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Identification of various droughts Prone talukas for Dahod district of Gujarat

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■ **ABSTRACT :** Drought is one of the most serious problems arising for human societies and ecosystems from climate variability. Although its impact does not come through sudden events, such as flood and storms, drought is the world's costliest natural disaster, causing an average $6–$8 billion in global damages annually and collectively affecting more people than any other form of natural disaster (Wilhite, 2000). The National Commission on Agriculture (MOA, 1976) identified 74 drought prone districts which all are located 13 states of India and Gujarat is one of the most drought prone areas of India in which, eleven districts of the state are in arid regions including Dahod region one of most backward district; agriculture based livelihood income and experienced drought problems many times throughout the years due to delayed in rainfall. Therefore, study was carried out to determine hydrological and agriculture panoramas of drought in the Dahod district includes 7 Talukas. It was found that annual rainfall in Dahod district varies between 690 mm at Garwada to 847 mm at limkheda with the average annual rainfall of 833mm and average drought frequency in Dahod district varies between 1 in 4 years at Jalod, Limkheda 1 in 3 years, Devgarh 1in 5 years, Garbada 1 in 3 years, Dhanpur 1 in 3 years, and 1 in 3 years at Fatepura. The relative departure index (RDI) was observed for various Talukas in which, Dahod district was recorded frequent drought prone taluka and considered for taking up drought mitigation activities. The standardized precipitation index (SPI) was analysed between the year of mid 1999-2003 taluka was suffered from moderate and severe drought conditions whereas, between the years of mid 1993 to mid 1999 meteorological condition was normal.

■ **KEY WORDS :** Drought prone, Identification, Annual rainfall, Departure analysis, Drought frequency, Drought severity

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Drought is a temporary aberration unlike aridity, which is permanent feature of climate. Seasonal aridity also needs to be distinguished from drought. Thus, drought is a normal, recurrent feature of climate and occurs in all climatic regimes (Capodici *et al.*, 2008). Drought results from long continued dry weather and/or insufficiency of rain, which causes exhaustion of soil moisture, depletion of underground water supply and reduction of stream flow. Drought is frequently defined according to disciplinary perspective and (Bandyopadhyay, 1988) lists mainly four types of droughts, namely (1) meteorological drought, (ii) surface water drought, (iii) groundwater drought and (iv) soil-water drought. The National Commission on Agriculture in India defines three types of droughts, namely: Meteorological, agricultural and hydrological droughts.

Meteorological drought is defined as a situation when there is significant decrease from normal precipitation over an area (*i.e.* more than 25 %) (Shouraseni *et al.*, 2004). Agricultural drought occurs when soil moisture and rainfall are inadequate during the growing season to support healthy crop growth to maturity and causes crop stress and wilting (Rawls *et al.*, 1993). Hydrological drought may be a result of long term meteorological droughts which result in the drying up of reservoirs, lakes, streams and rivers, and fall in groundwater level. In fact meteorological drought precedes the agricultural and hydrological drought (Svoboda *et al.*, 2002). The agricultural and hydrological drought needs not to occur simultaneously but occur subsequent to a meteorological drought. Agricultural drought is specifically concerned with cultivated plants, as opposed to natural vegetation (Dracup *et al.*, 1980). Owning to the continuous need of adequate water by plants, agricultural drought may set in rapidly and can similarly terminate suddenly. According to the Indian Meteorological Department (IMD), a meteorological subdivision is considered to be affected by drought if it receives total seasonal rainfall less than 75% of the normal value.

METHODOLOGY

Dahod is most backward district in Gujarat state. The district has 7 Talukas with 696 villages. The total geographical area of the district is about 3.7 Lakh hectares. The climate of district is usually hot and it was found that maximum temperature is about 44°C and the minimum temperature is about 6.5°C. Therefore, district was considered as rain fed area with an average rainfall 739 mm. Dahod district has faced drought condition many times due to delayed in rainfall Therefore, study was carried out to determine hydrological and agriculture panoramas of drought in terms of onset, severity and end of draughts (Le, 1996) and analysis made on the basis of major climatic factor, precipitation includes annual rainfall analysis, annual frequency analysis, relative departure index, standardization precipitation index for the Dahod district. The Table A shows the irrigated area and Table B major soils in Dahod and covered area are shown.

