ASSESSMENT OF DROUGHT VULNERABILITY OF ERNAKULAM DISTRICT USING SPI INDEX

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Abstract: Drought is a deceptive risk of nature. It is frequently alluded to as a "creeping phenomenon" and its effects fluctuate from area to district. The SPI calculation for any location is based on the long-term precipitation record for a desired period. This long-term record is fitted to a probability distribution, which is then transformed into a normal distribution so that the mean SPI for the location and desired period is zero. The rainfall data from year 1985 to 2015 was collected from the Indian meteorological department. We had assessed the drought from year 1985 to 2015 using SPI index. Year wise map was prepared separately for the same. Using ARIMA model we had predicted the SPI map of 2030.

***Index Terms* – SPI, Arima model, drought vulnerability map**

I. INTRODUCTION

Drought is a illusory risk of nature. It is frequently alluded to as a "creeping phenomenon" and its effects fluctuate from area to district. Drought can along these lines be exasperating for individuals to get it. In the broadest sense, drought begins from an insufficiency of precipitation over an expanded time frame typically a season or more bringing about a water deficiency for some action, multitude, or natural segment. Its effects result from the transaction between the characteristic occasion (less precipitation than anticipated) and the interest individuals place on water supply, and human exercises can aggravate the impacts of drought. Since dry season can't be seen exclusively as a physical marvel, it is generally characterized both conceptually and operationally.
Drought indices have a vast range of applications. The drought indices are Rainfall Anomaly Index (RAI), Standardized Precipitation Index (SPI), Standard Index Annual Precipitation Index (SIAP), Palmer Drought Severity Index (PDSI) etc. The Standard Precipitation Index is a universally used index signalise Meteorological drought on a range of timescales because it can be juxtapose across regions with strikingly different climates. SPI is a tool which was elucidated predominately for defining and superintending drought.

II.LITERATURE SURVEY

M. Naresh Kumara(2015) proposed that the range of SPI values of the high rainfall district indicated better prolonging, analogized to that of the low rainfall district. He wore monthly rainfall data from June to October for 39 years (1969-2007) to engender Standardized Precipitation Index (SPI) values based on Gamma distribution for a low rainfall and a high rainfall district of Andhra Pradesh state, India. He had compared SPI, with actual rainfall and rainfall deviation from the mean indicated that SPI values underrate the intensity of dryness or wetness when the rainfall is very low or very high respectively. As a result, the SPI in the trounce drought years of 2002 and 2006 in the low rainfall district had indicated only moderate dryness instead of extreme dryness. To comprehend whether non normality of SPI is a possible reason, normality tests were conducted.
Md. Anarul H. Mondol(2015) proposed that drought is one of the common and severe calamities in Bangladesh that causes monumental suffering to people in various ways. The research was carried out to scrutinize the frequency of meteorological droughts in Bangladesh using the long-term rainfall data of 30 meteorological observatories awning the period of 1948–2011. The study uses the Standard Precipitation Index (SPI) for drought appraisal in Bangladesh. By evaluating the meteorological droughts and the history of meteorological droughts of Bangladesh, the spatial distribution of meteorological drought indices were also perused. The results indicate that droughts were a normal and chronic feature and it occurred more or less all over the country in roughly all climatic region of the country. Irregularity of rainfall is the main cause of drought. Bangladesh experienced drought for 12 years before independence and 14 years after independence.
Han Zhou(2016) proffered that meteorological drought monitoring is important for drought early exemplar and catastrophe prevention. Regional meteorological drought can be assessed and perused with standardized precipitation index (SPI). Two main processing schemes which routinely adopted are mean of all SPI preconceived from precipitation at individual stations (SPI-mean), and SPI preconceived from all station averaged precipitation (precipitation-mean). It yet remains speculative if two processing stratagem could make difference in drought assessment, which is of significance to authentic drought monitoring. The precipitation mean and SPI mean were subsequently preconceived with the Thiessen Polygon weighting approach.
Patana Wichitarapongsakun(2016) proffered rainfall was prognosticated and used to confab the sternness level of meteorological drought in the Sakae Krang River basin. Three forecasting models based on the Time Series Prediction technique, Single Moving Average, Simple Exponential Smoothing and Double Exponential Smoothing (Holt's model) were used to conjecture rainfall using the data level headed from five rain gauge stations between 1970 and 2014. The minimum mean percentage error (MPE)

