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RAINFALL CHARACTERISTICS OF SEMI-ARID HISAR DISTRICT IN HARYANA

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Abstract

Among all weather parameters, rainfall is the main source of fresh water in all land based ecosystems. Study of rainfall over a long period of time not only reveals general trend of rainfall of a particular place but also helps in understanding its amount, intensity, distribution and other characteristics. Rainfall variability is an inherent challenge for domestic water supply, farming and irrigation in arid and semi-arid regions of the world. Therefore, the purpose of the present study is to analyze rainfall data for a period of last thirty years (1980-2009), collected from standard rain gauge stations of Hisar, Hansi and Adampur in semi-arid Hisar district of Haryana to understand its dependability and variability. The rainfall analysis of Hisar district revealed that mean annual rainfall in the region is less than 300 mm. The variability in annual rainfall distribution in the district is very large (> 40%) with high standard deviations indicating towards low dependability. The annual rainfall variability was observed to be 36% at Hisar followed by 37% at Adampur and 56% at Hansi. The analysis also revealed decreasing trends in annual rainfall at Hisar, Hansi and Adampur. However, the frequency of storms equal to 25 mm of rainfall accounts for 90% of the total rainy days at Hansi followed by 87% at Adampur and 85% at Hisar rain gauge stations. Also, a good number of rainy days in Hisar district provide a sufficient potential for rainwater harvesting. Therefore, to avoid the scarcity of water in the region it becomes mandatory to harvest every falling drop of rain for domestic water supply and farming activities.

Introduction

The agriculture based economy and food security of India is dependent on the timely availability of adequate amounts of water. Among all weather parameters, rainfall is the main source of fresh water in all land based ecosystems, whether natural or managed by humans. The land surface globally receives about 113000 km^3 of rainfall. Of this, approximately 41000 km^3 (36%) is manifested as surface runoff. The remaining 64% of rainfall is evaporated through vegetation, soil surface and water surfaces with in the lithosphere. Therefore, rainfall received over an area is one of the most important natural resource input to crop production, industrial production, domestic water supply and appropriate hydrological designing of water harvesting structures in the semi-arid and arid climates (Subash and Das, 2004; Kumar and Jain, 2011). Efficient cropping systems can be evolved by understanding the rainfall pattern besides taking decision on time of sowing, scheduling of irrigation and time of harvesting. Moreover, availability of water through runoff at a locality depends primarily on rainfall amount, its intensity, soil type and slope (Suryanarayana and Megeri, 1987). Study of rainfall over a long period reveals general pattern of rainfall of a particular place and helps in understanding the amount, intensity, distribution and other characteristics. Rainfall variability is an inherent challenge for farming and irrigation in arid and semi-arid regions of the world. Insufficient, erratic and unreliable rainfall pattern makes supplementary or full irrigation indispensable in arid and semi-arid regions. Irrigation expansion limitations, high population growth and scarcity of arable land are factors which call for more food production under rain-fed agriculture. Therefore, several research workers carried out the rainfall analysis for irrigation scheduling and appropriate hydrological designing of water conservation structures (Dhar et al., 1991; Rakhecha et al., 1995; Kumar, 2000; Tomar and Ranade, 2001; Rizvi et al., 2001; Sena and Kurothe, 2004; Kulkarni et al., 2005, 2010). Moreover, rainfall analysis may be useful to serve agricultural purpose in crop planning, land use, water management and agronomic practices including scheduling of irrigation and plant protection activities in a more scientific way. Collection of runoff water and its recycling for stabilizing crop production under rain-fed agriculture in semi-arid and arid climates has been advocated and much work on its feasibility on scientific lines is under way. Biswas and Maske (1981) have approximated the average time distribution of short duration of rainfall in the tropical region.

A comprehensive analysis of rainfall data is a crucial component in the management of water resources. Rainfall patterns in semi-arid areas are unpredictable, both in amount and time. Consequently, the ability to successfully manage the resulting runoff is extremely important (Mbilinyi et al., 2005). Due to these circumstances runoff harvesting is particularly significant because rainwater-runoff can be captured and efficiently utilized to maintain agricultural production in an economically and environmentally sustainable manner. Water scarcity in semi-arid Hisar district of Haryana is a tangible phenomenon and detailed studies on district rainfall have not been undertaken so far to understand the dependability, reliability, consistency and variability. This study therefore, is carried out to fill this gap.

Environmental Setting of the Study Area

The study area for the present research falls under Hisar district, which covers an area of about 4050 km^2. The district lies between 28° 56' 00" to 29° 38' 30" North latitudes and 75° 21' 12" to 76° 18' 12" East longitudes (Fig. 1). Administratively, district is divided into nine community development blocks and 275 villages. Hisar is predominantly an agricultural district. However, the district is regularly traversed by droughts, famines and scanty and erratic rainfall. The most severe famine in the district was recorded in the year 1783. The district has also experienced noticeable severe droughts and famines during 1860, 1869, 1877, 1896, 1899, 1929, 1932, 1936, 1938-41 and 1987 (Bhatia and Kumar, 1987).

The district is a part of Ghaggar-Yamuna alluvial plain and its southern and western portions mark a gradual transition to the Thar Desert. The bed-rock topography over which the alluvial deposits rest, slopes towards north-east. The maximum thickness of alluvium as encountered in a borehole is 345.5 m below ground level. The topographic pattern of the district owes its existence to geomorphic processes having closer affinity with the

