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A Polynomial Regression Analysis for the Estimation of Rainfall Pattern in Haryana

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Abstract

In the State of Haryana rainfall is the main determinant of groundwater regime. Rainfall is markedly restricted in season and dry conditions are usual occurrence in the State. The short rainy season is succeeded by long spells of dry season. The distribution of rainfall is irregular in both time and space and water deficiency is a problem everywhere. The main source of rainfall is the monsoon (northeast and southwest), which covers the entire State between the third week of June and middle of July. The amount and distribution of monthly rainfall are not uniform in space. Therefore, to determine the trend in the rainfall pattern in the State, a polynomial regression analysis is applied. The analysis shows that rainfall has a random pattern with a periodic trend.

Introduction

It is essential to assess the water availability in terms of rainfall in a region that shows water deficiency all the year round. The proper monitoring of rainfall received during monsoon and non-monsoon season in an area reveals a picture of total available water resources in the region. But this monitoring in the country at different levels is often found to be either not working even in the normal conditions or fails to record data when heavy downpour occurs. Therefore, under these constraints it becomes pertinent to evaluate availability and variability of rainfall before undertaking water resource studies. In the time series analysis, there are five general components, all of which may or may not be present in any one time series. The three components that can be characterized as systematic are secular, periodic, and cyclical trends. The name of these components is probably based on the importance of time trends within business forecasting. Therefore, to identify the existence of any trend in the rainfall series in Haryana, a polynomial regression analysis has been employed between total and monsoon rainfall.

Studies for identifying the trend and periodicity in the rainfall series have been carried out by several scholars since last many decades all over the world. Chidley and Key (1970) tried to determine the mean rainfall with the help of trend surface analysis. It attempts to decompose each observation on a spatially distributed variable into a component associated with regional trend. Namias (1968) had studied the trend in rainfall of Central Park Observatory, New York and related them to general circulation aberration. While dealing with aridity in Africa, Middle East and India, in 1973 Winstanley established a 200 and 700 years harmonic cycle in the behavior of rainfall and he also included Jodhpur and Bikaner in the cycle. Bhargava and Bansal(1968) had studied the secular trend and periodicity in the monsoon and annual rainfall of selected stations in India and noted the presence of quasi- biennial oscillation. Dhar, Mandal and Kulkarni (1990) made an attempt to present working estimates of mean rainfall for the two regions of Jammu and Kashmir. In Andhra Pradesh, Penchalaiah and Ramanaiah (1992) presented a very simple analysis of various aspects of rainfall like distribution, intensity variability in the drought prone area of Cuddapah district and also described the micro-level temporal pattern. Further, Kalita and Goswami (1996)studied the areal and seasonal variations of rainfall in three major tea growing districts of Assam. A seasonality index of rainfall on the basis of Ayode's (1970) formula has been computed. Similarly, Ahlawat and Thakur (1999) attempted to analyse the optimality of rainfall data recorded in Bundelkhand region. Similarly, Subramanian and Thankappan (1995) observed that rainfall during southwest monsoon season over Tamil Nadu has been quite significant from the point of view of water shortage in major reservoirs. Galkate and Thomas (2002) analysed rainfall pattern and persistence by employing various statistical techniques in Sagar division of Madhya Pradesh. Furthermore, Ahmed and Das (2004) while studying the rainfall pattern and number of rainy days for the five decades of Golpara District of Assam found that rainy days are decreasing and drought days are showing increasing trend. The foregoing studies have been conducted in different parts of the country at different times though the objective of these studies is to analyse the various constituents of rainfall, they differ vastly in approach and scale of study.

Study Area

The main source of rainfall in the state is the monsoon rainfall (northeast and southwest), which covers the entire State between the third week of June and middle of July. The amount and distribution of monthly rainfall are not uniform in space. It is clear from Table 1 and Figure 1(a) that a very large amount of rainfall is received during monsoon in the months from July to August. Similarly, a good amount of rainfall is also received from a few depressions in January to March in the northeaster parts of Haryana. The monsoon rainfall decreases from east to west and northeast to southwest and cyclonic rainfall decreases from north to south and there is a significant variability in rainfall from month to month. The intensity of rainfall at any station can be very high to very low in the northeastern parts where the monsoon winds are strong as compared to the northwest on account of the fading frequency and intensity of cyclones.

