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Drought Assessment and Monitoring for Rajshahi District Using Meteorological Drought Indices

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ABSTRACT

An analysis for drought condition has been made in the Rajshahi district of Bangladesh. The assessment of drought for the country has become an urgent need. The agriculture of the country is dependent on the amount of precipitation. As drought and precipitation are inversely related so it is desired to know the condition of Rajshahi. The main characteristics that define drought are the absence of precipitation for a lengthy period and a low distribution of rainfall in contrast to the normal climatic condition. The monthly maximum average temperature data, monthly minimum average temperature data and total monthly precipitation data for the last 48 years (1971-2019) from Bangladesh Meteorological Department (BMD) are utilized for the analysis process. An online software named DrinC is preferred due to its open-source platform and its user-friendly interface. The meteorological data serve as inputs for the software. The Deciles Index (DI), the Standardized Precipitation Index (SPI) and the Reconnaissance Drought Index (RDI) have been used to identify the drought condition of Rajshahi. The values of the DI and SPI are generated from the precipitation data. However, for the generation of the RDI, the precipitation data as well as the potential evapo-transpiration (PET) data, which is an intermediate data that is generated from the two different types of temperature data via DrinC software are used. The values of SPI, RDI and DI values are presented in a tabular as well as in graphical form. From the comparison of these data and from the study of the recurrence interval the state and the repetition of drought in Rajshahi district can be determined.

Keywords : Drought, Drought Indices, Precipitation, Temperature.

I. INTRODUCTION

Drought is a natural disaster which is characterized by low or no precipitation. It is a recurring disaster that Bangladesh often must face almost each year. Since Bangladesh is an agricultural country so its economy is mainly dependent on the production of food crops and cash crops. It also makes the environment unsuitable for human habitation [1]. According to statistics developed by researchers, about 35 countries of the world will encounter low water storage by the end of 2020 [2]. Wilhite & Glantz [3] and the American Meteorological Society [4] have classified droughts into four categories as hydrological, meteorological, socioeconomic, and agricultural. Since Rajshahi is one of the major regions of Bangladesh that contributes to the agricultural sector so the analysis of drought in Rajshahi has become a need. The geographical boundary of Rajshahi ranges from 24º20′ north latitude to 24º24′ north latitudes and from 88º32′ east longitude to 88º40′ east longitudes. Rajshahi occupies an area of about 120.98 km^2 and it has an elevation of 18 m.

The drought in a region can be identified with the help of drought indices. Drought indices not only identifies drought prone areas but also help in realizing the severity level by numerical values which have their own meaning or level they represent [5, 6]. Drought levels are characterized with the assimilation of various variables such as precipitation, temperature, stream flow, potential evapo-transpiration etc. [7]. They help researchers to make decisions based on the severity level and to undertake contingency plans if any [8]. DrinC [9] is an open-source software that allows users to make necessary analysis with its wide range of drought index. More than 150 drought indices have been developed and each of them requires their own set of data that need to be supplied to the software as input [10]. Maximum temperature data, minimum temperature data and monthly precipitation data of 49 years (1971-2019) has been analyzed in DrinC software. Generally, the Deciles Index (DI) is one of the simplest indices that is used for drought analysis [11]. The Standardized Precipitation Index (SPI) is also used to assess drought condition and used the most for its low data requirements and wide range of performance [12]. The DI and SPI need only precipitation data for its processing and analysis. The Reconnaissance Drought Index (RDI) needs the PET data and cumulative precipitation data for providing the result as output [13]. This index is quite sensitive and flexible.

II. RESEARCH METHODOLOGY

The aim is to have a good concept about the severity in drought level after obtaining the numerical values of the drought indices and their corresponding reference to their extent of dryness or wetness. This has been done by comparing the values of the drought indices if the DI, SPI and RDI.

