ASSESSMENT AND MAPPING OF METEOROLOGICAL DROUGHT USING STANDARDISED PRECIPITATION INDEX FOR SOUTHERN DISTRICT OF TAMILNADU

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***Abstract*: Among the different natural hazards, drought is one of the most disastrous as it inflicts untold numerous miseries on the human societies. Drought is a long time period of dry weather, when an area gets less than its normal amount of rain, over months or even years. Crops and other plants need water to grow, and animals need water to live. Some factors driving the climatic changes such as temperature, pressure, rainfall, humidity, sea surface temperature etc. Two third of India has low precipitation which means that the precipitation rate is less than 1000mm. As per Indian Meteorological Department (IMD), Tamilnadu has Mild and moderate drought conditions. In this project, the station wise rainfall data, Landsat 7 and Landsat 8 satellite images were used for drought assessment from 2004 to 2019 with five years interval. Study area of this project was Sothern districts of Tamilnadu such as Kanyakumari, Tirunelveli, Tenkasi, Thoothukudi, Virudhunagar, Ramanathapuram, Madurai, Sivaganga, Pudukkottai and Dindigul. In that, the Standardized Precipitation Index (SPI) values are used to identify the meteorological drought SPI was calculated through Microsoft excel software and mapping was done by ArcGIS 10.3 software. As a result, 2019 is considered as a drought year compared with 2004, 2009 and 2014.**

***Keywords*: ArcGIS 10.3, Indian Meteorological Department (IMD), Microsoft Excel, Standardized Precipitation Index (SPI)**

I. INTRODUCTION

Drought is the major natural disaster which is caused by the some climatic changes. Drought has no proper definition. It may define as the prolonged shortages in the water supply due to dry weather conditions or the deficiency of normal precipitation over an extend period of time. Drought differs from other natural disaster like cyclones, flood, earthquakes, Tsunamis etc. It has no universal definition, difficult to determine the beginning and end of the event, single Index value is not sufficient to identify the severity of drought .Multiple indices can give the effective result. Impacts are generally non-structural and difficult to quantify. Some factors driving the climatic changes such as temperature, pressure, rainfall, humidity, sea surface temperature etc. 2/3 rd of India has low precipitation which means that the precipitation rate is less than 1000mm. As per Indian Meteorological Department, Tamilnadu has Mild and moderate drought conditions. Droughts are generally classified into three categories in terms of impacts. Meteorological drought, Hydrological drought and Agricultural drought.

Meteorological drought is defined as a lack of precipitation over a region for a period of time. Precipitation has been commonly used for meteorological drought analysis. Meteorological drought leads to a depletion of soil moisture and this almost always has an impact on crop production. Based on rainfall, temperature, soil moisture various indicators of meteorological drought like Standardized Precipitation Index, Palmer Drought Severity Index and Moisture Index have been developed.

II. STUDY AREA

The study area of this project is in the southern districts of Tamilnadu. Name of the districts are Kanyakumari, Tirunelveli, Tenkasi, Thoothukudi, Ramanathapuram, Viruthunagar, Sivaganga, Madurai, Pudukkottai and Dindigul. The spatial map of the study area is shown in figure 1. The previous study said, Tamilnadu has mild and moderate drought condition. Kanniyakumari is the southernmost district of Tamilnadu. The district lies between 77˚15' and 77˚36' of the eastern longitudes and 8˚03' and 8˚35' of the northern latitudes. The geographical area of kanniyakumari district is 1672 sq.km. The average rainfall over the district varies from about 826mm to 1456mm. Tirunelveli district is having a geographical area of 3907 sq.km, in the southeastern portion of Tamilnadu and is triangular in shape. It lies between 8˚44' and 8˚67' of northern latitude and 77˚ 63' and 78˚56' of eastern longitude. The average annual rainfall over the district is 879mm. Thenkasi district occupies an area of 2916.13 sq.km. . It lies between 9˚17' and 9˚29' of northern latitude and 77˚ 32' and 78˚03' of eastern longitude. Thoothukudi district is situated between latitude 8˚4' and 9˚27' N and longitude 77˚45' and 78˚20' E. The geographical area of this district is 4621sq.km. The average annual rainfall over the district varies from about 570mm to 740mm. Virudhunagar district occupies an area of 4243sq.km. It lies between 9˚12' and 9˚47' N latitude and 77˚20' and 78˚26' E longitude. The average annual rainfall over the district varies from about 724 mm to 913mm. Ramanathapuram district lies between 9˚05' and 9˚08' N latitude and 78˚1' and 79˚27' E longitude. The district receives the rainfall under the influence of both southwest and northeast monsoons. The geographical position of Sivaganga district is between 9˚32 ' and 10˚18' N latitude and 78˚08' and 79˚01' E longitude. The district occupies an area of 4189 sq.km. The average annual rainfall over the district varies from about 861.8 mm to 988.6 mm. Madurai district lies between 77˚28' and 78˚27' E longitude and 9˚32' and 10˚18' N latitude. The district has an area of 3741.73sq.km. Thenormal annual rainfall varies from 806 mm in the northern part to 964.1 mm in the eastern part of the district. The district receives the rainfall during northeast monsoon 47%, southwest monsoon 32%, summer 17% and winter 4%. The district lies between 78˚25' and 76˚16' E longitude and between 9˚51' and 10˚44' N latitudes. Pudukkottai district has an area of 4663 sq.km.The normal annual rainfall of Pudukkottai district is 821 mm. During northeast monsoons this district receives the highest rainfall of 397 mm followed by, southwest monsoons with 303 mm of rainfall. Dindigul district lies between 10˚05' and 10˚09' N latitudes and 77˚30' and 78˚20' E longitudes. The district has an area of 6266.64sq.km. The average annual rainfall over the district varies from about 700mm to 1600mm.

