Inter-Annual and Spatial Rainfall Analysis for Environmental Restoration in Barak Valley of Assam

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Abstract: **Among the climatic elements the rainfall is the first index, ever thought of by farmers and climatic analyzers as it is the most important single factor which determines the cropping pattern of an area in general and the type of crop to be cultivated and its success or failure in particular. In the study area, Barak Valley of Assam (Cachar, Karimganj and Hailakandi), the rainfall is concentrated in a short period during rainy months interspersed with intra-seasonal dry spells. These locations are severely affected by greater inter-annual rainfall variability causing degradation of natural resources in the crop production systems. Therefore, inter annual (month, annual and seasonal) and spatial (station, districts and valley) rainfall analysis has been carried out to presents the rainfall characteristics for environmental restoration in Barak Valley. The average annual rainfall received by the districts Cachar, Karimganj and Hailakandi are 3337.99mm, 2967.03mm, 3321.92mm, respectively. The coefficient of variation of rainfall of Cachar, Karimganj and Hailakandi districts are 30.95, 18.31, 76.08, percent respectively. The average rainfall received by the districts Cachar, Karimganj and Hailakandi during the monsoon season (June-September) is 2208.87, 1967.44and 1182.98mm, respectively. It was found that the mean annual rainfall in Barak valley is 2954.87mm with a standard deviation of 1017.40mm and coefficient of variation of 34.43%. However, average rainfall during the summer, monsoon and winter season was recorded 823.15, 1927.24 and 204.48mm, respectively. The average contribution of mean annual rainfall in Summer (March to May), monsoon season (June-September) and Rabi or Winter (October to February) are found 28, 65, and 7%, respectively. The expected occurrence of rainfall at different probability levels during each season of the three districts were also found so high. Therefore, there is urgent need of special attention for controlling flood, soil erosion with the hydrologic structure design sustainable agricultural planning.**

1. INTRODUCTION

The hydrological behavior of a catchment is a very complex phenomenon which is controlled by a large number of climatic and physiographic factors that vary in time and space. Catchment hydrological models are widely used in climate change impact studies. Analysis of climatic and physiographic data of a particular catchment shall provide the accurate volume of surface runoff, which will be utilize for the designing of water storage, calculation of soil erosion losses etc.

The Barak Valley is located in the southern part of Assam, North East India, and comprises of three districts, (viz., Cachar, Hailakandi and Karimganj) which covers a geographical area of 6922 km^2. Barak Valley experiences humid climate with an annual rainfall ranging between 2500-3300 mm. About 80-85 % of this rainfall occurs during the months of April/May-September/October. The seasonal pattern of rainfall and its variations from year to year govern the flood pulse and determine the extent and duration of inundation of the flood plains by the overflowing river waters. The Barak valley, consisting of highly flood prone area have been ravaged by three major floods—in 1986, followed by the one in 1991, and more recently in 2004. Therefore, a detailed knowledge of rainfall regime is an important prerequisite for controlling flood, soil erosion with the hydrologic structure design sustainable agricultural planning.

Precipitation data is the most important input in hydrological models. In many river basins, records collected in long periods of time contain gaps. This could be due to different circumstances, for instance: absence of observers, problems with the measuring device, loss of records, or maybe the lack of funds to continue the measurements [6]. It is recognized as an essential component of most erosion and catchment water balance models [4] and is a critical factor controlling rill erosion and gully development [7]. Many studies have reported the advantages of working out weekly/monthly/seasonally rainfall probabilities for a station or for an agro-climatic region [1, 2, 3, 5]. However, very few studies have been carried for the North Eastern States of India. So, there is requirement for inter annual (month, annual and seasonal) and spatial (station, districts and valley) rainfall analysis to presents the rainfall characteristics for environmental restoration in Barak *Valley.*

2. MATERIALS AND METHODS

2.1 Study Area

The Barak Valley is situated in the southern part of the Indian state of Assam. The geographical position of Barak valley is N 24^{0}43'34.1"-E 93^o 4' 21.7" and with altitude of 31.40 m from MSL. Barak Valley is one of the six agro-climatic zone of Assam. The zone has a geographical area of 6941.2 sq. km (8.84% of state) with three districts, viz. Cachar, Hailakandi and Karimganj.

