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Appraisal of meteorological drought characteristics in Dholpur district, Rajasthan

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Abstract
Rajasthan is the largest state in India covering an area of 34.22 million hectare i.e. 10.5 % of the country's geographical area but sharing only 1.15 % of its water resources. The estimated per capita water availability in the state during 2001 was 840 m^3 and is expected to be 439 m^3 by the year 2050 against the national average of 1140 m^3 by 2050 [1]. More than 70% of its people depend upon agricultural activities. The occurrence of drought leads to reduction in reservoir and tank levels and depletion of soil moisture and groundwater. There is a need to develop suitable criteria for planning drought adaption to crops for increasing and stabilizing crop yields during non-drought conditions, and minimizing crop damages during drought. District is frequently facing monsoon failure from last one decade. Monsoon failure resulting in widespread drought implies a deepening of the already severe water crisis. The monsoons recharge the groundwater and surface-water systems. In past, Dholpur District has over-exploited her groundwater without recharging, creating a water famine. The food and water security of the Dholpur district solely rely on the intensity of monsoon and ground water. The present paper attempts to bring a detailed study of degree of drought and possible feasible approaches of drinking water supply for Dholpur district. The study is based on rainfall data collected by WRD Department Dholpur on their different stations. It is suggested that the recharging of wells using latest water conservation techniques, rehabilitation of traditional water bodies systems, better planning of water use. We conclude that if significant improvements are not made with respect to adaptation to drought, it is difficult to adapt to future regional climates which are expected to be marked by on average longer drier conditions than present.

Keywords: Meteorological Drought, Annual Rainfall Departure, Frequency of Drought etc.

Introduction
Drought is generally defined as water shortage caused by the imbalance between water supply and demand. Drought is generally viewed as a sustained and regionally extensive occurrence of appreciably below average natural water availability, either in the form of precipitation, surface water runoff or ground water [3]. Drought causes innumerable problems immediately or with the time lag as the economy gradually experiences the adverse shock of the phenomenon. According to Indian Meteorological Department (IMD), a meteorological subdivision (part of India) is considered to be affected by drought if it receives total seasonal rainfall less than 75% of the normal value.

A drought is an extended period of months or years when a region observes paucity in its water supply. It may be due to significant decrease in precipitation over a specified area or marked depletion of available surface water and fall in the water tables. On an average, 28% of the geographical area of India is susceptible to drought. The drought is just not the scarcity or absence of rainfall, but is more related to water resource management. More than 60% deficient rain fall comes in the category of severe draught. It can have a substantial impact on the ecosystem and agriculture of the affected region.

The present study is aimed to study meteorological drought in Dholpur district as the recurrence of drought in this part of the country in recent years caused unprecedented economic losses and great suffering to the affected areas.

Materials and methods
Location and Extent
Dholpur district with an area of 3033 sq. km is located in easternmost extremity of the state of Rajasthan and is situated within latitude 26°21'19" and 26°57'33" North and longitude 77°13'06" and 78°16'45" East. It is bounded by Bharatpur district in North West of Swaimadhopur and Karauli district in south west and rest of the boundaries are bordered by Agra district of Uttar Pradesh and Bhind – Morena district of Madhya Pradesh.

Climate
Climate of the district can be classified as semi arid type. The summers are very hot and dry and the winters are very cold. The summer season prevails from March to mid June after which the rainy season starts with the onset of monsoon rains lasting till the end of September. During the May / June month the mean daily temperature is about 40°C. The potential evapotranspiration is 1780.0 mm annually.