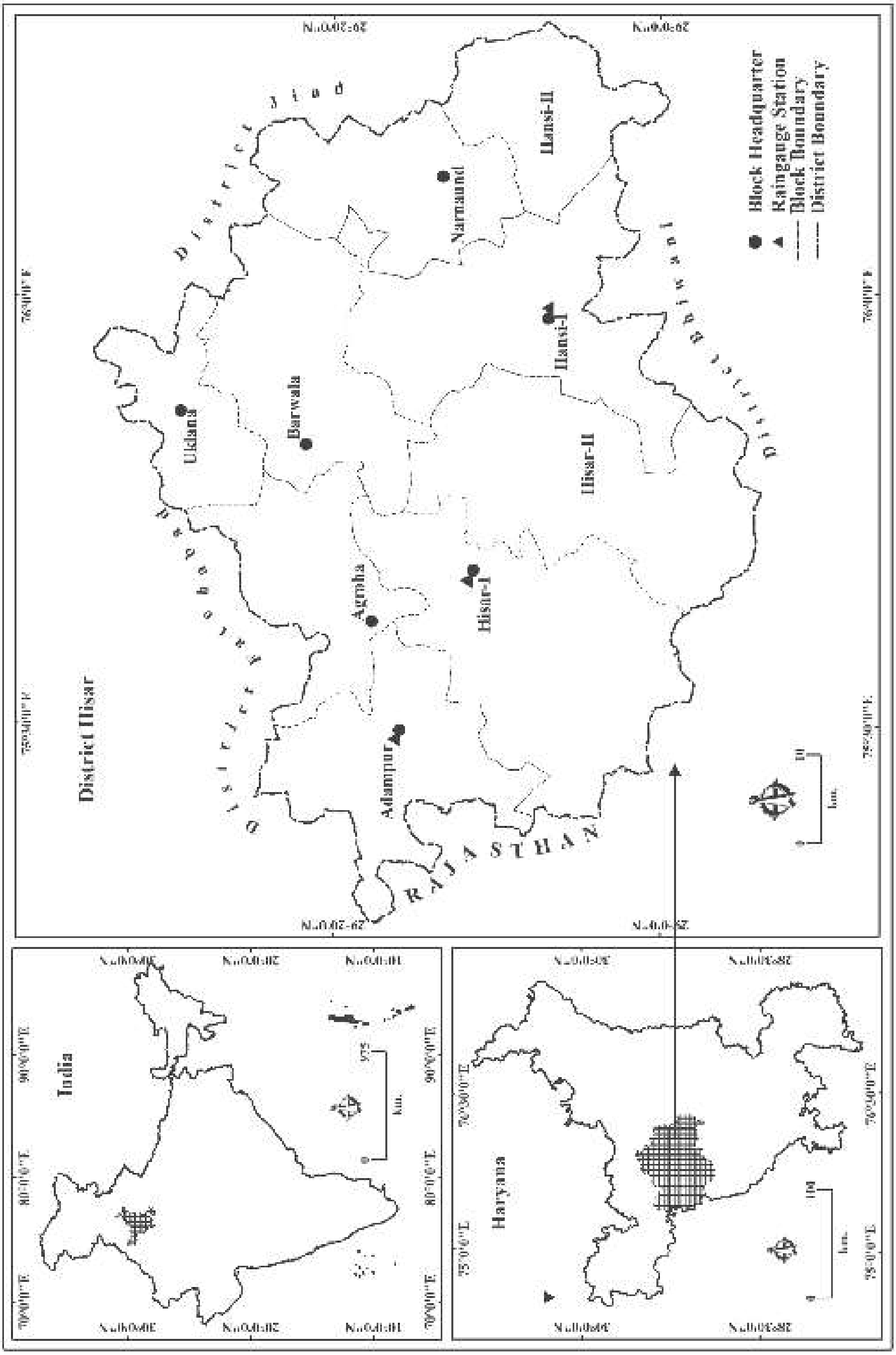
District Hisar
India
Haryana
Block Headquarter
Raingauge Station
Block Boundary
District Boundary
Uklana
Barwala
Narnaund
Hansi-II
Hansi-I
Hisar-II
Hisar-I
Agroha
Adampur
District Jind
District Fatehabad
District Bhiwani
RAJASTHAN

Fig. 1

climatic aridity, both of the recent and past geologic periods. The aeolian deposits comprising accumulation of sand blown from Thar Desert of Rajasthan are mostly confined to south-western part of the district. These sand accumulations occupy vast stretches of land and occur in the shape of sandy flats, mounds and ridges at places attaining dunal shapes over the sandy flats. In comparison to the other deserts around the world, the sand dunes of Hisar district are characterized by a finer composition of sand particles. The district area slopes from northeast to southwest and its altitude varies from 203 to 225 m above mean sea level (amsl). The active and moving sand dunes generally occur along the western fringe of the district. The vegetal cover in the district is scant and it resembles the treeless undulating desert. The ground water in the district is very deep and it is available at more than 80 m depth from the surface. Moreover, it is saline and unfit for domestic and agriculture consumption in most parts of the district.

According to the classification of Thornthwaite's (1948), the climate of the area falls under tropical steppe, semi-arid and hot type. It is mainly characterized by dryness and extremes of temperature with exception during southwest monsoon period when moist air of oceanic origin penetrates into the district. The variation in the annual rainfall from year to year is very large. Moreover, it occurs for about 23 days in a year and is unevenly distributed over the district. Rainfall in the area is seasonal in nature, most of which occurs during the period from July through to September. Cyclonic rain is also received in the area during winter season (January to February). Mean monthly wind speed at Hisar varies between 2.5-10 km/h. Dust storms are experienced occasionally during summer months and hail storm during winter months. Fog generally prevails during December and January months. Thunderstorms occur throughout the year but the highest incidences have been observed during monsoon season.

Objectives of the Study

Objectives of the present study are:

1. To analyse the nature of distribution of rainfall (annual, seasonal, monthly, daily, frequency analysis etc) in semi-arid Hisar district of Haryana;
2. To work out probable maximum precipitation (PMP) of Hisar district using Hershfield statistical technique.

Materials and Methods

Acquisition of Rainfall Data

The present study is primarily based on secondary data. The rainfall data for Hisar, Hansi and Adampur rain gauge stations located in Hisar district were collected from District Revenue officer, Hisar for a period of thirty years (1980-2009). In general, a data set for thirty or more years of rainfall is considered adequate to carry out any hydrological investigation; therefore, due to non availability of long period rainfall data for other rain gauge stations of the district (e.g. Uklana and Barwala) could not be incorporated for the analysis in the present study. Thus, the study has to depend upon thirty years rainfall data collected for Hisar, Hansi and Adampur rain gauge stations in semi-arid Hisar district of Haryana state to capture the general pattern of rainfall in the district. For average areal estimation of rainfall depth in the district area, arithmetic mean method was applied.

Coefficient of Variability

Mean annual rainfall figures for any given station do not reflect the reliability of rainfall because the values may represent the means of a number of actual totals widely dispersed on either side of the mean. Therefore, to depict the exact degree of variability in rainfall at different stations in Hisar district the following statistical equation has been used to represent the form of co-efficient of variability.

$$CV = \frac{\sigma}{\bar{x}} \times 100 \quad (1)$$

Where, CV = Co-efficient of variability in percent,

σ = Standard deviation and

$\bar{x}$ = the mean

Calculation of Anomalies of Rainfall

For better understanding of the observed trends in rainfall, anomalies were computed. Anomalies are more accurate than absolute rainfall to describe rainfall variability. To analyze anomalies in rainfall, the average annual and seasonal rainfall were calculated. Folland et al., (1990) suggested 30 years as a standard period for calculating the average to analyze the anomalies. In this research, the relative anomalies and comparison were made with the results obtained using the average from the whole data set. The rainfall anomalies obtained were plotted against time and the linear trends observed were represented graphically. The linear trend value, represented by the slope of a simple least-square regression line with time as the independent variable gives the magnitude of rise or fall in rainfall.

Calculation of Probable Maximum Precipitation (PMP)

PMP is theoretically defined as the greatest depth of precipitation for a given duration that is physically possible for a given size storm at a particular geographical location at a certain time of the year with no allowance made for long term climatic trends. Statistical procedure for estimating PMP is normally used whenever sufficient rainfall data are available and is particularly useful for making quick estimates. Hershfield was a pioneer for estimating PMP values for small areas around the world and this method was employed extensively for estimating PMP for stations having a long period of rainfall records. Therefore, in the present research Hershfield's statistical technique for estimating point PMP has been used (Hershfield, 1961, 1965) and it has been calculated as:

$$X_{PMP} = \overline{X_n} + S_n k_m \quad (2)$$

Where, X_{PMP} = PMP estimate for a station

$\overline{X_n}$ = Mean of the annual maximum series,

S_n = Standard deviation of the annual maximum series and

k_m = Frequency factor which depends upon the availability of data period and the return period. Values of the frequency factor K_m is obtained by using the following equation:

$$k_m = (X_{max} - \overline{X}_{n-1}) / S_{n-1} \quad (3)$$

X_{max} = largest value of the annual maximum series,

$\overline{X}_{n-1}$ = mean of the annual maximum series omitting the largest value from the series, and

S_{n-1} = standard deviation of the annual maximum series omitting the largest value from the series.

