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Rainfall zoning and its trend analysis for fruit crops in north-west India using GIS

Mohan Singh[1☼], Ram Niwas[2], Godara AK[3]

1.Sr. Scientist, Department of Environmental Science, YSP UHF, Solan 173230, India
2.Professor, Department of Agricultural Meteorology, CCS HAU, Hisar 125005, India
3.Professor, Department of Fruit Science, CCS HAU, Hisar 125004, India

☼ **Corresponding author:**
Department of Environmental Science,
YSP UHF, Solan 173230,
India,
E-mail: jangra_ms@live.com

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ABSTRACT

The weather data for the period of more than 30 years 1980 onward of twenty-two meteorological stations located in arid, semi-arid and humid agro-climatic zones in the hills and plains of north-west India were used in this study. The collected rainfall data was computed as normal rainfall for annual, seasonal, hills, plains and north-west India. For a given location the long period average of rainfall data was considered as normal rainfall. Rainfall trends (seasonal and annual) in north-west India were evaluated using regression trend analysis. The map of north-west India was digitized and different rainfall zones were delineated using GIS software (ArcMap 10.1). Normal annual rainfall was more than one thousand millimetres at eight stations and ranged between 500-900 mm at eleven stations and between 200 to 500 mm for remaining three stations. Normal rainfall was highest at Palampur and lowest at Ganganagar among the 22 meteorological stations. The coefficient of variation was less than fifty per cent for all the stations. The slope (mm/year) of trend line was negative for nine stations and positive for remaining thirteen stations. The slope 5.51, 1.58 and 5.82 were found in hills, plains and north-west India with standard error of 8.35, 6.12 and 6.73 mm, respectively. The confidence level of significant of correlation coefficient was 41.3, 54.7 and 51 per cent in hills, plains and north-west India, respectively. During effective growing season out of 22 stations the rainfall showed decreasing trend at eight stations and increasing trend at remaining fourteen stations. During dormant season it was decreasing with 57 mm per century in hills, 10.7 mm per 100 years in plains but increasing with 68.6 mm per 100 years in north-west India, respectively.

Key words: Rainfall, Trend analysis, Zoning, NW India, Fruit Crops, GIS

1. INTRDUCTION

The north-west India includes stations of Jammu & Kashmir, Himachal Pradesh, Utrakhand, Punjab, Chandigarh, Haryana, Delhi and parts of Uttar Pradesh and Rajasthan. Punjab and Haryana are not only self-sufficient in food production (wheat & rice) & largest contributor to India's central pool of food grains but also good producer of subtropical fruits (mango, ber, guava, citrus and litchi) and some temperate fruits (pear, peaches, plum, pomegranate etc). Similarly Jammu & Kashmir, Himachal Pradesh, Utrakhand are the largest producer of temperate fruits (apple, apricot, pear, peach, plum and cherry) in India. North-west India with diverse soil and climate comprising several agro-ecological regions provides ample opportunity to grow a variety of horticultural crops which form a significant part of total agricultural produce in the country. The Himalayas provide suitable ecological niches for the prevalence of large number of temperate fruit germplasm. The region also inhabits many Prunus species and indigenous edible temperate fruits, which could be exploited for commercial traits (Sharma and Pramanick, *2012*). The high value agriculture, particularly horticultural crops are the catalysts for the next wave of growth in the farm sector and be a better tool for the climate-smart agriculture (FAO, 2010).

The spatial data interpolation of temperature and precipitation is increasingly important in the development of agricultural, hydrological, and ecological models; spatially explicit modelling of ecosystem structure, for example requires estimates of variables at unsampled locations, usually on a regularly spaced grid (Skirvin *et al.,* 2003). A method based on the geographical information system (GIS) was used for spatial climate analysis (Baigorria *et al.,* 2000). Patel *et al*. (2000) used the modern information tools like remote sensing and geographical information system to extend applicability of agro ecological zoning in mountainous areas of Kumaon Himalayas India. Satellite remote sensing and GIS have been providing newer dimension to effectively monitor and manage natural resources. It has been well conceived that remote sensing and GIS have great role to play in agro ecological zoning.

In addition to temperature, rainfall is an important climatic resource, which meets the water requirement of an organism for its survival in its ecosystem. A comprehensive studies carried over NW Himalayas revealed that the change in winter precipitation is minimum but there is significant decrease in monsoon precipitation (Bhutiyani*, et. al.,* 2007*)*. Jangra and Singh (2011) and Ranbir (2010) observed variability in rainfall in middle and upper Himachal Pradesh. Another analysis with respect to climate of Shimla reveals that total precipitation and snowfall for all the season has a decreasing trend (Bhan & Manmohan*,* 2011) leaving long term impacts on agriculture horticulture production of the area (Baul and McDon ald, 2015; Sen *et. al.,* 2015; Fitsum Bekele *et al*. 2017; Mohan Singh and Ram Niwas, 2018). Changing climate results in extreme weather events like heavy downpours, flooding, longer wetter, landslides and during dry season increased evapotranspiration will lead to water scarcity (Sagun, 2009). Climate change is found to be relatively new challenge of global scale however; at a global scale climate change may have negligible impact but severe and substantial at local and regional scale (IPCC, 2007). Hence, with reference to climate change at local, present study was conducted to evaluate rainfall trend and zoning based on spatial distribution and pattern of rainfall in north-west India for efficient use of rain water.

