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Climatic variability and its characterisation over Punjab, India

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ABSTRACT

The climate data (maximum temperature, minimum temperature and rainfall) of forty year (1974-2013) was analysed for *kharif* (May to October) and *rabi* (November to April) seasons in Punjab, India. The non-parametric Mann-Kendall and Sen's methods were used to determine trend (positive or negative) in climate data over a period of 40 years. A decrease in rainfall and increase in temperature from north-east to south-west Punjab during both the *kharif* and *rabi* seasons was observed. No significant temporal variation was observed in maximum temperature and rainfall during both the seasons, but a significant increase in minimum temperature over the years was observed in different zones of Punjab. On an average, minimum temperature is increasing at 0.05°C per year during both the seasons.

Key words: Climatic variability, GIS, Mann-Kendall test, Punjab

Climate change is one of the most prominent global environmental issues. During the period from 1885 to 2012, the mean global temperature has increased by 0.85°C and is predicted to increase further by 1.6 – 5.8°C by the end of 21st century (IPCC, 2014). Developing countries are more vulnerable to such changes as they have limited resources to cope up with the disasters and agriculture plays dominant role in their national economy (Majumder *et al*, 2016). The northern part of Indian sub-continent has been placed under high risk zone for heat stress risks in view of future climate change scenarios (Teixeira *et al* 2013). Under such conditions, the sustainability of natural resources and food security for the burgeoning population in the region is at stake.

The Punjab state is also experiencing large fluctuations in temperature and precipitation patterns every year leading to large oscillations in agricultural productivity in the region. The abnormal weather conditions have already started taking a toll on productivity of wheat crop during last 5-6 years. To manage this alarming situation, there is a need to analyse the spatio-temporal variability of climatic conditions at regional scale so that viable mitigation / adaptation strategies could be developed and implemented on regional basis. Keeping this in view, the spatio-temporal climatic variability during *kharif* and *rabi* seasons has been studied for three different agroclimatic regions viz. North-east, central and south-west Punjab by using statistical procedures.

MATERIALS AND METHODS

Study area

The study was conducted for Punjab state with latitudinal extent of 29°30'N to 32°32'N, longitudinal extent of 73°55'E to 76°50'E, elevation of 230 to 260 m AMSL and representing transgangetic agroclimatic region of India. As there is a large climatic variability from north-east to south-west region, so the state was divided into three agroclimatic regions involving different districts as mentioned below:

1. North-east region- Gurdaspur, Hoshiarpur and Roopnagar
2. Central region- Amritsar, Jalandhar, Kapurthala, Ludhiana, Patiala and Sangrur
3. South-west region- Bathinda, Faridkot and Ferozepur

Data collection and analysis

The monthly data of maximum temperature, minimum temperature and rainfall for different locations of Punjab was collected from various sources (like Agrometeorological Observatory, School of Climate Change and Agricultural Meteorology, Punjab Agricultutral University (PAU), Ludhiana; different regional research stations of PAU, India Meteorological Department (Chandigarh) and Statistical Abstracts of Punjab) of 40 years (1974-75 to 2013-14).

Temporal variability analysis

The data was analysed for two major cropping seasons

Table 1: Results of the statistical tests for maximum temperature during *kharif* and *rabi* seasons over the period 1974-75 to 2013-14

Zone	T_{max} (°C) / Test	1974-75 to 1983-84	1984-85 to 1993-94	1994-95 to 2003-04	2004-05 to 2013-14	1974-75 to 2013-14
			***Kharif* season (May – October)**			
North-east	Mean±SD	32.9±0.4	33.0±0.5	32.9±0.5	33.1±0.6	32.8±0.2
	Z	-0.358	0.000	0.716	1.252	0.478
	Q	-0.044	0.004	0.031	0.184	0.005
Central	Mean±SD	34.9±0.9	34.9±0.9	34.8±0.9	34.9±0.6	34.9±0.7
	Z	-0.358	0.358	1.252	1.789+	0.000
	Q	-0.037	0.009	0.039	0.012	0.000
South-West	Mean±SD	36.0±0.1	36.1±0.1	35.9±0.1	36.6±0.4	35.9±0.1
	Z	-0.179	0.000	0.179	-0.537	-1.596
	Q	-0.027	0.018	0.036	-0.040	-0.015
			***Rabi* season (November – April)**			
North-east	Mean±SD	22.6±0.5	23.0±0.5	23.1±0.5	24.3±0.9	23.2±0.6
	Z	-1.968*	-0.716	1.073	0.537	2.645**
	Q	-0.187	-0.045	0.124	0.091	0.034
Central	Mean±SD	24.3±0.9	24.7±0.9	24.8±1.0	25.0±0.3	24.7±0.7
	Z	-1.789+	-0.537	0.716	-0.358	2.086*
	Q	-0.203	-0.077	0.119	-0.067	0.022
South-West	Mean±SD	25.7±0.8	26.3±0.7	26.2±0.8	25.4±0.1	25.9±1.0
	Z	-1.968*	-0.716	0.894	-1.968*	-1.456
	Q	-0.181	-0.079	0.093	-0.362	-0.019

