Rainfall Analysis of Jhelum Basin Kashmir Valley

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DECLARATION

We **Misbah Fayaz, Aqib Majied, Junaid Zahoor** and **Irtiza Nazir** declare that the project entitled **"Rainfall Analysis of Jhelum Basin of Kashmir Valley"** which is being submitted by us as a partial fulfillment for the award of Degree of **Bachelor of Technology in Civil Engineering of the Baba Ghulam Shah Badshah University, Rajouri** during the year 2019-2020, is an authentic record of our work carried out by us during B.Tech final year under the supervision of our guide **Dr. Nasir Ahmad Rather, Assistant Professor, Department of Civil Engineering, School of Engineering and Technology, BGSBU, Rajouri.**

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ABSTARCT

Kashmir is a part of UT Jammu and Kashmir. It is surrounded by greater Himalayas on all sides so, is also known as Kashmir valley. Kashmir has an area of about 15,502 km^2. It has variable topography due to which weather is mostly unpredictable. Climatic condition of Kashmir valley shows variability in nature. Any drastic change in the variables of the climate will affect the structures as well as living beings. The present study is intended to analyze the rainfall and temperature of the region for about last four decades. The data included six stations with the time series from 1980-2018. Srinagar station receives mean annual rainfall of 682.78 mm, which is very less as compared to other stations. Gulmarg station receives mean annual rainfall of 1417.03 mm, which is highest among all the stations. Before applying any test, the data was checked for the consistency with the help of double mass curve. The data showed consistency in accordance with the double mass curve. The analysis was done by performing various tests including Mann Kendall test, 5- year moving average and linear regression. This study also evaluated return period, frequency and probability of occurrence of all the six stations. The results showed decrease in the rainfall trend for all the stations. Among these stations Gulmarg station shows significant decrease in the trend. With the help of linear regression model all the stations showed decrease in trend with negative slope. While, the annual analysis of rainfall shows a decreasing trend at all station, Mann-Kendall test showed that the decreasing trend was significant (at 5% confidence level) only at Gulmarg station. Mean maximum temperature of all the station does not show similar trend. Some stations show increase in trend while some show decrease in trend. Srinagar, Pahalgam and Kupwara showed increase in trend with varying slope. There was decrease in trend in the mean maximum temperature for with varying negative slopes for Gulmarg, Qazigund and Kokernag. Rainfall versus mean maximum temperature variation was also evaluated in this study. Areas having high temperature received low rainfall and vice-versa.

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CHAPTER 1

INTRODUCTION

1. Introduction

1.0. General Introduction

There are many aspects of climate like Rainfall, Temperature, Atmospheric Pressure, Humidity. Each of these defines the weather conditions of a particular region. Climate is the average weather conditions of a particular region prevailing over a long period of time. It usually takes months or years to change. Weather is the atmospheric conditions of a region on weekly, daily and hourly basis. According to IPCC (2007) climate has become a serious concerns all over the world, if no such mitigation measures are taken to control the harmful gases likeCO_2,$N0_2$, green house gases, there may be the abrupt increase in the precipitation, rise in temperature, or even at some places droughts will occur. This will ultimately affect the agricultural production of a country. India has the Tropical monsoon type of climate. It is greatly influenced by the presence of Himalayas in North as they block the cold masses from Central Asia. It is because of Himalayas that the monsoon shed their water in India. The Tropic of Cancer divide India into two almost equal climatic zones, namely The Northern zone and the Southern zone. The Sub Tropical climate of the Northern zone gives it Cold Winter seasons and Hot Summer seasons while as the Southern Tropical Climate zone is warmer than North. Distribution of rainfall across country varies from region to region. There are the regions of very high rainfall above 200cm (Nagaland, Mizoram, Sikkim, West Bengal, Arunachal Pradesh). Areas of high rainfall 100-200cm (Northern Plain, Madhya Pradesh, Andhra Pradesh, Tamil Nadu). Areas of low rainfall 50-100cm (Gujarat, Maharashtra, Eastern Rajasthan). Areas of low rainfall below 50cm (Western Rajasthan, region of Ladakh).

India is one among the developing countries of the world where most of the economy is based on agriculture. Agriculture serves two-thirds of the overall population of the country. According to new series of National Income released by CSO the share of agriculture in total GDP is approx. 17% in 2017-2018. It also serves 58% of the total employment in the country. Thus, it becomes necessary to monitor and assess the different climatic variables of a country whose majority of the economy is Agrarian economy. Thus, the understanding of past and recent climate change will ultimately depict the future climatic scenarios.

CHAPTER 2

STUDY AREA

2.Study Area

2.1 Study Area

Kashmir is a valley between the PirPanjal and Himalayas and shares border with Himachal Pradesh and Punjab, Azad Kashmir and Gilgit Baltistan in south, west and northeast respectively. Pirpanjal isolates Kashmir from the northern plains while the great Himalayas divides from the Tibetan plateau. Kashmir has an area of about 15,502 km^2 and about 100 km wide. Kashmir because of its topography the weather is unpredictable. However, the climate is moderate, due to the geography that is Zanskar range, PirPanjal range and Karakorum range in its east, west and north respectively. The hilly areas of the valley have cooler weather as compared to the flat part of the valley. Usually the relative humidity is high and nights are cool in the summer part of the year however the precipitation occurs throughout the year no month remains dry throughout. The mean minimum temperature that occurs in Kashmir valley is -15^o C during December- January and the maximum temperature during these months are 0^{o}C. The hottest month that is July has the mean maximum temperature of 32^{o}Cand minimum is 16^{o}C. The average rainfall in the Kashmir valley is about 750 millimetres. Autumn is the driest season while spring is the wettest. The highest temperature that is recorded is 39.5 °C and the lowest is −20.0 °C. Kashmir valley has six meteorological stations- Gulmarg, Srinagar, Kupwara, Kokernag, Qazigund and Pahalgam. The Kashmir valley serves home for many towns the most famous is **Gulmarg**. Gauri Marg now known as Gulmarg is a town and also serves as hill station in Baramulla district. Gulmarg is situated in the cup shaped valley in Pirpanjal region. The altitude of this famous town is 2,730 meters from sea level and about 56 km from Srinagar. Because of the elevation the Gulmarg has humid continental climate. In summer the temperature is however moderate whereas the winter sees heavy snowfall especially because of latitude. Gulmarg has a sloping topography that is why it is suitable for skiing and attracts tourists. The town is much closer to the Indo-Pak Border. According to Indian Meteorological department based on the data of about 1951-2012 the maximum average relative humidity of the hill station has been recorded as 74% in the month of February and the minimum average relative humidity of the same has been recorded as 59% in the month of October. The mean maximum temperature has been recorded as 29.4^{o}C in the month of June and July. The mean minimum temperature has been recorded as -19.8^{o}C in the month of January. Another town which is usually famous for the tunnel is **Qazigund**. Qazigund is the town in Anantnag district. The elevation of this town is about 1670 m above the mean sea level. According to Indian meteorological department based on the data of about 1962-2012 the maximum average relative humidity of the famous town has been recorded as 69% in the month of January and the minimum average relative humidity of the same has been recorded as 51% in the month of October. The mean maximum temperature has been recorded as 35.7^{o}C in the month of June. The mean minimum temperature has been recorded as -16.7^{o}C in the month of February. **Kupwara** is also the known district in Kashmir. The latitude and longitude of which is about 34.5 and 74.2 respectively. The area of Kupwara is about 2379 km^2. Kupwara is situated in the northwest side of the Kashmir valley. The main source of the precipitation is the snowfall in the winter season. According to Indian Meteorological department based on the data of about

1977-2012 the maximum average relative humidity of the district has been recorded as 77% in the month of January and the minimum average relative humidity of the same has been recorded as 56% in the month of June. The mean maximum temperature has been recorded as 37.6^{o}C in the month of July. The mean minimum temperature has been recorded as -15.7^{o}C in the month of January. The very much acclaimed sub district of Kashmir valley is **Kokernag** which is situated in Anantnag district in Breng valley. Breng valley is referred as Golden crown of Kashmir. The sub district is famous because of its fresh water springs and garden. The place is about 25.4 km from the Anantnag district. The elevation of Kokernag is about 2000 from the mean sea level. Town situated in the sub district are Wangam, Nagam, Daksum etc. According to Indian meteorological department based on the data of about 1978-2010 the maximum average relative humidity of the sub district has been recorded as 79% in the month of January and the minimum average relative humidity of the same has been recorded as 55% in the month of June. The mean maximum temperature has been recorded as 34^{o}C in the month of June. The mean minimum temperature has been recorded as -15.3^{o}C in the month of January. In Anantnag district there is another town earlier known as Pahl Gaon now called as **Pahalgam** which is popular for tourist destination and hill station. It is situated on the banks of lidder river and is about 45km from Anantnag district. The elevation of the Pahalgam is about 2740m from the mean sea level. Pahalgam has a temperate climate with short and mild while long and cold summer and winter respectively. According to Indian meteorological department based on the data of about 1978-2012 the maximum average relative humidity of the hill station has been recorded as 82% in the month of January and the minimum average relative humidity of the same has been recorded as 57% in the month of May. The mean maximum temperature has been recorded as 32.2^{o}C in the month of august. The mean minimum temperature has been recorded as -18.6^{o}C in the month of January. The largest city of the Kashmir valley is **Srinagar.** Srinagar also serves as Summer capital of the Jammu and Kashmir. It is situated on the banks of Jhelum river in the Kashmir valley. Jhelum river is known as Vyath in Kashmir. The summer city has nine famous bridges and also known for the lakes for example the dal lake, the Anchar lake, the Wular lake, the Nigeen lake etc. the climate of Srinagar is sub-tropical humid climate. Srinagar experiences hot humid summers and cold and mild winters. According to Indian meteorological department based on the data of about 1978-2010 the maximum average relative humidity of the city has been recorded as 70% in the month of December and the minimum average relative humidity of the same has been recorded as 50% in the month of May. The mean maximum temperature has been recorded as 37.8^{o}C and 39.5^{o}C in the month of June and July respectively. The mean minimum temperature has been recorded as -20^{o}C in the month of February. The Srinagar has an elevation of about 1585m above sea level. the rainfall in Srinagar issignificant even in the driest months.

Fig 1. Jammu and Kashmir

- Srinagar
- Gulmarg
- Qazigund
- Pahalgam
- Kokernag
- Kupwara

CHAPTER 3

LITERATURE REVIEW

3. Literature Review

3.1. Literature

Various studies have analysed the trends of various climatic variables in order to find the various issues related to the unexpected change in the climate. Some of them include:

Rao (1993) showed the changes in climate and rainfall over Mahanadi river basin in India for a period of 1901-1980. Total area of Mahanadi river is about 1, 41, 600 km^2 and annual discharge of 66, 640 million m^3. For temperature analysis, (Sambalpur (SMB), Kanker (KNK), Cuttack (CTK), Jagdalpur (JDP), and Puri (PRI)) were selected, while as for rainfall analysis 125 rain gauge stations were selected and some important 10 stations were also considered.

The results of temperature analysis showed no trend at Sambalpur and Puri station in annual air temperature. All stations excluding above two showed increasing trend at 0.1-5%. Mean maximum, minimum and average surface temperatures showed trend levels at 0.1, 1 and 0.1%. The rate at which the temperature increased was depicted by the study as 1.1 ℃ per 100 year. In the winter season, significant increase in trend was observed at all stations except at Sambalpur and Puri stations. In pre-monsoon season no trend was found in Sambalpur, The Cuttack and Puri stations. Increasing trend was found in Jabalpur and Kanker. In monsoon season increasing trend was found at the Jabalpur, Kanker and Jagdalpur stations in the average mean temperature, and in Puri and Cuttack stations in maximum average temperature, in Jabalpur and Kanker in minimum average temperature. In post-monsoon an increasing trend was found in average mean temperature all the stations, except Sambalpur and Puri in mean maximum and minimum temperatures.

The results of rainfall analysis of 10 important stations selected did not show any significant trend neither in annual basis nor in monsoon season.