Soils of the zone vary from sandy type to clay soil mostly suitable for field crops including horticultural crops. The soil pH ranges from 4.6 to 5.7. The climate of Assam is characterized by its extreme humidity. The most distinguishing feature of the climate of Assam is the copious rainfall between March and May at a time. The neighborhood of Cherrapunji and Mawsynram are known to receive the highest rainfall in the whole world. Barak valley receives an average annual rainfall of 3000 mm. Climate of the valley is generally hot and humid with temperature ranges from 10^{o} C to 15^{o}C during winter season and 35^{o}C to 40^{o}C during hot summer season with the relative humidity of 92 to 98 per cent.

Barak Valley zone has 38.58 per cent of total geographical area under forest, 33.08 percent as net sown area and 8.48 per cent as area sown more than once. About 5.47 percent of land is used for plantation crops, miscellaneous trees and other.

Agriculture is the main occupation of the people. Rice is the staple diet of the people and cultivation of rice is the main occupation of those engaged in agriculture. Different pulses, jute, tea and fruit cultivation are the other agricultural crops. Sugarcane, potatoes, cotton, oil seeds, coconut and arecanut cultivation is also practiced on a substantial scale apart from the horticulture. Apart from crops, the zone is suitable for fish and animals rearing throughout the year.

2.2 Spatial and inter annual variability of rainfall

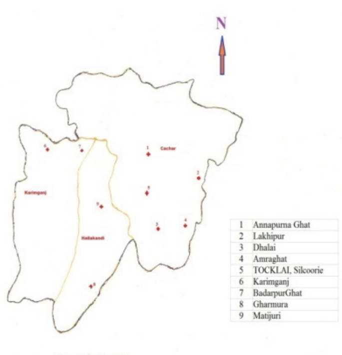


Figure 1. Location of raingauge stations in Barak Valley

The study area is covered by nine raingauge stations installed by the Central Water Commission, India, District Agriculture Office, Cachar, TOCKLAI, Silcoorie. These raingauge stations in the Barak valley are Annapurna Ghat, Lakhipur, Dhalai,Amraghat, Silcoorie located in Cachar district; Karimganj and BadarpurGhat in Karimganj district; and Gharmura and Matijuri located in Hailakandi district.The base map of Barak Valley has been prepared by tracing method and presented the location of all the raingauge station in Figure 1.

The rainfall data are collected on daily basis for nine numbers of raingauge stations in the Barak valley. The spatial variability of rainfall considers the pattern of rainfall in different stations, and districts of the valley. And the inter-annual variability of rainfall considers the long term variation in monthly, seasonally (Summer, Kharif and Rabi) and yearly basis.

2.3 Statistical Analysis

Daily rainfall data were collected for the rainguage stations of Barak Valley for the past 10 years. The daily rainfall data were aggregated to monthly, seasonal and annual totals. The statistical parameters such as mean, standard deviation, variability and expected rainfall at different probability levels were carried out using MS Excel. The details of estimation are explained in the next sections.

2.3.1. Standard deviation

Standard deviation, σ (mm) is calculated using the following formula:

$$\sigma = \sqrt{\frac{\sum_{1}^{m}(\mathrm{Pi}-\bar{\mathrm{P}})^2}{\mathrm{m}-1}} \qquad (1)$$

Where, m is the number of raingauge stations, $\bar{P}$ is the mean average annual rainfall values and Pi is the individual rainfall values.

2.3.2. Rainfall variability

"Variability defined as the deviation from mean" or "ratio of the standard deviation to the mean rainfall". In the present study the variability of rainfall for both spatial (station, district and valley) and temporal (seasonal and annual) variability has been analyzed. Co-efficient of variation, Cv (%) is computed using the formula as follows:

$$C_v = \frac{\sigma \times 100}{\bar{\mathrm{P}}} \qquad (2)$$

Where, σ is the standard deviation and $\bar{P}$ is the mean average annual rainfall values.

