International Journal of Research in Engineering, Science and Management
Volume-3, Issue-6, June-2020
www.ijresm.com | ISSN (Online): 2581-5792

Spatial and Temporal Analysis of Drought Using GIS Techniques

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***Abstract*: Drought is a natural disaster which leads to crops, food and water shortages along with destruction of ecological system. Drought are frequently occurring in our country in various regions so in Maharashtra in the satara district drought are occure in Man and khatav Taluka. In Satara District where about 80 percent of agriculture land is rain fed. Also this region is witnessing rapid urbanization due to which thirst for water for drinking as well as industrial use is demanding. The study of drought along various area is extremely important as it is related with crop farming and management of scarce water resource, which becomes critical in various of drought types. As the SPI-time scale is able to detect significant trend at rain gauge stations, number of stations having significant trend increases as the SPI time scale increases up to various SPI stations. This analysis of drought by using various method may help to solve problems related with floods, droughts and allocation of water for agriculture use, various industries, hydro-power generation, domestic use. With the help of SPI values we can study and gave solution to particular area according to severity of that area with help of severity chart of SPI method.**

To determine the severity of drought and the results of Standardized precipitation index are proven more accurate after studying using standardized precipitation index. We are preparing the triangular irregular network and after that we are trying to solve the problem of drought such that the suggesting crop patterns and also supplying water from the area were excess rainfall, takes place and by suggesting structure such as lakes, dams, etc., to overcome the problem of drought. By studying the topographical maps also finding economical way to supply were to the area with maximum efficiency also.

***Keywords*: Drought area, SPI Values, GIS Study, TIN model.**

1. Introduction

Drought is one of the most devastating natural disasters that often affect human life and performance. Drought indicators for drought monitoring analyse data from thousands of information about relative humidity (RH), rainfall, temperature, flow, wind speed, humidity, etc., and data at different times. It is very difficult to pinpoint the beginning or the middle of the period or even the end of the drought as a prediction of this phenomenon.

The concept and definition of drought depend on the natural weather conditions, agricultural methods, existing water resources, and the various economic and social characteristics of the various regions. The arid and semi-arid regions are more.

Vulnerable to drought in the world, which occurs in many different ways, and this is the same in India and particularly in parts of Maharashtra. There are different interpretations of the drought between different researchers, and some researchers consider the high rainfall to be a sign of drought in a short period of time, but this short period of good rainfall may not be stable, so we need to look at the historical data in the long period. The evidence and effects of drought and the increase in drought in India have been increasing rapidly in recent years.

To obtain the amount of drought occurring in the area as well as predicting future droughts, it is necessary to use different models of meteorology and satellite imagery, but some of these variations of droughts can also be derived from a historical survey of rainfall and humidity and change the air temperature is also checked.

Standardized Precipitation Index (SPI) use to study drought analysis and monitoring systems because it is suitable for different climate zones in the country, but maybe because India is a wide country and there are different climate in the country so it needs to look at what type of indices are used in each area. The SPI index calculates the drought in a region based on rainfall and can be used at different time scales. This indicator can be useful for both applications in agricultural and long term hydrological indicators. The SPI classification is shown in terms of rainfall, calculated at 3, 6, 9 or 12, and more often as severe aggression. When a drought occurs, the SPI is consistently negative and reaches a peak of -1.0 or less and when the SPI number is positive, it shows the wetness and absence of drought in the region. GIS Study prepare TIN (Triangular irregular network) model of drought area. Use GIS software to give solution for minimize drought problem by using various methods.

2. Literature Review

"Drought monitoring and analysing on typical karst ecological fragile area based on GIS"- Jiang Tao, Zhou Zhongfa and Cao Shui (2011).

This paper examined the various drought prone region of south west china using drought assessment system based on GIS with its strong managing and analysing function and this study shown the drought situation, grade and relief time of

study area**.**

"GIS based variability and drought characterization in Ethiopia over three decades" K. V. Suryabhagavan (2017).

In this paper the climate changes and drought frequency over p crop growing region of Ethiopia during the study period over analysed data from 87 weather station across the country over used for data analysis. Methodology adopted is standardisation precipitation index. Geographic information systems (GIS) and modelling are used for agricultural resource and natural resource management.

"Agricultural drought analysis using the NDVI and land surface temperature data; Case study of Raichur district"- Sruthi. S, M. A. Mohammed Aslam (2015).