Archer and Fowler (2004) studied the spatial and temporal variation in rainfall in the Upper Indus basin (UIB) for the period 1894-1999. Indus basin consists of Northern areas of Pakistan and also nearby areas of Kashmir. This study was carried over almost 17 stations, and covered east-west distance of 300 km and north-south distance of 200 km in Pakistan and in Leh. The data collected from various stations include Pakistan Meteorological Department (PMD), Indian Meteorological Department, Climate Research Unit at University of east Anglia, England and Pakistan Water and Power Development Authority (WAPDA). Correlation and Regression analysis were used for spatial variation in rainfall. The result of correlation and regression analysis showed correlations of significant value ($p<0.001$) obtained west-east area from Drosh to Srinagar. In Gilgit significant correlation were extracted but at lower level, while no significant correlation was obtained in Leh. Overall, positive correlations occur towards the north and south. It also depicted correlation of the winter North Atlantic Oscillation (NAO) sand Karakoram on the monthly and summer basis showing negative values. It also predicted negative correlation towards north-south of the Himalaya. The time series analysis was particularly done on the long-term records of Skardu, Gilgit and Srinagar. The time series was analysed yearly, three, six-month patterns. The time series were splitted into pre and post partition periods i.e., 1894-1947 and 1954-1999. In Srinagar there was no trend from 1894-1999 on yearly basis of rainfall while as Gilgit and Skardu showed rainfall trend which was not significant. There was a slight increase in winter rainfall of all three stations during the pre- partition period and at Skardu an upward trend of significant value ($p<0.05$) was found. Rainfall of summer showed no significant trend for the phase from 1849-1999. Summer rainfall showed an overall increasing trend at all the three stations.

Rauscher and Seth (2006) evaluated the sub seasonal rainfall statistics over South America for the period 1982-2002. The rainfall statistics included the precipitation intensity on daily basis, onset and withdrawal of rainy season, frequency and duration of dry spell. They mainly studied the Northern, Southern Amazon, Northern Brazil, monsoon region and south eastern area of South America. Their study involved the International Centre for Theoretical Physics regional climate model version 3 (RegCM3), which was driven with the help of NCEP-NCAR reanalysis and the European Centre-Hamburg GCM. The analysis of their study observed that rainy season timing first occurs on the monsoon region and going northward towards Southern Amazon, which was not as predicted by the earlier studies. They predicted strong relationship between the monsoon region and SST's of Equatorial Pacific with the help of correlation of withdrawal date. They further illustrated that it is not sufficient alone to capture various statistics like rainfall onset, withdrawal and duration of dry spells. Appropriate estimation of the physical processes has to be carried out so that better results can be achieved.

Guhathakurta and Rajeevan (2007) studied rainfall trends over India for the period 1901-2003 by fixing 1476 rain gauge stations. The study showed that Jharkhand, Chhattisgarh and Kerala showed negative trend and Gangetic West Bengal, West UP, Jammu and Kashmir, Konkan and Goa, Maharashtra sub division, Rayalaseema, coastal AP and inner side of north Karnataka followed a positive trend. The study also showed that the precipitation trend is decreasing for June, July and September while it increases for the month of August.

Rathod and Aruchamy (2010) studied the spatial trends of precipitation in Coimbatore, Tamil Nadu using GIS for period 1959-2008. The study showed that the district Coimbatore receives rainfall above normal rainfall of Tamil Nadu state, the study also showed that the area receives maximum rainfall in July, lowest in February and January being the month of dry spell. The study also showed that the south and south western part and the north-western part receives heavy rainfall in summer, southwest, northeast monsoon and central part of the district receives low rainfall.

Auestad and Henriksen (2012) worked the statistical model of daily precipitation for the period of 107 years in the Bergen and in Rogaland for the period of 115 years. Simple parametric modelling was used along with their components. Their study showed the occurrence of wet days, extreme events which are likely to occur, total rainfall to be expected and its spell length. Rainfall of high frequency on the daily data basis will have some important information to predict various meteorological processes. Parametric model only with few parameters was used to study trends and variations occurring over a time. The model used two variables for the daily rainfall data, one for the process of onset and the other for the total rain of a particular day. Between the period 1904-2010 total yearly rainfall in Bergen showed increase in trend, from which it can be declared more rain can be expected to proliferate evenly in a year for all seasons. Their study also indicated the formation of jumps rather than trends evolving slowly.

Jain and Kumar (2012) analysed the trend of precipitation and temperature for India with the help of Mann Kendall test, Sen's slope estimator. Total catchment area of major river basin in India is 2.528 million sq.km, which include The Indus, The Ganga, The Brahmaputra, The Sabarmati, The Narmada, The Tapi, TheSubarnarekha, The Cauvery and The Ganga–Brahmaputra–Meghna (Barak). Their study showed increase in annual trend precipitation in 6 basins whereas decrease in trend in 15 river basins. 4 river basins showed increasing trend and 15 river basin showed decreasing trend in monsoon. 9 river basins showed increasing trend in pre-monsoon season. In the post-monsoon season 13 river basin showed increasing trend while as 18 river basins showed the same result in winter season. Temperature showed a rising trend besides the maximum and minimum temperature at different locations is different.

Mondal et. al (2014) studied the spatial and temporal variation of two climatic variables (rainfall with temperature) for the entire region of India. Their study was carried over two data series, one for rainfall trend and other for temperature trend. The rainfall trend was analysed for 141 years from 1871-2011 and temperature trend was analysed for the period 1901-2007. Data of 306 rain gauge stations was used for this study. The trend was performed by using non-parametric test like Mann Kendall and Sen's slope and Mann-Whitney-Pettit test. For the detection of break point in the series Mann-Whitney-Pettit test was used. MK test was used for the detection of the trend while Sen's slope detected the value of trend. 1961 was detected as the year which has the most possibility to change and lag-1 serial correlation and pre whitening removed the existing correlation in the data series. The change between the two variables showed decrease in rainfall and increase in temperature. Total 15 stations showed increase in rainfall trend. Thus, it can be concluded for whole India trend is negative.

Oza and Kishtawal (2014) studied rainfall and temperature trends over North East India. This is a region of high rainfall and includes Brahmaputra basin. It consists of Arunachal Pradesh, Assam, Meghalaya, Nagaland, Mizoram, Manipur, Tripura, Himalayan West Bengal and Sikkim. The study was done to observe the long-term and short-term changes in Indian Summer Monsoon and temperature over North East India. The study was carried over two data series one for rainfall for the period 1871-2012 and the other for temperature for the period 1901-2007, as obtained from the Indian Meteorological Department (IMD). In this study Linear trend model and Mann Kendall rank statistic were analysed for the long-term fluctuations while as Cramer's t-test was useful for the short-term fluctuations. The study showed that there is decrease in trend in Indian Summer Monsoon rainfall in Northern part of East India as well for the entire country. The rate of decrease is steeper by a factor of two. The results further showed that in the year 1965 the patterns of rainfall data changed. With the help of null hypothesis Mann-Whitney test showed no change in Indian Summer

Monsoon rainfall. Cramer's t-test depicted a regularity of patterns in the data series, and considered the series as statistically significant due to the length of the series. Analysis of temperature data depicted no trend in the minimum temperature, but the maximum temperature statistically showed significant positive z-values in the post-monsoon and winter months, while in other two seasons non-significant positive z-values were found, and that the period of 1960-70 is the period in which reversal of patterns in rainfall and temperature occurred.

Ahmed et.al (2015) studied precipitation trends of Swat River basin, Pakistan. The study was carried over almost 15 stations for a period of 51 years from 1961-2011. The basin has a catchment area of 16750 km^2. Swat basin is divided into four sub-basins; upper sub-basin, Panjkora sub-basin, Ambahar sub-basin and lower sub-basin. In this study, The MK and SR tests were used to detect changes in precipitation on different seasons, months and years. The Standard Normal Homogeneity test and Buishand's range (BR) test detected the homogeneity while as Sen's slope was used to detect the slope of the data series. The data for this study was obtained from Pakistan Meteorological Department (PMD), Irrigation Department of KPK province (ID) and Surface Water Hydrology Project (SWEC). The data was first analysed to remove serial correlations. The monthly trends as observed by the MK test and SR test were similar and showed that trends of months are a mixture of positive and negative values at different stations. Results of annual and seasonal analysis had similar values of positive and negative trends at different stations. The results further showed positive trends in the months of June and November and negative trend in July and August in upper sub-basin. Overall, the Swat river basin showed the positive value of about 0.48 mm/year.

Gajbhiye et.al (2015) choose Sindh basin in India for the trend studies of rainfall. This trend included time series of different months and years from 1901-2002 and 1942-2002. The data was collected from Indian Meteorological Department. Their study included eight districts of Madhya Pradesh. By using methods like conventional Mann-Kendall test (MK), Mann-Kendall test (MMK), Sen's slope estimator and Kriging technique this trend was carried out. Mann-Kendall test and Sen's slope determined the trend and Kriging technique determined spatial pattern of rainfall using Arc GIS 9.3. The MK/MMK tests depicted all the stations showed increase in rainfall in summer and towards the end of monsoon seasons for the series 1901-2002. For the series 1942-2002, MK/MMK test depicted positive trend only in summer and only one station for the winter season, insignificant positive and negative trend towards the end of monsoon. They also depicted the number of decreasing trends increases considerably using the series 1942-2002 instead of 1901-2002.

Kundu et. al (2015) studied the Spatial and temporal variations in rainfall trend of Madhya Pradesh, India for the period 1901-2011. Madhya Pradesh is benefitted by river systems like Narmada, Mahanadi, Tapti, Wainganga etc. The study was carried over 45 stations using Mann Kendall test, Sen's slope estimator standard normal homogeneity test and Mann-Whitney-Pettit test. The MK test and Sen's slope estimator was used to detect the trend in the rainfall data, while as the standard normal homogeneity test and Mann-Whitney-Pettit test was used to detect the break point in the series. Trend analysis was done for 111 years by dividing the series into two divisions. Division of entire series was done on the basis of break point (1978). The study depicted that in the monsoon season eastern part showed negative trend, while the west and north has positive trend, in the post-monsoon and winter season show a decreasing trend. The magnitude of rainfall varies with different stations as depicted by Sen's slope estimator. In pre-monsoon months 19 stations show negative trend, 20 stations show positive trend, while the rest shows no trend. In monsoon months 40 stations show negative trend, while rest show positive trend. In post-monsoon and winter months no significant negative trend was observed. 1978 was observed as the year of most probable change. The trend from 1901-1978 shows overall increasing trend, while the trend from 1979-2011 shows overall decreasing trend.

Wu and Qian (2016) studied variation of yearly and seasonal rainfall in Shaanxi, China since 1950s, with the help of trend analysis, regression and Mann Kendall test. Their study mainly included over 14 stations in Shaanxi province. According to them, five out of 14 stations showed appreciable decrease in trend, while as spring, summer and autumn season showed decreasing trend.

Kalidoss et. al (2017) studied trend of temperature with rainfall for entire India. This study was carried over a period of 1901-2014 using Mann Kendall test, Sen's slope estimator, Mann-Whitney-Pettit test and regression models. Mann-Kendall test and linear regression detected the trend while as Sen's slope estimator detected the magnitude of the trend. The Pettit test detected the homogeneity in the data series. The data was obtained from Indian Meteorological Department (IMD) for 36 meteorological sub-divisions. The results showed that a negative correlation was found in annual, winter and monsoon precipitation. They also depicted that the winter, annual and monsoon precipitation had been declining since 1901. The calculated values of MK test depicted a negative trend in rainfall on yearly basis, a negative trend in rainfall during summer and post-monsoon seasons, a positive trend in rainfall during winter and monsoon seasons. Sen's slope estimator method showed decrease in trend in annual, winter and monsoon and increase in trend in summer and post-monsoon seasons. MK test and Sen's slope showed a positive trend in seasonal and annual temperature, which represents rise in temperature year-by-year. Their values also showed that the temperature is likely to increase by 1.7-2.0 ℃ by 2030 and 3.3-4.8℃ by 2080, while as the rainfall would increase from 4 to 5% by 2030 and 6 to 14% by 2080. This can also be concluded from their study that the annual and summer rainfall has decreased during the last 30 years, and temperature has increased seasonally by almost two-fold. The mean annual temperature showed an increase by 0.8℃ from the first two to last two decades.