score was used to evince the accuracy of augury. A standardized precipitation index (SPI) was used to betoken the drought asperity levels in the Sakae Krang River basin between 1970 and 2015. The Simple Exponential Smoothing model produced the most judicious rainfall divination followed by Double Exponential Smoothing (Holt's model) and the Single Moving Average model with MPE scores of 28%, 31% and 36%, respectively.

In this paper we aim to assess a drought vulnerability map of Ernakulam district using SPI index and suggests a method to predict the drought of Ernakulam after 30 years.

III. METHODOLOGY

3.1 Study Area

Situated at the central part of the Indian state, Kerala. Ernakulam is one of the prominent districts among the 14 districts of the state. Spread across an area of 3608 sq.km, the district is considered as the commercial capital. It has the best geographical location and condition that supports its existence in a brilliant way. Spreading from a distance of 38 km from the northern part to the southern end and around 48 km from the eastern end to the extreme of the west, which is surrounded by Arabian sea. The climate of Ernakulum district is essentially tropical since the district is based on the western coastal plains. It remains quite near to the sea and this affect the weather of Ernakulum district in a huge way. Even the sufficient number of lakes and rivers contribute to the pleasant weather of the district and this soothing temperature prevails almost round the year.For the study of drought we considered rain gauge stations in and around Ernakulam district. The rainfall data was collected from fifteen rain gauge stations viz. Laccadaive Sea, Ernakulam, Elanji, Kuniji, Idukki and Vengoor were used.

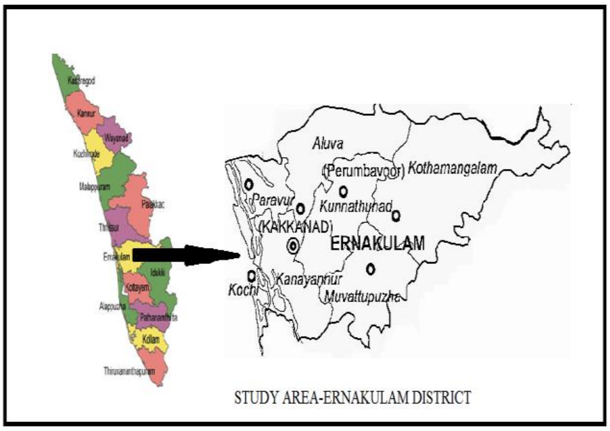

Fig 3.1 Study area Ernakulam district

3.2 Standard Precipitation Index

The SPI was instigated by McKee et al. (1993) as demarcate of the precipitation scantiness that is disparately related to probability. It can be reckoned for any hording timescale, usually from monthly precipitation surveillance, and is routinely expressed as SPI-n, where n is the number of months of accumulation. The reckoning of SPI is based on an equi-probability transformation of the probability of observed precipitation to the standard normal variable with mean 0 and variance 1. SPI is therefore expressed in units of the number of standard deviations from the mean, with negative values bespeaking drier conditions than presumed for the timescale and location. The standardization procedure to the standard normal variable means that the SPI is spatially and temporally invariant.

Precipitation is normalized using a probability distribution function so that values of SPI are actually seen as standard deviations from the median. A normalized distribution allows for guesstimate of both dry and wet periods. Accumulated values can be used to scrutinize drought severity (magnitude). At least 30 years of continuous monthly precipitation data are needed but longer term records would be preferable. SPI timescale interludes shorter than 1 month and longer than 24 months may be mutable. It is spatially invariant in its elucidation. Its probability-based nature (probability of observed precipitation transformed into an index) makes it well suited to risk management and triggers for decision making. The index was reckoned for the year 2016 and the map will be prepared in ArcGIS using the krigging option. The maps concocted by the above methods will be compared to assess the drought vulnerability of the study area.

