RESEARCH ARTICLE

STUDY OF TEMPORAL RAINFALL SCENARIO ON MACRO TO MICRO LEVEL AREAS

Avadhesh Kumar Koshal*

Faculty of Sciences, Motherhood University, Roorkee, Haridwar
Email: akkoshal@hotmail.com

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Abstract: The present study of the twenty five years (1990 to 2015) temporal data of rainfall of India (Country) to Uttar Pradesh (State) and Western U.P. (a part) to Meerut (District) studied to understand pattern of annual and monsoon rainfall. The average normal monthly rainfall of study area of country level to state and District level are observed in India 1152.3mm, in U.P. 955.3mm, in Western U.P. 743.2mm & in Meerut 836.7mm. The long term data analysis of year wise June, July August and September contributes rainfall in India 867.3mm, in U.P. 825.7mm, in Western U.P. 653.4 and In Meerut 692.2mm in south west monsoon rainfall season respectively. The overall study of temporal data of rainfall observed 251% rainfall in the part of Western U.P. whereas observed minimum 80% in the India level. The cumulative study of rainfall data observed in India the cumulative values are observed negative in years 1990-1993 & 2001-2014 The western U.P. positive values in year 1990-1994, 1997 & 2009 to 2015 whereas in Meerut district observed cumulative negative in year 1990 to 1993 & 2015. The overall study of data overall in India has lowest in normal (39%) whereas monsoon rainfall observed 33% precipitation ratio. The monsoon rainfall anomaly were observed in years of 1994 (1.74) , 2008(2.13), 2003 (2.15) &1.56 (1994) showing the highest positive normal rainfall anomaly in India, U.P., Parts of Western U.P. & Meerut respectively. In future, expected normal annual and south west rainfall may be less in year 2030 observed 1005.1mm, 513.4 & 725.7 India, Parts of Western U.P. & Meerut district respectively whereas the monsoon rainfall future expected rainfall are observed in India 812.5mm, in Parts of Western U.P. 417.5mm & in Meerut district 246.3mm. The expected annual & monsoon rainfall in year 2016 to 2030 rainfall patterns are declining stage. This is dynamic view to overall scenario of long term data study of future prospect.

Keyword: Anomaly, Drought, Monsoon, Precipitation, Western U.P.

INTRODUCTION

Rainfall is the primary natural resource of water on the earth and recharges the water in the ground water table. It is a great importance for India's Economy, specially its agriculture industry. It is highly variable over space and time, leads to flood and drought every year on one or the other part of the country. Over 75% of the annual rainfall is received in the four rainy months of June to September only thereby leading to large variations on temporal scale. The country level to district level study found the basic information about rainfall. The country received annual rainfall of 91% of its normal rainfall of 118.7 cm and during SW monsoon season, 86% of its normal rainfall of 89 cm.

The statistics is provided on monthly, 4 seasons *i.e.* Winter (Jan-Feb), Pre-Monsoon (Mar-May), Monsoon (may be referred as South West Monsoon) (Jun-Sep) and Post-Monsoon (Oct-Dec), and on annual basis (Kaur & Purohit, 2015).

The Uttar Pradesh is much fortunate to get better rainfall in comparison to most of the states of the country. The mean annual rainfall ranges from 650mm in south west corner of the state to 1000mm in the eastern and south eastern parts of the state (Roy & Ahmad 2015).

Western U.P is specific parts of Ganga Plain Region (Planning commission Report, 2005). It covers highly fertile Rohilkhand plain, upper, middle and part of lower Ganga Yamuna doab (Singh & Islam, 2010). The total geographical areas of UP 240,928sqkm and western UP has 72,018 sq.km percentage of total area is 29.6 % rest area 70.4% UP. The climate of the region is tropical monsoon, Rainfall ranges from 600 to 1,000 mm (24–39 in) in the western Uttar Pradesh. Western Uttar Pradesh consists of twenty three districts (Dainik Jagran, 2008) & *(Harit Pradesh, http://en.wikipedia.org /wiki/file:India_Harit_Pradesh_locator_map.svg.,*

Meerut has humid subtropical type climate which is characterized by cool winters and very hot summers. The average annual rainfall of Meerut is about 805.98 mm (Kumar *et al*., 2009). About 80% of the rainfall is received during the south west monsoon (Jain & Kumar, 2012). The monsoon begin by the end of June and last till the end of September.

The present study of the twenty five years (1990 to 2015) temporal data of rainfall of India (Country) to Uttar Pradesh (State) and Western U.P. (a part) to Meerut (District) studied to understand pattern of annual and monsoon rainfall. This is dynamic view to overall scenario of long term data study of future prospect.

RESEARCH ELABORATIONS

Objectives

The temporal rainfall data is useful to understand pattern of annual and monsoon rainfall. The long term dynamic data statistical analyses also help for study of future scenario in rainfall pattern.

*Corresponding Author

Study area

The proposed of combine study area (Fig.1) of country level to state and District level the rainfall play a common role. India, the seventh largest country in the world situated between latitudes 8° 4' and 37° 6' longitudes 68° 7' and 97° 25' (Figure 1) and occupies a geographical area of 32,87, 263 sq.km. (Shobha Rani *et al.,* 2010). The country exhibits great diversity in climate, topography, flora-fauna and land use patterns. The climate may be broadly described as tropical monsoon type. The state level study area, Uttar Pradesh is situated in northern India. Nepal is International boundary of the state. It covers 93,933 miles (243290 Km2). This is most populous state of India. It is the fifth largest state of India. It accounts for 6.88 percent of total area of the country. At present state has 75 districts, 327 tehsils, 822 blocks and 107452 revenue villages. The state is also dividend into 9 agro climatic zones, The largest Gangetic plain region is in the north it includes the Ganges,Yamuna, Doab and the Ghaghra plains. Rainfall is the main source of water resource. Western U.P is specific parts of Ganga Plain Region (Planning commission Report, 2005). It covers highly fertile Rohilkhand plain, upper, middle and part of lower Ganga Yamuna doab (Singh & Islam, 2010). The total geographical areas of UP 240,928sqkm and western UP has 72,018 sq.km percentage of total area is 29.6 % rest area 70.4% UP. Coordinates of Western Uttar Pradesh are as following: Latitudinal extent - 29° 58′ 12″ N to 26° 28′ 12″ N Longitudinal extent - 77° 35′ 0″ E to 80° 6′ 0″ E. It lies between the two important streams – the Ganga and the Yamuna (Koshal, 2013). Western Uttar Pradesh shares borders with the states of Uttarakhand, Haryana, Delhi, Rajasthan and Madhya Pradesh, as well as a brief international border with Nepal in Pilibhit district. It is one of the fertile regions of the state of Uttar Pradesh (Rehman, *et al*., 2008). Meerut District is the part of Upper Ganga-Yamuna doaba which lies between $28^0.98'$ & $29^0.15'$ north latitude and between $77^0.45'$ & $77^0.07'$ east longitude (Abst. & Souv., 2016). The altitude / elevation (above sea level) of the city are 224.6 m (Fig.1). The district is spread across 2564 square kilometer .The land of district is very fertile which is known as alluvial soil or loamy soil deposits by Ganga. Meerut has humid subtropical type climate which is characterized by cool winters and very hot summers. The rainfall pattern play vital role in study area and agricultural pattern or distribution.

