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Monitoring of drought situation in Kurnool district

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Abstract
Kurnool district lies between 14°54' to 16°11' N Latitude and 76°50' to 78°30' E Longitude. The geographical area of the district is 1.7658 Mha. Kurnool district has a semi-arid climate, with hot and dry conditions for most of the year.

In dryland agriculture situation, rainfall is an important source of irrigation. The Standardized Precipitation Index (SPI) is a widely used index to characterize meteorological drought on a range of timescales. The maximum drought percentage was observed in the Alur mandal and Peddakadburu (30%). The highest moderately dry years were observed in the Alur mandal (3) followed by Peddakadburu (2), Srisailam (2) and Veldurthi (2) mandals.

Yearly SPI values are useful for planning of stream flows, reservoir levels and even groundwater levels at the longer time scales. Drought is a predominant cause for reduce in crop yields or crop damage. There is an urgent need for more water efficient cropping systems facing large water consumption of irrigated agriculture and high unproductive losses via runoff and evaporation. Identification of drought resistant crops is the key to improved management of plant water stress.

Keywords: SPI, crop, umbilical hernia

Introduction
Drought usually refers to lack of precipitation over an extended period of time leading to moisture stress of the land. Although, drought may happen virtually in all climatic zones, yet, its characteristics differ considerably from one area to another.

The SPI is based on the probability of precipitation for any time scale. The probability of observed precipitation is then transformed into an index. It is also used by a variety of research institutions, universities, and National Meteorological and Hydrological Services across the world as part of drought monitoring and early warning efforts. McKee defined SPI suitable for different timescales (1, 3, 6, 12, 24 and 48 months) and the output values ranged from −2.0 to 2.0. The SPI was designed to quantify the precipitation deficit for multiple timescales. These timescales reflect the impact of drought on the availability of the different water resources. Soil moisture conditions respond to precipitation anomalies on a relatively short scale. Groundwater, stream flow and reservoir storage reflect the longer-term precipitation anomalies.

McKee and others used the classification system of the SPI values (Table 1) to define drought intensities resulting from the SPI. A drought event occurs any time the SPI is continuously negative and reaches an intensity of -1.0 or less. Each drought event, therefore, has a duration defined by its beginning and end, and anintensity for each month that the event continues. The positive sum of the SPI for all the months within a drought event can be termed the drought's "magnitude".

Table 1: Categorization of conditions through magnitude of SPI

S. No	Value	Condition
1	>2.0	Extremely Wet
2	1.5 to 1.99	Very wet
3	1.0 to 1.49	Moderately wet
4	-0.99 to 0.99	Near normal
5	-1.49 to -1.0	Moderately dry
6	-1.99 to -1.5	Very dry
7	<-2.0	Extremely dry

Study Area

Kurnool district lies between 14º54' to 16º11' N Latitude and 76º56' to 78º25' E Longitude. The geographical area of the district is 1.7658 Mha. Kurnool has a semi-arid climate, with hot and dry conditions for most of the year. Total mean annual rainfall is about 630.9 mm. Location map of Kurnool district is shown in Fig.1.

In Kurnool district, 58.60% of water source is from Krishna Basin and 41.40% from Pennar Basin. This district is bounded by Tungabhadra and Krishna rivers and Mahaboob Nagar district in North, Kadapa and Ananthapur districts on South, Karnataka state on West and Prakasham District in the East. The district is principally a hot country and temperatures vary from 26 °C to 46 °C. The main rivers flowing in the district are (1) Tungabhadra river which is a tributary to Krishna river (2) Hundri, a tributary to Tungabhadra (3) Kundu river is a major tributary to River Penna. Kurnool is city and the headquarters of Kurnool district in the Indian state of Andhra Pradesh.