The maximum values of annual rainfall are in the northeastern side with isohyets of 1100 mm rainfall passing through the administrative blocks of Naraingarh, Bilaspur and Chhachhrauli. Rainfall reduces from northeast to southwest. In the southeast side of Haryana where Faridabad and Gurgaon districts are situated, the average annual rainfall increases considerably. Thus,

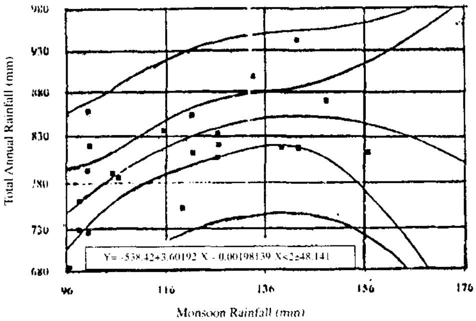

Fig. 1 **Dadupur Plot of fitted Model of Polynomial Regression**

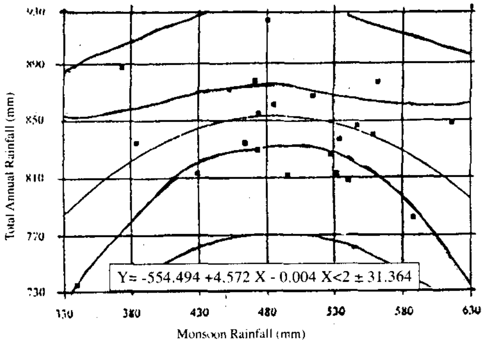

Fig. 2 **Thanesar Plot of fitted Model of Polynomial Regression**

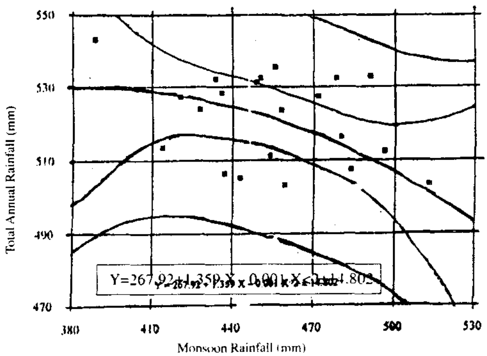

Fig. 3 **Sonipat Plot of fitted Model of Polynomial Regression**

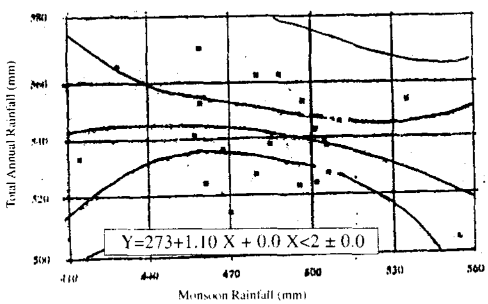

Fig. 4 **Rohtak Plot of fitted Model of Polynomial Regression**

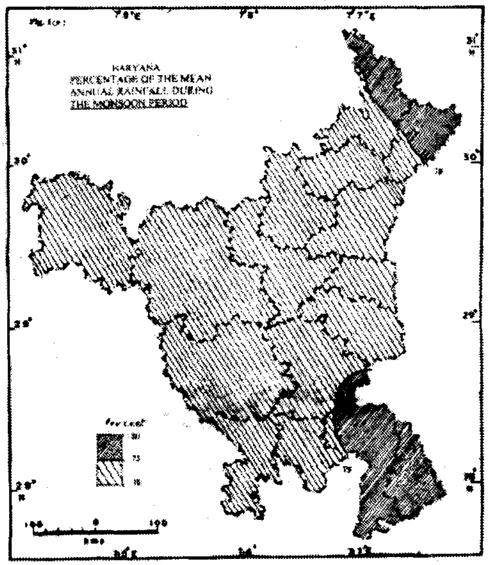

Fig. 1(a) **Percentage of the mean Annual Rainfall during the Monsoon period**

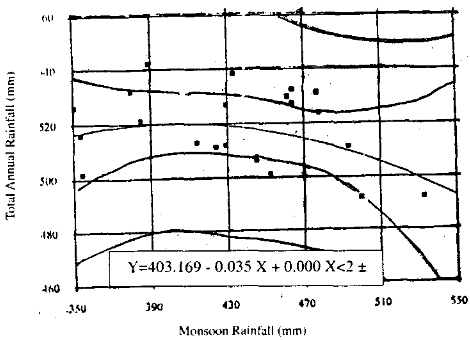

Fig. 5 **Sampla Plot of fitted Model of Polynomial Regression**

Table 1

Haryana: Mean Monthly, Seasonal and Annual Rainfall (mm)

District	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Average Annual Rainfall	Average Monsoon Rainfall	Percent of Annual Rainfall
1	2	3	4	5	6	7	8	9	10	11	12	13	l4	15	16
Ambala	38.7	41.9	20.8	11.6	14.8	89 1	275.9	230.0	154.6	18.1	4.3	14.6	947.49	793.23	83.7
Kurukshetra	25.0	25.9	16.7	11.9	10.7	51 2	127.3	134.0	108.4	II.33	1.98	6.86	562.0	459.5	81.7