2. MATERIAL AND METDODS

The present investigation was carried out in the Department of Agricultural Meteorology, Chaudhary Charan Singh Haryana Agricultural University, Hisar with collaboration of Haryana Space Application Centre (HARSAC), Hisar. The experimental site was the north-west India (includes Jammu & Kashmir, Himachal Pradesh, Utrakhand, Punjab, Chandigarh, Haryana, Delhi and parts of Uttar

Pradesh and Rajasthan) located between 25^0N to 35^0N latitude and between 74^0E and 80^0E longitude. The altitude of the region varies between 200 to 8600 m above mean sea level (*amsl*). For rainfall trend analysis the whole study area was divided into two parts hilly area and the plain area on the basis their altitude. The stations having was more than 1000 meters *amsl* altitude were taken (Srinagar, Manali, Shimla, Palampur, Solan and Ranichauri) and less than 500 meters *amsl* were considered as plains (Jammu, Chandigarh, Ambala, Saharanpur, Delhi, Karnal, Patiala, Ludhiana, Rohtak, Bathinda, Hisar, Sirsa, Bawal, Narnaul, Ganganagar and Jaipur). Further, keeping in view the growth behaviour of the fruit crops (mainly temperate fruits) the whole year was divided in to two seasons- first one was the effective growing season (EGS) and the second was the dormant season (DS). The effective growing season was taken from April-October in hills and from March-November in plains. Similarly the dormant season in hills was from November to March and in plains it was from December to February.

The rainfall data for the period of 35 years (1980-2014) of different meteorological stations located in north-west India were collected from the station observatory and India Meteorological Department, New Delhi. Rainfall data was summed up to get monthly, seasonal and annual normal rainfall from long period data series. Rainfall trends for all meteorological stations, hills, plains and north-west on annual and seasonal basis were analyzed using trend line analysis. Standard error, probability (p) of the standard error, and correlation coefficient (R^2), intercept and't' value was calculated using 'OP Stat" software. Map depicting spatial variation in annual and seasonal rainfall were prepared using Arc Info 10.1 GIS software. The percent share in rainfall of each station was calculated using the following formula: Percent Share in Rainfall (PSR) = Normal rainfall of the station/Total of normal rainfall x100

Rainfall maps were prepared in the GIS environment using Arc GIS 10.1 Following steps were followed to prepare the maps:

1. The hard copy of the map of the study area was digitized and shape file was created.
2. NW India polygon shape file was selected.

3. Rainfall data were collected from different 22 sites of Jammu & Kashmir, Himachal Pradesh, Utrakhand, Haryana, Punjab, Rajasthan, Delhi, Chandigarh and Uttar Pradesh using Global Positioning System (GPS) x, y coordinates (latitude-longitude).
4. The latitude-longitude values of each point were find out and converted to degree-decimal format to enter in GIS.
5. The coverage file (point) was then generated from the location data in Arc info GIS.
6. Then the point file was interpolated by GIS tools and converted to raster format by krigging/radial basis interpolation function.

3. RESULTS

3.1. Annual rainfall trend

The normal rainfall for eight stations was more than one thousand millimetres i.e. Patiala (1001.7 mm), Chandigarh (1071.4 mm), Solan (1131.6 mm), Jammu (1145 mm), Manali (1179 mm), Ranichauri (1269.7 mm), Shimla (1311.4 mm) and Palampur (1965.3 mm). Eleven stations (Srinagar, Ambala, Saharanpur, Delhi, Karnal, Ludhiana, Rohtak, Bathinda, Bawal, Narnaul and Jaipur) having normal rainfall between 500-900 mm and rainfall from200 to 500 mm at remaining three stations (Ganganagar, Sirsa, Hisar). The coefficient was between 40-50 % for two stations (Narnaul and Rohtak) between 30-40% for nine stations (Srinagar, Saharanpur, Delhi, Karnal, Hisar, Sirsa, Ganganagar and Jaipur) between 20-30 % for eight stations (Manali, Shimla, Ranichauri, Chandigarh, Ambala, Patiala, Ludhiana and Bathinda) between 10-20 % for Solan, Palampur and Jammu station (Table 1).

