Climate Change- An Analysis of Meteorological Data for Shimla and Dharamshala

Project Report submitted in partial fulfillment of the requirement for the degree of

Bachelor of Technology.

in

Civil Engineering

under Supervision of

Dr. Veeresh Gali

By

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to

Jaypee University of Information and Technology

Waknaghat, Solan – 173234, Himachal Pradesh

Certificate

This is to certify that project report entitled "Climate Change- An analysis of Meteorological Data for Shimla and Dharamshala", submitted by PARICHAYA THOMARE in partial fulfillment for the award of degree of Bachelor of Technology in Computer Science & Engineering to Jaypee University of Information Technology, Waknaghat, Solan has been carried out under my supervision.

This work has not been submitted partially or fully to any other University or Institute for the award of this or any other degree or diploma.

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Date: PARICHAYA THOMARE (111683)

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ABSTRACT

Climate Change has undoubtedly emerged as an issue of global concern. Climate Change has a potential to completely and adversely affect the way of human life. Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, which is attributed directly or indirectly to anthropogenic activities that alter the composition of global atmosphere and which are in addition to natural climatic variability observed over comparable time periods. According to Intergovernmental Penal on Climate Change (IPCC) reports continuous increase had taken place in temperature around lower hills of Himalayas. This project report carries assessment of factors which indicates the climate change directly. Temperature, Rainfall and Snowfall meteorological data is used to carry simple regression analysis to predict the changes occurring in precipitation pattern with change in temperature for 37 years. Conclusion is drawn from data analysis that climate change is a matter of concern and measures are required to control as to save earth from major environmental destruction.

CHAPTER-1
INTRODUCTION

1.1 GENERAL

Climate is the long-term average weather. The typical weather (e.g. temperature, rain and snowfall, wind) on any given day tends to be most controlled by the cycle of the seasons from spring through summer, autumn and winter. Other factors, with longer time scales, can cause systematic changes to the climate.

Climate Change has undoubtedly emerged as an issue of global concern. Climate Change has a potential to completely and adversely affect the way of human life. The terms ‘global warming’ and ‘climate change’ are often used interchangeably, but there is a difference. 'Global warming' is the gradual increase of the earth's average surface temperature due to greenhouse gases in the atmosphere, whereas the 'climate change' is a broader term. It refers to long-term changes in climate, including changes in average temperature and rainfall due to global warming. Climate change phenomenon which is much more complex is the result of activities that alters the composition of atmosphere, due to undesirable and unwanted over exploitation of our natural resources.

Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, which is attributed directly or indirectly to anthropogenic activities that alter the composition of global atmosphere and which are in addition to natural climatic variability observed over comparable time periods.

Climate change is the result of changes in our weather patterns because of an increase in the earth's average temperature. This is caused by increases in greenhouse gases in the earth's atmosphere. These gases soak up the heat from the sun but instead of the heat leaving the earth's atmosphere, some of it is trapped, making the earth warmer.

Greenhouse gases have always been a natural part of the atmosphere. They absorb and re-radiate the sun's warmth and maintain the earth's temperature at a level necessary to support life. The problem we now face is that the human actions are increasing the amount of the gases that trap heat. This is an enhanced greenhouse effect, which is contributing to the warming of earth's surface.

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR4) cover in the northern hemisphere during 1850 to the present that the warming of the earth's climate system is unequivocal. The global atmospheric concentration of carbon dioxide has increased from a preindustrial value of about 280 ppm to 379 ppm in 2005. Multi model averages show that the temperature increases during 2090-2099 relative to 1980-1999 may range from 1.1 to 6.4°C and sea level rise from 0.18 to 0.59 meters. These could lead to impacts on freshwater availability, oceanic acidification, and food production, flooding of coastal areas and increased burden of vector borne and water borne diseases associated with extreme weather events.

1.2 ISSUES AND PROBLEMS

Deforestation, landslides, land degradation, desertification and Glacier Lake Outbursts Floods (GLOF) are some of the common but critical environmental issues in the Himalayan regions. The major challenges currently faced by the Himalayan environment are the escalation of such issues through atmospheric as well as man-induced interferences. Himalayan ecosystems sustain a wide range of significant natural resources that play a critical role in the ecological and economic processes of the earth, thus it is very important that these systems are properly analyzed and taken care.

Himalayan eco-systems are predominantly sensitive to climate changes. Himachal Pradesh although a small Himalayan State, is nevertheless playing a very crucial role in sustaining the livelihoods of downstream areas. The conservation, sustenance of these ecologically fragile regions is a biggest challenge faced being faced at the moment which can get further aggravated due to financial constraints and limited resources.

Himalayan eco-systems are predominantly sensitive to climate changes. Himachal Pradesh although a small Himalayan State, is nevertheless playing a very crucial role in sustaining the livelihoods of downstream areas. The conservation, sustenance of these ecologically fragile regions is a biggest challenge faced being faced at the moment which can get further aggravated due to financial constraints and limited resources. Therefore, it can be safely stated that climate change will manifest most in Himachal Pradesh. The commonly observed events and likely ones in the State are as follows:

- State is likely to face warming, erratic rainfall and rainfall changes, floods.
- Change in precipitation pattern.
- There is likely to be a shift in snow line, agriculture /horticulture line; certain areas may open up with some good livelihood openings.
- Significant impacts on agriculture production, water resources, forests, natural wetlands.
- Health risks are likely to increase in the State. Instances as malaria, water borne disease, jaundice etc. may break along river bed predominantly.
- Impacts likely to adversely affect large percentage of population depending on natural resources.

The predicted potential impacts of climate change on Himachal Pradesh are both positive and negative. While many of the impacts would be disruptive and potentially very costly, none are likely to be on at par with the worst impacts elsewhere in the Country. Examples of the projected impacts based on scenarios generally within the range predicted in the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports and other research findings broadly include:

- Changes in precipitation (rain and snow fall) with the average water levels in rivers, lakes less than normal with serious drought like conditions, and in rainy seasons flooding being more frequent, areas currently subject to flooding would suffer flooding of greater severity and for more duration; areas currently flood-free would suffer from occasional floods and flash floods.
- Lesser spring, summer rainfall causing regular water shortages, especially in the mid hills would be affecting both people and the ecosystems. There would be less recharge of

reservoirs during the summer; water shortages would occur regularly and would be longer than at present. The change in rainfall patterns may further cause regular water deficits, leading to accelerated soil erosion and loss of fertility and biodiversity.

- Rising river water levels due to rapid glacier melt and more storm events and storm surge, particularly on the Satluj, Beas and Ravi rivers and their tributaries with storms of a greater severity are at risk from rising water levels, including related landslides, erosion, flooding and environmental changes with severe threat to infrastructures.
- Riverbed areas subject to human industrial development would be at risk, and could suffer loss of infrastructure. Human use of the river bed is quite intensive, and low lying areas of all valleys are highly developed with different key industries (mainly energy), and tourism, residential development along the river are under potential threat. Protective options include abandonment of land, stronger planning controls, and fiscal disincentives for river side development.
- Short-term increased agricultural production with new crops becoming viable in certain regions and agricultural production costs reduced if prolonged summer droughts do not become a problem. Grass growth could enjoy beneficial effects with a good increase with higher temperatures and changes in rainfall patterns. Increase in man-animal conflicts in the event of decreasing quality of forest cover/area.
- New grassland and livestock management systems would be possible, with a longer grazing season and the prospect of growing additional forage crops (e.g. maize, fodder beet). There would be little or no increase in cereal yields, but increases in other crops are possible, and the area for growth of many arable crops would migrate northwards. A number of new crops (e.g. sunflower best option) may become viable in our area as well.
- Some existing forestry species may suffer badly (e.g. where availability of water and nitrogen are limiting factors), with others becoming more productive (higher temperatures and increased CO_2 concentrations in the atmosphere supporting higher rates of photosynthesis and hence higher growth rates).

1.3 CLIMATE CHANGE – ISSUES OF CONCERN

The economy of the State is dependent on sectors like the hydel power generation, horticulture, agriculture, forestry and tourism etc. and these sectors are assumed to be under threat in the present scenario of changing climate. Any change in these sectors due to climate change, in every likelihood, will not only going to affect the livelihood prospects in the agrarian economies of mountain regions, but also everyone living below in the plains. The major issues of concern due to the emerging threat of climate change in Himachal Pradesh are:

- Agrarian economy of 90% rural population and their livelihood.
- Dependence on rains for agrarian activities.
- Sustainability of hydro economy as dependency on snow and glaciers.
- Water sources for drinking and irrigation.
- Rural livelihood dependency on forest for fuel wood, fodder and non-wood products etc.
- The role of medicinal herbs in economy.
- Climate induced and other natural hazards threat in the state.

1.4 INDICATORS OF CLIMATE CHANGE IN SHIMLA

- Rise in temperature in the NW Himalayan Region by about 1.6°C in the last century.
- Warming rate of Shimla was higher during the period 1991-2002 as compared to earlier decades.
- About 17% decrease in rainfall in Shimla was observed from 1996 onwards.
- The decreasing trend in seasonal snowfall in Shimla is very conspicuous since 1990 and it was lowest in 2009.
- Monsoon discharge in Beas River has shown a significant decrease.
- Winter discharge in River Chenab and Satluj has shown a significant increase.
- Quality of apple has been affected and the apple line has shifted upwards.
- Area under apple is being diverted to vegetable due to rising temperature.
- Incidence of pest and disease are more severe.
- Pine forest invading heights.

1.5 GLACIER STATUS IN HIMACHAL PRADESH

An overall reduction in glacier area from 2,077 sq. km. to 1,628 sq. km. from 1962-2001 in Chenab, Parbati & Baspa Basins, H.P. An overall deglaciation of 21% of total area in these basins. About 10% deglaciation is observed in Spiti Basin during 2001-2007. Prominent glaciers as studied by GSI in Himachal Pradesh shows:

- Chota Sigri 6.81 m/y retreat during 1962-95.
- Bara Sigri 29.78 m/y during 1906-1957.
- Trilokinath as 17.86 m/y during 1968-1996.
- Beas Kund as 18.8 m/y during 1963-2003.
- Manimahesh as 29.1 during 1968-2005.

2001

Fig. 1.1

2007

Fig. 1.2

According to experts, glaciers in the Himalaya have been reported to be in the retreating phase and in future, this can result in water scarcity for the people living in the mountain region and in downstream area who depend on glaciers and snow as a source of fresh water. Retreating glaciers, depleting snow cover and Glacial Lake Outburst Floods (GLOFs) are of immediate concern in the mountain environment as GLOFs can have a devastating impact on the hydro power, water sources, people, livestock, forests, farms and infrastructure. Decreases in snow accumulation and glacial retreat might lead to acute water shortages in the future.

CHAPTER – 2

LITERATURE REVIEW

PROFILE OF SHIMLA CITY

2.2 GEOGRAPHIC LOCATION OF SHIMLA

Shimla is the capital city of Himachal Pradesh. In 1864, Shimla was declared the summer capital of the British Raj in India. A popular tourist destination, Shimla is often referred to as the "Queen of Hills," a term coined by the British.

It is located in the north-west Himalayas at an average altitude of 2,205 meters (7,234 ft.), the city of Shimla, draped in forests of pine, rhododendron, and oak, experiences pleasant summers and cold, snowy winters. The coordinates of Shimla are 31°6'12" North and 77°10'20" East. It has an area of 31.60 sq. km.

Fig. 3

Fig.2.1 – Location of Shimla on Mpa of India

2.3 PHYSIOGRAPHIC SETTING OF SHIMLA

Shimla district of Himachal Pradesh, lies between the longitude 77.00" and 78.19" east and latitude 30.45" and 31.44" north, has its headquarters at Shimla city. It is surrounded by Mandi and Kullu in the north, Kinnaur in the east, Uttrakhand in the south, Sirmaur in the west. The elevation of the district ranges from 300 meters (984 ft.) to 6,000 meters (19,685 ft.).

Shimla is located in the north-western ranges of the Himalayas. At an average altitude of 2397.59 meters (7866.10 ft.) above mean sea level, the city is spread on a ridge and its seven spurs. The city stretches nearly 9.2 km from east to west. The highest point in Shimla, at 2454 meters (8051 ft.), is the Jakhu hill. Shimla is a Zone IV (High Damage Risk Zone) per the Earthquake hazard zoning of India. There are no bodies of water near the main city and the closest river, Sutlej, is about 21 km away. Other rivers that flow through the Shimla district, although further from the city, are Giri, and Pabbar (both are tributaries of Yamuna). The main forests in and around the city are that of pine, deodar, oak and rhododendron.

Fig. 2.2

Fig. 2.3

Fig.4 –Himachal Pradesh District Map

Fig.5- Shimla City Map

2.4 AREA DIVISION

The 25 square kilometer of the city area is spread over seven hill spurs. The average elevation of these spurs varies from 2073 m to 2454 m from the mean sea level. Jakhoo Hill is the most elevated spur of Shimla. These spurs are inter-connected by roads. The important character of the road network circumscribing these hills is that it is connected to the Mall Road from Boileauganj to Chhota Shimla.

Hill Spurs	**Elevations (Mt.)**
Jakhoo Hill	2454
Elysium Hill	2257
Museum Hill	2201
Prospect Hill	2177
Observatory Hill	2150
Summer Hill	2104
Potters Hill	2073

Table-2.1; Hill spurs and their mean elevations

2.5 SALIENT PHYSICAL FEATURES AND LAND USE PATTERNS

2.5.1 SOIL TYPE - The soil type of Shimla is mainly grey wooded or podzolic soils.

2.5.2 LAND USE PATTERN

Of the total area of 9950 hectares of Shimla Planning Area (SPA), about 1475 hectares which accounts for 15% of the total SPA is under urban use. The existing land use of urban area is given below:

Table-2.2; Land Use Pattern

SR. NO.	LAND USE	AREA IN HECTARES	% OF URBAN AREA	% OF PLANNING AREA
1.	Residential	903.13	61.19	9.07
2.	Commercial	25.22	1.71	0.25
3.	Industrial	9	.62	0.09
4.	Tourism	21.7	1.47	0.22
5.	Public and Semi-Public	138.78	9.4	1.39
6.	Parks & open spaces	6.0	.41	.06
7.	Traffic and Transportation	371.93	25.2	3.75
	Sub Total	**1475.76**	**100.00**	
8.	Agriculture	2174.75	-	21.85
	Forest	6080.15	-	61.12
	Water bodies and undevelopable land	219.34	-	2.2
	Grand Total	**9950**	**-**	**100**

2.5.3 GEOLOGY AND GEOMORPHOLOGY

In Shimla the sediment eroded from the Himalayas 30 million years ago and deposited by ancient rivers. The town is situated on the rocks of Jutogh Group and Shimla Group. Jutogh group occupies main Shimla area and extends from Annadale-Chaura Maidan-Prospect Hill- Jakhoo-US Club and highland area. Shimla Group comprising of earlier Chail Formation and Shimla Series represented by shale, slate, quartzite greywacke and local conglomerate is well exposed in Sanjauli-Dhalli area.

2.5.4 CLIMATE AND RAINFALL

Shimla in general has a mild highland climate, with temperature in peak winters, falling below 0°C. Shimla features a subtropical highland climate under the Koppen climate classification. The climate in Shimla is predominantly cool during winters and moderately warm during summers. The temperatures range from -4°C (24.8°F) to 31°C (87.8°F) over the year. The average temperature during summer is between 19°C and 28°C and between -1°C and 10°C in winter. Monthly precipitation varies between 24 mm. in November to 415 mm. in July. It is typically around 45 mm. per month during winter and spring and around 115 mm in June as the monsoon approaches. The average total annual precipitation is 1520 mm (62 inches). Snowfall in the region, which historically has taken place in the month of December, has lately (over the last fifteen years) been happening in January or early February every year.

2.5.5 DEMOGRAPHIC FEATURES

In 2011 the total population of District Shimla is 813,384 compared to 722,502 of 2001. Male and female are 424,486 and 388,898 respectively. Population Growth for Shimla District recorded in 2011 for the decade has remained 12.58 percent. Same figure for 1991-2001 decade was 17.02 percent. Total Area of Shimla District was 5,131 with average density of 159 per sq. km. Shimla Population constituted 11.86 percent of total Himachal Pradesh Population.

2.6 PAST & CURRENT CLIMATIC TRENDS IN SHIMLA

2.6.1 CLIMATIC PATTERN

The term climate is mainly determined by two variables viz. temperature and precipitation. The sub humid tropical (450-900 m) in the southern low tracts, warm and temperate (900-1,800 m), cool and temperate climate of the state varies from place to place depending on the altitude. It varies from hot and (1,900-2,400 m) and cold alpine and glacial (2,400-4,800 m) in the northern and eastern high mountain ranges.

The state is broadly divided into three physiogeographical regions, viz. Outer Himalaya, the Lesser Himalaya and the Greater Himalaya or the Alpines. Parts of Shimla are covered in Lesser Himalayas and receives average annual rainfall between 75cm to 100cm.

2.6.2 CURRENT CLIMATE TRENDS IN SHIMLA

In the context of understanding the climate trends in Himachal Pradesh, both precipitation (Rainfall & Snowfall) and temperature are considered significant indicators.

2.6.3 TEMPERATURE

Based on comprehensive studies carried over NW Himalayas on long term trends in maximum, minimum and mean annual air temperate by *Bhutiyani, et. al. 2007*, included observation from Shimla for a period 1901-2002, indicates that there is a significant increase in air temperature in the region by about 1.60C with winter warming at a faster pace.

Table – 3.1; Winter Monsoon & Annual Air Temperature in Himachal Pradesh

Observation Location	**Season**	**Winter ($_0$C)**	**Monsoon ($_0$C)**	**Annual ($_0$C)**
Shimla	Mean Max.	2.6	2.8	2.4
	Mean Min.	1.0	(-)0.1	0.5
	Average Annual	1.8	1.5	2.0

(-) negative sign indicates decrease in temperature.

According to *Bhutiyani et. al. 2007* based on short term analysis observed that in different altitudinal zones in Himachal Pradesh, the rate of increase in maximum temperature at higher altitudes was more than that at the lower altitudes and in last century north western Himalayan region warmed significantly higher than the global average.