Physiographic, Geomorphology and Soil Types
The Dholpur district can be divided into four main morphological divisions as follows'. Western hilly areas ii. Central undulating plains iii. The eastern plains (east of Dholpur- Maiwa alignment) iv. About 3 to 10 km wide strip of plateau along the southern boundary demarcated by Chambal river. Ravines are very common and prominent physiographic feature in the district.
The distribution of soil types has been studied, during the course of systematic hydro geological surveys. Based on these studies soils of the district has been classified in to six categories, where areal distribution has been shown in Fig.
i. Sandy soil: It is restricted with in a small NE-SW trending lanticular patch in the west of Dholpur district. ii. Loamy sandy soil: this type of soil in formed in a very small patch of the area in the western vicinity of Bari town.
iii. Sandy loamy soil: It is found in two small patches one is located to the west of Dholpur adjoining a sandy soil patch and the other patch is located around Turripura village situated in the western part of the district.
iv. Clayey soil : This variety of soil is formed in two isolated patches, one patch is formed in the eastern part of the district about 5 km SW of Rajakhera and other patch of found 5 km north of Turripura village in the north western part of the district.
v. Sandy clayey loam soil: This type of soil is formed in four isolated patches, two in north western part and two in the central part of the district.
vi. Sandy clayey soil: This type of soil is most prevalent in Dholpur district.

Geology
The rock formations exposed in Dholpur district are sedimentary in nature and belonging to Vindhyan Super Group and overlain is most part of the district by the Quaternary alluvium.

Ground Water Scenario
In Dholpur district, ground water occurs in mainly four hydro geological formations. These hydrogeological formations are alluvium, sandstone, shale and limestone and among these formations alluvium is the most important formation as it covers the maximum area and also it is the most potential among different hydro geological formations. Index map of Dholpur district shown in Fig.1.

(i) Standard Deviation
Square root of the mean deviation from the mean is known as standard deviation. The given equation (i) was used for computation of standard deviation.

$$\sigma = \sqrt{\frac{\Sigma(X-\bar{X})^2}{N-1}} \quad \ldots\ldots\ldots\ldots \text{(i)}$$

Where,
σ = Standard deviation
$\bar{X}$ = Mean of the rainfall data (mm)
N= Total no. of rainfall data

(ii) Variance
Variance can be represented by the average deviation about the mean. It is the square of the standard deviation. It is calculated by equation (ii).

$$\sigma^2 = \left(\sqrt{\frac{(X-\bar{X})^2}{N-1}}\right)^2 \quad \ldots\ldots\ldots\ldots \text{(ii)}$$

(iii) Coefficient of variance (C_v)
It is an important dispersion parameter for determining the variation amongst observations. It is computed as the ratio of standard deviation to the mean of given rainfall data. It is a dimensionless statistical parameter, expressed in % and calculated by equation (iii).

$$C_v = \frac{\sigma^2}{\mu} \quad \ldots\ldots\ldots\ldots \text{(iii)}$$

Where, μ= mean of annual rainfall

(iv) Assessment of Drought
A Drought Years can be defined as a temporary harmful and widespread lack of available water with respect to specific need. It implies a deficiency of rainfall of sufficient magnitude over a prolonged duration so as to interfere with some phases of regional economic activities. According to the India Meteorological department (IMD) an area / region is considered to be drought if it receives seasonal total rainfall less than 75% of its normal value. In the present study attempt has been made to assess the drought situation in Dholpur district of Rajasthan. Where the occurrence of recumbent drought have badly affected the agricultural production and economy of the area.

(v) Annual Rainfall Departure Analysis
According to the India Meteorological department (IMD) an area / region is considered to be drought if it receives seasonal total rainfall less than 75% of its normal value. Rainfall data has been subjected to various kind of analysis including seasonal and annual rainfall departures, probability distribution and dry spell analysis etc.
Calculation of departure
Step-1 - Take the annual discharge data (mm) of any district.
Step-2 - Firstly we will calculate the mean of annual rainfall data.
Step-3 - Now we calculate the standard deviations, skewness, maximum, minimum and median of the rainfall data.
Step-4 - For calculating the departure we will substrate the annual rainfall data of a year from the mean rainfall of the year.
Step-5 - Now we will find out the 75% of mean rainfall.
Step-6 -Then we calculate the drought year. for calculating the drought year we will to compare the annual rainfall. if the value of annual rainfall of year with 75%of mean rainfall, then it is called drought year but if the value of annual rainfall of year is greater than the 75% of mean rainfall then it is called the no drought year.
Step-7 - After calculating the drought year, we calculate the departure from mean rainfall. It is calculated with help of below given formula.
Departure from mean rainfall = (annual rainfall of year - mean

rainfall) / Mean rainfall*100

Step-8 - Finally we will calculate the class of severity of the particular station. If the value of departure from mean rainfall is less than -25% then mild drought condition, but if the value of departure from mean rainfall is coming between the -25 to -50% then it is called the moderate drought condition. If the value is generate then -50% then the condition of drought is severe for the particular area or block.

