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RESEARCH ARTICLE

Exploring the drought condition in Namakkal District, Tamilnadu, through standardized precipitation index

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Abstract

Drought has long been recognized as one of the major causes of human misery and being the natural disaster that annually claims the most victims. Droughts are recurring climatic events, which often hit everywhere, bringing significant water shortages, economic losses and adverse social consequences. Water scarcity can be said as the cause and effect of drought. It is not possible to avoid droughts. But drought preparedness can be developed and drought impacts can be managed. The levels of drought preparedness in countries of the region differ significantly. The success of both depends, amongst the others, on how well the droughts are defined and drought characteristics quantified. Hence, an attempt has been made in this study to identify the drought condition on rainfed namakkal district. Annual normal rainfall of Namakkal is found to vary from 478 to 860 mm with an average of 732 mm. Among the monsoons, Southwest monsoon (SWM) had higher amount of average rainfall followed by Northeast monsoon (NEM) rainfall. During SWM, except the locations Paramathy all other locations have dependable rainfall. During NEM, the locations Namakkal, Rasipuram and Paramathy had CV higher than 50 Per cent that are not dependable. Except this all other locations have dependable rainfall. Most of the locations had witnessed 1 to 6 moderate drought years in both the monsoons. The study based on SPI will be helpful for assessing the drought severity.

Keywords: Rainfall; SWM; CV; Drought; Index

Introduction

The climate of a region is determined by the long-term average, frequency and extremes of several meteorological variables, most notably temperature and precipitation. In countries such as India, precipitation is a precious natural resource and it is quite variable. Understanding spatiotemporal rainfall patterns has been directly implicated to combating extreme poverty and hunger through agricultural enhancement and natural resource management (IPCC, 2007). Therefore, it is essential to derive locally consistent drought scenarios for use in a variety of practical applications and in climate impact research. Agricultural production in India is highly dependent on rainfall; hence, drought has a direct effect on it.

Based on several perception drought can be defined as one of the complex phenomena (Wilhite and Glantz, 1987). Drought is a normal feature of climate and its recurrence is inevitable (Mishra and Desai, 2005). Operational definitions are formulated in terms of drought indices (Smakhtin and Hughes, 2004).

For monitoring drought occurrence many indices depend on hydro-meteorological parameters by hydrologists and meteorologists (Viau, 2000). To categorize drought severity at different scale drought indices are used generally (Rao Zahid, 2016). It is difficult to develop an accurate index for drought due to its complex relationships between hydro climatic variables (Baran, 2017). Standardized Precipitation Index (SPI) is being used to identify severity of meteorological drought and it was developed by McKee et al., (1993). SPI used effectively in many regions for drought monitoring (Vicente Seriano et al., 2004; Cancelliere et al., 2007; Raziei et al., 2009; Liu et al., 2012; Zhang et al., 2012; Mallya et al., 2016).

Standardized Precipitation Index (SPI) is more reliable for detecting emerging drought and it is becoming an increasingly important tool for assessing moisture condition and initiating drought response actions at state, regional and local level; planning for drought; monitoring drought; drought risk and impact analysis; and mitigating drought by putting a drought plan together for water conservation (Wilhite et al., 2000). SPI is a successful method for to study the drought climatology (Lloyd-Hughes and Saunders, 2002). Pai et al., (2010) calculated district-wise drought condition in India using SPI. This study aims at examining the changes in SPI time series on local and regional scales over the Namakkal region of Tamil Nadu. The 12 month, 3 month and 4 month SPI is calculated for 7 rainfall stations to represent the annual, SWM and NEM rainfall changes.

Materials and Methods

Study Area

The Namakkal District lies in the interior part of Tamil Nadu and extends between $11^{0}00'$ to $11^{0}36'10''$ north Latitudes and $77^{0}40'$ to $78^{0}30'$ east longitudes (Fig. 1). The total geographical area of the district is 3429.3 sq. km. The district area represents 2.64% of the total area of Tamil Nadu state.