Table-3.2; Increase in Winter Mean Air Temperature in Himachal Pradesh

Observation Stn	**Mean Max. (0C)**	**Mean Min. (0C)**	**Average Winter (0C)**
Bahang	4	1.8	3.8
Solang	4.4	-2.0	3.8
Dhundi	5.6	1.0	3.2
Patseo	3	-3.0	0
Shimla	2.8	2.2	2.4

2.6.4 RAINFALL

Trend analysis of annual rainfall data (Ranbir, 2010) of last 25 years in different districts in Himachal Pradesh revels that increasing trend of about 33.5%, 54.3% and 51.5% has been observed in the State in district Kinnaur, Chamba and Lahul & Spiti respectively on one hand and decrease of about 8.7%, 13.3% and 26.6% in District Solan, Shimla and Sirmour respectively.

The annual Rainfall Variation Trend in different districts oh H.P. is given as follow:

Table-3.3; District wise Variation in Annual Rainfall Trends

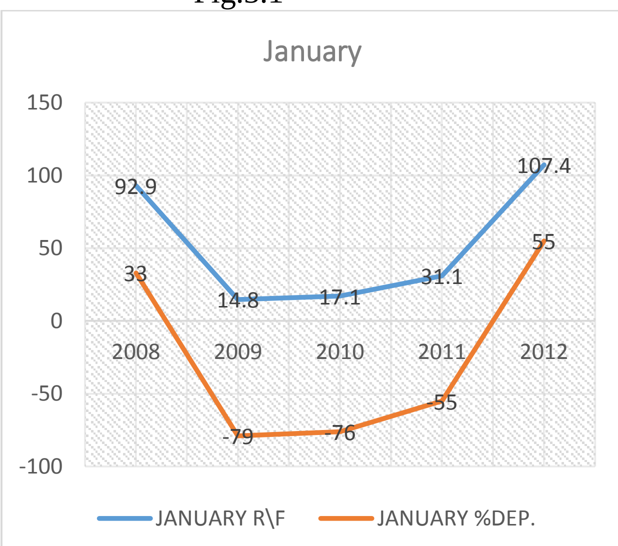
Districts	**Rainfall Variation of 25 years (%)**
Kinnaur	(+)33.5
Chamba	(+)54.3
Lahual Spiti	(+)51.5
Solan	(-)8.7
Shimla	(-)13.3
Sirmour	(-)26.6

2.6.5 MONTHLY RAINFALL AND DEPARTURE VARIATION OF PREVIOUS 5 YEARS

Table-3.4; five year Monthly Average Rainfall

YEAR	JANUARY		FEBRUARY		MARCH		APRIL	
	R\F	%DEP.	R\F	%DEP.	R\F	%DEP.	R\F	%DEP.
2008	92.9	33	44.5	-24	2.1	-97	39.5	-10
2009	14.8	-79	19	-67	39	-49	36.2	-18
2010	17.1	-76	87.7	50	9.3	-88	20.7	-53
2011	31.1	-55	60.7	-14	35.6	-56	33.7	-30
2012	107.4	55	33.3	-53	21.8	-73	73.4	52

Fig.3.1



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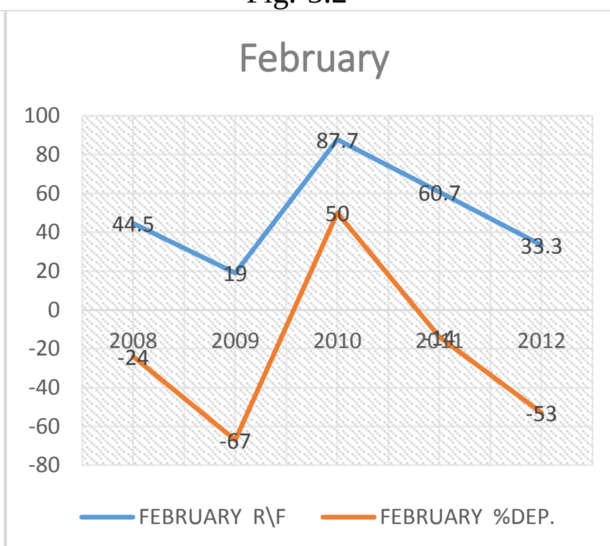

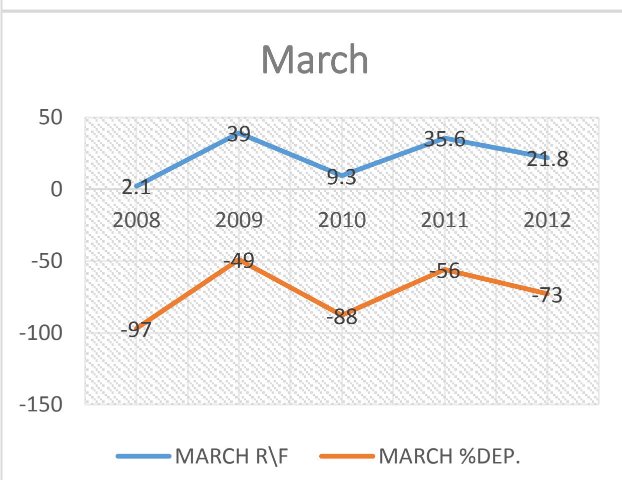

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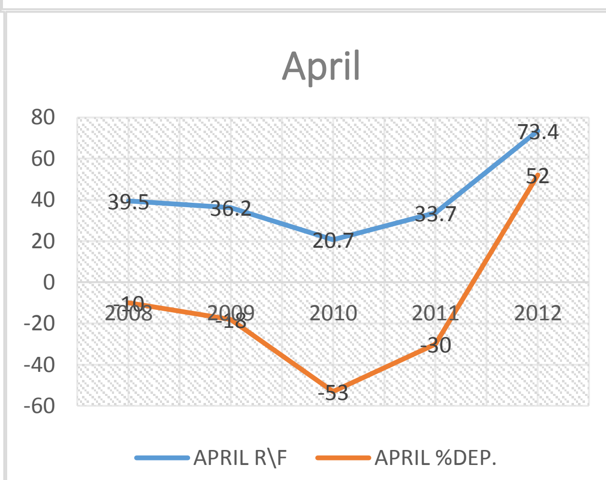


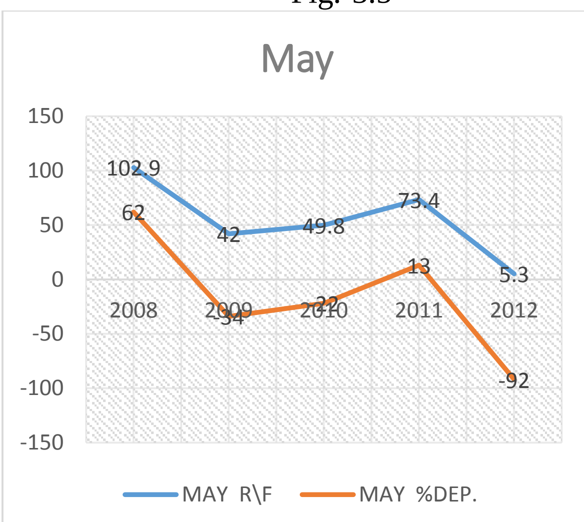
Fig.-3.4

Figures: Represent Variation of Rainfall and Departure from Average past year data

Table-3.5; five year Monthly Average Rainfall

YEAR	MAY		JUNE		JULY		AUGUST	
	R\F	%DEP.	R\F	%DEP.	R\F	%DEP.	R\F	%DEP.
2008	102.9	62	248	110	148.1	-46	284.2	34
2009	42	-34	39.5	-67	127.3	-54	110.2	-48
2010	49.8	-22	155	31	303.5	10	280.4	32
2011	73.4	13	143	37	150.8	-34	270.2	43
2012	5.3	-92	42.8	-59	169.3	-25	272.8	44

Fig.-3.5



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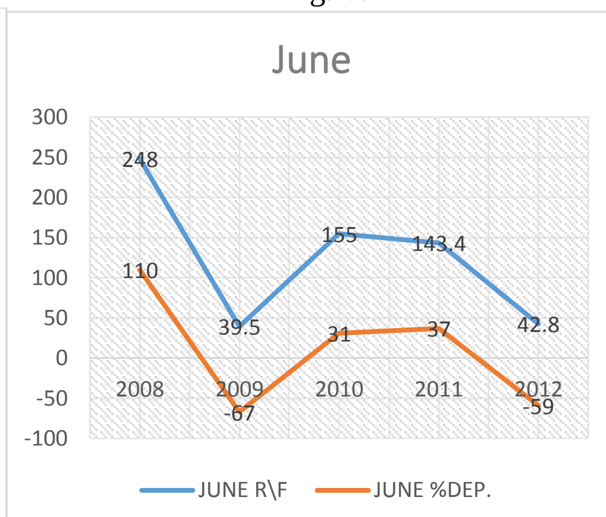

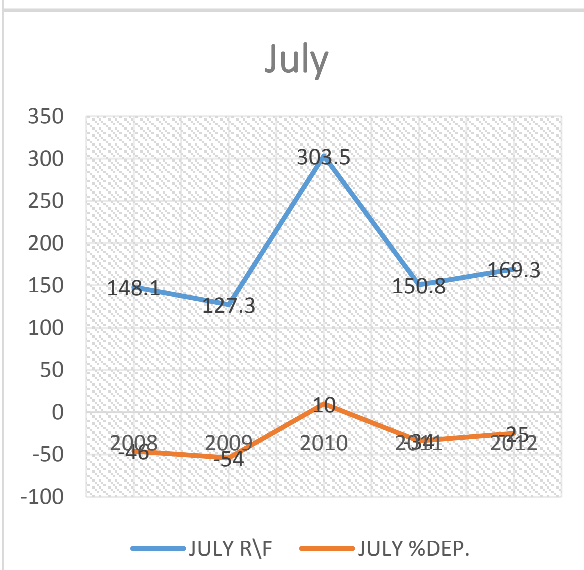

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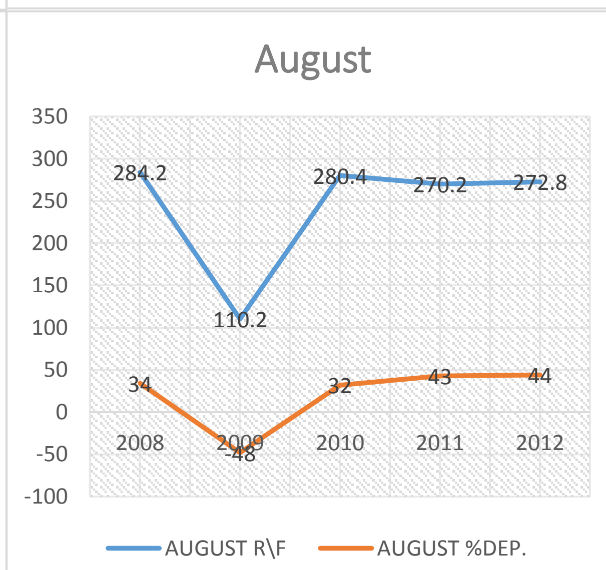


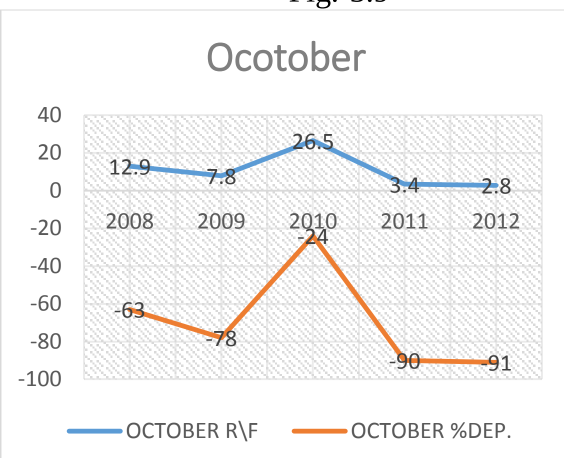
Fig.-3.8

Figures: Represent Variation of Rainfall and Departure from Average past year data

Table-3.6; five year Monthly Average Rainfall

YEAR	SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
	R\F	%DEP.	R\F	%DEP.	R\F	%DEP.	R\F	%DEP.
2008	243.7	117	12.9	-63	6.1	-51	12.7	-52
2009	270.3	141	7.8	-78	18	44	2.6	-90
2010	261.6	133	26.5	-24	8.3	-34	52.8	101
2011	101.7	-10	3.4	-90	0.1	-99	9.1	-68
2012	102.3	-10	2.8	-91	2.4	-83	16.3	-42

Fig.-3.9



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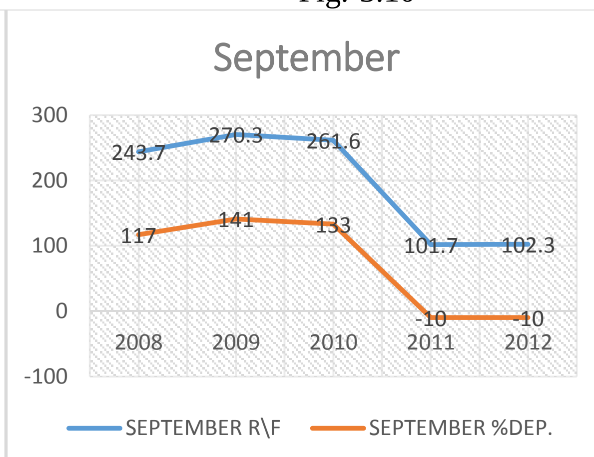

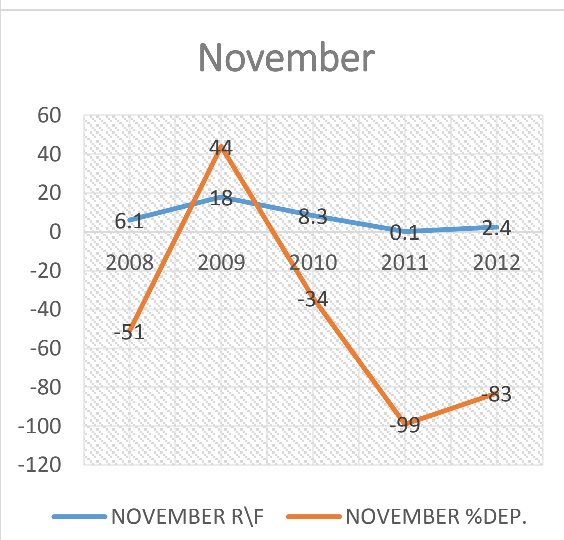

Fig.-3.11

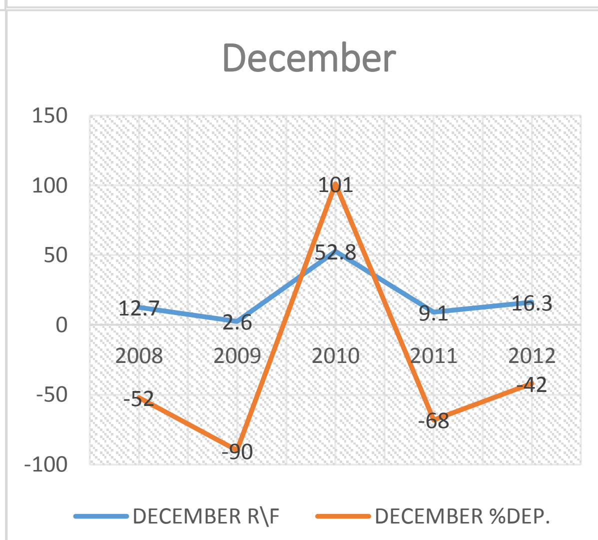

Fig.-3.12

Figures: Represent Variation of Rainfall and Departure from Average past year data

2.6.6 PREDICTION WITH THE HELP OF MS-EXCEL

Table-3.7; Annual average Rainfall of Shimla and HP

Year	Average Annual Rainfall of Shimla (mm)	Average Annual Rainfall of HP (mm)
2004	445.4	423
2005	677.8	568.6
2006	757	579.5
2007	487.1	495.7
2008	907.4	735.4
2009	547.3	507.5
2010	999.9	888.5
2011	665.9	730.3
2013	581.5	776.9

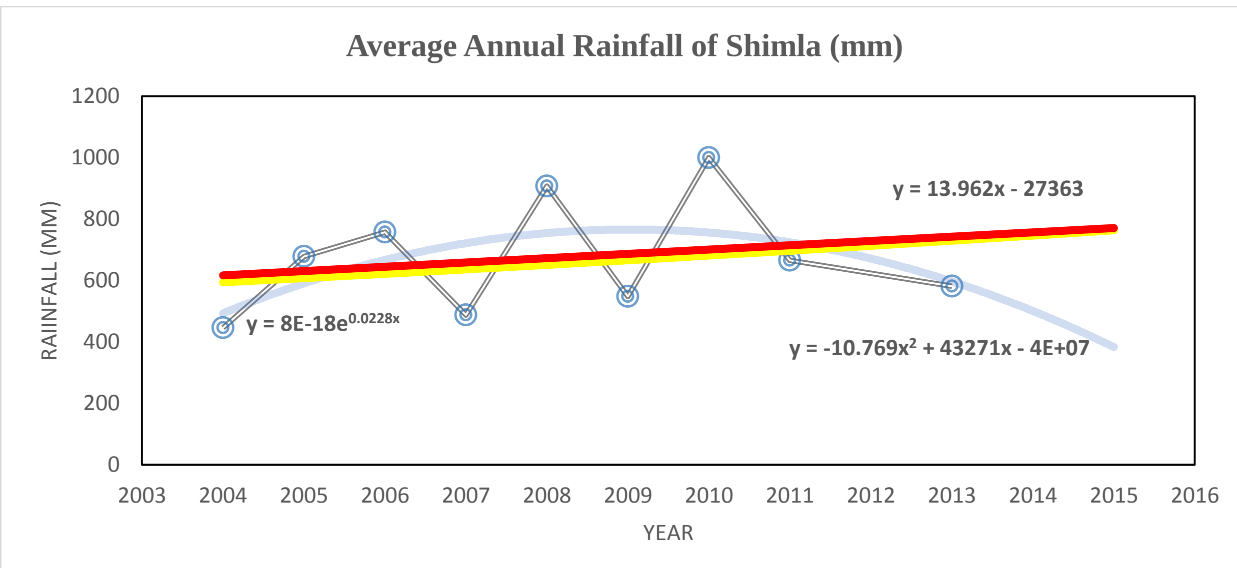

Fig.-3.13; Prediction with 9 years of data on Linear, Polynomial and Exponential curves.

Observation from graph cannot be made clearly due to lack of data quantity. Linear and Exponential curves are almost overlapping due to less number of observation points available. Still conclusion can be drawn that there is no linear trend followed by the rainfall in these 9 years.