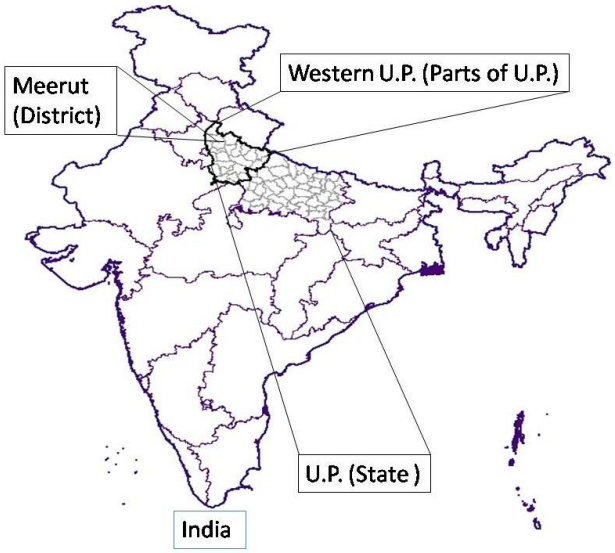


Fig. 1. Study Area

MATERIAL AND METHOD

Statistical Analysis It is inevitable to bring crops and climatic data into one common format preferably in excel. Handling and analyzing the data in this format is easy and conversion to other formats (Fig. 2).

The Data and Method

The present study is based on secondary sources of time series data obtained 25 years 1990- 2015. The data were collected from the published records, bulletin of the Directorate of Agricultural Statistics and the Institute of State Planning, U.P., ICAR, DRR and other national level institute.

The climatic data (annual rainfall) of study area for continuous 25years 1990 to 2015 data were obtained from India water portal website, IMD, New Delhi & NASA POWER (1990-2002, 2003, 2004-06 &2007-13 & 2014-15) (Rainfall data Info: a,b,c,d & e). The data set used in this study is derived from the time series of annual and monsoon precipitation. The S-W rainfall data analysis to observed pattern of trend and develop forecasting model for future scenario. The different type of statistical data analysis *viz.* Coefficient of Variation (CV), Standard deviation, Correlation of Coefficient (R^2), Departure and Cumulative departure and Trend Analysis to given important scenario of change pattern of time series data in MS Excel.

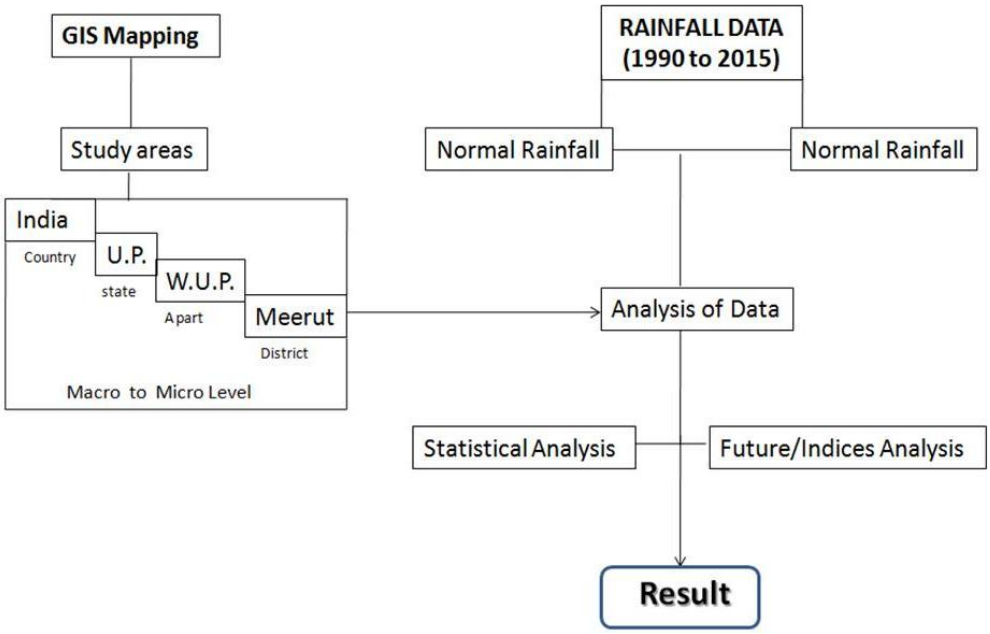


Fig. 2. Methodology

The Following formula has been used for determining Mean, Standard Deviation and Co-efficient of Variation.

(a) Mean $(\bar{x}) = \frac{\sum x}{N}$

Where,

x = rainfall variables, N = number of years

(b) Standard Deviation $(\sigma) = \frac{\sum(x-\bar{x})^2}{N}$

Where,

$\bar{x}$ = the mean value as is defined above.

In computing the deviation score $(\bar{x} - x)$ and the standardized anomaly, formula *viz.*

(c) Standardirzed anomaly $= \frac{(x-\bar{x})}{STD}$

Where,

x is the annual rainfall totals, $\bar{x}$ is the mean of the entire series and STD is the standard deviation from the mean of the series.

(d) Coefficient of variation $= \frac{\text{Standard Deviation}}{\text{Mean}} x100$

It is also referred to as the coefficient of mean deviation, is defined as the ratio of the standard deviation to the mean of the data set.

(e) Median: It is the middle value when the data is arranged in order of size.

(f) Coefficient of Skewness: The *coefficient of skewness* measures the skewness of a distribution. It is based on the notion of the moment of the distribution.

$$\text{Skewness} = \frac{\bar{x} - \text{Mode}}{\text{Standard Deviation}} x100$$

Where,

$\bar{x}$ represents the **arithmetic mean**

This measure is equal to zero if the data are distributed symmetrically.

Precipitation ratio (%)

The abnormalities of rainfall at any location may be brought by a simple ratio of precipitation. It is the difference between maximum and minimum rainfall of the annual rainfall series expressed in terms of mean.

$$P_R = \frac{(P_{Max} - P_{Min})}{P_{Mar}} x100$$

Where,

PR = Precipitation Ratio

P_{Max} = Maximum mean annual rainfall

P_{Min} = Minimum mean annual rainfall

P_{MAR} = Mean annual rainfall

RESULT AND DISCUSSION

The mathematical and statistical analyses of Normal and South-west rainfall (S-W rainfall) are discussed in below:

Variation of monthly rainfall

The average normal monthly rainfall of 25 years (1990-2015) for combine study area of country level to state (Table 1) and District level are observed in India 1152.3mm, in U.P. 955.3mm, in Western U.P. 743.2mm & in Meerut 836.7mm. the intensity of rainfall increasing from June to September (South-west Monsoon), and suddenly decreasing trend noticed from October to December (Post- monsoon). The analysis of 25 years monthly data observed minimum rainfall observed 447.6mm in Western U.P. (1997) and highest rainfall observed in 1401.4mm India (1990). The coefficient of variation for monthly mean rainfall observed highest in the U.P. and it is 214% whereas coefficient of variation is minimum observed in India and it is only 86% (Table 2).

