Journal of Agrometeorology 20 (3) : 265-267 (September 2018)

Short Communication

Rainfall trend analysis in north-west India

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North-west India with diverse soil and climate comprising different 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.Punjab and Haryana are largest contributor to India's central pool of food grains and also good producer of subtropical fruits (mango, ber, guava, citrus and litchi) and some temperate fruits (pear, peaches, plum, pomegranate etc) while Jammu & Kashmir, Himachal Pradesh, Uttarakhand are the largest producer of temperate fruits (apple, apricot, pear, peach, plum and cherry) in India.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) observed variability in rainfall in middle and upper Himachal Pradesh. Singh *et al.* (2016; 2018) have reported trend in potential evapotranspiration and chilling hours over north-west India.The present study was conducted to evaluate rainfall trend in north-west India for efficient use of rain water.

Twenty two meteorological stations of N-W India comprising comprising of Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Punjab, Haryana, Chandigarh, Delhi, western Uttar Pradesh and north parts of Rajasthan were selected for the study.The daily rainfall data for the period of 35 years (1980-2014) of different stations were collected from India Meteorological Department), Central Research Institutes for Dry Land Agriculture (CRIDA), revenue departments, State Agricultural Universities (SAUs), Regional Research Stations (RRS), Regional Horticultural Research Stations etc. Rainfall trends for all stations on annual and seasonal basis were analyzed. Statistical measures like standard deviation, coefficient of variation, slope, standard error, probability (p) of standard error, t-values, correlation coefficientwere computed using 'OP Stat" software.

Trend in annual rainfall

The normal rainfall was more than 1000 mm at eight stations (Patiala, Chandigarh, Solan, Jammu, Manali, Ranichauri, Shimla and Palampur). Eleven stations (Srinagar, Ambala, Saharanpur, Delhi, Karnal, Ludhiana, Rohtak, Bathinda, Bawal, Narnaul and Jaipur) have normal rainfall between 500-1000 mm and remaining three stations (Ganganagar, Sirsa, Hisar) have rainfall from 200 to 500 mm. The coefficient of variation varied between 14.7 and 48.1 per cent, Low CVs was observed in areas having high rainfall and high CVs in areas having low rainfall, with slight local specific variation. Based on the spatial distribution of annual rainfall the study area was divided into four zones viz. extremely dry (<400 mm), dry (400-800 mm), semidry (800-1200 mm) and wet (>1200 mm).

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 year^{-1}) followed by Srinagar (-4.29year^{-1}) and lowest for Ganganagar (-0.48) followed by Jammu (-0.9 year^{-1}). The value of increasing trend in rainfall was highest at Palampur 13.84mm per year and was lowest at Rohtak (0.31mmyear^{-1}).

The normal rainfall were 1288.5, 687.8 and 851.6 mm for hills, plains and whole of north-west Indiawith rainfall increasing trend of 5.51, 1.58 and 5.82mm per year respectively. Similar results were observed by Jangra and Singh (2011) in mid hills of Himachal Himalayas. 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. 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

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Table 1: Statistical measures for annual rainfall (mm) at different stations of N-W India

Station	Rainfall Group	Regions	Latitude	Longitude	Altitude (m)	Rainfall (mm)	CV (%)	Slope	't'	'p'	R^2
Shimla	>1200	Hills	32.1	76.5	1219	1965.3	14.7	13.84	0.74	0.446	0.330
Manali			31.1	77.2	2397	1311.4	24.7	13.69	2.41	0.022	0.158
Solan			30.1	78.9	1950	1269.7	22.4	4.45	0.68	0.488	0.016
Ranichauri	800-1200		32.3	77.2	2050	1178.9	23.4	3.27	0.71	0.486	0.014
Jammu			32.7	74.8	327	1145.0	17.9	-0.90	-0.16	0.871	0.001
Palampur			30.9	77.1	1600	1131.6	17.6	-4.62	-0.75	0.440	0.023
Chandigarh		Plains	30.7	76.7	321	1071.4	27.0	-4.87	-0.89	0.379	0.025
Patiala			30.3	76.3	350	1001.7	23.5	8.26	1.42	0.165	0.065
Srinagar			34.1	74.7	1600	874.1	30.6	-4.29	-0.52	0.594	0.011
Ambala			30.4	76.7	264	841.3	27.1	1.02	0.30	0.769	0.003
Karnal	400-800		29.7	76.9	245	752.0	33.3	-1.68	-0.58	0.564	0.008
Ludhiana			30.9	75.8	244	749.5	28.9	-1.30	-0.24	0.811	0.002
Saharanpur			29.9	77.5	268	749.4	30.7	-4.73	-0.12	0.898	0.002
Delhi			28.6	77.2	216	716.5	30.3	6.45	1.41	0.168	0.064
Bawal			28.1	76.5	266	627.3	34.4	-0.74	-0.20	0.842	0.001
Bathinda			30.2	74.9	201	572.6	27.1	6.10	1.53	0.125	0.077
Jaipur			26.9	75.8	431	572.3	37.3	2.63	0.73	0.470	0.016
Rohtak			28.8	76.5	220	547.5	48.1	0.31	0.09	0.931	0.000
Narnaul			28.0	76.1	308	510.4	44.7	8.44	2.66	0.009	0.165
Hisar			29.1	75.7	215	472.4	36.2	2.36	1.27	0.213	0.036
Sirsa	< 400		29.5	75.0	205	388.9	35.6	1.15	0.36	0.713	0.005
Ganganagar			29.9	73.8	178	286.0	38.9	-0.48	-0.23	0.822	0.002
Hills		NW India	-	-	-	1288.5	22.2	5.51	0.54	0.413	0.108
Plains			-	-	-	687.8	32.6	1.58	0.46	0.547	0.015
NW India			-	-	-	851.6	29.7	5.82	0.48	0.510	0.193