Results and discussion

Assessment of Drought and Annual Rainfall Departure Analysis

The mean annual rainfall in Dholpur district varies from 521.13 mm at Saipau to 578.59 mm at Dholpur station, which indicate that there is normal variation in the rainfall distribution pattern over the district. The coefficient of variation of annual rainfall is highest at Rajakheda side areas with 39.59%.the rainfall of the district generally increase from the southwest to northeast. Annual Rainfall Departure For identification of drought years and the extent of deficit of annual rainfall, the annual rainfall departure analysis has been carried out. A year is considered as drought year if the total amount of annual rainfall over an area is deficient by more than 25% of its normal value. The percentage annual rainfall departures in all stations of Dholpur district are given in Figures. From the annual rainfall departure analysis, the drought years have been identified and its average frequency of drought is presented in Table: 2. From the analysis it is observed that in years 1986, 1987,1989,1990,1991,2002,2006,2007 and 2014 as a moderate drought occurred in Dholpur district, the chance of occurrence of drought in every 10 years varies from 4 to 5. It means that year after every 2 to 3 year is a drought year. The annual rainfall departure analysis show that in the year 1986, 1987, 1990 maximum sites faced severe drought condition and about 90% area of the district was under severe drought condition. Where in 1983, 1984, 1988, 1993, 1994, 2000 and 2015 of district were subjected to moderate drought condition. The annual rainfall departure analysis shows that the deficiency of annual rainfall varies from 0-45% in the Dholpur district. It is observed that drought frequency varies from 16 to 21 out of 35 year period of rainfall data of all sites. This clearly shows that approximately one out of every two to three year is drought year, which is rather an alarming situation. The percentage annual rainfall departures in all sites of Dholpur district are given in Fig. 2, Fig. 3, Fig. 4, Fig. 5 Fig. 6, Fig.7 Fig. 8 and Fig. 9. Fig. 10 shows the overall result of Dholpur district. From the annual rainfall departure analysis, the drought years have been identified and its average frequency of drought represented in Table.2.

Table 1: Station wise rainfall distribution in Dholpur district.

S. No.	Name of Station	Mean annual rainfall (mm)	CV (%)	Standard Deviation
1	Dholpur	578.59	35.40	204.81
2	Bari	567.31	33.04	187.42
3	Angai	535.62	38.25	204.89
4	Baseri	522.49	38.77	202.55
5	Saipau	521.13	33.38	173.96
6	Talabshahi	531.90	38.74	206.06
7	Urmilasagar	531.24	37.34	198.37
8	Rajakhera	544.96	39.59	215.77
	Average Dholpur District	541.66	31.97	173.15

Table 2: Frequency of drought year in Dholpur district for Annual rainfall.

Sr. No.	Name of Station	Mean Annual Rainfall (mm)	Drought Frequency (In 35Yrs)	Mild Drought Year (Ave. Rainfall <25%)	Moderate Drought Year (Ave. Rainfall <25-50%)	Severe Drought Year (Ave. Rainfall<50%)
1	Dholpur	578.59	16	1984, 1989, 2016	1987,1990,1993,2000,2001,2002, 2006,2007,2009,2014,2015	1986,1991
2	Bari	567.31	21	1981,1983,1984,1985,1991,1992,1993, 1994,2000,2003,2005,2007,2014,2015	1987,1989,1990,2002,2006,2009	1986
3	Angai	535.62	20	1981,1984,1985,1988,1991,1994,1999, 2000,2003,2005,2009,2014,2015	1986,1987,1989,2002,2007	1990,2006
4	Baseri	522.49	20	1981,1983,1988,1997,2003,2004,2006, 2010,2014	1984,1986,1990,1991,1993,2000,2002,2007, 2009	1987,1989
5	Saipau	521.13	17	1981,1990,1993,1994,2002	1983,1986,1989,1991,2000,2004,2006,2007, 2009,2014,2015	1987
6	Talabshahi	531.90	21	1981,1983,1988,1989,1992,1994,1997, 2000,2001,2006,2007,2014,2015	1984,1986,1987,1990,1991,1993	2002,2009
7	Urmilasagar	531.24	21	1981,1982,1984,1987,1993,1994,1997, 2000,2001,2013,2014	1983,1986,1989,1991,2002,2006,2007,2009, 2015	1990
8	Rajakhera	544.96	20	1982,1983,1997,2001,2002,2003,2009	1984,1986,1988,1989,1991,1994,2000,2006, 2007,2014,2015	1987,1990
	Average Dholpur District	541.66	17	1983,1984,1988,1993,1994,2000,2015	1986,1987,1989,1990,1991,2002,2006,2007, 2014	NIL