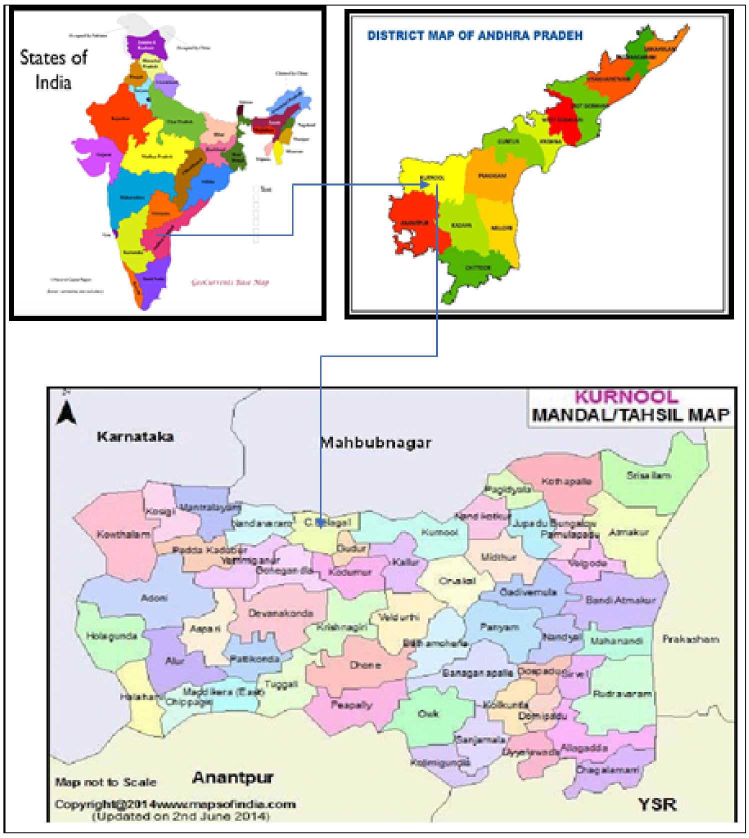
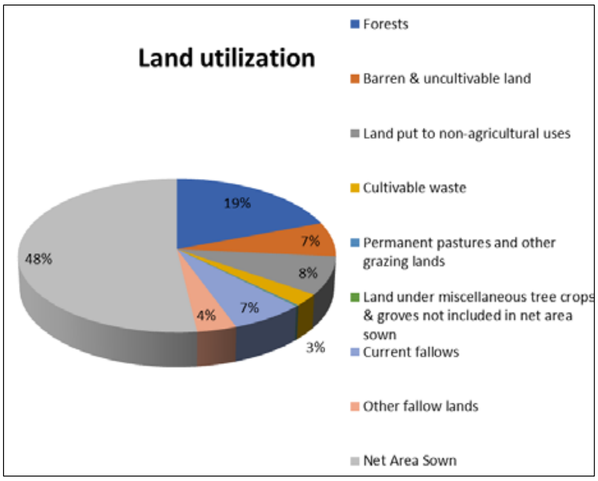


Fig 1: Location map of study area

The major irrigation projects are Kurnool–Cuddapah canal, Thunghabhadra low level canal, Aluru branch canal, Guntakal branch canal are the major irrigation projects in the Kurnool district with the catchment area of 7372.06, 61187.85, 5771.25 and 202.02 ha. The medium irrigation projects are Sanjeevaiah Sagar project and Varadaraja Swamy Gudi project with the area of 10230.77 and 4895.55 ha respectively. From the Fig. 2, the highest geographical area in Kurnool district is the net sown area (48.09%) followed by forest area (19.3%).



Source: http://irrigationap.cgg.gov.in/wrd/getDistricts

Fig 2: Land Utilization in Kurnool District

The procedure followed for computation of SPI is as follows

First, a probability density function that describes the long-term time series of rainfall observations is determined. The base time of rainfall observation series can be any, depending on the time scale of interest. In the present study, running series of total precipitation corresponding to 3-months, and 12-months were used and as result the corresponding SPIs were calculated: SPI-3, and SPI-12.

Once the probability density function is determined, the cumulative probability of an observed precipitation amount is computed. The inverse normal (Gaussian) function, with mean zero and variance one, is then applied to the cumulative probability distribution function, which results in SPI.

SPI at different time scales, e.g. 3-month SPI of a particular month represents deviation in precipitation totals for current plus previous two months. Positive values indicate greater than mean precipitation and negative values indicate less than mean precipitation.

The gamma distribution is defined by its probability density function is

$$g(x) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{-\frac{x}{\beta}} \quad \text{for } x > 0$$

Where α>0 is a shape factor, β>0 is a scale factor, and x>0 is the amount of precipitation.

