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Evaluation of Rainfall Characteristics and Temporal Trends in Rewa District, Madhya Pradesh using Statistical Methods

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Abstract

Rainfall serves as a critical input parameter in the design and analysis of hydraulic and water conservation structures, bridges, culverts, canals, stormwater sewers, and road drainage systems. Hence, a detailed statistical assessment of rainfall for a given region is essential to derive dependable design values and to support effective agricultural and water management planning. The present study focuses on the frequency and statistical analysis of seasonal rainfall data for Rewa District, Madhya Pradesh. Daily rainfall records spanning a 20-year period were analyzed to estimate design rainfall values using Weibull's formula. Rainfall variability was quantified through statistical parameters including the mean, standard deviation, and coefficient of variation (CV). The analysis revealed that the minimum mean monthly rainfall occurred in June (5.22 cm), while the maximum mean monthly rainfall was recorded in July (12.28 cm). The lowest coefficient of variation was observed in August, followed by July, indicating relatively consistent rainfall during the peak monsoon period. In contrast, the highest CV was noted in June, reflecting high variability in early monsoon rainfall. Overall, Rewa District experiences normal weather conditions in June, while July, August, and September display mixed rainfall behavior, characteristic of monsoon variability in central India.

Keywords: Frequency analysis: Rainfall variation: Probability distribution: Average method: Weibull's formula.

Introduction

Rainfall occupies an important position in the climatic studies of any region. It is a product of climatic phenomena such as evaporation, condensation, and formation of cloud. Because of its practical and climatologically implications, it is vital to place interest on its characteristics - amounts, monthly and seasonal variations, percentage, intensity, variability, and its areal distribution. The average annual rainfall of India is 1190 mm and it ranges from 350 to 2,000 mm. Most part of our country receives 80 percent of the total annual rainfall during four months June to September of a year (Bara and Lal, 2008). Rainfall events in a particular area vary, depending on its distance from the equator, inland or coastal location, and topography. Rainfall patterns are also affected by other factors including climate change, global warming, and changes in the sun's activity such as sunspots. The local hydrological, agricultural, and economic activities heavily depend on micro-level rainfall. Therefore, analysis of rainfall trends in important for water resources planning and management.

The objective of frequency analysis of hydrologic data is to relate the magnitude of extreme events to their frequency of occurrence using probability distributions. Hence, Probability and frequency

analysis of rainfall data enables us to determine the expected rainfall at various chances. Analysis of rainfall and determination of annual maximum daily rainfall would enhance the management of water resources applications as well as the effective

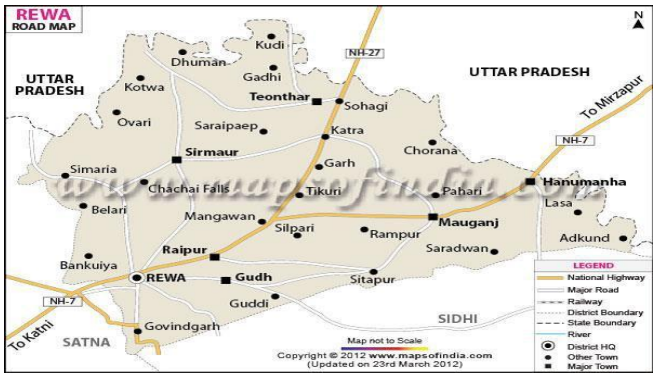

Fig. 1 A map of the district Rewa showing the boundaries

utilization of water resources (Subudhi, 2007).
Several researchers have conducted frequency analysis studies and applied for designing of hydraulic structures and also developed location specific models (Sethy et al., 2005; Bhaskar et al., 2006; Kwaku and Duke, 2007; Bhakar et al., 2008; Singh et al., 2012; Jain, 2013; Kumar et al., 2016; Rajendran and Venkatasubramani, 2017; Lavanya et al., 2018.The objective of the analysis is to understand the observed rainfall trend and variability Rewa District and perform frequency analysis of rainfall data.

Materials and Methods

Study Area

The study area is Rewa district lies in the central part of the state of Madhya Pradesh covering an area of 6287.45 km^2. It lies between north latitude 24016'30"and 25011' 15" and east longitude 8103'15" and 82018' 45". It is in the north eastern corner of the state and bounded by Satna district in the west; Sidhi district in the south and state of Uttar Pradesh in north and East Rewa town is the district headquarter for administrative purposes (Fig. 1). The normal annual rainfall of Rewa District is 1141.50 mm. It received maximum rainfall during south-west monsoon period i.e., June to September. About 90 percent annual rainfall received during monsoon season and only 10% of the annual rainfall takes place between October to May period.

