Rainfall Data Analysis and Environmental Impacts Study of Chhatarpur District, Central India

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ABSTRACT

The study focuses on the environmental impacts of rainfall data analysis on groundwater recharge Chhatarpur district, located in Central India, from 1950 to 2020, have been discussed and statistical methods of rainfall data analysis and environmental impacts of the Chhatarpur area have been employed. The computation of numerous statistical parameters such as mean, median, mode, coefficient of variation, coefficient of dispersion, skewness, kurtosis, and regression analysis are all used in the statistical analysis of rainfall data. The positive trends above from the average annual rainfall exhibit suitable periods for recharge of groundwater reservoirs as compared to the years of below-average rainfall records. It has been suggested that the implementation of the plan for rainwater harvesting and augmentation of groundwater resources by the construction of artificial recharge structures would resolve the prevailing problems of sustained water supply.

KEYWORDS: Rainfall data analysis, statistical parameters, regression model, Chhatarpur district, Central India.

INTRODUCTION

Rainfall is an essential hydrometeorological parameter that plays a vital role in the recharge phenomena of groundwater resources. Rainfall is also known as the 'precipitation' that acts as a primary significant source for the recharge of groundwater reservoirs of the study area. It also plays an important role in the estimation of the water balance of the basin. It is well-established fact that only 3% of freshwater occurs in streams, lakes, and reservoirs, whereas 97% of available freshwater is confined to the subsurface of the earth. Weisner (1970) defined the term rainfall as "the deposition of water from the
atmosphere on to the surface. This deposit may be either liquid or solid to give the various forms of precipitation." In India, rainfall mostly occurs during the monsoon period. Dhar and Rakhecha (1975) reviewed the hydrometeorological studies of Indian rainfall.

Global climatic change may influence long-term rainfall patterns impacting the variability of water, along with the danger of increasing occurrences of droughts and floods (Pal and Mishra, 2017). The Chhatarpur district of Central India has an economy predominantly based on rainfed agriculture. The monsoon rains are quite crucial and for the past several years, the district has received deficit rains leading to drought mostly for agriculture-associated activities (Shrivastava, 2020, et al.), the trend analysis of rainfall (Partal and Kahya, 2006; Addisu, et al., 2015; and Neil and Notodiputro, 2016).

Hence the purpose of this study is to incorporate rainfall data analysis and environment impacts studies on groundwater recharge of Chhatarpur district, Central India. The seasonal trend of the rainfall pattern has been investigated on an inter-annual basis and the fluctuations have been calculated on monthly basis with a major focus on the monsoon season (June-September). This includes an understanding of the area's rainfall trend and its impacts on groundwater recharge. Understanding the uncertainties associated with rainfall patterns will provide a knowledge base for better management of groundwater resources development, Groundwater recharge, Agricultural and irrigation, and other water-related activities in the associated area.

Figure 1: Location Map of the Study area

LOCATION OF THE STUDY AREA

Chattarpur district located at 24.06° & 25.20°N 78.59° & 80.26° E respectively. It has an average elevation of 305 meters (1,000 feet). The district has an area of 8,687 km². Chhatarpur district is bounded by Uttar Pradesh State to the north, and the Madhya Pradesh districts of Panna to the east, Damoh to the south, Sagar to the southwest, and Tikamgarh to the west. Chhatarpur district is part of the Sagar Division. The district Chhatarpur was known after the name of the great warrior, Maharaja Chhatrasal.
OBJECTIVE OF THE STUDY

- To collect the rainfall data between 1950 and 2020 from IMD and Local Land Record Department Chhatapur district (M.P.) and find out numerous statistical parameters such as Mean, Median, Mode, Standard Deviation, Coefficient of Dispersion, and Coefficient of Skewness.
- To apply regression model and time series analysis carried out for environmental Impacts study on rainfall data analysis in the study area.

