

# Assessment of Meteorological Drought for Semi-Arid Region of Maharashtra

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## ABSTRACT

With the inception of climate change phenomenon occurrence of drought in a region has impacted the agricultural production. Occurrence of rainfall, its frequency and intensity are important characteristics which are being studied to trace the climate variability of any region. Standardized precipitation index was used to assess the drought for Solapur region of Maharashtra. Monthly rainfall data of 42 years of four monsoon months i.e. June, July, August and September was used to generate SPI values, based on these values drought was categorized into mild, moderate, severe and extreme drought. This study showed that there was deviation in rainfall received than the normal rainfall, also drought categories indicated that rainfall and its variation are critical and important for dry climatic conditions for crop planning. Based on drought assessment one can adopt drought mitigation strategies for drought proof agriculture in such rainfall deficit zone.

## Highlights

- ① Drought intensity assessment for Dryland region is done using Standardized Precipitation Index (SPI).
- ② Rainfall deviation from normal rainfall is also studied for getting explicit idea of rainfall occurrence.

**Keywords:** Standardized Precipitation Index (SPI), rainfall deviation

High impact of climate change phenomenon is experienced by the farming community all over the globe. Change in seasonal climate has increase risk factor for crop production and has impacted water availability for agricultural production. One of the main factor on which agriculture depends is the rainfall received in particular area. Various studies by researchers, scientist has proved that there is tremendous and rapid variations in climatic factors in many regions. These changes had contributed towards great concern of food production. In context of India, rainfall is mainly received by south-west monsoon. This monsoon are generally onset at the southerner part of the country from 15 May onwards. Thus rainfall received during this period determines the future of the Indian agricultural crops. Experienced from last years shows that there is more regional and temporal variations in the

rainfall received in different parts of India. With inception of climate change phenomenon rainfall has been unpredictable. In India there are conditions where not enough amount of rainfall occurred, due which drought conditions are being experienced. To get the rainfall scenario of particular region drought monitoring is carried out by using some drought indicators. One of the important indicator used for drought monitoring is Standardized precipitation index (SPI). This SPI method is applied by various researchers to study the drought scenarios in semi-arid regions of the worldwide (Karavitis *et al.* 2011). The computation of SPI index requires long term data of precipitation to determine the probability distribution function which is then transformed to a normal distribution with mean zero and standard deviation of one. Therefore, SPI values are expressed in standard deviations. Positive

value of SPI indicates greater precipitation than median precipitation and negative values of SPI indicates less than median precipitation (Edwards and Mckee,1997). This study is carried out for rainfall deficit region to study the drought intensity assessment using Standardized Precipitation Index.

## MATERIAL AND METHODS

The study area selected for application of drought index is Solapur district of Maharashtra. This region comes under the rainfall deficit region of state, it is known for its Dryland climatic conditions. The total geographical region of this district is 1487.8 ha. The normal rainfall occurrence for this region is 550.5 mm and normal rainy days observed are 23 days in monsoon period. The location of Solapur district is as, 17° 41' lat., 70° 56' long. Altitude of 483.6 m respectively. Agro Ecological Sub Region (ICAR) for Solapur district comes under deccan plateau, hot semi-arid eco sub region. Major soil type observed in this region are shallow black soil (67.8%), deep black soil (18.2%) and medium black soil (13.2%). Crops sown by farmers in this region are namely sorghum, wheat, chickpea, pigeon pea, pomegranate, ber, tomato, onion etc.

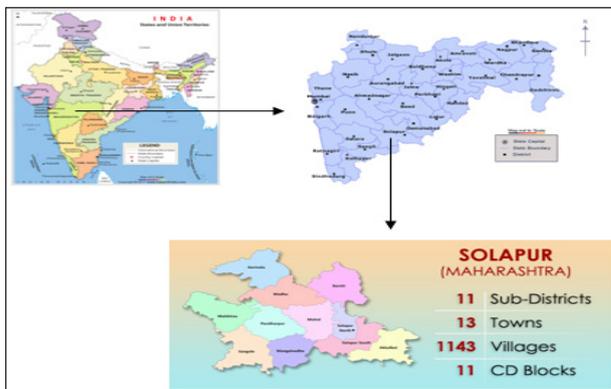


Fig. 1: Study area map of Solapur

Computation of standardized precipitation index (SPI) with time series data was done using two parameter Gamma distribution function. The computation of SPI involves transformation of precipitation data into log normal values followed by computation of U statistics, shape and scale parameters of gamma distribution. The resulting parameters are then used to find the incomplete gamma cumulative probability of an observed precipitation event. The incomplete gamma cumulative probability is then converted to gamma