The climate of Rewa District is characterized by a hot summer and general dryness except during the south west monsoon season. The year may be divide into four seasons. The cold season, December to February is followed by the hot season from March to about the middle or June. The period from the middle of June to September is the south west monsoon season. October and November form the post monsoon or transition period. The state Madhya Pradesh is also a major producer of linseed, mustard, sunflower, safflower, and niger. Agro-climatic diversity and topographical variations enable the state to grow a wide range of cereals, pulses, oilseeds and cash crops, besides being home to myriad varieties of plant species, both in forest areas and outside. Various tropical fruits and vegetables and spices like coriander, chili and garlic are also widely grown. The farmers of the state are highly adaptive towards undertaking the cultivation of new crops, which hold promise of economic returns. The success story of soybean in the state is a case in point. Madhya Pradesh leads in the production of gram, linseed, green pea, garlic and coriander. Areas under cultivation of safflower and sunflower are also expanding.

Data Collection and Analysis

The methodology adopted for the probability of rainfall data of 20 years (1994-2013) to predict June to September consecutive Monthly annual maximum rainfall and average monthly rainfall of Rewa region were collected from the website https://globalweather.tamu.edu/. These data were used for trend analysis. Microsoft office sub-module MS-Excel was used for data analysis. The formulation and conditional statements was also executed in MS-excel. From the daily rainfall data, monthly rainfall series of each station was computed and then monthly district rainfall series were constructed by considering arithmetic average of all the station rainfall values within the district. The monthly rainfall series of the state was computed by using area weighted rainfall values of all the districts within the state. Rainfall variation was estimated by calculating Mean, Standard deviation and Coefficient of variation. Trend analysis was statistically examined which shows a fluctuating graph. Then trend was computed by the Moving Average Method. To compute three yearly moving average, for instance, the values of

1st, 2nd and 3rd years are added up, and the quotient is placed against 2ndyear; then values of the 2nd, 3rd and 4th years are added up, averaged and the average is placed against the 3rd year, and so on. Weibull's formula was used for hydrologic frequency. The selection of the probability of exceedance (PX) or return period (TX) for design purposes is related to the damage

the excess or the shortage of rainfall may cause, the risk one wants to accept and the lifetime of the project. FAO (Smith, 1992) rules for the determination of dry, normal and humid weather conditions was used. The monthly rainfall trends were estimated by three year moving average method at Rewa (Fig. 2). It was observed that for the selected Rewa the monthly rainfall received during month of June was less than the other months for whole of the time period considered. For other months the monthly rainfall received in the July and August was more than the other months for the whole of the time period considered for the study. The frequency analysis of monthly rainfall data for Rewa District was carried out using Weibull's formula to estimate rainfall magnitudes corresponding to various return periods. The analysis was performed for the monsoon months — June, July, August, and September — using 20 years of daily rainfall records.

Table 1 Statistical analysis of rainfall data of Rewa district

Time Series	Mean rainfall (cm)	Maximum rainfall (cm)	Minimum rainfall (cm)	Standard Deviation	Coefficient of Variation
June	5.22	24.42	0	6.01	115.13
July	12.28	24.42	2.89	5.41	45.46
August	10.78	18.68	4.06	4.22	38.62
September	9.19	22.73	2.8	4.91	53.80
Seasonal	9.37	22.56	2.44	3.04	32.45

The results revealed that the maximum rainfall for June was 24.42 mm, corresponding to a return period of 21 years, indicating a relatively rare event. For July, the maximum rainfall was also 24.42 mm with a 21-year return period, while the minimum rainfall recorded was 2.89 mm, corresponding to a return period of 1.05 years, representing an almost annual occurrence. Similarly, the maximum rainfall for August was 18.68 mm (21-year return period), whereas the minimum rainfall was 4.06 mm (1.05-year return period). For September, the maximum rainfall was 22.73 mm (21-year return period), and the minimum rainfall recorded was 2.80 mm (1.05-year return period). The analysis indicates that higher rainfall magnitudes with longer return periods are associated with peak monsoon activity (July to September), whereas lower return period values correspond to more frequently occurring, low-intensity rainfall events. These findings are essential for designing hydraulic and drainage structures and for planning water conservation measures under varying rainfall intensities and probabilities.

Predication of rainfall for return period of 20, 35 and 50 years

The rainfall was predicted for return period of 20,35 and 50 years using graphical regression equation. The highest rainfall occurs in the month of July for return period as compared to June, August and September. The predicted rainfall values for different return periods indicate a clear increasing trend with longer return periods across all months in Rewa District. During June, the predicted rainfall rises from 20.12 cm for a 20-year return period to 24.15 cm for a 35-year return period and 26.72 cm for a 50-year return period, reflecting moderate variability during the onset of the monsoon. In July, which represents the peak monsoon month, the rainfall increases from 25.57 cm for 20 years to 29.22 cm for 35 years and 31.55 cm for 50 years, indicating the highest rainfall intensity among all months.

