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RESEARCH ARTICLE

Time Series Analysis of Rainfall in North Bangalore Metropolitan Region using Remote Sensing & Geographic Information System Techniques

***Ramesh L Dikpal[1] and T J Renuka Prasad[2]**

1. Research Scholar, Department of Geology, Bangalore University, Bangalore, Karnataka, India
2. Professor, Department of Geology, Bangalore University, Bangalore, Karnataka, India.

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****Corresponding Author***

Ramesh

Abstract

Rainfall studies are of utmost utility for understanding nature & hence the behaviour of climate changes. Time series is a set of observations taken at specified times usually at equal interval. The inherent variability displayed by many hydrological time series usually mask trends and periodic patterns. This situation has often led to "something" the original time series so that the effects of random variations are reduced and trends or cyclical patterns enhanced. Thus a set of data depending on time is called a Time series. Here, Rainfall series represent the time series. The time series analysis is helpful to compare the actual performance and analyse the cause of variations. By comparing different time series we can draw important conclusion. Graphical method implies in increasing trend for pre-monsoon, south-west monsoon, north-east monsoon and annually.Geo- informatics module consists of GIS mapping for Location map, Geomorphology map and Season wise Rainfall maps are generated. Autocorrelation indicates the periodicity observed as 37,16 & 6 years (PM), 12, 37 & 16 years (SWM), 8, 18 & 6 years (NEM) and 16, 22 & 8 years (Annual) respectively. Power spectral depicts the cyclicity of 37, 4 & 3 years (PM), 2, 4& 2 years (SWM), 3, 7 & 2 years (NEM) and 2, 4 & 2 years (Annual) respectively. Moving average displays prominent positive correlation coefficients at lags of 18 to 42 years in PM & SWM and 12 to 24 years in NEM & Annual. The southwest and southeast parts of the study area experience the heavy rainfall whereas the least rainfall areas are the northern parts of the study area.The short term and long term cyclicity observed in Autocorrelation, power spectrum and Moving Average. Spatial variation of rainfall for the three seasons and annual has been studied

Introduction

Changing precipitation pattern and its impact on surface water resources is an important climatic problem facing society today. Associated with global warming, there are strong indications that rainfall changes are already taking place on both the global and regional scales (Vyas et al., 2012). Spatial differences in trends can occur as a result of spatial differences in the changes in rainfall and temperature and spatial differences in the catchment characteristics that translate meteorological inputs into hydrological response (Burn and Elnur, 2002). Trend is present when a time series exhibits steady upward growth or a downward decline, at least over successive time periods. Trend may be loosely defined as "long-term change in the mean level", but there is no fully satisfactory mathematical definition. But trend analysis helps in finding 'forecasting'. The base of scientific forecasting is statistics. Trend analysis was carried out to examine the long term trends in rainfall over different subdivisions. The rainfall trend is very crucial

for the economic development and hydrological planning for the country. Long term trends of Indian Monsoon rainfall for the country as a whole as well as for smaller regions have been studied by several researchers.

In this paper, several approaches have been proposed for analysing time series such as Graphical, Auto Correlation, Power Spectrum, Smoothed Power Spectrum and Moving Average method. Geo- informatics module consists of GIS mapping for location map, Geomorphology map, Forest map, and Seasonal & Annual Rainfall maps are generated.The purpose of this research is to detect best trend for the time series taken into account. In recent years the techniques of forecasting have improved to a marked degree and are applicable everywhere. Though there are several methods, techniques have been developed in finding the trend and forecasting, the finding suitable method is an important task, because the rainfall trend is very crucial for the economic development and hydrological planning for the country.

Material and Methods

The study area encompasses a geographical area of 4,665 km^2 (**Fig:** 1) between 800 m and 1800 m altitude above mean sea level and the study area lies between latitude 12.50°N to 13.30°N and longitude 77.00°E to 78.10°E in Survey of India (1:50,000) Toposheet Nos. 57G/4, 57G/7, 57G/8, 57G/11, 57G/12, 57G/15, 57G/16, 57H/1, 57H/5, 57H/9 and 57H/13.