Γ (α) is the gamma function which is defined as

$$\Gamma(\alpha) = \int_0^{\infty} y^{\alpha-1} e^{-y}$$

Fitting the distribution to the data requires that α and β be estimated. Edwards and McKee (1997) suggested a method for estimating these parameters

$$\alpha = \frac{1}{4A}\left(1+\sqrt{\left(1+\frac{4A}{3}\right)}\right)$$

$$A = \ln(\bar{x}) - \frac{\Sigma \ln(x)}{n}$$

$$\beta = \frac{\bar{X}}{\alpha}$$

Since the gamma function is undefined for x = 0 and a precipitation distribution may contain zeros, the cumulative probability becomes:

$$H(x) = q + (1- q)\, G(x)$$

Where, q is the probability of zero precipitation. If m is the number of zeros in a rainfall time series, q can be estimated by m/n. For larger time scales (like 1, 3-, 6-, 9-, 12-months) the probability of monthly null precipitation is zero. So the errors in calculating the parameters α and β due to the monthly null precipitation does not affect the distribution at larger time scales.

The cumulative probability, H(x), is then transformed to the standard normal random variable Z with mean zero and standard deviation of one, which is the value of the SPI.

$$f(P,\mu,\sigma) = \frac{1}{\sqrt{2\Pi}\sigma} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

The obtained SPI values are segregated in terms of severity as moderate, severe and extremely dry/wet. The wet conditiondeviate towards the positive values of the mean while the dry condition deviate towards the negative. The software application “Meteorological Drought Monitor (MDM)” has been used for the estimation of SPI values (Salehnia *et al.* (2017) [11]. The weather data downloaded from NASA website (Fig. 3). The steps for calculation of SPI values are given in Fig.4. Drought studies were carried using Standard Precipitation Index in different climatologically conditions (Abhishek and Chennaverappa (2016) [1], Bhaskar and Nagaraj (2017) [2], Christos *et al.* (2011) [3], Hong *et al.* (2015) [4], Hoogen and Simon (2015) [5], Huicai *et al.* (2017) [6], Jalpa and Falguni (2012) [7], Michael and Vidya (2012) [8], Ravi *et al.* (2015) [9]

