Standardized Precipitation Index based drought assessment over the North Western Zone of Tamil Nadu, India

ABSTRACT

Drought is a natural disaster that tremendously affect the agriculture production and livelihood. Though the Tamil Nadu state is located at peninsular region of India and contributed from both the monsoons, the frequency of drought is high due to vagaries of monsoonal pattern. A study was conducted at Tamil Nadu Agricultural University to assess the drought characteristicsacross the north western Agro Climatic Zone (ACZ) of Tamil Nadu using Standardized Precipitation Index (SPI) during the past 30 years(1991-2020). The study clearly indicated that the Salem district had high vulnerability to drought followed byDharmapuri and Namakkal districts during the South West Monsoon (SWM), whereasthe Namakkalhad high vulnerability followed by Salem and Dharmapuri during North East Monsoon (NEM).

Key words: drought climatology, magnitude, intensity, drought risk, northwest agro climatic zone

1. INTRODUCTION

Drought is relatively long durations of rainless period that lead to a moisture deficit in the atmosphere [1,2]. Drought is considered as an extreme event which collapses the base of the socio-economic status of a state and country. Drought effects are accumulated over a period of time and affect the livelihood of the population. Occurrence of drought is generic to all climates but the prevalence is more frequent in arid and semi-arid regions. Study on drought based on historical data showed that 10 severe drought events were occurred during 1950-1990 (25%), while recent 20 years had six drought events (33%) in 2002, 2004, 2009, 2014, 2015 and 2016 [7]. The drought risk pattern over India reveals that the length of dry period and number of dry days were increased by 49% and 33%, respectively [6] and it is expected that drought to become more frequent and intense, especially during the near future from 2020 to 2050 [5]. The agricultureis the most vulnerable industry to drought, that affects the livelihood of farming community very negatively. Soil moisture stress induced by drought event inflict worst impact on growth, development and productivity of plants [3] whichled to food insecurity, health hazards and social abnormality [9].

Continuous monitoring and proper assessment of drought through surveillance approach by combining climate, water supply, soil moisture storage is essential to reduce the ill effect in the drought prone areas [2,13,14]. Spatial assessment of drought will alsohelp to develop government policies in effective use of water resources for tackling the drought [15].Numerous drought indices are available to monitor and assess the drought events which aid in understanding this phenomenon in simple way [16].Scientists had developed drought indices that precisely fit the climatology and assess the present kind and degree of drought to monitor continuously over a given region of the world [17].Most of the researchers used rainfall-based indices like Standardized Precipitation Index (SPI), Palmer Drought Severity Index (PDSI), Percent Normal Precipitation (PNP), Enhanced Drought Index (EDI) [13, 18-20].Receipt of inadequate amount of rainfall is a major driven force for drought [21,22] and hence rainfall based Standardized Precipitation Index (SPI) is used to assess the drought [1,19,23,24,25,26] in many studies across the globe.The SPI was developed to monitor precipitation shortfalls. The timescales show the effects of drought on the availability of various water resources. Precipitation anomalies can have an instantaneous effect on soil conditions. Groundwater, streamflow, and reservoir storage all show signs of prolonged precipitation anomalies. The SPI was calculated for 3, 6, 12, 24, and 48-month periods.The precipitation input parameter in SPI enables early drought warning and severity evaluation, which is less complicated than the Palmer Drought Severity Index [23].Maharashtra, Sikkim, Nagaland, Tamil Nadu evaluated the drought using SPI[26,27-31]. Keeping the above facts in view, the present study was carried out for the assessment of drought risk over North Western Zone of Tamil Nadu based on SPI.

2. MATERIALS AND METHODOLOGY

2.1 Study area

Krishnagiri, Dharmapuri, Salem, Namakkal districts fall under North Western Agro-climatic zone (NWZ) (Fig.1). Elevation of this zone ranges from 330 to 1070 meter above MSL. Annual precipitation received in this zone is 825 mm in 47 rainy days. This zone is a bimodal rainfall area which is contributed by both southwest monsoon and northeast monsoon. It receives more amount of rainfall (more than 150 mm) during NEM in the month of October. Maximum temperature ranges from 30.5 to 34^{0}C and the minimum temperature ranges from 20 to 23.5^{0}C.