2.3.3. Probability analysis

The different probability levels were taken up to find out the amount of rainfall anticipated for various categories of cumulative rainfall (monthly, seasonal and annual). Probability analysis was carried out using the SMADA **(Stormwater Management and Design Aid, version 6.0)** software for predicting the probability of amount of rainfall at different probability levels.

3. RESULTS AND DISCUSSION

In order to attain a comprehensive picture of surface rainfall in the Barak Valley, the rainfall pattern, long term (2001-2011) daily rainfall were collected and analyzed from individual raingauge stations. In Barak valley, the rainfall records were collected from the nine raingauge stations. The stations wise, district wise and also for the whole valley, monthly, seasonal and annual analyses of rainfall were carried out in details. The details of the results obtained from the spatio-inter annual rainfall and variability, statistical and probability analysis have been presented in the following sections.

3.1 Station-wise inter-annual rainfall analysis

Inter annual analysis for the different stations of the valley were carried out for determining the trends of variation of total and average monthly, yearly and seasonal rainfall and subsequent rainfall for the year of study. The station-wise daily rainfall data of 11 years (2001 to 2011) were converted to monthly rainfall for the eleven years at each raingauge stations. The average mean monthly rainfall regimes are shown in Figure 2. It was observed that the average monthly rainfall gradually increasing from the January to June and decreasing trend is noticed from July to December. The high intensity trends is noticed in the month of June and July and these months received much more rainfall and then started

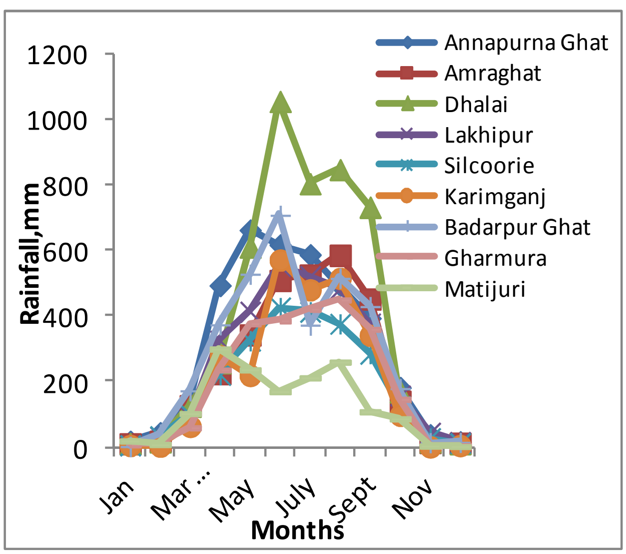


Figure 2. Station-wise variation of monthly rainfall in the Valley.

decreasing from the months of August and lowest of rainfall in the month of December-January. However, among all the nine stations, Dhalai recorded the highest value of rainfall i.e., 1054.85mm in the month of June and the lowest rainfall recorded at Karimganj which is 1.25 mm in the month of November.

3.2 Station-wise seasonal variation of rainfall

The station-wise average seasonal rainfall obtained are presented in Figure 3. During the summer the amount of rainfall gradually increases and however, the amount of rainfall occurrence in this season is largely due to convection effect. The highest amount of rainfall recorded at the Annapurna Ghat was 662.43mm in the month of May and seasonal average was1296.91mm. The lowest rainfall recorded at Gharmura was 59.17mm in March and its seasonal average was 672.1mm.

