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# Assessing the decadal features of rainfall and drought occurrence in Punjab

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**सार** – पंजाब में 1971-2011 की अवधि के दौरान वर्षा के विभिन्न संवर्गों (2.5-25, 25-50, 50-75, 75-100 और > 100 मिमी) के लिए वर्षा परिवर्तिता और इसकी संभाव्य,ता का अध्ययन करने के लिए एक विश्लेषण किया गया। राज्य के विभिन्न कृषि जलवायविक क्षेत्रों का निरूपण करने वाले लुधियाना, रूप नगर, होशियारपुर और फिरोजपुर में बारिश में कमी की प्रवृत्ति देखी गई। सार्थकताके विभिन्न स्तरों (90, 75, 50, 25, 10%) पर वर्षा की संभाव्यदता की गणना की गई और वर्षा की उच्चतम संभाव्यता 10% के स्तर पर देखी गई तथा सबसे कम वर्षा की संभाव्याता 90% के स्तर पर देखी गई। सूखे के अध्ययन से स्क्रेत मिलता है कि फरीदकोट में 4, मुक्तसर में 4, लुधियाना में 3, संगरूर में 3 और मोगा में 3 सूखे की आवृत्ति दर्ज की गई।

**ABSTRACT.** An analysis was carried out to study the rainfall variability and its probability for different categories of rainfall events (2.5-25, 25-50, 50-75, 75-100 and >100 mm) in Punjab during the period (1971-2011). The rainfall showed decreasing trend in Ludhiana, Roop Nagar, Hoshiarpur and Ferozpur representing different agroclimatic zones of the state. The probability of rainfall at different level of significance (90, 75, 50, 25, 10%) was computed and it was found that the highest probability rainfall was observed at 10% level and lowest rainfall probability was observed at 90% level of confidence. The study of drought indicated that the frequencies of drought were reported 4 times in Faridkot, 4 times in Mukatsar, 3 times in Ludhiana, 3 times in Sangrur and 3 times in Moga.

**Key words** – Rainfall trend, Rainfall, Rainy days, Probability, Drought, Moving average.

## 1. Introduction

Temporal and spatial variability in rainfall are highly important for agricultural planning and sustainability. Maintaining the ecological balance is difficult task in the arid and semi-arid regions. Since, monsoon fluctuations are of vital importance to agriculture, water supply and energy planning, numerous attempts have been made to develop techniques to predict monsoon rainfall and its variability. Virmani (1989) suggested three types of annual rainfall variation, *viz*., random yearly variation, trends in diminishing annual rainfall and oscillations in annual rainfall in a decade or two. The importance of monsoon prediction stems from the strong link between agricultural productivity and monsoon performance. Therefore, the understanding of monsoon behaviour, *viz*., annual, seasonal and intra-seasonal variability in a particular region is necessary to identify the optimal cropping strategies that ensure the sustainable ecological development (Sinha *et al*., 1989).

Kumar and Desai (1999) analyzed Indian summer monsoon rainfall variability and concluded less inter-annual variability in the decade from 1987 to 1996 in comparison with the earlier decades. It is indicated that in some years or epochs an out of phase relationship exists between the poor performances of the monsoon rains over India and the abnormal rain over the eastern/central pacific, suggesting very large scale tele-connection which operates through the displacement of the east-west circulation resulting from the changes in the thermal forcing in the equatorial regions on the planetary scale.

A lot of scientific Literature on the Indian and Asian monsoon is available (Chang and Krishnamurti, 1987) however possible connection between rainfall anomalies over the countries in the Asian monsoon region have received little attention. Some work in this direction has been done by investigating the relationship between rainfall variations over India with variations over china (Kriplani and Singh, 1993); Thailand (Kriplani *et al*., 1995)

**TABLE 1**

**Decadal features of rainfall at Ludhiana**

| Period | Average rainfall (mm) | Total No. of rainy days (2.5-25 mm) | Total No. of rainy days (25-50 mm) | Total No. of rainy days (50-75 mm) | Total No. of rainy days (75-100 mm) | Total No. of rainy days (>100 mm) |
|---|---|---|---|---|---|---|
| 1971-1980 | 594.5 | 406 | 36 | 4 | 1 | 0 |
| 1981-1990 | 653 | 344 | 41 | 2 | 3 | 2 |
| 1991-2000 | 557 | 403 | 47 | 8 | 2 | 1 |
| 2001-2010 | 478.5 | 449 | 43 | 5 | 3 | 0 |
| Mean | 570.7 | 400.5 | 41.75 | 4.75 | 2.25 | 0.75 |
| SD (mm) | 73 | - | - | - | - | - |
| CV (%) | 12.8 | - | - | - | - | - |

and over Bangladesh and Nepal. In view of this, the present study was undertaken to study the inter annual and decadal rainfall variability in Punjab.

