USE OF METEOROLOGICAL DATA FOR IDENTIFICATION OF DROUGHT

Karinki Ravi Kiran[1], Sanat Nalini Sahoo[2,]

[1]*Civil engineering Department, NIT Rourkela, Rourkela, 769008, India,Email:ravi.kirank99@gmail.com*

[2]*Civil engineering Department, NIT Rourkela, Rourkela, 769008, India, Email:sahoosanat@nitrkl.ac.in*

ABSTRACT

Drought has been called a creeping disaster because of the way it develops slowly. It can be defined according to meteorological, hydrological and agriculture criteria. In the present study, meteorological data i.e., monthly rainfall data from different rain gauges stations were used for identification of drought. Standardized Precipitation Index (SPI) values were generated based on Gamma distribution of precipitation data for 32 years (from 1985 to 2016) for Ananthpur district of Andhra Pradesh in India. Comparison of SPI, with actual rainfall and rainfall deviation from the mean indicated that SPI values underestimate the intensity of dryness/wetness when the rainfall is very low/very high respectively. This shows that the range of SPI values of the high rainfall district indicated better stretching, compared to that of the low rainfall district. SPI indicated deviation from normal probability in the lower and upper ranges. Therefore, it is suggested that SPI as a stand-alone indicator needs to be interpreted with caution to assess the intensity of drought.

Keywords: Meteorological drought, Standardized precipitation index (SPI), probability distribution function (gamma distribution)

INTRODUCTION

Drought is a very harmful hazard of nature. It originates from a deficiency of precipitation that persists long enough to produce a serious hydrologic imbalance. It should be considered relative to some long-term average condition of balance between precipitation and evapotranspiration (i.e., evaporation and transpiration) in a particular area.

Droughts are categorized as meteorological, hydrological, agricultural and socio-economic. Meteorological drought is related to the deficiency of rainfall compared to long-term average amounts on monthly, seasonal or annual time scales. Hydrological drought is associated with the effects of periods of precipitation shortfalls on surface or subsurface water supply (e.g., stream flow reservoir and lake levels, ground water). Socio-economic drought is connected with the supply and demand of economic goods such as water, forage, food grains, fish, hydroelectric power, etc. Meteorological Drought interlinks the agriculture drought as it occurs when soil moisture and rainfall are inadequate during the growing season to support healthy crop growth up to maturity, resulting in crop stress and wilting.

According to IMD (Indian Meteorological Department), meteorological drought is characterized when the seasonal rainfall collected over an area is not more than 75% of its long-term average value. It is further classified as moderate drought if the rainfall deficit is 26-50% and severe drought when the deficit exceeds 50% of normal. A year is considered to be a drought year for the country if the area affected by the drought is more than 20% of the total area of the country.

To identify the drought, drought indices are the prime variable for assessing the effects of a drought and for defining different drought parameters, which include intensity, duration, severity and spatial extent. There are several drought indices operational in drought assessment and monitoring that are based on rainfall data. A drought index is typically a single number, such as the Palmer Drought Severity Index (PDSI), which was widely used by the US Department of Agriculture to determine when to grant emergency drought assistance. The PDSI performs best when working with large areas of uniform topography. McKee, Doesken and Kleist of the Colorado Climate Center formulated the Standard Precipitation Index (SPI) in 1993. The advantage of this index is that it identifies emerging drought months sooner than the PDSI. (Jain et al. 2009). Keyantash and Dracup (2002) performed an evaluation among drought indices based on six criteria, i.e. robustness, tractability, transparency, sophistication, extendibility and dimensionality which shows SPI as the second highest ranked drought index, with a total score of 115 after the rainfall deciles with a score of 116. As a result, this index has been much used by different researchers for drought-related study (Duttaa et al. 2013). Past researches have proved that the SPI has many advantages over the Palmer Drought Severity Index (PDSI) and other indices because it is relatively simple, spatially consistent, and temporally flexible, thus allowing observation of water deficits at different scales (Guttman 1998, Hayes et al . 1999, 2000, Szalai and Szinell 2000). Based on a comparative study between SPI and PDSI, it is suggested that SPI is a representative of short-term precipitation and soil moisture variation and hence a better indicator of soil wetness. However, SPI calculation requires long-term precipitation records and it can be calculated for different time scales.