2.1 Deciles Index: The Deciles Index is one of the simplest meteorological drought indices. It is easy to work with this index because of its low information requirements. With the help of long term climatic and meteorological data records, this index gives an accurate statistical measurement of precipitation. Gibbs and Maher [11], in 1967, developed this index. The method is based on dividing the distribution of monthly recorded precipitation into ten percent of the whole precipitation distribution. Each of the tenths is called a decile. A first deciles indicate that the rainfall amount does not exceed by the lowest 10% of precipitation occurrence [14]. Similarly, the second decile indicate that the precipitation amount does not exceed by the lowest 20% of occurrences and so on. The fifth decile is the median and according to the definition of deciles, it is the sum of precipitations that does not surpass by 50% of the occurrence over the time period of record. In this method, the sum of a long-term monthly precipitation records is firstly ranked in a descending order i.e., from highest value to lowest value and a cumulative distribution is constructed. The fifth deciles, which is the median, is used to determine the central tendency of the record. The summation of precipitation for the surpassing 3 months records are ranked against climatologic records and when the summation falls within the documented distribution of 3 months total then the region is judged to be under drought criteria. The Decile Indices are grouped into five classes [9] in total and each class consists of two deciles (per class) which is shown below in Table 2.2.1.

Table 2.1.1: The precipitation Deciles Index (DI) classification table [9]

DI class	Description of moisture level
Deciles 1-2: lowest 20% of data	Much below normal
Deciles 3-4: next lowest 20% of data	Below normal
Deciles 5-6: middle 20% of data	Near normal
Deciles 7-8: next highest 20% of data	Above normal
Deciles 9-10: highest 20% of data	Much above normal

The deciles method is simple and provides a uniform classification for drought and it assists climatology and meteorology authorities to stimulate an appropriate drought response. However, a drawback of this method is that it requires an extensive record (over 25 years) of meteorological data.

2.2 Standardized Precipitation Index (SPI): The Standardized Precipitation Index (SPI) is a renowned and a widely used drought index which is used to specify meteorological drought on a range of timeframe. It is a versatile index, it can compute the drought index for different time range, it can provide an early warning of drought in the upcoming future and it helps in assessing drought severity. In 1993 T. B. McKee, N. J. Doesken, and J. Kleist developed this drought index [15]. It was developed to measure the precipitation deficiency for different time scales that demonstrate the effects of drought on the distinctive water resources. Based on precipitation value, the abnormal wetness and dryness of a region can be computed by using SPI method. In order to determine the SPI of a specific region, the difference between the normalized seasonal precipitation and the long-term seasonal mean of that region is first found out and later the difference is divided by the standard deviation of precipitation of that specific region. An expression for the SPI value can be equated as,

$$SPI = \frac{X_{ij}-\overline{X}}{\sigma}$$

(Equation 2.2.1)

Where,

Xij = the seasonal precipitation at the i-th rain gauge and j-th observation

$\overline{X}$ = the long-term seasonal mean

σ = the standard deviation of precipitation

The distinction of dry years from wet years as well as the distinction of water deficit years from surplus years can be obtained from the SPI value [17]. The SPI values are numerically represented using positive and negative sign before the number. The positive values of SPI precipitation, whilst the negative values of SPI index represent rainfall deficiency. McKee used a classification system to represent the drought severities and intensities from the values that result from SPI [16, 17]. The values and their respective severities are given in a tabular form.

Table 2.2.1: Classification of SPI values with respective criterion [16, 17]

SPI value	Moisture level criterion
≥ 2.0	Extremely wet
1.5 to 1.99	Very wet
to1.49	Moderately wet
0.99 to -0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
≤ -2.0	Extremely dry

A drought is said to have occurred when the value of the SPI is continuously negative and it reaches a value that has an intensity of -1.0 or less whilst the drought is said to have ended when the value of SPI becomes positive.

2.3 Reconnaissance Drought Index (RDI): The Reconnaissance Drought Index (RDI) is a popular meteorological index for assessing drought [18, 19]. The index was developed in an approach to explain the water deficit criteria in a more precise strategy. It was based on the theory of water balance between input and output system [20, 21]. On the other hand, RDI represents drought severity by talking in consideration of both precipitation data and potential evapotranspiration (PET) data. Since the RDI incorporates the PET data alongside the precipitation data to assist in determining drought severity, it is considered to yield more realistic representation of the drought. Hence it is used to determine and compare drought criteria among different areas with different meteorological and climatic characteristics. The RDI is demonstrated by the initial value (α_k), the normalized RDI (RDI_n) and the standardized RDI (RDI_{st}). With the help of the following equation, the initial value (α_k) for the i-th year and on a time basis of k months can be calculated as:

$$\alpha_k{}^i = \frac{\Sigma^k{}_{j=1} P_{ij}}{\Sigma^k{}_{j=1} PET_{ij}}, \; i = 1(1)\, N \text{ and } j = 1(1)\, k$$

(Equation 2.3.1)

where,

P_{ij} = precipitation of month j of the hydrological year i

PET_{ij} = potential evapotranspiration of month j of the hydrological year i

For different locations in a wide range of time scale, the values of α_k follow both the lognormal distribution and gamma distribution.