- ✓ The SPI computation is based on the long term precipitation data for the desired time step. Thom (1958) found the gamma distribution to fit precipitation time series well. The gamma distribution is defined by its frequency or probability density function:

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

Where α is a shape parameter,

β >0 is a scale parameter, for x>0 is the amount of precipitation

$$\alpha = \frac{1}{4A}\left(1 + \sqrt{1 + \frac{4A}{3}}\right) \quad , \quad A = \ln(\bar{x}) - \frac{\sum \ln(x)}{n}$$

$$\beta = \frac{\bar{x}}{\alpha} \quad , \text{ n= number of observations}$$

- ✓ Fitting the distribution to data requires α and β to be estimated. They are estimated for each station, for each time step of interest (3, 6, 9, 12, 48 months, etc) and for each month of the year. Integrating the probability density function with respect to x and inserting the estimates of α and β yields an expression for the cumulative probability G(x) of an observed amount of precipitation occurring for a given month and time step:

$$G(x) = \int_0^x g(x)\,dx = \frac{1}{\beta^{\alpha}\,\Gamma(\alpha)} \int_0^x x^{\alpha-1} e^{-x/\beta}$$

- ✓ Since the gamma distribution is undefined for x=0 and q=P(x=0) >0 where P(x=0) is the probability of zero precipitation, the cumulative probability becomes as follow:

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

Table 3.2 SPI represent number of standard deviation from mean

SPI	CLASSIFICATION
2.0>	Extremely wet
1.5 to 1.99	Very wet
1.00 to 1.49	Moderately wet
0 to 0.99	Mildly wet
0 to -.99	Mild drought

3.3. Drought Prediction Using ARIMA Model

The Autoregressive Moving Average model (ARMA) is used for sculpting and adumbrating moored, stochastic time-series processes. It is the amalgamation of two heretofore refined statistical techniques, the Autoregressive (AR) and Moving Average (MA) models and was genially epitomized by Peter Whittle in 1951.

In statistics and econometrics, and in particular in time series analysis, an autoregressive integrated moving average (ARIMA) model is a generalization of an autoregressive moving average (ARMA) model. Both of these models are conformable to time series data either to surpassing apprehend the data or to vaticinate future points in the series adumbrating. The AR part of ARIMA indicates that the excogitating spasmodic of interest is regressed on its own lagged values. The MA part symbolize that the regression error is actually a linear amalgamation of error terms whose values eventuated contemporaneously and at various times in the past. The I for "integrated" indicates that the data values have been recouped with the difference between their values and the erstwhile values and this differencing process may have been perk more than once. The bourn of each of these features is to make the model fit the data as well as possible.

Before we fit the ARIMA model, we need to counterpoise the volatility of the standard precipitation index values. To do that, we transform the series using a log transformation. The procedure for forecasting using time series method is as follows:

- Select the ARIMA function in the menu bar.
- The corresponding order of autoregressive (AR) component, integration component (d) and the component of moving average model were selected.
- By default, the model will generate a quick guess of model's parameters. But we have to choose the calibrated values for the model's coefficient.
- After completion, the ARIMA modelling function outputs the selected model parameters and the selected test or calculations in the Excel sheet.
- The predicted values will be displayed when we select the "Forecast" option from the menu bar.

IV. RESULTS AND DISCUSSIONS

4.1 Drought Vulnerability Maps Using SPI

We have hawked out the drought anatomization over Ernakulum a tropical wet station, by wily the standard precipitation index. The SPI index was preconceived for a period of 30 years (1985-2015). Monthly precipitation data of 15 rain gauge stations in the study area were apprehend into contemplation for drought study and also to engender drought extremity maps using GIS. It is discerned that the frequency of eventuality of mild drought is more than severe and extreme type of drought. The results manifested that moderate drought nicks are in more percentage when juxtaposed to the mild or severe drought.

