CHAPTER -IV

VARIATION OF ANNUAL PRECIPITATION

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4.1. INTRODUCTION

In the Terai Agro-Climate zone,above 75% of its annual rainfall occurs during June to September. The major share of the water need of this zone during the entire year has to be met with the rainfall that is received during these four monsoon months. Large variations in rainfall distribution have been observed from year to year in this zone. Deficient and excessive rainfall are the result of extremes of the rainfall distribution.Cooch Behar is one of the districts which receive this type of variations of rainfall.

Very few studies have been undertaken to statistically examine the interval between successive drought years and flood years. Here we assume that the drought and flood, in meteorology may be considered as the deficit and excess of average rainfall over the historic time series of rainfall. Studies of drought and flood from this angle would bring out more diagnostic feature which could be useful in deficit and excess rainfall in this district.

The main objectives of this chapter are given below :

i) To test the normality of time series of rainfall.

ii) To determine the probability distribution of time intervals between successive deficit rainfall years.

iii) To determine the probability distribution of time intervals between the successive excess rainfall years.

iv) To study the distribution of largest intervals of drought and flood years.

v) To test the homogeneity of the distribution of same event at different places.

4.2. INDEX :

More than 75% of the annual rainfall in Cooch Behar occurs in the deep monsoon season months i.e. from June to September. For the purpose of identifing the excess and deficit years of rainfall,we introduce an index, which is the standardized annual rainfall to the time series data. The index,in the present study,serves the requirements to identify and to quantify the behaviour of the rainfall character. This criterion of rainfall series would express a standardized normal variate and is defined as

$$\text{Index} = \frac{(X_i - \overline{X})}{\sigma}$$

where X_i is the rainfall in the ith year in terms of annual.

$\overline{X}$ is the mean of annual rainfall over the time frame of the study period.

σ is the standard deviation of annual rainfall over the study period.

A desirable condition for the proposed index is that it should be a dimensionless number with negative and positive sign. The index should take into account the year to year variability of rainfall in this district.

The index would be positive when the ith year rainfall is greater than the mean rainfall and these would be regarded as the excess year of rainfall. And when the index is negative, the year would be treated as deficient year or drought year.

The index and its intensity would also be considered to identify the intensity of drought and flood year.

The classification of drought and flood intensities are shown in Table 4.I.

4.3. YEAR OF DROUGHT AND FLOOD

The drought years along with their intensities and ranking order to index values are given in Tables 4.2(a) and 4.2(b) for the stations, Cooch Behar and Dinhata respectively. All the drought years for each of the above mentioned stations are arranged in ascending order of magnitude of the index to their intensities and are given the rank number. The value of the index for individual year is considered for the ranking. The years which experienced drought of moderate intensity, are 1901, 1930, 1933, 1939, 1942, 1947, 1957, 1972, 1979 and 1980 at the Cooch Behar station where it is ascertained in the northern part of Cooch Behar district. In this area, 1930 appears to be the worst affected drought year. At the station Dinhata the moderate drought years are experienced in the years 1901, 1907, 1914, 1919, 1930, 1933, 1939, 1950, 1957, 1978 and 1980. 1978 experiences to be the worst drought affected year.

The occurrence of drought in two consecutive years is observed on eight occasions at Cooch Behar and four occasions at

Dinhata. These are 1903-4,1914-15,1922-23,1925-26,1936-37,1939-40, 1946-47 and 1972-73 at Cooch Behar and 1914-15,1929-30,1950-51, and 1970-71 at Dinhata.

The consecutive occurrence of drought in three years is observed two times at Cooch Behar viz. 1928-30 and 1952-54 while it appears at Dinhata in four times viz. 1917-19,1932-34,1945-47 and 1980-82.

Occurrence of drought in five and eight consecutive years is observed once each time respectively and these years are 1959-63 and 1975-82 at the Cooch Behar station. But at Dinhata,the occurrence of drought in four,five and six consecutive years appeared once each time respectively and the years are 1959-62,1936-40 and 1906-11.

The flood years along with their intensities and the ranking order of index values are given in Tables **4.3(a)** and **4.3(b)** for Cooch Behar and Dinhata stations respectivly.

The years which experienced flood of moderate intensity are 1902,1905,1906,1907,1910,1916 and 1974 at Cooch Behar and that at Dinhata are 1916,1927,1954,1956,1973,1977 and 1988. The severe flood years experienced at Cooch Behar are 1920 and 1988 while at Dinhata are 1969,1974,1984 and 1987. At the Cooch Behar station 1921 appeared to be the extreme flood affected year.

The occurrence of worst flood in two consecutive years is observed on three occasions at Dinhata and two occasions at Cooch Behar. These are 1927-28, 1973-74 and 1987-88 at Dinhata and 1910-11 and 1920-21 at Cooch Behar.

The consecutive three years of moderate flood years are observed once at each station,1920-22 at Dinhata and 1905-07 at Cooch Behar.

The annual rainfall series of Cooch Behar are illustrated in Figure 4.1 and that of Dinhata are given in Figure 4.2.

It is interesting to note that the ariel distance of two rain gauge stations is very small,about 15 K.M. but the intensity of rainfall differs from each other.

4.4. S T A T I S T I C A L   P R O P E R T I E S   O F   I N D E X

We wish to learn something of the naturally occurring variability of time-averaged mean by calculating the standard deviation of the time average means determined from different realizations. For these standard deviations to be truly representative of naturally occurring variability, time averaged means determined from one realization should be independent. Therefore,it is important that the assumption of the independence of yearly realization is to be reasonable one. Therefore,the index from the realization of annual rainfall is also considered as independent.

Before applying any statistical test to the index,it is necessary to ensure the homogeneity of the data. For this purpose this index series is divided into two parts,viz. 1901 to 1944 and 1945 to 1988. And Standard Normal test and Snedecor's F-test have been applied to establish the homogeneity of the whole series .The tests are applied to the index of annual rainfall data for the two raingauge stations in Cooch Behar district. Test of significance for difference of means and test of significance for difference of standard deviations are given herewith.

4.4.1. TEST OF SIGNIFICANCE FOR DIFFERENCE OF MEANS.

Let $\overline{X}_1$ be the mean of a sample of size n_1 with standard deviation S_1 and let $\overline{X}_2$ be the mean of a sample of size n_2 with standard deviation S_2, Thus, null hypothesis is that the means of the two sub-periods are equal. Under the null hypothesis the test statistic becomes

$$Z = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}} \sim N(0, 1)$$

The calculated values of mean and standard deviation are given in Table **4.4.** for both the rainfall series. The calculated values of Z for Cooch Behar and Dinhata are 1.37and 1.75 respectively.Calculated values of Z for both cases are less than the critical value i.e. 1.96 at 5% level of significance. The values of Z, then, are not significant. So, it is, as such, considered that the two sub-periods for each time series do not significantly differ from each other.