Z: Mann-Kendall test, Q: Sen's slope estimator; *N Statistically significant trends at the 5% significance level, ** Statistically significant trends at the 1% significance level, *** Statistically significant trends at the 0.1% significance level

in Punjab: *kharif* (May to October) and *rabi* (November to April) (Kaur *et al* 2006). The decadal averages and standard deviations in maximum and minimum temperatures and rainfall were calculated separately for *kharif* and *rabi* seasons, apart from the overall of averages and standard deviations during the period 1974-2013 for both *kharif* and *rabi* seasons. In this study, two non-parametric statistical tests (Mann-Kendall and Sen's slope estimator) were used to detect the meteorological variables' trends (Meals *et al*., 2011).

RESULTS AND DISCUSSION

Maximum temperature

Among the three zones, maximum temperature was highest in the south-west zone followed by central and north-east zone (Table 1). The decadal variation in different zones of Punjab showed an increase in *rabi* season maximum temperature in north-eastern and central Punjab from first decade (1974-83) to fourth decade (1984-2013), but it increased from first decade (1974-83) to third decade (1984-1993) in the south-western zone and then decreased from third decade (1984-1993) to fourth decade (2004-13). The maximum temperature increased from 22.6 to 24.3°C in the north-eastern zone, from 24.3 to 25.0°C in the central Punjab, whereas in the south-western region it increased from 25.7 to 26.3°C from 1974-83 to 1984-93, but decreased thereafter to 25.4°C during 2004-13.

The MK Z-values of maximum temperature were not significant during *kharif* season in all the three regions of Punjab but it decreased significantly during *rabi* season in the first decade (1974-75 to 1983-84) in north-east (-0.187°C $year^{-1}$) and south-west regions (-0.181°C $year^{-1}$). The change in maximum temperature from 1983-84 to 2013-14 was variable (Table 1), however maximum temperature has significantly increased during *rabi* season in north-east

Table 2: Results of the statistical tests for minimum temperature during *kharif* and *rabi* seasons over the period 1974-75 to 2013-14

Zone	T_{min} (°C) / Test	1974-75 to 1983-84	1984-85 to 1993-94	1994-95 to 2003-04	2004-05 to 2013-14	1974-75 to 2013-14
			***Kharif* season (May – October)**			
North-east	Mean±SD	20.7±0.5	20.8±0.5	21.3±0.4	22.9±0.8	21.5±0.8
	Z	0.000	-0.179	0.894	1.789+	4.509***
	Q	0.003	-0.010	0.062	0.350	0.044
Central	Mean±SD	22.3±0.4	22.4±0.6	22.8±0.5	23.6±0.4	22.8±0.5
	Z	1.073	0.716	1.968*	2.326*	5.604***
	Q	0.061	0.044	0.100	0.154	0.051
South-West	Mean±SD	22.9±0.1	23.2±0.1	23.5±0.1	24.2±0.3	23.4±0.2
	Z	0.358	0.358	1.252	1.968*	5.138***
	Q	0.041	0.001	0.077	0.154	0.047
			***Rabi* season (November – April)**			
North-east	Mean±SD	8.5±0.4	8.8±0.5	9.2±0.5	10.4±0.5	9.1±0.2
	Z	0.000	0.000	1.968*	0.894	4.742***
	Q	0.007	-0.003	0.110	0.266	0.052
Central	Mean±SD	9.3±0.4	9.5±0.8	10.0±0.5	10.4±0.6	9.7±0.6
	Z	1.252	0.000	2.862**	-0.358	4.276***
	Q	0.133	0.039	0.189	-0.065	0.046
South-West	Mean±SD	9.6±0.1	10.0±0.2	10.3±0.2	10.8±0.5	10.0±0.3
	Z	0.716	0.000	1.610	0.179	4.602***
	Q	0.043	0.000	0.117	0.070	0.047

Z: Mann-Kendall test, Q: Sen's slope estimator; * Statistically significant trends at the 5% significance level, **Statistically significant trends at the 1% significance level, ***Statistically significant trends at the 0.1% significance level

(0.034°C year^{-1}) and central regions (0.022°C year^{-1}) of Punjab over a period of 40 years (Table 1).