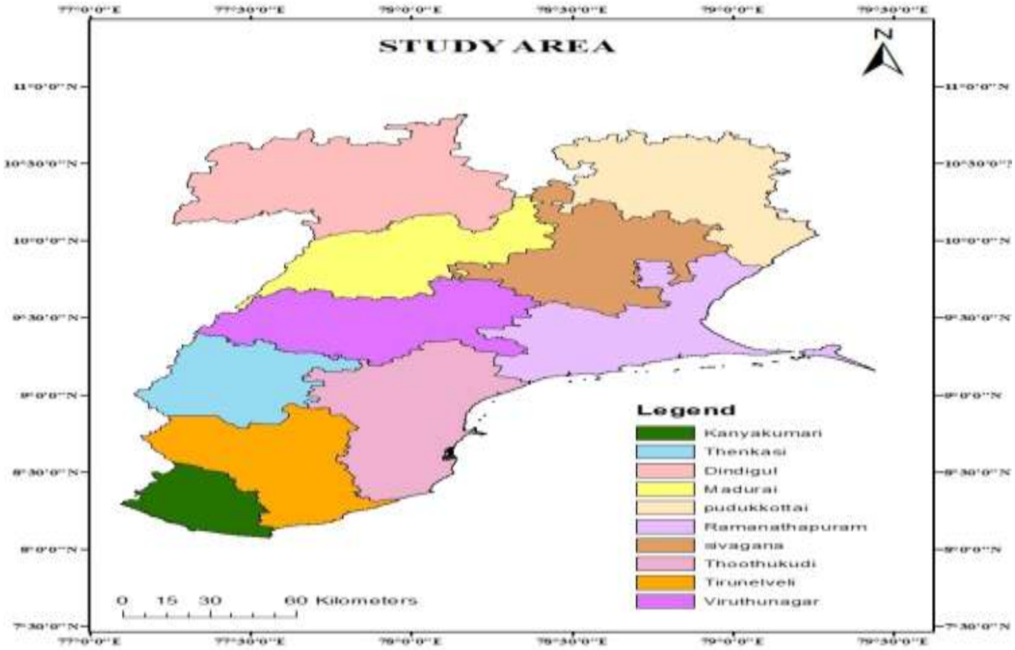


Fig 1. *Spatial Map of the study area*

III. DATA USED

Landsat 7 launched on April 15, 1999.The Landsat program is managed and operated by the USGS, and data from Landsat 7 is collected and distributed by the USGS.Landsat 7 is in a polar, sun-synchronous orbit, it scans across the entire earth's surface with an altitude of 705 km +/- 5 km. It has the repeat coverage of 16 days and the swath width of 185 km. Since June 2003, the sensor has acquired and delivered data with the data gaps caused by scan line corrector (SLC) failure. The spectral bands for Landsat 7 satellite is shown in table 1.

TABLE 1.SENSOR SPECIFICATIONS FOR LAMDSAT 7 IMAGES

Band No	Colour	Spectral Values (micrometer)	Resolution (meter)
1	Blue	0.45-0.52	30
2	Green	0.52-0.60	30
3	Red	0.63-0.69	30
4	NIR	0.77-0.90	30
5	SWIR 1	1.55-1.75	30
6	TIR	10.40-12.50	60
7	SWIR 2	2.08-2.35	30
8	PAN	0.52-0.90	15

Landsat 8 is an American Earth Observation satellite launched on February 11, 2013. It is the eighth satellite in Landsat program. The Landsat 8 satellite images the entire earth every 16 days. The Landsat 8 payload consists of two instruments – the Operational Land Imager (OLI) and the Thermal Infrared Senor and the swath width of 185 km and the band details of Landsat 8 satellite are given in table 2.

