Original Research Article

Occurrence of climatic drought over western zone of TamilNadu

Abstract:

Drought is the major precipitation anomaly that has greater impact on water resource management, ground water table and agricultural production. The WASP index (Weighted Anomaly of Standardized Precipitation Index) was estimated for a period 1901-2019 (119 years) – four time scales (12 months, 9 months, 6 months and 3 months) based on the IMD precipitation dataset to analyse the dry events. Analysis over different time scales is necessary to find out the impact of the slowly evolving drought on the agricultural production as well as water resources. The numbers of moderate dry events were 276, 256, 188 and 100 for $WASP_{12}$, $WASP_9$, $WASP_6$, and $WASP_3$ respectively for the whole of 119 years data. The number of extreme dry events with $WASP_{12}$, $WASP_9$, $WASP_6$, and $WASP_3$ were 0, 4, 29 and 59, respectively, for 119 years. There was no specific trend in number of dry events over the study region and 1991-2019 was found to have higher number of dry events when compared with the other tri-decadal periods.

Key words: WASP, Drought, Dry months, Precipitation deficit, historical data.

Introduction:

In Tamil Nadu about 70 per cent of the area is under rainfed agriculture which experiences a higher uncertainty in production due to variations in rainfall events. This precipitation regime is characterized by large intra and inter-annual variability with high vulnerability to floods and droughts (Belo-Pereira *et al.*, 2011; Cardoso *et al.*, 2013). Drought is one of the most destructive natural extreme weather events affecting agricultural production. The rising population and intensification of water leads to higher demand for water. Dry events and droughts not only affects crop production, hydroelectric power generation, and in turn food security and standard of living. Consequently, drought monitoring is of utmost relevance, since the money spend on drought relief is more and also the time to overcome the damage is also more.Drought is a phenomenon that develops slowly

and needs sensitive monitoring system. Also, in the changing climate, the frequency and intensity of extreme weather events are expected to increase.

There are several indicators and indices used to assess the severity, duration and magnitude of drought (Zargaret al., 2011). No index is universally suitable based on quantity of climate data available for the particular region makes index to detect drought event. One of the widely used indices is the Weighted Anomaly of Standardized Precipitation (WASP).

WASP is a simple index that can be calculated using rainfall data alone (single variable) to measure the relative anomalies of rainfall on different time scales. But it requires atleast 25 years of historical data for the analysis.One of the major advantages of WASP-Index is the use of the weighting factor *Pi/P*A, which allows to damp large standardized anomalies that result from small precipitation amounts occurring near the beginning or end of dry seasons and to emphasize anomalies during the heart of rainy seasons (Lyon and Barnston, 2005). This index considers the seasonality of the rainfall in determining the magnitude of drought. Similar to SPI, WASP also depends only on the precipitation data, hence WASP over short scales (like 3 to 6 months) can be used to key out the impact on agricultural crops, over a period of 9 months or higher can be used to describe the water resource management anddepicting the groundwater level. Moreover, $WASP_{12}$ appears to be a good proxy for soil moisture variability on shorter time scales being well correlated with other drought indices such as the Palmer Drought Severity Index (PDSI) (Lyon, 2006). Hence the WASP-Index is computed and the intensity and frequency with long term precipitation data for a time scales of 3 months, 6 months, 9 months and 12 months are discussed in this paper.

Data and methodology:

Coimbatore is a district situated in the western zone of TamilNadu between latitude~~of~~ 10.13'4"N and 11.24'5" N; longitude of 76.39'25" E and 77.18'26" E. Monthly observed data for 119 years (1901-2019) obtained from IMD was used for analysis of Weighted Anomaly of Standardized Precipitation (WASP). The temporal variability of droughts was evaluated using the WASP presented by Lyon and Barnston (2005). The WASP-Index is attained summing the weighted standardized monthly precipitation anomalies as follows:

$$\mathrm{WASP}_N = \frac{\mathrm{SUM}N}{\sigma_{\mathrm{SUM}\,N}}$$

Comment [WU1]: When you start by putting this in italic, make sure you are consistent throughout the manuscript.