Table 1. Temporal Normal & Monsoon Rainfall (1990 to 2015)

Temporal Normal & Monsoon Rainfall (1990 to 2015)									
	Normal Rainfall				**Monsoon Rainfall**				
Year	**India**	**UP**	**Western U.P.**	**Meerut**	**Year**	**India**	**UP**	**Western U.P.**	**Meerut**
1990	1401.4	1048.1	963.1	916.7	965.2	922.3	963.1	825.9	739.2
1991	1170.2	809.5	771.1	649.7	872.7	749.7	771.1	699.2	569.3
1992	1102.7	829.7	820.1	751.2	848	706.7	820.1	707.7	663.1
1993	1207.8	843	768.8	752.6	889.3	766.9	768.8	699.2	676.3
1994	1295.3	864.7	805.9	1003.8	987.4	796.8	805.9	745.5	930.9
1995	1242.4	876.8	829.4	975.9	914.7	804.6	829.4	774	842.7
1996	1182.9	991.7	940.9	943.1	886.2	812.9	940.9	816.6	793.8
1997	1183.1	954.6	447.6	926.5	866.5	762.9	447.6	376.4	628.6
1998	1208.8	1077.5	865.2	1152.7	882.6	937.3	865.2	770.7	926
1999	1116.6	970.2	787.3	720.2	827.9	856	787.3	723.7	611.9
2000	1035.4	951	773	853.6	798.1	872.1	773	713.9	702.9
2001	1105.2	857.9	696	701.5	822.4	760.2	696	605	626.6
2002	981.9	681.8	729.1	733.6	740.1	581.6	729.1	608.8	630.5
2003	1243.6	1035.2	1129.5	1028.1	947.9	952.7	1129.5	1005.3	883.4
2004	1080.5	814.6	647.2	734.6	774.1	682.7	647.2	496.9	534.3
2005	1208.3	908.4	752.6	842.9	874.4	797.1	752.6	690.1	712.8
2006	1161.6	889.9	510.4	865	889.3	774.8	510.4	438.2	733.3
2007	1179.3	980.7	586.1	1002.1	943	790.9	586.1	469.5	792.8
2008	1118	1194.9	840.4	785.6	877.8	1091.6	840.4	798.3	629.6
2009	953.7	803.9	552.4	569.8	698.3	644	552.4	442.3	444.7
2010	1215.5	992.4	818.7	948.9	911.1	911.8	818.7	772.2	864.5
2011	1116.3	1133.3	776	938.1	901.3	1019.3	776	724.1	794
2012	1054.7	960.7	582.7	759.4	823.9	891	582.7	548.1	685.2
2013	1092.5	1302.3	855.6	1049.2	937.2	1025.3	855.6	758.7	836.1
2014	1045.2	874.2	487	561.4	782.1	645.7	487	339.3	360
2015	1256.7	1190	586.4	587.5	887.1	912	586.4	439.9	384.5

Table 2. Statistical Analysis of rainfall data (1990 to 2015)

Annual Normal Rainfall				
Parameters	**India (av)**	**Uttar Pradesh**	**Western Uttar Pradesh**	**Meerut**
Mean	1152.29	955.27	743.17	836.68
SD	99.31	141.74	159.04	158.25
CV	0.09	0.15	0.21	0.19
CV%	8.62	14.84	21.40	18.91
MIN	953.70	681.84	447.60	561.40
MAX	1401.40	1302.31	1129.50	1152.70
MEDIAN	1165.90	952.83	772.05	848.25
COFF OF SKEWNESS	0.19	0.63	0.08	-0.05
Annual Monsoon Rainfall				
Parameters	**India (av)**	**Uttar Pradesh**	**Western Uttar Pradesh**	**Meerut**

Mean	867.25	825.73	653.44	692.19
SD	69.25	125.10	163.81	153.16
CV	0.08	0.15	0.25	0.22
CV%	7.98	15.15	25.07	22.13
MIN	698.30	581.63	339.30	360.00
MAX	987.40	1091.64	1005.30	930.90
MEDIAN	880.20	800.89	703.45	694.05
COFF OF SKEWNESS	-0.60	0.17	-0.28	-0.48

This shows that rainfall is more stable in the year wise study and is more variable in the month of Meerut and UP. areas. The part of Western U.P. most of the areas are agrarian land and most of the land cover in Kharif and Rabi season of rice-wheat system, it is a primary and dominant system. But due to changing of rainfall pattern showed rainfall deviated 159 then India level only deviated 99.3.

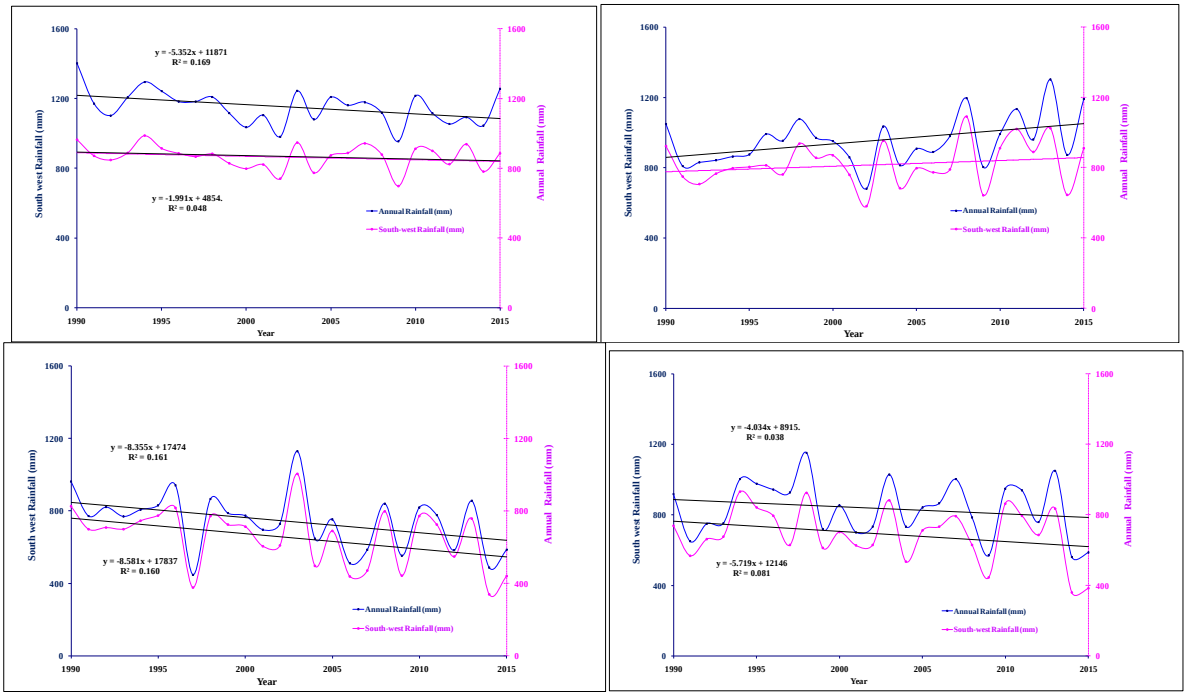


Fig. 3. Rainfall pattern of Normal & Monsoon rainfall

The scenario of temporal rainfall data observed South-west monsoon has maximum rainfall then other seasonal rainfall (Table 1)

Yearly variation of South west monsoon

The long term data analysis of year wise June, July August and September contributes rainfall in India 867.3mm, in U.P. 825.7mm, in Western U.P. 653.4 and In Meerut 692.2mm in south west monsoon rainfall season respectively, the results of the analysis are given in Table 5.