probabilities after including the occurrence of zero precipitation events. The gamma probabilities are then transformed in to standardized normal distribution using equi-probability transformation techniques (Abramowitz and Stegun 1965). For transformation statistical method was followed given by Edwards and McKee, 1997. The detail procedure for this is given below and SPI is calculated using the methodology given by Kumar *et al.* 2009.

Rainfall deviation from normal was calculated using formula:

$$\left\{ \frac{\text{Actual rainfall} - \text{Normal rainfall}}{\text{Normal rainfall}} \right\} * 100 \quad \dots(1)$$

Which is expresses the actual rainfall as percent deviation from normal. The normal rainfall is the long term average of the actual rainfall.

### Procedure for computation of SPI index:

1. The purpose of transformation of the precipitation value in to standardized precipitation index:
  - Transforming the mean of the precipitation value adjusted to zero.
  - Standard deviation of the precipitation is adjusted to 1.
  - Skewness of the existing data has to be readjusted to zero.
  - After this the standardized precipitation index can be interpreted as mean 0 and standard deviation of 1.
2. Mean of the precipitation can be computed as:

$$\text{Mean} = \bar{X} = \frac{\sum X}{N} \quad \dots(2)$$

Where, N is the number of precipitation observations.

3. The standard deviation for the precipitation is computed as:

$$S = \sqrt{\frac{\sum (X - \bar{X})^2}{N}} \quad \dots(3)$$



4. The skewness of the given precipitation is computed as:

$$Skew = \frac{N}{(N-1)(N-2)} \sum \left( \frac{(X - \bar{X})^3}{S} \right) \quad \dots(4)$$

5. The precipitation is converted to log normal values and the statistics U, shape and scale parameters of Gamma distribution are computed.

$$\log mean = \bar{X}_{ln} = \ln(\bar{X}) \quad \dots(5)$$

$$U = \frac{\bar{X}_{ln} - \frac{\sum \ln(X)}{N}}{N} \quad \dots(6)$$

$$Shape\ parameter = \beta = \frac{1 + \sqrt{1 + \frac{4U}{3}}}{4U} \quad \dots(7)$$

$$\alpha = \frac{\bar{X}}{\beta} \quad \dots(8)$$

The resulting parameters are then used to find the cumulative probability of an observed precipitation event. The cumulative probability is given by:

$$G(x) = \frac{\int_0^x x^{\alpha-1} e^{-\frac{x}{\beta}} dx}{\beta^\alpha \Gamma(\alpha)} \quad \dots(9)$$

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

$$H(x) = q + (1-q)G(x) \quad \dots(10)$$

Where q is the probability of zero. 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 as per Edwards and Mc Kee (1997); the approximate conversion provided by Abromowitz and Stegun (1965) is applied:

$$Z = SPI = - \left( t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3} \right) \quad 0 < H(x) \leq 0.5 \quad \dots(11)$$

$$Z = SPI = + \left( t - \frac{c_0 + c_1 t + c_2 t}{+ d_1 t + d_2 t^2 + d_3 t^3} \right) \quad 0.5 < H(x) \leq 1 \quad \dots(12)$$

Where,

$$t = \sqrt{\ln \left( \frac{1}{H(x)^2} \right)} \quad 0 < H(x) \leq 0.5$$

$$t = \sqrt{\ln \left( \frac{1}{(1-H(x))^2} \right)} \quad 0.05 < H(x) \leq 1.0$$

$$c_0 = 2.515517$$

$$c_1 = 0.802583$$

$$c_2 = 0.010328$$

$$d_1 = 1.432788$$

$$d_2 = 0.189269$$

$$d_3 = 0.001308$$

The values of above given equation are constants being widely used for computation of SPI.