The study area covers seven taluks namely Bangalore North, Magadi, Nelamangala, Doddaballapura, Devanahalli, Hoskote and Malur. For the present study monthly accumulated rainfall data was collected for the period of 1901 to 2010 from India Meteorological Department (IMD) and Karnataka State Natural Disaster Monitoring Centre (KSNDMC), Bangalore and obtained seasonal and yearly rainfall over the region. The rainfall pattern in the study area was classified as Pre-Monsoon (January-May), South-West Monsoon (June–September) and North-East Monsoon (October–December).

The summary statistics like Mean, Median and Standard deviation have been analyzed to study the cyclicity of rainfall to by Power spectrum; Moving Average and Autocorrelation methods for period of 110 years using FORTRAN programme. The spatial variation of rainfall indifferent seasons and annual is obtained using GIS platform. The forest region has been delineated using remotely sensed data. The geomorphology (**Fig.** 2) studies will be correlated to rainfall for the water management purposes.

Result and Discussion

a. Geomorphology

Geomorphology reflects various landforms and structural features. Many of these features are favorable for the occurrence of groundwater and are classified in terms of groundwater potentiality. These units are deciphered from the remote sensing data, generated by using ArcGIS software are shown in **Fig.** 2. The major geomorphological units found in the study area are Denudational Hills, Pediplain, Plateau and Structural Hills. These are briefly described as follows:

Denudational hills (DH): These are formed due to differential erosion and weathering. Erosion and Weathering in the study area are majorly depends on rainfall. Denudational hills occupy the northern and western edge of the area. The groundwater prospect in his zone is negligible.

Pediplain: This unit will be developed as a result of continuous processes of pedimentation. The latitudinal variations are relatively high for rolling plain to the extent of 5-10 m. These areas are described as nearly flat terrain with gentle slope. The area is underlain by relatively thick weathered material.

Plateau: Flat topped and arcuate arc showing definite trends. Comprises thin veneer of soil, which varies from place to place, scanty vegetation Weathering is also found at some places.

Structural Hills (SH): Structural hills are linear or arcuate hills exhibiting definite trend. These hills are structurally controlled with complex folding, faulting and crisscrossed by numerous joints/fractures, which facilitate some infiltration and mostly act as run off zones. These units are found in the northern and eastern parts of the study area.

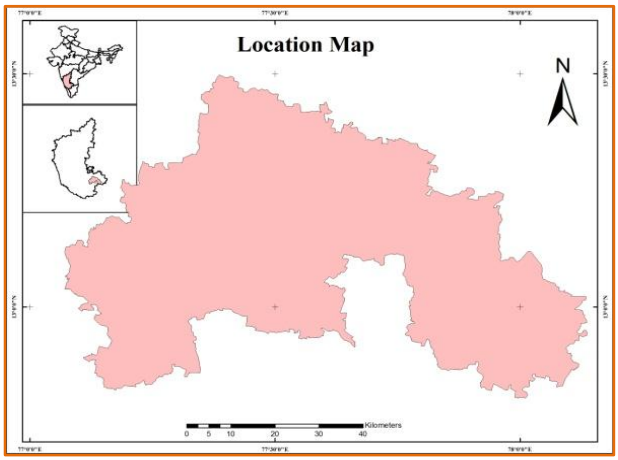


Figure 1: Location Map of North Bangalore Metropolitan Region

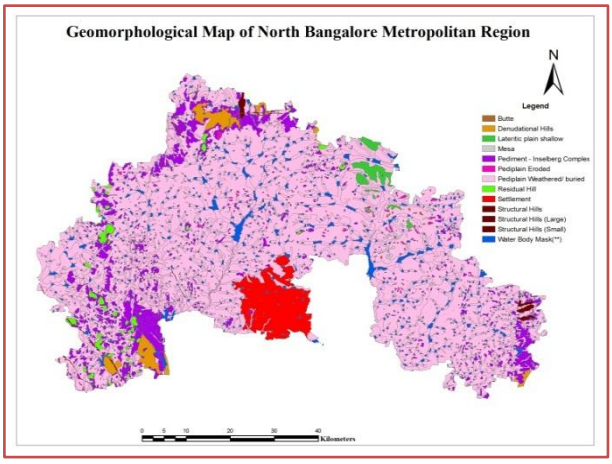


Figure 2: Geomorphology Map

In the study area, majorly exists Pediplains (3946 Sq. km), Denudational Hills (124.9 Sq.km), Plateau (12.6 Sq.km) and Structural Hills (24.9 Sq.km). Eastern part of the study area experiences 700-800mm rainfall and Western part of the study experiences 800-891 mm of rainfall. The rainfall is positively correlating to the Pediment (Inselberg Complex) as well as Residual hills of the study area. The study reveals more scope for infiltration and leads to take up ground water recharge very effectively.

