Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2017; 6(4): 452-457
Received: 01-05-2017
Accepted: 02-06-2017

Sujitha E
Research Scholar,
Department of Soil and Water Conservation Engineering,
Agricultural Engineering College & Research Institute, Kumulur,
Trichy, Tamil Nadu, India

Shanmugasundaram K
Professor, Department of Soil and Water Conservation Engineering, Agricultural Engineering College & Research Institute, Kumulur, Trichy,
Tamil Nadu, India

Correspondence
Sujitha E
Research Scholar,
Department of Soil and Water Conservation Engineering,
Agricultural Engineering College & Research Institute, Kumulur,
Trichy, Tamil Nadu, India

Analysis of dry/wet conditions using the Standardized Precipitation Index and its potential usefulness for drought /flood monitoring in the regions of Trichy

Sujitha E and Shanmugasundaram K

Abstract
Standard Precipitation Index is a tool for the investigation of drought by taking into accounts its intensity and duration. The rarity of a drought or an anomalously wet event at a particular time scale for any location in the world that has a precipitation record can be analysed using SPI. Shorter timescale SPIs, for example 1, 2, 3 month SPIs, can provide early warning of drought and help assess drought severity. It is spatially consistent. Precipitation data for Trichy region (1982-2011) is analysed by SPI method for SPI-3 (a and b)* and SPI-6. The result revealed that, SPI -3 (a) shows the drought condition during that period of 1984 were extremely dry, 1982 and 1985 shows severely dry condition (-1.50 to 1.99), 1994, 1997 and 1999 were moderately dry (-1.00 to -1.49), 2008 was moderately wet (1.00 to 1.49) and SPI-3 (b) shows 1984 was extremely wet (>2.00), 1987, 1989, 1993 2002, 2007 were moderately dry (-1.00 to -1.49), 1996 severely dry (-1.50 to -1.99). SPI -6 (June to November) shows the severe drought condition during the period of 1987 and 2003 (-1.50 to-1.99), moderately dry was in 1982, 1985, 1988 & 1999 (-1.00 to -1.49). From this Study, SPI helps to identify the frequency of occurrence of dry & wet years and to reveal trends of dry & wet condition severity. Plotting against year and SPI gives a good indication of the drought history of a particular station and serves as good indicator tool for drought analysis.
*(a and b)**- (June to August and September to November)

Keywords: Drought analysis, Gamma distribution, SPI, Dry and Wet condition

Introduction
Agriculture, the climate-sensitive sector, is one of the most important determinant factors for Indian economy. The combined and interacting influences of climate change and its variations in rainfall and temperature conditions directly affects Indian agriculture mainly plant and animal production. It indirectly affects the agricultural production through changes in soil, water, pests, and diseases making agriculture more vulnerable. This leads to the identification of different types of drought (meteorological, agricultural, hydrological, socio-economic, ecological), which reflect the perspectives of different sectors on water shortages. Drought affects virtually all climatic regions and more than one half of the earth is susceptible to drought each year. The SPI method was first developed by Mckee *et al*., (1993) [8] transforms the precipitation parameter to a single numerical value for defining the drought condition of areas with different climates. Its main advantage is that it can be calculated for several time scales (McKee *et al*., 1995) [9] and identifies various drought types: hydrological, agricultural or environmental. Calculation of the SPI is easier than on more complex indices such as the Palmer Drought Severity Index (PDSI; Palmer, 1965) [11], because the SPI requires only precipitation data. Main objective of this study is to predict agricultural drought for past (1982 -2011) and for validation the known rainfall data (2012-2015) were taken. Comparison of the calibrated and validated data will predict the future trend to take mitigation measures.

Methodology
The study was conducted in Trichy which is located in the latitude of 10.7904833 and longitude of 78.7046725. The rainfall data were collected from the metrological station for the last 30 years (1982-2011). The maximum rainfall occur in the month of June, July, August, September, October, November, the 6 month rainfall data were taken for analysis. For 1 month, 3 months and 6 months the data were analysed and fitted to gamma distribution, the SPI value is calculated. The graphs were drawn between actual rainfall and the SPI value for six month to know the relationship between the actual and the SPI value. If both the graph fallows the same trend then the SPI graph drawn is concluded as accurate one. Based on this the prevention and mitigation measures were to be carried out.