MATERIALS AND METHODS

In the present study, records on rainfall data have been collected from the IMD, New Delhi and Land Record Department District Chhatapur, Madhya Pradesh and were further used for analysis. Moreover, the rainfall records at the Chhatapur station were selected for seventy-one years (1950-1920) having continuous rainfall data. The meteorological station Chhatapur district Madhya Pradesh used in this study of changes in rainfall data analysis and environment impacts studies on groundwater recharge of Chhatapur district, Central India. Rainfall characteristics like, mean, median, mode, standard deviation, coefficient of dispersion, coefficient of variation, and coefficient of skewness, were computed for monthly and seasonwise viz, pre-monsoon (March-May), Monsoon (June-September), post-monsoon (October-November), and Winter (December-February). All statistical analysis, which includes in this study, computed using computer-based R studio and Graph is prepared using Microsoft Excel software. One of the most useful parametric models used to detect the trend is the "Simple Linear Regression" model. The method of linear regression requires the assumptions of normality of residuals, constant variance, and linearity of relationship (Davis 1986, Rossi et al. 1992 Sahu and Dev 2007). The model for Y (e.g., precipitation) can be described by an equation of the form:

\[ Y = at + b \]  

Where
\[ t = \text{time (year)} \]
\[ a = \text{slope coefficient;} \]
\[ b = \text{least-squares estimate of the intercept} \]

The slope coefficient indicates the annual average rate of change in the hydrometeorological characteristic. If the slope is significantly different from zero statistically, it is entirely reasonable to interpret that there is a real change occurring over time. The sign of the slope defines the direction of the trend of the variable: increasing if the sign is positive, and decreasing if the sign is negative.

RESULT AND DISCUSSION

Statistical Analysis

The result of the basic statistical analysis for the parameters maximum and minimum, mean, median, standard deviation, coefficient of dispersion, coefficient of variation, skewness, and kurtosis are discussed in the table 1. The average rainfall of the Chhatapur district has been calculated and found to be 1119.089 mm. The standard deviation shows the heterogeneity of data compared to the mean. The coefficient of variation showed a similar rate from every rainfall type which large variability. The greater the coefficient value the rainfall variation more fluctuates. Monthly rainfall data has the highest variability compared to seasonal and annual rainfall data.

The coefficients of skewness and kurtosis are tested and found that if the coefficient of skewness is between ±0.6 and kurtosis is between 2 and 4 then the rainfall distribution is normal (Basu et al., 2004). The skewness parameter showed positive and negative values. This means the distribution of the data is positively skewed in monthly and seasonal which means the tendency of rainfall above the average and annual rainfall data is negatively skewed which means the tendency of rainfall distribution below the average. The kurtosis showed a negative value for monthly (July, August), seasonal (Monsoon), and annual rainfall data which means flatter than normal peak distribution, and this kurtosis rainfall data peak flattest than the average. The standard deviation monthly, Seasonal and annual rainfall showed the most heterogeneous data of the area. The most fluctuating data are Monthly (August), Seasonal (Monsoon), and Annual rainfall.

Trend Analysis and Environmental Impact

Monthly rainfall trends for the Chhatapur district during the last seventy-one years
(1950-2020) are comprised of January to May and September to December are show significantly decreasing trends of the district. Only one significant increasing trend appears in the area towards June-August (Fig. 2).

Table 1: Statistical information rainfall data of Chhatarpur District, Central India.