Considering that the lognormal distribution is used, the value of RDI_{st} can be calculated by the following equation:

$$RDI_{st} = \frac{y^{(i)} - \bar{y}}{\sigma_y}$$

(Equation 2.3.2)

where,

$y^{(i)} = \ln(\alpha_k)$

$\bar{y}$ = arithmetic mean

σ_y = standard deviation

When compared with the normal conditions of the area, the positive values of RDI indicate wet periods whilst the negative values of RDI indicate dry periods [9]. The RDI values can be assigned in the following table:

Table 2.3.1: Classification of RDI values with respective criterion [9]

RDI values	Moisture level criterion
2.00 or more	Extremely wet
1.99 to 1.50	Severely wet
1.49 to 1.00	Moderately wet
0.99 to 0.00	Normal wet condition
0.00 to -0.99	Normal dry condition
-1.00 to -1.49	Moderately dry
-1.50 to -1.99	Severely dry
-2.00 or less	Extremely dry

III. RESULTS AND DISCUSSION

The raw data after collection and processing has been used to produce the DI, SPI and RDI values. To obtain the potential evapo-transpiration (PET) data, the maximum average temperature data and the minimum average temperature data are provided to the DrinC software and after analysis gives the PET values.

Table 3.1 : PET data from the year of 1971-2019 in Rajshahi

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1971 - 1972	168.4	121.7	110.8	113.6	142.3	209.6	234.9	287.8	244.3	207.2	168.7	191.1
1972 - 1973	158.6	125.1	116.8	138.2	147.5	232.6	243.3	215.8	203.3	176.3	160.8	146.0
1973 - 1974	137.6	117.6	101.7	113.8	151.5	201.7	236.7	243.9	215.2	174.3	167.8	154.7
1974 - 1975	160.9	125.5	102.4	109.6	141.4	210.0	239.1	258.6	225.4	182.3	171.6	145.0
1975 - 1976	128.9	120.6	102.0	112.7	139.8	205.9	230.8	269.6	200.7	181.7	167.7	147.5

