SPATIAL TEMPORAL ANALYSIS OF FREQUENCY AND INTENSITY OF PRRECIPITATION OF LAHORE

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BY

FAIZA WAHEED KHAN

DEPARTMENT OF GEOGRAPHY

KINNAIRD COLLEGE FOR WOMEN, LAHORE

RESEARCH COMPLETION CERTIFICATE

It is certified that Faiza Waheed Khan of Bachelors (2018-2022), Department of Geography has carried out research work **entitled "Spatial Temporal Analysis of Frequency and Intensity of precipitation of Lahore"** under my supervision.

It is assured that research work is original and has not yet been published anywhere else.

Dr. Ambreena Javaid
Signature of Supervisor Ambreena Javaid 16-6-2022
Assistant Professor

Dated: 16-6-2022

Dr Ambreena Javaid
Signature of HOD Ambreena Javaid 16-6-2022
Head of Department

"All changes suggested by examiners during defense are incorporated in this final copy"

Ambreena Javaid
16-6-2022

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Faiza Waheed Khan

F18BGEO016

BSc.Geography

Signature:Faiza Waheed Khan

Dr. Ambreena Javaid

Signature of Supervisor 16-6-2022

Dr.Ambreena Javaid

Signature of HOD 16-6-2022

Head of Department

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Faiza Waheed Khan

Abstract

The issue of climate changes causes damages from past two decades on environment. Increase in temperature and its affect on hydrology and rainfall is proof around the world. Exchange in precipitation pattern at once have an effect on water and catastrophe control. The aim of this research is to determine the pattern of rainfall of Lahore using GIS applications. Rainfall records for the duration of 20 years of monthly data 2000-2020 is provided by Meteorological Department and TRMM data is also obtained to applied interpolation method. Krigning method is used to map the precipitation of Lahore.

The Meteorological Department plays important role in monitoring the situation and issued the assertion of modifications in climate and provide resources and gives warnings when situation calls for. We evaluated the traits in Spatial Temporal models of annual and periodic rainfall of Lahore in past 20 years (2000-2020) using precipitation data from the Meteorological Department,using Giovanni Tropical Rainfall Measuring Mission (TRMM) satellite data, using Pearson Correlation test which can discriminates Long-term potentiation from trends. The outcome obtained that importance in tendencies acquire using Pearson test is increasing over past years. The annual precipitation of Lahore is increasing over past 20 years.

SPATIAL TEMPORAL ANALYSIS OF FREQUENCY AND INTENSITY OF PRRECIPITATION OF LAHORE

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LIST OF ABBREVIATIONS:

GIS: Geographic Information System

TRMM: Tropical Rainfall Measuring Mission

LTP: Long –term potentiation

PMD: Pakistan meteorological Department

PR: Precipitation Radar

TMI: TRMM Microwave Imager

VIRS: Visible Infrared Scanner

CERES: Clouds & Earth Radiant Energy System

LSI: Lighting Imaging Scanner

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CHAPTER 1

INTRODUCTION

1.1:Background:

In atmosphere, Precipitation is any made of the distillation of atmosphere water vapors that comes down underneath from clouds. The principal form of precipitation consists of rain, storm, and hail.Precipiitation occurs when atmosphere become saturated with water vapors than this water condenses and as a result of this, precipitation falls (Weng et al. 1994). There are methods that is appearing together that may show to air turning into saturated, cooling of air.

Precipitation is a main issue of hydrological cycle and is principal source of garage of clean water in the world. Approximately, 505,000 cubic kilometer of water comes down as rainfall on earth and 107,000cubic kilometer over land (Weng et al. 1994).

1.2:Units and instruments:

Rainfall is generally measured the usage of a Rain Gauge and expressed in devices of millimeters (mm) of heights or intensity (Kriplani 1995).

Average Precipitation in Pakistan and Lahore:

Rainfall averaged 25.03mm from 1901 till 2015, achieving an all time high of 170.66 mm in August of 1916 and low of 0.15 mm in December of 2014

Lahore, Punjab gains an average of 628.8 mm (2.1 in) of rainfall per year or 52.4 mm(2.1in)per month.

There are 49 days/year with more than 0.1mm (0.0004) of rainfall or 4.1 days with quantity of rain, sleet etc (WCRP 1986).

Between dry and wet months, the variation in precipitation is 159mm/6 inch. Throughout the year, temperature changes by 21.2 C/38.1F. The month with the best relative humidity is August (76.01%)and the month with the low relative humidity is May (30.05%) (Janowiak and Arkin 1991). The month with the very best variety of rainy days is July (18) days and the month with the lowest quantity of rainy days is November. Lahore is in Northern hemisphere. Summer starts at quite of June and ends in September. In 2009, the average percent of the sky covered by cloud undergo significant periodic version over course of year. The cloudier part of the year begins around November 23 (Hanif,2013).

The dew factor ought to be cooled that allows to turn out to be saturated, and condenses to water (Chang et al.,1995). Stratus cloud which has a tendency to shape to whilst a cool, solid air mass is captured under a hot air mass. It additionally forms because of lifting of fog all through breezy situation.

1.3:Monsoon season:

Monsoon is the seasonal change due to prevailing winds of a region. Monsoon are always associated with Indian ocean and causes wet and dry seasons. Summer monsoon usually causes heavy rainfall from the month of April to September. Winds blow from Southwest Indian Ocean towards the India,Srilanka, Bangladesh (Salma ,Rehman &Shah,2012).

Monsoon rains start from ultimate week of June to till end of September. In 2009, Lahore receive ordinary monsoon rainfalls because of El-Nino over Pakistan. Monsoon and western

disturbances are essential elements that have an effect on the climate. It usually takes place at some stage in winters and effect slight rainfall, thunderstorm additionally takes place.

In Pakistan, monsoon season is considered to be bliss for the country as it plays the role of backbone in the agriculture sector creating 24% of the GDP for the country. About 40% of human beings of Pakistan are extraordinarily vulnerable to frequent a couple of failures with variant in rainfall styles and floods and droughts (Husain et al,2010,Oxfam Report on Climate Change, 2011).

1.4:Impacts of heavy rainfall on Urban Areas:

In majority areas of the country, rainfall emerge as undesirable and unexpected, get in hard for group to make essential preparations for the protection. The wetted winters and heavier summers showers are anticipated to put pressure on urban drainage. Heavy rainfall can lead to numerous risks for example: flooding which includes danger to human existence, harm to buildings and infrastructure and lack of plants and farm animals. Landslides, which can be threaten human existence, disrupt transport and communications, and can cause damage to homes and infrastructures (Immerzeel et al., 2012, Karki et al., 2011).

Rainwater performs an crucial role in numerous elements. This water provides important assist for agriculture, home intake and hydropower generation, all commercial for the financial system of Pakistan. The weather version expect the winter weather rainfall will increase with the aid of 20-30% by 2080s such an increase may want to result in a far large up to 200% increase in flood risk (Aziz et al, 2018).

1.5: Factors that affects weather of Lahore:

Monsoon and western disturbances are two principal elements that affect the climate of Lahorewestern disturbances are generally arise in the course of wintry weather months and purposes slight rainfall , hailstorm additionally take place . Fog is heavy all through winter season and stays for days to weeks (Gordy 1991).

Southwest monsoons also arise within the summer season, from June till September (Becker et al., 2013). These heavy monsoon rains deliver comfort from extreme warmth. Continental air prevails for the duration of the length while there may be no precipitation in the metropolis.

1.6: Monsoon Rainfalls:

628.8millimeters (24.76inches) is the total monsoon rainfall of Lahore. Lahore noticed under everyday monsoon rainfall due to El-Nino over Pakistan.

2003-337millimeters (14.8 in)

2005-426millimeters (16.8 in)

2006-606millimeters (23.9 in)

2007- 531millimeters (20.9 in)

2008-800millimeters (31 in)

2009-318 millimeters (12.5 in)

2010-711millimeters (28.0 in)

2011-1,439millimeters (56.7in)

2012-576.2millimeters (22.69 in)

2013-1,430millimeters (56 in)

1.7: Annual Rainfall :

Lahore especially gets rainfall during the monsoon season from June to till September. The maximum rainfall was recorded in 2011 while 1,576.8millimeters (62.08 in) of rainfall was received. Lahore obtained underneath ordinary rains in 2009 and normal rain in 2007 and 2010.

1.8: Importance of Geographic Information (GIS) in Precipitation:

Geographic Information System GIS are generally used to generate rainfall patterns in visible formation with a combination of characteristics of rainfall formation after which may be used to facilitate the method of analysis and forecasting.

GIS helps employ weather, climate models and visualizations and can be used for predictions using intelligence and big data.

1.9:Application of Geographic Information System(GIS)in Analysing Rainfall Distribution Patterns:

Rainfall forecasting are vital to offer statistics and warnings to the populace in a vicinity of Pakistan (Min et al., 2011). Meteorological Department (PMD) is a department that performs an

vital function in tracking the scenario and issued the announcement of modifications in climate and offers offerings such as climate advisories and provide warnings whilst the situation requires (Knapp et al.,2008;Hallegatte et al.,2013). Uncertain climate situation typically have created panic situation, especially in big towns because of flash floods due to terrible drainage control. Usually local authorities supplied rainfall statistics in tables and its far tough to analyse to gather the rainfall fashion. Therefore Geographic Information System GIS programs are typically used to generate rainfall styles in visible formation with a combination of characteristics of rainfall data and then may be used to facilitate the manner of analysis and forecasting rainfall (Kiktev et al., 2003). The aim of the research is to determine the patterns of rainfall distribution using GIS applications and it is smooth to examine the rainfall facts in visual shape and mapping form (Alexander et al., 2006). Rainfall information for a duration of two decades from 2000-2020 become supplied with the help of Meteorological Department and rainfall maps of every year is received. The rainfall maps then analyzed to perceive the very best rainfall that become obtained at some stage in the duration of observe.

STUDY AREA

Lahore is the metropolis of Pakistan's province Punjab and a densely populated metropolis. Location of Lahore (31º34`N and 74º19` E). Lahore is the secong largest city of Pakistan.

Lahore is surrounded by means of Sheikhupura District, Wagha and Kasur District on the eastern side and sourthern side respectively. River river also flows in the northern side.

Lahore is the largest district of Punjab and largest metropolitan city in Pakistan and 26th largest city of the world.

It is middle mendacity with 25km of International border with India. It is located at 31.5204º N,74.3587º E.

The current study area of this research is Lahore.

Study Area Maps

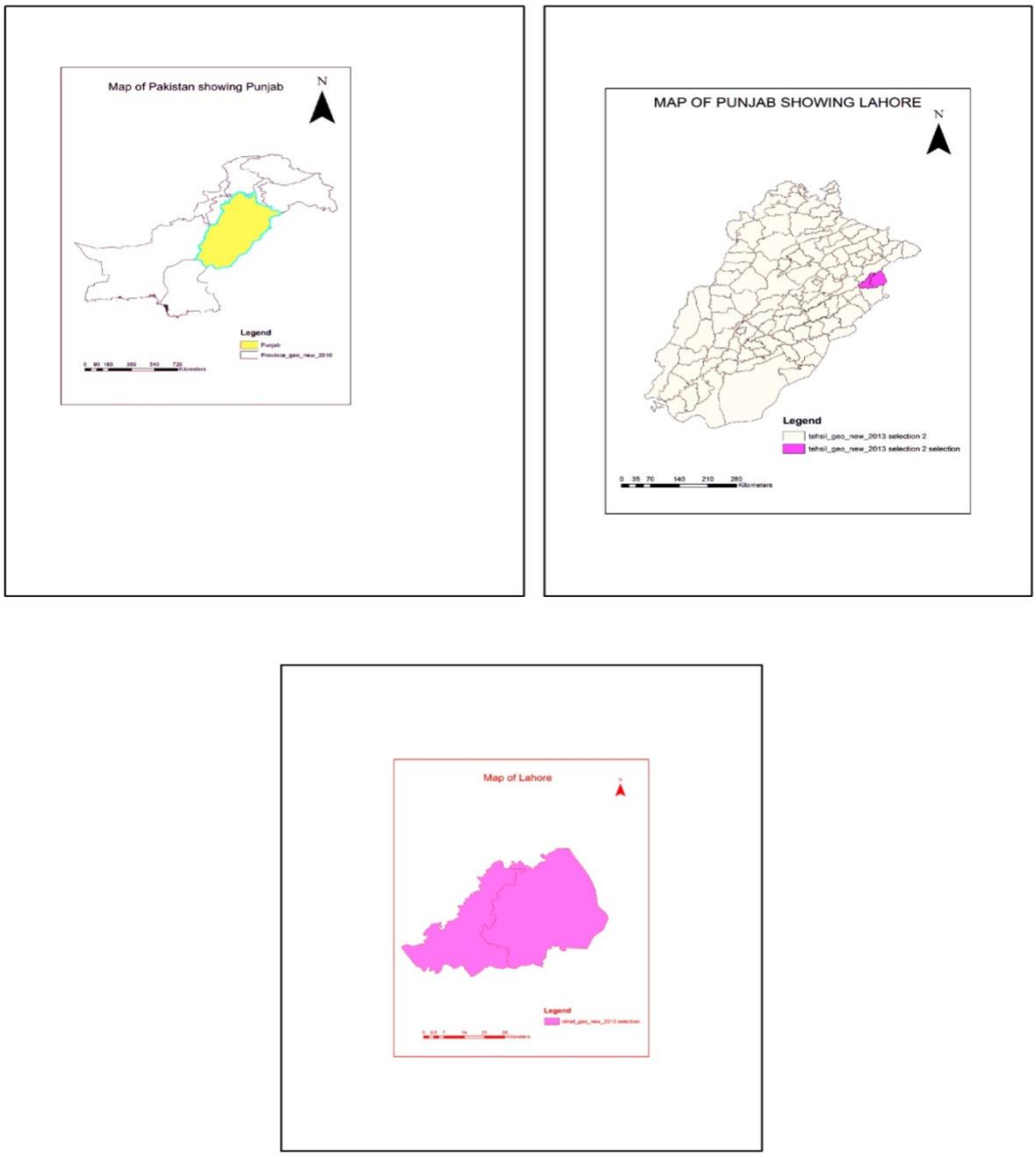


Figure 1.1 Map of Study Area

STATEMENT OF PROBLEM

The rate of precipitation of Lahore is changing over past 20 years.

RATIONAL

The capability for intensity of intense rainfall to boom with climate change is of vast situation. Data is provided by Meteorological Department for 20 years of Lahore. The globally averaged 20^{th} and 21^{st} century rate of growth in maximum day by day rainfall intensity become estimated to be among 5. Each year received different amount of rainfall. June, July, August are the months that received more rainfall as compared to other months.

The important goal of this study is to bring attention to the increase in precipitation rate of Lahore. People do not have enough awareness about it, just they do not have enough understanding about environmental issues, but it can be hazardous.

HYPOTHESIS

H_0: The rate of precipitation of Lahore is not changing over past 20 years**.**

H_1: The rate of precipitation is changing over past 20 years.

OBJECTIVES

- To examine 20- years precipitation pattern of Lahore.
- To develop map through GIS to show pattern of rains in the study area.
- To examine 20 years pattern of rainfall using satellite images

CHAPTER 2

LITERATURE REVIEWS

Adnan, Ullah, Gao, Khosa, & Wang (2019) examined that adro-climate type helps to decide the unique capabilities of a place and this weather type offers usefull awareness for a farmer to develop their crops keeping with the condition in the area. The study identified the transferring moisture index from common values in unique agro-climatic zones of Pakistan. The research revealed that nearly 87% of Pakistan is in extremely arid to semi -arid zones,5% decrease in over last 30% years (1981-2010). The largest lower of 8%and increase of 5% had been located in extraordinarily arid and humid zones. The minimum temperature showed an increase over the entire area, which can also stress on water needs of vegetation.

Aftab, Ahmad, Hameed, Bashir, Ali, & Nawaz (2018) examined to research the performance of document data mining stratergies on rainfall prediction in Lahore metropolis the usage of class form of framework. Weka is used for classification and performance analysis in this study. The category framework used on this research includes 4 levels, selection of appropitate dataset, Preprocessing, Prediction and Simulation. According to the results, used category strategies preformed nicely for no rain magnificence,stratergies did not performed nicel. The reason in the back of the lower accuracy in rain elegance may additionally encompass, lacking values, absences of climatic attributes in dataset and ordinary decrease rate of rainfall in metropolis.

Ahmad, et al., (2018) examined the yearly and seasonal precipitation variability at 20 stations over upper Indus River basin usage of an innovative trend analysis(ITA) method, Mann-Kendall and Sen's slope estimator exams. Annual rainfall revealed an increasing trait at 4 stations inside

the northwest place and lowering trends 2 stations inside the soputhwest areas of higher Indus River basin. The effects of mild rainfall depth revealed that both seasons are more prone to the occurance of the extended droughts occurences.

Ahmad, Tang, Wang, & Wagan, 2015 examined the precipitation tendencies exchanged from summer time to autumn season. The saidu sharif station found out the high-quality development(7.48mm/12months) in rainfall. Different statistical techniques are discover tendencies in hydrological and hydrometeorological time series. This take a look at investigated variability in monthy to month rainfall over a 51 year study at duration (1961-2011). Precipitation had been also examinefor every subbasin and whole swat basin. Saidu sharif station confirmed the most increasing slope of (7.48mm) among station in swat. Findings have been consistent with outcomes from Dimri[56], Ghaffar and Javaid[57], and Rasul[58],they observed increase in traits in winter precipitation for northwest.

Ahmed, Shahid, Ali, Harun, & Wang (2017) examined the tested guage based gridded precipitation estimates are emerged as a supplementary supply of precipitation records had been in-situ precipitation facts are not effectively available. In this study. 4 extensively used guage based gridded precipitation merchandise have been as compared with in-situ precipitation at 3 stations placed n semi-arid, arid and hyper arid-areas of Balochistan province, Pakistan. The assessment is accomplished at monthly scale and at 0.5 resolutions during 1961-2007. The effects revealed that the overall performance of different varies at one of a kind stations GPCC is discovered significantly better than different merchandise displaying higher settlement with annual and seasonal precipitation. GPCC precipitation expected as maximum suitable product for the climate and hydrological studies in a predominantly arid place like Balochistan.

Ahmed, Shahid, Chung, Ismail, & Wang (2017) examined the existence of autocorrelation and long term patience (LTP) can cause large alternate in the significance of developments in hydroclimatic time collection.This examine assessed the traits in spatiotemporal patterns of annual and seasonal precipitation of Pakistan in 1961-2010 using precipitation statistics from Global Precipitation Climatology Center GPCC. The effects indicated that importance in trend acquired using MK check is decreased while LTP is considered. The annual precipitation in Pakistan where monsoon rainfall is also increasing

Ahmed, Shahid, Ismail, Nawaz, & Wang (2018) examined that homogeneity evaluation are done on overall annual precipitation records which frequently did not detects non-homogeneity in seasonal precipitation. This is specially important for arid areas where distribution of annual and seasonal rainfall are frequently nin-normal. Results counseled that rainfall collection for most of the the months in all stations are beneficial. The rainfall time series become located doubtful for the month of June at station, for April at one station and for November at simplest on station. The annual time collection information at 12 out of 14 stations had been determines usefull at the same time as were found suspected. The acquired results were demonstrated with unique test and the destroy factor in non-homogeneous rainfall time series were detected.

Ali & Ahmad (2015) examined the evaluation of long term monthly and annual precipitation series for 48 stations of Pakistan from 1891-2010. In this study, non parametric techniques as Mann-Kendall check were used for the method to locate the importance of the trend and Sen's slope estimator,to locate exchange according to unit time , importance of trend and also for resolution of path,presume a linear inside the data. The series which show widespread serial

correalation were subjected to written. From month-to-month series, December,January and Febuary showed negative trend as compared to different months, displaying a combined conduct of tremendous and negative tendencies. Islamabad is the station where month-to-month great contribution is highest to make the annaual series significant with maximum effective trend.

Boota, Nabi, Ahsan, & Abbas (2015) examined the one day precipitation duration in Gujjar Khan Potwar region Pakistan. The major source of water in this area is rainfall. About 30% of rainfall is lost which is sufficient to irrigate two million acres if properly managed. Precipitation in Potwar region varies from 500 to 1000mm. 60% of rainfall occurs in monsoon season and 40% in the remaining season. During the dry spell, (1997-2003) there was little rainfall. Statistical techniques changed into used and encouraged to estimate the PMP because of drawback of records availability.PMP estimated in this study is helpful to design soil and water collection structure in Gujjar Khan. The result derived are applicable in crop plan and to calculate layout flow price for maximizing crop production.

Cheema & Hannif (2013) examined that frequency of rainfall is higher in northern part of the country as compared to the other part of the country.The excessive amount of water is a threat to the mankind and ultimately to the economy of the country. Winter precipitation serves as a excellent water supply within the shape of snow.The study showed that rainfall is maximum in 12 months and remained regular for the subsequent 2 years. It is found that there is five increasing tendencies and 3 lowering trends during summer 1961-2005 and overall location of 0.09mm.