Pal et. al (2017) showed the variation of various variables (rainfall, temperature and runoff) of Rangoon basin in Dadeldhura area of Nepal. The Rangoon watershed is a part of Mahakali basin. Mann-Kendall test detected the trend while as Sen's slope estimator test analyzed the magnitude and direction of the trend. The time series was splitted separately for rainfall and temperature from 1979-2010 and for runoff 1979-2010. The data was obtained from Hydrology and Meteorology Department of Nepal. Data obtained was analysed for series correlation by lag-1 autocorrelation. The estimation by Sen's slope detected a negative trend in month of January, March and December with significance of 0.1, whereas positive trend in June and September with 0.05. The rainfall showed an overall increasing trend in Rangoon watershed with Z value +1.70 annually. The results of temperature trend analysis detected a decreasing trend in the months of July, August and September with 0.1, whereas months like March and April showed a rising trend with 0.001. The maximum temperature indicated an increasing trend with Z value +1.2 on average yearly basis. The results of runoff analysis depicted that the months like August showed a falling trend with 0.01 level significance, whereas the months like December and January showed a rising trend with0.05 level significance.

Balasmeh et. al (2018) used ARIMA modelling for forecasting precipitation and analysed the rainfall trend. The data for five rainfall stations included Wadi Sheuib catchment area in Jordan. The study area being water deficit, it was necessary to find the trend of various climatic parameters. Daily precipitation was obtained for five rain gauge stations in this area. The trend was done for different months, seasons and average time series for the period of 44 years. The various methods opted Mann Kendall test, Sen's slope estimator and Innovative trend analysis. MK test depicted the trend at two stations within 10% significance, no trend was seen at other stations, while Sen's slope showed value of 0.71-1.52. The ITA method detected trends at all stations in different levels ranging from low, medium and high. Time series was of two groups i.e., (1973-2006) and (2007-2016). Autoregressive Integrated Moving Average (ARIMA) models predicted the future precipitation changes upto year 2026, while ITA showed precipitation trend in coming years. It showed rain of high intensity is decreasing while as rain of low intensity is increasing.

Sani Khani et. al (2018) showed precipitation variation over central India from 1901-2010. In this study rainfall trends of months, various seasons and yearly time scales using Revised form of Mann Kendall (RMK) test, Sen's slope estimator, and innovative trend method (ITM). The study was carried over states of Madhya Pradesh and Chhattisgarh, having total area of about 4,43,000 km^2. Seasons are usually divided into four different seasons; winter, summer, monsoon, and post-monsoon. In this study monthly rainfall data of 20 stations of Madhya Pradesh and Chhattisgarh was studied. The study showed that 2 out of 15 stations of Madhya Pradesh and 4 out of 5 station of Chhattisgarh showed significant trend, and no significant trend for the months of January and October as per Revised Mann Kendall test, while as according to innovative trend method annual, summer (16 stations), and monsoon (11 stations) seasons showed decrease in trend, while as winter (12 stations) and post-monsoon (11 stations) seasons showed increase in rainfall trend.

Rasool and Shafiq (2018), showed the trends of various climatic parameters in valley of Kashmir from the years 1980-2014 using Mann Kendall test. Their study showed that the average yearly temperature of Kashmir valley shows an increasing trend during the years 1980-2014. The rainfall showed significant variability over all the regions of the valley. This showed a decrease in trend with different rate like mountainous parts showed a drastic decrease, flood plains showed relatively less rate of decrease and Karewa's showed rate of decrease which was inbetween. From this it was concluded that the variability of temperature and rainfall is different for different locations.

Krakauer et. al (2019) showed the rainfall variation over the Indus basin. The study included Sen's slope method and the Mann Kendall test of 186 raingauge stations respectively. This included two data series: 100-150 years, and 40-60 years. The rainfall information obtained was from the remote sensing and from global weather observations. The data was obtained from "Global Historical Climatology Network-Daily (GHCN), Pakistan Meteorological department (PMD) and International Water Management Institute (IWMI)". Different data sets were used for comparison, some data sets showed lower precipitation then estimated, while others showed overestimate precipitation. They showed that the "Global Precipitation Climatology Centre (GPCC)" data set had an mean precipitation of about 500 mm per year and an increase in mean precipitation for years 1891 and 2016 of about 15%, no precipitation trend for 1958 and 1979, while "Remote sensing data sets", "Tropical Rainfall Measuring Mission Multi-Satellite Precipitation Analysis (TMPA)" compared best to station observations. The study concluded that there is increase in trend for Indus basin.

Sasireka and Surianarayanam (2019) studied the trend analysis of rainfall for The Thanjavar town of Tamil Nadu state. Study of the trend analysis for various climatic parameters is important for any geographical area. It detects the variation that has occurred over the period of time. Further it predicts the future impact of these climatic factors on the various hydraulic structures. Similar analysis was done in this study. The time period analyzed was for 70 years. The variation or the trend was mainly done with the help of Moving average method. This method showed the trend of rainfall for months, various seasons and separate years. From 3, 4 and 5 year moving average there does not occur a regular cycle in the seasons of Winter, Summer, North-East, South-West monsoon rainfall whereas when 30, 40, and 50 year moving average was used it was found that a horizontal linear cycle persisted. From their study it can be concluded that there is no large variation of rainfall in the Thanjavar town.

Shafiq et. al (2019) showed the precipitation trends of Kashmir valley in India. Kashmir is a valley which is surrounded by PirPanjal range in south and south-west direction and by the Greater sHimalayas towards the north and east direction. It has an area of 15,948 km^2 with 6 meteorological stations (Srinagar, Gulmarg, Kokernag, Kupwara, Pahalgam and Qazigund). Kashmir valley experiences four different seasons; winter, spring, summer and autumn. The valley experiences temperature of 9℃ in winter and 38℃ in summer, and an average annual rainfall of 84 cm. This study included precipitation data for different months from the Indian Meteorological Department (IMD) for 6 stations for the period 1980-2016. This data was added to obtain the precipitation for various seasons and years. The trend was performed by using Mann-Kendall (MK) test, Theil-Sen Approach (TSA) and Sen's slope estimator test. MK test and TSA test detected the trend as well as slope. The result of these tests showed that on yearly basis there is significant decrease ($p<0.1$) in precipitation at a rate of about -5.1 mm/year, while in 1996 no such trend was obtained ($p=0.10$). Individually, Gulmarg showed significant negative trend of -15.6 mm/year, Pahalgam showed insignificant negative trend of -1.7 mm/year, Srinagar, Kokernag and Qazigund showed insignificant negative trend of -26 mm/year, -1.8 mm/year and -5.5 mm/year respectively, and Kupwara showed significant negative trend of -5.5 mm/year. The results further showed that seasonally a decreasing trend was found in winter, spring and summer precipitation of -1.1 mm/season, -5 mm/season and 0.3mm/season respectively, while as an increasing trend was found in autumn precipitation.

3.1. Objectives of the Study

1. Trend analysis has proved to be a useful tool for effective water resources planning, design and management.
2. The trend analysis of rainfall, temperature and other climatic variables on different spatial scales will help in the construction of future climate scenarios.
3. Analysis of trend in rainfall data also aids to see the result of rainfall variability on the occurrence of drought and flood.
4. Trend analysis could help to understand the hydrological features of a basin in the future.
5. Trend analysis can be useful for irrigation and agricultural managers.

3.2. Scope of Work

1. Trend analysis can be used to predict the future climatic scenarios.
2. Trend analysis will be useful for pre-management of dams, reservoirs and banks of rivers.
3. The present study will be helpful for meteorological department to see the change which has occurred for long time period.
4. The study will also be helpful to locate the areas which are rainfall deficit and accordingly pre-management of water can be done.
5. Higher mean maximum temperature will indicate that the areas have more presence of carbon dioxide.

CHAPTER 4

METHODOLOGY

4. Methodology

4.1. Methods

Daily rainfall and monthly temperature data was collected from the Indian Meteorological Department Srinagar. The data included a period of 39 years (1980-2018). Daily rainfall data was converted into monthly and then into annual rainfall. Data so obtained had some missing data for some years which was computed with the help of Normal Ratio method. Another method of comparison also computes the missing data but Normal Ratio method being more precise and accurate. Normal Ratio method further includes two methods:

i) **Simple Average Method**: When the mean annual rainfall data of each of the index station is within 10% of the mean annual rainfall of missing station simple average method is used.

$P_x = 1/N (P_A + P_B + \ldots. P_N)$

Where, P_x , P_A, P_B and P_N are the annual precipitations of the stations X, A, B and N.

N is the number of stations.

ii) **Normal Ratio Method:** When the mean annual rainfall data of the index stations differs more than 10% of the missing station, normal ratio method is used:

$P_x = N_x/n (P_A/N_A + P_B/N_B + \ldots\ldots.. + P_n/N_n)$

Where, P_x , P_A, P_B and P_n are the annual precipitations of stations A, B and N corresponding to the missing year.

N_A, N_B, …… N_n are the mean annual precipitation of the stations A, B and N.

n is the number of stations.

The present data of the index station differs from the missing stations by more than 10%, so, it was necessary to use the Normal Ratio Method.

Consistency of the rainfall data of six stations was analysed with the help of Double Mass Curve before applying any method for trend analysis. Double Mass Curve is the curve plotted between the commulative rainfall of X station with the commulative rainfall of group of available stations. Rainfall of X station is plotted along the ordinate while the rainfall of group of stations plotted along the abscissa. When the commulative data of Srinagar station was plotted with commulative of Gulmarg, Pahalgam, Kupwara, Qazigund, and Kokernag stations, it showed the consistency of the data and indicated further analysis of the data can be carried out. Similar observation can be seen by varying the one stations and making the group of other stations.

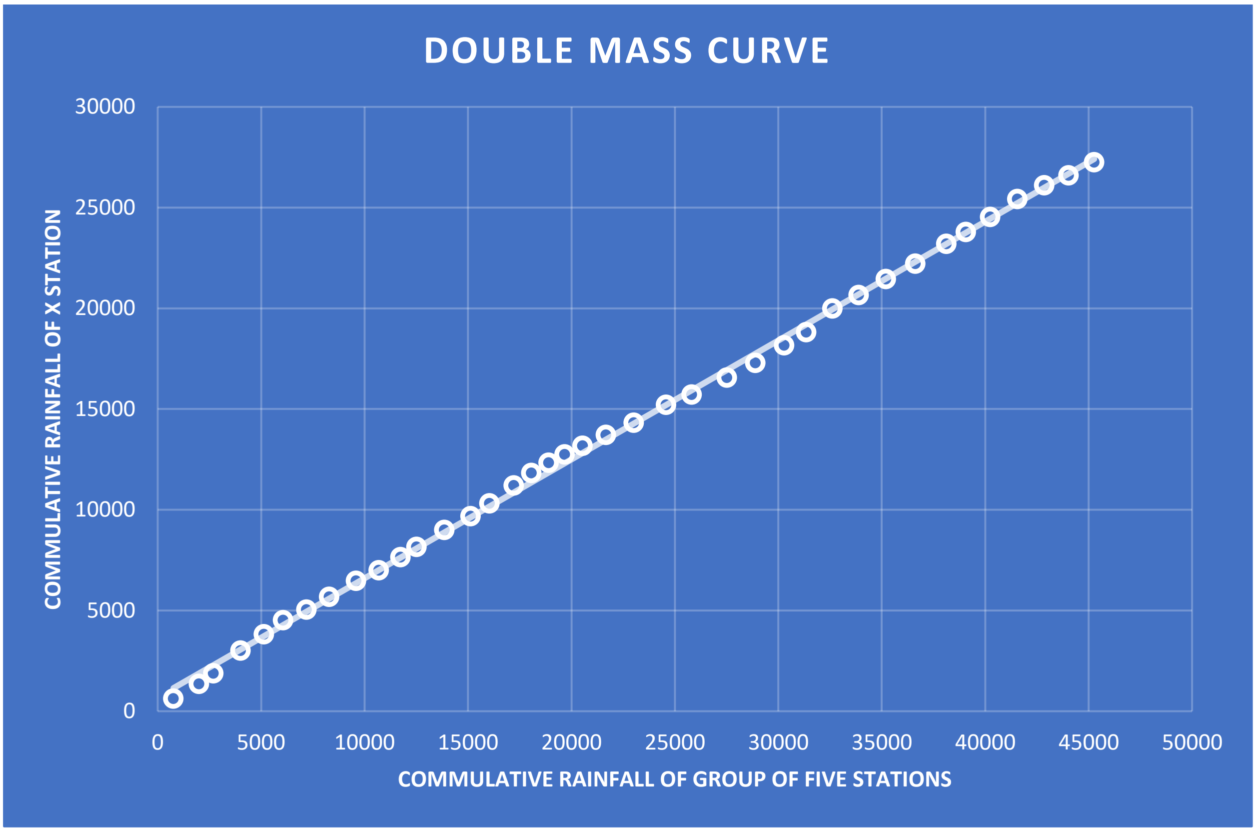


Fig 2. Double Mass Curve.

