SPATIAL AND TEMPORAL DROUGHT ANALYSISBY USING GIS AND SPIIN RAICHUR DISTRICT, INDIA

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ABSTRACT:

Drought is a natural phenomenon that has occurred over the years from the life of the earth, and it is always happening due to natural and artificial factors, and its effects have increased in recent years with population growth, increasing water use, deforestation, urbanization and growth of population on the earth. Drought is one of the natural disasters that result in less than normal rainfall or expected precipitation, and it depends on how low this rainfall is for several years and continues to indicate the severity of droughts. To monitor the drought, a variety of data, including historical meteorological data, satellite imagery and create metadata is required. Raichur is effected by the drought in the past few years with losses to agricultural products and water resources. Therefore, the present study was conducted to find drought from 1996 to 2016 and climate change indicators in the Raichur area using data sets such as rainfall, humidity, temperature and wind speed. This study has been analysed with different methods such as statistical probability based on GIS and SPI with the help of satellite imagery and NDVI preparation for the area. The reason for the use of many different methods is to compare them with each other, as well as obtaining precise results of drought.

KEYWORDS: Drought, GIS, SPI, NDVI, Rainfall and Raichur.

1. INTRODUCTION:

Drought is one of the most devastating natural disasters that often affect human life and performance. The researchers have developed and designed a number of tools for defining, initiating, impacting, intensifying and ending the drought, although these tools still do not have the required efficiency and accuracy, but are in development, and some of these indicators are also of quality and with high precision. 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. Drought is one of the main causes of agricultural, economic and environmental damage to modern humans (Wilhite 1993).

Drought in general, short or long-term rainfall in one season or more, is characterized by drought and the shortage of water needed for drinking and other uses for humans and animals and vegetables.Every definition and description of drought in India is legally accepted. Some states mention climatic conditions, refer to droughts in their definitions. The state government affects the final power as a region as a drought. In a particular area of the state, drought can occur under various climatic conditions, but their effects and events occur more in dry and semi-arid conditions (Quiring (2009).

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 Karnataka. 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. There are several ways to develop drought indicators and research for the performance of previous indicators and improvement (Gonzalez and Valdes, 2006).

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. Therefore, researchers have used various methods to measure the accuracy of these data, one of which is the use of SPI indices. In India, researchers use this Standardized Precipitation Index (SPI) 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.

2. STUDY AREA

The Raichur area is in the administrative district of Karnataka, centered at Raichur City,It is located 409 km from the state capital, Bangalore.In the northern part of Bajapur and Bagalkot in the northwest, Koppal in the west, the Bellary district in the south, Mahabubnagar district of Telangana and Kurnool Andhra Pradeshin the East, the Krishna River in almost the North and the Tangabad River in the south. Raichur city is located at 16.2°N 77.37°E with an average elevation of 407 meters is the main city of this district.