b. Trend Analysis

The annual rainfall series in respect of seven and adjacent taluk rain gauge stations data were verified for the presence of trends by applying the one or more of the below maintained methods.

i. Graphical method of Trend analysis
ii. Auto Correlation
iii. Power Spectrum
iv. Smoothed Power Spectrum
v. Moving Averages (5, 7, 9 and 11 years)

i. *Graphical Method of Trend analysis:*

In Graphical method by (**Fig:**3.1 to 3.4), seasonal precipitation for all season's viz., Pre-Monsoon, South-West Monsoon, North-East Monsoon and Annual are presenting increasing in trend of 70 to 80 mm for pre-monsoon, 350 to 450 mm for south-west monsoon, 200 to 225 mm for north-east monsoon and 700 to 850mm annually.

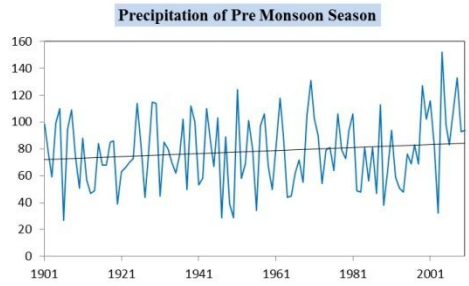


Figure 3.1: Pre Monsoon Season

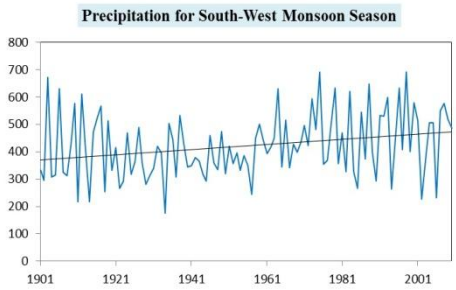


Figure 3.2: South-West Monsoon Season

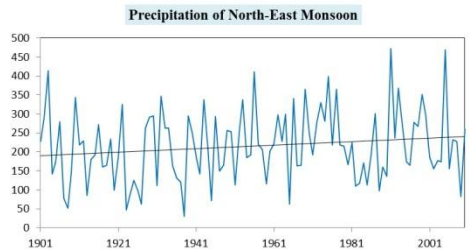


Figure 3.3: North-East Monsoon Season

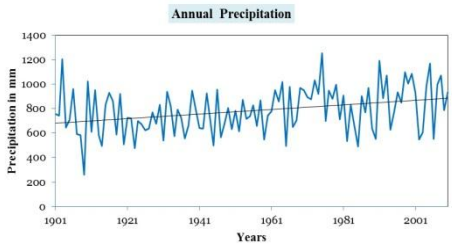


Figure 3.4: Annual Trend Graph

ii. ***Auto Correlation:***

Autocorrelation is the cross-correlation of a signal with itself. Informally, it is the similarity between observations as a function of the time lag between them. It is often used in signal processing for analyzing functions or series of values, such as time domain signals. Autocorrelation coefficients ranges lag 6 to 37years have been determined for seasonal as well as annual **Fig**: 4.1 to 4.4. Periodicity observed as 37,16 & 6 years (PM), 12, 37 & 16 years (SWM), 8, 18 & 6 years (NEM) and 16, 22 & 8 years (Annual) respectively.