4.4.2. TEST OF SIGNIFICANCE FOR EQUALITY OF VARIANCES .

Suppose we want to test whether the two independent estimates of the variance are homogeneous or not.

Under the null hypothesis that the standard deviations of two subperiods are equal the statistic is given by

$$F = \frac{S_1^2}{S_2^2}$$

$$\text{if} \quad S_1^2 > S_2^2$$

The greater of the two variances is to be taken in the numerator. The calculated values of F-statistic for the two stations are also given in the same table. It is observed from Table **4.4.** that the F-Values are 1.38 and 1.20. The tabular value of F is 1.58 with the degrees of freedom 43 and 43 at the 5% level of significance. The calculated value of F is less than the tabular value of variance ratio at 5% level of significance with 43 and 43 degrees freedom. So,it is not significant,we cannot reject the null hypothesis that the standard deviations are equal for these two sub-periods. The results are the same for the two rainfall indices. Considering these results of the two tests i.e., the mean test and the standard deviation test,the homogeneity of the data can be ensured. So, the two index series of 88 years are taken to be homogeneous to the first and second half period.

4.4.3. NORMALITY TEST

Before studying the long term variations in the precipitation data each rainfall series is examined for its normality aspect. Though the assumption of the normal distribution of climatic time series may not be strictly true, for a large number of variables such an assumption is reasonable. However, we may apply a test statistic which is known as Geary's test. The test criterion depends on the ratio of the mean deviation to the standard deviation under the null hypothesis that a normal distribution is a valid model to the long term rainfall data.

The test statistic is

$$G = \frac{\Sigma(|X_i - \overline{X}|)/N}{\sqrt{\Sigma(X_i - \overline{X})^2/N}}$$

Where X_i = *observation of the series*

$i = 1,2,\ldots\ldots\ldots\ldots N$

$\overline{X}$ = mean of the series

N = Total number of observations

From the table of the G-statistic the critical values of the test for different number of observations can be shown and *the null hypothesis may be tested. The normality test is carried out to the two time series data i.e., the annual rainfall at the two raingauge stations at Cooch Behar and Dinhata.*

We have to begin with a hypothesis to be tested, namely, that a particular data set is correctly modeled by a specified distribution. If the G value is less than 0.80 as in the case of annual rainfall at Cooch Behar, the nature of the distribution is skewed and leptokurtic while if the value of G is greater than 0.80, the nature of distribution as in the case of annual rainfall at Dinhata is symmetric and platykurtic. But it may be assumed that approximately the nature of the distribution in the latter case is symmetric and mesokurtic.

So, it may be concluded that the rainfall time series of the two raingauge stations approximately follow the normal distribution.

Table **4.5.** gives the statistics of the two annual rainfall time series where the mean, the standard deviation, the mean deviation and the value of Geary test with their tabular values are shown. The normal rainfall at Cooch Behar and Dinhata are 3533 mm and 2895 mm respectively. The mean and the standard deviation at Cooch Behar are greater than those at Dinhata but in the case of the mean deviation it is reversed. The normality test is carried out to the two time series data of annual rainfall. We have for the annual rainfall data of Cooch Behar whose mean deviation and standard deviation are 525.2 and 710 respectively and the value of G = 0.74. And the values of the mean deviation, the standard deviation and G for Dinhata centre are 450.58, 560 and 0.81 respectively.

The total number of observations N = 88 here, the table value gives a lower and upper 2.5 percent critical values of G-test. These are approximately 0.74 and 0.85 respectively. So, our calculated values of G are within this acceptance region. Then we may come to the conclusion that the normal distribution is shown to be an acceptable model. Table **4.4.** gives the values of G and other relative statistics.

4.4.4. RANK CORRELATION TEST

Considering the magnitude of each index ranking have been placed for the sets of the flood year as well as the drought year sequence. Spearman rank correlation has been applied to all the sequences of droughts and floods. The time of occurrence of drought and flood spells may be considered as a variable. And another variable is the rank of the observed data which can be evaluated on the intensity of the index of drought and flood sequence. The Spearman rank correlation (r_s) is defined by

$$r_s = 1 - \frac{6\Sigma(R_i - \quad)^2}{n(n^2 - 1)}$$

Where R_i is the rank of the h event and n is the number of pairs of variables.

The rank correlation coefficient is nothing more than the product moment correlation coefficient with the rank values treated as numerical variable values in the correlation coefficient formula. The standard error of the rank correlation is obtained as $\frac{1}{\sqrt{n-1}}$.

The test statistic is defined as

$$Z = r_s \sqrt{n-1}$$

which is distributed as standard normal distribution.

We have the drought sequence for the two stations and the flood sequence for the two stations also. The Spearman rank correlation has been applied to both the sequences. The calculated rank correlation co-efficients are given in Table 4.6. with their standard errors. The calculated Z values and its hypothetical values are also given in that table.

The rank correlation coefficients of the drought sequence at Cooch Behar and of the flood sequence at Dinhata are very low and their standard errors are quite high in relation to their respective correlation coefficient. This shows that the rank correlation coefficient in above mentioned cases are statistically non-significant.We may come to the conclusion that the flood sequence of Dinhata and the drought sequence of Cooch Behar do not indicate any trend to the occurrence of flood at Dinhata and drought at Cooch Behar. Thus the drought at Cooch Behar and the flood at Dinhata have occurred randomly.

The rank correlation coefficient for the drought sequence of Dinhata is equal to its standard error subsequently the Z-value is one,so we may come to the conclusion as described in the above case. Thus the drought sequence does not indicate trend as it is also non-significant.

The rank correlation coefficient of the flood sequence at Cooch Behar is slightly greater than its standard error but the Z-value cannot give any significant evidence that we may come to any conclusion reversely.

The analyses of trend and homogeneity are carried out in this sub-section in using the Spearman rank correlation,Standard Normal-test and Snedecor's F-test. These analyses indicate that there is no significant change in rainfall amounts over Cooch Behar district during last 88 year.

The analyses are in agreement with Rao and Jagannathan (1963) who observed no significant change in rainfall over India during last 100 years.

