MAUSAM, **68**, 4 (October 2017), 733-750

L E T T E R S

556.121 (540.15)

LONG TERM AND RECENT VARIABILITY IN RAINFALL AMOUNT AND DISTRIBUTION IN DIFFERENT AGROCLIMATIC REGIONS OF PUNJAB

1. Rainfall amount and its distribution constitute the most important factors which affects the economy of a country as a whole especially developing country like India. However, over the years, the change of land use, urbanization and creation of concrete jungles apart from increasing the level of green house gases (GHG) in the atmosphere has disturbed the normal distribution of rain amount over time and space. Temporal variability in precipitation is a key factor influencing the structure and functioning of an ecosystem (Knapp and Smith, 2001; Collins *et al*., 2008). The crops are affected by rainfall amount, distribution, dry spells, wet spells, length of growing season etc. The total rain amount over certain period is of little use in agriculture as its distribution over time and space fulfills the crop water requirements especially in dry land regions.

Long term trends of Indian monsoon rainfall for the country as a whole as well as for smaller regions (Parthasarathy *et al*., 1994) indicate that the monsoon rainfall has been random in nature over a long period of time (Parthasarathy, 1984; Rupa Kumar *et al*., 1992). The contribution of June, July and September rainfall to annual rainfall is decreasing in some sub-divisions while contribution of August rainfall is increasing in others. In Punjab, a decreasing trend in annual rainfall amount has been observed in most of the districts (Kaur *et al*., 2013) but monsoon rain shows an increasing trend over the time. The monsoon season rain not only directly influences the kharif season crops like rice but also reduces dependence on energy sources for drawing ground waters. Moreover, the well-distributed monsoon rains are important for ground water recharge. A large inter and intra-annual rain variability is being observed during the last few years in different agro-climatic regions of the state. There is, thus, need to study in detail the monsoon rain variability in time and space over the years for better management of rain water for agriculture. The present study is an attempt in this direction and aims to study spatial and temporal variations in rainfall amount and its distribution in the state of Punjab.

The Punjab state has been mainly differentiated in three agroclimatic zones mainly on the basis of rainfall

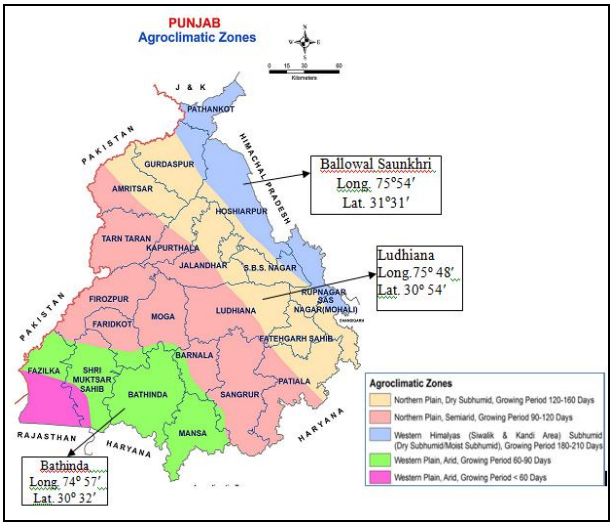


Fig. 1. Agroclimatic regions of Punjab

Amount, *viz*., sub-mountaneous undulating zone, central plain zone and south-western zone lying between 30^{o} 09′ to 31^{o} 06′ N latitude and 74^{o} 55′ to 76^{o} 23′ E longitude, respectively and at an altitude of 211-355 m above mean sea level. The normal annual rainfall in sub-mountainous undulating, central plain and south-western zone is 1070, 750 and 530 mm, respectively, whereas, the normal monsoon rainfall for these regions is 849, 604 and 406 mm, respectively. The monsoon rain occurring during July to September with pre-monsoon showers during the month of June constitutes 80% of the annual rainfall. The monsoon season rainfall data was collected for these regions during the period 1970-2014 and analyzed using simple statistical techniques, *viz*., average rain amount and its departure from the average annual rain to study the rainfall pattern. The statistical analysis was done by Daniel Soper calculator and significance was checked at 1% and 5% level of significance.