The mean of maximum rainfall is 1091.6mm observed in the U.P.(2008) whereas minimum rainfall is 581.6 observed also in UP (2002). The detail analysis of data the year 2002, 2009 and 2011 were drought year. The most of the Districts were without rainfall.

The overall study of temporal data of rainfall observed 251% rainfall in the part of Western U.P. whereas observed minimum 80% in the India level. The analysis of rainfall data observed deviated rainfall is 163.8 in the parts of Western part of U.P. because of the part more sensible then other areas in South –west rainfall pattern (Table 2 & Fig.3). Because of these pattern of rainfall observed more than 250 and lowest observed only 80% changes are observed. The monthly south-west monsoon rainfall variability in years is observed maximum after 21th century. It is most important period of rainfall temporal cycle.

Rainfall departure and cumulative departure of Normal rainfall

The departure and cumulative departure from average rainfall for the study area has been depicted in Table.3. The trend of annual departure from the computed value of average annual rainfall reveals that;

(a) Years showing annual positive departure with respect to average annual rainfall were

In India: 1990-91, 1993-1998, 2003, 2005-07, 2010 & 2015; In U.P. : 1990, 1996, 1998-99, 2003, 2007-08, 2010-13& 2015; In Western U.P.: 1990-96, 1998-00, 2003, 2005, 2008, 2010-11 & 2013 & In Meerut :1990, 1994-98, 2000, 2003, 2005-07, 2010-11 & 2013. The positive trend of rainfall shows the favourable conditions for recharge.

(b) Years showing annual negative departure with respect to average annual rainfall were

In India: 1992, 1999-02, 2004, 2008-09 & 2011-14; In U.P. : 1991-95, 1997, 2000-02, 2004-06, 2009 & 2014; In Western U.P.: 1997,2001-02, 2004, 2006-07, 2009, 2012 & 2014-15 & In Meerut :1991-93, 1999, 2001-02, 2004, 2008-09, 2012 & 2014-15. The negative trend of rainfall shows the unfavourable conditions for recharge.

The cumulative study of rainfall data observed in India positive in year 1995-99& negative in year 1990-1994 & 2000-15 whereas In U.P. all values of the study area observed negative values. The western U.P. positive values in year 1995-96, 1998-2008 & 2011 whereas in Meerut district observed cumulative value are positive in year 1997 to 2014.

Rainfall departure and cumulative departure of south west rainfall

The departure and cumulative departure from average South west rainfall for the study area has been depicted in Table.4. The trend of annual departure from the computed value of average annual rainfall reveals that;

(a) Years showing annual positive departure with respect to average monsoon rainfall were

In India: 1990-91, 1993-1996, 1998, 2003, 2005-08, 2010 & 2010-11, 2013 &2015; In U.P. : 1990, 1998-00, 2003, 2008, 2010-13& 2015; In Western U.P.: 1990-96, 1998-00, 2003, 2005, 2008, 2010-11 & 2013 & In Meerut :1990, 1994-96,1998, 2000, 2003, 2005-07, 2010-11 & 2013. The positive trend of rainfall shows the favourable conditions for recharge.

(b) Years showing annual negative departure with respect to average annual rainfall were

In India: 1992, 1997, 1999-02, 2004, 2009,2012 & 2014; In U.P. : 1991-97, 2001-02, 2004-07, 2009 & 2014; In Western U.P.: 1997,2001-02, 2004, 2006-07, 2009, 2012 & 2014-15 & In Meerut :1991-93, 1997, 1999, 2001-02, 2004, 2008-09, 2012 & 2014-15. The negative trend of rainfall shows the unfavourable conditions for recharge.

The cumulative study of rainfall data observed in India the cumulative values are observed negative in years 1990-1993 & 2001-2014 whereas in U.P. all values of the study area are observed negative . The western U.P. positive values in year 1990-1994, 1997 & 2009 to 2015 whereas in Meerut district observed 1990 to 1993 & 2015 cumulative value are negative.

Table 3. Rainfall departure and cumulative departure of normal rainfall

Year	Departure from average rainfall India	Departure from average rainfall U.P.	Departure from average rainfall Western U.P.	Departure from average rainfall Meerut	Cumulative departure from average rainfall India	Cumulative departure from average rainfall U.P.	Cumulative departure from average rainfall Western U.P.	Cumulative departure from average rainfall Meerut
1990	249.1	92.8	219.9	80.0	-249.1	-92.8	-219.9	-80.0
1991	17.9	-145.8	27.9	-187.0	-231.2	-238.6	-192.0	-267.0
1992	-49.6	-125.6	76.9	-85.5	-280.8	-364.2	-115.1	-352.5
1993	55.5	-112.3	25.6	-84.1	-225.3	-476.5	-89.4	-436.6
1994	143.0	-90.6	62.7	167.1	-82.3	-567.1	-26.7	-269.4
1995	90.1	-78.5	86.2	139.2	7.8	-645.6	59.5	-130.2
1996	30.6	36.4	197.7	106.4	38.4	-609.2	257.2	-23.8
1997	30.8	-0.6	-295.6	89.8	69.2	-609.9	-38.3	66.0
1998	56.5	122.3	122.0	316.0	125.8	-487.6	83.7	382.0
1999	-35.7	15.0	44.1	-116.5	90.1	-472.7	127.8	265.6
2000	-116.9	-4.2	29.8	16.9	-26.8	-476.9	157.6	282.5
2001	-47.1	-97.4	-47.2	-135.2	-73.9	-574.3	110.5	147.3
2002	-170.4	-273.4	-14.1	-103.1	-244.3	-847.7	96.4	44.2
2003	91.3	79.9	386.3	191.4	-153.0	-767.8	482.7	235.6
2004	-71.8	-140.6	-96.0	-102.1	-224.8	-908.4	386.7	133.5
2005	56.0	-46.9	9.4	6.2	-168.8	-955.3	396.2	139.8
2006	9.3	-65.3	-232.8	28.3	-159.5	-1020.6	163.4	168.1
2007	27.0	25.4	-157.1	165.4	-132.5	-995.2	6.3	333.5
2008	-34.3	239.7	97.2	-51.1	-166.8	-755.5	103.6	282.4