It has also been observed that there has been about 40% reduction in rainfall over the last 25 years as it was 948 mm in 1987 which is reduced to about 470 mm during 2009. Another analysis with respect to climate of Shimla reveals that total precipitation and snowfall for all the season has a decreasing trend. The analysis of twenty years data by (*Bhan & Manmohan, 2011, IMD*) reveals that the season tends to end by about 10-12 days earlier per decade leaving long term impacts on agriculture, horticulture production of the State.

2.6.7 SNOWFALL

According to the State Strategy Action Plan Report Snowfall and winter rainfall trends are analyzed by IMD with 20 years of data.

Table-3.8; Observed Decreasing Trend in Rain Fall & Snow Fall at Shimla

Months	**Trends in Total Precipitation, Rainfall and Snowfall**		**No. of days with Snowfall (years)**	
	Trend (mm per decade)		**Avg. no. of days with snowfall**	**Max. No. Of days with Snowfall**
	Rainfall	**Snowfall**		
December	-3.8	-8.4	0.8	3
January	-46	-29.6	3.1	8
February	-20.9	-14.5	3.9	12 (2000)
March	-19.2	-4.3	0.4	2
Season	-89.9	-56.9	8.2	20 (1994-1995)

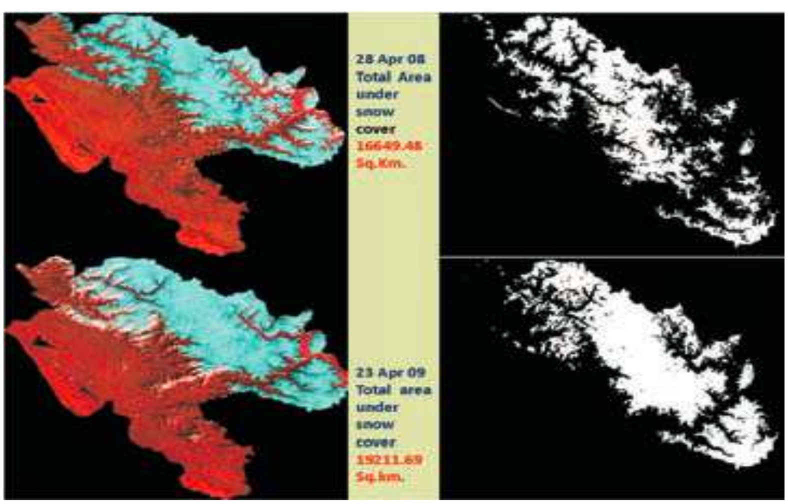

Fig.-3.14; Impact of Climate Change on the seasonal snow cover patterns

CHAPTER-3
ASSESSMENT OF METEOROLOGICAL DATA FROM 1969 TO 2007 (SHIMLA)

3.1 LINEAR REGRESSION MODEL

Linear regression is a statistical procedure for predicting the value of a dependent variable from an independent variable when the relationship between the variables can be described with a linear model.

A linear regression equation can be written as Yp= bX + a, where Yp is the predicted value of the dependent variable, b is the slope of the regression line, and a is the Y-intercept of the regression line.

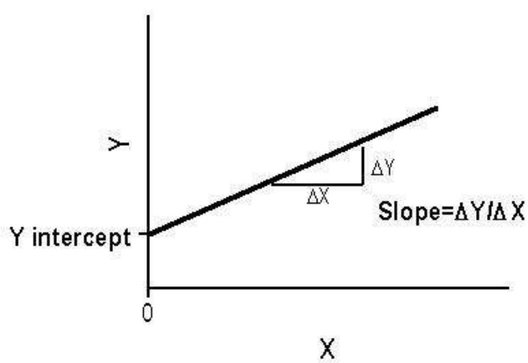

Fig.-4.1; Graph represents simple regression line, y intercept and slope.

In statistics, linear regression is a method of estimating the conditional expected value of one variable y given the values of some other variable or variables x. The variable of interest, y, is conventionally called the "dependent variable". The terms "endogenous variable" and "output variable" are also used. The other variables x are called the "independent variables". The terms "exogenous variables" and "input variables" are also used. The dependent and independent variables may be scalars or vectors. If the independent variable is a vector, one speaks of multiple linear regression.

Formula Used:

$$a = \frac{(\Sigma y)(\Sigma x^2) - (\Sigma x)(\Sigma x y)}{n(\Sigma x^2) - (\Sigma x)^2}$$

$$b = \frac{n(\Sigma x y) - (\Sigma x)(\Sigma y)}{n(\Sigma x^2) - (\Sigma x)^2}$$

3.2 DATA ANALYSIS

Data from 1969 to 2007 is given in tabular form of Average Temperature and Total Monthly Rainfall is given to produce Linear Regression Analysis and to find the Correlation factor.

Table-4.1; Average Monthly Temperature and Average Monthly Rainfall for 1969 to 1974.

Year	Month	Avg. Temp	Avg. Rainfall	Year	Month	Avg. Temp	Avg. Rainfall	Year	Month	Avg. Temp	Avg. Rainfall
1969	Jan	10.55	7.41	1971	Jan	9.9	9.26	1973	Jan	10.1	16.38
1969	Feb	12.75	8.16	1971	Feb	12.95	16.84	1973	Feb	13.65	9.26
1969	Mar	20.35	10.9	1971	Mar	18.3	0.3	1973	Mar	16.35	8.91
1969	Apr	21.7	6.73	1971	Apr	23.55	4.9	1973	Apr	24.75	0.53
1969	May	25.75	7.38	1971	May	25	7.99	1973	May	28.1	5.34
1969	Jun	29.1	19.32	1971	Jun	24.45	48.48	1973	Jun	26.45	20.33
1969	Jul	24.65	66.57	1971	Jul	23.8	76.72	1973	Jul	24.35	67.55
1969	Aug	23.65	145.83	1971	Aug	22.8	130.96	1973	Aug	23.2	98.44
1969	Sep	22.7	16.28	1971	Sep	22.75	13.84	1973	Sep	22.65	63.38
1969	Oct	21.55	8.19	1971	Oct	21.05	2.24	1973	Oct	19.8	5.96
1969	Nov	17.7	0	1971	Nov	14.95	3.41	1973	Nov	15.65	0
1969	Dec	13.6	0.1	1971	Dec	12.8	0.18	1973	Dec	10.9	3.25
1970	Jan	10.1	16.95	1972	Jan	11.4	6.84	1974	Jan	10.1	6.78
1970	Feb	12.3	4.05	1972	Feb	9.85	12.83	1974	Feb	11.25	62.68
1970	Mar	16.55	3.48	1972	Mar	17.7	10.14	1974	Mar	18.5	2.58
1970	Apr	24.2	0.59	1972	Apr	20.35	9.94	1974	Apr	24.75	1.64
1970	May	28.4	11.02	1972	May	27.25	0.79	1974	May	26.3	4.68
1970	Jun	26	23.82	1972	Jun	28.7	15.5	1974	Jun	26.65	13.38
1970	Jul	25.3	81.8	1972	Jul	24.8	69.91	1974	Jul	24.45	91.91
1970	Aug	23.55	29.76	1972	Aug	23.2	43.98	1974	Aug	23.65	69.45
1970	Sep	22.75	49.81	1972	Sep	22.15	22.62	1974	Sep	23.05	9.46
1970	Oct	21.2	4.21	1972	Oct	19.8	3.17	1974	Oct	20.8	0.91
1970	Nov	15.45	0.38	1972	Nov	15.95	3.67	1974	Nov	15.95	0.05
1970	Dec	12.65	0	1972	Dec	12.05	2.74	1974	Dec	10.05	7.42

Table-4.2; Average Monthly Temperature and Average Monthly Rainfall for 1975 and 1984

Year	Month	Avg. Temp	Avg. Rainfall	Year	Month	Avg. Temp	Avg. Rainfall	Year	Month	Avg. Temp	Avg. Rainfall
1975	Jan	8.6	20.67	1978	Jan	9.65	3.87	1981	Nov	14.5	10.7
1975	Feb	10.5	14.67	1978	Feb	11.15	13.59	1981	Dec	10.85	0.89
1975	Mar	15.8	12.3	1978	Mar	14.5	19.57	1982	Jan	10.1	20.96
1975	Apr	22.45	1.14	1978	Apr	22.8	1.95	1982	Feb	9.7	15.69
1975	May	26.65	2.53	1978	May	30.55	2.55	1982	Mar	13.5	31.97
1975	Jun	26.5	13.17	1978	Jun	27.15	79.48	1982	Apr	20.7	14.5
1975	Jul	23.65	105.71	1978	Jul	23.35	130.53	1982	May	23.95	9.91
1975	Aug	23	72.29	1978	Aug	23.35	120.57	1982	Jun	27.15	7.35
1975	Sep	21.9	68.87	1978	Sep	22.2	32.81	1982	Jul	26.35	48.09
1975	Oct	20.7	3.25	1978	Oct	20.4	1.65	1982	Aug	24.1	48.92
1975	Nov	14.75	0	1978	Nov	15.7	2.3	1982	Sep	23.6	3.06
1975	Dec	12.15	0	1979	Sep	21.6	3.66	1982	Oct	20.5	3.03
1976	Jan	10.55	10.59	1979	Oct	20.9	0.31	1982	Nov	15.6	3.04
1976	Feb	11.3	16.81	1979	Nov	17.15	4.24	1983	Jan	11.55	8.48
1976	Mar	15.15	21.73	1979	Dec	11.5	6.19	1983	Feb	9.15	11.47
1976	Apr	20.85	6.14	1980	Jan	10.2	9.02	1983	Mar	10.1	18.5
1976	May	25.3	2.1	1980	Feb	12.6	7.69	1983	Apr	15.2	13.09
1976	Jun	26.05	14.03	1980	Mar	15.4	7.17	1983	May	19.2	18.92
1976	Jul	24	122.31	1980	Apr	24	1.75	1983	Jun	23.3	14.82
1976	Aug	22.8	61.41	1980	May	28.3	2.87	1983	Jul	27.25	13.7
1976	Sep	22.25	19.7	1980	Jun	26.85	36.85	1983	Aug	25.2	43.38
1976	Oct	20.25	1.41	1980	Jul	23.85	111.03	1983	Sep	23.55	78.48
1976	Nov	16.4	0	1980	Aug	23.55	59.5	1983	Oct	23.25	59.01
1976	Dec	11.4	1.83	1980	Sep	22.65	8.79	1983	Nov	19.75	3.51
1977	Jan	9.8	13.07	1980	Oct	20.15	1.68	1983	Dec	15.2	0
1977	Feb	13.15	0	1980	Nov	11.65	4.69	1984	Jan	10.7	1.33
1977	Mar	20.1	0.19	1981	Jan	8.85	13.32	1984	Feb	8.95	1.72
1977	Apr	21.55	9.47	1981	Feb	12.4	12.65	1984	Mar	10.2	11.18
1977	May	23.9	15.31	1981	Mar	15.1	19.35	1984	Apr	19.4	4.63
1977	Jun	25.45	41.67	1981	Apr	22.2	2.25	1984	May	22.7	3.46
1977	Jul	23.3	50.6	1981	May	25.65	5.54	1984	Jun	14.65	0.59
1977	Aug	23.1	70.58	1981	Jun	27.75	29.81	1984	Jul	26.2	24.87
1977	Sep	21.85	52.42	1981	Jul	23.9	73.5	1984	Aug	23.05	67.87
1977	Oct	20.4	2.92	1981	Aug	23.65	76.54	1984	Sep	23.15	91.71
1977	Nov	16.8	1.04	1981	Sep	23.5	12.68	1984	Oct	22.1	23.06
1977	Dec	11.5	11.71	1981	Oct	20.8	20	1984	Nov	20.25	0

Table-4.3; Average Monthly Temperature and Average Monthly Rainfall for 1985 to 1994

Year	Month	Avg. Temp	Avg. Rainfall	Year	Month	Avg. Temp	Avg. Rainfall	Year	Month	Avg. Temp	Avg. Rainfall
1984	Dec	15.35	1.21	1987	Dec	16	0.03	1990	Dec	16.8	0.28
1985	Jan	11.5	4.91	1988	Jan	12.8	0.84	1991	Jan	11.9	20.61
1985	Feb	10	8.2	1988	Feb	11.3	5.16	1991	Feb	10.25	0.75
1985	Mar	13.85	2.86	1988	Mar	13.7	15.03	1991	Mar	13	11.07
1985	Apr	19.9	1.18	1988	Apr	16.05	21.14	1991	Apr	18.15	5.68
1985	May	23	6.46	1988	May	24.45	5.61	1991	May	21.35	8.44
1985	Jun	28.5	1.79	1988	Jun	29.2	2.42	1991	Jun	26.75	5.23
1985	Jul	28.05	15.52	1988	Jul	27.45	22.04	1991	Jul	27.4	19.84
1985	Aug	23.6	80.94	1988	Aug	23.5	135.08	1991	Aug	25.95	52.89
1985	Sep	23.3	89.93	1988	Sep	23.4	98.47	1991	Sep	23.95	99.37
1985	Oct	22.3	57.34	1988	Oct	22.5	59.58	1991	Oct	23.25	51.86
1985	Nov	19	15.42	1988	Nov	20.75	0	1991	Nov	21	0.26
1985	Dec	15.1	0.03	1988	Dec	16.1	0	1991	Dec	15.1	1.62
1986	Jan	11.7	14.22	1989	Jan	12.35	14.71	1992	Jan	11.35	3.45
1986	Feb	10.55	0.54	1989	Feb	9.15	14.53	1992	Feb	10.6	22.08
1986	Mar	11.85	11.59	1989	Mar	11.55	4.63	1992	Mar	11.25	19.41
1986	Apr	15.65	7.88	1989	Apr	16.35	10.32	1992	Apr	15.7	14.3
1986	May	22.25	8.06	1989	May	20.95	1.37	1992	May	21.35	5.18
1986	Jun	24.3	9.41	1989	Jun	27.15	2.65	1992	Jun	24.8	6.2
1986	Jul	27.6	25.08	1989	Jul	19.6	0.06	1992	Jul	27.85	8.83
1986	Aug	23.5	106.45	1989	Aug	24.45	81.43	1992	Aug	24	65.8
1986	Sep	23.35	72.12	1989	Sep	24.1	59.73	1992	Sep	23.25	101.23
1986	Oct	22.95	11	1989	Oct	23.8	11.39	1992	Oct	23.05	28.8
1986	Nov	19.25	20.55	1989	Nov	21.8	0.64	1992	Nov	20.75	0.23
1986	Dec	15.8	4.74	1989	Dec	16.05	5.1	1993	Jan	15.9	1.07
1987	Jan	10.6	64.86	1990	Jan	11.25	10.25	1993	Feb	4.95	0.25
1987	Feb	11.15	10.13	1990	Feb	13.2	2.77	1993	Mar	5.2	0.94
1987	Mar	13.2	6.76	1990	Mar	11.7	16.11	1993	Apr	10.35	0.55
1987	Apr	16.7	7.59	1990	Apr	14.7	22.12	1993	May	14.2	0.69
1987	May	22.5	5.74	1990	May	22.05	3.41	1993	Jun	16.25	0.9
1987	Jun	22.1	52.44	1990	Jun	26.35	24.45	1993	Jul	17.55	0.51
1987	Jul	28.65	15.25	1990	Jul	28.05	19.84	1993	Aug	17.25	0.18
1987	Aug	27.3	22.52	1990	Aug	24.05	90.83	1993	Sep	15.05	0.56
1987	Sep	24.65	68.5	1990	Sep	23.8	91.95	1993	Oct	8.95	0.28
1987	Oct	24.35	14.71	1990	Oct	23.15	49.89	1993	Nov	6.5	0.43
1987	Nov	20.5	10.26	1990	Nov	20.55	0.25	1994	Dec	3.9	0.67

Table-4.4; Average Monthly Temperature and Average Monthly Rainfall for 1994 to 2007

Year	Avg. Temp	Avg. Rainfall	Year	Avg. Temp	Avg. Rainfall	Year	Avg. Temp	Avg. Rainfall	Year	Avg. Temp	Avg. Rainfall
1994	11.7	0.35	1997	17.1	0.26	2001	19.35	9.13	2004	15.35	0
1994	12.45	0.24	1997	20.25	0.06	2001	19.6	8.59	2005	12.9	3.77
1994	19.5	0.35	1997	24.2	0.53	2001	19	10.87	2005	11.9	9.41
1994	21	0.78	1997	24.95	0.13	2001	18.5	32.9	2005	12	19.95
1994	27.25	0.41	1997	24.55	0.41	2001	16.2	33.98	2005	16.6	19.64
1994	28.45	0.87	1997	23.1	0.3	2001	11.4	27.7	2005	26.1	39.71
1994	23.9	0.55	1997	22.65	0.34	2002	8.8	2.59	2005	29.6	6.03
1994	22.95	0.08	1997	18	0.19	2002	14	0.08	2005	24	11.52
1994	20.7	0.1	1997	15.1	0.08	2002	27.1	0.57	2005	24.35	0.56
1995	12.3	0.1	1998	10.05	0.21	2002	25.75	2.75	2005	23.25	0.72
1995	9.7	0.09	1998	10.85	0.05	2002	23.75	5	2005	22.95	8.62
1995	12	0.1	1998	12.4	0.07	2002	22.25	14.53	2005	18.4	14.53
1995	16.45	0.13	1998	15.2	0.07	2002	20.9	12.18	2006	14.45	11.58
1995	21.1	0.12	1998	22.6	2.07	2002	16.4	9.98	2006	13.8	4.53
1995	28.75	0.4	1998	27.45	27.61	2003	12.8	6.35	2006	19.1	2.89
1995	30.3	0.4	1998	27.5	14.49	2003	11.4	12.22	2006	18.5	13.62
1995	24.2	0.29	1998	25.1	12.91	2003	12.35	11.64	2006	24.2	3.11
1995	22.85	0.48	1998	24.25	4.65	2003	16.75	37.97	2006	27.75	16.36
1995	23.35	0.57	2000	23.15	6.48	2003	22.75	19.51	2006	26.65	16.42
1995	21.5	0.08	2000	2.55	89.57	2003	25.6	0.96	2006	24.5	0.13
1995	16.8	0	2000	1.65	70.71	2003	25.95	1.81	2006	24	0
1996	11.85	0.33	2000	5.5	28.87	2003	23.75	0.63	2006	23.65	0.11
1996	2	0.22	2000	10.25	0.04	2003	23.25	4.33	2006	22.3	7.33
1996	3.85	0.31	2000	15.4	0.08	2003	22.85	10.99	2006	17.5	0.66
1996	7.7	0.11	2000	16.8	0.06	2003	19.8	11.06	2007	13.6	11.86
1996	9.7	0.08	2000	17.55	0.1	2003	15.3	4.66	2007	13.1	6.69
1996	12.3	0.29	2000	18.85	0.13	2004	13.05	2.97	2007	13.1	11.69
1996	16.7	0.4	2000	17.75	0.11	2004	11	10.75	2007	17.75	13.89
1996	17.55	0.35	2000	24.25	0	2004	20	34.96	2007	27	34.74
1996	17.25	0.38	2000	29.5	20.89	2004	23.2	55.55	2007	26.45	21.44
1996	15.75	0.18	2001	9.45	4.5	2004	23.05	17.26	2007	27.7	3.12
1996	10.45	0.21	2001	7.05	3.1	2004	22.75	0	2007	25.45	0
1996	6.9	0.09	2001	9.1	5.9	2004	24	1.9	2007	24.4	0.01
1997	3.35	0.2	2001	11.25	0.02	2004	23.45	6.28	2007	21.9	0.03
1997	9.8	0.32	2001	16.25	3.94	2004	23.15	16.18	2007	19.7	0.04
1997	11.65	0.2	2001	20.8	2.82	2004	18.45	0.9	2007	15.15	0.08
									2007	10.9	0.3