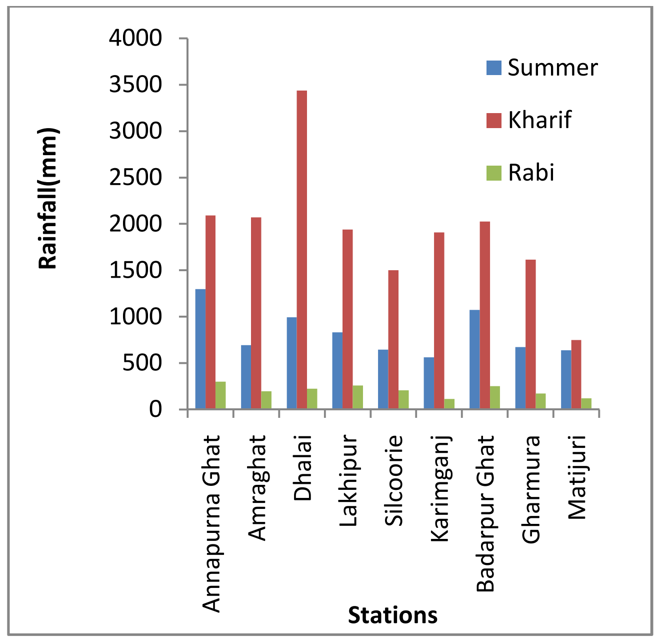


Figure 3. Station-wise variation of mean seasonal rainfall in the Barak Valley.

The kharif season is hot weather season where the amount of rainfall gradually increases, however during this season the valley experiences high rainfall and it is wettest among all the season. The maximum rainfall recorded at Dhalai was1054.85mm in the month of June and lowest recorded at Matijuri was108.1mm in the month of September.

Rabi season is characterized by cold weather season which receives least rainfall throughout the year. It is driest among the all seasons in which maximum rainfall recorded at Annapurna Ghat of 182.29mm in the month of October and lowest rainfall recorded at Karimganj of 1.25mm in the month of November.

3.3 Station-wise annual rainfall analysis

The station-wise annual rainfall variations for the eleven years are presented in Figure 4. Among the stations, the maximum and minimum rainfall was found 4656.13 mm and1509.03mm at the station Dholai and Matijuri, respectively.

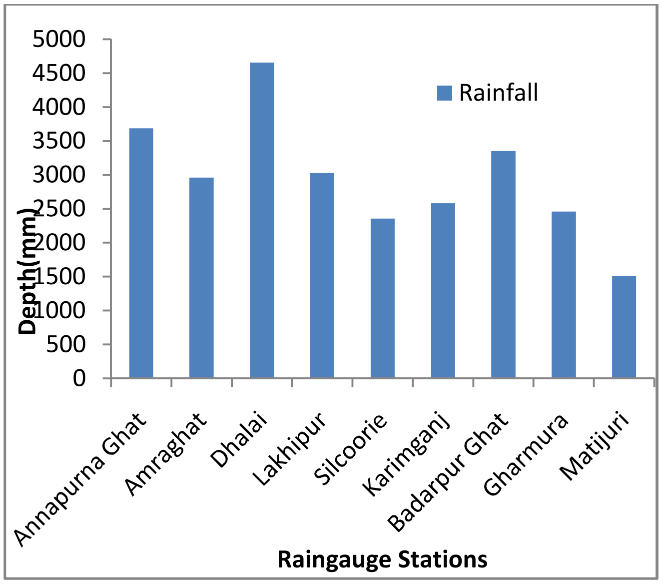


Figure 4. Station-wise annual variation of rainfall in Barak Valley.

The average annual rainfall of the station of Annapurna Ghat, Silchar was found to be 3689.26 mm. While analyzing the long term rainfall, the average annual rainfall for Lakhipur, Cachar was found to be 3028.04 mm. The long term mean annual rainfall of Dhalai, Cachar was found to be 4656.13 mm.

Amraghat climate is mildly sub-tropical with warm, dry summers from April to late May, a strong monsoon from June to September and cool, dry winters from late October to March. It experienced an average annual rainfall of 2962 mm.

