RESEARCH ARTICLE

STUDY OF SPATIO-TEMPORAL ANALYSIS OF ANNUAL RAINFALL VARIABILITY IN UTTAR PRADESH

Avadhesh Kumar Koshal* and Prafull Kumar

ICAR- P.D.F.S.R. College of Agriculture Modipuram, Meerut (U.P.) S.V.P.U.A. &T., Meerut (U.P.)
Email: akkoshal@hotmail.com

Received-10.03.2016, Revised-21.03.2016

Abstract: Uttar Pradesh is Humid subtropical and semi arid climatic region situated between 23° 52' N and 31° 28' N latitudes and 77° 3' and 84° 39'E longitudes. The state is divided into 18 divisions and 71 districts. The statistical analysis of annual rainfall data of past to present 100 years (1915-2014) ranged from 532.7mm in year in 1991 to 1313.1 mm in year 2013 with an average annual rainfall of the area is 929.6 mm. The average rainfall with 2013 showing the highest positive rainfall anomaly (2.26) while the other years show rainfall below normal with 1991 Showing the lowest negative rainfall deviation (-2.34). The calculated value of standard deviation reveals that deviation of rainfall is of 169.7 mm. in a century. The trend analysis in XLSTAT 2014.6.02 ver. observed trend of rainfall, the R^2 value 0.018 means that only 1.8 percent variation is observed in hundred years. The coefficient of skewness has been computed as -0.06 for annual rainfall indicates a negative trend or going to decline pattern. The maximum standard deviation value and CV(%) is observed 210 & 23% in year 1935-44 and minimum standard deviation and CV(%) is observed 80.7 & 10% in year 1995-04. The overall decadal dataset observed decadal maximum rainfall 1328.9 in year 1955-64 whereas minimum rainfall 493.9mm in year 2005-14 observed. In future, expected annual rainfall may be less in year 2025 observed 881.9mm in the state. In the year 2021; expected rainfall may be 893mm. The geostatistical analysis is the ARCGIS 10.3.1 extension used for interpolation and kriging. The prediction map of dataset year 1995-2004 was highest rainfall in east side of some place of Uttar Pradesh. The western part of Uttar Pradesh covered less rainfall the other side cover area. The central part of state decadal map covered maximum area in year 1966-74. The objective of this study is to analyze the recent and future trend of annual rainfall pattern.

Keywords: Anomaly**,** GIS, Geostatistical method, Kriging & Monsoon

INTRODUCTION

The rainfall is the meteorological phenomenon is a major source of water on the earth. It is also one of the most important climatic variables because of its two sided effects one is deficient resource, such as droughts and as a catastrophic agent, such as floods (Alam, 2011). Agriculture is dependent on climatic factors: temperature, rainfall, sunshine hours, relative humidity and air direction. The changing of rainfall pattern in rabi, kharif & zaid seasons are change the cropping pattern if changes are seen for long time. Because water having vital role to agriculture crops growth and crops are having short period for complete life cycle. The change of rainfall pattern is affecting the crops productivity. The Kharif crop is the summer crop or monsoon crop in India. Kharif crops are usually sown with the beginning of the first rains in July, during the south-west monsoon season. The South west monsoon is very important for Uttar Pradesh agriculture. The major socio-economic infrastructures are dependent on rainfall because greater percentages of the peoples are dependent agriculture related work (www.gktoday.in). Rainfall in pre-monsoon and winter season had a decreasing trend whereas it had an increasing trend during monsoon and post monsoon seasons (Rimi *et al.*). The IMD (Indian meteorology Department, New Delhi) divided Indian season in four categories: pre-monsoon (April-June), monsoon (July-September), post-monsoon (October-November) and winter season (December-March). IMD defines a four month period from June to September as Indian summer monsoon (ISM) period (Attri and Tyagi, 2010). The Statistical techniques are essential tools for analyzing large datasets. It also helps us to identify which of the many pieces of information derived from observations of the climate system are worthy of synthesis and interpretation. It is also helpful for testing hypotheses, estimations of parameters and in predictions of the data set (Cobanovic, 2002). The climatic research is complex, large level and long time period's process. The natural or human-induced factors are cause of climates change. Agricultural statistics are needed to provide information used to monitor trends and estimate future prospects. Geostatistics assumes that at least some of the spatial variations of natural phenomena can be modelled by random processes with spatial autocorrelation. Many methods are associated with geostatistics, but they are all in the Kriging family. Ordinary, Simple, Universal, probability, Indicator, and Disjunctive kriging, along with their counterparts in cokriging, are available in the geostatistical analysis. The changing climatic condition has been attributable to rainfall (Adger *et al.* 2003 & Obot *et al.* 2010), studies have also shown that the climate is changing based on the changing pattern of rainfall (Goswami *et al.* 2006 & Adger *et al.* 2003). Prediction of the spatial and

*Corresponding Author

temporal variability in rainfall is a major problem in an agricultural country like India and particularly in the state U.P. Measurement and prediction of change using statistical methods is a very important tool for decision making.

Objective

The objective of this study is to analyze the recent and future trend of annual rainfall pattern.

Study area

Uttar Pradesh is Humid subtropical (warm summer) and semi arid climatic region situated between 23° 52' N and 31° 28' N latitudes and 77° 3' and 84° 39'E longitudes, this is the fifth largest state in the country after Rajasthan, Maharashtra, Madhya Pradesh and Andhra Pradesh in area (Fig.1). Total geographical area of the state is 24,170 thousand hectare which is 7.33% of total area of India out of which 16,573 thousand hectare is under cultivation **(FSI, 2015).** It is divided into three distinct hypsographical regions: The Himalayan region in the North, The Gangetic plain in the centre & The Vindya hills and plateau in the south. It is lies largely in the plains formed by the Ganges and Yamuna rivers. State climate is subtropical and congenial for agriculture. Uttar Pradesh is largest producer of wheat, potato, sugarcane and milk whereas third largest producer of rice. For administrative purposes, the state is divided into 18 divisions and 71 districts. The state divided into nine agro-climatic zones, namely, Bhabhar & Tarai, Western Plain, Central-Western Plain, South-Western Plain, Central Plain, Bundelkhand, North-Eastern Plain, Eastern Plain, and Vindhyan region. It is also divided into four economic regions, viz., Western, Eastern, Central and Bundelkhand (Guha & Basu, 1996). The western region comprises of 27 districts and the eastern region 27 districts. Ten districts constitute the central region whereas the Bundelkhand region has only 7 districts. Rising of urbanization, populations and de-forestation are causing adverse impacts on the state's biosphere.