## RESULTS AND DISCUSSION

The analysis and severity of drought for Solapur region is analysed by using standardized precipitation index (SPI). The results obtained from this study are presented and described in this section. The amount of rainfall occurred and its variation is shown in Fig. 2 for the study area. Higher rainfall values were observed for July and September month for the study period and June and august received lower rainfall as compared to former months. Variation in rainfall amount was also observed for all the four rainy months for Solapur region. The normal rainfall for June, July, August and September is 150.7, 254.4, 175.2 and 143.5 mm as shown in Fig. 3. Statistical analysis of rainfall data i.e. standard deviation skewness and mean were also calculated and which were used further for estimation SPI, these values are shown in Table 1.

**Table 1:** Statistical analysis of rainfall data

	June	July	August	September
Standard deviation	35.503	68.293	50.099	76.817
Skewness	0.482	0.078	0.143	0.918
Mean	101.31	174.40	123.22	133.21

Standardised precipitation index (SPI) for the Solapur region was calculated using the methodology given in equation 1 to 12. The SPI based drought classes proposed by Mc Kee *et al.* 1993, have been adopted

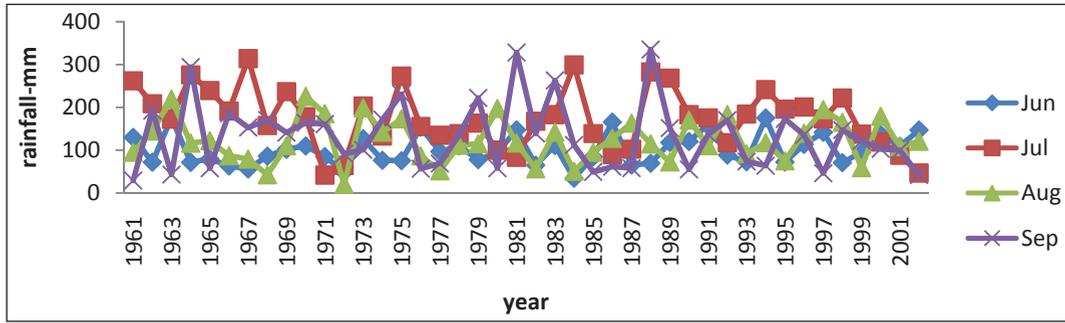


Fig. 2: Variation of rainfall (mm) for Solapur district

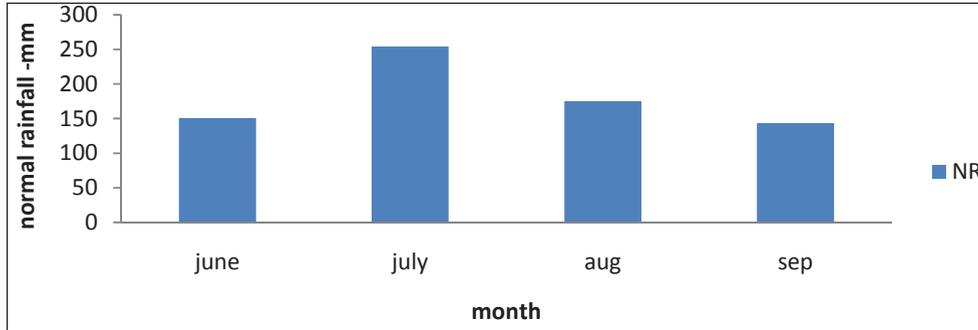


Fig. 3: Normal rainfall for the monsoon months for Solapur region

in this study as mentioned in Table 2. The SPI values estimated for the month of June for the study period (1961-2002) is shown in Fig. 4. According to the figure mild drought was observed in the range of -0.066 to -0.803 followed by moderate drought in the range of -1.00 to -1.462 and severe drought of -1.81 for the year 1967 and extreme drought of -2.188 for the year 1972 was observed. Remaining years for the June were not in rainfall deficit category. Hence, percentage of drought for study period for June is mild drought 26.19%, moderate drought is 21.42% and that for severe and extreme drought is 2.38% respectively.