Namakkal district has hills and forests with undulating terrain. The important hill ranges in the district are Kolli Hills, Bodamalai hills, Naraikinaru hills and Pachamalai hills. The altitude of the district is 300 meters above MSL.The plain area of the district can be divided into 3 elevating stages. The lower elevation (below 150 m) has a part of Kabilarmalai, Namakkal and Paramathy blocks which are being benefitted by the Cauvery River. The mid elevation (150-300 m above M.S.L.) occupies the major area in all blocks. The high elevation area (between 300-600 m) spreads over mainly in the blocks as a part in Rasipuram, Namakkal and Namagiripettai. The area above 600 m is mainly spread over Kolli Hills and Namagiripettai.

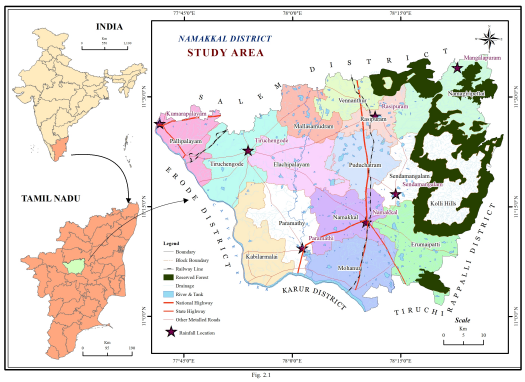

Fig. 1. Location of study area with rainfall locations and administrative blocks in Namakkal district

Data Source

The study area map has been prepared by using Survey of India Toposheet (SOI) in the scale of 1: 50,000. The toposheet has been geo-referenced by using suitable co-ordinate system. Daily rainfall data for 18 different rain guage stations over Namakkal district and its surrounding area was collected from Department of Economics and Statistics, Government of Tamil Nadu for 30 years (1983 – 2013). The rainfall data was quality checked and utilized. The rainfall data used were from seven rainfall stations spread over the district; Tiruchengode, Namakkal, Kumarapalayam, Mangalapuram, Paramathy, Rasipuram and Senthamangalam.

Data analysis

The data was sliced to represent southwest monsoon (SWM - June to September), northeast monsoon (NEM - October to December) and annual period to study the rainfall over the location and its drought situation over the study area through SPI tool for thirty years (1983-2013) and the result has been brought out cartographically by using the software Arc GIS.

Standard Precipitation Index (SPI)

The Standard Precipitation Index (SPI) was proposed by McKee et al. (1993) to quantify precipitation deficits / surpluses on a variety of time scales (usually between 1-month and 24-month sums). Because of the fact that the SPI is normalized, wetter and drier climates can be represented in the same way, and wet periods can also be monitored using the SPI. Those time scales reflect different aspects of the hydrological cycle. Soil moisture conditions respond

to precipitation anomalies on a relatively short scale (2–3 months), stream flow may be described by SPIs with time scales of 2–6 months, while ground water and reservoir storage reflect longer-term precipitation anomalies (Lloyd-Hughes and Saunders 2002). Hence, the different time scales for which the index is computed address the various types of drought: the shorter seasons for agricultural and meteorological drought, the longer seasons for hydrological drought (Heim 2002). The SPI programme developed by National Drought Mitigation Centre of University of Nebraska was utilized and the criteria defined by McKee et al. (1993) for a "drought event" and classification of the SPI to define drought intensities for any time steps used for interpretation. The classification was given in Table 1.

Table 1. lassification of Standard Precipitation Index values and their intensities

SPI	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

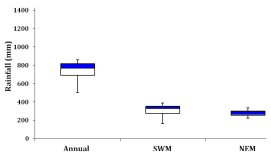

Fig. 2. Box-plot showing Annual and Monsoon rainfall normals

Table 2. Annual and Monsoon rainfall normals Namakkal district and their Coefficient of Variation