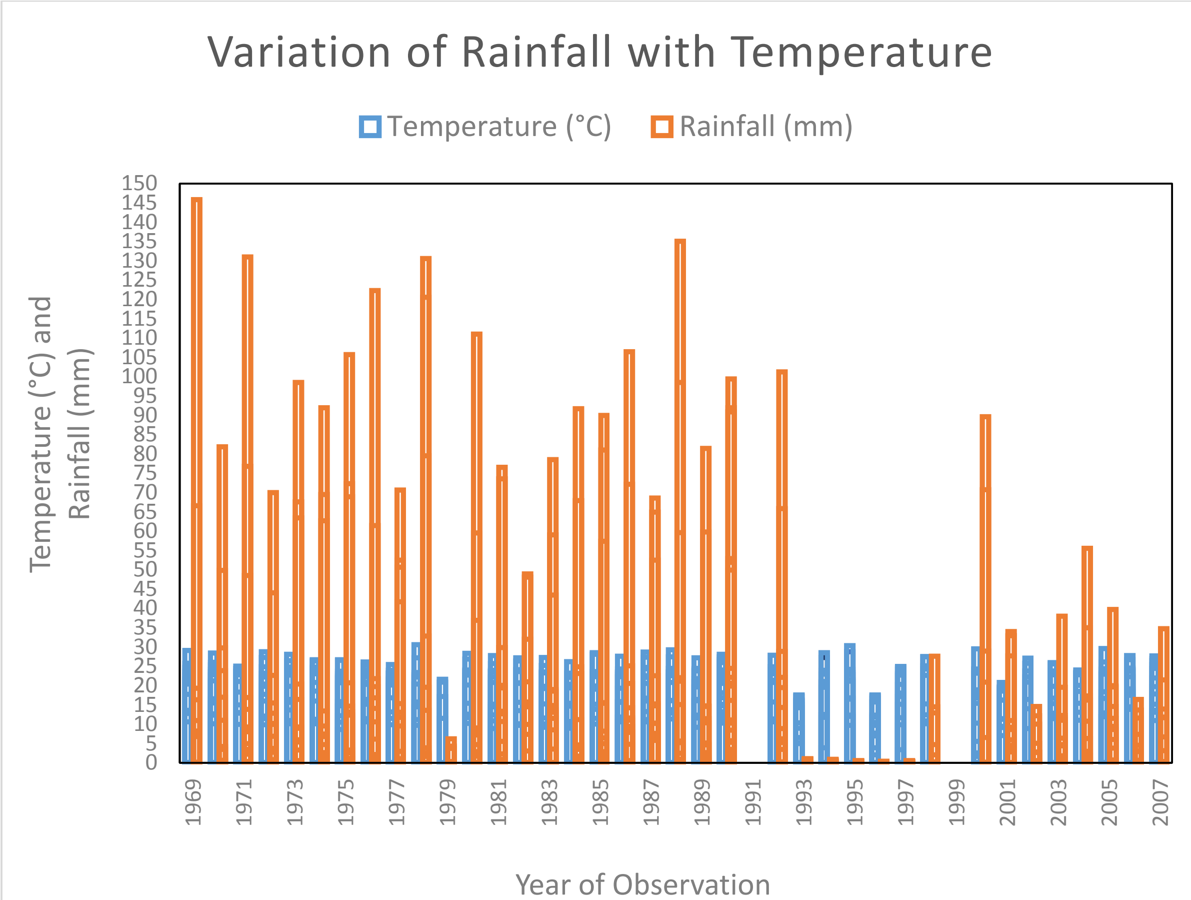

Fig.-4.2; Variation of Average Monthly Temperature and Average Monthly Rainfall from 1969 to 2007.

3.3 REGRESSION ANALYSIS

Simple Linear Regression is carried by taking Average Rainfall as dependent Variable on Average Monthly Temperature. Best suitable line is drawn in respect of the random plot between average rainfall and average temperature.

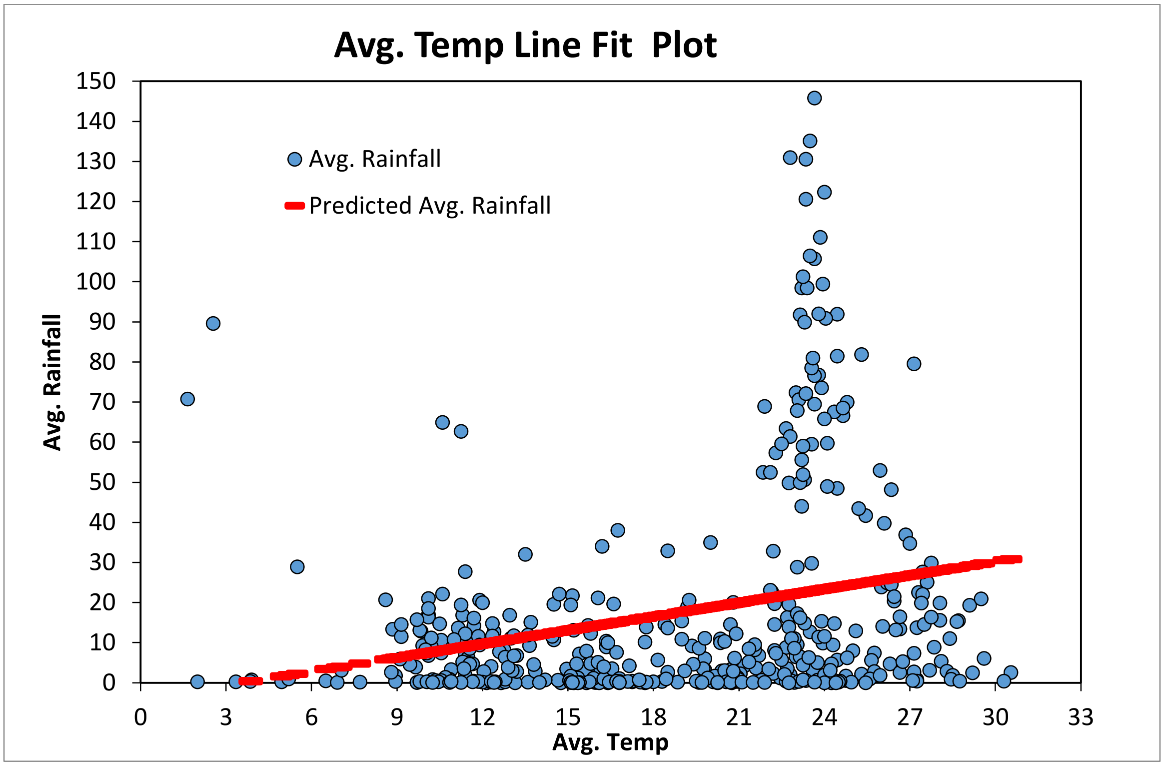

Fig.-4.3; Average monthly Temperature vs Average Rainfall and a predicted line for rainfall by linear regression analysis.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.26
R Square	**0.06**
Adjusted R Square	0.06
Standard Error	26.23
Observations	433

	Coefficients	*Std Error*	*t Stat*	***P-value***	*Lower 95%*	*Uppe r 95%*
Intercept	**-4.079**	4.04	-1	0.31	-12.02	3.86
Avg. Temp	**1.141**	0.20	5.58	0.00	0.74	1.54

3.3.1 OUTPUT ANALYSIS

From the Avg. Temperature and Avg. Rainfall plot it can be clearly observed that there is no such pattern for the obtained data points. Equation obtained for best fit line is as follow:

$$\mathbf{Y = -4.079 + 1.141\ X}$$

From regression statistics value of **R** square is obtained is 0.068 which signifies that there is no significant relationship between the two variables. However, the regression analysis conducted can be particularly conducted over each month or on the rainy season months that can show significant change of precipitation with respect to temperature increase.

3.4 CORRELATION ANALYSIS

Correlation is another way to determine how two variables are related. In addition to telling you whether variables are positively or inversely related, correlation also tells you the degree to which the variables tend to move together.

Correlation standardizes the measure of interdependence between two variables and, consequently, tells you how closely the two variables move. The correlation measurement, called a correlation coefficient, will always take on a value between 1 and – 1:

- *If the correlation coefficient is one,* the variables have a perfect positive correlation. This means that if one variable moves a given amount, the second moves proportionally in the same direction. A positive correlation coefficient less than one indicates a less than perfect positive correlation, with the strength of the correlation growing as the number approaches one.
- *If correlation coefficient is zero,* no relationship exists between the variables. If one variable moves, you can make no predictions about the movement of the other variable; they are uncorrelated.
- *If correlation coefficient is –1,* the variables are perfectly negatively correlated (or inversely correlated) and move in opposition to each other. If one variable increases, the

other variable decreases proportionally. A negative correlation coefficient greater than –1 indicates a less than perfect negative correlation, with the strength of the correlation growing as the number approaches –1.

Formula used for correlation is as follow:

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

Where,
n = Number of pairs of variable
$\sum xy$ = sum of product of paired variables
$\sum x$ = sum of Average Monthly Temperature
$\sum y$ = sum of Average Monthly Precipitation
$\sum x^2$ = sum of squared x variables
$\sum y^2$ = sum of squared y variables

3.4.1 OUTPUT ANALYSIS

Correlation is carried on the above average precipitation and average temperature data is as follow:

	Year	*Avg. Temp*	*Avg. Rainfall*
Year	1		
Avg. Temp	-0.07	1	
Avg. Rainfall	-0.22	0.25	1

Form correlation analysis with respect to time there is a slight decrease in monthly average rainfall, correlation coefficient is -0.22, this is the only significant relation that can be drawn from the correlation coefficient method.

ASSESSMENT OF METEOROLOGICAL DATA FORM 1969 TO 2007 (DHARAMSHALA)

3.5 DATA ANALYSYS

For Dharamshala data analysis is performed by segregation of each month data for Total Monthly Rainfall and Average Monthly Temperature. Correlation coefficient is calculated for each month.

3.5.1 JANUARY MONTH

Table-5.1; Monthly Average Temperature and Total Monthly Rainfall for 1969 to 2007

YEAR	AVG TEMP	TMRF	YEAR	AVG TEMP	TMRF
1969	10.25	75.1	1988	11.45	51.6
1970	10	169.5	1989	9.1	147.3
1971	9.85	92.6	1990	13.75	27.7
1972	11.3	62.9	1991	10.95	8.6
1973	9.95	163.8	1992	11.4	178.8
1974	9.95	57.7	1993	9.75	103.1
1975	8.55	205	1994	12.4	80
1976	10.45	83.8	1995	10.05	86.4
1977	9.85	130.7	1996	10.95	120.5
1978	9.4	38.7	1997	10.6	89.1
1980	9.6	89.4	1998	11.1	22.7
1981	8.6	131.9	2000	7.75	98.7
1982	9.15	209.6	2001	8.35	39.6
1983	9.6	114.7	2002	7.35	50
1984	9.2	17.2	2003	13.6	51.8
1985	10.05	87.8	2005	8.4	4
1986	10.55	5.4	2006	11.75	97.8
1987	11.15	101.3	2007	11.1	0

CORRELATION

	AVG TEMP	*TMRF*
AVG TEMP	1	
TMRF	**-0.20**	1

The variables are perfectly negatively correlated (or inversely correlated) and move in opposition to each other. If one variable increases, the other variable decreases proportionally. The correlation coefficient's value is small hence it shows the inverse relation is weak.

Graphical representation for both variables with time is as follow:

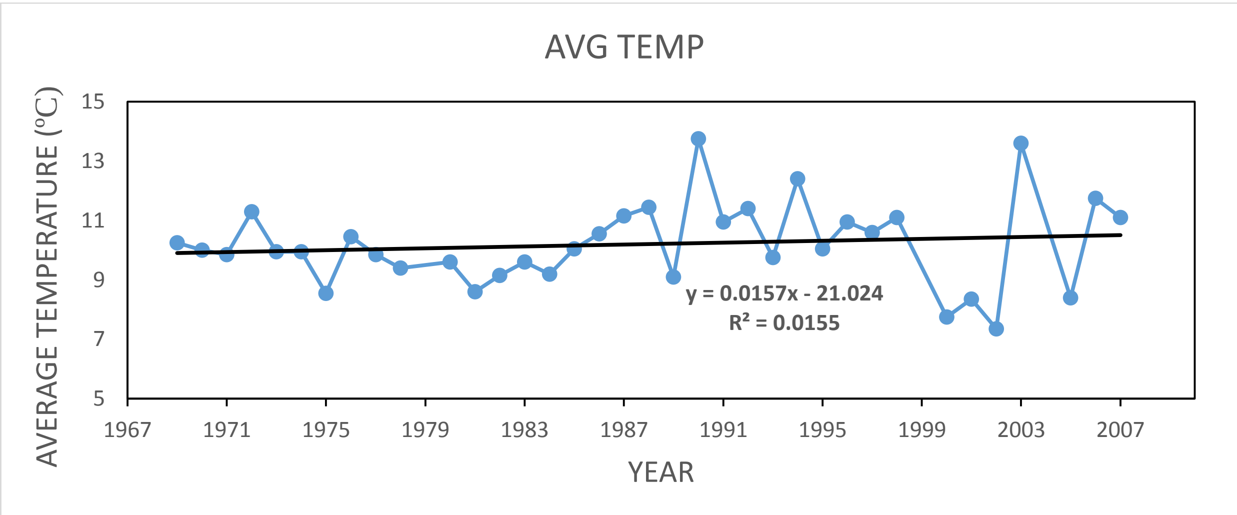

Fig.-5.1; Variation of Average Monthly Temperature from 1969 to 2007.

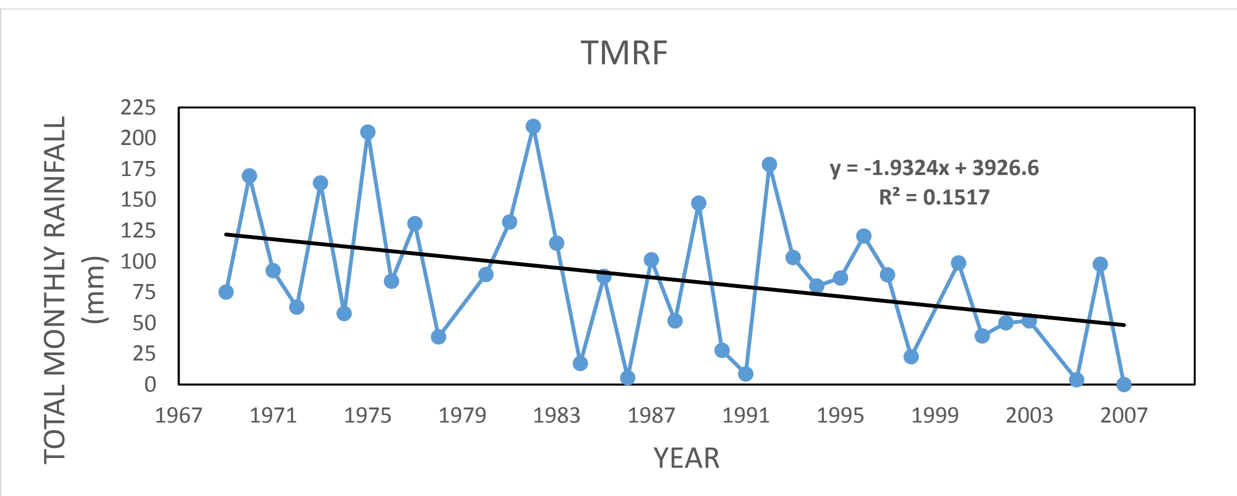

Fig.-5.2; Variation of Total Monthly Rainfall from 1969-2007.

3.5.2 FEBRUARY MONTH

Table-5.2; Monthly Average Temperature and Total Monthly Rainfall for 1969 to 2007.

YEAR	AVG TEMP	TMRF	YEAR	AVG TEMP	TMRF
1969	12.1	81.8	1988	13.4	150.3
1970	11.65	35	1989	11.25	46.3
1971	12.85	168.4	1990	11.9	157.7
1972	10	189.9	1991	13.15	137.3
1973	13.25	92.6	1992	11.75	192.3
1974	10.75	27.4	1993	14.8	55.5
1975	10.05	148.4	1994	12.25	65.7
1976	10.9	189.1	1995	12.3	163.4
1977	12.5	0	1996	12.8	112.8
1978	10.5	135.9	1997	11.75	59.7
1980	11.7	73.9	1998	12.3	231
1981	11.6	102.5	2000	5.4	89.7
1982	8.95	138.7	2001	10.4	28.2
1983	10.1	185	2002	8.2	145.3
1984	10	111.8	2003	14.1	173.6
1985	13.1	18.7	2004	10.1	0
1986	11.45	135.9	2005	7.75	11
1987	13.15	65.7	2006	17.35	27.8
			2007	11.5	245.4

CORRELATION

	AVG TEMP	*TMRF*
AVG TEMP	1	
TMRF	-0.05	1

Correlation between two variables is very week and close to zero. Hence there is no as such relation can be claimed.