Table A : Irrigated area of Dahod

Irrigation water availability and use	Area ('000 ha)
Net irrigated area	80.9
Gross irrigated area	94.8
Rainfed area	143.37

Table B : Major soils in Dahod and covered area

Major soils	Area (000' ha)	Per cent (%) of total geographical area
Hilly light soils	155.9	42.7
Sandy loam shallow soils	39.2	10.7
Deep black shallow soils	31.6	8.6

Identification of drought years :

Drought has many facts and it always starts with lack of precipitation, Therefore, It leads to different types of drought (Meteorological, Agricultural, Hydrological, Socio-Economic and Physiological droughts) (Smakhtin and Hughes, 2004). According to the Indian Meteorological Department (IMD), an area is considered to be drought affected if it receives seasonal total rainfall less than 75% of Normal rainfall (Appa Rao, 1986). The annual rainfall data of all the 7 Talukas of Dahod district was collected from the office of Survey and Land Records, Gujarat for analysis of drought years. The Taluka wise rainfall distribution is given Table C.

Table C : Taluka wise annual rainfall distribution in Dahod district

Sr. No.	Name of talukas	Mean annual rainfall (mm)
1.	Dahod	738
2.	Jhalod	804
3.	Limkheda	847
4.	Devgarh bariya	726
5.	Garwada	690
6.	Dhanpur	820
7.	Fatepura	791

Identification of drought Prone blocks :

The probability analysis of annual rainfall is important to predict the relative frequency of occurrence in different group interval of annual rainfall with reasonable accuracy (Gore *et al.*, 2010). The estimated probability of an event is taken as the relative frequency of occurrence of the event when the number of observations is very large. The probability of occurrence of 75% of mean annual rainfall has been computed to delineate the drought proneness in various Talukas of Dahod region. An area can be considered as drought prone if the probability of occurrence of 75% of normal rainfall is less than 80% (Banerjee and Raman, 1976). The percentage probability of occurrence of 75% of mean annual rainfall has been worked out to delineate the

drought proneness of various blocks of the district Dahod. The principle of probability analysis was shaped up in following manner:

– Arrange the rainfall record with respect to the year and calculate the normal.

$$\text{Normal} \quad \bar{X} = \frac{\sum x}{N} \qquad (1)$$

– Rearrange the data in the descending order.

– Rank the data M = 1, 2, 3 upto last record.

– Determine the cumulative probability(*P*)

$$\text{Probability} \quad P = \frac{M}{N+1} \times 100 \qquad (2)$$

– Calculate 75% of the normal of the rainfall data

$$X_{75} = \frac{\bar{X}}{100} \times 75 \qquad (3)$$

If the probability of occurrence of the X_{75} be $P_{75,}$ then

If $P_{75} < 80$ area is drought prone and

if $P_{75} \geq 80$ area is under normal condition

Relative departure index :

The relative departure index gives an idea of the ranking of the occurrence of droughts of varying severities solely based on the departure analysis (Francis and Gadgil, 2006). Based on the ranking provided by this index, priorities can be assigned for initiation of drought mitigation strategies for the various blocks in the district (Dash *et al.,* 2009). In order to assess the relative drought proneness of the blocks in the district a weighting scheme was designed. This scheme consists of the following steps:

– Assign different weights based on the severity of the drought.

– Mild drought weight - 1
Moderate drought weight - 2
Severe drought weight - 3

– Calculate the total weights by summing up individual weights for all the drought years in a block.

– Relative departure index for each block can be computed by dividing the total weight of the block by the total number of years considered for the analysis in that particular block.

Standardized precipitation index (SPI) :

The standardized precipitation index (SPI) is a tool which was developed primarily for defining and monitoring drought. It can be used to determine periods of anomalously wet events. The SPI was designed to quantify the precipitation deficient for multiple time scales. These time scales reflects the impact of drought on the availability of the different water resources. Soil moisture condition respond to precipitation anomalies on a relatively short scale. Groundwater, stream flow, and reservoir storage reflect the longer term precipitation anomalies. For these reasons, (McKee *et al.*, 1993) originally calculated the SPI for 3, 6, 12, 24, 48 month time scales. A drought event occurs any time during the period where SPI is continuously negative and reaches an intensity of -1.0 or less. The event ends when the SPI becomes positive. In order to evaluate of drought severity in different areas using SPI, one of the most commonly used classification was proposed at the National Drought Mitigation Centre (NDMC).