In these paper study is based on increasing temperatures and altered precipitation patterns with help of NDVI and land surface temperature techniques. The MODIS data is used for the calculation of NDVI as well as land surface temperature the combination of NDVI and LST, provides vary useful information for agricultural drought monitoring and early warning system for farmers.

"Spatial assessment of drought severity in Cape Town area, South Africa" I. R. Orimoloye, O. O. Ololade, S. P. Mazinyo, A. M. Kalumba (2019).

In these paper many African countries including south Africa often with devastating implication on food security studies have shown that temperature has increased over recent years which can trigger drought occurrence and climate related hazards. This study is aim at apprising drought severity in cape town area using GIS and remotely sensed data obtain from USGS (united states geological survey) data based between years 2014-2018.

"Spatial and temporal drought Analysis of Raichure district, INDIA"–Reza Rawanshad, Maruthi. N. E and H. T. Basavarajappa (2019).

In these paper study was conducted to find drought from 1996 to 2016 and climate change indicators in Raichure area using data sets such as rainfall, humidity, temperature and wind speed. These study has been analyzed with different methods such as statistical probability based on GIS and SPI with help of satellite imagery and NDVI preparation for the area.

3. Proposed Area

Khatav Taluka: Khatav is situated to the south of the Satara district. Khatav is in between the Man, Karad, Phaltan and Koregaon talukas and Sangli district boundary. The Khatav taluka receives less rainfall than most of other and is categorised as a drought affected region. Coordinates: 17.6545°N 74.3614°E.

Mann Taluka: It is one of the important taluka of Satara District. Maan is located at Dahivadi (Maan coordinates: N, 74° 30' E) lies on the right bank of the Maan on the Pusesavali-Shingnapur road, 60 km east of Satara and about 6.4 km from the junction of the above-mentioned road with the Satara Pandharpur road.

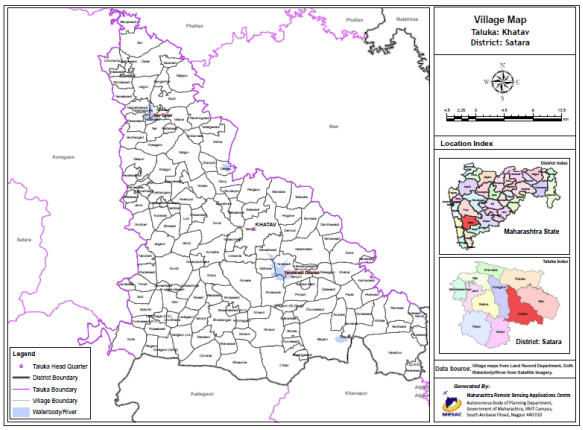

Fig. 1. Location map of Study area (Khatav Taluka)

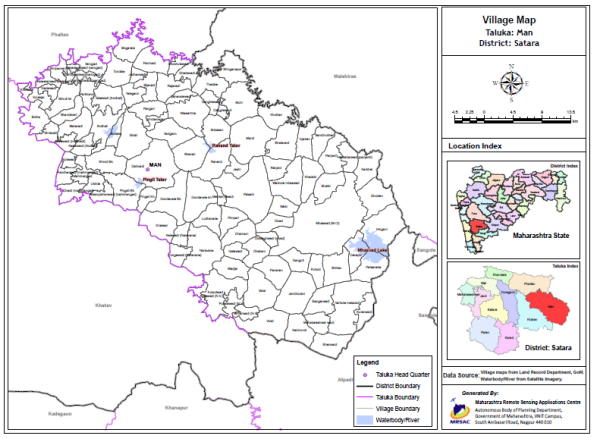

Fig. 2. Location map of study area (Mann Taluka)

4. Methodology

Important parameters of drought monitoring is rainfall, which affects the amount and distribution of vegetation in one area Drought monitoring and evaluation requires a large set of historical data, which includes sophisticated communication between meteorological data and various sciences. To analyze the changes in the climate due to the change in rainfall and the identification of areas at risk of drought, rainfall data from 1999 to 2019 were surveyed. In this research, two different methods have been used to obtain drought severity and increase the accuracy of data. The first method is data acquisition from meteorological stations and data analysis, and use of the SPI index, which has been studied over different periods. The second method is use of Q-GIS software for preparation of TIN model, use triangular irregular network(TIN) to solve the problem of drought such that the suggesting crop patterns and also supplying water from the area were excess rainfall, takes place and by suggesting structure such as lakes, dams, etc to overcome the problem of drought

Standardized Precipitation Index(SPI):

The Standardized Precipitation Index (SPI) is an indicator used to classify and quantify meteorological droughts in a range of different timing across different parts of the earth. In recent

decades, many studies have been conducted on the performance of SPI in various climatic locations, indicating that SPI index has good performance in different area, but it is still recommended for each individual index location use different types of indicators.