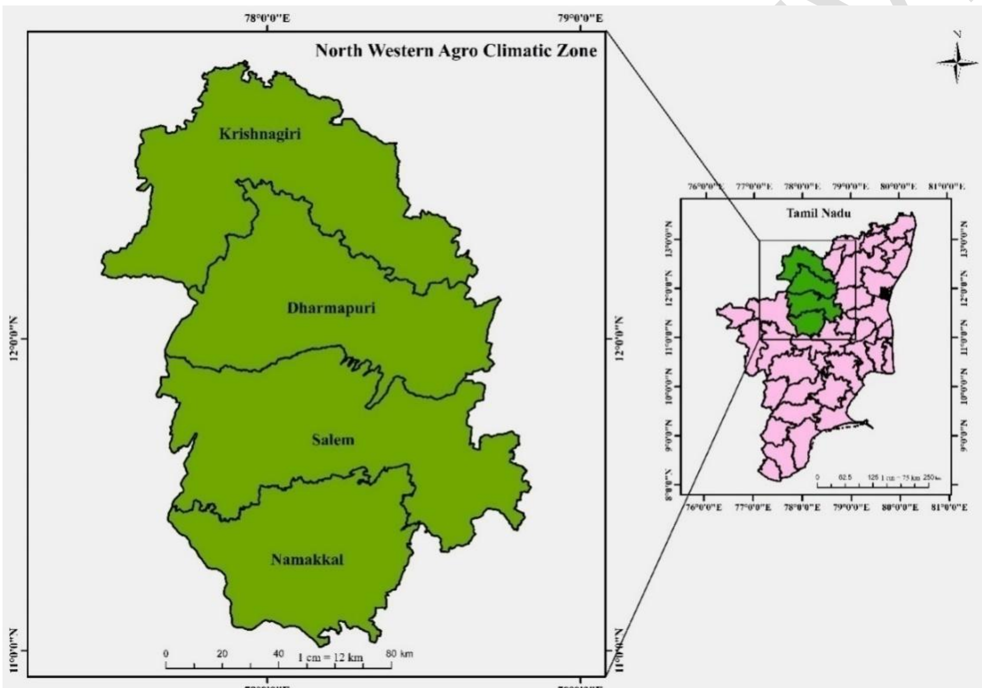

Figure.1North Western - ACZ of Tamil Nadu, India

2.2 Data

To characterize the drought in detail over the study area, the daily gridded precipitation data sets (0.25 x 0.25 degree) for the period 1991-2020 (30 years) was collected from India Meteorological Department (IMD). The subset of grids pertains to the Northwest zone (Krishinagiri, Dharmapuri, Salem, Namakkal) of Tamil Nadu was retrieved using climate data operator (CDO) and ArcGIS.

2.3 Methodology

In order to understand general rainfall climatology of the study area, deviation of rainfall from normal rainfall was computed as follow:

$$Rainfall\ Deviation = [\frac{Actual\ \ Rainfall\ - Normal\ \ Rainfall}{Normal\ \ Rainall}]x\ 100$$

As per IMD, rainfall below 20 per cent than normal is defined as a drought condition (Table 1). The maximum deviation of rainfall is -100 and100 per cent indicates no rain or twice the amount of precipitation received on the particular year, respectively [22].

Table 1. Precipitation deviation classification by IMD

Precipitation deviation (%)	Category
Greater than + 60	Wet
+20 to +59	Excess
+19 to -19	Normal
-20 to -59	Deficit
Less than -60	Scanty

A probability indicator called SPI is used to monitor drought, developed by fitting a station frequency distribution of precipitation totals with a gamma probability distribution [32] and drought intensity classification is furnished in Table 2. SPI is popular drought index is used in the present study to identify drought event during southwest monsoon (SWM) and northeast monsoon (NEM).

$$\boldsymbol{SPI = \frac{a - A}{SD}}$$

Where, SPI = Standardized Precipitation Index,
a = Current period precipitation (mm)
A = Historical average precipitation (mm)
SD = Standard Deviation of precipitation for the given period

Table.2 SPI classification and their respective drought intensities

SPI value	Intensity
2.00 and more	Extremely wet
1.99 to 1.50	Very wet
1.49 to 1.00	Moderate wet
0.99 to -0.99	Near normal
-1.00 to -1.49	Moderate drought
-1.50 to -1.99	Severe drought
-2.00 and less	Extremely drought

Rainfall deficit accumulation over different time scales becomes more crucial and helps to classify different types of droughts. However, the monthly accumulated precipitation is the base shortest time scaleto study the agricultural drought while longer time scale (>6 months) is considered to study hydrological drought [31].