Graphical representation for both variables with time is as follow:

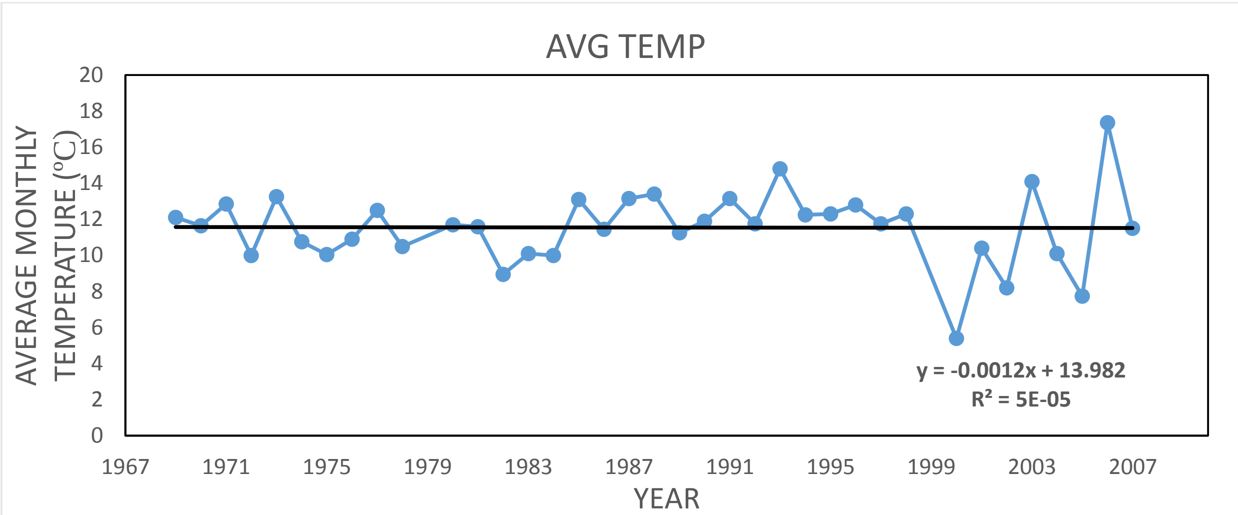

Fig.-5.3; Variation of Average Monthly Temperature from 1969 to 2007.

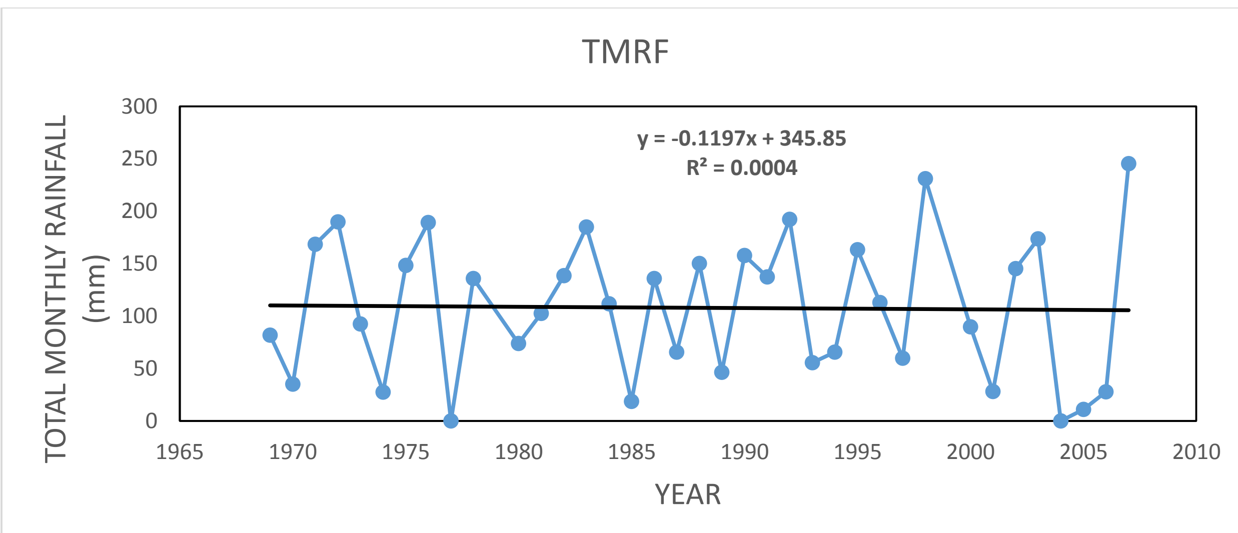

Fig.-5.4; Variation of Total Monthly Rainfall from 1969-2007.

3.5.3 MARCH MONTH

Table-5.3; Monthly Average Temperature and Total Monthly Rainfall for 1969 to 2007.

YEAR	AVG TEMP	TMRF	YEAR	AVG TEMP	TMRF
1969	18.55	109	1988	15.05	211.4
1970	15.75	40.3	1989	15.45	103.8
1971	17.25	3	1990	13.95	223.8
1972	17.55	101.4	1991	17.15	83.3
1973	15.8	84.7	1992	16.15	152.4
1974	18.05	25.8	1993	14.3	253.9
1975	14.5	123	1994	18.7	6.7
1976	14.75	207.5	1995	16	64.8
1977	19.15	1.9	1996	16.9	150.7
1978	13.5	223.6	1997	16.75	104.6
1980	14.05	71.7	1998	14.75	168.6
1981	13.95	211.7	2000	10.85	67.2
1982	12.05	337.9	2001	12.55	36.6
1983	14.6	128.9	2002	13.1	123.8
1984	18.1	46.3	2003	17.9	171
1985	18.65	17.1	2004	13.1	0
1986	15.05	78.8	2005	10.85	8
1987	15.9	78.2	2006	16.25	145.6
			2007	14.7	280.2

CORRELATION

	AVG TEMP	*TMRF*
AVG TEMP	1	
TMRF	**-0.31**	1

Correlation coefficient value is found to be -0.315 which clearly indicates the mild relation between two variables. It shows the dependency of two variables follow an inverse relation.

Graphical representation for both variables with time is as follow:

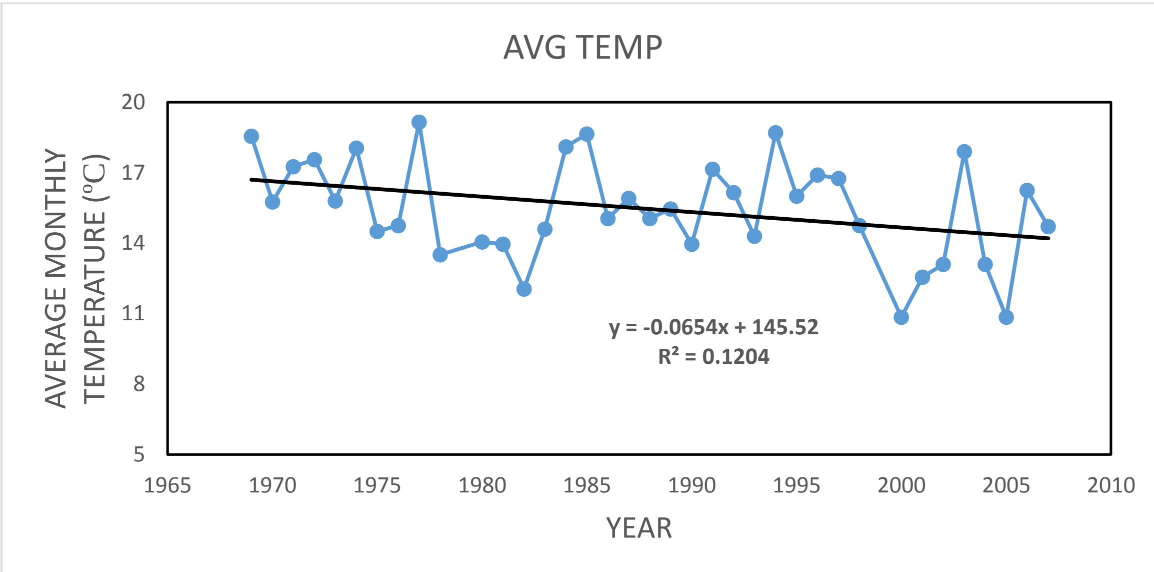

Fig.-5.5; Variation of Average Monthly Temperature from 1969 to 2007.

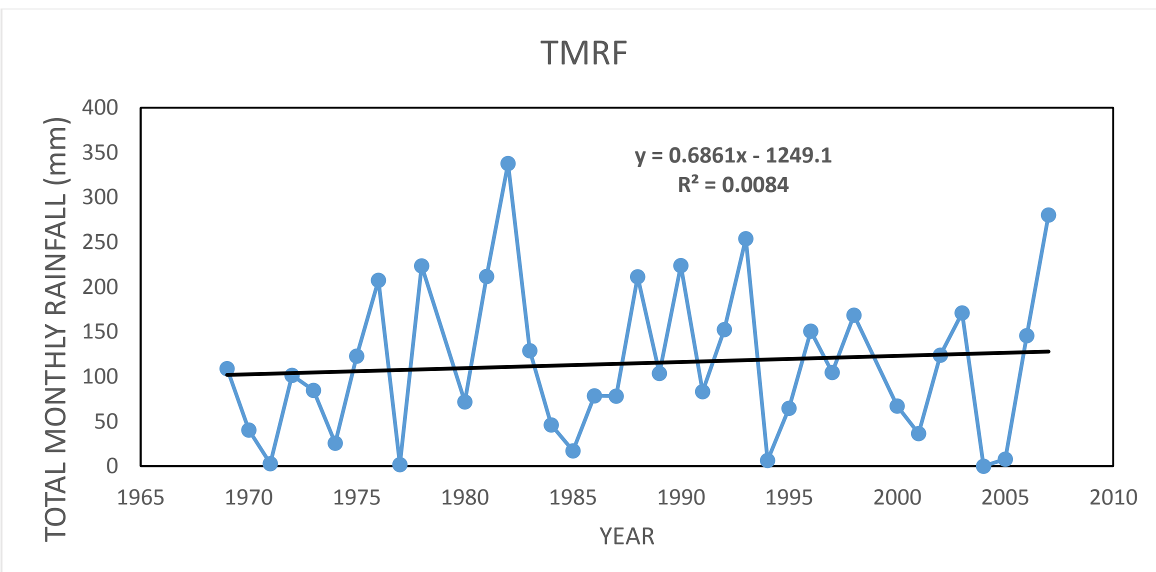

Fig.-5.6; Variation of Total Monthly Rainfall from 1969-2007.

3.5.4 APRIL MONTH

Table-5.4; Monthly Average Temperature and Total Monthly Rainfall for 1969 to 2007.

YEAR	AVG TEMP	TMRF	YEAR	AVG TEMP	TMRF
1969	20.4	67.3	1988	22.7	56.1
1970	23.6	5.9	1989	19.7	19.1
1971	22.5	49.6	1990	20.65	34.4
1972	19.65	99.4	1991	19.7	84.4
1973	23.5	9.7	1992	21.1	53.9
1974	23.5	16.4	1993	21.85	14.2
1975	21.55	11.4	1994	19.8	95.1
1976	19.6	66	1995	20.05	55.5
1977	20.7	96.2	1996	21.55	59.4
1978	21	19.5	1997	19.3	144
1980	22.2	17.5	1998	21.45	168.4
1981	20.7	21.5	2000	18.55	43.8
1982	18.75	145	2001	16.2	95
1983	17.75	160.8	2002	17.8	99.8
1984	21.35	34.6	2003	23.6	48.4
1985	21.35	64.6	2004	14.65	4
1986	20.7	80.6	2006	21.4	33.2
1987	20.9	67.8	2007	23.15	16.4

CORRELATION

	AVG TEMP	*TMRF*
AVG TEMP	1	
TMRF	**-0.39**	1

Correlation coefficient is -.31, it indicates moderate inverse relation between two variables. The inverse dependency is found to be stronger as compare to previous month correlation coefficients.

Graphical representation for both variables with time is as follow:

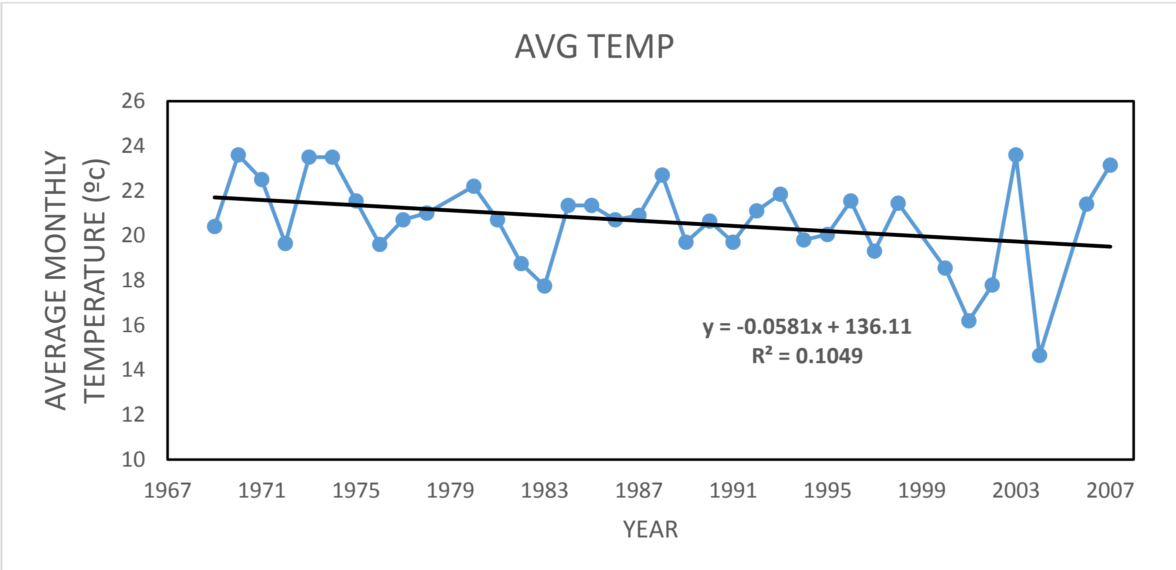

Fig.-5.7; Variation of Average Monthly Temperature from 1969 to 2007.

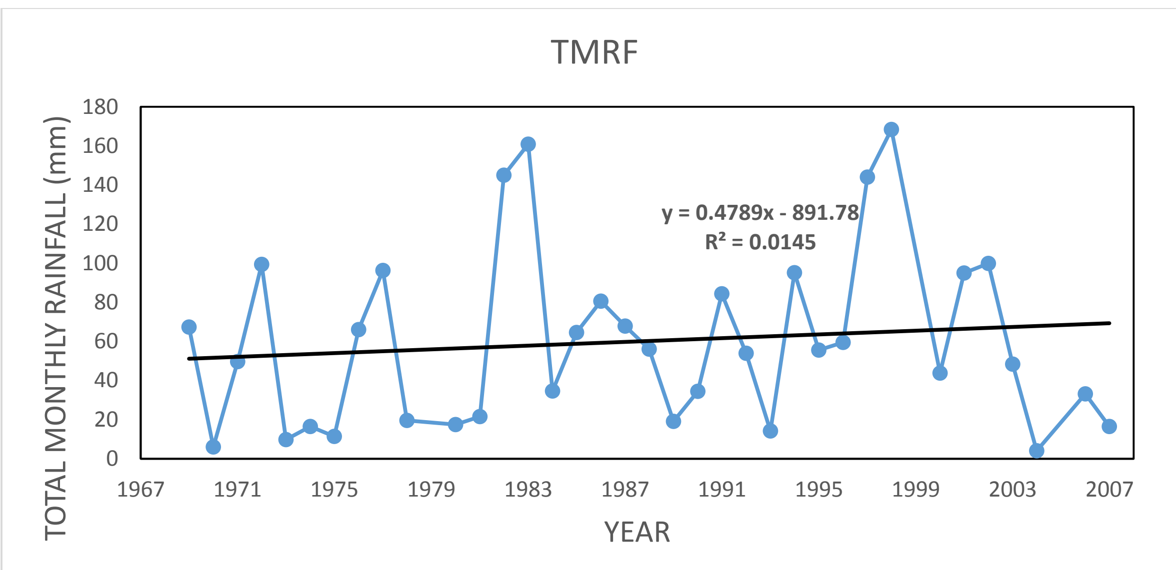

Fig.-5.8; Variation of Total Monthly Rainfall from 1969-2007.

REGRESSION ANALYSIS

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.39
R Square	**0.15**
Adjusted R Square	0.13
Standard Error	41.79
Observations	36

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	**240.65**	72.52	3.32	0.00
AVG TEMP	**-8.76**	3.50	-2.50	0.02

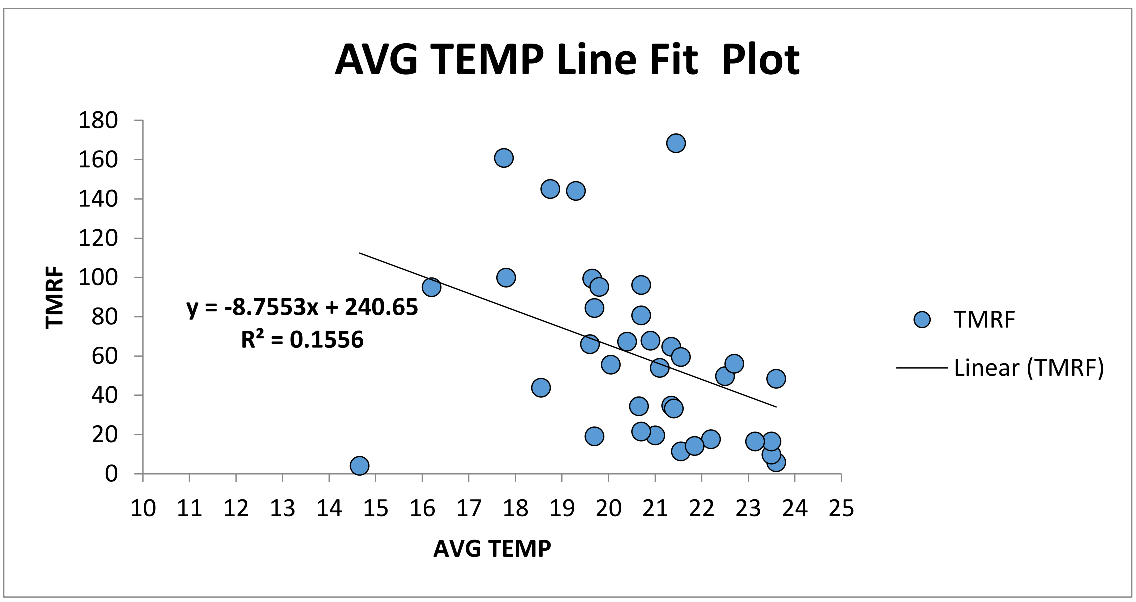

Fig.-5.9; Linear regression model between Average Temperature and Total Monthly Rainfall

3.5.5 MAY MONTH

Table-5.5; Monthly Average Temperature and Total Monthly Rainfall for 1969 to 2007.

