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DROUGHTS AND THEIR ANALYSIS FOR AMRITSAR DISTRICT IN PUNJAB

Mani Bhushan[1], Aditya Raj[2] and L. B. Roy[3]

ABSTRACT

In India, nearly 75% of rainfall occurs during the south-west monsoon season i.e. from June to September. Deficiency of rainfall creates a situation of drought. In the present study one hundred ten years (1901-2010) average monthly rainfall data was analyzed to determine monthly and yearly meteorological drought occurrence in Amritsar district of the state of Punjab, India. The average annual rainfall in Amritsar is 477.1 mm with the maximum of 957.5 mm in the year 2006 and the minimum of 240.44 mm in the year 1920 during the period of study. The mean south-west monsoon rainfall (369.70 mm) contributes 77.2% of annual rainfall (477.1 mm). The decadal mean (% departure from normal) and frequencies of drought years were determined using different approaches. From this it was found that 2nd and 4th decades of 20th century had the maximum number[1] of deficient years. The rainfall data was analyzed on the basis of Palmer Index and Standardized Precipitation Index. Also, the drought months and years were determined using standard procedure given by IMD (1971). All the above issues have been described and discussed in detail in this paper.

Keywords: *Drought, Drought month, decadal mean, seasonal rainfall, Standardized Precipitation Index, drought frequency*

INTRODUCTION

Being an agricultural based country, the economic growth of India primarily depends on the vagaries of the weather and particularly on the extreme weather events. Sixty percent of the population works in agriculture, and it accounts for roughly one fifth of the country's gross domestic product. Thus, the agricultural sector lies at the core of Indian society. The economy of the country is heavily dependent on the monsoon rain that brings in over 75 % of rainfall over a major portion of the country. Monsoon is crucial for farm production and economic growth as about sixty percent of the arable land is rain fed. Rain fed agriculture has to meet its rainfall requirement in less than four months. Deficiency of rainfall is the basic reason for meteorological drought. Meteorological drought is an abnormally long period without or very less precipitation. Even though India receives a normal annual rainfall of 118 cm, the spatial and temporal variation lead to anomalies and which in turn lead to droughts and floods. Consequently, droughts have been an even-present feature at some part or other, of the country. The principal causes of drought may be attributed to erratic behavior of summer monsoon. The summer monsoon has a strategic hold on the Indian agriculture and Indian economy and, consequently on the livelihood of majority of people. When the surface water is scarce, as in a drought year, the ground water becomes scarcer, the wells dry up and the water will not be available even for drinking purpose. Droughts directly damage crops and degrade the land and desiccate the underground reservoir. Malnutrition and starvation are other impacts. Repeated droughts may lead to desertification.

In India, drought is a frequent natural calamity. The failure of monsoon both in time and space creates this situation. Ninety-nine districts spread over thirteen states have been identified as drought prone areas. The north-western parts of the country, where the annual rainfall is less than 700 mm are the most affected area.

1. *Ph. D Scholar, NIT Patna, Patna- 5, email:mani.tuntun@gmail.com*
2. *M. Tech (WRE), NIT Patna, Patna-5, email: adityaraj126@gmail.com*
3. *Professor of Civil Engineering, NIT Patna, Patna-5, email: lbroy@nitp.ac.in*

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Aridity is a permanent feature of climate while drought is a temporary event. Drought is viewed relative to some long-term average which is often considered as "normal" (Ragab, 2004).

Floods and droughts in India are the two aspects of the weather associated with abundance or deficit of monsoon rains. A large no. of studies is available on various aspects of floods and droughts. Chaudhary, Dandekar and Raut (1989) have ranked the year 1918 as the worst drought year of the last century – a year when about 68.7 % of the total area of the country was affected from drought. Of all the major natural disasters, droughts account for nearly 22 % of significant damages though the number of deaths is only 3 % world-wide (De and Joshi, 1998).