Karnal	27.0	26.5	14.6	10.4	12.07	56.6	194.0	173.0	122.2	11.5	3.1	5.6	662.0	508.0	76.7
Panipat	22.03	21.6	13.9	9.31	12.01	51.9	173.0	162.0	114.24	10.20	2.09	0.87	602.02	512.12	85.0
Sonipat	21.2	17.4	12.0	3.7	14.2	42.1	154.1	80.0	98.2	11.31	1.6	0.13	532.0	405.5	76.2
Faridabad	14.7	27.4	22.1	7.4	8.7	45.0	165.8	159.0	110.6	13.9	1.68	6.3	518.1	488.5	94.2
Gurgaon	15.60	13.3	11.0	6.94	12.0	49.7	147.4	157.0	104.8	13.2	2.0	6.0	490.5	486.5	99.1
Jind	16.90	10.2	9.70	9.17	11.79	53.4	132.2	121.0	95 44	9 95	2.08	7.64	500.00	424.97	84.9
Rohtak	15.5	12.3	8.96	5.82	7.31	38.0	123.7	106.0	83.35	9.24	1.81	5.82	417.44	351.51	84.2
Jhajjar	17.91	12.0	11.0	5.17	1.37	45.7	143.0	132.0	101 00	10.78	2.10	5.46	501.52	444.30	88.5
Bhiwani	15.03	11.3	8.69	4.68	7.63	37.6	93.39	81.3	59.85	7.26	4.40	5.09	384.5	346.76	90.6
Sirsa	12.94	9.05	9.24	5.59	7.35	33.4	80.52	75.0	61.62	5.31	1.35	7.93	465.64	398.75	85.6
Hisar	16.14	13.96	15.1	8.34	35.39	103.	122.7	68.5	9 32	1 49	6.85	7.54	386.42	324.70	84.0
M.Garh	13.42	12.2	9.15	3.80	10.37	41.5	128.9	1230	93 17	991	1.85	3.28	391.19	345.44	88.3
Rewari	17.11	12.3	12.0	4.03	13.30	47.4	140.8	135.0	1 12 56	14.15	2.65	3.34	432.76	402.17	92.9

Source: India Meteorological Department, Government of India isohyets through Faridabad, Gurgaon and Ballabgarh blocks gain a value of 650 mm rainfall. Table 2 shows mean, standard deviation and coefficient of variability of rainfall of the selected stations, where continuous data is available.