The amount of 2.5 mm or more rain on a single day quantified it to be a rainy day. The deviation in number of rainy days was worked out by subtracting the normal rainy days from the actual rainy days during that particular year. The normal rainfall and number of rainy days were obtained by averaging the long term data (30 years) of rainfall and number of rainy days in three districts of Ballowal Saunkhri (submountaneous region), Ludhiana (central plain region) and Bathinda (south-west region) Fig. 1.

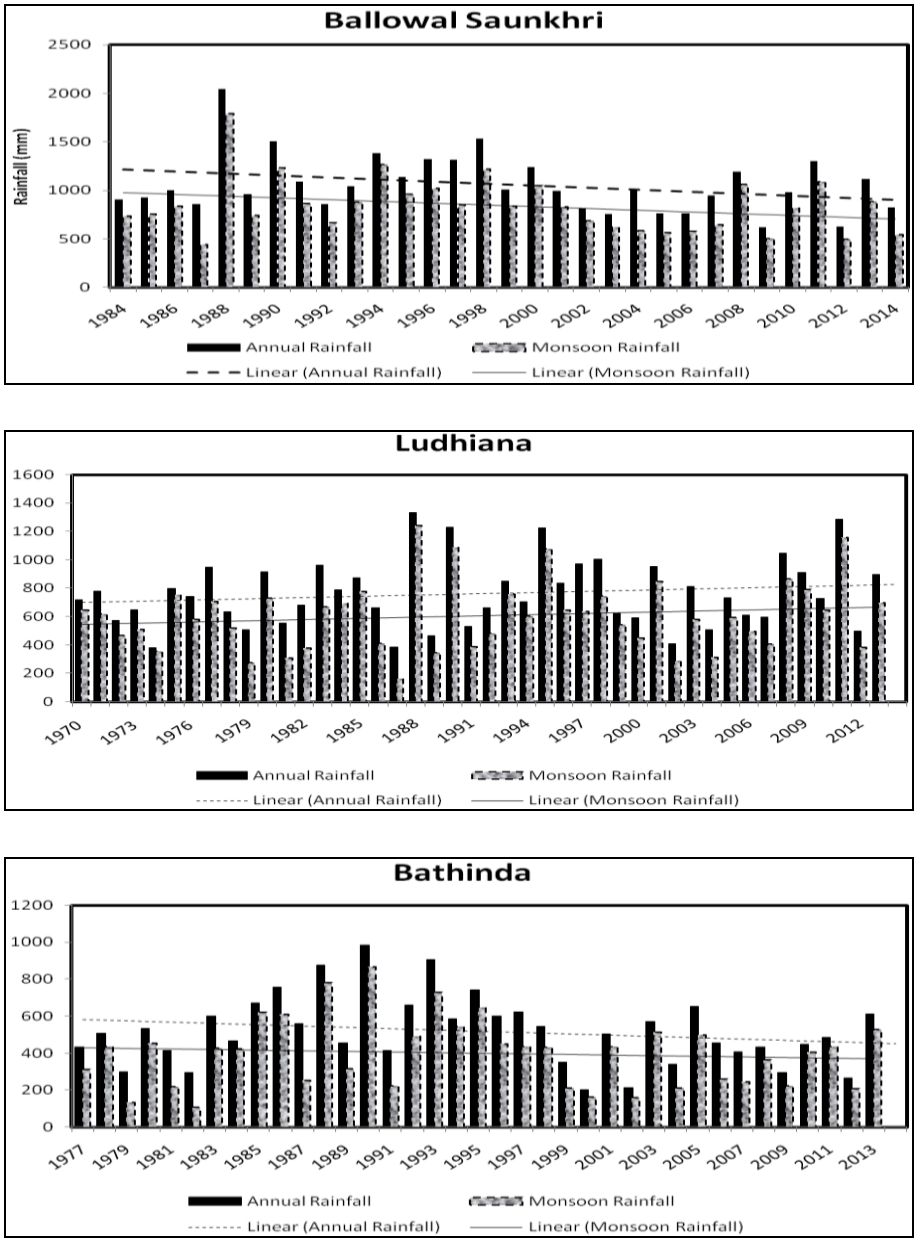


Fig. 2. Temporal variations in annual & monsoon rainfall in submontane (Ballowal Saunkhri), central (Ludhiana) and southwest (Bathinda) regions of Punjab