STUDY AREA

Andhra Pradesh (figure 1) is the fourth largest State in India covering geographical area of 2,75, 068 sq.km. Based on geographical position the state is divided in to two regions viz., Coastal Andhra, and Rayalaseema. The Coastal Andhra region comprises nine districts namely Srikakulam, Vizianagaram, Visakhapatnam, East Godavari, West Godavari, Krishna, Guntur, Prakasam and Nellore districts. The Rayalaseema region is comprised of four districts viz., Kurnool, Kadapa, Anantapur and Chittoor districts. The normal annual rainfall of the state is 952mm. Season-wise normal rainfall is 555 mm, 285 mm, 9.8 mm and 96.3mm in monsoon (June-Sept), post-monsoon (Oct-Dec), winter (Jan-Feb) and summer (March-May) respectively, contributing 58% of annual in SW monsoon, 30% of annual rainfall in north-east monsoon and 12% in non-monsoon season. In the present study one district of Andhra Pradesh state, India, namely, Ananthpur was selected for drought analysis where the annual normal rainfall is found as 574 mm.

Anantapur district (figure 2) is one of the four districts of Rayalaseema Region and the largest among the 13 districts of Andhra Pradesh. The district is economically backward and chronically drought affected declared by the state administration as chronic drought prone area because of its low rainfall with high inter-annual variability. The district has three revenue districts, 63 mandals and 932 revenue villages and 7 municipalities. The district lies between North latitudes 13° 40’ and 16°15’ and between East longitudes 70° 50’ and 78° 38’. The district occupies the southern part of the State and is bounded on the north by Bellary district of Karnataka State and Kurnool district of Andhra Pradesh, on the East by Cuddapah and Chittoor districts of Andhra Pradesh and on the South and West by Karnataka state. The geographical area of the district is 19,197 sq.km with a population of 40.83 lakhs. The population density, which was 54 persons per sq.km during 1901, has risen to 213 persons per sq.km as per 2011census. Out of the total geographical area of 19.197 sq. km, forests cover 10% of the area. Similarly, barren and uncultivable land is 9% and land put to non-agricultural use is 8%. The total net area sown is 824955 ha. The important crops harvested in the district are paddy, jowar, ragi, chilies, sugarcane, onions and groundnut. Paddy and ground nut are the most important crops accounting for gross hactarage of 65,550 and 36,500 respectively. This data is collected from the Directorate of Economics and Statistics, Government of Andhra Pradesh, India, was used as input data in the analysis.