Table D : Classification of SPI values

Sr. No.	SPI	Classification
1.	2>	Extreme wet
2.	1.50 to 1.99	Sever wet
3.	1 to 1.49	Moderate wet
4.	0 to 0.99	Mild wet
5.	0 to -0.99	Mild drought
6.	-1 to -1.49	Moderate drought
7.	-1.50 to -1.99	Severe drought
8.	-2.00<	Extreme drought

■ RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Rainfall distribution in Dahod district :

The distribution of annual rainfall and standard deviation in various Talukas of the Dahod district in Gujrat is given in Table 1, Fig. 1 and 2. The standard deviation in Dahod district varied between 262.30, at Jalod 293.46, at Limkheda 339.05, at Devgarh 277.57, at Garwada 235.19, at Dhanpur 330.27 and at Fatepura 342.45. The table indicates that Limkheda was subjected to higher rainfall with lower standard deviation while Garbada was subjected to lower rainfall with higher standard deviation.

The distribution of annual rainfall and standard deviation in various Talukas of the Dahod district in Gujarat is given in Table 1. The standard deviation in Dahod district varies between 263.308, at Jalod 293.463, at Limkheda 339.058, at Devgarh 277.575, at Garwada

Table 1 : Taluka wise annual rainfall distribution in Dahod district

Sr. No.	Name of talukas	Mean annual rainfall(mm)	Standard deviation	C.V. (%)
1.	Dahod	738	262.30	35.45
2.	Jhalod	804	293.46	36.5
3.	Limkheda	847	339.05	40.03
4.	Devgarh	726	277.57	38.23
5.	Garwada	690	235.19	34.08
6.	Dhanpur	820	330.27	40.27
7.	Fatepura	791	342.45	43.29

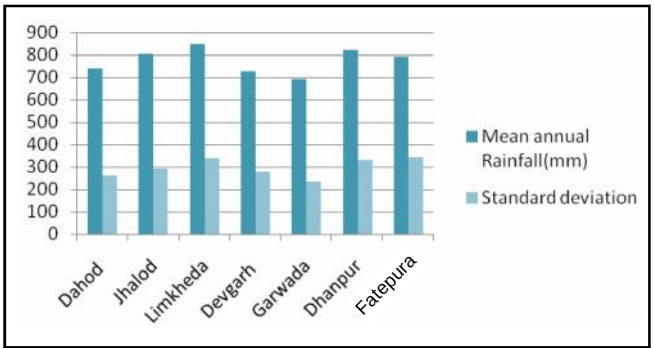

Fig. 1 : Talukas wise annual rainfall distribution in Dahod district

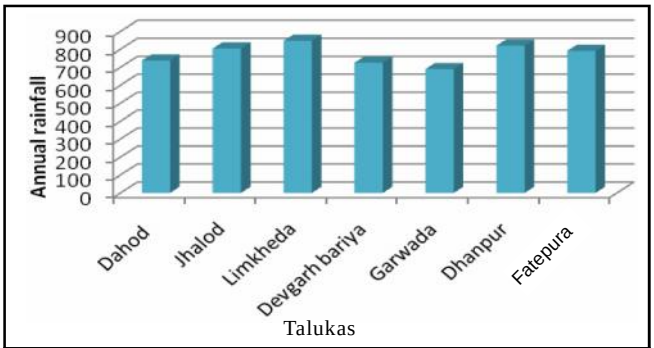

Fig. 2 : Talukas wise annual rainfall and standard deviation distribution in Dahod district

235.198, at Dhanpur 330.277, at Fatepura 342.451. From the above table it indicates that Limkheda are subjected to higher rainfall due to lower standard deviation while Garbada is subjected to lower rainfall due to higher standard deviation.