For August, the rainfall values show a steady rise from 21.32 cm to 24.12 cm and 25.91 cm for the same return periods, suggesting consistent mid-monsoon precipitation. Similarly, September exhibits rainfall increasing from 21.33 cm to 24.63 cm and 26.73 cm, showing persistence of significant rainfall during the late monsoon period (Table 2). These results are vital for engineering design, as rainfall corresponding to 35- to 50-year return periods should be considered for the design of major hydraulic and drainage structures, while 20-year return period values may be adequate

for crop planning and water conservation structures. The rainfall distribution thus reflects the typical monsoon pattern of central India, with peak intensity in July and a gradual decline toward the end of the seasonJuly dominates most quantiles, confirming it as the peak-monsoon month for design storms; August and September are moderately high and close to each other, while June is clearly lower and more variable (Table 3). For quick design points by linear interpolation: the 2-year (P=50%) daily rainfall is 4.1 mm (June), 11.1 mm (July), 9.7 mm (August), and 8.6 mm (September); the 5-year (P=20%) values are 9.6 mm (June), 17.3 mm (July), 15.4 mm (August), and 11.6 mm (September); the 10 year values are effectively your m=2 row (10.5-year) giving 13.35, 19.22, 18.54, 19.22 mm for June–September; and the 21 year maxima are your m=1 row (24.42, 24.42, 18.68, 22.73 mm).

Table 2 Predication of rainfall for return Period of 20, 35 and 50 Years

Return Period (Years)/Month	**20**	**35**	**50**
	Predicted rainfall (cm)		
June	20.121	24.153	26.7231
July	25.571	29.224	31.553
August	21.315	24.123	25.913
September	21.326	24.629	26.733

Table 3 Probability of Exceedance of rainfall (mm) for month June

Rank (m)	**Probability %**	**Return Period (T)**	**June**	**July**	**August**	**September**
1	5	21	24.42	24.42	18.68	22.73
2	10	10.5	13.35	19.22	18.54	19.22
3	14	7	12.53	18.83	16.57	14.02
4	19	5.25	10.43	17.56	15.41	11.95
5	24	4.2	6.26	16.28	15.15	10.2
6	29	3.5	6.02	15.79	14.41	9.49
7	33	3	5.15	14.78	12.43	9.35
8	38	2.62	4.65	12.97	11.09	9.06
9	43	2.33	4.57	12.94	10.57	8.95
10	48	2.1	4.52	11.62	10.16	8.7
11	52	1.91	3.7	10.58	9.13	8.47
12	57	1.75	2.62	10.31	9.08	8.22
13	62	1.62	1.52	10.01	9.07	7.3
14	67	1.5	1.29	9.23	8.92	6.88
15	71		1.08	7.86	7.98	6.26
16	76	1.31	1	7.83	7.63	5.35
17	81	1.24	0.68	7.5	7.31	5.26
18	86	1.17	0.4	7	6.34	5.02
19	90	1.11	0.3	3.83	6.31	3.31
20	95	1.05	0.2	2.89	4.06	2.8

Table 4 Meteorological events classification based on rainfall return periods

Classification	Return Periods
Normal	<6
Abnormal	6-10
Very Abnormal	10-30
Exceptional	30-100
Very Exceptional	>100

Table 5 Normality distribution of Rainfall according to return Periods in Rewa

Sl.no.	Month	Return period		
		Classification of meteorological Events (P cm)		
		Normal	Abnormal	Very Abnormal
1.	June	0.2-5.15	6.02-6.26	10.43-24.42
2.	July	2.89-3.83	7-9.23	10.01-24.42
3.	August	4.06	6.31-9.13	10.16-18.68
4.	September	2.8-5.35	6.26-9.49	10.2-22.73

Conclusions

The daily rainfall data were used to compute the seasonal rainfall, and statistical parameters such as mean, standard deviation, and coefficient of variation were determined to understand the variability in rainfall distribution. The trend in rainfall was analyzed using the moving average method, while frequency analysis was performed using Weibull's formula. The study revealed that the months of July and August contribute the highest amount of rainfall across all tahsils, whereas the lowest coefficient of variation was recorded in August, followed by July, indicating more consistent rainfall during these months. In contrast, June exhibited the highest coefficient of variation, reflecting greater variability in early monsoon rainfall.

The trend analysis of rainfall data across different tahsils showed that in Rewa, the monthly rainfall during June was consistently lower than in other months throughout the study period, whereas July and August consistently received the highest rainfall. Frequency analysis indicated that the maximum seasonal rainfall observed during the study period (1994–2013) corresponds to a return period of approximately 24 years. Based on the rainfall characteristics, Rewa District experiences normal weather conditions in June, while the months of July, August, and September exhibit mixed conditions, ranging from normal to humid, reflecting the variability typical of monsoon behavior in central India.

Data Availability Statement

The datasets generated during the current study are available from the corresponding author on reasonable request.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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