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Frequency and Trend Analysis of Rainfall Data of Guwahati, Assam, India

Avrodeep Paul[1], Anish Kumar Ekka[1],

Hardik Dwivedi[1], Priya Kumari[1], Rishikesh Ratan[1], Vikram Singh[1]

[1]Vaugh Institute of Agricultural Engineering and Technology, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, U.P., India

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***Corresponding author:** Vikram Singh

Email: vikram.singhd@shuats.edu.in

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Abstract

In this study, 35 years of daily rainfall data (1979–2013) from the Global Weather Data for SWAT were used to analyse rainfall characteristics for the selected station. The dataset was processed to determine the annual maximum and minimum rainfall, monthly rainfall variations, and key statistical indicators including standard deviation and coefficient of variation (CV). The analysis revealed that annual maximum rainfall over the period ranged from as low as 0.04 mm to as high as 1609.38 mm, indicating substantial inter-annual variability. Monthly rainfall assessment showed that October consistently received lower rainfall compared to other monsoon months throughout the period of record, whereas July and August exhibited the highest rainfall across all years analysed. In terms of variability, the lowest coefficient of variation was observed during July (47.34%), followed by June (50.03%), while November recorded the highest CV (140.63%), indicating large fluctuations during the post-monsoon season. Frequency analysis conducted using the Normal distribution and Log-Pearson Type III distribution showed that the maximum rainfall values at a 20% probability of exceedance (corresponding to a 5-year return period) occurred during the peak monsoon months of July to October.

Keywords: Frequency analysis: Rainfall variation: Rainfall: Probability distribution: California formula.

Introduction

Agriculture, food security, and the economy of India directly or indirectly depend on the timely availability of adequate rainfall and favorable climatic conditions. The Indian economy has traditionally been agrarian, with nearly 55–60% of the population engaged in agriculture and about 80% of agricultural income derived from rainfed farming (Planning Commission, 2014; FAO, 2021). However, rainfall in India exhibits significant spatial and temporal variability—some regions experience recurrent floods while others suffer from persistent droughts. Most of the annual rainfall occurs under the influence of the southwest monsoon between June and September, characterized by high variability, unequal seasonal and geographical distribution, and frequent departures from the long-term average (IMD, 2020; Roxy et al., 2017). The most common variables applied in climate change studies are surface observations of precipitation, solar radiation, humidity, wind speed; temperature and snow cover.

Efficient utilization of rainfall is crucial for improving agricultural productivity and sustaining groundwater resources. Although rainfall is erratic and varies with time and space, probability analysis offers a scientific approach for estimating design rainfall corresponding to different return periods. Statistical methods using probability distribution functions such as Normal, Log-Normal, Gamma, or Gumbel distributions—are commonly applied to predict future rainfall magnitudes based on long-term records (Subramanya, 2013; Bhakar et al., 2008). These estimates are essential for the safe and economic planning and design of hydraulic structures such as small dams, culverts, spillways, check dams, and drainage works within watersheds (Chow et al., 1988). Extreme variations in rainfall and their frequency significantly influence runoff, groundwater recharge, streamflow, and soil moisture dynamics, which in turn affect crop productivity and water availability (Mall et al., 2006). Therefore, rainfall trend analysis at spatial and temporal scales has gained importance in recent decades, particularly in the context of climate change impacts on regional hydrology (IPCC, 2021). The present study focuses on Guwahati, Assam, situated at an elevation of approximately 56 m above mean sea level with a humid subtropical climate. The city frequently experiences flooding and waterlogging during intense monsoon events, severely affecting agriculture and infrastructure (Das, 2019). Rapid urbanization has also increased the occurrence of landslides and surface runoff during heavy rainfall events. While natural disasters cannot be avoided, long-term rainfall data and trend analyses provide valuable insights for irrigation scheduling, drainage design, reservoir operation, and water resources planning.

