Trend Analysis of Rainfall and Temperature of Patiala City

A Thesis Submitted in Fulfilment of the Requirement for the Award of

the Degree of

MASTER OF ENGINEERING

in

INFRASTRUCTURE ENGINEERING

Submitted by

GURNOOR SINGH

(801723011)

Under Supervision of

Dr. Dwarikanath Ratha

Associate Professor

Department of Civil Engineering

Thapar Institute Of Engineering & Technology

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

DEPARTMENT OF CIVIL ENGINEERING

THAPAR INSTITUTE OF ENGINEERING & TECHNOLOGY

PATIALA, PUNJAB

JULY 2019

DECLARATION

I hereby declare that this work which is being presented in the thesis entitled"Trend Analysis of Rainfall and Temperature of Patiala city " in partial fulfillment of the requirement for the award of degree of Master of Engineering in the field of Civil Engineering with specialization in Infrastructure Engineering submitted at Thapar Institute of Engineering & Technology (Patiala) is an authentic record of my own work carried out during the period from 07.01.2019 to 30.07.2019 under the guidance of Dr. Dwarikanath Ratha.

The matter embodied in this thesis has not submitted by me for the award of any other degree or diploma.

Date: 31-07-2019

Place: Patiala

(GURNOOR SINGH)

Roll No. 801723011

This is to certify that the above declaration made by the student concerned is correct according to best of our knowledge and belief.

30/7/19

Dr. Dwarikanath Ratha

Associate Professor, CED

Thapar Institute of Engineering & Technology

Patiala.

ACKNOWLEDGEMENT

A thesis can't be finished without the assistance of numerous individuals who contributed straight forwardly or in a roundabout way through their useful feedback in the advancement and arrangement of this work.

I am highly indebted to **Dr. Dwarika Nath Ratha**, Associate Professor of Department of Civil Engineering for their guidance and their supervision as well as for providing necessary information regarding the thesis and also for his support in completing the thesis. Mr. Sanjoy Gorai, research scholar of School of Energy and Environment, Thapar Institute of Engineering & Technology, Patiala also guided in this study.

I would like to express my gratitude towards the professors of *THAPAR INSTITUTE OF ENGINEERING & TECHNOLOGY* for their kind cooperation and encouragement which helps me completion of this thesis.

Furthermore, I might likewise want to thank all the friends and Class fellow furthermore my folks whose support helped me finish my proposition in time. I would like to extend my sincere thanks to all of them.

Gurnoor Singh

(801723011)

ABSTRACT

The temperature and rainfall are the most dominant variable of hydrological and weather studies. Any change in these variables will affect the water demand, stream flow and hydrological cycle. This study mainly focuses on detecting trends in temperature and rainfall for the Patiala city, Punjab. For this study, Mann-Kendall test is used at 5% significance level and quantified with Sen slope estimator test for the time period 1998 to 2015. The statistical analysis using box and whisker plots are also made to study the uniformity of the data. Furthermore, a correlation between the rainfall and average temperature is found out using Pearson correlation, Kendall Tau and Spearman rank correlation test. The results of Mann-Kendall test revealed that in the monthly analysis, decreasing significant trends of average temperature is found for the month of April at 0.13°C per year and an increasing significant trend of minimum temperature is seen for November month with 0.37°C per year. For the seasonal analysis, positive significant trends are seen for the average temperature in the southwest monsoon and the post monsoon season. Also increasing significant trends of maximum temperature is seen for the winter season. In the annual analysis, significant increasing trend is seen for the minimum temperature. The present study did not find any significant trend for rainfall.

The present study established the correlation between rainfall and average temperature. It is found that in the monthly analysis, significant correlations exists for the March, June, July and August months at 0.01and 0.05 significance level. Also it is found that post monsoon season is significant for the seasonally correlation between rainfall and average temperature.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1 INTRODUCTION

1.1 General

In the last few decades, it is observed that the climate of earth's atmosphere is changing rapidly. The human exercises on earth surface are changing the level of natural greenhouse gases. The increased consumption of petroleum products result in increment of the carbon dioxide (CO_2) and other greenhouse gases in atmosphere. This climate change is resulting in changes in the pattern of rainfall and temperature on earth surface. According to NASA's Goddard Organization for Space Studies (GISS), the worldwide temperature is 0.83 °C warmer than the mean of 1951 to 1980. Due to climate change, number of countries are facing changes in rainfall pattern which leads to effect hydrological cycles and ecological cycles (Dai et al. 2011). The changes in the trends of rainfall and temperature is resulting either draught or flood in that area. There are number of events occurred due to the changes in trends of rainfall and precipitation.

The increment of temperature trends results in warming the surface. The warmer air of earth surface holds more humidity and for each °C temperature, water vapour increases by seven percent. The evaporation process is escalated due to continuous rising temperatures which lead to changes in the earth's water cycle. The result is clear that the number of extreme events will increase as the affected areas will receive more rainfall and as a result, the chances of floods are greater. The pattern of wind direction also plays an important role in rainfall. It is not certain that the area facing high temperature will receive rainfall, as due to the winds the water vapour present of that region can be carried to the other regions. This situation will result in less rainfall which might lead to droughts in that area.

The temperature and rainfall are the most dominant variable of hydrological and weather studies. Any change in these variables will affect the water demand, stream flow and hydrological cycle (Jain and Kumar, 2012). Trend analysis of rainfall and temperature is generally conducted to get the knowledge regarding any abrupt climate changes.

India is majorly dependent for its water supply on the southwest monsoon which is used for the domestic use, agriculture, energy sectors, and industries. In India, the annual rainfall occurs more than 80 percent during monsoon (Kumar et al., 2010). If any significant change comes in the monsoon period due to climate change, it will severely impact the farming sector in India. The water supply is already under strain in many regions due to the increasing food demand because of constant increment in population (Mall et al., 2006). Punjab state is also experiencing the variations in rainfall and temperature from past few years. According to the IMD report on the "State level climate change trends in India" (2013), there is significant increase in rainfall trends of Punjab for the month of June by 0.51mm/year and annually decreasing trend by 2.41mm/year. For temperature, significant decreasing monthly trends were found for January and June by 0.03°C/year and 0.05°C/year.

1.2 Origin of study

The behaviour of the hydro climatic parameters is not uniformly spread all over the area; every region has its own unique pattern. Due to the increasing number of extreme events and for better management of water resources, there is need to study the changing rainfall patterns so that if natural calamities like droughts and flood occur, there should be optimum readiness against them.

The Historical trend analysis gives a better vision of the local rainfall patterns and also helps regulatory bodies to provide a better hydrological strategies to combat with natural calamities like floods and droughts with optimum water resource management (Bisht et al. 2018).

1.3 Need of study

Exceptionally large variations can be seen in the atmosphere due to manmade emissions. From the 19th century, average surface temperature has increased by 0.9°C of earth. If the surface temperature keeps on increasing, more cases might be recorded of extreme events like floods, droughts and irresistible precipitation will increase.

To understand the variations in rainfall patterns more precisely there is a need to do perform analysis on small scale areas. In India, from the past few years there is increased number of occurrence of extreme events. The areas remote from the rainfall tracks are probably going to see less precipitation and have expanded risks of dry whereas the storm influential regions are experiencing increments in precipitation and prolonged danger of flooding (www.nasa.gov).

Patiala region is experiencing non-significant variations in trends of rainfall from the past few years. Increased maximum temperatures and higher rainfall can be seen in this area. Due to flooding, the villages near the Ghaggar River are flooding from the past years. There is need of proper management water resources due to which there is a need to understand the historical trends in this area for a better vision.

1.4 Scope of study

The variations in climate occur at different time scales for example monthly, seasonally, annually. The analysis of trends of rainfall and temperature will help us to control any significant variations seen in the historic datasets. It further provide a better information to the decision makers to resolve the uncertainties and helps in making decisions related to industry, irrigation, agriculture and other human activities(Ninu Krishnan, Prasanna, and Vijith 2019).

1.5 Organization of thesis

In the first chapter, climate change and its impact worldwide and on India was discussed. Then the origin, scope and need to study the historical trends were discussed. In the second chapter, firstly reviewed the different methodologies that can be used to perform analysis and further a research review of previously work done on this study internationally and nationally have been done. In the third chapter, the study area, data collection, statistical analysis and the methods adopted to analyse and quantify trends was discussed. At last different methodologies adopted to find correlation between climate parameters was discussed. The results and there significance were discussed in the fourth chapter.

1.6 Concluding remarks

In this chapter, the climate change, its impact worldwide and at India, its relation with rainfall and temperature is reviewed. Then the origin, scope and need of study were discussed. In the next chapter different methodologies previously adopted by researchers and a research review of the work related to analysis of trends on national and international level have been reviewed.

CHAPTER 2 LITERATURE REVIEW

2.1 Introductory comments

In the last chapter, a brief introduction about the climate change and its impact worldwide and on India was given. Then the relation between the climate change and rainfall, temperature was discussed. In this chapter, a brief review of the previous research work done at national and international level for the trend analysis is discussed.

2.2 Research review

Jaiswal, Lohani, & Tiwari, (2015) carried out the change point and trend analysis of Raipur district of Chhattisgarh The dataset used of relative humidity, wind speed, minimum and maximum temperature for the time period of 1971 to 2012 in addition to pan evaporation and sunshine from 1981 to 2012.The methods used by him for change detection analysis are pettitt test, buishand ratio test, von Neumann ratio test, standard normal homogeneity test(SNH) and for rainfall trend analysis are linear regression analysis, MK test, spearman rho test. The outcomes of the analysis were that change point was present for relative humidity, sunshine hour, minimum temperature and evaporation monthly and seasonal analysis of summer. For the time period of 1900-2000, a significant change point was seen due to fast developing industrial activities. The increasing trend in temperature indicated impact on climate change.

Rajeevan, Bhate, & Jaswal, (2008) carried out change point and trend analysis of India using data of 1384 stations. High resolution historical dataset of 1901 to 2004 was used. The interpolation method was used. The outcomes were that the climate seems to warm in response to greenhouse gases and the concentration is increased by 4-5% per decade. The decreasing trends in SST(sea surface temperature) and VHR (very heavy rain)events from 1940 to 1960 were seen and increasing trend in 1910 to 1940.

Jain, Kumar, & Saharia,(2013) carried out the trend analysis of rainfall and temperature of India’s NE region covering an area of 255168 km^2. The time period for data varied as for rainfall (1871-2008) and temperature (1901-2003) using SSE test, MK test. The outcomes revealed that different temperature variables gave increasing trend. In rainfall trend analysis, major variations were seen only in seasonal analysis. This related that a 1°C rise temperature will decrease wheat production by 5 million tons.

Mondal, Kundu, & Mukhopadhyay, (2012) carried out the analysis of NE part of Cuttack district, Orissa. The study was conducted for the daily data of rainfall for the time period of 1971 to 2010 and in methodology, SSE test and MK test are used. The outcomes of the analysis were that the significant increasing trend was present for months of January, May, June, September, October and November and negative trend for months of February, March, April, July, August and December.

Rajwade & Kumari, (2018) carried out study of the change point and of trends of rainfall data for a time period of 1901-2002. The study area for analysis is Andhra Pradesh and Telangana, India. The methods used here were SSE test, MK test, Mann Whitney test and Pettitt test. The data was of 16 stations. The analysis shows a significant rising trend in annual rainfall. The change point analysis showed that the most probable year of change was 1953.

Sharma, Dubey, & Mirdha, (2018) carried out trend analysis of rainfall of Madhya Pradesh (Malwa Plateau, a part of dhar and Jhabua districts) for the time period of 1901 to 2014.The methods used here are MK test and SSE test. The outcomes varied with the regions as for Indore, increasing trend with high 99.0% of significance level was seen with annual positive growth in Z statistics 2.69%. For Dewas, increasing trend with no significance level. For, a decreasing trend (-1.27) with non-significance level. For Shajapu, decreasing trend (-1.14) with non-significance level. For Neemuch, a decreasing trend (-0.41) with non-significance was seen. For Mandsaur, decreasing trend (-0.20) with non-significance. Ratlam showed an increasing trend (Z-0.24) with non-significance. Rajgarh showed a decreasing trend (-0.30) with non-significance trend.

Karmeshu, (2012) carried out study on the analysis of trend of rainfall as well as temperature for NE region of United States. The time period used for the analysis was from 1900 to 2011. MK test was used for the trend detection. The outcomes revealed an increasing trend for Vermont, Pennsylvania, Rhode Island, Massachusetts, Connecticut, New York, and New Jersey. No trend is seen for Hampshire and Maine. For the temperature, increasing trend for Rhode Island, New Jersey, Massachusetts, Vermont, New York, and Connecticut.

Shadmani, Marofi, & Roknian, (2012) carried out trend analysis for the Arid regions of Iran. Arid regions based on the aridity index (AI).The time period used was from 1965 to 2005 and data of 11 stations was used. The methods used for analysis are MK test, spearman rho test, SSE test, TFPW approach. The outcomes for monthly analysis is that no significant trend at Sabzevar, Semnan and Bandarabbas stations. A decreasing trend was seen in Birjand and Esfahan station and increasing trend at Mashhad station. For annual and seasonal analysis Sabzevar, Ahvaz, Kashan, Bandarabbas, and Semnan stations didn't show any significant trend. Birjand and Esfahan stations showed decreasing trend except in winter. For Kerman Station, monthly decreasing ET_0 seen during summer, autumn and for Bushehr Station, decreasing trend was present for winter and autumn seasons as well as annually. Furthermore for Mashhad, increasing trend was present for the annual ET_0 of 7.50 mm/year. At last for Esfahan, decreasing trend of 6.38 mm/year was present.

Mrad, Djebbar, & Hammar, (2018) carried out trend analysis for annual rainfall for 35 stations. The mean annual rainfall showed a variation from 583 mm for Ramdan Djemel and 936.4 mm for Taher. In addition, all the five stations in Macta region have a decreased trend of at least 20% of the total annual rainfall. It outcome to be decrease in total rainfall in the region and wet days together with an increase for Morocco and western region in duration of dry periods.

Emmanuel, Hounguè, Biaou, & Badou, (2019) carried out study on the analysis of trends of rainfall as well as temperature of the Mono river, Togo for the time period of 1981–2010. MK test, Pettitt and at last Standardized Normal Homogeneity (SNH) tests was used**.** The outcomes show that annual scale of temperature and rainfall all over the watershed showed a rising trend. The second rainfall peak in the south will be extended to October along with the increase in value which usually occurs in September. Further, rainfall analysis revealed a trend in September month and till June; less precipitation was projected in the central as well as northern parts.