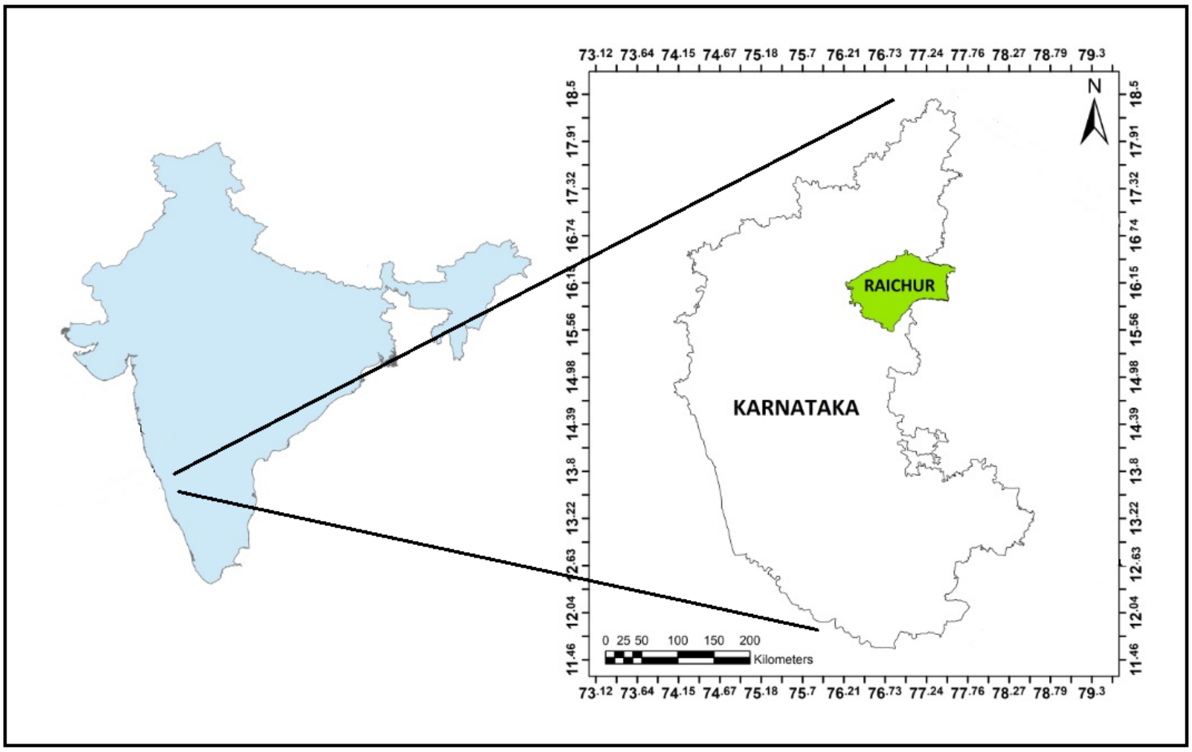

Fig.1. location map of the study area

3. METHODOLOGY:

Drought monitoring and evaluation requires a large set of historical data, which includes sophisticated communication between meteorological data and various sciences. One of the important parameters of drought monitoring is rainfall, which affects the amount and distribution of vegetation in one area. 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 1996 to 2016 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 the preparation of maps and diagrams of rainfall change over the past 21years, the second method is the use of the SPI index, which has been studied over different periods.

Standardized Precipitation Index(SPI):

The Colorado State University researchers at SPI in 1993 developed an indicator that used simple methods compared to other indicators and was first used for critical water conditions in Colorado and as a supplement to the PDSI index and several other drought indicators for water problems.Short-term time scales allow the SPI to identify information on monitoring short-term sources of water, such as water for agricultural production, soil moisture, and for long-term indications of groundwater resources and their predictions. SPI is a method with standard deviations that observe rainfall from the meteorological average. Some of the parameters of the SPI index are different from those of other indexes. The ability to examine different timing allows short and long-term droughts to be identified and monitored. SPI describes meteorological droughts around the world (Hayes 2000).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 this index has good performance in different locations, but it is still recommended for each individual index area use different indicators.

Advantages of the Standardized Precipitation Index(SPI):

- Simple operation in entering overhead data without special complexity.
- View and describe drought at different time scales
- Describe the dry and wet period in the same way and this can be compared in regions with very different weather conditions.
- Applicable for different periods of 1 to 36 months.
- SPI standardization allows this indicator to determine the frequency of the current drought.
- SPI only needs monthly precipitation. Describe the dry and wet period as well.

Disadvantages of the Standardized Precipitation Index (SPI):

- Short-term courses (1 to 2 months) of low rainfall areas can determine misleading SPI values.
- Short-term courses (1, 2 months) Low-scaled areas can be a misleading SPI, access to a long and reliable time scale, is most likely to work for meteorological droughts.

In this research in the Raichur area, a total of 3-month data was used. Then, the SPI values were sorted and drought evaluated.

The choice of the gamma distribution function in a particular region was preferred in this study because it is suitable for data on the speed of time and temperature variations. Gamma distribution is expressed in terms of its probability density function.

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

In this formula 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).

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

$$\beta = \frac{\bar{x}}{\alpha}$$

Where; α, β, x have the same meaning as given in Equation 1, and A is a sample statistic.

$$A = \ln(\bar{x}) = \frac{\ln x}{n}$$

n is the number of observations

$$SPI = -\left(k - \frac{c_0 + c_1 k + c_2 k^2}{1 + d_1 k + d_2 k^2 + d_3 k^3}\right) \; for \; 0 < H(x) \leq 0.5$$

$$SPI = +\left(k - \frac{c_0 + c_1 k + c_2 k^2}{1 + d_1 k + d_2 k^2 + d_3 k^3}\right) \; for \; 0.5 < H(x) < 1$$

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

$$k = \sqrt{\ln\left(\frac{1}{H(x)^2}\right)} \; for \; 0 < H(x) \leq 0.5$$

$$k = \sqrt{\ln\left(\frac{1}{1 - H(x)^2}\right)} \; for \; 0.5 < H(x) < 1$$

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 monthly time scale.

3. ANALYSIS

The SPI calculation for a specific time period in each location requires a monthly database for both short and long term periods. Any long-term information for more than 30 years shows a better result for SPI, so there's a need to get a database of historical rainfall data from previous years, because the longer it takes, the result will be better.The probability distribution function is determined by a long-term record using a function to the data. The cumulative distribution is then converted using probability, is equal to the normal distribution with mean zero and standard deviation of one, so the SPI value is in standard deviation (Edwards and McKee 1997).

SPI values are calculated for a normal distribution, it can be expected that these values are the standard deviation of approximately 68% of the time, during two standard deviations of 95% of the time and at three standard deviations of 99% of the time. An appropriate interpretation is that the SPI value is less than -1.0 in the past 100 years, 16 times, SPI is less than -2.0 -2 to three times in 100 years, and SPI is less than -3.0 once in about 200 years.