1976 - 1977	148.2	129.6	111.7	118.6	152.4	209.1	218.6	250.7	213.6	174.2	188.7	160.6
1977 - 1978	148.1	121.6	108.7	116.3	135.9	199.0	211.7	222.6	190.0	158.2	151.3	144.0
1978 - 1979	137.0	123.3	102.7	110.1	133.9	224.1	235.1	274.7	265.4	188.2	200.1	188.6
1979 - 1980	140.9	122.1	103.6	116.3	141.0	214.8	260.0	256.0	213.3	189.6	209.7	142.1
1980 - 1981	139.0	115.2	107.7	107.7	147.0	193.9	208.5	214.3	225.5	168.4	155.7	146.7
1981 - 1982	152.4	122.0	107.9	110.3	142.6	189.4	217.8	225.9	207.7	218.3	162.8	162.5
Year	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
1982 - 1983	157.7	132.1	103.0	118.6	142.9	217.4	234.8	227.9	240.1	194.1	168.3	139.5
1983 - 1984	148.9	119.7	108.3	109.4	127.8	220.5	251.0	250.8	210.8	167.5	177.4	153.2
1984 - 1985	148.6	115.5	110.8	114.3	136.5	216.5	257.8	214.6	208.8	170.2	169.0	147.2
1985 - 1986	152.7	124.9	108.2	121.2	138.4	234.3	243.6	248.7	241.4	171.7	181.8	166.7
1986 - 1987	140.3	120.0	110.5	115.4	145.0	212.3	238.5	274.8	234.3	178.3	205.1	162.5
1987 - 1988	158.2	129.2	109.1	114.3	133.6	202.1	249.6	247.9	218.0	171.7	170.5	167.6
1988 - 1989	147.6	134.8	102.9	112.4	147.8	214.5	259.8	279.9	195.7	199.5	179.7	175.0
1989 - 1990	152.2	126.4	111.4	124.1	130.0	202.3	237.5	216.3	202.6	167.1	190.3	170.1
1990 - 1991	156.3	133.7	114.7	123.0	146.1	215.5	235.8	252.1	190.3	185.0	189.1	160.7
1991 - 1992	158.5	129.2	113.0	113.2	121.8	221.5	254.3	258.7	231.5	197.6	188.1	166.7
1992 - 1993	164.3	128.5	108.1	133.0	149.2	208.9	231.2	240.7	212.5	175.9	160.2	154.9
1993 - 1994	152.9	118.9	109.2	114.6	136.9	213.2	230.4	267.5	218.9	166.1	170.9	163.3
1994 - 1995	151.6	122.4	110.4	111.5	127.2	225.1	251.4	269.7	218.9	172.4	170.2	153.1
1995 - 1996	151.6	133.8	107.6	109.5	135.2	211.5	254.0	259.2	207.1	178.8	178.4	162.6
1996 - 1997	151.3	130.1	107.5	107.6	134.1	193.3	214.9	245.0	217.0	179.9	181.8	151.6
1997 - 1998	148.2	124.9	106.1	105.9	136.2	197.9	223.3	261.7	244.3	180.6	165.0	165.5
1998 - 1999	158.3	120.4	110.2	117.4	150.3	216.1	239.5	243.4	223.3	199.3	172.8	147.3
1999 - 2000	132.0	126.0	108.1	117.3	122.8	196.3	225.6	231.0	189.7	174.3	173.9	153.9
2000 - 2001	154.2	118.8	102.2	116.3	136.5	212.2	227.7	219.7	184.8	170.0	171.6	154.7
2001 - 2002	140.2	128.7	102.9	113.9	142.3	207.0	218.7	241.8	187.2	207.3	176.4	154.6
2002 - 2003	163.3	120.4	112.7	110.9	139.5	200.5	227.1	258.5	219.3	176.0	172.1	151.8
2003 - 2004	139.8	125.4	110.6	105.3	152.7	223.0	234.0	261.3	199.3	193.0	170.9	162.0
2004 - 2005	153.9	115.6	112.8	108.0	143.7	192.8	218.5	248.0	252.0	174.8	175.2	166.2
2005 - 2006	144.2	121.1	105.8	115.3	156.6	220.3	222.9	241.8	210.2	188.7	178.8	157.4
2006 - 2007	157.4	127.0	107.3	117.8	128.4	208.8	226.0	245.4	238.0	202.4	188.5	157.7
2007 - 2008	156.9	125.0	109.0	117.2	132.8	209.6	232.7	228.2	195.7	171.4	171.7	153.0
2008 - 2009	152.4	127.0	109.9	109.1	145.9	198.2	239.2	256.6	224.3	187.1	174.6	157.0
2009 - 2010	157.0	136.3	115.2	113.6	143.2	225.5	246.0	247.7	216.6	181.8	195.3	168.3
2010 - 2011	161.4	129.1	109.2	111.0	140.2	215.7	209.6	219.9	203.0	189.0	182.0	161.6
2011 - 2012	164.3	120.9	114.0	109.8	144.6	219.5	232.2	258.5	247.2	181.7	174.5	160.9

2012 - 2013	166.3	124.9	108.4	94.8	139.5	218.8	243.7	257.4	242.5	199.8	177.1	161.4
2013 - 2014	145.9	112.9	97.7	103.8	138.2	221.6	227.4	236.3	228.5	212.9	236.8	158.9
2014 - 2015	130.9	112.4	115.9	106.1	142.1	196.1	206.3	201.3	183.1	174.0	176.0	133.5
2015 - 2016	110.3	117.9	110.1	116.5	139.5	214.3	221.8	234.0	246.0	248.3	174.7	150.1
2016 - 2017	148.5	133.4	98.7	113.4	146.9	222.5	264.0	293.1	264.0	216.1	194.2	158.5
Year	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
2017 - 2018	129.6	88.0	104.3	115.3	153.2	208.1	249.8	237.5	205.2	172.9	157.0	148.7
2018 - 2019	145.9	127.1	104.7	121.1	131.7	184.1	217.6	256.3	243.0	222.5	167.4	152.2

The PET data obtained as an intermediate data was then utilized as an input data along with the monthly precipitation data, maximum temperature data and minimum temperature data.