Locations	Rainfall			Coefficient of Variation (%)		
	Annual	SWM	NEM	Annual	SWM	NEM
Kumara-palayam	676	260	264	27	39	50
Mangalapu-ram	860	363	335	25	26	46
Namakkal	828	349	307	33	42	51
Paramathy	478	164	224	46	65	57
Rasipuram	807	389	265	34	45	54
Senthaman-galam	708	328	251	28	41	43
Tiruchengode	768	292	296	27	44	47
Namakkal District	732	306	277			

Results and Discussion

Variation in rainfall

Rainfall data of Namakkal district was analyzed to understand its distribution in space and time. Rainfall data was obtained for the spatially scattered locations (7) over the study area to understand the distribution. Annual normal rainfall of Namakkal (Table 2) as a whole is found to be 732 mm (Figure 2). Among the monsoons, Southwest monsoon (SWM) had higher amount of rainfall 306 mm followed by Northeast monsoon (NEM) with 277 mm of rainfall. Among the locations, Mangalapuram receives highest annual rainfall among the study locations (860 mm) and the lowest rainfall (478 mm) was received at Paramathy. In SWM, highest rainfall was received at Rasipuram (389 mm) while the lowest was received at Paramathy (164 mm). In NEM, Mangalapuram receives highest rainfall (335 mm) and Paramathy receives the lowest rainfall (224 mm).

Coefficient of variation is a measure used here to understand the dependability of rainfall in a particular period. According to the criteria, annual rainfall with less than 25 per cent CV is dependable (Veeraputhiran et al. 2003). In the study locations, Mangalapuram had CV that is dependable while all other locations had CV above 25 percent. Among the locations Paramathy had the highest (46) per cent of CV (Table 2). During SWM, except the locations Paramathy all other locations have dependable rainfall. During NEM, the locations Namakkal, Rasipuram and Paramathy had CV higher than 50 Per cent that are not dependable. Except this all other locations have dependable rainfall. Interestingly, Paramathy have CV more than 50 per cent for both the monsoons. The lowest coefficient of variation observed indicates that this monsoon system over the region is a stable one as has been recorded by Dhar et al. (1982) and Sathyamoorthy et al. (2017 & 2018).

Extreme rainfall anomalies

The SPI value derived for the locations is an indicator of deficit or surplus rainfall of a location. Rainfall deficit are represented by negative SPI values, whereas positive SPI values indicate rainfall surplus by Wu M (2013). The general trend of 12 months SPI values for the each location has shown in Figure 3. The trend indicates that the behaviors of SPI values are varied in nature in all the locations. The extreme positive and negative anomalies witnessed by the locations were extracted and analyzed (Table 3). Among the annual SPI values, Kumarapalayam had the highest positive anomaly of 2.37 while the lowest was in Sendamangalam 1.56 (Figure 4). Highest negative anomaly was in Sendamangalam (-2.73) while the lowest was in Namakkal (-1.8).

Table 3. Historically extreme positive and negative SPI values attained

Locations	Annual		Southwest Monsoon		Northeast MonHsoon	
	Max	Min	Max	Min	Max	Min
Kumara-palayam	2.37	-2.4	2.25	-2.10	1.96	-1.83
Mangalapuram	2.19	-1.84	2.64	-1.72	1.82	-2.55
Namakkal	1.97	-1.8	1.74	-1.95	2.38	-2.07
Paramathy	1.70	-1.83	1.61	-1.28	2.24	-1.50
Rasipuram	2.11	-1.91	2.92	-2.51	2.09	-2.21
Sendaman-galam	1.56	-2.73	1.45	-1.83	1.69	-1.94
Tiruchengode	1.83	-2.26	1.91	-2.26	2.08	-2.12

During SWM, the location Rasipuram had highest positive SPI values (2.92) and also the highest negative (-2.51) anomaly (Figure 5). During NEM (Figure 6), Namakkal had highest positive SPI value (2.38) while highest negative anomaly was occurred in Mangalapuram (-2.55).