Chen, You, Sielmann, & Raun (2016) examined the precipitation inside the Tibetan Plateau (TP) extend its top in summer season. The seasonal projection skill of a statistical downscaling modal

(SDM) for summer season precipitation within the TP changed into in comparison with that of direct version output. The CCA discovered the styles at the back of the seasonal projection ability of summer time precipitation inside between 1961-2012 and qualifies its relative contribution. The following results have been acquired. The SDM forecasts for every determinant is better than of MPI-ESM-LC climatic version and ECC execute even better. The quantity of summer time precipitation within the Tibetan Plateau will barely lower under RCP2.6 with the help of 0.4mm decade 1, where are RCP4.5 and RCP8.5 display increase by using 2.4 and 18.4mm decade respectively.

Dahri, Ludwig, Moors, Ahmad, Khan, & Kabat (2016) examined the scarcity of in-situ remark combined with excessive orographic impacts has averted a complete evaluation of precipitation distribution inside the high altitude catchments of Indus basin. Available records was generally fragmented and scattered with unique oraganizations and usually covers the valleys. The obtained observations signifies the importance of orography in each sub hydrological basin however couldn't correct the distribution of precipitation with altitude. The study confirmed that the gridded precipitation products overlying this area are liable to widespread mistakes

Das, Sharma, Sharma, & Dadhwah (2015) examined month-to-month gridded 0.5x0.5 standardrized precipitation evapotranspiration index SPEI data of 1901-2008. The data become used to locate spatial temporal trend in meteorological drought at some stage in summer season monsoon period. The SPEI facts have been transformed into drought length value and brands of occurance to seize universal drought senerio. A identified paramatic Mann-Kendall techniques changed into used to check monotonic traits at each grfid level. The time collection analyzed of rainfall and capability evotranspiration is show that over a part of India the growth become

reviewed due to lower in rainfall, while the lower in drought occurance over western and region changed mainly because of decrease in PET.

Iqbal & Athar (2018) examined to evaluate the Tropical Rainfall Measuring Mission TRMM multi-satellite Precipitation analysis product statistics with 0.25x0.25 spatial and put up actual time 3hr temporal resolution using point based surface precipitation guage information from 40 stations, for the period 1998-2013 and using asian precipitation. The TMPA generally underestimates each SPG and APH in excessive elevation areas, in which in simple and medium elevation areas it offers higher consequences. This observes concluded that TMPA cab be suitable alternative of SPG for water sources control in undenialble and areas in principal, during four seasons.

Iqbal, Shahid, Ahmed, Ismail, & Nawaz (2019) examined the modifications in precipitation and precipitation extremes inside the location have intense influences on water protection and hydrology of Pakistan. The results discorved no huge trade in annual precipitation but increase in summer season rainfall inside the range of 0.25m to 1.25mm/year in the upper element and decrease in precipitation from 0 to 0.25mm/year within the west part of the region. The increase in both continous dry days and intense rainfall indicates greater droughts and flood have adverse influences on the hydrology of Pakistan.

Iqbal, syed, Nikulin, Kjellstrom, & Hannachi (2017) examined a stimulation with the fourth release Rossby Center Regional Climate Model were carried out with the CORDEX framework for South Asia at 50km horizontal resolution became assessed for December-March and summer season June climate for the duration of 1980-2005. The datasets ERA-interium and preferred circulate model EC-Earth has been examined except the RCA4 stimulation to address the

delivered fee. Both somali jet and tropical easterly jet emerge as stronger during summer monsoon years.

Khattak & Ali (2015) examined the objectives that become to asses development in most and maximum temperatures and month to month rainfall in Punjab. Data of most and maximum temperature and overall rainfall was acquired from Regional Meteorological Department from 9 districtsof Punjab over 1961-2014. The effects shows that spring season is warming and reducing in summer season temperature is as a result of increase rainfall trends in Punjab.

Markonis & Koutsoyiannis, (2016) examined the long term period persistence and hurst kolmogorav conduct behavior that has been diagnosed in lots of hydroclimatic records. They also highly relevant for the water recourses managers because these gadgets exhibit continual. During recent years the developing number of palaeoclimatic reconstruction has allowed investigation of the long term period statistical properties of weather. The later advised that droughts and extremely moist periods arise less often than depicted within the palaeoclimatic reconstruction.

Nawaz,Li,Chen,Guo,Wang,&Nawaz(2019) examined the variation in the precipitation in Punjab province during 50 years. The significance of temperature precipitation were calculated through statistical methods. This research also indicated that seasonal (crops growing) Tmax had a increase trend in most stations in Rabi season, at the same time as Kharif season had a minor lower in Tmax. A negative trend was tested at guage web sites of Murree and Islamabad for Rabi season,while guage sites Murree and Bhalawalnagar confirmed poor trend in Kharif season. Due to change in precipitation ,snow melting cause the river to overflow which is responsible for the flood in low elevation zones,

Rashid, Mansoor, Haider, & Nasir, 2020 examined that precipitation and surface morphology within the result of several mechanism, molecular increase and secondary approaches and the using pressure for production of nonoparticles is great saturated. Nucleation is step one for the formation of nonoparticles. The observe is focused on generating magnetic nonoparticles by using coprecipitation prodecure. It is determined that iron oxide nonparticles have been prepared through precipitation process the use of precursor aggregate of iron chloride. The nonoparticles are produced in precise yield with high purity and deliver the reaction charge value of 7.5x10. The surface fee additionally effects in big resistence closer to aggregation and coalease of nonoparticles. TEM analysis confirmed that shape of these debris are spherical and giving a porous texture.

Sajjad, Batool, Qadri, & Shirazi (2015) examined the yearly and seasonal development of surface temperature of two stations of Lahore on placed in centre of the city and another one the the airport of Lahore about 40 km far away from site. The temperature information of minimum and most accumulated from Pakistan Meteorological Department PMD was analyzed the use of linear regression. The outcomes at each station is not growing substantially. The highest increase in minimum temperature is measured in spring season. It was examined that during 1972, city has a populace of 2.17 million which reached to 9.75 million in 2014 with an increase of 350percent in four growing urban areas population. It may be visible that the highest increase discovered in temperature at urban station over the studied duration is measured in spring season. Where its miles expanded 3.24 C at some stage in the each seasons and lowest is determined at some point of summer season in which it is computed 0.98C for the duration of 40 years even at the minimum temperature for the duration has shown lowering trends.

Soomro, Hadi, Awase, Koondhar, & ahmed, 2015 dicussed the diagnostic approach using produced water chemistry, WGR history and Nodal evaluation are expecting the gold standard backside stress to avoid salt precipitation. A wide variety of wells in regions had excessive salt buildup trouble and sharp decline become found. Different techniques like wellbore cleanout and to get rid of salt plugging were applied. This paper affords a technique to stop salt measuring in low stress gasoline wells in United Energy Pakistan Limited locations.

Waseem, et al., (2020) examined that exploration of spatiotemporal precipitation tendencies from weather change angle is important,especially in the areas with rained agriculture which will reason sustainable adaption schemes. The consequences specify that form totally on one monthly, annual and seasonal time series, no regular rainfall sample turned into located throughout the entire observe. On common, a development changed into located within the east plateau at the same time as lowering within the west plataeau. The results additionally indicated that weather trade goes to noticeably influence the place as a reducing trend at the station.

Zahid & Rasul (2011)examined that common increase in the acute temperature with a purpose to in the end consequences in expanded depletion of ice from glaciers and features severe impacts on future generation. For example Siachen Glacier that is reduced to 2.9km. It is prime origin of water besides monsoon system. The evaluation of precipitation occasions has proven increasing trend in the course of the country from 1965-2009. The consequences found out a statistically big and sharp increasing trend of precipitation events frequently in Sindh and Azad Jammu and Kashmir areas at all ceiteria's (50mm,10mm,150mm). It is concluded that essential parts of the country have experiencing warming development in line with extremes temperature.

Zia, Shirazi, Bhalli, & Alam (2014) examined the worldwide temperature become growing and this changed into a extreme problem. Temperature is vital parameter for findings for climate of anywhere. In this study, temperature tendencies on seasonal and annual foundation for five years protected the region of 2306sq was tested. Anomalies of temperature had been plotted and it become discovered that percent of annual suggest temperature and imply minimal temperature have been increased at the 2.5 and 5.5 percent consistent with 12 months respectively. Temperature variable blanketed suggest MAT,imply most MMxT were considered for studing both on annual and seasonal basis. The chances of trends received for every parameter in exclusive season, showed increasing temperature developments for the duration of 8 months of 12 months except in June to September were determined.

CHAPTER 3

METHODOLOGY

Considering, the scope of subject and objective of the study, secondary data approach will be adopted and the data was collected from different sources.

Following software's were used to complete the work.

Table3.1: Methodology used for the study:

Software's Name	Application
Giovanni (Global Precipitation Measurement)	Used to download satellite image
ArcGIS 10.7	Used for the image Processing
SPSS	Used for making Graphs
Microsoft Word	Used for final presentation of research work

3.1:Meteorological Data:

20 years of rainfall data was obtained through Meteorological Department Jail Road Lahore to see change in the pattern of rainfall and it was thoroughly analyzed. The monthly data of per year was obtained.

Monthly data was each year was analyzed and graph was obtained to get the result.

Table 3.2 :Meteorological Department Data (2000-2020)(mm/hr):

year	Jan	Feb	March	April	May	June	July	Augus t	Sept	Oct	Nov	Dec
2000	21.5	9.2	1.8	2.8	8.4	79.6	327.2	78	23.5	0	5.3	-1
2001	7.8	4.4	34.6	3.4	28.1	106.5	293.1	2.5	48.3	-1	-1	7
2002	0.6	3.2	11.3	1.7	35.6	34.5	56.4	92	85	6.4	0	7
2003	0.5	103.5	59.6	2	18.2	41.7	252.3	108.5	16.4	0	16	8.8
2004	38.2	13.2	0	12.1	42	72.9	144	143.5	11.2	5.8	4	8.3
2005	64.2	55.6	64.2	11.4	1.7	32	223.5	129	69.8	0.8	-1	0
2006	18.9	4.9	42.1	-1	22.4	87.9	185.5	145.7	157.6	46	9	30.8
2007	-1	106.4	65.2	-1	19.1	196.9	81.7	101.7	75.8	0	10.2	3.3
2008	24.3	5.6	-1	38	36.7	68.4	17.9	287.2	22	6.1	0	7.8
2009	19.8	26.9	52.3	19.9	6.1	20.2	110.9	92	20.4	2.6	1.1	-1
2010	0.3	9.4	5.4	2.6	7.2	4.8	288	119.4	88..4	0.2	0	15
2011	-1	28.1	7	16	6	147.6	244	253.9	154.3	-1	-1	-1
2012	18.6	6.8	10	49.9	0.2	13.3	37.7	197.1	199.4	28.8	0.2	21
2013	13.2	71	19	7.3	1.2	136	242.2	352.3	30.7	18.4	4.5	7
2014	4	22.6	32.3	64.8	29.5	50.1	43.4	56.7	450.3	3	29.3	0
2015	19.9	61.3	141.8	5.2	31.7	45.6	328	92.7	126.8	3.8	0.4	-1
2016	28.7	2.8	27.4	2.9	31.2	118.2	151.1	315.1	127.7	0.6	0.2	0
2017	69.4	6.8	28	19.6	9.8	201.6	149.1	70.3	52.2	0	6.6	14.7

2018	0	0	3.2	0	0	8.5	19.2	2.9	10.8	115	25.8	77.1
2019	32.6	83.7	12.9	54.5	0	23.1	28.5	400.9	0	106.2	110.6	27.6
2020	34.6	0	9	105.7	0	25.1	18.7	43.7	0	151.8	316.4	107.7

3.2:Download Data:

The Satellite images of Pakistan Rainfall Data from 2000-2019 was obtained through Giovanni Global Precipitation Measurement.

Giovanni is an internet- based totally utility advanced by using the Earth Science data that provide a easy manner to visualize,examine and get entry to the information.

The product used:

Precipitation Rate(TRMM_3B43v7	mm/hr	TRMM	Monthly	0.25	1998-01-01	2019-12-31

The model was Tropical Rainfall Measuring Mission (TRMM) which give records between 1998-2019.

3.3:Softwares:

Different softwares are used in the study to analyze and visual data. Microsoft excel was used to draw graph of each year e:g; 2000,2001,2002,2003…2020.

Data of each month was entered to the table e.g: For 2000, different values of each month was entered and sum of each year is calculated to show how much rainfall is observed in one year.

3.4:SPSS StatisticsIBM:

This software is used to test the hypothesis which is selected according to the study area. In this study, On sample t-test is used to test the hypothesis.

Histograms is made for visual representation and to analyze the results.

3.4:ArcGIS: ArcMap 10.7 is used in this research. In this study, It is used to create map of the study area. The shapefile is created of Lahore boundary and used in ArcMap to create map. Interpolation predicts values for cells in a raster from restricted number of pattern data points. It can be used to expect unknown values for any geographic facts points including rainfall. Kriging and IDW interpolated Distance Weighted methods are good and suitable for rainfall data interpolation. In this study, kriging is used to anlayze the data

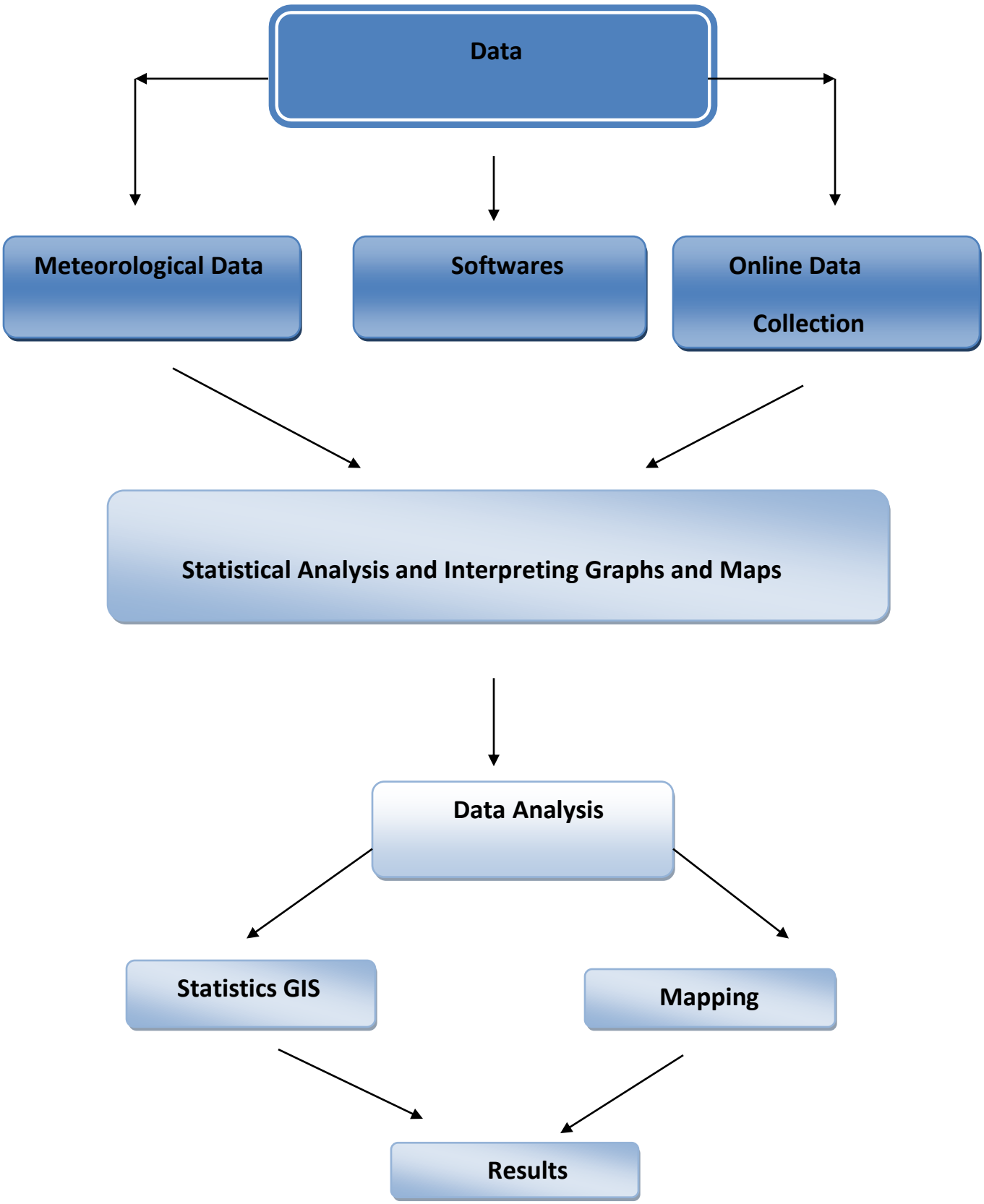

Data
Meteorological Data
Softwares
Online Data Collection
Statistical Analysis and Interpreting Graphs and Maps
Data Analysis
Statistics GIS
Mapping
Results

Figure 3.1 Flow chart of Methodology

CHAPTER 4

RESULTS

Monthly Precipitation of Lahore 2000-2020:

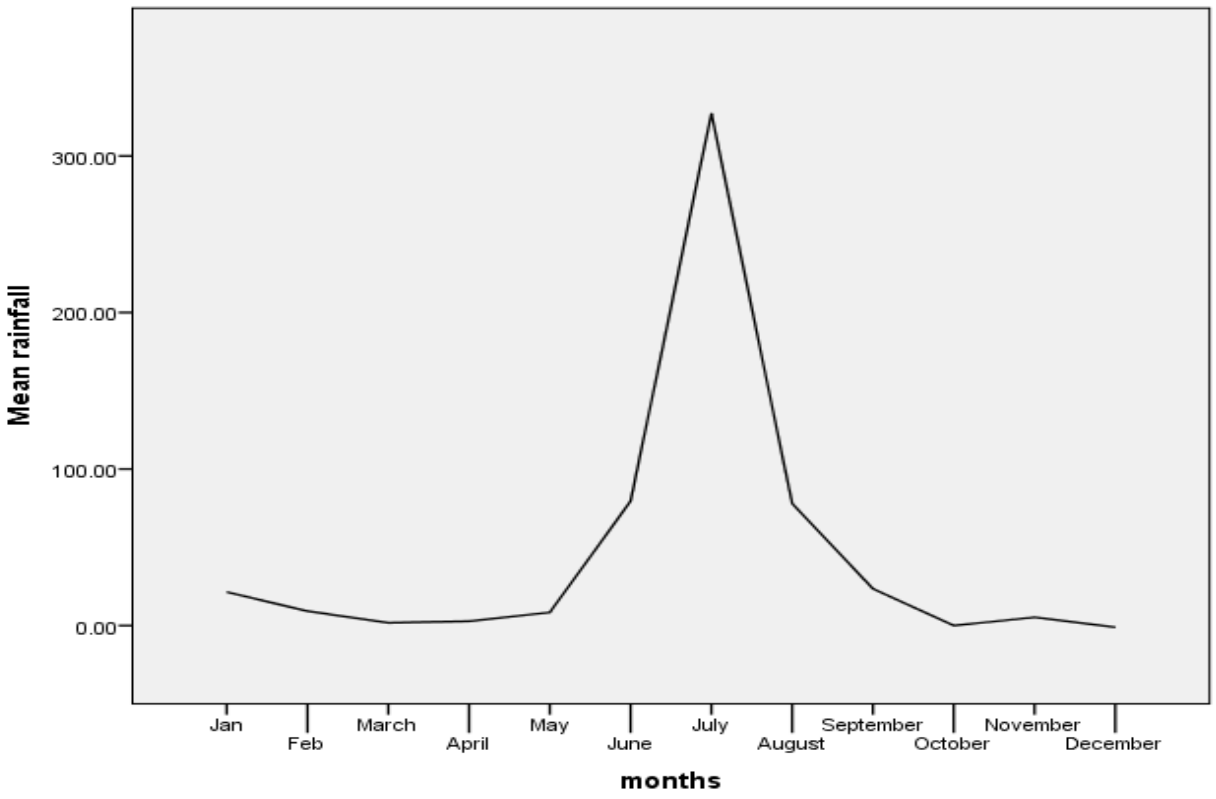


Figure 4.1 Monthly Precipitation(mm) of Lahore 2000

The graph showing the monthly rainfall of Lahore for year 2000. From January to may, there is no major increase in the rainfall but in June it starts increasing and in July(327.2mm),Lahore received the highest rainfall of the year.August received (78 mm) of rainfall. The rainfall value is decreasing again from august to December.October received no rainfall in Lahore.