Average frequency analysis of Dahod talukas :

The average drought frequency in Dahod district varied between 1 in 4 years at Jalod, Limkheda 1 in 3 years, Devgarh 1in 5 years, Garbada 1 in 3 years, Dhanpur 1 in 3 years, and 1 in 3 years at Fatepura.

Identification of drought Prone talukas :

Drought is an extended shortfall of precipitation that results in water supplies insufficient to meet the needs of human and the environment (Wilhite and Buchanan, Smith, 2005) and occurs routinely as part of the natural hydrologic cycle. So the occurrence of event does not scale the proneness of that particular area. Probability distribution of annual rainfall has been carried out to identify the drought prone talukas in Dahod district. The probability of occurrence of rainfall equivalent to the 75% of normal rainfall with the identification of drought condition for Dahod district is presented in Table 3 and Fig. 3 and 4. From the table, probability analysis resulted as the whole area is under the situation of drought, also the three blocks namely Devgarh, Jhalod and Garbada were the most probable drought prone entity as per the probabilities of 77.4, 74.19 and 67.74 %, respectively.

Table 2 : Frequency of drought for all talukas of Dahod district

Sr. No.	Station	Total year's	No. of drought year's	Frequency
1.	Dahod	30	8	3.8
2.	Jhalod	30	7	4
3.	Limkheda	30	10	3
4.	Devgarh	30	6	5
5.	Garbada	30	9	3.3
6.	Dhanpur	30	10	3
7.	Fatepura	30	10	3

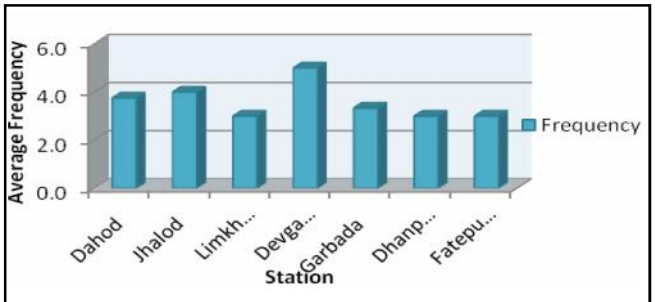

Fig. 3 : Average frequency analysis of station in Dahod district

Table 3 : Probability analysis of Annual rainfall in Dahod district

Sr. No.	Name of talukas	Mean annual rainfall (mm)	Rainfall at 75% probability level (mm)	Probability of occurrence of rainfall equivalent of 75% of normal	Drought condition
1.	Dahod	738.133	553.6	67.7	Drought prone
2.	Jhalod	803.933	602.95	74.19	Drought prone
3.	Limkheda	838.4	928.5	32.26	Drought prone
4.	Devgarh	826.533	619.9	77.4	Drought prone
5.	Garbada	692	519.1	67.74	Drought prone
6.	Dhanpur	820	614.625	64.5	Drought prone
7.	Fatepura	791	593.35	64.5	Drought prone

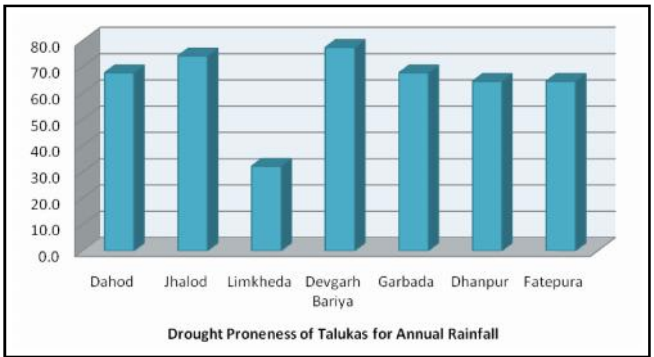

Fig. 4 : Probability distribution of annual rainfall equivalent to 75% of normal

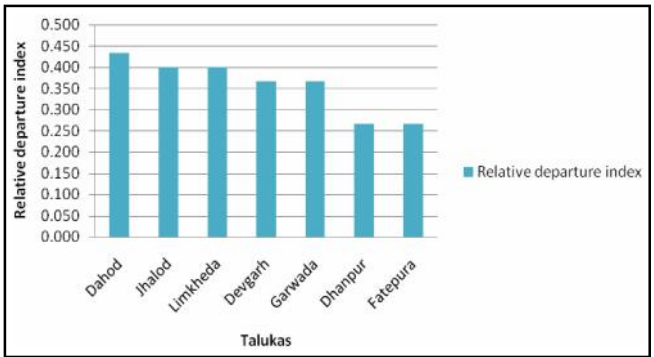

Fig. 5 : Relative departure index analysis of the Talukas in Dahod district

Identification of relative departure index (RDI):