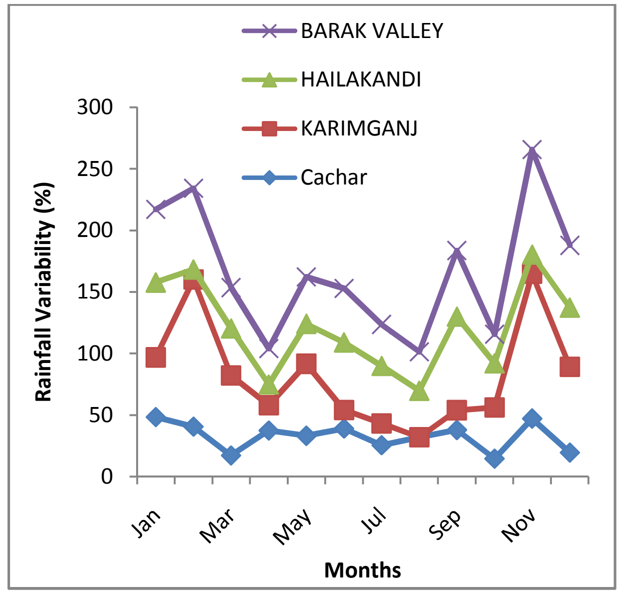
3.4 Inter annual rainfall variation in the Valley

The average monthly rainfall of 11 years (2001 to 2011) for nine raingauge station of three districts of Barak Valley inferred that the variation of rainfall were found in every month, and the intensity of rainfall gradually increasing from the January to June and decreasing trend is noticed from July to December. The highly intensity trends is noticed in the month of June and July and these months get highest rainfall which reaches its maximum peak and also it starts to decrease from the months of August and lowest of rainfall in the month of December-January.

The average annual rainfall has been worked out for the entire Barak Valley on the basis of nine rain gauge stations spread uniformly all over the valley for each year of the 11-year period from 2001 to 2011. The long term average annual rainfall of the valley was found to be 3208.98mm. The valley is characterized with unique aerial topography in quantum of rainfall due to the influence of three hills from three sides and its western plane of Bangladesh.

3.5 Spatio-temporal statistics of rainfall

District-wise average monthly, and seasonal and annual variability (%) of rainfall in the valley is shown in Figure 5.



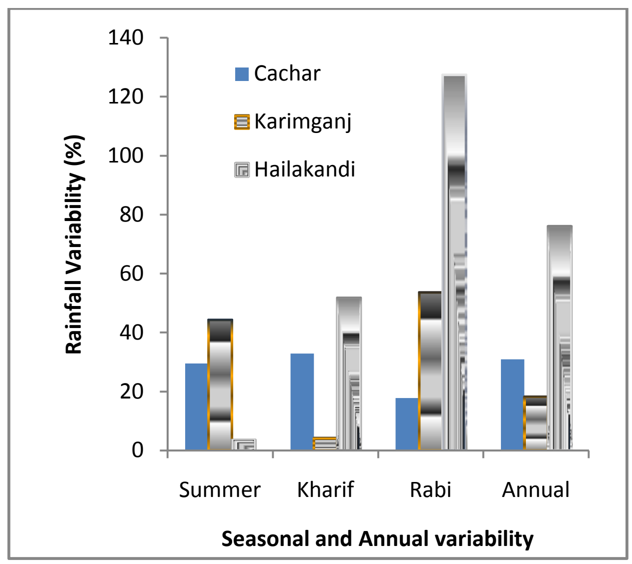


Figure 5. District-wise monthly, seasonal and annual variability of rainfall in the valley.

The mean annual rainfall of Cachar, Karimganj and Hailakandi are 3337.99mm, 2967.02mm and 3321.92mm with the annual co-efficient of variation (C_V) of 30.95, 18.31 and 76.08 percent, respectively. The result indicated that the annual rainfall variability is relatively greater at Cachar than Hailakandi and Karimganj.

Seasonal and annual statistical analyses of rainfall for three districts of Barak Valley are presented in Table 1.

Table 1. Seasonal statistical analysis of rainfall for the districts of Barak Valley.