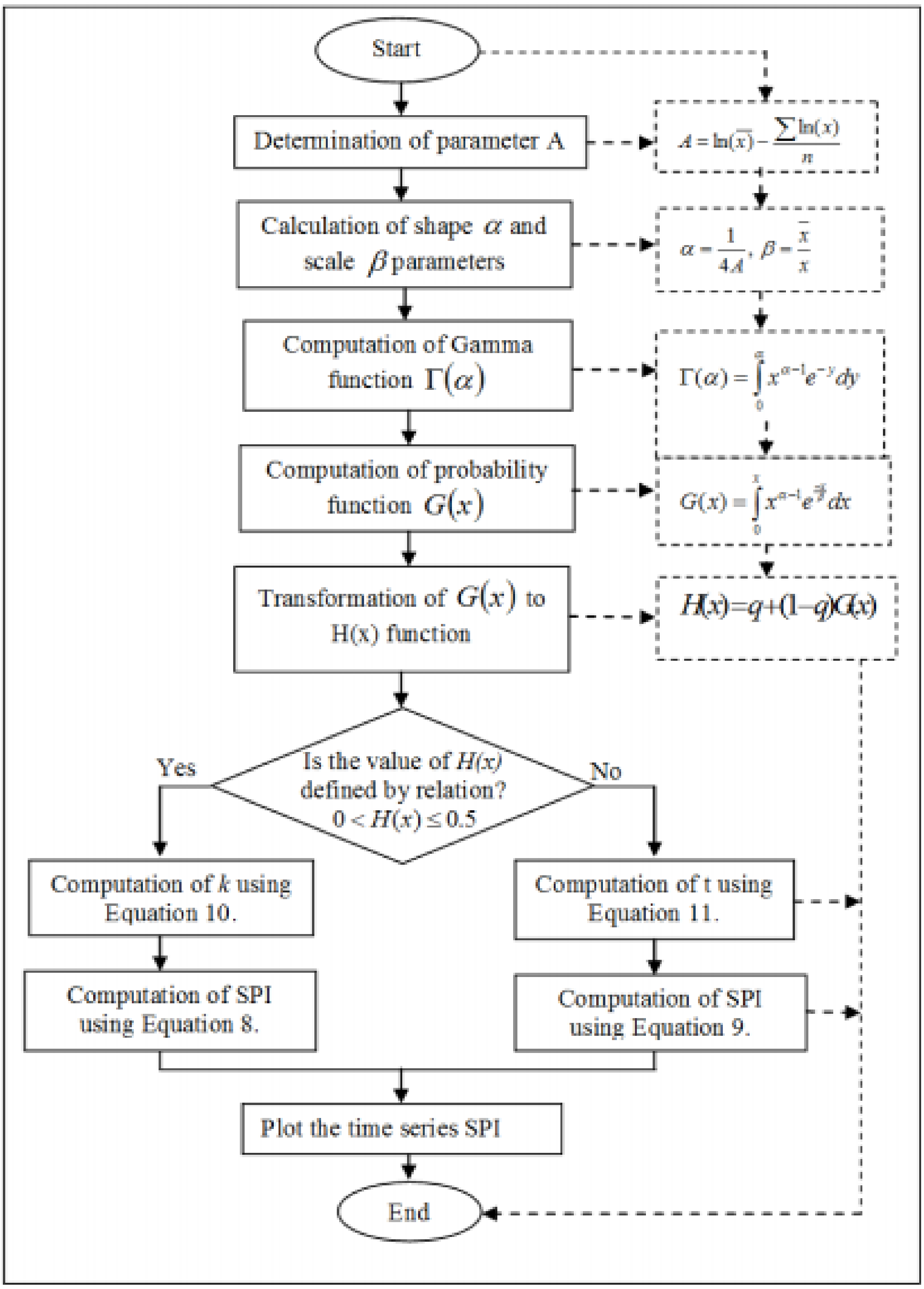

Fig.2.Flow chart for SPI computation

Drought analysis with rainfall data of the Raichur district was 21 years (1996 to 2016). For presenting the prepared map and rainfall data for the last couple of years and providing SPI data, the drought distribution in the Raichur area shows and indicates what kind of area might have a higher drought in the future.