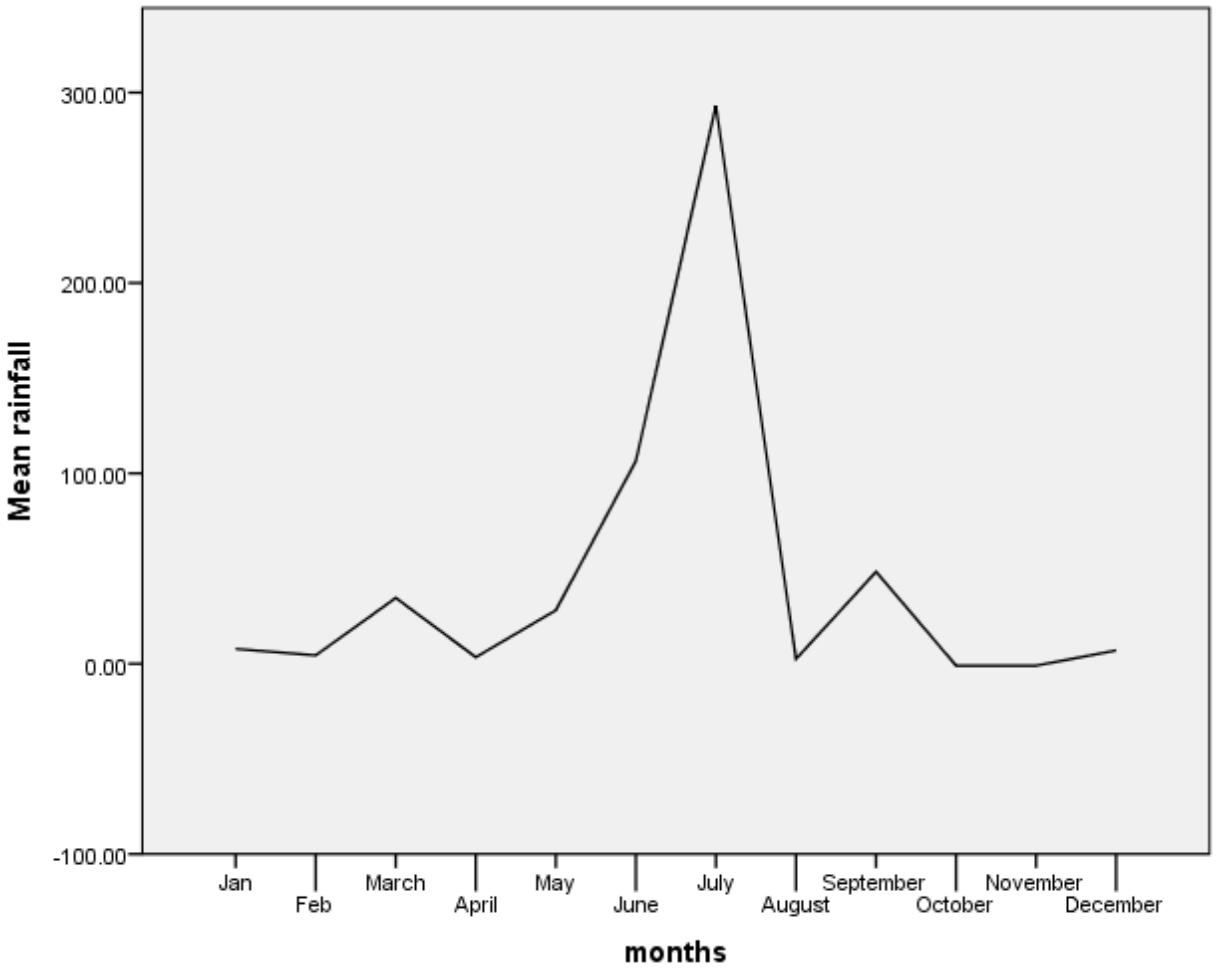


Figure 4.2 Monthly Precipitation(mm) of Lahore 2001.

Lahore received highest rainfall in the months of June(106.5 mm) and July(293.1 mm).Other months receive less rainfall. November and December received no rainfall.

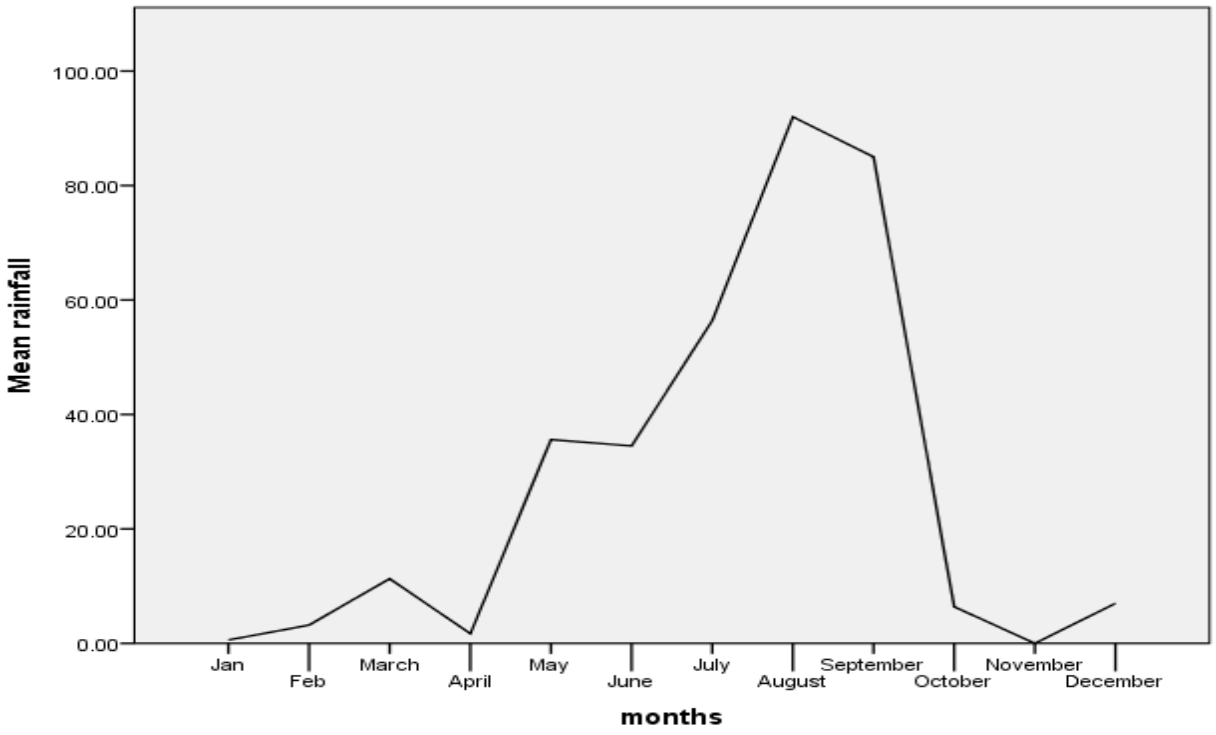


Figure 4.3 Monthly Precipitation(mm) of Lahore 2002.

Lahore received heavy rainfall in July(56.4 mm) August(92 mm) and received lowest rainfall in January November .

Figure 4.4 Monthly Precipitatation(mm) of Lahore 2003

There is increase and decrease trend two times in a year. In January to March the precipitation rate is increasing and from April to May its decreasing. From June to August its again increase and the decreases in the months of ,November and December.October received no rainfall.

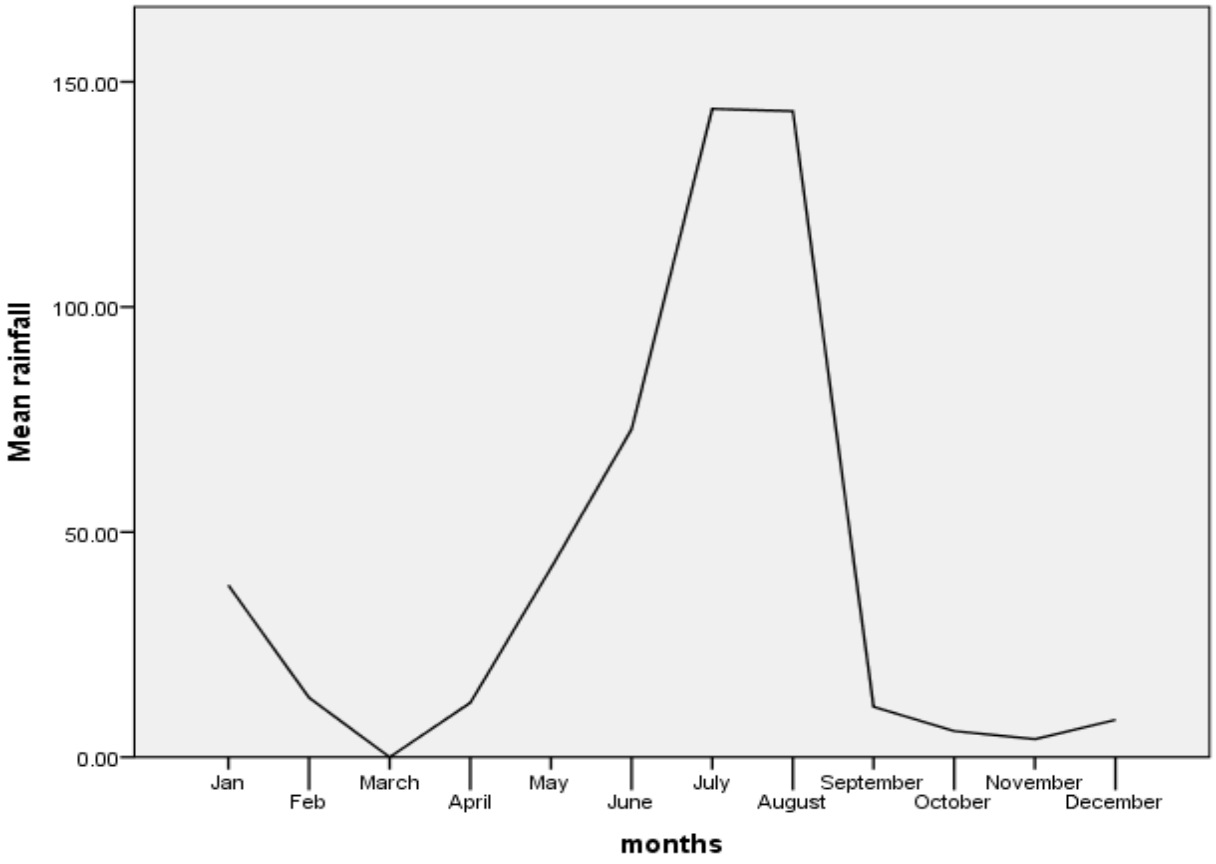


Figure 4.5 Monthly Precipitation(mm) of Lahore 2004.

There is an increase in the precipitation rate from May to August. July(144 mm) and August (143.5 mm) received the highest rainfall in the year.Lahore received less rainfall in January to April and September to December in 2004.

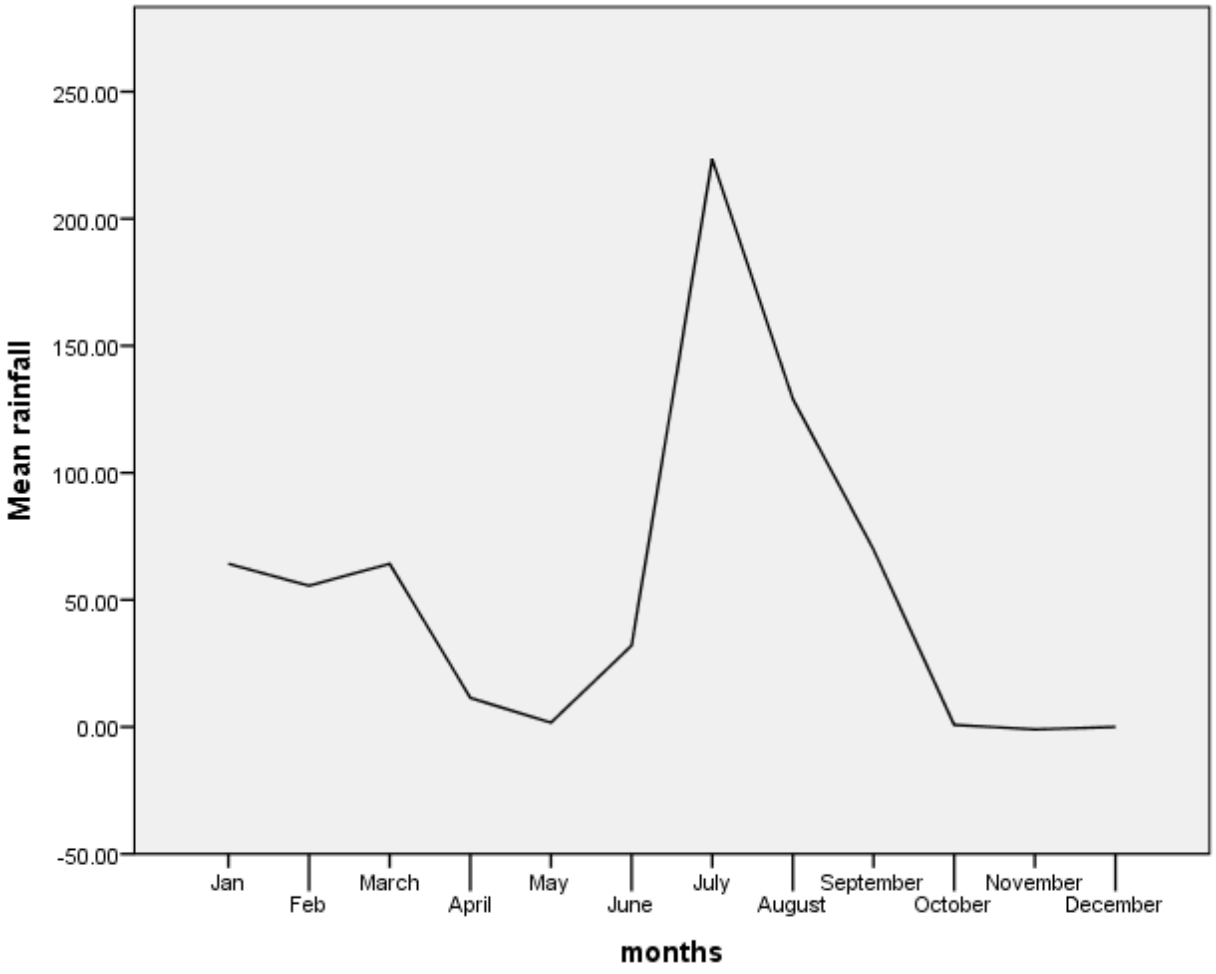


Figure 4.6 Monthly Precipitation (mm) of Lahore 2005.

Lahore (223.5 mm) received highest rainfall in July and In August (129 mm) and September(69.8 mm) it received heavy rainfall and lowest rainfall in October,

and November and December received no rainfall.

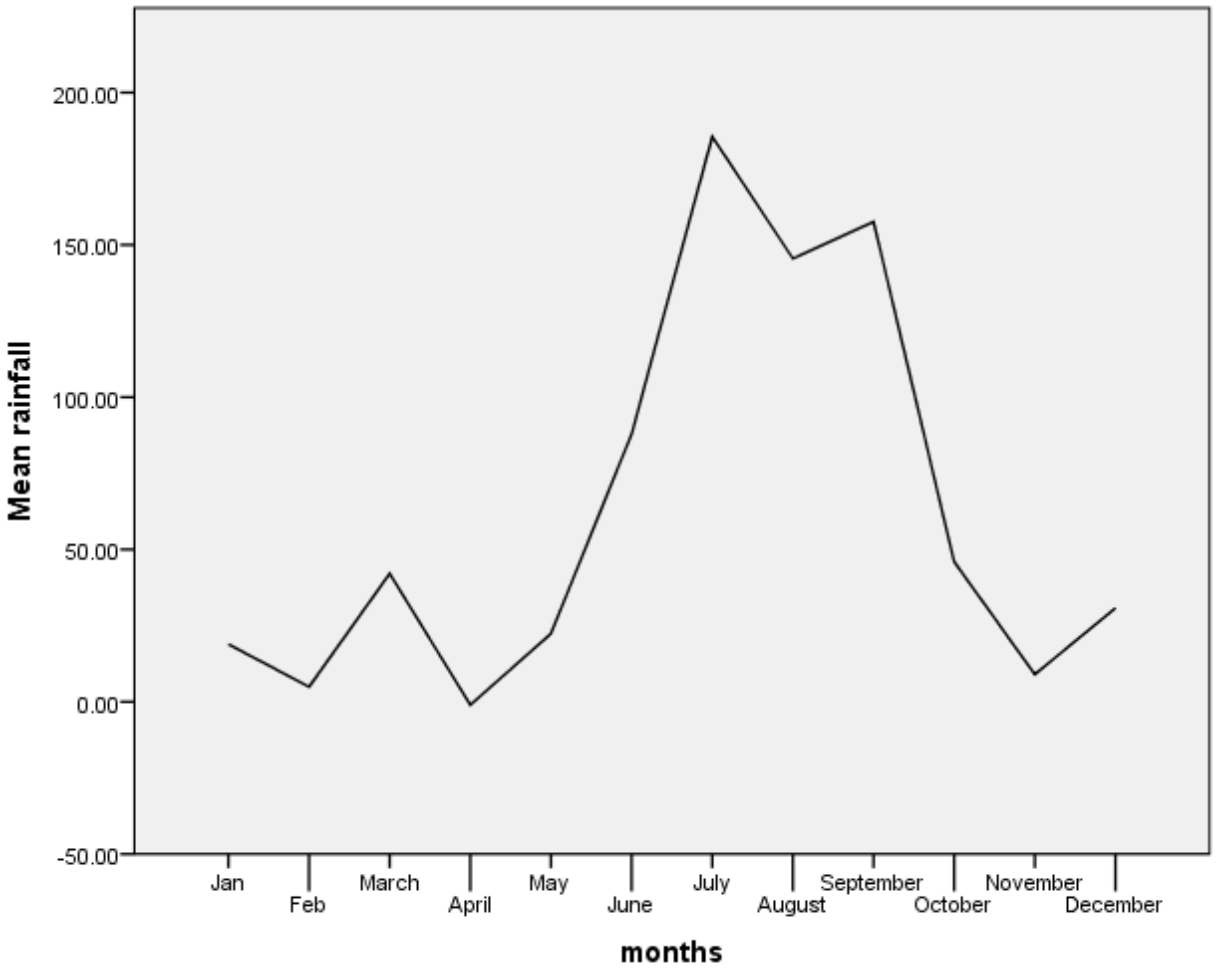


Figure 4.7 Monthly Precipitation(mm) of Lahore 2006:

In 2006,Lahore received rainfall heavy rainfall in the month of June (87.9 mm),July(185.5mm),August(145.7mm),September(157.6 mm) and October. In November and December,Lahore received less rainfall.

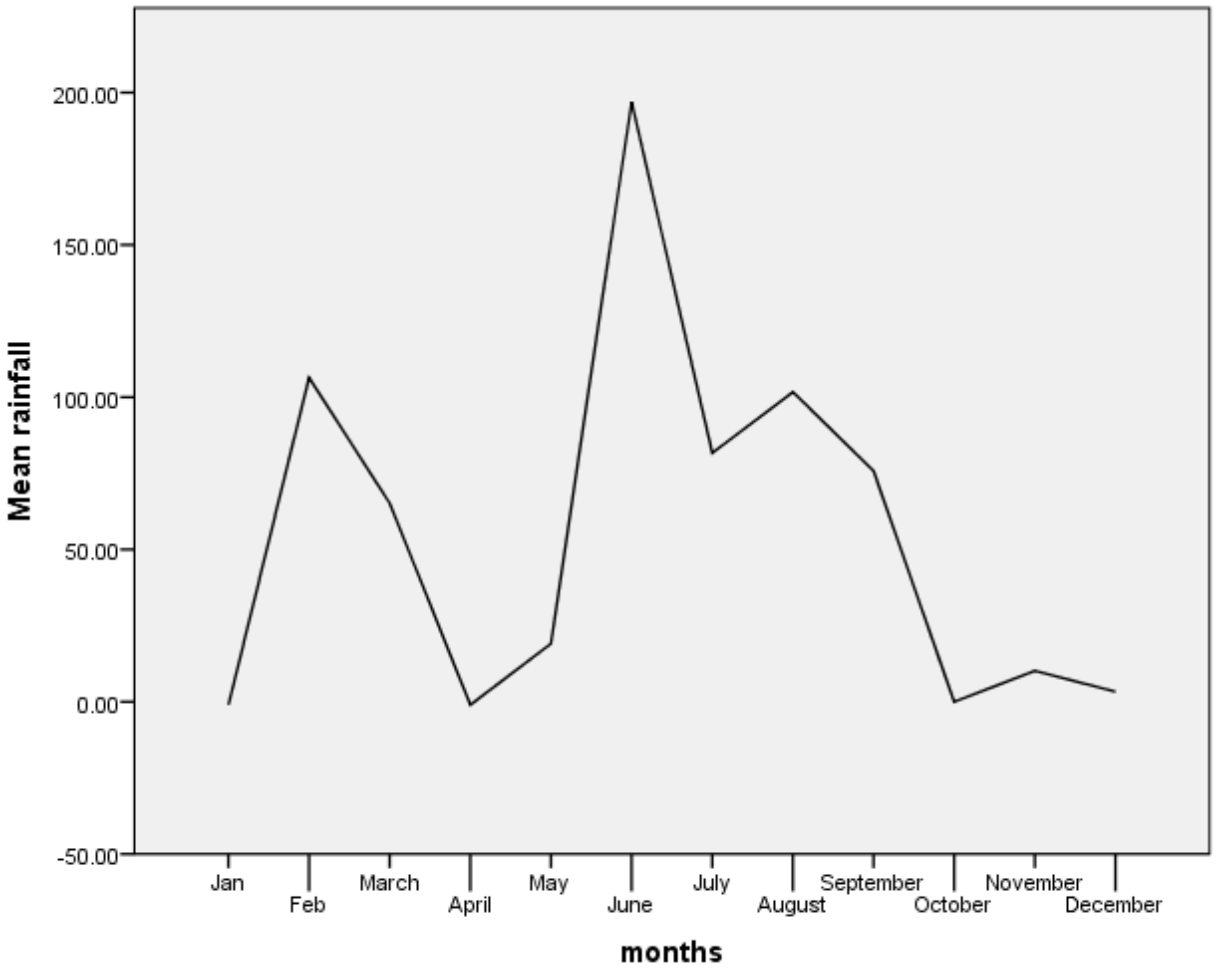


Figure 4.8 Monthly Precipitation(mm) of Lahore 2007.