4.5. INTERARRIVAL TIME OF DROUGHT AND FLOOD

The index has the dual purpose for assessing drought and flood years also with their varying intensity. Here,we introduce the flood as success event and the drought as failure event in the statistical point of view. On the basis of the value of the index,we have obtained the basic data of the drought sequence separated by drought free intervals of varying lengths. And applying the same method we would have the flood sequence separated by flood free intervals of varying length. Present sub-section of this study introduces some statistical techniques in the analysis of such time intervals. The equality of the mean and the variance is an important characteristic of the Poisson distribution. Whereas the negative binomial distribution provides an excellent model because the distribution has a variance larger than the mean. An interesting point is that the mean and the variance are measured from the origin zero,the mean alone is affected. But the variance remains unchanged. The distribution of interarrival times of drought or flood sequences, the zero class missing, is assumed to be meaningless when we consider to fit the probability distribution on the time interval between the successive occurrence of drought or flood sequences. Many research workers have used different statistical methods to study frequency distributions of drought occurrences in a fixed interval of time or in an interval of varying length with the omission of zero class. And the data have been fitted to the Poisson distribution. Here the mean value of the Poisson process has a significant role in determining the density function for successive occurrence of drought and flood sequences. In this process we consider the mean of the Poisson process as a constant or as a stochastic process.

Now,the parameter of a Poisson distribu tion is a random variable having gamma distribution then the process is a mixed Poisson process. Barn Droff-Neilson t 1.1969) *confirmed the result. But the problem arises when the behaviour of the parameter of Poisson process is unknown.*

In the sampling procedure,Kendall and Stuart (1977) suggested that the arbitrary assumptions about the distribution of the parameter of the Poisson process are of no use to fit the data on negative binomial distribution. Now we proceed on this angle of direction.

Let f(x : r,p) denote the probability that there are x failure years preceding the r-th success year in r + x trial. Now the last trial must be a success whose probability is p. In the remaining (x+r-1) trials (years) we must have (r-1) success whose probability is given by

$$\binom{x+r-1}{r-1} p^{r-1} q^{x}$$

where $q = 1-p$

Therefore ,by compound probability theorem

f(x:r,p) is the product of these two probabilities,i.e.

$$\binom{x+r-1}{r-1} p^{r-1} q^{x} p = \binom{x+r-1}{r-1} p^{r} q^{x}$$

Which is the required density function of negative binomial distribution.

4.5.1 ESTIMATION OF PARAMETERS OF NEGATIVE BINOMIAL DISTRIBUTION

The method of moments and the maximum likelihood method have been applied to estimate the parameters of this distribution. The estimators are unbiased also. The estimation of r is not so straight forward. However, the method of moments can be applied in an indirect fashion.

We have to estimate the parameters for the negative binomial distribution which are given by

$$\text{Mean} \quad (\mu) = \frac{rq}{p}$$

$$\text{Variance} \quad = \frac{rq}{p^2}$$

Thus, p, q and r have been calculated from the observed frequency distribution by using the estimates of the mean and the ariance of the distribution.

The recurrence relation for fitting the negative binomial distribution is given by

$$f(x+1) = \frac{r+x}{x+1} \quad f(x)$$

where $x = 0,1,2,\ldots\ldots\ldots\ldots$

and, $f(0) = p^r$

Subsequently, we get the probabilities of each class. The calculated probability of each class is multiplied by the total number of frequency. We get the expected frequencies of each class which are presented in Tables **4.7.**(a & b) for both drought and flood sequences of the stations.

4.5.2. GOODNESS OF FIT TEST

A very powerful test for testing the significance of the discrepancy between the theory and experiment is Chi-square test of goodness of fit.

If, O_i (i = 1,.......n) is a set of experimental frequencies and E_i (i = 1,.......n) is the corresponding set of theoretical frequencies, then Karl pearson's Chi-square given by

$$X^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i} \quad \text{where} \quad \sum_i O_i = \sum_i E_i$$

follows Chi-square distribution with (n-1) degrees of freedom.

Tables **4.2.(a & b)** show the years of drought or flood. A perusal of the occurrence of drought or flood years show that the sequence for both categories are rather random which have been tested earlier.

Following the procedure mentioned earlier we get the frequency distribution of interarrival times of drought years as well as interarrival times of flood years for both the raingauge stations.

The observed frequency distribution of drought intervals for Cooch Behar and Dinhata are shown in Tables **4.7.(a)**,and the observed frequency distribution of flood intervals for both the stations are given in Table **4.7(b)**. The observed frequency distribution of time intervals between the occurrence of successive droughts and floods are illustrated in Figures **4.3.(a)** and **4.4.(a)** for Coochbehar station and in Figures **4.3.(b)**, and **4.4.(b)** for Dinhata station.

The frequency distributions of time intervals between the occurrence of successive droughts and floods are of the nature of exponential. The observed data are fitted to the negative binomial distribution. The parameters of the distribution are estimated from the observed frequency distribution. The parameters for the interarrival times of drought years for both the stations are given in Table **4.7(a)**. And that for the interarrival times of flood years for both the stations are given in Table **4.7(b)**. Introducing the recurrence relation we get the expected value of the corresponding frequencies which are also given in these tables. The observed and expected frequencies are denoted by 'O' and 'E' in the tables. All the frequency distributions for the interarrival times of flood or drought years are fitted to the negative binomial distribution.

Chi-square goodness of fit test has been applied to test the validity of the negative binomial model. The observed and expected frequencies are given in Table **4.7(a)** for the interarrival times of droughts and in Table **4.7(b)** for the interarrival times of floods at both the stations. After applying the chi-square goodness of fit test to the expected and observed frequencies,we get the calculated value of chi-square. These values are also given in the tables. Tables **4.7(a & b)** also show the critical values with suitable degrees of freedom.

The computed values of Chi-square are not found significant at 5 percent level for all cases. We,therefore,accept the null hypothesis that there are no significant differences between the observed values and the theoretical values of the time interval for both the events. So, the distribution of interarrival times of droughts at Cooch Behar and Dinhata can be considered to follow the negative binomial distribution. And the distribution of interarrival times of floods, the negative binomial distribution may be judged a valid model. Therefore the distribution of interarrival times of drought and flood years for Cooch Behar and Dinhata are overall best fitted to negative binomial model.

Hence, we may come to the conclusion that the negative binomial distribution is a good fit to the experimental data.

