Analysis of precipitation data of Orissa

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology
In
Civil Engineering

By

Anil Kumar Kapoor
Department of Civil Engineering
National Institute of Technology Rourkela
May 2011

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Under the supreme guidance of Prof. Ramakar Jha

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CERTIFICATE

This is to certify that the project entitled, "Analysis of precipitation data of Orissa" submitted by'Anil Kumar Kapoor' in partial fulfillments for the requirements for the award of Bachelor of Technology Degree in Civil Engineering at National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the report has not been submitted to any other University / Institute for the award of any Degree or Diploma.

Date:

(Prof. Ramakar Jha)

Dept. of Civil Engineering,
National Institute of Technology
Rourkela - 769008, Orissa

ACKNOWLEDGEMENT

We express our gratitude and sincere thanks to Prof. Ramakar Jha for his guidance and constant encouragement and support during the course of my work. We truly appreciate the value and his esteemed guidance and encouragement from beginning to the end of the thesis, his knowledge and company at the time of crisis would be remembered lifelong.

Our Sincere thanks to Prof. M. Panda, Head of the Civil Engineering Department, National Institute of Technology, Rourkela for providing all kind of help and support. We are also thankful to all the professors of Civil Engineering Department.

We also thank our friends who directly or indirectly helped us in our project work and completion of the report.

Last but not the least we would like to thank our parents who taught us the values of hard work by their own example. We would like to share this moment of happiness with our mother and father. They rendered us enormous support during the whole tenure of stay at NIT Rourkela.

Anil Kumar Kapoor
(107CE031)
Department of Civil Engineering
National Institute of Technology Rourkela

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ABSTRACT

The precipitation analysis is a mathematical approach to model the data and use it for different purposes for each station. There can be many methods used for the analysis, the methods used in current report are

- Time series analysis
- Inter station correlation
- Probability Distributions

These methods are used to analyze the different parameters of the precipitation for the period 1990-2001. As time series analysis is done to find the trend in precipitation and to forecast it for the future event, inter station correlation is helpful to give the best replacement of a missing data for a station and probability distribution gives the best fitted model for each precipitation data set.

For inter station correlation the performance of comparison (R^2) is taken to be 0.8 and above for the analysis. Probability distribution is done by chi-square check.

CHAPTER-1

INTRODUCTION

1.1 General

In meteorology, **precipitation** is any product of the condensation of atmospheric water vapor that falls under gravity [1]. The main forms of precipitation include drizzle, rain, sleet, snow, graupel and hail.It occurs when a local portion of the atmosphere becomes saturated with water vapour and the water condenses [2]. Two processes, possibly acting together, can lead to air becoming saturated: cooling the air or adding water vapour to the air[3].Water is the source of all life on Earth. It is the only known substance that can exist naturally as a gas, liquid, and solid within the relatively small range of air temperatures and pressures found on the surface of the Earth. The total amount of water present on the Earth is fixed and does not change. However, powered by the Sun, water is continually being circulated between the oceans, the atmosphere and the land. This circulation and conservation of the Earth's water, known as the water cycle, is crucial component of weather and climate. Climate dictates the amount of rainfall the soil receives and how much water is cycled back to the atmosphere through evaporation.

The northern Deccan region, bounded by the Western Ghats, the Vindhya Range and the Narmada River to the north, and the Eastern Ghats, receives most of its annual rainfall during the summer monsoon season. The southern Deccan area is in a "rain shadow" and receives only fifty to 1,000 millimeters of rainfall a year. Temperature ranges are wide--from some 15°C to 38°C--making this one of India's most comfortable climatic areas [4].

1.2 Importance of Rainfall

Rain is associated with water. During the summer season from time to time we ask God for rain. We need rain not only because it is hot and rain usually refreshes us but also because we know that crops depends much on rain. The more crops we get the better for us and for economy of the country we live in and for other countries as well. Rainfall predictions associated with climate change may be variable across even one country, not speaking about larger areas on a global scale. For example across Australia some areas are getting more and other less rain. Since 1975 to 2005 Perth annual average rainfall is half what is was from 1911 to 1974.

1.3 Variation of rainfall

The southwest monsoon occurs in two branches. After breaking on the southern part of the Peninsula in early June, the branch known as the Arabian Sea monsoon reaches Bombay around June 10, and it has settled over most of South Asia by late June, bringing cooler but more humid weather. The other branch, known as the Bay of Bengal monsoon, moves northward in the Bay of Bengal and spreads over most of Assam by the first week of June. The withdrawal of the monsoon is a far more gradual process than its onset. It usually withdraws from northwest India by the beginning of October and from the remaining parts of the country by the end of November. During this period, the northeast winds contribute to the formation of the northeast monsoon over the southern half of the Peninsula in October. It is also known as the retreating monsoon because it follows in the wake of the southwest monsoon. The states of Tamil Nadu, Karnataka, and Kerala receive most of their rainfall from the northeast monsoon during November and December. However, 80 percent of the country receives most of its rainfall from the southwest monsoon from June to September [5].

1.4 Objective

2.1 Time Series analysis

The main objective of the time series analysis of the precipitation data is to find out any trend in the data and to forecast it for the future events. Hence by forecasting we can predict the upcoming drought and flood areas.

Time-series analysis has become a major tool in hydrology. It is used for building mathematical models to generate synthetic hydrologic records, to forecast hydrologic events, to detect trends and shifts in hydrologic records and to fill in missing data and extend records.[6](P.E. Naill and M. Momani,2009)

2.2 Inter station Correlation

The inter station correlation is used to correlate the precipitation data of different stations with each other and also to show the variation of the correlation with the distance. If the data of a particular station is missing then the data can be replaced by the station which is best correlated with the station.

2.3 Probability Distribution

On application of the different distribution models, the best fitted distribution for the given precipitation data is obtained. A best fitted plot signifies the data set that follows a given distribution in the best way possible.

Analysis of rainfall would enhance the management of water resources applications as well as the effective utilization of water resources. Such information can also be used to prevent floods and droughts, and applied to the planning and designing of water resources related engineering, such as reservoir design, flood control work, drainage design, and soil and water conservation planning, etc[7](Chin-Yu Lee 2005)

CHAPTER-3

LITERATURE REVIEW

3.1 Time series analysis

In early 1970's, Box and Jenkins pioneered in evolving methodologies for time series modeling in the univariate case often referred to as Univariate Box-Jenkins (UBJ) ARIMA modeling (Box, G.E.P., Jenkins, G.M. and Reinsel, G.C.,1994)[8] In course of time, various organizations/ workers in India and abroad have done Modeling/ forecasting (of course, not necessarily for agricultural systems) based on time series data using the different methodologies viz. time series decomposition models, Exponential smoothing models, ARIMA models and their variations such as seasonal ARIMA models, vector ARIMA models using multivariate time series, ARMAX models i.e. ARIMA with explanatory variables etc. A good account on exponential smoothing methods is given in Makridakis et al. 1998[9]. A practical treatment on ARIMA modeling along with several case studies can be found in Pankratz (1983). A reference book on ARIMA and related topics with a more rigorous theoretical flavor is by Box et al. (1994). (Ramasubramanian, 2005)[10]

Chiew*et al*[11] conducted a comparison of six rainfall-runoff modeling approaches to simulate daily, monthly and annual flows in eight unregulated catchments. They concluded that time-series approach can provide adequate estimates of monthly and annual yields in the water resources of the catchments. Kuoand Sun[12] employed an intervention model for average10 days stream flow forecast and synthesis which was investigated by to deal with the extraordinary phenomena caused by typhoons and other serious abnormalities of the weather of the Tanshui River basin in Taiwan. Time series analysis was used by Langu[13] to detect changes in rainfall and runoff patterns to search for significant changes in the components of a number of rainfall time series.(Naill P.E. and Momani M.,2009)[6]

3.2 Inter station Correlation

Efforts are being made during the last one century about the long-range forecast of Indian monsoon rainfall. Recently, Parthasarathy et al. (1988) and Gowariker et al. (1989, 1991)[13] have made a comprehensive study of many parameters related to the Indian monsoon rainfall and developed regression equations. However, the search for new parameters continues, as no forecasting scheme is as yet consistently successful over a period of time. In the sixteen- parameter model developed by Gowariker et al. (1991)[14], the SSTs over Indian region have not been considered. There is sufficient evidence both on empirical and theoretical basis to believe that sea surface temperatures exert significant control over the atmosphere. Many workers viz. Ranjit Singh (1983), Joseph and Pillai (1984)[15], Rao and Goswamy (1988)[16], Vinayachandran and Shetye (1991)[17], Sadhuram et al. (1991) have brought out the importance of SST over Arabian sea as an input parameter for the Indian monsoon rainfall.