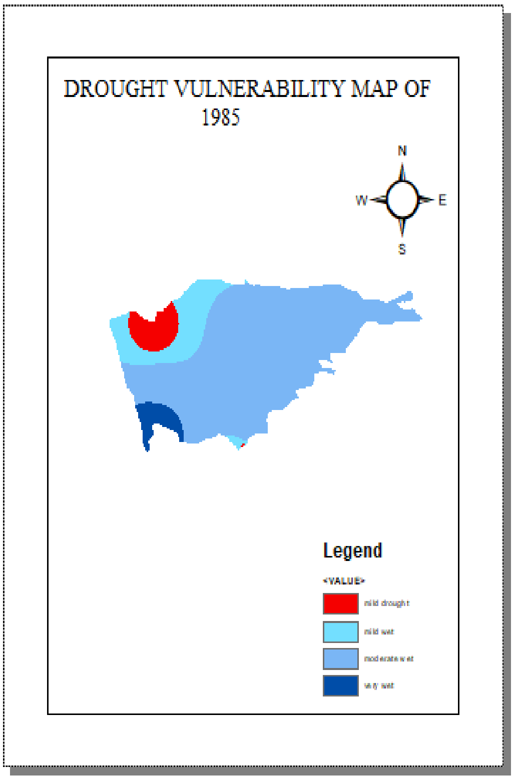

Fig 4.1.1: Drought vulnerability map of year 1985

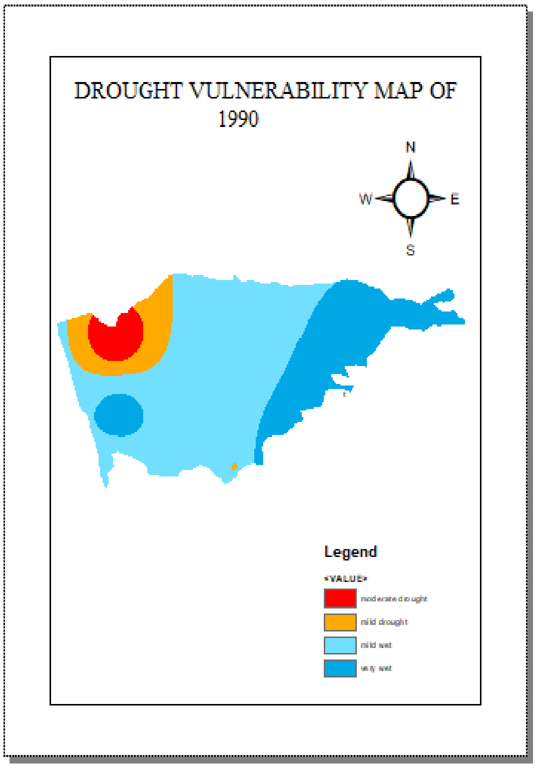

Fig 4.1.2: Drought vulnerability map of year 1990

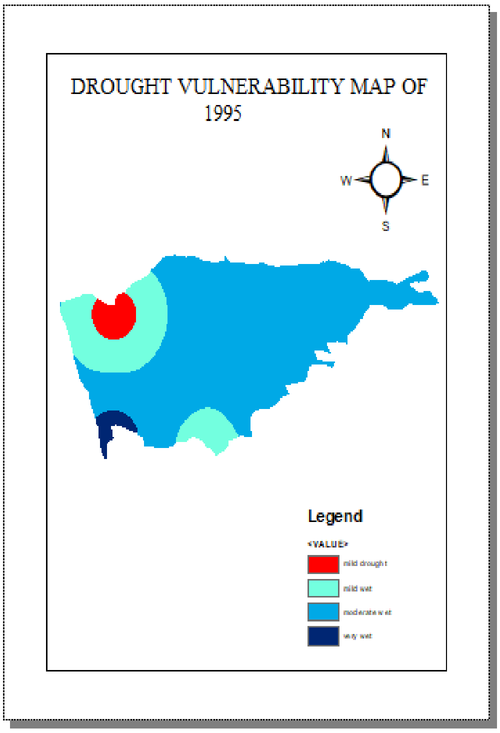

Fig 4.1.3: Drought vulnerability map of year 1995

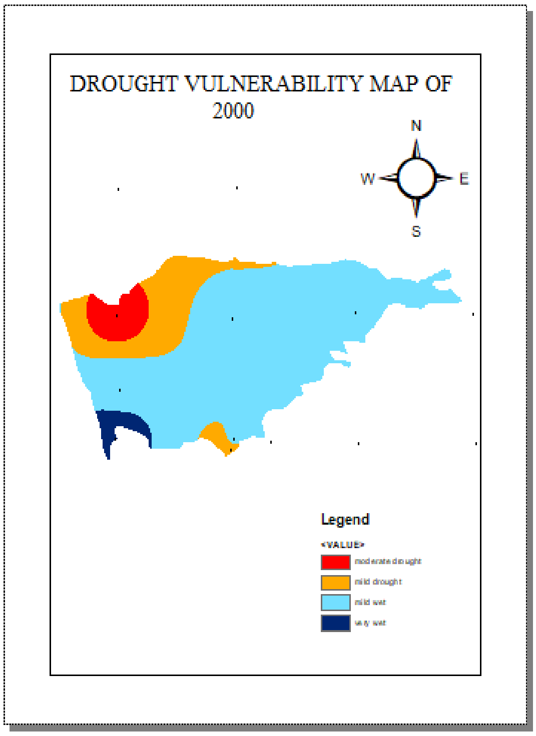

Fig 4.1.4: Drought vulnerability map of year
2000

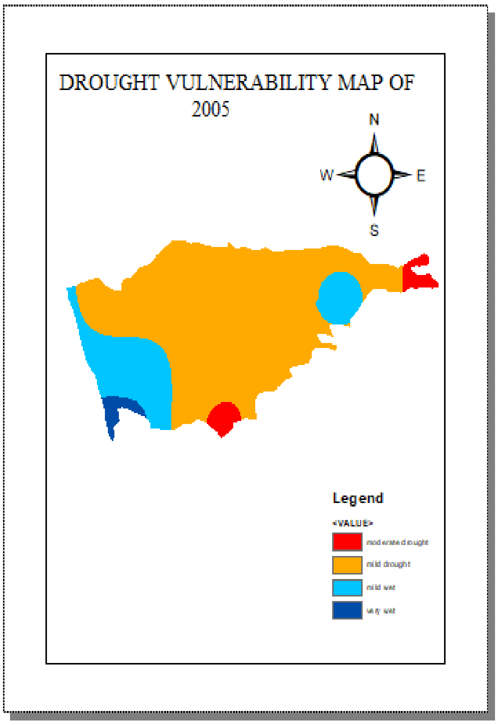

Fig 4.1.5:Drought vulnerability map of year 2005

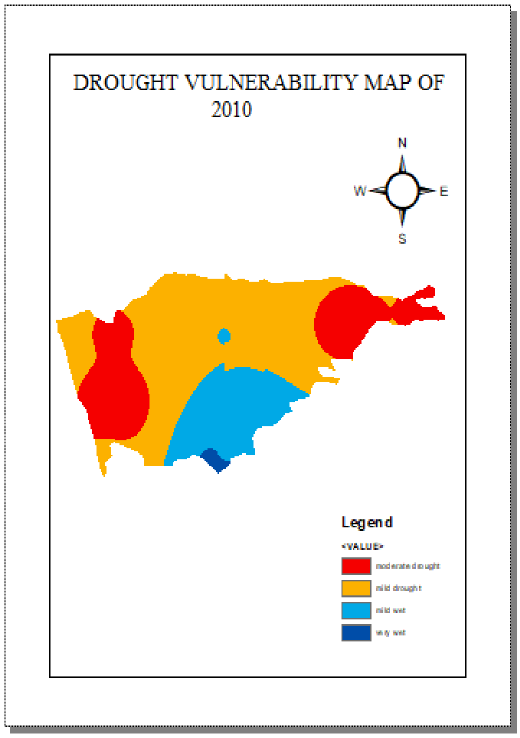

Fig 4.1.6: Drought vulnerability map of year 2010

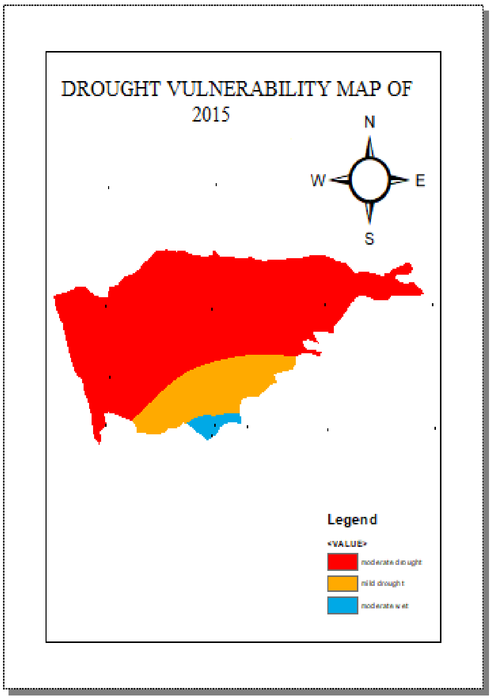

Fig 4.1.7: Drought vulnerability map of year 2015

The SPI map from the Figure 4.1.7 shows that the percentage of area suffering with moderate drought is higher than the area having mild drought.From the figure it