4.5.3. DISTRIBUTION OF THE LARGEST INTERVAL.

Fisher's 'g' statistic is introduced here to test cyclic order of the largest interval of drought or flood sequences. Fisher's 'g' statistic is the ratio of largest interval between occurrence of an event to the sum of such intervals. If t_L be the largest among n independent time intervals $\bar{t}$ be the mean of the intervals then the test statistic 'g' is defined as

$$g = \frac{t_L}{n\bar{t}}$$

For testing significance of the largest interval, it is assumed that each of the n intervals contributes a certain fraction to the total sum of squares and 'g' is taken to be the largest of these fractions. The probability of 'g' exceeding any given value has been worked out by Fisher as described by Priestly (1981).

If the value at 5 percent level of significance is $g_{.05}$ then the largest interval t_L is significant if

$$t_L \geq g_{.05}\, n\bar{t}$$

The significance test described above is based on the assumption that the probability that the largest of the n intervals should exceed 'g' is given by

$$\alpha = n(1-z)^{n-1}$$

where α is the level of significance.

z is the critical value of the test.

n is the total number of frequencies.

The procedure outlined above may also be used to test the largest interval for its occurrence on drought and flood aspect.

The computed value of 'g' and the theoretical value of 'g' are given at the end of Table **4.7(b)**. The maximum interval between droughts at Cooch Behar and Dinhata are 6 years and 5 years respectively. The computed values of 'g' are 0.15 and 0.14 and the hypothetical values of 'g' are 0.13 and 0.14 respectively for the two stations as given in Table **4.7(a)**. The hypothetical values of the maximum interval for droughts are 5.07 and 5.05 years for Cooch Behar and Dinhata respectively. The hypothetical value of the drought interval for Dinhata is greater than the observed interval of 5 years. So this largest interval between droughts is not significant,so the maximum drought interval at

Dinhata may not maintain any cyclic order. Thus this may occur purely randomly. But the largest interval between droughts for Cooch Behar is something different. Here the hypothetical value of t_L is less than the observed interval of 6 years. Hence,the largest interval is significant. Therefore,the largest drought interval at Cooch Behar may be expected to occur periodically by 6 years.

The analysis of the largest interval between droughts at Cooch Behar may recognize in agreement with Sarkar (1979) and chowdhury and Abhyankar (1984) that drought may experience once in 6 to 8 years in Sub-Himalayan West Bengal region. The hypothetical values of the largest interval for flood are 7.54 and 6.74 for Cooch Behar and Dinhata respectively. The hypothetical value of thelargest interval between floods is less than the observed interval of 8 years at Cooch Behar. So it seems to be significant. Therefore,the largest interval between floods may occur cyclically by 8 years. So,it may be concluded that the flood can be expected to occur once in 8 years. The hypothetical value of the largest interval between floods is greater than the observed value of the flood interval of 6 years. Hence,it shows statistically non-significant.

Studies with this technique of flood incidence in any place of India are also not available. The hypothetical values of drought and flood intervals for Cooch Behar and Dinhata are given in Tables **4.7(a & b)**. So,we come to the conclusion that drought and flood may be expected to occur once in 6 years and 8 years respectively. And drought can occur more frequently than floods at Cooch Behar.

4.6. EQUALITY OF DISTRIBUTIONS OF SAME EVENT :

A problem of great importance is that whether several random realizations of the same meteorological event can be considered as drawn from the same population of rainfall. We have two distributions of the same meteorological event like drought and flood. We may consider that the distributions of drought intervals and flood intervals come from the same population of the respective events. We also have that the interarrival times of drought years as well as flood years are considered to follow the negative binomial distribution. We like to test here that the two distributions of interarrival times of drought or flood years are homogeneous. To test this,we set the null hypothesis that the two negative binomial distributionsfor each event are same.

We group the frequencies of each class and the last group includes all frequencies greater than 4. The groups and their corresponding frequencies are given in Table **4.8.** By using the method of moments and the maximum likelihood method,we have to estimate the parameters of the common negative binomial distribution of each event like drought and flood separately.

The expected frequencies of each group are estimated by recurrence relation as usual. To estimate the expected frequency of each group,we have multiplied the fitted probabilities by the average number of observations of the respective event. The observed frequencies and the expected frequencies are given in

Table 4.8. The hypothesis can be tested in a variety of ways one of which is the limiting chi-square distribution as given below :

$$G_{2k} = \sum_{i=1}^{2} \sum_{j=0}^{K} \frac{(N_{ij} - n_i p_j)^2}{n_i p_j}.$$

has a limiting chi-square distribution with (2K-2) degrees of freedom. Here 2 degrees of freedom are lost due to two parameters being estimated from the observed values.

Where K is the number of groups, N_{ij} is the frequency of the j-th. group in the distribution.

$n_i p_j$ is replaced here by the estimated frequencies of the common distribution.

*The calculated value of the test statistic and tabulated value of the Chi-square with suitable degrees of freedom at 5 percent level of significance are given in Table **4.8.** It is found that the calculated value of Chi-square for the time interval of drought years is less than the tabulated value of Chi-square with 6(8-2) degrees of freedom at the 5 percent level of significance. So, we may accept the null hypothesis. We come to the conclusion that there is no evidence from the data to support that the two distributions of interarrival time of drought years for two different places are different negative binomial populations. The calculated value of test statistic for the time interval of flood years is less than the tabular value of Chi-square with 6(8-2) degree of freedom at 5 percent level of significance. So, it is statistically non-significant, hence, we cannot reject the null hypothesis that the two distributions of interarrival time of flood years are drawn from the same population.*

4.7 CONCLUSION

The annual rainfalls recorded in this region are independently and normally distributed. The drought and flood years,in this district appear to have no trend i.e., they occur randomly.The frequency distribution of time interval between the occurrence of successive drought and flood years are considered to follow the negative binomial distribution. The behaviour of occurrence of successive drought as well as flood,in meteorology are identical for both the places. Drought and flood may be expected to appear once in 6 years and 8 years respectively in the district of Cooch Behar.

TABLE - 4.1

CLASSIFICATION OF DROUGHT AND FLOOD YEARS CONSIDERING THEIR INTENSITIES.