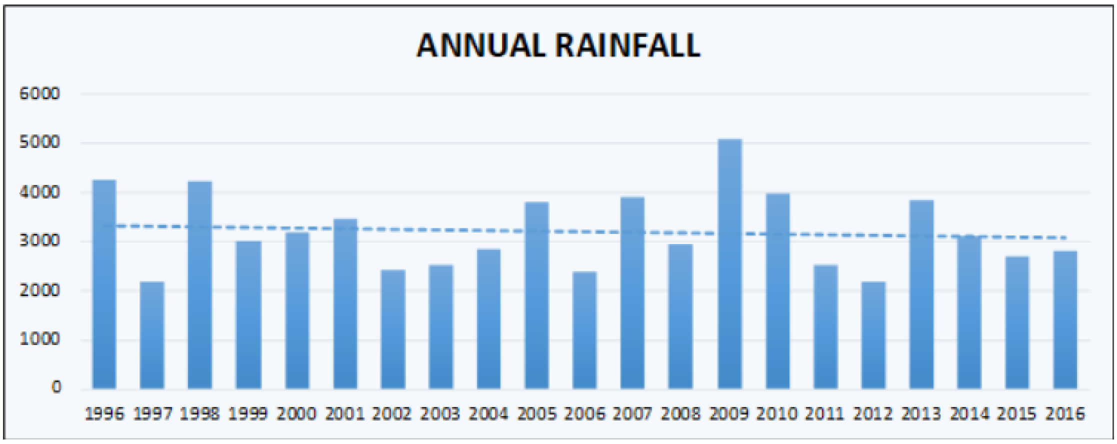

Fig 3: Average of the amount of rainfall from 1996 to 2016 in Raichur district

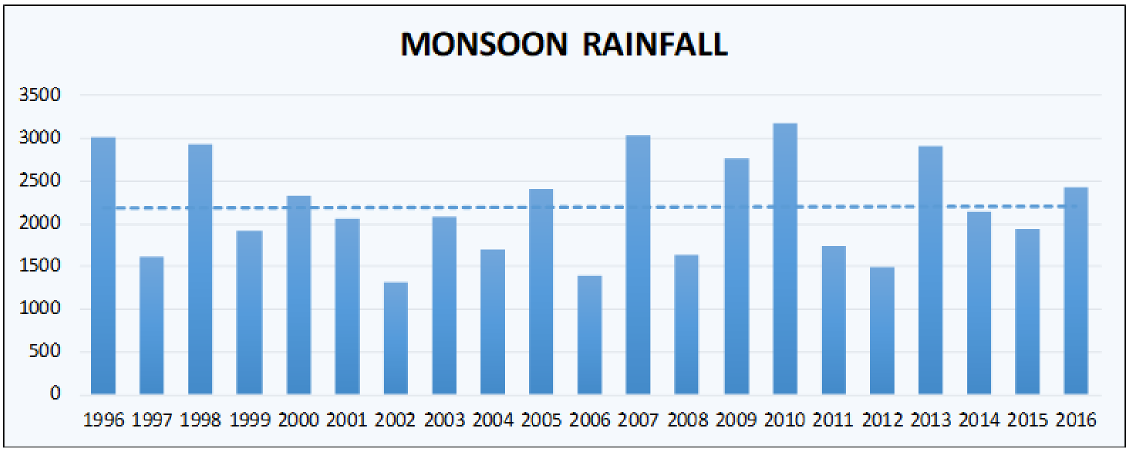

Fig 4: Average of the amount of monsoon rainfall from 1996 to 2016 in Raichur district

The rainfall and otherindicators in the SPI formula have a different accumulation and classificationprobability, which in many SPI studies show a good gamma distribution that isvery suitable for describing monthly rainfall (Saunders 2002).

SPI often has a zscore that calculates standard deviations and averages. In this model, the SPIwas calculated three months with an average monthly load of three months, andit was evaluated with the next three months, and the total rainfall was calculatedfor the same annual period in the full study period.

Tabl.1:Standard of SPI value and classification in the study area

SPI value	Classification	Cumulative probability (%)
2.00 or more	Extremely wet	2.3
1.50 do 1.99	Very wet	0.4
1.00 do 1.49	Moderately wet	9.2
0 do 0.99	Mildly wet	34.1
0 do -0.99	Mild wet	34.1
-1 do -1.49	Moderate drought	9.2
-1.50 do -1.99	Severe drought	4.4
-2 or less	Extreme drought	2.3

For illustrative purposesand a better understanding, Figure 4 shows the drought conditions in the annualtime series for rainfall measurement, which shows the metering stations in theRaichur area at low altitudes and above the basin for better measurements.

Meteorological stationsand time series graphs show that SPI varies with annual precipitation andrepresents the amount of drought in the region and the obtained maps show thatthere is drought at all in the area andtaluks with a different time intervalof drought.