Standardized Precipitation Index (SPI)

Develop the SPI to understanding that a deficit of precipitation has different impacts on groundwater, reservoir storage, soil moisture, and stream flow. The SPI was designed to quantify the precipitation deficit for multiple time scales. These time scales 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. The SPI calculation for any location is based on the long-term precipitation record for a desired period. This long-term record is fitted to a probability distribution (Gamma), which is then transformed into a normal distribution so that the mean 3-months SPI for the location and desired period is zero (Edwards and McKee, 1997) [4, 5]. Positive SPI values indicate greater than median precipitation, and negative values indicate less than median precipitation. Because the 3-months SPI is normalized, wetter and drier climates can be represented in the same way, and wet periods can also be monitored using the 3-months SPI.

McKee *et al*. (1993) [8] used the classification system shown in the SPI values table 3.1 to define drought intensities resulting from the SPI. McKee *et al*. (1993) [8] also defined the criteria for a drought event for any of the time scales. 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 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".

Table 1: Classification by SPI

SPI values	Category Probability
2.00 or more	Extremely wet
1.5 to 1.99	Severely wet
1.00 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.49 to -1.00	Moderately dry
-1.99 to -1.50	Severely dry
-2 to less	Extremely dry

Step by step procedure to calculate SPI value

Step 1: Parameter estimation for Gamma distribution.

α - shape parameter, β - scale parameter

Parameters of Gamma distribution are determined for each station and time scale of interest (1 month, 2 months,...)

Step 2: Thom (1966) determined parameters based on maximum likelihood method

$$A = \ln(\bar{X}) - \frac{\sum \ln(x)}{n}, \alpha = \left(\frac{1+\sqrt{\frac{4A}{3}}}{4A}\right), \beta = \frac{\bar{x}}{\alpha}$$

Step 3: The gamma distribution is defined by its frequency or probability density function

$$g(x) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{-x/\beta} \longrightarrow (1)$$

Step 4: Estimated parameters are then used for calculating cumulative probability distribution for a specific precipitation event, which has been observed on a defined time scale (e.g. month)

$$G(x) = \int_0^x g(x)\,dx$$

$$G(x) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} \int_0^x x^{\alpha-1} e^{-x/\beta}\,dt \longrightarrow (2)$$

Letting t = X/β, this equation becomes the incomplete gamma function

$$G(x) = \frac{1}{\Gamma(\alpha)} \int_0^x t^{\alpha-1} e^{-t}\,dt \longrightarrow (3)$$

Step 5: Gamma function is not defined at x=0 (but there is large number of no rainfall occurrences as we move to shorter time scales); cumulative distribution is therefore modified to include these events

$$H(x) = q + (1-q)\,G(x) \longrightarrow (4)$$

q (Probability of a zero) = m/n

m = the number of zeros in a precipitation time series

n = the number of non zeros in a precipitation time series

Step 6: The cumulative probability, H(x), is then transformed to the standard normal random variable Z with mean zero and variance of one, which is the value of the SPI. Abramowitz and Stegun (1965).

Condition 1: $0 < H(x) \leq 0.5$

$$Z = -\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right) \longrightarrow (5)$$

Where

$$t = \sqrt{\ln\left(\frac{1}{(H(x))^2}\right)} \longrightarrow (6)$$

Condition 2: $0.5 < H(x) < 1$

$$Z = \left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right) \longrightarrow (7)$$

Where

$$t = \sqrt{\ln\left(\frac{1}{(1-H(x))^2}\right)} \longrightarrow (8)$$

$c_0 = 2.515517$	$d_1 = 1.432788$
$c_1 = 0.802853$	$d_2 = 0.189269$,
$c_2 = 0.010328$	$d_3 = 0.001308$

The graphs were drawn between calculated SPI values (1-month, 3-months and 6 months) versus years. It shows the drought severity condition, whether the area is to be mitigated or prevention measures are to be carried out. Based on this conclusion were made. Fig.1. shows the flow chart to calculate the SPI value in detailed.

