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Research Article

LONG TERM TRENDS IN WEATHER PARAMETERS AT HISAR (HARYANA): A LOCATION IN SEMI ARID REGION OF NORTH WEST INDIA

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ABSTRACT

The study conducted to evaluate trends in different weather variables by long term record of climatic data (1980-2014) of Hisar, Haryana (26.10 N; 75.46 E & 215.2 m AMSL). Hisar station is representative of western agroclimatic region of Haryana. Trend analysis of different weather parameters was carried out by Mann-Kendall test and the magnitudes of the trends were estimated using Sen's slope. Analysis was carried out by using MAKESENS, an MS Excel macro template. Results revealed that rainfall in September month was increasing significantly @ 2.15 mm/year over long term period (1980-2014). The long term trends were compared with meteorological records of recent past of 20 years (1995-2014) to assess rate of change in changing scenario of climate. In recent past (1995-2014), rainfall in the same month showed significant increasing trend with higher rate of change @ 5.14 mm/year. Maximum temperature of January and September months was found decreasing significantly @ -0.07 and -0.05 ^{o}C/annum. The annual trend of wind speed showed highly significant decreasing trend but rate of change/annum was slightly less during recent past (@ -0.03 kmph/annum) as compared to normal/long term trends (@ -0.04 kmph/annum). Similarly other weather parameters like relative humidity, evaporation etc. were also analysed.

INTRODUCTION

Weather and climate extremes have always been remained serious issues for society. The long term changes in climate variables may have permanent significant impacts on the growth and yields of various crops. Numerous researches implied significant long-term changes in monsoon rainfall on a national scale In India. In IPCC studies scientists have revealed statistically significant warming trends in different parts of the world (IPCC, 2014). However, decreasing trends in weather parameters have also been reported in some part of the world. Regardless of the definition used, the characteristics of what is called an 'extreme weather event' may vary from place to place. Extreme positive departure from normal maximum temperature results in heat wave during summer season (Dubey *et al*., 2005). In recent years due to deterioration of the air quality in urban locations of India the deaths and discomfort from cold waves have been substantial (De and Ray Sinha, 2000). The climatic trends also reported in extreme weather events in Bihar (Kumar and Kumar, 2017). Increasing trend of annual rainfall in Haryana was also reported by India Meteorological Department (Rathore *et al*., 2013). India is among the countries that are most vulnerable to climate change due to its high dependency on rain-fed agriculture and lack of adaptation strategies. A proper assessment of likely incidences of such events and their trends would be helpful to the planners in their disaster mitigation and implementations. In north west regions on India, Haryana is a state where irrigation facility has developed considerably, yet effect of erratic nature of rainfall on agriculture and hydrological cycle cannot be ignored. Therefore, the study was conducted to characterize the long-term trend of different weather parameters at Hisar, Haryana.

MATERIALS AND METHODS

Site of study and climate: The study conducted at Department of Agricultural Meteorology CCS HAU, Hisar by using meteorological recorded at agro-meteorological observatory situated at the Research area of the department (29^{0} 10' N latitude, 75^{0} 46' E longitude and altitude 215.2 meters AMSL). The Hisar region is characterized by hot summer and cool winter, receiving mean annual precipitation of about 472 mm, which is typical of arid regions. The climate of Hisar region is

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continental and it lies at the outer margins of the monsoon region, 1600 km away from the ocean. It has semi arid subtropical monsoonal climate. South westerly monsoon current in the summer brings rain generally from last week of June to middle of September. From October to the end of June next, the weather remains extremely dry, except for a few light showers received due to westerly disturbances. About 80 per cent of annual precipitation is received in the south-west monsoon season. Summers are very hot (maximum temperature touches 45 ^{0}C or sometimes even more) and winters are fairly cool (minimum temperature around 1 to 2 ^{0}C or sometimes less). Some time temperature may fall below 0 ^{0}C in the month of December and January.

Climatic data: The daily weather parameters (temperature, rainfall, wind speed, relative humidity, and evaporation) of Hisar stations of Haryana for long period i.e. 1980 – 2014 were used. The data were checked thoroughly for homogeneity and verified. After performing the quality check it was processed and analysed.