Drought is a normal, recurrent feature of climate; it can take place almost everywhere, although its manifestation varies from region to region. Therefore, its global definition is a difficult task (Dracup et. al. 1980). Different countries have different definitions for a drought. In the U.S.A, a drought is said to have occurred when the rainfall is less than normal for the place and time for a period of at least 21 consecutive days. In Bali, a period of 6 days without rain is a drought. In Libya, drought is recognized only after 2 years without rain. In Egypt, any year the Nile does not flood is a drought year. In Australia, drought means a period of months and years with little rainfall such that the country gets burnt up, grasses and water disappear, crops become worthless, sheep and cattle die. British Rainfall Organization has called drought as "a period of at least 15 consecutive days, none of which has created rainfall of 0.01 inch or more". In India, less monsoon rainfall leading to agriculture failure is regarded as a drought. Drought is a condition when the amount of rainfall in a particular region is less than half the normal precipitation of that region as per IMD (1971). In India, the whole year is divided into four seasons as per Subramanya (2012) i.e. the winter season (January- February), the pre-monsoon (March, April and May), the monsoon (June, July, August and September), and the post monsoon (October, November and December) are the four seasons of a year.

Dhar et al. (1979), Ramdas and Malik (1948), Sharma et al. (1979) have analyzed the meteorological drought in different regions of India. Shrivastava et al. (2008) studied the meteorological drought in North Lakhimpur district of Assam.

Tiwari et al. (2007) assessed the meteorological drought indices using the daily rainfall data of Hazaribagh station. Dabral (1996) analyzed the weekly, monthly, seasonal and yearly data for drought situation at Ranchi station. Shakir Ali (2003) reviewed different drought indices and emphasized to use a particular index in a particular agro-ecological region. Devappa (2009) studied droughts in Gulbarga district of Karnataka State, India. He assessed the drought condition for monthly time steps using rainfall data for 48 years (1961-2008) taking the average values for available stations. Lala (2012) analyzed twenty-eight years (1983-2010) daily rainfall data to find weekly, monthly, seasonal and yearly meteorological drought occurrence at Barapani station of Ri-Bhoi district in Meghalaya.

Reconnaissance drought index (RDI) is used as a climatic index for determining possible climatic charges of any geographical area. The main advantage of this approach is that RDI incorporates both precipitation and potential evapotranspiration in a single index (Tigkas et.al. 2013).

Drought is common in all climatic regimes of the country. It is a complex and slow process. Its onset phenomenon affects more number of people than any other natural hazards. It results in serious economic, social and environmental impacts. The country has suffered badly from drought during many recent years. Punjab is enlisted under the frequent drought (10-20 percent probability) prone areas as per the Indian Meteorological Department's (IMD) classification of drought incidences based on the study for the period 1875-2004. It is worth mentioning that Punjab is one of the fastest developing states in India. The state has posted a steady growth during the last several decades. Therefore, in this paper an attempt has been made to analyze and discuss the occurrence of meteorological drought in the Amritsar district of Punjab, India.

MATERIALS AND METHODS

Amritsar district in Punjab lies between 31° 7' and 32° 3' North latitude and 74° 29' and 75° 23' in the East longitude and has international boundary with Pakistan. It is bounded by river Beas in the South-Eastern side and river Ravi on the North-West side. The city is situated 217 km northwest of state capital Chandigarh and 456 km northwest of Delhi. It is near Pakistan, with the Wagah border at only 28 km away. The location map of the study area is as shown in Figure-1. According to the 2011 census, population of Amritsar was 1,132,761. The district comprises of 976 villages with total geographical area of 2.64 lakh ha, out of which 2.22 lakh ha are cultivable. It experiences extremes of climatic conditions. Summers are extremely hot and winters are very cold. A year may be divided into three seasons, namely, the cold winter (November to February), the hot summer (March to June) and monsoon season (mid-June to mid -September). Monsoon generally starts in the first week of July. The mean annual rainfall fluctuates around 477.1 mm, the major part of which is received during the months of July, August and September with a few showers of rain during winter months. Paddy is the major crop of the kharif season as it covers more than 85% of the net sown area and wheat, accounting for more than 90% area, is the major crop of the Rabi season. Other crops like maize, sugarcane and oilseeds are also grown in the district.