Table 2: Drought categories from SPI (Mc Kee *et al.* 1993)

SPI	Drought category
0 to -0.99	Mild drought
-1 to -1.49	Moderate drought
-1.5 to -1.99	Severe drought
-2.00 or less	Extreme drought

Table 3: Values of Scale parameter ( $\beta$ ) and shape parameter ( $\alpha$ )

	June	July	August	September
$\beta$	7.97	8.05	8.07	8.24
$\alpha$	12.70	21.69	15.26	16.16

The SPI values estimated for the month of July for the study period (1961-2002) is shown in Fig. 5. According to the estimated values of SPI for July, mild drought was observed in the range of -0.049 to -0.624, moderate drought was in the range of -1.107 to -1.407 and severe drought of -1.786, -1.935 for the year 1968 and 1979 was observed. Extreme drought range of -2.047 to -5.042 was observed. Remaining years for the July are not in the drought category. Hence percentage of drought for study period for July is mild drought 11.90%, moderate drought is 9.52% and that for severe is 4.76% and extreme drought is 33.33% respectively.

The SPI values estimated for the month of August for the study period (1961-2002) is shown in Fig. 6. According to the estimated values of SPI for August, mild drought was observed in the range of -0.12 to -0.919, moderate drought was of -1.445 for year 1962 and severe drought range of -1.669 to -1.988. Extreme drought range of -2.437 to -4.455 was observed. Remaining years for the August are not in the drought category. Hence, percentage of drought for study period for August is mild drought 26.19%, moderate drought is 4.76% and that for severe is 9.52% and extreme drought is 16.66% respectively. The SPI values estimated for the month of September