In this study, SPI was worked out at one month time scale to find out the intra seasonal rainfall variability for South West Monsoon (SWM, June to September) and North East Monsoon (NEM, October to December). Drought event is considered whenever SPI value falls below (-)1.0. Drought duration (DD) is calculated by counting the consecutive months with SPI value falls below the threshold. The sum of the negative SPI values for each drought event was used to calculate drought magnitude (DM). Drought intensity was done by dividing the drought magnitude by the duration the drought event. Mean drought magnitude (MDM) and mean drought intensity (MDI) were worked out by dividing drought magnitude and intensity by number of drought events [33,34].

3. Result and Discussion

3.1 Analysis drought based on precipitation deviation

In order to comprehend the rainfall climatology of the North Western Zone (NWZ), precipitation data had averaged over time and its seasonal distribution was investigated for SWM and NEM seasons. During SWM season of 1990 – 2020 (30 years), Dharmapuri and Salem faced more deficit rainfall years (7) than Namakkal and Krishnagiri districts (Fig.2). While the greater number of scanty rainfall years (2) was noticed in Namakkal than other districts of the zone.

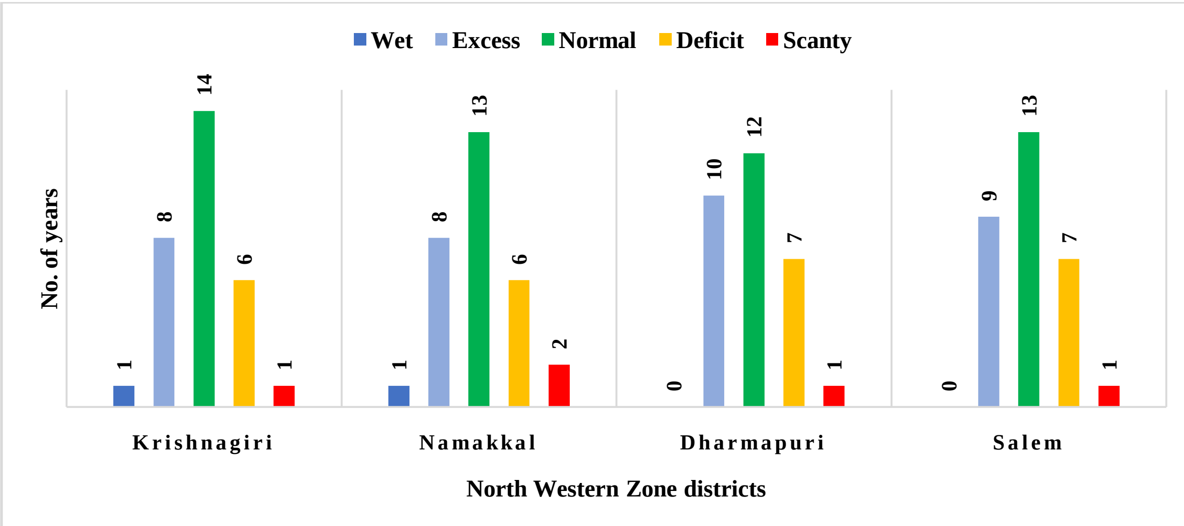

Fig. 2. Precipitation deviaiton for SWM (1991 – 2020)

During NEM season, deficit rainfall years were higher in Krishnagiri and Dharmapuri districts (10) followed by Salem district (8) and only 4 deficit rainfall years were observed in Namakkal. However, more number of scanty rainfall years (3) was noticed in Namakkal district while other three districts in the zone scanty rainfall received in two years during the study period. This shows north east monsoon has more variability in rainfall distribution [35]. During 1950 to 2010, themonsoon shift in rainy season over the period [36]. (Fig. 3).