Result and Discussion

The analysis was focused on understanding the sensitivity of SPI to actual rainfall and the behaviour of SPI in drought and normal years

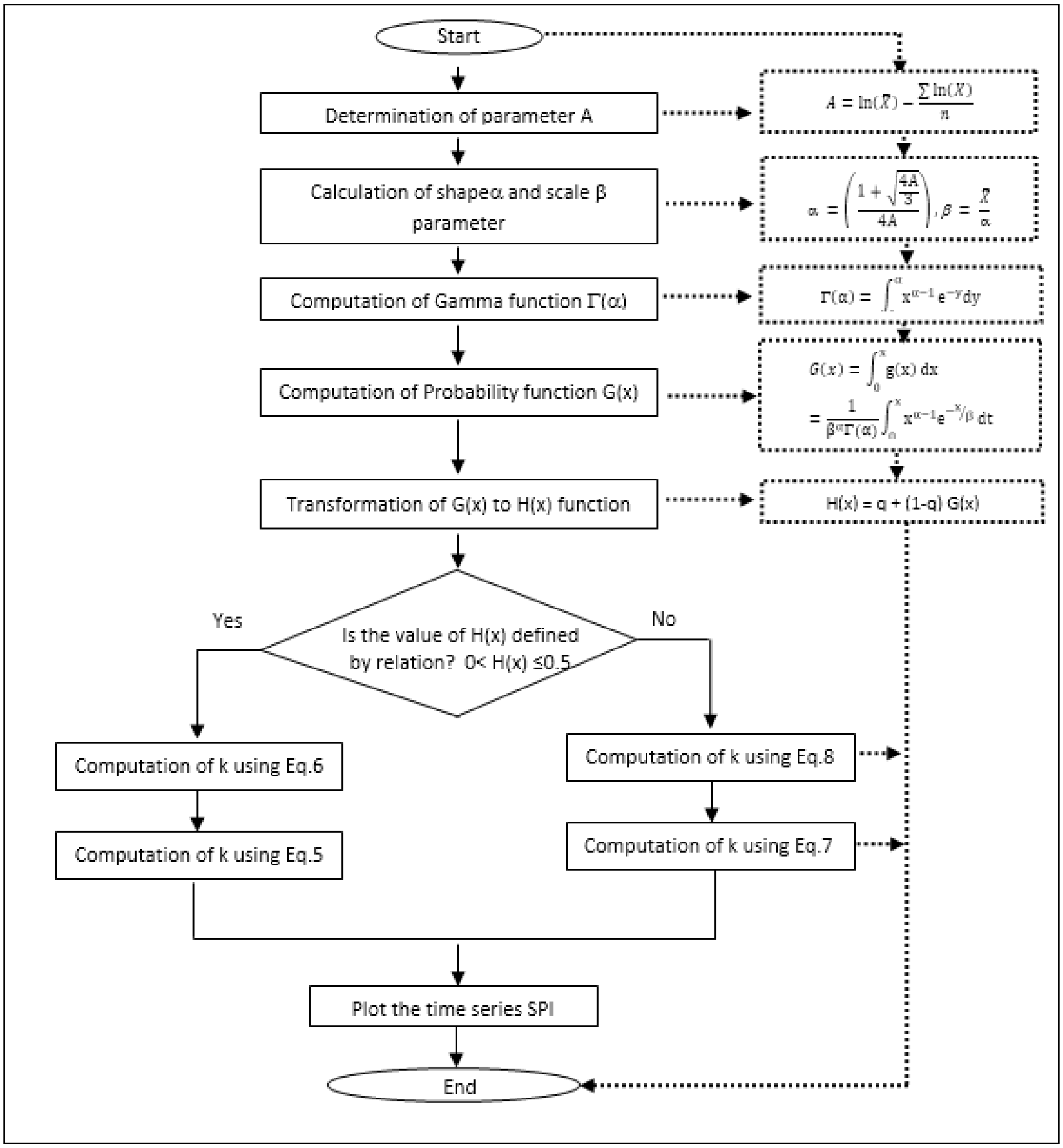

Fig 1: Flow chart to calculate SPI value

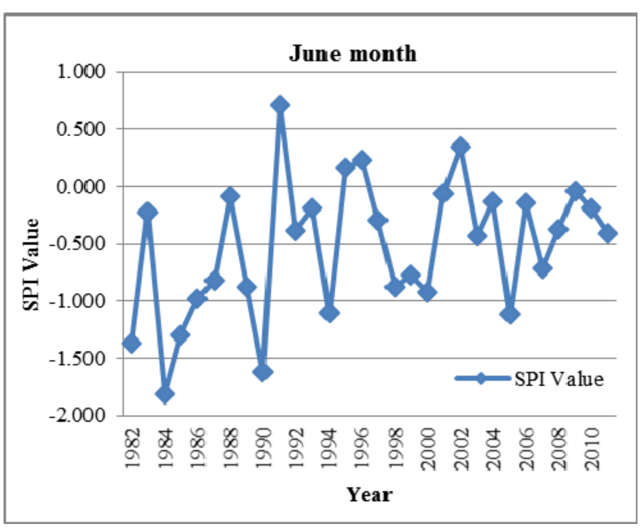