Return period, probability of occurrence and frequency of each of the stations were found. Higher the precipitation of the station, higher is the return period and lower is the probability of occurrence of that event.

Return Period: Return period or the recurrence interval is the average time interval that elapses between the two events that equal or exceed a particular level. For example, if the rainfall of 30cm in a particular day on an average equal or exceed once in 40 years, then the return period of 30cm rainfall is 40 years. It does not mean rainfall of 30cm will occur after 40 years rather than it implies if we consider a long period

Probability of Occurrence: The probability of an event that equals or exceeds in a particular one year is defined as the probability of occurrence of that event. In other words, it the inverse of return period.

$$p = 1/T_r$$

Frequency: Probability of occurrence when expressed as a percentage is known as frequency. It is denoted by f.

$$f = 100\,p = (1/T_r) \times 100$$

MANN KENDALL'S TEST

Mann Kendall test is non-parametric test given by Mann in the year 1945 and was further studied by Kendall in the year 1975.This test is used for the trend analysis of various climatic factors like rainfall, temperature and runoff and can be done by a number of softwares such as XLSTAT, MATLAB, etc. More the data points or the time series more is the accuracy of the result. The test has two hypothesis:

1) **Null hypothesis:** is that there is no trend in the series.

2) **Alternate hypothesis:** is that there is a trend which may be positive, negative or non-null.

Mann Kendall test checks the variation in signs between two data points first being the earliest and the second being the latest. If the trend is present the sign values will either decrease or increase constantly. The Mann Kendall Statistic for the trend is:

$$S = \sum_{k=1}^{n-1} 1 \sum_{j=k+1}^{n} sgn(xj - xk)$$

The trend test is applied to a time series $x_{K,}$ which is ranked from k = 1,2, 3 ……... n-1. x_J which is ranked from j=i+1, i+2, i+3……. n.

Each of the data points is taken as reference point,

$$sgn(x_J - x_{K,}) = 1 \text{ if } x_J - x_{K,} > 0$$

$$= 0 \text{ if } x_J - x_{K,} = 0$$

$$= -1 \text{ if } x_J - x_{K,} < 0$$

A very high positive value of S is an indicator of an increasing trend and a very low negative value indicates a decreasing trend.

Sen's Slope Estimator Test:

This is a non- parametric test. To estimate the true slope of an existing trend such as positive value of Sen's slope indicates an upward or increasing trend and a negative value gives a downward or decreasing trend in the time series.

Moving Average method:

Trend analysis is also done with help of moving average method. This method is suitable for long term trends. There are various time periods for which we can calculate the trend analysis which include 2-year, 3-year, 4-year, 5-year etc. We can calculate the trend with the 20-year, 30-year moving average. The lower the value of the moving average higher is the accuracy of the result.

Linear Regression:

This is the graphical method of doing the trend analysis. The slope of the trend line gives the trend value. If the slope of the trend line is negative it indicates trend is decreasing. When the slope of trend line is positive it indicates trend is increasing. This method also gives the value coefficient of co-relation which indicates whether the variables are related to each other or not. If the value of R^2 is close to 1, it means the two variables are closely co-related. If the value of R^2=1, it indicates the two variables are dependent on each other. The value of R^2 lies between 0 and 1. The value 0 implies two variables are independent of each other.

CHAPTER 5

RESULTS AND DISCUSSIONS

5. Results and Discussions

5.1 Rainfall

In the past years various studies has been done to find the trend analysis of temperature, rainfall, humidity etc. with the help of various methods. These include MK test, linear regression and Sen slope estimators test. Before applying these tests to the present data, it is checked for consistency with the help of double mass curve. Data shows in accordance with the double mass curve. Return period, probability of occurrence and frequency of each of the stations is calculated separately as shown in the table.1-6. Results showed more is the annual rainfall, more is the Return period of that event and less is the probability of occurrence. This attributes to the fact, that the rainfall having highest magnitude will take more time to repeat itself. For example, in case of Srinagar station rainfall of 1131.2mm has the return period of about 39 years which indicates if we consider the long time series of 200 years, it will repeat its occurrence (200/39=5) times in 200 years. As we move down the table annual rainfall goes on decreasing and similar is the case for return period.

Probability of highest rainfall event is rarest while as the rainfall of lowest value will have the chances of repeating itself more among all the events. Since, the probability of occurrence of highest rainfall event is minimum, frequency of that particular event will also show the minimum value. Similar explanations can be concluded for other stations also.

Table 1 Return period, frequency and probability of occurrence for Srinagar station

42027	SRINAGAR	A.RF	RANK	R.PERIOD	POC	FREQ
		1165.01	1	40	0.025	2.5
		1131.2	2	20	0.05	5
		990.3	3	13.33333	0.075	7.5
		892.2	4	10	0.1	10
		889.3	5	8	0.125	12.5
		884.4	6	6.666667	0.15	15
		875.8	7	5.714286	0.175	17.5
		851.1	8	5	0.2	20
		840.4	9	4.444444	0.225	22.5
		818.6	10	4	0.25	25
		803.4	11	3.636364	0.275	27.5
		786.5	12	3.333333	0.3	30
		753.5	13	3.076923	0.325	32.5
		751.8	14	2.857143	0.35	35
		738.2	15	2.666667	0.375	37.5
		734.2	16	2.5	0.4	40
		684.7	17	2.352941	0.425	42.5
		682	18	2.222222	0.45	45
		679.6	19	2.105263	0.475	47.5
		672	20	2	0.5	50
		651.3	21	1.904762	0.525	52.5
		648.9	22	1.818182	0.55	55
		646.6	23	1.73913	0.575	57.5
		644.6	24	1.666667	0.6	60
		635.3	25	1.6	0.625	62.5
		620.4	26	1.538462	0.65	65
		617.9	27	1.481481	0.675	67.5
		597.3	28	1.428571	0.7	70
		585.5	29	1.37931	0.725	72.5
		551.2	30	1.333333	0.75	75
		533.3	31	1.290323	0.775	77.5
		523.7	32	1.25	0.8	80
		514.1	33	1.212121	0.825	82.5
		512.1	34	1.176471	0.85	85
		509.4	35	1.142857	0.875	87.5
		501.8	36	1.111111	0.9	90
		490.8	37	1.081081	0.925	92.5
		420.3	38	1.052632	0.95	95
		415.8	39	1.025641	0.975	97.5

Table 2 Return period, frequency and probability of occurrence for Gulmarg station

42026	GULMRG	A.RF	RANK	R.PERIOD	POC	FREQ
		2382.3	1	40	0.025	2.5
		2228	2	20	0.05	5
		2015.9	3	13.33333	0.075	7.5
		1929.9	4	10	0.1	10
		1925.3	5	8	0.125	12.5
		1911.2	6	6.666667	0.15	15
		1911.2	7	5.714286	0.175	17.5
		1895.6	8	5	0.2	20
		1822.4	9	4.444444	0.225	22.5
		1775.1	10	4	0.25	25
		1721.7	11	3.636364	0.275	27.5
		1690.1	12	3.333333	0.3	30
		1667.1	13	3.076923	0.325	32.5
		1661.7	14	2.857143	0.35	35
		1656	15	2.666667	0.375	37.5
		1598.9	16	2.5	0.4	40
		1569.4	17	2.352941	0.425	42.5
		1521.6	18	2.222222	0.45	45
		1514.8	19	2.105263	0.475	47.5
		1430.2	20	2	0.5	50
		1380.4	21	1.904762	0.525	52.5
		1321.1	22	1.818182	0.55	55
		1270.1	23	1.73913	0.575	57.5
		1269.6	24	1.666667	0.6	60
		1213.6	25	1.6	0.625	62.5
		1195.5	26	1.538462	0.65	65
		1190.9	27	1.481481	0.675	67.5
		1162.2	28	1.428571	0.7	70
		1075.3	29	1.37931	0.725	72.5
		1065.5	30	1.333333	0.75	75
		1035.3	31	1.290323	0.775	77.5
		998.1	32	1.25	0.8	80
		988.2	33	1.212121	0.825	82.5
		977.2	34	1.176471	0.85	85
		959.36	35	1.142857	0.875	87.5
		952.7	36	1.111111	0.9	90
		843.9	37	1.081081	0.925	92.5
		831	38	1.052632	0.95	95
		759.4	39	1.025641	0.975	97.5

Table 3 Return period, frequency and probability of occurrence for Kupwara station

42031	KUPWARA	A.RF	RANK	R.PERIOD	POC	FREQ
		1419.8	1	40	0.025	2.5
		1404.7	2	20	0.05	5
		1286.9	3	13.33333	0.075	7.5
		1246.6	4	10	0.1	10
		1216.3	5	8	0.125	12.5
		1196.8	6	6.666667	0.15	15
		1186.6	7	5.714286	0.175	17.5
		1175.219	8	5	0.2	20
		1163.3	9	4.444444	0.225	22.5
		1158.2	10	4	0.25	25
		1134.2	11	3.636364	0.275	27.5
		1134	12	3.333333	0.3	30
		1116.4	13	3.076923	0.325	32.5
		1101.7	14	2.857143	0.35	35
		1074.5	15	2.666667	0.375	37.5
		1064.5	16	2.5	0.4	40
		1006.3	17	2.352941	0.425	42.5
		991.3	18	2.222222	0.45	45
		989.5	19	2.105263	0.475	47.5
		983.8	20	2	0.5	50
		973	21	1.904762	0.525	52.5
		906.8	22	1.818182	0.55	55
		885	23	1.73913	0.575	57.5
		869	24	1.666667	0.6	60
		859.3	25	1.6	0.625	62.5
		835.8	26	1.538462	0.65	65
		834.129	27	1.481481	0.675	67.5
		822.4	28	1.428571	0.7	70
		800.1	29	1.37931	0.725	72.5
		783.7	30	1.333333	0.75	75
		722.709	31	1.290323	0.775	77.5
		674.332	32	1.25	0.8	80
		663.807	33	1.212121	0.825	82.5
		656.9	34	1.176471	0.85	85
		617.5	35	1.142857	0.875	87.5
		610.1	36	1.111111	0.9	90
		596.77	37	1.081081	0.925	92.5
		567.757	38	1.052632	0.95	95
		487.763	39	1.025641	0.975	97.5

Table 4 Return period, frequency and probability of occurrence for Qazigund station