Characterization of seasonal drought occurrence

For the SWM, number of years with positive anomaly varied from 13 to 18 and the number of years with negative anomaly varied from 12 to 17 with an average of 15 positive and 15 negative anomaly years. In case of NEM, number of years with positive anomaly varied from 12 to 20 and the number of years with negative anomaly varied from 10 to 18 with an average of 16 positive and 14 negative anomaly years. From this, the variability of both monsoons is evident and the rainfall anomaly is almost equally distributed during both the NEM period and SWM period and there is no significant difference, where the numbers of positive years were comparatively more than negative years (Tables 4 and 5).

Further, the years were categorized into moderate, severe and extreme drought years based on the SPI index. Interestingly, during both SWM and NEM the locations Rasipuram witnessed extreme drought conditions in the past 30 years of study period. Rather than these locations, Kumarapalayam, during SWM and Tiruchengode, Namakkal and Mangalapuram during NEM also witnessed extreme drought conditions during the study period. But the year of occurrence varied from one location to another location and it is clearly explained in the Table 4.

Namakkal, Senthamangalam and Mangalapuram experienced severe drought during the SWM period. The location

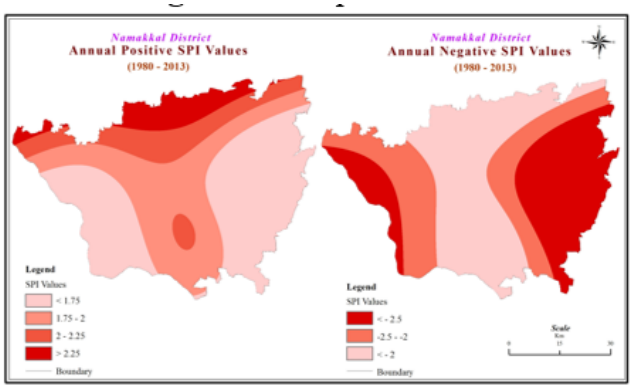

Fig. 4. Annual positive SPI values

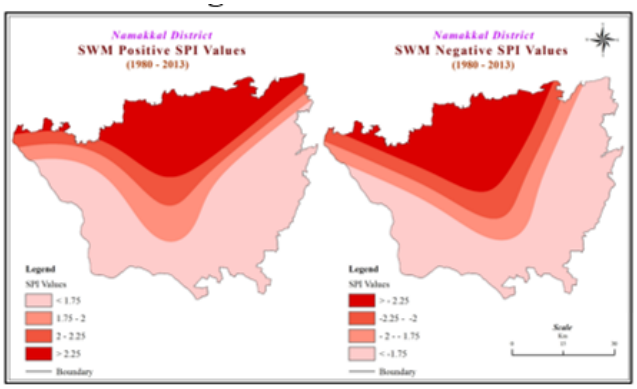

Fig. 5. SWM Positive SPI values

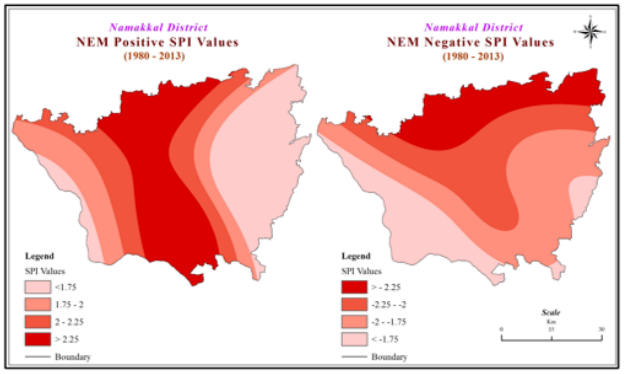

Fig. 6. NEM SPI values

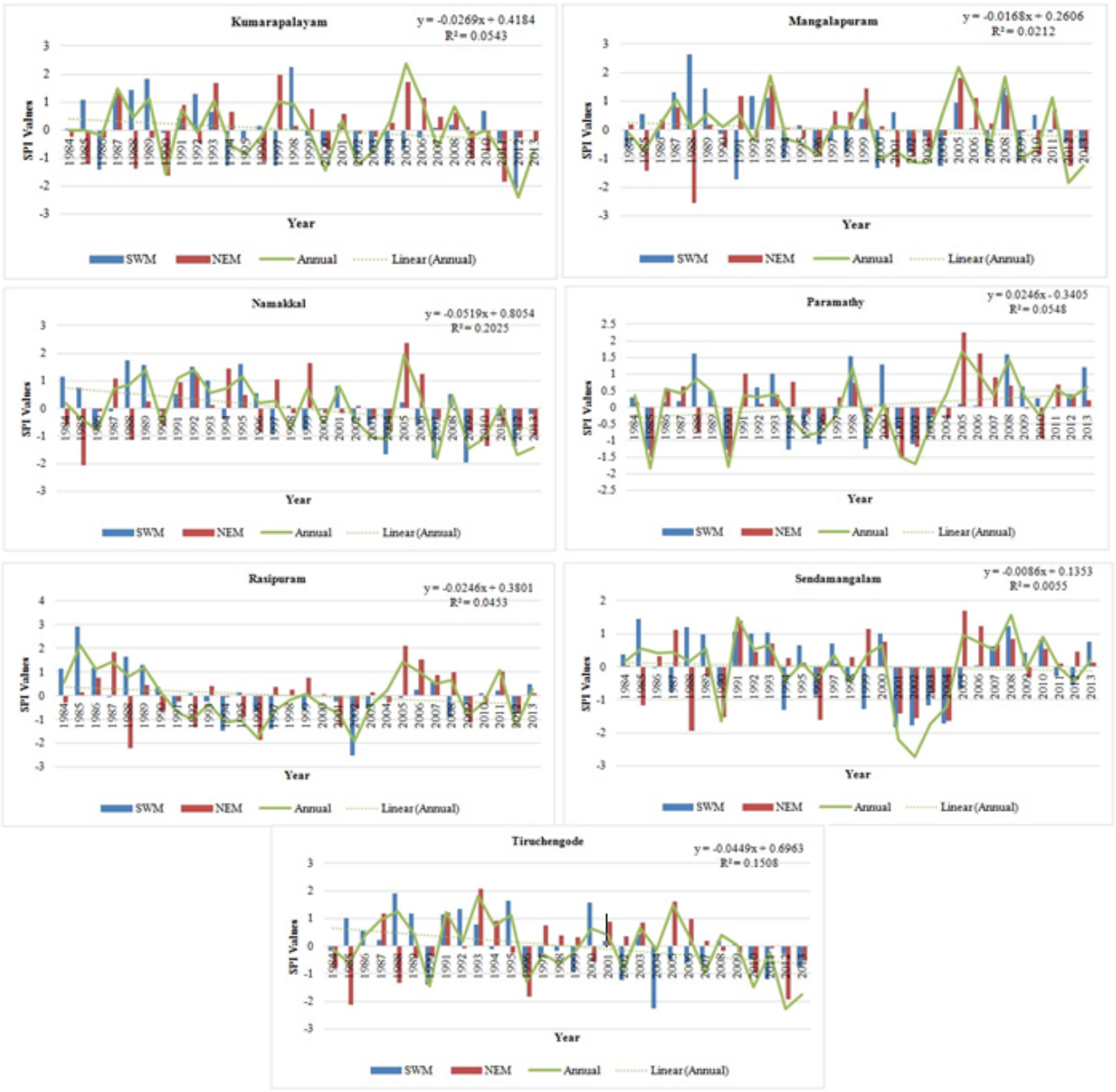

Fig. 3. Trend of SPI values for each rainfall location in Namakkal district (1984 – 2013)

Namakkal and Senthamangalam witnessed severe drought marking in highest number of occurrences among the locations. All other locations witnessed one or no years of severe drought conditions.

In case of NEM, except Namakkal, and Mangalapuram all other locations experienced severe drought condition during the study period. The location Senthamangalam witnessed severe drought during 1988, 1990, 1996, 2002 and 2004 marking highest number of occurrences among the locations. Similar works has been carried out by Ramaraj et al. (2015) over the southern zone of Tamil Nadu.