To analyze the drought condition in Amritsar district, one hundred and ten years of average monthly rainfall data (1901-2010) were used. Data were taken from Indian water portal. The following indices were used to find the drought intensity in the study area.

Percentage deviation from normal (IMD, 1971)

Indian Meteorological Department (IMD, 1971) classified droughts on the basis of deficiency in annual rainfall. The suggestion is based on percentage deviation of rainfall from its long-term mean. The drought intensities based on percentage departure of rainfall from normal are as given in Table 1. When the actual rainfall is less than 50% of the average monthly rainfall, the condition is called drought month.

Table 1: Drought Intensities as per IMD (1971)

Percentage departure from normal rainfall	Intensity of meteorological drought
0.0 or above	No drought
0.0 to -25.0	Mild drought
-25 to -50	Moderate drought
-50 or above	Severe drought

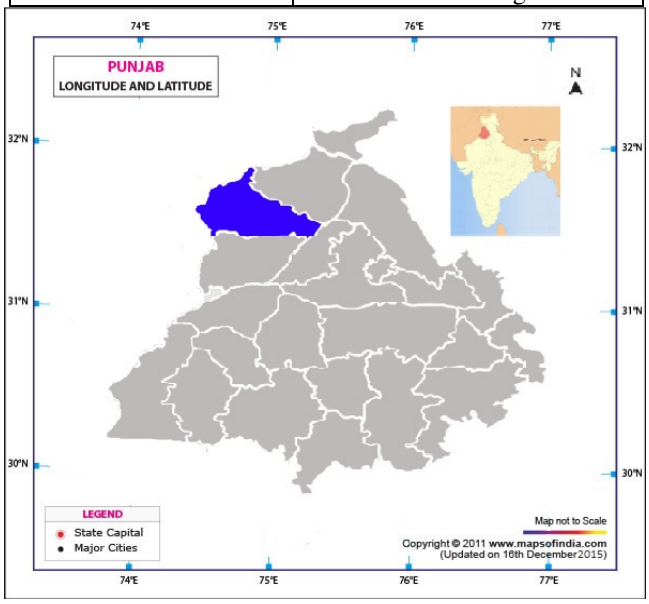

Fig. 1: Location Map of the study area i.e. Amritsar District in Punjab

Palmer Index (1965)

Palmer Index (PI) is a meteorological drought index developed by Wayne Palmer in 1965 to measure departure of moisture supply. It is developed for United States and tested for regional climate of United States. Table 2 shows the prevailing condition and the corresponding PI values. Palmer's Index is a soil moisture algorithm calibrated for relatively homogenous regions. It was the first comprehensive drought index developed in USA. It is less well suited to mountainous areas or areas of frequent climatic extremes. It is an index developed to measure the departure of the moisture supply (Ragab, 2004).

Table 2: PI Values and their corresponding conditions as per Palmer (1965)

PI Value	Condition
4.0 or more	Extremely wet
3.0 to 3.99	Very wet
2.0 to 2.99	Moderately wet
1.0 to 1.99	Slightly wet
0.5 to 0.99	Incipient wet spell
0.49 to -0.49	Near normal
-0.5 to -0.99	Incipient dry spell
-1.0 to -1.99	Mild drought
-2.0 to -2.99	Moderate drought
-3.0 to -3.99	Severe drought
-4.0 or less	Extreme drought

Standardized Precipitation Index (McKee et. al, 1993)

SPI is a tool which is used to define and monitor droughts. It analyses rarity of a drought. SPI is not a drought prediction tool. It was developed by McKee et. al (1993) and the values of SPI are given in Table 3. SPI is based on precipitation only. It can be used on a variety of time scales which allows it to be useful for both short term agricultural and long term hydrological applications. Many drought planners appreciate the versatility of SPI. Positive SPI values indicate greater than mean precipitation and negative values indicate less than mean precipitation. As SPI is normalized wetted and drier climates can be represented in the same way. Wet periods can also be monitored using the SPI values. The drought event ends when the SPI becomes positive. Therefore, each drought event has a duration defined by its beginning and end. The positive sum of SPI for all the months within a drought event can be termed as the magnitude of the drought (Ragab, 2004).