All the calculations in the present research were made through the Microsoft office based spread sheet. However, given the large size of the data set, straight tabulations and cross-tabulations were also computed and compiled. Subsequently, these tables were subject to various bar and line graphs for the representation and interpretation of rainfall characteristics of semi-arid Hisar district.

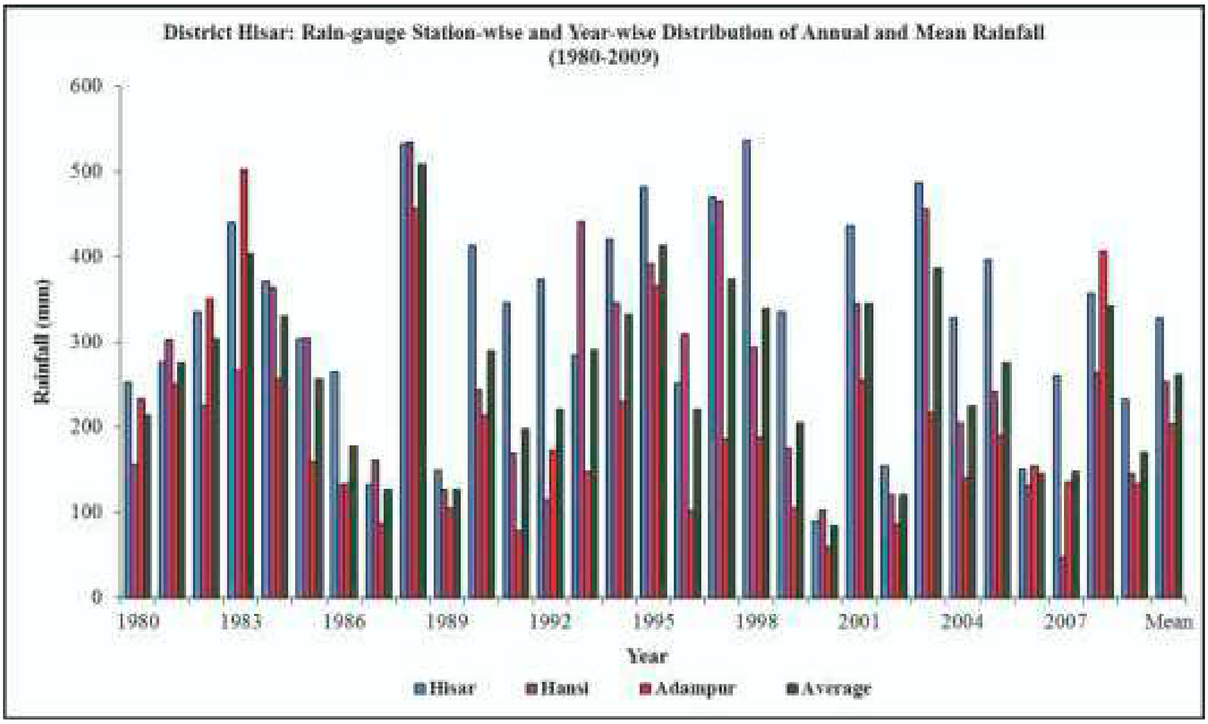

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Fig. 2

Results and Discussion

Annual Rainfall Analysis

The Hisar district in Haryana receives rainfall both form southwest monsoon and western disturbances. However, the district does not have the full benefit of southwest monsoons as it is situated in semi-arid area on the fringe of Thar Desert. Fig. 2 shows the variations in the annual rainfall depth at different stations in Hisar district of Haryana. It has been revealed from the analysis that about 261 mm mean annual rainfall depth is available for rainwater supply. The mean annual rainfall during 1980-2009 periods was found to be 328, 252 and 203 mm at Hisar, Hansi and Adampur stations, respectively. The highest average annual rainfall depth of 508 mm in the district was observed in 1988 while the lowest annual rainfall depth of 83 mm was observed in 2000 during 1980-2009 study period. The highest annual rainfall depth of 536 mm was observed in 1998 at Hisar followed by 534 mm at Hansi in 1988 and 502 mm at Adampur in 1983. The lowest annual rainfall of 89 and 47 mm was observed at Hisar and Adampur in the year 2000 whereas it was observed 59 mm in the year 2007 at Hansi rain gauge station.

No assessment of rainfall can be meaningful without some appreciation of its variability from day to day, month to month, season to season and year to year. The analysis of annual rainfall further revealed that the variability in annual rainfall distributions in the district is very large (> 40%) with high standard deviations which in turn affects the natural recharge to ground water from year to year. The annual rainfall variability was observed to be 36% at Hisar followed by 37% at Adampur and 56% at Hansi. These results indicate that rainfall is more reliable at Hisar station than Hansi and Adampur in the district.

The annual rainfall trends in Hisar district with five year moving averages and their anomalies have been presented in Fig. 3

and 4 with their linear trends. The data on five year moving averages almost followed the trend line. The analysis demonstrated that negative anomalies are more prominent in annual rainfall in Hisar district. Maximum negative anomaly of 239 mm was recorded at Hisar during the year 2000 followed by 206 mm at Hansi in the year 2007 and 144 mm at Adampur in the year 2000. However, maximum positive anomaly of 299 mm was observed at Adampur in the year 1983 followed by 282 mm at Hansi in the year 1988 and 207 mm at Hisar in the year 1998. This analysis demonstrated that the rainfall received at Adampur is more erratic in relation to Hansi and Hisar rain gauge stations of the district. Moreover, the analysis also revealed decreasing trends in annual rainfall at Hisar, Hansi and Adampur. One of the obvious effects of decreasing trends in annual rainfall in Hisar district may lead to serious implications on hydrological cycle and agricultural productivity.

Monthly Rainfall Analysis

The major amount of the rainfall in Hisar district is received from southwest monsoons during the period from June to September and minor amount of rainfall due to western disturbances and other local conditions during rest of the year. The average rainfall contribution between June to September is 80% of the total annual average rainfall. Table 1 shows the distribution of average monthly rainfall along with standard deviation, per cent rainfall and coefficient of variation at different stations during 1980-2009 periods. It was revealed from the analysis that July and August are the rainiest months in Hisar district during the study period. The higher coefficient of variability (>200%) in the months of October, November and December at all stations in the district revealed wide variations of rainfall in these months. Also, month of April at Hisar rain gauge station revealed wide variation of rainfall (311%).

Distribution of Daily Rainfall and Number of Rainy Days

The distribution of daily rainfall in Hisar district at different rain gauge stations has been presented in Fig. 5. It was observed from the analysis that the diurnal pattern of rainfall in Hisar district at different rain gauge stations is more or less analogues. However, rain events above 50 mm are more pronounced at Hisar and Hansi than Adampur. The occurrence of rainy days in Hisar district at different rain gauge stations during 1980-2009 has been demonstrated in Fig. 6. The analysis revealed that Hansi rain gauge station has higher rainy days (708) compared to Hisar (695) and Adampur (524) rain gauge stations during the analysis period. Also, maximum rainy days during 1997 were recorded at Hansi (40) followed by Hisar and Adampur (36) during the year 1997 and 2008, respectively. The intensity of rainfall and number of rainy days are higher during July, August, June and September months at Hisar, Hansi and Adampur rain gauge stations (Fig. 7). Therefore, these months can be considered potential months for the rainwater harvesting in the district. However, all the rain gauge stations in the district experienced less than one rainy day during the months of October, November and December. Also, the amount of rainfall recorded was very less during these months. These prolonged dry meteorological conditions in these months make the district water deficient particularly during the summer months.