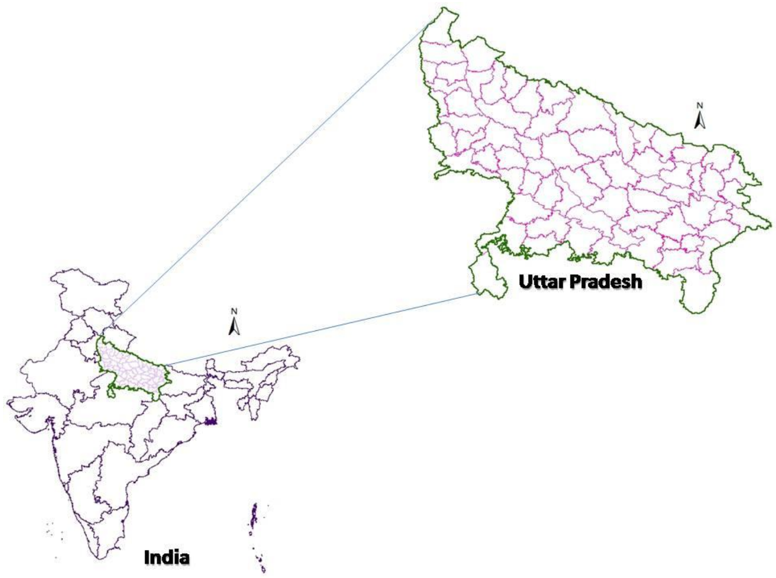

Fig.1 Study area

MATERIAL AND METHOD

The monthly rainfall data were collected from IMD, New Delhi & India water portal for the periods 1915-2014 (India water Portal, IMD New Delhi & NASA/POWER Agrometeorology website). The district wise collected monthly data were converted to annual time scale before statistical and interpolation analysis is done. The rainfall data processed on Excel sheets according to the requirements to obtain critical area maps using ArcGIS 10.2 software. ESRI's Geo-statistical analyst extension has been used for these analyses. The rainfall surfaces were predicted using ordinary kriging method.

METHODOLOGY

Time series analysis of the monthly and annual rainfall values were used to illustrate the trend in the behaviour of rainfall and in estimating seasonal variation. Linear regression analysis was also employed using Microsoft Excel statistical tool as it has proved effective in investigating trends in many climatic time series (Hutchinson, 1985 & Ayoade, 1973). One of the important indices standardized anomalies was evaluated.

Several statistics are applied to monthly rainfall series such as mean, variance, standard deviation, coefficient of variation, and skewness. For identifying the trend in the rainfall data, the statistical analysis of linear regression was used. All these different analyses constitute the continuity of the study of Uttar Pradesh rainfall, which started about a century ago. The descriptive statistical analyses are:

(i) **Mean** is the arithmetic average of a set of values or distribution and represents the average of the data set.

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

Where x is the rainfall data & N= Number of years

(ii) The **Standard deviation** (STD) is measure of the dispersion of a set of data from its mean.

$$STD = \frac{\sqrt{\sum(x-\bar{x})^2}}{N}$$

(iii) The **median** is the middle value when the data is arranged in order of size.

(iv) The **coefficient of variation** is a normalized measure of dispersion of a probability distribution which is defined as the ratio of the standard deviation σ to the mean $\bar{x}$.

$$CV = \frac{\sigma}{\bar{x}} x100$$

(v) **Deviation score** = $x - \bar{x}$

(vi) **Standardized anomalies**, also referred to as normalized anomalies, are calculated by dividing anomalies by the climatological standard deviation.

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

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.

(vii) Skewness is a measure of the asymmetry of the probability distribution. The skewness value can be positive or negative, or even undefined. It is a dimensionless quantity.

$$\text{Skewness} = \frac{\text{Mean} - \text{Mode}}{\text{Standard deviation}}$$

Recently, geographic information systems GIS interpolation technique has emerged as a method to map the distribution of evapotranspiration, temperature and precipitation (Haberlandt 2007 & Cheng et al. 2007) and it gives the layout and drawing tools necessary to present the results visually. GIS technique assist researchers and practitioners to understand the natural environment (Jang et al. 2007). That method was successfully used to study spatial distributions of precipitation by Dingman et. al. The Geostatistical analysis provides many tools to help determine which parameters to use, and also provides reliable defaults that can be used to make a surface quickly. The geostatistical analysis is the ARCGIS extension used for interpolation and kriging. There is numerous interpolation methods are used for rainfall data analysis. After detail study of kriging method is observed, two interpolation methods are explained distribution pattern of rainfall for the study area after different decadal dataset study.

RESULT AND DISCUSSION

The annual rainfall data series during the period 1915 to 2014 are analysis using time series analysis. The result shows that over Uttar Pradesh state. South-west rainfall or monsoon season covered almost districts over the state in June to September months. It is a most dominant session of the cyclic rainfall. The Kharif crops production is dependent on this rainfall.

Standardized anomalies of Annual Rainfall

Table 1 depicts the computed annual mean rainfall and standardized anomalies within the year under consideration (1915 to 2014) over Uttar Pradesh State. Fig. 2 shows the standardized rainfall deviations viz; 1915 to 1919, 1922, 1924-25, 1927, 1931, 1933, 1936, 1938,1942-43, 1946 to 1951, 1955-56, 1958, 1960 to 1964, 1967, 1969 to 1971, 1973, 1975, 1977-78, 1980 to 1982, 1985, 1990, 1994, 1996, 2003, 2007 -08 and 2012-13 are years with above average rainfall with 2013 Showing the highest positive rainfall anomaly (2.26) while the other years show rainfall below normal with 1991 Showing the lowest negative rainfall deviation (-2.34).

