06 and 07 show the results obtained for the number of rainy days in 2025, 2050 and 2090. When compared to the base period rainy days from 1985 to 2014, the seasonal number of rainy days decreases by 47.95, 43.87 and 42.85 percent under RCP 4.5 and 44.89, 40.81 and 39.79 percent under RCP 8.5. Annual rainy days are reduced by 36.44, 29.66 and 26.27 percent under RCP 4.5 and 31.35, 25.42 and 32.20 percent under RCP 8.5 over the base period in 2025, 2050 and 2090, respectively. The number of rainy days decreases across the RCP scenarios, while rainfall amounts increase in both seasonal and annual time series, indicating that extreme rainfall events are more likely in the region.
The rainfall and temperature analysis for three time scenarios (2025, 2050 and 2090) under RCP 4.5 and 8.5 revealed that seasonal and annual rainfall increased in all three time periods over the base period (1985-2014). Under the RCP 4.5 and 8.5 scenarios, the standard deviations for seasonal and annual mean rainfall show a positive trend, indicating an increase in interseasonal and annual variability in the future.
In all three time scenarios, the increase in seasonal and annual mean rainfall is greatest for RCP 8.5 compared to RCP 4.5. The average annual rainfall (mm) increased by 30.53 to 40% under RCP 4.5 and 35.83 to 49% under RCP 8.5 from 2025 to 2090, while the average seasonal rainfall (mm) increased by 51, 55.87 to 52.98% under RCP 4.5 and 58.52 to 82.98% under RCP 8.5 from 2025 to 2090. This could be because, under the RCP 8.5 scenario, most climate change models predict a northward shift in monsoon circulation by the end of the twenty-first century compared to the historic period [3] [21]. Similar findings were reported for peninsular India [24] [35], as well as for India under representative concentration pathways (RCP) of 4.5 and 8.5 [4] [10]. Rainfall projections are generally less reliable than temperature projections, and rainfall projections increase from RCP 4.5 to RCP 8.5, as well as from near century to end-of-century projections, indicating that long-term rainfall projections are generally more robust than short-term counterparts, and there is a consistent positive trend in the frequency of extreme rainfall days (e.g. > 40 mm day-1) for the decades 2050s and beyond [2]. The majority of models predict an increase in rainfall across almost all of India by the end of the twenty-first century compared to the end of the twentieth [5] [14] [25].
The monthly and weekly rainfall analyses show that the number of wet weeks has decreased from 14 in the base period to 9 and 10 under RCP 4.5 and 8.5, respectively. However, under RCP 4.5 and 8.5, the dry weeks are increased from 3 to 8 weeks in all three time steps, compared to 5 dry weeks during seasonal weeks. Rainfall is increasing seasonally and annually, and extreme events have been observed in all three time scenarios. It is well established that the global average surface temperature has risen over the last 150 years, with the last eleven years (1995-2006) being among the warmest. During the last century, the global land surface has warmed at a rate of 0.07 °C per decade [12] [17]. The increase in sea surface temperature causes more evaporation, while the increase in surface air temperature causes deeper convection. Similar outcomes are obtained. [18] [32] indicating that, the majority of models predict an increase in extremely heavy rainfall under the highest emission scenario (RCP 8.5). The weather extremes forecasts an increase in the frequency of heavy precipitation in many parts of the world in the twenty-first century [13] [15]. The literature estimates an increase in rainfall intensity over most Indian regions in the twenty-first century [14] [35].