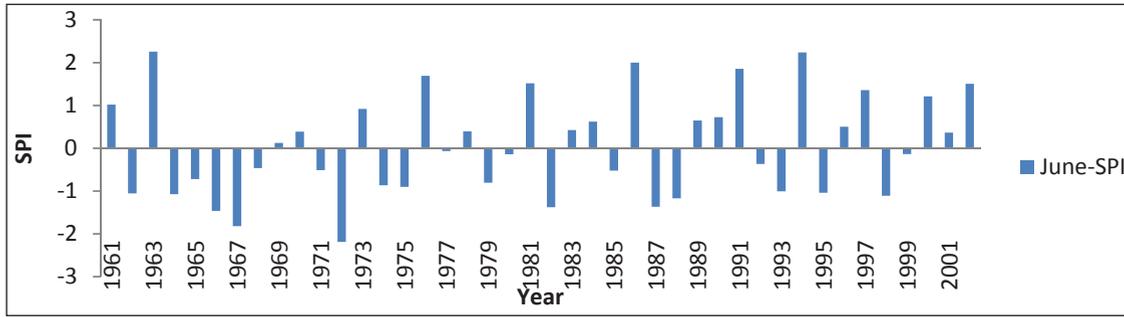


Fig. 4: Standardised precipitation index values for June

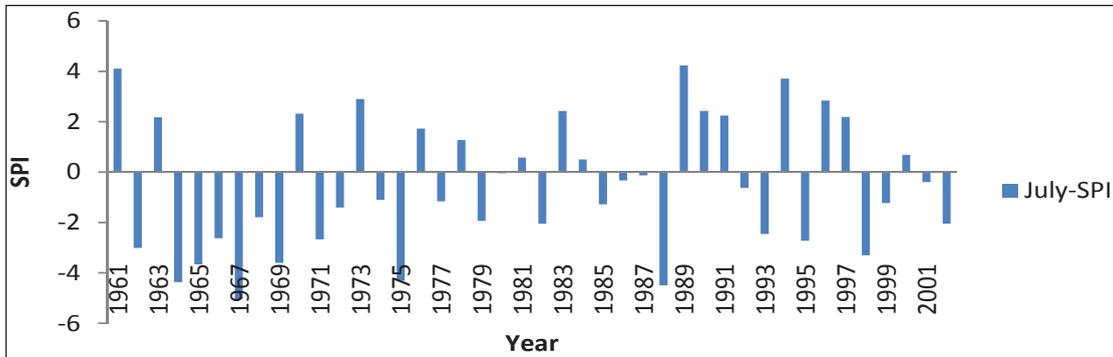


Fig. 5: Standardised precipitation index values for July

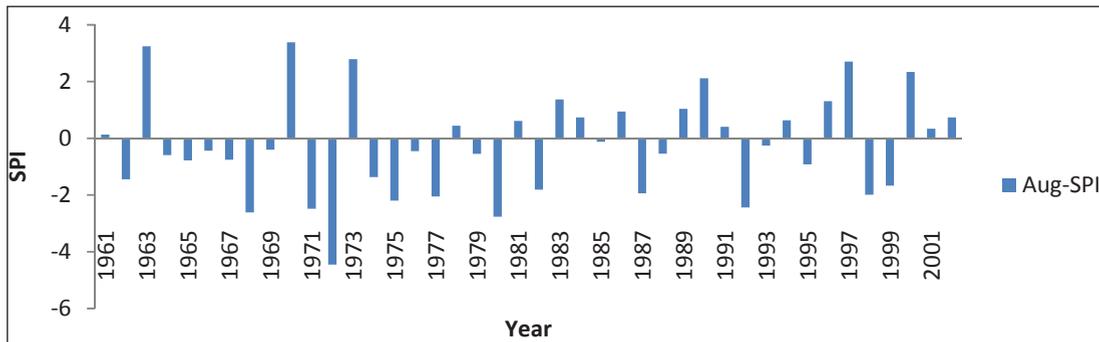


Fig. 6: Standardised precipitation index values for August

for the study period (1961-2002) is shown in Fig. 7. According to the estimated values of SPI for September, mild drought was observed in the range of -0.262, -0.985 for 1973 and 1992, moderate drought was of -1.188 to -1.480 and severe drought range of -1.515 to -1.885. Extreme drought range of -2.127 to -5.401 was observed. Remaining years for the September are not in the drought category. Hence, percentage of drought for study period for September is mild drought 4.76%, moderate drought is 9.52% and that for severe is 14.28% and extreme drought is 21.42% respectively.

Fig. 8 to 11 shows the rainfall deviation percentage from the normal rainfall for all the rainy months

for study area. Rainfall deviation percentage is either positive or negative as seen from the above figures. Positive rainfall deviations, indicates that actual rainfall is more than the normal and negative values indicates that actual rainfall is less than the normal rainfall. From the study it was observed that the positive values of rainfall deviation are associated to the positive values of SPI, which indicates wetness or moisture in that particular year. But it was also observed that some positive values of rainfall deviation did not commensurate with extent of positive values of SPI. SPI value of 2.509 for September 1964 and rainfall deviation for same year was 105.11 % indicates that there was no

