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RESEARCH ARTICLE

PERFORMANCE EVALUATION OF TWO METEOROLOGICAL INDICES FOR DROUGHT ASSESSMENT IN JALNA

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ABSTRACT

Drought is a creeping and recurring hydro-meteorological event, which originates from reduced precipitation, high temperature, and high evaporation over extended period of time. It is normal in any climatic region and, perhaps the most complex natural hazard, because it develops slowly, is difficult to detect and has many facets in any single region. Drought preparedness and mitigation depends upon timely information on drought onset, development in time and spatial extent. This information may be obtained through continuous drought monitoring, which is normally performed using drought indices. This paper describes drought assessment, using two different meteorological indices, RAI (Rainfall Anomaly Index) and SPI (Standardized Precipitation Index). The Marathwada region of Maharashtra was chosen as the study area and this region is characterized as a 'frequently drought prone area', where drought can be expected every 6 to 10 years. A comparison of RAI and SPI values were done for determination of drought severity and temporal extension of drought for planning of mitigation measures for farmers. Using the SPI and RAI as indicators of drought severity from 1901-2002, the characteristics of drought were examined. The maximum annual SPI was -2.61 in the year 1920 similarly the RAI values also showed the same results which was -4.748. Whereas in the month of June the SPI value was -2.09 in the year 1941 and the RAI value was -3.29, in the month of July the SPI value was -2.34 in the year 1971 and the RAI value was -3.85. The overall study shows that RAI is highly correlated with SPI for determining the characteristics of droughts in the study area. The overall outcome of this study demonstrates that extreme and severe droughts were experienced in the year 1920, 1972 and 1911, 1912, 1918, 2000, 2001 across the study area leading to unfavorable results on agricultural practices and water resources in the area.

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INTRODUCTION

Drought is a weather-related natural disaster which affects vast regions for months or years. It has an impact on food production and it reduces life expectancy and the economic performance of large regions or entire country. Drought can also be defined as climatic anomaly, characterized by deficient supply of moisture resulting either from insufficient rainfall, erratic rainfall distribution, higher water need or a combination of all these factors. The escalating impacts of drought includes widespread crop failure, unreplenished ground water resources, depletion of water level in lakes/ reservoirs, leading to shortage of drinking water, reduced food and fodder availability etc.

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Hence, the occurrence of drought must be understood and appropriate drought indices should be investigated for different goals such as agriculture practices, engineering practices and water resources management. A Drought Index (DI) is a prime variable for assessing the effect of drought and defining different drought parameters, which include intensity, duration, severity and spatial extent. A drought variable should be able to quantify the drought for different time scales for which a long time series of meteorological data is essential. The most commonly used time scale for drought analysis is a year or a month. A number of drought indices have been developed to quantify drought events based on precipitation, each with its own strengths and weaknesses. They include the Palmer Drought Severity Index (PDSI); (Palmer, 1965), Rainfall Anomaly Index (RAI); (Van Rooy, 1965), Deciles (Gibbs, 1967), Crop Moisture Index (CMI); (Palmer, 1968), etc. Based on the studies for drought indices, practically all drought indices use precipitation either singly or in combination with

other meteorological elements, depending upon the type of requirements, It was found that SPI (Palmer, 1965), and RAI (Van Rooy, 1965), has following advantages over the other indices.

- SPI is spatially invariant in its interpretation, and probabilistic, so it can be used in risk and decision analysis.
- SPI is calculated by rainfall alone so that drought assessment is possible even if other meteor-hydrological measurements are not available.
- The SPI has the ability to quantify precipitation deficit for multiple time scales.
- SPI is standardized and can compare dry and wet periods on different locations.
- SPI is a better predictor of crop production, as it represents the moisture state of soil better.

Similarly, it was found that RAI has following advantages over the other indices:

- RAI uses normalized precipitation values based upon the station history of a particular location.
- RAI addresses droughts that affect agriculture, water resource and other sectors, as RAI is flexible, it can be analyzed at various timescales.
- RAI is easy to calculate, with a single input (precipitation) that can be analyzed on monthly, seasonal and annual time scales.