Rainfall Frequency

Analysis of rainfall records demonstrate that the frequency of storms equal to 25 mm of rainfall accounts for 90% of the total rainy days

Table I

Hisar District: Mean Monthly, Percent, Standard Deviation and Coefficient of Variability in Rainfall (1980-2009)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Hisar													
Mean Rainfall (mm)	8.1	12.4	9.2	8.8	14.3	40.1	99.8	82.1	43.7	9.3	2.2	2.2	332.2
Percent rainfall	2.4	3.7	2.8	2.7	4.3	12.1	30.1	24.7	13.1	2.8	0.7	0.7	100.0
SD	11.5	18.3	16.1	27.4	23.3	43.2	73.5	72.2	61.0	27.5	8.6	5.2	119.2
CV	141.9	148.0	174.7	310.6	163.4	107.9	73.6	88.0	139.7	295.2	390.6	236.5	35.9
Hansi													
Avg. rainfall	8.4	7.1	6.6	15.3	8.7	25.6	73.4	90.1	23.0	3.8	0.6	1.9	264.4
Percent rainfall	3.2	2.7	2.5	5.8	3.3	9.7	27.7	34.1	8.7	1.4	0.2	0.7	100.0
SD	7.9	9.6	7.1	16.4	13.5	20.7	68.5	126.5	26.0	9.1	1.7	4.8	146.9
CV	94.4	135.5	107.1	107.1	156.0	81.0	93.4	140.4	113.2	238.5	263.8	247.5	55.6
Adampur													
Avg. rainfall	8.9	7.1	6.6	7.8	8.2	17.8	70.8	51.2	19.5	2.1	0.2	1.6	201.6
Percent rainfall	4.4	3.5	3.3	3.9	4.1	8.8	35.1	25.4	9.7	1.0	0.1	0.8	100.0
SD	12.6	8.4	8.4	14.3	10.2	16.9	51.7	44.0	21.8	4.9	0.6	3.4	75.1
CV	141.8	117.2	125.9	183.9	124.1	94.8	73.0	85.9	112.0	238.0	347.8	210.5	37.2