In 2007, Lahore received heavy rainfall in Febuary(106.4 mm), March(65.2 mm), June(196.9mm), July(81.7 mm),August(101.7mm)and September(75.8mm) and October,November and December are the months which received less rainfall.

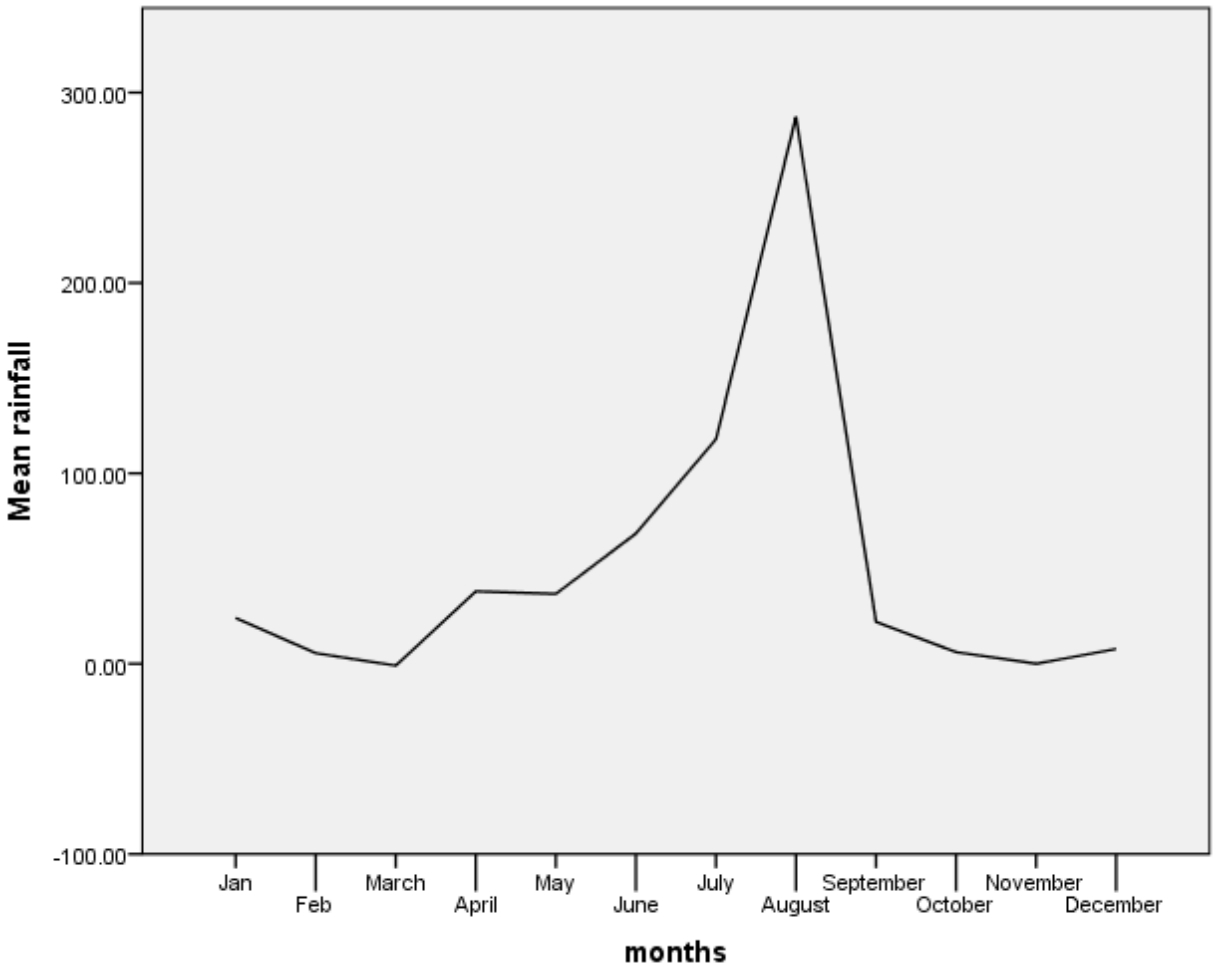


Figure 4.9 Monthly Precipitation(mm) of Lahore 2008:

July and August are the months that received heavy rainfall in Lahore. In these two months the rainfall was 117.9 mm and 287.2mm respectively. Other months have less rainfall e.g:January,February,March April,May and June and Lowest rainfall in October(6.1mm) and December.(7.8mm) and November received no rainfall.

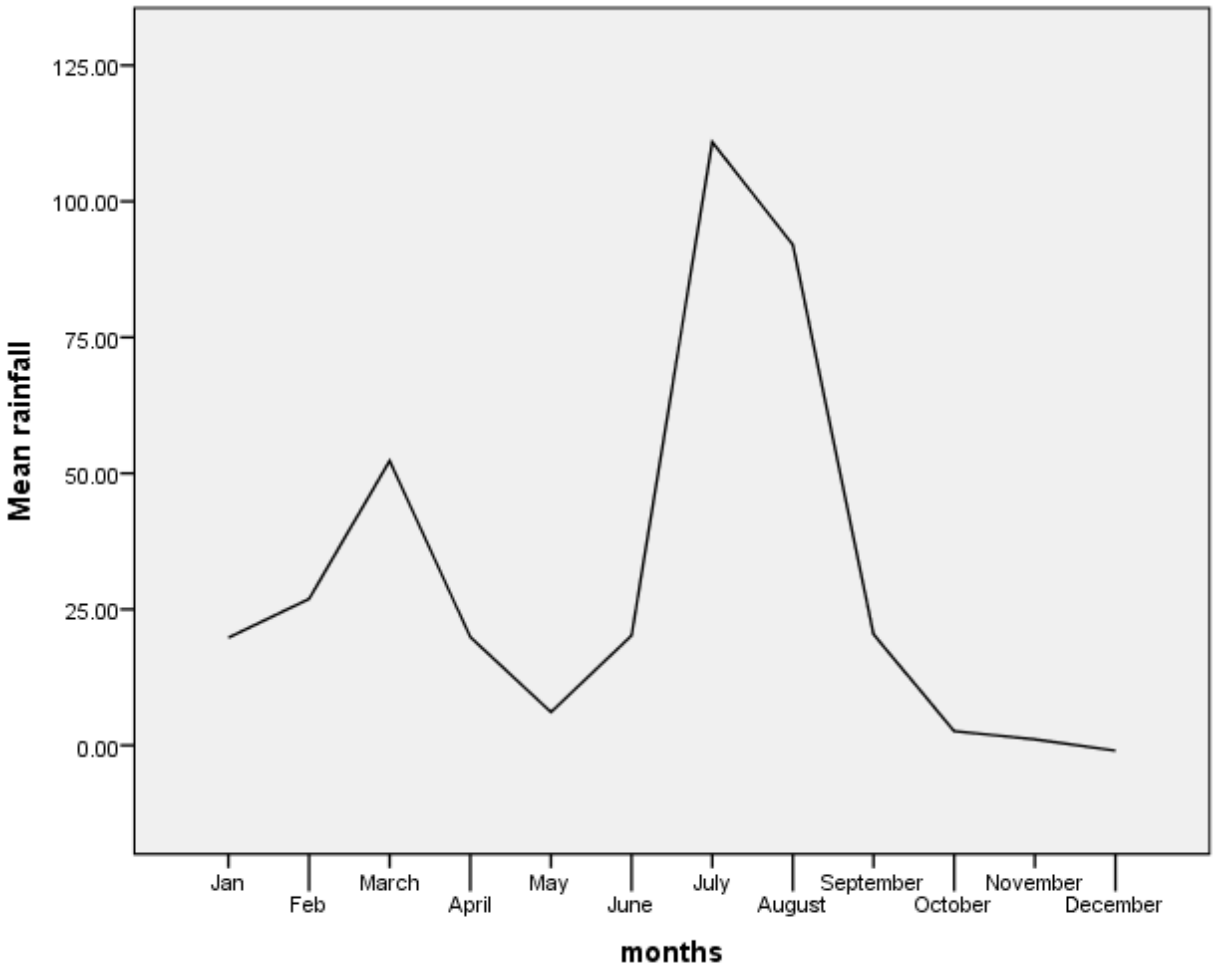


Figure 4.10 Monthly Precipitation(mm) of Lahore 2009.

In 2009:Lahore received heavy rainfall in July(110.9) and august(92mm).March also received heavy rainfall (52.3mm).

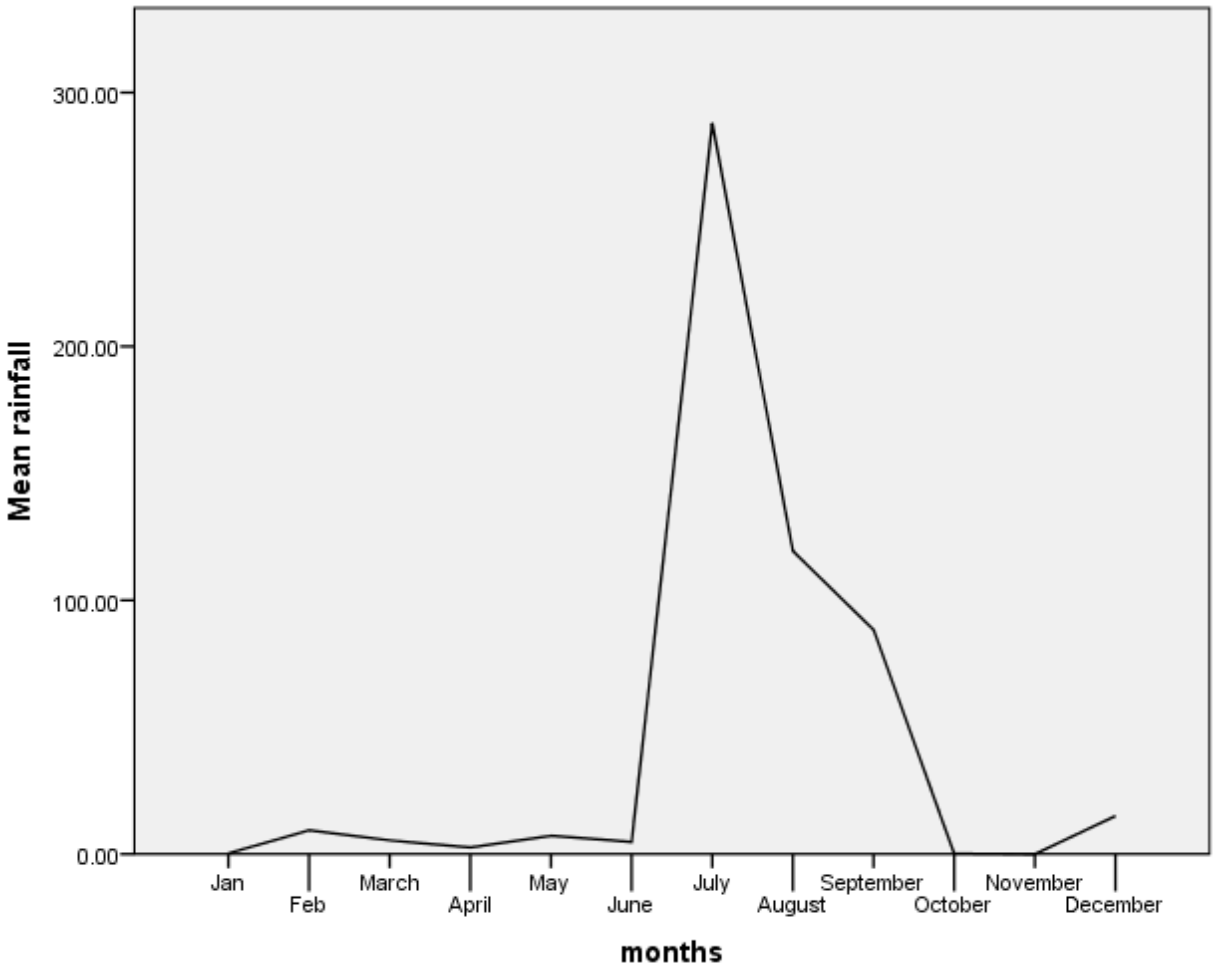


Figure 4.11 Monthly Precipitation(mm) of Lahore 2010.

July (288 mm)and August (119.4 mm)received the heavy rainfall of the year. October (0.2 mm) received the lowest rainfall and In November there is no rainfall in Lahore.

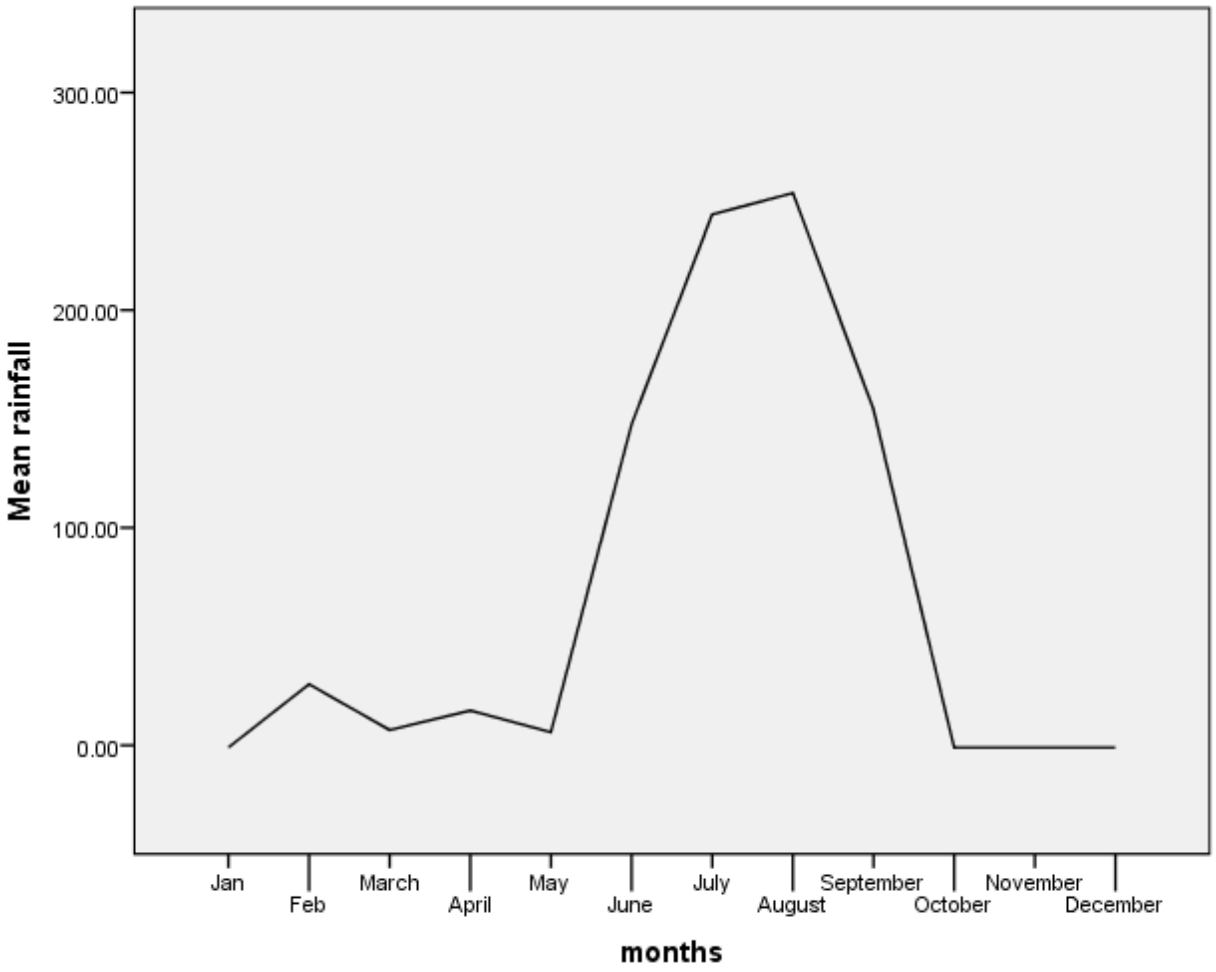


Figure 4.12 Monthly Precipitation(mm) of Lahore 2011.

June (147.6mm),July(244 mm),August (253.9 mm)and September (154.3 mm) are the months in which Lahore received heavy rainfall. October,November and December are the months which receive no rainfall.

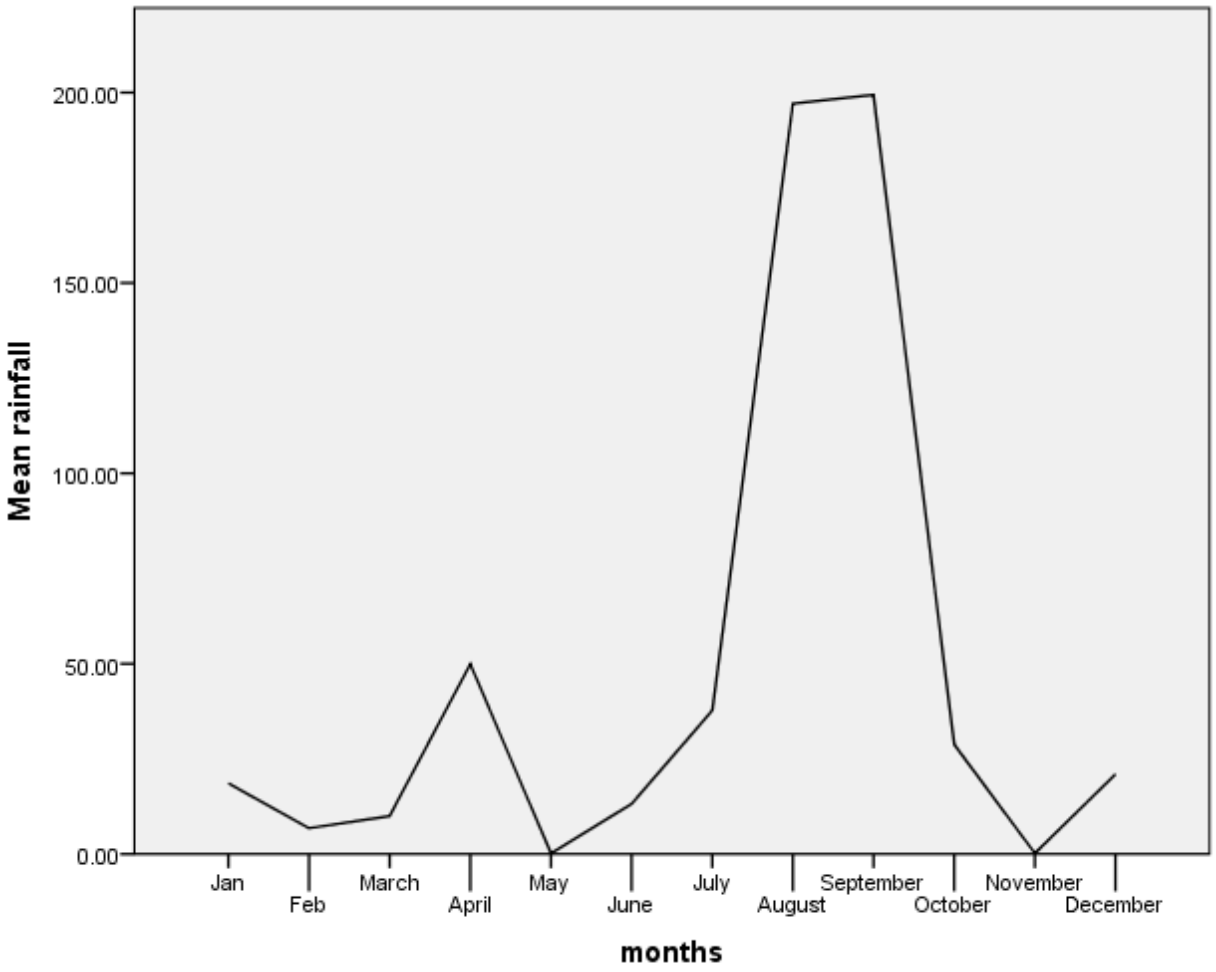


Figure 4.13 Monthly Precipitation(mm) of Lahore 2012.

August (197.1mm) and September (199.4 mm) are the months which received heavy rainfall in Lahore. January,February,March,May and November and December.