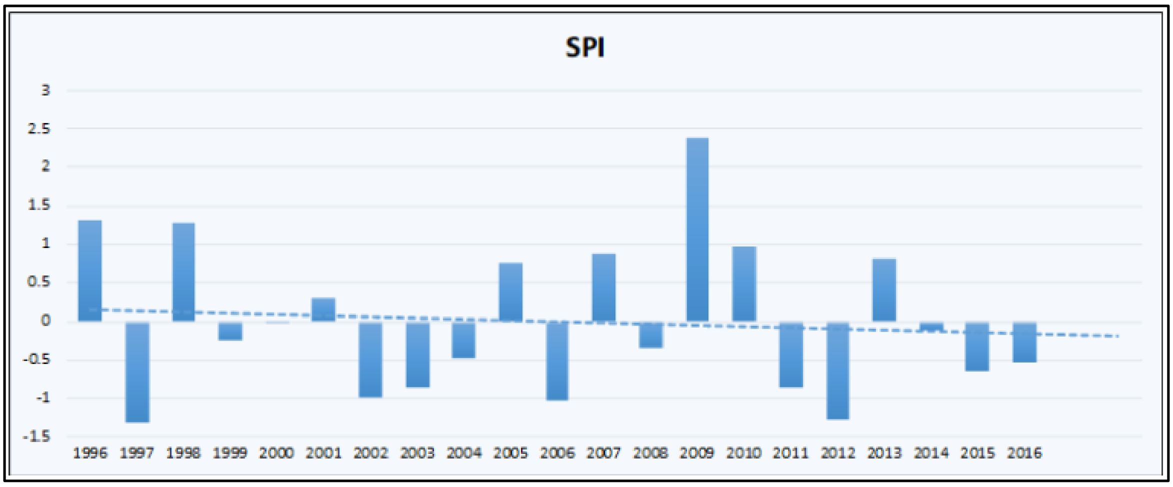

Fig 5: SPI value to show the severity of Drought in the study area

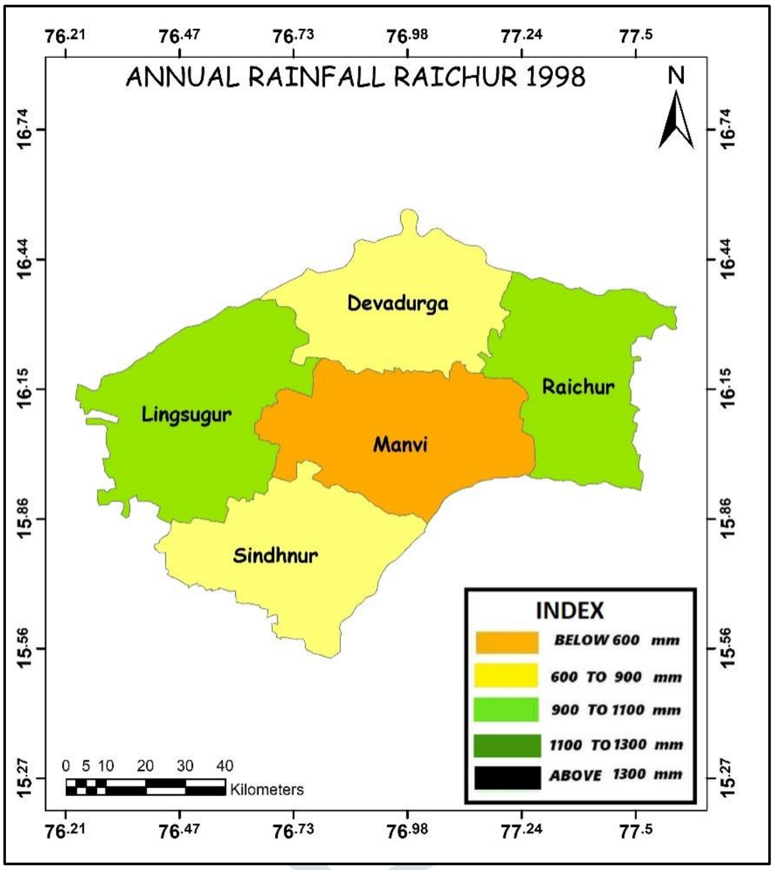

Fig.6. Annual rainfall map of Raichur district in 1998

Theadvantage of usingremote sensing and geographic information systems is more than other commonlyused methods, especially when the amount of vector data is high, requires theGeodatabase.GIS, the widespread use ofstatistical analysis,integrate cartography anddatabase technology for interpretation, comparison, mapping, and existingcoverage features as vector data ornon-spatial data in different aspects of risk and drought vulnerability andmakes use of GIS essential. In spatial and non-spatialinformation as well as in the combination of spatial data from various sourcesand GIS, spatial data is used to identify and describe various models forprediction. These rain data wereanalysed using GIS software for the past 21 years, and various roles in droughtseverity were provided and it was shown in which Raichur areas there is moredrought and how drought movement speeds are.