Considering these aspects, the present study analyzes 35 years (1979–2013) of rainfall data from a single station in Guwahati, Assam, to assess rainfall variability and identify long-term trends for sustainable water resource and agricultural management in the region. Jain (2013) developed a hydrological model for the Northeast Region (NER) of India, covering an area of approximately 26 million km², to analyze rainfall characteristics and variability. The Third IPCC emphasizes that climate change is likely to intensify the global hydrological cycle, influencing both surface and groundwater availability. Changes in the intensity of precipitation have been projected to impact regional hydrology. Surplus rainfall may alter the magnitude and timing of runoff, while rainfall deficits could lead to drought-like conditions.

Interpreting historical rainfall data to determine the likelihood of future occurrences is one of hydrology's biggest problems. The features of the available rainfall data for a particular location play a major role in the selection of an acceptable probability distribution model. In order to determine the best-fit probability distributions, Sharma and Singh (2010) examined 37 years of daily rainfall data from GB Pant University of Agriculture and Technology, Pantnagar. According to their research, the Generalized Extreme Value (GEV) distribution worked best for weekly rainfall intervals, while the Log-Normal and Gamma distributions offered the greatest fit for annual and monsoon season rainfall, respectively.

Similar to this, Singh et al. (2012) used four well-known probability distributions—Normal, Log-Normal, Log-Pearson Type III, and Gumbel—to analyze annual one-day maximum rainfall data for Jhalarapatan, Rajasthan, and used the Chi-square method to assess goodness of fit. The best distribution for forecasting annual one-day maximum rainfall over various return times was found to be the Log-Pearson Type III distribution. In a different study, Rajendran and Venkatasubramani (2017) used Weibull's approach to evaluate the frequency and distribution of rainfall in ten years (2004–2013) of daily rainfall data for the Dharmapuri district. According to their findings, an annual rainfall of 757.55 mm might be anticipated once every 11 years (probability 9.1%), while September and October were the most predictable months for rainfall occurrence, with monthly dependable rainfall ($p > 68\%$). The region is dominated by rain-fed agriculture, and any sudden change in climate variables hinders the food grain production chain. In particular, rainfall patterns pose a major danger to the region's food and environmental security. Thus, the California Formula, Moving Average, Recurrence approach, and statistical approach were used in the current study to predict the rainfall trend in Guwahati.

Materials and Methods

Description of Study Area

Guwahati, which is located between latitudes 26°10′20°N and longitudes 91°44′45°E, is the research area. The average annual rainfall in Guwahati is 1722 mm. Alluvial, piedmont, hill, and lateritic soils are the four primary categories into which Assamese soils can be generically classified. The Brahmaputra and Barak plain are home to a large number of extremely productive alluvial soils. The state's most common land use category is agriculture. It makes up roughly 54% of the state's total land area. The state's economy greatly benefits from agricultural expansion, but the ecological effects of shifting land use patterns must be taken into account. Guwahati is not quite a tropical savanna due to its humid subtropical climate.

Data Collection and Analysis

Precipitation data for the period of 1979 to were collected from the online portal (https://globalweather.tamu.edu/). The data was further processed to find out its maximum and minimum annual rainfall along with average rainfall.

Trend variability and mean rainfall patterns were analyzed using daily rainfall data. Each station's monthly rainfall series was calculated from the daily rainfall data, and monthly district rainfall series were then created by taking into account the arithmetic average of all the district's station rainfall values. Area weighted rainfall values for each district in the state were used to calculate the state's monthly rainfall series. The mean, standard deviation, and coefficient of variation were computed to estimate rainfall variation.

Rainfall Trend Analysis

Trend analysis was statistically examined which shows a fluctuating graph. Then trend is also calculated and computed by the Moving average. The trend of rainfall data was analyzed in annual and monthly time series. A straightforward technique for minimizing volatility and generating trend values with a reasonable level of accuracy is the moving average method. The moving averages are a sequence of succeeding averages that are obtained from a sequence of values by averaging sets of successive series data. When using the moving average method to identify a trend, the average value for a number of years (months or weeks) is obtained, and this average is used as the normal or trend value for the unit of time falling in the middle of the period covered in the calculation of the period. For example, the values of $1st$, $2nd$, $3rd$, 4 and 5 years are added up, and the quotient is placed against the $3rd$ year; next, the values of $2nd$, $3rd$, $4th$, 5th and 6th year, and so on (Yogish, 2007).

