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Exploring the Drought Scenario of Namakkal through Standardized Precipitation Index

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Abstract

Drought has long been recognized as one of the major causes of human distress and is a natural disaster that claims so many fatalities annually. Droughts are a series of climate events that often hit South Asia, causing 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 success of both depends, amongst the others, on how well the droughts are defined and drought characteristics quantified. Hence, preparedness to drought should form the important part of national environmental policies. The degree of drought preparedness varies considerably from one country to another. Average annual normal rainfall of Namakkal is found to be 678 mm. Among the monsoons, southwest monsoon (SWM) had higher amount of average rainfall followed by northeast monsoon (NEM) rainfall. Annual extreme SPI negative value was found over Tiruchengode as -4.52. Frequency of SPI is maximum of 20 in Namakkal and drought years varied from 3 to 6 annually. Paramathy and Senthamangalam experience a maximum of 8 drought years in SWM. The frequency of negative SPI value is varied from 16 to 21and interestingly no extreme drought events are noted in NEM. The study based on SPI will be helpful for assessing the drought severity.

Keywords: Rainfall; SWM; CV; Drought; SPI

Introduction

The climate of an area is determined by the long-lasting average, frequency and extremes of several climate variables, most notably temperature and precipitation. In countries such as India, precipitation is a precious natural resource and it is quite variable. Thus any fluctuations or trends in its geographical distribution and quantity could have significant implications for socioeconomic sectors such as agricultural productivity, food security, water quality, water resource management, land use, human health, as well as ecological impacts such as biodiversity. Perceptive of temporal rainfall patterns has been directly involved to combating extreme impoverishment and hunger through agricultural improvement 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. Drought is a multifarious event which will be outlined from many views (Wilhite and Glantz, 1987). Drought is a normal feature of climate and its recurrence is inevitable (Mishra and Desai, 2005). The start, end and their spatial extent are clearly understood by reviewing the literatures and from definitions. It is also helpful to access the severity of drought. They are mostly regional-based and based on scientific reasoning, following the analysis of certain quantities of hydro-meteorological information.

They are beneficial in developing drought policies, monitoring systems, mitigation strategies and preparedness plans. Operational definitions are formulated in terms of drought indices (Smakhtin and Hughes, 2004). Drought indices integrate thousands of bit data on rainfall, snowfall, stream flow and other water supply indicators into an understandable large picture. A drought index value is more helpful than raw data, even though it is a single value.

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 has been widely used for monitoring drought in many regions (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).

The Standardized Rainfall Index (SPI) is very reliable for detecting growing drought. Moisture content and drought response measures are also possible to assess with the help of this tool for macro, meso and micro 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) analyzed the district-level drought scenario in India with the help of 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. Changes in the spatial and temporal patterns of the SPI are also analyzed.

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 (Figure 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.

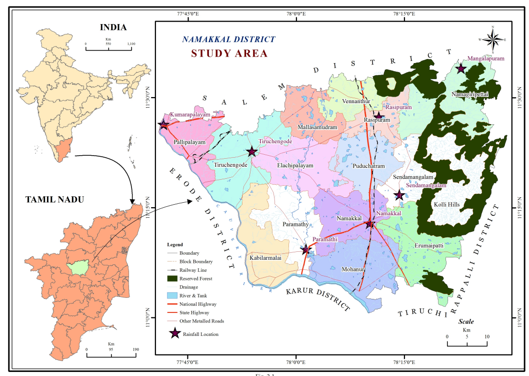

Fig. 2.1

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

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 Paramathi 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 (Figure 2).