Table 1. Average Annual rainfall & Standardized rainfall anomaly of Uttar Pradesh (1915-2014)

Year	Average Rainfall (mm)	Standardized rainfall anomaly	Year	Average Rainfall (mm)	Standardized rainfall anomaly
1915	971.5	0.25	1965	650.6	-1.64
1916	1099.9	1.00	1966	736.5	-1.14
1917	1188.1	1.52	1967	1112.4	1.08
1918	611.5	-1.87	1968	641.6	-1.70
1919	954.7	0.15	1969	955.1	0.15
1920	801.3	-0.76	1970	1137.6	1.23
1921	825.1	-0.62	1971	1196.0	1.57
1922	1139.5	1.24	1972	804.1	-0.74

1923	927.0	-0.02	1973	1075.8	0.86
1924	1033.4	0.61	1974	663.1	-1.57
1925	1242.4	1.84	1975	1004.4	0.44
1926	889.2	-0.24	1976	850.9	-0.46
1927	976.7	0.28	1977	976.7	0.28
1928	653.7	-1.63	1978	974.3	0.26
1929	914.6	-0.09	1979	620.5	-1.82
1930	907.5	-0.13	1980	1267.8	1.99
1931	969.1	0.23	1981	1043.8	0.67
1932	763.6	-0.98	1982	1088.9	0.94
1933	1065.2	0.80	1983	921.6	-0.05
1934	864.0	-0.39	1984	800.7	-0.76
1935	925.6	-0.02	1985	1041.2	0.66
1936	1309.2	2.24	1986	882.9	-0.28
1937	837.8	-0.54	1987	567.7	-2.13
1938	972.4	0.25	1988	913.5	-0.09
1939	873.9	-0.33	1989	772.7	-0.92
1940	804.7	-0.74	1990	1085.6	0.92
1941	626.8	-1.78	1991	532.7	-2.34
1942	1052.1	0.72	1992	628.4	-1.77
1943	983.5	0.32	1993	799.1	-0.77
1944	914.1	-0.09	1994	997.0	0.40
1945	880.7	-0.29	1995	849.4	-0.47
1946	952.0	0.13	1996	985.0	0.33
1947	1025.8	0.57	1997	755.2	-1.03
1948	1179.3	1.47	1998	874.2	-0.33
1949	1122.6	1.14	1999	825.0	-0.62
1950	971.9	0.25	2000	683.8	-1.45
1951	934.6	0.03	2001	690.9	-1.41
1952	884.5	-0.27	2002	685.2	-1.44
1953	924.8	-0.03	2003	1038.6	0.64
1954	885.7	-0.26	2004	810.8	-0.70
1955	1123.2	1.14	2005	907.5	-0.13
1956	1145.3	1.27	2006	887.4	-0.25
1957	907.2	-0.13	2007	981.1	0.30
1958	991.4	0.36	2008	1274.4	2.03
1959	892.8	-0.22	2009	838.3	-0.54
1960	1057.5	0.75	2010	841.7	-0.52
1961	1115.4	1.09	2011	892.1	-0.22
1962	990.2	0.36	2012	971.4	0.25
1963	1115.9	1.10	2013	1313.1	2.26
1964	1035.0	0.62	2014	881.4	-0.28
Average Rainfall (mm) 929.6					

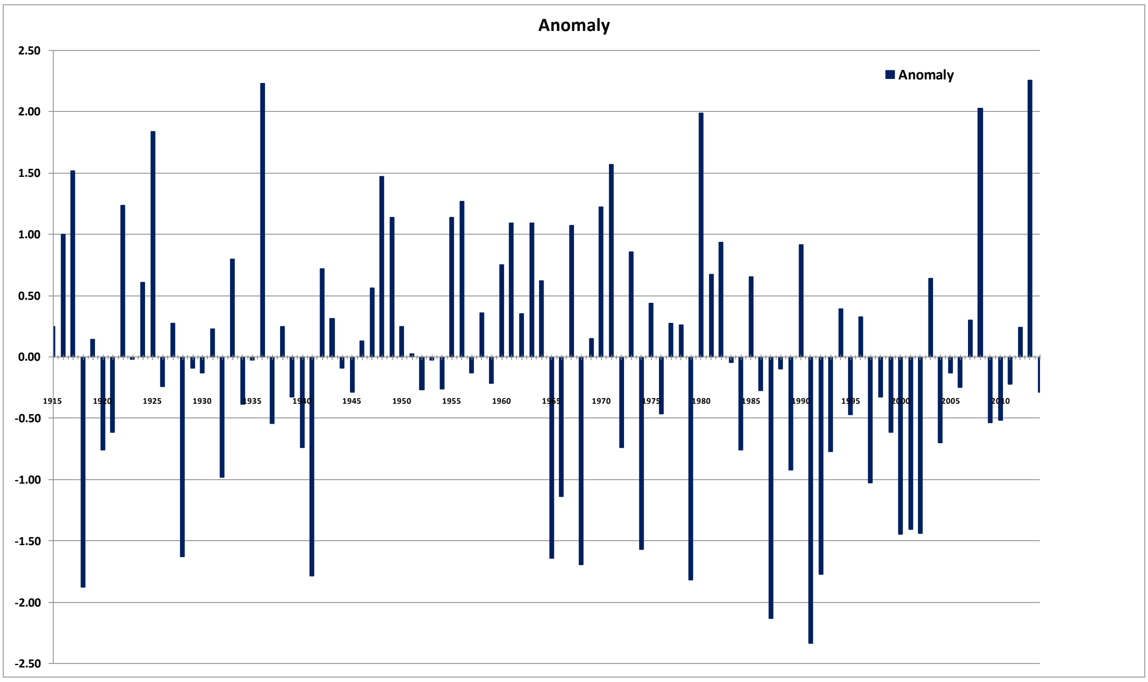

Fig. 2. Standardized rainfall anomaly of Uttar Pradesh from 1915-2014

Rainfall departure and cumulative departure of rainfall

The departure and cumulative departure from average rainfall for the study area has been depicted in Table.2. 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 1915-17, 1919, 1922, 1924-25, 1927, 1931, 1933, 1936, 1938, 1942-43, 1946-51, 1955-56, 1958, 1960-64, 1967, 1969-71, 1973, 1975, 1977-78, 1980-82, 1985, 1990, 1994, 1996, 2003, 2007-08 & 2012-13. The positive trend of rainfall shows the favourable conditions for recharge.

(b) Years showing annual negative departure with respect to average annual rainfall were 1918, 1920-21, 1923, 1926, 1928-30, 1932,1934-35,1937,1939-1941,1944-45,1952-54,1957, 1959, 1965-66,1968,1972, 1974, 1976, 1979,1983-84,1986-89,1991-93, 1995, 1997-02, 2004-06, 2009-11 & 2014. The negative trend of rainfall shows the unfavourable conditions for recharge.