TABLE 2. SENSOR SPECIFICATIONS FOR LAMDSAT 8 IMAGES

Band No	Colour	Spectral Values (micrometer)	Resolution (meter)
1	Coastal aerosol	0.433-0.453	30
2	Blue	0.45-0.515	30
3	Green	0.525-0.6	30
4	Red	0.63-0.68	30
5	NIR	0.845-0.885	30
6	SWIR 1	1.56-1.66	30
7	SWIR 2	2.1-2.3	30
8	PAN	0.5-0.68	15
9	Cirrus	1.36-1.39	30
10	TIR 1	10.6-11.2	100
11	TIR 2	11.5-12.5	100

The station wise rainfall data collected from Statistical Department of each districts. Totally 134 rainfall station vales used for this study. The satellite data of the study area is given in table 3.

TABLE 3.DESCRIPTION OF SATELLITE DATA

Satellite Name	Sensor	Path/Row	Date Of Acquisition
LANDSAT 7	ETM+	143/53	21/04/2004
LANDSAT 7	ETM+	143/54	04/03/2004
LANDSAT 7	ETM+	142/54	10/04/2004
LANDSAT 7	ETM+	142/53	27/05/2004
LANDSAT 7	ETM+	143/53	18/03/2009
LANDSAT 7	ETM+	143/54	19/04/2009
LANDSAT 7	ETM+	142/54	27/04/2009
LANDSAT 7	ETM+	142/53	19/05/2009
LANDSAT 8	OLI	142/53	09/04/2014
LANDSAT 8	OLI	143/54	11/05/2014
LANDSAT 8	OLI	142/54	22/05/2014
LANDSAT 8	OLI	142/53	19/05/2014
LANDSAT 8	OLI	143/53	06/03/2019
LANDSAT 8	OLI	143/54	07/04/2019
LANDSAT 8	OLI	142/54	22/04/2019
LANDSAT 8	OLI	142/53	07/04/2019

IV. METHODOLOGY

This methodology is mainly deals with the assessment of drought in various years 2004, 2009, 2014, and 2019and is shown in figure 2. Collect the rainfall data from the District statistical department and collect the Landsat images from USGS for our study area. To correct the errors from the data, do the cloud correction and strip adjustment process then mosaic the data in ArcGIS software. Using the Gamma distribution function, the SPI can calculate in Microsoft excel. Then calculate the meteorological drought for the study area.

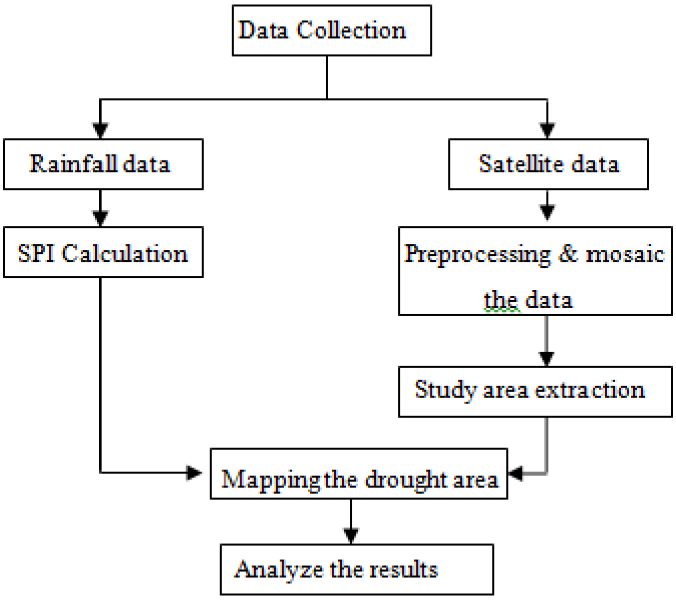


Fig 2. Flow chart for meteorological drought assessment

SPI is one of the best methods to calculate Meteorological drought. It needs only the precipitation data. The SPI is an indicator used to classify and quantify meteorological droughts in a range of different timing across different parts of the earth. It can calculate for 1month, 3-months, 6-months and 12 months time period. In that, 3-months SPI (March, April, and May) was calculated by using Gamma Distribution Function with the help of Microsoft Excel software. The condition of the study area is classified based on the SPI value (National Institute of Hydrology- Roorkee) which is shown in table 4.

i. To calculate Gamma distribution function:

$$g(x) = \frac{x^{\alpha-1}}{\beta\Gamma(\alpha)} \times e^{-x/\beta}$$

Where,

G(x) = Probability Distribution Function

x = Rainfall Rate (mm)

α = shape factor (α >0)