is clear that nearby areas of Aluva,Perumbavoor,North Paravoor is having moderatedrought.Also the mild drought was felt in areas of Kothamangalam,Muvattupuzha and moderate wet in areas near Piravom ,Koothattukulam,Thodupuzha.

4.2 Predicted Map of Year 2030 Using SPI

In statistics and econometrics, and in particular in time series analysis, an autoregressive integrated moving average (ARIMA) model is a generalization of an autoregressive moving average (ARMA) model. Both of these models are fitted to time series data either to better understand the data or to predict future points in the series forecasting. The drought vulnerability map of year 2030 was forecasted using ARIMA model and is shown in figure.

In Figure 4.1.8 it was concluded that nearby areas of Elanji will experience mild wet and nearby areas of Muvattupuzha will have mild drought. The remaining area of Ernakulam district would experience moderate drought. The percentage of area which experience moderate drought is higher when compared with SPI map of 2015.

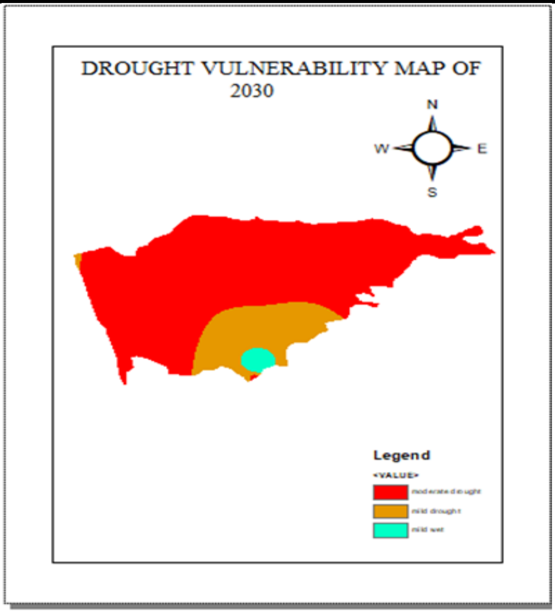

Fig 4.1.8: Drought vulnerability map of year 2030

V.CONCLUSION

Through this study we have assessed the drought of Ernakulam district for a period of 30 years .It has been observed that the intensity of drought changes from year to year due to variation in precipitation .From the observations it was found that the drought intensity was more in year 2015.The chance for occurrence of drought is higher in year 2030. So we need to take suitable precaution for preventing future drought.

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