Earlier studies of Hastenrath (1987) and Parthasarathy et al. (1988) on the relationships between the Indian monsoon rainfall and regional/global circulation parameters have brought out that data 340length of 30-years is necessary and sufficient to establish a stable correlation for prediction purposes. Further, a period of 30 years is generally considered adequate for establishing the climate norms. The present study mainly considers the data period 1951-80, for which excellent data sets on various parameters related to Indian monsoon are available. Aralikatti S.S.(1995)[18]

3.3 Probability Distribution

Attempts have been made on the joint distribution with regard to a rainfall event (see for example Hashino, 1985; Singh & Singh, 1991[19]; Bacchi *et al,* 1994[20]). Hashino (1985)[21] generalized the Freund bivariate exponential distribution (Freund, 1961) and used it to represent the joint probability distribution of rainfall intensities and the corresponding maximum storm surges in the Osaka Bay, Japan. Singh & Singh (1991) derived a bivariate probability density function with exponential marginals and used it to describe the joint distribution of rainfall intensities and the corresponding depths. Bacchi*et al.,* (1994) proposed another bivariate exponential model with exponential marginals and applied it to analyse the joint distribution of rainfall intensities and durations.(Sheng Yue 2000)**[22]**

In this paper one of the distribution used is Gamma distribution. Previous work in this area indicates that rainfall probabilities can be estimated from the gamma distribution. Thom (1958) [23] developed methods of estimating the parameters of this distribution. Friedman and Janes(1957)[24]made use of his methods in the estimation of rainfall probabilities for Connecticut. Other applications were made by Barger et al. (1959)[25] and Strommen and Horsfield(1969)[26] in predicting rainfall probabilities for different areas of the United States. Greenwood and Durand (1960)[27] presented approximations for estimating the maximum likelihood parameters for the gamma distribution. Shentonand Bowman (1970)[28] discuss some properties of Thom'sestimatorsfor the gamma distribution. In using the gamma distribution, these investigators made little mention of the reliability of the precipitation estimates.Mooley and Crutcher (1968)[29] investigated the number of years of record needed to stabilize the gamma parameters in a study of rainfall in India. This report sets forth a method for determining the reliability of the precipitation estimates as a function of the number of observations available for analysis. Bridges T.C. and *Haan(1972)[30]*

CHAPTER-4

STUDY AREA

4.1 Study area

The climate of Orissa falls under the category of tropical monsoon type of climate and in this, Orissa is not different from the rest of the country. Orissa receives a decent annual average rainfall of about 200 cm. The rainfall has a key role to play in the climate of Orissa. Copious rainfall or absence of it directly affects the crop production in Orissa. Rainfall of about 140 cm is considered heavy and anything less than 120 cm is counted as low though it is helpful for paddy harvest. Rainfall in the winter months are also welcomed in Orissa as it gives a fillip to the growth of second crop in the state.

Standing on the coastal belt, the weather in Orissa is greatly influenced by the sea. The climate of the region is tropical resulting in very high temperature in the months of April and May. On the contrary, the Eastern Ghats of the state experience an extremely cold climate.

The average rainfall is 150 cm, experienced as the result of south west monsoon during July-September. The month of July is the wettest and the major rivers may get flooded. The state also experiences small rainfall from the retreating monsoon in the months of October-November. January and February are dry.

CHAPTER-5

METHODOLOGY

5.1 Time series analysis

Monthly precipitation data for each district (30 districts in all) for a time period of 1901 to 2001 was collected from Indian water portal. By the summation of the monthly data, the annual rainfall data was obtained. Hence for each districts for given period the data was used to plot the yearly and seasonal rainfall.

Definition:

Time series forecasting is the use of a model to forecast future events based on known past events to predict data points before they are measured.
There are several types of data analysis available for time series which are appropriate for different purposes. Here we used the following one

- Graphical examination of data series

5.2 Inter station Correlation

Correlation is a measure of the relation between two or more variables. *Correlation* coefficients can range from -1.00 to +1.00. The value of -1.00 represents a perfect negative *correlation* while a value of +1.00 represents a perfect positive *correlation*. A value of 0.00 represents a lack of *correlation*.

For the present study, correlation among rainfall values for all districts was found out. To calculate it annual rainfall for all the stations was imported in Statistica and a correlation matrix was calculated. For further analysis this correlation matrix was used.

Stations showing a correlation value of more than 0.8 (indicating a strong relationship between data) were selected from the correlation matrix. These correlation values were plotted on the y axis against the distance of each district from the one under consideration on the x axis.

Coefficient of Determination (R^2)

The coefficientof determination. Compares estimated and actual y-values, and ranges in value from 0 to 1. If it is 1, there is a perfect correlation in the sample — there is no difference between the estimated y-value and the actual y-value. At the other extreme, if the coefficient of determination is 0, the regression equation is not helpful in predicting a y-value.

In this case the value of coefficient of Determination is calculated for the plot between distance and correlation value. A Coefficient of determination more than 0.8 shows a considerable correlation between the stations.

As the distance increases the Correlation Value is expected to be Decrease but this is not always true due to different climatic conditions. For a regression line to be nearly linear its coefficient of Determination value can be consider to be above 0.8.

For the purpose Distance and Correlation Value is plotted and regression line is drawn. Now considering coefficient of Determination value, elimination of data is done so that its value becomes nearly 0.8.

Similarity between the eliminated data

All the stations has been eliminated shows two kind of some similarity

- Station with low correlation value at less distance (adjacent stations).

Stations with high correlation value at higher distance

5.3Probability Distribution

Based on the value of the chi-square goodness-of-fit value the annual rainfall of the thirty stations is best described by the respective theoretical probability distributions indicated in the table (1).Theoretical probability distributions superimposed on respective frequency histograms of annual rainfall. Out of the thirty stations considered, the no. of stations with annual rainfall following the given distributions is Log Normal (22), Normal (4), Gamma (4)

Function	Equation
Normal Distribution	$F(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$
Lognormal Distribution	$F(x) = \frac{1}{x\,\sigma\,\sqrt{2\pi}} e^{-\frac{(lnx-\mu)^2}{2\sigma^2}}$, x>0
Rectangular Distribution	$f(x) = \frac{1}{b-a}$ for $a \le x \le b$ = 0 for elsewhere
Gamma Distribution	$f(x) = x^{\alpha-1} \frac{e^{\frac{-x}{\theta}}}{\theta^{\alpha}\Gamma(\alpha)}$ for x>0 and α, θ>0
Chi-square Distribution	$f(x) = \frac{1}{2^{\frac{k}{2}}\Gamma\left(\frac{k}{2}\right)} x^{\frac{k}{2}-1} e^{-\frac{x}{2}}$ $x \ge 0$
Exponential Distribution	$f(x) = \lambda e^{-\lambda x}$ $x \ge 0$ 0 $x \le 0$

CHAPTER-6

RESULTS AND DISCUSSIONS

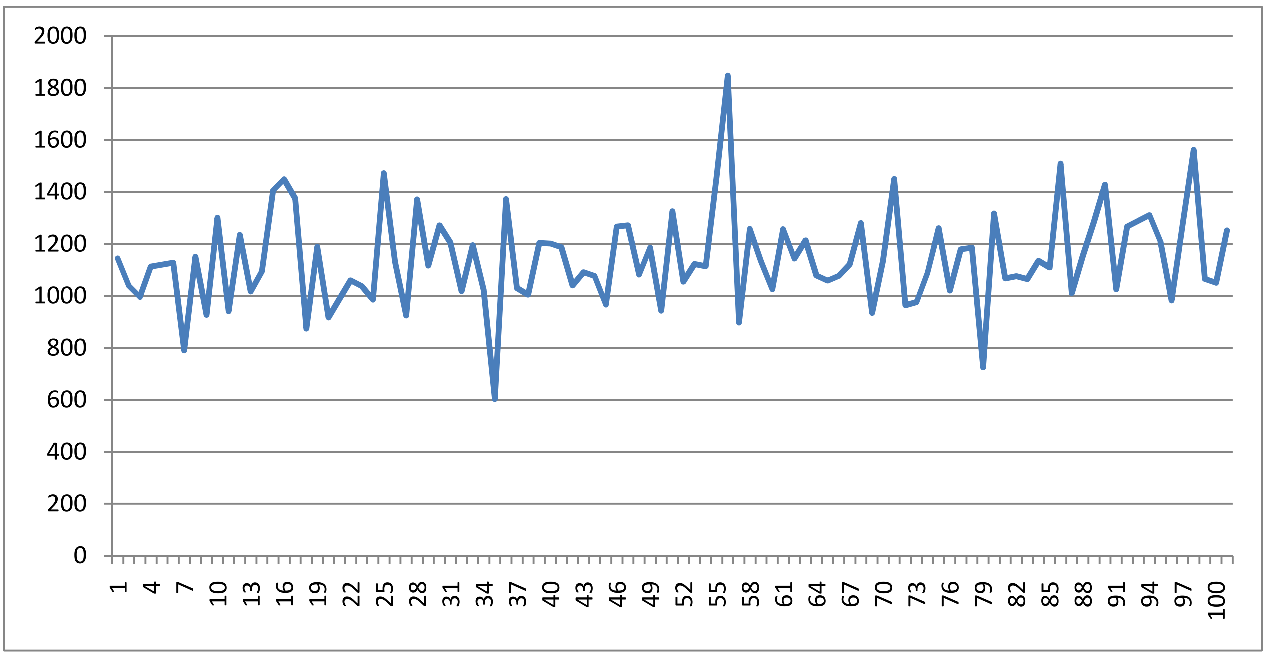
6.1 Time series analysis

Observations

From the time series plots the following interpretation are drawn (Ref fig .1-4)