(c) Years showing negative annual cumulative departure from average rainfall were observed in a centum data 1915, 1920-21, 1941 and 2000 to 2014.

Table 2. The annual rainfall data and its departure and cumulative departure from average rainfall in Uttar Pradesh (1915-2014)

Year	Annual rainfall (mm)	Departure from average rainfall	Cumulative departure from average rainfall	Year	Annual rainfall (mm)	Departure from average rainfall	Cumulative departure from average rainfall
1915	971.5	41.9	-42	1965	650.6	-279.0	1389
1916	1099.9	170.3	128	1966	736.5	-193.1	1196
1917	1188.1	258.5	387	1967	1112.4	182.8	1379
1918	611.5	-318.2	69	1968	641.6	-288.0	1091
1919	954.7	25.1	94	1969	955.1	25.4	1116
1920	801.3	-128.3	-35	1970	1137.6	208.0	1324
1921	825.1	-104.6	-139	1971	1196.0	266.4	1590
1922	1139.5	209.8	71	1972	804.1	-125.6	1465
1923	927.0	-2.6	68	1973	1075.8	146.2	1611

1924	1033.4	103.8	172	1974	663.1	-266.6	1344
1925	1242.4	312.8	485	1975	1004.4	74.8	1419
1926	889.2	-40.5	444	1976	850.9	-78.8	1341
1927	976.7	47.1	491	1977	976.7	47.1	1388
1928	653.7	-276.0	215	1978	974.3	44.7	1432
1929	914.6	-15.1	200	1979	620.5	-309.1	1123
1930	907.5	-22.1	178	1980	1267.8	338.2	1461
1931	969.1	39.4	218	1981	1043.8	114.2	1576
1932	763.6	-166.0	52	1982	1088.9	159.3	1735
1933	1065.2	135.5	187	1983	921.6	-8.0	1727
1934	864.0	-65.6	121	1984	800.7	-128.9	1598
1935	925.6	-4.1	117	1985	1041.2	111.6	1709
1936	1309.2	379.6	497	1986	882.9	-46.7	1663
1937	837.8	-91.8	405	1987	567.7	-361.9	1301
1938	972.4	42.7	448	1988	913.5	-16.1	1285
1939	873.9	-55.7	392	1989.0	772.7	-156.9	1128
1940	804.7	-125.0	267	1990.0	1085.6	156.0	1284
1941	626.8	-302.8	-36	1991	532.7	-396.9	887
1942	1052.1	122.5	87	1992	628.4	-301.3	586
1943	983.5	53.8	141	1993	799.1	-130.5	455
1944	914.1	-15.5	125	1994	997.0	67.4	522
1945	880.7	-48.9	76	1995	849.4	-80.2	442
1946	952.0	22.4	99	1996	985.0	55.4	498
1947	1025.8	96.1	195	1997	755.2	-174.4	323
1948	1179.3	249.7	444	1998	874.2	-55.4	268
1949	1122.6	193.0	637	1999	825.0	-104.7	163
1950	971.9	42.3	680	2000	683.8	-245.9	-83
1951	934.6	4.9	685	2001	690.9	-238.8	-322
1952	884.5	-45.1	639	2002	685.2	-244.4	-566
1953	924.8	-4.8	635	2003	1038.6	108.9	-457
1954	885.7	-43.9	591	2004	810.8	-118.8	-576
1955	1123.2	193.6	784	2005	907.5	-22.1	-598
1956	1145.3	215.6	1000	2006	887.4	-42.3	-640
1957	907.2	-22.4	977	2007	981.1	51.5	-589
1958	991.4	61.8	1039	2008	1274.4	344.8	-244
1959	892.8	-36.8	1002	2009	838.3	-91.4	-335
1960	1057.5	127.8	1130	2010	841.7	-87.9	-423
1961	1115.4	185.8	1316	2011	892.1	-37.5	-461
1962	990.2	60.5	1377	2012	971.4	41.7	-419
1963	1115.9	186.2	1563	2013	1313.1	383.5	-36
1964	1035.0	105.3	1668	2014	881.4	-48.2	-84
Annual average rainfall (mm) = 929.6							

Statistical parameters of Annual rainfall

The statistical analysis of annual rainfall data of past to present 100 years (1915-2014) ranged from 532.7mm in year in 1991 to 1313.1 mm in year 2013 with an average annual rainfall of the area is 929.6 mm (Table -3).

Table 3. Mann-Kendall trend tests of rainfall data (1915-2014)

XLSTAT 2014.6.02 - Mann-Kendall trend tests - on 14-11-2015 at 16:20:43							
Time series: Workbook = up100.xlsx / Sheet = Sheet1 / Range = Sheet1!$B$1:$B$101 / 100 rows and 1 column							
Date data: Workbook = up100.xlsx / Sheet = Sheet1 / Range = Sheet1!$A$1:$A$101 / 100 rows and 1 column							
Significance level (%): 5							
Summary statistics:							
Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
UP	100	0	100	532.739	1313.112	929.637	169.736
Mann-Kendall trend test / Lower-tailed test (UP):							
Kendall's tau	-0.096						
S	-474.00						
Var(S)	112750.00						
p-value (one-tailed)	0.079						
alpha	0.05						
The exact p-value could not be computed. An approximation has been used to compute the p-value.							
Test interpretation:							
H0: There is no trend in the series							
Ha: There is a negative trend in the series							
As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H0.							
The risk to reject the null hypothesis H0 while it is true is 7.95%.							
The continuity correction has been applied.							
Sen's slope:	-0.84						
Confidence interval:	] -33.383 ,	32.960 [					

The computed value of the median 925.2mm indicates ideal rainfall of the area. The coefficient of variation (%) was found to be 18.26. The calculated value of standard deviation reveals that deviation of rainfall is of 169.7 mm. in a century. The coefficient of skewness has been computed as -0.06 for annual rainfall indicates a negative trend. The trend analysis was done in XLSTAT 2014.6.02 ver. Fig.3 &4 shows that the trend of rainfall, the R^2 value 0.018 means that only 1.8 percent variation is observed in hundred years.