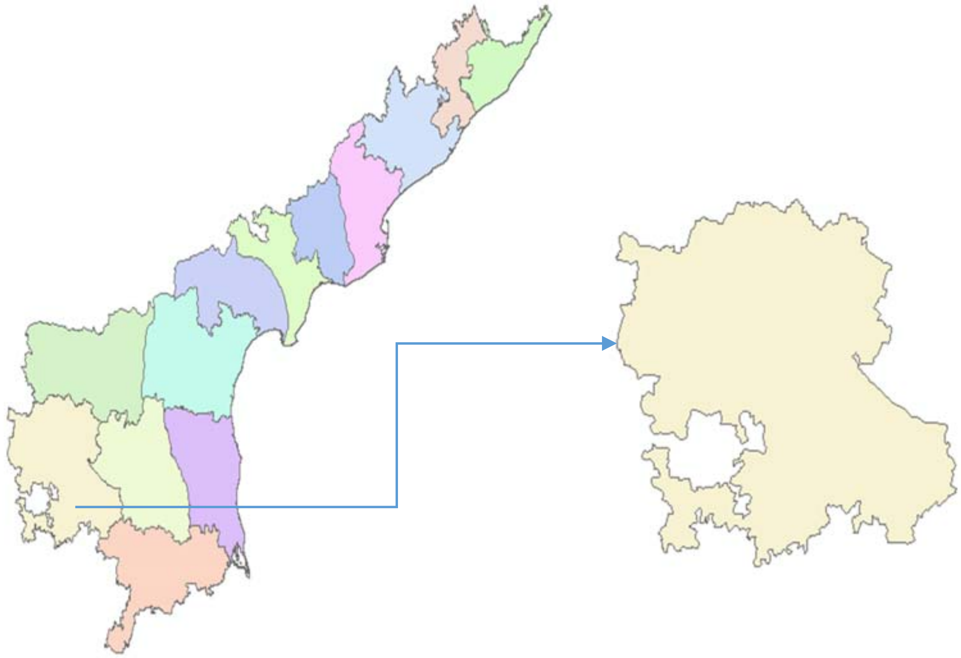

Figure 1: Andhra Pradesh state **figure 2: Ananthpur District**

DATA AND METHODOLOGY

In this study mean month to month precipitation information for the from 1985 to 2016 is as utilized meteorological information. The SPI based on precipitation data were applied to identify the drought prone area. SPI express the precipitation values as a standardized deviation with respect to rainfall probability function and hence this index got more importance in recent years as potential drought indicator with space and time. The SPI was obtained by fitting a gamma distribution function to a given frequency distribution of precipitation and then it is transforming the gamma distribution to a normal distribution (The values lie in one standard deviation approximately 68% of time, 2 sigma within 95% of time, 3 sigma within 98% of time) with mean zero and variance of one using a computer program in excel. (Asadi Zarch, et al., 2014). The gamma distribution is normally defined by Eq. 1.

$$g(x) = \frac{x^{\alpha-1}.e^{-x/\beta}}{\beta^{\alpha}.\Gamma\alpha}\ , for\ x > 0 \qquad (1)$$

Where $\alpha > 0$ is a shape parameter (statistical), $\beta > 0$ is a scale parameter, x is the precipitation amount and $\Gamma\alpha$ is the gamma function. The purpose of SPI is to assign a single numerical value to the precipitation data and is compared within the regions of different climates. McKee et al. (1993) defined the criteria for a drought event for any time-scale as occurring at any time when the value of the SPI is continuously negative. They proposed a seven-category classification for SPI values as shown in table 1 (Jain et al. 2009). Because the SPI is normalized, wetter and drier climates can be represented.

TABLE 1: Classification of SPI (adapted from Jain et al. 2009)

SPI	Drought category
>2	Extremely wet
1.5 to 1.99	very wet
1.0 to 1.49	moderately wet
-0.99 to 0.99	near normal
-1.49 to -1.0	moderately dry
-1.99 to -1.5	severely dry
< -2	extremely dry

RESULTS AND DISSCUSION

As SPI is drought index, a drought event occurs if SPI is -1 (negative) or less and the positive values shows non-drought event (Bordi et al.2001). This represents negative values, suffering from drought and the positive values represent non-drought condition.