CLASS		INTENSITY
	DROUGHT	
- .01 to - 0.99		Slight
- 1.0 to - 1.99		Moderate
- 2.0 to - 3.00		Severe
	FLOOD	
+ .01 to +0.99		Slight
+ 1.0 to +1.99		Moderate
+ 2.0 to +3.00		Severe
+ 3.00 and above		Extreme

TABLE : 4.2(a)

YEAR OF DROUGHT AT COOCH BEHAR

YEAR	INDEX VALUE	CATEGORY	RANKING
1901	1.059	Moderate	13
1903	0.171	Slight	42
1904	0.191	Do	41
1908	0.459	Do	31
1912	0.126	Do	46
1914	0.868	Do	16
1915	0.875	Do	15
1917	0.746	Do	19
1919	0.337	Do	36
1922	.284	Do	38
1923	0.623	Do	24
1925	0.467	Do	30
1926	0.282	Do	39
1928	0.352	Do	35
1929	0.695	Do	22
1930	1.780	Moderate	01
1933	1.056	Do	11
1934	0.136	Slight	44
1936	0.49	Do	29
1937	0.725	Do	21
1939	1.116	Moderate	07
1940	0.905	Slight	13
1942	1.07	Moderate	18

1944	0.655	Slight	23
1946	0.96	Do	12
1947	1.216	Moderate	05
1950	0.409	Slight	32
1952	0.902	Do	14
1953	0.103	Do	47
1954	0.086	Do	48
1957	1.287	Moderate	04
1959	1.065	Do	09
1960	0.733	Slight	20
1961	0.853	Do	17
1962	0.613	Do	25
1963	0.518	Do	27
1970	0.171	Do	43
1972	1.166	Moderate	06
1973	0.246	Slight	40
1975	0.30	Do	37
1976	0.779	Do	80
1977	0.372	Do	34
1978	0.398	Do	33
1979	1.419	Moderate	03
1980	1.441	Do	02
1981	0.499	Slight	28
1982	0.061	Do	49
1984	0.128	Do	45
1986	0.535	Do	26

TABLE 4.2(b).

YEARS OF DROUGHT AT DINHATA

YEARS	INDEX VALUE	CATEGORY	RANKING
1901	1.133	Moderate	13
1904	0.949	Slight	90
1906	0.757	Do	22
1907	1.081	Moderate	14
1908	1.717	Do	03
1909	0.366	Slight	33
1910	0.560	Do	30
1911	0.106	Do	43
1914	1.049	Moderate	15
1915	0.742	Slight	23
1917	0.830	Do	20
1918	0.209	Do	38
1919	1,124	Moderate	09
1923	0.348	Slight	34
1929	0.687	Do	25
1930	1.235	Moderate	07
1932	0.332	Slight	35
1933	1.03	Moderate	16
1934	1.128	Do	08
1935	1.394	Do	05
1937	1.185	Do	10
1938	0.592	Slight	29

1939	1.16	Moderate	11
1940	1.722	Do	02
1942	0.983	Slight	17
1945	0.171	Slight	41
1946	0.107	Do	44
1947	0.621	Do	27
1950	1.115	Moderate	12
1951	0.175	Slight	40
1953	0.170	Do	42
1957	1.263	Moderate	06
1959	0.617	Slight	28
1960	0.318	Do	36
1961	0.955	Do	18
1962	0.512	Do	31
1966	0.792	Do	21
1968	0.009	Do	45
1970	0.191	Do	39
1971	0.225	Do	37
1975	0.726	Do	22
1978	1.847	Moderate	01
1980	1.676	Do	04
1981	0.476	Slight	32
1982	0.626	Do	26

T A B L E 4.3(a)

Y E A R O F F L O O D A T C O O C H B E H A R

YEARS	INDEX VALUE	CATEGORY	RANKING
1902	1.395	Moderate	10
1905	1.748	Do	07
1906	1.758	Do	06
1907	1.889	Do	04
1909	0.088	Slight	35
1910	1.409	Moderate	09
1911	1.302	Do	11
1913	.249	Slight	30
1916	1.794	Moderate	05
1918	0.364	Slight	25
1920	2.74	Severe	02
1921	4.25	Extreme	01
1924	0.825	Slight	15
1927	0.542	Do	90
1931	0.60	Do	16
1932	0.575	Do	17
1935	0.349	Do	26
1938	0.367	Do	23
1941	0.088	Do	36
1943	0.365	Do	24
1945	0.214	Do	31
1948	0.311	Do	27

1949	0.87	Do	37
1951	0.105	Slight	34
1955	0.034	Do	39
1956	0.171	Do	33
1958	0.84	Do	14
1964	00.392	Do	22
1965	0.049	Do	38
1966	0.294	Do	28
1967	0.419	Do	21
1968	.445	Slight	20
1969	.26	Slight	29
1971	.549	Do	18
1974	1.416	Moderate	08
1983	0.176	Slight	32
1985	0.963	Do	12
1987	0.884	Do	13
1988	2.596	Severe	03

TABLE – 4.3(b).

YEAR OF FLOOD AT DINHATA

YEAR	INDEX VALUE	CATEGORY	RANKING
1902	0.96	Slight	19
1903	0.353	Do	34
1905	0.387	Do	31
1912	0.342	Do	35
1913	0.99	Do	18

1916	1.32	Moderate	10
1920	1.558	Moderate	06
1921	1.599	Do	05
1922	1.422	Do	09
1924	1.535	Do	07
1925	0.412	Slight	29
1926	0.359	Do	33
1927	1.192	Moderate	12
1928	1.008	Do	17
1931	0.939	Slight	21
1935	0.02	Do	42
1941	0.896	Slight	22
1943	0.571	Slight	26
1944	0.161	Do	37
1948	0.764	Do	23
1949	0.714	Do	24
1952	0.002	Do	43
1954	1.03	Moderate	15
1955	0.6	Slight	25
1956	1.027	Moderate	16
1958	1.119	Do	13
1963	0.09	Slight	40
1964	0.093	Do	39
1965	0.405	Do	30
1967	0.155	Do	38
1969	2.55	Severe	04

1972	0.951	Slight	20
1973	1.105	Moderate	14
1974	2.659	Severe	02
1976	0.387	Slight	32
1977	1.224	Moderate	11
1979	0.039	Slight	41
1983	0.294	Do	36
1984	2.761	Severe	01
1985	0.564	Slight	27
1986	0.430	Do	28
1987	2.580	Severe	03
1988	1.517	Moderate	08

TABLE - 4.4

Z VALUE AND F VALUE OF THE SUB-PERIOD OF INDEX SERIES

STATISTICS	COOCH BEHAR		DINHATA	
	1st Half	2nd Half	1st Half	2nd Half
n	44 (n_1)	44 (n_2)	44 (n_1)	44 (n_2)
Mean	0.163	- 0.151	- 0.145	0.238
Standard	1.157	0.9836	0.974	1.0667
Calculated value of Z		1.37		1.75
Hypothetical value at 5%		1.96		1.96
Calculated value of F	1.38			1.20
Table value F at 5%	1.58			1.58
D.F.	(43,43)			(43,43)

TABLE = 4.5.