Marathwada Region of Maharashtra, which is facing severe drought every year, has become the graveyard of farmers. Total number of suicides in January 2016 crossed 1,000 and every week 25 to 30 farmers are committing suicide. This should be treated as the national epidemic. Due to less agricultural activities the economy of the nation is indirectly affected. Even if Jalna and the other parts of the Marathwada region has been reeling under chronic drought conditions since many decades, only socio-economic analysis of drought has been carried out till now. However, a more detailed technical analysis of the severity and duration of drought conditions using drought indices would give a better picture of drought scenario in this region. Hence this study has been taken up to analyze the the intensity and duration of drought in the Jalna region using Drought Indices with following objectives.

- To carry out drought assessment using SPI and RAI.
- Performance evaluation of both indices for drought assessment in Jalna.

Study area: Maharashtra state of India has a geographical area of 3,07,713 sq.km. The State has 35 districts and 353 talukas. It has six administrative subdivisions with Headquarters at Konkan (New Bombay), Pune, Nasik, Aurangabad, Amravati and Nagpur. Marathwada Region, which is mainly located in the main drainage of Godavari River is facing severe Drought. Actually, the region is facing the recurrent droughts with constant variations of rains and prolonged dry spells. This situation arises due to increased temperature, reduced precipitation, delayed onset of monsoon and reduction in number of rainy days. Jalna district in Marathwada has a semi-arid climate with an average annual rainfall of 729.7 mm, and an average monsoon from June to September with rainfall of 606.4 mm.

MATERIALS AND METHODS

In this study, the monthly rainfall data for a period of 1901-2002 was collected from Indian water portal (IMD). Rainfall analysis as well as drought analysis was carried out using the rainfall data.

Drought Assessment Using SPI: A deficit of precipitation impacts on soil moisture, stream flow, reservoir storage, and ground water level, etc. on different time scales. McKee *et al*., (1993) developed the SPI to quantify precipitation deficits on multiple time scales. The SPI allows a researcher to determine the drought or an wet event at a particular time scale for any location in the world that has a precipitation record. A drought event occurs at the time when the value of SPI is continuously negative. The event ends when the SPI becomes positive. Table no.1 provides a drought classification based on SPI. SPI can be calculated using the following mathematical expression. The SPI is calculated by taking the difference of the precipitation from the mean for a particular time scale, then dividing it by the standard deviation.

SPI = (Xik - Xi)/ói

Where,

ói = Standardized deviation for the “i” th station
Xik = Precipitation for the “i” th station and “ k” th Observation
Xi = Mean precipitation for the “i” th station

Drought Assessment Using RAI: RAI was developed by Van Rooy (1965). The positive and negative RAI indices are calculated by taking the average of ten extreme values.

Let,
Ḿ = The mean of the ten highest precipitation records from the period under study.
Ṕ = The mean precipitation of all the records for the period
P = The precipitation for the specific year.
Then the positive RAI (for positive anomalies) for that year is ,
RAI = 3((P-Ṕ)/(Ḿ-Ṕ))
Let,
ḿ = The mean of the ten lowest precipitation records from the period under study.
Then the negative RAI (for negative anomalies) for that year is,

RAI = -3((P-Ṕ)/(ḿ-Ṕ))

Comparison of SPI &RAI: SPI is capable of assessing droughts in different time-scales (i.e., short-term to long-term). RAI can be used (in different time scales exceeding 1 month) instead of SPI, as the more complex calculation of the SPI has no appreciable advantage for the evaluation of future precipitation anomaly trends. Hence both SPI and RAI indices were calculated in this study to check the performance of both indices for drought assessment in Jalna.

RESULTS AND DISCUSSION

Drought Analysis using SPI: A detailed monthly drought analysis was done using SPI to have a clear picture of agricultural drought during crop growth period.