YEAR	AVG TEMP	TMRF	YEAR	AVG TEMP	TMRF
1969	22.95	73.4	1988	27.25	19
1970	26.7	65.4	1989	25.4	26.5
1971	23.5	79.7	1990	25.15	244.5
1972	25.95	7.9	1991	25.6	53.6
1973	26.45	51.1	1992	23.75	71.5
1974	25.45	46.8	1993	26.9	70.4
1975	25.5	25.3	1994	24.9	67.5
1976	24	71	1995	26.8	3
1977	22.3	152.8	1996	24.8	35.3
1978	27.9	25.5	1997	23.3	70.8
1980	26.6	30.9	1998	25.8	5.8
1981	23.95	56.4	2000	20.7	123.4
1982	21.8	99.1	2001	20.4	108.9
1983	21.95	148.2	2002	21.7	63.5
1984	28.2	4.5	2003	26.05	31.6
1985	26.25	44.9	2004	15.7	4
1986	22.3	102.4	2005	23.95	17.2
1987	20.55	208.4	2006	24.85	215.6
			2007	23.65	121.4

CORRELATION

	AVG TEMP	*TMRF*
AVG TEMP	1	
TMRF	**-0.34**	1

Correlation coefficient is -.34, it indicates moderate inverse relation between two variables. The inverse dependency is found to be stronger as compare to previous month correlation coefficients.

Graphical representation for both variables with time is as follow:

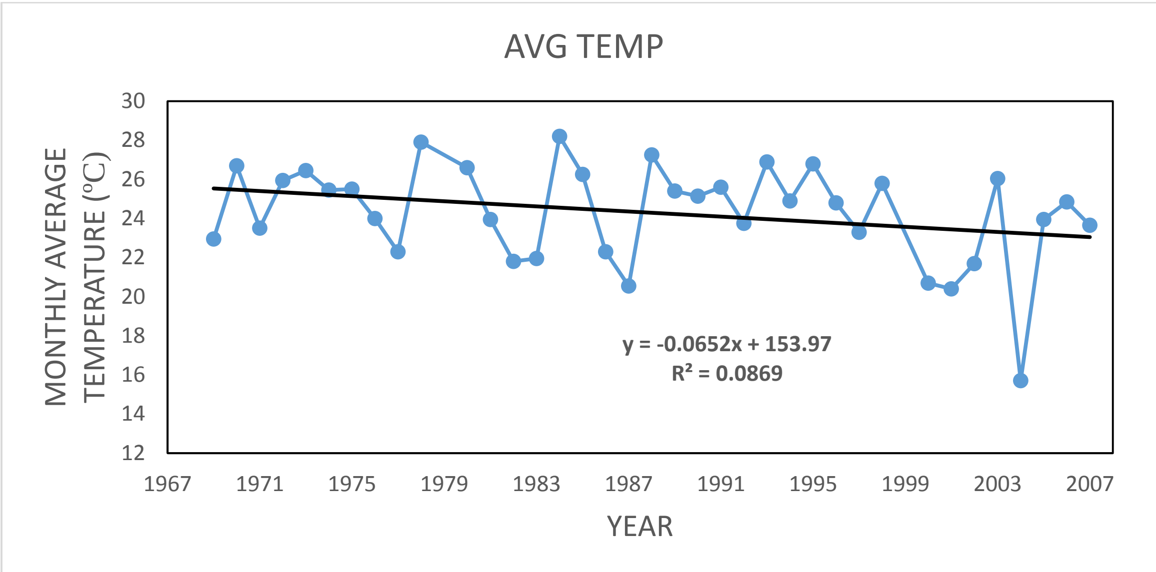

Fig.-5.10; Variation of Average Monthly Temperature from 1969 to 2007.

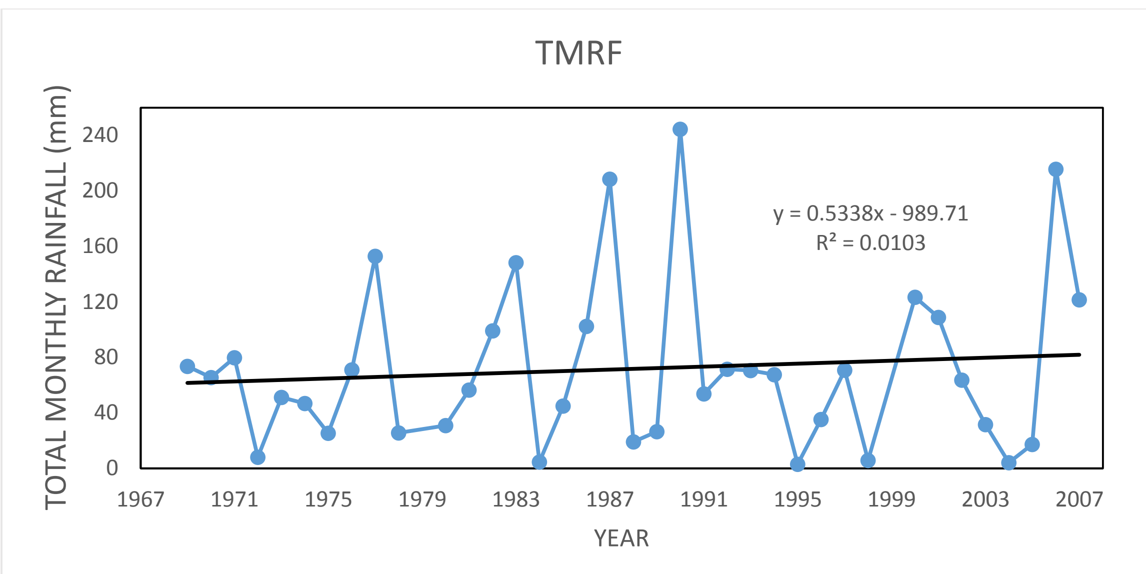

Fig.-5.11; Variation of Total Monthly Rainfall from 1969-2007.

3.5.6 JUNE MONTH

Table-5.6; Monthly Average Temperature and Total Monthly Rainfall for 1969 to 2007.

YEAR	AVG TEMP	TMRF	YEAR	AVG TEMP	TMRF
1969	27.55	181.6	1988	26.55	220.4
1970	24.65	286.2	1989	25.5	56.3
1971	24.4	514.7	1990	26.4	217
1972	27.55	153.7	1991	26.4	198.4
1973	25.8	205.6	1992	26.4	94.7
1974	25.2	133.8	1993	26.75	181.5
1975	25.75	129.7	1994	27.65	451.7
1976	24.9	140.3	1995	29.05	51.5
1977	24.7	362.1	1996	25.4	352.3
1978	26.35	793.8	1997	24.15	226.9
1980	25.75	368.7	1998	26.65	154.8
1981	26.55	248.1	2000	19.7	375.8
1982	25.9	62.3	2001	19.05	314.1
1983	25.55	123.8	2002	20.9	122.2
1984	25.75	211.2	2003	27.85	160.8
1985	26.7	167.2	2004	14.55	13
1986	25.9	236.3	2005	22.8	1133
1987	26.2	152.6	2006	24.65	430
			2007	25.1	433.2

CORRELATION

	AVG TEMP	*TMRF*
AVG TEMP	1	
TMRF	**-0.08**	1

Correlation between two variables is very week and close to zero. Hence there is no as such relation can be claimed.

Graphical representation for both variables with time is as follow:

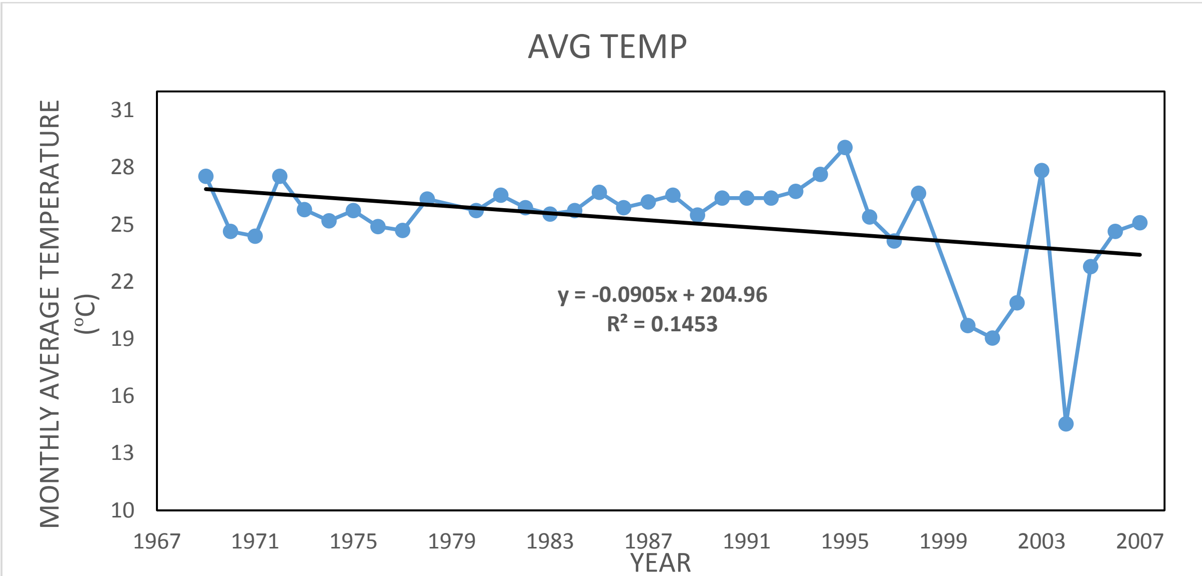

Fig.-5.12; Variation of Average Monthly Temperature from 1969 to 2007.

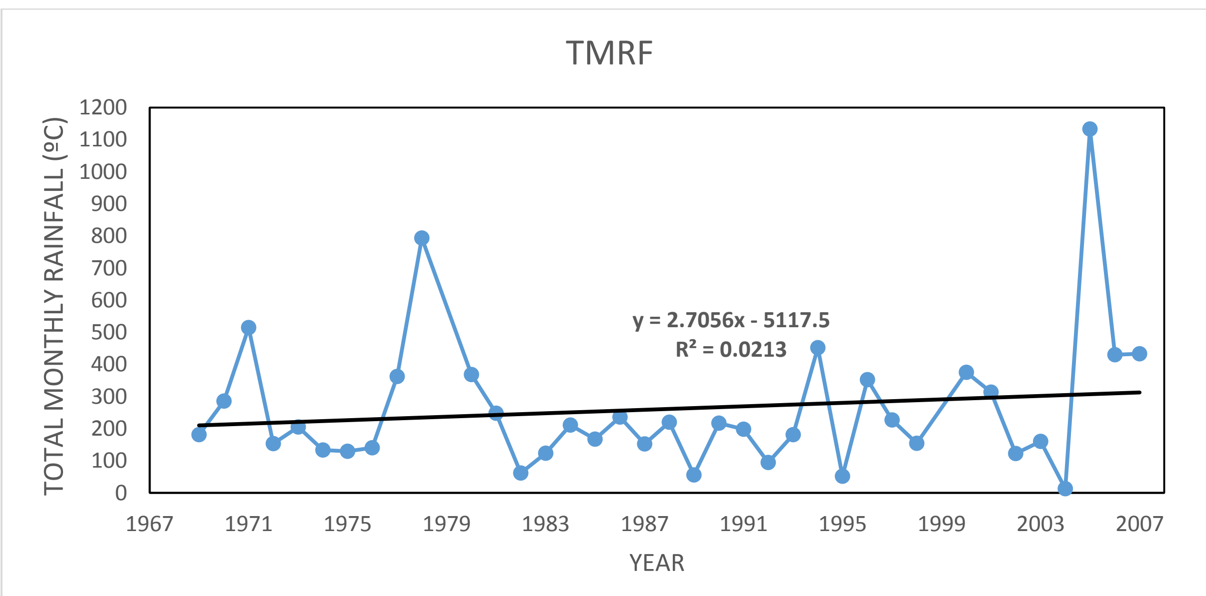

Fig.-5.13; Variation of Total Monthly Rainfall from 1969-2007.

3.5.7 JULY MONTH

Table-5.7; Monthly Average Temperature and Total Monthly Rainfall for 1969 to 2007.

YEAR	AVG TEMP	TMRF	YEAR	AVG TEMP	TMRF
1969	23.95	677.3	1988	23.2	1318.8
1970	24.15	818.6	1989	23.75	803.6
1971	23.4	760.2	1990	23.45	896.7
1972	24.05	700.4	1991	25.4	558.7
1973	24.2	675.3	1992	23.15	706.5
1974	23.8	888.9	1993	23.6	752.3
1975	23.15	1041.7	1994	23.7	1059.4
1976	23.85	1219.9	1995	24.2	719.3
1977	23	1639.9	1996	23.8	460.8
1978	23.15	1294.6	1997	24.45	431
1980	23.5	991.8	1998	24.65	982
1981	23.2	783.1	2000	19.15	407.5
1982	25.5	552.1	2001	20	341.8
1983	24	447	2002	20.85	122.5
1984	22.8	697.4	2003	19.9	31
1985	23.05	840.1	2004	14	22
1986	23	1070.4	2005	22.8	1133
1987	25.7	225.2	2006	23.2	930.6
			2007	23.95	737.6

CORRELATION

	AVG TEMP	*TMRF*
AVG TEMP	1	
TMRF	**0.40**	1

A positive correlation coefficient less than one indicates a less than perfect positive correlation, with the strength of the correlation growing as the number approaches one.

Graphical representation for both variables with time is as follow:

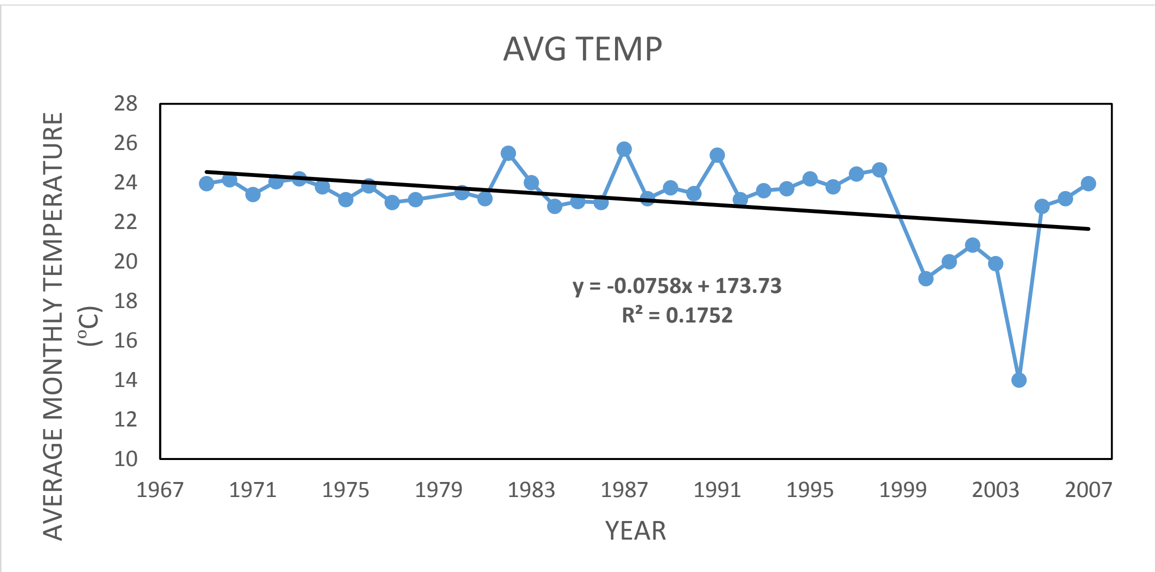

Fig.-5.14; Variation of Average Monthly Temperature from 1969 to 2007.

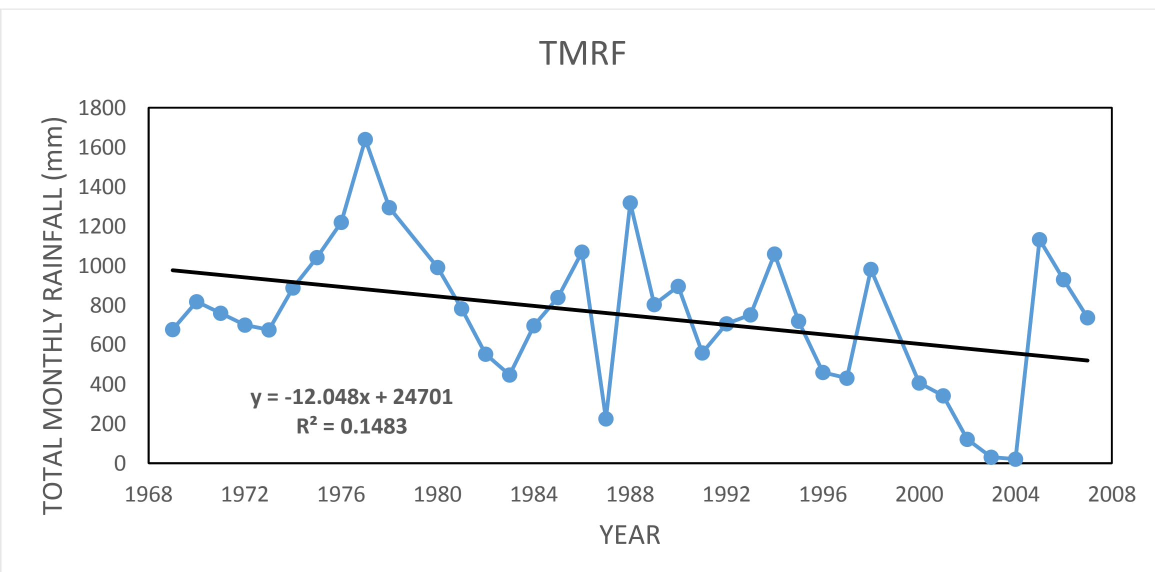

Fig.-5.15; Variation of Total Monthly Rainfall from 1969-2007.

3.5.8 AUGUST MONTH

Table-5.8; Monthly Average Temperature and Total Monthly Rainfall for 1969 to 2007.