Source: Compiled and Computed by Authors

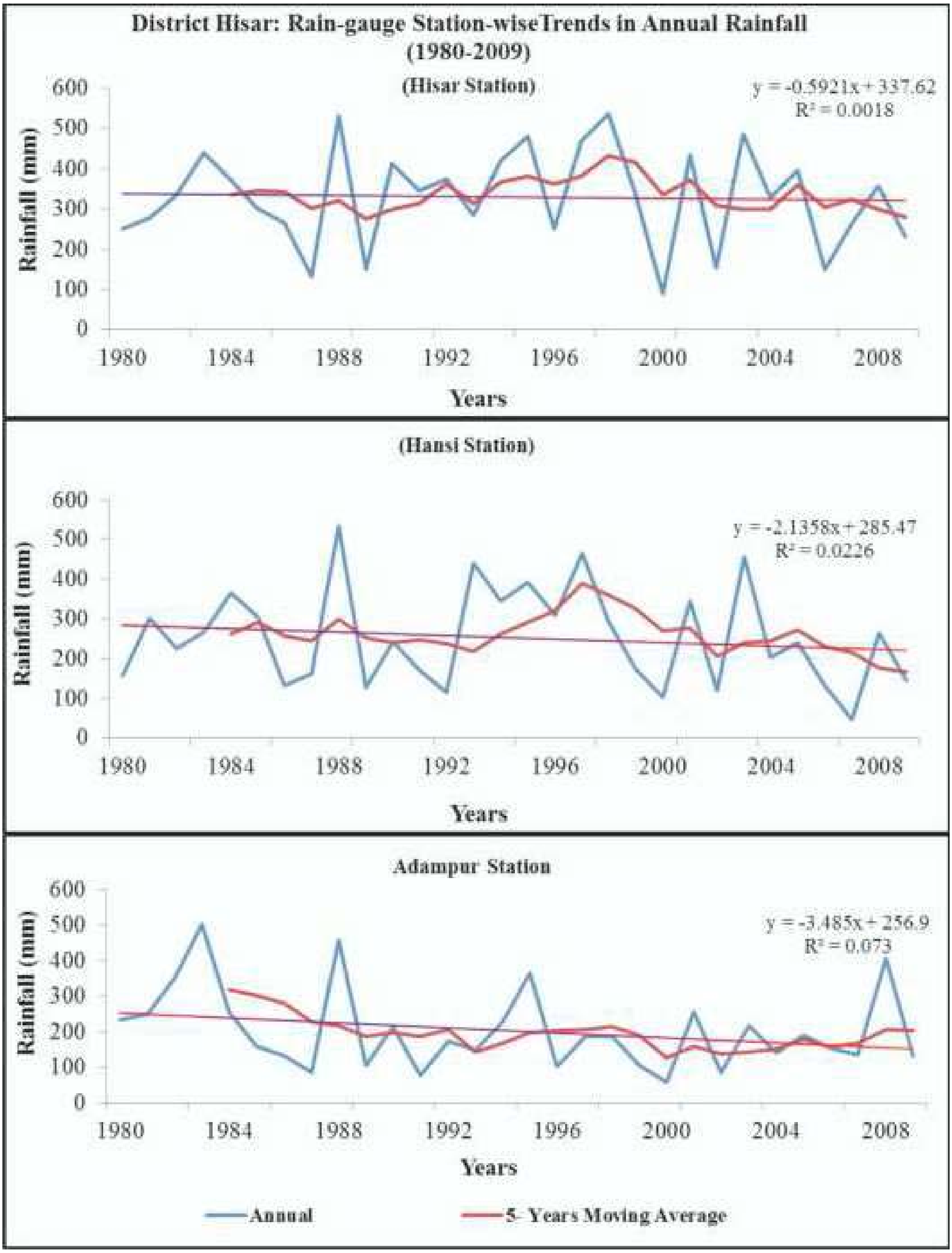

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Fig. 3

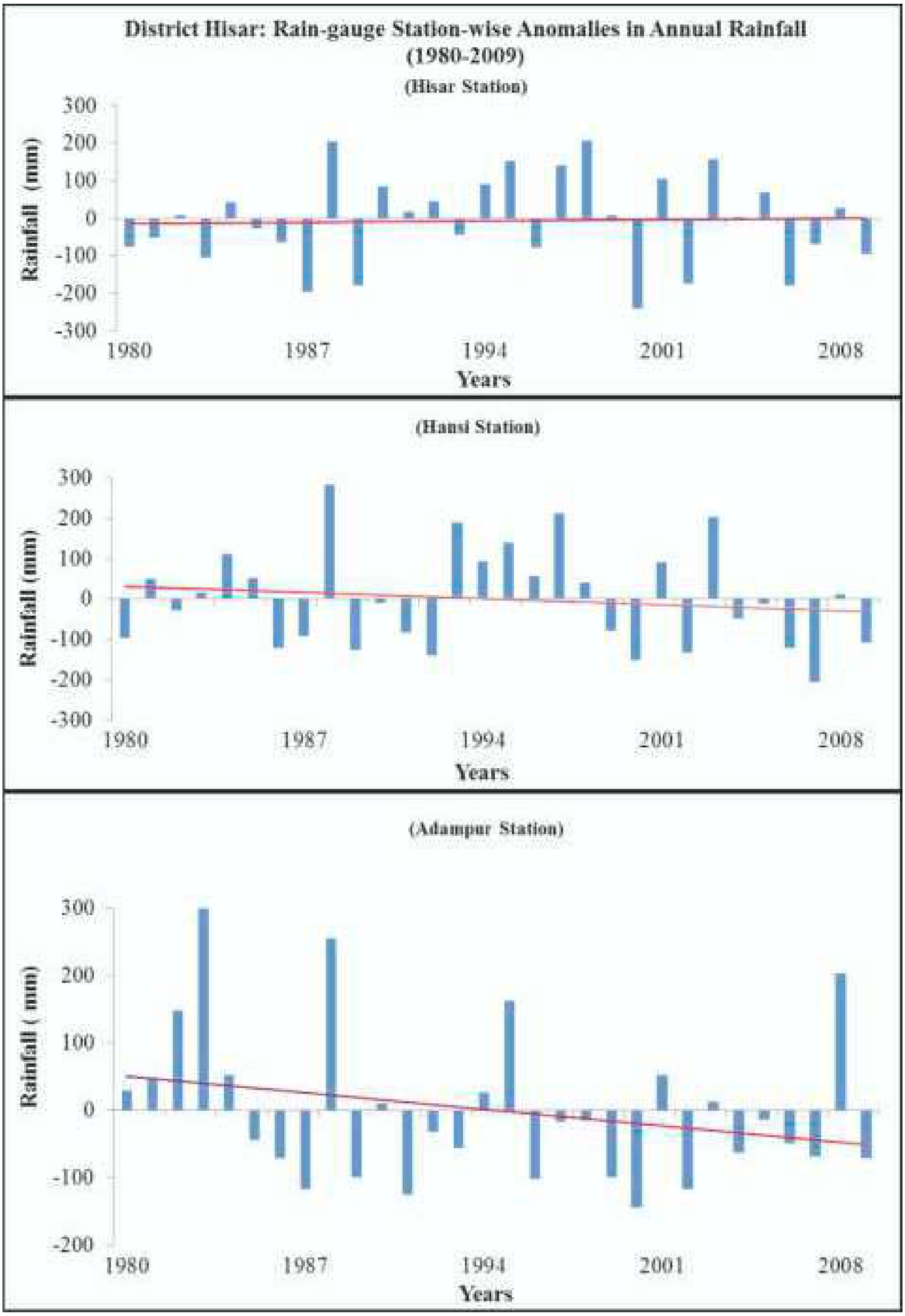

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Fig. 4

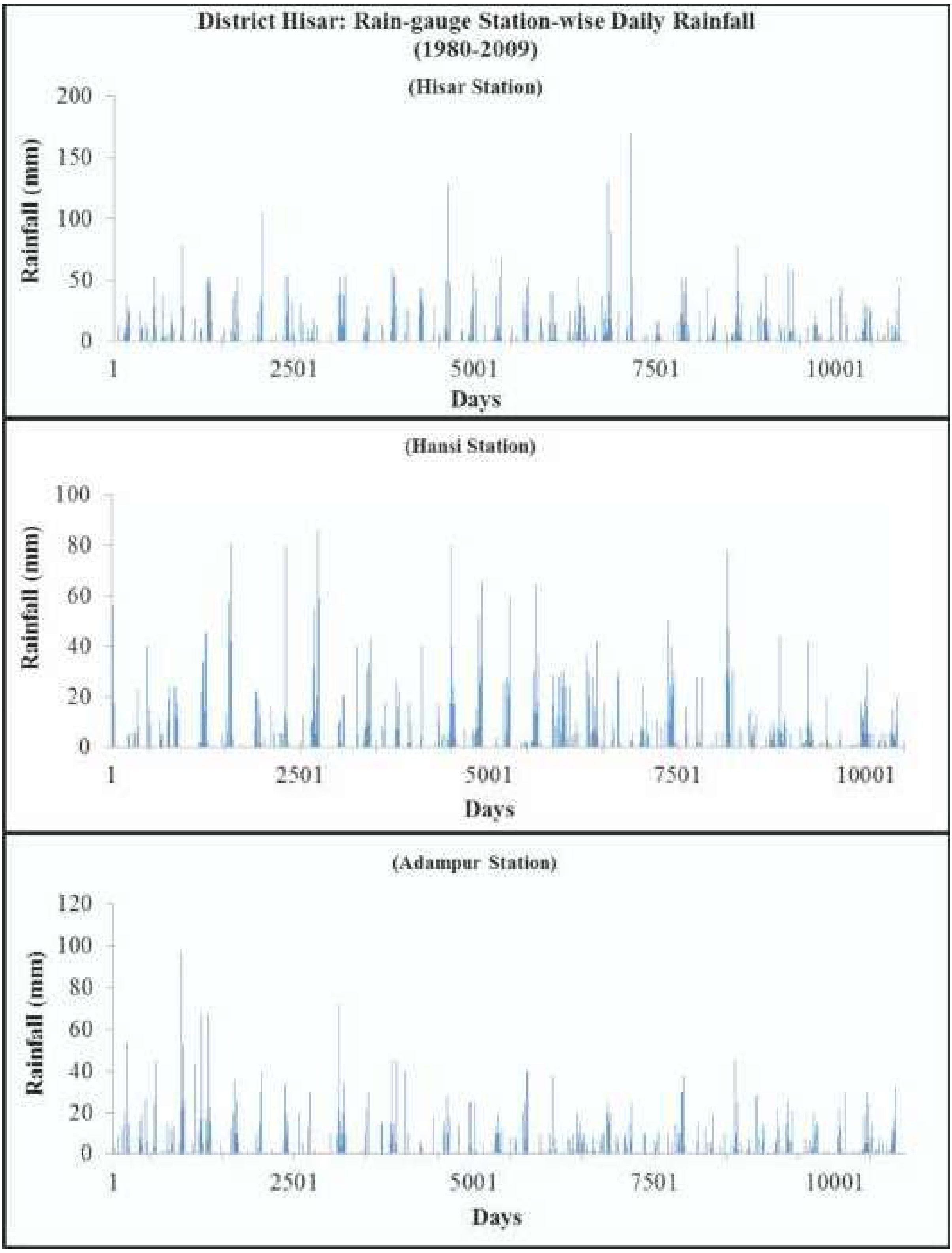

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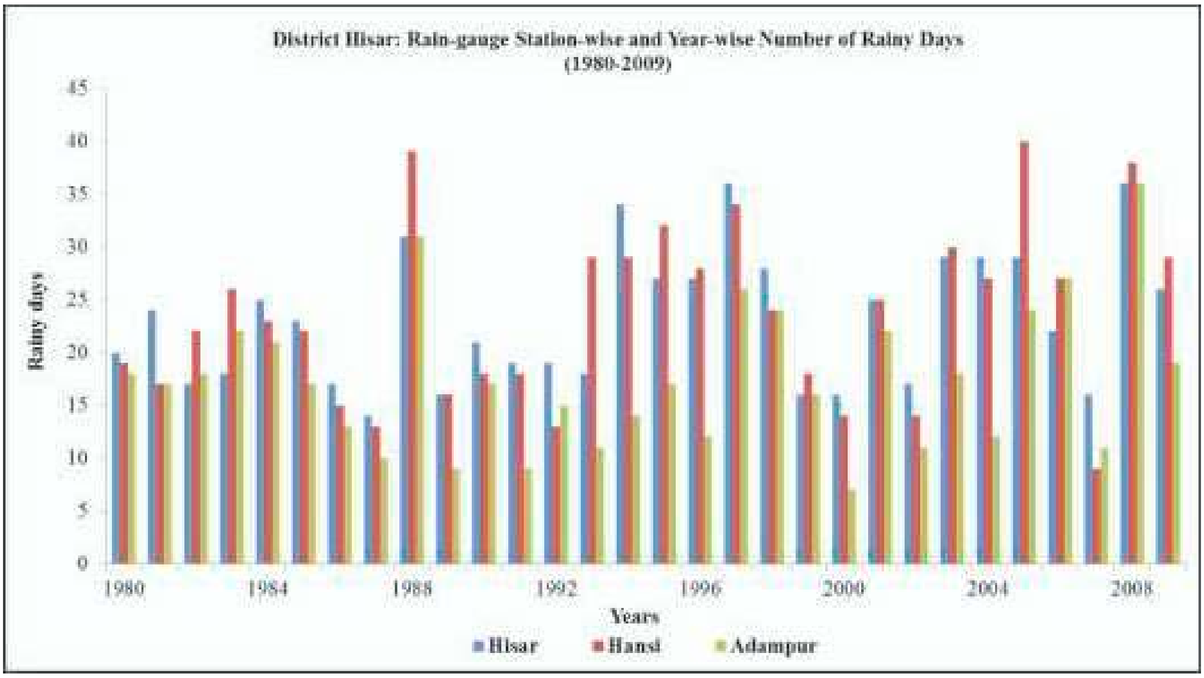
Fig. 5



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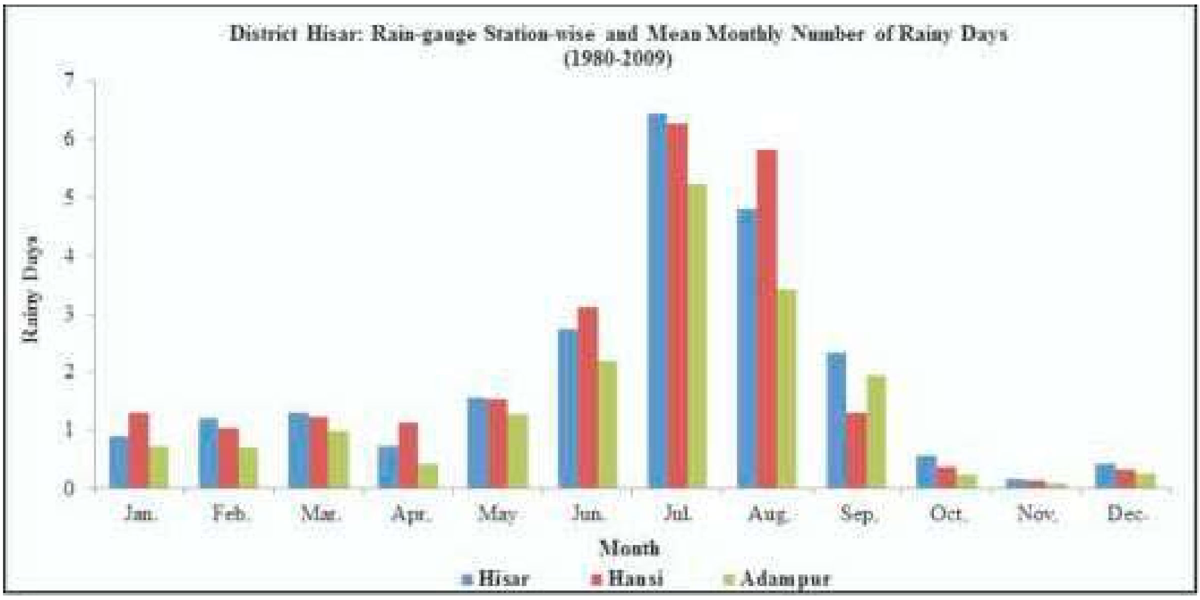

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Fig. 7

Table 2

Hisar District: Rainfall Frequency at Hisar, Hansi and Adampur Rain Gauge Stations (1980-2009)

Rainfall depth range (mm)

	Hisar						Hansi						Adampur					
Year	0-5	6-10	11-25	26-50	51-100	>100	0-5	6-10	11-25	26-50	51-100	>100	0-5	6-10	11-25	26-50	51-100	> 100
1980	6	5	7	2	0	0	7	6	6	0	0	0	7	6	4	1	0	0
1981	8	8	5	2	[illegible]	0	5	9	3	0	0	0	9	2	4	2	0	0
1982	4	3	6	3	[illegible]	0	8	7	3	4	0	0	7	3	5	1	2	0
1983	6	2	6	2	2	0	12	3	11	0	0	0	4	5	9	3	1	0