Table 1 Statistical measures of annual rainfall (mm) at different meteorological stations in north-west India

Stations	PSR (%)	SD	CV (%)	Intercept	Slope (rate)	S.E.	't' value	p	R^2
Srinagar	4.67	267.3	30.6	932.0	-4.29	8.27	-0.52	0.594	0.011
Manali	6.29	275.5	23.4	1119.8	3.27	4.64	0.71	0.486	0.014
Shimla	7.00	324.1	24.7	1072.8	13.69	5.68	2.41	0.022	0.158
Palampur	10.49	288.8	14.7	1833.8	13.84	18.81	0.74	0.446	0.330
Solan	6.04	199.0	17.6	1192.3	-4.62	6.12	-0.75	0.440	0.023
Ranichauri	6.78	284.0	22.4	1201.1	4.45	6.55	0.68	0.488	0.016
Jammu	6.11	204.6	17.9	1156.1	-0.90	5.47	-0.16	0.871	0.001
Chandigarh	5.72	288.8	27.0	1154.1	-4.87	5.46	-0.89	0.379	0.025
Ambala	4.49	227.8	27.1	821.1	1.02	3.45	0.30	0.769	0.003
Saharanpur	4.00	230.2	30.7	981.4	-4.73	39.65	-0.12	0.898	0.002
Delhi	3.82	217.0	30.3	611.9	6.45	4.56	1.41	0.168	0.064
Karnal	4.01	250.1	33.3	789.2	-1.68	2.88	-0.58	0.564	0.008
Patiala	5.35	235.8	23.5	791.0	8.26	5.80	1.42	0.165	0.065
Ludhiana	4.00	216.8	28.9	772.5	-1.30	5.39	-0.24	0.811	0.002
Rohtak	2.92	263.5	48.1	556.0	0.31	3.57	0.09	0.931	0.000
Bathinda	3.06	155.4	27.1	434.9	6.10	4.00	1.53	0.125	0.077
Hisar	2.52	170.9	36.2	418.6	2.36	1.86	1.27	0.213	0.036
Sirsa	2.08	138.4	35.6	370.1	1.15	3.21	0.36	0.713	0.005
Bawal	3.35	215.7	34.4	573.0	-0.74	3.68	-0.20	0.842	0.001
Narnaul	2.72	228.4	44.7	346.5	8.44	3.17	2.66	0.009	0.165
Ganganagar	1.53	111.4	38.9	295.0	-0.48	2.13	-0.23	0.822	0.002
Jaipur	3.05	213.3	37.3	525.0	2.63	3.59	0.73	0.470	0.016
Hills	45.56	273.1	22.2	1160.0	5.51	8.35	0.54	0.413	0.108
Plains	24.32	210.5	32.6	652.2	1.58	6.12	0.46	0.547	0.015
NW India	30.11	227.6	29.7	734.1	5.82	6.73	0.48	0.510	0.193

PSR = Percent share in rainfall p: probability of error; 't' = 2.750 at 1% and 2.042 at 5%

The slope of rainfall trend line was negative at Srinagar, Solan, Jammu, Chandigarh, Saharanpur, Karnal, Ludhiana, Bawal and Ganganagar and positive at Manali, Shimla, Palampur, Ranichauri, Ambala, Delhi, Patiala, Rohtak, Bathinda, Hisar, Sirsa, Narnaul and Jaipur. The deceasing trend in rainfall was highest at Chandigarh (-4.62) followed by Srinagar (-4.29) and lowest for Ganganagar (-0.48) followed by Jammu (-0.9/year). The value of increasing trend in rainfall was highest at Palampur 13.84mm per year and was lowest at Rohtak (0.31mm/year).

The normal rainfall computed was 1288.5, 687.8 and 851.6 mm at hills, plains and whole of north-west India with coefficient of variation of 22.2%, 32.6% and 29.7%, respectively. The increasing trend in rainfall at hills, plain and whole of north-west India was of 5.51, 1.58 and 5.82mm per year (Figure 1) with standard error of 8.35, 6.12 and 6.73mm, respectively. These slope values of trend line were significant at p≤0.41, 0.55 and 0.51 for hills, plain and north-west India, respectively.