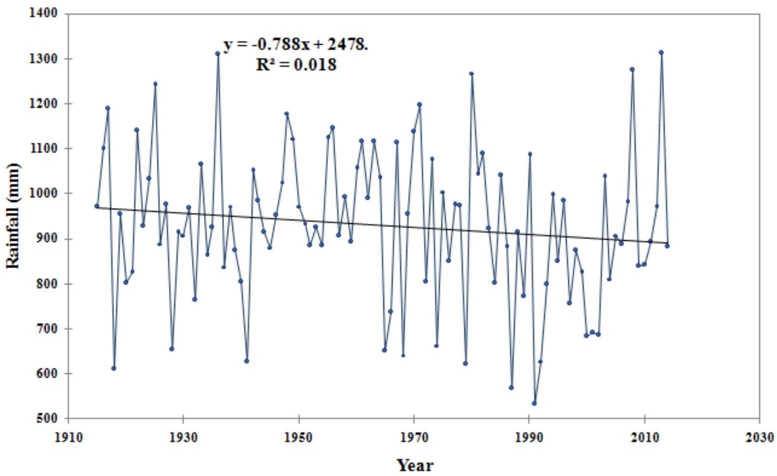

Fig. 3 Trend analysis of Average rainfall of Uttar Pradesh

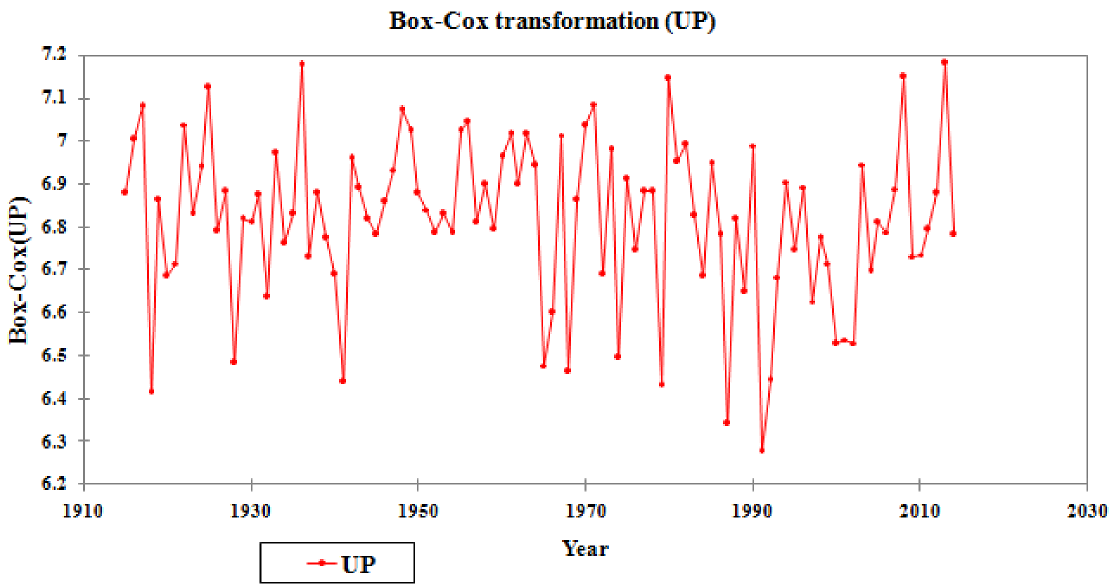

Fig.4. Box-Cox analysis of Average rainfall of Uttar Pradesh

Table 4. Computation of statistical parameters of Uttar Pradesh

Statistical parameters	**Computed value**
	Annual Rainfall (mm)
Mean	929.6 mm
Min	532.7 mm
Max	1313.1 mm
Median	925.2 mm
Std. Dev.	169.7
CV%	18.26
Coefficient of skewness	-0.06

Trend analysis of annual rainfall

A trend analysis of the average south west rainfall of Uttar Pradesh state for 100 year period from 1915 to 2014 was statistical test MS Excel in Table 5. Trend analysis was also performed on seasonal scale to examine if there are trends in the data at this scale. The trend analysis helps to measure the deviation from the trend and also provides information pertaining to the nature of trend. The analysis can be used as a tool to forecast the future behaviour of the trend. The method of least square fit for straight line has been used for trend analysis of the behaviour of annual rainfall. After trend analysis of data observed rainfall trend is going to decline pattern.

Table 5. Time series analysis of South-west rainfall (mm) data of Uttar Pradesh

Year	**X**	**Y**	**X2**	**XY**	**Trend value**	**Year**	**X**	**Y**	**X2**	**XY**	**Trend value**
1915	-49	971.5	2401	-47605.2	968.7	1965	1	650.6	1	650.6	929.2
1916	-48	1099.9	2304	-52795.4	967.9	1966	2	736.5	4	1473.0	928.5
1917	-47	1188.1	2209	-55841.7	967.1	1967	3	1112.4	9	3337.3	927.7
1918	-46	611.5	2116	-28127.5	966.3	1968	4	641.6	16	2566.4	926.9
1919	-45	954.7	2025	-42962.9	965.5	1969	5	955.1	25	4775.3	926.1
1920	-44	801.3	1936	-35256.7	964.7	1970	6	1137.6	36	6825.7	925.3