Procedure and Formula for Computation of SPI

1) Mean of the precipitation can be computed as:

$$\text{Mean} = \bar{X} = \frac{\sum x}{N}$$

Where; N is the number of precipitation observations

2) The standard deviation for the precipitation is computed as:

$$S = \sqrt{\left[\frac{\sum(X-\bar{X})^2}{N}\right]}$$

3) The skewness of the given precipitation is computed as:

$$\text{Skew} = \frac{N}{(N-1)(N-2)} \sum \frac{(X-\bar{X})^3}{S}$$

4) Gamma distribution is expressed in terms of its probability density function.

$$g(x) = \frac{1}{\beta^{\alpha}\tau(\alpha)} x^{\alpha-1} e^{-x/\beta} \quad \text{For } x>0$$

α is the shape parameter, β is a scale parameter, x is the rainfall amount (mm), Γ(α) is the value taken by Gamma function, The Γ(α) is the value defined by a standard mathematical equation called Gamma function and -x is mean rainfall (mm).

$$\tau(\alpha) = \int_0^{\infty} y^{\alpha-1} e^{-y}\, dy$$

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

Where; α, β, x have the same meaning as given in Equation

$$\text{SPI} = -\left(K - \frac{c0 + c1K + c2K^2}{1 + d1K^2 + d2K^3}\right) \quad 0 < H(X) \leq 0.5$$

$$\text{SPI} = +\left(K - \frac{c0 + c1K + c2K^2}{1 + d1K^2 + d2K^3}\right) \quad 0.5 < H(X) \leq 1$$

Where

c0 = 2.515517, c1 = 0.802583, c2 = 0.010328, d1 = 1.432788, d2 = 0.189269, d3 = 0.001308

The value of k in SPI + and SPI - were determined using K given as:

$$K = \sqrt{\text{In}\left[\frac{1}{H(X)^2}\right]} \quad \text{for } 0 < H(X) \leq 0.5$$

$$K = \sqrt{\text{In}\left[\frac{1}{H(X)^2}\right]} \quad \text{for } 0.5 < H(X) \leq 1$$

The SPI calculation process follows these flow charts using a monthly time scale in rain and temperature. In this study, SPI values were calculated using a SPI value drought is classified by following category:

SPI	Drought category
0 to -0.99	Mild drought
-1.00 to -1.49	Moderate drought
-1.5 to -1.99	Severe drought
-2.00 or less	Extreme drought

5. Analysis

By using GIS technique and average annual rainfall of the area the TIN (triangular irregular network) of Khatav talukha are plotted in QGIS software and map of average annual rainfall formed with different color shade for different rainfall are as given below,

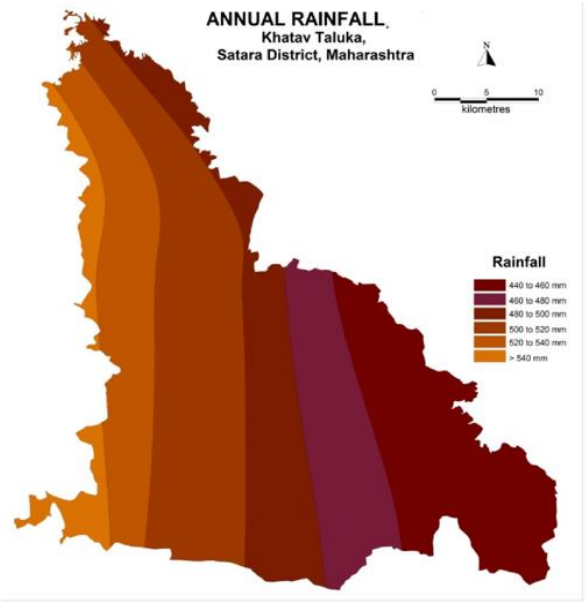

Fig. 3. Annual Rainfall - Khatav Taluka

Average Annual Rainfall in mm

YEAR	RAINFALL DATA		
	Station KHATAV	Station MHASWAD	Station MANN
2004	534.2	451.5	560.4
2005	572.8	584.2	585.6
2006	570.6	439.6	389.7
2007	595.3	293.4	585.9
2008	455.1	219.7	440.6
2009	377.1	306.1	422.1
2010	227.5	396.9	552.4
2011	242.2	393.9	443.4
2012	269.6	275.4	469.9
2013	392.6	402	433.7
2014	483.1	401.6	523.2
2015	381.3	543.7	357.6
2016	149.4	398.1	218.1
2017	353.9	192.9	386.9
2018	311	322.7	434.2