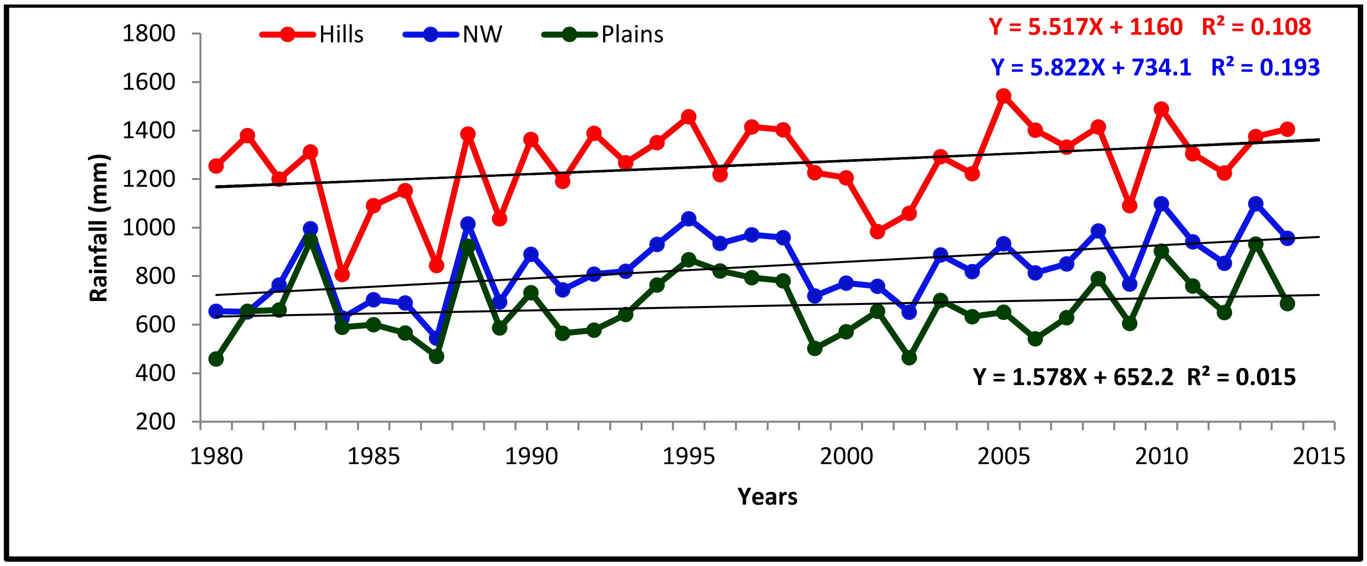


Figure 1 Trend in normal annual rainfall (mm)