1921	-43	825.1	1849	-35478.1	963.9	1971	7	1196.0	49	8372.2	924.5
1922	-42	1139.5	1764	-47857.4	963.2	1972	8	804.1	64	6432.5	923.7
1923	-41	927.0	1681	-38006.9	962.4	1973	9	1075.8	81	9682.2	922.9
1924	-40	1033.4	1600	-41337.2	961.6	1974	10	663.1	100	6630.5	922.1
1925	-39	1242.4	1521	-48453.2	960.8	1975	11	1004.4	121	11048.8	921.4
1926	-38	889.2	1444	-33788.7	960.0	1976	12	850.9	144	10210.4	920.6
1927	-37	976.7	1369	-36139.1	959.2	1977	13	976.7	169	12697.2	919.8
1928	-36	653.7	1296	-23531.8	958.4	1978	14	974.3	196	13640.8	919.0
1929	-35	914.6	1225	-32009.7	957.6	1979	15	620.5	225	9307.9	918.2
1930	-34	907.5	1156	-30856.6	956.8	1980	16	1267.8	256	20285.0	917.4
1931	-33	969.1	1089	-31979.3	956.1	1981	17	1043.8	289	17744.9	916.6
1932	-32	763.6	1024	-24436.6	955.3	1982	18	1088.9	324	19600.0	915.8
1933	-31	1065.2	961	-33020.6	954.5	1983	19	921.6	361	17510.7	915.0
1934	-30	864.0	900	-25920.7	953.7	1984	20	800.7	400	16014.3	914.3
1935	-29	925.6	841	-26841.0	952.9	1985	21	1041.2	441	21865.9	913.5
1936	-28	1309.2	784	-36658.0	952.1	1986	22	882.9	484	19424.4	912.7
1937	-27	837.8	729	-22620.7	951.3	1987	23	567.7	529	13058.2	911.9
1938	-26	972.4	676	-25281.2	950.5	1988	24	913.5	576	21924.8	911.1
1939	-25	873.9	625	-21848.4	949.7	1989.0	25	772.7	625	19318.5	910.3
1940	-24	804.7	576	-19312.1	949.0	1990.0	26	1085.6	676	28226.2	909.5
1941	-23	626.8	529	-14416.4	948.2	1991	27	532.7	729	14384.0	908.7
1942	-22	1052.1	484	-23146.4	947.4	1992	28	628.4	784	17594.1	908.0
1943	-21	983.5	441	-20652.5	946.6	1993	29	799.1	841	23173.7	907.2
1944	-20	914.1	400	-18282.1	945.8	1994	30	997.0	900	29910.5	906.4
1945	-19	880.7	361	-16733.7	945.0	1995	31	849.4	961	26332.5	905.6
1946	-18	952.0	324	-17136.7	944.2	1996	32	985.0	1024	31521.1	904.8
1947	-17	1025.8	289	-17438.1	943.4	1997	33	755.2	1089	24922.0	904.0
1948	-16	1179.3	256	-18869.5	942.6	1998	34	874.2	1156	29723.4	903.2
1949	-15	1122.6	225	-16838.9	941.9	1999	35	825.0	1225	28873.6	902.4
1950	-14	971.9	196	-13606.5	941.1	2000	36	683.8	1296	24615.5	901.6
1951	-13	934.6	169	-12149.3	940.3	2001	37	690.9	1369	25561.7	900.9

1952	-12	884.5	144	-10614.0	939.5	2002	38	685.2	1444	26037.9	900.1
1953	-11	924.8	121	-10173.1	938.7	2003	39	1038.6	1521	40503.6	899.3
1954	-10	885.7	100	-8857.3	937.9	2004	40	810.8	1600	32431.9	898.5
1955	-9	1123.2	81	-10108.9	937.1	2005	41	907.5	1681	37209.1	897.7
1956	-8	1145.3	64	-9162.3	936.3	2006	42	887.4	1764	37269.9	896.9
1957	-7	907.2	49	-6350.4	935.6	2007	43	981.1	1849	42188.2	896.1
1958	-6	991.4	36	-5948.4	934.8	2008	44	1274.4	1936	56073.9	895.3
1959	-5	892.8	25	-4464.0	934.0	2009	45	838.3	2025	37722.3	894.5
1960	-4	1057.5	16	-4229.9	933.2	2010	46	841.7	2116	38718.3	893.8
1961	-3	1115.4	9	-3346.2	932.4	2011	47	892.1	2209	41929.7	893.0
1962	-2	990.2	4	-1980.4	931.6	2012	48	971.4	2304	46626.4	892.2
1963	-1	1115.9	1	-1115.9	930.8	2013	49	1313.1	2401	64342.5	891.4
1964	0	1035.0	0	0.0	930.0	2014		881.4			890.6
							Σ=0	**Σy= 92963.7**	**Σx2= 80850**	**Σx2= - 63298.2**	

Forecasting of annual rainfall

On the basis, the future forecast of rainfall for a period of ten years from 2016 to 2025 has been made (Table 6), which shows a negative trend for the coming years. In future, expected annual rainfall may be less in year 2025 observed 881.9mm in the state. In the year 2021; expected rainfall may be 893mm. The trend analysis gives the scenario of current to expected future situation. So in view of future rainfall is going tobe decline. It will also affect the production of rabi and Kharif season crops.

Table 6. Expected future Annual rainfall (mm) trend

Expected future rainfall trend (mm)	
Year	**Annual Rainfall (mm)**
2016	889.0
2017	888.2
2018	887.4
2019	886.7
2020	885.9
2021	893.0
2022	884.3
2023	883.5
2024	882.7
2025	881.9

The statistical data of hundred years (1915 to 2014) rainfall dataset of Uttar Pradesh was divided in ten decadal datasets *viz.* 1915-24, 1925-34, 1935-44, 1945-54, 1955-64, 1965-74, 1975-84, 1985-94, 1995-04 & 2005-14 were analyzed (Table 7) and observed 5^{th} decadal dataset (1955-64) having maximum rainfall 1037.4mm whereas in 8th dataset observed minimum rainfall 822.1mm. The maximum standard deviation value and CV(%) is observed 210 & 23% in year 1935-44 and minimum standard deviation and CV(%) is observed 80.7 & 10% in year 1995-04. The overall decadal dataset observed decadal maximum rainfall 1328.9 in year 1955-64 whereas minimum rainfall 493.9mm in year 2005-14 observed. The highest coefficient of skewness observed negative value -0.49 in year 1945-54. The highest median value of decadal dataset is observed 1060.4.

Table 7. Decadal Computation of statistical parameters of Uttar Pradesh

Parameters	Mean Decadal Uttar Pradesh									
	1915-24	**1925-34**	**1935-44**	**1945-54**	**1955-64**	**1965-74**	**1975-84**	**1985-94**	**1995-04**	**2005-14**
Mean	955.2	924.6	930.0	976.2	1037.4	897.3	955.0	822.1	819.9	977.3
SD	191.4	179.5	210.0	178.0	142.7	135.0	143.9	94.1	80.7	174.3
CV	0.20	0.19	0.23	0.18	0.14	0.15	0.15	0.11	0.10	0.18
CV%	20.0	19.4	22.6	18.2	13.8	15.0	15.1	11.4	9.8	17.8
MIN	541.5	543.1	502.0	569.1	684.8	601.9	713.4	626.3	660.2	493.9
MAX	1291.6	1256.7	1263.5	1311.5	1328.9	1107.1	1266.9	1049.8	973.9	1283.1
MEDIAN	1015.5	977.2	989.7	1006.4	1060.4	937.8	995.9	819.3	815.2	980.8
COFF OF SKEWNESS	-0.48	-0.37	-0.44	-0.49	-0.41	-0.44	-0.12	0.29	-0.09	-0.33

GIS anlysis of time series data

Spatial interpolation s of decadal study

Geographical Information System (GIS) plays a vital role in interpolating and displaying various attributes of rainfall. It is effectively used in this attempt to compute and produce maps. ArcGIS Geostatistical Analyst is an interactive tools are use for generate optimal surfaces from sample data and evaluate predictions for better decision making (http://www.esri.com).