Fig 2: The 1- month SPI value – June

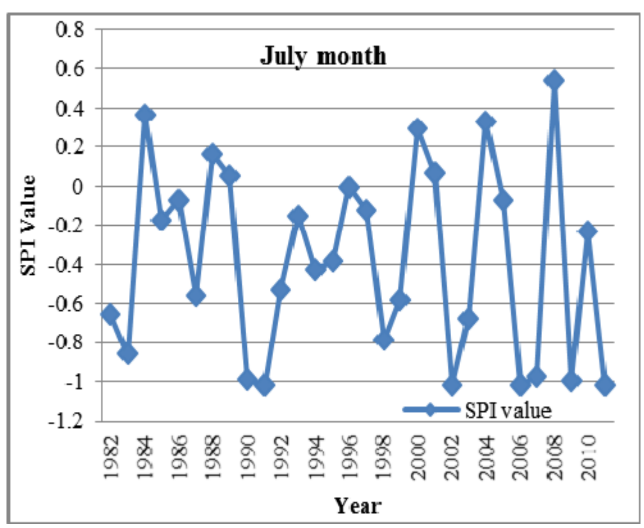

Fig 3: The 1- month SPI value - July

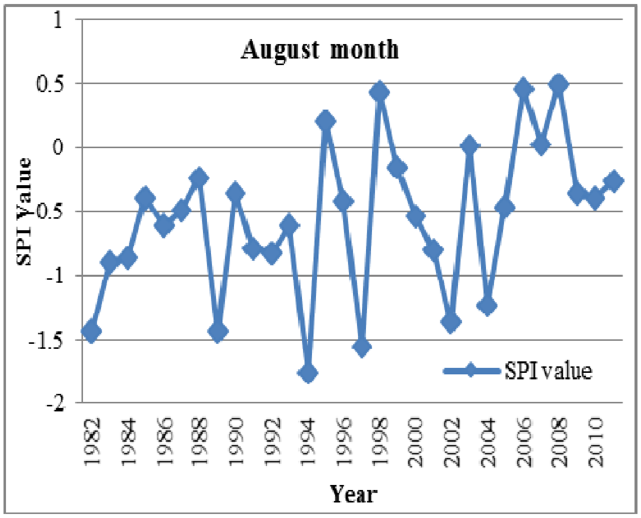

Fig 4: The 1 month SPI value – August

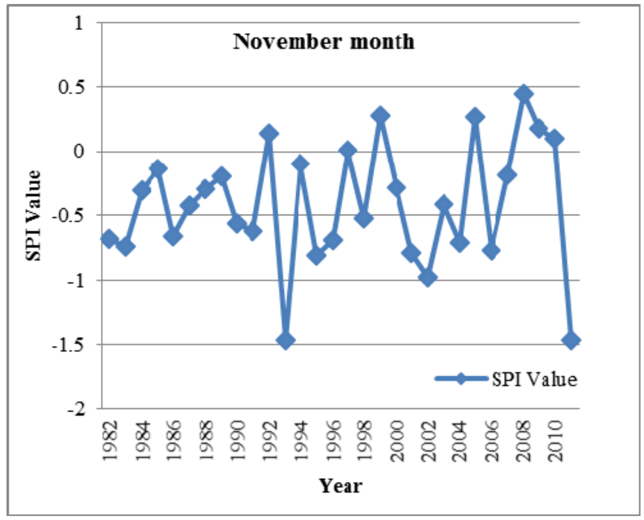

Fig 7: The 1 month SPI value - November