The variation of the SPI, RDI and the DI are given in a tabular form from the year of 1971-2019 for Rajshahi station of Rajshahi district.

Table 3.2 : Variation of SPI, RDI and DI from the year of 1971-2019 in Rajshahi

Year	**1971 - 1972**	**1972 - 1973**	**1973 - 1974**	**1974 - 1975**	**1975 - 1976**	**1976 - 1977**	**1977 - 1978**	**1978 - 1979**	**1979 - 1980**	**1980 - 1981**	**1981 - 1982**	**1982 - 1983**	**1983 - 1984**	**1984 - 1985**
SPI	-1.61	1.07	0.94	-0.99	0.20	0.95	1.14	0.16	0.42	2.30	-1.20	-0.30	0.92	-0.21
RDI	-1.75	0.99	0.98	-0.94	0.30	0.86	1.43	-0.09	0.3	2.49	-1.04	-0.31	0.90	-0.09
DI	1	9	9	2	6	9	9	6	8	10	1	4	9	5
Year	**1985 - 1986**	**1986 - 1987**	**1987 - 1988**	**1988 - 1989**	**1989 - 1990**	**1990 - 1991**	**1991 - 1992**	**1992 - 1993**	**1993 - 1994**	**1994 - 1995**	**1995 - 1996**	**1996 - 1997**	**1997 - 1998**	**1998 - 1999**
SPI	-0.23	0.65	0.20	-0.27	0.88	-0.15	-1.49	0.01	-0.82	0.26	-0.79	1.86	-0.21	1.45
RDI	-0.36	0.45	0.17	-0.42	0.90	-0.22	-1.56	0.00	-0.76	0.2	-0.79	1.85	-0.19	1.27
DI	4	8	7	4	8	5	1	6	2	7	2	10	5	10
Year	**1999 - 2000**	**2000 - 2001**	**2001 - 2002**	**2002 - 2003**	**2003 - 2004**	**2004 - 2005**	**2005 - 2006**	**2006 - 2007**	**2007 - 2008**	**2008 - 2009**	**2009 - 2010**	**2010 - 2011**	**2011 - 2012**	**2012 - 2013**
SPI	0.91	-0.53	0.38	-0.89	1.40	-0.53	-0.22	1.55	-0.57	-1.12	-3.13	0.50	-1.60	-0.65
RDI	1.11	-0.30	0.44	-0.82	1.28	-0.49	-0.21	1.35	-0.41	-1.08	-3.06	0.54	-1.61	-0.75
DI	8	3	7	2	10	3	4	10	3	2	1	8	1	3
Year	**2013 - 2014**	**2014 - 2015**	**2015 - 2016**	**2016 - 2017**	**2017 - 2018**	**2018 - 2019**								
SPI	-0.18	-0.10	-0.49	-0.17	0.00	0.29								
RDI	-0.28	0.31	-0.50	-0.52	0.20	0.25								
DI	5	6	3	5	6	7								

The variation of the SPI is given in a graphical form from the year of 1971-2019 for Rajshahi.