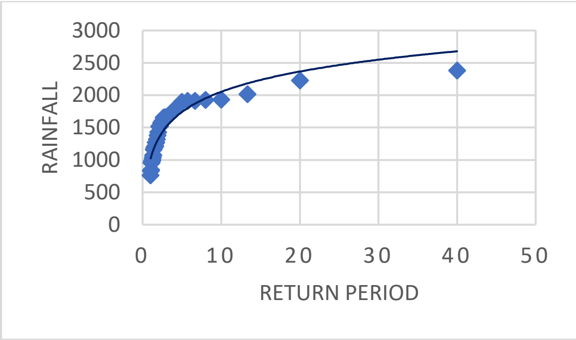
42044	QAZIGND	A.RF	RANK	R.PERIOD	POC	FREQ
		1765.5	1	40	0.025	2.5
		1737.9	2	20	0.05	5
		1526.6	3	13.33333	0.075	7.5
		1525.3	4	10	0.1	10
		1451.3	5	8	0.125	12.5
		1416.9	6	6.666667	0.15	15
		1398	7	5.714286	0.175	17.5
		1382.7	8	5	0.2	20
		1377.7	9	4.444444	0.225	22.5
		1346.9	10	4	0.25	25
		1324.1	11	3.636364	0.275	27.5
		1309.5	12	3.333333	0.3	30
		1291.37	13	3.076923	0.325	32.5
		1288.4	14	2.857143	0.35	35
		1275.7	15	2.666667	0.375	37.5
		1221.4	16	2.5	0.4	40
		1192.3	17	2.352941	0.425	42.5
		1175.9	18	2.222222	0.45	45
		1152.4	19	2.105263	0.475	47.5
		1131.2	20	2	0.5	50
		1123.2	21	1.904762	0.525	52.5
		1121	22	1.818182	0.55	55
		1086.9	23	1.73913	0.575	57.5
		1080.4	24	1.666667	0.6	60
		1052.3	25	1.6	0.625	62.5
		1042	26	1.538462	0.65	65
		1034.3	27	1.481481	0.675	67.5
		1006.1	28	1.428571	0.7	70
		994.2	29	1.37931	0.725	72.5
		955.7	30	1.333333	0.75	75
		898.9	31	1.290323	0.775	77.5
		894.8	32	1.25	0.8	80
		885	33	1.212121	0.825	82.5
		818.7	34	1.176471	0.85	85
		789.4	35	1.142857	0.875	87.5
		783.1	36	1.111111	0.9	90
		753	37	1.081081	0.925	92.5
		751.6	38	1.052632	0.95	95
		627	39	1.025641	0.975	97.5

Table 5 Return period, frequency and probability of occurrence for Pahalgam station

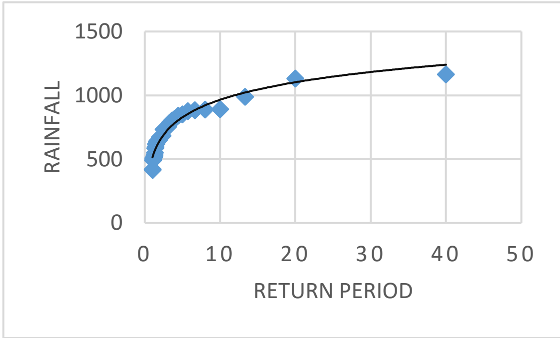
42028	PAHLGM	A.RF	RANK	R.PERIOD	POC	FREQ
		1629	1	40	0.025	2.5
		1614.6	2	20	0.05	5
		1603.9	3	13.33333	0.075	7.5
		1557.3	4	10	0.1	10
		1543.2	5	8	0.125	12.5
		1527.3	6	6.666667	0.15	15
		1511.3	7	5.714286	0.175	17.5
		1484.53	8	5	0.2	20
		1429.7	9	4.444444	0.225	22.5
		1410.9	10	4	0.25	25
		1404.7	11	3.636364	0.275	27.5
		1376.9	12	3.333333	0.3	30
		1369	13	3.076923	0.325	32.5
		1357	14	2.857143	0.35	35
		1354.2	15	2.666667	0.375	37.5
		1342.8	16	2.5	0.4	40
		1331.4	17	2.352941	0.425	42.5
		1299.24	18	2.222222	0.45	45
		1286	19	2.105263	0.475	47.5
		1274.1	20	2	0.5	50
		1266.2	21	1.904762	0.525	52.5
		1259	22	1.818182	0.55	55
		1242.7	23	1.73913	0.575	57.5
		1238.8	24	1.666667	0.6	60
		1234.1	25	1.6	0.625	62.5
		1165.9	26	1.538462	0.65	65
		1048.9	27	1.481481	0.675	67.5
		1022.3	28	1.428571	0.7	70
		1020.5	29	1.37931	0.725	72.5
		1012.6	30	1.333333	0.75	75
		982.8	31	1.290323	0.775	77.5
		973.5	32	1.25	0.8	80
		968.9	33	1.212121	0.825	82.5
		955.2	34	1.176471	0.85	85
		920.8	35	1.142857	0.875	87.5
		911.3	36	1.111111	0.9	90
		899.9	37	1.081081	0.925	92.5
		860.8	38	1.052632	0.95	95
		705.8	39	1.025641	0.975	97.5

Table 6 Return period, frequency and probability of occurrence for Kokernag station

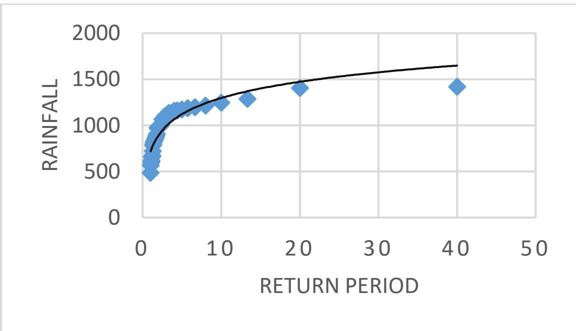
42046	KOKRNG	A.RF	RANK	R.PERIOD	POC	FREQ
		1448.7	1	40	0.025	2.5
		1374.9	2	20	0.05	5
		1353.4	3	13.33333	0.075	7.5
		1346.5	4	10	0.1	10
		1299.5	5	8	0.125	12.5
		1292.9	6	6.666667	0.15	15
		1243.1	7	5.714286	0.175	17.5
		1243.1	8	5	0.2	20
		1226.5	9	4.444444	0.225	22.5
		1223.9	10	4	0.25	25
		1206.5	11	3.636364	0.275	27.5
		1194.4	12	3.333333	0.3	30
		1187.6	13	3.076923	0.325	32.5
		1129	14	2.857143	0.35	35
		1114.1	15	2.666667	0.375	37.5
		1108.2	16	2.5	0.4	40
		1102.7	17	2.352941	0.425	42.5
		1073.5	18	2.222222	0.45	45
		1057.2	19	2.105263	0.475	47.5
		1028.7	20	2	0.5	50
		1017.7	21	1.904762	0.525	52.5
		1007.4	22	1.818182	0.55	55
		1001.6	23	1.73913	0.575	57.5
		975.4	24	1.666667	0.6	60
		970	25	1.6	0.625	62.5
		967.2	26	1.538462	0.65	65
		955.7	27	1.481481	0.675	67.5
		953.64	28	1.428571	0.7	70
		886	29	1.37931	0.725	72.5
		782	30	1.333333	0.75	75
		768.5	31	1.290323	0.775	77.5
		711.3	32	1.25	0.8	80
		671	33	1.212121	0.825	82.5
		670.1	34	1.176471	0.85	85
		652.6	35	1.142857	0.875	87.5
		642.4	36	1.111111	0.9	90
		579.9	37	1.081081	0.925	92.5
		568.6	38	1.052632	0.95	95
		391.3	39	1.025641	0.975	97.5



1. Srinagar



2. Gulmarg



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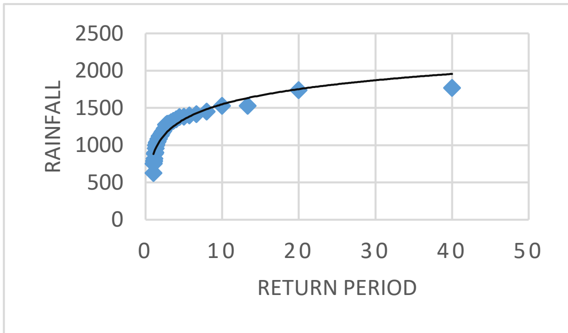

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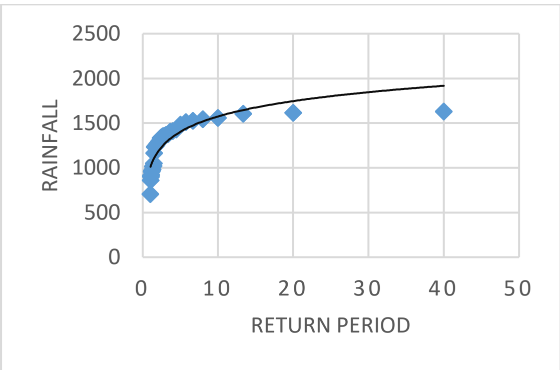

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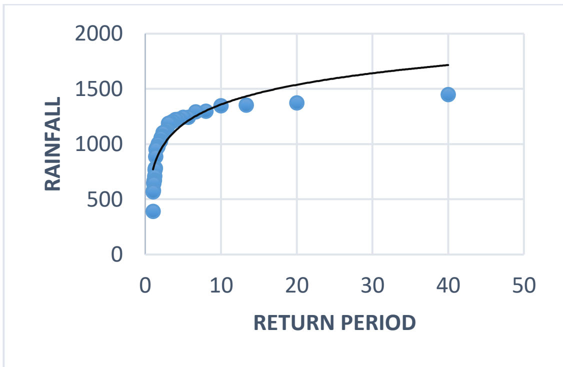


6. Kokernag

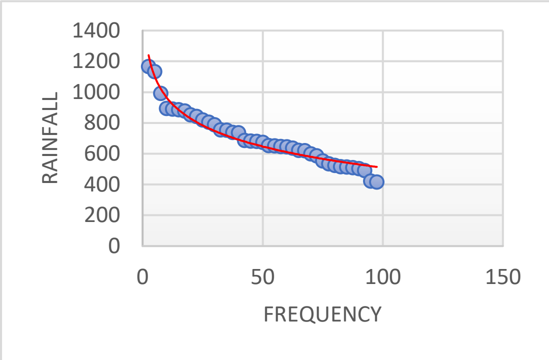
Fig.3. Rainfall vs Return period.

All the six stations have annual rainfall of different magnitude. Srinagar has minimum mean annual rainfall of approx.(682.78mm). Gulmarg has maximum mean annual rainfall of approx. (1417.03mm). This attributes to the fact Srinagar will have drier climate, higher temperature and more chances of droughts. This can also be explained with more density of population in case of Srinagar. Gulmarg having more forest covered area and high hilly area will be less prone to the dry climate and higher degree of temperatures. Mean annual rainfall of all the stations is given in the table 7.

Table 7 Mean Annual Rainfall of six stations

Station	**Station Index**	**Mean Annual Rainfall (mm)**
Srinagar	42027	682.78
Qazigund	42044	1153.08
Pahalgam	42028	1209.15
Kupwara	42031	1007.12
Kokernag	42046	980.80
Gulmarg	42026	1417.03

Frequency vs rainfall for each of the stations is drawn. A storm with high frequency will have low return period and high probability of occurrence. High frequency of a particular storm indicates there has been very low rainfall over that period of time. It shows the rainfall of higher magnitude has less frequency which pertains to the fact that this rainfall will cause much delay in occurrence. Frequency vs rainfall of all the six stations have been plotted separately on the graphs.