It is evident from the table that coefficient of rainfall and dispersion from the normal is more in Narnaul and Hisar districts. These districts are situated in the southwestern and western parts of the State. As one moves towards the north and southern side of the State, the values of both standard deviation and coefficient of variability are smaller. But in Gurgaon district again these values are abnormally high. This abnormality might be due to the location of this district which is situated at the outcrops of the Aravalli hills. Moreover, everywhere rainfall is restricted in its seasonal distribution. Therefore, in the wide areas where average rainfall is marginal in amount this variability is crucial. The coefficients of variability in monsoon and cyclonic rainfall are not identical in Haryana as the latter is highly variable. The cyclonic rainfall is least reliable and the same is true of monsoon rainfall in areas bordering Rajasthan. Variability in excess of 20 per cent implies great risk in farming (Williamson, 1925). The annual, seasonal and weekly coefficients of variation of rainfall are over 20 per cent in the State. The significance of variations in the amount of rainfall from year to year or season to season is difficult to assess unless these are related to defined water requirements of the area. This can be done by estimating the probability of specified amount of rain being obtained within a year. It is obvious from the foregoing paragraphs that the variability of rainfall is inversely related to amount of rainfall. The areas of maximum variability experience the least reliability of rainfall. On the contrary, areas of least variability witness greater reliability of rainfall. As the State receives 80 to 90 per cent of its annual rainfall during the southwest monsoon season, variability of rain during this season indicates the trend of its annual variability.

Purpose

In the time series analysis, there are three components that can be characterized as systematic are secular, periodic, and cyclical trends. The name of these components is probably based on the importance of time trends with in business forecasting. Therefore, the present research is concerned with the study to identify the existence of any trend in the rainfall series.

Methodology

In the present investigation, second order polynomial regression is employed to extract any trend in the total annual and total monsoon rainfall. At the same time it is also tried to find out the relationship and dependency of total rainfall on the monsoon rainfall. In this analysis, 22 stations depending on the availability of data has been taken into consideration for this analysis. In this analysis, the average value of rainfall data for the last twenty years i.e., 1981-2001 is examined. A polynomial equation is an equation in which one of the terms is raised to a power greater than 1.

For example, the regression equation:

$Y = a + b_1 x + b_2 x^2 + b_3 x^3$ is polynomial because x is raised to the second and third power. The highest power of a term gives the equation its degree or order. The

Table 2 : **Mean, Standard Deviation and Coefficient of Variability of Rainfall**

Sr.No.	Station	Mean	Std. Error	Std. Deviation	Coefficient of Variability (%)
1	2	3	4	5	6
1.	Ambala	875.1810	50.0814	229.5017	34.2
2.	Karnal	628.5857	49.5224	226.9403	36.1
3.	Gurgaon	764.5095	54.1031	247.9317	35.9
4.	Narnaul	536.7714	24.1563	110.6979	42.6
5.	Rohtak	588.0381	24.4871	112.2138	39.0
6.	Hissar	468.8238	20.8049	95.3399	40.3

Source: Calculated by Author

equation shown above is third order polynomial equation. The polynomial regression analysis calculates a polynomial regression model between a single dependent variable Y and a single independent variable X.

Analysis of Result

The result shown in table 3 reveal that except Dadupur, Thanesar, Sonipat, Sampla, Rohtak and Rewari administrative blocks, no significant relationship exists between total and monsoon rainfall in the State (Fig. 1-5). All these cases show a significant relationship at 90 per cent confidence level, the statistic R-squared also has significant values. At Dadupur R-squared value explains 22.34 per cent of the variability to total annual rainfall. Similarly at Thanesar, Sonipat, Sampla and Rohtak the explained variation is 100.0, 24.47, 19.24, and 31.82 per cent respectively. This implies that at these places the total annual rainfall has a significant dependency on the monsoon rainfall. These relationships become further clear when they are plotted on the scatter diagram.