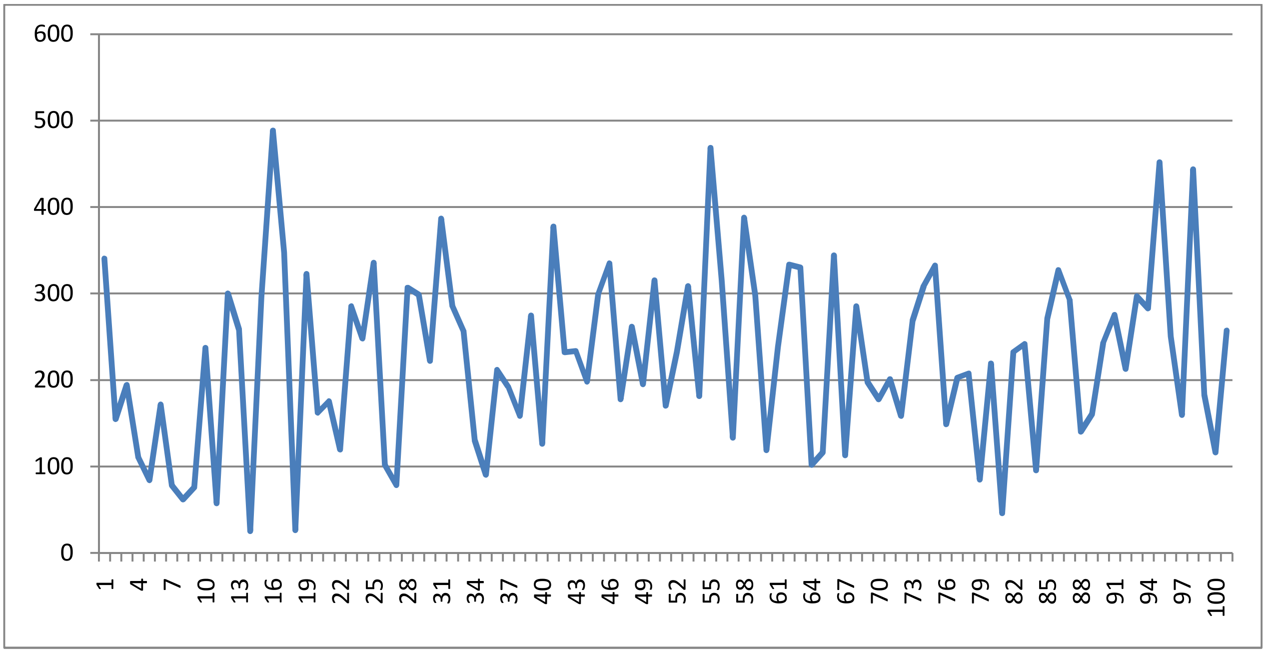
- The average annual rainfall for Puri is increasing progressively with the years.
- Winter season shows a periodic trend of increasing and decreasing rainfall.
- No trend was observed for summer season.
- Average rainfall for the monsoon season lies around the 800mm line and also it does not show any remarkable trend since the last 100 yrs.