Temperature

The analysis indicated that, the air temperatures are fairly high in the predicted climate. Overall, temperature is expected to increase in all cases, with higher temperature changes expected under RCP 8.5 than 4.5. The results of seasonal temperature analysis are represented in Figure 08. Air temperatures in the predicted climate are fairly high, according to the analysis. Temperature is expected to rise in all cases, with RCP 8.5 expecting a higher rise than RCP 4.5. Figure 08 depicts the seasonal temperature analysis results. Under RCP 4.5 and 8.5, average minimum temperature increased by 2.24 percent (0.44 °C) and 5.95 percent (1.17 °C), 9.62 percent (1.89 °C) and 11.91 percent (2.34 °C), 8.75 percent (1.72 °C) and 18.17 percent (3.57 °C), respectively. Under RCP 4.5 and 8.5, the average maximum temperature increased by 14.7 percent (4.83 °C) and 15.13 percent (4.97 °C), 16.65 percent (5.47 °C) and 17.93 percent (5.89 °C), 17.69 percent (5.81°C) and 20.58 percent (6.76 °C), respectively. Under RCP 4.5 and 8.5, the seasonal average temperature increased by 10.04 and 11.71 percent in 2025, 14.04 and 15.69 percent in 2050, and 14.33 and 19.69 percent in 2090, respectively, over the base period average temperature (26.25 °C). Under RCP 4.5 and 8.5, the average annual minimum temperature was reduced by 21.72 percent (2.7 °C) and 18.18 percent (2.26 °C), 9.98 percent (1.24 °C) and 4.26 percent (0.53 °C), 4.02 percent (0.5 °C), and 8.05 percent (1 °C) in the three time scenarios of 2025, 2050 and 2090, respectively (Fig. 09). Similarly, for the same periods, the maximum temperature increased by 13.31 percent (5.17 °C) and 14.34 percent (5.57 °C), 16.16 percent (6.28 °C) and 17.18 percent (6.67 °C), 17.37 percent (6.75 °C) and 21.9 percent (8.51 °C) under RCP 4.5 and 8.5. Under RCP 4.5 and 8.5, the annual average temperature rises by 4.83 and 6.46 percent in 2025, 9.84 and 11.98 percent in 2050 and 12.20 and 18.55 percent in 2090, respectively, compared to the base period average temperature (25.64°C).

The results clearly showed that the temperature change is uniform and steady from one time step to the next. Seasonal mean air temperature projections in Rangareddy district are likely to rise under both RCPs in near, mid, and end-of-century scenarios. The decade 2071-2100 is the warmest time slice projected by RCP 4.5 and RCP 8.5. Changes in mean temperature are greater under RCP 8.5 than under RCP 4.5, and the change in mean air temperature is robust for both RCPs and all time scenarios. Under RCP 4.5 and 8.5, the changes in mean air temperature compared to the base period data are examined in three time slices: Near Century (2010-2040), Mid Century (2041-2070), and End Century (2071-2100). To better understand the changes for each time period, the results are presented in three time scenarios. The future air temperature analysis revealed that the highest temperatures are obtained under RCP-8.5 (highest CO_2 emission), where the annual mean temperature increased by 6.46 to 18.55 percent compared to 4.83 to 12.20 percent and seasonal mean temperature increased by 11.71 to 19.69 percent compared to 10.04 to 14.33 percent from 2020 to 2090 under RCP 4.5. Seasonal and annual mean air temperatures have been increasing steadily from the early twentieth century to the end of the century. According to RCP 6.5 and RCP8.5, mean temperature in India is likely to be in the range of 1.7-2°C by 2030s and 3.3-4.8°C by 2080s. The significant change has been projected for the south eastern Indian region, with a change in mean temperature being less than 4°C under RCP 4.5 and greater than 5°C under RCP 8.55 [23]. They also reported that the summer mean air temperature projections for central and peninsular India show the greatest spread in the far future time slice [30]. The projected change is significant, and it is expected that this increase will exacerbate the monsoon's erratic behaviour in the future [7].

This analysis reveals that future projections are widely dispersed across the monsoon zone, indicating higher variability in temperature projections for the monsoon season. These findings will provide local policymakers with comprehensive information to combat the negative effects of climate change. As a result, for the region's on-farm infrastructure for water resource development and efficient use with climate smart crop planning [29].

CONCLUSION

Future climate change predictions are critical for efficient crop planning, on-farm water resource development, and SWC planning in SAT regions like South Telangana to boost agricultural productivity. In all time periods (2025-2090), the maximum increase in annual and seasonal rainfall was observed under RCP8.5 compared to RCP 4.5. A similar pattern was observed in the distribution of monthly rainfall. However, dry weeks (20mm) were found to be more common under RCPs than in the base period, despite the fact that rainfall amounts were much higher in the base period. It was because the number of rainy days decreased from 43 to 48 percent in annual series and 40 to 45 percent in seasonal series under RCP4.5 and 8.5 from 2025 to 2090 over the base period. The increase in seasonal average across RCPs and time periods over the base period may have a direct impact on increased water requirements for future crops in climate change scenarios over Southern Telangana over long periods. The study indicates the region's need for on-farm infrastructure for water resource development and efficient use with climate smart crop planning.