<table>
<thead>
<tr>
<th>Month/Seasons</th>
<th>Max.</th>
<th>Min.</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>CD</th>
<th>CV (%)</th>
<th>Skew.</th>
<th>Kurt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>118.602</td>
<td>0.000</td>
<td>20.19883</td>
<td>13.7165</td>
<td>21.47477</td>
<td>1.063169</td>
<td>106.3167</td>
<td>2.324538</td>
<td></td>
</tr>
<tr>
<td>February</td>
<td>71.513</td>
<td>0.000</td>
<td>20.19883</td>
<td>13.7165</td>
<td>16.18825</td>
<td>1.168037</td>
<td>1.684002</td>
<td>2.017327</td>
<td></td>
</tr>
<tr>
<td>March</td>
<td>55.462</td>
<td>0.000</td>
<td>10.56739</td>
<td>5.809</td>
<td>13.09608</td>
<td>1.2392918</td>
<td>116.80357</td>
<td>2.324538</td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>35.600</td>
<td>0.000</td>
<td>4.599875</td>
<td>1.8385</td>
<td>5.97144</td>
<td>1.3015884</td>
<td>130.15884</td>
<td>4.993279</td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>39.700</td>
<td>0.000</td>
<td>5.488033</td>
<td>2.9885</td>
<td>6.971824</td>
<td>1.2703569</td>
<td>127.03569</td>
<td>7.756285</td>
<td></td>
</tr>
<tr>
<td>June</td>
<td>322.000</td>
<td>0.000</td>
<td>85.6825</td>
<td>46.59625</td>
<td>73.62783</td>
<td>0.8852791</td>
<td>68.527914</td>
<td>0.9290847</td>
<td></td>
</tr>
<tr>
<td>July</td>
<td>741.637</td>
<td>78.042</td>
<td>336.453</td>
<td>227.2375</td>
<td>133.8596</td>
<td>0.3900993</td>
<td>39.009927</td>
<td>0.2548189</td>
<td></td>
</tr>
<tr>
<td>August</td>
<td>826.691</td>
<td>127.502</td>
<td>378.2375</td>
<td>262.4125</td>
<td>139.6412</td>
<td>0.3642994</td>
<td>36.429938</td>
<td>0.0077043</td>
<td></td>
</tr>
<tr>
<td>September</td>
<td>642.500</td>
<td>3.779</td>
<td>174.127</td>
<td>65.809</td>
<td>104.612</td>
<td>0.5804554</td>
<td>104.612</td>
<td>2.552508</td>
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<tr>
<td>October</td>
<td>159.800</td>
<td>0.000</td>
<td>15.6205</td>
<td>5.9871824</td>
<td>6.971824</td>
<td>1.2703569</td>
<td>68.527914</td>
<td>0.9290847</td>
<td></td>
</tr>
<tr>
<td>November</td>
<td>118.428</td>
<td>0.000</td>
<td>14.53502</td>
<td>0.6835</td>
<td>26.37955</td>
<td>1.814896</td>
<td>181.4896</td>
<td>3.01148</td>
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<tr>
<td>December</td>
<td>75.593</td>
<td>0.000</td>
<td>5.809</td>
<td>2.5485</td>
<td>13.36146</td>
<td>1.5174252</td>
<td>151.74252</td>
<td>9.563946</td>
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<tr>
<td>Pri- Monsoon</td>
<td>106.000</td>
<td>0.000</td>
<td>17.4885</td>
<td>17.4885</td>
<td>20.81153</td>
<td>1.88153</td>
<td>180.224</td>
<td>7.756285</td>
<td></td>
</tr>
<tr>
<td>Monsoon</td>
<td>1350.400</td>
<td>345.414</td>
<td>839.8988</td>
<td>839.8985</td>
<td>839.8985</td>
<td>0.2640862</td>
<td>345.414</td>
<td>5.953946</td>
<td></td>
</tr>
<tr>
<td>Post Monsoon</td>
<td>685.200</td>
<td>9.455</td>
<td>221.6706</td>
<td>213.176</td>
<td>221.6706</td>
<td>0.7260603</td>
<td>221.6706</td>
<td>-0.493885</td>
<td></td>
</tr>
<tr>
<td>Winter</td>
<td>168.300</td>
<td>0.000</td>
<td>17.4885</td>
<td>17.4885</td>
<td>20.81153</td>
<td>1.88153</td>
<td>180.224</td>
<td>7.756285</td>
<td></td>
</tr>
<tr>
<td>Annual</td>
<td>1682.096</td>
<td>575.2</td>
<td>1119.088</td>
<td>1119.088</td>
<td>259.743</td>
<td>0.2321023</td>
<td>1119.088</td>
<td>-0.8283381</td>
<td></td>
</tr>
</tbody>
</table>

The average seasonal rainfall (Years, 1950-2020) displaying one significant increasing trend pre-monsoon to Monsoon and one significant decreasing trend monsoon to winter are showing (Fig. 3) of the district. The pre-monsoon seasonal rainfall and their rainfall deviation trend both are showing increasing trends (Fig. 4 and Fig. 5).