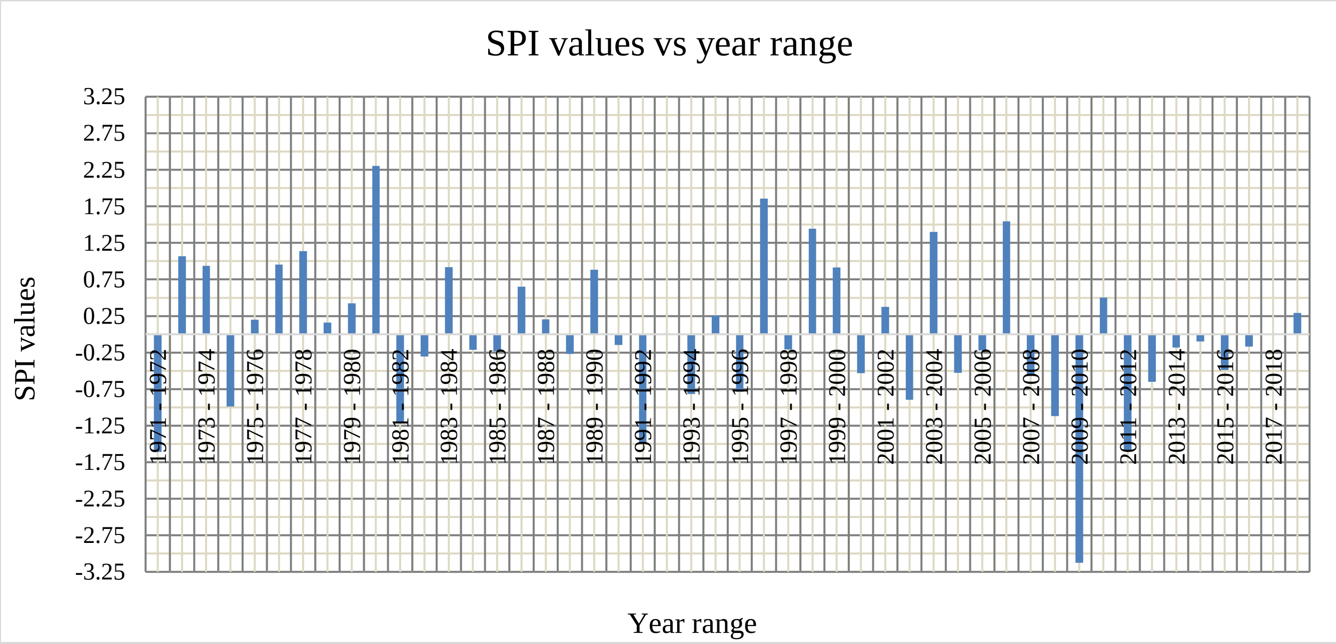

Fig. no. 3.1: - SPI variation at Rajshahi

The above figure shows the condition of drought as represented by the SPI index. It is seen that a 'severely dry' condition is seen in the year range 1971-1972. Condition like this has again occurred in the year range 1991-1992 with 'moderately dry' condition. Such a condition has a return period of 20 years. Again, the same condition repeated in the year range 2011-2012 as 'severely dry' condition. But an exceptional breach of this recurrence interval was encountered in the year range 2009-2010 as 'extremely dry' condition. An analysis of the wet conditions shows 'moderately wet' condition in 1972-1973 and 'near normal' condition in the consecutive year 1973-1974. This pattern has shown an irregularity as time proceeds.

The variation of the RDI is given in a graphical form from the year of 1971-2019 for Rajshahi.