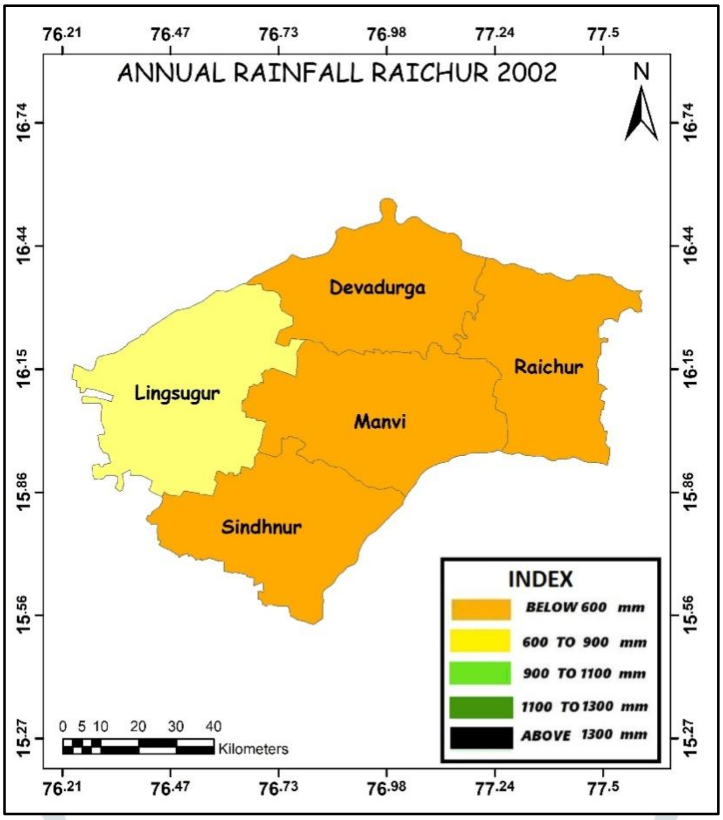

Fig.7. Annual rainfall map of Raichur district in 2002

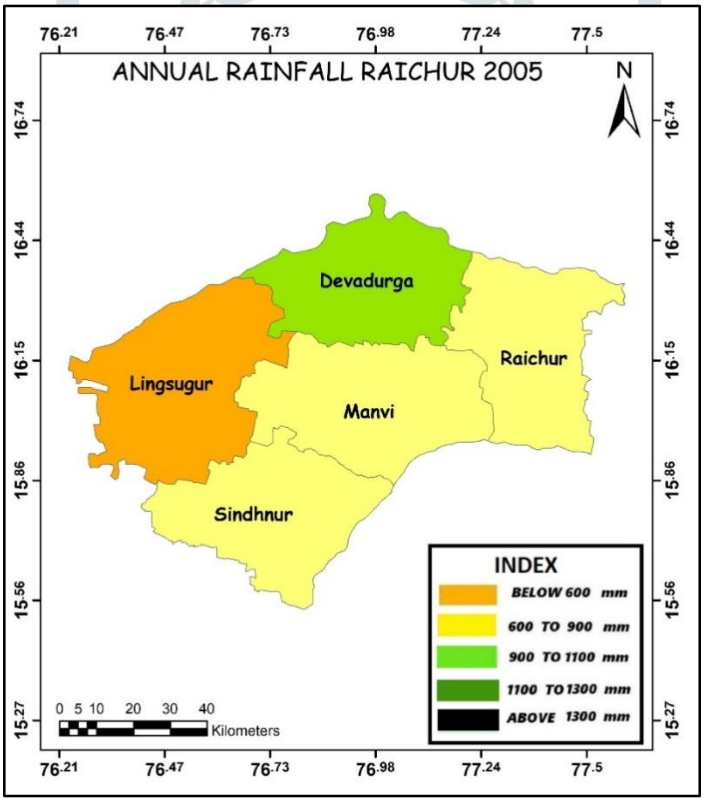

Fig.8. Annual rainfall map of Raichur district in 2005

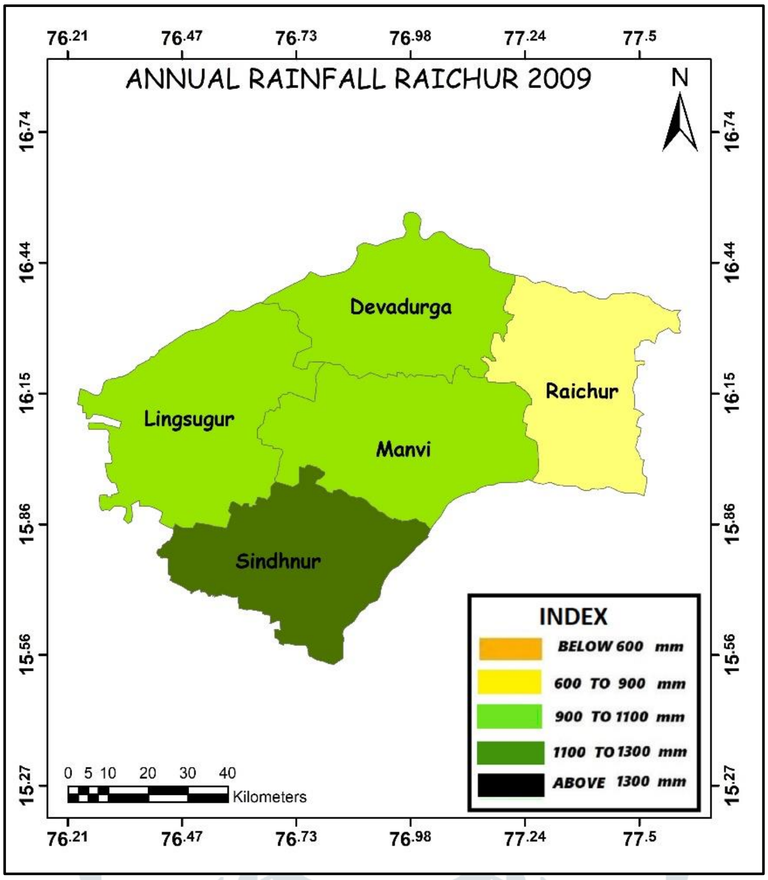

Fig.9. Annual rainfall map of Raichur district in 2009

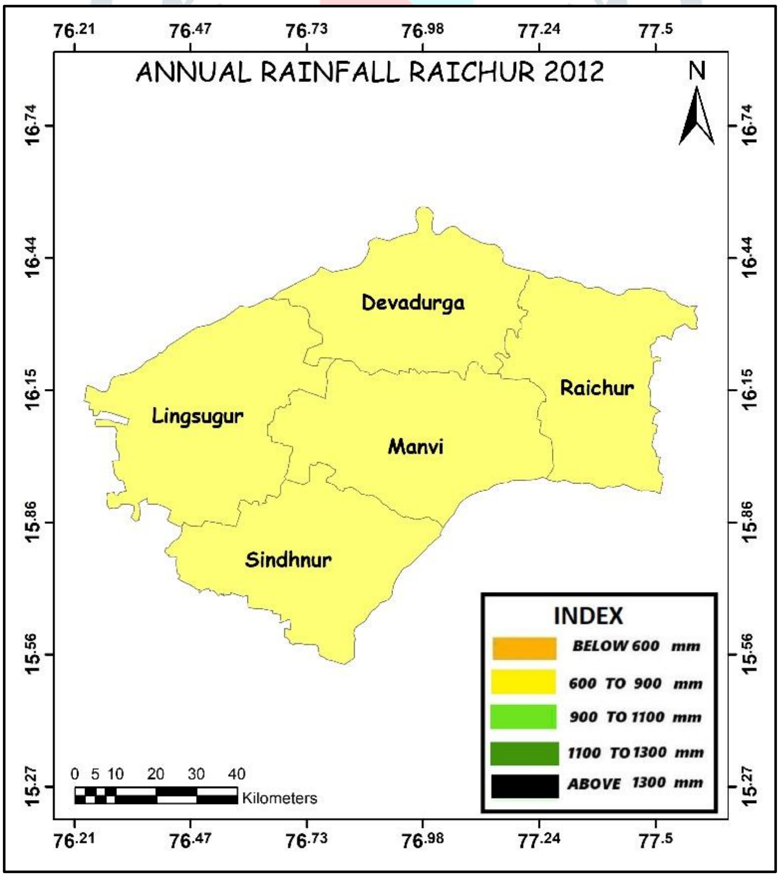

Fig.10. Annual rainfall map of Raichur district in 2012

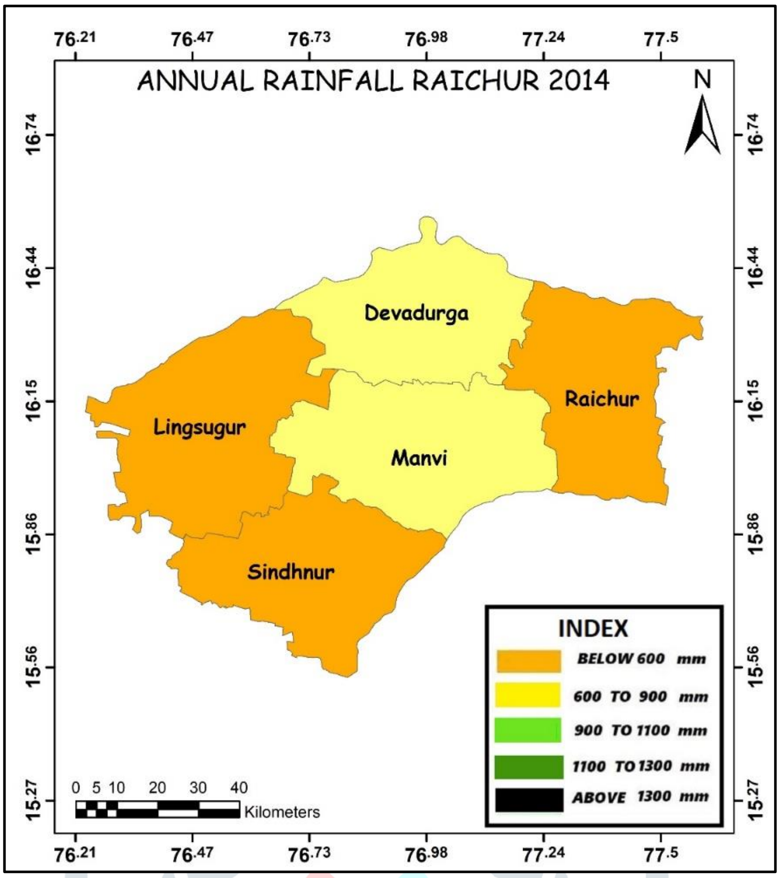

Fig.11. Annual rainfall map of Raichur district in 2014

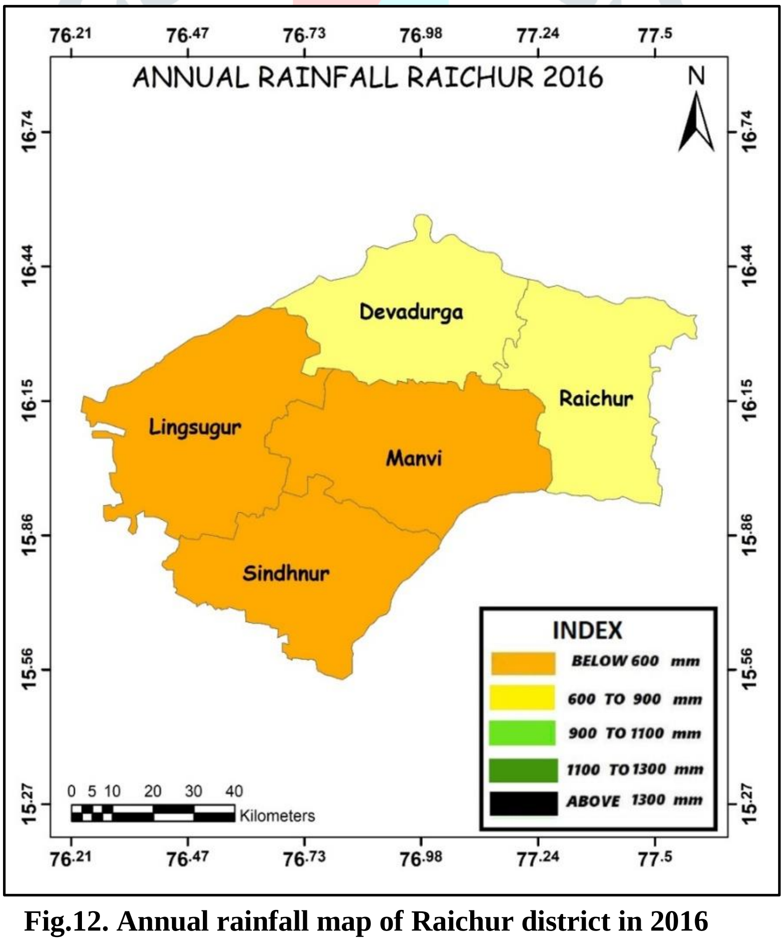

Fig.12. Annual rainfall map of Raichur district in 2016

4. CONCLUSION

In this research, droughtand climate change monitoring were carried out by analysing varieties ofrainfall varieties in different Taluks that indicate the growth of drought inthe Raichur district but, according to studies conducted in other districts around thisdrought time, severity is low. There are other methods that can be used in thisprocess, the SPI method and the detection of satellite image