Puri



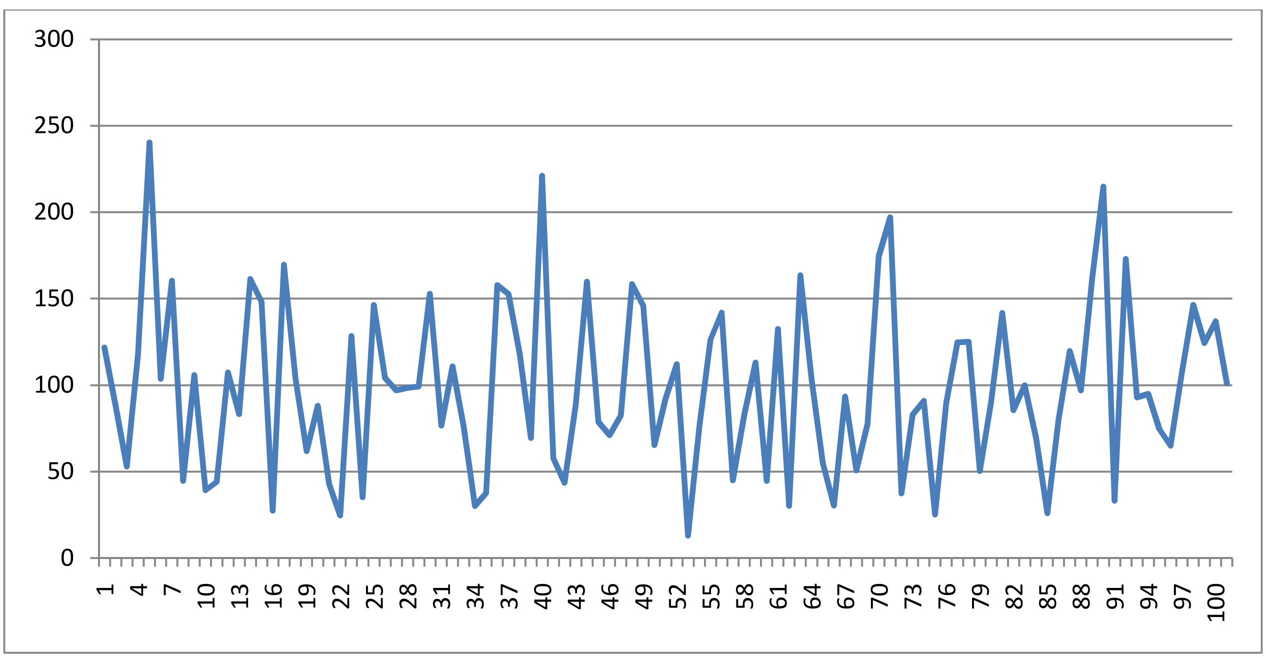
Annual

Fig.1



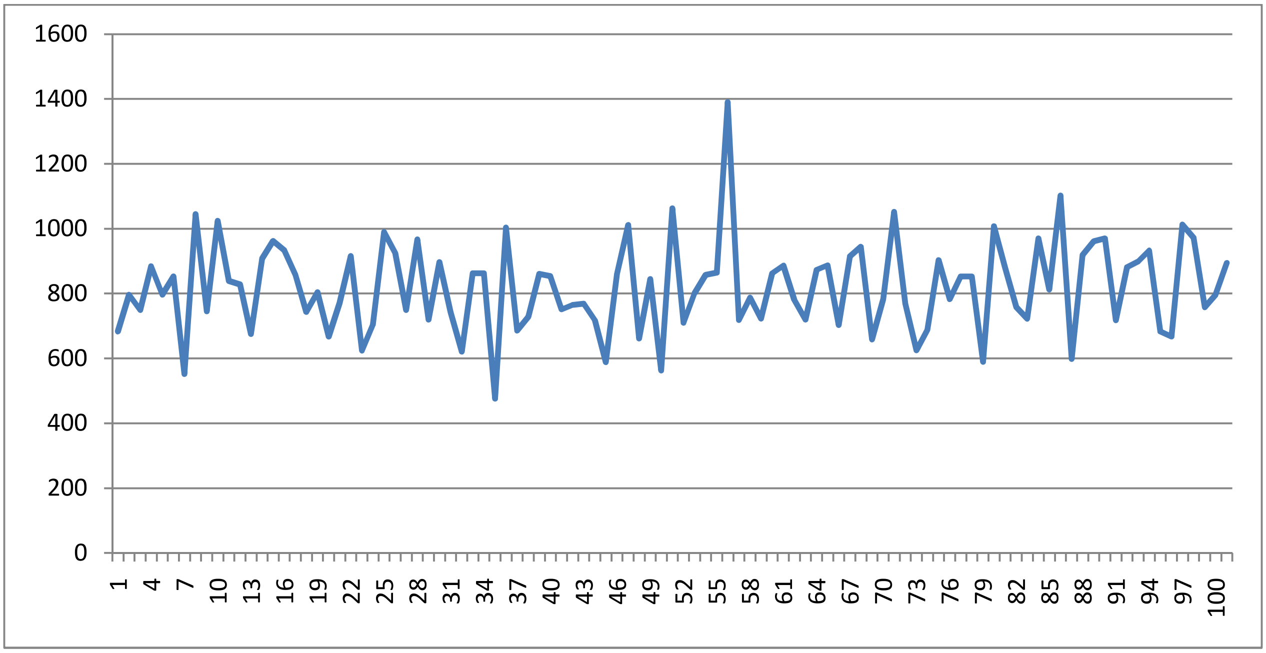
Winter

Fig.2



Summer

Fig.3



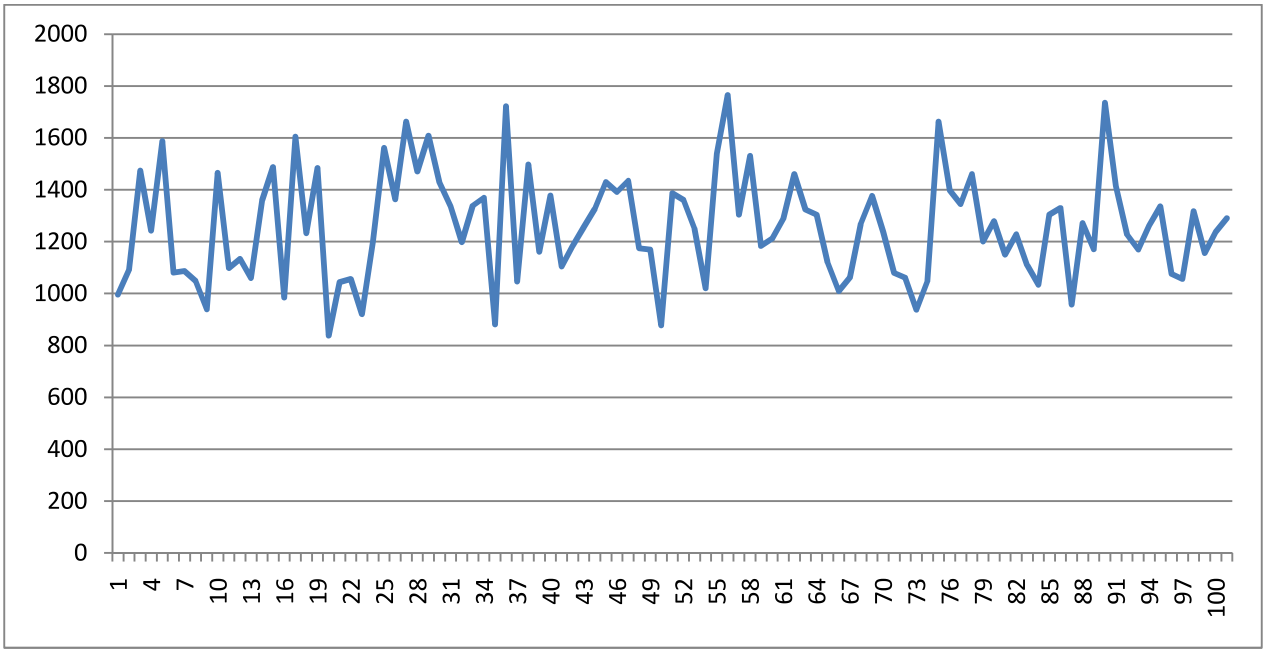
Monsoon

Fig.4

Koraput

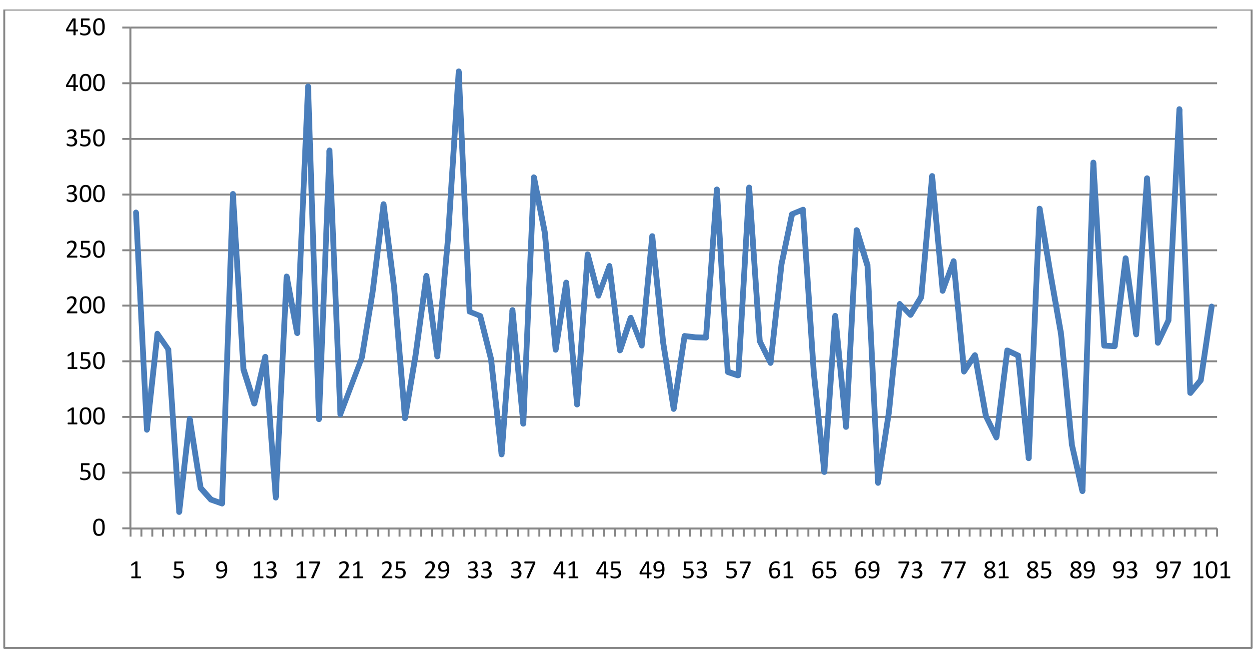
From the time series plots for Koraput district the following interpretation are drawn (Ref fig .5-8)

- The average annual rainfall for Koraput is increasing progressively with the years.
- Winter season shows a periodic trend of increasing and decreasing rainfall with a maximum rainfall of 420mm.
- No trend was observed for summer season.
- There is an increasing trend is observed for the monsoon season for Koraput district.