Probability Distribution

A key idea in statistics is probability distributions. They are applied in both theoretical and practical contexts. A list of every potential result of a random variable and the associated probability values is called a probability distribution. Interpreting a historical record of rainfall events in terms of future probabilities of occurrences is one of the major issues in hydrology. Hydrologic frequency analysis has been found to benefit from a variety of probability distributions.

California formula was used in this study which is given below:

$$P = M/n \quad (1)$$

where,

P = probability of occurrence

M= position of that rainfall

n= total number of years

Recurrence interval of given storm is the time interval during which the given storm is likely to be equal or exceeded. For design purposes, choosing the probability of exceedance (PX) or return period (TX) depends on the project's lifetime, the risk one wishes to take, and the potential harm that excess or insufficient rainfall could produce. FAO (Smith, 1992) prescribes objective criteria for classifying weather as dry, normal, or humid. A period is considered dry if the expected rainfall at that probability level is exceeded more than 80% of the time; normal when the rainfall amount corresponds to the 50% probability of exceedance; and humid when the rainfall amount is exceeded less than 20% of the time. These thresholds help in categorizing climatic conditions and assessing rainfall variability for agricultural water-management planning (Smith, 1992).

The rainfall corresponding to different probabilities of exceedance were obtained from the probability plot by fitting a straight line through the spots. The coefficient of determination (R2) was used to assess the goodness of fit. The fitted line (R2 = 0.98) was used to estimate the annual total rainfall XP for REVA for specific probabilities of exceedance. The data in a probability plot will precisely fall on the normal line when annual rainfall is fully dispersed. Rainfall can be estimated for specific probabilities or return periods using the normal distribution's average and standard deviation, which fully characterize the distribution:

$$X_p = X + k.s$$

where X is the sample mean, s is the standard deviation, k is a frequency factor, and X_pis the rainfall depth with a particular probability of exceedance. Depending on the chosen likelihood of exceedance, the frequency factor's sign and amplitude change. Normal distribution and Log Pearson III distribution were used.

Results and Discussion

The statistical analysis of rainfall data of selected region was done using central tendency parameters. Statistical analysis of rainfall data illustrated that minimum mean monthly rainfall (mm) occurred in the month of November (0.09 mm) for all these 23-year data followed by April (3.9 mm) and October (5.42 mm), while maximum mean monthly rainfall (mm) occurred in the month of August (1609.4 mm). Average annual rainfall of Guwahati district is 226.726 mm with maximum average annual 636.3 mm and minimum average annual amount of rainfall 9.572 mm. The first step in designing engineering projects dealing with flood control, gully control etc. is to determine the probability of occurrence of a

particular extreme rainfall. Frequency analysis deals with the chance of occurrence of an event over a specified period of time. The rainfall and respective return period for June month from 1979 to 2013 was analyzed. The maximum rainfall for the June month is 1063 mm with return period of 35 years. While the minimum rainfall is 49.29 mm and its return period is 1 year. The maximum rainfall for the July month is 1511.61 mm and its return period is 35 years. While the minimum rainfall is 128.62 mm and its return period is 1 year. Similarly, for August, the maximum rainfall was found to be as 1609.38 mm with return period of 35 years. The maximum rainfall for the September month is 1145.27 mm and its return period is 35 years. While the minimum rainfall is 66.21 mm and its return period is 1 year.

Probability Distribution of Rainfall

For the return period of 18 years with a 5% probability, the maximum monthly rainfall was predicted to be 997.45 mm; for the return periods of 10, 20, 25, 50, and 100 years, the rainfall was predicted to be 902.09, 715.50, 689.33, 506.68, and 75.79 mm, respectively (Fig. 1). The regression model's coefficient of determination (R^2) for the maximum monthly rainfall and return period was calculated to be 0.9125, indicating a strong correlation.