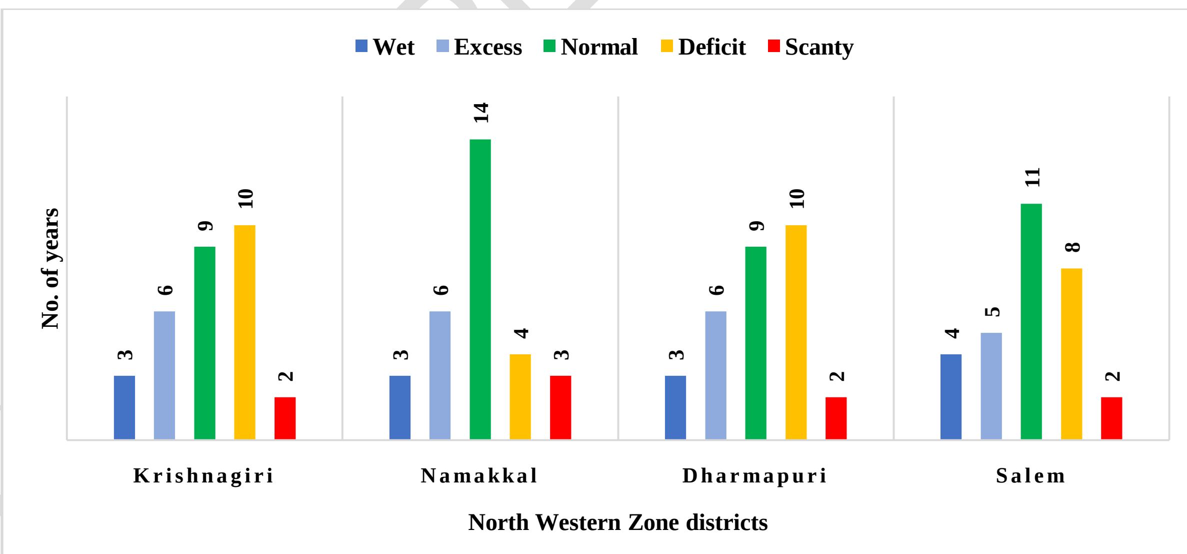

Fig 3. Precipitiation deviation NEM (1991-2020)

3.2 Drought duration, magnitude and intensity

SPI at one month time scale had been taken to analyze the intra seasonal drought. During the study period 1991-2020, there were 120 months in SWM and 90 months in NEM. Drought duration which is nothing but number of months with SPI ≤ -1.0 was observed more in Dharmapuri and Salem districts (21-22 out 120 months) during southwest monsoon period. The number of months under drought was less in Namakkal and Krishnagiri districts (15-17 out of 120 months) in southwest monsoon during the study period (Fig. 4A). At the same time, during north east monsoon season the highest drought duration was noticed in Namakkal district (16-17 out of 90 months) while lowest was in Krishnagiri district (10-12 events) (Fig. B).