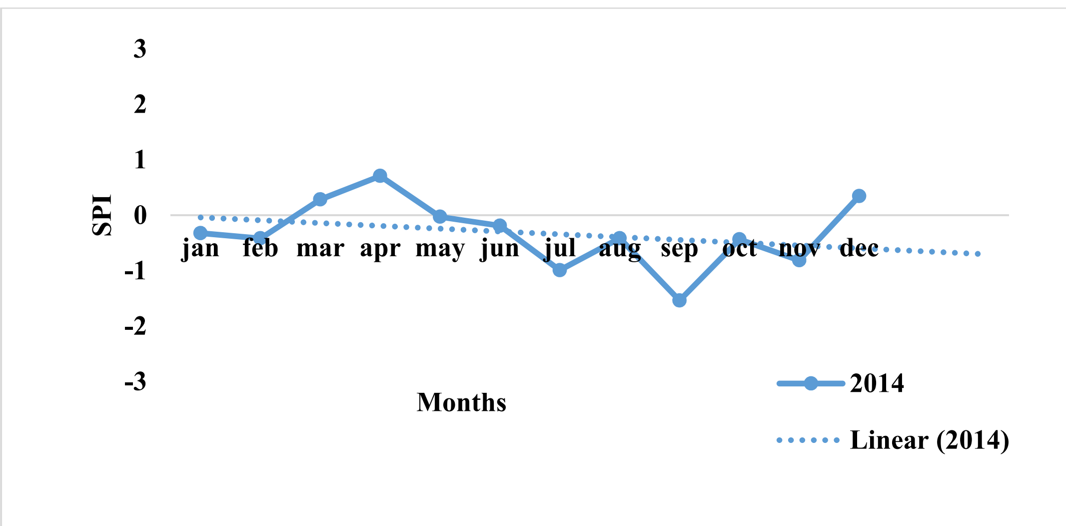

Figure 3: variation of SPI in the year 2014

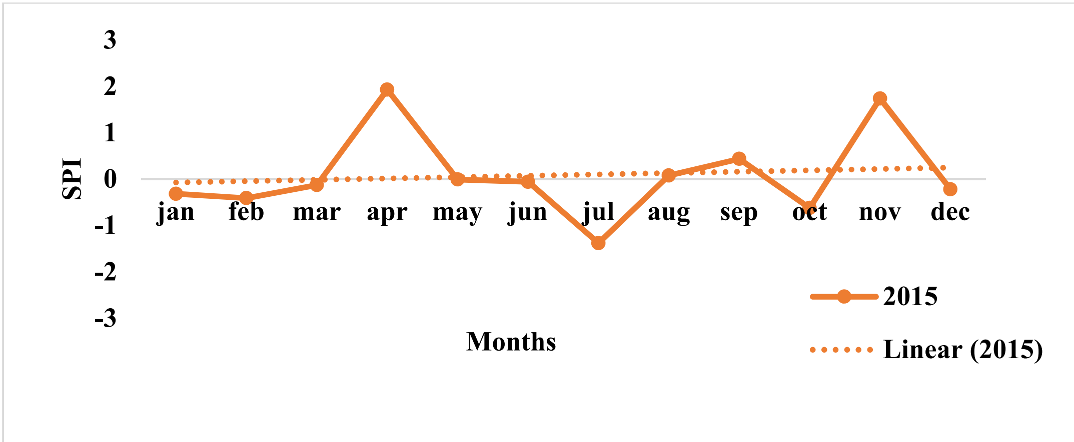

Figure 4: variation of SPI in the 2015 year

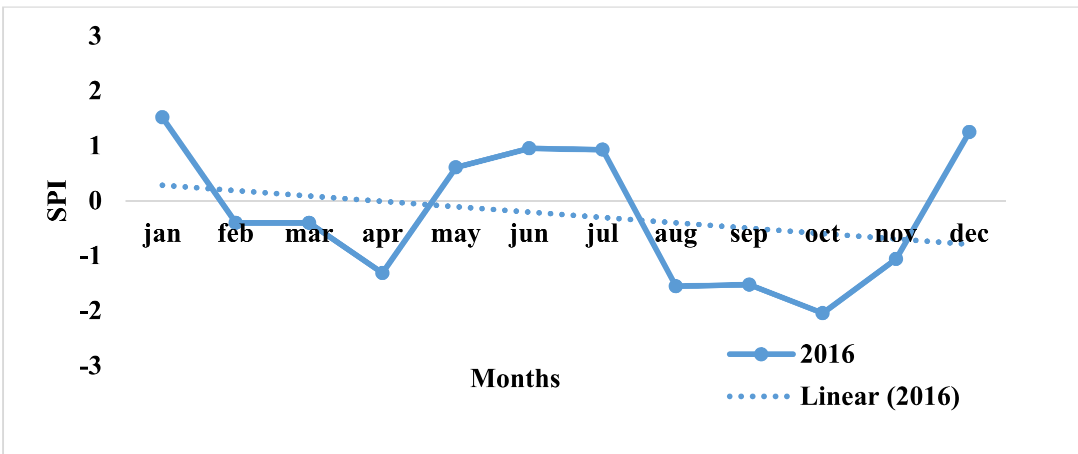

Figure 5: variation of SPI in the year 2016

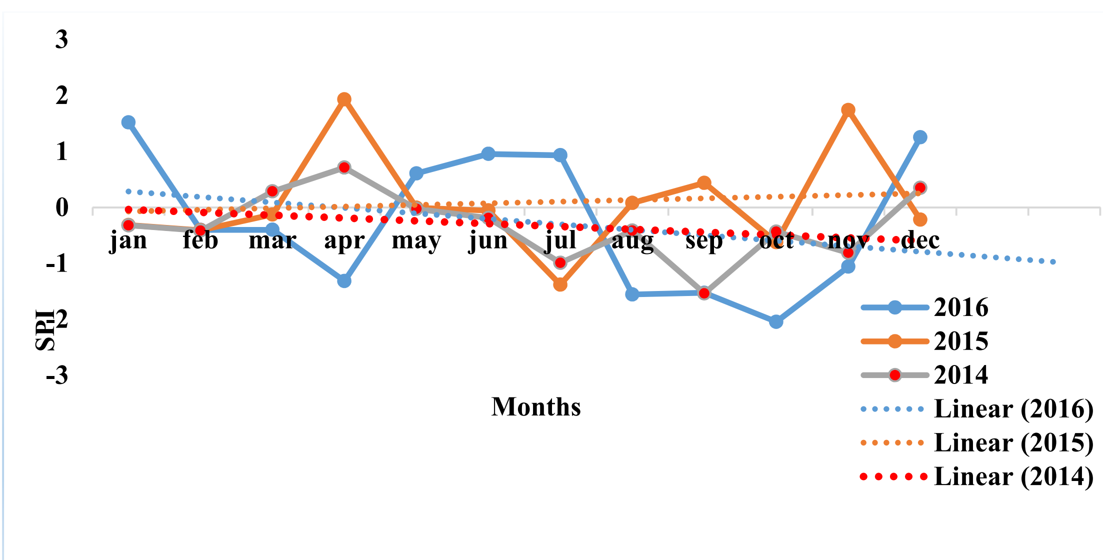

Figure 6: comparison of SPI in different years with linear forecast trend lines

In this study, the SPI values of different years are analyzed with actual rainfall and rainfall deviation from normal in a low rainfall and drought prone district. These SPI values are plotted and from the plot in 2014 (figure 3), the peak values of the plot show, the month September is in severely dry condition and rest of the months are in near normal condition i.e., normal growth of vegetation, where as in 2015 (figure 4) the peak values of the graph shows April and November are in very wet condition i.e., more than normal growth, and July is in moderately dry and the rest of the months are in near normal condition. While coming to the year 2016 (figure 5) the rainfall variations are more i.e., January is in very wet condition, August and September is in severely dry, October is in extremely dry and coming to April and November is in moderately dry condition and rest are fall in near normal condition.

Scatter plots of SPI which is obtained from rainfall values and their trend lines shows 2014 and 2016 are drought years in the monsoon season (Jul-Sept) and when 2015 is a non-Drought year (figure 6). This Shows 2014 and 2016 are agriculture Drought years as rainfall deficient compared to 2015, a non-Drought agriculture year.

Conclusion

In this study, the SPI values of different years are analyzed with actual rainfall and rainfall deviation from low normal rainfall and drought prone district. As SPI is statistical nature with different time scales of rainfall deviations it is found to be more sensitive to find drought area in different years. From the results, SPI shows better Drought indicator.