## 2. Materials and method

Analysis of past 41 years (1971-2011) rainfall data was carried out to examine the variability in rainfall features in different district of Punjab. The state of Punjab receives rainfall ranging from 1000 to 1100 mm in the north-eastern part of Punjab and less than 400 mm extreme in south western Punjab (Kingra *et al*., 2018). As the Punjab state is divided into five agro climatic zones, thus one district from each zone was selected for rainfall analysis namely Ludhiana representing central plain zone, Roop nagar representing sub-mountain undulating zone, Hoshiarpur representing undulating plain zone, Ferozpur representing western plain zone and Bathinda representing western zone. The climate is generally very hot in summers and remarkably cold in winters. High temperatures of more than 45 °C is recorded during the month of May in most parts, whereas, in winters the temperature goes down to –2 to –3 °C for a few days.

### 2.1. *Data collected*

The rainfall data of past 41 year were collected from Department of Climate change and Agricultural Meteorology PAU, Ludhiana, India Meteorological Department, Statistical Abstracts of Punjab and Central Research Institute for Dry land Agriculture. The rainfall collected from different agencies was analysed using M.S. Excel and "Weather Cock" a software developed by Central Research Institute for Dryland Agriculture (CRIDA) Hyderabad. The moving average analysis was conducted to remove the variability in the data for trend analysis of rainfall features (increasing/decreasing). Statistics in all the study was carried out with decadal time span in one district of each agro climatic zone of Punjab. Number of rainy days in different categories (2.5-25, 25-50, 50-75, 75-100 and >100 mm) and rainfall probability with different confidence levels were computed using weather cock. The long term trend in the rainfall for various time domains for the period (1971-2011) was conducted by taking 2, 3 and 5 years moving average analysis. The drought intensities of different levels were calculated using the weather cock software developed by CRIDA, Hyderabad assuming if:

$Y = (i, 1) – \text{tyr/tyr*100}$; $X = y*(-1)$.

If $Y >= 0$ and $Y <= -25$ Then No Drought

If $x <= 25$ Then No Drought

If $x > 26$ and $x <= 50$ Then Moderate Drought

If $x > 50$ Then Severe Drought

## 3. Results and discussion

### 3.1. *Decadal analysis*

In Ludhiana district, higher number of rainy days were observed in the range of 2.5 to 25 mm rainfall during 2001 to 2010 (449) and lowest during 1981 to 1990 (344). Total number of rainy days in the range of 25-50 mm were highest (47) in the decade 1991 to 2000 followed 2001 to 2010 (43). Number of rainy days in the range of 50 to 75 mm increased from 2 in during 1981 to 1990 to 8 during 1991 to 2000. Two events of extreme rainfall (>100 mm) were reported during 1981 to 1990 and followed by one during 1991 to 2000 (Table 1). Bhatla *et al*. (2016) also examined the variations in the seasonal rainfall during the period 1971-2010. The regression equation depicted very small decreasing trend of the order of 2.5 mm/year. The

**TABLE 2**

**Decadal features of rainfall at Hoshiarpur**

| Period | Average rainfall (mm) | Total No. of rainy days (2.5-25 mm) | Total No. of rainy days (25-50 mm) | Total No. of rainy days (50-75 mm) | Total No. of rainy days (75-100 mm) | Total No. of rainy days (>100 mm) |
|---|---|---|---|---|---|---|
| 1971-1980 | 830.5 | 623 | 60 | 1 | 1 | 1 |
| 1981-1990 | 877.5 | 631 | 75 | 12 | 4 | 0 |
| 1991-2000 | 896.3 | 678 | 62 | 12 | 3 | 5 |
| 2001-2010 | 584.4 | 708 | 54 | 7 | 1 | 1 |
| Mean | 797.175 | 660 | 62.75 | 8 | 2.25 | 1.75 |
| SD (mm) | 144.5 | - | - | - | - | - |
| CV (%) | 18.1 | - | - | - | - | - |