BASIC STATISTICS OF TWO SERIES

	COOCH BEHAR	DINHATA
N	88	88
Mean	3533	2895
Standard deviation	710.00	560.00
Mean deviation	525.2	450.58
Calculated value of G	0.74	0.80
Theoretical value of G		
(Lower & Upper)	0.74 - 0.85	

TABLE = 4.6.

RANK CORRELATION OF DROUGHT AND FLOOD SEQUENCE

COOCH BEHAR	DROUGHT	FLOOD
No. of pairs.	49	58
Correlation coefficient.	-.027	0.17
S.E.of Correlation coefficient.	0.144	0.164
Calculated Z-value.	0.19	1.034

DINHATA	DROUGHT	FLOOD
No. of pairs	45	43
Correlation of Coefficient	0.15	- 0.04
S.E.of correlation Coefficient.	0.15	0.15
Calculated Z value	1.00	.26
Hypothetical value at 5%	1.96	1.96

TABLE - 4.7(a)

THE OBSERVED AND EXPECTED FREQUENCY OF DROUGHT SEQUENCE.

INTERVAL	COOCH BEHAR		DINHATA	
	O	E	O	E
0	23	24.66	25	23.32
1	18	13.03	9	10.44
2	4	5.04	5	5.15
3	2	3.67	4	3.5
4			0	1.04
5			1	0.82
6	1	1.60		
Total (n)	48	48	44	44
$\bar{x}$	0.8125		.82	
σ^2	1.1942		1.37	
p	0.68		0.59	
q	0.32		0.41	
r	1.7265		1.2	
x^2(cal)	3.20		0.35	
DF	1		1	
X^2tab(5%)	3.84		3.84	
g^*(cal)	0.15		0.14	
g(theoretical)5%	0.13		0.14	
Hypothetical t_L	5.07		5.05	

T A B L E = 4.7(b)

THE OBSERVED AND EXPECTED FREQUENCY OF FLOOD SEQUENCE.

INTERVAL	COOCH BEHAR		DINHATA	
	O	E	O	E
0	14	16.03	21	20.07
1	12	10.03	10	10.66
2	8	5.62	4	5.51
3	2	3.02	4	2.82
4	0	1.59	1	1.51
5	1	1.00	1	1.00
6	0		1	0.43
7	0			
8	1	0.71		
Total(n)	38	38	42	42
$\overline{X}$	1.24		1.07	
σ^2	2.44		2.16	
p	0.506		0.496	
q	0.494		0.506	
r	1.267		1.053	
x^2(cal)		2.50		0.76
DF		1		1
x^2-tab(5%)		3.84		3.84
g^*(cal)		0.17		013
g (theoretical)5%		0.16		.15
Hypothetical t_L		7.54		6.74

T A B L E = 4.8.

DISTRIBUTION OF INTERVAL OF TIME FOR TWO PLACES

DROUGHT

	COOCH BEHAR OBSERVED	DINHATA OBSERVED	COMMON	EXPECTED
0	23	23	48	22.78
1	18	9	27	14.67
2	4	5	9	5.84
3	2	4	8	2.89
4	0	0	–	–
5	0	1	–	–
6	1	0	–	–
Total	48	44	92	46
X^2(cal)				4.71
DF				6
X^2 at 5% (tab)				12.6

FLOOD

	COOCH BEHAR OBSERVED	DINHATA OBSERVED	COMMON	EXPECTED
0	14	21	35	16.28
1	12	10	22	12.91
2	8	4	12	6.58
3	2	4	11	4.23
4	0	1		
5	1	1		
6	0	1		
7	0	0		
8	1	0		
Total	38	42	80	40
X^2(cal)			5.55	
DF			6	
X^2 at 5%(tab)			12.6	