Trend analysis of weather parameters: Variability and trends were carried out for all weather parameters. Trend analysis was carried out by Mann-Kendall test and the magnitudes of the trends were estimated using Sen's slope. Analysis was carried out by using MAKESENS, an excel template for trend analysis (Salmi *et al*, 2002), which tests the presence of monotonic increasing and decreasing trends and quantifies the slope/magnitude of change per unit time.

The non parametric statistical test determines whether the observations in the data are increasing or decreasing with study time period and further it was also analyzed and compared with recent past of 20 years (1995-2014)

RESULTS AND DISCUSSION

The results revealed that the annual mean maximum temperature decreased by 0.1 ^{o}C while mean minimum temperature increased by 0.1 ^{o}C during last 20 years (1985-2014) form normal (Long Period Average of 1985-2014) (Table1). Minimum temperature during August month had shown a significant increasing trend @0.08 ^{o}C/annum. January and September months observed significant decreasing trend in maximum temperature@-0.07 & -0.05 ^{o}C/annum (Table 2). Mean monthly rainfall increased in June (14.1mm) followed by September (13.4 mm), May (9.8 mm) and March (4.5 mm), whereas July and August months had decreased rainfall than normal (10.0 mm in July and 4.8 mm in August) as shown in Table 1.

Maximum Temperature

On long term period, maximum temperature of January and September months was decreasing significantly @ -0.07 and -0.05 ^{o}C/annum respectively, whereas in recent past i.e. study period (1995-2004), month of September only showed a significant decreasing trend.

Minimum Temperature

On long term period basis (1980-2014), minimum temperature of September showed an increasing trend. However, rate of change (Sen's slope) was not quantifiable. In recent past i.e. study period (1995-2004) month of August only showed significant (5%) increasing trend @ 0.08 ^{o}C/annum. Somewhat increasing trend in months of March, June and November was also found but the rate of change was not remarkable. The annual minimum temperature showed no trend on long term basis while however, during the recent past an increasing trend was exhibited at less significance level (Table 2).

Table 1 Variability of Maximum & minimum temperature and rainfall at Hisar

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Maximum Temperature													
Normal (1970-2014)	19.5	22.8	28.7	36.2	40.2	39.9	36.3	34.8	34.7	33.4	28.4	22.3	31.4
SD (Standard Deviation)	1.4	1.7	2.1	1.9	1.9	1.5	1.6	1.4	1.3	1.3	1.0	1.5	0.6
CV (Coeff. of Variation %)	6.9	7.5	7.4	5.4	4.6	3.8	4.4	4.1	3.7	4.0	3.6	6.7	2.0
Period 1995-2014													
Mean	18.6	22.8	28.9	36.4	40.2	39.4	36.5	34.9	34.5	33.1	28.4	21.9	31.3
SD	1.3	1.8	2.2	2.1	1.4	1.8	1.5	1.5	1.1	1.7	1.2	1.8	0.7
CV	6.8	7.7	7.6	5.8	3.5	4.6	4.1	4.4	3.2	5.1	4.3	8.4	2.4
Departure from normal	-1.0	0.0	0.2	0.3	0.0	-0.5	0.3	0.0	-0.2	-0.3	0.0	-0.4	-0.1
Minimum Temperature													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Normal (1970-2014)	4.7	6.9	11.3	17.3	22.9	26.0	26.4	25.5	22.7	16.2	9.8	5.5	16.3
SD	1.3	1.5	1.1	1.3	1.5	1.3	0.9	0.8	1.0	1.5	1.5	1.4	0.6
CV	27.4	21.1	10.1	7.4	6.6	4.9	3.5	3.3	4.5	9.0	14.9	24.8	3.7
Period 1995-2014													
Mean	4.6	7.2	11.5	17.3	23.1	25.8	26.5	25.6	23.0	16.6	9.9	5.4	16.4
SD	1.3	1.4	1.5	1.2	1.4	1.3	0.9	0.9	0.9	1.7	1.0	1.5	0.6
CV	29.4	20.2	12.9	7.0	6.1	5.0	3.5	3.6	3.8	10.2	9.9	26.9	3.9
Departure from normal	-0.1	0.2	0.2	0.1	0.3	-0.3	0.2	0.1	0.3	0.4	0.0	-0.1	0.1
Rainfall													
Normal (1970-2014)	12.3	17.7	13.4	12.2	31.1	56.0	128.4	115.1	68.9	9.5	3.2	5.2	472.9
SD	11.8	19.1	16.5	19.9	31.5	38.9	77.9	83.6	66.4	26.4	11.7	8.9	163.4
CV	96.5	107.9	123.5	163.5	101.1	69.4	60.6	72.7	96.4	279.8	361.4	173.3	34.6
Period 1995-2014													
Mean	12.6	20.5	17.9	12.6	40.9	70.2	118.4	110.3	82.2	16.4	1.3	6.0	509.3
SD	13.9	22.5	20.4	14.4	32.9	44.2	82.6	93.8	64.8	37.8	2.4	11.4	186.4
CV	110.3	109.6	114.2	113.8	80.4	62.9	69.8	85.1	78.8	230.0	190.3	189.9	36.6