1984	10	6	4	4	[illegible]	0	5	4	5	6	0	0	4	9	7	1	0	0
1985	12	5	3	2	0	1	11	4	4	3	0	0	10	3	2	1	1	0
1986	5	5	3	2	2	0	7	2	6	0	0	0	5	5	2	1	0	0
1987	4	5	4	1	0	0	6	4	2	0	1	0	6	1	2	1	0	0
1988	10	5	8	5	3	0	17	11	8	1	2	0	14	8	6	2	1	0
1989	8	3	4	1	0	0	8	4	4	0	0	0	4	2	2	1	0	0
1990	5	3	8	2	3	0	6	5	3	4	0	0	7	4	4	2	0	0
1991	2	6	5	6	0	0	4	7	7	0	0	0	5	1	1	2	0	0
1992	6	5	4	3	0	1	7	3	1	2	0	0	4	5	4	2	0	0
1993	6	3	5	3	[illegible]	0	10	8	7	2	2	0	4	1	4	2	0	0
1994	18	2	10	2	2	0	11	9	7	1	1	0	6	3	4	0	1	0
1995	6	3	13	4	[illegible]	0	18	1	9	3	1	0	3	6	5	2	1	0
1996	13	5	7	2	0	0	15	1	8	3	1	0	6	3	1	2	0	0
1997	14	6	11	4	[illegible]	0	9	6	14	5	0	0	15	9	1	1	0	0
1998	11	4	9	3	[illegible]	0	9	6	4	5	0	0	14	5	3	2	0	0
1999	6	3	5	0	[illegible]	1	9	4	2	3	0	0	7	3	4	2	0	0
2000	10	4	7	0	0	0	8	4	7	0	0	0	2	1	1	2	1	0
2001	5	4	11	3	2	0	10	4	8	3	0	0	10	5	4	3	0	0
2002	10	2	4	1	0	0	8	2	2	2	0	0	3	4	2	1	1	0
2003	8	10	6	3	2	0	11	6	7	5	1	0	6	5	4	2	1	0
2004	15	1	11	1	[illegible]	0	14	6	6	0	1	0	2	2	5	3	0	0
2005	9	8	9	1	2	0	24	12	3	1	0	0	8	4	6	5	1	0
2006	10	6	5	1	0	0	18	7	1	1	0	0	15	6	3	2	1	0