Machiwal, Gupta, Jha, & Kamble, (2019) carried out analysis of trend in temperature and rainfall for the study area of Indian arid region for the time period of 1979 to 2013. The box-whisker plots, Kendall rank correlation, MK test, modified MK test, Spearman rank order correlation, innovative trend analysis and SSE test was used. The outcomes showed significant increased trend of 9mm per year in annual and monsoon rainfall. It was discovered that in this region, both agriculture and water resources are at risk due climate change.

Ninu Krishnan, Prasanna, & Vijith, (2019) carried out seasonal and annual rainfall trends of river basin, Malaysia for the period 1948–2016. The study was conducted using MK test and Spearman Rho method. The outcomes showed that Southwest monsoon mostly shows a decreasing rainfall trend, whereas an increasing rainfall trend showed by NE monsoon. The annual, seasonal rainfall revealed varying significant and non-significant increasing trends.

Salman et al., (2019) carried out seasonal and annual trend analysis of temperature as well as rainfall of Iraq for the time period of 1961 to 2010. SSE test, MK test and the modified MK test are used in this analysis. The outcomes reveal that trends in different variables of annual temperature revealed increment in most part of the country. The outcomes of this study were helpful in understanding the effects of climate change.

Sanikhani, Kisi, Mirabbasi, & Meshram, (2018) carried out trend analysis of rainfall of Central India for the time period of 1901 to 2010. The SSE test, Revised MK test and innovative trend method are used in this analysis. The outcomes showed both the trend analysis methods gave same results for monthly, seasonally and annually analysis. The findings of this study were useful for water resource planning, irrigation and management purpose.

Ghahraman & Taghvaeian, (2008) carried out a yearly precipitation trends investigation in Iran using a regression line slope method. Mean annual rainfalls with data of 50 years or less than 50 years were collected from 30 synoptic stations along with a reasonable geographic distribution. It was noted for whole period at 95% level of importance that negative trend was shown by seven stations whereas positive trend was shown by six stations. Further, same data for last 40 years showed that negative trend was found at four stations while positive trend was found at eight stations. Furthermore, only three stations showed negative trends over a period of 30 years. However, the trend was numb to mean annual rainfall but shown inconsistent behaviour for different record lengths.

Buhairi, (2010) carried out monthly, seasonal and annual trend analysis of surface air temperature for the duration of 1979-2006 in the Taiz city, Republic of Yemen. The MK test is used for this analysis. The outcomes revealed that for average temperature, a significant warming trend was found of around 1.5°C in the past 30 years which was majorly for spring and summer months. The analysis of minimum and maximum temperature revealed increment in annual and seasonal data. Significant increasing trends for the summer as well as winter seasons were revealed with 0.064℃/year, 0.042℃/year, correspondingly.

Croitoru & Piticar, (2013) carried out analysis of daily extreme temperature trends for the region of Carpathians Chain of Romania of time period 1961–2010. Homogeneity test, MK test and SSE test were used for this analysis. The outcomes show that the daily minimum and maximum temperatures in the analysed areas have increased. An increase in the maximum values of minimum and maximum daily temperatures was observed for the tropical nights and summer days.

Karpouzos, Kavalieratou, & Babajimopoulos, (2015) carried out trend analysis of precipitation in Pieria region of Greece for the time period of 1974-2007. Sequential versions of the MK test, distribution-free CUSUM test, SSE test were used here for analysis. The outcomes revealed an overall downward precipitation trend. Moreover, a decline in precipitation was identified at all stations for the duration of 1987-1993. For the Aison river basin, downward trend was found. Further the spring season in both stations suffered a decline in precipitation but was statistically significant at only one station.

Asfaw, Simane, Hassen, & Bantider, (2018) carried out the trend analysis of rainfall and temperature in north-central Ethiopia for the time period of 1901-2014. An anomaly index, coefficient of variation, Palmer drought severity index and precipitation concentration index were used to analyse the data. MK test was used in this study. The outcomes revealed an increased number of drought years, proved by the value of Palmer drought severity index. For annual analysis, a statistically significant decreasing trend for rainfall was found. Further, degree of change of temperature was observed to be 0.046^{o}C/decade, 0.067^{o}C/decade and 0.026^{o}C/decade. It has been observed from the MK test that the increased trend for mean and minimum temperature varied significantly whereas the increased trend for maximum temperature varied non-significantly.

Singh, (2018) carried out a study to analyse the change as well as variability of rainfall and extreme indices pattern change in Haryana, India for the period of 1985-2014 . The inverse distance weighted interpolation method was used in this analysis. The outcomes revealed that the highest rainfall (890mm-1000mm) has occurred in the northern parts of the state which includes Panchkula and Yamunanagar districts while the lowest rainfall (340mm-450mm) has occurred in the western parts of the state which includes Sirsa and parts of Fatehabad, Hisar and Bhiwani districts. Moreover, to manage the surplus and low occurrence of the rainfall, surface level water management practices are required in the entire zone. For comprehensive agricultural planning for ecological restoration and water management to achieve sustainable development in the area, the better understanding of the extreme rainfall is required.

Sayyad et al., (2019) did study on rainfall trend analysis of Parbhani, Maharshtra for the time period of 1987-2016. The MK test was used for trend analysis. The outcomes revealed varied significant and non-significant trends. According to SSE test, the months of May, September and July shows rising trends while the months of June, August and October shown the falling trend. Further, it is noted through the Kendall tau test and SSE test slope that the rainfall has a non-significant decreasing trend in post-monsoon, monsoon seasons and rainfall has a non-significant increasing trend in winter, pre monsoon seasons.

Bhuyan, Islam, & Bhuiyan, (2018) carried out the trend analysis of temperature and rainfall for north-western region of Bangladesh for the period of 1981-2008. MK test, SSE test was used for the analysis. The outcomes revealed that seasonally, maximum temperature has significantly increased in all season excluding winter season. Further, the normal temperature is predicted to be beyond 31˚C and the highest future normal temperature is seen in Bogra at 8˚C per century. For north-western region, the highest rainfall has occurred in monsoon 63.58% and 63.80%.

Gedefaw, Yan, et al., (2018) carried out the trend analysis of seasonal and annual rainfall for Amhara regional state in Ethiopia for the time period of the 1980–2016. The innovative trend analysis methods, MK test and SSE test was used for the analysis. For kiremt and belg seasons, increasing trend was seen in Gondar station significant and non-significant increasing trends were found. In Dangla and Bahir Dar, rainfall is significantly decreased for bega season.

Bisht, Chatterjee, Raghuwanshi, & Sridhar, (2018) carried out spatial-temporal trends analysis of rainfall of Indian river basins for the time period of 1901–2015. MK test and SSE test was used for analysis. The outcomes revealed that the shift in the rainfall was due to the decrease in monsoon rainfall and increase of the post monsoon rainfall. Downward trends in seasonal as well as annual rainfall were found and for extreme events, upward trends were found after year 1970.

Blanchet, Molinié, & Touati, (2018) carried out spatial analysis trend of southern France for the time period of 52 years. In this analysis**,** non-stationary GEV modelling is adopted and applied on aerial rainfall data of 8×8 km^2 grids. The outcomes revealed that at regional level, the trend lies amongst the 80's and the 90's, with 1985 as the utmost likely. Significant positive trends of less magnitude was seen in this area overall. The highest magnitude was seen in Cévennes-Vivarais ridge and nearby Alès with more than 62 mm per day in 20 years.

Byakatonda, Parida, Kenabatho, & Moalafhi, (2018) carried out the study for the variability and trend analysis of rainfall and temperature for the semi-arid region of Botswana of the time period 1960–2014. The MK test and SSE test is used in this study. The outcomes show that for winter and annual maximum temperature, increasing trends were observed. During annual and winter season, warming trends of 1.7% and 6.5% were reported by the minimum temperature. More climate variability can be observed across Botswana due to the decreased trends in rainfall. Maximum temperature time series except at Shakawe, were found to be random. Moreover, persistence tendencies in minimum temperature were shown by 57% of the stations.

Kumar, Tischbein, & Beg, (2018) carried out trend analysis of temperature and rainfall for a monsoon-dominated catchment in India for the time period of 1961-2011. The Prais–Winsten AR test, linear regression, spearman rank correlation test, Pearson product-moment correlation test, Gaussian-linear trend detection test, MK test and SSE test were considered for this study. The observations revealed that an increasing trend of 1.94 mm per year was seen for maximum monthly rainfall. Increasing trends in low lying areas reveal that there are higher flood risks. An increased trend for November month is seen for monthly maximum temperature and for minimum temperature, an increased trend is seen for August, July and March. An increased trend for monthly average temperature is seen by December, November, August and July.

Ogungbenro & Morakinyo, (2014) carried out change detection and variation in rainfall pattern in Nigeria for the time period of 1910–1999. The Wilcoxon signed-rank test, Pettit test, probability density function and paired sample test were used in this study. The outcomes revealed that an increasing trend from dry to wet was observed in all the areas. The results were useful for agricultural development in that area and the study suggested that farmers must now plant early maturing crop or drought resistant crops in the Sahelian zone.

Proper measures should be taken by the government for the changing rainfall pattern to eliminate the food insecurity in the future.

Salman et al., (2018) carried out trend analysis of extreme daily rainfall of Iraq for the time period of 1965–2015. The modified version of MK test and MK test was used in this study. The outcomes revealed that there is significant decrease in the winter and annual at some stations. Despite the above confirmation, the number of stations with considerable changes was found to decrease in the modified MK test. Thus, it is confirmed that the dry spells and droughts were increased in the region.

Shiru, Shahid, Alias, & Chung, (2018) carried out the trend analysis of droughts in Nigeria which mainly of crop growing seasons for the time period of 1961 to 2010. The standardized precipitation evapotranspiration index (SPEI), MK test and binary logistic regression were used in this study. Further, at some point in the cropping seasons, an increase in the areal extent of droughts was present. Furthermore, an increase in occurrence of some particular moderate droughts which were having smaller areal extents was observed in all the seasons. Moreover, the regions with decreased rainfall were found to have decreased standardized precipitation evapotranspiration index (SPEI) values. Thus, it was concluded that the droughts with smaller areal extents occurred because of the recent changes in climate.

Mahajan & Dodamani, (2015) carried out the trend analysis of droughts at the upper Krishna river basin in Maharashtra for the time period of 1960 to 2012. The standardized precipitation index(SPI), MK test and SSE test were used in this study. The outcomes revealed that the seasonal rainfall drought trend varied with the classes. Pre-monsoon and monsoon time scale detected no significant positive trend respectively. Further, it is indicated by the results that the pre-monsoon rainfall showed negative trend at over 63 per cent of area and also significant trend at over 84 per cent of area was detected by the SPI- 48 time scale. The analysis done will be useful for studying floods, droughts as well as provision of water for farming sector, hydroelectricity generation and industrial use.

Gedefaw, Yan, et al., (2018) carried out the trend analysis of various climatic parameters in the Awash River basin of Ethiopia for the time period of 1980 to 2016. The innovative trend analysis methods, MK test and SSE test were used in this test. The outcomes revealed that there is significant increase in annual precipitation trends in Gewane and Fitche. Further, significant increasing trend was observed in Bui, Fitche and Gewane. Further, in the investigation of temperature trends, a decreased trend with statistical significance was seen in Sekoru .Thus, the change in trends was indicated due to increased and decreased levels of precipitation and temperature.

Worku, Teferi, Bantider, & Dile, (2019) studied the changes in extremes of daily temperature and rainfall in Jemma Sub-Basin and Upper Blue Nile Basin of Ethiopia for the time period of 1981 to 2014. The MK test, seasonal MK test and SSE test were used in this study. The outcomes revealed that an increased annual rainfall was seen by 78%. On the other hand, most of the stations suffered from the decreased trend of the spring rainfall. Further, wetting trends in the sub-basin was shown by several rainfall extreme indices, where partial indices specified the dryness at most stations. Increasing trend is seen for the extreme temperature, minimum and annual maximum indices in the sub-basin. The signs of climatic change were shown by the presence of increasing temperature trend and extreme rainfall in Jemma Sub-Basin.

Negi, Gautam, & Singh, (2018) carried out analysis of temperature and rainfall in Alaknanda valley of Srinagar of the time period of seven years. The linear trend analysis technique was used in this study. The outcomes revealed that mean monthly temperature, for all the months had significantly increased. The maximum temperature of 27.93 °C, 27.65 °C and 27.59 °C was observed in the month of July, June and August, respectively. Further, the minimum temperature of 12.00°C and 12.28°C was observed in the months of January and December. The highest and lowest value of coefficient of variation for mean temperature of Srinagar Garhwal valley was noticed in the month of February and August. Thus, it is concluded that the month of August had the most stable mean temperature. Thus, the month of July showed the most stable rainfall while the month of November shown the most variability in the rainfall, for the Srinagar Garhwal Valley.

2.3 Research Gaps

It is seen from literature review that, from past decade no work has been carried out in Patiala region to study the historical trends. A greater variability is been noticed in the past few years and the occurrence of extreme events is been seen which domino effect life loss and property. The study will help policy makers to take necessity actions for a better water resource management.

2.4 Objectives of the study

- To perform statistical distribution of rainfall and temperature of Patiala city.
- To find the trends and magnitude of rainfall and temperature of the study area.
- To determine the relation between rainfall and temperature of the study area.

2.5 Concluding remarks

In this chapter, research work done on the trend analysis and correlation at national and international level was discussed. In subsequent chapter, different methodologies adopted for verifying the statistical distribution of rainfall, trend analysis and its magnitude and for correlation between the rainfall and temperature will be explained.

CHAPTER 3 METHODOLOGY

3.1. Introductory comments

In the last chapter, different methodologies adopted by the researchers for the study of the historical trends of rainfall as well as temperature were discussed. Then review of the work done on the trend analysis nationally and internationally is conducted. At last the gaps in research and the main motive of the present study have been discussed. The present chapter will discuss about the area selected for the analysis and the collection of data. The present chapter is divided into four parts according to the analysis as:-

1. Statistical analysis and description of the methodology used.

2. Trend analysis and description of the methodology used.

3. Quantification of trends and description of the methodology used.

4. Correlation of parameters and description of different methodologies used.

3.2. Study area

The study area selected for the present research work is the Patiala city. The Patiala district is divided into six sub-divisions (tehsils) namely Nabha, Patiala, Patran, Dudhan Sadhan, Samana and Rajpura which further subdivided into nine blocks namely :- Patran, Patiala City, Sanaur, Nabha, Rajpura, Shambu Kalan, Ghanaur, Samana and Bhunerheri. The geographic midpoint of the district is Patiala city.