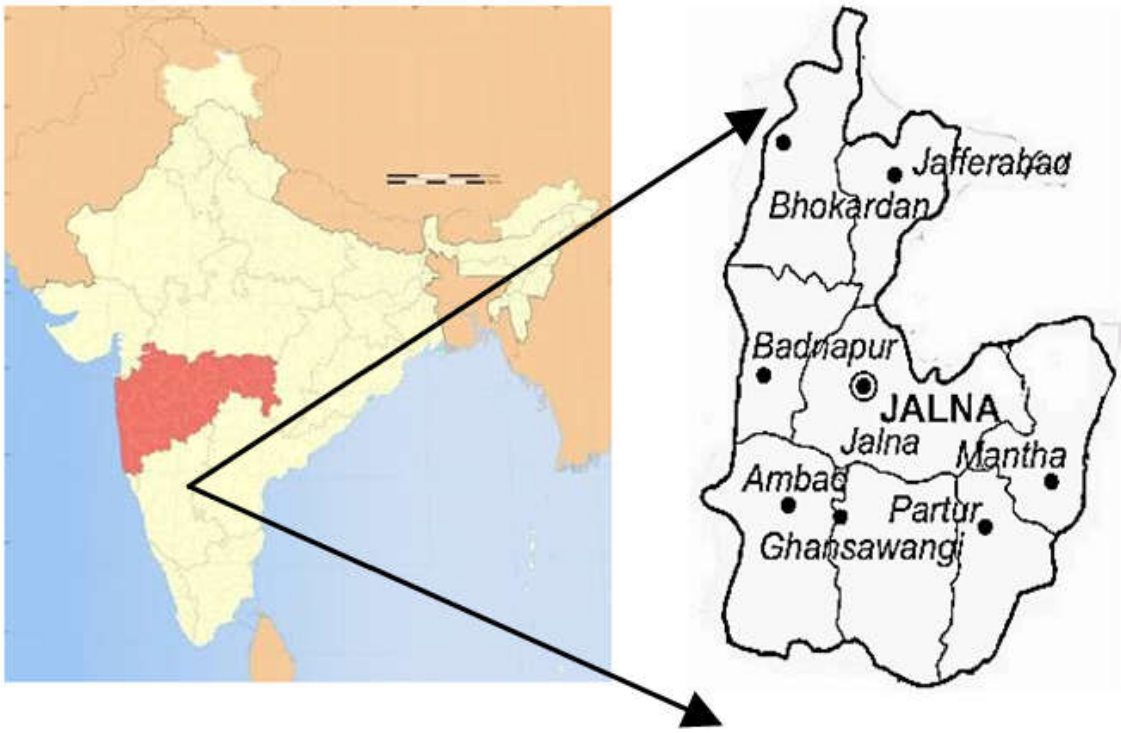

Fig. 1. Location map of Study area (Jalna)

Figure 2 shows that the graphical data the most extreme drought was occurred in the year 1920 i.e (SPI index was -2.61) which comes in to the category of Extreme drought condition and its standard range is n > -2

Severe Drought Conditions was observed for 7 years in the study area whose SPI range lie between -1.5 to -2.For Moderate Drought Condition of 10 years were observed whose range lie between -1 to -1.5.

Table 1. Drought categories using SPI

SPI values	Drought Category
0 to – 0.99	Mild drought
-1.00 to -1.49	Moderate drought
-1.50 to -1.99	Severe drought
-2.0 or more	Extreme drought

Table 2. Drought categories using RAI

RAI	Class description
≥4.00	Extremely wet
2.00 to 4	Very wet
0 to 2	Wet
-2 to 0	Dry
-4 to -2	Very Dry
Below -4	Extremely Dry

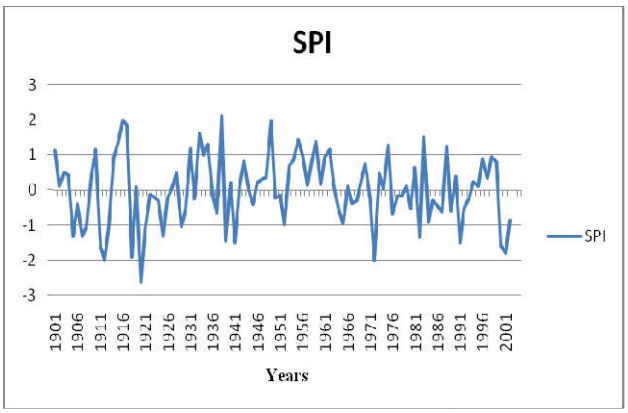

Figure 2. Analysis of Annual SPI in Jalna (1901-2002)