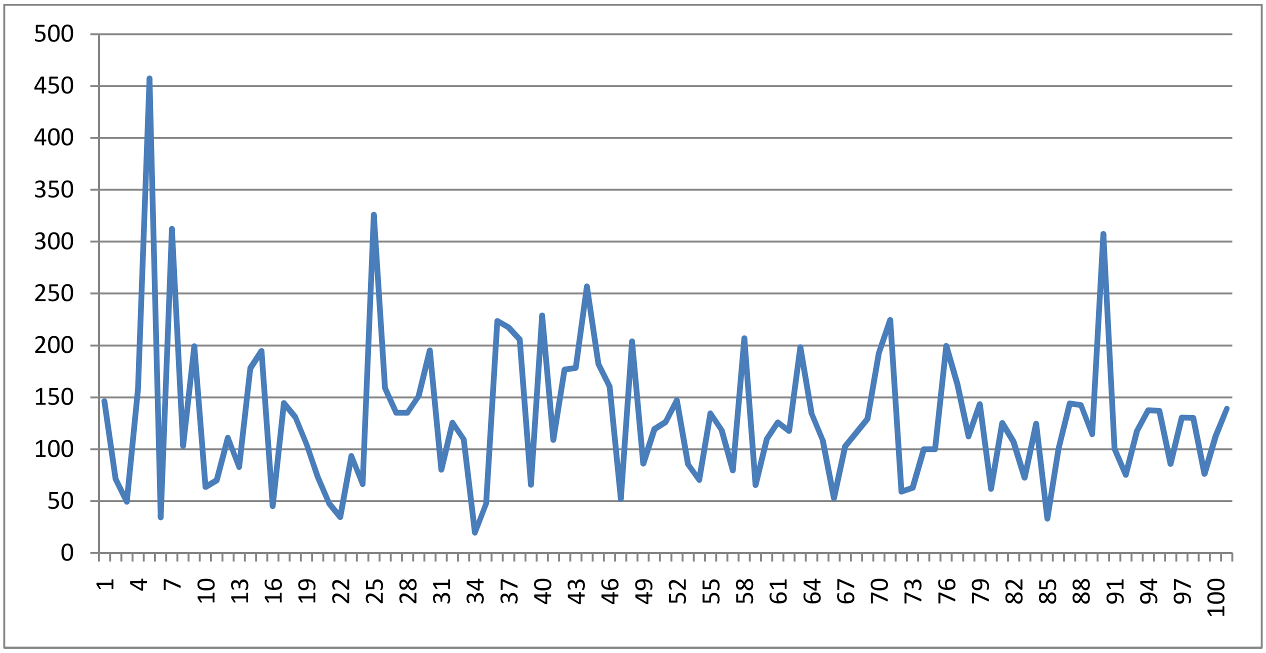
Annual

Fig.5



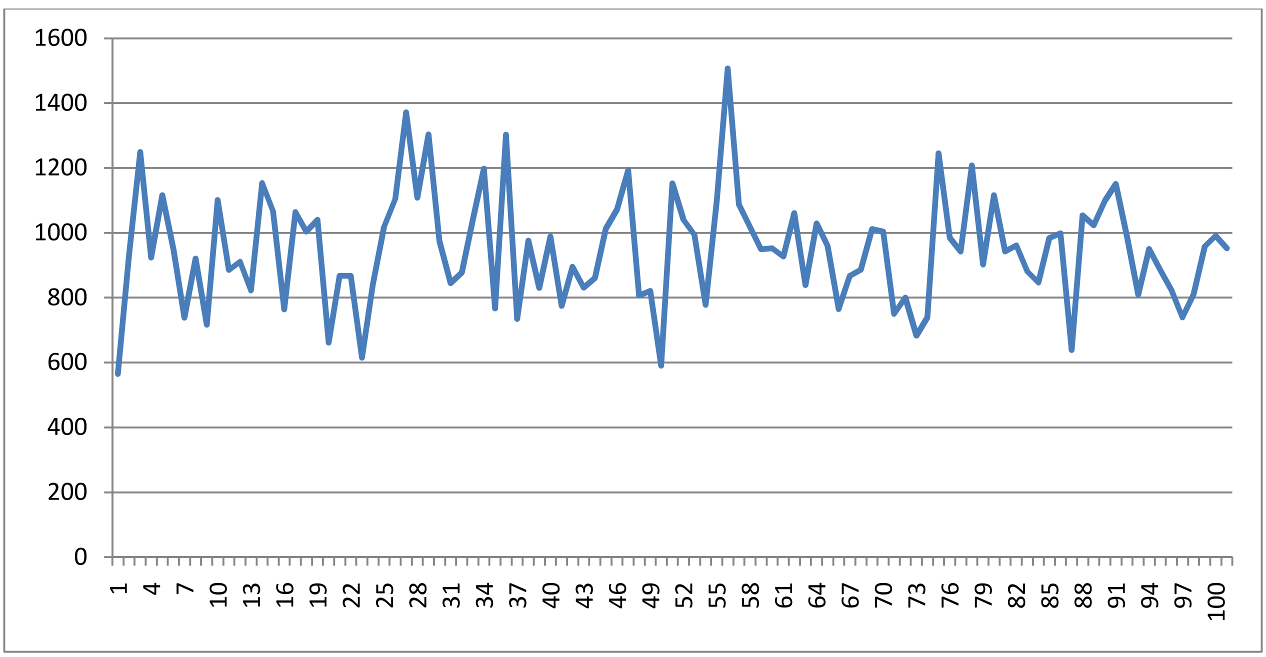
Winter

Fig.6



Summer

Fig-7



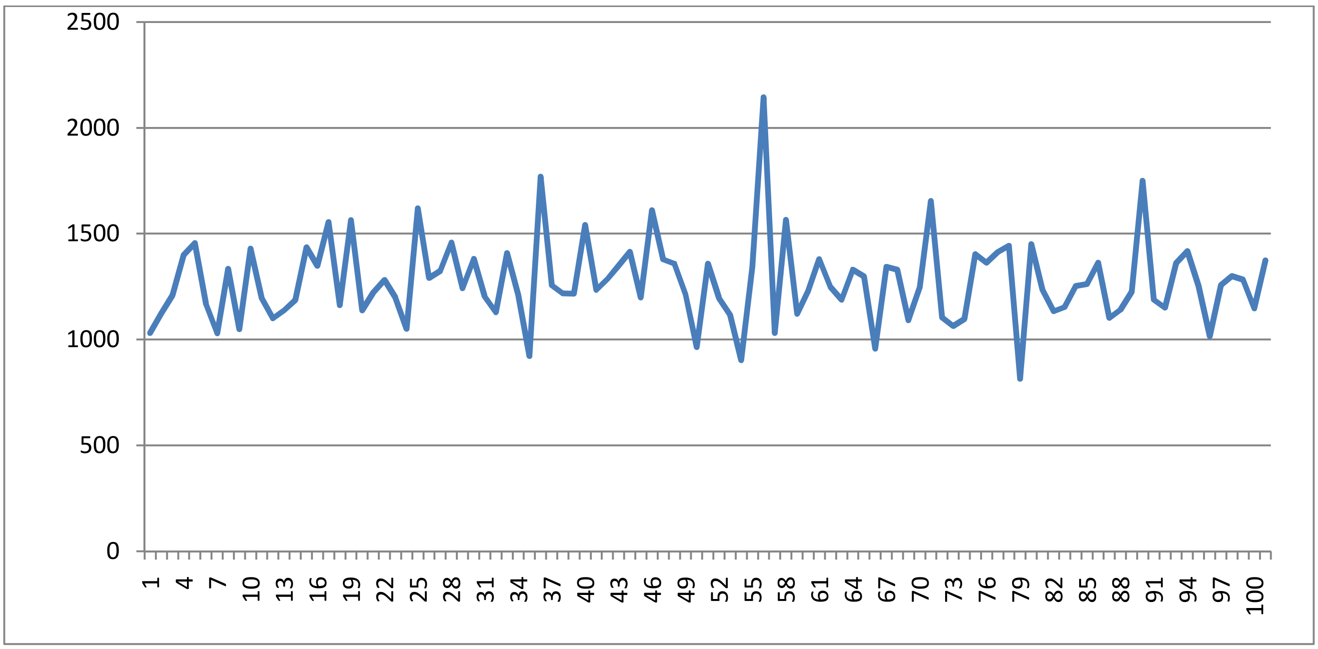
Monsoon

Fig.8

Angul

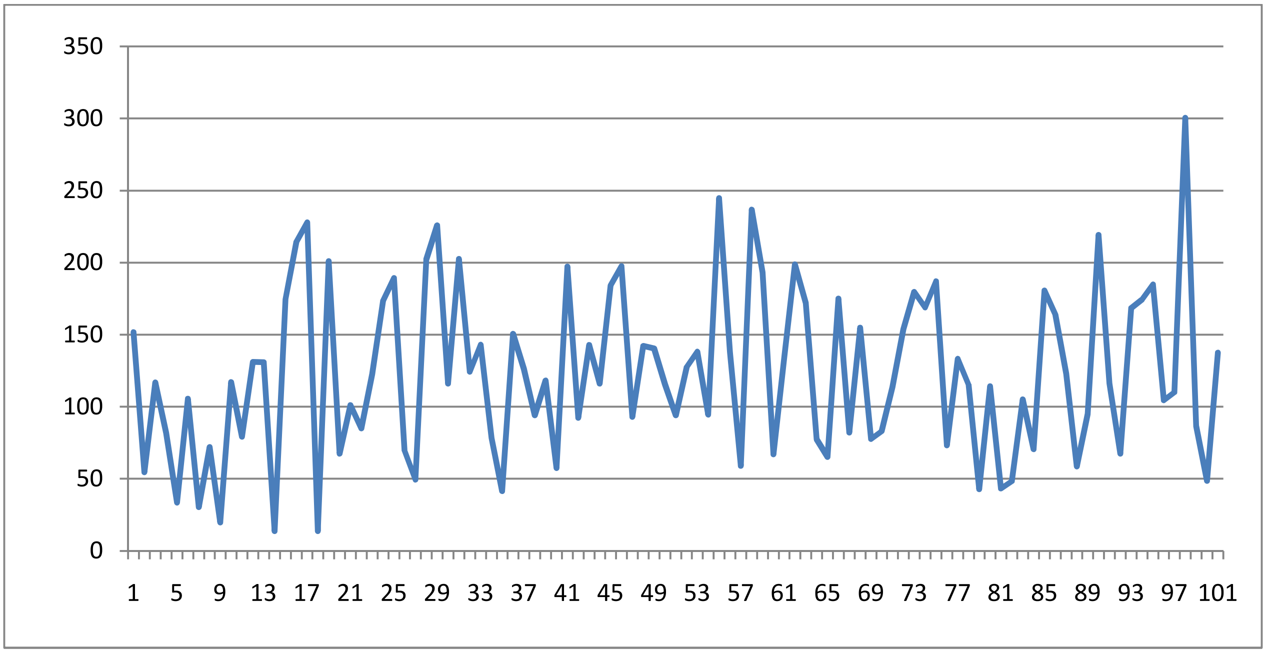
From the time series plots for Angul district the following interpretation are drawn (Ref fig .9-12)

- Average annual rainfall lies between 1000-1500mm but it does not show any trend.
- Winter season shows a periodic trend of increasing and decreasing rainfall with a maximum rainfall of 300mm in the year 1998.
- Summer season rainfall for Angul is increasing progressively with the years.
- Average rainfall is about 1000 mm and no trend is observed.