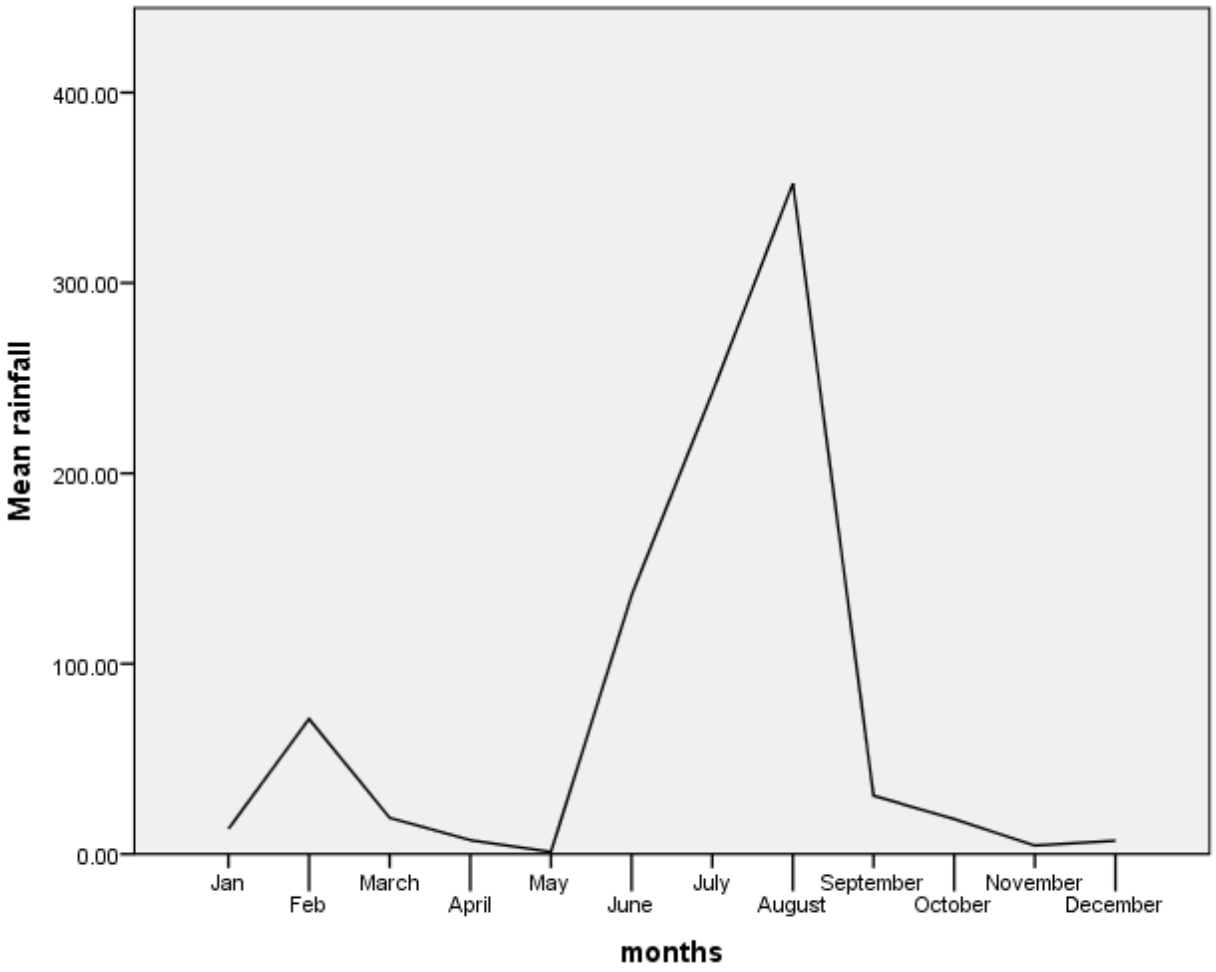


Figure 4.14 Monthly Precipitation(mm) of Lahore 2013.

Lahore received heavy rainfall in June(136mm), july (242.2 mm),August (352.3mm) and lowest rainfall in December.

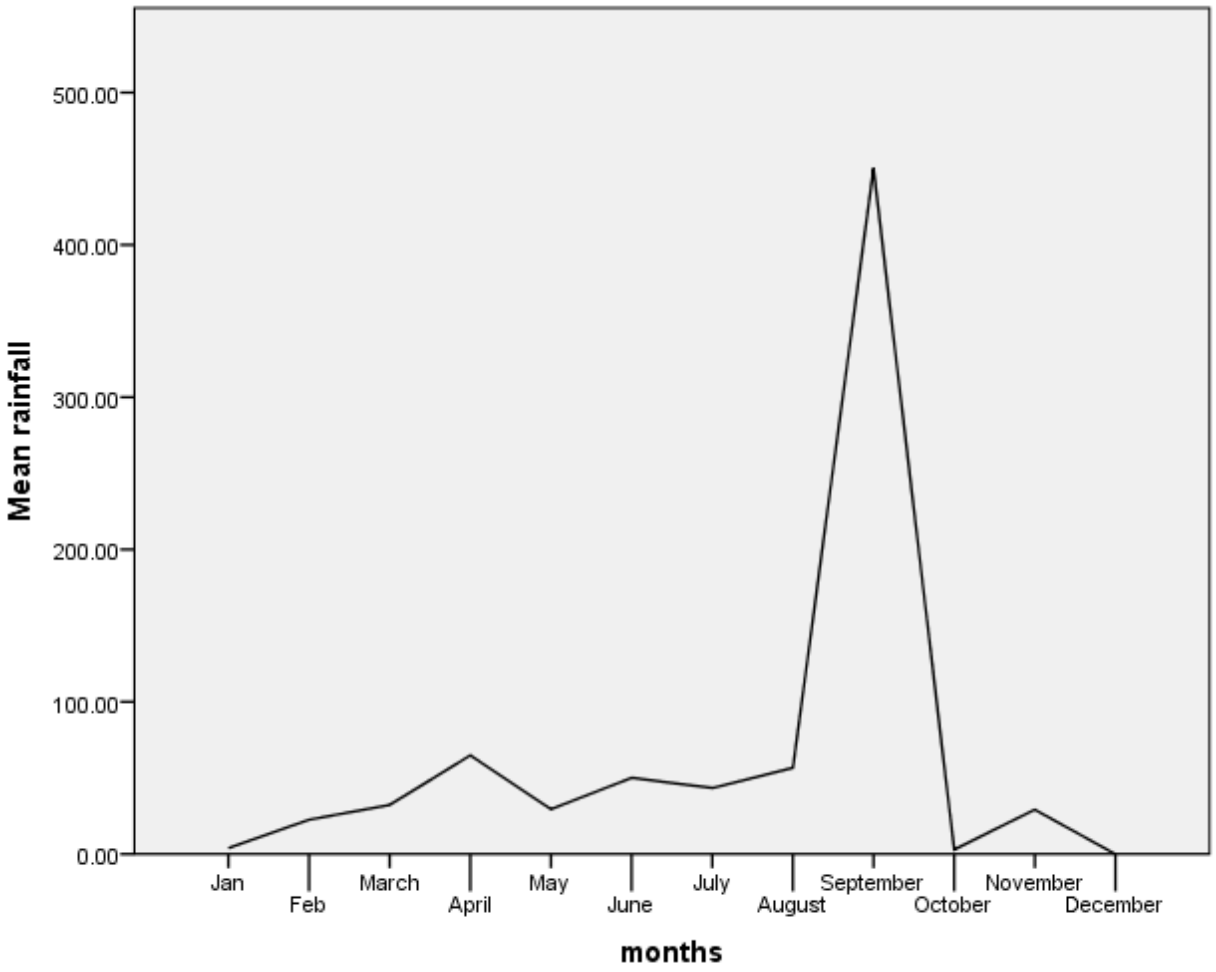


Figure 4.15 Monthly Precipitation(mm) of Lahore 2014.

In 2014,September received (450.3 mm) amount of rainfall in Lahore and January and February received less amount of rainfall whereas December received no rainfall.

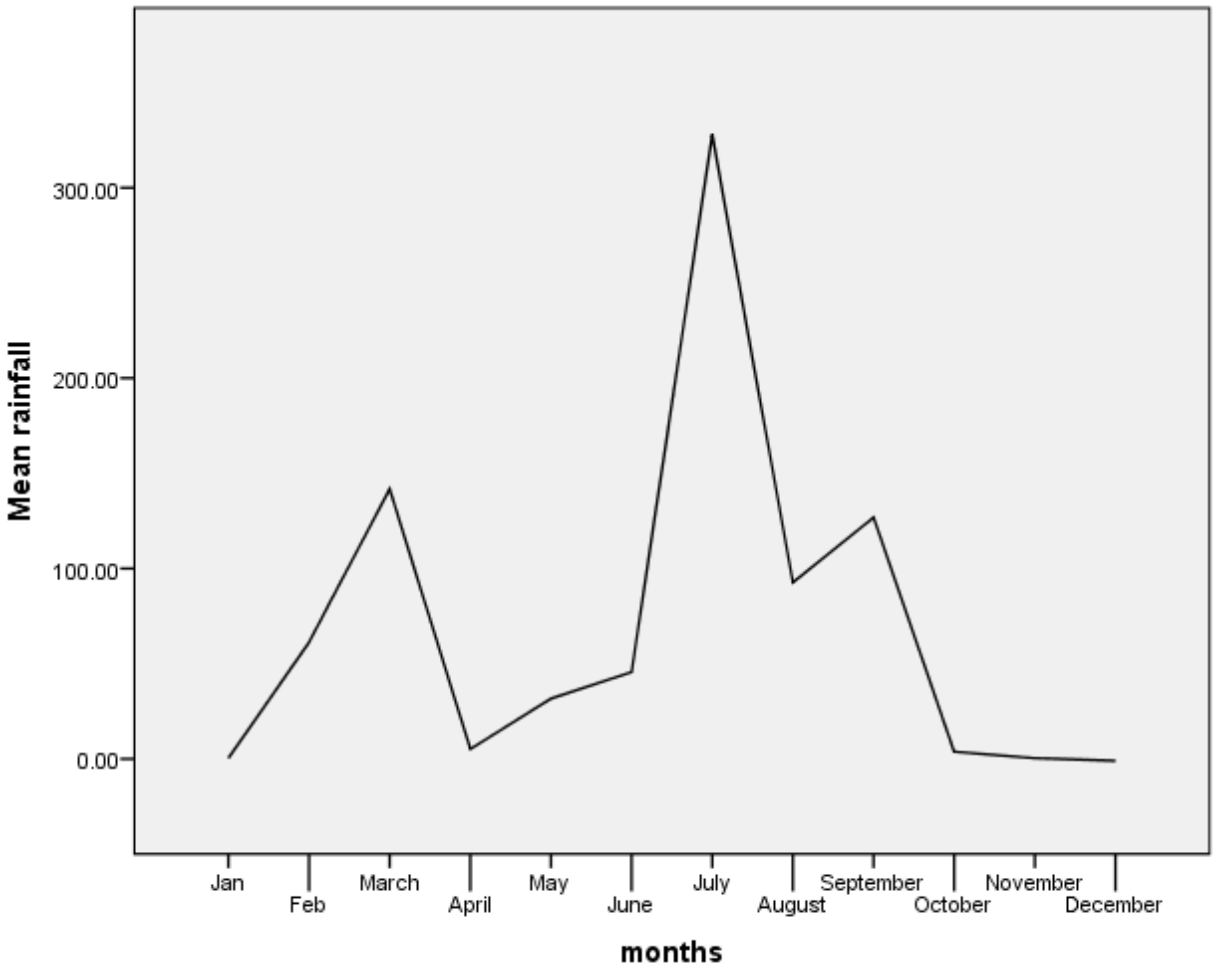


Figure 4.16 Monthly Precipitation(mm) of Lahore 2015.

Lahore received heavy rainfall in March (141.8)and in July (328 mm),August (92.7mm)and September (126.8 mm) and received less rainfall in October, November and December.

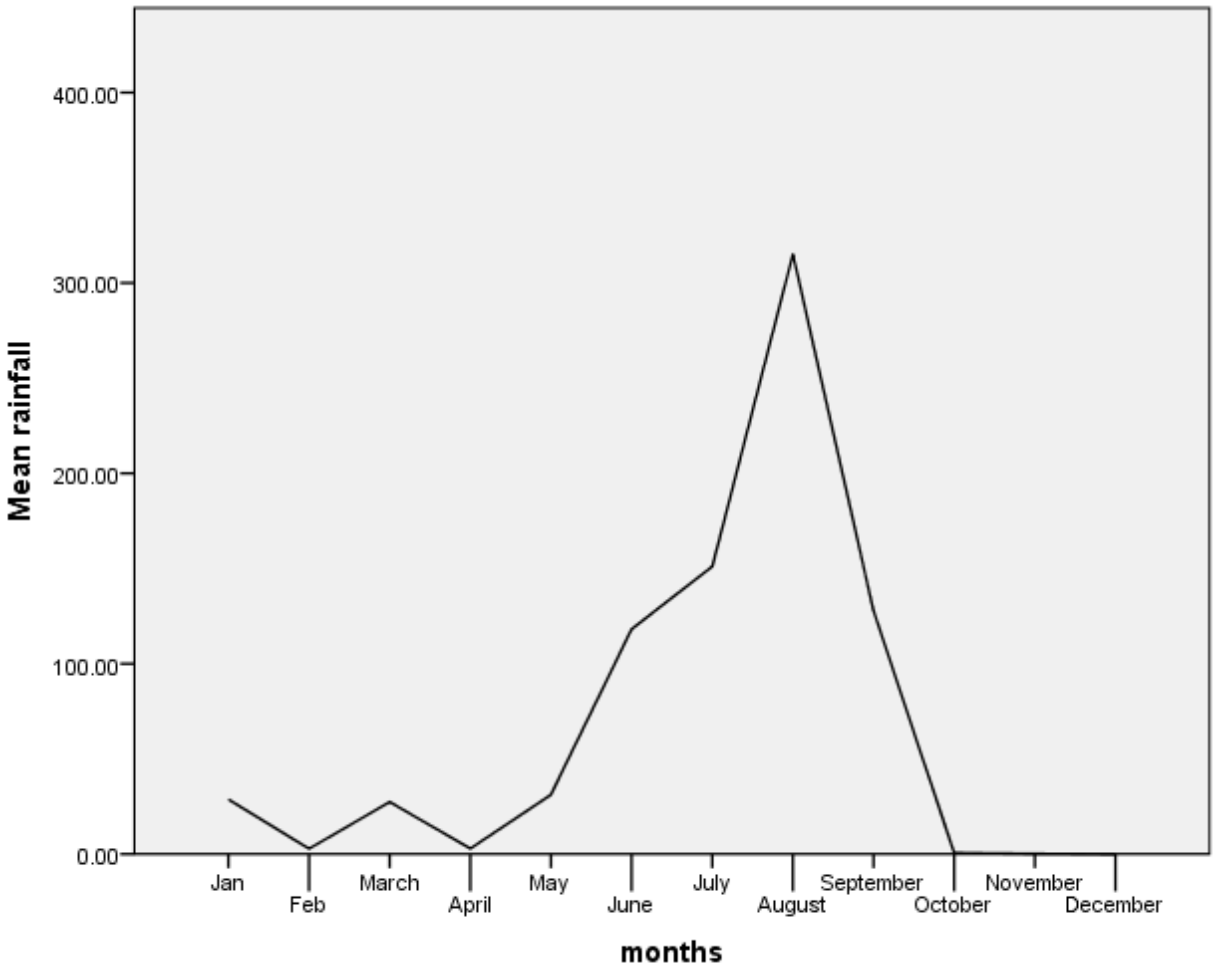


Figure 4.17 Monthly Precipitation(mm) of Lahore 2016.

In 2016,Lahore received heavy rainfall in in the month of June (118.2 mm), July (151.1 mm),August (315.1 mm)and September (127.7 mm) and receives lowest rainfall in the month of October (0.6 mm), November (0.2mm)and December received no rainfall.

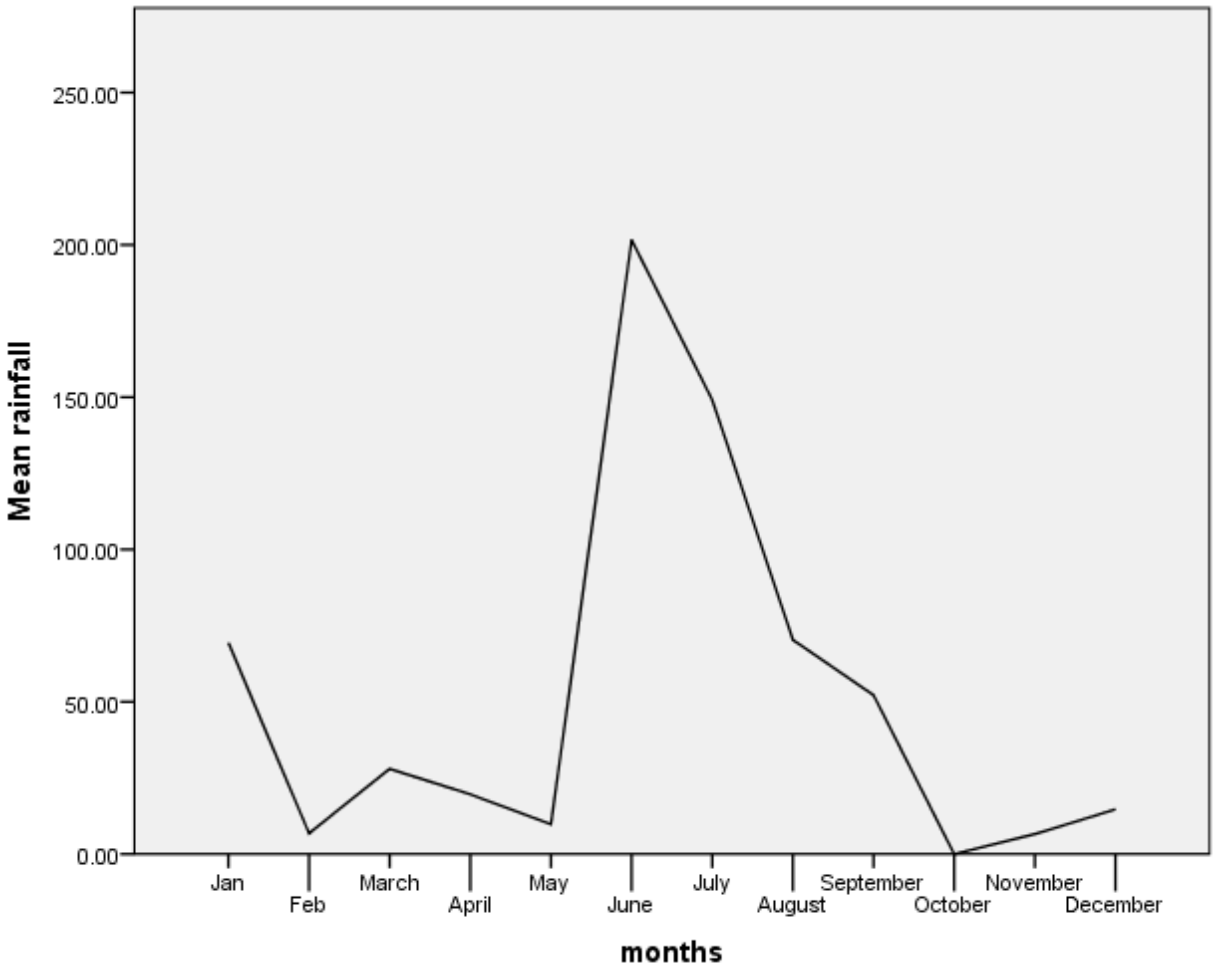


Figure 4.18 Monthly Precipitation(mm) of Lahore 2017.

Lahore received heavy amount of rainfall in June (201.6mm), July(149.1 mm),August (70.3mm) and September (52.2 mm). October received no rainfall.February and November received Lowest amount of rainfall.