changes are veryuseful methods. In this research, spatial and temporal drought characteristicsof Raichur were evaluated using SPI drought index. The process of environmentalsurveys and the use of various meteorological models also benefited from thedrought phenomenon in the region and provided valuable results.The information and dataobtained in this area for monitoring and forecasting drought arealso useful for the future, with specific plans to control and reduce theimpact of drought on drinking water and agriculture in the region.

SPI is used in differenttime series to show severe drought and the years without drought, whichwas calculated at Raichur at many stations over different periods of time andshowed that the lowest rainfall in 1997, 2002, and 2012,it was less than 1500mm, indicating that
SPI = -1 with moderate drought, is still not very dry. Ingeneral, the drought does not show difficulty for Raichur, but because of thedifference in altitude in the region and the difference in point pressure, inrecent years, there may be point dry in areas with higher air temperatures.
As noted in the datacollected, rainfall and SPI in different parts of the Raichur show thatdroughts have progressed in years from 1996 to 2016. After a rainy year, one orthree times the dry years. One of the problemsidentified in the research was that in some years there was a drought in someyears of drought for two or three years of low rainfall that had an effect onwater resources and agriculture, but it was compensated in the years to come.

The final conclusion isthat annual rainfall is less than normal .The averagetemperature is the normal, but in 2016, we had a high temperature (above 21 years ago) and Relative Humidity (RH), the amount of water vapour (vapourpressure) that increases in the air at an upper limit We have seen that 2016 isa dry year.The maps of satelliteimagery and NDVI confirm the SPI index data and predict a mild drought in thearea.

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