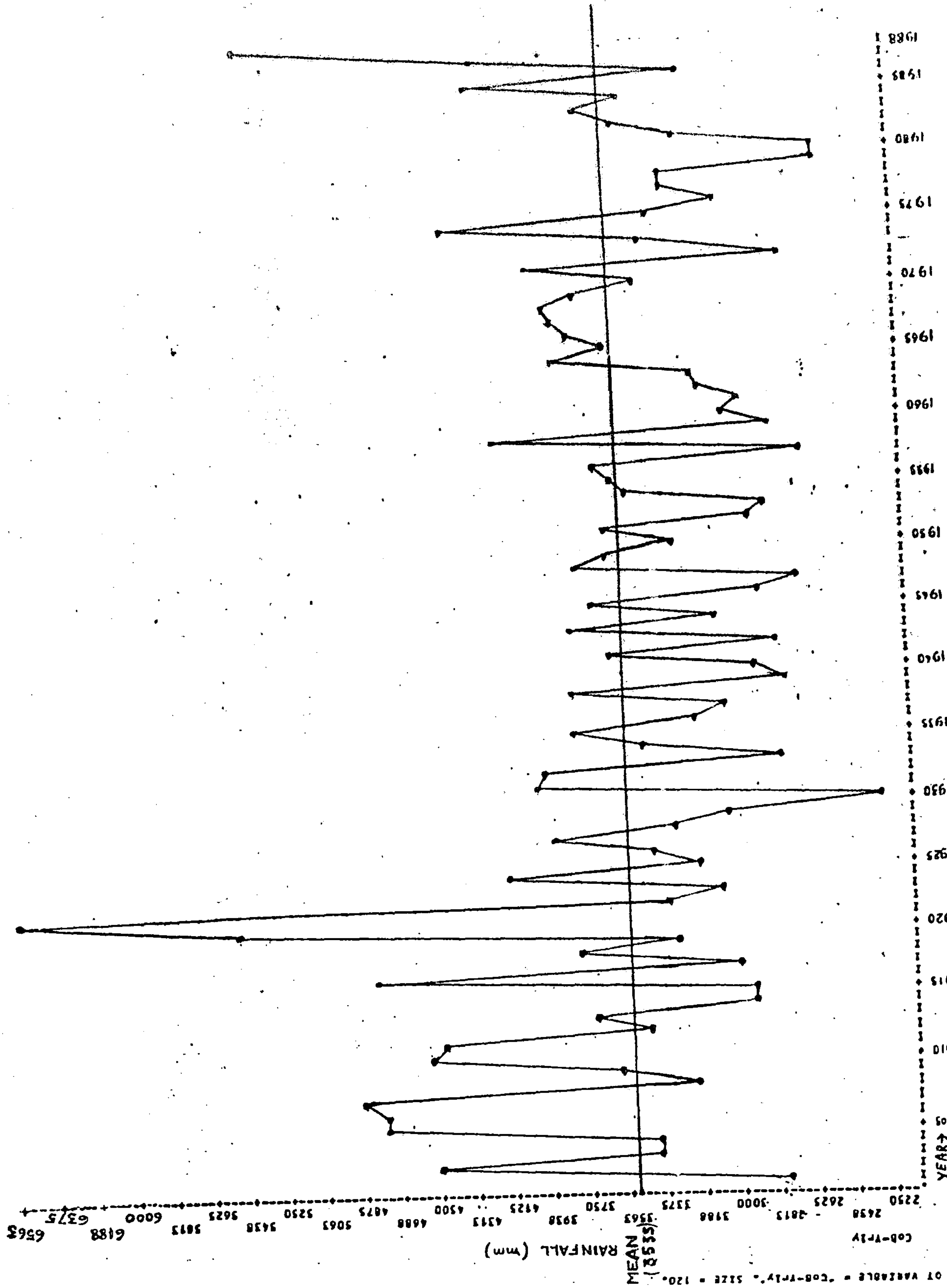


Fig.4.1. Annual rainfall of Cooch Behar from 1901 to 1988 .

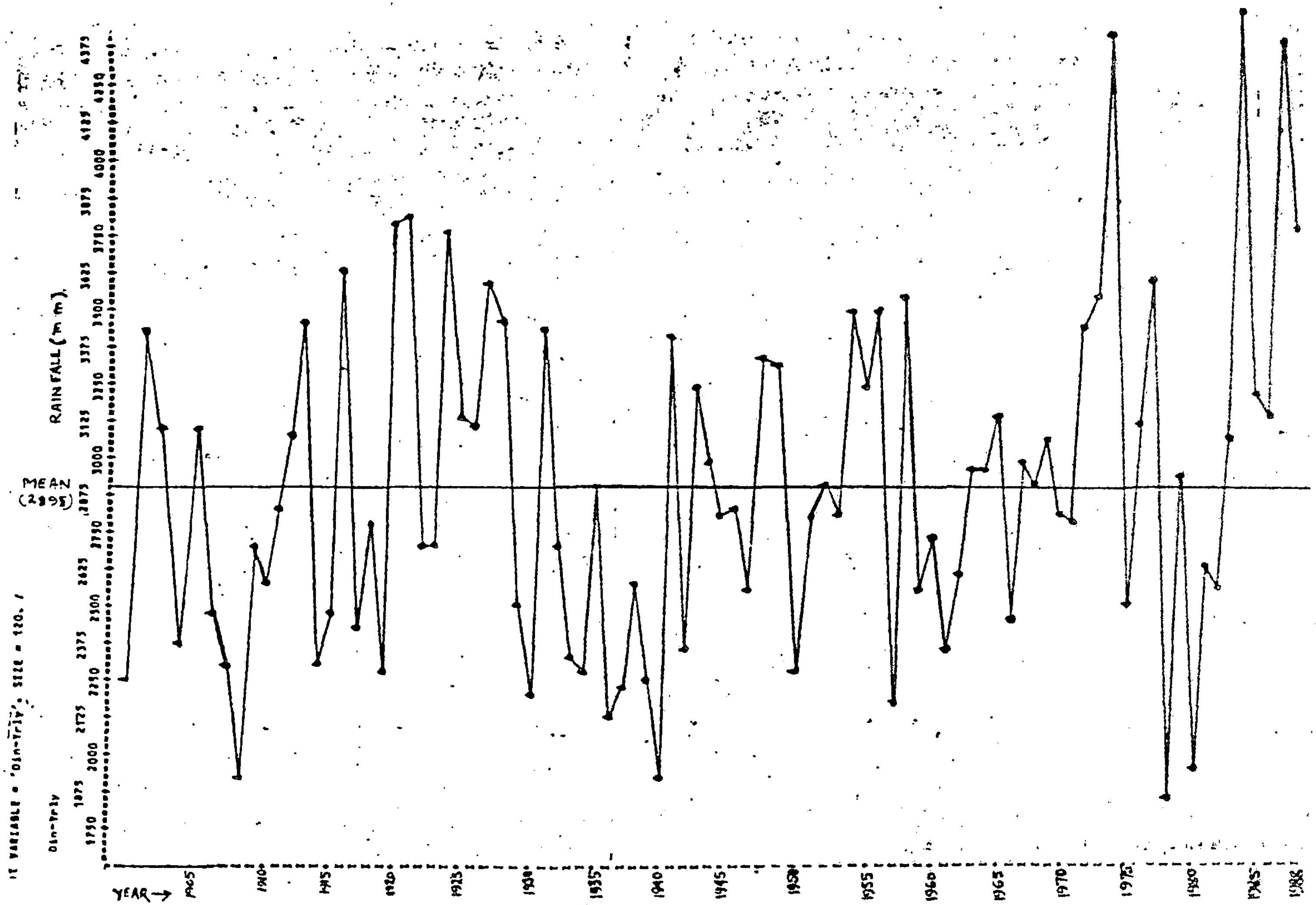


Fig.4.2 Annual rainfall of Dinhata from 1901 to 1988.

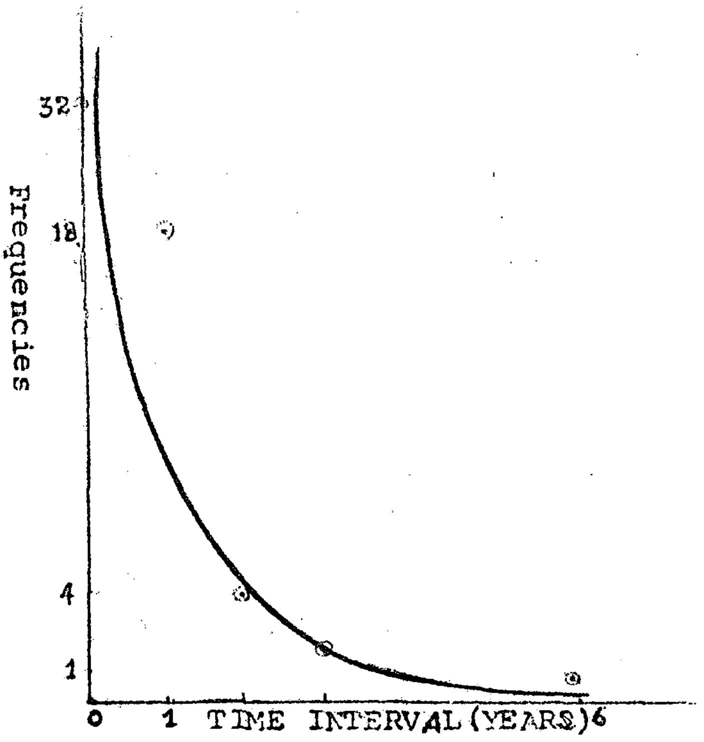


Fig.4.3 (a) DROUGHT TIME INTERVAL (COOCHBEHAR)