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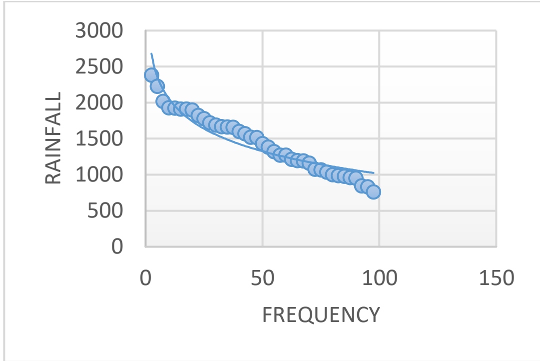

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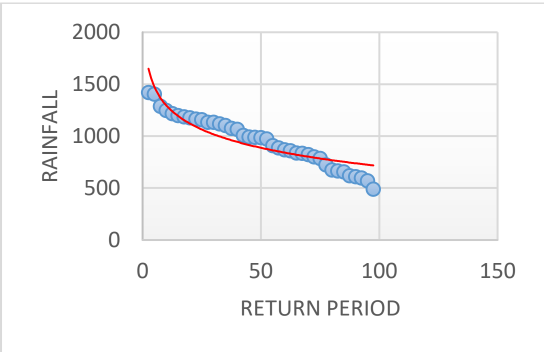

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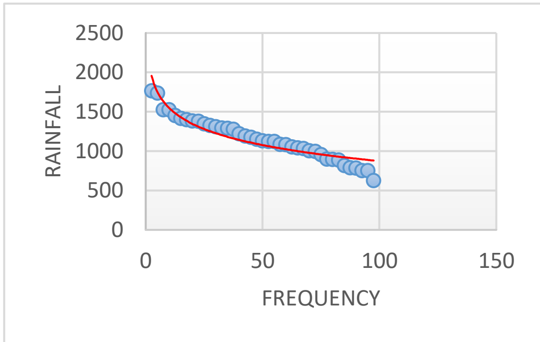

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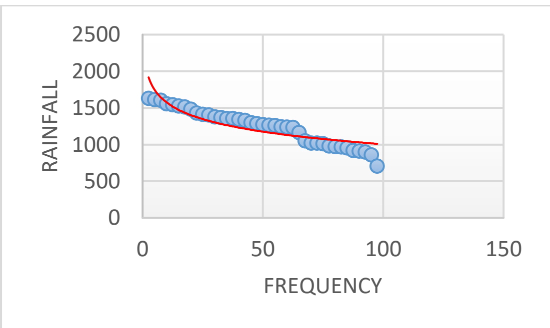
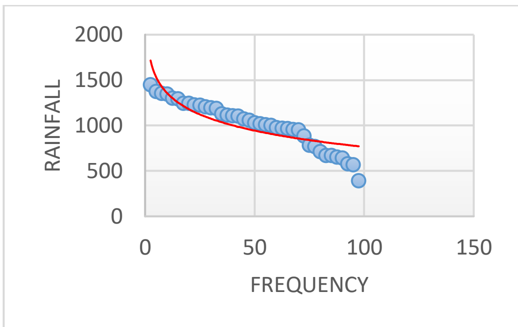
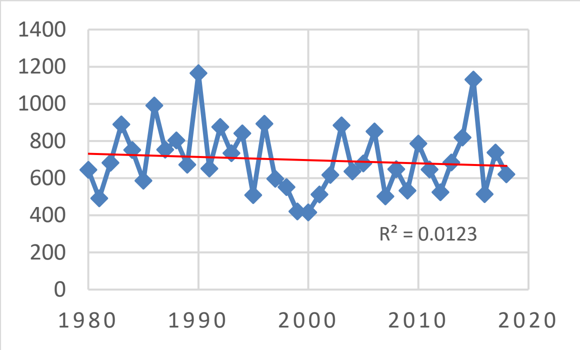


5. Pahalgam

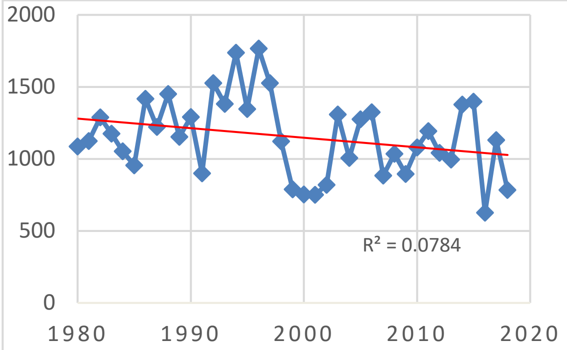


6. Kokernag

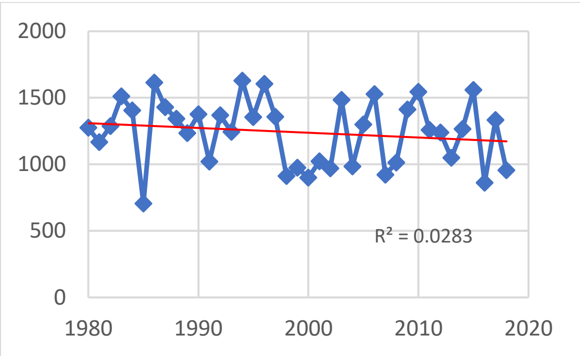
Fig.4. Rainfall vs Frequency.



1. Srinagar



2. Qazigund



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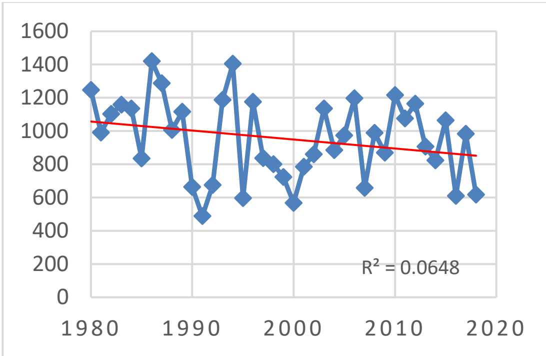

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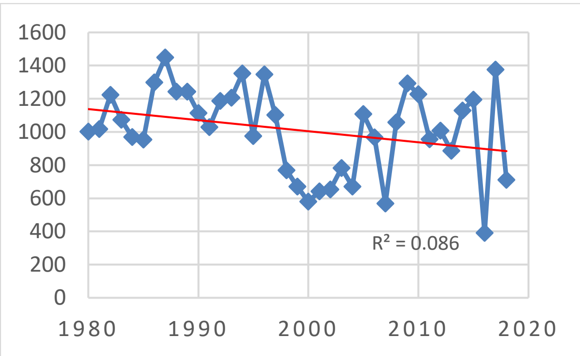
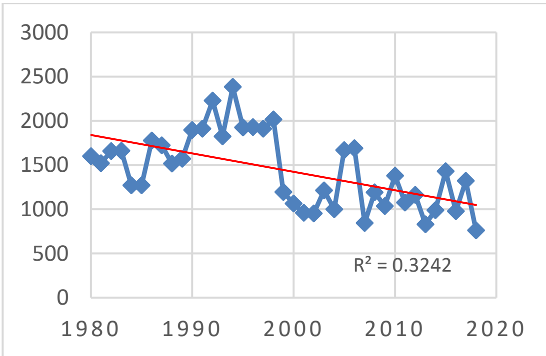


5. Kokernag

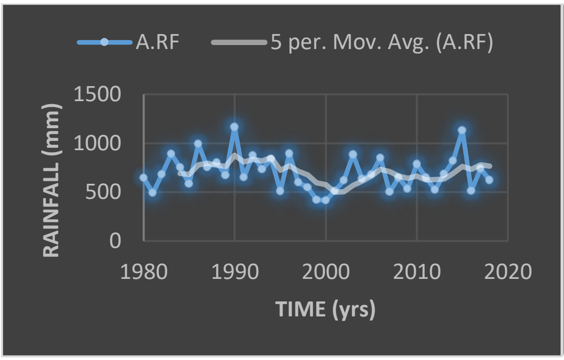


6. Gulmarg

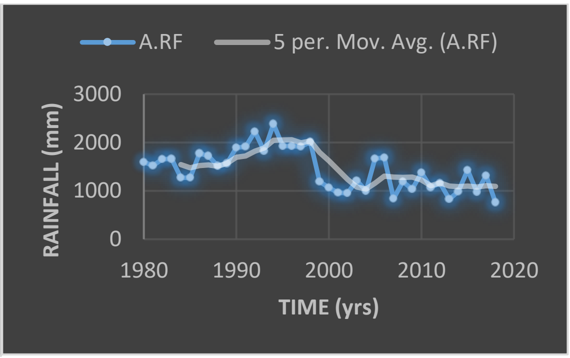
Fig 5. Rainfall trend analysis

Rainfall trend analysis is shown by the regression analysis. Fig 3 illustrates the trend of rainfall for all the stations. All the stations showed decrease in the trend with the negative slope. Gulmarg shows decrease in trend with the negative slope of -20.819. Srinagar has the negative slope of -1.724. Further coefficient of co-relation shows that the two variables are not closely related to one another. Highest co-relation is shown at the Gulmarg station with the value of R^2 =0.324. In all other stations the value of coefficient of co-relation has very less value which indicates there is not strong relation between the two variables.

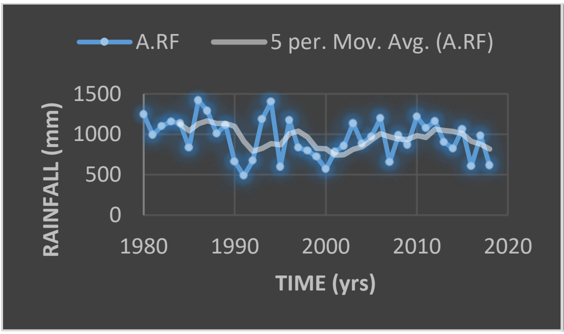
Moving average method is another method used for trend analysis. This is method is useful for defining the long-term trends. Five year moving average of all the stations has been shown in the graphs.



1. Srinagar



2. Gulmarg



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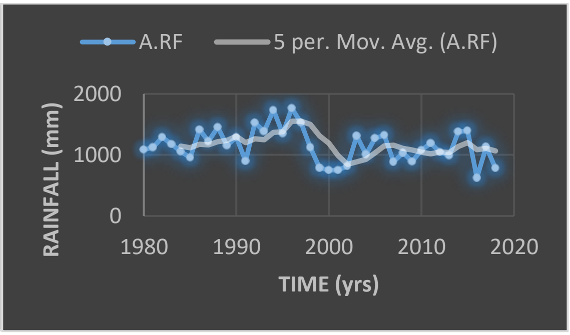
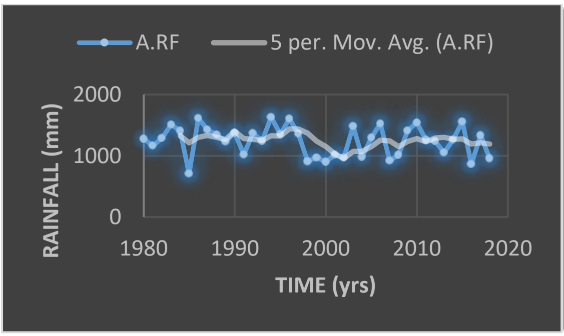
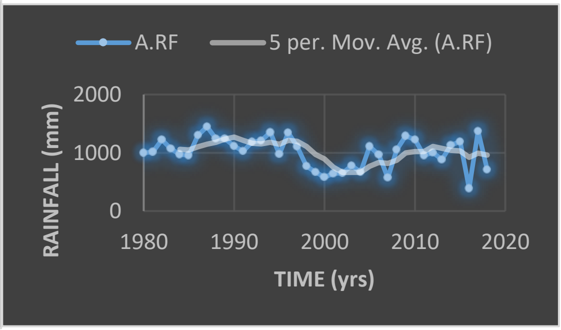


4. Qazigund



5. Pahalgam



6. Kokernag

Fig.6. Five Year Moving Average of six stations.

Rainfall of Srinagar station upto year 1995 shows similar trend, after that there is decrease in rainfall upto year 2000. From the year 2000 there is slight increase upto year 2005, after that rainfall again follows the same trend as it started from 1980-1995. For Gulmarg station there is no smooth trend first it increases upto the year 2000, then it shows large decrease upto the year 2005. After 2005 it does not show fluctuations hence can be predicted the trend is smooth. Among all the stations Kupwara shows more fluctuations in the rainfall. There is no common trend for this station. As is indicated by the graph from the year 1990-2000 there is initially a drop, in the middle it is somewhat smooth then again increases. In the end it decreases upto the year 2000. From the year 2000 it increases and then remains smooth.