Future scope of the study

The present study helps the policy decision making, academicians and researcher to take up further climate variability studies. This information would also help to farming community to adopt climate resilient technologies for addressing climate change impact in southern part of Telangana state.

Conflict of interest

No potential conflict of interest was reported by the authors.

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Table 01. Details of four representative concentration pathways (RCPs)

RCPs	*Atmospheric CO_2 equivalent (parts per million)	When
8.5	>1370	By 2100, but rising
6.5	850	Stabilization after 2100
4.5	650	Stabilization after 2100
2.5	490	Peak before 2100 then decline

Table 02. Mean seasonal weekly rainfall (mm) under base period, RCPs and time periods

Std Weeks	1985-2014	2025		2050		2090	
		RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
22	16.55	02.01	02.57	02.22	10.38	02.61	04.46
23	15.69	19.02	14.16	19.12	15.41	39.76	15.72
24	36.52	32.43	21.73	18.56	35.13	19.27	19.39
25	19.92	51.79	48.23	71.96	69.54	66.19	57.66
26	24.00	84.91	67.91	78.66	56.50	80.78	91.68
27	22.02	118.44	157.59	115.61	132.67	126.98	131.99

28	20.84	78.58	59.12	70.92	49.64	68.79	50.11
29	36.44	73.17	63.88	62.50	60.01	61.42	104.98
30	33.59	49.09	75.48	44.97	60.16	41.33	62.08
31	29.25	17.40	25.79	17.49	19.97	19.82	19.86
32	31.55	20.38	19.83	30.72	19.78	16.33	19.23
33	31.45	06.99	01.30	00.00	10.98	06.20	14.74
34	25.10	02.03	01.87	31.64	02.08	01.87	26.31
35	18.45	61.71	69.46	67.19	102.46	98.30	123.87
36	27.65	07.10	07.00	11.86	07.10	06.60	08.13
37	18.35	126.33	115.19	113.08	118.77	113.59	127.69
38	39.66	31.69	40.61	19.28	32.89	19.69	23.99
39	42.95	03.61	05.46	09.17	03.43	03.93	03.87
40	35.65	04.30	04.67	06.53	02.70	02.82	01.09
Seasonal (22-40) Wet weeks	**14.00**	**11.00**	**11.00**	**10.00**	**10.00**	**09.00**	**10.00**
Seasonal (22-40) Dry weeks	**05.00**	**08.00**	**08.00**	**09.00**	**09.00**	**10.00**	**09.00**
Maximum	**42.95**	**126.33**	**157.59**	**115.61**	**132.67**	**126.98**	**131.99**
Minimum	**15.69**	**2.01**	**01.30**	**00.00**	**02.08**	**01.87**	**01.09**
Mean	**13.50**	**17.62**	**18.33**	**17.82**	**17.70**	**18.67**	**19.79**
SD	**12.56**	**30.20**	**31.74**	**28.70**	**30.67**	**30.65**	**34.94**
CV	**93.08**	**171.39**	**173.10**	**161.03**	**173.31**	**164.12**	**176.52**

Table 03. Mean monthly rainfall (mm)and rainy days of base period, RCPs and time periods