2009	-198.6	-151.3	-190.8	-266.9	-365.4	-906.9	-87.2	15.5
2010	63.2	37.1	75.5	112.2	-302.2	-869.8	-11.7	127.8
2011	-36.0	178.1	32.8	101.4	-338.1	-691.7	21.1	229.2
2012	-97.6	5.5	-160.5	-77.3	-435.7	-686.3	-139.3	151.9
2013	-59.8	347.0	112.4	212.5	-495.5	-339.2	-26.9	364.4
2014	-107.1	-81.1	-256.2	-275.3	-602.6	-420.4	-283.1	89.1
2015	104.4	234.7	-156.8	-249.2	-498.2	-185.6	-439.9	-160.0

Table 4. Rainfall departure and cumulative departure of Monsoon rainfall

Year	**Departure from average rainfall Monsoon India**	**Departure from average rainfall monsoon U.P.**	**Departure from average rainfall Western U.P. Monsoon**	**Departure from average rainfall Monsoon**	**Cumulative departure from average rainfall Monsoon India**	**Cumulative departure from average rainfall Monsoon U.P.**	**Cumulative departure from average rainfall Western U.P. Monsoon**	**Cumulative departure from average rainfall monsoon Meerut**
1990	97.9	96.5	219.9	47.0	-97.9	-96.5	-219.9	-47.0
1991	5.4	-76.0	27.9	-122.9	-92.5	-172.6	-192.0	-169.9
1992	-19.3	-119.1	76.9	-29.1	-111.8	-291.6	-115.1	-199.0
1993	22.0	-58.9	25.6	-15.9	-89.7	-350.5	-89.4	-214.9
1994	120.1	-28.9	62.7	238.7	30.4	-379.4	-26.7	23.8
1995	47.4	-21.1	86.2	150.5	77.9	-400.5	59.5	174.3
1996	18.9	-12.8	197.7	101.6	96.8	-413.3	257.2	275.9
1997	-0.8	-62.8	-295.6	-63.6	96.1	-476.1	-38.3	212.3
1998	15.3	111.6	122.0	233.8	111.4	-364.6	83.7	446.2
1999	-39.4	30.2	44.1	-80.3	72.1	-334.3	127.8	365.9
2000	-69.2	46.3	29.8	10.7	2.9	-288.0	157.6	376.6
2001	-44.9	-65.6	-47.2	-65.6	-41.9	-353.5	110.5	311.0
2002	-127.2	-244.1	-14.1	-61.7	-169.1	-597.6	96.4	249.3
2003	80.6	127.0	386.3	191.2	-88.4	-470.7	482.7	440.5
2004	-93.2	-143.0	-96.0	-157.9	-181.6	-613.7	386.7	282.6
2005	7.1	-28.6	9.4	20.6	-174.5	-642.3	396.2	303.2
2006	22.0	-50.9	-232.8	41.1	-152.4	-693.2	163.4	344.3
2007	75.7	-34.8	-157.1	100.6	-76.7	-728.0	6.3	444.9
2008	10.5	265.9	97.2	-62.6	-66.1	-462.1	103.6	382.3
2009	-169.0	-181.7	-190.8	-247.5	-235.1	-643.8	-87.2	134.8
2010	43.8	86.1	75.5	172.3	-191.2	-557.7	-11.7	307.1
2011	34.0	193.6	32.8	101.8	-157.2	-364.2	21.1	409.0
2012	-43.4	65.2	-160.5	-7.0	-200.5	-298.9	-139.3	402.0
2013	69.9	199.5	112.4	143.9	-130.6	-99.4	-26.9	545.9
2014	-85.2	-180.0	-256.2	-332.2	-215.7	-279.4	-283.1	213.7
2015	19.8	86.3	-156.8	-307.7	-195.9	-193.1	-439.9	-94.0

Precipitation ratio (%)

This ratio may give the stability of rainfall with special relationship. Higher the ratio, higher is the abnormality in rainfall and vice versa (Rathod and Aruchamy, 2010). The minimum and maximum precipitation ratios for different decades were worked out for Meerut District is given in Table 5.

In the study areas observed Western U.P. has maximum abnormality (i.e. 92%) in normal rainfall and also observed in monsoon rainfall (102%) was recorded during 1990-2015 (Tables 4) .The overall study of data overall in India has lowest in normal (39%) whereas monsoon rainfall observed 33% precipitation ratio.

Table 5. Precipitation ratio of Normal and Monsoon rainfall

Precipitation Ratio		
Study area	**Normal Rainfall**	**Monsoon Rainfall**
India	39	33
Uttar Pradesh	65	62
Western UP	92	102
Meerut	71	82

Standardized Normal & Monsoon rainfall anomaly

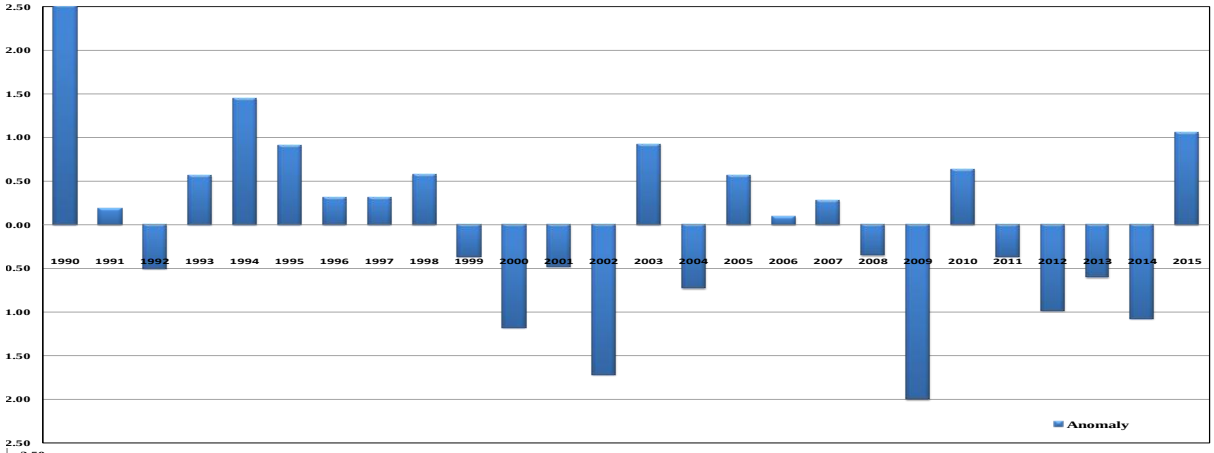
Table 4 depicts the computed annual mean rainfall, departure & cumulative departure of rainfall, seasonal trend and standardized anomalies within the year under consideration (1990-2015) over India, U.P, Parts of Western U.P. & Meerut District. Fig. 4a & 4b. shows the standardized normal rainfall deviations *viz.* in India : 1990-91, 1993-98, 2003, 2005-2008, 2010 & 2015; In U.P.:1990, 1996-99, 2003, 2007-08, 2010-13 & 2015; In Western U.P. : 1990-96,1998-00,2003, 2005, 2008, 2010-11& 2013 and in Meerut: 1990, 1994-98, 2000, 2003, 2005-07, 2010-11& 2013. The monsoon season shows the standardized normal rainfall deviations *viz.* in India :1990-911993-96, 1998, 2003, 2005-08, 2010-11,2013 &2015; In U.P.:1990, 1998-00, 2003, 2008, 2010-13 & 2015; In Western U.P. : 1990-96,1998-00,2003,2005, 2008, 2010-11& 2013 and in Meerut: 1990, 1994-98, 2000, 2003, 2005-07, 2010-11& 2013 are years with above average rainfall. The years of 1990 (2.51) ,2013(2.45), 2003 (2.43) &1998 (2.00) showing the highest positive normal rainfall anomaly in India, U.P., Parts of Western U.P. & Meerut respectively while the other years show rainfall below normal with 2009 (-2.00) ,2002 (-1.93), 1997 (-1.86) & 2014 (-1.74) showing the lowest negative rainfall deviation; those years were drought year of the study area.