In case of NEM, 5 out of 7 locations witnessed severe drought conditions. During NEM, almost all the 5 locations witnessed severe drought either once or more than once. Interestingly during SWM, consecutive droughts were experienced in Senthamangalam (2001, 2002), were such consecutive severe drought years were missing during NEM.

Moderate drought was experienced in both monsoons. Most of the locations had witnessed 1 to 6 moderate drought years in both the monsoons. Typically in SWM,

Table 4. Drought categorization through SPI for SWM (1984-2013)

Sl. No	Location	Frequency of SPI value		Moderately drought	Severe drought	Extreme drought	Total drought years
		-ve	+ve				
1.	Kumarapalayam	15	15	1986, 1994, 1997, 2002, 2004	0	2012	6
2.	Mangalapuram	17	13	2000, 2004, 2009	1991	0	4
3.	Namakkal	17	13	2012	2004, 2007, 2009	0	4
4.	Paramathy	12	18	1985, 1990, 1994, 1996, 1999, 2002	0	0	6
5.	Rasipuram	15	15	1994, 1997	0	2002	3
6.	Senthamangalam	14	16	1994, 1999, 2003	2001, 2002, 2004	0	6
7.	Tiruchengode	16	14	1990, 1996, 2002, 2011	0	2004	5

Table 5. Drought categorization through SPI for NEM (1984-2013)

Sl. No	Location	Frequency of SPI value		Moderately drought	Severe drought	Extreme drought	Total drought years
		-ve	+ve				
1.	Kumarapalayam	16	14	1985, 1988, 1996, 2009	1990, 2011	0	6
2.	Mangalapuram	14	16	1985, 2001, 2012	0	1988	4
3.	Namakkal	18	12	1988, 2010, 2013	0	1985	4
4.	Paramathy	13	17	2001, 2002	1985, 1990	0	4
5.	Rasipuram	14	16	1992, 2001, 2009	1996	1988	5
6.	Senthamangalam	10	20	1985, 2001	1988, 1990, 1996, 2002, 2004	0	7
7.	Tiruchengode	15	15	1988	1996, 2012	1985	4

Paramathy had 6 such years affected by drought followed by Kumarapalayam (4) and Tiruchengode (4). It is important to note there were consecutive years with moderate drought. During SWM, there are no consecutive years with moderate drought that were noticed during the study period. The consecutive drought years during NEM were observed in Paramathy (2001, 2002) location only.

Drought Analysis through SPI

Anomaly in rainfall for Annual and Monsoon seasons were studied through SPI, The number of years with positive anomaly and negative anomaly was derived.

The number of moderate, severe and extreme drought years for individual locations were considered for the present study and the abstract of the analysis was presented in Table 6. The frequency of drought events varied among the seasons as well as the locations. Moderate drought events were more compared to severe and extreme drought events in all the locations and in seasons. Moderate drought occurence was highest over Mangalapuram, and Namakkal with 5 occurences followed by Rasipuram and Tiruchengode with 3 occurrences. All the rainfall locations have moderate drought events while the locations Paramathy and Sendamangalam had the occurrence of single moderate drought event. Paramathy had 3 severe drought events highest among the locations followed by Namakkal, Rasipuram and Sendamangalam. 2 extreme drought incidents are witnessed in Sendamangalam rainfall location and interesting that it comes in all the drought occurences.

Anomalies in annual rainfall over a period gives a clear picture about the rainfall status of the locations while seasonal status is crucial to make decisions for various applications including agriculture. Both the monsoon seasons had more number of moderate drought occurrences with variations among the locations. During SWM, Paramathy witnessed the highest number (6) of moderate drought occurrences followed by Kumarapalayam (5). Sendamangalam and Namakkal had (3) severe drought occurrences and extreme drought occurrences are noticed only in Kumarapalayam (1), Rasipuram (1) and Tiruchengode (1).