**TABLE 3**

**Decadal features of rainfall at Roop Nagar**

| Period | Average rainfall (mm) | Total No. of rainy days (2.5-25 mm) | Total No. of rainy days (25-50 mm) | Total No. of rainy days (50-75 mm) | Total No. of rainy days (75-100 mm) | Total No. of rainy days (>100 mm) |
|---|---|---|---|---|---|---|
| 1971-1980 | 845.5 | 566 | 60 | 8 | 5 | 0 |
| 1981-1990 | 948 | 545 | 58 | 11 | 6 | 3 |
| 1991-2000 | 783 | 596 | 45 | 14 | 3 | 2 |
| 2001-2010 | 730 | 673 | 57 | 9 | 2 | 1 |
| Mean | 826 | 595 | 55 | 10.5 | 4 | 1.5 |
| SD (mm) | 93.6 | - | - | - | - | - |
| CV (%) | 11.3 | - | - | - | - | - |

**TABLE 4**

**Decadal features of rainfall at Ferozpur**

| Period | Average rainfall (mm) | Total No. of rainy days (2.5-25 mm) | Total No. of rainy days (25-50 mm) | Total No. of rainy days (50-75 mm) | Total No. of rainy days (75-100 mm) | Total No. of rainy days (>100 mm) |
|---|---|---|---|---|---|---|
| 1971-1980 | 449 | 302 | 31 | 2 | 0 | 0 |
| 1981-1990 | 423 | 310 | 27 | 6 | 4 | 0 |
| 1991-2000 | 344 | 333 | 28 | 9 | 2 | 1 |
| 2001-2010 | 159 | 346 | 19 | 2 | 1 | 0 |
| Mean | 343.75 | 322.75 | 26.25 | 4.75 | 1.75 | 0.25 |
| SD (mm) | 131 | - | - | - | - | - |
| CV (%) | 38.1 | - | - | - | - | - |

highest cumulative rainfall of 1438.7 mm was observed in the year 1971 and lowest of 511.3 mm was observed in 2004. The trend in the month of June for entire study period 1971-2010 was not noticeable, although, it was towards negative side.

In Hoshiarpur district, highest number of rainy days in the category of 2.5 to 25 mm rainfall were observed in 2001 to 2010 (708) and lowest number during 1971 to 1980 (623). In the range of 25-50 mm, number of rainy days during 1981 -1990 were observed to be the highest

**TABLE 5**

**Decadal features of rainfall at Bathinda**

| Period | Average rainfall (mm) | Total No. of rainy days (2.5-25 mm) | Total No. of rainy days (25-50 mm) | Total No. of rainy days (50-75 mm) | Total No. of rainy days (75-100 mm) | Total No. of rainy days (>100 mm) |
|---|---|---|---|---|---|---|
| 1971-1980 | 390.5 | 160 | 40 | 11 | 0 | 0 |
| 1981-1990 | 405 | 210 | 30 | 14 | 4 | 2 |
| 1991-2000 | 374 | 187 | 20 | 12 | 4 | 3 |
| 2001-2010 | 430 | 214 | 21 | 3 | 0 | 0 |
| SD (mm) | 23.7 | - | - | - | - | - |
| CV (%) | 5.9 | - | - | - | - | - |

**TABLE 6**

**Temporal variability of drought condition in different districts of Punjab**

| District | Moderate drought | Severe drought |
|---|---|---|
| Bathinda | 1974, 1979-1982, 1984, 1987, 1991-1992, 1999, 2002, 2004 (12 time) | Nil |
| Ferozpur | 1974, 1979, 1982, 1989, 1991, 1999, 2001-2002, 2004, 2009 (10 times) | Nil |
| Hoshiarpur | 1972, 1974, 1987, 1991 (4 times) | Nil |
| Ludhiana | 1979, 1992, 1999 (3 times) | 1974, 1984, 1987 (3 times) |
| Roop Nagar | 1974, 1979, 1987 (3 times) | Nil |

(75) and highest rainfall (896.3 mm) was reported during 1991-2000. The highest number of extreme events (5) in the category of >100 mm have been during 1991 to 2000. The coefficient of variation was 18.1% with SD of 144.5 mm (Table 2). In all the three categories number of rainfall events has decreased in the recent decade.