β = scale factor (β>0)

ii. To find α:

$$\alpha = \frac{1\{1+\sqrt{(1+4a)/3}\}}{4A}$$

Where,

$$A = \ln(x) - \frac{\sum \ln(x)}{N}$$

N= Number of rainfall

iii. To find β:

$$\beta = \frac{X}{\alpha}$$

X= Mean rainfall (mm)

iv. To find mean rainfall:

$$X = \frac{\sum x}{N}$$

v. To find Cumulative Probability Function H(x):

$$H(x) = q + (1-q)G(x)$$

Where,

q = Probability distribution function

vi. To find SPI, Z:

a) 0<H(x)<=0.5

$$Z = -\left(t - \frac{c_0+c_1t+c_2t^2}{1+d_1t+d_2t^2+d_3t^3}\right)$$

b) 0.5<H(x)<=1

$$Z = +\left(t - \frac{c_0+c_1t+c_2t^2}{1+d_1t+d_2t^2+d_3t^3}\right)$$

Where,

$c_o = 2.515517$, $c_1 = 0.802583$, $c_2 = 0.010328$, $d_1 = 1.432788$, $d_2 = 0.189269$, $d_3 = 0.001308$

a) 0<H(x)<=0.5

$$t = \sqrt{ln\left(\frac{1}{H(x)^2}\right)}$$

b) 0.5<H(x)<=1

$$t = \sqrt{ln\left(\frac{1}{[1 - H(x)]^2}\right)}$$

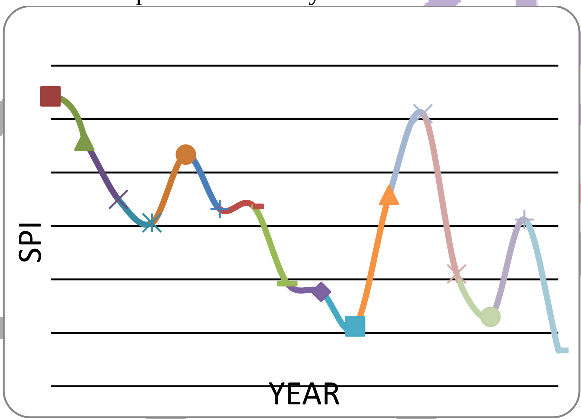
TABLE 4. DROUGHT CONDITION BASED ON SPI VALUES

SPI Values	Conditions
>2	Extremely wet
1.5 to 1.99	Very wet
1 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
<-2	Extremely dry

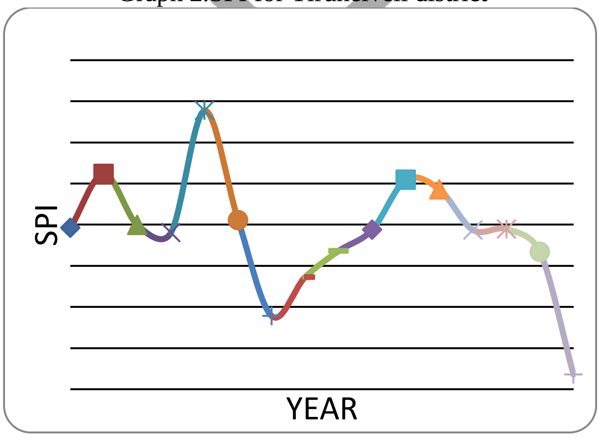
V. RESULTS AND DISCUSSION

The SPI values of summer season (March to May) for 2004 to 2019 were calculated through Microsoft excel software. Total of 134 rain gauge station values used for calculating SPI. The SPI distribution map was generated using IDW tool in Arc map. The SPI map shows that it varying with different years. Graphical representations of SPI values are shown following:

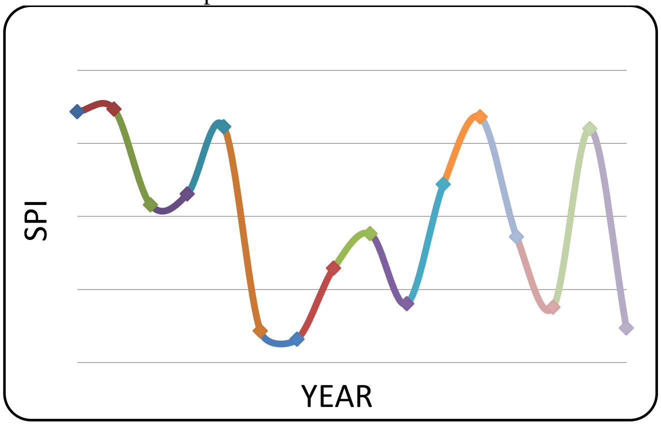
Graph 1.SPI for kanyakumari district



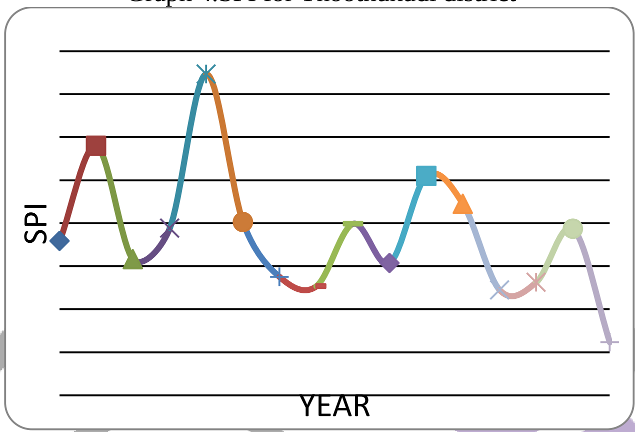
Graph 2.SPI for Tirunelveli district



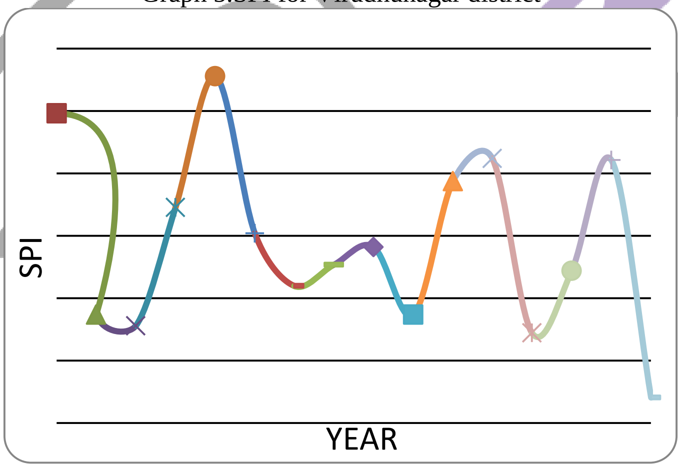
Graph 3.SPI for Tenkasi district



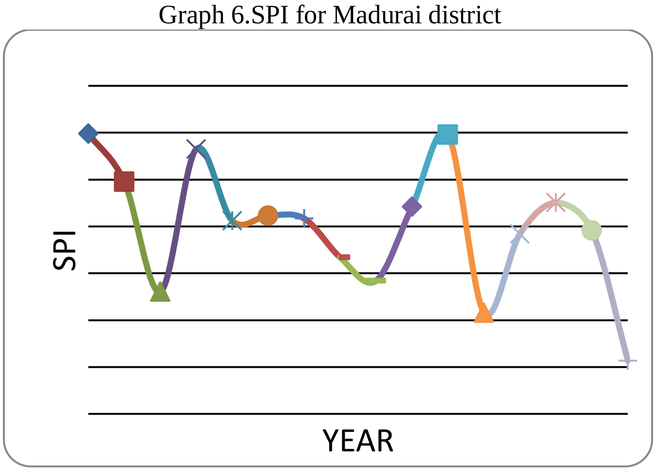
Graph 4.SPI for Thoothukudi district



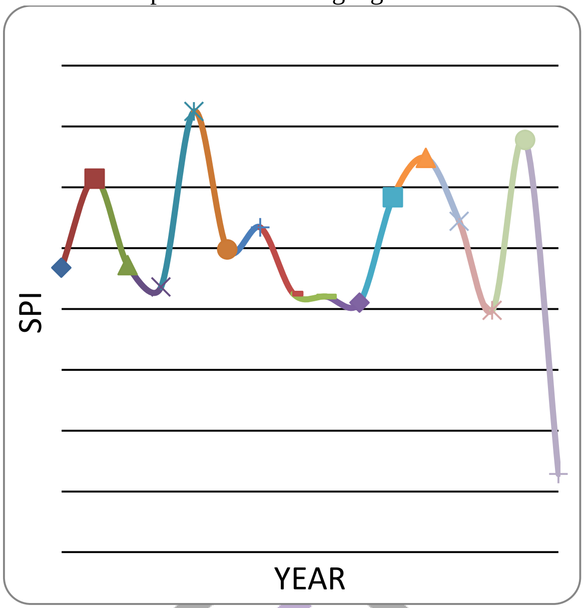
Graph 5.SPI for Virudhunagar district



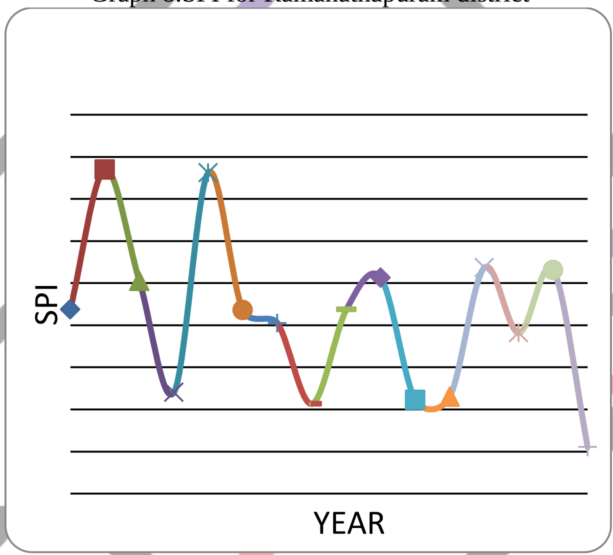
Graph 6.SPI for Madurai district



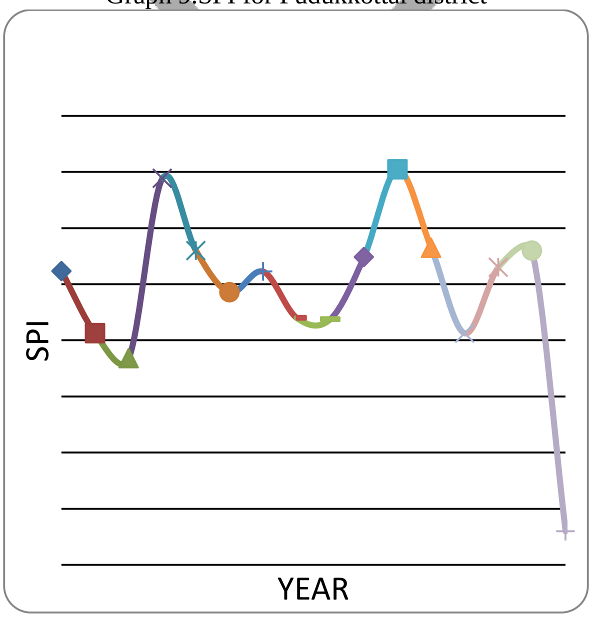
Graph 7.SPI for Sivaganga district



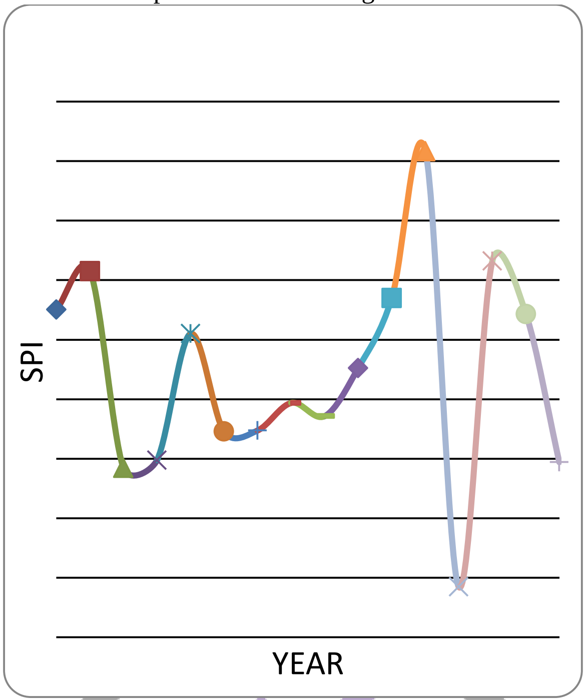
Graph 8.SPI for Ramanathapuram district



Graph 9.SPI for Pudukkottai district



Graph 10.SPI for Dindigul district



From Gamma distribution function, the SPI values are calculated and the study area can be classified based on the drought conditions. The drought conditions of study area are shown in table 5 and the RMSE calculation using cumulative probability values are shown in table 6.

TABLE 5.METEOROLOGICAL DROUGHT CONDITIONS

Districts	2004	2009	2014	2019
Kanyakumari	MW	NN	NN	MD
Tirunelveli	NN	NN	NN	SD
Thoothukudi	NN	NN	NN	MD
Tenkasi	NN	NN	NN	NN
Virudhunagar	NN	NN	NN	MD
Ramanathapuram	NN	NN	NN	SD
Madurai	NN	NN	NN	MD
Sivaganga	NN	NN	NN	SD
Pudukkottai	NN	NN	MW	ED
Dindigul	NN	NN	NN	MD

Here,

NN- Near normal condition
MW- Moderate wet condition
MD- Moderate dry condition
SD-Severely dry condition
ED-Extremely dry condition

The SPI distribution map for 2004 is shown in figure 3. Kanyakumari district and some areas in Madurai & Virudhunagar districts get moderate wet conditions in 2004. The SPI distribution map for 2009 is shown in figure 4. From that, most of the area gets near normal condition. Figure 5 shows the SPI distribution map for 2014 and Figure 6 shows the SPI distribution map for 2019. Compare to 2009, the rainfall rate has increased in 2014. The SPI map 2019 indicates more drought condition compare to previous year.