Patiala climate is mainly dry, with hot summer and cold winter. The seasons here are the same classified by Indian meteorological department. The normal monsoon and annual rainfall of Patiala is approximately 547 mm and 677 mm. The south west monsoon contributes to 81% of annual rainfall and the period is generally of 29 days. The remaining percentage of rainfall is received during non-monsoon period which is generally due to the western disturbances as well as thunderstorms.

According to the report of Central ground water board 2013, the mean least and extreme temperature in the area ranges from 7.1^0C to 40.4^0C.

The Patiala geomorphology is plain in area and major drainage as Ghaggar River. Patiala land use pattern is distributed as 120sq.km of forest area, 2630sq.km of net area sown and

2810 sq.km of cultivable area. The area under principal crops is 5190 sq.km. Major soil types found in Patiala district are of tropical arid brown and arid brown type soil.

3.3. Data collection

The main objective of the data collection is to be available of maximum time period and have less missing values. So keeping this in mind there are four different sources for datasets was found for Patiala region. The different datasets available were present in hourly, daily and monthly which were converted to monthly according to the analysis. The data sets available for Patiala region is shown below:-

1. CRHS Portal (Via location) (2003-2019)

2. CRHS Portal (Via rectangle) (2003-2019)

3. TRMM data, NASA (3B42V7) (1998-2015)

4. Water resource Department, Punjab (2015-2018)

In order to check the continuity of the data collected from available source, these datasets were compared month wise. For example, the monthly data for the month of June of year 2015 is compared and shown below in figure 3.1.

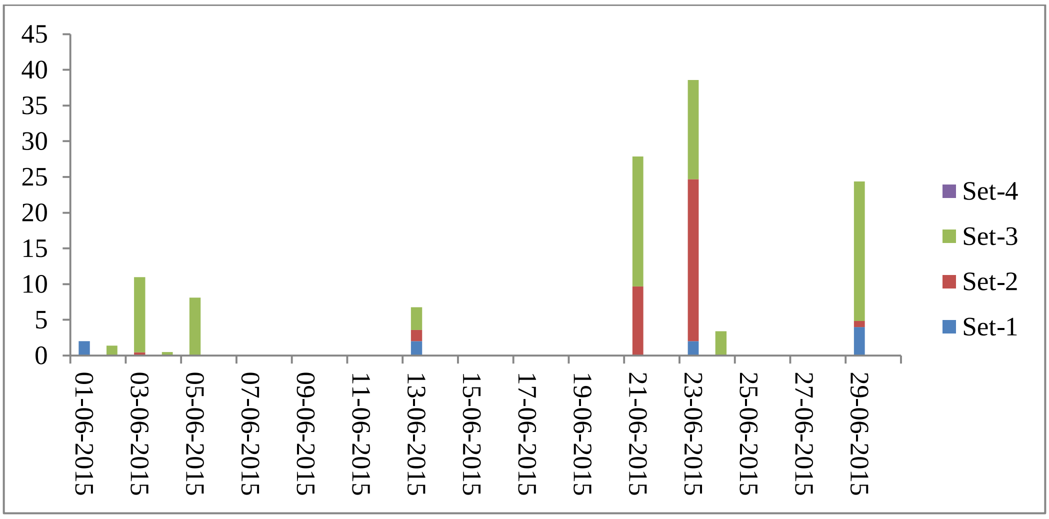

Figure 3.1 : Comparison of rainfall datasets

After comparison the dataset-3 of TRMM data, NASA was found with less discontinuity in comparison to other sources. So further trend analysis is carried out using this dataset. The data of time period 1998-2015 was taken for study. The temperature data of the same duration was collected from the NCDC (CDO), Asheville, California. The rainfall datasets are prepared monthly, seasonally and annually.

3.4. Statistical analysis

The statistical analysis is done with box and whisker plots. Figure: 3.2 shows graphical plot of data, which signifies the median, the outer range, the extremes and the interquartile range (IQR).

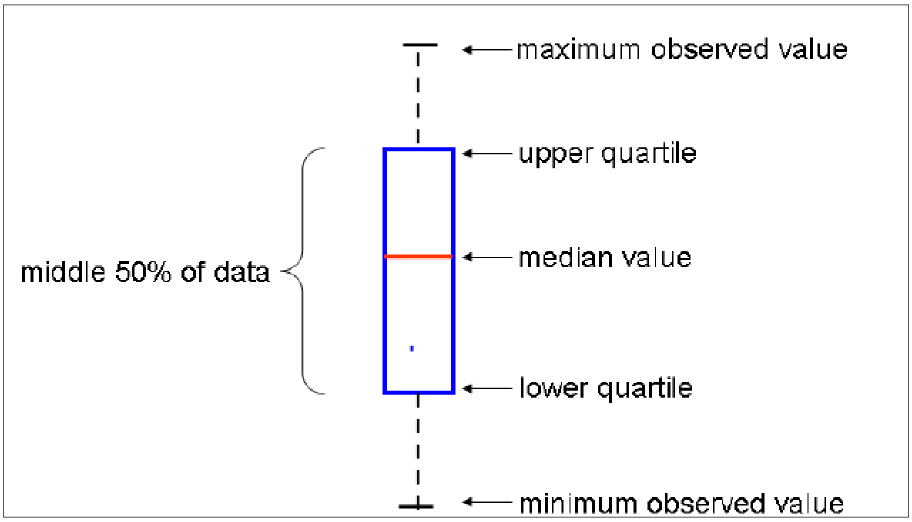

Figure 3.2 : Box and whisker plot

3.4.1 Median

Median is the centre value of the ranked data if the number of data in the datasets is odd and means of two centre values if the number of data in the datasets are even. The median line of the plot corresponds to the 50th percentile or the centre point of the total number of observations. If the box is divided equally by the median, there will be no skewness present in the data. If the box is not divided equally by the median, positive or negative skewness is seen in the dataset.

3.4.2 Interquartile range

It tells us about the central 50% arranged data and is calculated by the difference between lower quartile value and upper quartile value. Lower quartile is calculated by compelling the median of lower half of data. The difference among the upper and lower quartile values is said to be as the interquartile range (IQR), and the height of the box shows 50 percent of data.

3.4.3 Outer range

The vertical lines expanding outside the box is called whiskers and it represents external range. It tells us about the highest and the lowest data values in the data.

3.4.4 Maximum and minimum values

It tells us about the minimum and the maximum values of the data set. If any significant variations occur in the datasets, it is helpful to climatologists and meteorologists for future predictions.

3.5. Trend test

3.5.1 Mann Kendall test

The present study is analysed using non-parametric MK test for analysing trends of rainfall and temperature. For the study of the historical trends, this methodology is majorly used for the analysis of climatological parameters and is also used by Indian Meteorological Department and researchers (Jain, Kumar, and Saharia 2013; Jaiswal, Lohani, and Tiwari 2015; Machiwal et al. 2019; Ninu Krishnan, Prasanna, and Vijith 2019; Shadmani, Marofi, and Roknian 2012) also used this test for analysis. In this methodology, the null hypothesis denoted by 'H_0' adopts that there is no trend and it is then tested with 'H_1' hypothesis which adopts that there is trend. There are many benefits of using this methodology as there is no need of data to be normally distributed. For the data having values below 10, S-test is used and for number of values greater than 10, normal approximation is used.

For conducting the S-test, missing values are allowed and number of total values are denoted by 'n'. The Eq 3.1 and 3.2 is used for the calculation of S-test.

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(x_j - x_k) \tag{3.1}$$

Where,

$$\operatorname{sgn}(x_j - x_k) = \begin{cases} 1 \ if \ (x_j - x_k) > 0 \\ 0 \ if \ (x_j - x_k) = 0 \\ -1 if \ (x_j - x_k) < 0 \end{cases} \tag{3.2}$$

Where x_j and x_k are data values with j greater than k.

The present study considers the significance level of 0.05 which means that there is 5% probability that randomly distributed values are of x_j and H_0 is rejected by mistake giving no trend.

Now for the n greater than 10 in numbers, normal distribution is used. The Eq 3.3 tells us about the formulation for the calculation of variance of ‘S’.

$$\mathrm{VAR(S)} = \frac{n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p-1)(2t_p+5)}{18} \tag{3.3}$$

Where ‘q’ signifies number of tied groups and ‘t_p’ signifies number of observations in the p^{th} group. The values obtained from ‘S’ and VAR(S) are then used in Eq 3.4 to perform Z-test.

$$Z = \begin{cases} \frac{\mathrm{S}-1}{\sqrt{\mathrm{VAR(S)}}} for\ S > 0 \\ 0\ for\ S = 0 \\ \frac{\mathrm{S}+1}{\sqrt{\mathrm{VAR(S)}}} for\ S < 0 \end{cases} \tag{3.4}$$

The trend to be significant or non-significant is expressed by the value of ‘Z’. Further a positive trend is signified by positive value of ‘Z’ and a negative value of ‘Z’ signifies a negative trend. To quantify the trends obtained, SSE test is used.

3.6. Magnitude of trend

3.6.1 Sen slope estimator test

The magnitude of the trend is anticipated with Sen slope estimator method(SSE). The test is applicable to linear trend and represents quantified change per unit time (Sen 1968; Gilbert 1987). In the same manner, the researchers (Bhuyan, Islam, and Bhuiyan 2018; Buhairi 2010; Gedefaw, Wang, et al. 2018; Gedefaw, Yan, et al. 2018; Jain, Kumar, and Saharia 2013; Jaiswal, Lohani, and Tiwari 2015; Karpouzos, Kavalieratou, and Babajimopoulos 2015; Machiwal et al. 2019; Mahajan and Dodamani 2015; Mondal, Kundu, and Mukhopadhyay

2012; Mrad, Djebbar, and Hammar 2018; Salman et al. 2018, 2019; Sharma, Dubey, and Mirdha 2018) and many more used this method for evaluating the magnitude of trend.

The slope (Q_i) is calculated by

$$Q_i = \frac{x_j - x_k}{j - k} \tag{3.5}$$

Where i= 1…N

Here x_j & x_k are data values with j greater than k. The estimator is the median of N values Q_i. For n values in the data, $N = \frac{n(n-1)}{2}$ this is one less than the total number. In the next step, the calculated values of N are ranked in increasing order. Further, the slope is calculated as

$$Q_{median} = \frac{Q(N+1)}{2} \tag{3.6}$$

If N has odd number of values

$$Q_{median} = \frac{[QN/2 + Q(N+2)/2]}{2} \tag{3.7}$$

If N has even number of values.

3.7. Correlation

3.7.1 Spearman rho test

The strength among two variables is evaluated using this test with a monotonic function and helps to find the correlation between them. After finding the difference in between the data pairs, the '+1', '0' and '-1' values are assigned according to the positive, no and negative differences. If we obtain equal ranks, then the values are said to be tied. Researchers (Jaiswal, Lohani, and Tiwari 2015; Ninu Krishnan, Prasanna, and Vijith 2019; Shadmani, Marofi, and Roknian 2012) also used this methodology for finding the correlation in-between the different parameters.

There are two techniques to ascertain Spearman's relying upon having tied value or not.

$$\rho = 1 - \frac{6\sum d_i^2}{n(n^2-1)} \tag{3.8}$$

$$\rho = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (x_i - \bar{x})^2 \sum_i (y_i - \bar{y})^2}} \tag{3.9}$$

Where *i* = paired score, d = difference between ranks and d^2 = difference squared.

3.7.2 Kendall tau rank correlation

The non-parametric Kendall's tau correlation was talked about by G.T. Fechner and others in the year 1900, and was rediscovered (independently) by M.G. Kendall in year 1938. This methodology also finds correlation and strength within two variables. The plus point of this methodology over spearman rank correlation test is that it improvises strength and dependency when the null hypothesis is rejected.

The initial steps of computation are same as the spearman rank correlation test. The formulation for not having tied ranks as in Eq 3.10 and your data has tied ranks Eq 3.11 is shown.

$$\tau = \frac{n_c - n_d}{\frac{n(n-1)}{2}} \tag{3.10}$$

$$\tau_b = \frac{S}{\sqrt{\left[\frac{n(n-1)}{2} - \sum_{i=1}^{t} \frac{t_i(t_i-1)}{2}\right]\left[\frac{n(n-1)}{2} - \sum_{i=1}^{u} \frac{u_i(u_i-1)}{2}\right]}} \tag{3.11}$$

Where t_i is number of tied values of the dataset 'x' and u_i is the number of tied of dataset 'y'.

3.7.3 Pearson correlation

The linear dependency among the data set is done through the Pearson Correlation. The values obtained after correlation lies in-between -1 to +1 and negative value tells us about the negative correlation and positive value tells us about the positive correlation. When zero comes as a result, no relation in between the observation is found. The correlation coefficient is generally indicated by “r”. The Eq 3.12 tells us about the formulation of Pearson correlation.

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}} \tag{3.12}$$

Where, r_{xy} is Pearson correlation coefficient, ‘x’ denotes the values of first set of data, ‘y’ denotes the values of second set of data and n signifies total number of values.

3.8. Concluding remarks

In the present chapter, firstly study area and the collection of data were discussed. Subsequently, different methodologies adopted for the statistical analysis, trend analysis and correlation was discussed. Further in the next chapter, outcomes of the different methodologies are approved with the help of figures and tables.

CHAPTER 4 RESULT AND DISCUSSION

4.1 Introductory comments

The data and methodology section describes about the complete methodology and the data of rainfall and temperature of 18 years (1998-2015) which were further analysed. This section divides into four subsections according to objectives which are statistical distribution, trend analysis, magnitude of trends and relation between temperature and rainfall. Statistical distribution was performed in Origin Pro 2019 and SPSS. Trend analysis using MK test and magnitude of trend analysis using SSE test was analysed in Microsoft excel 2010. Correlation between temperature and rainfall was analysed using Pearson correlation, Spearmen Rho and Kendall's Tau which is performed in SPSS. The graphs of this section were plotted in Origin Pro.

4.2 Statistical distribution

Temperature was analysed in three forms of average, maximum and minimum. Rainfall was used in analysis is in the form of total rainfall of the session. This study data was analysed for monthly, seasonally and annually. The results are described below.