Months	1985-2014		2025				2050				2090			
	MRF	RD	RCP 4.5		RCP 8.5		RCP 4.5		RCP 8.5		RCP 4.5		RCP 8.5	
			MRF	RD	MRF	RD	MRF	RD	MRF	RD	MRF	RD	MRF	RD
Jan	04.66	00.00	01.28	00.00	01.57	00.00	00.60	00.00	00.63	00.00	02.93	01.00	01.91	00.00
Feb	12.10	01.00	05.58	00.00	06.81	00.00	04.60	00.00	03.48	01.00	12.33	02.00	07.77	00.00
Mar	14.69	00.00	00.92	00.00	01.23	00.00	01.37	00.00	00.00	00.00	01.98	00.00	01.23	00.00
Apr	22.67	00.00	28.00	06.00	40.04	07.00	34.71	06.00	28.12	05.00	42.59	05.00	21.23	03.00
May	38.43	03.00	61.31	06.00	60.64	05.00	50.83	08.00	57.44	08.00	66.94	08.00	49.49	08.00
Jun	103.71	18.0	160.20	16.00	142.80	15.00	168.49	16.00	166.79	18.00	189.73	20.00	164.24	16.00
Jul	119.09	24.00	359.07	23.00	376.76	26.00	322.22	25.00	318.11	26.00	344.11	25.00	394.42	27.00
Aug	126.42	27.00	96.68	08.00	106.79	08.00	139.62	10.00	155.42	11.00	131.19	09.00	198.94	10.00
Sep	133.86	25.0	168.73	11.00	168.26	13.00	168.38	11.00	162.19	11.00	147.81	11.00	163.68	11.00
Oct	88.25	17.00	15.70	02.00	10.73	00.00	14.41	02.00	10.76	02.00	13.58	02.00	09.52	02.00
Nov	36.43	04.00	20.01	03.00	38.19	07.00	35.34	05.00	39.98	06.00	28.89	04.00	33.97	03.00
Dec	06.24	00.00	00.00	00.00	01.10	00.00	00.00	00.00	00.00	00.00	04.47	01.00	01.32	00.00
Mean	**58.88**	**09.92**	**76.46**	**06.25**	**79.58**	**06.75**	**78.38**	**06.92**	**78.58**	**07.33**	**82.21**	**07.33**	**87.31**	**06.67**
SD	**51.14**	**11.24**	**107.66**	**06.25**	**109.95**	**06.75**	**100.73**	**07.73**	**100.54**	**08.13**	**104.39**	**07.96**	**121.22**	**08.30**
CV	**86.85**	**113.31**	**140.81**	**7.30**	**138.16**	**08.04**	**128.51**	**111.73**	**127.96**	**110.83**	**126.97**	**108.52**	**138.84**	**124.57**

MRF- Monthly Rainfall (mm), RD- Rainy Days

Table 04. Seasonal and annual rainfall under RCPs and base period for selected time periods

	Time scenarios	Min (mm)	Max (mm)	Mean (mm)	SD (mm)	CV (%)
		Seasonal rainfall (mm)				
Base Period	(1985-2014)	241.30	731.60	479.00	88.00	18.40
RCP 4.5	2025	689.23	853.52	721.84	134.00	18.56
	2050	692.20	910.23	744.87	140.01	18.76
	2090	752.10	950.53	731.36	145.00	19.82
RCP 8.5	2025	680.10	861.32	758.29	140.20	18.48
	2050	691.03	911.30	744.34	145.24	19.51
	2090	756.25	952.01	874.76	165.10	18.87
		Annual rainfall (mm)				
Base period	(1985-2014)	423.50	1045.00	702.00	130.00	18.52
RCP 4.5	2025	910.32	1125.00	916.20	176.40	19.25
	2050	915.35	1131.00	939.98	189.35	20.14
	2090	975.00	1135.00	982.60	201.01	20.45
RCP 8.5	2025	975.25	1152.00	953.36	182.40	19.13
	2050	981.63	1161.00	942.29	183.12	19.43
	2090	989.52	1285.00	1045.82	210.10	20.08

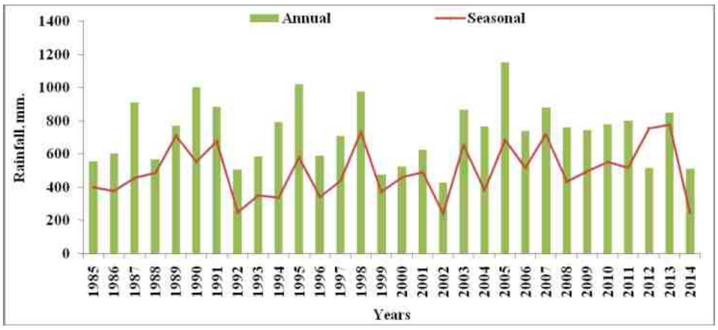

Fig 01. Annual & seasonal rainfall (mm) during base period (1985-2014)