2. *Total and monsoon rain amount* : The average annual and monsoon rainfall amount in Punjab state fluctuated considerably over the last 45 years (Table 1). The annual rain amount during 1971-80 was 567±141.6 mm, which increased to 858±323.2 mm during 1980-81, remained unchanged during the decade 1991-2000 (848±206 mm) and decreased significantly to 698±198.2 mm during the most recent decade (2001-2014). The average monsoon rain amount decreased (549±173.7 mm) during the last decade (2001-2012) compared to that during the decades 1991-2000 (672±188.3 mm) and 1981-90 (669±348.7 mm). However, it increased over the long period from 443 ± 153.5 mm during 1971-80 to 549±173.7 mm during 2001-14. The monsoon rainfall when averaged over different time periods was quite variable in all the agro-climatic regions of the state (Fig. 4). It is 602, 619, 637, 598, 648 and 673 mm, when averaged over 45, 35, 25, 15, 10 and 5 years, respectively in central Punjab indicating an increase in average monsoon rain during the recent years. The corresponding values were 841, 830, 730, 719 and 894 mm, when averaged over 32, 25, 15, 10 and 5 years

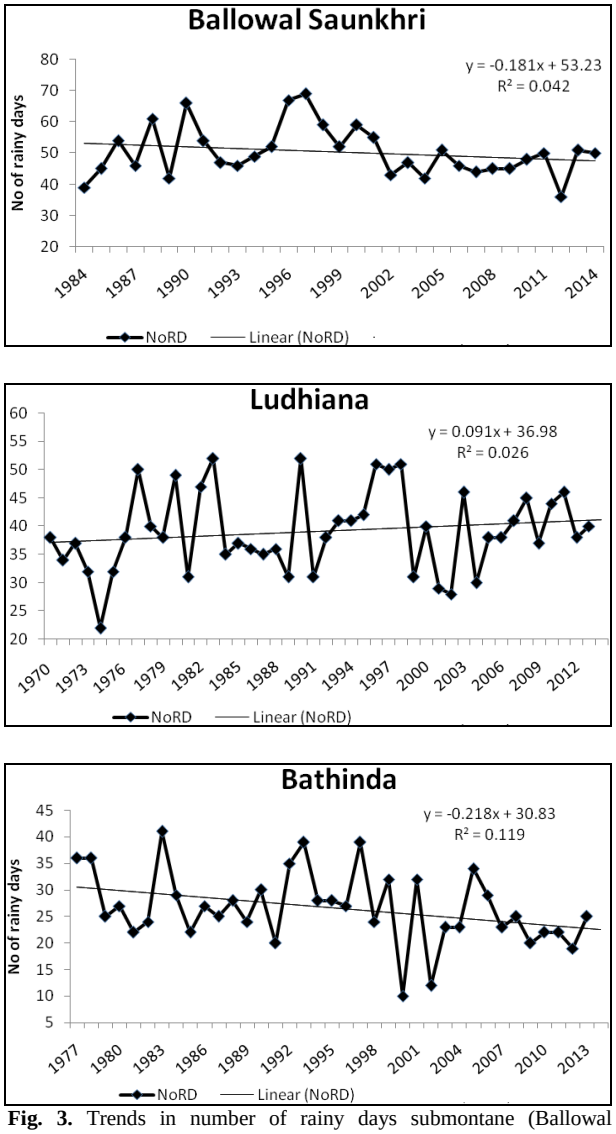


Fig. 3. Trends in number of rainy days submontane (Ballowal Saunkhri), central (Ludhiana) and southwest (Bathinda) regions of Punjab