Table 3: SPI Values and Their Corresponding Conditions (McKee et. al, 1993)

Value of SPI	Condition
≥ 2	Extremely wet
1.5 to 1.99	Very wet
1 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
≤ 2	Extremely dry

RESULTS AND DISCUSSION

The statistical parameters for the rainfall data for Amritsar for 110 years were determined and are given in Table 4, which indicates that there is high fluctuation in occurrence of rain in the study area. The intensities of droughts as per IMD criteria were determined and the same are given in Table 5. From this, it is found that there were no severe droughts, 33 moderate droughts, and 27 mild droughts in Amritsar for the period from 1901 to 2010.

When the 110 years rainfall data of Amritsar district were analyzed to find Palmer Index, it was found that there was never a condition of moderate, severe or extreme drought in the span of 110 years. However, there were 19 mild droughts and 20 incipient dry spells. It was also found that 42 times it was near normal condition as given in Table 6.

Then the rainfall data were analyzed as per the Standardized Precipitation Index and it was found that extremely dry condition never prevailed in the study area in the span of 110 years. However, severely dry condition once prevailed in the year 1920. Moderately dry condition was found 18 times and for 75 times it was near normal condition as given in the Table 7.

From analysis of the data, the average annual rainfall in Amritsar is found to be 477.1 mm with a maximum of 957.5 mm in the year 2006 and minimum of 240.44 mm in the year 1920. Mean rainfall for July is 139.9 mm, which is the highest and contributes 29.33% of the annual rainfall. August contributes 26% of the mean annual rainfall. The mean south-west monsoon rainfall (369.70 mm) contributes 77.2% of annual mean rainfall (477.1 mm). The contribution of winter rainfall is 7.81%. The contribution of pre-monsoon and post monsoon rains are 10.5% and 4.18% respectively.

The monthly analysis of rainfall for Amritsar district is given in the Table 8. The Table 8 is based on the assumption that a month is with drought when the rainfall for the month is less than half of the average rainfall for this month. The percentage of droughts in a month was calculated as (number of drought months for a particular month / total number of drought months) multiplied by 100 viz for January, the percentage of drought months is equal to (41/510)*100 i.e. 8.03%. Also, the highest average rainfall was observed as 139.1 mm in the month of July and the lowest average rainfall was observed in the month of November as 3.5 mm. In the span of 110 years, November was a drought month for 72 times, October for 60 times, indicating that these months must be provided with assured irrigation. The months of July and August had minimum number of drought months i.e. 19 and 20 respectively.

Table 9 and Fig. 2 show the decadal mean (% departure from normal) and frequencies of drought years. From this table, it can be inferred that 2nd and 4th decades of 20th century had the maximum number of deficient years. Also, it is seen that the first 6 decades of the 20th century had dry spells and the last four decades had wet spells.

On comparison of the three indices, for number of drought years, the results show that the number of no drought year are quite different from the three methods, i.e. number of no drought years is 50 as per IMD approach, 71 as per Palmer's Index approach and 91 as per SPI approach. The number of mild drought years and moderate drought years from the above approaches are also not matching, i.e. number of mild and moderate drought years is 60 as per IMD approach, 19 as per Palmer's Index (PI) approach and 18 as per Standardized Precipitation Index (SPI) approach. However, the results from PI and SPI are matching well as these numbers are 19 years and 18 years respectively. As these approaches were formulated for different climatic conditions, it is better to use the IMD approach for Indian condition.