In Roop nagar, highest number of rainy days in the range of 2.5 to 25 mm rainfall were observed in 2001 to 2010 (673) and lowest during 1981 to 1990 (545). The extreme events were reported to decrease as reflected by decreasing number of rainy days. The number of rainy days decreased from 60 during 1971-1980 to 45 during 1991-2000 (Table 3). Dubey *et al.* (2014) also studied the variation in frequency of occurrence of heavy and very heavy rainfall in the light of antecedent synoptic situations. It was confirmed from 400 case studies that low pressure area producing around 50% of the total number of heavy and very heavy rainfall in July.

In Ferozpur, highest number of rainy days in the range of 2.5 to 25 mm rainfall in 2001 to 2010 (346) and lowest during 1971 to 1980 (302). It was observed that the rainfall in the recent past has decreased drastically from 449 mm in 1971 to 1980 to 159 mm during 2001-2010 (Table 4). In Bathinda, highest number of rainy days in the range of 2.5 to 25 mm rainfall were observed in 2001 to 2010 (214) and lowest during 1971 to 1980 (160). The extreme events were reported to increase from 2 during 1981-1990 to 3 during 1991-2000 (Table 5).

### 3.2. *Rainfall trend*

Trends analysis of rainfall data of different districts of Punjab, *viz*., Ludhiana, Hoshiarpur, Roop nagar, Ferozpur and Bathinda was carried out. The variability for rainfall data with respect to year was smoothen for better presentation of the rainfall trend over the year that was done by taking 2 year, 3 year and 5 year moving average.

Ludhiana falling in the Central Plain Agro-climatic zone of Punjab was found to receive an average rainfall of 570.7 mm with the highest (653.0 mm) in the decade of 1981to 1990 and lowest (478.5 mm) being in 2001 to 2010. The standard deviation and coefficient of variation of rainfall at Ludhiana was 73 mm and 12.8 per cent