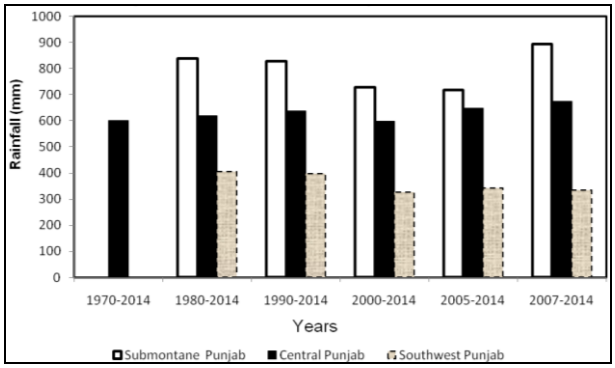


Fig. 4. Average monsoon rain amount over different time intervals in different agroclimatic regions of Punjab

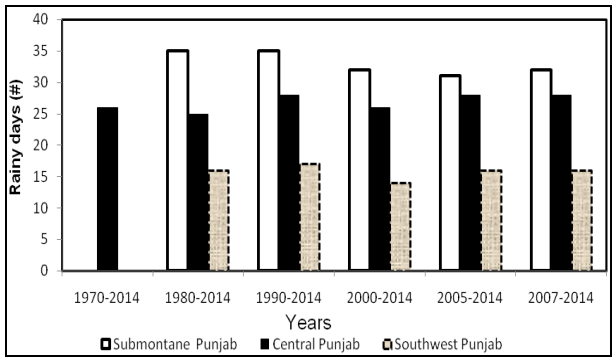


Fig. 5. Average number of rainy days over different time intervals in different agroclimatic regions of Punjab

in submontane Punjab and 404, 398, 328, 344 & 335 mm in southwest Punjab, thereby indicating that average rain amount has decreased in submontane but increased in southwest Punjab during the recent years. The number of rainy days remained unaffected in southwest and central Punjab but decreased in submontane Punjab (Fig. 5).

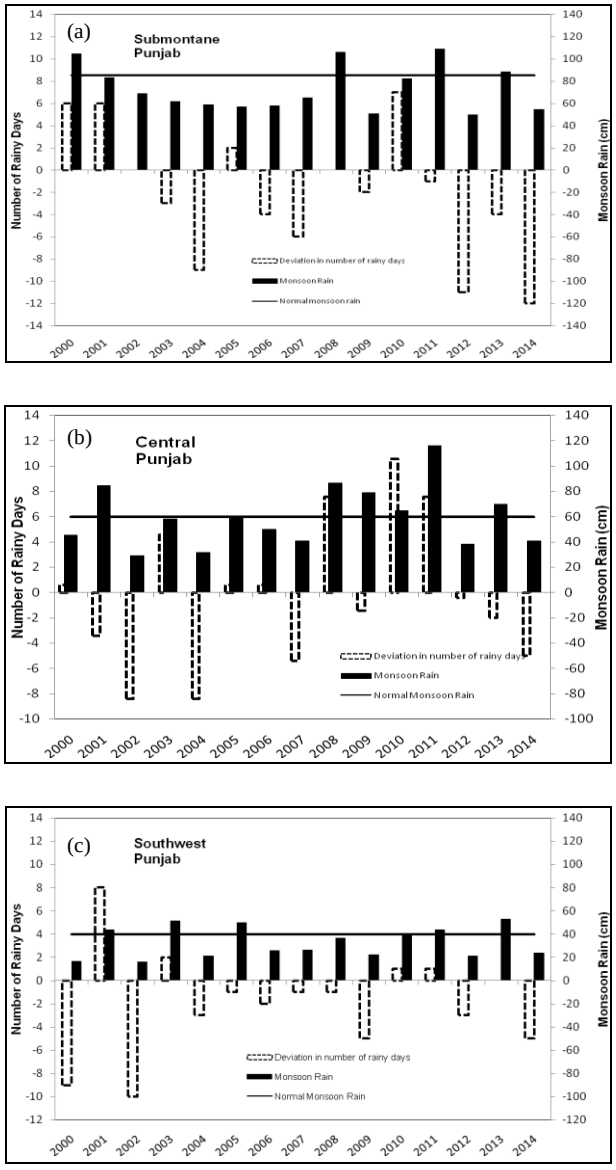
The average annual and monsoon season rain amounts were highest in submontane Punjab (1081 and 863 mm), followed by central Punjab (760 and 602 mm) and lowest in southwestern Punjab (509 and 389 mm) (Table 1). The annual average rain amount in submontane Punjab decreased over the last 30 years (since 1981) from 1173±440.8 mm to 903±203.0 mm. It, however increased in central Punjab from 692±178.8 mm to 760±36.2 mm over the last forty-five years (since 1971), whereas, it remained unchanged in southwestern Punjab. Similarly, the monsoon average rain amount in submontane Punjab decreased from 936±443.5 mm to 706±196.6 mm since 1981 to 2014. In central Punjab, the average monsoon rain increased since 1971 to 2000 from 552±158.7 to 634±197.4 mm but decreased to 601±244.9 mm in recent decade, *i.e.*, 2001-14. However, no significant change has been noticed in southwestern Punjab in the last four decades, *i.e.*, 333±148.3 (1971-80) to 340±128.1 (2001-14).