4.2.1 Average temperature

4.2.1.1 Monthly average temperature statistical distribution

Average monthly temperature analysed from the 18 year data of 1998-2015 and graph is plotted in box plot. Figure: 4.1 show the statistical distribution of monthly average temperature. The result showed a normal distribution over the monthly time period where it is highest in June and lowest at January or December. The dotted line in the graph shows the mean monthly normal distribution. The boxes in the graph represent 25%-75% data range. The boxes are extended with interquartile range of single multiplication. The monthly average temperature is lowest in January (13.5°C) and highest in June (34.6°C) recorded. The table: 4.1 show minimum, maximum, mean, median standard deviation of the average temperature. Maximum of all statistics are seen in June and minimum in January but minimum average temperature is recorded in July.

Table 4.1: Statistical distribution table of monthly average temperature.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Maximum	**13.5**	18.7	23.7	29.7	33.7	**34.6**	32.3	31.0	28.5	25.0	19.9	14.8
Minimum	**9.7**	13.3	19.0	23.6	29.4	29.0	**29.2**	28.5	25.3	22.7	17.4	12.3
Mean	**11.7**	15.5	20.9	27.2	31.7	**31.8**	30.3	29.4	27.7	24.3	18.6	13.5
Median	**12.0**	15.5	20.6	27.2	31.8	**31.8**	30.1	29.4	27.9	24.5	18.4	13.5
Std Dev	0.92	1.23	1.31	1.41	1.06	1.49	0.76	0.55	0.81	0.65	0.67	0.65

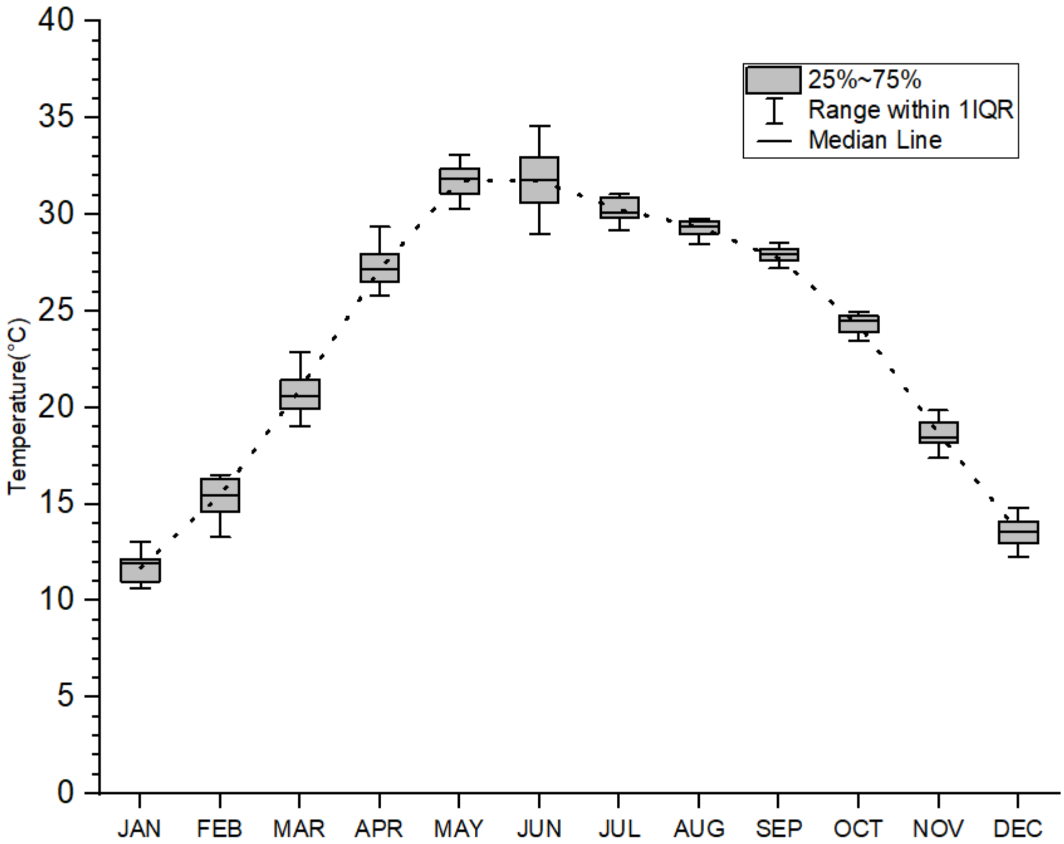

Figure 4.1: Statistical distribution of monthly average temperature

4.2.1.2 Seasonally average temperature statistical distribution

Figure 4.2 and table 4.2 shows the statistical distribution of the seasonal average temperature from 1998 to 2015. The minimum average temperature ranges from 12.4°C to 28.7°C and maximum average temperature ranges from 15.8°C to 30.9°C. Seasonal average temperature is mostly same in both pre-monsoon seasons and south west monsoon seasons as it maximum range between 28.8°C to 30.9°C. It is also found that there is little difference between winter and post-monsoon seasons in mean, maximum and minimum temperature. The statistical distribution of temperature is extending between 0.58°C to 0.99°C.

Table 4.2: Statistical distribution table of seasonally average temperature

	WIN	PRM	SWM	POM
Maximum	**15.8**	28.8	**30.9**	19.4
Minimum	**12.4**	25.1	**28.7**	18.0
Mean	**13.5**	26.6	**29.7**	18.8
Median	**13.3**	26.5	**29.7**	18.9
Std Dev	0.97	0.99	0.58	0.45

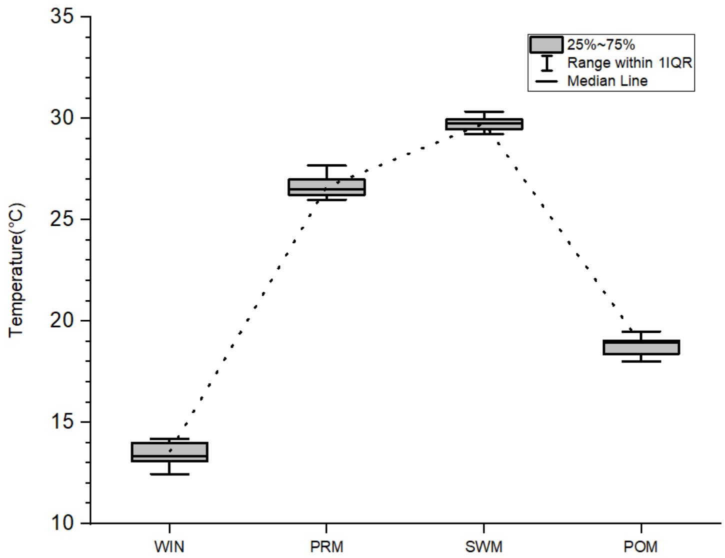

Figure 4.2: Statistical distribution of seasonal average temperature

4.2.2 Maximum temperature

4.2.2.1Monthly maximum temperature statistical distribution

The figure: 4.3 show the graph of the statistical distribution of monthly maximum temperature with maximum in May and lowest in January. Table: 4.3 show the maximum, minimum, mean, median and standard deviation of the monthly maximum temperature. The maximum temperature varies from 29.44°C to 47.22°C for the months of January and may. The maximum range of temperature was present for the month of January with 22.22°C to 29.44°C and an increase in temperature is expected in future as shown in graph.

Table 4.3: Statistical distribution table of monthly maximum temperature

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Maximum	**29.44**	32.22	37.78	43.33	**47.22**	46.11	42.22	38.33	42.22	36.67	35.56	30.56
Minimum	**22.22**	24.44	30.56	36.67	**41.67**	40.00	36.11	35.00	34.44	33.89	30.00	24.44
Mean	**24.41**	27.41	34.23	40.80	**44.20**	43.30	38.40	36.54	35.86	35.06	31.70	26.45
Median	**23.61**	27.22	34.44	41.11	**43.89**	43.61	38.06	36.39	35.56	35.00	31.67	26.11
Std Dev	2.21	1.98	2.22	1.81	1.52	1.98	1.55	0.98	1.69	0.71	1.28	1.39

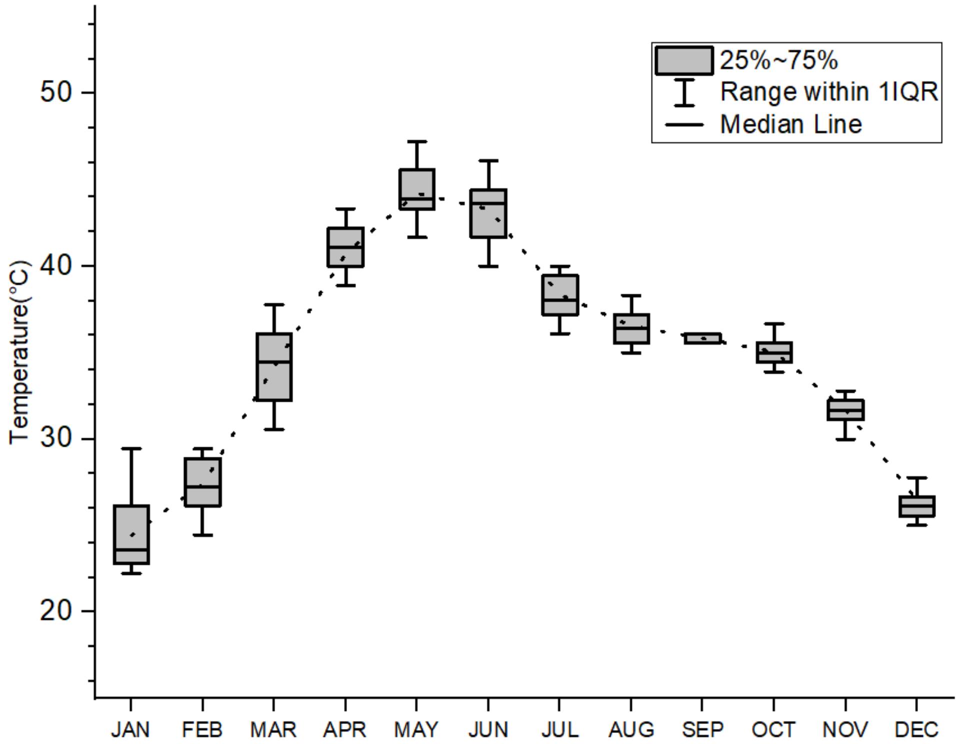

Figure 4.3: Statistical distribution of monthly maximum temperature

4.2.2.2Seasonally maximum temperature statistical distribution

Figure 4.4 shows the graph of seasonally statistical distribution of the maximum temperature. From the table: 4.4, the range of the maximum temperature varies in-between 32.22°C – 47.22°C for the winter and pre-monsoon season. The maximum range of temperature lies for the winter season. The dotted line joins the medians of all seasons. More variation is expected for the winter, pre-monsoon season and the south west monsoon whereas for the post monsoon season, less variation is expected. For the winter season, variation is expected at both the upper and the lower quartile temperature values. For the pre-monsoon season, variation is expected at the upper quartile temperature value and for the south west monsoon; variation is expected at the lower temperature range in the future.

Table 4.4: Statistical distribution of seasonal maximum temperature

	WIN	PRM	SWM	POM
Maximum	**32.22**	**47.22**	46.11	36.67
Minimum	**24.44**	**41.67**	40.00	33.89
Mean	**27.72**	**44.20**	43.30	35.09
Median	**27.78**	**43.89**	43.61	35.00
Std Dev	1.94	1.52	1.98	0.72

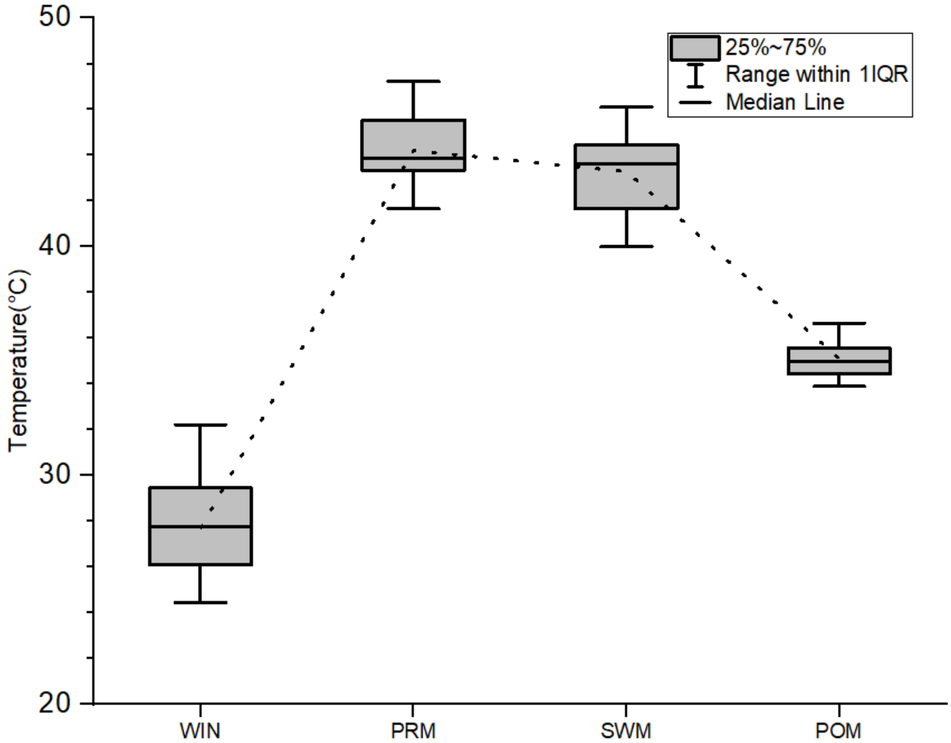

Figure 4.4: Statistical distribution of seasonal maximum temperature

4.2.3 Minimum temperature

4.2.3.1Monthly minimum temperature statistical distribution

The figure: 4.5 show the graph of box and whisker plot of minimum monthly temperature. The values of the mean, maximum, minimum median and standard deviation are shown in table: 4.5. The data presents that the maximum range lies between 5°C – 25.6°C for the months of January and august whereas the minimum range lies between -1.1°C – 20.6°C for the months of January and July. Maximum range is been seen for the months of January, February, March, September and November. The dotted line shows the normal curve connecting the median of the monthly data. The data signifies that for the months of February and October, more variation can be seen in the lower quartile range values. For the months of April, and August, the probability of increase in the minimum temperature can be seen in the future.