Parameter	Summer	Kharif	Rabi	Annual
Cachar				
Mean (mm)	892.35	2208.87	236.77	3337.99
% Contribution	26.73	66.17	7.09	100.00
Standard Deviation (mm)	263.43	727.52	42.17	1033.11
CV (%)	29.52	32.94	17.81	30.95
Karimganj				
Mean (mm)	817.86	1967.44	181.73	2967.03
% Contribution	27.57	66.31	6.12	100.00
Standard Deviation (mm)	362.73	82.96	97.51	543.20
CV (%)	44.35	4.22	53.66	18.31
Hailakandi				
Mean (mm)	655.43	1182.98	1483.51	3321.92
% Contribution	19.73	35.61	44.66	100.00
Standard Deviation (mm)	23.58	612.70	1891.16	2527.44
CV (%)	3.60	51.79	127.48	76.08
Barak Valley				
Mean (mm)	823.15	1927.24	204.48	2954.87
% Contribution	27.86	65.22	6.92	100.00
Standard Deviation (mm)	247.48	707.73	62.19	1017.40
CV (%)	30.06	36.72	30.41	34.43

3.6 Expected inter-annual variation of rainfall

In general a Normal distribution is found to be best suitable distribution for rainy season and non-rainy season of monthly rainfall for three districts of Barak Valley. The expected rainfall at different probability levels at different districts and valley are presented in Fig. 6.

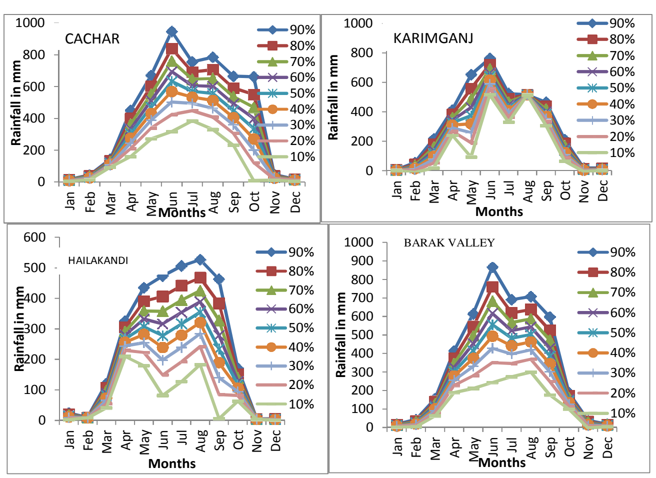


Figure 6. Expected monthly rainfall at different probability levels.

However, the expected seasonal and annual rainfall at different probability levels at different districts and valley are presented in Figure 7. It was found that there is considerable variation of monthly, seasonal and annual rainfall exists from year to year.

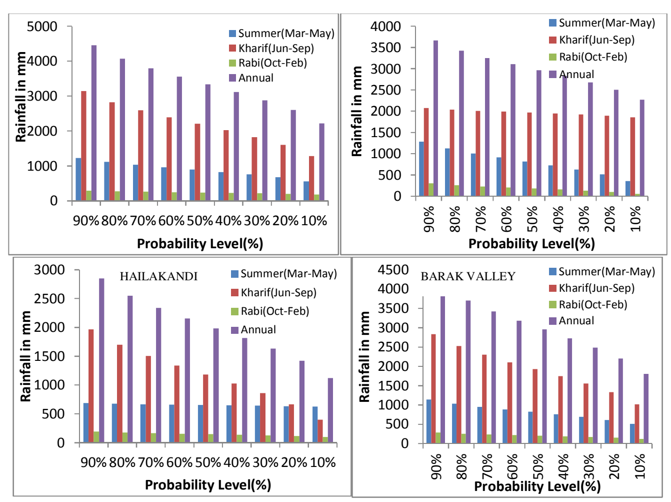


Figure 7. Expected seasonal and annual monthly rainfall at different probability levels.

4. CONCLUSIONS

Barak valley is surrounded by hills from all the three sides except its western plain boundary with Bangladesh and is consisting of highly flood prone area. Normal rainfall of region is 2954.87mm and the valley receives above normal rainfall of Assam state (2818 mm). The heavy rainfall experiences at Cachar district i.e., 3337.99mm followed by Hailakandi (3321.92 mm) and Karimganj (2967.03 mm). During kharif season there is excess rainfall which needs to be harvested and further the total amount runoff generated could be quantified for design of hydrological structure as well as restore environment from soil erosion, landslides and floods and supplemental irrigation for sustainable agriculture in the valley.

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