The annual, monsoon & rainy days over the last decades for different agroclimatic regions were shown in Figs. 2 & 3. The annual & monsoon season rainfall at Ballowal Saunkhri and Bathinda showed a decreasing trend while at Ludhiana both the annual & monsoon rainfall showed an increasing trend. The rate of decrease in annual rainfall at Ballowal Saunkhri is 10 mm/year, whereas the rate of decrease of monsoon rainfall is 9.2 mm/year. The rate of decrease of rainfall is little less in southwestern region, *i.e.*, Bathinda, where rate of decrease of annual rainfall is 3.5 mm/year and monsoon

TABLE 1

Total amount of average annual & monsoon rainfall and number of rainy days in different agroclimatic regions of Punjab during 1971-2014

Regions	Rainfall Amount (mm)		Number of rainy days	
	Mean Annual ± SD	Mean Monsoon ± SD	Mean Annual ± SD	Mean Monsoon ± SD
Submontane Punjab	1085 ± 281	864 ± 274	51 ± 7	35 ± 7
Central Punjab	761 ± 237	599 ± 238	39 ± 7	26 ± 6
Southwest Punjab	511 ± 163	392 ± 179	28 ± 6	18 ± 6
Punjab State	786 ± 227	618 ± 230	39 ± 7	26 ± 6



Figs. 6(a-c). Monsoon rain amount and deviation in number of rainy days during 2000-2014 in (a) Submontane Punjab (b) Central Punjab and (c) Southwestern Punjab

rainfall is 1.7 mm/year. Similarly, the rainy days have also showed a decreasing trend at both the places. The rate of decrease is more at Bathinda region, *i.e*., 0.22 days/year & relatively less at Ballowal Saunkhri, *i.e*., 0.18 days/year. Both the regions, *i.e*., Ballowal Saunkhri and Bathinda revealed a non-significant decreasing trend in rainfall and rainy days in the last 45 years.

The Ludhiana district representing central plain region showed an increasing trend in rainfall at almost same rate. The rate of increase of annual and monsoon rainfall is 2.9 and 2.8 mm/year, respectively. A slight increasing trend has been observed in rainy days at Ludhiana with a rate of 0.09 days/year. Overall a non-significant increase in rainfall as well as rainy days has been noticed at Ludhiana.