Table 4.5: Statistical distribution of monthly minimum temperature

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Maximum	**5.0**	8.3	11.7	17.2	21.7	25.0	25.0	**25.6**	22.8	17.2	10.0	5.0
Minimum	**-1.1**	0.0	5.6	12.2	15.0	18.9	**20.6**	20.6	17.8	10.6	0.0	2.2
Mean	**2.4**	4.7	8.8	14.2	18.6	21.4	**22.9**	23.4	20.3	13.5	6.4	3.4
Median	**2.5**	4.7	8.6	14.2	18.9	21.7	22.8	**23.3**	20.3	13.9	6.9	3.3
Std Dev	1.8	2.1	1.3	1.6	1.8	1.6	1.0	1.2	1.5	1.6	2.8	0.9

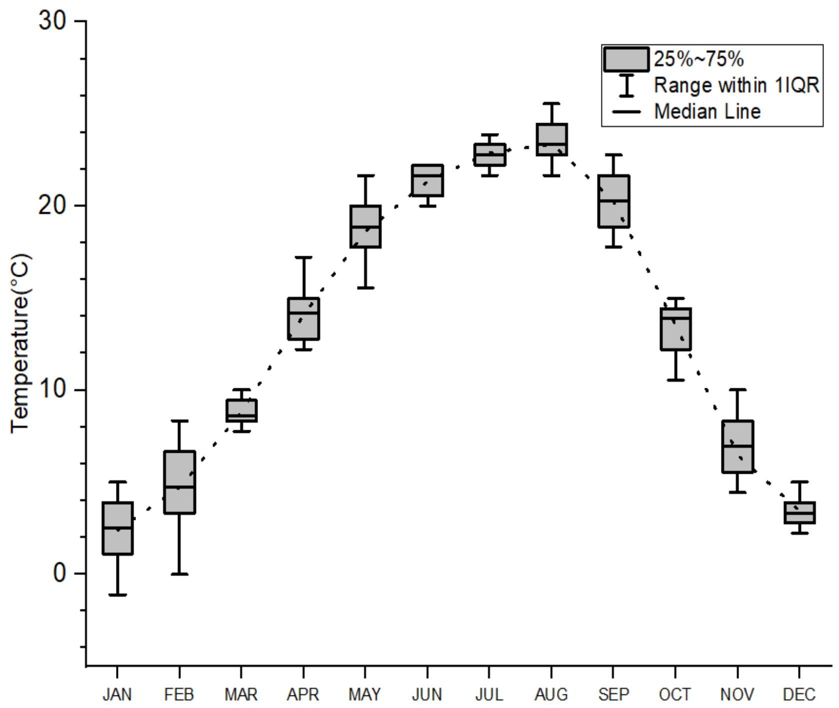

Figure 4.5: Statistical distribution of monthly minimum temperature

4.2.3.2Seasonally minimum temperature statistical distribution

The box and whisker plot of the seasonally maximum temperature is shown in Figure: 4.6. The table: 4.6 presents that the maximum range for the minimum temperature lies between 4.44°C – 21.67°C for the winter and the southwest monsoon season whereas the minimum range lies between -1.11°C – 17.78°C for the winter and southwest monsoon season. The dotted line shows the normal curve adjoining the median value of the minimum temperature data. From the graph, maximum temperature range of this dataset is seen for the winter season of -1.11°C – 17.78°C. The data signifies that for the southwest monsoon season, more variation can be seen in the upper quartile range values which might tend to increase in temperature in the future.

Table 4.6: Statistical distribution of seasonal minimum temperature

	WIN	PRM	SWM	POM
Maximum	**4.44**	11.67	**21.67**	5.00
Minimum	**-1.11**	5.56	**17.78**	0.00
Mean	**2.28**	8.83	**19.72**	3.06
Median	**2.50**	8.61	**19.17**	3.33
Std Dev	1.70	1.29	1.22	1.42

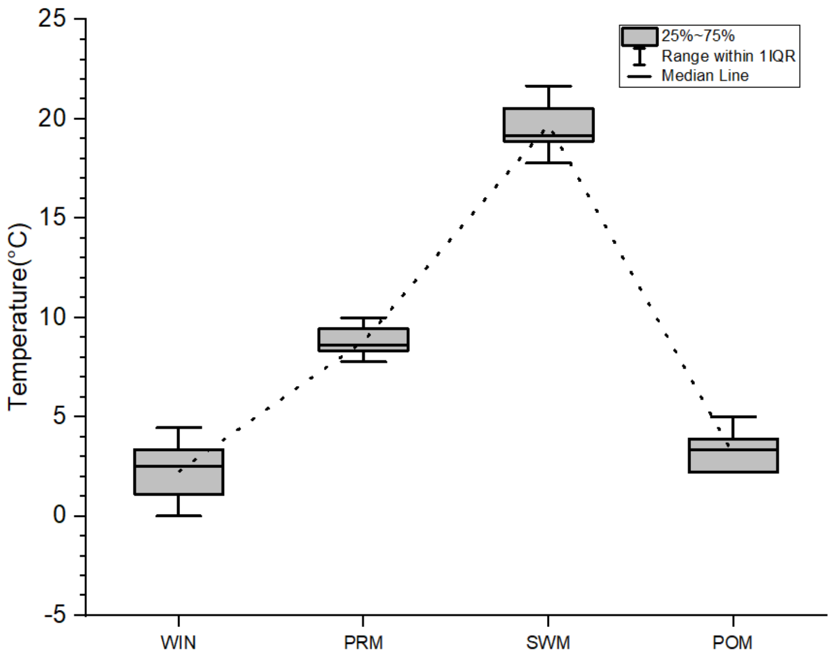

Figure 4.6: Statistical distribution of seasonal minimum temperature

4.2.4 Rainfall

4.2.4.1 Monthly rainfall statistical distribution

The figure: 4.7 show the graph box and whisker plot of the monthly rainfall. From the data of the table: 4.7, the maximum range of rainfall of 6.30 mm – 353.20 mm for the months of November and June whereas for the minimum rainfall range of 0 – 43.20 for the months of March and July. The dotted line shows a normal curve connecting the median values of the monthly rainfall temperature. From the graph the maximum rainfall variation is seen for the months of June to September with maximum for all in the upper quartile range values which means increase in rainfall can be seen in the future.

Table 4.7: Statistical distribution of monthly rainfall

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Maximum	76.60	122.80	150.30	63.80	115.70	**353.20**	342.30	298.10	341.80	91.20	**6.30**	69.00
Minimum	4.00	2.10	**0.00**	0.10	0.20	10.50	**43.20**	25.20	1.40	0.00	0.00	0.00
Mean	37.81	40.49	31.58	22.68	32.19	87.07	**140.30**	125.49	122.22	11.61	**1.82**	13.90
Median	38.85	39.75	20.80	16.10	23.60	61.65	**115.95**	112.80	101.90	2.65	**0.95**	10.95
Std Dev	21.31	34.59	37.88	20.75	33.53	88.27	82.07	76.33	99.18	22.30	2.20	16.78

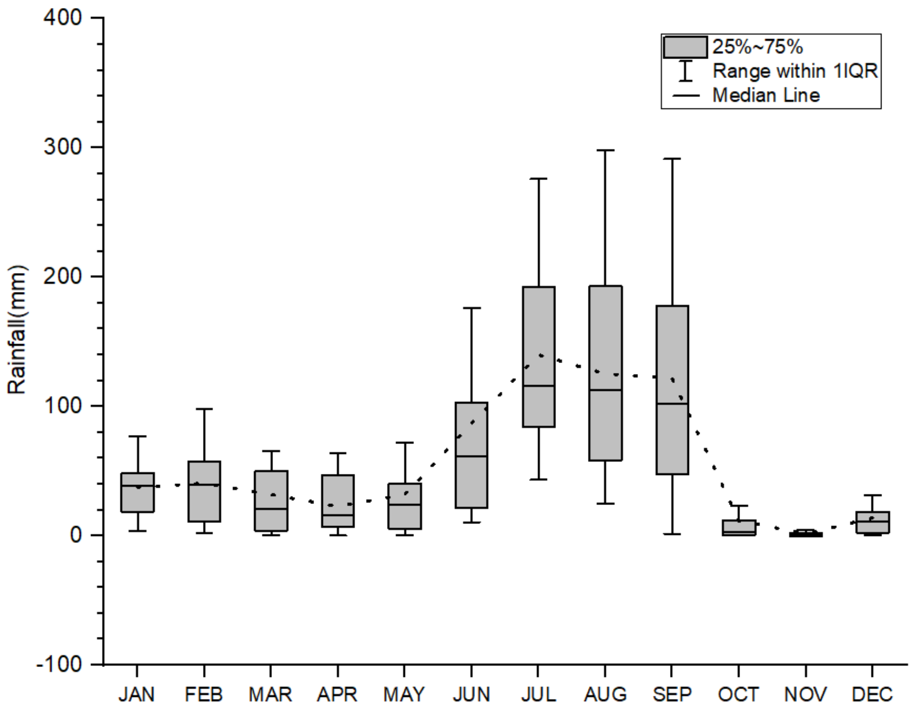

Figure 4.7: Statistical distribution of monthly rainfall

4.2.4.2 Seasonally rainfall statistical distribution

The box and whisker plot of the seasonally rainfall is shown in Figure: 4.8. From the data presented in table:4.8 , maximum seasonal rainfall range is seen of 94.10 mm – 801.50mm for the post monsoon and the south west monsoon whereas for the minimum rainfall range of 0.10 mm – 233.90mm for the post monsoon season and southwest monsoon seasons. The dotted line plots a normal curve for the seasonally rainfall connecting there medians. From the graph, the maximum variation rainfall range is seen for the southwest monsoon of the upper quartile range values which gives the probability of increase of rainfall in this season.

Table 4.8: Statistical distribution of seasonal rainfall

	WIN	PRM	SWM	POM
Maximum	162.10	224.10	**801.50**	**94.10**
Minimum	23.50	21.30	**233.90**	**0.10**
Mean	78.29	86.44	**475.08**	**27.33**
Median	64.45	83.15	**417.45**	**20.75**
Std Dev	40.43	51.81	188.10	24.95

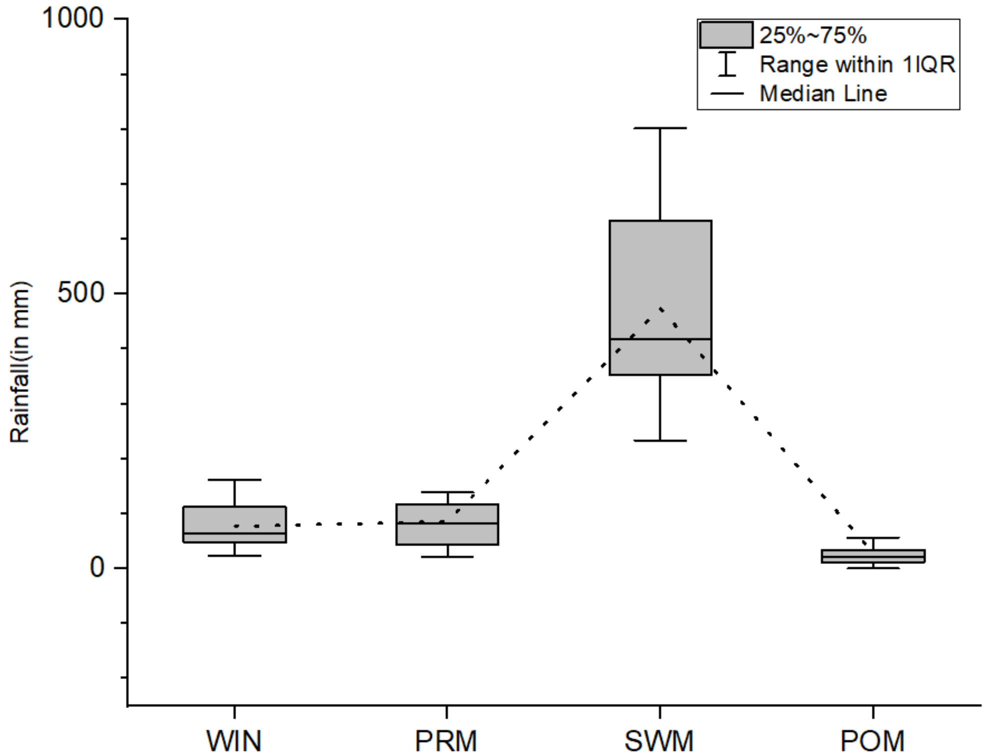

Figure 4.8: Statistical distribution of seasonal rainfall

4.3 Analysis of trends

4.3.1 Monthly trends

4.3.1.1 Monthly rainfall trends

The trend test results of the monthly rainfall calculated using the MK test demonstrates both increasing and decreasing trends. The results of the monthly trends from the MK test are evaluated at 99% confidence level are shown in figure: 4.9.The trends in rainfall are shown in figure: 4.9, from where varying non-significant trends were found except September as there was no trend. The MK test is calculated by keeping value of $\alpha = 0.05$ and the values obtained of P and Z for rainfall are shown in table 4.9. The trend value varies from -1.06 to 1.17. Increasing non-significant trends were found for the months of January, February, March, April, august, October, November, December and decreasing non-significant trends for the May, June, July.

Table 4.9: Trend value of monthly rainfall

Rainfall												
	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
Z-test	0.61	0.83	1.21	1.52	-1.06	-0.45	-0.53	0.98	0.00	0.87	0.65	0.15
P-value	0.54	0.40	0.22	0.13	0.29	0.65	0.59	0.32	1.00	0.38	0.51	0.87

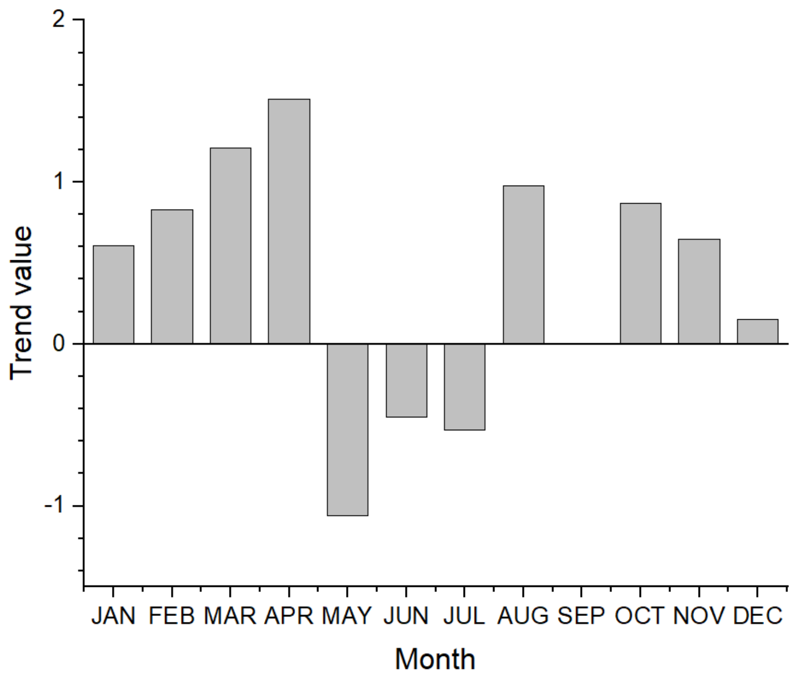

Figure 4.9: Trend value of monthly rainfall

4.3.1.2 Monthly average temperature trends

For the average temperature, the graph between the trend value and months is shown in figure: 4.10 from where significant trend was found for the month of April and non-significant varying trends were found for the rest of the months. The values of P and Z-test obtained from MK test are shown in table: 4.10. The trend value varies from -2.12 to 1.36 with α=0.05. February, march, June, July, September, October, December showed increasing non-significant trends and January, may, august, November showed decreasing non-significant trends. The April month showed a decreasing significant trend with trend value of -2.12.