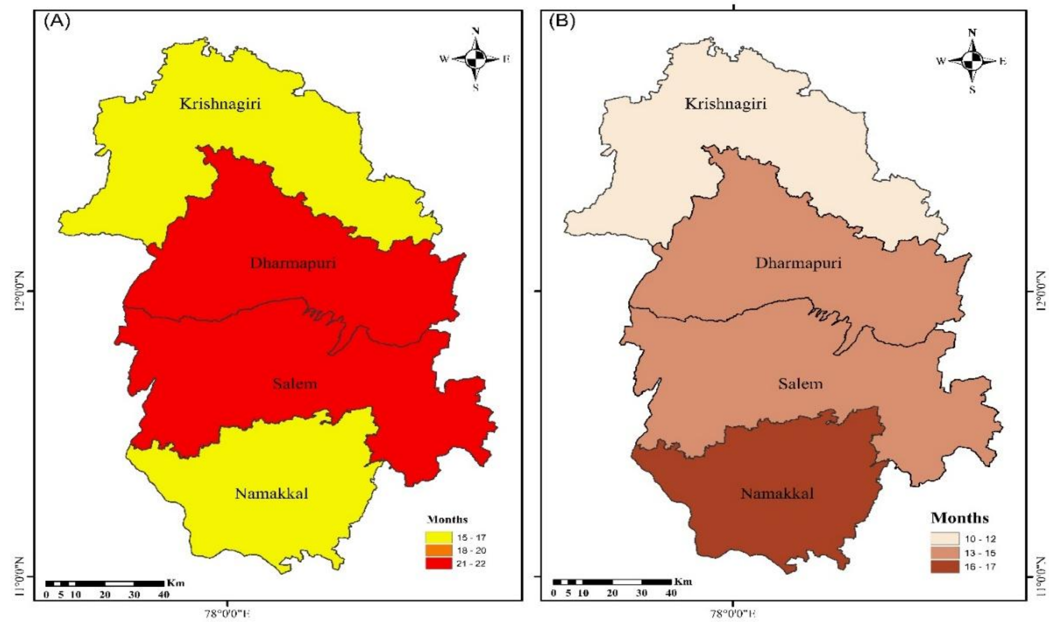

Fig.4 Drought duration (months) in SWM (A) and NEM (B) over NWZ during 1991-2020

Spatial distribution of drought magnitude showed that lowest drought magnitude was observed in Krishnagiri district (SPI -1.67) while the highest drought magnitude was found in other three districts of the northwest zone during southwest monsoon period (Fig. 5A). In northeast monsoon season, drought magnitude was higher (SPI -2.6) in western part of the zone especially southern part of Namakkal district while the eastern parts of the zone(SPI -1.4) experienced drought at low magnitude.

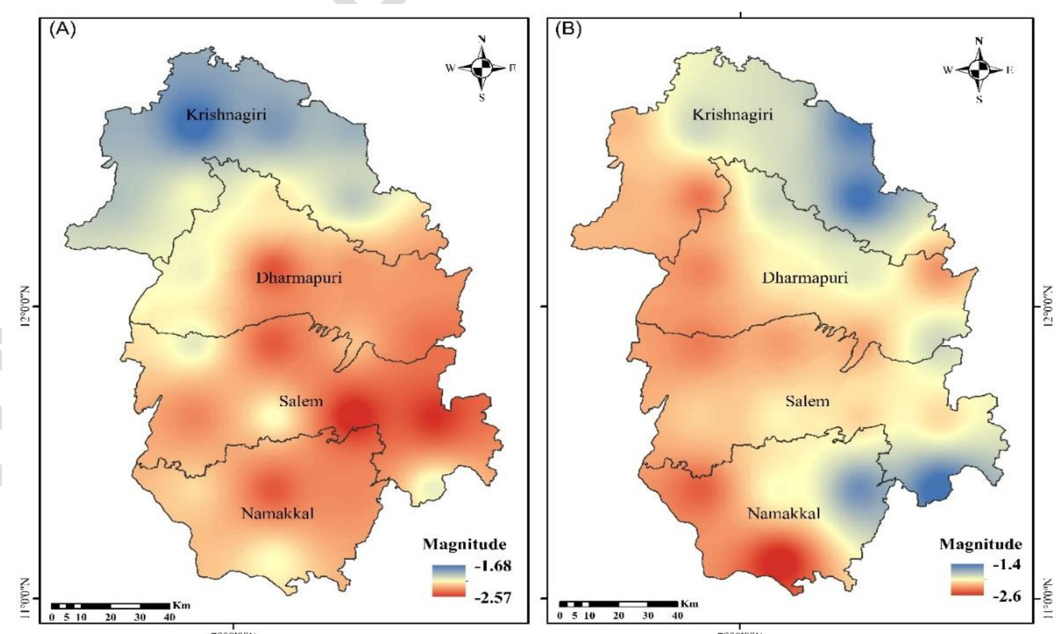

Fig.5. Drought magnitude in SWM (A) and NEM (B)over NWZ during 1991-2020

In the case of mean drought intensity, it was varied between SPI (-)1.50 and SPI (-)1.94 from central part of Dharmapuri to south end of Namakkal district whereas the highest (SPI -1.94) was noticed in south central part of Salem district. In Krishnagiri district, the mean drought intensity was the lowest during southwest monsoon period (Fig.6A). Earlier study also found that severe drought occurred in Namakkal and Salem districts for more years than in Krishnagiri district during southwest monsoon [20]. During north east monsoon season, mean drought intensity was less and ranged from SPI -1.24 to -1.81 which is less than southwest monsoon. Higher mean drought intensity was in western part of the zone than the eastern part of the northwest zone (Fig. 6B).