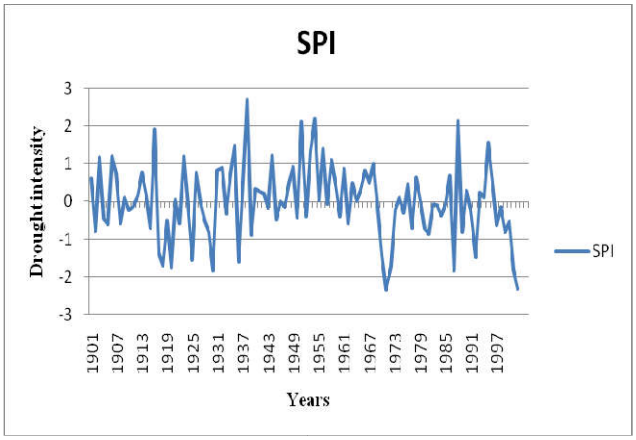

Figure 3. Analysis of SPI July (1901-2002)

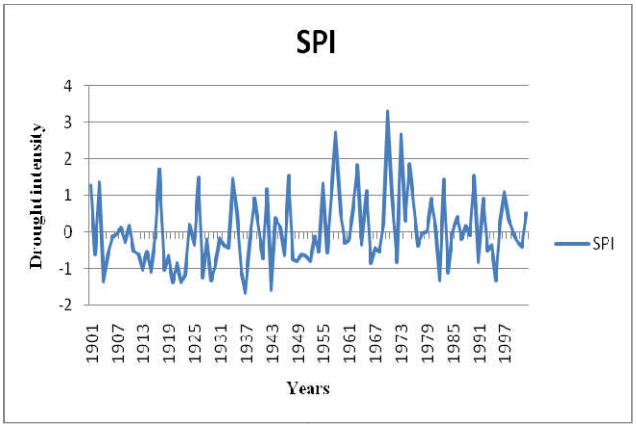

Figure 4. Analysis of SPI August (1901-2002)

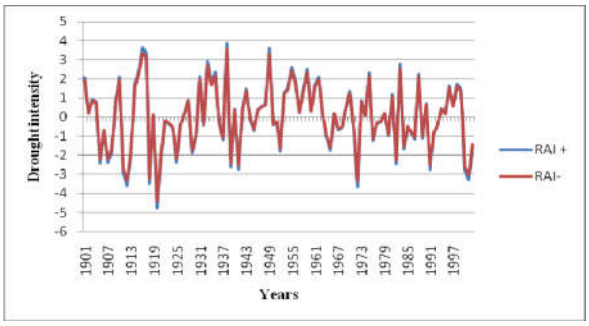

Figure 5. Analysis of Annual RAI (1901-2002)

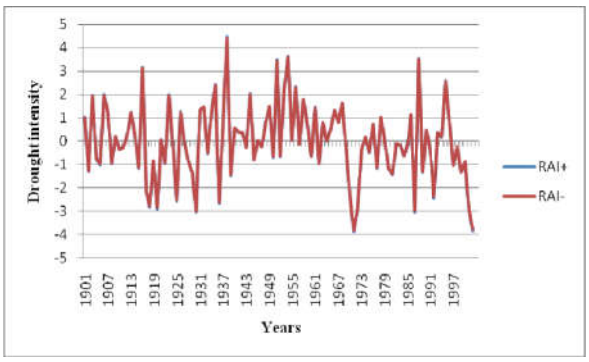

Figure 6. Analysis of RAI July (1901-2002)

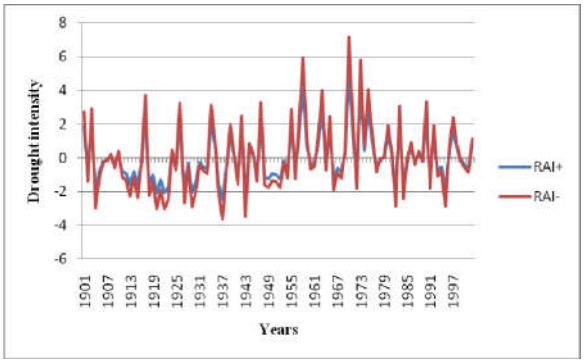

Figure.7 Analysis of RAI August (1901-2002)