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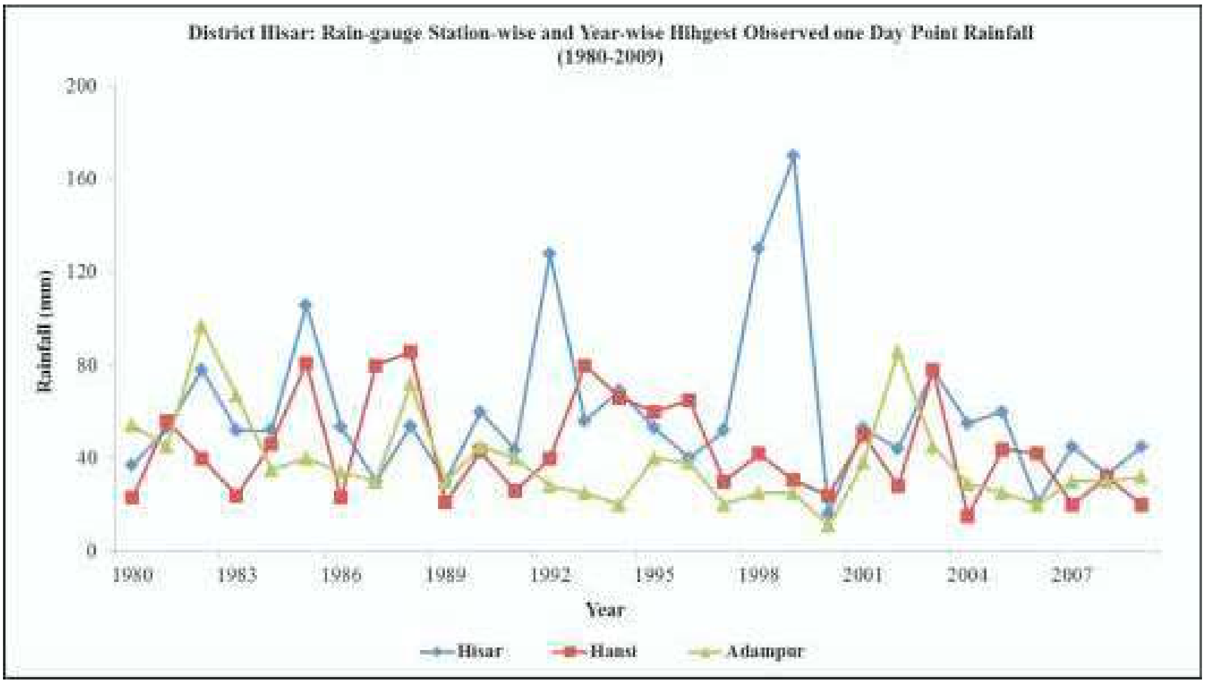

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Fig. 8

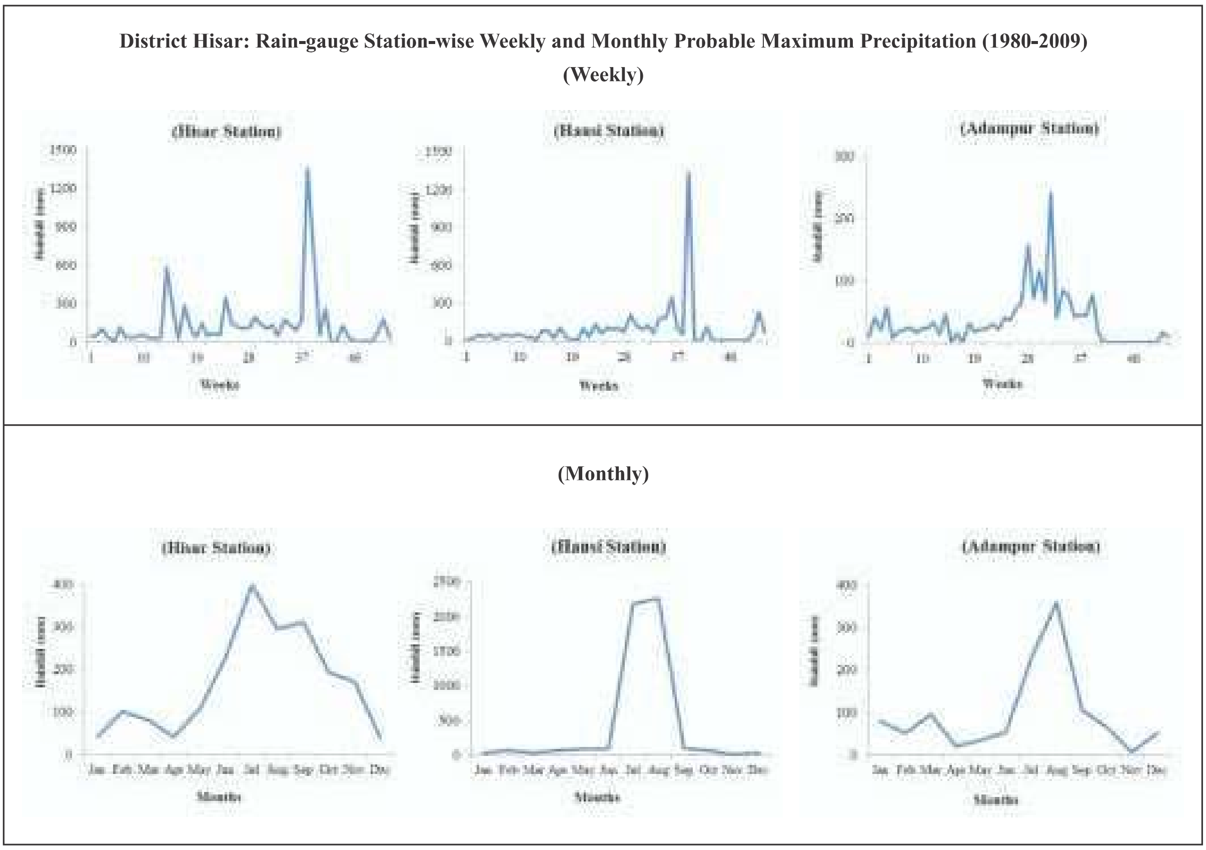

Fig. 9

at Hansi followed by 87% at Adampur and 85% at Hisar rain gauge station respectively (Table 2). Therefore, a good number of rainy days in Hisar district provide a good potential for water harvesting. More large storms of rainfall exceeding 25 mm of rainfall will generate runoff in huge quantities and it does not provide ideal conditions for the rainwater harvesting in the district. Storms exceeding 25 mm of rainfall account for 15% at Hisar rain gauge station, followed by Adampur (13 %) and Hansi (10%) rain gauge stations respectively.

Highest Observed One Day Point Rainfall

Information about the highest observed one-day rainfall over a region is required by the design engineers and hydrologists for planning hydraulic structures of medium and minor nature. Maximum rainfall on a single day has been recorded on July 10, 1999 (170 mm) at Hisar, on September 24, 1988 (86 mm) at Hansi and on July 22, 1982 (97 mm) at Adampur in the district (Fig. 8). Moreover, rainfall more than 100 mm was recorded four times at Hisar rain gauge station during 1980-2009 period. These isolated showers at Hisar tend to produce flashy runoff in the semi-arid district where the area has few storage possibilities.