Table 4: Seasonal Rainfall in mm for Amritsar District

Rainfall parameters	June	July	August	Sept	Winter (Jan-Feb)	Pre-monsoon (March to May)	SW monsoon (June-Sept)	Post monsoon (Oct-Dec)
Mean Rainfall	42.3	140.0	124.5	63.0	37.3	50.1	369.7	20.0
Standard Deviation	37.6	82.9	78.4	58.5	25.6	29.2	145.7	16.1

Table 5: Yearly Intensity of Drought for Amritsar during the period 1901-2010

Serial No.	Type of Drought	Year	Frequency
1.	No Drought	1908, 1909, 1913, 1914, 1916, 1917, 1924, 1929, 1931, 1936, 1945, 1948, 1949, 1950, 1953, 1954, 1955, 1956, 1957, 1958, 1959, 1961, 1962, 1964, 1966, 1967, 1971, 1973, 1975, 1976, 1977, 1978, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1988, 1990, 1992, 1995, 1996, 1997, 2005, 2006, 2007, 2008, 2010	50
2.	Mild Drought	1901, 1905, 1906, 1919, 1921, 1922, 1923, 1925, 1926, 1928, 1933, 1937, 1942, 1944, 1946, 1951, 1965, 1968, 1969, 1979, 1989, 1991, 1994, 1998, 2000, 2001, 2004	27
3.	Moderate Drought	1902, 1903, 1904, 1907, 1910, 1911, 1912, 1915, 1918, 1920, 1927, 1930, 1932, 1934, 1935, 1938, 1939, 1940, 1941, 1943, 1947, 1952, 1960, 1963, 1970, 1972, 1974, 1987, 1993, 1999, 2002, 2003, 2009	33
4.	Severe Drought	-	0

Table 6: Drought Intensity as per Palmer Index

Serial No.	Condition	Years	Frequency
1.	Extremely Wet	-	0
2.	Very Wet	2006	1
3.	Moderately Wet	1950, 1976, 1978, 1980, 1997, 2008	6
4.	Slightly Wet	1908, 1909, 1917, 1981, 1983, 1984, 1990, 1995, 2005	9
5.	Incipient Wet Spell	1914, 1931, 1948, 1959, 1961, 1964, 1966, 1975, 1985, 1986, 1988, 1996, 2007	13
6.	Near Normal	1905, 1906, 1913, 1916, 1919, 1921, 1922, 1923, 1924, 1925, 1926, 1928, 1929, 1933, 1936, 1937, 1942, 1944, 1945, 1949, 1953, 1954, 1955, 1956, 1957, 1958, 1962, 1967, 1969, 1971, 1973, 1977, 1979, 1982, 1989, 1991, 1992, 1994, 1998, 2000, 2001, 2010	42
7.	Incipient Dry Spell	1901, 1903, 1907, 1910, 1911, 1912, 1927, 1930, 1935, 1941, 1946, 1951, 1965, 1968, 1972, 1987, 1993, 1999, 2002, 2004	20
8.	Mild Drought	1902, 1904, 1915, 1918, 1920, 1932, 1934, 1938, 1939, 1940, 1943, 1947, 1952, 1960, 1963, 1970, 1974, 2003, 2009	19
9.	Moderate Drought	-	0
10.	Severe Drought	-	0
11.	Extreme Drought	-	0

Table 7: Drought Intensity as per Standardized Precipitation Index

Serial No.	Condition	Years	Frequency
1.	Extremely Wet	1950, 1976, 1978, 1980, 1997, 2006, 2008	7
2.	Very Wet	1984, 1990	2
3.	Moderately Wet	1908, 1909, 1917, 1981, 1983, 1995, 2005,	7
4.	Near Normal	1901, 1903, 1905, 1906, 1907, 1910, 1911, 1912, 1913, 1914, 1916, 1919, 1921, 1922, 1923, 1924, 1925, 1926, 1927, 1928, 1929, 1930, 1931, 1933, 1935, 1936, 1937, 1941, 1942, 1944, 1945, 1945, 1946, 1948, 1949, 1951, 1953, 1954, 1955, 1956, 1957, 1958, 1959, 1961, 1962, 1964, 1965, 1966, 1967, 1968, 1969, 1971, 1972, 1973, 1975, 1977, 1979, 1982, 1985, 1986, 1987, 1988, 1989, 1991, 1992, 1993, 1994, 1996, 1998, 1999, 2000, 2001, 2002, 2004, 2007, 2010	75
5.	Moderately Dry	1902, 1904, 1915, 1918, 1932, 1934, 1938, 1939, 1940, 1943, 1947, 1952, 1960, 1963, 1970, 1974, 2003, 2009	18
6.	Severely Dry	1920	1
7.	Extremely Dry	-	0