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 rainguage stations over Namakkal district and its surrounding area was collected from Department of Economics and Statistics, Government of Tamil Nadu for 39 years (1980 – 2018). The rainfall data used were from seven rainfall stations spread over the district;

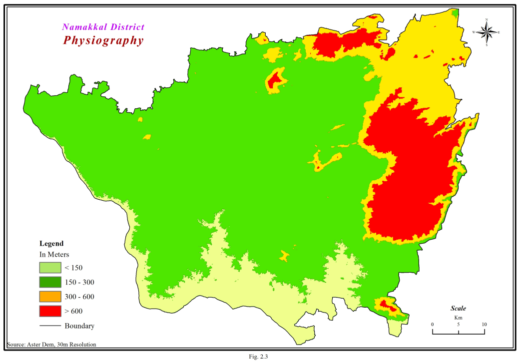

Fig. 2. Physiography of Namakkal district

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. The coefficient of variation has been calculated by using the following formula,

$$\text{Standard Deviation} = \frac{\sum x^2 - (\sum x)^2/n}{n-1}$$

$$\text{Coefficient of Variation (CV)} = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100$$

The drought situation over the study area through SPI tool from National drought Mitigation centre from University of Nebraska for thirty-nine years (1980-2018) were analyzed 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 replicate completely 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 long term rainfall anomalies is based on ground water and basin storage (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). Due to its robustness and convenience to use, SPI has already been widely used to characterize dry and wet conditions in many countries and regions, such as the United States (Wu et al., 2001); Canada (Quiring and Papakryiakou 2003); Italy (Piccarreta et al., 2004; Vergni and Todisco 2010); Iran (Moradi et al., 2011; Nafarzadegana et al., 2012); Korea (Min et al., 2003; Kim et al., 2009); and China (Bordi et al., 2004).

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. Classification 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

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 678 mm (Figure 3). Among the monsoons, Southwest monsoon (SWM) had higher amount of rainfall 310 mm followed by Northeast monsoon (NEM) with 282 mm of rainfall. Among the locations, Rasipuram receives the highest annual rainfall among the study locations (769 mm) and the lowest rainfall (490 mm) was received at Paramathy. In SWM, highest rainfall was received at Rasipuram (398 mm) while the lowest was received at Paramathi (173 mm). In NEM, Mangalapuram receives highest rainfall (337 mm) and Paramathy receives the lowest rainfall (232 mm). Paramathy rain gauge station is the least rainfall location in the study area.

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

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

Locations	Rainfall			Coefficient of Variation (%)		
	Annual	SWM	NEM	Annual	SWM	NEM
Kumarapalayam	698	266	280	27	38	48
Mangalapuram	734	358	337	29	31	49
Namakkal	704	347	304	34	42	54
Paramathy	490	173	232	43	61	57
Rasipuram	769	398	271	33	42	54
Senthamangalam	659	334	249	28	39	46
Tiruchengode	695	293	300	29	44	47
Namakkal District	678	310	282			

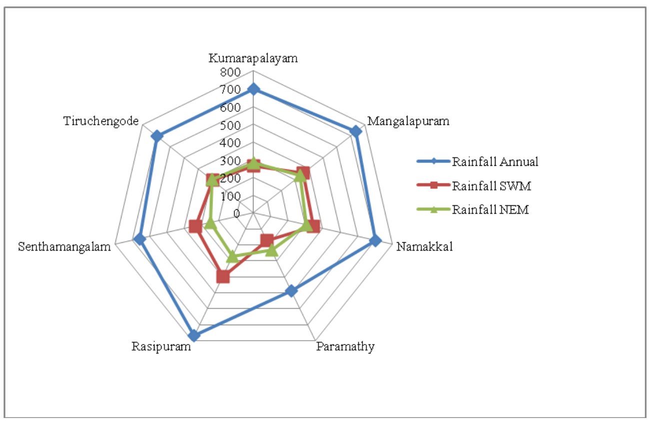

Fig. 3. Radar plot showing Annual and Monsoon rainfall normal for Namakkal district

the study locations, all the station having the CV of above 25 percent indicates non dependable. Among the locations Paramathy had the highest (43) 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 stable one by Dhar et.al., (1982) and Sathyamoorthy et al., (2017 & 2018).

Annual Trends and its temporal changes

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 yearly variation of SPI index values for annual and seasonal indicates that, 2006 experiences maximum negative index value and 2005 has maximum positive SPI value (Figure 4). The general trend of SPI values for each location has shown in Figure 5. The trend indicates that the behaviors of SPI values are varied in nature in all the locations.