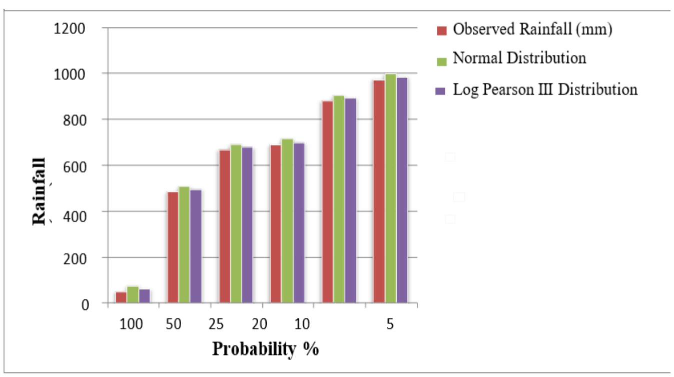

Fig. 1 Comparison of observed and predicted rainfall for various distribution levels for the month June

For the return period of 18 years with a 5% chance, the highest monthly rainfall was predicted to be 1355.45 mm; for the return periods of 10, 20, 25, 50, and 100 years, the rainfall was predicted to be 998.09, 904.50, 841.33, 588.68, and 136.33 mm, respectively (Fig. 2). The highest anticipated maximum monthly rainfall in the area under study was 588.68 mm throughout the return period of two years, which is becoming close to its average rainfall of 636.3 mm.

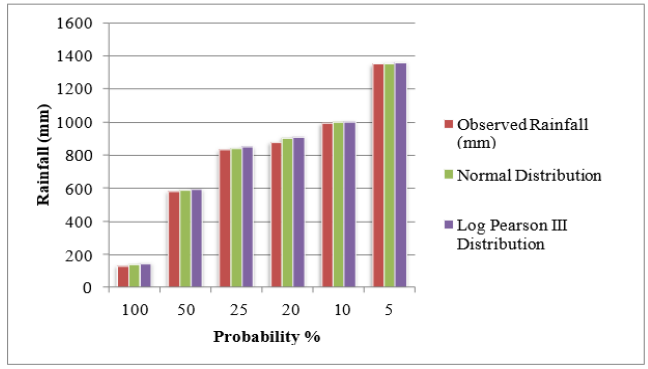

Fig. 2 Comparison of observed and predicted rainfall for various distribution levels for the month July

In August, the maximum monthly rainfall for the 18-year return period with a 5% probability was calculated to be 1381.57 mm, while the rainfall for the 10, 20, 25, 50, and 100-year return periods was predicted to be 1014.53, 794.22, 741.5, 611.3, and 60.02 mm, respectively (Fig. 3). The highest anticipated maximum monthly rainfall in the area under study was 611.30 mm throughout the return period of two years, which is becoming close to its average rainfall of 616.74 mm. Y=390.59ln(x)+246.26 is the formula for the logarithmic transformed regression model, which was created using the observed maximum monthly rainfall magnitude (Y) as a function of the return period (X). The coefficient of determination (R^2) for the regression model relating maximum monthly rainfall with return period was estimated to be 0.9617 which showed that there is a very close relationship.

Figure 4 displays the results of the normal distribution analysis for the month of September. It indicates that the maximum monthly rainfall for the 18-year return period with a 5% probability was 807.49 mm, while the rainfall for the return periods of 10, 20, 25, 50, and 100 years was 754.76, 649.21, 598.65, 328.74, and 54.53 mm, respectively.