REFERENCE

McKee, T. B., Doesken, N.J. and Kleist, J., (1993), "The relationship of drought frequency and duration to Time scales". *8th conference on Applied climatology,* 17:22, 179-148

Jain, S.K, Keshri. R, Goswami. A, Sarkar. A and Chaudary. A., (2009). "Identification of drought Vulnerable areas using NOAA AVHRR data", *International Journal of Remote Sensing*, 30 (10), 2653-2668.

Keyantash, J. and Dracup, J.A., (2002). "The quantification of drought: an evaluation of drought indices", *Bulletin of American Meteorological Society,* 83, 1167-1179.

Dutta, D. A. K, and N.R. Patel. (2013). "Predicting agricultural drought in eastern Rajasthan Of India using NDVI and standardized Precipitation index (SPI)", *Geocarto International,* 28, 192-209.

Guttman, N.B., (1998). "Comparing the palmer drought index and the standardized precipitation index", Journal *Of the American Water Resources Association*, 34 (1), 113-121.

Hayes, M., Svoboda, M, and Wilhite, D.A, (2000). "Monitoring drought using the standardized precipitation index", *A Global Assessment, London Routledge*, 168-180.

Hayes, M., et al., (1999). "Monitoring the 1996 drought using the standardized precipitation index", *Bulletin of the Americian Meteorological society,* 80, 429-438.

Szalai, S., and Szinell, C., (2000). "comparison of two drought indices for monitoring in Hungary", *drought and Drought Mitigation in Europe., Dordrecht: Kluwer Academic Publishers,* 161-166.

Asadi Zarch, M.A., Sivakumar, B., Sharma, A., (2014). "Droughts in a warming Climate: A global assessment Of standardized Precipitation Index (SPI) and Reconnaissance drought index (RDI)", *hydrological Journel,* S0022-1694(14)00763-X

Bordi, I., et al., (2001). "The analysis of the standardized precipitation index in the Mediterranean area: Large-large Patterns". *Annali Di Geofisica*, 44, 965-978.