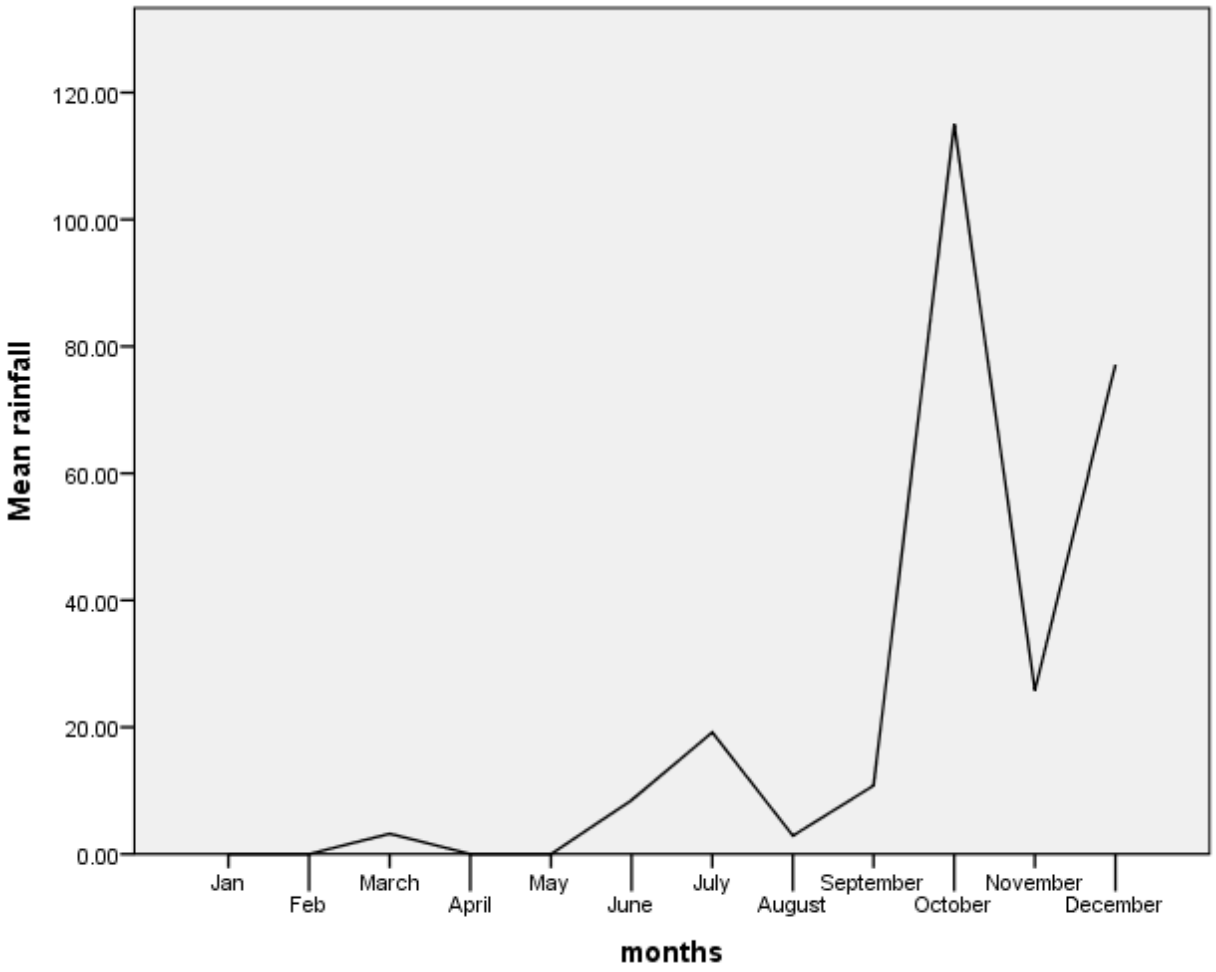


Figure 4.19 Monthly Precipitation(mm) of Lahore 2018.

In 2018,January,February,April and May received no rainfall.October (115 mm) received heavy amount of rainfall. December (77.1 mm) also received heavy amount of rainfall.

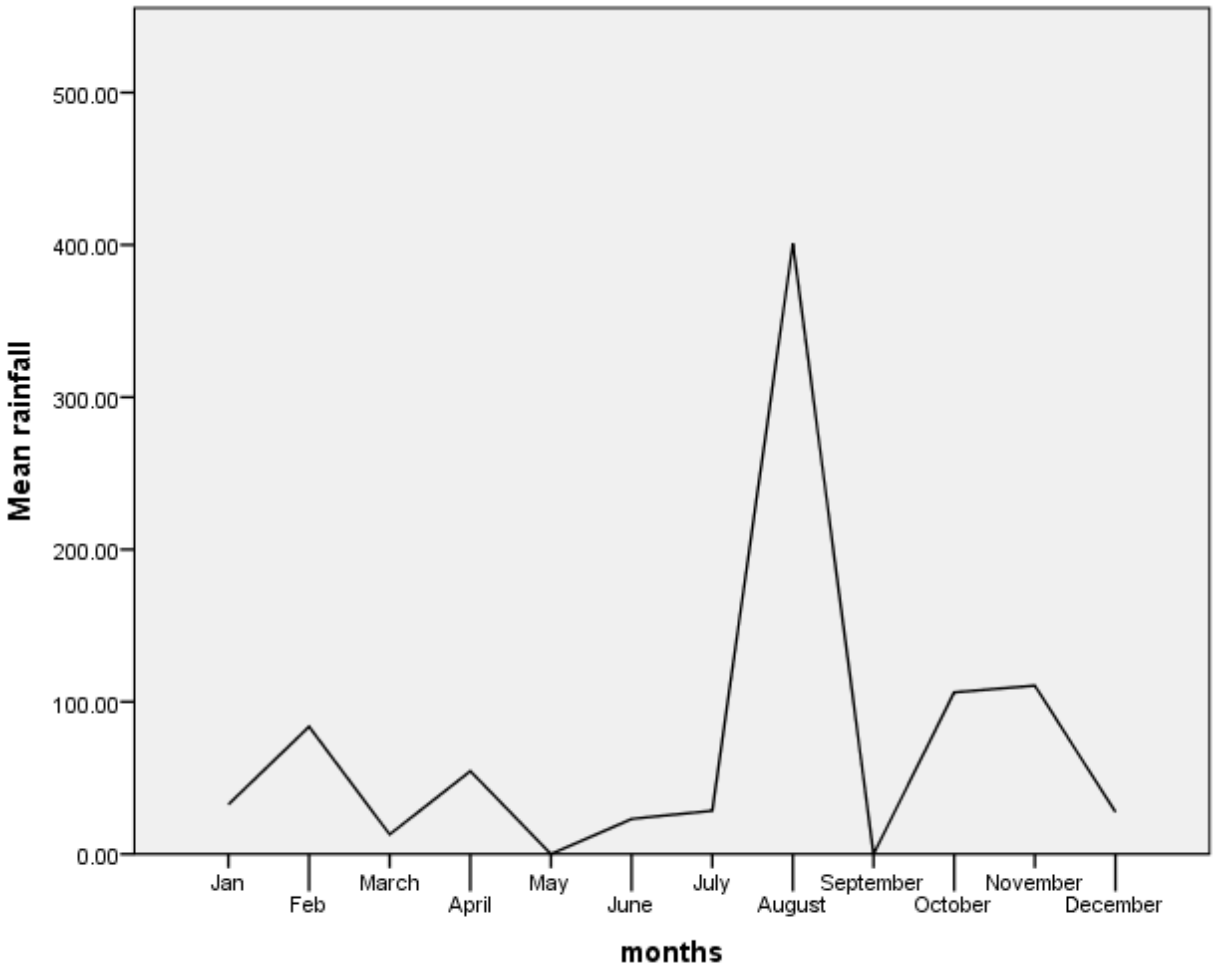


Figure4.20 Monthly Precipitation(mm) of Lahore 2019.

In 2019, August is the month that received heaviest amount of rainfall (400.9 mm). Jaanuary. October(106.2mm) and November (110.mm)also received heavy amount of rainfall.May and September received 0 amount of rainfall.

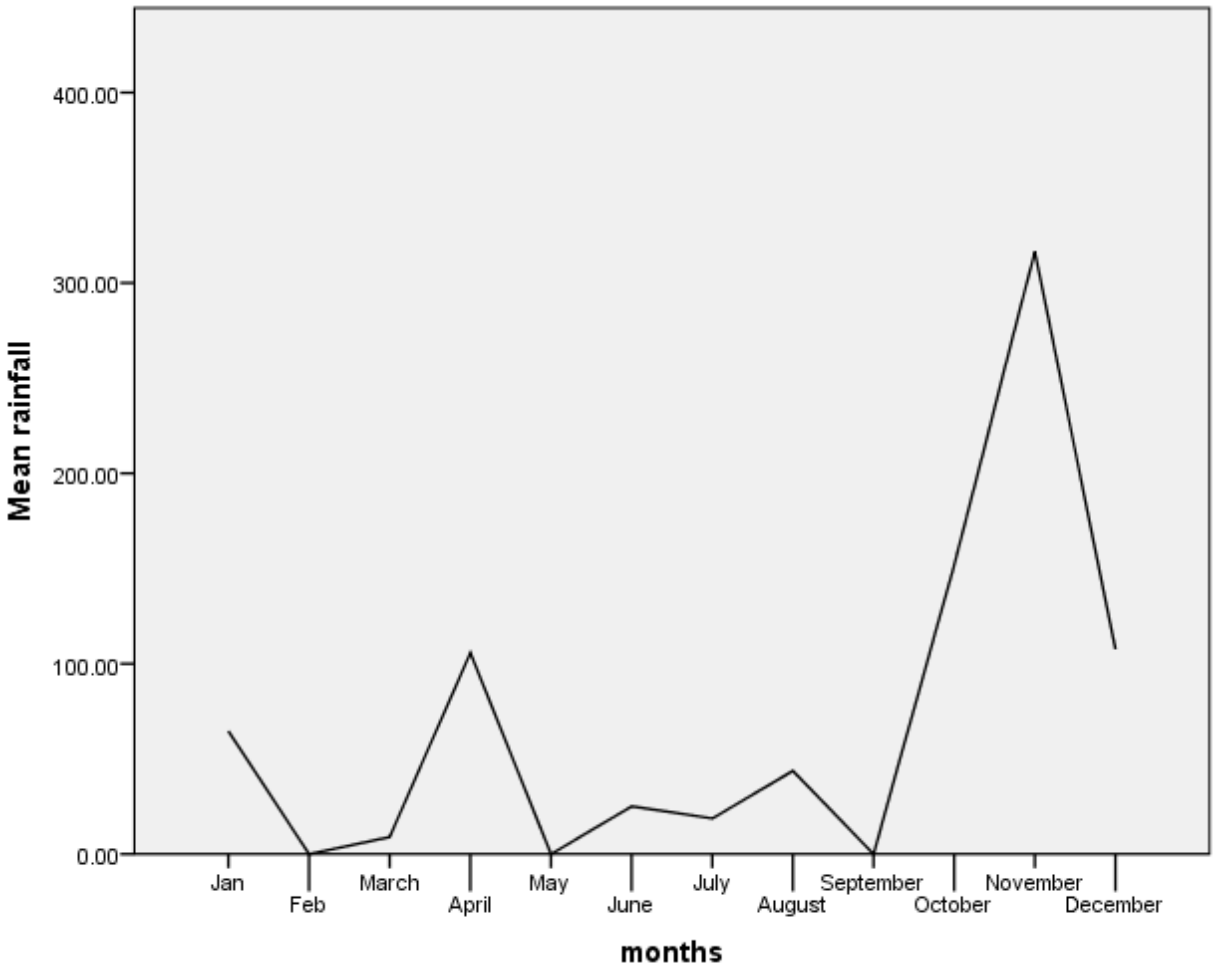


Figure 4.21: Monthly Precipitation(mm) of Lahore 2020.

January received 64.6 mm of rainfall in the year whereas February,March,May, and September received 0 amount of rainfall.April received (105.7 mm)amount of rainfall in the year.October(151.8 mm),November (316.4 mm) and December (107.7 mm) received heaviest amount of rainfall of the year.

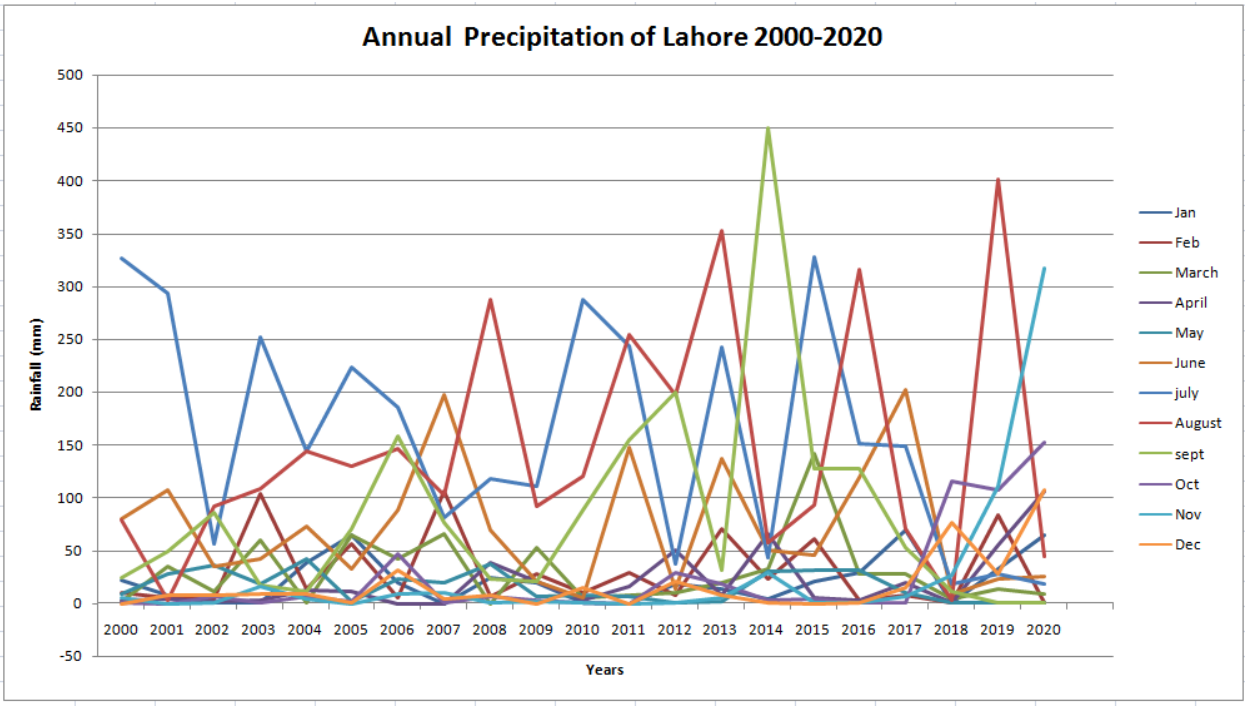


Figure 4.22 Annual Precipitation of Lahore 2000-2020.

The graph is showing the annual precipitation of Lahore from 2000-2020. Every year received different amount of rainfall. Mostly in every year, June, July and August are the months that received heavy amount of rainfall as compared to other months. November and December received lowest amount of rainfall.

Lahore Precipitation Rate 2000-2020:

The rate of precipitation is changing from 2000 to 2020.

Table 4.1 Mean of Lahore Precipitation Rate 2000-2020

Years	Average
2000	46.35833
2001	44.475
2002	27.80833
2003	52.29167
2004	41.26667
2005	54.26667
2006	62.48333
2007	54.85833
2008	51.08333
2009	30.93333
2010	45.05833
2011	71.075
2012	48.575
2013	75.23333
2014	65.49167
2015	71.35
2016	67.15833
2017	52.34167
2018	21.875

2019	73.38333
2020	70.225

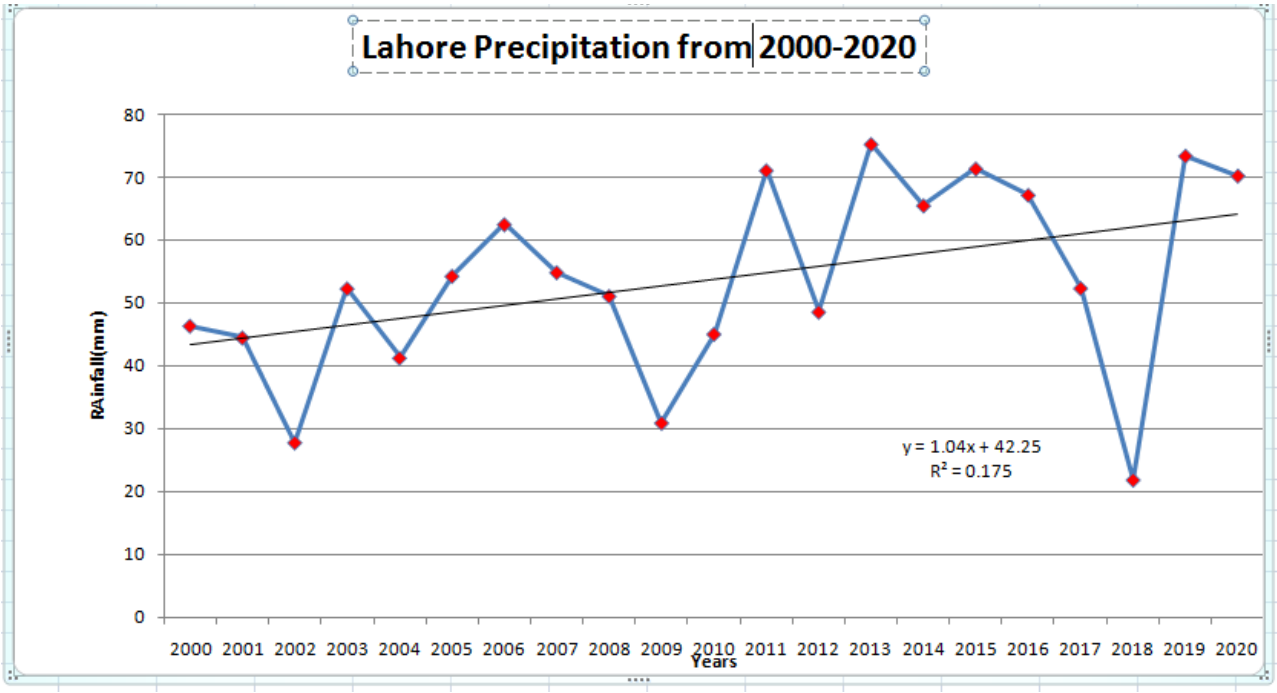


Figure 4.23 Lahore Precipitation from 2000-2020.

Annual Mean of Precipitation of Lahore 2000-2020:

Precipitation of Lahore of year 2000 is calculated by adding each month rainfall value e.g:

Total Precipitation of one year P= P1+P2+P3+……

2000:21.5+ 9.2+ 1.8 +2.8 +8.4+ 79.6 +327.2+ 78 +23.5 +0 +5.3 +-1=556.3

Table 4.2 Annual Mean Precipitation of Lahore2000-2020:

Years	Rainfall(mm)
2000	556.3
2001	533.7
2002	333.7
2003	627.5
2004	495.2
2005	651.2
2006	749.8
2007	658.3
2008	613
2009	371.2
2010	540.7
2011	852.9
2012	582.9
2013	902.8
2014	785.9
2015	856.2
2016	805.9
2017	628.1
2018	262.5

2019	880.6
2020	842.7

Table 4.3 Annual Mean of Lahore Precipitation from 2000-2004:

Years	Rainfall
2000	556.3
2001	533.7
2002	333.7
2003	627.5
2004	495.2

Yearly rainfall is obtained by adding 12 months rainfall value.

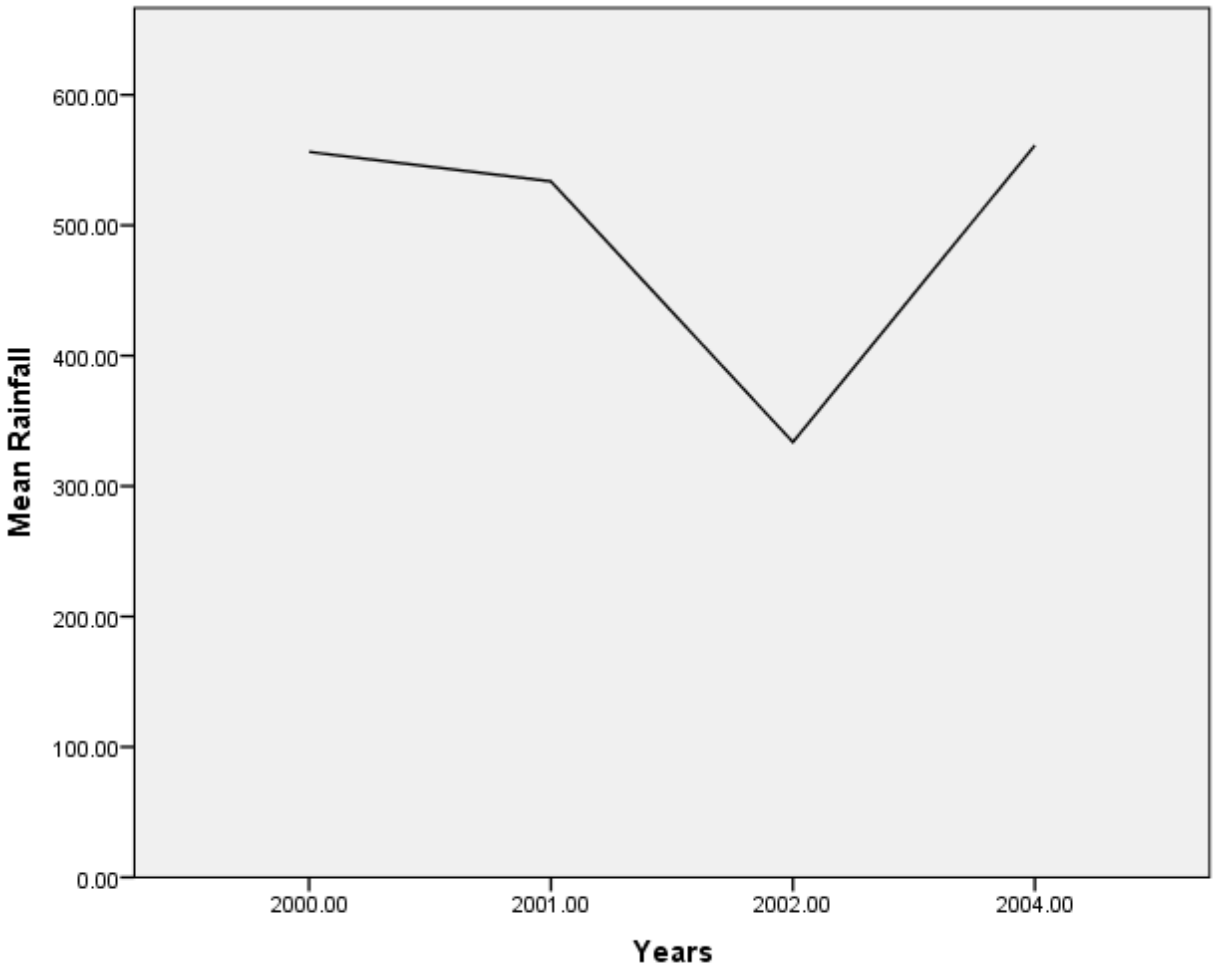


Figure 4.24 Annual mean of Lahore precipitation 2000-2004.