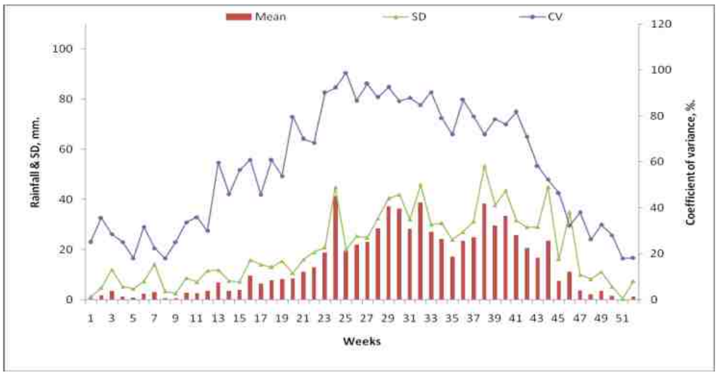

Fig 02. Weekly rainfall (mm) during base period (1985-2014)

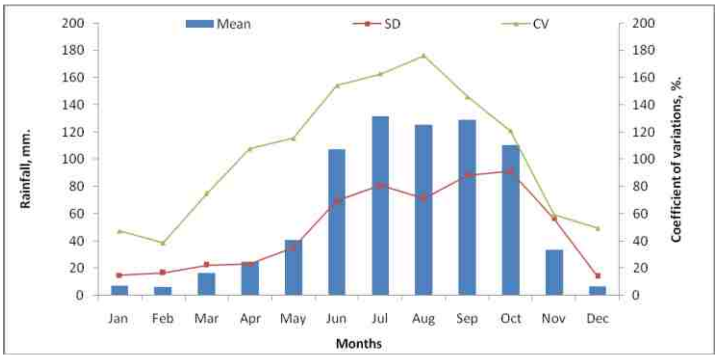

Fig 03. Monthly rainfall (mm) during base period (1985-2014)

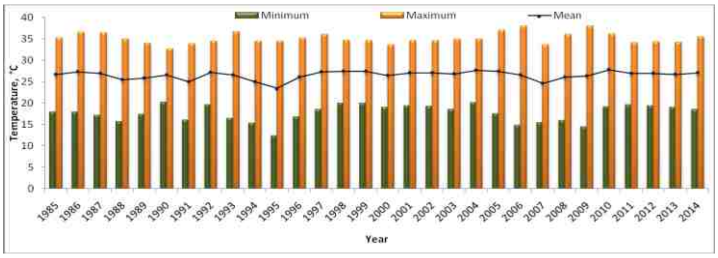

Fig 04. Annual mean, minimum and maximum temperature (°C) during base period (1985-2014)

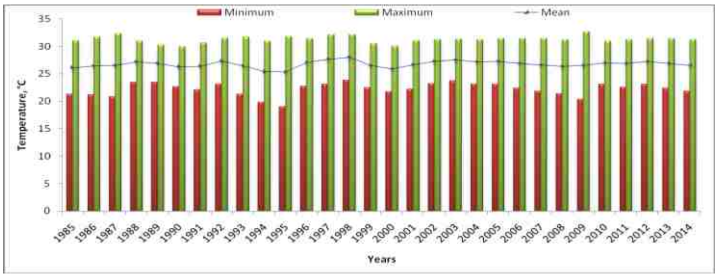

Fig 05. Seasonal mean, minimum and maximum temperature (°C) during base period (1985-2014)