3. *Annual and monsoon rain distribution* : The average monsoon rain amount followed similar trend in all the three agroclimatic regions (Table 1). The number of rainy days varied differently in different agro-climatic regions of Punjab**.** The number of rainy days followed similar trend as rain amount. The average number of annual rainy days in the state increased from 34±7.0 in 1971-80 to 39±7.9 during 1981-90 and 42±7.8 during 1991-2000 but again decreased to 37±6.0 during the most recent decade of 2001-14. The number of rainy days during monsoon season did not vary considerably over the time. Earlier during 1971-80 the number of rainy days were 23±5.6 and with little rise in number it increased to 24±8.1 during 1981-90. During third decade 1991-2000, the number increased to 28±5.3 but again decreased to 26±5.0 during 2001-14. Overall there is no significant change in number of rainy days during monsoon season over the past four decades in Punjab.

The number of rainy days decreased in submontane and southwest Punjab over a period of 30 and 40 years, respectively (Table 1) but remained unchanged in central Punjab. The number of rainy days during monsoon season (July-September) in southwestern Punjab decreased from

20 to 16 over a period of 40 years, but remained unchanged in central and submontane Punjab. Since the rain amount in southwest Punjab remained unchanged, a decrease in number of rainy days indicates ill distributed rain during monsoon period in the region. Similarly, no change in number of rainy days being unchanged coupled with substantial increase in rain amount over time indicates poor rain distribution during the monsoon season. The poor distribution of rain has negative impact on ground water recharge and leads to greater runoff from the water sheds.

4. *Recent changes in monsoon rain distribution*: The analysis of deviation in number of rainy days during 2000-2014 [Figs. 6.(a-c)] shows that the decrease in frequency and number of rainy days is more in submontane and southwest Punjab during the recent decade. In central Punjab, frequency of subnormal rainy days was similar to above normal rainy days. However, subnormal rainy days in combination with normal or just normal monsoon rain means ill-distributed rains with a large gap among the rain events. This type of rain distribution results in higher runoff generation leading to soil erosion in submontane Punjab (Kukal *et al*., 1991) and floods in central and southwest Punjab.

The annual and monsoon rainfall has shown an increasing trend in central Punjab, whereas in submontane Punjab, it has decreased over a period of about 40 years (different regions) from the long term average rainfall but trends are statistically non-significant. In southwest zone, the rains increased sufficiently during the period 2001-14. The number of rain events followed similar trend. However, during the recent years (2001-14) the numbers of rain events were below normal for about 8-10 years in all the agroclimatic zones being observed continuously for 6 years in central zone and 9 years in submontane and southwest zones.

References

Collins, S. L., Sinsabaugh, R. L., Crenshaw, C., Green, L., Porras, A. L. faro, A., Strusova M. and Zeglin, L. H., 2008, "Pulse dynamics and microbial processes in aridland ecosystem", *J. Ecology*., **96,** 413-420.

Kaur, Prabhjyot, Sandhu, S. S., Singh, Simaranjit and Gill, K. K., 2013, "Climate Change - Punjab Scenario", *Research Bulletin*, School of Climate Change & Agricultural Meteorology", Punjab Agricultural University, Ludhiana.

Knapp, A. K. and Smith, M. D., 2001, "Variation among biomass in temporal dynamics of above ground primary production", *Science*, **291**, 481-84.

Kukal, S. S., Sur, H. S. and Gill, S. S., 1991, "Factors responsible for soil erosion hazard in submontane Punjab, *India*", *Soil Use and Management*, **7**, 1, 38-44.

Parthasarathy, B., Munot, A. and Kothawale, D. R., 1994, "All-India monthly and seasonal rainfall series 1887-1993", *Theoretical and Applied Climatology*, **49**, 217-224.

Parthasarathy, B, 1984, "Inter-annual and long term variability of Indian summer monsoon rainfall", *Proc. Indian Acad. Sci. (Earth Planet. Sci.*), **93**, 371-385.

Rupa Kumar, K., Pant, G. B., Parthasarathy, B. and Sontakke, N. A., 1992, "Spatial and sub-seasonal patterns of the long-term trends of Indian summer monsoon rainfall", *Int. J. of Climatol*., **12**, 257-268.

K. K .GILL,
*S. S. KUKAL

School of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana, India
(*Received 3 August, 2015 , Accepted 8 May 2017*)
***e mail : sharma23shonam@gmail.com**