The indices shows priority of drought occurring in particular taluka corresponding to its ranking, as per RDI value Dahod (0.433) and Fatepura (0.267) were ranked first and last, respectively. In other words, mitigation activities can take-up followed by ranking of Talukas and their respective RDI values. Priority ranking will be helpful to implement aid to the most severe areas at an earlier date based on the actual drought scenario prevailing in the various talukas of the district. The relative departure index for the various Talukas in the Dahod district along with their respective priority ranking is given in Table 4 and Fig. 5.

Table 4 : Relative departure index of 7 talukas

Sr. No.	Station	Relative departure index	Rank
1.	Dahod	0.433	1
2.	Jhalod	0.400	2
3.	Limkheda	0.400	3
4.	Devgarh	0.367	4
5.	Garwada	0.367	5
6.	Dhanpur	0.267	6
7.	Fatepura	0.267	7

Standardized precipitation index (SPI) :

The aim of the work was to analyse the rainfall records for identification of drought characteristics for the various Talukas in the Dahod district. Standardized precipitation index (SPI), have been computed for different time scales of 3, 6 and 12 months. The SPI for time scale of 12-month for Devgarh Talukas in Dahod district was considered (Fig. 6).The drought is perceived to be commenced when the SPI value falls below -1.0 and continues so till the SPI value reaches above this (Hayes *et al.*, 1999). As drought has immediate impact

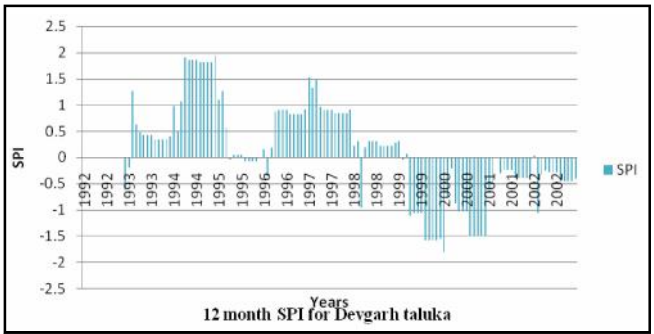

Fig. 6 : Twelve month SPI values for various years in Devgarh Taluka

on the agricultural sector, SPI for 3-month time scale was considered for evaluating the drought characteristics as it is directly related to the build up of soil moisture essential for the crop growth. As per SPI analysis between the year of mid 1999-2003 taluka was suffered from moderate and severe drought conditions whereas, between the years of mid 1993 to mid 1999 meteorological condition was normal

Conclusion :

– In the frequency analysis of drought, 1 in 3 years of frequency found for Limkeda, Garbada, Dhanpur, and Fatepura talukas whereas, for other talukas the phenomenon of drought was not much frequent.

– Probability analysis of rainfall data of the district resulted as drought prone as per criterion, an area can be considered as drought prone if the probability of occurrence of 75% of normal rainfall is less than 80%.

– To identify more frequently drought experiencing Talukas in Dahod district, relative departure index (RDI) have been developed. The result of indexes can be concluded by their ranking followed by respective RDI values, from which Dahod is ranked first (RDI=0.433) and Fatepura is ranked last (RDI=0.267) out of 7 talukas.

– For Defining and monitoring drought, the Standardized Precipitation Index (SPI) was used as tool to determine the rarity of a drought at a given time scale (temporal resolution) with accessible historic Data. The SPI for time scale of 12-month for Devgarh Talukas in Dahod district was considered. As per SPI analysis between the year of mid 1999-2003 taluka was suffered from moderate and severe drought conditions whereas, between the years of mid 1993 to mid 1999 meteorological condition was normal.

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