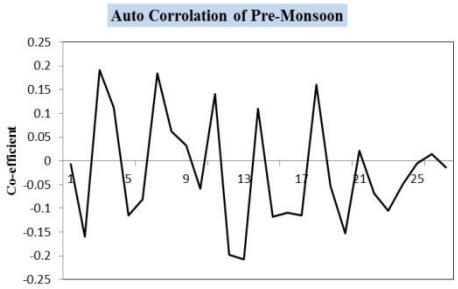


Figure 4.1: Auto Correlation of Pre-Monsoon

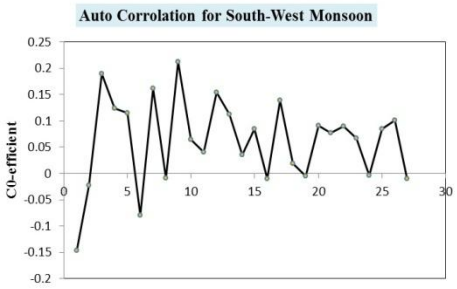


Figure 4.2: Auto Correlation of SW Monsoon

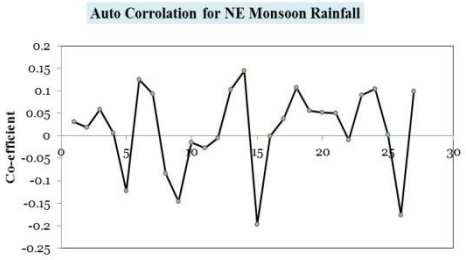


Figure 4.3: Auto Correlation of NE Monsoon

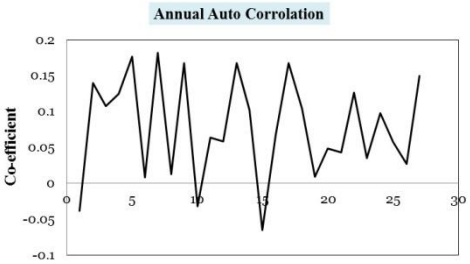


Figure 4.4: Annual Auto Correlation

iii. ***Power Spectrum***

The Periodicities have been calculated using Fourier series method and power spectrum plotted in **Fig:**5.1 to 5.4 indicates that their exists periodicity in the PM as 37, 4 &3 years, SWM as 2, 4 &2 years, NEM as 3, 7 & 2years and Annual as2, 4&2years. The periodicity ranges from 2 to 37 years in this method.

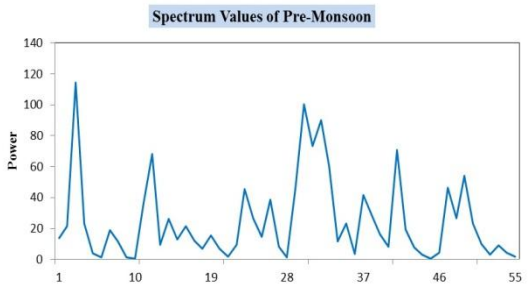


Figure 5.1: Power Spectrum of Pre-Monsoon

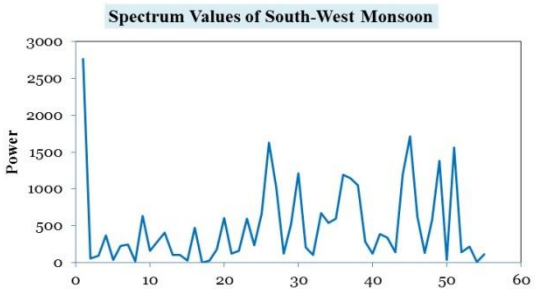


Figure 5.2: Power Spectrum of SW Monsoon

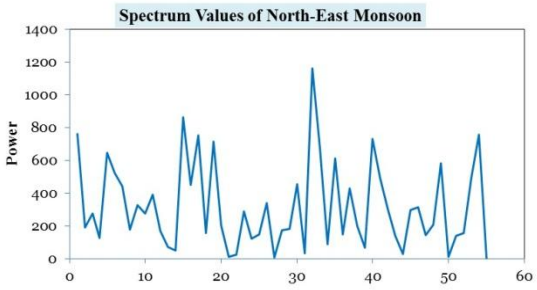


Figure 5.3: Power Spectrum of NE Monsoon

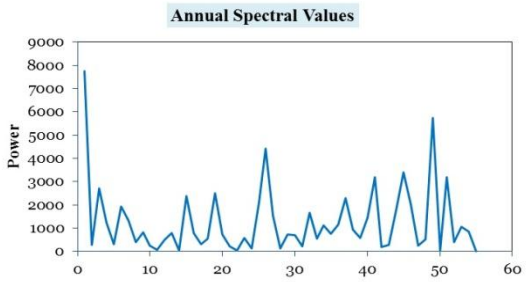


Figure 5.4: Annual Power Spectrum

iv. ***Smoothed Power Spectrum:***

The Periodicities have been calculated using smoothed power spectrum plotted in **Fig:**6.1 to 6.4 indicate that exists periodicity in the PM, SWM,NEM and Annual are(3, 4 &3)years, (2, 4&3) years, (3, 3 &7)years and (4, 2 & 55)years respectively. The periodicity ranges from 2 to 55 years in this method.