Figure 2: Average monthly Rainfall of the Chhatarpur District, Central India.

The monsoon seasonal rainfall and their rainfall deviation trend both are decreasing trends (Fig. 6 and Fig. 7). The post-monsoon seasonal rainfall and their rainfall deviation trend both are decreasing trends (Fig. 8 and Fig. 9). The winter seasonal rainfall and their rainfall deviation trend both are decreasing trends (Fig. 10 and Fig. 11). The yearly rainfall and trend detection of the annual rainfall of the study place suggests that in the year 1950 to 2020 (Fig. 12 and Fig. 13).
The annual rainfall and their deviation trend both are displaying notably decreasing trend to the adversely affect rainfall environment and those changes are not favorable agriculture development of the area. The linear regression equations are given all most figures followed by seasonal and yearly rainfall time series. Hence, this year's rainfall data was above the average line which years were favorable for groundwater recharge of the area and these years' rainfall data found below the line of average were not favorable for groundwater recharge of the area.

The rainfall pattern plays a vital role in the recharge phenomena of groundwater resources. The evaluation of rainfall records of the Chhatarpur district indicates a fairly good range of variation pointing out the positive as well as negative trends that affect the recharge of the groundwater reservoir.

Figure 3: Average Seasonal rainfall of the Chhatarpur District, Central India.

Figure 4: Pre-monsoon rainfall trend of the Chhatarpur District, Central India.
Figure 5: Pre-monsoon rainfall deviation trend of the Chhatarpur District, Central India.

Figure 6: Monsoon rainfall trend of the Chhatarpur District, Central India.

Figure 7: Monsoon rainfall deviation trend of the Chhatarpur District, Central India.
Figure 8: Post-monsoon rainfall trend of the Chhatarpur District, Central India.

Figure 9: Post-monsoon rainfall deviation trend of the Chhatarpur District, Central India.

Figure 10: Winter rainfall trend of the Chhatarpur District, Central India.
Figure 11: Winter rainfall deviation trend of the Chhatarpur District, Central India.

Figure 12: Average annual rainfall trend of the Chhatarpur District, Central India.

Figure 13: Average annual rainfall deviation trend of the Chhatarpur District, Central India.
The present trend of overexploitation and scanty rainfall is causing depletion in the groundwater levels. Todd (1980) remarked that "Groundwater level may show seasonal variation due to rainfall. Drought extending for numerous years, contribute to declining water level". The depletion of groundwater levels may be recognized by seasonal variations in the static groundwater levels, which are controlled by the infiltration of rainwater. This process is dependent on the intensity and amount of rainfall.

The recharge phenomena of groundwater can be improved by the augmentation of rainwater. It is recommended that the implementation of appropriate measures may provide a remedy in minimizing the rapidly developing situation of groundwater level depletion resulting in the drought conditions in the Chhatarpur district.

CONCLUSION

The detection of trends and magnitude of variations due to environmental changes in hydrometeorological data particularly rainfall/precipitation and streamflow is essential for the assessment of impacts of environmental variability and change on the groundwater resources of the vicinity. The present study is based on the analysis of the trend in rainfall data using statistical and linear regression) methods on the seasonal and annual time scale for the Chhatarpur district Madhya Pradesh, India. The analysis shows these years' rainfall data above the average line which years were favorable for groundwater recharge of the area and those years rainfall data found below the line of average were not favorable for groundwater recharge of the area and also indicate for the environmental impact of rainfall of the area. The statistical measurement gives a precise value of rainfall data and it reveals good variation values indicating significant fluctuation and trend. The environmental impacts of rainfall variation on the groundwater system have been discussed and observed that rainfall directly controls the recharge of the groundwater reservoir of the district.

Acknowledgments

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