Above data gives average annual rainfall of Khatav, Mhaswad, Mann station which are three stations of satara district. By using the annual rainfall, we calculate the mean of precipitation, standard deviation, skewness, gamma distribution and SPI values by using the standard formulae's. After

calculating the SPI values we compare this values with SPI table and finding the drought severity.

SPI values:

Standardized Precipitation Index (SPI) gives probability distribution function. SPI index has importance in previous years as drought indicator gives comparisons across space and time in area. Computation of SPI requires long term data of precipitation to determine the probability distribution function which is then transformed to normal distribution with mean of zero and standard deviation one. Computation of SPI value using two parameter gamma distribution and evaluation of SPI as a drought indicator in two districts having contrasting rainfall patterns constitute the subject of the current research paper. Computation of SPI with time series data, at a monthly scale, was carried out basis on the two parameter gamma distribution function. The annual rainfall data were transformed into log normal values which can be used for computation of U statistics, shape and scale parameters of the gamma distribution. Using methodology, SPI value calculated are as follows:

Year	Station KHATAV		Station MHASWAD		Station MANN	
	Rainfall Data	SPI Value	Rainfall Data	SPI Value	Rainfall Data	SPI Value
2004	534.2	-0.93	451.5	-1.2	560.4	-0.86
2005	572.8	-0.84	584.2	-0.835	585.6	-0.83
2006	570.6	-0.85	439.6	-1.24	389.7	-1.32
2007	595.3	-0.79	293.4	-1.51	585.9	-0.83
2008	455.1	-1.21	219.7	-1.65	440.6	-1.2
2009	377.1	-1.35	306.1	-1.43	422.1	-1.26
2010	227.5	1.64	396.9	-1.299	552.4	-0.87
2011	242.2	-1.57	393.9	-1.30	443.4	-1.23
2012	269.6	-1.54	275.4	-1.4	469.9	-1.19
2013	392.6	-1.31	402	-1.27	433.7	-1.25
2014	483.1	-1.15	401.6	-1.28	523.2	-0.99
2015	381.3	-1.34	543.7	-0.89	357.6	-1.36
2016	149.4	-1.77	398.1	-1.3	218.1	-1.66
2017	353.9	-1.37	192.9	-1.71	386.9	-1.33
2018	311	-1.401	322.7	-1.39	434.2	-1.245

6. Conclusion

In this research, drought and climate change monitoring were carried out by analyzing varieties of rainfall varieties in different Talukas that indicate the growth of drought in the Satara district but, according to studies conducted in other districts around this drought time, severity is low. There are other methods that can be used in this process, the SPI method is very useful methods. In this research, spatial and temporal drought characteristics of Mann and khatav were evaluated using SPI drought index. The process of environmental surveys and the use of various meteorological models also benefited from the drought phenomenon in the region and provided valuable results. The information and data obtained in this area for monitoring and forecasting drought are also useful for the future, with specific plans to control and reduce the impact of drought on drinking water and agriculture in the region.

SPI is used in different time series to show severe drought and the years without drought, which was calculated at Mann and khatav at many stations over different periods of time and showed that the lowest rainfall in Khatav station in 2010, 2011, and 2016, it was less than 250mm, In Mhaswad 2008and 2017, in Mann 2016 indicating that SPI value about -1.6 with severe drought, is still not very dry. In general, the drought does not show difficulty for mann and khatav, but because of the difference in altitude in the region and the difference in point pressure, in recent years, there may be point dry in areas with higher air temperatures.

As noted in the data collected, rainfall and SPI in different parts of the Mann and Khatav show that droughts have progressed in years from 2004 to 2018. After a rainy year, one or three times the dry years. One of the problems identified in the research was that in some years there was a drought in some years of drought for two or three years of low rainfall that had an effect on water resources and agriculture, but it was compensated in the years to come.

The final conclusion is that annual rainfall is less than normal. The average temperature is the normal, but in 2016, we had a high temperature and Relative Humidity (RH), the amount of water vapour (vapour pressure) that increases in the air at an upper limit We have seen that 2016 is a dry year. The SPI index data predict a severe drought in the area.

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