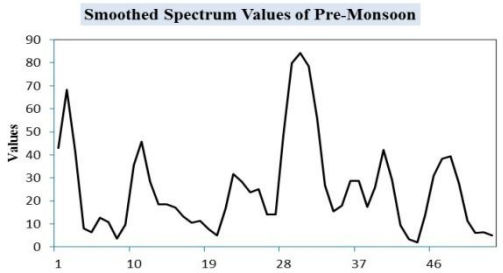


Figure 6.1: Smoothed Spectrum Values of Pre-Monsoon

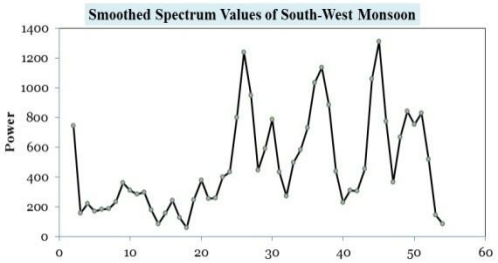


Figure 6.2: Smoothed Spectrum Values of SW Monsoon

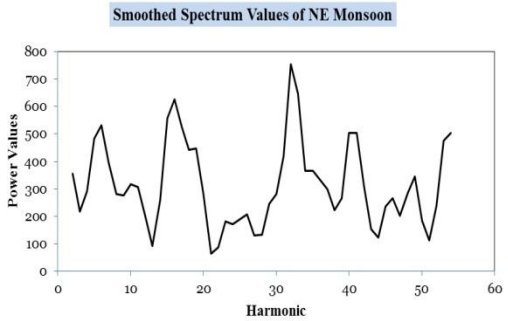


Figure 6.3: Smoothed Power Spectrum Values of NE Monsoon

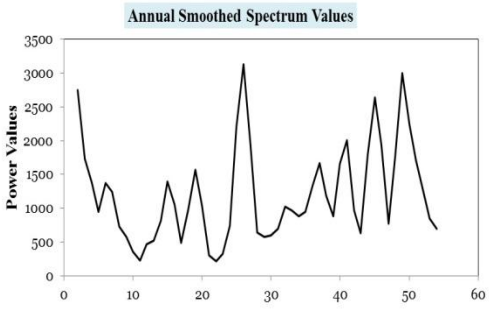


Figure 6.4: Annual Smooth Spectrum Values

Similarity of frequencies is existing for Power Spectrum and Smoothed Power Spectrum Values of Pre Monsoon, South-West Monsoon, North-East Monsoon and Annually.

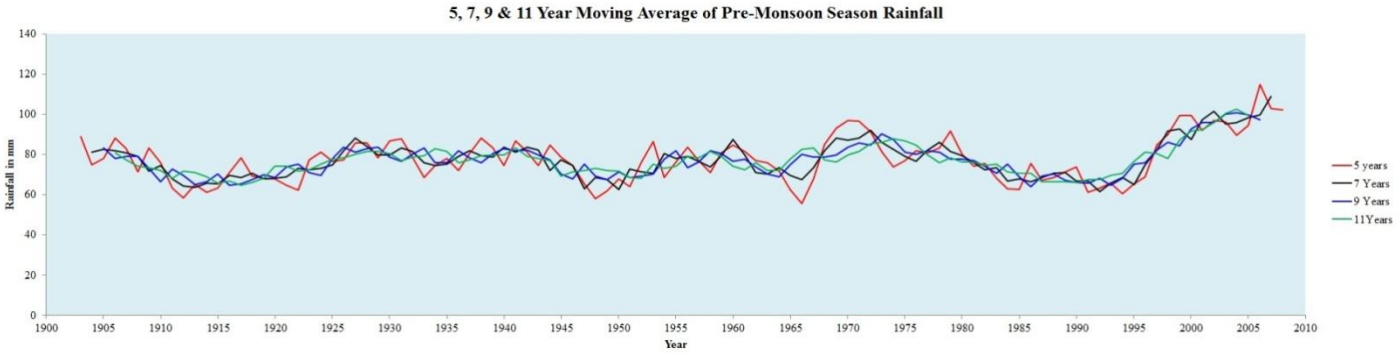
Table 1: Frequencies obtained by spectral analysis.