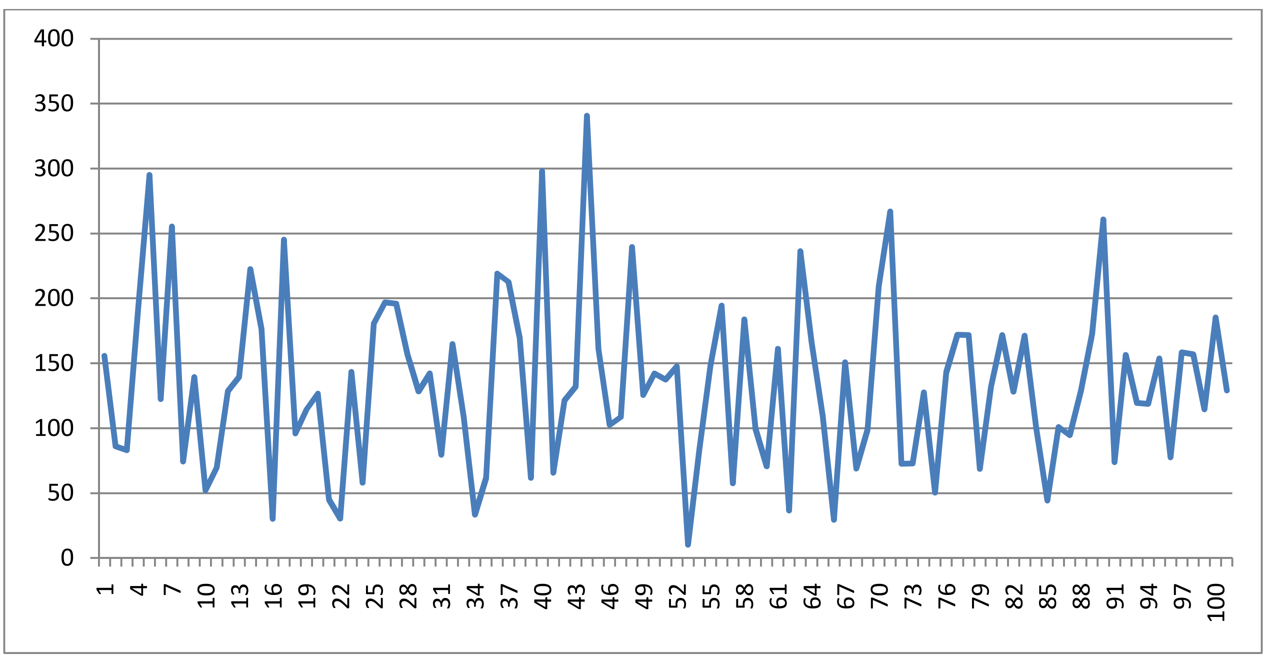
Annual

Fig.9



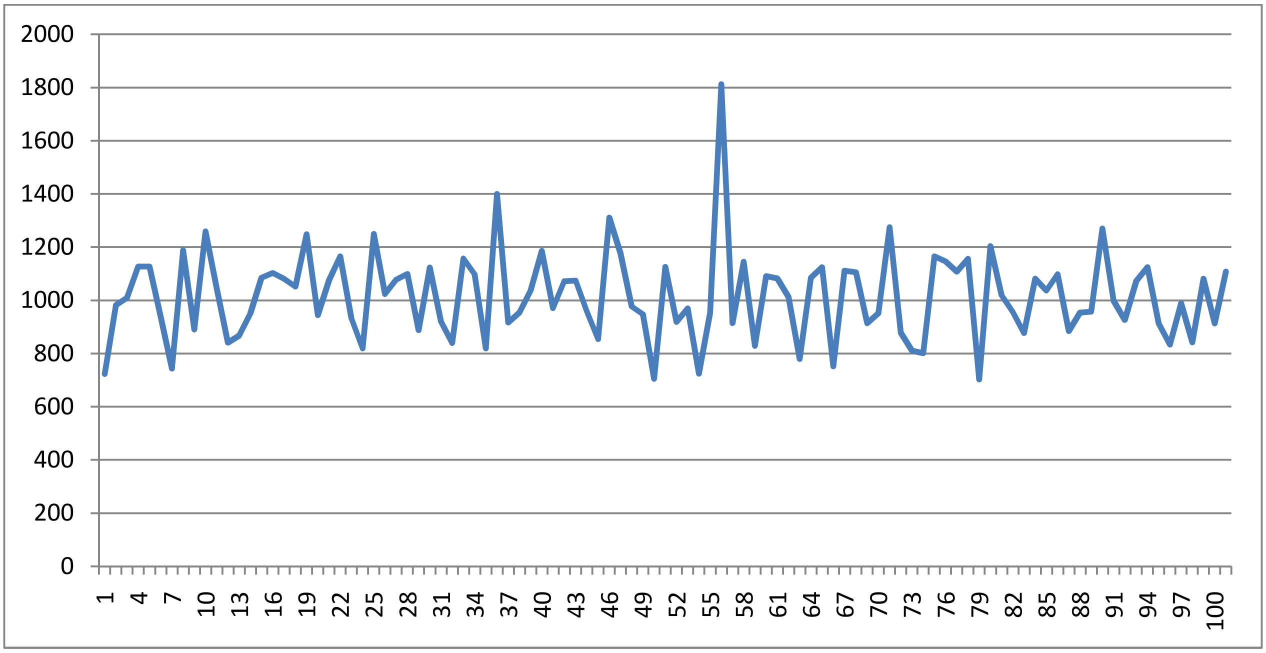
Winter

Fig.10



Summer

Fig.11



Monsoon

Fig.12

6.2 Inter Station Correlation

Puri

From the plot obtained between distance and correlation value it is observed that Puri being a coastal district gives good correlation with its nearby coastal districts independent of the distance between them.(Ref fig.13-14)

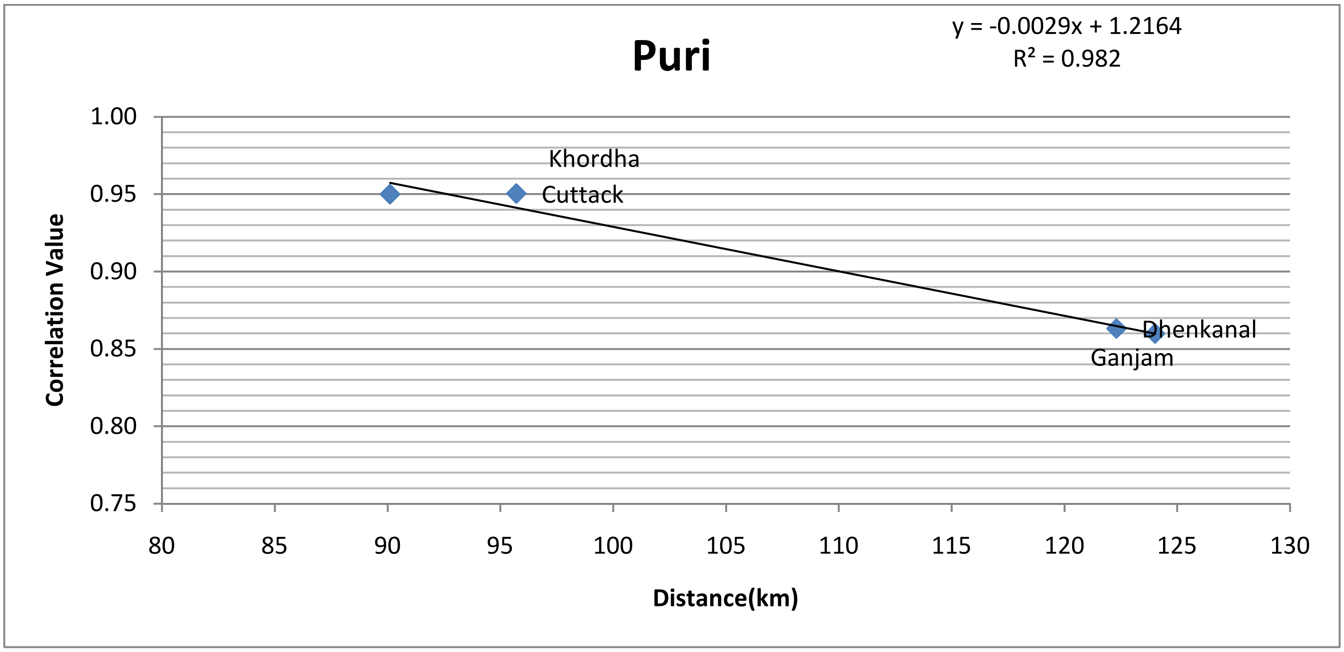


Fig.13

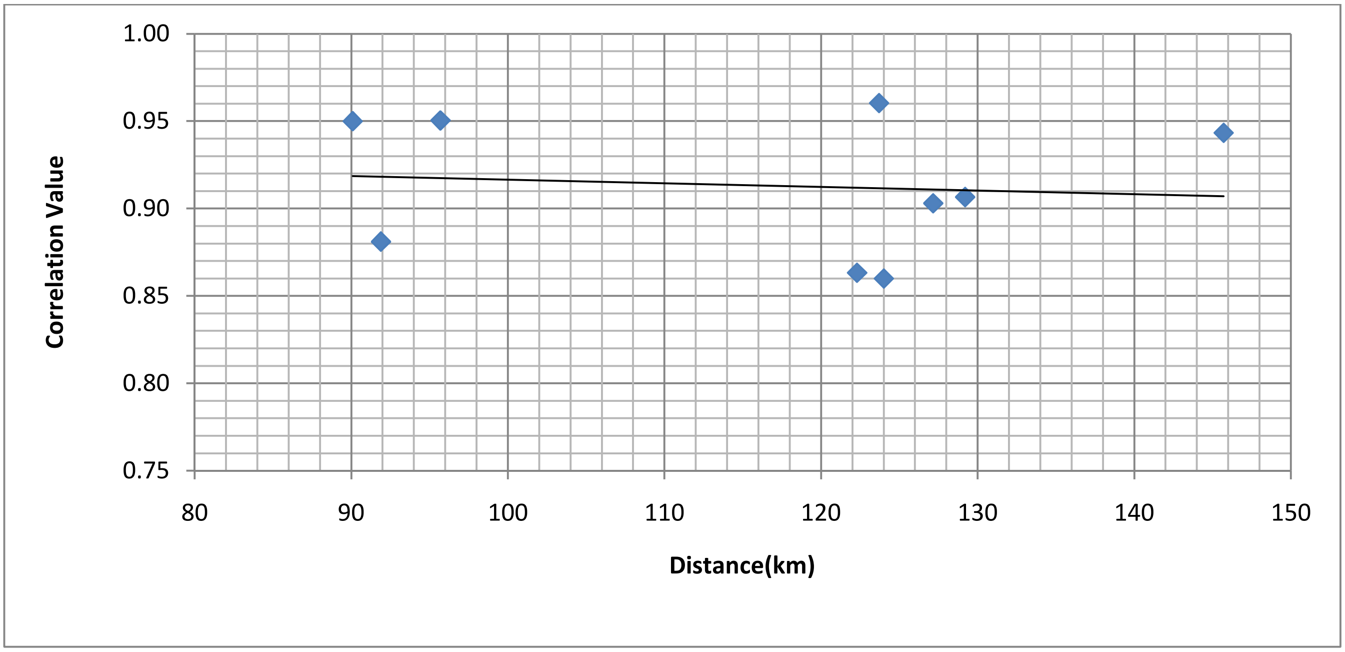


Fig.14

Koraput

Koraput does not show a good correlation with many of its neighboring districts because its topography is rough and hilly. (Fig 15-16)