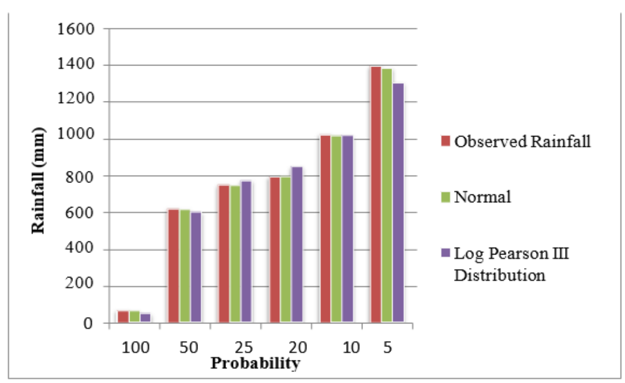

Fig. 3 Comparison of observed and predicted rainfall for distribution levels for August

The highest anticipated maximum monthly rainfall in the area under study was 143 mm throughout the return period of two years, which is becoming close to its average rainfall of 159.20 mm. The observed maximum monthly rainfall magnitude (Y) as a function of the return period (X) was used to create the logarithmic transformed regression model, which has the following formula: $y = 115.42\ln(x)+52.717$. The regression model's coefficient of determination (R2) for the maximum monthly rainfall and return period was calculated to be 0.8968, indicating a strong correlation (Fig. 5).

For the entire period, it was noted that October had less rainfall each month than the other months. For the duration of the era, July and August had higher monthly rainfall than the other months.

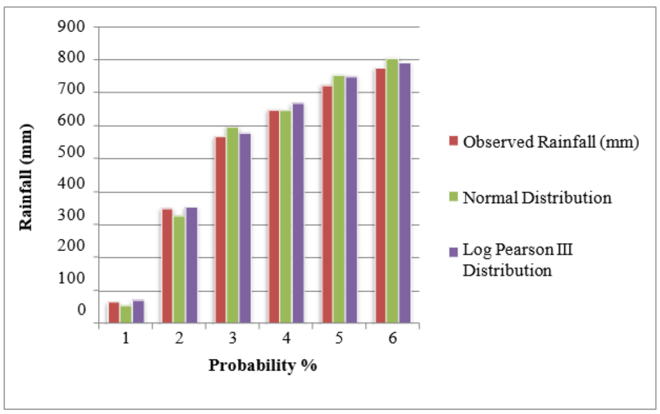

Fig. 4 Comparison of observed and predicted rainfall for various distribution levels for the month September

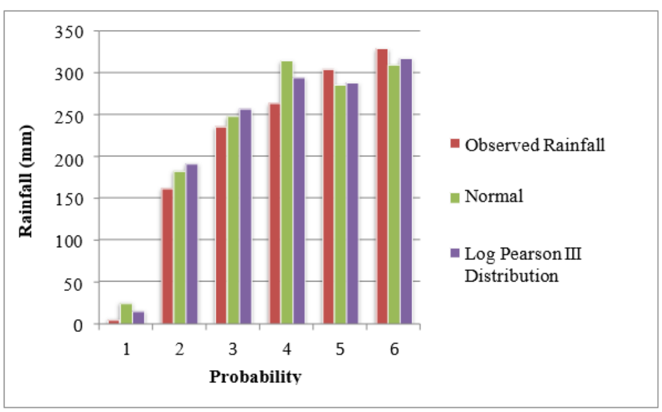

Fig. 5 Comparison of observed and predicted rainfall for various distribution levels for the month October

Conclusions

This study analyses rainfall frequency and trends for Guwahati District using daily data aggregated to monthly and annual totals. Statistical descriptors (mean, standard deviation, coefficient of variation) were computed, frequency analysis was carried out with the Normal distribution and the Log-Pearson Type III distribution, and interannual trends were examined using a 5-year moving average. Monsoon months dominate the regime: June, July, August and September contribute the highest rainfall, totaling 1062.99 mm, 1511.61 mm, 1609.38 mm and 1145.27 mm, respectively. Intra-annual variability is lowest in July (CV ≈ 47.34%) followed by June (CV ≈ 50.03%), while November shows the highest variability (CV ≈ 140.63%). Frequency curves indicate increasing design rainfall with return period; within the range assessed, the largest design magnitude corresponds to a 35-year return period. Trend diagnostics show increasing rainfall in June, July, August, September and October over the analysis period.

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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