During NEM, Kumarapalayam had witnessed more number of moderate droughts (4) followed by Mangalapuram (3), Namakkal (3) and Rasipuram (3). The locations Tiruchengode had witnessed least of only one moderate drought occurrence. Sendamangalam had witnessed highest (5) Severe drought occurrences and Mangalapuram, Namakkal, Rasipu-

Table 6. Frequency of drought events categorized based on SPI values for annual and monsoon rainfall

Sl. No.	Location	Annual			Southwest Monsoon			Northeast Monsoon		
		Moderate	Severe	Extreme	Moderate	Severe	Extreme	Moderate	Severe	Extreme
1	Kumarapalayam	2	1	1	5	0	1	4	2	0
2	Mangalapuram	5	1	0	3	1	0	3	0	1
3	Namakkal	5	2	0	1	3	0	3	0	1
4	Paramathy	1	3	0	6	0	0	2	2	0
5	Rasipuram	3	2	0	2	0	1	3	1	1
6	Sendamangalam	1	2	2	3	3	0	2	5	0
7	Tiruchengode	3	1	1	4	0	1	1	2	1

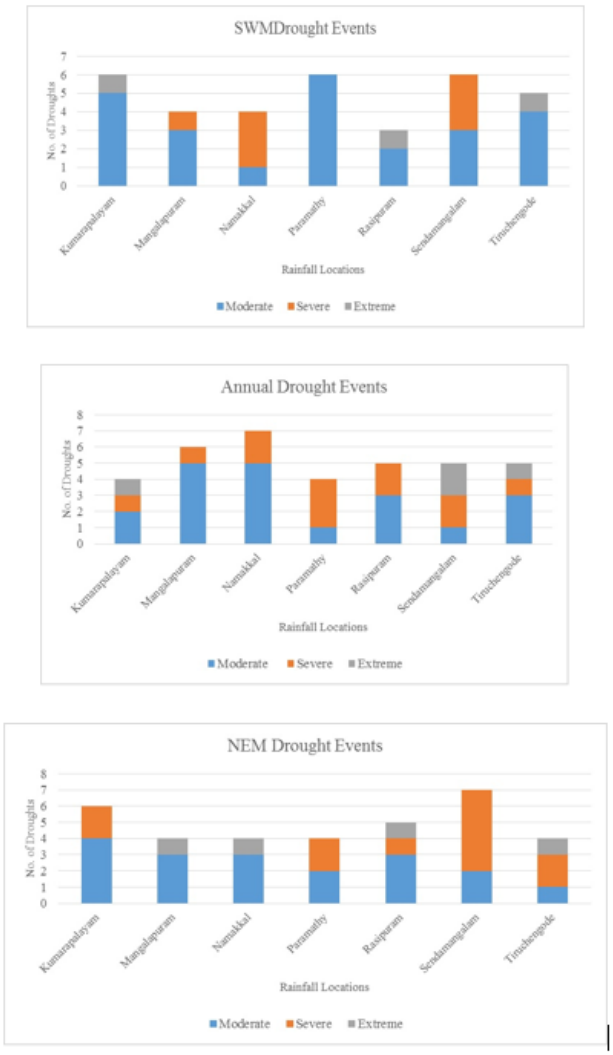

Fig. 7. Frequency of drought occurrences in Namakkal district for annual, SWM and NEM seasons

ram and Tiruchengode witnessed one extreme drought occurrences. It is quite interesting that Rasipuram and Tiruchengode had comes under the entire drought events.

Conclusion

Based on the above analysis, it is evident that the study locations receive rainfall during both the monsoons and are nearly equitable. Dependability of this rainfall has both spatial and temporal variability. Few locations like Mangalapuram have high rainfall and are dependable while location like Paramathy have less rainfall and is not dependable. The study further employed SPI to identify the frequencies of drought occurrence in the rainfall locations dispersed in the Namakkal district. SPI index undoubtedly indicates the rainfall anomaly situation of a location. The numbers of drought years are almost similar in both SWM and NEM. The spatial variability gives clear indication for making site-specific management decisions based on monsoon rainfall. The study may be useful for the agriculture department for planning alternate cropping to avoid crop failure.

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