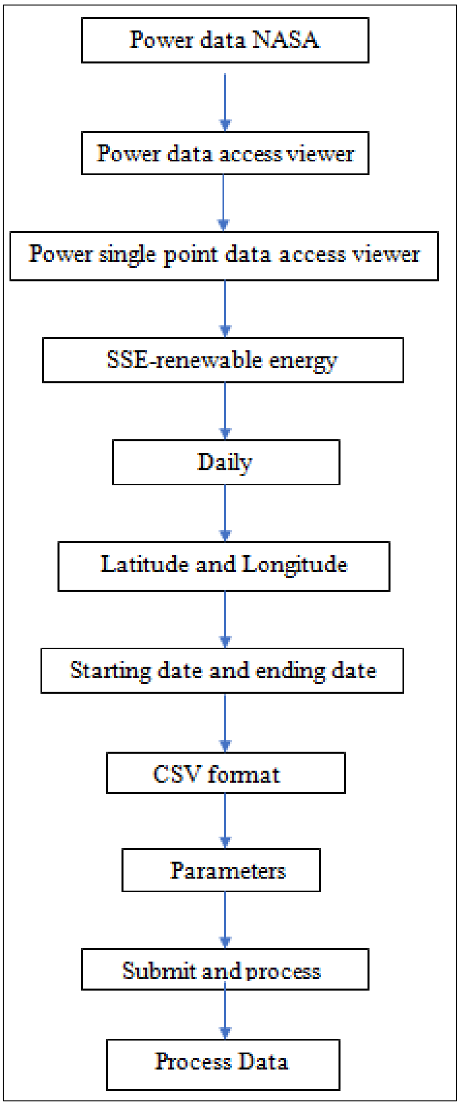


Fig 3: Flow chart for Download of weather data from NASA website

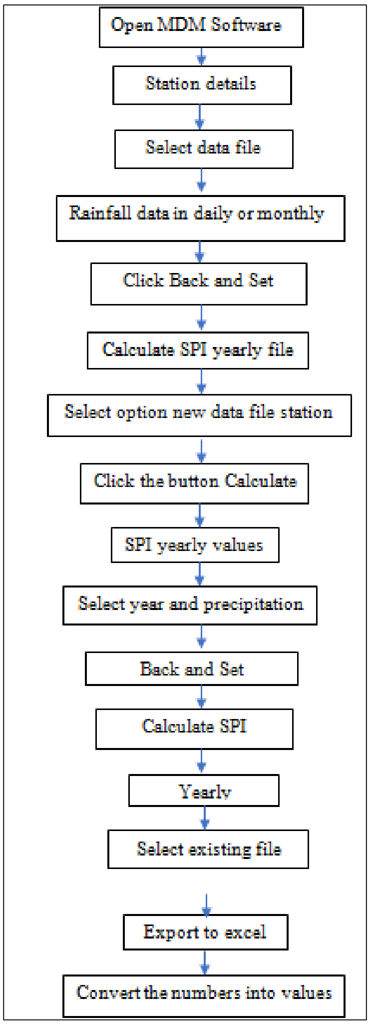


Fig 4: Flow chart for calculation of SPI values using MDM software

Results and Discussion

The results of investigations on the present study are on "Monitoring of drought situationin Kurnool district". From the Table.2, the minimum SPI value (-2.07) was observed in Banaganapalle, Bethamcherla, Dornipadu, Gospadu, Koilakuntla, Kolimigundla, Mahanandi, Nandhyala, Orwakal, Owk, Sanjamala, Uyyalawada and Velgodemandals in the year 2018.Based on the study 2018 year can be observed as the drought year.

Table 2: SPI-12 values for mandals of Kurnool district for the period from 2011 to 2020

S. No	Mandal	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	Adoni	-1.17	-0.34	0.28	0.56	-0.35	0.07	0.52	-1.82	0.13	2.1
2	Allagadda	-0.68	-0.3	0.34	-0.12	0.27	-0.68	0.47	-2.04	0.79	1.95
3	Alur	0.96	0.63	1.56	1.17	-0.3	-1.26	-1.1	-1.29	-0.56	0.18
4	Aspari	-0.86	-0.33	0.15	0.25	-0.2	-0.36	0.54	-1.97	0.69	2.07
5	Atmakur	-1.03	-0.1	0.67	0.18	-0.42	-0.49	0.38	-1.85	0.64	2.02
6	Banaganapalle	-0.62	-0.26	0.27	-0.06	-0.04	-0.53	0.54	-2.07	0.75	2.01
7	BandiAtmakur	-1.03	-0.1	0.67	0.18	-0.42	-0.49	0.38	-1.85	0.64	2.02
8	Bethamcherla	-0.62	-0.26	0.27	-0.06	-0.04	-0.53	0.54	-2.07	0.75	2.01
9	C Belagal	-1.11	-0.19	0.4	0.46	-0.43	-0.05	0.45	-1.86	0.23	2.11
10	Chagalamarri	-0.3	-0.53	0.08	-0.45	1.05	-0.94	0.65	-1.88	0.57	1.77
11	Chippagiri	-0.86	-0.33	0.15	0.25	-0.2	-0.36	0.54	-1.97	0.69	2.07
12	Devanakonda	-1.11	-0.19	0.4	0.46	-0.43	-0.05	0.45	-1.86	0.23	2.11
13	Dhone	-0.68	-0.28	0.18	0.04	-0.16	-0.41	0.59	-2.05	0.73	2.03
14	Dornipadu	-0.62	-0.26	0.27	-0.06	-0.04	-0.53	0.54	-2.07	0.75	2.01
15	Gadivemula	-1.04	-0.1	0.54	0.29	-0.48	-0.25	0.38	-1.86	0.41	2.11
16	Gonegandla	-1.11	-0.19	0.4	0.46	-0.43	-0.05	0.45	-1.86	0.23	2.11
17	Gospadu	-0.62	-0.26	0.27	-0.06	-0.04	-0.53	0.54	-2.07	0.75	2.01
18	Gudur	-1.11	-0.19	0.4	0.46	-0.43	-0.05	0.45	-1.86	0.23	2.11
19	Halaharvi	-0.86	-0.33	0.15	0.25	-0.2	-0.36	0.54	-1.97	0.69	2.07
20	Holagunda	-0.86	-0.33	0.15	0.25	-0.2	-0.36	0.54	-1.97	0.69	2.07
21	JupaduBunglow	-1.04	-0.1	0.54	0.29	-0.48	-0.25	0.38	-1.86	0.41	2.11
22	Kallur	-1.04	-0.1	0.54	0.29	-0.48	-0.25	0.38	-1.86	0.41	2.11