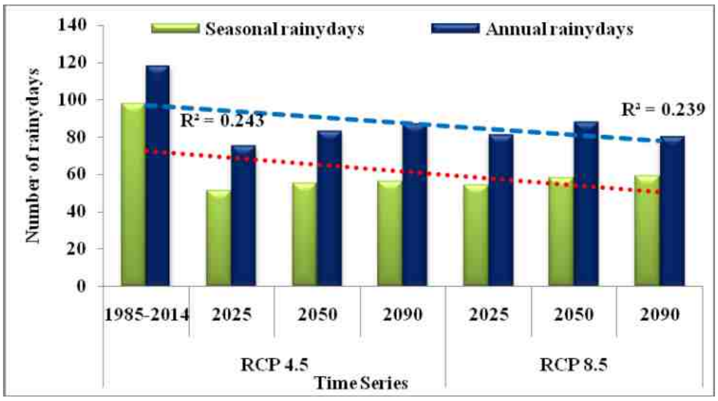

Fig 06. Seasonal and annual rainy days under RCPs and time periods

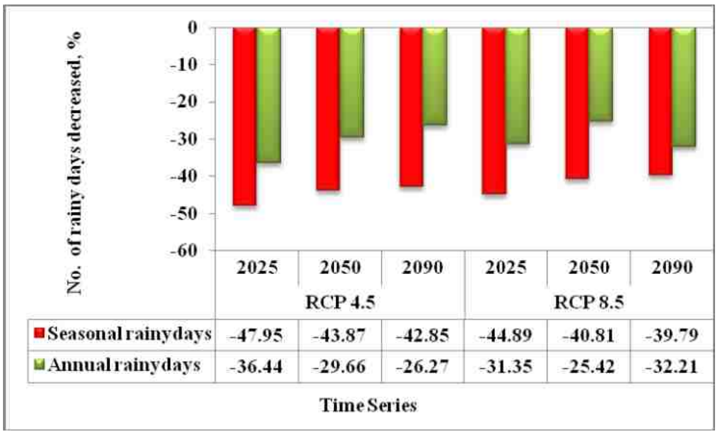

Fig 07. Percentage decrease in seasonal and annual rainy days under RCPs and time periods

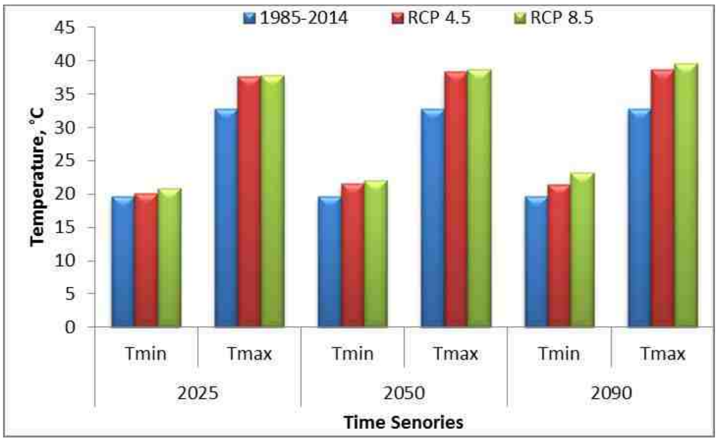

Fig 08. Seasonal mean maximum and minimum temperatures under RCPs and different time periods

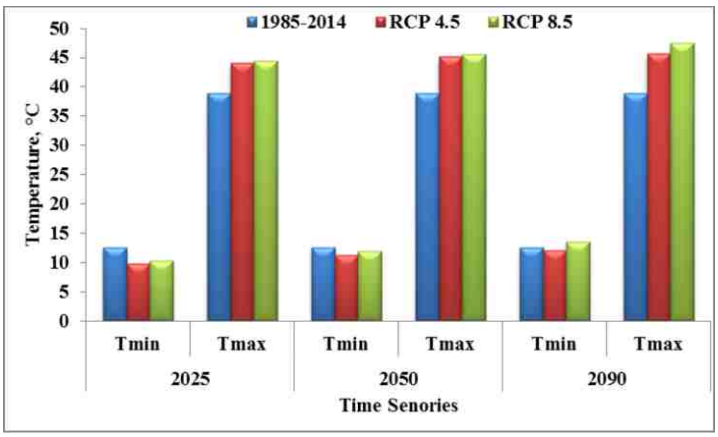

Fig 09. Annual mean maximum and minimum temperatures under RCPs and different time periods

REFERENCES

1. Ahmadi M., Hadi Ramezani Etedali, Ahmed Elbeltagi, 2021, Evaluation of the effect of climate change on maize water footprint under RCPs scenarios in Qazvin plain, Iran, *Agricultural Water Management,* 254, 106969.

2. Amit Garg, Vimal Mishra and Hem Dholakia, 2015.*Climate Change and India: Adaptation Gap, (2015) - A Preliminary Assessment.* Working paper of Indian Institute of Management Ahmedabad, (IIMA) W.P. No. 2015-11-01.