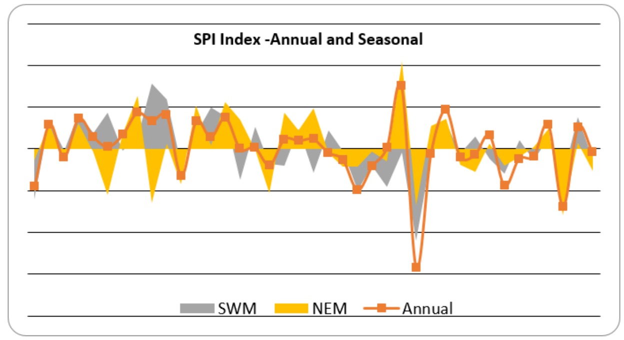

Fig. 4. Yearly trend of SPI Index - Annual and Seasonal over Namakkal (1980 - 2018)

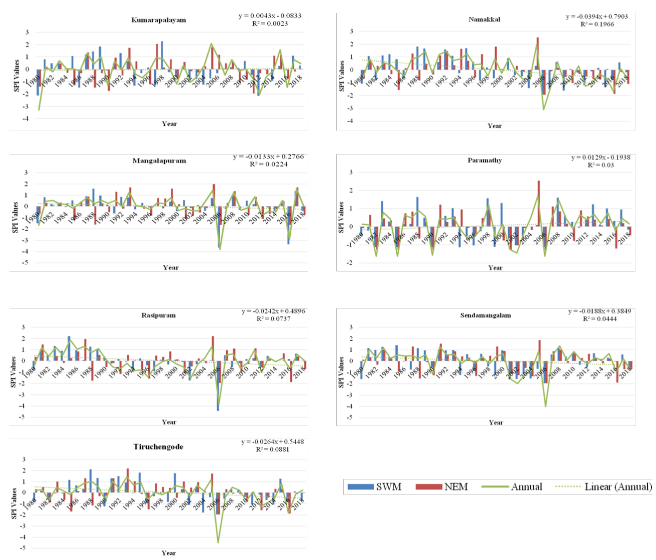

Fig. 5. Trend of SPI values for each rainfall location in Namakkal district (1980 – 2018)

The temporal changes in annual and seasonal SPI values clearly portray the general drought scenario of the study area (Figure 6 a, b, c). The temporal changes have been studied for annual and also for monsoon seasons (SWM and NEM) to understand annual and seasonal behavior drought condition. It clearly displays that most of the study area are under near normal.

A temporal change for annual reveals that the drought conditions over the study area has significant difference from