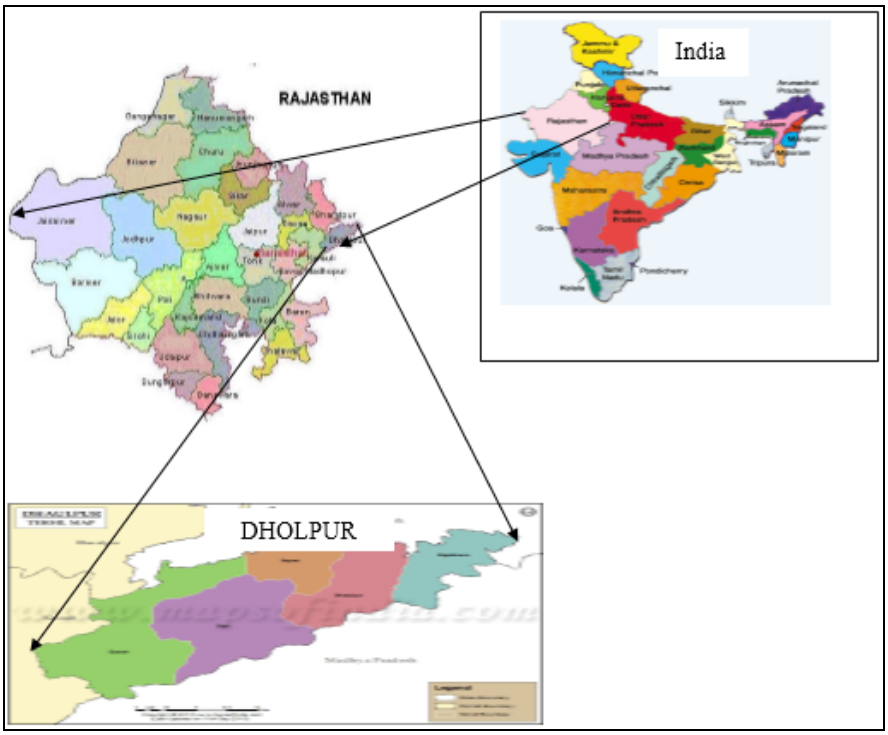

Fig 1: Index Map of Dholpur District, Rajasthan

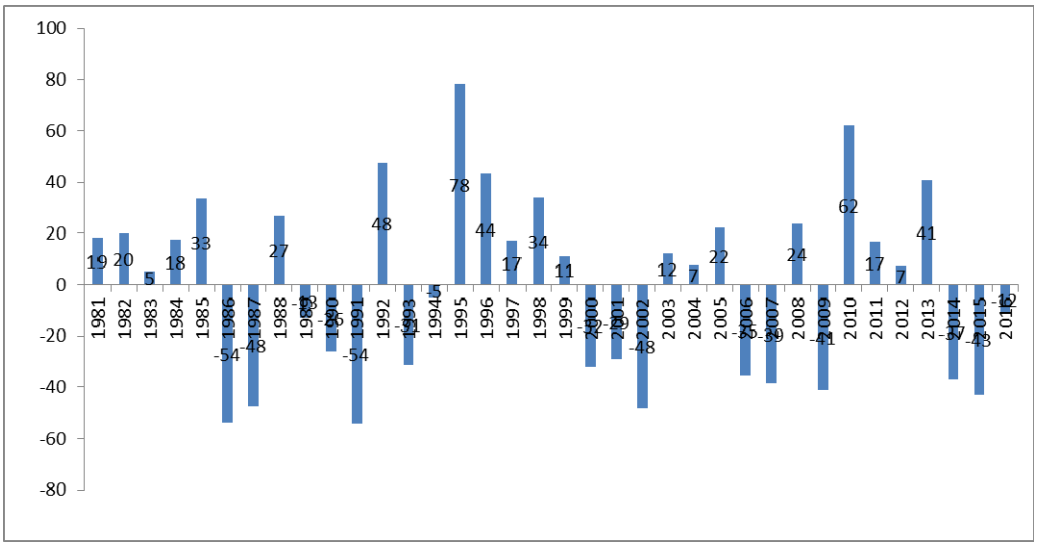

Fig 2: Annual rainfall departure of Dholpur Station

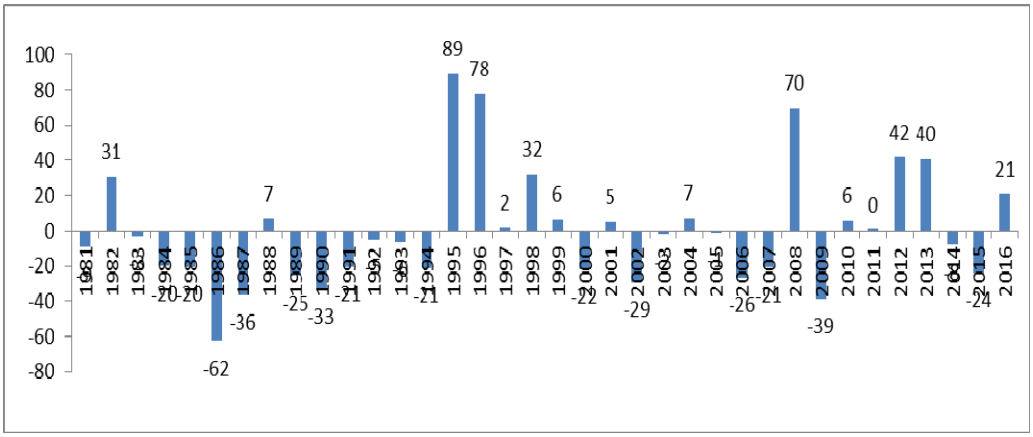