Comment [WU2]: Separate the words

Comment [WU3]: Latitudes

Comment [WU4]: Longitudes

$$\mathrm{SUM}_N = \sum_{i=1}^{N} \left(\frac{P_i - \overline{P_i}}{\sigma_i} \right) \frac{\overline{P_i}}{\overline{P_A}}$$

in which

P_i is the observed monthly precipitation,

$\overline{P_i}$ is the precipitation baseline climatology (1901−2019) for the ith month with respect to the month/year that is actually being computed,

σ_i is the monthly precipitation standard deviation and

P_A is the mean annual precipitation for a given grid point.

The SUM_N for a given Nth month is obtained considering the preceding N months (where i=1 is the first, i=2 is the second, …, i=N is the current month). The WASP-Index allows a qualitative classification of dry and wet severity through its values, as described inTable 1. The time frequency of droughts affecting Coimbatore district will be assessed for four tri-decadal time periods.

Table 1. WASP-Index values and their corresponding classifications

WASP	**Interpretation**
WASP ≤-2	Severely dry
-2 < WASP <-1	Moderately dry
-1 ≤ WASP ≤ 1	Near Normal
1 < WASP < 2	Moderately wet
WASP ≥ 2	Severely wet

Intensity and frequency ofdry events:

Intensity is defined as the average index value per month, which is high and has asevere impact when a large magnitude occurs over a short period.

The frequency of the event is probability of occurrence of the dry event. The frequency of occurrence can be calculated using the formula,

$$Probability\ \% = \frac{Number\ of\ dry\ months}{Total\ number\ of\ months} x100$$

Result and discussion:

$WASP_{12}$:

The numbers of moderate dry events were 276, 256, 188 and 100 for $WASP_{12}$, $WASP_9$, $WASP_6$, and $WASP_3$ respectively for the whole of 119 years data. The number of extreme dry events with $WASP_{12}$, $WASP_9$, $WASP_6$, and $WASP_3$ were 0, 4, 29 and 59, respectively, for 119 years. The occurrence of extreme dry event was found to be nil during all the tri-decadal time slots with $WASP_{12}$, whereas the occurrence of moderate dry event was 276, 177, 0, 1 and 98 for the time periods of 1901-2019, 1901-1930, 1931-1960, 1961-1990 and 1991-2019, respectively. From this it was evident that there was an increase in the extreme dry events with decrease in time scale. Also, this shows that the study region have not experienced any major extreme droughts that could have affected the ground water levels. The results of the study done by Arul Prasad *et al.*, (2019) have reported 1991, 1995, 2000, 2002 and 2013 the year to be moderate drought years and 2012 as severely drought year. This supports the increase in number of dry events during the period of 1991-2019.

The 9 month time scale WASP was found to be 168 during 1901- 1930, 1 during 1931-1960, 0 during 1961-1990 and 87 during 1991-2019 moderate dry events and only 1 extreme dry event during 1901-1930 as well as 3 during 1991-2019 were identified. This shows that the water resources of the study region might not have effected severely because of deficit in rainfall.

The 6 and 3 month WASP shows that only during the first tri-decadal period (1901-1930) and during the recent tri-decadal period (1991-2019) there were occurrence of extreme dry events. The extreme dry events were identified to be nil with $WASP_6$ and$WASP_3$ for the period of 1931 to 1990 and also the number of moderate dry months were also minimal. The data is depicted in the table 2. It was also noticed that there was an increase in the number of dry events during 1991-2019 period.

Analysing the recent three decades separately, it was keyed out that the number of dry events were increased during the recent years i.e. 2001-2010 and 2011-2019 for all the time scale of the index. The highest numbers of events were recorded during 2001-2010 period. The data is presented in ~~the~~table 3. ~~This data shows an increase in dry events in the recent years~~.

Table 2. Number of moderate and extreme dry events and the frequency of occurrence (given in brackets) during the study period of 1901-2019 and the four tri-decadal periods.