Table 2 Monthly Trends (significant) in weather variables at Hisar during long period and recent past.

Weather parameter	Duration (Months/ annual)	Long period 1980-2014 (Normal)		Recent past (1995-2014)	
		Mann-Kendall trend (Test Z)	*Sen's slope estimate (Q)*	*Mann-Kendall trend (Test Z)*	*Sen's slope estimate (Q)*
Maximum Temperature	Jan	-3.01**	-0.07**	-1.07	-0.05
	Sep	-2.46*	-0.05*	-1.95^{+}	-0.07
	Annual	-1.19	-0.02	-1.01	-0.03
Minimum Temperature	Mar	0.11	0.00	1.85^{+}	0.05
	Jun	-0.57	-0.01	1.72^{+}	0.09
	Aug	0.87	0.01	2.17*	0.08*
	Sep	1.76^{+}	0.02	1.59	0.05
	Nov	0.20	0.00	1.78^{+}	0.08
	Annual	1.05	0.01	1.91^{+}	0.06
Relative Humidity (morning)	Jan	3.47**	0.16**	1.98*	0.21*
	Feb	3.00**	0.19**	2.08*	0.23*
	Sep	2.27*	0.21*	1.52	0.40
	Oct	2.16*	0.17*	1.46	0.26
	Nov	2.13*	0.16*	2.40*	0.36*
	Dec	3.44**	0.16*	2.44*	0.27*
	Annual	2.56*	0.13*	2.30*	0.26*
Relative Humidity (evening)	Jan	1.99*	0.35*	0.23	0.14
	Feb	1.85^{+}	0.34	0.81	0.45
	Apr	0.91	0.14	1.88^{+}	0.62
	Jun	2.03*	0.29*	0.29	0.10
	Sep	1.79^{+}	0.30	0.81	0.31
	Oct	1.76^{+}	0.26	0.55	0.22
	Nov	1.68^{+}	0.19	2.24*	0.58*
	Dec	2.34*	0.39*	1.46	0.83
	Annual	3.38**	0.24**	2.04*	0.30*
Wind Speed	Feb	-3.27**	-0.04**	-0.29	-0.01
	Mar	-3.92**	-0.05**	-1.65^{+}	-0.04
	Apr	-3.72**	-0.05**	-1.72^{+}	-0.03
	May	-2.27*	-0.06*	-1.59	-0.10
	Jun	-3.95**	-0.07**	-2.04*	-0.08*
	Jul	-3.66**	-0.08**	-1.91^{+}	-0.09
	Oct	-1.82^{+}	-0.03	0.55	0.02
	Nov	-3.08**	-0.03**	-1.36	-0.02
	Dec	-1.78^{+}	-0.02	0.68	0.01
	Annual	-5.42**	-0.04**	-2.95**	-0.03**
Pan Evaporation	Jan.	-4.09**	-0.02**	-1.33	-0.02
	Feb.	-4.52**	-0.03**	-2.69**	-0.04**
	March	-2.61**	-0.03**	-1.59	-0.05
	Apr.	-2.33*	-0.06*	-1.91^{+}	-0.13
	May.	-3.12**	-0.09**	-2.82**	-0.13**
	June	-3.78**	-0.10**	-0.29	-0.02
	July	-1.14	-0.03	-0.55	-0.04
	Aug.	-1.11	-0.03	-0.49	-0.04
	Sep.	-3.01**	-0.05**	-1.46	-0.04
	Oct.	-3.38**	-0.04**	-1.59	-0.06
	Nov.	-2.54*	-0.03*	-2.43*	-0.07*
	Dec.	-3.71**	-0.02**	-1.85^{+}	-0.03
	Annual	-4.29**	-0.05**	-2.43*	-0.06*
Rainfall	May	1.72^{+}	0.71	0.03	0.17
	Sep	2.51*	2.15*	1.98*	5.14*
	Annual	1.53	4.98	0.55	5.69