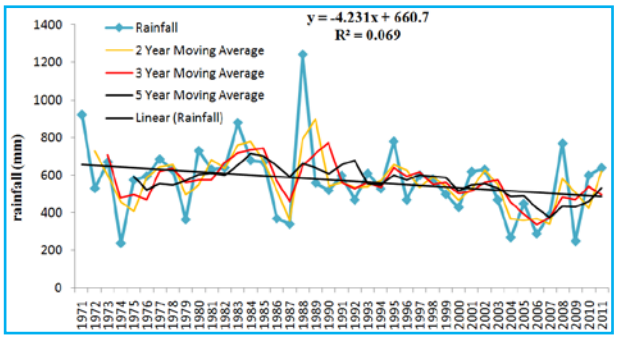


**Fig. 1.** Annual rainfall variability in Ludhiana from 1971-2011

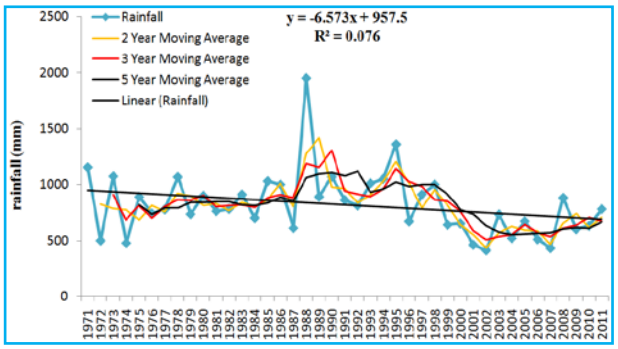


**Fig. 2.** Annual rainfall variability in Hoshiarpur from 1971-2011

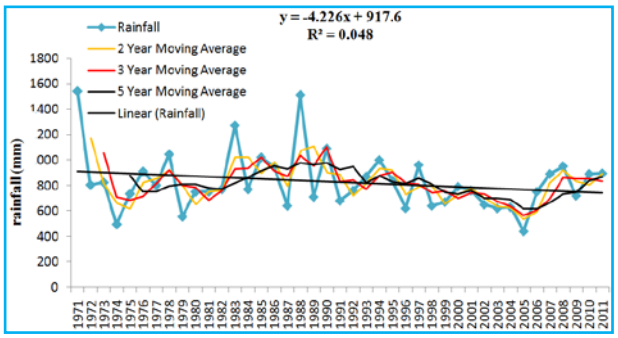


**Fig. 3.** Annual rainfall variability in Roop Nagar from 1971-2011

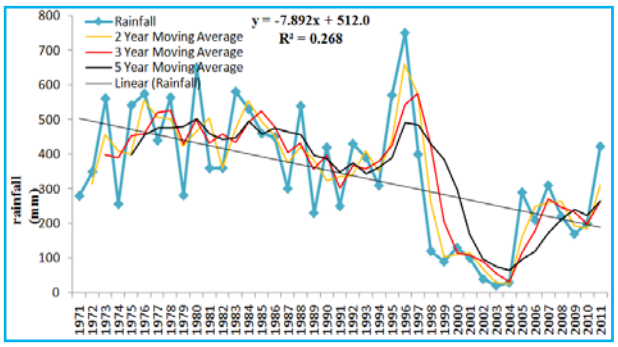


**Fig. 4.** Annual rainfall variability in Ferozpur from 1971-2011

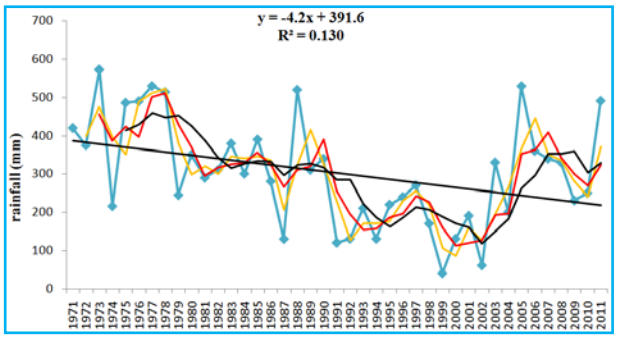


**Fig. 5.** Annual rainfall variability in Bathinda from 1971-2011

respectively. The moving average obtained across the span of 41 years indicated a decreasing trend and the rainfall was found to decrease at a rate of -4.231 mm per year (Fig. 1). Dubey *et al*. (2014) examined that 59% of the stations did not show any trend, whereas 19% of stations have shown positive significant trends.

In Hoshiarpur, rainfall varied from 584.4 mm to 896.3 mm with a standard deviation of 144.5 and Coefficient of variation of 18.1. The highest rainfall (896.3) was observed during 1991 to 2000 and lowest (584.4 mm) during 2001 to 2010. The moving average attempted at 2 year, 3 year, 5 year interval showed a slightly decreasing trend of rainfall (6.573 mm per year) (Fig. 2). The Roopnagar district received an average rainfall of 826.0 mm with the maximum (948 mm) during 1981 to 1990 and lowest (730 mm) in the decade of 2001 to 2010. The rainfall deviation from the mean was by 93.6 mm and variability was 11.3 per cent. The rainfall showed the decreasing trend (4.226 mm per year) for all the scenario of moving average (Fig. 3).

This district has been characterized as a zone of low intensity rainfall and received 343.75 mm of rainfall annually. The highest rainfall (449.00 mm) was reported to occur in the decade of 1971-1980 and lowest (159 mm) in the 2001-2010 with a SD and CV of 131 mm and 38.1 per cent, respectively. The rainfall of this region has been showing a decreasing trend at the rate of -7.892 mm per year (Fig. 4). This district received 408 mm average rainfall annually is characterized low rainfall zone. The analysis over the 41 year of time series data showed that the rainfall has been showing a decreasing trend at the rate of -4.226 mm per year (Fig. 5).