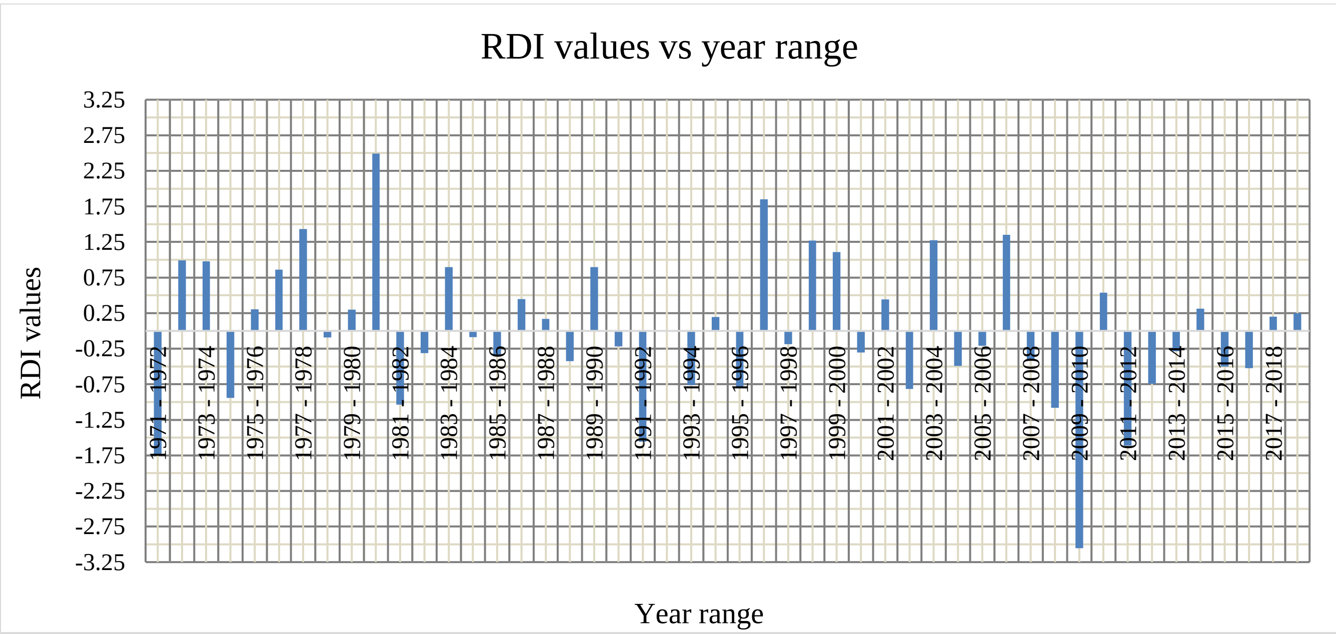

Fig. no. 3.2: - RDI variation at Rajshahi

The bar chart for RDI shows that 'severely dry' condition was encountered in 1971-1972 and after 20years the conditions repeated and again after a further 20 years. However, like the SPI chart, an exceptional 'extremely dry' condition was found in 2009-2010. The study of the wet conditions shows the same case as shown in the SPI values; 'moderately wet' condition in 1972-1973 and 'near normal' condition in 1973-1974. The wetness of Rajshahi has shown a decreasing pattern in the preceding year ranges.

The variation of the DI is given in a graphical form from the year of 1971-2019 Rajshahi.

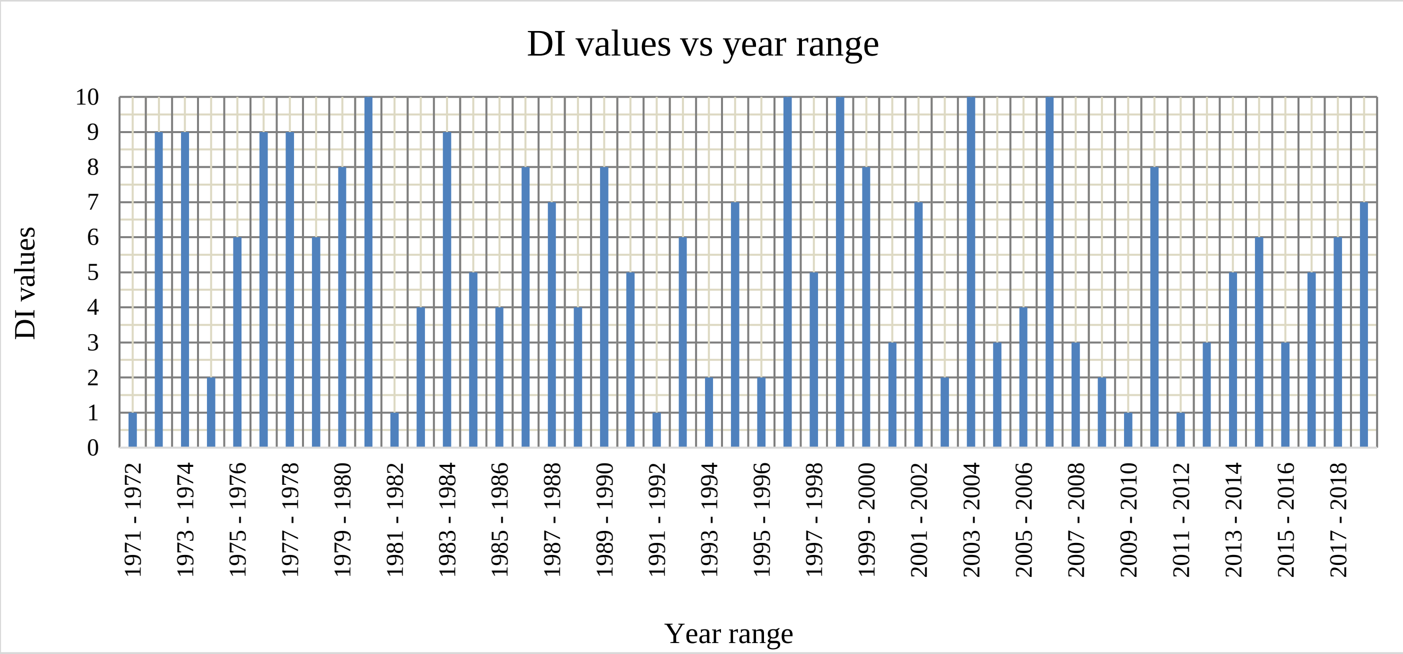

Fig. no. 3.3: - DI variation at Rajshahi

The DI chart shows that in 1971-1972 a 'much below normal' humidity condition encountered but in the next two consecutive year range the values indicated a 'much above normal' condition of humidity. If the recurrence interval for 'much below normal' and 'much above normal' levels are analyzed then it is seen that the relative distance from each other in the graph tends to increase as time moves on.