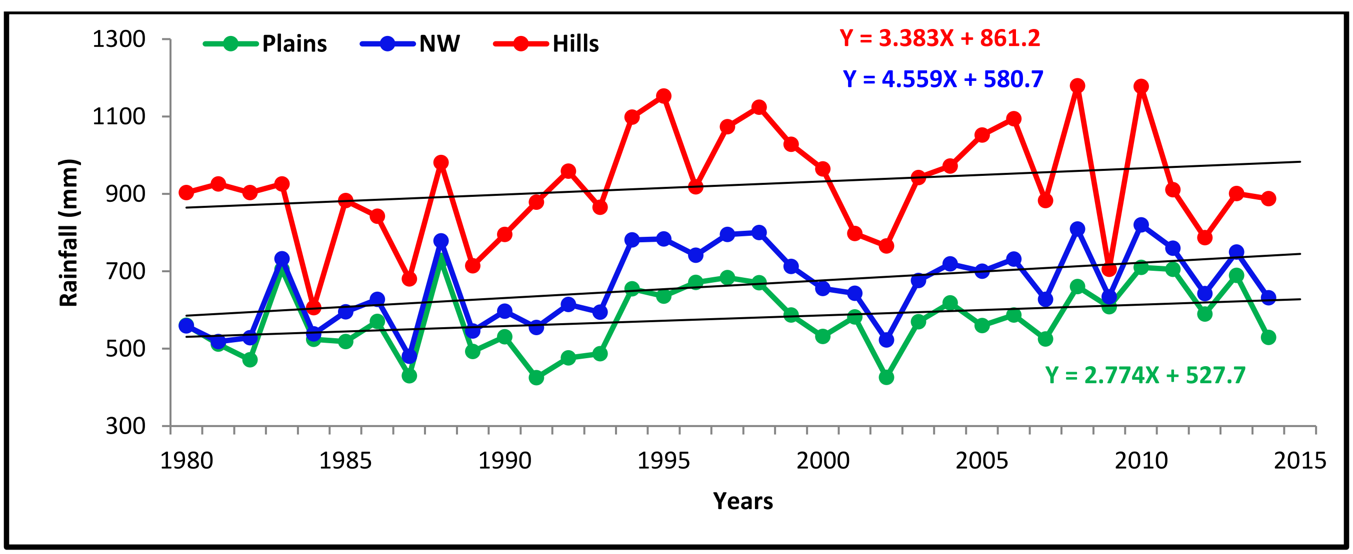


Figure 2 Trend in rainfall during effective growing season

3.2. Seasonal rainfall trend

During effective growing season, the normal rainfall was more than one thousand millimeter at Shimla (1062.1 mm), Jammu (1143 mm) and Palampur (1667.4 mm), and between 1000-500 mm at Srinagar, Manali, Solan, Ranichauri, Chandigarh, Ambala, Saharanpur, Delhi, Karnal, Patiala, Ludhiana, Rohtak, Bawal & Jaipur and rest of stations had less than 500 mm (Table 2). It was highest at Manali with coefficient of variation of 144.3 per cent and lowest at Ganganagar with coefficient of variation of 44.3 per cent. Srinagar, Solan, Jammu, Chandigarh, Saharanpur, Karnal, Ludhiana and Ganganagar showed decreasing trend but remaining fourteen stations: Manali, Shimla, Palampur, Ranichauri, Ambala, Delhi, Patiala, Rohtak, Bathinda, Hisar, Sirsa, Bawal, Narnaul and Jaipur showed increasing trend during this season. Shimla showed a highest increasing trend of 13.72 mm/years followed by Palampur (13.08mm/years). Probability of slope values of trend line five stations (Jammu, Saharanpur, Ludhiana, Rohtak and Ganganagar) was 0.70 four stations had less than 0.40 and rest of the stations had between 0.40 and 0.70, respectively. The normal rainfall during effective growing season was 973.5 mm at hills 634.5 mm at plains and 726.9 mm at whole of north-west India with coefficient of variation of 26.4 %, 35.3 % and 32.1 % respectively. The rainfall trend was positive with values of 3.38, 2.77 and 4.56 mm per year for hills, plains and north-west India with standard error of 5.79, 3.70 and 4.27mm, respectively (Table 2). The correlation coefficient was less than 25 per cent (Fig 2) for hills, plains and north-west India with significance (p) value of 0.266, 0.489 and 0.428, respectively.

Table 2 Statistical measures of rainfall (mm) during effective growing season at different meteorological stations in north-west India

Stations	PSR (%)	SD	CV (%)	Intercept	Slope (rate)	S.E.	't' value	p	R^2
Srinagar	3.19	255.0	50.0	1283.6	-0.49	0.18	-2.79	0.007	0.245
Manali	4.46	204.2	144.3	648.7	3.61	3.41	1.06	0.298	0.033
Shimla	6.64	282.7	26.6	836.4	13.27	4.68	2.84	0.008	0.206
Palampur	10.43	348.9	20.9	1543.1	13.08	16.01	0.82	0.399	0.040
Solan	5.58	188.8	21.2	919.3	-2.02	5.02	-0.40	0.680	0.007
Ranichauri	6.22	261.3	26.2	889.0	6.87	5.46	1.26	0.203	0.054
Jammu	6.40	211.9	20.7	1027.6	-0.33	5.05	-0.07	0.949	0.000
Chandigarh	6.05	290.5	30.0	1028.1	-3.52	5.36	-0.66	0.515	0.014
Ambala	4.68	230.6	30.8	705.6	2.27	3.58	0.63	0.530	0.011
Saharanpur	5.44	343.8	39.5	921.9	-9.39	4.01	-0.24	0.800	0.007
Delhi	4.17	217.4	32.6	571.2	5.99	4.38	1.37	0.181	0.061
Karnal	4.25	225.7	33.2	82.0	-0.29	0.31	-0.94	0.352	0.021
Patiala	5.27	292.3	34.7	719.4	7.69	5.80	1.33	0.194	0.057
Ludhiana	4.21	242.7	36.0	688.2	-0.96	5.48	-0.17	0.863	0.001
Rohtak	3.29	260.7	49.5	517.6	0.42	3.48	0.12	0.904	0.000
Bathinda	2.99	188.6	39.5	408.7	4.45	3.96	1.12	0.254	0.043
Hisar	2.74	158.0	36.1	388.2	2.15	1.81	1.19	0.240	0.032
Sirsa	2.23	145.5	40.8	334.6	1.42	3.11	0.46	0.641	0.007
Bawal	3.68	219.9	37.4	453.7	8.13	4.01	2.03	0.051	0.120
Narnaul	2.98	231.0	48.5	324.6	7.77	3.21	2.42	0.017	0.140
Ganganagar	1.62	115.1	44.3	265.3	-0.33	2.14	-0.16	0.877	0.001
Jaipur	3.48	212.3	38.2	506.9	2.73	3.58	0.76	0.450	0.017
Hills	41.69	256.8	26.4	861.2	3.38	5.79	0.46	0.266	0.059
Plains	27.17	224.1	35.3	527.7	2.77	3.70	0.58	0.489	0.106
NW India	31.13	233.1	32.1	580.7	4.56	4.27	0.54	0.428	0.225

PSR = Percent share in rainfall; p: probability of error; 't' = 2.750 at 1% and 2.042 at 5%