In 2000-2004, the graph is showing that, in 2003 lahore received the highest of rainfall as compared to other years. 2002 received low rainfall in Lahore.

Table 4.4 Annual Mean of Lahore Precipitation 2005-2010:

Years	Rainfall
2005	651.2
2006	749.8
2007	658.3
2008	613
2009	371.2
2010	540.7

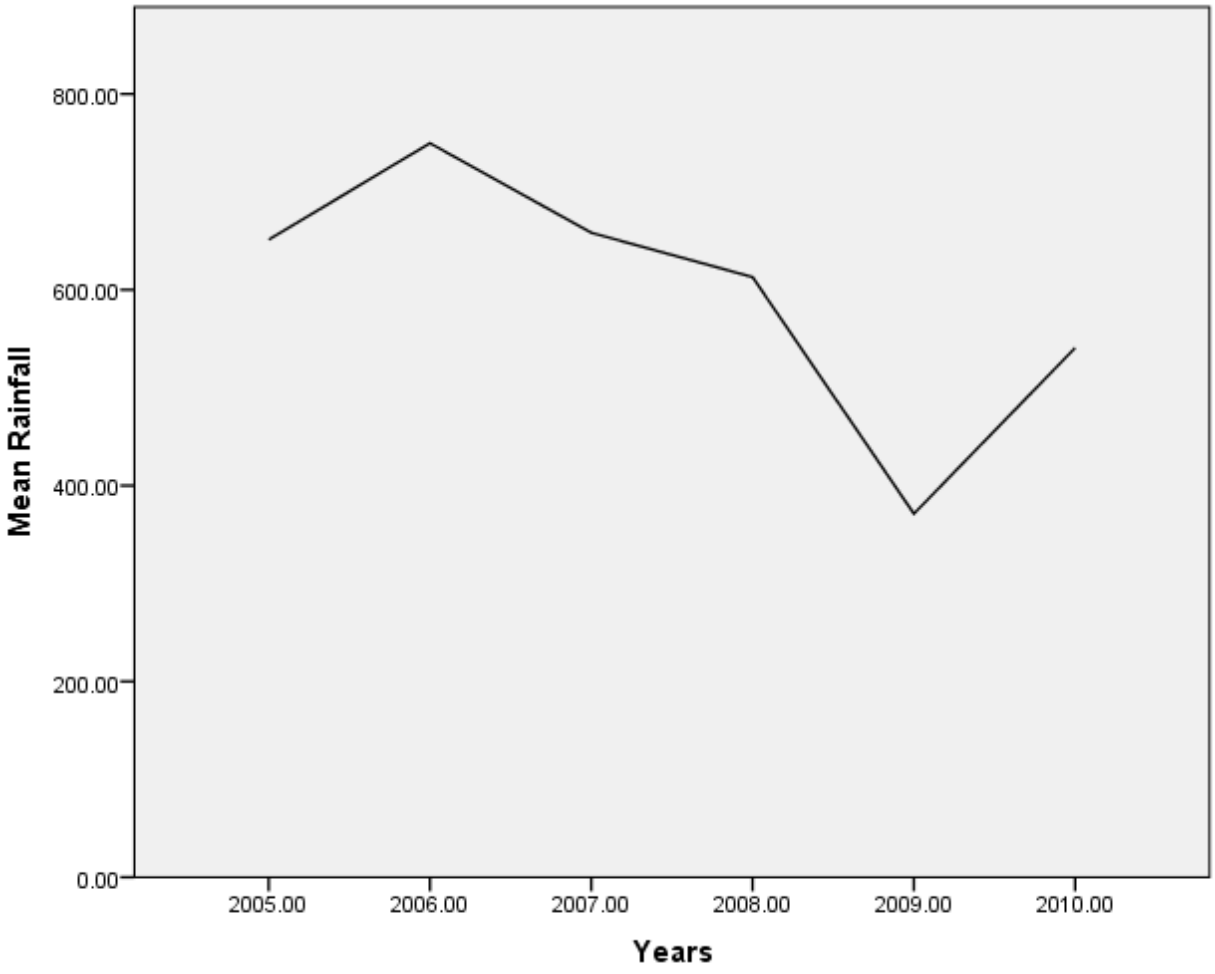


Figure 4.25 Annual Mean of Precipitation Lahore 2005-2010.

The graph is showing that rainfall pattern is changing in 2005-2010. The highest rainfall was received in 2006 (749.8mm) in Lahore and 2009 was received the lowest amount of rainfall as compared to other years .

Annual Mean of Lahore Precipitation 2011-2015:

Table 4.5 Annual Mean of Lahore Precipitation 2011-2015

Years	Rainfall
2011	852.9
2012	582.9
2013	902.8
2014	785.9
2015	856.2

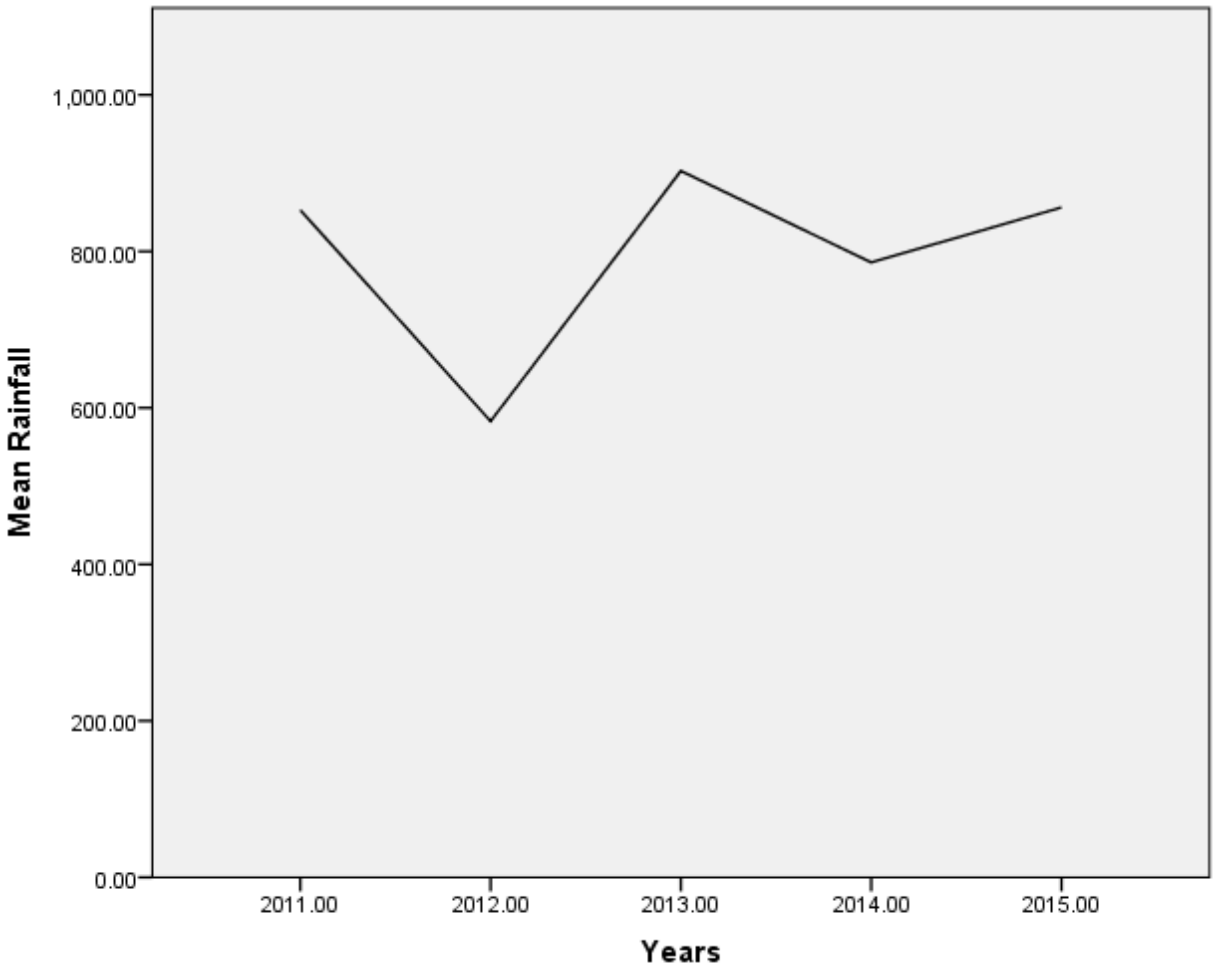


Figure 4.26 Annual Mean of Precitation Of Lahore 2011-2015.

The Graph is showing that 2013 is the year which received the highest rainfall 902.8mm.and 2012 received the lowest rainfall in five year span period.

Annual Mean of Lahore Precipitation 2016-2020:

Table 4.6 Annaul Mean of Precipitation 2016-2020

Years	Rainfall
2016	805.9
2017	628.1
2018	262.5
2019	880.6
2020	842.7

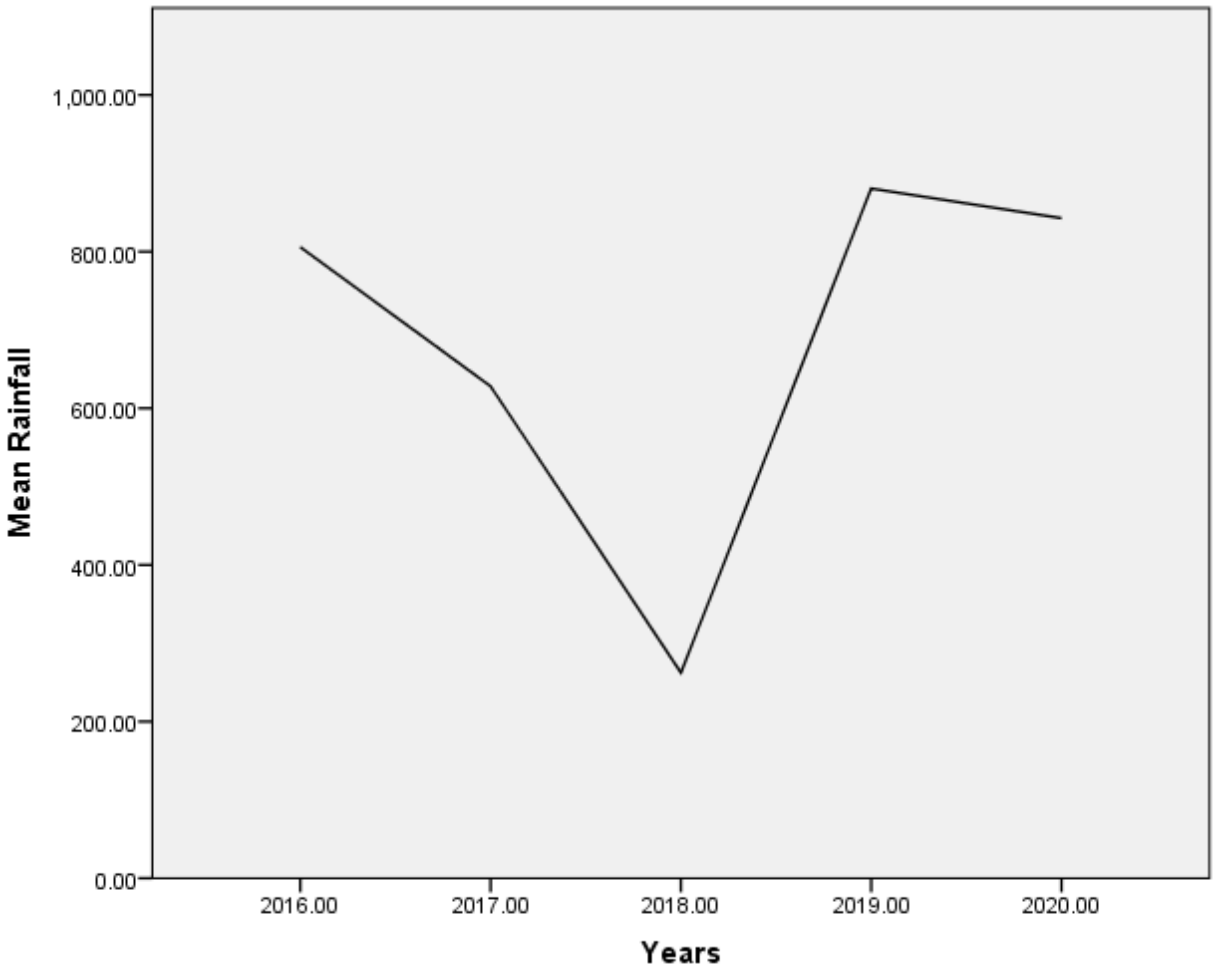


Figure 4.27 Annual Mean of Precipitation of Lahore 2016-2020.

The graph of 2015-2020, 2019 received the highest rainfall (880.6mm)and 2018 received lowest amount of rainfall (262.5mm) as compared to other years.

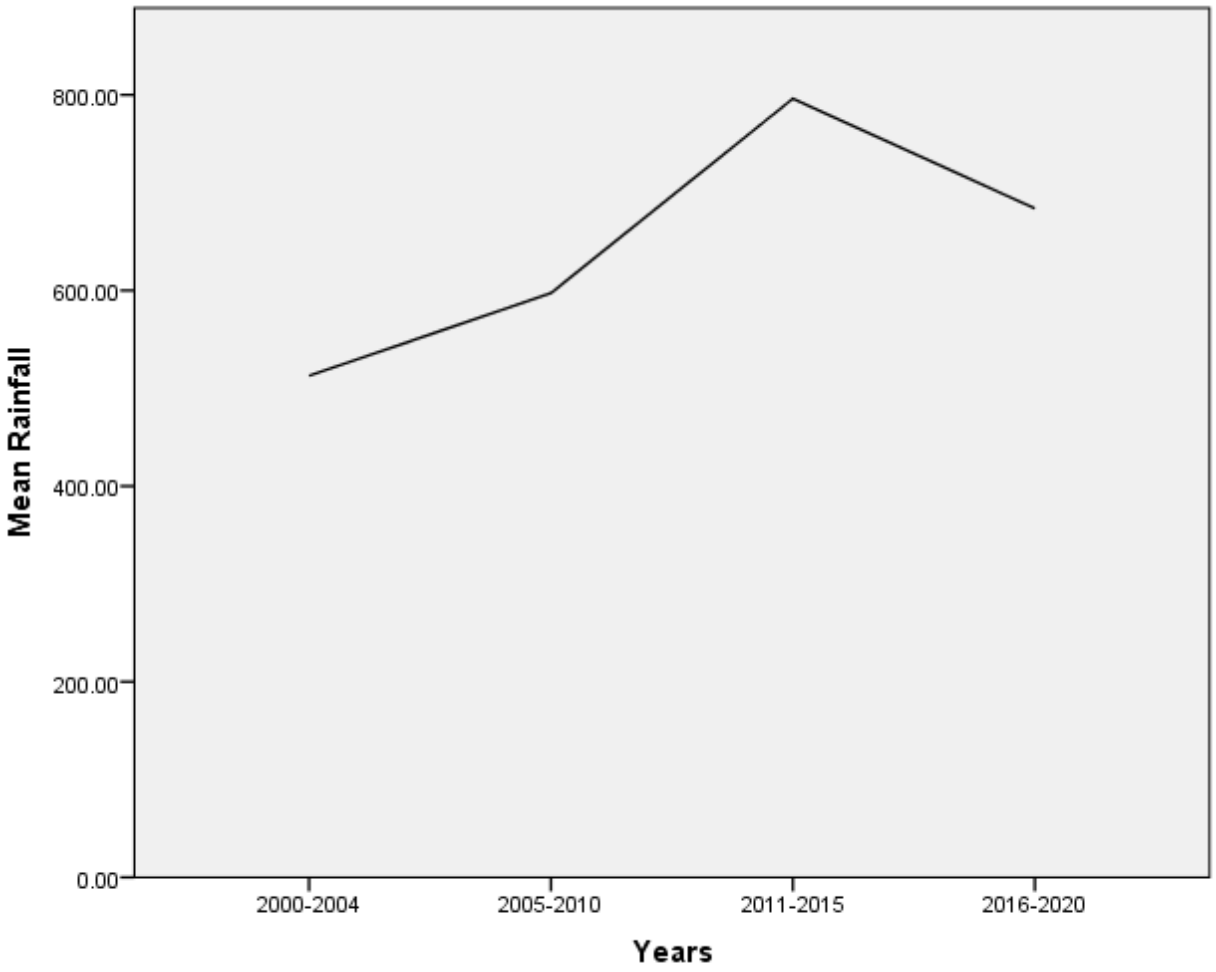


Figure 4.28 Annual Mean of Precipitation of Lahore 2000-2020.

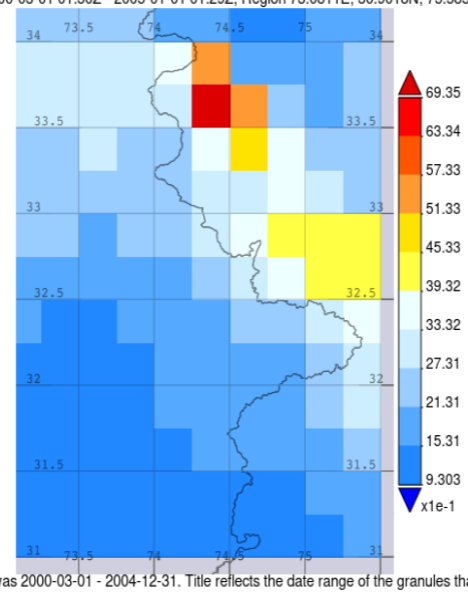
Time series, Area-Averaged of Precipitation Rate Monthly[TRMM 3B43]:

This is the product used to get the data .

The product used:

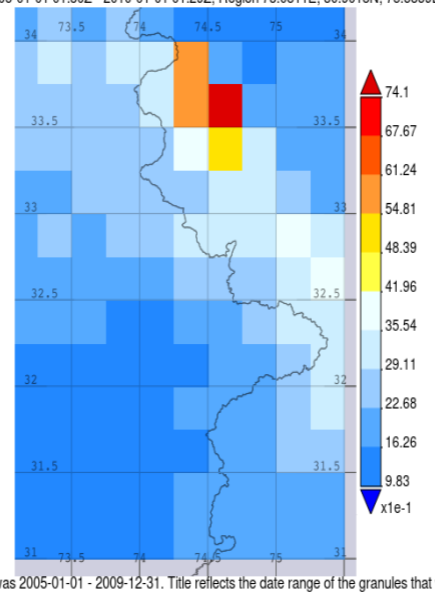
Precipitation Rate(TRMM_3B43v7	mm/hr	TRMM	Monthly	0.25	1998-01-01	2019-12-31

Time Averaged Map of Near-Real-Time Precipitation Rate daily 0.25 deg. [TRMM TRMM_3B42RT_Daily v7] mm/day
over 2000-03-01 01:30Z - 2005-01-01 01:29Z, Region 73.0811E, 30.9018N, 75.5859E, 34.1977N



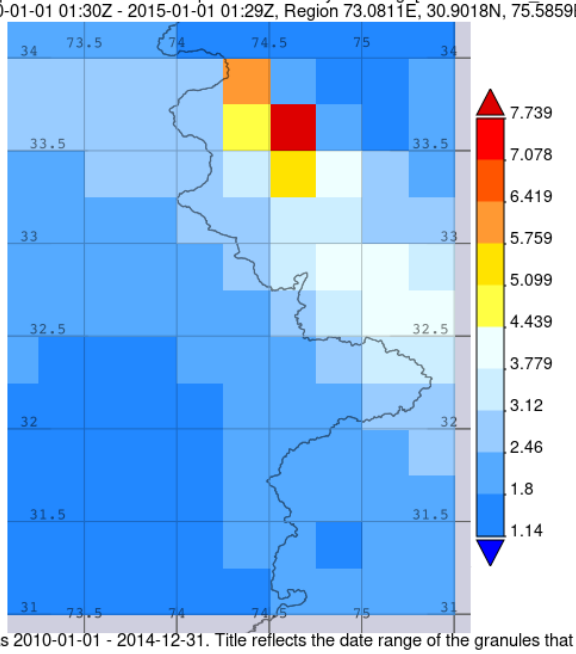
- Selected date range was 2000-03-01 - 2004-12-31. Title reflects the date range of the granules that went into making this result.