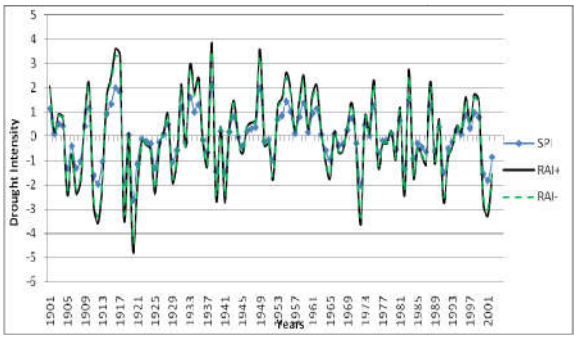

Figure 8. Comparison of Annual SPI and RAI

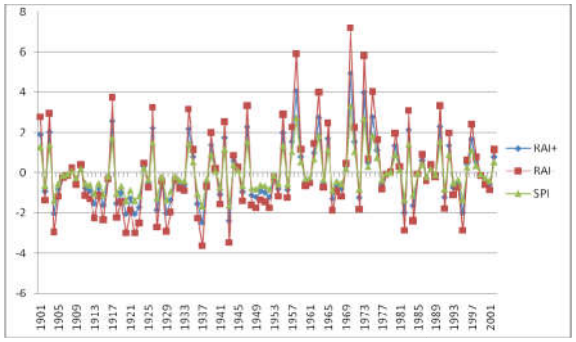

Figure 9. Comparison of SPI and RAI August

Mild Drought Condition were observed for 30 years whose range lie between 0 to -1. Figure 3 shows that extreme drought was occurred in the year 1971 i.e (SPI index was -2.34). Severe Drought Condition was observed for 8 years whose SPI range lie between -1.5 to -2. Moderate Drought Condition for 3 years were observed with SPI between -1 to -1.5. Mild drought Condition were observed for 32 years. Almost 52 years were drought affected. No extreme drought was found in August month (Figure 4). However, severe drought Condition was observed for 2 years with SPI range between -1.5 to -2. Moderate Drought Conditions were observed for 17 years whose range lie between -1 to -1.5. Mild Drought conditions were observed for 32 years whose range lie between 0 to -1. Almost 61 years were drought affected.

Drought Analysis using RAI: Drought assessment for the monsoon months was also carried out using RAI and results are shown below. The figure 5 shows extreme drought in the year 1920 i.e (RAI index was -4.748) which comes in to the category of Extreme drought condition and its standard range is n > -4. Severe Drought Conditions was observed for 14 years in the study area whose RAI range lie between -2 to -4. 34 years were dry whose RAI range lie between 0 to -2. The figure 6 shows that the most extreme drought was occured in the year 1971 i.e (RAI index was -3.800) which comes in the category of Extreme drought condition and its standard range is n > -4. Severe Drought Condition was observed for 13 years whose RAI range lie between -2 to -4. 39 years were dry whose range lie between 0 to -2. No extreme drought was found in August month (Figure 7). However, severe drought Condition was observed for 15 years with RAI range between -2 to -4. 45 years were observed to be dry whose range lie between 0 to -2.

Comparison OF SPI and RAI: The Comparison of SPI and RAI was carried out to validate both the SPI and RAI values and to evaluate the drought conditions in the study area. Both SPI and RAI indices were calculated for Annual as well as for the Monsoon season. But it is practically impossible to show all the results. Hence the representative result is being shown here. As per the figure 8 and figure 9 it is observed that the maximum value of SPI for extreme and severe is -2.61 and -1.67 respectively. Similarly the maximum value of RAI- for extreme and severe is -4.748 and -3.6236 respectively which shows the same intensity of Drought in the study area. From the study it is clear that the RAI- is highly correlated with the SPI values. The coefficient of correlation is nearing 1. Hence wherever SPI cannot be used RAI- can be used for drought assessment with greater efficiency.

Conclusion

The present study concerned the performance evaluation between SPI and RAI in a chronically drought prone region (Jalna district) of Aurangabad, India. Using the SPI and RAI as indicators of drought severity from 1901-2002, the characteristics of drought were examined. The SPI analysis showed that the study area had been suffering from mild to extreme droughts almost every year for the period under observation. Similarly the RAI- analysis shows the same years as drought affected with more and less severity of drought. The overall study shows that RAI- is highly correlated with SPI for determining the characteristics of droughts in the study area. The overall outcome of this study demonstrates that extreme and severe droughts were experienced in the year 1920, 1972 and 1911, 1912, 1918, 2000, 2001 across the study area

leading to unfavorable results on agricultural practices and water resources in Jalna.

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