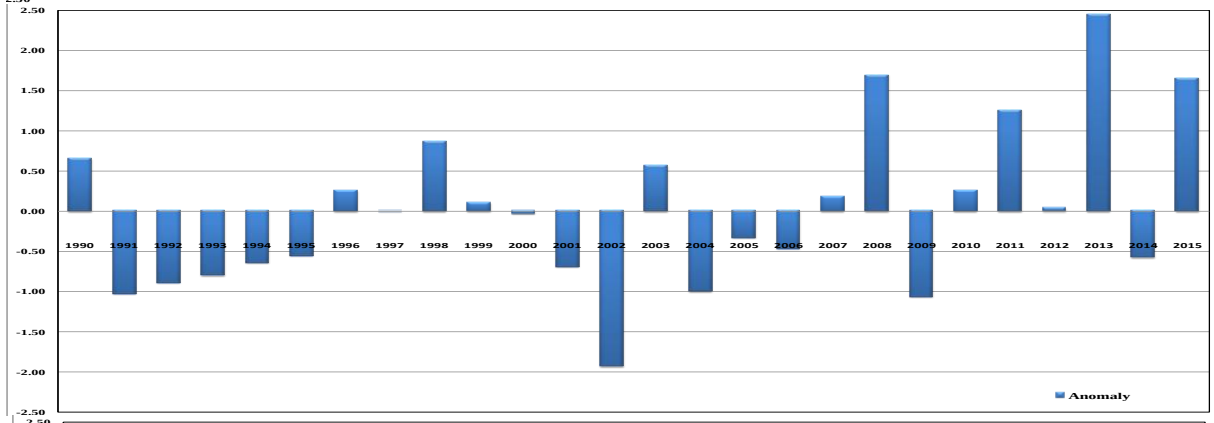
The monsoon rainfall anomaly were observed after data analysis, these years of 1994 (1.74) , 2008(2.13), 2003 (2.15) &1.56 (1994) showing the highest positive normal rainfall anomaly in India, U.P., Parts of Western U.P. & Meerut respectively while the other years show rainfall below normal with 2009 (-2.44) ,2002 (-1.95), 2014 (-1.92) & 2014 (-2.17) showing the lowest negative monsoon rainfall deviation; those years were drought year of the study area.

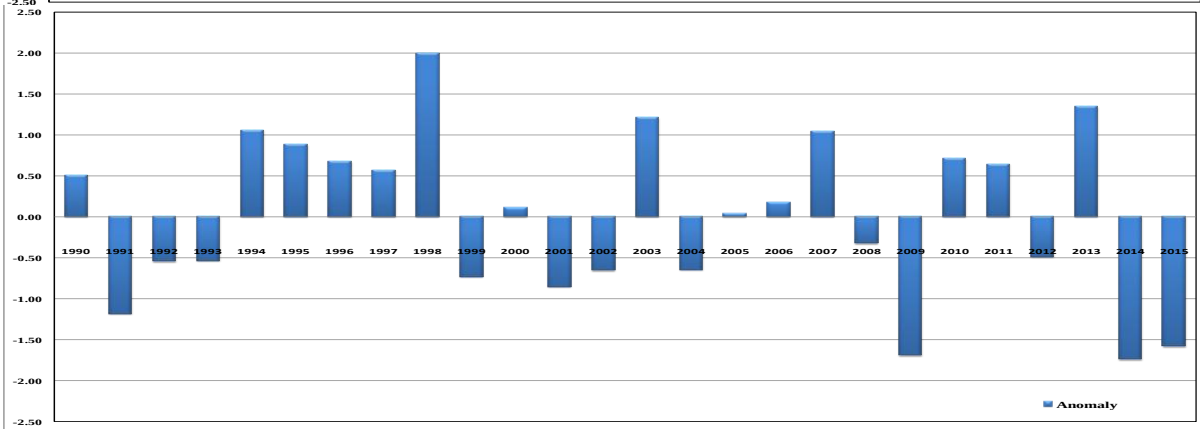
Table 6. Standardized Rainfall Anomaly of Macro to Micro level (1990 to 2015)

Standardized Rainfall Anomaly									
Year	**Normal Rainfall**				**Monsoon Rainfall**				
	India	**UP**	**Western U.P.**	**Meerut**	**Year**	**India**	**UP**	**Western U.P.**	**Meerut**
1990	2.51	0.65	1.38	0.51	2.51	1.41	0.77	1.05	0.31
1991	0.18	-1.03	0.18	-1.18	0.18	0.08	-0.61	0.28	-0.8
1992	-0.5	-0.89	0.48	-0.54	-0.5	-0.28	-0.95	0.33	-0.19
1993	0.56	-0.79	0.16	-0.53	0.56	0.32	-0.47	0.28	-0.1
1994	1.44	-0.64	0.39	1.06	1.44	1.74	-0.23	0.56	1.56
1995	0.91	-0.55	0.54	0.88	0.91	0.69	-0.17	0.74	0.98
1996	0.31	0.26	1.24	0.67	0.31	0.27	-0.1	1.00	0.66
1997	0.31	0	-1.86	0.57	0.31	-0.01	-0.5	-1.69	-0.42
1998	0.57	0.86	0.77	2	0.57	0.22	0.89	0.72	1.53
1999	-0.36	0.11	0.28	-0.74	-0.36	-0.57	0.24	0.43	-0.52
2000	-1.18	-0.03	0.19	0.11	-1.18	-1	0.37	0.37	0.07
2001	-0.47	-0.69	-0.3	-0.85	-0.47	-0.65	-0.52	-0.3	-0.43
2002	-1.72	-1.93	-0.09	-0.65	-1.72	-1.84	-1.95	-0.27	-0.4
2003	0.92	0.56	2.43	1.21	0.92	1.16	1.01	2.15	1.25

