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Short Communication

Assessing the variability in temperature and rainfall extremes using RClimdex in Jalandhar district of Punjab

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The increase in the frequency of the occurrence of weather extremes has been identified as a major global environmental concern. The significant societal, ecological, and economic consequences of the climate extremes such as dry spells, floods, cold waves, and heat waves have been noticed almost everywhere in the world. The observations on extreme weather events form a foundation for an understanding of long-term climate change and variability (Alexander, 2016). These events have a particularly broad impact affecting a wide range of industries including agriculture, public works, transportation, and water resources. Therefore, long-term changes in extremes are required to be analyzed to understand and prevent future climate-related damage to social infrastructure. Allen and Ingram (2002) suggested more increase in extreme precipitation than the average precipitation due to changing climate that affects the current hydrological cycle to a greater extent (Trenberth *et al.*, 2003) along with an increase in the frequency of extreme precipitation events worldwide (Goswami *et al .*, 2006; Boo *et al.*, 2006; Prodanovic and Simonovic, 2010).
Numerous studies on climatic extremes concerned with constantly occurring changes in average values have been conducted, but fewer are available on the extreme rainfall and temperature trends in central Punjab (District Jalandhar), India. In the present investigation, an effort has been made to evaluate the changes in extreme weather based on the observed rainfall and temperature (both minimum and maximum).

The daily maximum temperature, minimum temperature, and rainfall during the period 1971-2019 at Jalandhar district of Punjab, India was obtained from the Agrometeorological observatory. The data was analysed on annual basis to compute various indices. The frequency, duration and intensity were described by these characteristics of extreme climate events. In this study, 25 indices defined by ETCCDI were analyzed, including 17 temperature indices and 8 rainfall indices used by Mamta *et al* (2020). These daily data were found to be homogenous. The characteristic analysis of extreme temperature and rainfall data to construct time series of indices in Jalandhar was carried out using *RClimdex package* (Zhang and Yang, 2004).The trends in extreme climatic indices time series were determined using the Innovative Trend Analysis (ITA) approach by Sen (2011).

Annual characteristics of temperature and rainfall related extreme indices were considered. The warmest daily maximum air temperature (TXx) exhibited no trend while the coldest daily maximum air temperature (TXn) showed a negative trend but non-significantly (Table 1). However, the warmest daily minimum temperature (TNx) showed a positive trend at the rate of 0.03^{o}C and the coldest daily minimum air temperature (TNn) also showed a similar trend at p=0.05. Similar results were revealed through a study by Mamta *et al* (2020).

The hot and cold-day threshold temperature indices revealed that trend and slope of the night extremes (TN90P and TN10P) were significantly higher than the day extremes (TX90P and TX10P). Overall, it was clear that the increase in minimum temperature is more profound than the increase in maximum temperature. The extreme temperatures cause plant water stress resulting in cessation of photosynthesis and even death (Steffen et al, 2014). They also reported the negative response of global yield of wheat, maize and barley due to extreme temperatures. The extreme heat-wave duration has decreased from1971 to 2019 whereas the number of heat waves events and its amplitude has increased over the above said period (Table 1). While the cold wave number and duration increased and cold wave amplitude showed a decreasing trend. The annual number of summer days (SU) have decreased non-significantly while the tropical nights (TR) has

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Table 1: Absolute and threshold temperature and rainfall indices during 1971 to 2019 at Jalandhar

Extreme indices	Sen's slope	Trend	Remarks
TXx	0.00	+	ns
TXn	0.09	-	ns
TNx	0.03	+	*
TNn	0.03	+	*
TX90P	0.12	-	ns
TX10P	0.06	+	ns
TN90P	0.22	+	*
TN10P	0.31	+	*
HWD	0.02	-	ns
HWN	0.03	+	ns
HWA	0.02	+	ns
CWD	0.11	+	ns
CWN	0.02	+	ns
CWA	2.13	-	ns
SU	0.02	-	ns
TR	0.43*	+	*
FD	0.66*	-	*
RX1day	0.43	+	ns
RX5day	0.78	+	ns
R10mm	0.03	+	ns
R20mm	0.06	+	ns
R30mm	0.04	+	ns
CWD	0.04	-	ns
CDD	0.15	-	ns
Sdii	0.16	+	ns

ns-non-significant, *-significant at p=0.05

significantly increased (p=0.05). Also, the number of frost days have decreased significantly at p=0.05, indicating the increase in minimum temperature.

The trend and slope of absolute and threshold rainfall indices like maximum one day (RX1day), five day (RX5day), number of days having total rainfall of 10mm, 20mm and 30mm (R10mm, R20mm and R30mm) showed increasing trend but non-significant. The consecutive wet days (CWD) and consecutive dry days (CDD) showed negative and non-significant trend. The simple duration intensity index (SDII) of rainfall also showed positive non-significant trend. Rainfall is becoming highly variable and unpredictable along with potential increase in temperature, causing extreme events like floods and droughts. This indicated the erratic nature of rainfall over the region and the changes in rainfall are less significant than those for temperature. The results are consistent with the findings of study by Kaur *et al* (2021) and Mamta *et al* (2020). This erratic behavior of rainfall will impact the crop productivity significantly as revealed by studies of Gitay *et al* 2001.

The data revealed an overall warming compared to previous three decades in the Jalandhar district based on the results indicating an increasing trend in the temperatures particularly minimum temperature. Lunagaria *et al* (2015) also argued that in Gujarat, the cooling during the cold nights was decreased and rainfall had no uniform increasing or decreasing trend either. Zhao and Khalil (1993) also observed similar phenomenon in the United States and linked it to climate change. Similarly, Kug *et al.* (2015) observed an increase in the frequency of extreme weather events in many countries of East Asia and Northern America during the recent years as a result of Arctic warming. Besides that, Dosio (2020) evaluated ETCCDI indices and reported that 0.5 ^{O}C to 2.0 ^{O}C increase in air temperature may decrease the frost night (FD) and frost day indices, that can impact agriculture and environment, as well as an increase in agricultural pests, whereas an increase in the Frost Days and Tropical nights indices will negatively affect public health.

It has been clear from the study that minimum air temperature has increased significantly that is apparent from the decrease in number of frost days and increase in number of tropical nights leading to extended summers. Heat wave and cold wave events have also shown non-significantly increasing trend. The rainfall behavior has become non-uniform and erratic. The extreme climatic indices could be used for forecasting the crop productivity, outbreak of diseases, ground water levels under present and future scenarios.

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