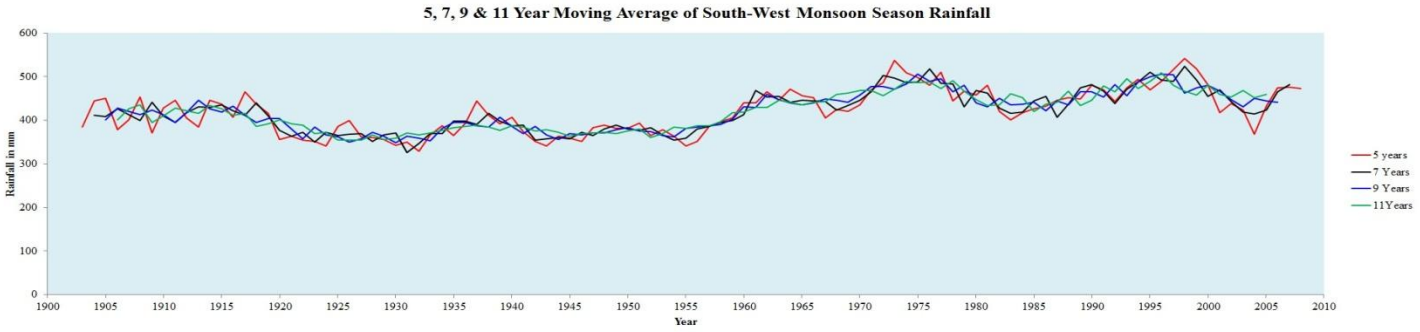
	Harmonic Value			Year			Power		
	AC	PS	SPS	AC	PS	SPS	AC	PS	SPS
Pre Monsoon	3	3	31	37	37	3	0.2	114	84.2
	7	30	30	16	4	4	0.2	100	80
	18	32	32	6	3	3	0.2	90.1	78.5
South-west Monsoon	9	45	45	12	2	2	0.2	2764	1311
	3	26	26	37	4	4	0.2	1715	1237
	7	51	37	16	2	3	0.2	1633	1133
North-East Monsoon	14	32	32	8	3	3	0.1	1159	756
	6	15	33	18	7	3	0.1	863	648
	18	54	16	6	2	7	0.1	761	628
Annual	7	49	26	16	2	4	0.2	5727	3126
	5	26	49	22	4	2	0.2	4419	3001
	13	45	2	8	2	55	0.2	3387	2754

AC- Autocorrelation**, PS-** Power Spectrum**, SPS-** Smoothed Power Spectrum

v. ***Moving Average (5, 7, 9 & 11 Years):***

Moving average is the important method of understand the periodicity of rainfall. One of the simplest, and perhaps most common, smoothing technique employed is that of fitting a moving average (e.g., Thompson and Ibbitt, 1978, Tomlison, 1980b), In the case of simple moving average, all values are weighted equally.