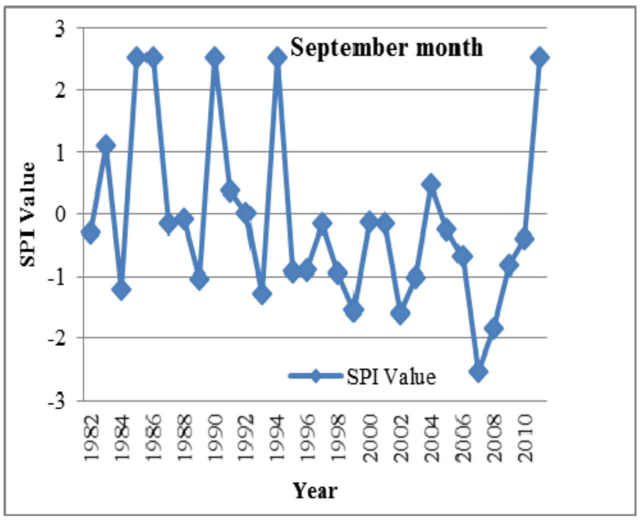

Fig 5: The 1 month SPI value – September

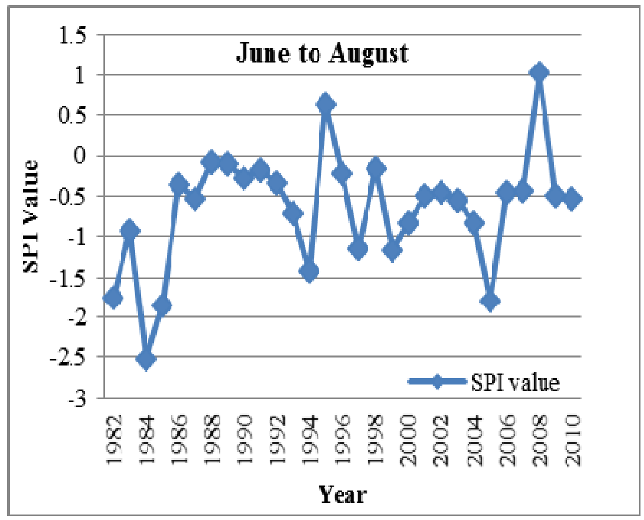

Fig 8: The average 3 month SPI value - June to August

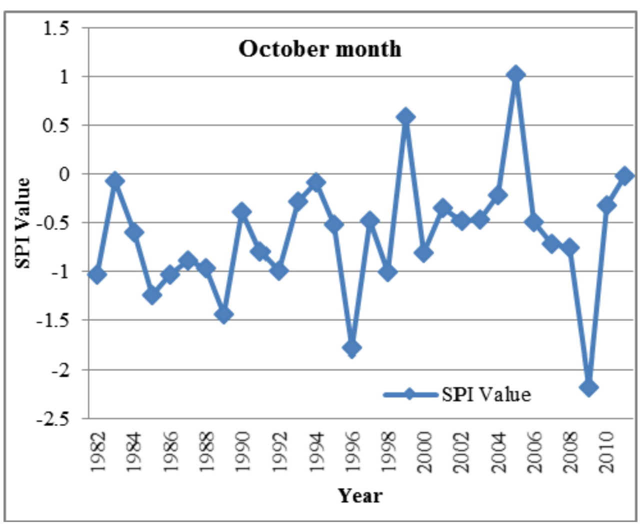

Fig 6: The 1 month SPI value – October

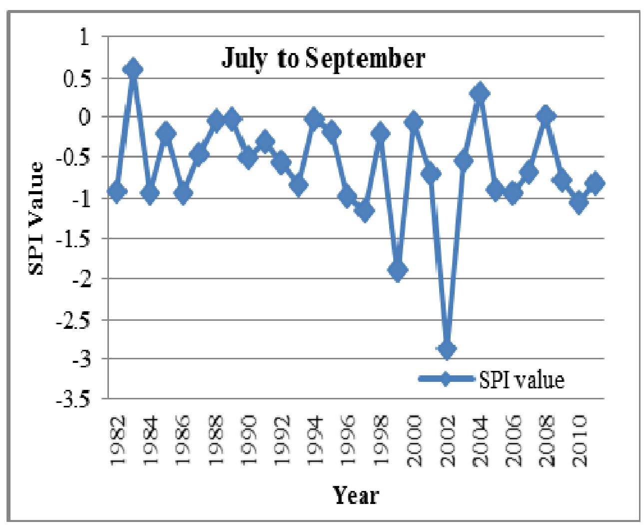