Table 4.10: Trend value of monthly average temperature

Average temperature												
	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
Z-test	-0.61	0.23	0.30	**-2.12**	-0.38	0.83	0.38	-0.53	0.45	1.36	-0.23	0.15
P-value	0.54	0.82	0.76	**0.03**	0.70	0.40	0.70	0.60	0.65	0.17	0.82	0.88

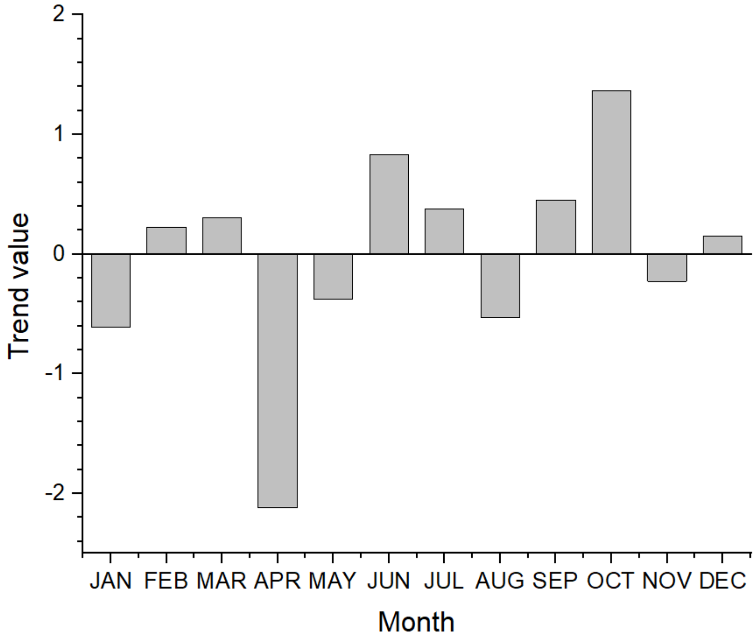

Figure 4.10: Trend value of monthly average temperature

4.3.1.3 Monthly maximum temperature trends

Table .4.11: Trend value of monthly maximum temperature

Maximum temperature												
	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
Z-test	-0.23	-0.11	-0.49	-1.70	-0.68	1.82	1.48	1.14	-0.64	-1.58	-0.23	0.46
P-value	0.82	0.91	0.62	0.09	0.50	0.07	0.14	0.25	0.52	0.11	0.82	0.65

For the maximum temperature, the graph between the trend value and months is shown in figure: 4.11 from where non-significant varying trends were found. The values of P and Z-test obtained from MK test are shown in table: 4.11. The trend value varies from -2.12 to 1.36

with α=0.05. June, July, august, December showed non-significant increasing trends and January to May, September to November showed non-significant decreasing trends.

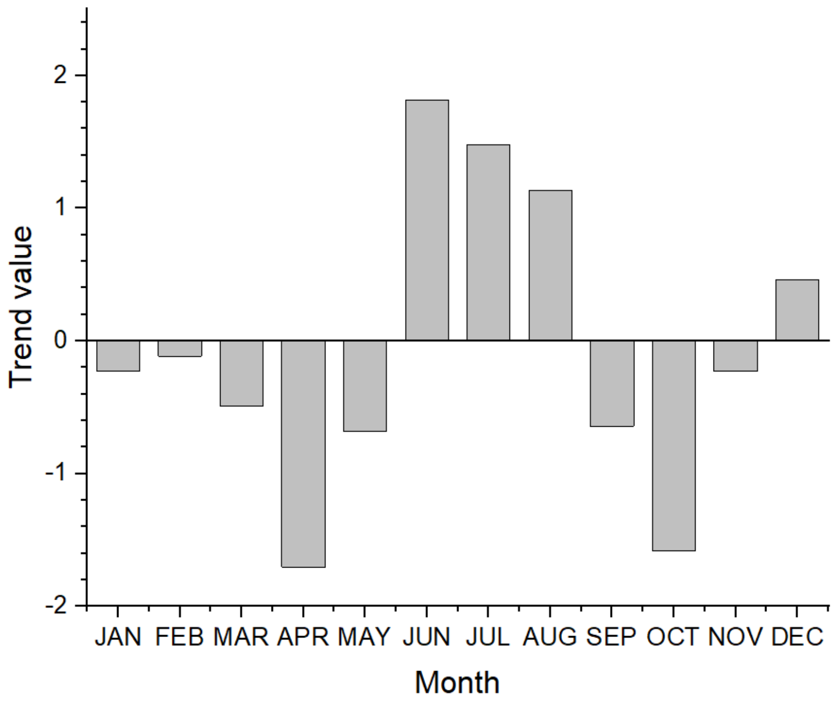

Figure 4.11: Trend value of monthly maximum temperature

4.3.1.4 Monthly minimum temperature trends

For the minimum temperature, the graph between the trend value and months is shown in figure: 4.12 from where non-significant varying trends were found. The values of P and Z-test obtained from MK test are shown in table: 4.12. The trend value varies from -0.73 to 3.28 with α=0.05. November showed significant trend with trend value of 3.28, rest all months showed non-significant varying trends. January to September, November showed increasing trends and October, December showed decreasing trend.

Table 4.12: Trend value of monthly minimum temperature

Minimum temperature												
	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
Z-test	1.17	1.06	0.80	0.98	1.33	1.06	0.19	0.61	0.64	-0.73	**3.28**	-0.19
P-value	0.24	0.29	0.43	0.32	0.18	0.29	0.85	0.54	0.52	0.46	**0.00**	0.85

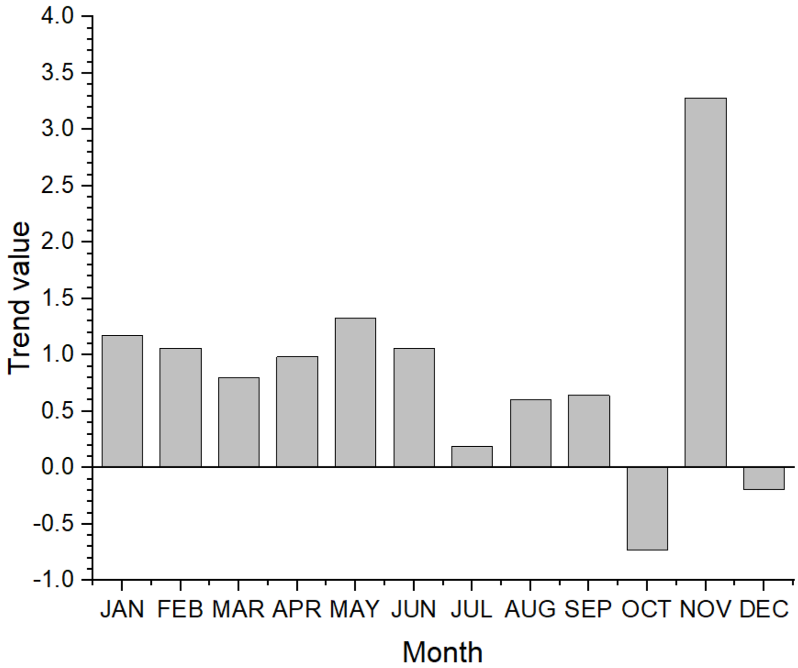

Figure 4.12: Trend value of monthly minimum temperature

4.3.2 Seasonal trends

The seasons are divided into four: - Winter(January-February), Premonsoon(March-May), Southwest monsoon(June-September), Post monsoon(October-December). The seasons are divided accordingly as being classified as by the Indian Meteorological Department, Pune.

4.3.2.1 Seasonal rainfall trends

For the seasonal rainfall, the graph between the trend value and seasons is shown in figure: 4.133 from where non-significant varying trends were found. The values of P and Z-test obtained from MK test are shown in table: 4.13. The trend value varies from -0.30 to 1.17 with α=0.05. The winter, pre-monsoon showed increasing trend and southwest monsoon, post monsoon showed decreasing trend for rainfall.

Table 4.13: Trend value of Seasonal rainfall

Rainfall				
	WIN	**PRM**	**SWM**	**POM**
Z-test	1.14	1.17	-0.30	-0.23
P-value	0.26	0.24	0.76	0.82

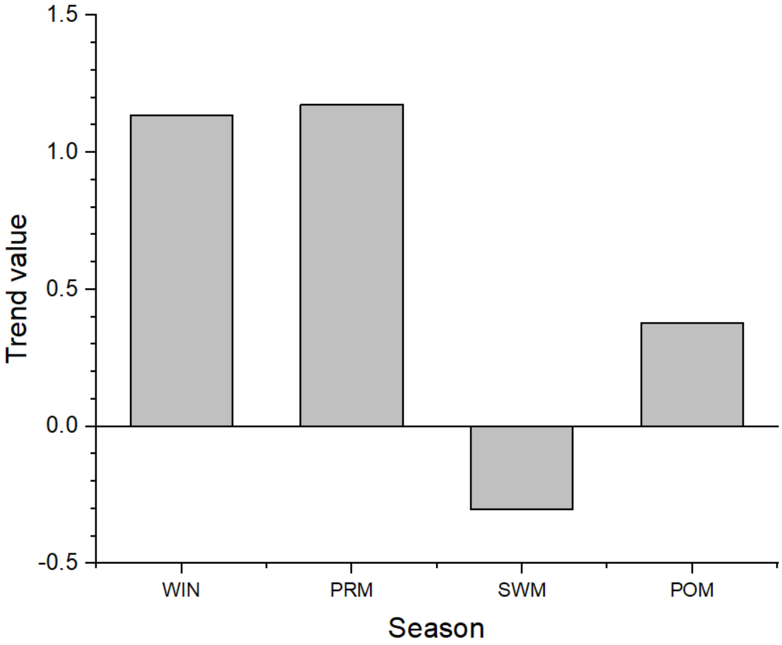

Figure 4.13: Trend value of seasonal rainfall

4.3.2.2 Seasonal average temperature trends

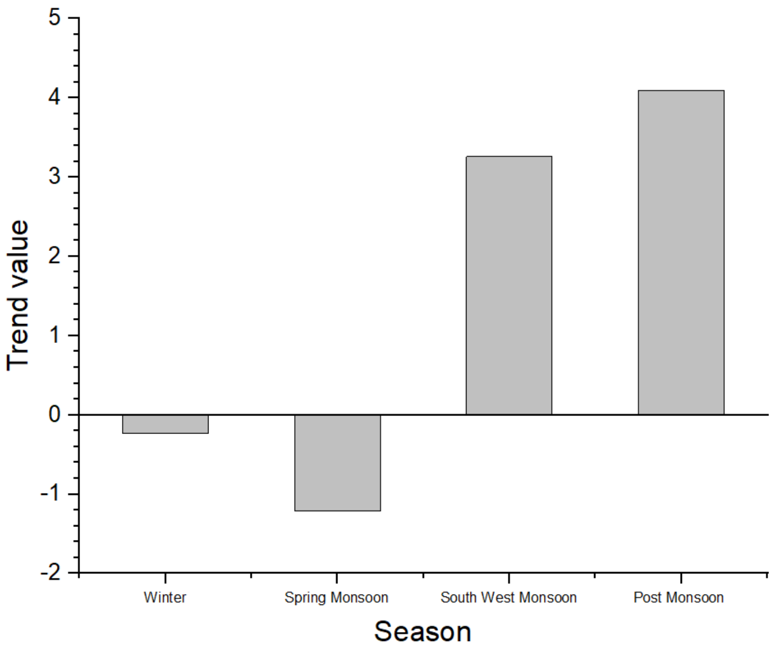

Figure 4.14: Trend value of seasonal average temperature

For the seasonal average temperature, the graph between the trend value and seasons is shown in figure: 4.14 from where significant increasing trends were found for southwest monsoon, post monsoon. The values of P and Z-test obtained from MK test are shown in table: 4.14. The trend value varies from -1.21 to 4.09 with α=0.05. The winter and pre-monsoon showed non-significant decreasing trend.

Table 4.14: Seasonal average temperature

Average temperature``				
	WIN	**PRM**	**SWM**	**POM**
Z-test	-0.23	-1.21	**3.26**	**4.09**
P-value	0.82	0.23	**0.00**	**0.00**

4.3.2.3 Seasonal maximum temperature

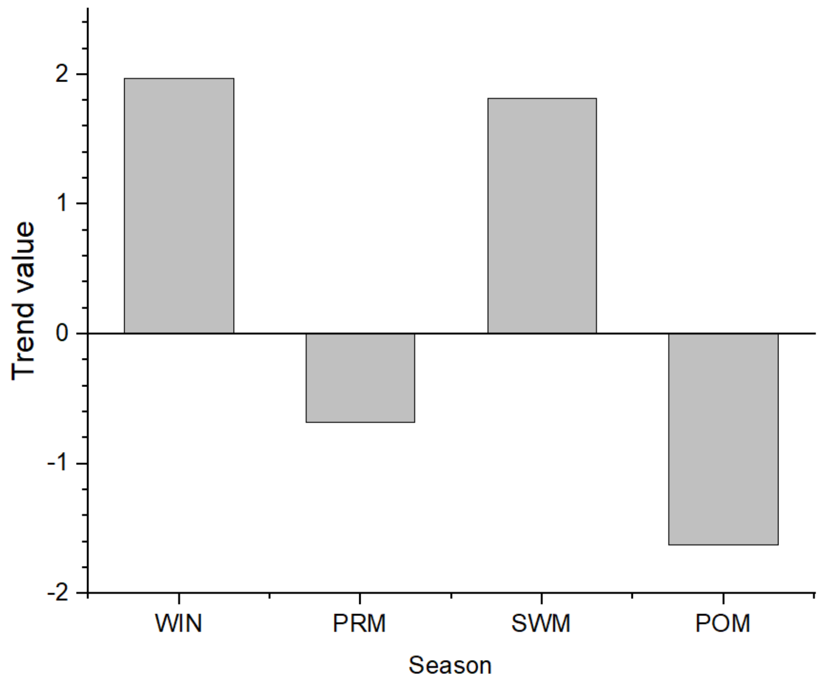

Figure 4.15: Trend value of seasonal maximum temperatu**re**

For the seasonal maximum temperature, the graph between the trend value and seasons is shown in figure: 4.15 from where significant increasing trends were found for winter season with trend value of 1.97. The values of P and Z-test obtained from MK test are shown in table: 4.15. The trend value varies from -1.63 to 1.97 with α=0.05. The pre-monsoon, post monsoon showed non-significant decreasing trend and the southwest monsoon showed non-significant increasing trend.