		1901-2019	1901-1930	1931-1960	1961-1990	1991-2019
$WASP_{12}$	Moderate dry	276 (19%)	177 (49%)	0	1	98 (28%)
	Extreme dry	0	0	0	0	0
$WASP_9$	Moderate dry	256 (17.9%)	168 (46.7%)	1 (0.3%)	0	87 (25%)
	Extreme dry	4 (0.3%)	1	0	0	3 (0.9%)
$WASP_6$	Moderate dry	188 (13.2%)	125 (34.7%)	3 (0.8%)	1 (0.3%)	59 (17%)
	Extreme dry	29 (2%)	12 (3.3%)	0	0	17 (4.9%)
$WASP_3$	Moderate dry	100 (7%)	57 (15.8%)	6 (1.7%)	9 (2.5%)	28 (8.0%)
	Extreme dry	59 (4.1%)	32 (8.9%)	0	0	27 (7.8%)

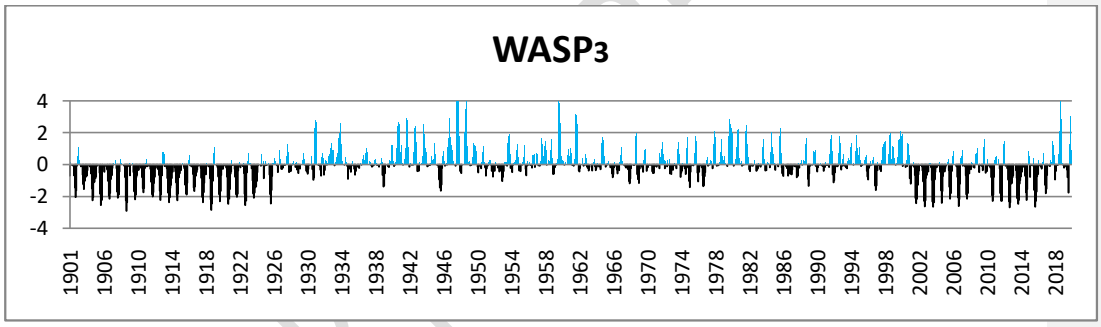

Fig. 1. **Dry and wet events using 3months time scale during the study period of 1901-2019**

Table 3. Number of moderate and extreme dry events occurrence during the recent three decadal period

		1991-2000	2001-2010	2011-2019
$WASP_{12}$	Moderate dry	0	65	33
	Extreme dry	0	0	0
$WASP_9$	Moderate dry	0	55	32
	Extreme dry	0	0	3

$WASP_6$	Moderate dry	1	37	21
	Extreme dry	0	8	9
$WASP_3$	Moderate dry	5	11	12
	Extreme dry	0	16	11

The outcomes of this study show that this drought index would be a good indicator of the moderate dry events which would have an impact on the rain dependent agriculture. Since droughts have deep impacts on water resources,agriculture and the environment, this is particularly relevant.

Conclusion:

The analysis of dry events over 119 years in Coimbatore showed a highest number of dry events as 177 and the highest frequency of 48 per cent for 12 months running periodwas also noticed. WASP has a higher efficiency in capturing dry events over short period that would have a much higher impact on agricultural crops production. Harvesting of rainfall is essential for complementing the shortage during dry events.

Reference:

Belo-Pereira M, Dutra E, Viterbo P. 2011. Evaluation of global precipitation data sets over the Iberian Peninsula. *Journal of Geophysical Research* **116**: D20101, doi: 10.1029/2010JD015481.

Cardoso RM, Soares PMM, Miranda PMA, Belo-Pereira M. 2013. WRF high resolution simulation of Iberian mean and extreme precipitation climate. *International Journal of Climatology* **33**(11): 2591– 2608, doi: 10.1002/joc.3616.

Lyon, B. (2006). Robustness of the influence of El Nino on the spatial extent of tropical drought. *Advances in Geosciences, 6*, 207-209.

Lyon, B., &Barnston, A. G. (2005). ENSO and the spatial extent of interannual precipitation extremes in tropical land areas. *Journal of Climate, 18*(23), 5095-5109.

Maccioni, P.; Kossida, M.; Brocca, L.; Moramarco, T. Assessment of the Drought Hazard in the Tiber River Basin in Central Italy and a Comparison of New and Commonly Used Meteorological Indicators. J. Hydrol. Eng. **2015**, 20, 05014029.

Spinoni, J.; Naumann, G.; Carrao, H.; Barbosa, P.; Vogt, J. World Drought Frequency, Duration, and Severity for 1951–2010. Int. J. Climatol. **2014**, 34, 2792–2804.

Zargar A, Sadiq R, Naser B, Khan FI. "A review of drought indices," Environmental Review. 2011; 19:333- 349