Fig 9: The average 3 month SPI value - July to September

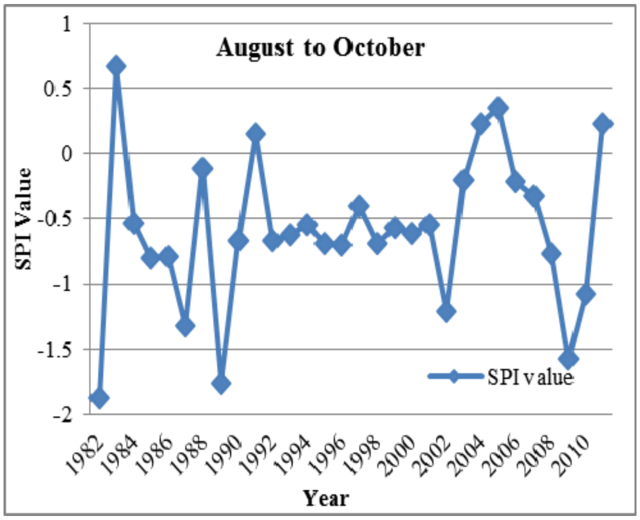

Fig 10: The average 3 month SPI value - Aug to Oct

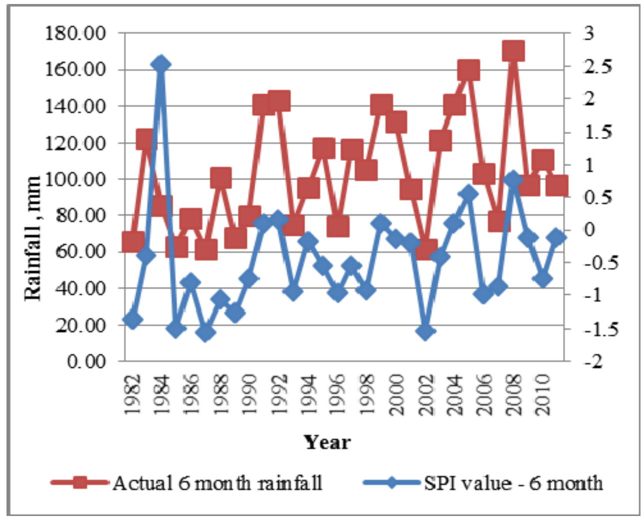

Fig 12: Comparison of Actual average 6 month rainfall and SPI Value of 6 month rainfall (June-Nov)