Table 4.15: Seasonal maximum temperature

Maximum tenperature`				
	WIN	**PRM**	**SWM**	**POM**
Z-test	**1.97**	-0.68	1.82	-1.63
P-value	**0.05**	0.50	0.07	0.10

4.3.2.4 Seasonal minimum temperature

For the seasonal minimum temperature, the graph between the trend value and seasons is shown in figure: 4.16 from where no significant trends were found. The values of P and Z-test obtained from MK test are shown in table: 4.16. The trend value varies from 0.68 to 1.33 with α=0.05. All seasons showed non-significant increasing trend.

Table 4.16: Seasonal minimum temperature

Minimum temperature`				
	WIN	**PRM**	**SWM**	**POM**
Z-test	1.33	0.80	1.06	0.68
P-value	0.18	0.43	0.29	0.50

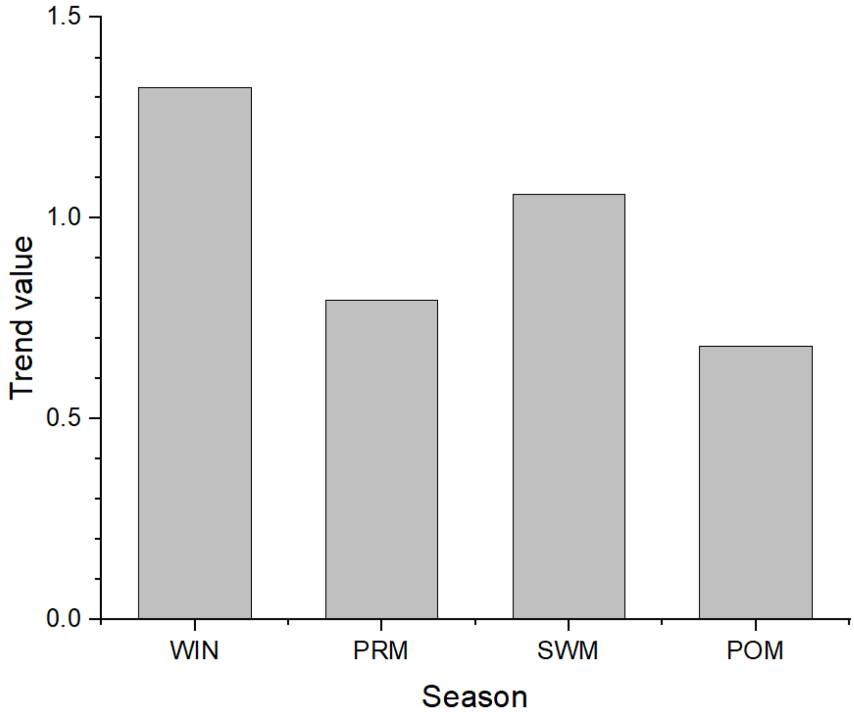

Figure 4.16: Trend value of seasonal minimum temperature

4.3.3 Annual trends

The annual trends of average rainfall (AVRA), average temperature (AVAT), maximum temperature (MXAT) and minimum temperature (MIAT) graph between the trend value and seasons is shown in figure: 4.17 from where significant trends were found for minimum annual temperature with trend value of 2.73. The values of P and Z-test obtained from MK test are shown in table: 4.17. The trend value varies from -0.30 to 2.73 with α=0.05. Annual rainfall, maximum annual temperature showed increasing non-significant trend and average annual temperature showed non-significant decreasing trend.

Table 4.17: Annual trends of rainfall and temperature

Annual				
	AVRA	**AVAT**	**MXAT**	**MIAT+**
Z-test	0.45	-0.30	0.23	**2.73**
P-value	0.65	0.76	0.82	**0.01**

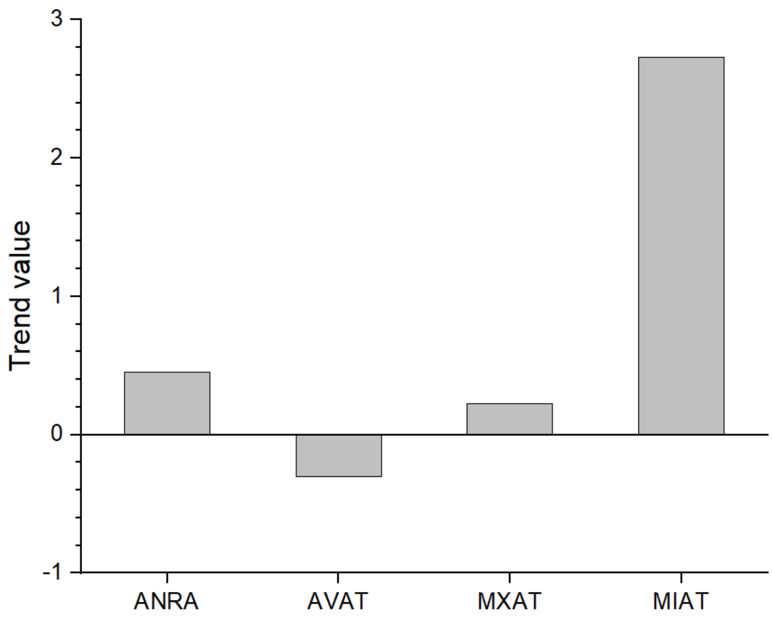

Figure 4.17: Trend value of annual data

4.4 Magnitude of trends

The quantification of the increasing and decreasing trends in the monthly, seasonal and annual time series of rainfall, average temperature, maximum temperature and minimum temperature are work out from the SSE test and are presented for Patiala in Tables 4.18-4.25. The values of Q_{min} and Q_{max} are calculated at 95 percent significance level.

4.4.1 Monthly quantification

4.4.1.1 Magnitude of monthly rainfall

The magnitudes of the monthly rainfall are varying from -3.166 to 3.5 mm per year with mean value of 0.0901 mm per year. The values evaluated of the magnitudes using SSE test are shown in the table: 4.19. The increasing magnitudes were seen for the months of February to April, august to December and decreasing magnitudes for the January, May to July.

4.4.1.2 Magnitude of average temperature

The magnitude of the average temperature varies from -0.033 to 0.082°C per year with the mean value of -0.00597 degree per year. The values evaluated of the magnitudes of average temperature using SSE test are shown in the table: 4.20. The increasing magnitudes were seen for the months of February, June, July, September, October, December and decreasing magnitudes for the January, April, May, August, November.

4.4.1.3 Magnitude of maximum temperature

The magnitude of the maximum temperature varies from -0.159 to 0.093°C per year with the mean value of -0.00072°C per year. The values evaluated of the magnitudes of maximum temperature using SSE test are shown in the table: 4.21. The increasing magnitudes were seen for the months of June, July, august and decreasing magnitudes for the January, April, October.

4.4.1.4 Magnitude of minimum temperature

The magnitude of the minimum temperature varies from -0.185 to 0.111°C per year with the mean value of 0.046741°C per year. The values evaluated of the magnitudes of minimum temperature using SSE test are shown in the table: 4.22. The increasing magnitudes were seen for the months of February, April to June, September, November and decreasing magnitudes for the January, October.

4.4.2 Seasonal quantification

4.4.2.1 Magnitudes of seasonal rainfall

The magnitudes of the seasonal rainfall are varying from -4.771 to 2.813mm per year with mean value of -1.70557mm per year. The values evaluated of the magnitudes using SSE test are shown in the table: 4.18. The increasing magnitudes were seen for the premonsoon season and decreasing magnitudes for the winter, southwest monsoon, post monsoon.

Table 4.18: Magnitude of trends of Seasonal rainfall

Rainfall				
	WIN	**PRM**	**SWM**	**POM**
Slope	-1.650	2.813	-3.213	-4.771
Q_{min}	0.086	-1.567	-15.575	-34.257
Q_{max}	5.375	7.967	13.862	29.392

4.4.2.2 Magnitudes of seasonal average temperature

The magnitudes of the seasonal average temperature are varying from -0.078 to 0.025°C per year with mean value of -0.02293°C per year. The values evaluated of the magnitudes using SSE test are shown in the table: 4.23. The increasing magnitudes were seen for the southwest monsoon, post monsoon and decreasing magnitudes for the winter, premonsoon season.

Table 4.19: Magnitude of trends of rainfall using SSE test

Rainfall												
	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
Slope	-0.800	1.210	1.933	0.785	-1.310	-1.373	-3.166	3.500	0.042	0.166	0.038	0.057
Q_{min}	-0.880	-2.640	-0.450	-0.433	-3.400	-7.123	-10.350	-4.200	-10.630	-0.300	-0.088	-1.054
Q_{max}	3.300	3.925	5.570	3.293	1.260	5.069	5.322	10.900	10.310	1.076	0.200	1.170

Table 4.20: Magnitude of trends of average temperature using SSE test

Average temperature												
	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
Slope	-0.063	0.019	0.022	-0.134	-0.033	0.082	0.023	-0.023	0.008	0.026	-0.010	0.012
Q_{min}	-0.092	-0.113	-0.114	-0.252	-0.168	-0.111	-0.072	-0.060	-0.050	-0.027	-0.078	-0.059
Q_{max}	0.072	0.099	0.158	-0.007	0.092	0.222	0.090	0.042	0.049	0.098	0.081	0.099

Table 4.21: Magnitude of trends of maximum temperature using SSE test

Maximum temperature												
	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
Slope	-0.128	0.000	0.000	-0.159	0.000	0.167	0.093	0.062	0.000	-0.043	0.000	0.000
Q_{min}	-0.093	-0.185	-0.231	-0.333	-0.128	0.000	0.000	0.000	-0.069	-0.101	-0.111	-0.079
Q_{max}	0.185	0.185	0.159	0.000	0.062	0.370	0.214	0.139	0.000	0.000	0.062	0.139

Table 4.22: Magnitude of trends of minimum temperature using SSE test

Minimum temperature												
	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
Slope	-0.185	0.111	0.000	0.069	0.101	0.069	0.000	0.000	0.062	-0.037	0.370	0.000
Q_{min}	0.000	-0.079	-0.033	-0.037	0.000	0.000	-0.079	-0.043	-0.101	-0.222	0.208	-0.085
Q_{max}	0.247	0.278	0.119	0.185	0.278	0.222	0.093	0.111	0.208	0.051	0.556	0.079

Table 4.23: Magnitude of trends of average temperature

Average temperature				
	WIN	**PRM**	**SWM**	**POM**
Slope	-0.078	-0.059	0.020	0.025
Q_{max}	-0.062	-0.106	0.007	0.018
Q_{max}	0.060	0.021	0.030	0.031

4.4.2.3 Magnitudes of seasonal maximum temperature

The magnitudes of the seasonal maximum temperature are varying from -0.043 to 0.193°C per year with mean value of 0.079247°C per year. The values evaluated of the magnitudes using SSE test are shown in the table: 4.24. The increasing magnitudes were seen for the winter, southwest monsoon and decreasing magnitudes for the post monsoon.

Table 4.24: Magnitude of trends of maximum temperature

Maximum temperature				
	WIN	**PRM**	**SWM**	**POM**
Slope	0.193	0.000	0.167	-0.043
Q_{max}	0.141	-0.185	0.000	-0.123
Q_{max}	3.902	0.101	0.370	0.000

4.4.2.4 Magnitudes of seasonal minimum temperature

The magnitudes of the seasonal minimum temperature are varying from -0.043 to 0.069 mm per year with mean value of 0.017318 mm per year. The values evaluated of the magnitudes using SSE test are shown in the table: 4.25. The increasing magnitudes were seen for the southwest monsoon, post monsoon and decreasing magnitudes for the winter season.

Table 4.25: Magnitude of trends of minimum temperature

Minimum temperature				
	WIN	**PRM**	**SWM**	**POM**
Slope	-0.043	0.000	0.069	0.043
Q_{max}	-0.043	-0.062	0.000	-0.085
Q_{max}	0.278	0.152	0.208	0.222

4.4.3 Annual quantification

The magnitudes of the annual climatological parameters are varying from -0.411 to 0.185 mm per year with mean value of -0.0588674 mm per year. The values evaluated of the magnitudes using SSE test are shown in the table: 4.26. The increasing magnitudes were seen for the minimum annual temperature and decreasing magnitudes for the annual rainfall, annual average temperature.

Table 4.26: Magnitude of trends annualy

Annual				
	AVRA	**AVAT**	**MXAT**	**MIAT**
Slope	-0.411	-0.010	0.000	0.185
Q_{max}	-10.767	-0.039	-0.119	0.001
Q_{max}	25.514	0.029	0.111	0.296

4.5 Correlation between rainfall and average temperature

The correlation between rainfall and average temperature is done for the monthly and seasonally for the time period of 1998 to 2015. The correlation is done with three methods namely: - Pearson correlation, Kendall tau correlation and spearman rho test. Varying significant and non-significant negative correlation was found for the monthly and seasonally data. The correlation is checked at a significance level of 0.05 and 0.01.