During the dormant season, the normal rainfall was more than 100 mm at Srinagar, Manali, Shimla, Palampur, Solan, Ranichauri, Jammu and Chandigarh. Ambala, Saharanpur, Karnal, Patiala, Ludhiana, and Bathinda had between 100 to 50 mm of rainfall and remaining eight stations: Delhi, Rohtak, Hisar, Sirsa, Bawal, Narnaul, Ganganagar and Jaipur had less than 50 mm (Table 3). It was highest at Manali (465.3 mm) and lowest (16.2 mm) at Jaipur during dormant season. The long period average of rainfall during dormant season was 319.6 mm, 54.9 mm and 122.7 mm with coefficient of variation 31%, 29.9% and 36 per cent in hills, plains and north-west India, respectively. The rainfall trend during this season was negative in hills and plain but it was positive in north-west India. Rainfall was decreasing with a rate of 0.571 mm per year in hills and 0.107 mm per year in plains but increasing with a rate of 0.686 mm per year in north-west India. The standard error was highest (3.28) for hills followed by north-west India (1.36) and plain (0.64). The slope values are significant at $p \leq 0.667$ for hills, 0.50 for north-west India and 0.432 for plains.

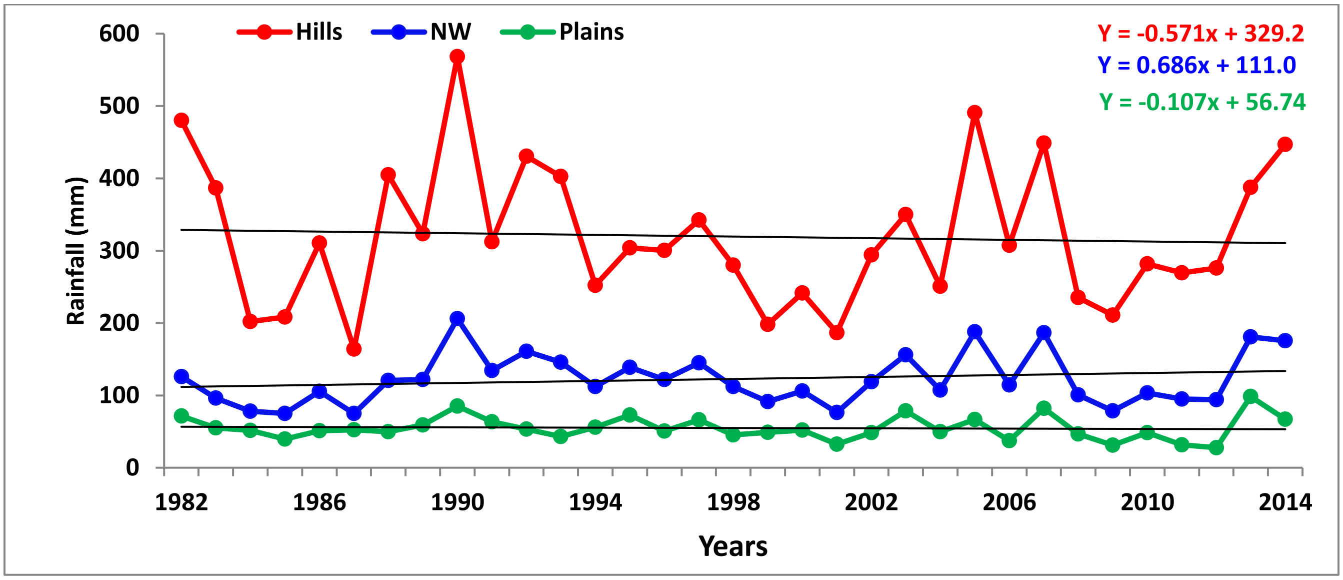


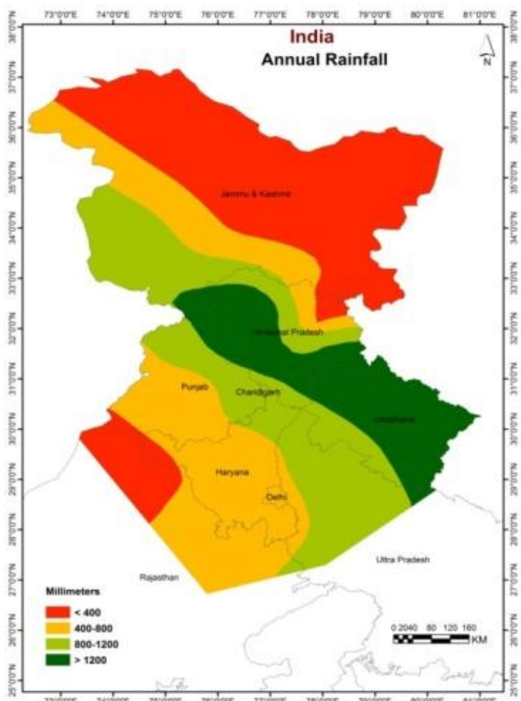
Figure 3 Trend in rainfall during dormant season