23	Kodumur	-1.11	-0.19	0.4	0.46	-0.43	-0.05	0.45	-1.86	0.23	2.11
24	Koilkuntla	-0.62	-0.26	0.27	-0.06	-0.04	-0.53	0.54	-2.07	0.75	2.01
25	Kolimigundla	-0.62	-0.26	0.27	-0.06	-0.04	-0.53	0.54	-2.07	0.75	2.01
26	Kosigi	-1.04	-0.1	0.54	0.29	-0.48	-0.25	0.38	-1.86	0.41	2.11
27	Kothapalle	-1.58	0.97	0.56	-1.68	0.06	0.17	-0.11	-0.18	-0.04	1.83
28	Kowthalam	-1.17	-0.34	0.28	0.56	-0.35	0.07	0.52	-1.82	0.13	2.1
29	Krishnagiri	-1.11	-0.19	0.4	0.46	-0.43	-0.05	0.45	-1.86	0.23	2.11
30	Kurnool mandal	-1.04	-0.1	0.54	0.29	-0.48	-0.25	0.38	-1.86	0.41	2.11
31	Kurnool urban	-1.04	-0.1	0.54	0.29	-0.48	-0.25	0.38	-1.86	0.41	2.11
32	Maddikera East	-0.86	-0.33	0.15	0.25	-0.2	-0.36	0.54	-1.97	0.69	2.07
33	Mahanandi	-0.62	-0.26	0.27	-0.06	-0.04	-0.53	0.54	-2.07	0.75	2.01
34	Mantralayam	-1.17	-0.34	0.28	0.56	-0.35	0.07	0.52	-1.82	0.13	2.1
35	Midthur	-1.04	-0.1	0.54	0.29	-0.48	-0.25	0.38	-1.86	0.41	2.11
36	Nandavaram	-1.17	-0.34	0.28	0.56	-0.35	0.07	0.52	-1.82	0.13	2.1
37	Nandikottukur	-1.04	-0.1	0.54	0.29	-0.48	-0.25	0.38	-1.86	0.41	2.11
38	Nandyala	-0.62	-0.26	0.27	-0.06	-0.04	-0.53	0.54	-2.07	0.75	2.01
39	Orwakal	-0.62	-0.26	0.27	-0.06	-0.04	-0.53	0.54	-2.07	0.75	2.01
40	Owk	-0.62	-0.26	0.27	-0.06	-0.04	-0.53	0.54	-2.07	0.75	2.01
41	Pagidyala	-1.04	-0.1	0.54	0.29	-0.48	-0.25	0.38	-1.86	0.41	2.11
42	Pamulapadu	-1.04	-0.1	0.54	0.29	-0.48	-0.25	0.38	-1.86	0.41	2.11
43	Panyam	-1.04	-0.1	0.54	0.29	-0.48	-0.25	0.38	-1.86	0.41	2.11
44	Pattikonda	-0.68	-0.28	0.18	0.04	-0.16	-0.41	0.59	-2.05	0.73	2.03
45	Peapally	-0.86	-0.33	0.15	0.25	-0.2	-0.36	0.54	-1.97	0.69	2.07
46	PeddaKaduburur	-1.55	-1.27	-0.38	0.07	0.65	1.04	1.16	1.28	0.21	-1.21
47	Rudravaram	-0.68	-0.3	0.34	-0.12	0.27	-0.68	0.47	-2.04	0.79	1.95
48	Sanjamala	-0.62	-0.26	0.27	-0.06	-0.04	-0.53	0.54	-2.07	0.75	2.01
49	Sirvel	-0.68	-0.3	0.34	-0.12	0.27	-0.68	0.47	-2.04	0.79	1.95
50	Srisailam	-1.15	-0.04	0.99	0.26	-0.85	-0.41	0.37	-1.49	0.24	2.08
51	Tuggali	-0.68	-0.28	0.18	0.04	-0.16	-0.41	0.59	-2.05	0.73	2.03
52	Uyyalawada	-0.62	-0.26	0.27	-0.06	-0.04	-0.53	0.54	-2.07	0.75	2.01
53	Veldhurthi	-1.29	0.01	1.22	-0.02	-0.87	-0.51	0.46	-1.38	0.5	1.86
54	Velgode	-0.62	-0.26	0.27	-0.06	-0.04	-0.53	0.54	-2.07	0.75	2.01
55	Yemmiganur	-1.11	-0.19	0.4	0.46	-0.43	-0.05	0.45	-1.86	0.23	2.11