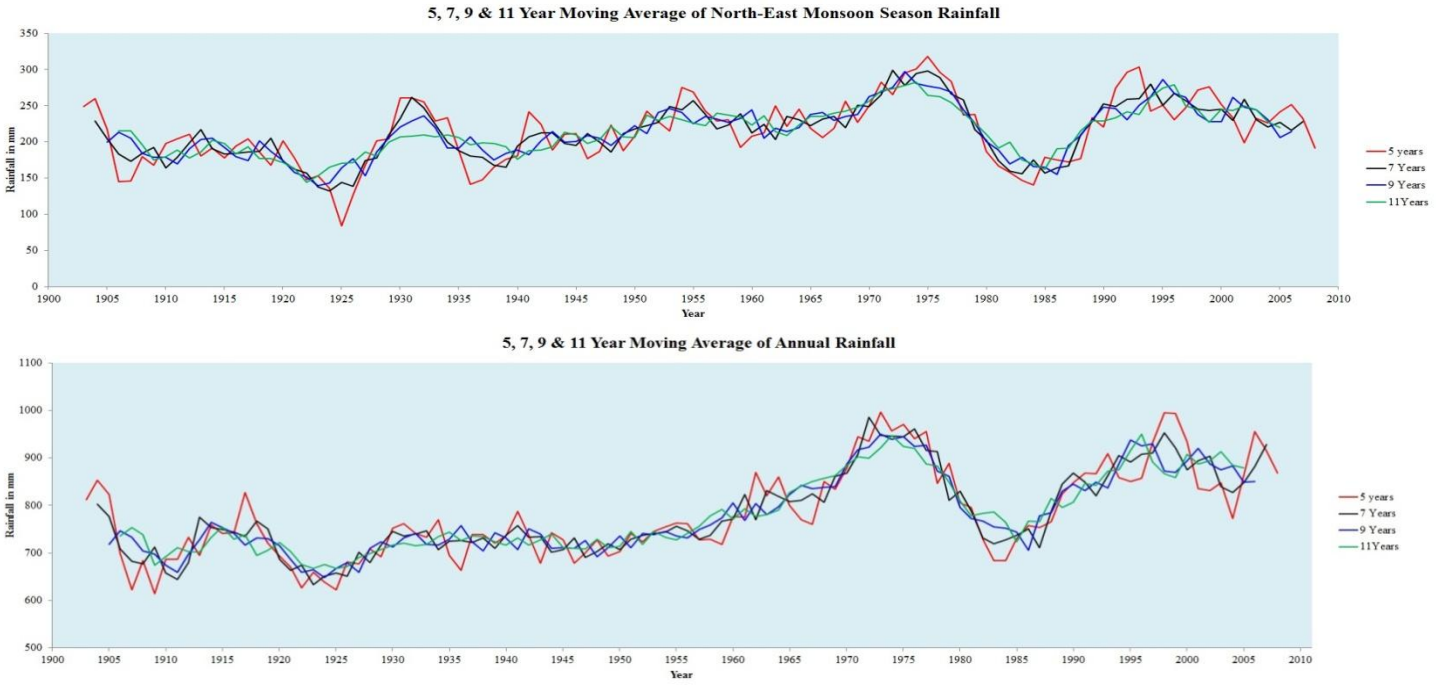


Figure 7: Moving Average of 5, 7, 9 and 11yearsfor **(a)** of Pre-Monsoon, **(b)** SW-Monsoon, **(c)**NE-Monsoon and **(d)** Annual.

In Pre-Monsoon season the Moving Average of 5, 7, 9 and 11years are 7 to 47 years and followed by South-West Monsoon season having 13 to 60 years, North-East Monsoon season is 17 to 41 years and annually as 11 to 46 years. Normal moving average for 5, 7, 9 & 11 years of all seasons represents7to 57 years.

Table 2: Season wise Moving average analysis of Rainfall

Years	Pre Monsoon	South-west Monsoon	North-East Monsoon	Annual	Average
5	29,7	20,36,25	23,21,18	13,45,25	7 to 57
7	33,12,30	43,15,22	41,23	57,11,26	
9	21,47,30	49,13,21	21,20,22	46,13,22	
11	33,29	60,22	17,22	44,22	