Fig 3: Annual rainfall departure of Bari Station

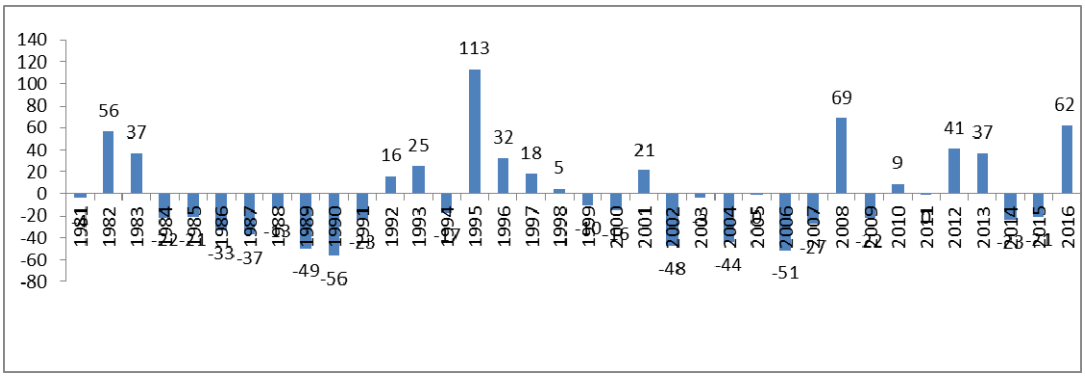

Fig 4: Annual rainfall departure of Angai Station

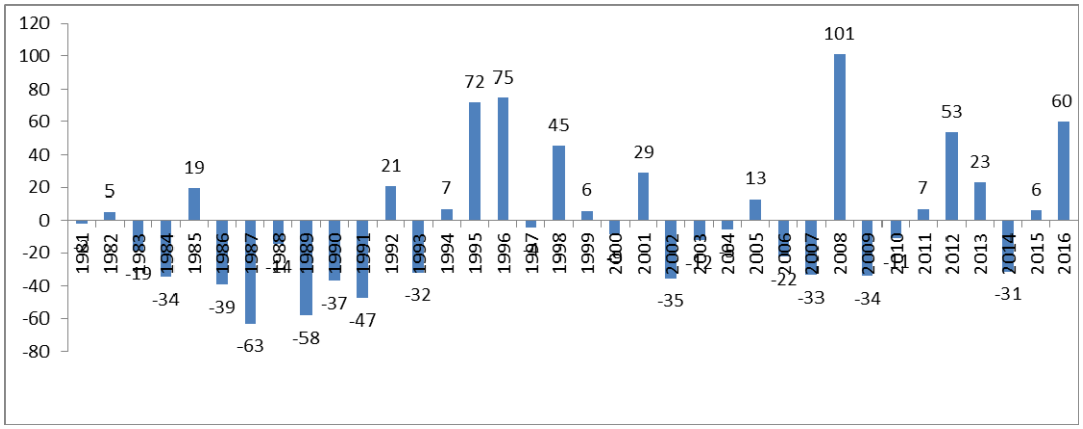

Fig 5: Annual rainfall departure of Baseri Station