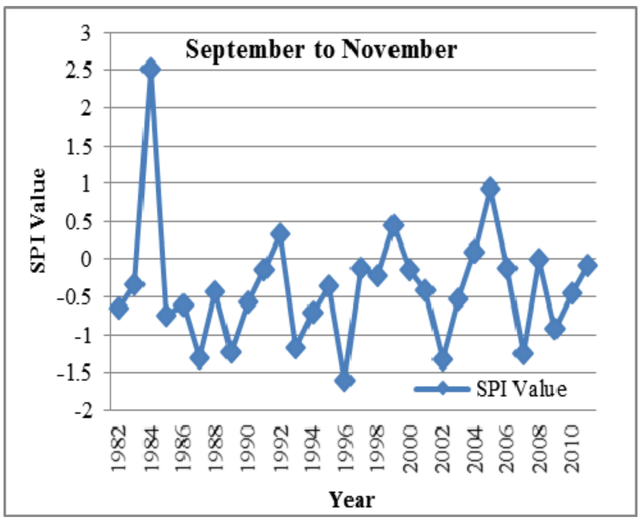

Fig 11: The average 3 month SPI value - Sep to Nov

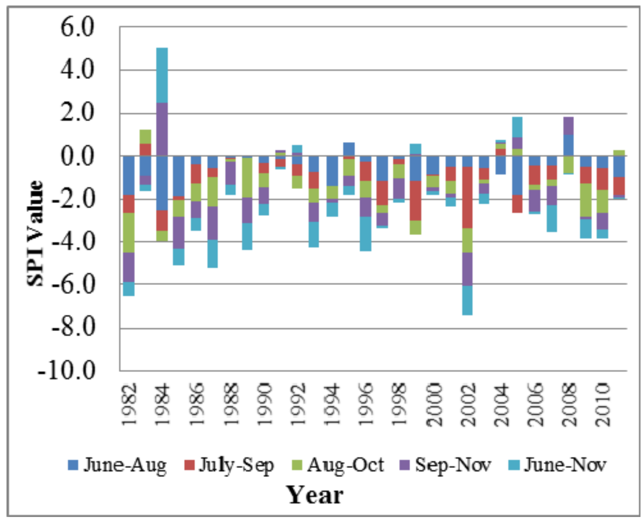

Fig 13: SPI series for the reference periods June-Aug, July- Sep, Aug- Oct, Sep-Nov, June-Nov.

Table 2: Percentage of Probability of SPI value for the 1 month, 3 months and 6 month

						1982-2011						
SPI values	**Category Probability**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**June-Aug**	**July-Sep**	**Aug-Oct**	**Sep-Nov**	**June -Nov**
2.00 or more	Extremely wet				16.66						3.33	
1.5 to 1.99	Severely wet											
1.00 to 1.49	Moderately wet		3.33		3.33	3.33	6.66	3.33				
-0.99 to 0.99	**Near normal**	**80**	**83.33**	**80**	**53.33**	**73.33**	**93.33**	**76.66**	**86.66**	**80**	**76.66**	**80**
-1.49 to -1.00	Moderately dry	13.33	13.33	13.33	13.33	16.66		10	6.66	10	16.66	13.33
-1.99 to -1.50	Severely dry	6.66		6.66	10	3.33		6.66	3.33	10	3.33	6.66
-2 to less	Extremely dry				3.33	3.33		3.33	3.33			
Total percentage		100	100	100	100	100	100	100	100	100	100	100
						2012-2015						
SPI values	**Category Probability**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**June-Aug**	**July-Sept**	**Aug-Oct**	**Sept-Nov**	**June -Nov**
2.00 or more	Extremely wet											
1.5 to 1.99	Severely wet											
1.00 to 1.49	Moderately wet											
-0.99 to 0.99	**Near normal**	**75**	**75**	**75**	**75**	**50**	**75**	**75**	**75**	**75**	**100**	**100**
-1.49 to -1.00	Moderately dry					50	25	25	25	25		
-1.99 to -1.50	Severely dry	25	25	25	25							
-2 to less	Extremely dry	100	100	100	100	100	100	100	100	100	100	100

The SPI-based drought classes proposed by McKee *et al.* (1993) [8] were adopted in this study because of their wider applicability to different regions of climatology. As suggested by McKee *et al.* (1993, 1995) [8, 9], SPI represents wetter and drier climates in a similar way.

Drought based on SPI time series

The study produced the maps of drought severity at 1, 3 and 6 months time steps, in the Trichy district of Tamil Nadu, India. Month of September was chosen for calculating SPI for 3 and 6 month time step as August to October is normally wet season for the study area. Month of September was chosen for the calculation as negative SPI values in the wet season will indicate drought throughout the year. Fig.2 to 11 shows SPI values for time scales of 1 month, 3 months and 6 months for the stations. Fig.12 shows the graph between actual rainfall verses year of 6 month data. The time series plot shows that the SPI varies with the monthly precipitation within the study period.

From Fig.2.show that for the station the moderate SPI value -1.81 and -1.62 for a month of June time scale in the year of 1984 and 1990 respectively, which is classified as severely dry period. In the year of 1982, 1985, 1994 and 2005 the respective SPI Value was -1.37, -1.30, -1.10 and -1.12 which shows the moderately dry period. Other than this all year were registered nearly normal period.