Minimum temperature

The mean long-term (1974-2013) minimum temperature during *rabi* season was 9.1±0.2°C in north-east, 9.7±0.6°C in central and 10.0±0.3°C in south-western zones of Punjab (Table 2). The decadal analysis indicated that mean minimum temperature during *rabi* season increased from 8.5 to 10.4°C in north-east, 9.3 to 10.4°C in central and 9.6 to 10.8°C in the south-western zones of Punjab. The MK Z-values of minimum temperature indicated a significant shift from the normal. During *kharif* season, the rate of increase in minimum temperature was 0.044 °C year^{1} in north-east regions, 0.051 °C per year in central region and 0.047 °C year^{1} in south-west. During *rabi* season, the rate of increase was 0.052 °C year^{1} in north-east regions, 0.046 °C per year in central region and 0.047 °C year^{1} in south-west. Decade-wise analysis during *kharif* season indicated significant increase in the central region (0.100°C year^{-1}) from 1994-95 to 2003-04 and also in the south-west (0.154°C year^{-1}) and central regions (0.154°C year^{-1}) from 2004-05 to 2013-14. During *rabi* season, significant increase in minimum temperature was observed in north-east (0.110°C year^{-1}) and central plain region (0.189°C year^{-1}) from 1994-95 to 2003-04 (Table 2).

Rainfall

The average long-term (1974 to 2013) *kharif* season rainfall was 790±52.2mm in north-east, 581±120mm in central and 306±119mm in south-western zones of Punjab (Table 3). The decadal pattern of rainfall in different zones showed that *kharif* season rainfall increased from 692.6 mm during 1974-83 to 891.4 mm during 1994-2003, but decreased to 794.2mm during 2004-13 in the north-eastern

Table 3: Results of the statistical tests for rainfall during *kharif* and *rabi* seasons over the period 1974-75 to 2013-14

Zone	Rainfall (mm) / Test	1974-75 to 1983-84	1984-85 to 1993-94	1994-95 to 2003-04	2004-05 to 2013-14	1974-75 to 2013-14
			***Kharif* season (May – October)**			
North-east	Mean±SD	693±59.5	780±63.9	891±80.5	794±58.7	790±52.2
	Z	-0.358	-0.358	-2.326*	-0.537	0.664
	Q	-2.414	-2.718	-9.452	-1.711	0.194
Central	Mean±SD	501±124	556±160	664 ±118	605±95.7	581±120.1
	Z	0.000	-0.358	0.179	-0.358	0.944
	Q	-0.017	-3.007	0.926	-2.423	0.408
South-West	Mean±SD	281±101	314±134	321±136	307±123	306±119
	Z	-1.252	-0.537	-1.431	0.716	0.618
	Q	-3.992	-1.408	-4.051	3.900	0.261
			***Rabi* season (November – April)**			
North-east	Mean±SD	222±43.9	162±37.3	166±34.2	141±35.4	173±79.3
	Z	2.683**	0.537	-0.537	0.179	-1.130
	Q	4.985	0.900	-1.270	0.232	-0.193
Central	Mean±SD	158±44.6	109±38.2	118±29.1	97.9±31.8	121±33.3
	Z	3.578***	0.179	-0.894	-0.179	-1.247
	Q	4.724	0.194	-0.418	-0.366	-0.130
South-West	Mean±SD	84.7±6.9	63.4±8.8	67.8±7.9	52.5±10.6	67.1±5.5
	Z	2.504*	0.000	-0.894	0.358	-0.711
	Q	1.762	0.022	-0.282	0.133	-0.058

Z: Mann-Kendall test, Q: Sen's slope estimator; *Statistically significant trends at the 5% significance level, **Statistically significant trends at the 1% significance level, ***Statistically significant trends at the 0.1% significance level

zone. However, in central zone the annual rainfall varied from 501 mm during 1974-83 to 664 mm during 1994-2003, but again decreased to 605 mm during 2004-13. In south-west zone, it varied from 281 mm during 1974-83 to 321 mm during 1994-2003 and then again decreased to 306.9 mm during 2004-13. The average *kharif* season rainfall in the state increased from 493m during 1974-83 to 633 mm during 1994-2003 and then decreased to 576 mm during 2004-13. However, in all the cases there was an increase in rainfall compared to the first decade.

The average rainfall during *rabi* season was highest in north-eastern region (173±79.3mm) followed by central (121±33.3mm) and south-western (67.1±5.5mm) zones. There was no consistent pattern of change in rainfall over different decades in the three zones of Punjab (Table 3). The lower Mann-Kendall's Z values indicated highly variable and erratic nature of rainfall in the region. In general, trend in rainfall over 40 years showed that it increased during *kharif* season but decreased during *rabi* season. during *rabi* season, significant increase in rainfall was from 1974-75 to 1983-84 and the rate of increase was 4.985 mm year^{-1} (Z = 2.683) in north-east, 4.728 mm year^{-1} (Z = 3.578) in central and 1.762 mm year^{-1} (Z = 2.504) in south-west region (Table 3).

CONCLUSIONS

There is a significant decrease in rainfall and increase in temperature from north-east to south-western Punjab but no significant temporal variability trend was observed in maximum temperature and rainfall in the state. However, significant increase in minimum temperature has been observed in different zones of Punjab.

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