Probable Maximum Precipitation (PMP)

Probable maximum precipitation synthesizes reliable and consistent estimates of rainfall at any location for hydraulic structure designs. Therefore, weekly and monthly PMP for different rain gauge stations in Hisar district of Haryana has been demonstrated in Fig. 9. It was visualized from the analysis that weekly PMP was observed to be highest at Hisar (1355 mm during 38th week of the year) followed by Hansi (1333 mm during 39th week of the year) and Adampur (240 mm during 32nd week of the year). Moreover, the weekly PMP in Hisar district at different rain gauge stations ranged from 0 to 1355 mm. Mostly, probable maximum precipitation with 0 mm amount of rainfall was recorded during October, November and December months in the district due to non- occurrence of rainfall in these months. Monthly PMP over the study district ranged from 6 mm to 2261 mm. Minimum monthly PMP was observed at Adampur (6 mm) during the month of December while it was observed to be highest at Hansi during the month of August (2261 mm).

Utility and Limitations of the Study

An understanding of the rainfall characteristics in semi-arid Hisar district of Haryana is a basic requirement for the planning of crop production and water resources in the region. By knowing the rainfall patterns the irrigation scheduling and agricultural planning can be made effective. Analysis of rainfall variability also helps in the selection of suitable crops and introduction of agricultural methods which may provide better production in case of variability in rainfall. Therefore, the results derived from the analysis of long-term rainfall records may be extremely beneficial for agricultural scientists, water resource managers, extension workers and farmers of the region. Knowledge of rainfall variability can also help in the choice and designing water harvesting structures of suitable size. This will not only help in providing irrigation to crops but will also help in surface storage replenishment through artificial recharge. In addition, rainwater harvesting provides the long-term answers to the problem of water scarcity. The major limitation of the present study is the spatial availability of rainfall data. The long-term rainfall data of Hisar, Hansi and Adampur stations may not be able to determine the exact nature and distribution of rainfall in the district. Long-term rainfall data for more rain gauge stations can improve the understanding of rainfall variability in semi-arid Hisar district of Haryana. Therefore, installation of rain gauge stations at block headquarter is a pre-requisite to capture the exact nature (intensity, consistency and reliability) and distribution of rainfall in the district.

Conclusions

The characteristic feature of the rainfall of Hisar district is its high variability both in temporal and spatial perspective. The rainfall analysis of Hisar, Hansi and Adampur rain gauge stations revealed that mean annual rainfall in the district is less than 300 mm. The variability in annual rainfall distribution in the district is very large (> 40%) with high standard deviations which in turn affects the natural recharge to ground water from year to year. The annual rainfall variability was observed to be 36% at Hisar followed by 37% at Adampur and 56% at Hansi. Moreover, the analysis also revealed decreasing trends in annual rainfall at Hisar, Hansi and Adampur stations. One of the obvious effects of decreasing trends in annual rainfall in Hisar district may lead to serious implications on hydrological cycle and agricultural productivity. Therefore, to avoid the scarcity of water in the district it becomes mandatory to harvest every falling drop of rain in the district. It is also observed from the results that the co-efficient of variability is low in the months of higher rainfall. Therefore, these months can be considered potential months for the rainwater harvesting and if harvested properly it can substantially increase the water availability and the level of agricultural production in the district.

References

Bhatia, S.P. and Kumar, N. (1987): *District Gazetteer, Hisar*, Haryana Gazetteer Organization, Revenue Department, Chandigarh. pp. 97-98.

Biswas, B.C. and Maske, S.J. (1981): "Rainfall Analysis for use in Dry-land Agriculture". *Indian Journal of Soil Conservation*, Vol. 9, pp. 8-19.

Dhar, O. N., Kulkarni, B. D. and Nandargi, S. S. (1991): "Design Storm Estimation for Wainganga Basin up to Dhapewada Dam Site: A brief Appraisal". *Journal of Applied Hydrology*, Vol. 4, pp. 43–49.

Folland, C.K., Miller, C., Bader, D., Crowe, M., Jones, P., Plummer, P., Richman, M., Parker, D.E., Rogers, J. and Sholefield, P. (1999): "Temperature Indices for Climate Extremes". *Climatic Change*, Vol. 42, pp. 31-43.

Hershfield, D.M. (1961): "Estimating the Probable Maximum Precipitation". *Journal of Hydraulics of the American Society of Civil Engineers*, Vol. 87, pp. 99-116.

Hershfield, D.M. (1965): "Method for Estimating the Probable Maximum Precipitation". *Journal of American Water Works Association*, Vol. 57, pp. 965-972.

Kulkarni, B. D, Mandal, B. N., Mulye, S. S. and Deshpande, N. R. (2005): "Estimation of Design Storm for the Manjra Catchment". *Journal of Applied Hydrology*, Vol. 17, pp. 52–59.

Kulkarni, B.D., Nandargi, S. and Mulye, S.S. (2010): "Zonal Estimation of Probable Maximum Precipitation Rain Depths over the Krishna Basin in Peninsular India". *Hydrological Science Journal*, Vol. 55, pp. 93-103.

Kumar, A. (2000): "Prediction of Annual Maximum Daily Rainfall of Ranichauri (Tehri Garhwal) Based on Probability Analysis".

Indian Journal of Soil Conservation, Vol. 28, pp. 178-180.

Kumar, V. and Jain, S.K. (2011): "Trends in Rainfall Amount of Rainy Days in River Basins of India (1951-2004)". *Hydrology Research*, Vol. 42, pp. 290-306.

Mbilinyi, B.P., Tumbo, S.D., Mahoo, H.F., Senkondo, E.M. and Hatibu, N. (2005): "Indigenous knowledge as Decision Support Tool in Rainwater Harvesting". *Physics and Chemistry of the Earth*, Vol. 30, pp.792–798.

Rakhecha, P.R., Deshpande, N. R., Kulkarni, A.K., Mandal, B.N. and Sangam, R.B. (1995): "Design Storm Studies for the Upper Krishna River Catchment Upstream of the Almatti Dam Site". *Theoretical and Applied Climatology*, Vol. 52, pp. 219-229.

Rizvi, R.H., Singh, R., Yadav, R.S., Tewari, R.K., Dadhwal, K.S. and Solanki, K.R. (2001): "Probability Analysis of Annual Maximum Daily Rainfall for Bundelkhand Region of Uttar Pradesh India". *Indian Journal of Soil Conservation*, Vol. 29, pp. 259-262.

Sena, D.R. and Kurothe, R.S. (2004): "Application of Rainfall Analysis for Planning Soil and Water Conservation Structures in Semi-arid Gujarat". *Indian Journal of Soil Conservation*, Vol. 32, pp. 156-160.

Subash, N. and Das, P.K. (2004): "Rainfall Characteristics and Probability Analysis for Crop planning under Rice-wheat System in Sub-humid Climate". *Indian Journal of Soil Conservation*, Vol. 32, pp. 124-128.

Suryanarayana, G. and Megeri, S.N. (1987): "Climatological Assessment of Water Harvesting Technology through Dug-out Ponds in Arid Regions". *Mausam*, Vol. 38, pp. 441-444.

Thronthwaite, C.W. (1948): "An Approach towards a Rational Classification of Climate". *Geographical Review*, Vol. 38, pp. 55-94.

Tomar, A.S. and Ranade, D.H. (2001): "Predicting Rainfall Probability for Irrigation Scheduling in Black Clay Soil of Indore Region of Madhya Pradesh". *Indian Journal of Soil Conservation*, Vol. 29, pp. 82-83.

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