YEAR	AVG TEMP	TMRF	YEAR	AVG TEMP	TMRF
1969	23.45	1415.3	1988	23.05	1011.5
1970	23.35	1015.2	1989	23.35	589.3
1971	22.5	1337	1990	23.45	799.8
1972	23.05	398	1991	23.8	1009.4
1973	23.55	950.2	1992	22.55	302.5
1974	23.25	718.8	1993	24.55	335.7
1975	22.9	740.3	1994	23.4	938
1976	22.4	617.3	1995	23.1	952.3
1977	23.05	718.6	1996	23.15	782.6
1978	23	1209	1997	22.65	690.2
1980	23.3	604.9	1998	24.3	754.6
1981	22.95	767.3	2000	19.6	208.4
1982	23.55	489.2	2001	19.6	283.4
1983	23.6	784.5	2002	19.2	383.2
1984	23.3	936.2	2003	13.6	18
1985	23.3	888.2	2004	13.35	19
1986	22.9	689.4	2005	22.9	676.4
1987	23.85	691.4	2006	22.75	840.2
			2007	23.5	751

CORRELATION

	AVG TEMP	*TMRF*
AVG TEMP	1	
TMRF	**0.63**	1

A positive correlation coefficient less than one indicates a less than perfect positive correlation, with the strength of the correlation growing as the number approaches one.

Graphical representation for both variables with time is as follow:

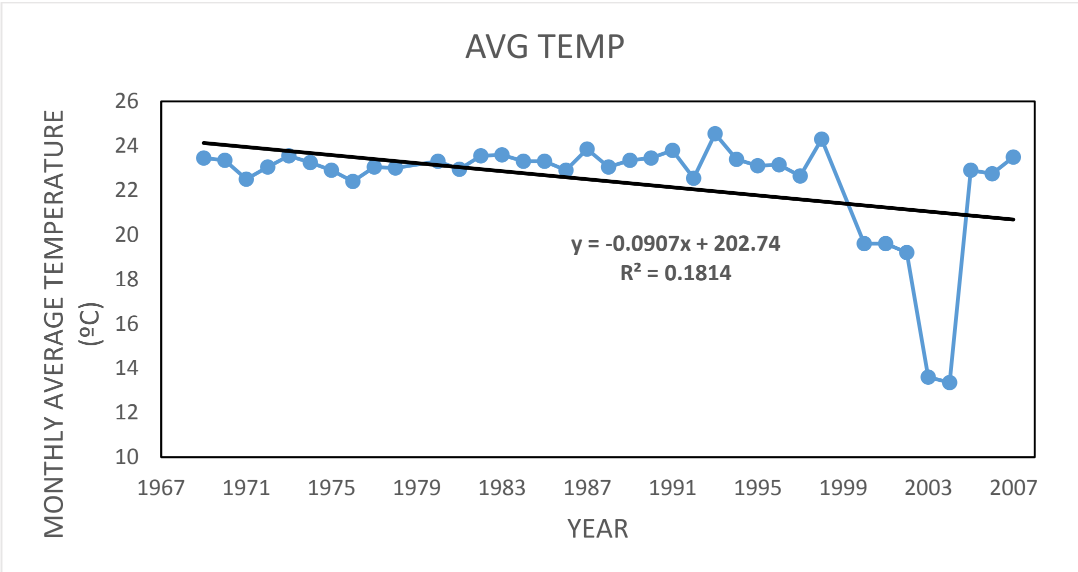

Fig.-5.16; Variation of Average Monthly Temperature from 1969 to 2007.

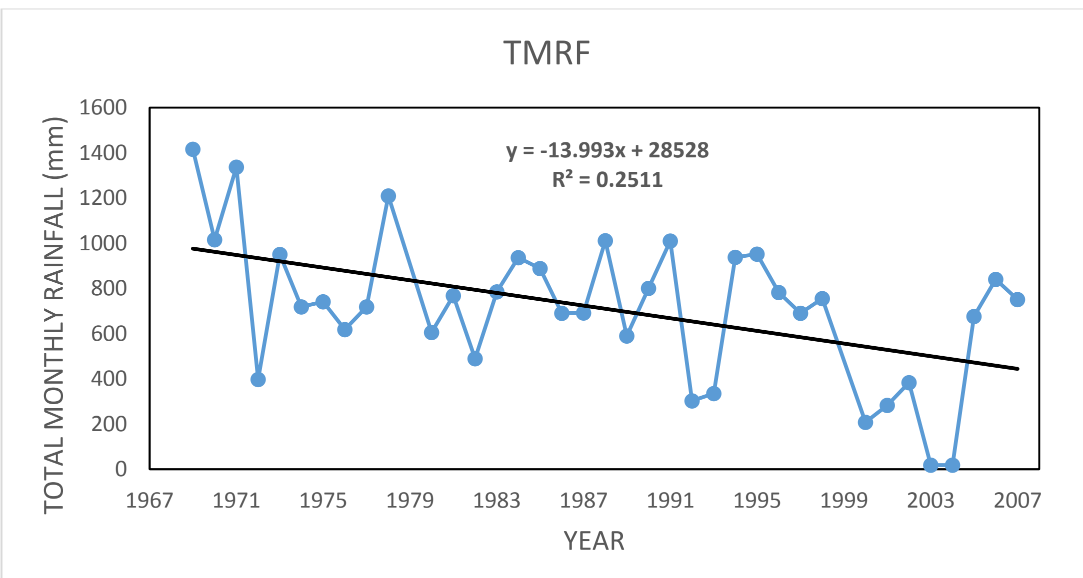

Fig.-5.17; Variation of Total Monthly Rainfall from 1969-2007.

REGRESSION ANALYSIS

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.63
R Square	**0.40**
Adjusted R Square	0.38
Standard Error	250.75
Observations	37

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	**-1156.29**	385.45	-2.99	0.004
AVG TEMP	**83.34**	17.10	4.87	2.35E-05

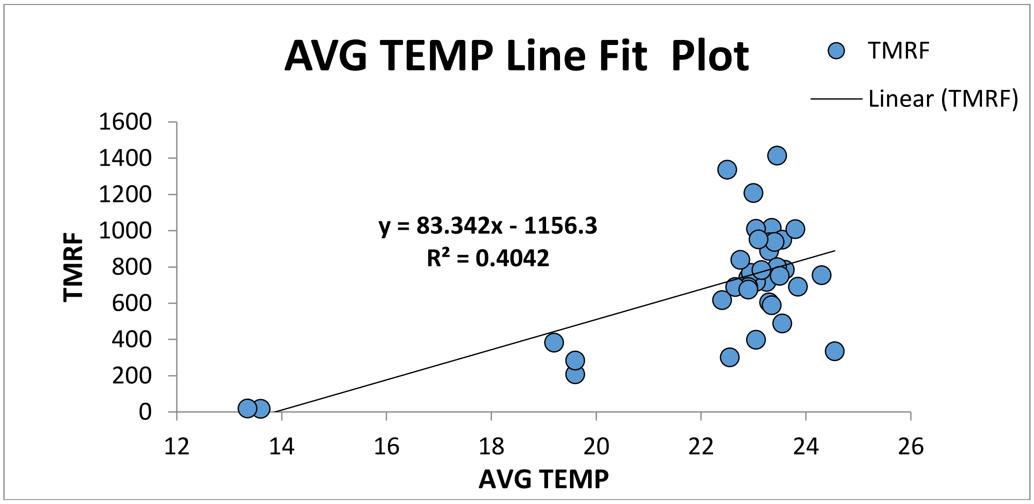

Fig.-5.18; Linear regression model between Average Temperature and Total Monthly Rainfall

3.5.9 SEPTEMBER MONTH

Table-5.9; Monthly Average Temperature and Total Monthly Rainfall for 1969 to 2007.

YEAR	AVG TEMP	TMRF	YEAR	AVG TEMP	TMRF
1969	22.6	205.8	1987	23.4	128.8
1970	22.9	545.2	1988	22	595.8
1971	22.35	138.8	1989	23.2	111.9
1972	21.85	274.4	1990	22.7	498.2
1973	22.65	668	1991	23.05	492.9
1974	22.65	100.5	1993	21.9	471
1975	21.9	688.7	1995	22.9	472.1
1976	21.95	192.8	1996	22.7	368.1
1977	21.65	519.8	1997	22.75	556.4
1978	22.1	306.4	1998	23	270.7
1980	22.25	88	2000	18.95	46.3
1981	22.15	126.8	2001	19.3	25.9
1982	22.65	120.8	2002	17.6	197.1
1983	22.7	590.6	2003	13.4	13
1984	21.2	230.6	2004	13.7	7
1985	21.95	526.3	2005	21.9	590.8
1986	22.15	117.2	2006	21.7	295.6
1987	23.4	128.8	2007	22.35	341

CORRELATION

	AVG TEMP	*TMRF*
AVG TEMP	1	
TMRF	**0.443**	1

A positive correlation coefficient less than one indicates a less than perfect positive correlation, with the strength of the correlation growing as the number approaches one.

Graphical representation for both variables with time is as follow:

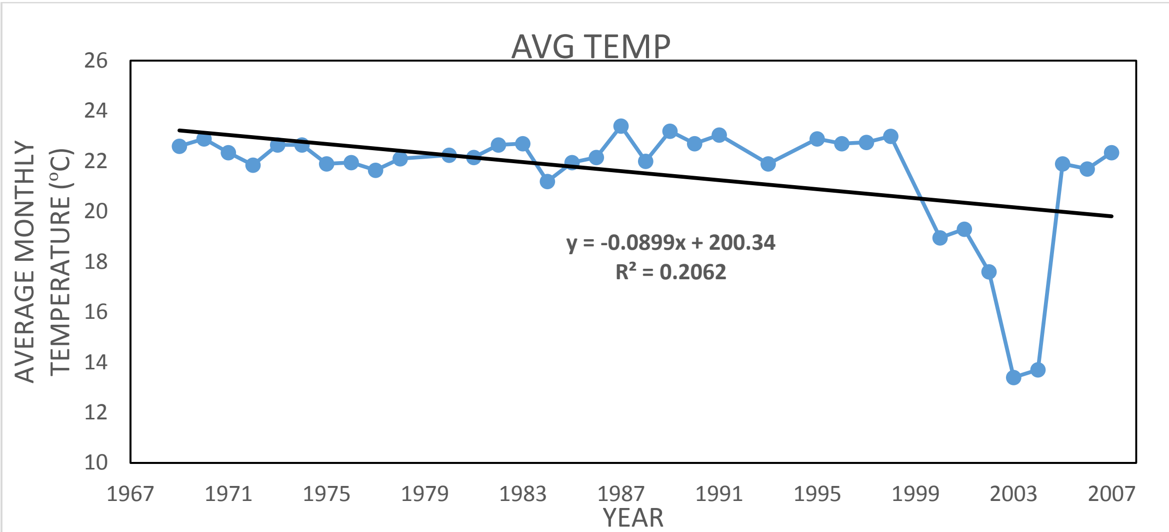

Fig.-5.19; Variation of Average Monthly Temperature from 1969 to 2007.

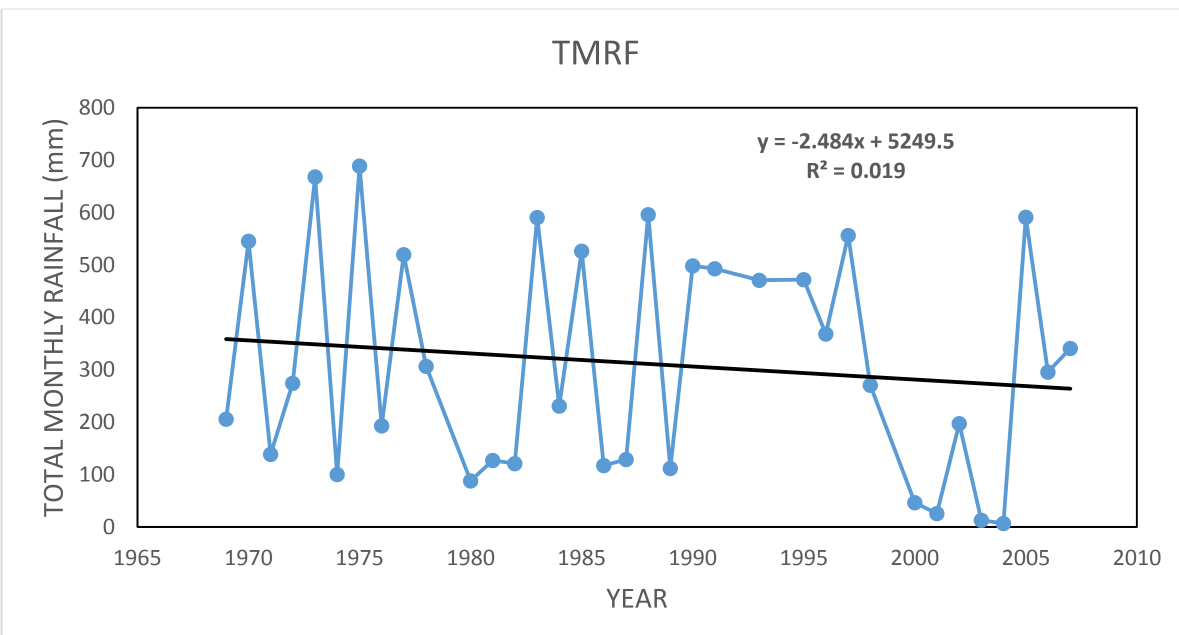

Fig.-5.20; Variation of Total Monthly Rainfall from 1969-2007.

3.5.10 OCTOBER MONTH

Table-5.10; Monthly Average Temperature and Total Monthly Rainfall for 1969 to 2007.

YEAR	AVG TEMP	TMRF	YEAR	AVG TEMP	TMRF
1969	20.4	81.9	1988	19.85	149.6
1970	20.45	43.8	1989	20.05	0
1971	20.4	22.4	1990	21.2	6.4
1972	19.3	31.7	1991	19.9	2.5
1973	19.5	59.6	1992	20.6	2.6
1974	20.25	0	1993	20.4	5.1
1975	20.2	32.5	1994	20.7	0
1976	19.7	31.1	1995	20.35	16.7
1977	19.8	33.4	1996	21.05	2.4
1978	19.8	38.2	1997	19.65	67.2
1980	20.15	3.1	2000	17.8	129.6
1981	19.65	17	2001	17.95	0
1982	18.8	0	2002	17.7	0.8
1983	19.75	30.3	2003	16.5	9.8
1984	18.9	35.1	2004	12.9	0
1985	19.7	0	2005	12	5
1986	18.6	189.3	2006	20.05	32
1987	18.55	206.3	2007	19.6	77.8

CORRELATION

	AVG TEMP	*TMRF*
AVG TEMP	1	
TMRF	**0.0037**	1

Graphical representation for both variables with time is as follow:

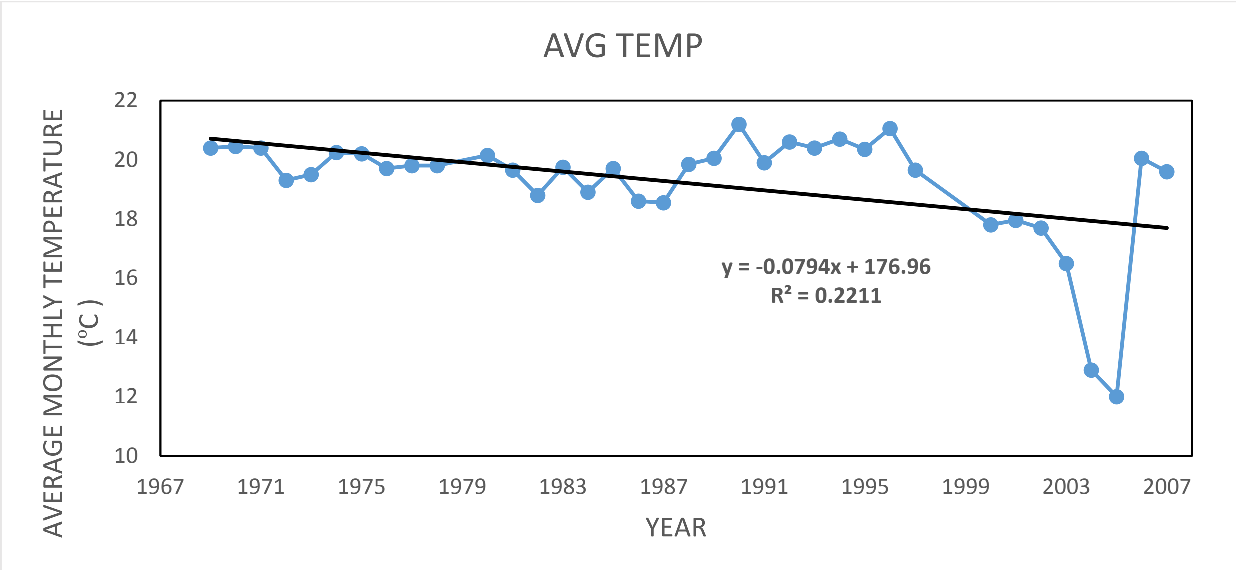

Fig.-5.21; Variation of Average Monthly Temperature from 1969 to 2007.

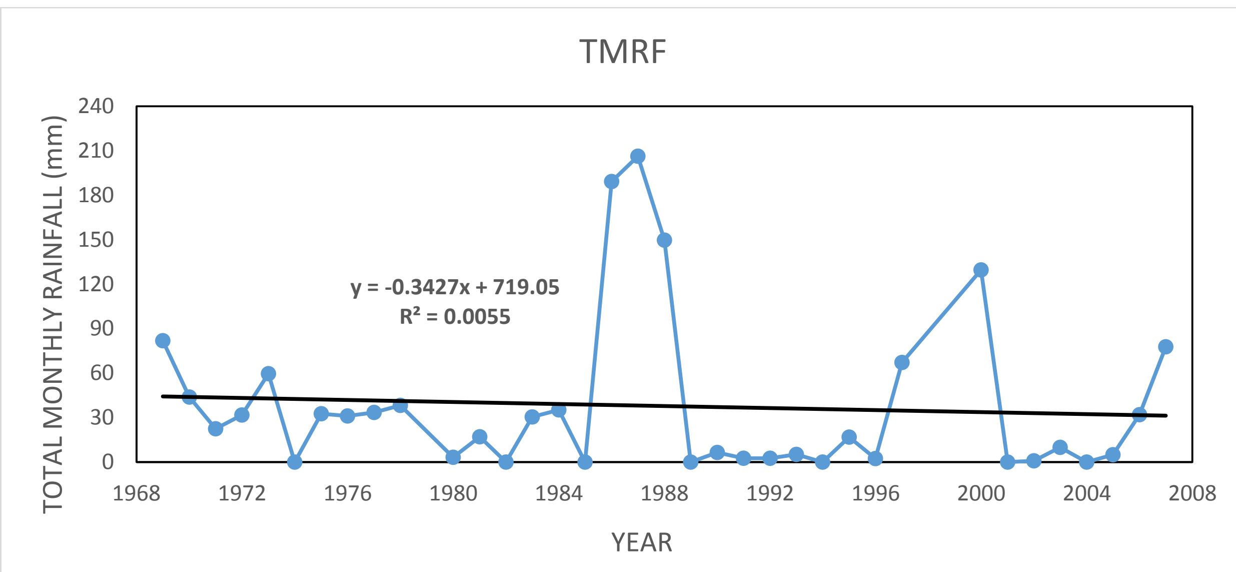

Fig.-5.22; Variation of Total Monthly Rainfall from 1969-2007.