A

B

C

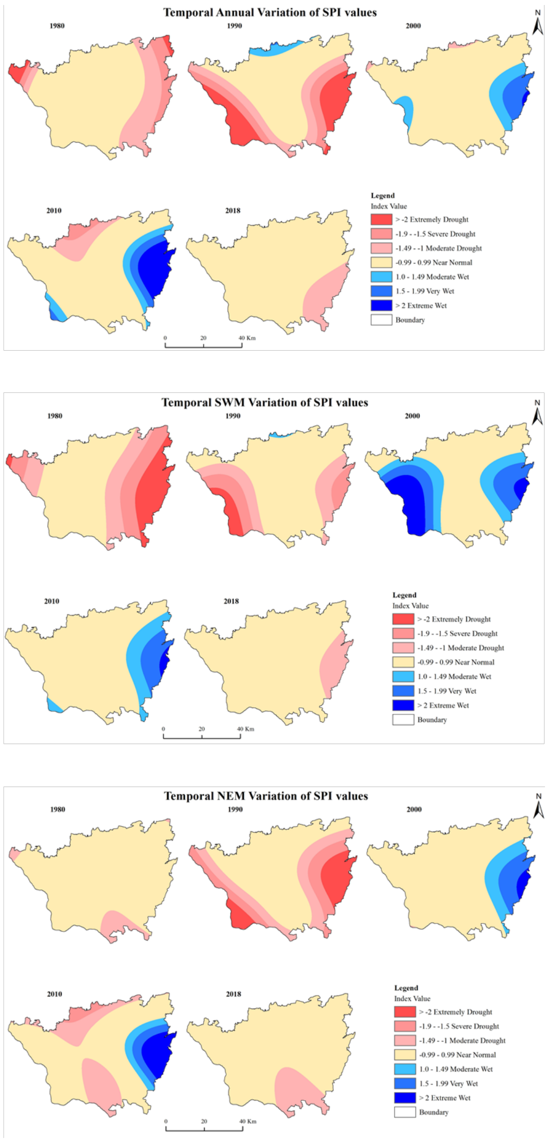

Fig. 6. Decadal variation of SPI values in Namakkal district for Annual and Seasonal (1980 – 2018)

one decade to another based on rainfall intensity. Extreme drought conditions has noted during 1980 and 1990 but those worst situations has not noted in other years studied.

Even though study area receives maximum rainfall during SWM compared to NEM, extreme drought condition has prevailed during 1980 and 1990 in SWM but it restricted to 1990 in NEM. Seasonal difference clearly portrays the drought variation over the study area.

Extreme rainfall anomalies

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 2.08 while the lowest was in Sendamangalam 1.34. Highest negative anomaly was in Tiruchengode (-4.52) while the lowest was in Paramathy (-1.63).

During SWM, the location Kumarapalayam had highest positive SPI values (2.27) and the highest negative (-4.44) anomaly was found in Rasipuram. During NEM, Paramathy had the highest positive SPI value (2.54) while the highest negative (-1.95) anomaly was occurred almost all the location except Mangalapuram and Paramathy locations.

Table 3. Historically extreme positive and negative SPI values attained

Locations	Annual		Southwest Monsoon		Northeast Monsoon	
	Max	Min	Max	Min	Max	Min
Kumara-palayam	2.08	-3.3	2.27	-2.14	2.05	-1.95
Mangalapuram	1.54	-3.81	1.57	-3.64	1.98	-1.63
Namakkal	1.95	-3.1	1.81	-1.95	2.53	-1.95
Paramathy	1.69	-1.63	1.64	-1.13	2.54	-1.27
Rasipuram	1.86	-3.81	2.20	-4.44	2.19	-1.95
Sendaman-galam	1.34	-4.01	1.40	-1.95	1.85	-1.95
Tiruchengode	1.40	-4.52	2.09	-1.95	2.18	-1.95

Characterization of seasonal drought occurrence

Annually, number of positive and negative anomalies is varied from 19 to 26 and 13 to 20 respectively (Table 4). Except Paramathy all other locations experienced extreme drought events particularly during 2006. Severe drought has been experienced by all the locations except Kumarapalayam, but the drought years are varied in nature. It is interesting that there is a consecutive drought years are noticed over Senthamangalam (2001, 2002). Moderate drought events are maximum over Kumarapalayam and Namakkal (4) followed by all other locations except Mangalapuram (0). Consecutive drought events are noticed only in Paramathy location (2001, 2002).

For the SWM, number of years with positive anomaly varied from 17 to 23 and the number of years with negative anomaly varied from 16 to 22 with an average of 21 positive and 18 negative anomaly years. In case of NEM, number of years with positive anomaly varied from 18 to 23 and the number of years with negative anomaly varied from 16 to 21 with an average of 21 positive and 18 negative anomaly years. From this, the variability of both monsoons is evident and the

Table 4. Drought categorization through SPI for Annual (1980-2018)

Sl. No	Location	Frequency of SPI value		Moderately drought	Severe drought	Extreme drought	Total drought years
		-ve	+ve				
1.	Kumarapalayam	18	21	1990,2000,2002,2016	0	1980, 2012	6
2.	Mangalapuram	16	23	0	1980	2006, 2016	3
3.	Namakkal	20	19	2007, 2009,2012,2013	2016	2006	6
4.	Paramathy	14	25	2001,2002	1982,1985,1990,2006	0	6
5.	Rasipuram	19	20	1996,2012	2002	2006	4
6.	Senthamangalam	13	26	1990,2003	2001,2002	2006	5
7.	Tiruchengode	14	25	2012	2016	2006	3

rainfall anomaly is equally distributed during both the NEM period and SWM period and there is no significant difference, where the numbers of positive years and negative years are comparatively similar.