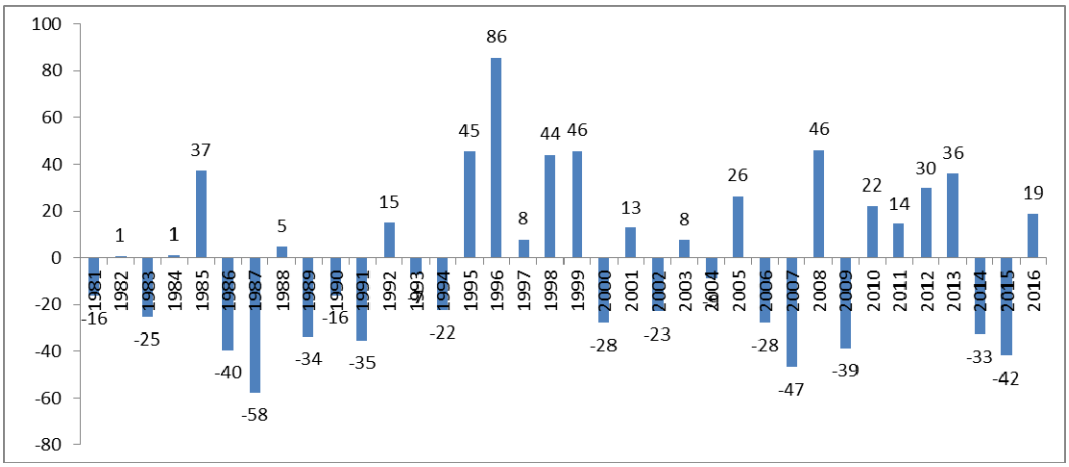

Fig 6: Annual rainfall departure of Saipau Station

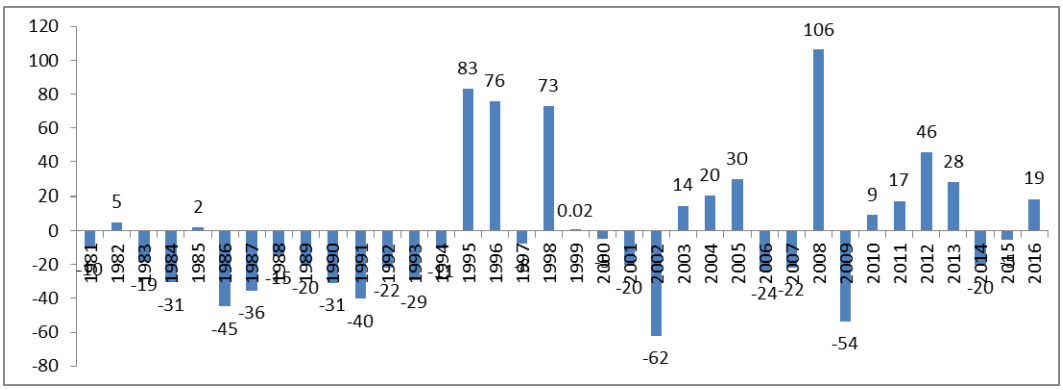

Fig 7: Annual rainfall departure of Talab-E-Sahi Station

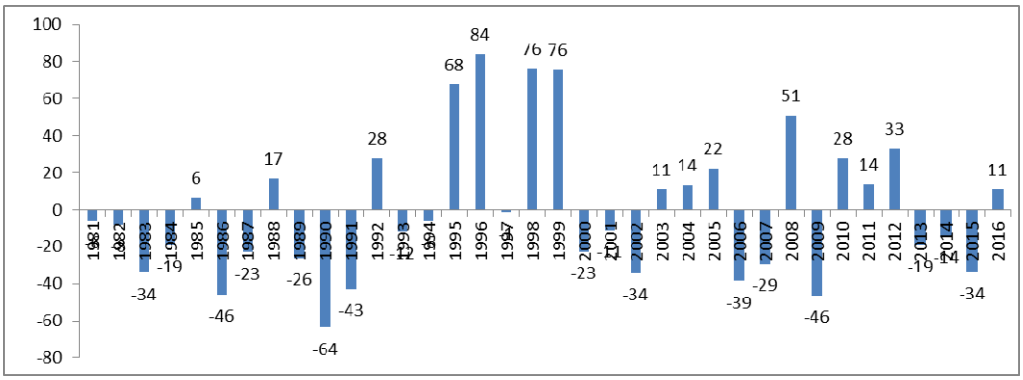