Figure 1 shows the result of fitting a second order polynomial model to describe the relationship between total annual rainfall and monsoon rainfall at 90 per cent confidence level at Dadupur in Ambala district. In this diagram points are nonlinear in arrangement. The regression of Y on X is determined by drawing curvilinear line. Then, the regression coefficient is tested by calculating the standard error of estimate (Sey) which determines the expected errors in estimating Y from the given value of X. At this station standard error of estimate shows a deviation of residual'to be 48.1417. In the present case, the value of regression coefficient of Y along with the standard error of estimate has been found. The polynomial regression of total annual and monsoon rainfall at. Thanesar is clear from Fig. 2. The value of regression coefficient of Y along with the standard error of estimate has been calculated. The points on this diagram show a perfect curvilinear line with absolute nonlinear arrangement. The value of Y increases with the increase in the value of X. This indicates a positive and close

Table 3 : **Polynomial Regression Coefficient of Total annual Rainfall and Monsoon Rainfall**

District	Station	Estimate	R-squared	R-squared (Adjtd for d.f.)	Std. Error of list	P-Value at 90% C.I.	Darhin Watson Staitstics
AMBALA	Ambala	-543.08	3.020	0.0	204.0	0.747	2.011
	Jagadhari	1012.7	1.723	0.0	39.41	0.862	2.738
	Dadupur	-538.14	22.34	14.17	48.14	0.090 < 0.10	1.31<1.4*
	Naraingarh	2832.35	8.79	0.0	52.17	0.416	1.63
KAITIIAL	Gulha	56383.3	12.19	2.95	1638.4	0.290	1.780
	Kaithal	-36954.5	6.35	0.0	1707.63	0.536	2.254
KURUKSFIETR	Thanesar	2.273	100.0	100.0	0.0	0.0 < 0.10	0.00<1.4*A
KARNAL	Karnal	-3137.51	5.41	0.0	1716.1	0.589	2.22
PANIPAT	Panipat	751.13	0.77	0.0	42.13	0.928	1.716
SONIPAT	Gohana	284.57	16.36	7.55	17.07	0.183	1.57
	Sonipat	267.92	24.47	16.52	14.80	0.069< 0.10	2.05*
ROHTAK	Bahadurgarh	609.62	12.53	3.32	15.93	0.280	2.319
	Sampla	403.16	26.92	19.24	39.91	0.050< 0.10	2.11
	Rohtak	-554.49	31.82	24.65	31.36	0.026 < 0.10	2.17*
	Jhajjar	-228.51	5.74	0.0	32.61	0.568	2.46
GURGAON	Gurgaon	76.83	5.32	0.0	17.57	0.594	1.46
	Sohna	1514.69	13.71	4.63	16.41	0.263	1.24
	Hassanpur	487.87	2.87	0.0	16.78	0.750	2.423
	Firozpur	142.90	11.71	2.41	16.97	0.306	1.67
	Zhirka						
BHIWANI	Bhiwani	-1083.96	15.94	7.09	30.8	0.192	2.67
	Siwani	184.62	11.60	2.30	30.81	0.309	2.47
MAHANDRA	Narnaul	1018.43	1.14	0.0	47.75	0.896	1.20 <1.4
GARH	Rewari	430.75	27.09	19.42	47.20	0.704	1.22 <1.4
H1SAR	Hisar	! 709.53	9.18	0.0	23.01	0.40	2.38
	Sirsa	533.87	0.622	0.0	46.84	0.94	1.35
	Fatchabad	695.82	0.315	0.0	24.11	0.97	2.20

relationship between both the variables. At Sonipat the plot of the fitted model of polynomial regression shows that the relationship is positive at the first power of the polynomial regression but it has a negative relationship at the highest degree (Fig. 3). Similarly, at Sampla, (Fig. 4) relationship is curvilinear and standard error of estimates shows the standard deviation of the residuals to be 39.912. However, slope of the curve in this is not steep, therefore, the relationship at first order of regression is negative and it changes to positive at the second order polynomial regression. At Rohtak (Fig. 5) too the relationship is similar to that of Sonipat.

Conclusion

It is established by the analysis employed on rainfall data in the study area that the rainfall has a random pattern with periodic trends. Periodic trends are very common in hydrological time series. Rainfall shows periodic trends with in annual cyclic period. Usually, seasonal trends are common in hydrological data as in the case of rainfall in the study area. Where a periodic trend is expected, polynomial regression is most suited technique. Random fluctuations are often a dominant source of variation in time series. This source of variation results from physical occurrences that are not measurable and these are known as environmental factors since they are considered to be external to the physical processes that compose the system.

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