From the Table 3, the coverage of drought percentage for 10 years in Kurnool district. The maximum drought percentage was observed in the Alur and Peddakadburumandals (30%). The highest moderately dry years were observed in the Alur mandal (3) followed by Peddakadburu (2), Srisailam (2) and Veldurthi (2) mandals

Table 3: Coverage of drought (%) for 10 years of Kurnool District

S. No.	Mandal Name	Number of moderately dry years	Number of very dry years	Number of extremely dry years	Coverage drought (%)
1	Adoni	1	1	0	20
2	Allagadda	0	0	1	10
3	Alur	3	0	0	**30**
4	Aspari	0	1	0	10
5	Atmakur	1	1	0	20
6	Banaganapalle	0	0	1	10
7	BandiAtmakur	1	1	0	20
8	Bethamcherla	0	0	1	10
9	C Belagal	1	1	0	20
10	Chagalamarri	0	1	0	10
11	Chippagiri	0	1	0	10
12	Devanakonda	1	1	0	20
13	Dhone	0	0	1	10
14	Dornipadu	0	0	1	10
15	Gadivemula	1	1	0	20
16	Gonegandla	1	1	0	20
17	Gospadu	0	0	1	10
18	Gudur	1	1	0	20
19	Haalaharvi	0	1	0	10
20	Holagunda	0	1	0	10
21	JupaaduBunglow	1	1	0	20
22	Kallur	1	1	0	20
23	Kodumur	1	1	0	20
24	Koilakuntla	0	0	1	10
25	Kolimigundla	0	0	1	10
26	Kosigi	1	1	0	20
27	Kothapalle	0	2	0	20

28	Kowthalam	1	1	0	20
29	Krishnagiri	1	1	0	20
30	Kurnool	1	1	0	20
31	Kurnool Urban	1	1	0	20
32	Maddikera East	0	1	0	10
33	Mahanandi	0	0	1	10
34	Mantralayam	1	1	0	20
35	Midthur	1	1	0	20
36	Nandavaram	1	1	0	20
37	Nandikotkur	1	1	0	20
38	Nandyala	0	0	1	10
39	Orvakal	0	0	1	10
40	Owk	0	0	1	10
41	Pagidyala	1	1	0	20
42	Pamulapadu	1	1	0	20
43	Panyam	1	1	0	20
44	Pattikonda	0	0	1	10
45	Peapally	0	0	1	10
46	Peddakadburu	2	1	0	30
47	Rudravaram	0	0	1	10
48	Sanjamala	0	0	1	10
49	Sirivel	0	0	1	10
50	Srisailam	2	0	0	20
51	Tuggali	0	0	1	10
52	Uyyalawada	0	0	1	10
53	Veldurthi	2	0	0	20
54	Velgode	0	0	1	10
55	Yemmiganur	1	1	0	20

Summary and Conclusions

1. The analysis from SPI from rainfall data (2011 to 2020) is useful to determine the distribution and characteristics of drought in the 55 mandals of Kurnool district, Andhra Pradesh, India. It has been found that the Standard Precipitation Index is the best tool to estimate the drought severity.
2. The minimum SPI value (-2.07) was observed in Banaganapalle, Bethamcherla, Dornipadu, Gospadu, Koilakuntla, Kolimigundla, Mahanandi, Nandhyala, Orwakal, Owk, Sanjamala, Uyyalawada and Velgode mandals. Based on the study, the year 2018 can be observed as the drought year.
3. The maximum drought percentage was observed in the Alur and Peddakadburu mandals is (30%). The highest moderately dry years were observed in the Alur mandal (3) followed by Peddakadburu (2), Srisailam (2) and Veldurthi (2) mandals.
4. Yearly SPI values are useful for planning of stream flows, reservoir levels, and even groundwater levels at the longer time scales. Drought is a predominant cause for reduce in crop yields or crop damage. There is an urgent need for more water efficient cropping systems facing large water consumption of irrigated agriculture and high unproductive losses via runoff and evaporation. Identification of drought resistant crops is the key to improved management of plant water stress.

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