Fig 8: Annual rainfall departure of Urmilasagar Station

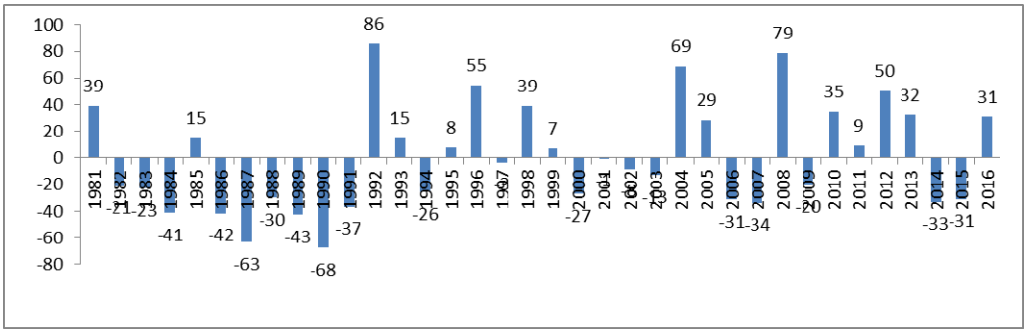

Fig 9: Annual rainfall departure of Rajakheda Station.

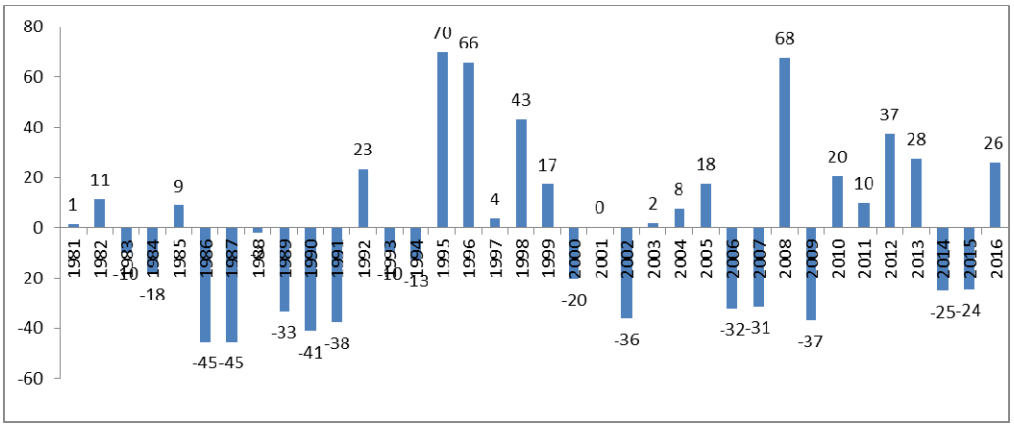

Fig 10: Annual rainfall departure of Average Dholpur District.