Qazigund shows similar trend as that of the Srinagar station. This indicates that there is similar climatic variability between the two stations. Only difference lies in the amount of annual rainfall. For Pahalgam the trend is same throughout except from the year 1995-2000 where there is a decrease in trend. Kokernag station shows the similar behaviour as that of the Pahalgam which again can be explained with similar climatic variability. All the stations show nearly similar trend except Kupwara.

Table.8. Results of the Mann Kendall test for rainfall data of the six stations

Station	**Mk statistic (S)**	**Kendall's Tau**	**Variance (S)**	**p- value**	**Alpha**	**Test Interpretation**	**Sen's slope**
Srinagar	-55.00	-0.074	6833.66	0.514	0.05	-	-1.717
Qazigund	-117.00	-0.158	6833.66	0.161	0.05	-	-6.130
Pahalgam	-83.00	-0.112	6833.66	0.321	0.05	-	-3.936
Kupwara	-111.00	-0.150	6833.66	0.183	0.05	-	-0.011
Kokernag	-120.00	-0.162	6832.66	0.150	0.05	-	-6.412
Gulmarg	-336.00	-0.454	6830.66	<0.0001	0.05	Significant trend	-32.48

Mann Kendall test is a non-parametric test used to analyse the trend. It was used for annual time series precipitation trend analysis in six meteorological stations of the Kashmir Valley. The annual averages were computed using the 39 years data from 1980-2018. Mann-Kendall and Sen Slope tests were used to see the trend and slope of the data. The results, when studied on annual basis showed decrease in annual precipitation which was especially significant at the Gulmarg Station. The MK and Sen's slope test statistics are presented in Table 8. If the p-value is less than alpha value, it implies null hypothesis is rejected. When the p-value is greater than alpha value, it implies null hypothesis is accepted. Out of the six stations, only Gulmarg station showed a significant decreasing trend with p-value very less than 0.05. That means, the decreasing trend at Gulmarg station is significant at 5% Confidence level. However, there may be a trend in the data behind the selected threshold at other stations as well.

The MK test results can be interpreted on the basis of p-value. Such as for Qazigund station, p-vale is 0.161, it means that for the null hypothesis at 5% significant level (95% Confidence level), there is no trend based on the null hypothesis. However, there is a trend significant at 16% significance level. Similar is true for all other stations. So, the Mann-Kendall trend test is followed by Sen slope estimator which gives the magnitude of the trends detected.

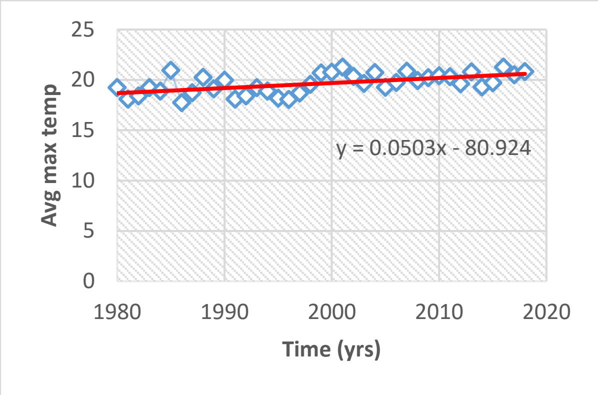
Based on the test results presented in the Table 8, it is recommended to go for the Mann-Kendall trend detection on monthly and seasonal basis, to derive an interpretation more precisely. Also, Modified Mann-Kendall trend test is suggested for refining the results obtained.

5.2 Temperature

Mean maximum temperature of all the stations is given in the table 9. The mean maximum temperature of Srinagar is 19.63°C. Among all the stations Srinagar, Qazigund and Kupwara shows almost similar mean maximum temperature. Gulmarg has the lowest mean maximum temperature 11.48°C. Kokernag and Pahalgam also does not show much difference it their temperature. This explains the fact that the stations having high temperatures will experience very low rainfall and may be vulnerable to dry weather periods. Those areas where there is low temperature will receive ample amount of rainfall and will be less susceptible to droughts and dry weather periods. Therefore, storage reservoirs have to be constructed in the areas of low rainfall and it will not be suitable to construct hydraulic structure in those areas.

Table. 9 Mean maximum temperature of six stations

Station	Mean Maximum Temperature (°C)
Srinagar	19.63
Gulmarg	11.48
Qazigund	19.09
Pahalgam	16.43
Kupwara	19.91
Kokernag	17.59



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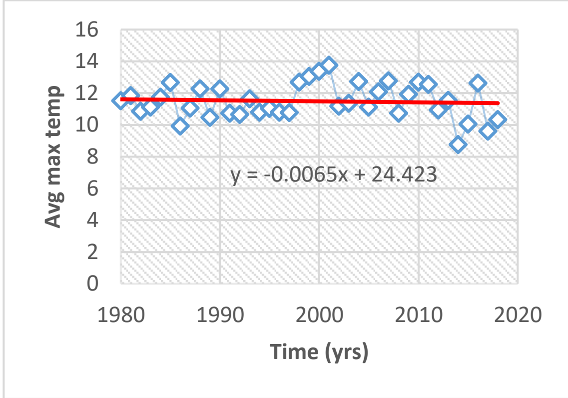
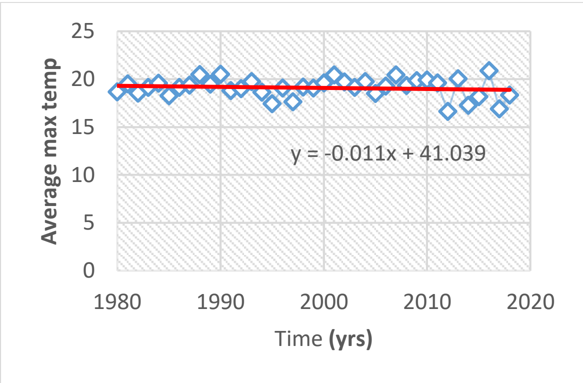


2. Gulmarg



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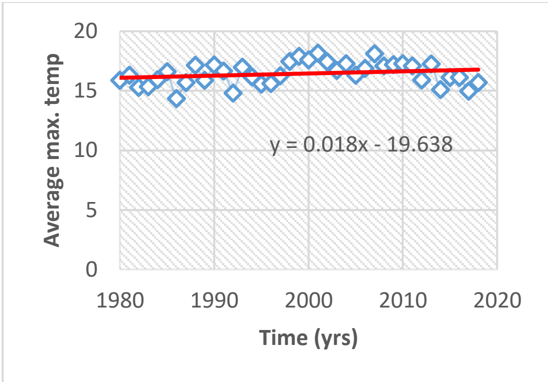

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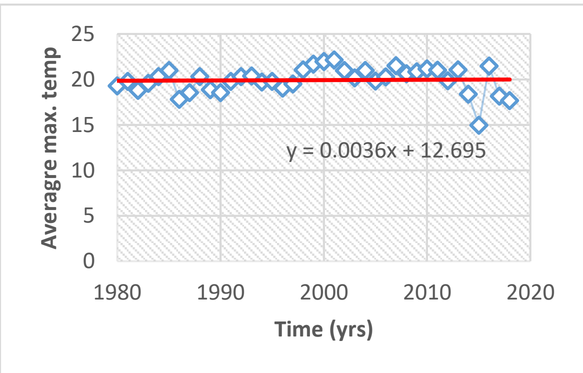
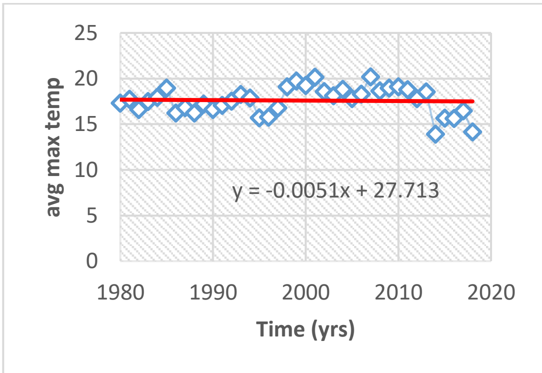
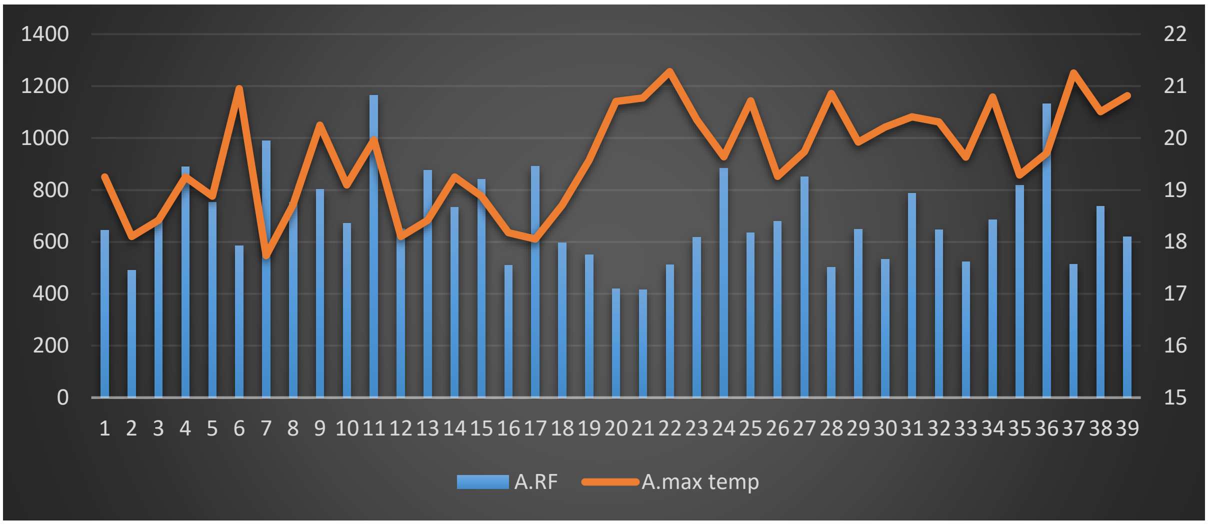