Geostatistical methods (krigings) are widely used in spatial interpolation from point measurement to continuous surfaces. Spatial interpolation with the geostatistical and Inverse Distance Weighting (IDW) algorithms outperformed considerably interpolation with the Thiessen polygon that is commonly used in various hydrological models.

ESRI's Geo-statistical analyst extension has been used for these analyses. The rainfall surfaces were predicted using ordinary kriging method. The co-kriging analysis has been done to improve the accuracy of prediction, by including the elevation as a covariate. (Mesnard, 2013). It is applied to study Spatio-temporal distributions of the annual rainfall in Uttar Pradesh.

In this research, the spatial distribution of rainfall for different decadal pattern in a century, and the prediction of rainfall have been made using geostatistical analysis in geographic information system (GIS) software. ESRI's ArcGIS Geostatistical Analyst generate optimal surfaces from sample data and evaluate predictions for better decision making & used for decadal datasets analyses. The spatial temporal decadal maps are generated and observed trends and pattern of rainfall. The prediction map of dataset year 1995-2004 was highest rainfall in east side of some place of Uttar Pradesh. The western part of Uttar Pradesh covered less rainfall the other side cover area. The central part of state decadal map covered maximum area in year 1966-74 (Fig.5).

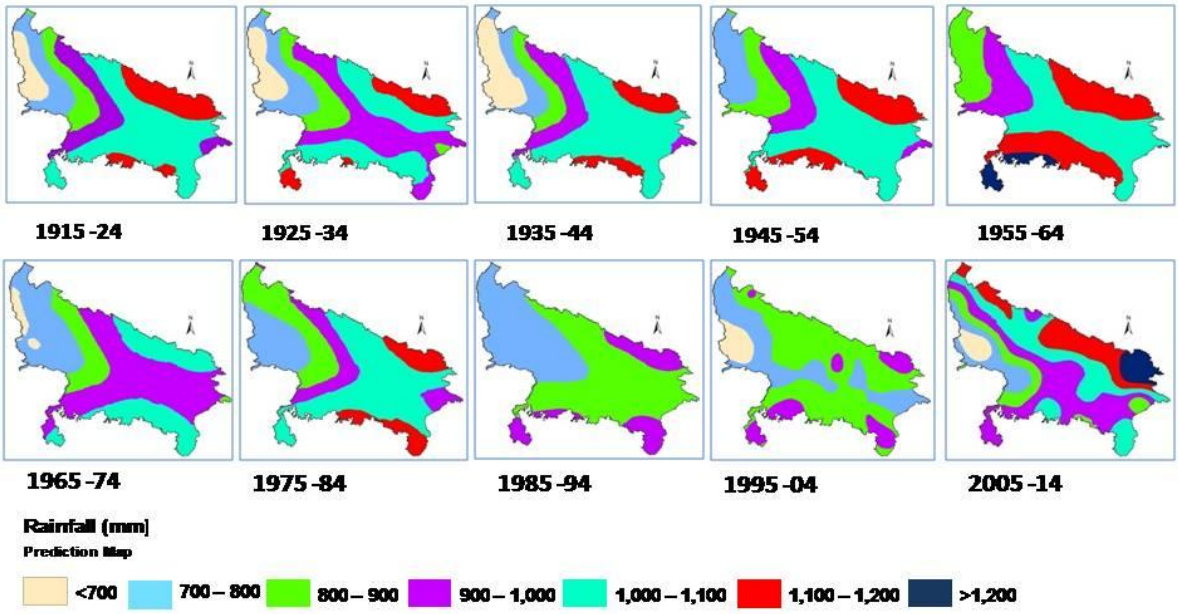

Fig.5. Geostatistical analysis of decadal rainfall (mm) pattern in Uttar Pradesh

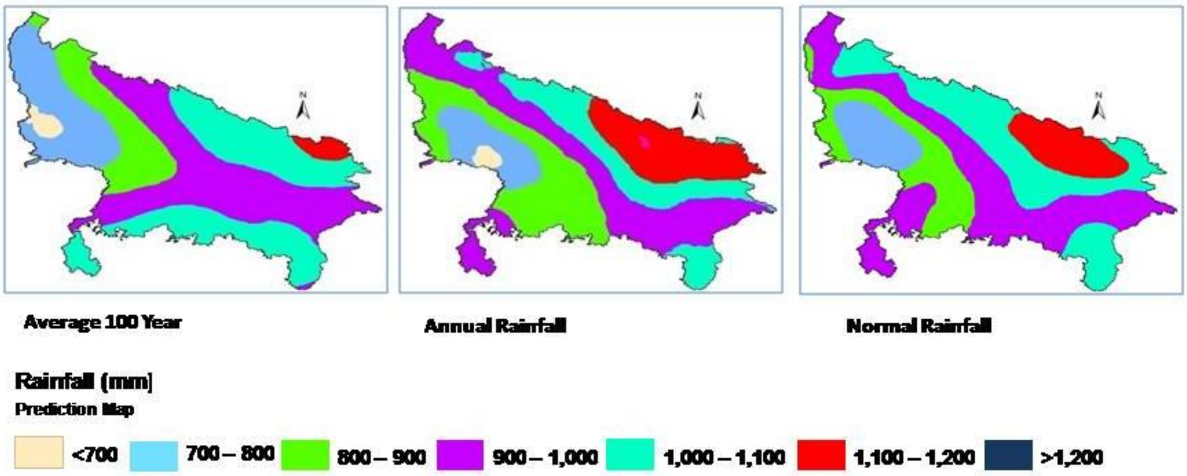

Fig.6. Geostatistical analysis of a centum (average), annual and normal rainfall (mm) pattern in Uttar Pradesh

The prediction map shown in Fig. 6 observed the pattern of rainfall of a century based average data study the lowest rainfall observed in western part of the Uttar Pradesh but maximum rainfall (1100-1200 mm) covered part in red tone observed in small areas of eastern Uttar Pradesh. The central part of the Uttar Pradesh covered rainfall range 900-1000 mm in violet color. The annual rainfall map study the maximum rainfall 1000 to 1100mm covered in eastern part of U.P. The normal rainfall pattern is like to annual rainfall.

