Assessment of drought using standard precipitation index in Prakasam district Andhra Pradesh, India

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DOI: https://doi.org/10.22271/phyto.2021.v10.i45a.14268

Abstract
This paper discusses a method for calculating the severity of meteorological droughts based on historical precipitation data as the primary criterion. Monthly precipitation data from 1970 to 2020 were used to obtain Standardized Precipitation Index (SPI) values for Prakasam district, Andhra Pradesh. SPI has the ability to analyse the drought at various time scales and for a variety of applications. SPI is calculated at various time scales (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 etc. months). Temporal SPI graphs show that the maximum SPI value (extreme drought) occurred in the year 2018 in that year, the SPI value was -2.6. Furthermore, in severe and extreme drought years, SPI values indicated only moderate dryness rather than extreme dryness, with SPI values never falling below -2.5. Severe and moderate drought occurred in 1984, 2002 and 2014. Drought patterns were evaluated, yielding many interesting results on the variability of drought occurrence in the region. The study’s findings are relevant to climate change studies in order to understand historical patterns and build future scenarios of drought occurrences.

Keywords: Precipitation, meteorological drought, standard precipitation index, climate change

Introduction
Since the dawn of time, extreme meteorological events such as heat waves, cold waves, droughts, floods, etc. had affected human life, animal life, agriculture, and all other sectors collectively. Climate change is one of the causes for these extreme events as a consequence it adversely affects the social and economic conditions. The Sixth IPCC report summarizes warming even 1.5 degrees of global warming will still lead to large-scale drought, famine, heat stress, death of species, loss of entire ecosystems, and loss of habitable land, plunging more than 100 Million into economically low. Large variations in the frequency and intensity of excessive activities can result from enormously small fluctuations within the average of a distribution of precipitation, temperatures, or different weather variables. Among the extreme meteorological events, droughts had the least predictability and affecting greater humans than other dangers. Drought is unpredictable and also the most complex and least understood phenomenon among all the natural hazards (Hagman, 1984; Amrit et al., 2018) [1, 2]. Meteorological drought is the earliest and the maximum explicit event inside the manner of prevalence and progression of drought situations.

Drought is one of the extreme climatic event that is tricky in nature since it grows gradually and regularly sneaks up on one (Mukherjee, S et al., 2018) [3]. Effect of drought under a global warming situation is bound to disturb later on (Dai, A 2011) [4]. Obviously dry spells have consistently happened, and the inconstancy in ocean surface temperature inconsistencies can cause worldwide droughts (Seager, R 2020) [5]. Droughts happen in practically all climatic zones, for example, high just as low precipitation regions and are for the most part identified with the decrease in the measure of precipitation got throughout a drawn out timeframe, like a season or a year (Mishra, A.K., and Singh, V.P. 2010) [6]. Drought is characterized as a cataclysmic event that happens when precipitation is altogether not as much as its ordinary time (Dikici, M.2020) [7]. Dry spells sway both surface and groundwater assets and can prompt decreased water supply, deteriorated water quality, crop failure, diminished reach usefulness, reduced force age, upset riparian natural surroundings, and suspended amusement exercises, just as influence a large group of monetary and social exercises (Riebsame et al., 1991) [8].
The event of dry season makes the land unequipped for development consistently and the present circumstance renders brutal and cold ecological condition for person, domesticated animals populace and biomass potential and plant species (Dipanwita Dutta et al., 2015)⁹. Dry spell occasions are viewed as made out of span, size (average water deficiency), and seriousness (Cumulative water insufficiency). (Dracup et al., 1980)¹⁰.

Drought index is an effective tool to monitor the current drought conditions. Globally there are several drought indices in the past dependent on precipitation as the single variable, consists of widely used deciles, Standardized Precipitation Index (SPI), and Effective Drought Index). There is additionally another notable index Palmer Drought Severity Index (PDSI), which considers temperature and precipitation. In this research study, the SPI tool has been decided to evaluate the drought condition because of its ease and simplicity, its capacity to address dry spell on different time scales, and on the grounds that it depends on likelihood. Agriculture, temperature, wind, and hydrological drought are the significant components. One of the significant difficulties of agrarian frameworks is the way to decrease the effects of dry seasons during crop growth. Dry spell impacts rural frameworks, financially just as naturally. According to a environment point of view, dry seasons can delay yields and soils of essential precipitation and also to increase the salt substance in soils and water system frameworks.

Droughts can be categorized as meteorological, hydrological, agricultural and socioeconomic drought (Wilhite and Glantz 1985)¹¹. Meteorological drought is related to the deficiency of rainfall compared to long-term average amounts on monthly, seasonal or annual time scales (Linsley and Kohler 1958)¹². Hydrological drought is associated with the effects of periods of precipitation shortfalls on surface or subsurface water supply (Linsley et al., 1975; Dracup et al., 1980)¹³,¹⁴. Agriculture drought occurs when there is insufficient rainfall for the soil moisture during crop growing season (National Commission on Agriculture, India) leading to less production (Rathore 2004)¹⁵. Socioeconomic drought is connected with the supply and demand of economic goods such as water, forage, food grains, fish and hydropower electric (Marshall and Zhou 2004)¹⁶.