Conclusions

The occurrence of drought in India is not recent phenomenon. In order to find out whether the sufficient rainfall areas in Dholpur district are affected by the rainfall deficiency, the 35 years of rainfall data were analyzed to assess the yearly drought condition of the Dholpur district, Rajasthan. On the basis of the present study, following salient conclusions have been drawn.

- The average frequency of drought recurrence in the area on the basis of annual departure is 2 to 3 years, some blocks are severely affected by drought and some are moderately affected.
- The year 1986, 1987,1989,1990,1991,2002,2006,2007 and 2014 are found to be moderately drought affected year in the period of 35 years on the basis of annual analysis.
- The trend in the rainfall showed that the rainfall is decreasing in the area.
- Dholpur district has to live with drought. The experience indicates that the frequency and severity of drought is continuously increasing.
- Bad experiences of 1986, 1987 and 1990 drought is an eye opening for the policy makers. It clearly indicates that droughts largely mean water famines' than 'food famines'.
- It is high time to make people aware for water uses and everyone has to realize the importance of single drop of water.
- All water harvesting techniques used in the state shall be revamped again.
- There has to be strong linkages between policy makers, users, agriculture scientists, public health and irrigation department. Now onwards, particular area has to be year marked for a particular crop depending upon the availability of water and water consumption.
- Water saving measures should be made mandatory to reduce the pressure on water resources. This can be achieved by implementing economical technical

measures without compromising in standard of living and life style of human beings.

Water management strategies

Drought affects all components of the water cycle; deficit in soil moisture, reduced groundwater levels and dried up ponds and reservoirs. The specific issue of droughts can be planned on the long term basis by drought management committee by keeping in mind the following remedial measures:

1. With the water crisis worsening in the desert state of Rajasthan, the state government should focus on community-based water management solutions instead of predominantly engineering-based ones. Present study depicts that the every village has community based drinking system such as village pond, Tanka, Anicut and Talab
2. All the traditional water harvesting structures and sources should be renovated and people should be encouraged for roof-top rain water harvesting, storm-water harvesting, recycling and reuse of waste water. It has been noticed that the funds needed for renovating all water harvesting structures would be less as compared to the expenditures made by state government in averting the famine for one year.
3. Authors observed that people getting support from government during drought have become immune to this help and loves a good drought. They are describing this relief as the third crop. To avoid this, responsibility shall be fixed with the administrators so that such mal practices can be avoided.
4. Only less water consuming crops shall be permitted to avoid the use of excessive water in irrigation. Total consumption of ground water in irrigation is more than 90% hence this should be bringing down to 50% only by restricting the cultivation.
5. Organization of district-level coordination meetings among NGOs, government officials, and agencies involved in order to facilitate the information-sharing process and the coordination of relief interventions
6. Preparation of community-based drought proofing plans for affected communities
7. Support to the livelihood and animal husbandry sectors through employment generation and establishment of cattle camps.

Immediate Actions

- Prioritization of critical water users and estimation of their critical demand through the rapid development of a critical user's inventory.
- Implementation of water demand management and water restrictions should be initiated in accordance with existing legislation, statutes and rules of operation. It is expected that this would include appropriate measures to restrict all non-potable uses of potable water.
- Increase awareness of appropriate household water treatment options when receiving water from unregulated suppliers to prevent chemical, viral and bacterial illnesses.
- Efficient and cost-effective infrastructure to augment the water supply system should be installed. In some islands where water is in surplus at various locations but there is no infrastructure to bring the water to where it is needed this action may be considered especially if financial resources are accessible.
- Acquisition of PVC tanks for storage of rain water in vulnerable communities should be encouraged by Governments, the regional private sector and NGOs. This should be encouraged through various legislative and institutional mechanisms.
- Access surplus water production capacity from private sources by establishing relationships with business such as bottled water suppliers, hotels and other commercial enterprises with excess desalination capacity.
- Transportation of water from countries with surplus capacity to those with water deficits if financially feasible and no other financially affordable options are available that are consistent with national water security objectives.

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