3.5.11 NOVEMBER MONTH

Table-5.11; Monthly Average Temperature and Total Monthly Rainfall for 1969 to 2007.

YEAR	AVG TEMP	TMRF	YEAR	AVG TEMP	TMRF
1969	16.4	0	1987	15.9	84.6
1970	15.25	3.8	1988	16.05	1.9
1971	15.2	34.1	1989	15.9	0
1972	15.85	36.7	1990	16.25	51.3
1973	15.3	0	1991	17.4	2.8
1974	15.75	0.5	1992	15.85	16.2
1975	14.2	0	1994	17.05	11.6
1976	16.3	0	1995	16.55	27.6
1977	16.4	0.7	1996	16.5	0
1978	15.2	23	1997	14.95	78.5
1980	17.05	39.2	2000	13.05	1.9
1981	11	46.9	2001	13.55	5.7
1982	13.25	107	2002	13.5	20.7
1983	15.6	30.4	2003	10.8	2
1984	15.35	0.7	2004	11.15	1
1985	15.25	12.1	2005	15.95	0
1986	15.15	0	2006	15.35	19.6
			2007	17.55	0

CORRELATION

	AVG TEMP	TMRF
AVG TEMP	1	
TMRF	**-0.115**	1

Graphical representation for both variables with time is as follow:

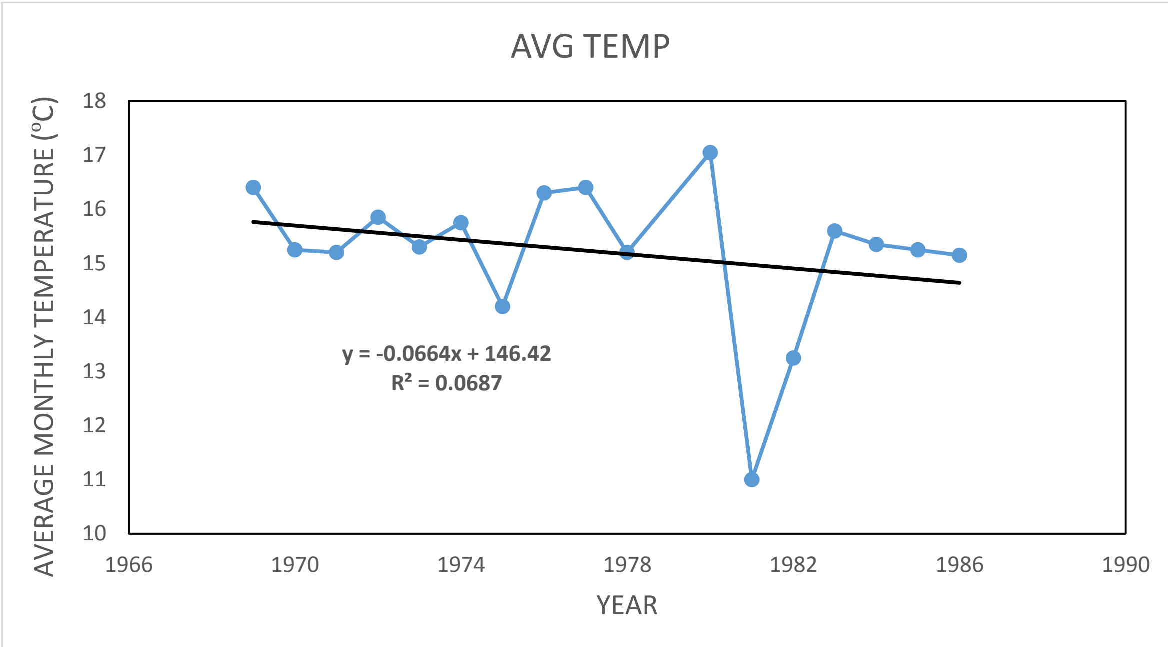

Fig.-5.23; Variation of Average Monthly Temperature from 1969 to 2007.

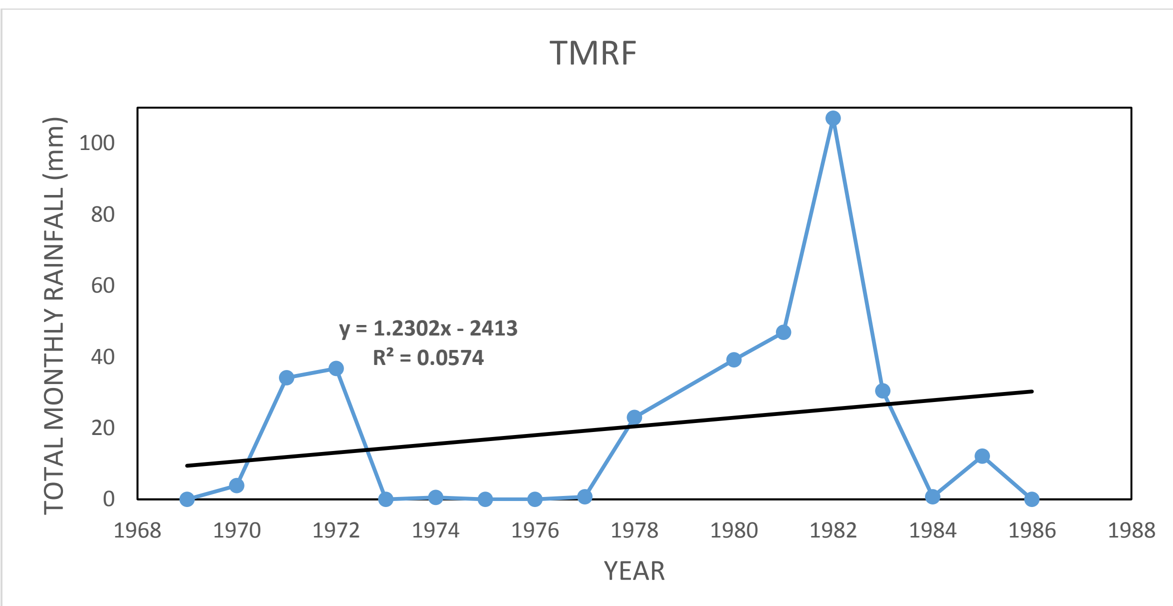

Fig.-5.24; Variation of Total Monthly Rainfall from 1969-2007.

3.5.12 DECEMBER MONTH

Table-5.12; Monthly Average Temperature and Total Monthly Rainfall for 1969 to 2007.

YEAR	AVG TEMP	TMRF	YEAR	AVG TEMP	TMRF
1969	12.9	1	1987	12.4	138.9
1970	12.7	0	1988	12	74.5
1971	12.7	1.8	1989	13.05	205.8
1972	12.1	27.4	1990	13.35	21.5
1973	10.95	32.8	1991	13.7	0
1974	9.95	74.2	1992	14.15	0
1975	12.05	0	1993	12.6	61.8
1976	11.4	11.1	1994	12.6	10.5
1977	11.1	126.8	1995	13.1	9.6
1978	11.45	61.9	1996	10.75	89.1
1979	11	46.9	1998	10.9	0
1980	10.25	8.9	1999	10.4	27.5
1981	11.75	84.8	2000	10.05	0.5
1982	11.35	13.3	2001	9.6	3
1983	12.05	45.8	2002	9.6	2
1984	12.35	144.4	2003	12.5	0
1985	10.8	48.6	2004	12.15	76
1986	13.05	2	2005	13.3	33

CORRELATION

	AVG TEMP	*TMRF*
AVG TEMP	1	
TMRF	**0.031**	1

Graphical representation for both variables with time is as follow:

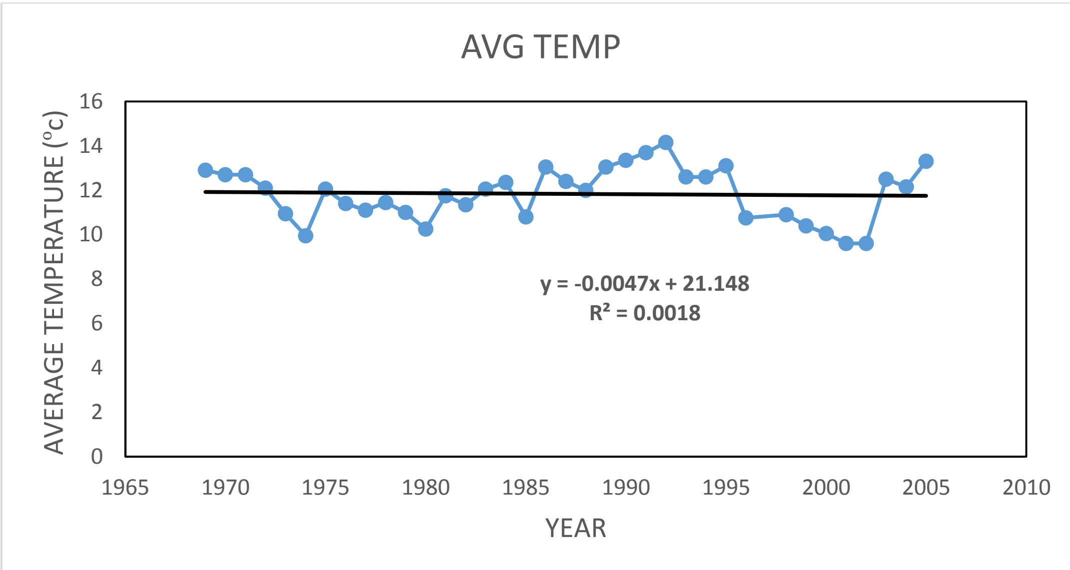

Fig.-5.25; Variation of Average Monthly Temperature from 1969 to 2007.

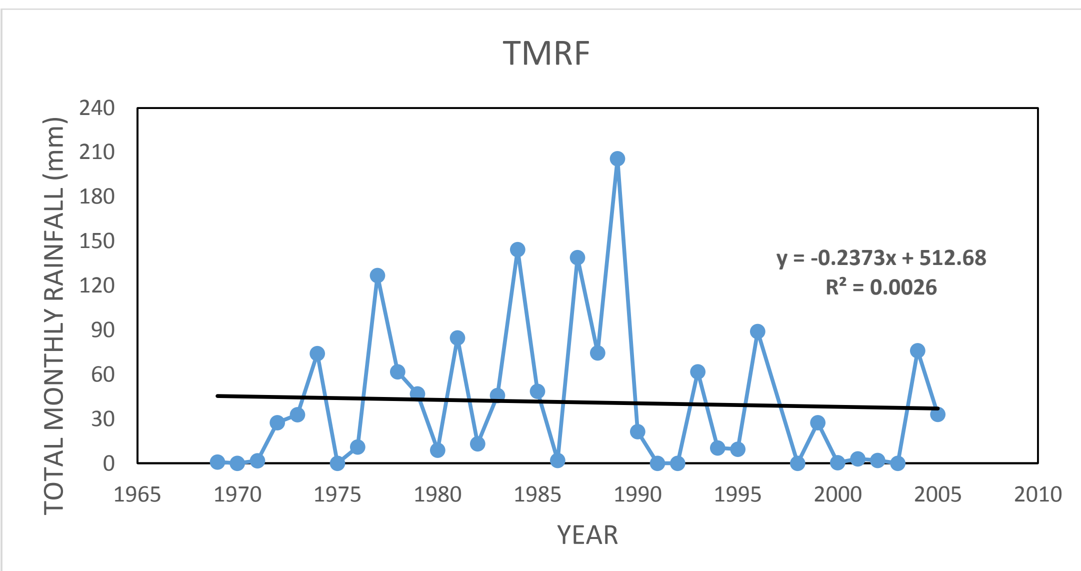

Fig.-5.26; Variation of Total Monthly Rainfall from 1969-2007.

3.6 SNOWFALL DAYS GRAPHICAL REPRESENTATION

Table-5.13; Yearly number of Snowfall days for 1969 to 2007.

YEAR	NO SN	YEAR	NO SN
1969	62	1988	0
1970	58	1989	8
1971	45	1990	9
1972	43	1991	0
1973	40	1992	0
1974	44	1993	0
1975	0	1994	1
1976	0	1995	1
1977	0	1996	0
1978	0	1997	2
1979	0	1998	3
1980	0	1999	0
1981	0	2000	38
1982	0	2001	65
1983	0	2002	57
1984	0	2003	0
1985	0	2004	0
1986	0	2005	0
1987	0	2006	0
		2007	0

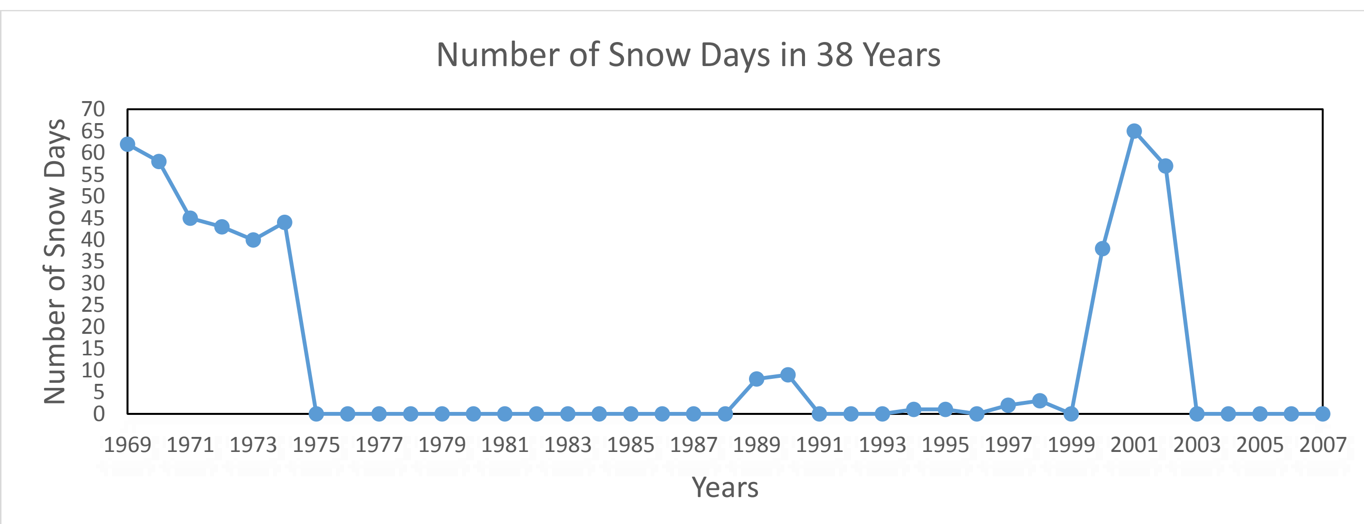

Fig.-5.27; Graphical representation of number of snowfall days for 37 years.

CHAPTER – 4
RESULTS, CONCLUSION AND FUTURE WORK

4.1 RESULTS

	Jan	Feb	Mar	Apr	May	Jun
Correlation coefficient	-0.2	-0.05	-0.31	-0.39	-0.34	-0.08
	Jul	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Correlation coefficient	0.4	0.63	0.44	0.003	-0.115	0.031

- For the months of January, February, March, April, May, June and November coefficient of correlation is obtained negative. Negative correlation depicts inverse relation between two variables.
- For the month of July, August, September, October and December Correlation coefficient is positive. It indicates direct relation between two variables.
- For the month of March, April and May correlation coefficient value is higher which shows moderately stronger dependency of Rainfall on Temperature change.
- For the month of April Simple Regression analysis is carried which provides value of R square 0.15, which is quite higher as compared to other months.
- R square obtained from Simple Regression Analysis for the month of August is 0.4, which indicates dependency of Rainfall over Temperature as higher than any other month.

4.2 CONCLUSION

From the Meteorological Data Assessment of Temperature and Rainfall Data following conclusions can be drawn:

- There is slight dependency of Rainfall on Temperature and increase in Temperature can causes variation in Rainfall pattern.
- Correlation coefficients are lower in values, hence more surface data variables can be included for regression analysis and clear dependency can be judged.

From above discussions it is observed that in Himachal Pradesh the climate change variations are set to arrive in following manner:

4.2.1 TEMPERATURE

- The annual temperatures are set to rise.
- The rise in temperature with respect to 1970s shows a range between 1.5 0C to 2.8 0C.
- Temperatures are also showing a rising trend in all seasons.

4.2.2 PRECIPITATION

- The mean annual rainfall likely to vary between 544.0 mm to 764.4 mm.
- There may be staggering decrease in snowfall patterns in mid-hills temperate wet agro climatic zone.
- The number of rainy days may increase in Himachal Pradesh with decrease in average intensity.
- An increase in rainfall in the pre-monsoon and post-monsoon months with increasing incidence of storms in Himachal Pradesh.
- Decrease in number of snowfall days in Shimla.
- Observed decreasing trend in amount of Snowfall in Shimla.

4.2.3 EXTREME EVENTS

- Change in rainfall patterns with increased variability in future some regions (Southeastern parts) may be experiencing less rainfall. Drought like conditions may prevail in given projections.
- Projected increase in temperature, rainfall, rainfall variations and intensities in the city may lead to accelerated summer flows leading to situations like floods/flash floods.
- Health risks are also associated indirectly with extreme events in sub montane, low hills, and sub humid agro climatic zones of the State.

4.3 FUTURE WORK

- Collection of surface data which includes more parameter for 25 to 30 years.
- Preparing dependency Relation Analysis between more than two variables of Surface data.
- Future Projection of Precipitation and Temperature of year 2020 by extension of curve by obtaining best suitable curve.
- Study of effect of Climate Change on following:
    - Agriculture
    - Water Resources
    - Forest
    - Health
    - Urban Planning
- Adaptation and Mitigation measures to reduce regional vulnerability.

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