2004	-0.72	-0.99	-0.6	-0.65	-0.72	-1.35	-1.14	-0.96	-1.03
2005	0.56	-0.33	0.06	0.04	0.56	0.1	-0.23	0.22	0.13
2006	0.09	-0.46	-1.46	0.18	0.09	0.32	-0.41	-1.31	0.27
2007	0.27	0.18	-0.99	1.05	0.27	1.09	-0.28	-1.12	0.66
2008	-0.35	1.69	0.61	-0.32	-0.35	0.15	2.13	0.88	-0.41
2009	-2	-1.07	-1.2	-1.69	-2	-2.44	-1.45	-1.29	-1.62
2010	0.64	0.26	0.47	0.71	0.64	0.63	0.69	0.72	1.12
2011	-0.36	1.26	0.21	0.64	-0.36	0.49	1.55	0.43	0.66
2012	-0.98	0.04	-1.01	-0.49	-0.98	-0.63	0.52	-0.64	-0.05
2013	-0.6	2.45	0.71	1.34	-0.6	1.01	1.6	0.64	0.94
2014	-1.08	-0.57	-1.61	-1.74	-1.08	-1.23	-1.44	-1.92	-2.17
2015	1.05	1.66	-0.99	-1.57	1.05	0.29	0.69	-1.3	-2.01







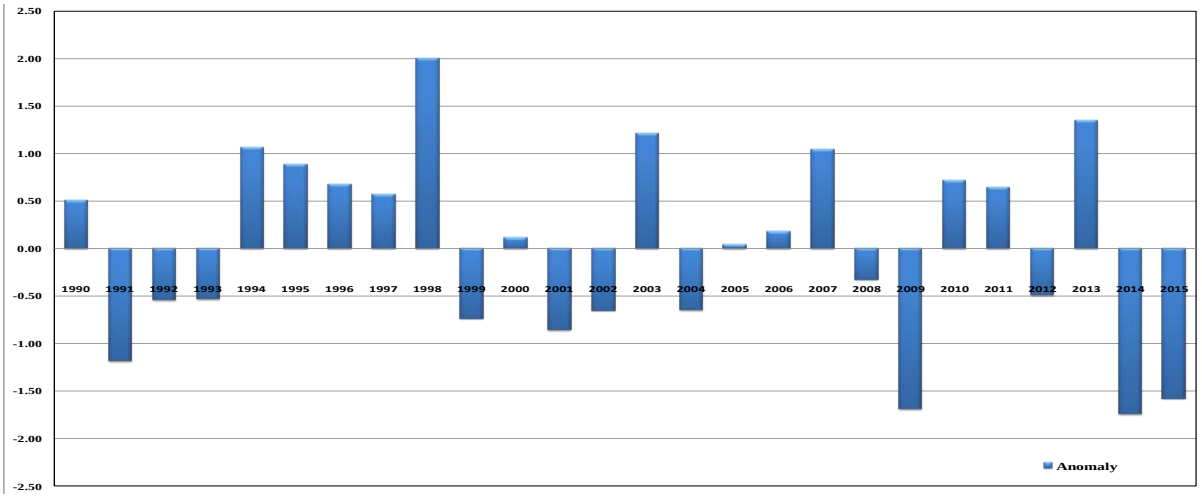
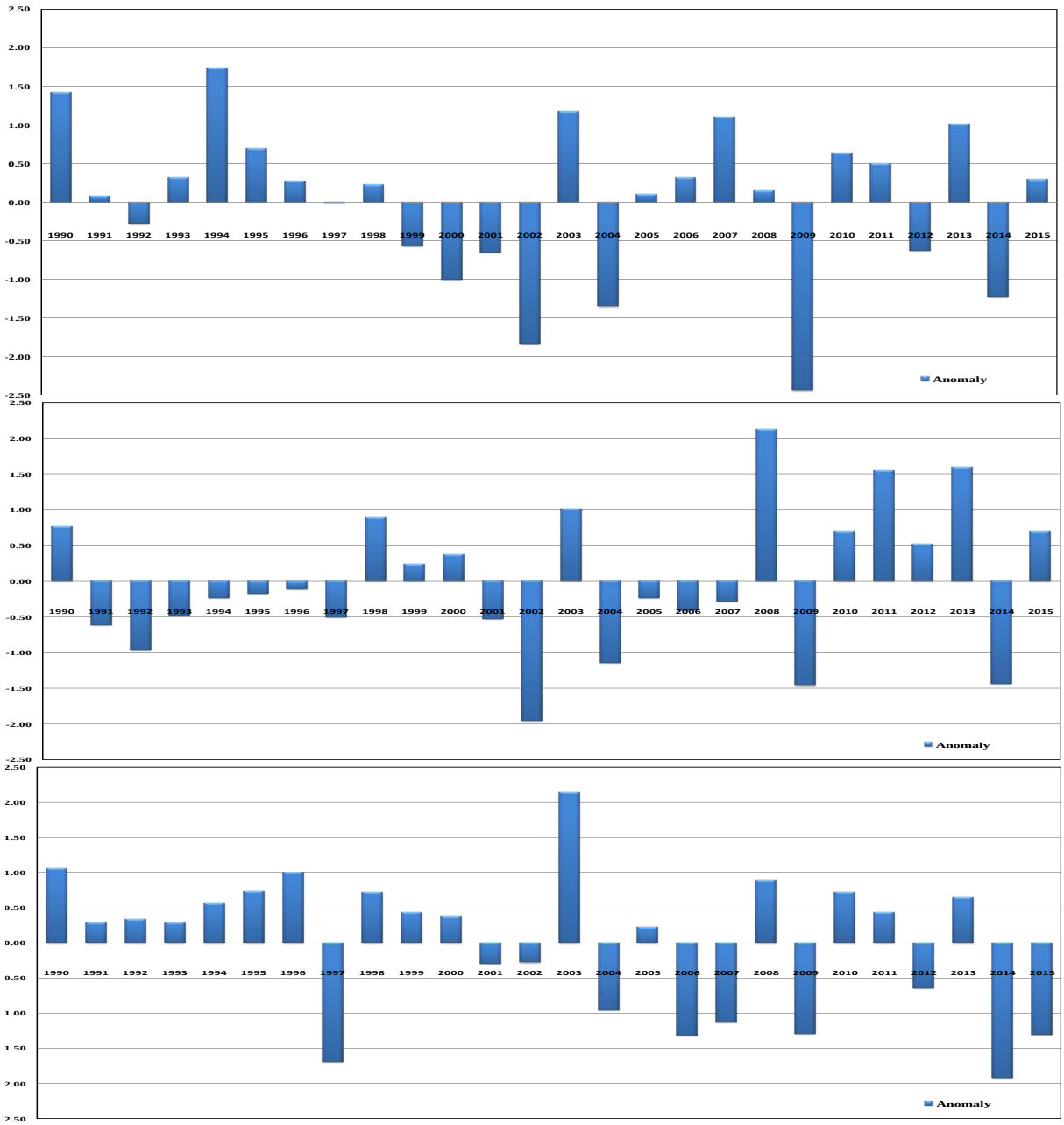