5. Kupwara

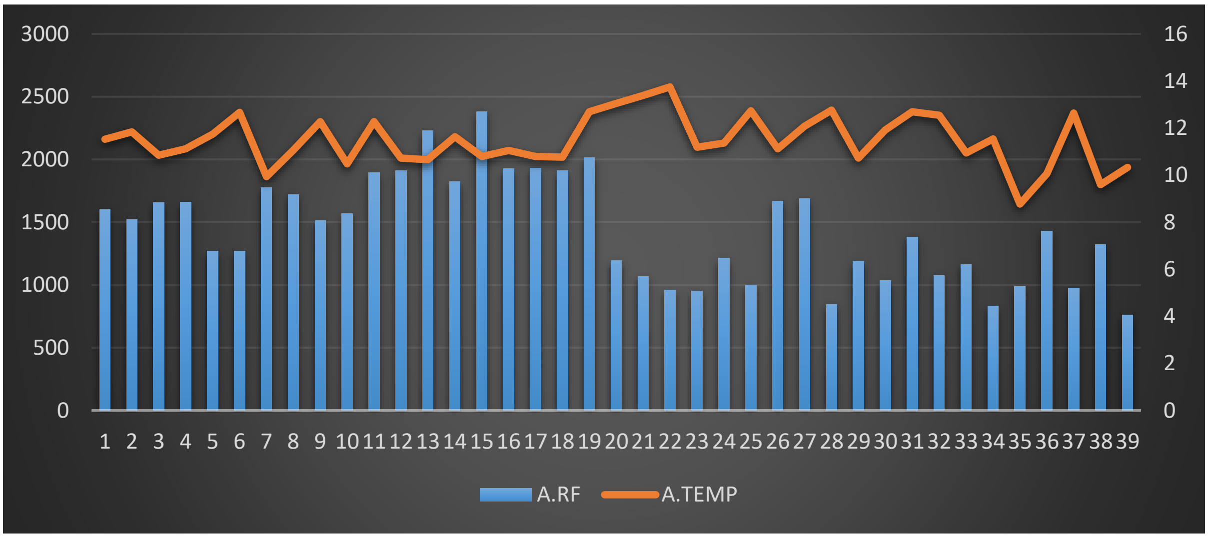


6. Kokernag

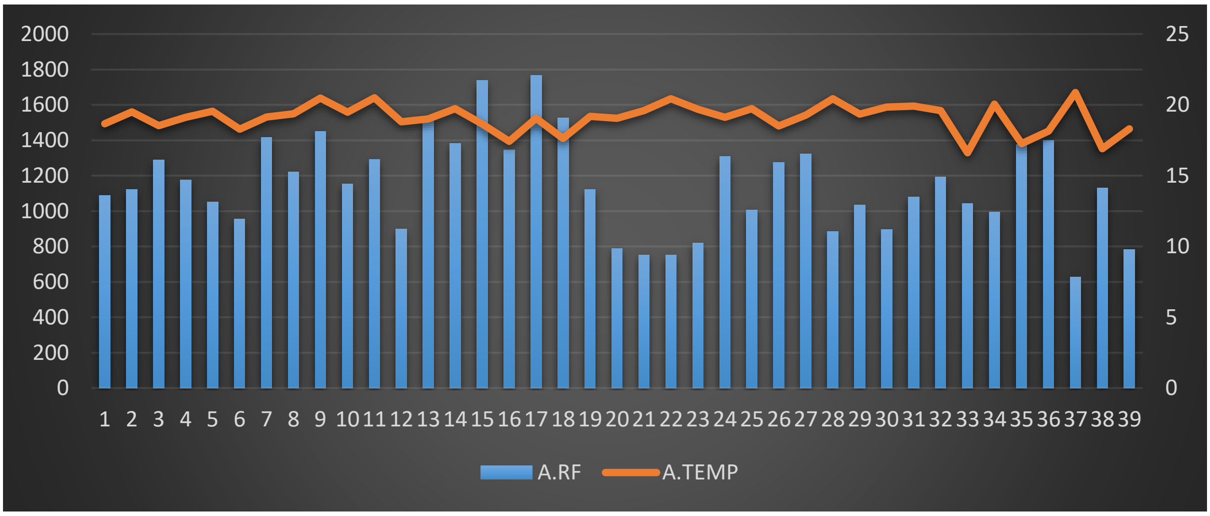
Fig.7., Average maximum temperature trend



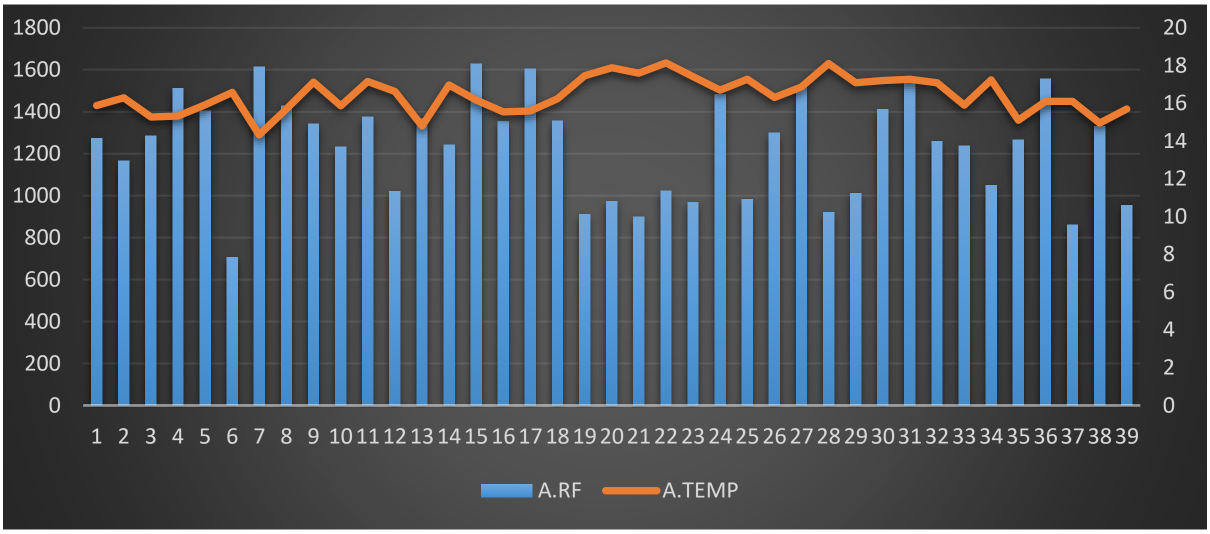
1. Srinagar



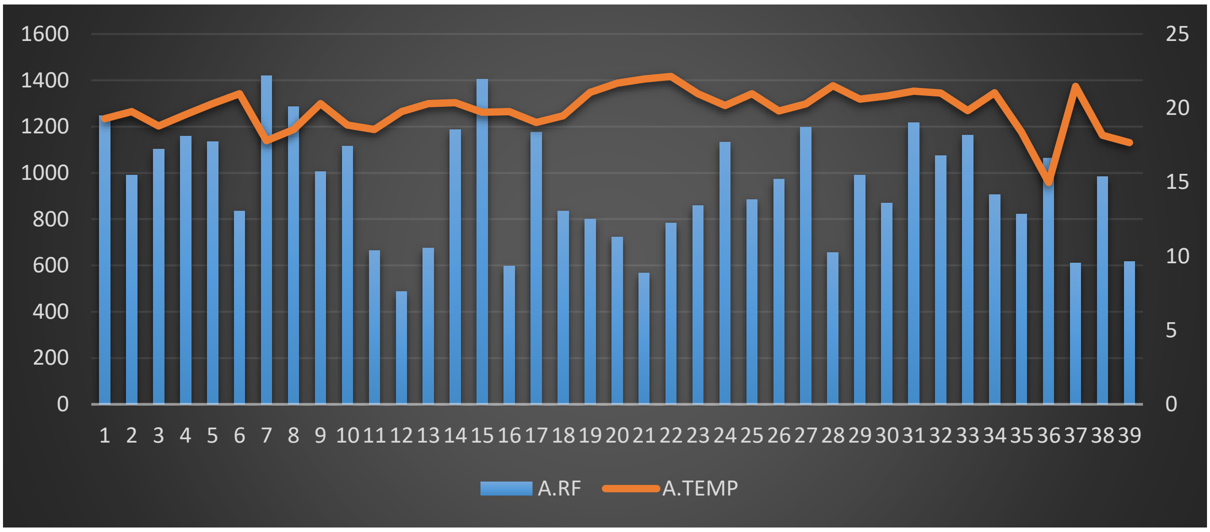
2. Gulmarg



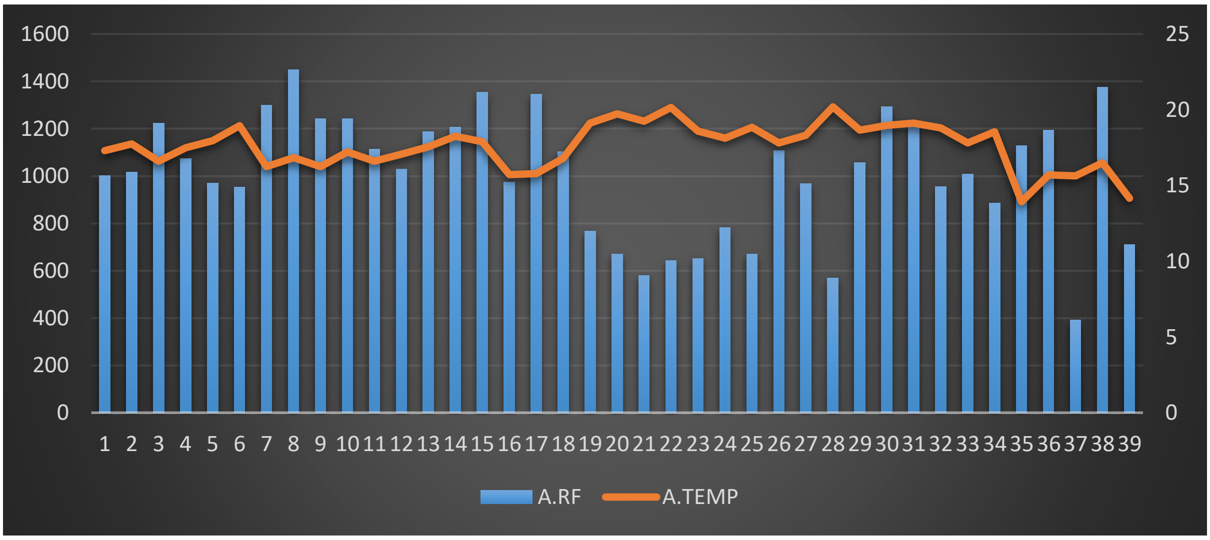
3. Pahalgam



4. Qazigund



5. Kupwara



6. Kokernag

Fig.8. Rainfall vs Mean Maximum Temperature

Trend of mean maximum temperatures is given in the fig 4. All the stations do not follow the similar pattern. Some stations show increase in trend while as some show decrease in trend. Srinagar shows increase in trend with a positive slope of 0.0503. Gulmarg shows the decrease in trend as is indicated by the negative slope of -0.0065. Qazigund and Kokernag also shows decrease in trend but with negative slope of -0.011 and -0.0051. Pahalgam and Kupwara show increase in trend with positive slope of 0.018 and 0.0036. Srinagar has highest increase in the temperature trend which is followed by Pahalgam and then Kupwara.

Rainfall vs mean maximum temperature variation is shown in the fig 5. From the above figure it can be clearly said that the station having low rainfall has high mean maximum temperature which is indicated by the Srinagar station. Gulmarg receives high annual rainfall will experience low temperature. This shows that soil moisture content of Gulmarg will possess higher value than Srinagar and will be suitable for doing agricultural activities. All the areas except Srinagar can be best suited for the agriculture, horticulture and aquaculture as there is sufficient amount of rainfall available for doing these exercises.

CHAPTER 6

CONCLUSION

6.Conclusion

6.1. Conclusion

The study area of Kashmir includes six stations Srinagar, Gulmarg, Qazigund, Kupwara, Kokernag and Pahalgam. The data for the analysis was obtained from Indian Meteorological Department Srinagar. The data included rainfall as well temperature data for the period from 1980-2018. The rainfall data showed a decreasing trend although based on p-value at a confidence level of 5%, only Gulmarg station showed a significant decrease. This was explained with Mann Kendall Test. 5-year moving average and Regression showed decrease in trend at all stations. Results also predicted that Srinagar receives minimum amount of rainfall while Gulmarg receives highest amount of rainfall. The area of Srinagar being more urbanized, more populated and forest cover leads to the high temperature and low rainfall. More is the urbanization more will the global warming in that particular area. As per IPCC with every 1^{o}C increase in temperature, leads to melting of glaciers at a rapid rate. There will be rise in the sea level which ultimately cause the chances of flood. The decrease in trend of rainfall adds to the fact that more forest covered area has been brought either under cultivation or under construction. All the stations showed significant decrease in the trend. Decrease in rainfall trend will ultimately lead to higher temperatures, droughts and less soil moisture content.

Temperature of all the stations does not follow the similar trend. Some stations show increase in trend while some decrease in trend. High temperatures and low rainfall of a region directly affect its climatic variability. From the past years there has been increase in the urbanization, deforestation and industrialisation which leads to low rainfall and high temperatures. If the current situation continues there may be further increase in the evolution of harmful gases from the industries. It been estimated that CFC's and CO_2 released from various industries and household activities have caused hole in the ozone. This will cause the harmful UV rays of the sun directly reach the earth's surface which will cause various diseases among living organisms. Trend analysis of Kashmir Valley was necessary as it will help to look after the change in the climatic variables which has occurred over the period of time.

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