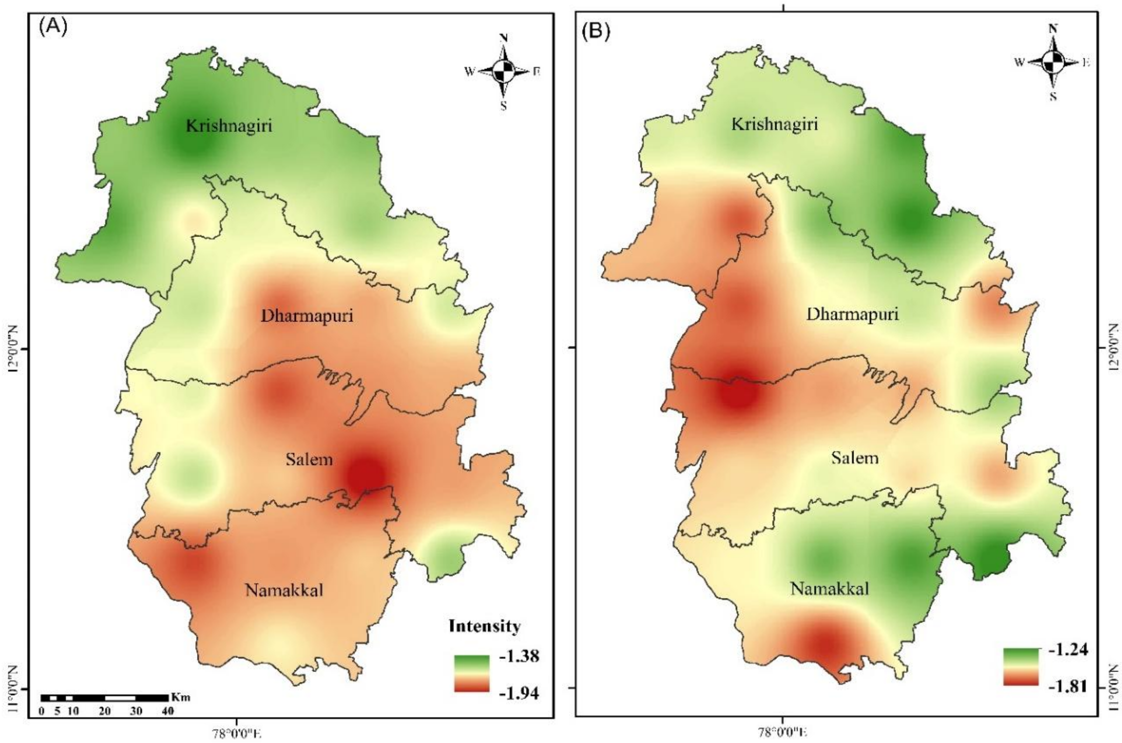

Fig.6Drought intensity in southwest monsoon (A) and north east monsoon (B) over NWZ during 1991-2020

SPI analysis revealed that Salem and Dharmapuri districts are more prone to drought as it is evidenced by high drought duration, magnitude and intensity. During north east monsoon season, SPI values showed high drought duration, magnitude and intensity for Namakkal and Salem districts. Study on identifying agricultural drought vulnerable areas using multi criteria analysis also in agreement with this study results that Dharmapuri, Salem and Namakkal are the drought vulnerable districts [20]. Rainfall deviation analysis for planning of cropping system was studied in different regions of the state [37,38]. Monthly rainfall deviation for northeast monsoon season indicated that drought was experienced in consecutive months during 2001-2004 and 2016-2018 in Namakkal and Salem districts [20].

4. CONCLUSION

The present investigation employed one month SPI, which gave an overview of drought during SWM and NEM seasons over North Western Zone of Tamil Nadu. The study region experienced more drought occurrences in 2000-03 and again in 2016–18. It was clear that the degree of the drought varied in different parts of the region. Drought risk parameters (duration, magnitude and intensity) indicates that Salem and Dharmapuri districts stands first followed by Namakkal.Whereas, lowest drought risk was observed in Krishanagiri district in SWM during the period of 1991-2020. During NEM, Namakkal is the most drought risk prone district followed by Salem and Dharmapuri.While,Krishnagiri is the least drought prone district. To reduce the negative impacts of drought in drought prone districts multi-pronged approaches is to be taken and techniques like remote sensing-based assessments based on different vegetative indicators would help in better understanding and effective management of droughts.

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