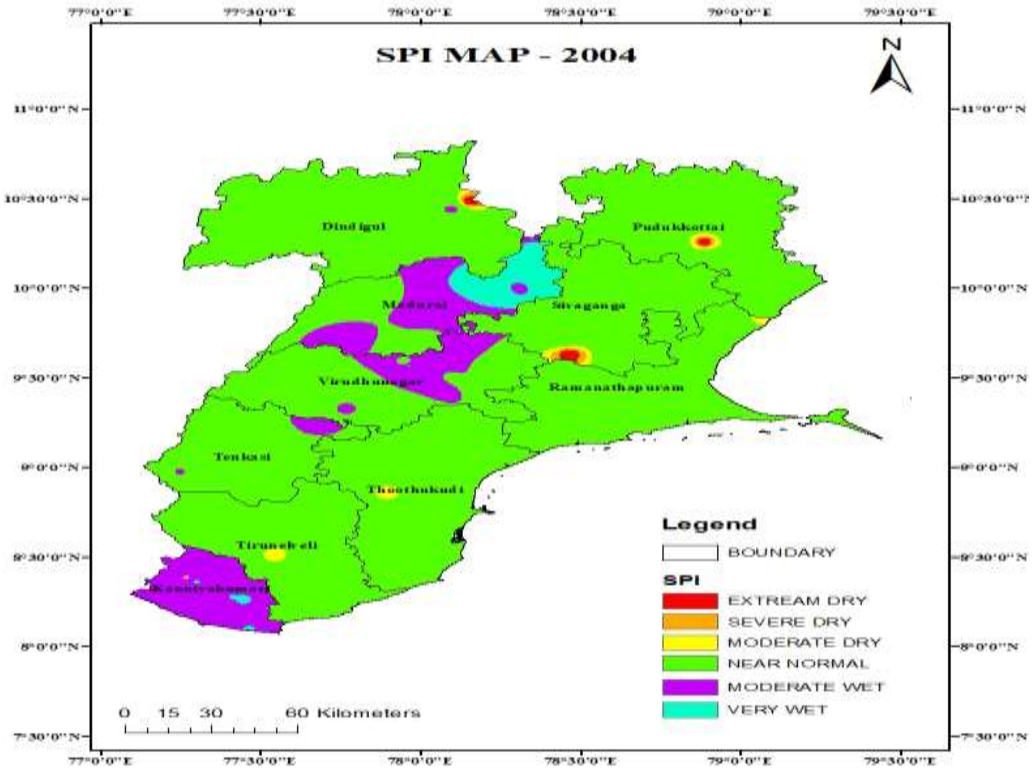


Fig 3. SPI map for the year 2004

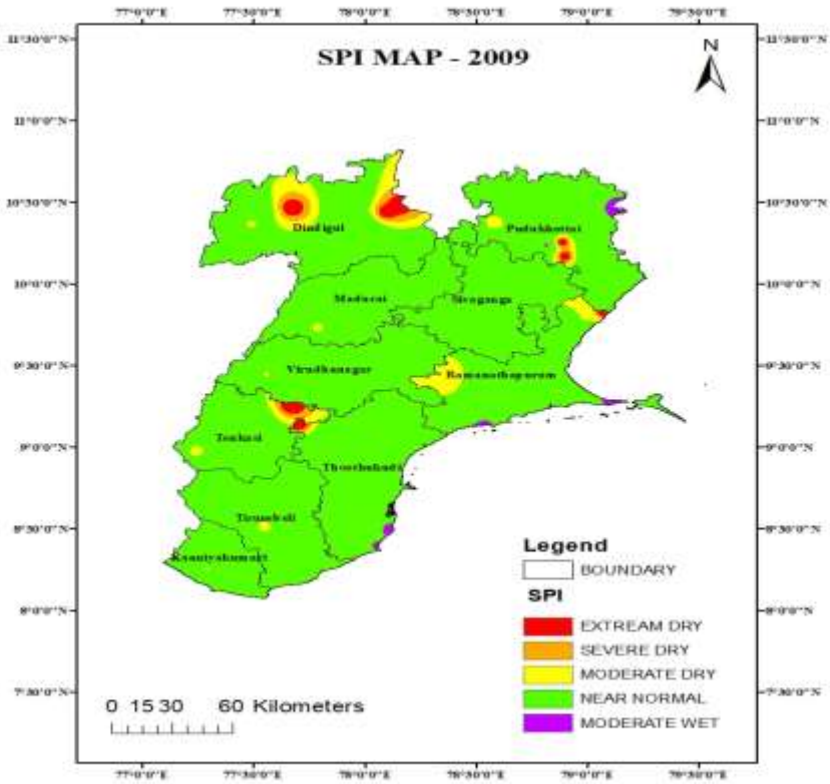


Fig 4. SPI map for the year 2009

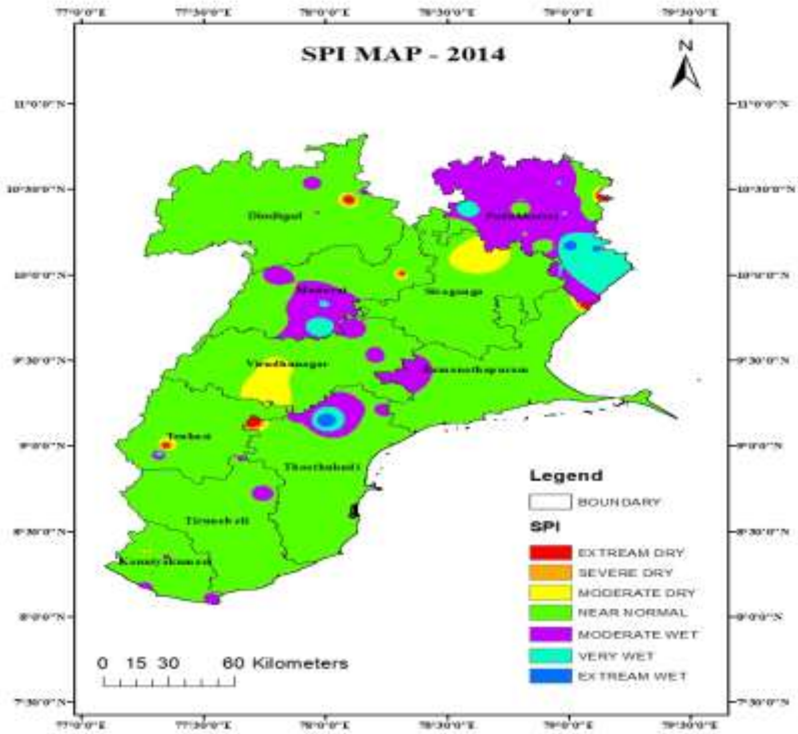


Fig 5. SPI map for the year 2014

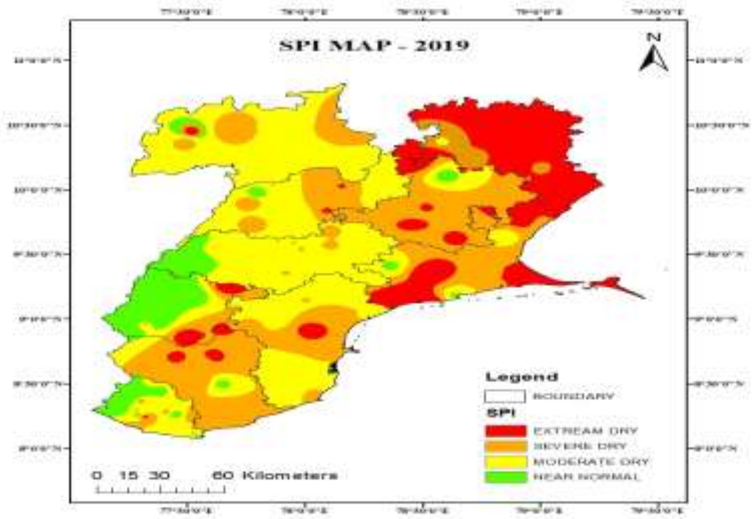


Fig 6. SPI map for the year 2019

TABLE 6. CUMULATIVE PROBABILITY FOR SPI VALUES

SPI	Actual probability	Observed probabilty	RMSE
-2	0.028	0.020	
-1.5	0.0668	0.061	
-1	0.1587	0.161	
-0.5	0.3085	0.310	
0	0.5	0.504	0.00342
0.5	0.6915	0.694	
1	0.8413	0.844	
1.5	0.9332	0.932	
2	0.977	0.972	

VI. CONCLUSION

This study attempts to identify the meteorological drought for southern districts of tamilnadu such as kanyakumari, tiruneveli, tenkasi, thoothukudi, virudhunagar, ramanahapuram, Madurai, sivaganga, pudukkottai and dindigul for last 15 years (2004 to 2019). The index properties are used to found the various droughts. In addition, it can also be employed to explain drought classes in the research areas through various indices. From meteorological drought assessment, the year 2004 gets moderate wet condition to near normal condition over the study area. But the year 2019 gets moderate dry to severe dry condition because the amount of rainfall decreases from 2004 to 2019.

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