IV. CONCLUSIONS

The assessment and monitoring of drought for Rajshahi city was done from 1971-72 to 2018-19 in order to gain knowledge about the drought patterns, recurrence interval and severity level. The exceptional condition for the year 2009-2010 can be explained by **Annexure-A** which shows that for that particular year range the maximum average temperature was the second highest and the annual rainfall was the lowest which resulted in an 'extremely dry' condition as stated by SPI and RDI. The deciles index for 2009-2010 shows a 'much below normal' condition of humidity which also occurred in the year range 1971-72, 1981-82, 1991-92, 2011-2012. But in those years, there was precipitation as stated by SPI and RDI graph. Again in 2001-02 there is 'above normal condition' from DI graph unlike the other 10 years recurrence interval because there was precipitation as seen in SPI and RDI. But on a whole, it is seen that the SPI values tend to decrease more, the RDI values show the same concept and the DI values comply with the other two indices as the relative distance between the dry years and wet years increase. So, it can be said that Rajshahi may become a drought prone zone. This may be due to the fluctuation in the different climatic condition, the effect of climate change of neighboring zones or states, global warming etc.

Annexure-A

Year range	1971-1972	1972-1973	1973-1974	1974-1975	1975-1976	1976-1977	1977-1978	1978-1979	1979-1980	1980-1981	1981-1982	1982-1983
Annual precipitation	82.75	150.5	146.6	96.17	125.6	147.1	152.7	124.6	131.8	191.3	91.50	112.4
Maximum annual average temperature	35.90	35.51	34.36	34.94	34.28	35.03	33.47	35.44	35.40	33.28	34.13	34.70
Minimum annual average temperature	16.51	17.63	17.26	17.48	17.52	16.96	17.44	16.23	17.38	16.93	16.77	15.86
Year range	**1983-1984**	**1984-1985**	**1985-1986**	**1986-1987**	**1987-1988**	**1988-1989**	**1989-1990**	**1990-1991**	**1991-1992**	**1992-1993**	**1993-1994**	**1994-1995**
Annual precipitation	146.0	114.8	114.3	138.2	125.7	113.3	145.0	116.4	85.3	120.5	100.1	127.2
Maximum annual average temperature	34.28	34.31	35.23	35.25	34.67	35.24	34.13	34.95	35.18	34.91	34.70	34.85
Minimum annual average temperature	16.30	17.12	16.13	16.62	16.51	15.68	15.88	15.63	15.88	16.08	16.90	16.61
Year range	**1995-1996**	**1996-1997**	**1997-1998**	**1998-1999**	**1999-2000**	**2000-2001**	**2001-2002**	**2002-2003**	**2003-2004**	**2004-2005**	**2005-2006**	**2006-2007**
Annual precipitation	100.8	175.8	114.9	162.3	145.8	106.8	130.4	98.3	160.9	106.9	114.5	165.6
Maximum annual average temperature	34.82	34.08	34.69	35.29	33.88	34.07	34.45	34.67	35.06	34.82	34.97	35.03
Minimum annual average temperature	16.29	16.73	17.08	17.16	17.63	17.41	17.26	16.81	17.18	17.33	17.30	16.77
Year range	**2007-2008**	**2008-2009**	**2009-2010**	**2010-2011**	**2011-2012**	**2012-2013**	**2013-2014**	**2014-2015**	**2015-2016**	**2016-2017**	**2017-2018**	**2018-2019**
Annual precipitation	105.9	93.3	55.7	134.0	83.0	104.0	115.6	117.7	107.8	115.9	120.3	128.1
Maximum annual average temperature	34.34	35.07	35.77	34.57	35.48	34.83	34.12	33.23	34.28	35.33	34.82	34.83
Minimum annual average temperature	17.03	17.21	16.70	16.76	16.66	15.27	13.41	17.63	14.97	12.72	18.80	17.26

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