Similarly for 1 month, 3 months, 6 months the graphs were drawn for SPI value verses year and severity classes were identified according to table 1. Simultaneously (2012 to 2015) for the 1, 3 and 6 months the SPI value were calculated. Table.2. Shows the calibrated (1982-2011) and validated (2012-2015) SPI value for 1, 3 and 6 months. The 30 years calibrated SPI value shows, the percentage of probability of nearly normal SPI value ranges from 73.33% to 93.33% in all 1,3 and 6 months. Comparison of validated SPI value also shows percentage of probability (75 %to 100%) of nearly normal SPI value for all 1, 3 and 6 months.

Comparison of both Actual 6 month rainfall and 6 month SPI value curve (Fig.13) follows the same trend. Hence the SPI graph drawn is concluded as accurate one. For the needs of the monitoring of drought 3-month SPI is a suitable representation of short and medium term moisture conditions. It offers a seasonal estimation of precipitation deficit or surplus that is particularly useful in agricultural activities. Fig. 13 shows that the time series of SPI_3 can be used effectively to predict the reference period of SPI_6 or later period calculations. Based on this the prevention and the mitigation measures can be taken according to the severity level of the station mentioned in table 2.

Summary and conclusion

SPI is a valuable tool for assessing the spatiotemporal variability of dryness/wetness due to its capacity to represent precipitation anomaly. This paper has applied SPI to identify the occurrence of dry and wet years and to reveal trends of dry and wet condition in Trichy over 30 years. The study was focused on presenting a framework of methodologies for analysis of drought in Trichy region, Tamil Nadu. The SPI computed at various time scales was used an indicator of drought severity. The SPI was computed using gamma distribution for the period of June, July, August, September, October and November (1982-2015). The SPI can effectively represent the amount of rainfall over a given time scale, with the advantage that it provides not only information on the amount of rainfall, but that it also gives an indication of what this amount is in relation to the normal, thus leading to definition of whether a station is experiencing drought or not.

Reference

1. Abramowitz M, Stegun A. (eds). Handbook of Mathematical Formulas, Graphs, and Mathematical Tables. Dover Publications, Inc.: New York, 1965.
2. Anctil F, Larouche W, Viau AA, Parent LE. Exploration of the standardized precipitation index with regional analysis. Canadian J. Soil Science. 2002; 82:115-125.
3. Nithya D, Suja rose RS. Assessing agricultural vulnerability using geomatic technology: A case study of Srivilliputhur taluk of Virudhunagar district, Tamil Nadu. International journal of advancement in remote sensing, GIS and geography, 2014; 2:2.
4. Edwards DC, McKee TB. Characteristics of 20th century drought in the United States at multiple timescales. Colorado State University: Fort Collins. Climatology Report. 1997; 97-2.
5. Edwards DC, McKee TB. Characteristics of 20th Century Drought in the United States at Multiple Time Scales. Fort Collins, Colorado, Department of Atmospheric Science, Colorado State University, 1997.
6. Jaber Almedeij. Drought Analysis for Kuwait Using Standardized Precipitation Index. Hindawi Publishing Corporation. The Scientific World Journal, 2014 Article ID 451841:9.
7. Naresh Kumar M, Murthy CS, Sesha Sai MVR, Roy PS. Meteorological Applications. 2009; 16:381-389.
8. McKee TB, Doesken NJ, Kleist J. Drought monitoring with multiple time scales. Paper presented at the Preprints, Eighth Conference on Applied Climatology, Anaheim, California, 1993.
9. McKee TB, Doesken NJ, Kleist J. Drought monitoring with multiple time scales. Preprints, 9th Conference on Applied Climatology, 1995, 233-236
10. Moumita Palchaudhuri, Sujata Biswas. Analysis of Meteorological Drought Using Standardized Precipitation Index –A Case Study of Puruliya District, West Bengal, India. International Science Index, Environmental and Ecological Engineering, 2013; 7:3. waset.org/Publication/9996966.
11. Palmer W. Meteorological drought, Tech. Rep. U.S. Weather Bureau, Washington. D.C. 1965; 45:58
12. Seiler RA, Hayes M, Bressan L. Using the standardized precipitation index for flood risk monitoring. *Int. J. Climatol.* 2002; 22:1365-1376.
13. Sims AP, Niyogi DDS, Raman S. Adopting drought indices for estimating soil moisture: A North Carolina case study. Geophysical Research Letters. 2002; 29:1183.