Fig. 4a. Standardized Rainfall Anomaly of Normal rainfall (1990 to 2015)



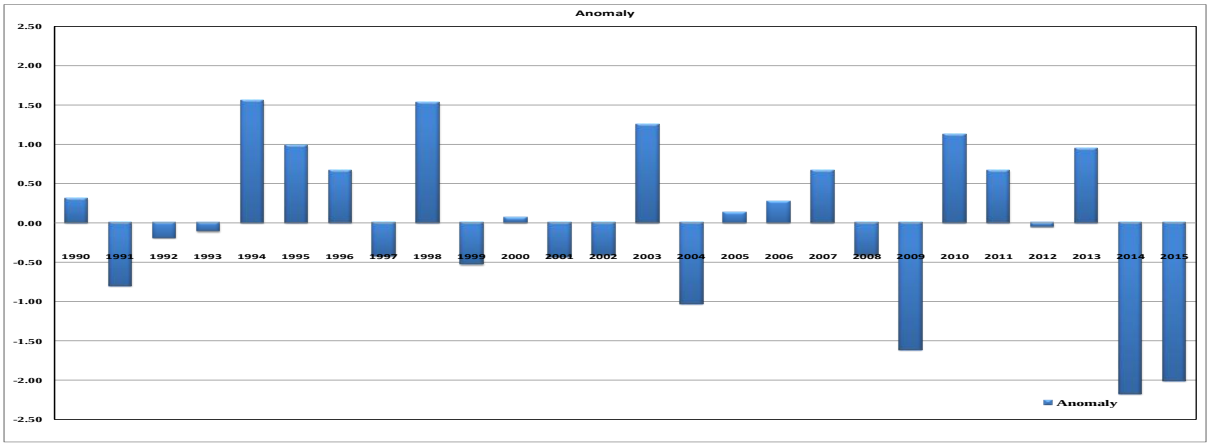


Fig. 4b. Standardized Rainfall Anomaly of Monsoon rainfall (1990 to 2015)

Forecasting of annual rainfall and S-W rainfall

On the basis, the future forecast of rainfall and yield amount for a period of fifteen years from 2016 to 2030 has been made (Table 7), which shows a negative trend for the coming years. In future, expected normal annual and south west rainfall may be less in year 2030 observed 1005.1mm, 513.4 & 725.7 India, Parts of Western U.P. & Meerut district respectively whereas the monsoon rainfall future expected rainfall are observed in India 812.5mm, in Parts of Western U.P. 417.5mm & in Meerut district 246.3mm. The expected annual & monsoon rainfall in year 2016 to 2030 rainfall patterns are declining stage. But the future temporal data analysis of normal monsoon rainfall observed not in declined pattern after 2021 rainfall pattern increasing showed. It may be due to changing scenario of the pattern and observed normal and monsoon rainfall 1164.7mm and 930 mm respectively. The trend analysis gives the scenario of current to expected future situation. Monsoon rainfall is one of the key factor play vital role in Indian agriculture.

Table 7. Future scenario of normal & monsoon rainfall pattern (2016 to2030)

Future	Normal Rainfall				Monsoon Rainfall			
Year	India	UP	Western U.P.	Meerut	India	UP	Western U.P.	Meerut
2016	1080	1058.1	630.4	782.2	840.4	876.9	537.6	395.2
2017	1074.7	1065.7	622	778.2	838.4	880.7	529	384.6
2018	1069.3	1073.3	613.7	774.2	836.4	884.5	520.4	373.9
2019	1064	1080.9	605.3	770.1	834.4	888.3	511.9	363.3
2020	1058.6	1088.6	597	766.1	832.4	892.1	503.3	352.7
2021	1053.3	1096.2	588.6	762	830.4	895.9	494.7	342
2022	1047.9	1103.8	580.2	758	828.4	899.7	486.1	331.4
2023	1042.6	1111.4	571.9	754	826.4	903.5	477.5	320.7
2024	1037.2	1119	563.5	749.9	824.4	907.2	469	310.1
2025	1031.9	1126.6	555.2	745.9	822.5	911	460.4	299.5
2026	1026.5	1134.3	546.8	741.9	820.5	914.8	451.8	288.8
2027	1021.2	1141.9	538.5	737.8	818.5	918.6	443.2	278.2
2028	1015.8	1149.5	530.1	733.8	816.5	922.4	434.6	267.5
2029	1010.4	1157.1	521.8	729.8	814.5	926.2	426	256.9
2030	1005.1	1164.7	513.4	725.7	812.5	930	417.5	246.3

CONCLUSION

Rainfall is a important part of water cycle and all cropping patterns are dependent on rainfall distribution. The study of rainfall pattern at the macro to micro level study normal to monsoon rainfall given the idea of understand pattern of rainfall. The combine study areas from country level to state with parts of area and District level the rainfall play a vital common role. After detail study found pattern of rainfall are more or less same pattern but differences are observed in state level

study. The normal rainfall received during 25years 1990 to 2015 District level are observed in India 1152.3mm, in U.P. 955.3mm, in Western U.P. 743.2mm & in Meerut 836.7mm. The intensity of rainfall are observed increasing from June to September (South-west Monsoon). The mean of maximum rainfall is 1091.6mm observed in the U.P. (2008) whereas minimum rainfall is 581.6 observed also in UP (2002). The detail analysis of data the year 2002, 2009 and 2011 were drought year. The overall study of temporal data of rainfall observed 251% rainfall in the part of Western U.P. whereas observed minimum 80% in the India level. The cumulative study of rainfall data observed in India the cumulative values are observed negative in years 1990-1993 & 2001-2014 The western U.P. positive values in year 1990-1994, 1997 & 2009 to 2015 whereas in Meerut district observed cumulative negative in year 1990 to 1993 & 2015. The overall study of data overall in India has lowest in normal (39%) whereas monsoon rainfall observed 33% precipitation ratio. The monsoon rainfall anomaly were observed in years of 1994 (1.74) , 2008(2.13), 2003 (2.15) &1.56 (1994) showing the highest positive normal rainfall anomaly in India, U.P., Parts of Western U.P. & Meerut respectively. In future, expected normal annual and south west rainfall may be less in year 2030 observed 1005.1mm, 513.4 & 725.7 India, Parts of Western U.P. & Meerut district respectively whereas the monsoon rainfall future expected rainfall are observed in India 812.5mm, in Parts of Western U.P. 417.5mm & in Meerut district 246.3mm. The expected annual & monsoon rainfall in year 2016 to 2030 rainfall patterns are declining stage. The future rainfall pattern are drastically declining rainfall pattern are observed at all levels. The management and improvement in natural conditions means planting of tree and develop reforestation in wasteland areas can control changing scenario of rainfall. The overall study provide a statically information about macro to micro level study.

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