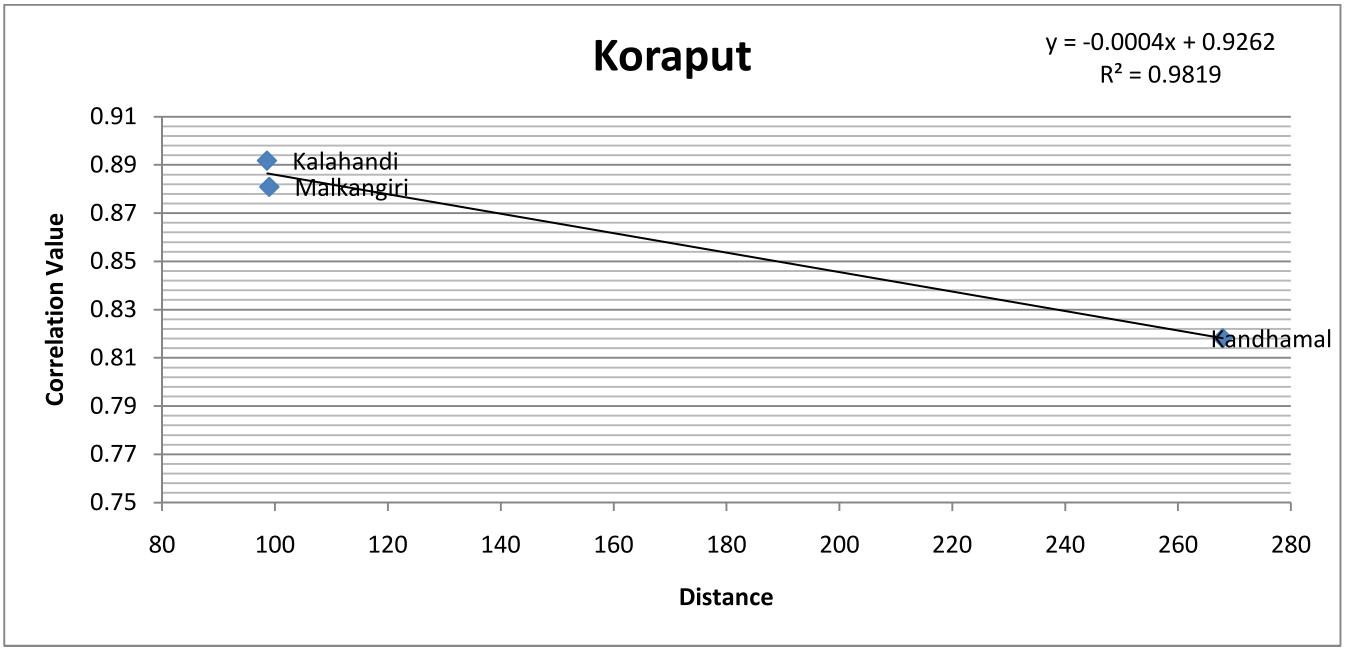


Fig.15

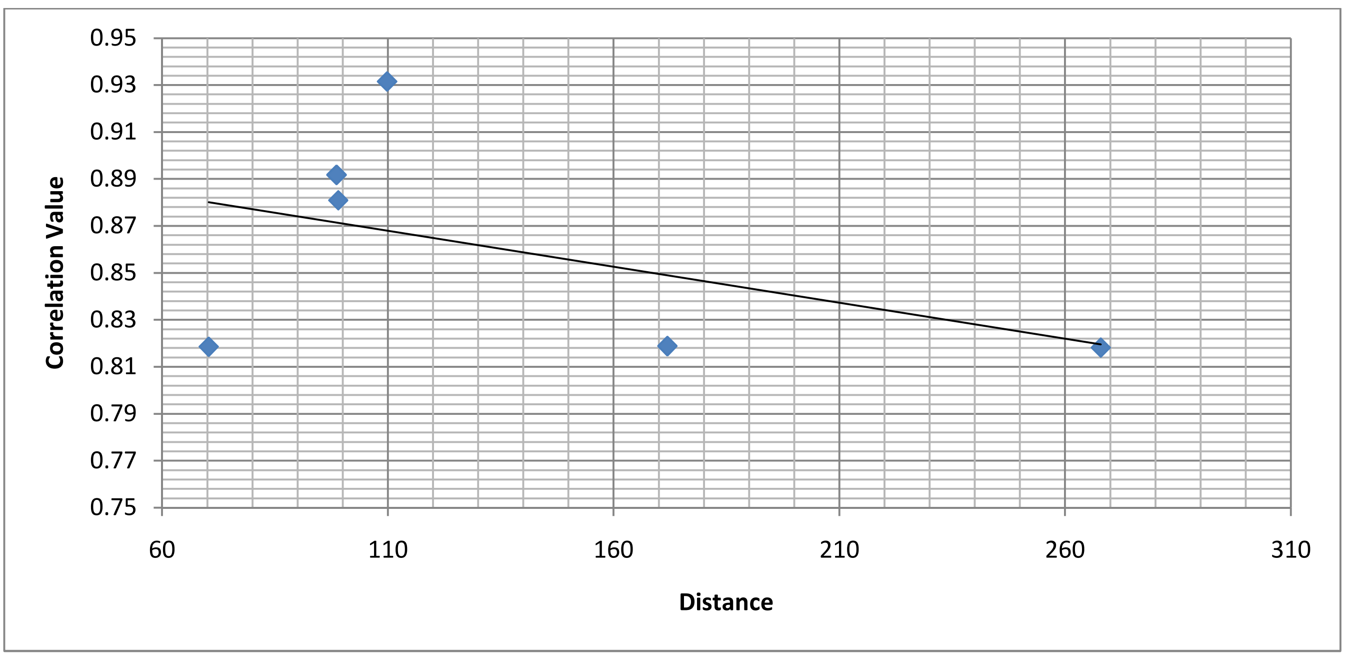


Fig.16

Angul

Angul, located in a plane land shows a uniform correlation with distance with its neighboring districts. (Fig.17-18)

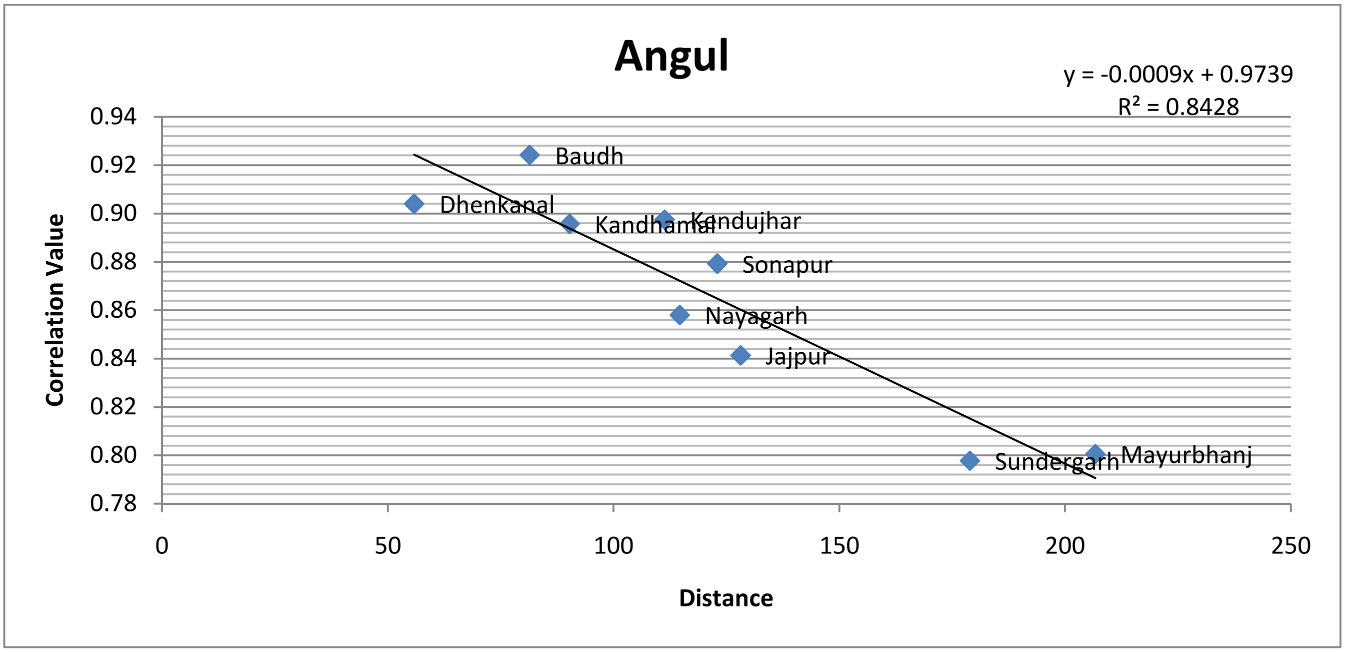

Angul
y = -0.0009x + 0.9739
R² = 0.8428
0.94
0.92
0.90
0.88
0.86
0.84
0.82
0.80
0.78
Correlation Value
Baudh
Dhenkanal
Kandhamal
Kandujhar
Sonapur
Nayagarh
Jajpur
Sundergarh
Mayurbhanj
0
50
100
150
200
250
Distance