A minimum of 30-year precipitation data is required to compute the SPI but a data of more than 60-year data is often analyzed (World Meteorological Organization (WMO) (2012)¹⁷. Standardized Precipitation Index User Guide. Geneva: World Meteorological Organization. Standardized Precipitation Index (SPI) expresses the actual rainfall as standardized departure from rainfall probability distribution function and, hence, this index has gained importance in recent years as a potential drought indicator permitting comparisons across space and time. Computation of SPI requires long term data on precipitation to determine the probability distribution function which is then transformed to normal distribution with mean of zero and standard deviation of one (On the use of Standardized Precipitation Index (SPI) for drought intensity assessment). Thus, the values of SPI are expressed in standard deviations with positive SPI values indicating greater than median precipitation and negative values indicating less than median precipitation (Edwards and McKee, 1997)¹⁸.

Methodology

SPI, which is solely based on precipitation data, can distinguish drought-prone areas. SPI reflects precipitation values as a standardized deviation from the rainfall probability function, and as a result, this index has gained attention recently as a potential drought indicator. SPI has the advantage of being simple to calculate and requiring modest form of data. (Agnew 2004)²⁰.

SPI has the ability to analyse the drought at various time scales and for a variety of applications. (wu et al., 2001)²¹. Drought was analyzed for 1, 3, 6 and 12-month time scales by researchers throughout the world (Carlos et al., 2016; Kumar et al., 2016; Malakiya et al., 2016)²²,²³,²⁴. SPI is calculated at various time scales (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 etc. months) (Homdee et al., 2016)²⁵. Amongst all those time scales, 1, 3, 6, 9, 12, 24, and 48 show the most variation in reflecting agricultural and hydrological drought/impacts. (Karavitis et al., 2011; Zargar et al., 2011)²⁶,²⁷. Time scales of one, two, and three months are effective for agriculture, while time scales of six, nine, and twelve months are useful for hydrology. (Bergman 2009)²⁸.

For any location, SPI index can be calculated based on the longterm precipitation record for a desired length of time. This long-term record is fitted to a probability distribution, which is then transformed into a normal distribution so that the mean SPI for the location and desired period is zero (Edwards and McKee, 1997)¹⁶ as the SPI index a value is normalized, wet and dry climates can be shown as same way, positive SPI index value represents greater than median.
precipitation negative values represents less than median precipitation.

SPI algorithms analyse the input data to optimally estimate two key coefficients which govern the transformation, and the observed precipitation data are transformed to Gaussian (normal) equivalents. The transformed precipitation data are then used to compute the dimensionless SPI value, defined as the standardized anomaly of the precipitation:

\[ \text{SPI} = \frac{P - P^*}{\sigma_P} \]

Where \( P \) = precipitation, \( P^* \) = mean precipitation, \( \sigma_P \) = standard deviation of precipitation

McKee and others (1993) used the classification system shown in the SPI value table below (Table 1) to define drought intensities resulting from the SPI. They also defined the criteria for a drought event for any of the timescales. A drought event occurs any time the SPI is continuously negative and reaches an intensity of -1.0 or less. The event ends when the SPI becomes positive. Each drought event, therefore, has a duration defined by its beginning and end, and an intensity 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”. In table no.1 shows the SPI values from extremely wet condition to extremely dry conditions to delineate the dry and wet spells.

| SPI Values | Condition          |
|------------|--------------------|
| 2.0+       | extremely wet      |
| 1.5 to 1.99| very wet           |
| 1.0 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 and less| extremely dry      |

Results and Discussion

Descriptive statistics

A yearly rainfall departure analysis was performed on rainfall data to identify drought years and the magnitude of annual rainfall deficits. If the total quantity of annual rainfall falls below 25% of the normal rainfall value, the year is considered as a drought year. The annual rainfall (fig no.1) and deviation in Prakasam district is shown in fig no.2. Analyse shows that in years 1970, 1971, 1984, 2002, 2014, 2016, 2017 drought occurred Prakasam district. it is also evident that the region also experienced severe drought in 2018 when the deficit rainfall about greater than -50% in addition to it trend analysis showed that decrease in precipitation over the past 50 years with linear regression \( Y = -0.1555x + 4.0429 \) \( R^2 = 0.0094 \) (fig no.2)

Drought assessment

The annual SPI for Prakasam district was calculated from 1970 to 2020 to show the frequency of occurrence of dry and wet conditions. SPI-based’s drought classification (McKee et al., 1993) was used in this study. The SPI value is a measure of the severity of a wet or dry event. A drought event occurs when the SPI value is -1.0 or less and the event lasts for at least one month when the index becomes positive (Bordi et al.
SPI was calculated at 1-month, 3-month, 6-month, 9-month, and 12-month timescales. On smaller scales, such as the SPI-1 and SPI-3 series, drought intensities are highly variable, becoming less than 1.0 and greater than 1.0 on several occasions. SPI-6, SPI-9, and SPI-12 drought intensity, on the other hand, decreases over longer timescales. This variation is due to a seasonal component found in the rainfall data since SPI is relative to the rainfall characteristics of that area.