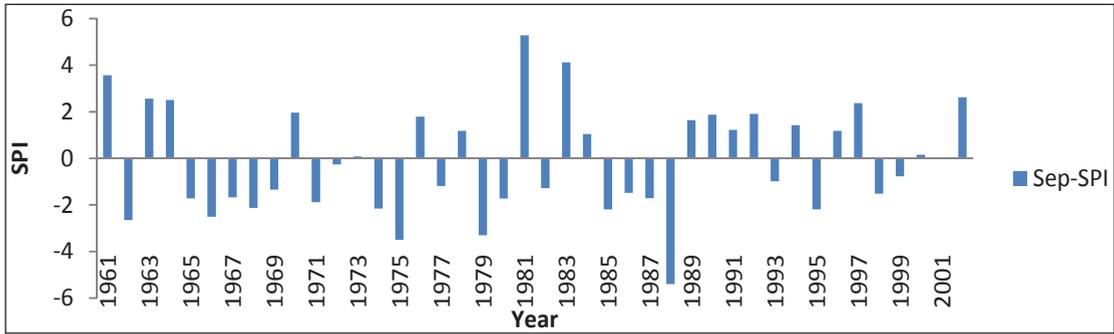


Fig. 7: Standardised precipitation index values for September

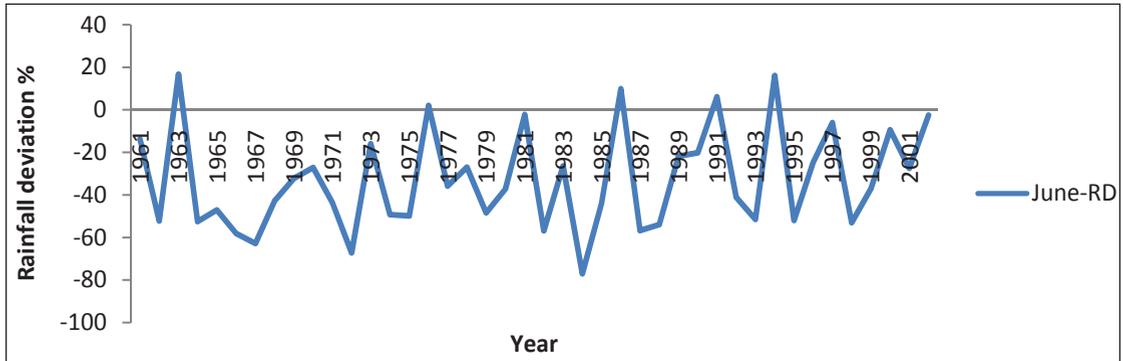


Fig. 8: Rainfall deviation % from normal rainfall for June

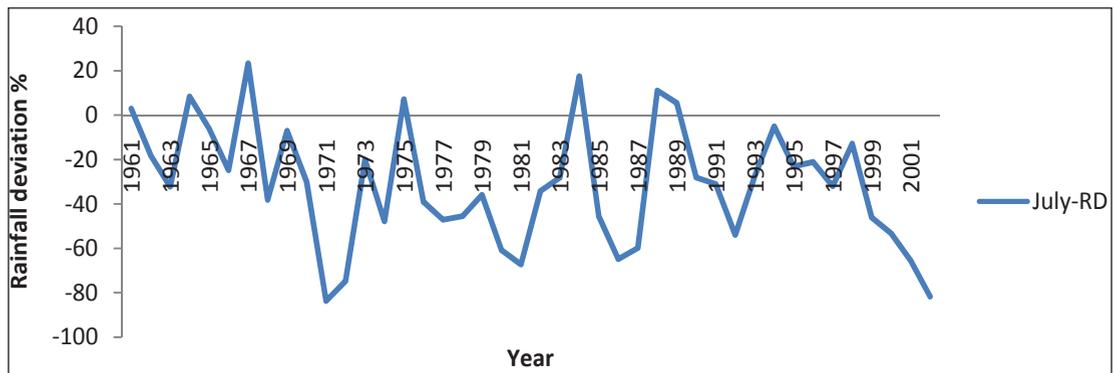


Fig. 9: Rainfall deviation % from normal rainfall for July

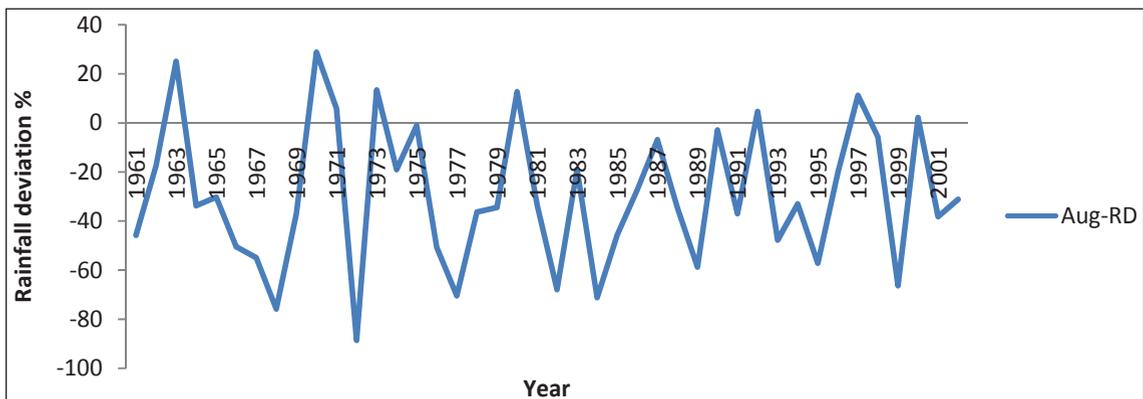


Fig. 10: Rainfall deviation % from normal rainfall for August

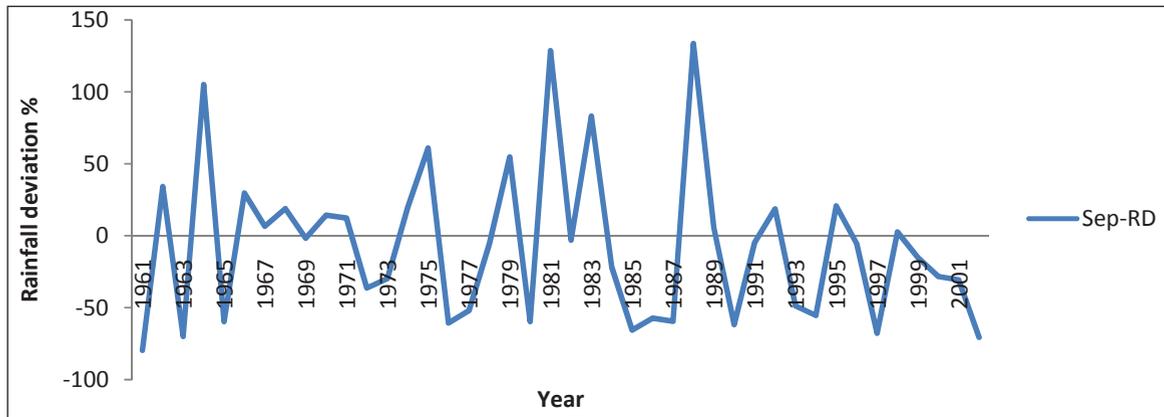


Fig. 11: Rainfall deviation % from normal rainfall for September

drought and also rainfall was 105.11% of normal. Rationale for negative values of SPI associated with some positive rainfall deviation are due to fact that rainfall amount was not enough to maintain enough soil moisture for agriculture, indicates extreme dryness (Kumar *et al.* 2009).

## CONCLUSION

The study area selected for this study comes under semi-arid region where drought is mostly common phenomenon. From above results obtained meteorological drought assessment for four monsoon months gave clear scenario of rainfall deficit years. For the month of June mild drought was mostly dominant for the study period, July experienced extreme drought situation, for August it was observed mild drought and for September extreme drought was observed from the results obtained. Remaining years for the study period did not experienced meteorological drought. Occurrence of less rainfall than the normal rainfall was observed from the study for this study area. This study also showed that rainfall and its variations are critical