Table 8: Drought Analysis based on Monthly Rainfall for Amritsar District

Month	Average Rainfall, mm	Half of the Average Rainfall, mm	No. of Drought Months	Percentage of Drought Months
January	17.3	8.7	41	8.03
February	19.0	9.5	43	8.43
March	20.8	10.4	39	7.65
April	15.0	7.5	47	9.22
May	14.0	7.0	40	7.84
June	39.8	19.9	38	7.45
July	139.9	70.0	19	3.73
August	123.2	61.6	20	3.92
September	62.0	31.0	35	6.86
October	5.8	2.9	60	11.76
November	3.5	1.7	72	14.12
December	10.4	5.2	56	10.98
Total Number of Drought Months			510	

Table 9: Decadal Mean (% Departure from Normal) and Frequency of Drought for Amritsar

Decade	Decadal mean % departure from normal	Frequency of Deficient year
1901-1910	-8.0	2
1911-1920	-14.9	4
1921-1930	-6.4	0
1931-1940	-23.2	4
1941-1950	-3.9	1
1951-1960	-3.5	2
1961-1970	-8.0	1
1971-1980	29.6	0
1981-1990	17.6	2
1991-2000	6.6	0
2001-2010	14.3	2

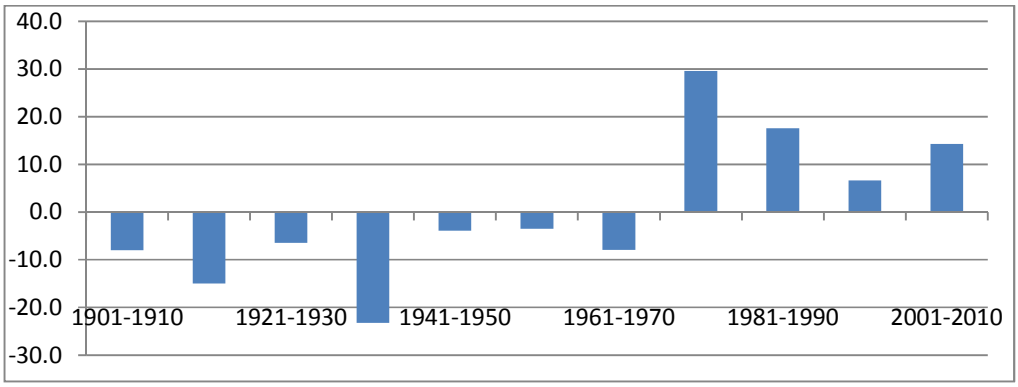

Fig. 2: Decadal Mean of Summer Monsoon Rainfall (% Departure from Mean)

CONCLUSIONS

The key role is played by rainfall in agriculture and its crucial variables are distribution, variability, and its capacity to meet the evapotranspiration needs. In general drought gives an impression of water scarcity resulting due to insufficient precipitation, high evapotranspiration and over exploitation of water resources. The probability of drought is 54% in the study area. From the study, it was also seen that for most of the times, moderate drought comes for two or three consecutive years or when it comes for a single year it is followed by mild drought. From the analysis of decadal mean, it is observed that 2nd and 4th decades of the 20th century were having maximum number of deficient years. On an average, it is seen that first six decades of the 20th century was having dry spells and last four decades were having wet spells. In the month of October and November, the irrigation water must be provided in the fields as these months had high percentage of drought months for the study area. The months of July and August had least number of drought months during the period of study. Drought zonation is a difficult task as a drought spreads up in a very slow and silent manner. However, efforts should be made to have drought zonation for drought prone states in India.

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