3, 6, 9, 12 month SPI Analysis

The 3-month (fig no.3) SPI specifies both short- and medium-term moisture conditions and provides an estimate of seasonal precipitation. A 3-month SPI is more useful than many other hydrological indices in emphasising existing moisture levels in major agricultural regions. Figure 3 depicts the 3-month SPI in Prakasam district from 1970 to 2020. The lowest SPI on a 3-month timescale below – 2 was which occurred in these years 1971, 1972, 1975, 1991, 2001, 2005 and 2018.

The 6-month (fig no.4) SPI specifies seasonal to medium-term precipitation trends and is very potent at depicting precipitation over different seasons. From 1970 to 2020, the lowest 6-month SPI on a 6-month timescale was which occurred in the year 1972, 2001, 2017 and 2018.

The 9-month (fig no.5) SPI gives an insight into inter-seasonal precipitation patterns over a medium time scale. Droughts typically develop over the course of a season or more. An SPI value of -1.5 or less for a 9-month time scale indicates that dryness has a significant impact on agriculture as well as other sectors. Figure represents the 9-month SPI for the Prakasam district from 1970 to 2020. The lowest SPI on a 9-month timescale was below – 2 was which recorded in these years 2017, 2018 and 2019.
At long timescales, 12-month SPI (fig no.6) values are generally linked to stream flows, reservoir levels, and even groundwater levels. Figure depicts the 12-month SPI in Prakasam district from 1970 to 2020. The lowest 12-month SPI on a 12-month timescale was below the value – 2 was recorded in these years 2001, 2015, 2018, 2019.

In India based on monsoon, cropping season is classified into two main seasons kharif and rabi. There is need to identify the drought condition in these seasons. The major crops grown in this season are Paddy, Redgram, Cotton, Black gram, Green gram, Chilli. June represents the start of the Agriculture field operations, in prakasam most of the farmers start the sowing of seed during end of July to early August moreover in end of October to fortnight of November second season starts. Therefore, keeping in view the crop phenology and crop calendar, rainfall during June, July, August and September play a vital role in crop production.

Results show for Kharif season (fig no. 7) show that moderate drought occurred in the years 1973, 1977, 1979, 1992, 1994, 1997, 2002 and 2011; severe drought occurred in the years 1970, 1971, 1987, 2001 and 2006; whereas extreme drought occurred in 1972, 1975, 1984, 1994 and 2009. For Rabi season, (fig no. 8) moderate drought occurred in the years 1970, 1979, 1982 and 1992; severe drought occurred in the years 1970, 1989 and 2009; whereas extreme drought occurred in the years 1971, 1988, 2016 and 2018. Thus, the most critical drought year in the area was 2018 with greater than 50% deviation from the normal rainfall.
In this study we had taken a yield attributes of major crops growing in prakasam district in comparison with the SPI values from 1995 – 2020. From the fig no.9 it shows the severe drought year 2016 and extreme drought year 2018 observed -2.8 SPI, -1.81 at the same period yields of red gram are 133 kg/hectare and Bengal gram is 833 kg /hectare and chillies 3737kg/ hectare in 2018 was observed and in 2016 yields of Red gram are 442 kg/hectare and Bengal gram is 1490 kg /hectare and chillies 3016 kg/ hectare. But the average yields of redgram is 462.1 kg/ha, Bengal garam 1530 kg/ha and chilli 2820.8 kg/ha respectively. So we can conclude it that dry periods affected the growth and development of plant and yielded comparatively less yields than average year yields which are not prone to drought. And however there may be many factors included in declining the yield.

![Graph showing yield values of Red gram, Chilli, Bengal gram with SPI values](image)

**Fig 9:** Graph showing yield values of Red gram, Chilli, Bengal gram with SPI values

### Conclusion

The purpose of this study was to use the Standardized Precipitation Index criterion to assess droughts observed in the prakasam district. Drought patterns were evaluated, yielding many interesting results on the variability of drought occurrence in the region. For the given rainfall data, a decreasing trend was observed in the area, indicating that the area under consideration is under drought prone. Temporal SPI graphs show that the maximum SPI value (extreme drought) occurred in the year 2018 in that year, the SPI value was -2.61. Furthermore, in severe and extreme drought years, SPI values indicated only moderate dryness rather than extreme dryness, with SPI values never falling below -2.5. Severe and moderate drought occurred in 1984, 2002 and 2014. It was found that SPI is a valuable tool for assessing drought characteristics like frequency and severity. With respect to agriculture the widespread adoption of improved farming techniques, advances in breeding programmes that yield more resilient crops, and biotechnology adoption in local communities will assist farmers in making better use of water on their farms to meet demand and nourish a growing world and moreover drought can be overcome by adopting climate resilient dry farming crops (drought tolerant crops), micro irrigation, capturing and storing water, growing cover crops, conservation tillage practices. The study's findings are relevant to climate change studies in order to understand historical patterns and build future scenarios of drought occurrences.

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