vi. ***Seasonal and Annual Rainfall***

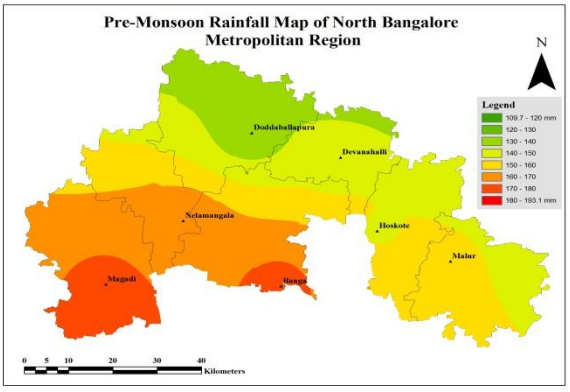


Figure 8.1: Pre-Monsoon Rainfall Map

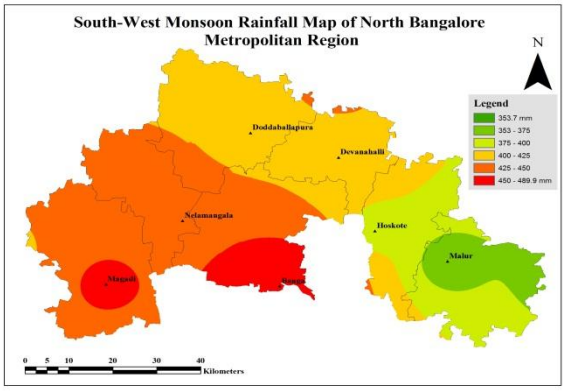


Figure 8.2: South-WestMonsoon Rainfall Map

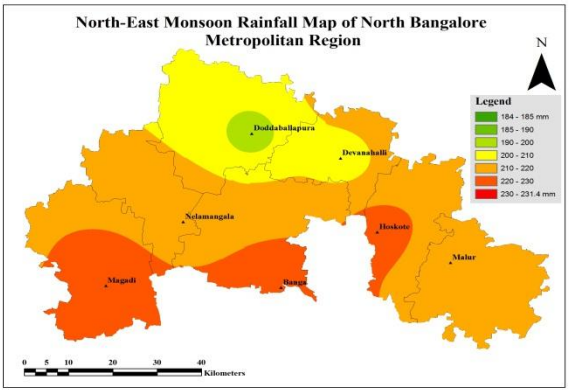


Figure 8.3: North-EastMonsoon Rainfall Map

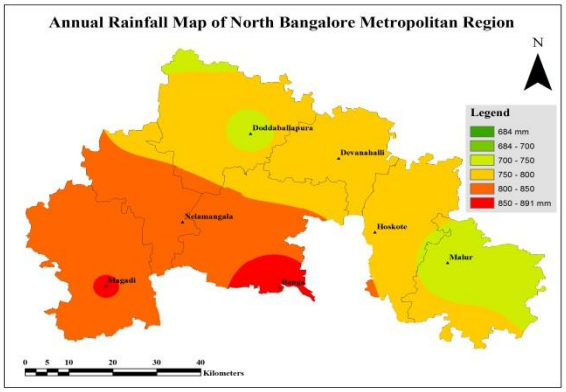


Figure 8.4: Annual Rainfall Map

Table 3: Seasonal and Annual average Rainfall

Sl No	Taluk	PM	SWM	NEM	ANNUAL
1	Bangalore North	176	490	225	891
2	Devanahalli	147	406	205	759
3	Doddaballapura	134	410	196	740
4	Hosakote	148	385	224	757
5	Nelamangala	166	447	218	831
6	Magadi	173	454	225	852
7	Malur	151	358	214	722

The rainfall maps of all seasons and annual proves the Köppen Classification system of Climatic zones for the study area as follows:

1. Semi Arid Zone (Western part)
2. Tropical Wet and Dry (Eastern part)

The rainfall of study area experiences 109.7 to 193.1 mm in Pre-Monsoon, 353.7 to 489.9 mm in South-West Monsoon, 184 to 321.4 mm in North-East Monsoon and 684 to 891 mm annually is presented in **Table 3**.South-Western part of the study area is experiences heavy rainfall and North-Eastern part is experiencing least rainfall.

Conclusion

The rainfall maps of all seasons and annual proves the Köppen Classification system of Climatic zones for the study area. Rainfall being the only source of water in the region, sustenance of the forest depends on amount of rainfall, water availability in the year. The knowledge of excess or drought in the study area is important from the water management point of view. Artificial recharge and creation of water bodies in this region may be considered effectively. From the graphical method indicates the increasing trend of rainfall for Pre-monsoon, South-West Monsoon, North-East monsoon and annually. The study reveals that the periodicity varies from 5to 57years by moving average study; 6 to 37 years by autocorrelation study, 2 to 37 years by Fourier spectral analysis and2 to 55 years by smoothing Fourier analysis. Rainfall in the study area is influencing in South-Western part for Pre-monsoon, South-West Monsoon, North-East monsoon and annually. The southwest and southeast parts of the study area experience the heavy rainfall whereas the least rainfall areas are the northern parts of the study area.The short term and long term cyclicity observed in Autocorrelation, power spectrum and Moving Average.

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