Further, the years were categorized into moderate, severe and extreme drought years based on the SPI index. Interestingly, during both SWM and NEM seasons, SWM monsoon faces extreme drought events and no such single event has been noted over NEM seasons during past 39 years of study period. Among the locations, Kumarapalayam and Mangalapuram had a maximum of 2 extreme drought events in SWM season. But the year of occurrence of extreme drought was varied from one location to another location and it is clearly explained in the Table 5.

Namakkal, Senthamangalam, Tiruchengode, Rasipuram and Mangalapuram experienced severe drought during the SWM period. The location Senthamangalam and Namakkal witnessed severe drought marking in highest number of occurrences among the locations. All other locations witnessed one or no years of severe drought conditions.

During NEM, except Paramathy all other locations experienced severe drought condition during the study period. The location Senthamangalam and Tiruchengode witnessed severe drought and 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.

During NEM, almost all the 6 locations witnessed severe drought either once or more than once. Interestingly during SWM, consecutive droughts were experienced in Senthamangalam (2001, 2002) and Namakkal (2006, 2007) such consecutive severe drought years were missing during NEM (Table 6).

Moderate drought was experienced in both monsoons. Most of the locations had witnessed 1 to 8 moderate drought years in both the monsoons. Typically in SWM, Paramathi had 8 such years affected by drought followed by Kumarapalayam (5), Namakkal and Tiruchengode (4). It is important to note that there were no consecutive years with moderate drought in SWM but it is interesting to witnessed that similar year over Paramathy (2001, 2002) and Sendamangalam (2001, 2002) experiences consecutive moderate drought during NEM.

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 7. The frequency of drought events varied among the seasons as well as the locations (Figure 7). 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 Kumarapalayam and Namakkal with 4 occurences followed by Paramathy, Rasipuram and Sendamangalam with 2 occurrences. All the rainfall locations have moderate drought events except Mangalapuram, while the location Tiruchengode had the occurrence of single moderate drought event. Paramathy had 4 severe drought events highest among the locations followed by Sendamangalam (2). It is interesting that, Namakkal, Rasipuram, Sendamangalam and Tiruchengode comes in all the drought occurrences.

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 (8) of moderate drought occurrences followed by Kumarapalayam (5). Sendamangalam (5) and Namakkal had (3) severe drought occurrences and extreme drought occurrences are noticed only in Kumarapalayam (2), Mangalapuram (2), Rasipuram (1) and Tiruchengode (1).

During NEM, Paramathy had witnessed more number of moderate droughts (7) followed by Kumarapalayam and Sendamangalam (5), Mangalapuram (3), Namakkal (2) and Rasipuram (2). The locations Tiruchengode had witnessed

Table 5. Drought categorization through SPI for SWM (1980-2018)

Sl. No	Location	Frequency of SPI value		Moderately drought	Severe drought	Extreme drought	Total drought years
		-ve	+ve				
1.	Kumarapalayam	18	21	1986, 1994, 1997, 2002, 2004	0	1980, 2012	7
2.	Mangalapuram	16	23	0	1980	2006, 2016	3
3.	Namakkal	20	19	1980,2004,2012,2015	2006, 2007, 2009	0	7
4.	Paramathy	17	22	1982,1985, 1990, 1994, 1996, 1999, 2002,2006	0	0	8
5.	Rasipuram	16	22	1994, 1999,2003	2002	2006	5
6.	Senthamangalam	18	21	1994, 1999, 2003	1980,2001, 2002, 2004, 2006	0	8
7.	Tiruchengode	22	17	1990, 2002,2011,2014	2004,2006	2004	7

Table 6. Drought categorization through SPI for NEM (1980-2018)