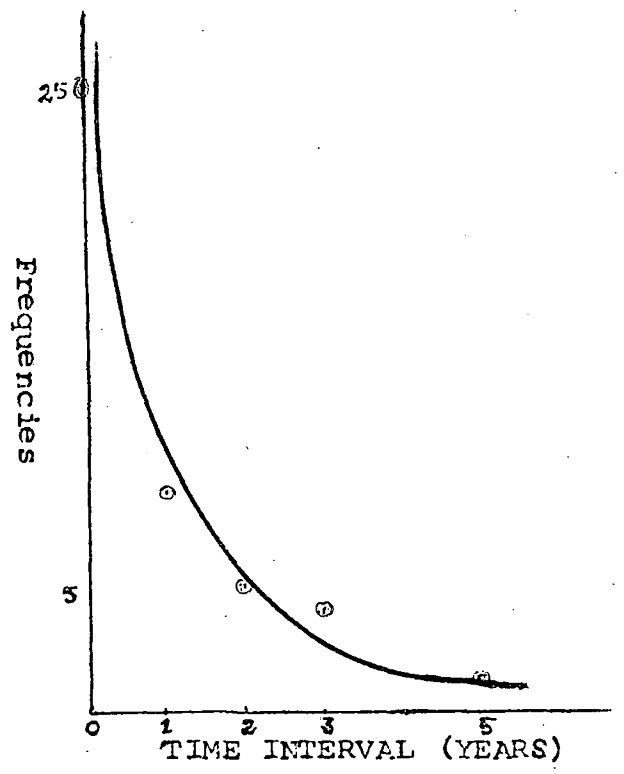
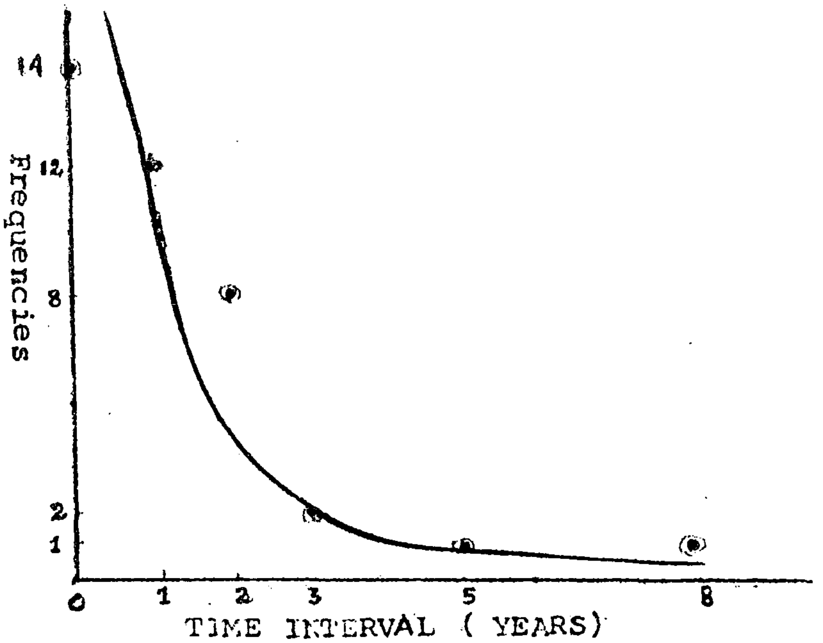


Fig.4.3 (b) DROUGHT TIME INTERVAL (DINHATA)

Fig.4.4.(a) .FLOOD TIME INTERVAL (COOCHBEHAR)



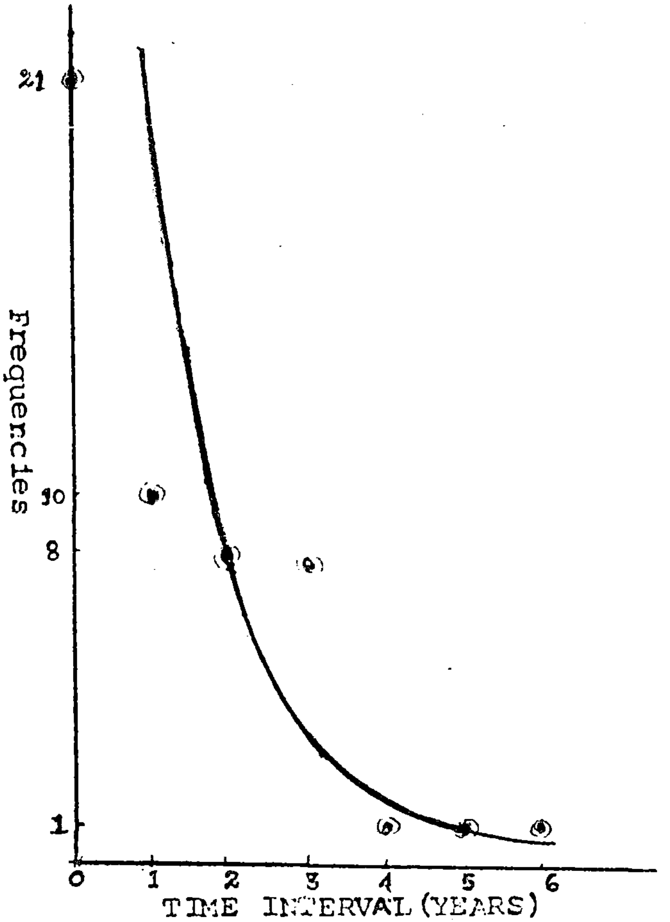


Fig.4.4.(b) FLOOD TIME INTERVAL (DINHATA)

CHAPTER - V

PATTERN OF DAILY RAINFALL