### 3.3. *Probability of the rainfall*

The probability of the rainfall was computed on 10, 25, 50, 75 and 90 per cent confidence level. The probability of rainfall was found to increase from 90 per cent level of significance to 75, 50, 25, 10 per cent and

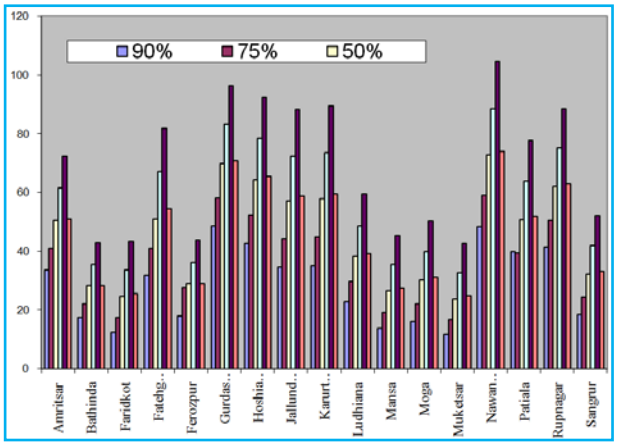


**Fig. 6.** probability of the rainfall

mean levels (Fig. 6). Kumar and Kumar (2014) studied that a rainfall at 75% and 90% probability was assured rainfall and at 50% probability was the median limit for taking risk. On the other hand lowest probability was observed when the probability level is kept at 90 per cent. Baweja (2011) also studied the rainfall probability for different levels of significance for Himachal Pradesh.

### 3.4. *Spatio-temporal variability of drought in Punjab*

The drought conditions were determined as per the limits provided in the Weather Cock for computation of drought intensities. It was observed that Ferozepur, Hoshiarpur and Roop nagar, no severe droughts were observed during the period under study. The moderate drought was also reported in different districts during different time span, which included Bathinda (12 times), Hoshiarpur (4 times) and Ludhiana (3 times). Severe Drought intensity was observed at Ludhiana (3 times). However, no severe drought was observed at Bathinda, Ferozpur, Hoshiarpur and Roop Nagar during the time series of 41 years (Table 6).

## 4. Conclusions

Large rainfall variability has been observed in different agro-climatic regions of Punjab. Average decadal rainfall in the state has been observed to decrease, whereas number of heavy rainfall events are on the rise. Moderate to severe drought conditions have been observed at different temporal scales in all the regions of the state.

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### References

Baweja, P. K., 2011, "Rainfall variability and probability for crop planning in Solan", Himachal Pradesh", *Journal of Farm Sciences*, **1**, 1, 75-88.

Bhatla, R. Tripathi, A. and Singh, R. S., 2016, "Analysis of rainfall pattern and extreme events during southwest monsoon season over Varanasi during 1971-2010", *MAUSAM*, **67**, 4, 103-108.

Chang, C. P. and Krishnamurti, T. N., (eds), 1987, "Monsoon meteorology, Oxford University Press", Oxford, p544.

Dubey, D. P. and kumar, G. K., 2014, "Trends in precipitation extremes over Central India", *MAUSAM*, **65**, 103-108.

Kingra, P. K., Setia, R., Kaur, S., Kaur, J., Singh, S., Singh, S. P., Kukal, S. S. and Pateriya, B., 2018, "Analysis and mapping of spatio-temporal climate variability in Punjab using classical statistics and geostatistics", *MAUSAM*, **69**, 147-160.

Kripalani, R. H., Singh, S. V., Panchawagh, N. and Brikshavana, M. 1995, "Variability of the summer monsoon rainfall over Thailand Ð Comparison with features over India", *Int. J. Climatol*., **15**, 657-672.

Kriplani, R. H. and Singh, S. V., 1993, "Large scale aspect of India - China summer monsoon rainfall", *Adv. Atmos. Sci*., **10**, 71-84.

Kumar, J. R. and Desai, D. S., 1999, "Monsoon variability in recent years from synoptic scale disturbances and semi-permanent system", *MAUSAM*, **50**, 2, 135-144.

Kumar, Sunil and Kumar, Surjeet, 2014 "Long-term trends and probability of rainfall for crop planning in Bihar", *J. Agrometeorol*., **16**, 1, 146-148.

Sinha, S. K. Rao, N. H. and Swaminathan, M. S., 1989, "Food security in the changing global climate", Climate and Food Security. International Rice Research Institute, Manila, Phillipines, 579-597.

Virmani, S. M., 1989, "Cropping systems strategies for coping with climatic fluctuations", IRRI, Climate and Food Security, PO Box 933, Manila, Philippines.