3. Bal, S.K., Chandran, M.A.S., Madhavan, S.V., Rao, A.V.M.S., Manikandan, N., Praveen Kumar, R., Parameswaran, P.V., Attri, S.D., Singh, P., Mohanty, A., 2022. Water Demand in Maize Is Projected to Decrease under Changing Climate in India. *Sustainability,*14, 1419.https://doi.org/10.3390/su14031419.

4. Balvanshi, A and Tiwari, H.L. 2021. Quantitative Estimation of the Impact of Climate Change on Crop Evapotranspiration and Yield in Central Region of India. , *Russ. Meteorol.Hydrol.* 46, 696–700. https://doi.org/10.3103/S1068373921100071.

5. Boral D and Moktan S, 2021, Predictive distribution modeling of Swertia bimaculata in Darjeeling-Sikkim Eastern Himalaya using MaxEnt: current and future Scenarios, Ecological Processes, 10:26, https://doi.org/10.1186/s13717-021-00294-5.

6. CSTEP. (2020). Climate Change Risks to Rainfed Agriculture in Karnataka: Implications for Building Resilience. (CSTEP-RR-2021-<02>).

7. Das U, Ansari MA (2021) The nexus of climate change, sustainable agriculture and farm livelihood: contextualizing climate smart agriculture. Clim Res 84:23-40. https://doi.org/10.3354/cr01648.

8. Darand M (2020) Projected changes in extreme precipitation events over Iran in the 21st century based on CMIP5 models. Clim Res 82:75-95. https://doi.org/10.3354/cr01625

9. Dubey S, K and Sharma D, 2018. Assessment of climate change impact on yield of major crops in the Banas River Basin, India, *Science of the Total Environment*, 635, 10–19.

10. Gunawat, A., Sharma, D and Sharma, A., 2022. Assessment of climate change impact and potential adaptation measures on wheat yield using the DSSAT model in the semi-arid environment. *Nat Hazards*. https://doi.org/10.1007/s11069-021-05130-9.

11. Gupta M and Sharif K M (2021). Spatio-temporal analysis of temperature projections based on representative concentration pathways for Satluj River Basin, India, Cogent Engineering, 8:1, 1933683, DOI: 10.1080/23311916.2021.1933683.

12. Han Z, Zhang B, Hoogenboom G, Li X, He C (2021) Climate change impacts and adaptation strategies on rainfed and irrigated maize in the agro-pastoral ecotone of Northwestern China. Clim Res 83:75-90. https://doi.org/10.3354/cr01635.

13. Iqbal, W. and Zahid, M., 2014, Historical and future trends of summer mean air temperature over south Asia. *Pakistan J. of Meteorology*, l0 (20): 67-74.

14. Jha, R.K.; Kalita, P.K.; Cooke, R.A., 2021, Assessment of Climatic Parameters for Future Climate Change in a Major Agricultural State in India.Climate, 2021, 9, 111. https://doi.org/10.3390/cli9070111.

15. Khubaib N, Asad SA, Khalil T, Baig A and others (2021) Predicting areas suitable for wheat and maize cultivation under future climate change scenarios in Pakistan. Clim Res 83:15-25. https://doi.org/10.3354/cr01631.

16. Kadiyala M.D.M., Nedumaran S, Jyosthnaa P, Murali Krishna G, Sridhar G, Srinivas Reddy S, Richard R, Anthony W, 2021. Modeling the potential impacts of climate change and adaptation strategies on groundnut production in India, *Science of the Total Environment*, 776, 145996.

17. Katzenberger A, Jacob Schewe, Julia Pongratz, and Anders Levermann, 2021, Robust increase of Indian monsoon rainfall and its variability under future warming in CMIP6 models, Earth Syst. Dynam., 12, 367–386, https://doi.org/10.5194/esd-12-367-2021.

18. Kundu, A., Dwivedi, S. and Chandra, V., 2014, Precipitation trend analysis over eastern region of India using CMIP5 based climatic models, The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL-8, ISPRS Technical Commission VIII Symposium, 09-12 December 2014, Hyderabad, India.

19. Loganathan P and Mahindrakar AB (2021) Intercomparison of statistical downscaling models: a case study of a large-scale river basin. Clim Res 83:147-159. https://doi.org/10.3354/cr01642.