CONCLUSION

Normal rainfall of region during 1915-2014 is 929.6.mm. The maximum rainfall recoded 1313.1mm in year 2013 and lowest rainfall recoded 532.7mm in year 1991. The south west monsoon plays a vital role in rainfall for water cycle. It contributes the highest percentage of rainfall and kharif season crops are most of dependent on rainfall. The average rainfall with 2013 showing the highest positive rainfall anomaly (2.26) while the other years show rainfall below normal with 1991 Showing the lowest negative rainfall deviation (-2.34). The calculated value of standard deviation reveals that deviation of rainfall is of 169.7 mm. in a century. The trend analysis in XLSTAT *2014.6.02* ver. observed trend of rainfall, the R^2 value 0.018 means that only 1.8 percent variation is observed in hundred years. The coefficient of skewness has been computed as -0.06 for annual rainfall indicates a negative trend or going to decline pattern. In future, expected annual rainfall may be less in year 2025 observed 881.9mm in the state. In the year 2021; expected rainfall may be 893mm. The trend analysis gives the scenario of current to expected future situation. Geographical Information System (GIS) plays a vital role in interpolating and displaying various attributes of rainfall. The spatial temporal decadal maps are generated and observed trends and pattern of rainfall. The prediction map of dataset year 1995-2004 was highest rainfall in east side of some place of Uttar Pradesh. The western part of Uttar Pradesh covered less rainfall the other side cover area. The central part of state decadal map covered maximum area in year 1966-74.

The statistical data of hundred years (1915 to 2014) rainfall dataset of Uttar Pradesh was divided in ten decadal datasets; and observed 5th decadal dataset (1955-64) having maximum rainfall 1037.4mm whereas in 8th dataset observed minimum rainfall 822.1mm. Water is a vital component for agricultural crops and in abnormal period crops are irrigated by available source *viz.* tube well, submersible, canal, irrigation channels and other sources. Today rainfall is not regular fashion so farmers are not more dependent much more on rainfall. The source of irrigation, mechanization and knowledge of current situation of weather and climate change related pattern and adaptation of technology is maintend to crops yield trend. The precise technologies are use for fast and reliable information for proper future management. The spatial temporal decadal maps are generated and observed trends and prediction of rainfall patterns. The geostatistical methods are use for pattern of rainfall study. The statistical and geostatistical methods for temporal data studies are helpful for planning and efficient use of agriculture water resources. Techniques of geostatistics are used to perform traditional statistical analysis and spatial analysis with ArcGIS, geostatistical software and statistical software XLSAT in order to obtain the knowledge of characteristics of distribution and spatial variability of rainfall in different parts of Uttar Prdesh.

REFERENCES

Adger, W.N., Huq, S., Brown, K., Conway, D. & Hulme, M. (2003). Adaptation to climate change in the developing world, Progress Dev. Stud., 3: 179-195.

Alam, M. M., Toriman, M. E. bin, Siwar,C. & Talib,B. (2011). Rainfall variation and changing pattern of agricultural cycle. American Journal of Environmental Sciences 7 (1): 82-89.

Attri, S.D. and Tyagi, A. (2010). Climate profile of India. India Meteorological Department, Ministry of Earth Sciences, New Delhi: Met Monograph No. Environment Meteorology- 01/2010.

Ayoade, J.O. (1973). Annual rainfall trends and periodicities in Nigeria, Nigerian Geog. J., 16(2):167-176.

Cheng, J., Shi, Z., & Zhu, Y. (2007). Assessment and mapping of environmental quality in agricultural soils of Zhejiang Province. Journal of Environmental Sciences, 191: 50–54.

Cobanovic, K. (2002). Role of statistics in the education of agricultureal science students . ICOTS6. 1-4. http://iase-web.org/documents/papers/icots6/4i2_coba.pdf

Dingman, S.L., Seely-Reynolds, D.M. and Reynolds, R.C. (1988). Application of kriging to estimate mean annual precipitation in a region of orographic influence. Water Resour. Bull. 24(2):329-339.

http://www.esri.com/software/arcgis/extensions/geostatistical

India State of Forest Report (2015). Forest survey of India, Ministry of Environment & Forests, Govt. of India, Pp. 1-300.

http://fsi.nic.in/isfr-2015/isfr-2015-forest-and-tree-resources-in-states-and-union-territories.pdf

Jang, M., Choi, J., and Lee, J. (2007). A spatial reasoning approach to estimating paddy rice water demand in Hwanghaenam-do, North Korea. Agricultural Water Management, 893:185–198.

Goswami, B.N., Venugopal, V., Sengupa, D., Madhusoodanan, M.S. & Xavier, P.K. (2006). Increasing trend of extreme rain events over India in a warming environment, Science. 314:1442-1445.

Guha, G.S. & D.N. Basu (1996). Agroclimtic regional planning in India (Vol.1: concept & applicatons). Pp. 1-235

Haberlandt, U. (2007). Geostatistical interpolation of hourly precipitation from rain gauges and radar for a large-scale extreme rainfall event. Journal of Hydrology, 332: 144–157.

Hutchinson, P. (1985). Rainfall analysis of the Sahelian drought in the Gambia, J. Climatology. 5: 665-672.

Mesnard, L. de (2013). Pollution models and inverse distance weighting: Some critical remarks. Computers & Geosciences. 52: 459-469.

Obot, N.I., Emberga, T.T. & Ishola, K.S. (2011). 22 years characterized trends of rainfall in Abeokuta, Nigeria, Research Journal of Applied Sciences. 6(4) : 264-271.

http://www.gktoday.in/major-crops-of-india/

Rainfall data: IMD New Delhi, India water Portal & NASA/POWER Agrometeorology webs: India Water Portal (1901-2002 & 2004-2010):
http://www.indiawaterportal.org
IMD (Indian Meteorology Department, New Delhi, (2007 to2013):
www.imd.gov.in
NASA/POWER Agroclimatology Daily Averaged Data (2003 & 2014):
http://power.larc.nasa.gov/common/Agroclimatology Methodology/Agro1d0_Methodology_Content.html
& http://power.larc.nasa.gov

Rimi, R. H., Rahman, S.H., Karmakar, S., Hussain. Sk. G. ( ). Trend Analysis of climate change and investigation on Its probable impacts on rice production at Satkhira, Bangladesh. Pakistan Journal of Meteorology. 6 (11).