Level of Significance: ** = 1%, * = 5%, and + = 10%

Relative Humidity (morning)

Relative humidity (RH) in morning for the moths of January, February and September to December was found increasing significantly when studied over long term period. The increasing rate was highest for September i.e. 0.21%/annum followed by February @ 0.19%/annum. Increasing trend of RH morning found mainly in winter months and was highly significant for January and February moths (Table 2). Similar trends were also noticed in recent past (1995-2004), but with slightly less significance. The rate of increase in RH was quite higher for all months (January, February, November and December) in recent past as compared to normal.

Annual RH at morning time was found increasing significantly throughout the spans but with double increasing rate (@ 0.26%/annum) in recent past as compared to normal (@ 0.13%/annum).

Relative Humidity (evening)

Over long term period; relative humidity in evening for the moths of January, February, June and September to December was found increasing significantly. The increasing rate was found mainly in winter months and was highly significant for January and December months (@ 0.35% & @ 0.39%/annum respectively). In summer, June month also showed an increasing trend @ 0.29%/annum whereas no such change was notice in morning RH in June. In recent past i.e. study period

(1995-2004), RH evening in November showed a high significant increasing trend with a higher rate of change of 0.58%/annum. Annual RH at evening time was found increasing significantly (Table 2). The Sen's slope estimates showed that rate of change per year has also increased in recent past in evening RH (@ 0.30 %/annum) as compared to normal (@ 0.24%/annum).

Wind speed

Wind speed showed a decreasing trend throughout year except for January, August and September months during long period 1980-2014. The downward rate of change in wind speed was more in summer months as compared to winter. The maximum decline was -0.08 kmph/annum for July (Table 2). In recent past (1995-2004) March, April, June and July showed a significant decreasing trend. Annual trend of wind speed showed a highly significant decreasing trend but rate of change/annum was slightly less during recent past (@ -0.03 kmph/annum) as compared to normal (@ -0.04 kmph/annum.

Evaporation

The long term analysis (1980-2014) indicated that the rate of evaporation was decreasing significantly throughout year. Excepts for the months with maximum rainfall (July and Aug.) all months had a significant decreasing trend. As per Sen's slope estimates, rate of decrease was maximum for June (@ -0.1 mm/year followed by May (@ -0.09 mm/year). Declining trend of evaporation was more in summer months. During recent past, the decreasing trend was not much pronounced and observed in months of November, December, February, April and May. Evaporation was found decreasing @ -0.13 mm/year during April and May month whereas for rest of the months the rate of change was less. Annually, the evaporation rate was found decreasing significantly @ -0.05 mm/year (Table 2).

Rainfall

Rainfall in June and September months showed significant increasing trends @ 0.7 and 1.1 mm/year respectively over a longer period of 1970-2014 (Anurag *et al*. 2017). In present study the same had found with increasing trends in September @ 2.15 mm/year. A less significant increasing trend was also seen in May while Sen's slope estimates were not significant. In recent past (1995-2014), rainfall showed significant increasing trend only in September with higher rate of change i.e. 5.14 mm/year. In rest of the months, no trend was observed in rainfall throughout the span as shown in the Table 2.

CONCLUSIONS

Variability and monthly trend of important weather parameter were derived from Hisar station for long period and compared respectively with resent past of twenty years.

The overall results revealed that the near all parameters showed either positive or negative trends in different months. Annual mean maximum temperature decreased by 0.1 ^{o}C whereas the mean minimum temperature increased by 0.1 ^{o}C during the period 1995-2014. The minimum temperature during August month found significant increasing trend @0.08 ^{o}C/annum. January and September months observed significant decreasing trend in maximum temperature@-0.07 & -0.05^{o}C/annum. Similarly RH morning and evening and other parameter such as Wind speed, evaporation etc. showed considerable changes. Owning to continental climatic conditions of Hisar and being located in semi arid region of north-west India, changing trends of whether parameter is a matter of serious concern for agriculture and as well as its environment settings.

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