20. Mali S S., Paresh B. Shirsath & Adlul Islam, 2021. A high-resolution assessment of climate change impact on water footprints of cereal production in India, Scientific Reports, 11:8715 | https://doi.org/10.1038/s41598-021-88223-6.

21. Menon, A, A., Lcvermann, J., Schewe, J., Lehmann and Fricler, K., 2013, Consistent increase in Indian monsoon rainfall and its variability across CMIP-5 models. *Earth System Dynamics,* 4: 287-300.

22. Munawar S A, B, Naveed Tahir M and Hassan Ali Baig M, 2021, Future climate change impacts on runoff of scarcely gauged Jhelum river basin using SDSM and RCPs, Journal of Water and Climate Change Vol 12 No 7, 2993 doi: 10.2166/wcc.2021.283.

23. Pandey, K. C., 2014, Extreme point rainfall events analysis of Gorakhpur under climate change scenario. *J. of Climatology and Weather Forec.,* 2(l): 108-l15.

24. Parth Sarthi, P., Praveen, K. and Soumik, G., 2015, Possible future rainfall over Gangetic plains (OP), India, in multi-model simulations of CMIP3 and CMIP5, *Theoretical Applied Clirnatology,* 3(5): 56-68.

REFERENCES

25. Rajiv, K. C., Jaideep Joshi, Mathangi, J., Bala, G. and Ravindranath, N. H., 2012, Multi-model climate change projections for India under representative concentration pathways, *Curr. Sci.,* 103(7): 791-802.

26. Raju G and Phanindra G, 2020. The impact of climate change on maize yields and its variability in Telangana, India: A panel approach study, *J Public Affairs*.;e2088. https://doi.org/10.1002/pa.2088.

27. Reddy K S, Sandra Ricart, Maruthi V, Pankaj P.K, Krishna T S, Amarender Reddy A, 2020., –Economic assessment of water harvesting plus supplemental irrigation for improving water productivity of a pulsecotton based integrated farming system in Telangana, India, *Irrigation and Drainage*, 69, 25-37.

28. Reddy, K. S., Kumar, M., Maruthi, V., Umesha, B., Vijayalaxmi and Nageswar Rao, C. V. K., 2014, Climate change analysis in southern Telangana region, Andhra Pradesh using LARS-WG mode. *Curr. Sci.,* 107(1): 54-61.

29. Sarangi and Sekhar M. 2022. Technologies for Enhancing Water Productivity in Irrigated Agriculture. In: Ray C., Muddu S., Sharma S. (eds) Food, Energy, and Water Nexus. *Springer, Cham.*https://doi.org/10.1007/978-3-030-85728-8_4.

30. Srivastav, A.L., Dhyani, R., Ranjan, M., 2021. Climate-resilient strategies for sustainable management of water resources and agriculture. *Environ Sci Pollut Res,* 28, 41576–41595. https://doi.org/10.1007/s11356-021-14332-4.

31. Srivastava R.K., R.K. Panda and Arun Chakraborty, 2021. Assessment of climate change impact on maize yield and yield attributes under different climate change scenarios in eastern India, *Ecological Indicators,* 120, 106881.

32. Surendran U., P. Raja, M. Jayakumar, and S. Rama Subramoniam, 2021. Use of efficient water saving techniques for production of rice in India under climate change scenario: A critical review, *Journal of Cleaner Production*, 309, 127272.

33. Vijayakumar S., A. K. Nayak, A. P. Ramaraj, C. K. Swain, V. Geethalakshmi, S. Pazhanivelan, Rahul Tripathi and N. S. Sudarmanian, 2021, Rainfall and temperature projections and their impact assessment using CMIP5 models under different RCP scenarios for the eastern coastal region of India, Current Science, Vol. 121 [2]: 222-232.

34. Xiao D, De Li Liu, Bin Wang, Puyu Feng, Huizi Bai, Jianzhao Tang, 2020. Climate change impact on yields and water use of wheat and maize in the North China Plain under future climate change scenarios, *Agricultural Water Management*, 238, 1062-38.

35. Yaduvanshi A, Tiro Nkemelang, Ramkumar Bendapudi, Mark New, 2021, Temperature and rainfall extremes change under current and future global warming levels across Indian climate zones, *Weather and Climate Extremes,* 31, 100291.