Sl. No	Location	Frequency of SPI value		Moderately drought	Severe drought	Extreme drought	Total drought years
		-ve	+ve				
1.	Kumarapalayam	21	18	1980, 1985, 1988, 1996, 2009	1990, 2011	0	7
2.	Mangalapuram	18	21	1985, 2001, 2012	2006, 2016	0	5
3.	Namakkal	19	20	2010, 2018	1985, 2006, 2016	0	5
4.	Paramathy	16	23	1982,1985,1990,2001, 2002,2006,2016	0	0	7
5.	Rasipuram	18	21	1992, 2001	1996	0	3
6.	Senthamangalam	16	23	1990,1996,2001,2002, 2004	1988, 1990, 1996, 2002, 2004	0	10
7.	Tiruchengode	18	21	1988	1985,1996, 2006, 2012, 2016	0	6

Table 7. Frequency of drought events categorized based on SPI values for annual and monsoon rainfall

		Annual			Southwest Monsoon			Northeast Monsoon		
Sl.No	Locations	Moderate	Severe	Extreme	Moderate	Severe	Extreme	Moderate	Severe	Extreme
1	Kumarapalayam	4	0	2	5	0	2	5	2	0
2	Mangalapuram	0	1	2	0	1	2	3	2	0
3	Namakkal	4	1	1	4	3	0	2	3	0
4	Paramathy	2	4	0	8	0	0	7	0	0
5	Rasipuram	2	1	1	3	1	1	2	1	0
6	Sendaman-galam	2	2	1	3	5	0	5	5	0
7	Tiruchengode	1	1	1	4	2	1	1	5	0

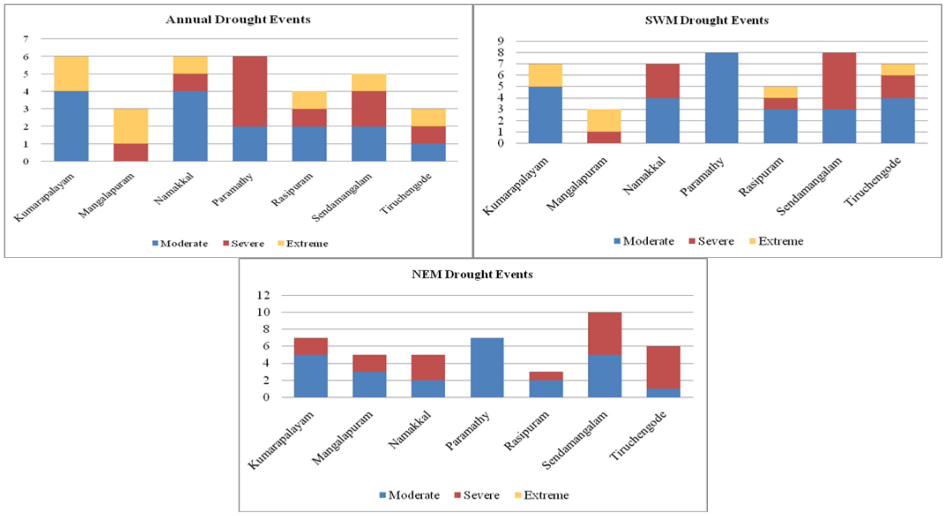

Fig. 7. Frequency of drought occurrences in Namakkal district

least of only one moderate drought occurrence. Sendamangalam and Tiruchengode had witnessed highest (5) severe drought occurrences followed by Namakkal (3). It is exciting that no locations in the study area under extreme drought during the study period. It is quite interesting that Paramathy is the only stations faces only moderate drought in both monsoon seasons.

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. Historically annual extreme negative SPI of -4.52 is observed over Tiruchengode and in SWM it is -4.44 in Rasipuram locations. The frequency of negative SPI value is varied from 13 to 20, 16 to 22 and 16 to 21 in Annual, SWM and NEM respectively. Annually, maximum extreme drought events of 2 are noted over Kumarapalayam and Mangalapuram locations. Moderate and severe drought occurrence is maximum over NEM compared to SWM; interestingly extreme drought is maximum in SWM and not observed in any location during NEM. This kind of study implicates to understand the severity and intensity of drought in location aspect for drought measurement. The spatial variability gives clear indication for making site-specific management decisions based on monsoon rainfall. This may bring out the outline scenario of drought condition over the study area and requires proper drought management plans to overcome.

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