Table 3 Statistical measures of rainfall (mm) during dormant season at different meteorological stations in north-west India

Stations	PSR (%)	SD	CV (%)	Intercept	Slope (rate)	S.E.	't' value	p	R^2
Srinagar	12.85	112.8	31.0	377.9	-1.03	3.00	-0.34	0.725	0.005
Manali	16.42	168.2	151.3	471.6	-0.35	2.86	-0.12	0.903	0.001
Shimla	8.60	98.8	40.6	236.4	0.42	1.83	0.23	0.820	0.002
Palampur	10.51	146.2	49.1	290.6	0.76	6.85	0.11	0.907	0.001
Solan	8.40	101.3	42.6	273.0	-2.60	2.65	-0.98	0.318	0.038
Ranichauri	9.69	118.8	43.3	312.0	-2.42	2.51	-0.97	0.326	0.032
Jammu	4.24	63.6	52.9	128.5	-0.57	1.51	-0.38	0.709	0.005
Chandigarh	3.64	56.3	54.5	126.0	-1.34	1.02	-1.32	0.196	0.053
Ambala	3.24	50.2	54.7	115.5	-1.25	0.76	-1.65	0.107	0.072
Saharanpur	3.01	34.9	41.0	55.1	0.37	0.58	0.64	0.495	0.048
Delhi	1.69	35.5	74.0	40.6	0.46	0.73	0.62	0.538	0.013
Karnal	2.54	49.0	67.9	17.1	0.32	0.20	1.60	0.117	0.059
Patiala	2.85	38.4	47.6	71.7	0.56	0.78	0.73	0.474	0.018
Ludhiana	2.79	39.0	49.3	84.3	-0.35	0.88	-0.39	0.697	0.006
Rohtak	1.27	29.8	82.9	38.4	-0.11	0.40	-0.29	0.776	0.002

Bathinda	1.83	36.5	70.4	26.2	1.65	0.72	2.30	0.024	0.159
Hisar	1.24	21.3	60.7	30.4	0.21	0.25	0.84	0.405	0.016
Sirsa	1.11	23.4	74.4	35.5	-0.26	0.50	-0.53	0.590	0.010
Bawal	1.32	42.8	114.2	22.4	0.91	0.82	1.12	0.272	0.040
Narnaul	1.23	34.3	98.6	21.9	0.67	0.50	1.32	0.182	0.046
Ganganagar	0.96	16.3	60.2	29.7	-0.15	0.30	-0.49	0.626	0.008
Jaipur	0.57	16.2	99.9	18.1	-0.11	0.28	-0.39	0.702	0.005
Hills	64.28	98.9	31.0	329.2	-0.57	3.28	-0.34	0.667	0.003
Plains	11.04	16.4	29.9	56.7	0.11	0.64	0.23	0.432	0.004
NW India	24.68	36.0	29.3	111.0	0.69	1.36	0.08	0.496	0.034

PSR = Percent share in rainfall; p: probability of error; 't' = 2.750 at 1% and 2.042 at 5%