4.5.1 Monthly correlation

Table 4.27: Monthly correlation of rainfall and average temperature

		JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**
Pearson correlation	**Coefficient**	-0.04	-0.33	-0.39	-0.44	-0.45	**-0.73**
	P value	0.86	0.18	0.11	0.07	0.06	**>0.01**
Kendall Tau	**Coefficient**	-0.03	-0.25	**-0.39**	-0.19	-0.27	**-0.60**
	P value	0.88	0.14	**0.03**	0.27	0.12	**>0.01**
Spearman correlation	**Coefficient**	-0.02	-0.38	**-0.53**	-0.29	-0.42	**-0.76**
	P value	0.93	0.12	**0.02**	0.25	0.08	**>0.01**
		JUL	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
Pearson correlation	**Coefficient**	**-0.55**	**-0.71**	-0.04	-0.10	-0.04	-0.20
	P value	**0.02**	**0.00**	0.88	0.68	0.86	0.42
Kendall Tau	**Coefficient**	**-0.40**	**-0.48**	-0.24	-0.03	-0.14	0.01
	P value	**0.02**	**0.01**	0.17	0.88	0.44	0.97
Spearman correlation	**Coefficient**	**-0.59**	**-0.65**	-0.33	-0.05	-0.18	0.03
	P value	**0.01**	**>0.01**	0.19	0.83	0.47	0.90

The correlation between rainfall and average temperature was done by using above mentioned three methodologies. Mostly the significant results were approved by all of them. The outcomes of these results are shown in Table: 4.27. For the January month, negative non-significant result with mean value of -0.3133 and P value of 0.890512. The February month showed negative non-significant result with mean value of -0.3219 and P value of 0.146. The March month showed negative significant result from Kendall tau, spearman rho with value of -0.386, -0.527 and P value of 0.0254, 0.0245. The values obtained are significant at 0.05 levels. The April month showed negative non-significant result with mean value of -0.305 and P value of 0.197. For the May month, negative non-significant result with mean value of -0.3779 and P value of 0.0877 were present. The June month showed negative significant result from Kendall tau, spearman rho with mean value of -0.695 and P value of 0.0877. The values obtained are significant at 0.01 levels. The July month showed negative significant result from Kendall tau, spearman rho with mean value of -0.511 and P value of 0.016. The values obtained are significant at 0.05 levels. August month showed negative significant result from Kendall tau, spearman rho with mean value of -0.609 and P value of 0.003 .September month showed negative non-significant result with mean value of -0.2009 and P value of 0.4123. October month showed negative non-significant result with mean value of -0.061 and P value of 0.791. November month showed negative non-significant result with mean value of -0.120 and P value of 0.592. December month showed negative non-significant result with mean value of -0.055 and P value of 0.762.

4.5.2 Seasonal correlation

Table 4.28: Seasonally correlation between rainfall and temperature

		WIN	PRM	SWM	POM
Pearson correlation	**Coefficient**	-0.29	-0.45	**-0.61**	0.33
	P value	0.24	0.06	**0.01**	0.18
Kendall Tau	**Coefficient**	-0.14	-0.20	**-0.41**	0.23
	P value	0.43	0.26	**0.02**	0.18
Spearman correlation	**Coefficient**	-0.18	-0.26	**-0.58**	0.33
	P value	0.46	0.29	**0.01**	0.19

The seasonal correlation between rainfall and average temperature was done by using above mentioned three methodologies. Mostly the significant results were approved by all of them. The outcomes of these results are shown in Table: 4.28. The correlation between rainfall and average temperature for the winter season showed negative non-significant result with mean value of -0.204 and P value of 0.376. The premonsoon season showed negative non-significant result with mean value of -0.301 and P value of 0.204. Winter season showed negative significant result with Pearson correlation value of -0.612, significant at 0.01 level and with Kendall tau, spearman rho test values of -0.412, -0.581 got significant at 0.05 level. For the post monsoon season, negative non-significant result with mean value of -0.294 and P value of 0.184 were present.

CHAPTER 5 CONCLUSION

The study of trends of rainfall and temperature are important to understand the climate change and any abrupt changes in observations helps to know the occurrence of extreme events in the future. By applying MK test for the trend analysis and quantifying with the SSE test made it is to better analyse the trends. Furthermore, analysing trends at monthly, seasonally and annually give us better understanding of the trends.

Monthly analysis showed that decreasing significant trends were present of average temperature for the month of April with of 0.13 °C per year and an increasing significant trend is seen of minimum average temperature of November month with 0.37°C per year. For the season analysis, positive significant trends were seen for the average temperature in the southwest monsoon and the post monsoon season. Further, increasing significant trends were seen for the winter season. In the annual analysis, significant increasing trend were seen for the minimum temperature.

The correlation was found between rainfall and average temperature. It was found that in the monthly analysis, significant trends were found for the March, June, July and august months found at 0.001and 0.005 significance level. For the seasonally correlation, south west monsoon was found significant. The Historical trend analysis gives a better vision of the local rainfall patterns and also helps regulatory bodies to provide better hydrological strategies to combat with natural calamities like floods and droughts with optimum water resource management.

FUTURE SCOPE

The variations in climate occur at different time scales for example monthly, seasonally, annually. The analysis of trends of rainfall and temperature will help us to control any significant variations seen in the historic datasets. Further this analysis will give a better vision of the local rainfall patterns and also helps regulatory bodies to provide better hydrological strategies to combat with natural calamities like floods and droughts with optimum water resource management.

REFERENCES

Asfaw, Amogne, Belay Simane, Ali Hassen, and Amare Bantider. 2018. "Variability and Time Series Trend Analysis of Rainfall and Temperature in Northcentral Ethiopia: A Case Study in Woleka Sub-Basin." *Weather and Climate Extremes* 19(December 2017): 29–41. Https://doi.org/10.1016/j.wace.2017.12.002.

Bhuyan, Md. Didarul Islam, Md. Mohymenul Islam, and Md. Ebrahim Khalil Bhuiyan. 2018. "A Trend Analysis of Temperature and Rainfall to Predict Climate Change for Northwestern Region of Bangladesh." *American Journal of Climate Change* 07(02): 115–34.

Bisht, Deepak Singh, Chandranath Chatterjee, Narendra Singh Raghuwanshi, and Venkataramana Sridhar. 2018. "Spatio-Temporal Trends of Rainfall across Indian River Basins." *Theoretical and Applied Climatology* 132(1–2): 419–36.

Blanchet, Juliette, Gilles Molinié, and Julien Touati. 2018. "Spatial Analysis of Trend in Extreme Daily Rainfall in Southern France." *Climate Dynamics* 51(3): 799–812.

Buhairi, Mahyoub H Al. 2010. "Analysis of Monthly , Seasonal and Annual Air Temperature Variability and Trends in Taiz City - Republic of Yemen." 2010(December): 401–9.

Byakatonda, Jimmy, B. P. Parida, Piet K. Kenabatho, and D. B. Moalafhi. 2018. "Analysis of Rainfall and Temperature Time Series to Detect Long-Term Climatic Trends and Variability over Semi-Arid Botswana." *Journal of Earth System Science* 127(2): 1–20. Https://doi.org/10.1007/s12040-018-0926-3.

Croitoru, Adina-eliza, and Adrian Piticar. 2013. "Changes in Daily Extreme Temperatures in the Extra-Carpathians Regions of Romania." 2001(August 2012): 1987–2001.

Dai, Shu-Wei et al. 2011. "Changes of China Agricultural Climate Resources under the Background of Climate Change. II. Spatiotemporal Change Characteristics of Agricultural Climate Resources in Southwest China." *Chinese Journal of Applied Ecology* 22(2): 442–52.

Emmanuel, Lawin, Nina Houngué, Chabi Biaou, and Djigbo Badou. 2019. "Statistical

Analysis of Recent and Future Rainfall and Temperature Variability in the Mono River Watershed (Benin, Togo).” *Climate* 7(1): 8.

Gedefaw, Mohammed, Denghua Yan, et al. 2018. “Innovative Trend Analysis of Annual and Seasonal Rainfall Variability in Amhara Regional State, Ethiopia.” *Atmosphere* 9(9): 326.

Gedefaw, Mohammed, Hao Wang, et al. 2018. “Trend Analysis of Climatic and Hydrological Variables in the Awash River Basin, Ethiopia.” *Water (Switzerland)* 10(11): 1–14.

Ghahraman, Bijan, and Saleh Taghvaeian. 2008. “Investigation of Annual Rainfall Trends in Iran Investigation of Annual Rainfall Trends in Iran.” (January).

Jain, S. K., Vijay Kumar, and M. Saharia. 2013. “Analysis of Rainfall and Temperature Trends in Northeast India.” *International Journal of Climatology* 33(4): 968–78.

Jaiswal, R. K., A. K. Lohani, and H. L. Tiwari. 2015. “Statistical Analysis for Change Detection and Trend Assessment in Climatological Parameters.” *Environmental Processes* 2(4): 729–49.

Karmeshu, Neha. 2012. “Trend Detection in Annual Temperature & Precipitation Using the Mann Kendall Test – A Case Study to Assess Climate Change on Select States in the Northeastern United States Trend Detection in Annual Temperature & Precipitation Using the Mann.”

Karpouzos, D K, S Kavalieratou, and C Babajimopoulos. 2015. “Trend Analysis of Precipitation Data in Pieria Region (Greece).” (November).

Kumar, Navneet, Bernhard Tischbein, and Mirza Kaleem Beg. 2018. “Multiple Trend Analysis of Rainfall and Temperature for a Monsoon-Dominated Catchment in India.” *Meteorology and Atmospheric Physics* (0123456789): 1–15. Https://doi.org/10.1007/s00703-018-0617-2.

Machiwal, Deepesh, Ankit Gupta, Madan Kumar Jha, and Trupti Kamble. 2019. “Analysis of Trend in Temperature and Rainfall Time Series of an Indian Arid Region: Comparative Evaluation of Salient Techniques.” *Theoretical and Applied Climatology* 136(1–2): 301–20.

Mahajan, D.R., and B.M. Dodamani. 2015. “Trend Analysis of Drought Events Over Upper Krishna Basin in Maharashtra.” *Aquatic Procedia* 4(Icwrcoe): 1250–57. Http://dx.doi.org/10.1016/j.aqpro.2015.02.163.

Mondal, Arun, Sananda Kundu, and Anirban Mukhopadhyay. 2012. “Case Study 70 RAINFALL TREND ANALYSIS BY MANN-KENDALL TEST: A CASE STUDY OF NORTH-EASTERN PART OF CUTTACK DISTRICT, ORISSA.” *Online) An Online International Journal Available at* 2(1): 70–78. Http://www.cibtech.org/jgee.htm.

Mrad, Dounia, Yassine Djebbar, and Yahia Hammar. 2018. “Analysis of Trend Rainfall: Case of North-Eastern Algeria.” *Journal of Water and Land Development* 36(1): 105–15.

Negi, R S, Alok Sagar Gautam, and Santosh Singh. 2018. “Temperature and Rainfall Trend in Alaknanda Valley Srinagar Garhwal , Uttarakhand , India.” 108(August): 207–14.

Ninu Krishnan, M. V., M. V. Prasanna, and H. Vijith. 2019. “Annual and Seasonal Rainfall Trends in an Equatorial Tropical River Basin in Malaysian Borneo.” *Environmental Modeling and Assessment*.

Ogungbenro, Stephen Bunmi, and Tobi Eniolu Morakinyo. 2014. “Rainfall Distribution and Change Detection across Climatic Zones in Nigeria.” *Weather and Climate Extremes* 5(1): 1–6. Http://dx.doi.org/10.1016/j.wace.2014.10.002.

Rajeevan, M., Jyoti Bhate, and A. K. Jaswal. 2008. “Analysis of Variability and Trends of Extreme Rainfall Events over India Using 104 Years of Gridded Daily Rainfall Data.” *Geophysical Research Letters* 35(18): 1–6.

Rajwade, Yogesh, and Nidhi Kumari. 2018. “Trend Analysis and Change Point Detection of Rainfall for Andhra Pradesh and Trend Analysis and Change Point Detection of Rainfall of Andhra Pradesh And.” (June).

Salman, Saleem A. Et al. 2018. “Unidirectional Trends in Daily Rainfall Extremes of Iraq.” *Theoretical and Applied Climatology* 134(3–4): 1165–77.

Sanikhani, Hadi, Ozgur Kisi, Rasoul Mirabbasi, and Sarita Gajbhiye Meshram. 2018. “Trend Analysis of Rainfall Pattern over the Central India during 1901–2010.” *Arabian Journal* *of Geosciences* 11(15).

Sayyad, R S et al. 2019. “Analysis of Rainfall Trend of Parbhani , Maharshtra Using Mann – Kendall Test.” 21(2): 2–3.

Shadmani, Mojtaba, Safar Marofi, and Majid Roknian. 2012. “Trend Analysis in Reference Evapotranspiration Using Mann-Kendall and Spearman’s Rho Tests in Arid Regions of Iran.” *Water Resources Management* 26(1): 211–24.

Sharma, Sanjay, Pratiksha Dubey, and Indra Singh Mirdha. 2018. “Precipitation Trend Analysis by Mann-Kendall Test of Different Districts of Malwa Agroclimatic Zone Climatic Parameters at a Global Level . However , the All Especially in India . These Changes Must Be Quan- of Global Climate Change . The Purpose of This .” 36(June): 664–71.

Shiru, Mohammed Sanusi, Shamsuddin Shahid, Noraliani Alias, and Eun Sung Chung. 2018. “Trend Analysis of Droughts during Crop Growing Seasons of Nigeria.” *Sustainability (Switzerland)* 10(3): 1–13.

Singh, Diwan. 2018. “The Spatial Distribution of Rainfall , Extreme Indices in Haryana (INDIA) Using Geographic Information System.” 7(2): 3624–29.

Worku, Gebrekidan, Ermias Teferi, Amare Bantider, and Yihun T. Dile. 2019. “Observed Changes in Extremes of Daily Rainfall and Temperature in Jemma Sub-Basin, Upper Blue Nile Basin, Ethiopia.” *Theoretical and Applied Climatology* 135(3–4): 839–54.

gurnoor_thesis

ORIGINALITY REPORT

9%	4%	4%	6%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	www.gvrd.bc.ca Internet Source	1%
2	Submitted to Associatie K.U.Leuven Student Paper	1%
3	Submitted to Federal University of Technology Student Paper	1%
4	Md. Didarul Islam Bhuyan, Md. Mohymenul Islam, Md. Ebrahim Khalil Bhuiyan. "A Trend Analysis of Temperature and Rainfall to Predict Climate Change for Northwestern Region of Bangladesh", American Journal of Climate Change, 2018 Publication	<1%
5	opwall.com Internet Source	<1%
6	documents.mx Internet Source	<1%
7	R. K. Jaiswal, A. K. Lohani, H. L. Tiwari. "Statistical Analysis for Change Detection and	<1%