and important for dry climatic regions. Effect of climate change phenomenon in rainfall occurrence is evidence from this study as there was variation in the rainfall received. Hence, drought proof strategies such as percolation pond, farm pond,

recharge wells and water saving techniques like drip and sprinkler irrigation should be adopted in this region. Such application of methods are used to mitigate drought situation and to provide irrigation for crops. Moisture conservation measures such as farm trenches, field plastic mulches, organic mulches which reduces evaporation losses should be adopted.

## REFERENCES

- Abramowitz M, Stegun A (eds). 1965. Handbook of Mathematical Formulas, Graphs, and Mathematical Tables. Dover Publications. Inc.: New York.
- Edwards, D.C. and McKee, T.B. 1997. Characteristics of 20<sup>th</sup> century drought in the United States at multiple scales, *Atmospheric Science*, paper no. 634, May 1-30.
- Kumar Naresh, M., Murty, C.S., Sessa Sai, M.V.R. and Roy, P.S. 2009. On the use of Standardized Precipitation Index (SPI) for drought intensity assessment. *Meteorological Applications*, **16**(3): 381-389.
- Karavitis, C.A., Alexandris, S., Tsismelis, D.E. and Athanasopoulos, G. 2011. Application of the Standardized Precipitation Index (SPI) in Greece. *Water*, **3**: 787-805.
- McKee B Thomas., Doesken J Nolan. and Kleist John, 1993. The relationship of drought frequency and duration to time scales, Proceedings of ninth Conference on Applied Climatology, American Meteorological Society, Boston, 179-184.