Fig.17

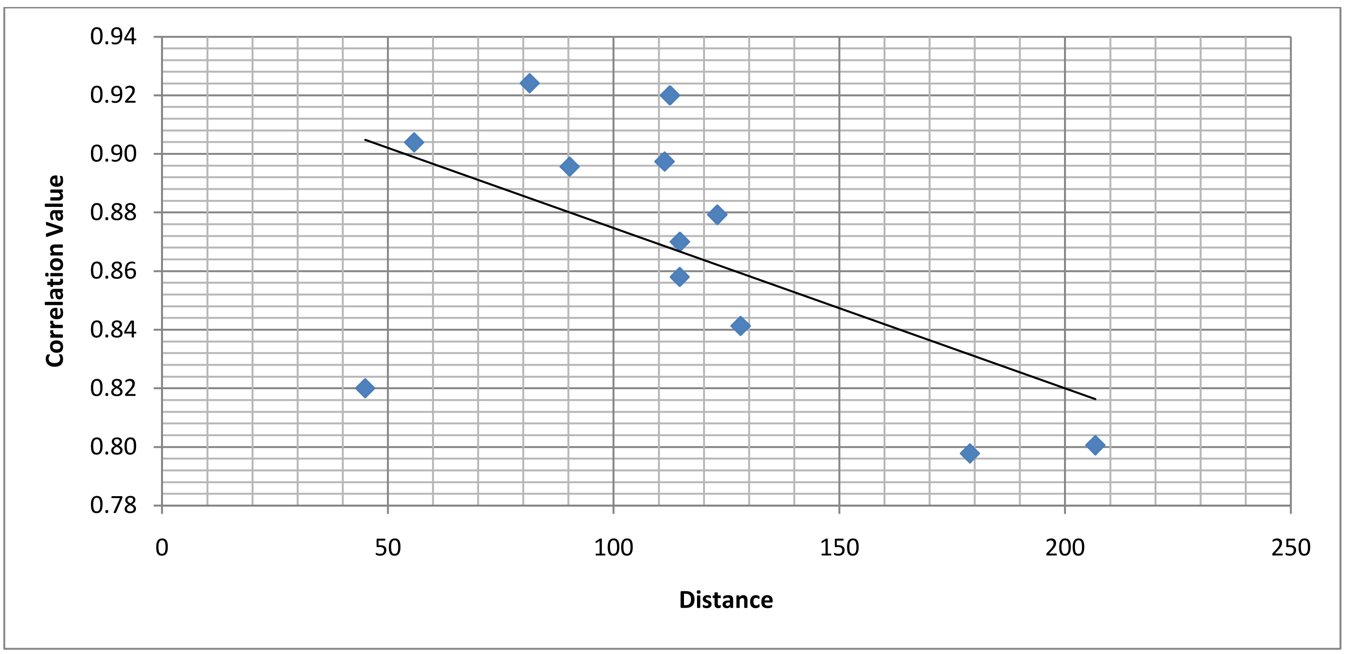

0.94
0.92
0.90
0.88
0.86
0.84
0.82
0.80
0.78
Correlation Value
0
50
100
150
200
250
Distance

Fig.18

6.3 Probability Distributions

From the Histograms plots it can be clearly seen that the heavy rainfall (1200mm-1800mm) have high frequencies and rainfall values below 1200mm and over 1800mm occurs less no. of times**.**(Fig.19-21)

Puri

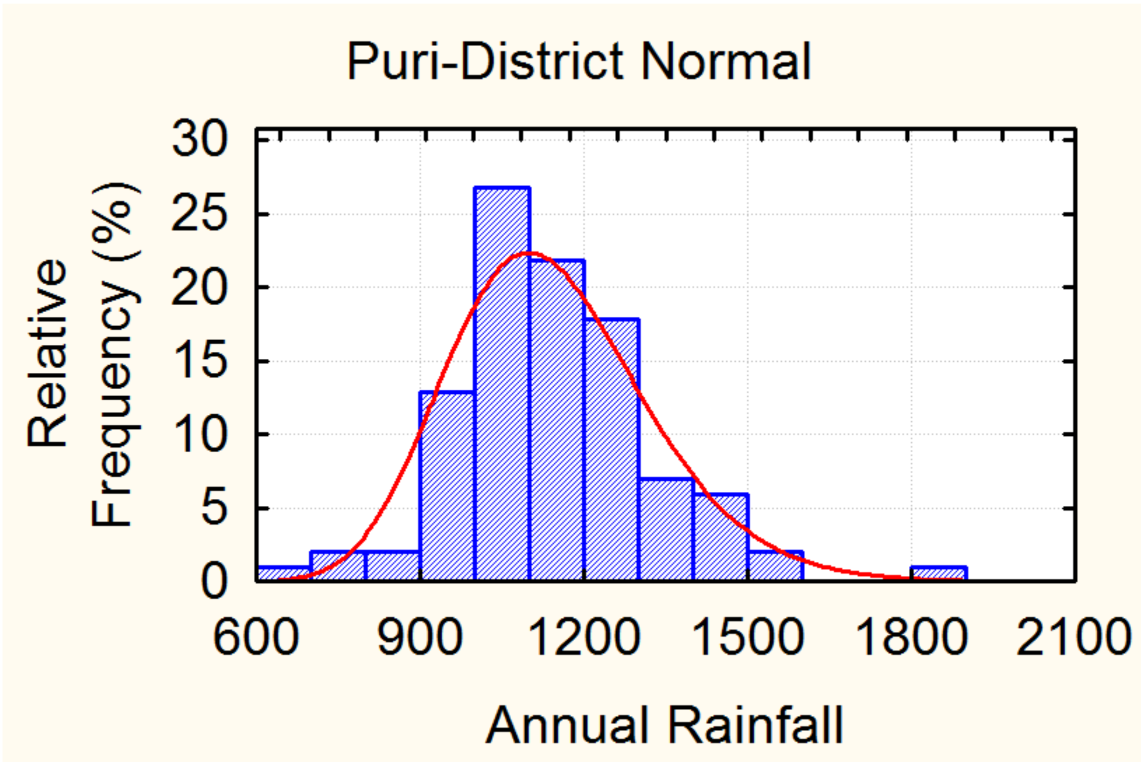


Fig.19

Koraput

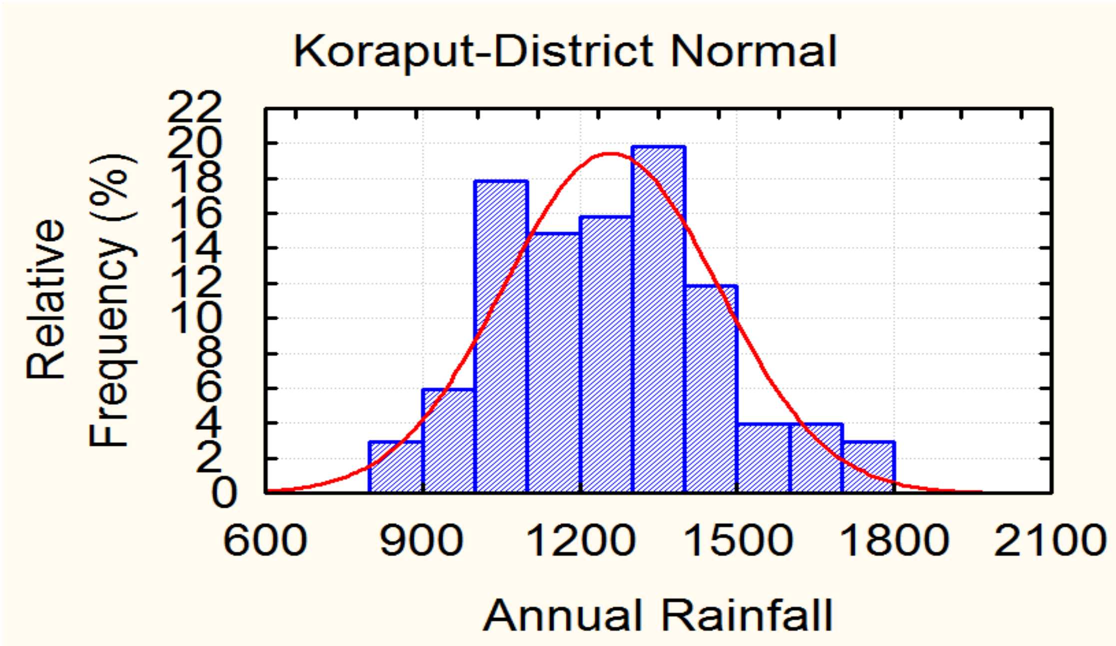


Fig.20

Angul

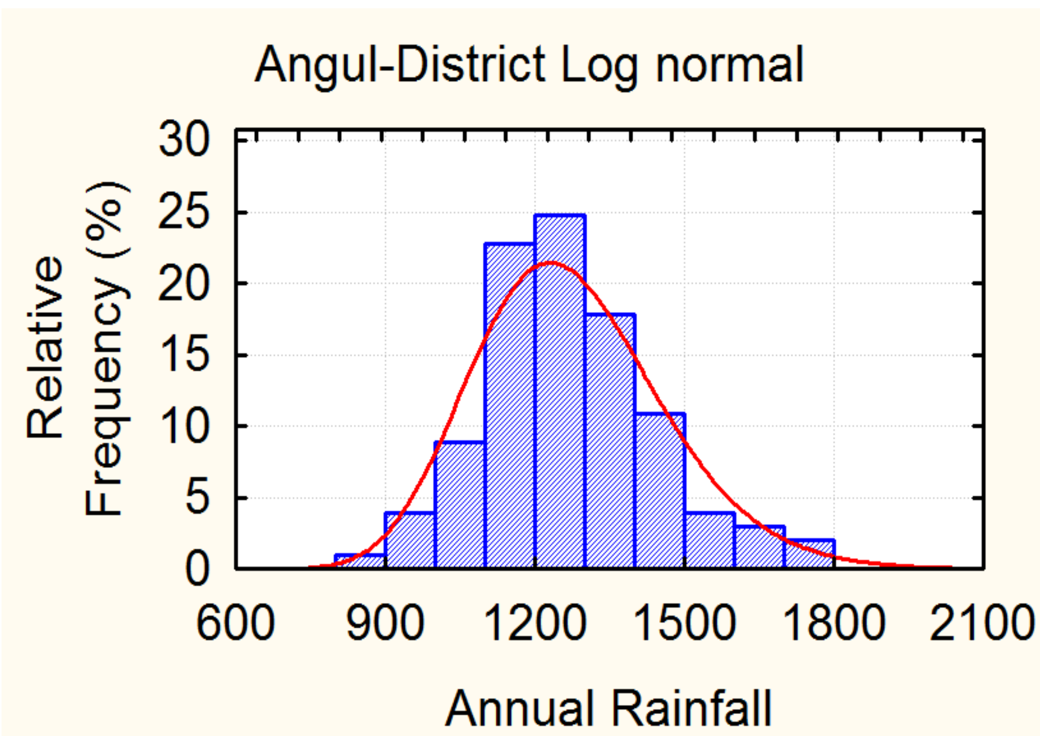


Fig.21

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