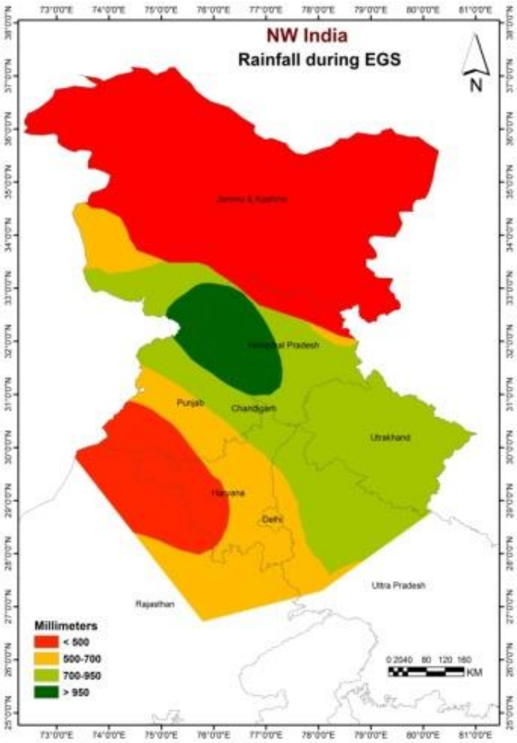
Map 1

3.3. Spatial distribution of rainfall

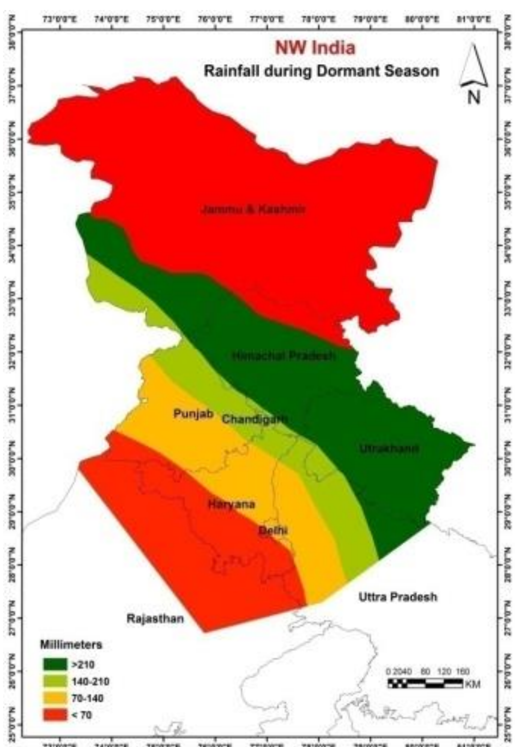
Spatial variation in annual rainfall of north-west India is depicted in Map 1 which indicates that rainfall was decreased towards north and south from the central which had maximum rainfall of 1965.3 mm at Palampur. The study area was divided into four zones (extremely dry<400 mm, dry 400-800 mm, semidry 800-1200 mm and wet >1200 mm) based on the spatial variation in annual rainfall. The average annual rainfall normal was 851.6 mm. Normal annual rainfall varied spatially from 1965.3 mm in the central area to 874.1 mm toward north and 286 mm toward south of study area and average value was 851.6 mm. A method based on the geographical information system (GIS) was used for spatial climate analysis (Baigorria *et al.,* 2000).

Spatial variation in seasonal rainfall of north-west India during the effective growing season and dormant season is depicted in Map 2 and 3. On the basis of spatial variation in rainfall during the effective growing season north-west India was divided into four zones (<500 mm, 500-700 mm, 700-950 mm and >950 mm). Similarly four different rainfall zones were delineated in dormant season (<70mm, 70-140 mm, 140-210 mm and >210 mm). The average normal rainfall during effective growing season was 726.9 mm which varied spatially from 259.7 mm to 1667.4 mm and during dormant season the average rainfall was 122.7 mm with average of 16.2 to 465.3 mm. The study area was divided into four zones (extremely dry<400 mm, dry 400-800 mm, semidry 800-

1200 mm and wet >1200 mm) based on the spatial variation in annual rainfall. Similarly four different rainfall zones were delineated for effective growing and dormant season, respectively.



Map 2



Map 3

4. DISCUSSION

From the results it was found that the annual normal rainfall for eight stations was more than one thousand millimeters for eleven stations between 500-900 mm and from 200 to 500 mm at remaining three stations. The deceasing trend in rainfall was highest at Chandigarh (-4.62) followed by Srinagar (-4.29) and lowest for Ganganagar (-0.48) followed by Jammu (-0.9/year). The value of increasing trend in rainfall was highest at Palampur 13.84mm per year and was lowest at Rohtak (0.31mm/year). The increasing trend in rainfall at hills, plain and whole of north-west India was of 5.51, 1.58 and 5.82mm per year. The increasing trend in annual rainfall at most of the stations might be due to regional warming which resulted in high convection currents. Increase in water vapors in atmosphere due to flood irrigation facilities in most of Haryana might cause more local rains. Kaur and Hundal (2006) confirmed these results and they reported an increase in rainfall (10.5 mm/year) in Ludhiana, Punjab. During the effective growing season the rainfall trend was positive for hills, plains and north-west India whereas during the dormant season it was decreasing in hills and plains but increasing for whole of north-west India. Geethalakshmi *et al.* (2011) projected the climate change over Cauvery basin of Tamil Nadu scenario using regional climate models for A1B and showed an increasing trend for maximum, minimum temperatures and rainfall.

SUMMARY OF RESEARCH

1. The annual rainfall showed an increasing trend in hills (5.51 mm per year) in plains (1.58 mm per year) and in the whole of north-west India increasing rate was (5.82 mm per year).
2. During the effective growing season the rainfall showed an increasing trend with the rate of 3.38 mm/ years in hilly area, 2.77 mm/ years in pain area and 4.56 mm per year in the north-west India.
3. During the dormant season the rainfall was decreasing with 0.57mm per year in hills and 0.11mm per year in plains but it was increasing with 0.69mm per year in north-west India.
4. North-west India was divided into four rainfall zones: extremely dry, dry, semidry and wet.

FUTURE ISSUES

I believe that many scientists in sphere of Earth Science have to pay attention to the real geophysical and climatological data obtained for last few decades and summarized a little in this work. Apparently, ripened time to refuse in geology and astronomy from any assumptions and hypothesis existing now and to begin the broad scientific research the processes of the Earth's climatic dynamics for sustainable livelihood, climate smart agriculture and food security.

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