Time Averaged Map of Near-Real-Time Precipitation Rate daily 0.25 deg. [TRMM TRMM_3B42RT_Daily v7] mm/day
over 2005-01-01 01:30Z - 2010-01-01 01:29Z, Region 73.0811E, 30.9018N, 75.5859E, 34.1977N



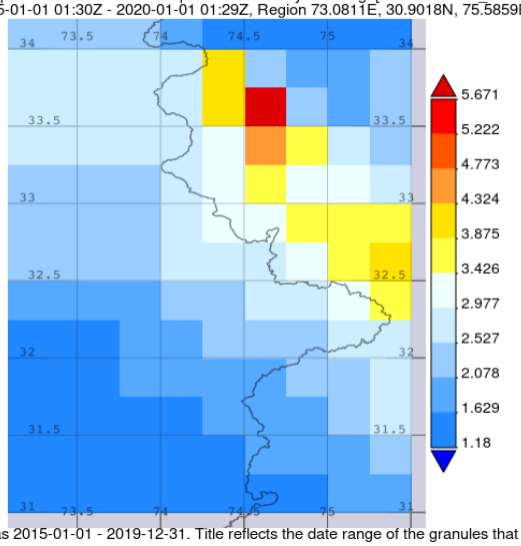
- Selected date range was 2005-01-01 - 2009-12-31. Title reflects the date range of the granules that went into making this result.

Time Averaged Map of Near-Real-Time Precipitation Rate daily 0.25 deg. [TRMM TRMM_3B42RT_Daily v7] mm/day
over 2010-01-01 01:30Z - 2015-01-01 01:29Z, Region 73.0811E, 30.9018N, 75.5859E, 34.1977N



- Selected date range was 2010-01-01 - 2014-12-31. Title reflects the date range of the granules that went into making this result.

Time Averaged Map of Near-Real-Time Precipitation Rate daily 0.25 deg. [TRMM TRMM_3B42RT_Daily v7] mm/day
over 2015-01-01 01:30Z - 2020-01-01 01:29Z, Region 73.0811E, 30.9018N, 75.5859E, 34.1977N



- Selected date range was 2015-01-01 - 2019-12-31. Title reflects the date range of the granules that went into making this result.

Table 4.7 Average Mean TRMM Precipitation of Lahore 2000-2020

Years	TRMM
2000	501.09
2001	568.86
2002	364.63
2003	625.89
2004	479.15
2005	653.36
2006	754.03
2007	648.24
2008	733.74
2009	423.76
2010	645.40
2011	748.23
2012	539.14
2013	860.92
2014	818.96
2015	800.35
2016	560.803
2017	620.01
2018	536.10
2019	758.24

The data was collected through satellite images and the the mean of each year was calculated to show the result. The data was available in TRMM model is from 2000-2019.

The graph is showing that the rate of precipitation is changing from over past 20 years. There is an increase in the precipitation rate.

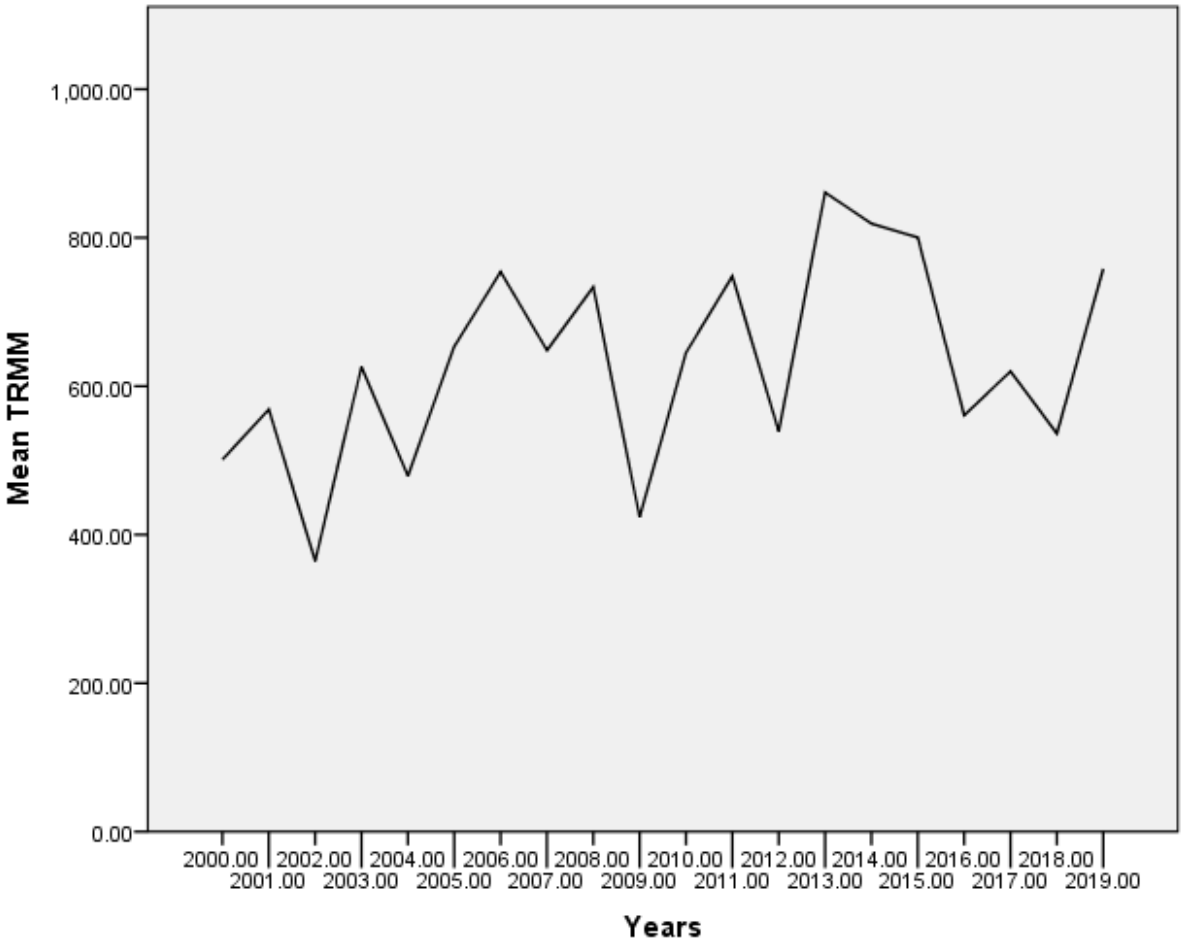


Figure 4.28 Mean TRMM Precipitation of Lahore 2000-2020.

Correlation between Station Data or Satellite Data:

The relation between both the datasets is positive.R=0.7 which shows that there is a strong relation between both data sets. As the slope is positive, there is an increasing trend (y=3.46E2+0.4x).The pearson two tailed correlation is used between thr TRMM and Station Data. The Pearson correlation between two data set is 1.

Correlations

		TRMM	StationData
TRMM	Pearson Correlation	1	.383
	Sig. (2-tailed)		.087
	N	21	21
StationData	Pearson Correlation	.383	1
	Sig. (2-tailed)	.087	
	N	21	21

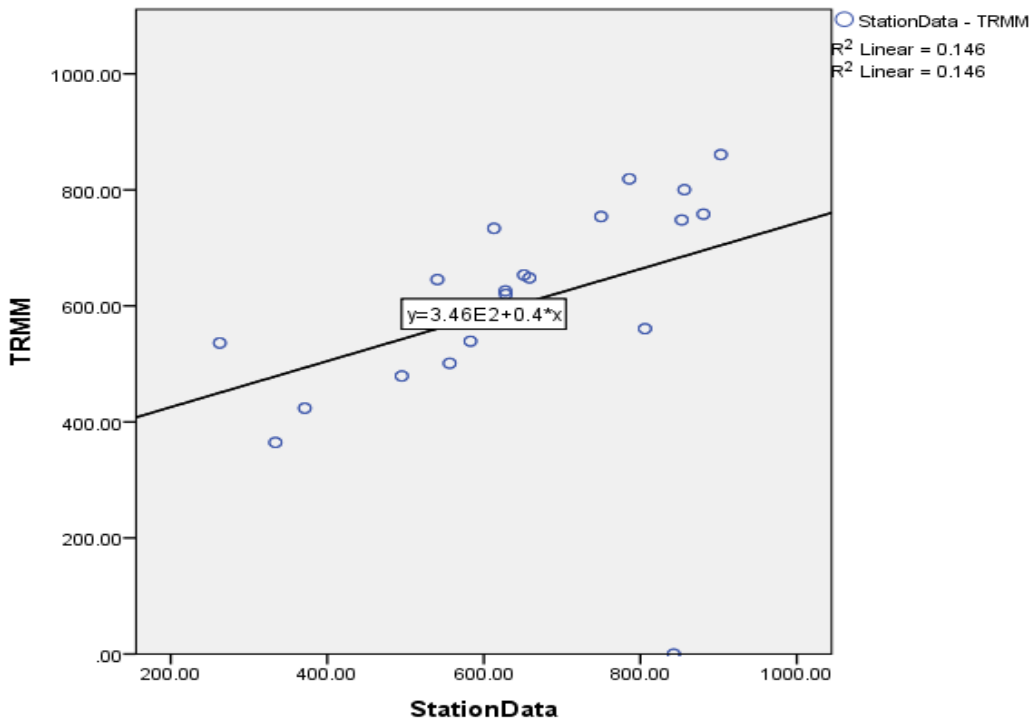


Figure 4.29 Correlation between TRMM and Station Data.

Precipitation on areas of Lahore:

The data is collected through satellite images, the longitudes x and latitudes y are taken and the product used for the process is TRMM_3B43v7) mm/hr, 0.25º spatial resolution.

To analysis the rainfall on different area of Lahore, one type of Interpolation,Kriging is used.

It is the best method for this study. The red zone is showing that there is maximum precipitation in the area and green zone is showing less rainfall in the areas of Lahore.

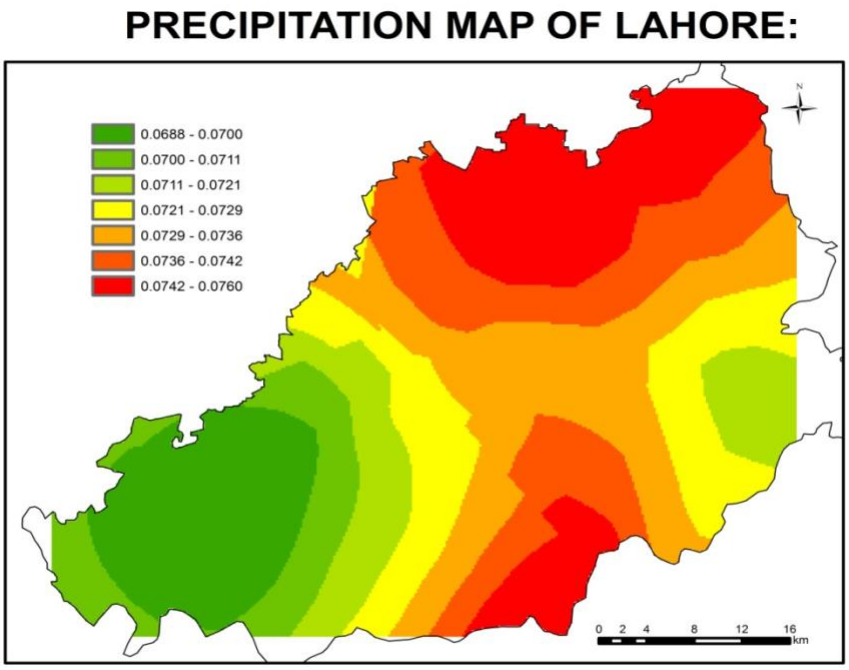


Figure 4.30 Precipitation Map of Lahore.

Dard Red colour is showing maximum amount of rainfall in the areas whereas Green is showing minimum amount of rainfall in the areas of Lahore. Northern side of Lahore is having more rainfall as compared to southern side.

In Pakistan,Total rate Precipitation is57.3 and the maximum rate of precipitation is 111.2.

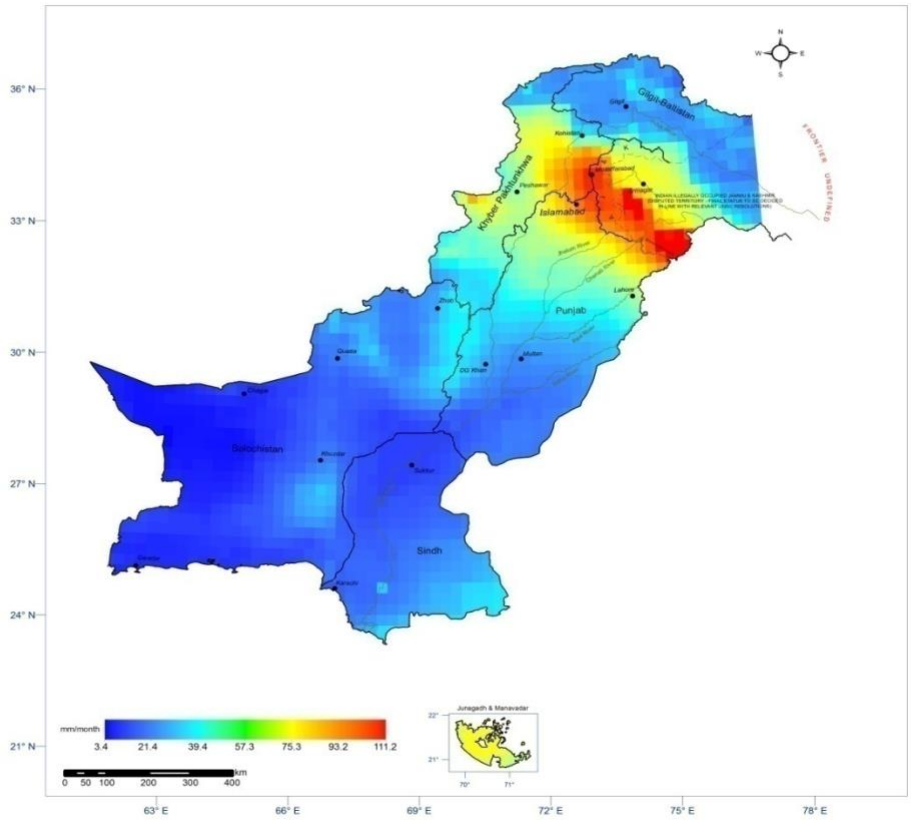


Figure 4.31 Map of Pakistan showing Lahore precipitation rate.

CHAPTER 5

DISCUSSION

The Rate of Precipitation is changing in 20 years. In 2000, the average wa 46.3558 mm and in 2001 it is decrease to 44.475 mm. In 2002, 27.80833 mm amount of rainfall is received which is low as compared to other two years.

In 2003, Lahore received 52.29167 mm of total Precipitation. |In 2004 and 2005,Lahore received 41.26667 mm and 54.26667 mm amount of precipitation respectively.

In 2006 and 2007, 62.48333 mm and 54.85833 mm respectively and in 2008,Lahore received 51.08333 mm of total precipitation. 2009 (30.93333) mm received less rainfall as compared to other years.

In 201, Lahore received (71.075 mm) of precipitation. 2012 received 48.575 mm. 2013 received the heaviest (75.23333 mm) amount of rainfall. 2015 received the (71.35 mm) of rainfall.

2016 and 2017 received (67.15833 mm)and (52.34167 mm) of rainfall respectively. Like 2002, 2018 received less rainfall as compared to other years. 2019 (73.38333 mm) received heaviest amount of rainfall and in 2020,Lahore received (70.225 mm) of rainfall.

It is observed that in 2000-2010, the precipitation rate is not much high as compared to 2010-2020. 2010-2020 received more amount of rainfall. For example,

2011: received (71.075 mm) of total rainfall

2013: received (75.23333 mm) of total rainfall

2015: received (71.35 mm) of total rainfall

2019: received (73.38333 mm) of total rainfall

2020:received (70.225 mm) of total rainfall.

Through these observation, it is seen that Lahore's Precipitation rate is increasing.2011-2020 received more rainfall as compared to 2000-2010.

Null Hypothesis :

H^o=The rate of Precipitation of Lahore is not changing over past 20 years

Alternative Hypothesis:

H1:The rate of Precipitation is changing over past 20 years.

Level of Significance:

The level of significance =0.05%

Test:

The one sample t-test is used for the study.

Output:

One-Sample Statistics

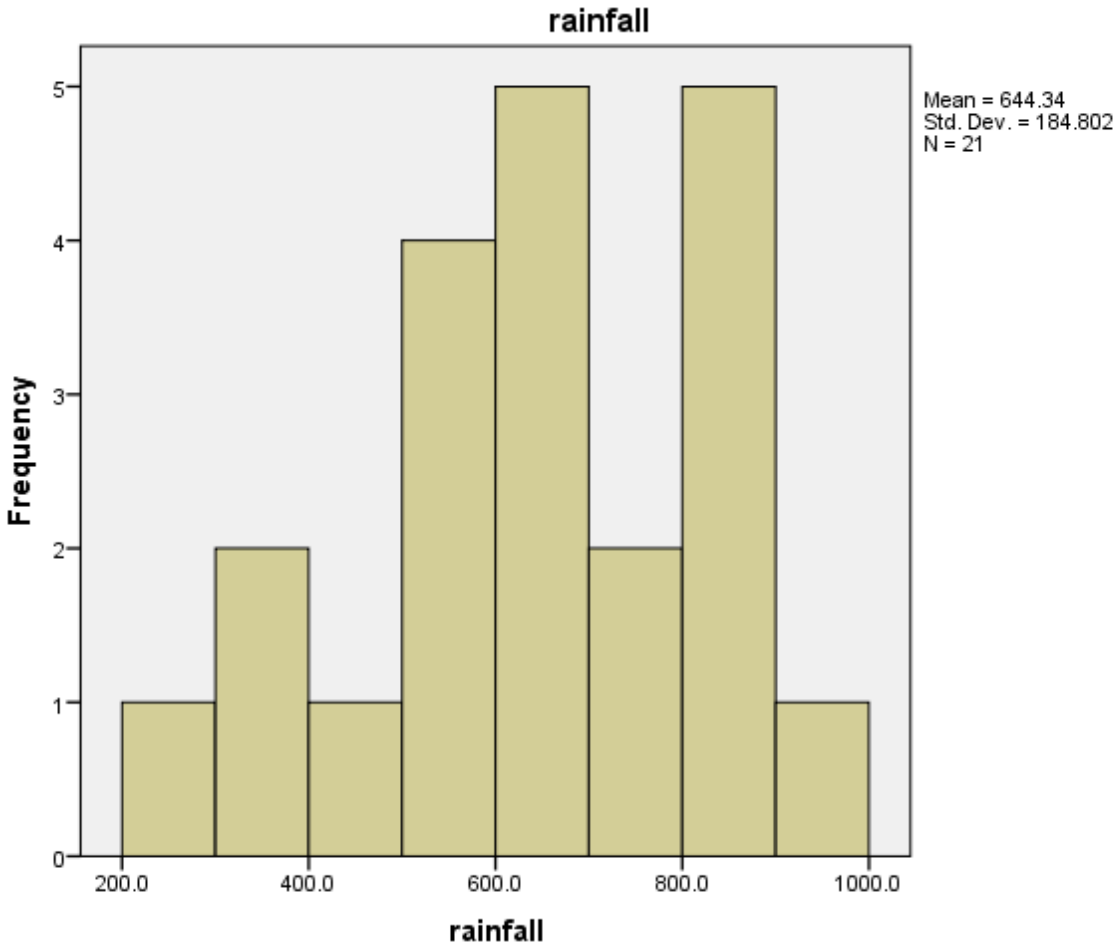
	N	Mean	Std. Deviation	Std. Error Mean
year	21	10.00	6.205	1.354

rainfall	21	644.338	184.8024	40.3272

One-Sample Test

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
year	7.385	20	.000	10.000	7.18	12.82
rainfall	15.978	20	.000	644.3381	560.217	728.459

Significant P-value of T-test=0.000



Interpretation:

It is observed through SPSS output that the p-value is (0.000)that is much less than (0.05).Therefore, rejecting the null hypothesis, i.e.,the rate of Precipitation of Lahore is not changing in 20 years and accepting the alternative hypothesis, which is accepting that rate of Precipitation of Lahore is changing in 20 years. Therefore, the rate of Precipitation of Lahore is changing in 20 years.

CONCLUSION

It is concluded that the precipitation rate of Lahore is increasing over past 20 years. In 2000-2004, it is showed that 2003 received high amount of rainfall in these years and in 2005-2010,2006 is the year that received highest rainfall in years. In 2011-2015, 2013 received highest amount of rainfall in these years. In 2016-2020, 2019 received the highest amount of rainfall in these years. This study concluded by stating that rate of precipitation of Lahore is increasing over past 20 years.

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