p= probability of error; 't' = 2.750 at 1% and 2.042 at 5%

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.

Trend in seasonal rainfall

The normal rainfall during effective growing season (March to October) was 973.5 mm in hills 634.5 mm in plains and 726.9 mm on whole of north-west India with coefficient of between variation 26.4 and 32.1 per cent. The rainfall trend was positive with values of 3.38, 2.77 and 4.56mm per year for hills, plains and north-west India (Table 2). The correlation coefficient was less than 25 per cent for hills, plains and north-west India with significance (p) value of 0.266, 0.489 and 0.428, respectively. The rainfall trend during dormant season (November to February) was negative in hills and plains but it was positive 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 were significant at $p \leq 0.667$ for hills, 0.50 for north-west India and 0.432 for plains. 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.

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Table 2: Statistical measures for seasonal rainfall (mm) at different stations of N-W India

Stations	Effective growing season (March to October)					Dormant season (November to February)				
	Rainfall (mm)	CV (%)	Trend (rate)	't' value	'p'	Rainfall (mm)	CV (%)	Trend (rate)	't' value	'p'
Shimla	1062.1	26.6	13.27	2.84	0.008	243.6	40.6	0.42	0.23	0.820
Manali	713.7	144.3	3.61	1.06	0.298	465.3	151.3	-0.35	-0.12	0.903
Solan	892.1	21.2	-2.02	-0.40	0.680	237.9	42.6	-2.60	-0.98	0.318
Ranichauri	995.5	26.2	6.87	1.26	0.203	274.5	43.3	-2.42	-0.97	0.326
Jammu	1022.8	20.7	-0.33	-0.07	0.949	120.2	52.9	-0.57	-0.38	0.709
Palampur	1667.4	20.9	13.08	0.82	0.399	297.9	49.1	0.76	0.11	0.907
Chandigarh	968.2	30.0	-3.52	-0.66	0.515	103.2	54.5	-1.34	-1.32	0.196
Patiala	842.4	34.7	7.69	1.33	0.194	80.7	47.6	0.56	0.73	0.474
Srinagar	510.1	50.0	-0.49	-2.79	0.007	364.1	31.0	-1.03	-0.34	0.725
Ambala	748.7	30.8	2.27	0.63	0.530	91.8	54.7	-1.25	-1.65	0.107
Karnal	680.3	33.2	-0.29	-0.94	0.352	72.1	67.9	0.32	1.60	0.117
Ludhiana	673.8	36.0	-0.96	-0.17	0.863	79.1	49.3	-0.35	-0.39	0.697
Saharanpur	870.3	39.5	-9.39	-0.24	0.800	85.2	41.0	0.37	0.64	0.495
Delhi	667.1	32.6	5.99	1.37	0.181	47.9	74.0	0.46	0.62	0.538
Bawal	587.8	37.4	8.13	2.03	0.051	37.4	114.2	0.91	1.12	0.272
Bathinda	477.8	39.5	4.45	1.12	0.254	51.8	70.4	1.65	2.30	0.024
Jaipur	556.1	38.2	2.73	0.76	0.450	16.2	99.9	-0.11	-0.39	0.702
Rohtak	526.5	49.5	0.42	0.12	0.904	36.0	82.9	-0.11	-0.29	0.776
Narnaul	476.2	48.5	7.77	2.42	0.017	34.8	98.6	0.67	1.32	0.182
Hisar	437.7	36.1	2.15	1.19	0.240	35.2	60.7	0.21	0.84	0.405
Sirsa	356.5	40.8	1.42	0.46	0.641	31.5	74.4	-0.26	-0.53	0.590
Ganganagar	259.6	44.3	-0.33	-0.16	0.877	27.1	60.2	-0.15	-0.49	0.626
Hills	973.5	26.4	3.38	0.46	0.266	319.6	31.0	-0.57	-0.34	0.667
Plains	634.5	35.3	2.77	0.58	0.489	54.9	29.9	0.11	0.23	0.432
NW India	726.9	32.1	4.56	0.54	0.428	122.7	29.3	0.69	0.08	0.496

p: probability of error;'t' = 2.750 at 1% and 2.042 at 5%

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Received : September 2015; Accepted: July 2018