Meteorological Drought Index Computation of Jalna Tehsil (Maharashtra) Using Standardized Precipitation Index

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Abstract. The most complicated but least recognised of all natural disasters is drought. It is comprehensively characterized as "sever water deficiency". This study stresses upon the use of R Studio software for analysis of precipitation data by using SPI in the field of Meteorological Drought assessment. In this study an effort has been made to derive meteorological based Standardized Precipitation Index (SPI). The precipitation index where processed and analyzed with different graphical representation. The outcomes acquired can be useful for dry spell the executives designs and will help in uncovering genuine dry season circumstance nearby. The precipitation data of Jalna tehsil (Maharashtra) of last 21 years is being observed for assessment and analysis. Geospatial technology enables the monitoring, forecasting, and evaluation of such natural disasters' consequences at all scales. The frequency and recurrence of droughts in a certain area may now be quickly and thoroughly monitored and mapped thanks to recent improvements in remote sensing and GIS technology. With the aid of satellite photos, some drought indicators have been identified and evaluated.

Keywords: Drought · SPI · RAI

1 Introduction

By definition dry season is a significant stretch of uncommonly low precipitation, particularly one that seriously influences developing or day to day environments. Precipitation is to be accepted as an ordinary, wet and dry state of the environment. It extraordinarily affects farming, hydrological, financial, natural and social frameworks. Understanding these effects is pivotal for dry spell arranging, alleviation, and reaction. It likewise helps decision makers recognize and diminish weakness to drought [1]. Dry season seems when precipitation in an area is not exactly factual long term normal for that locale throughout a lengthy time span. There are four sorts of dry spell specifically; meteorological dry season, rural dry season, hydrological dry season and financial dry season. Meteorological dry spell is insufficiency of precipitation which can be noticed right away. Remote Sensing and GIS assumes a significant part in distinguishing, evaluating and overseeing dry spells as they offer cutting-edge data on spatial and fleeting scales. To survey

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dry spell conditions in a space, distinctive dry season files are utilized. Significant dry spell records use boundaries like precipitation, vegetation and land surface temperature, soil dampness [2]. The event of dry spell makes the land unequipped for development consistently and the present circumstance renders unforgiving and unwelcoming natural condition people, population, biomass potential, and plant species. Meteorological data from ground stations has great exactness and is well known around the world. In this unique circumstance, dry spell observing through satellite based data has been prevalently acknowledged as of late for its minimal expense, brief view, reiteration of information securing and reliability. The Standardized Precipitation Index (SPI) is an exceptionally valuable tool just as a record to screen meteorological dry season which is only in view of precipitation information. Likewise, the Rainfall Anomaly Index (RAI) were determined to show the deviation of precipitation [3].

2 Study Area

For the research, Jalna Tehsil has been selected as study area. It is located with the GPS coordinates of 19° 50' 48.5196" N and 75° 53' 26.2788" E. The Jalna district is located in the central part of Maharashtra State in Marathwada region. Location map of the study area is shown in Fig. 1. Jalna district comprising 8 tehsils, 2 sub-divisions, and eight panchayat samities. The geographical area of Jalna district is 7612 Sq.KM. According to 2011 census, the total population of Jalna district has 19, 58,483. Out of total population (19, 58,483), about 80.76% (15, 81,251) population lives in rural area whereas 19.24% (3,77,232) population lives in urban area. The weather of The Jalna region is typically dry and not very harsh. The average day temperature ranges between 270C to 380C while it falls from 260C to 200C during night. The region experiences large scale variation in summer and winter temperatures. The highest temperature during summer is 460C while the lowest during winter is 60C. The relative humidity is extremely in the low ranges

Fig. 1. Map of the Jalna District, Maharashtra

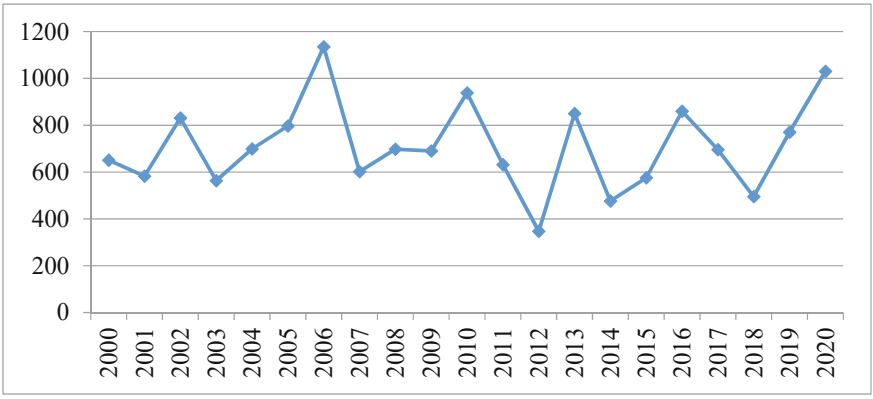

Fig. 2. Yearly precipitation (mm) from 2000 to 2021 years for Jalna Tehsil region

between 35% to 50% for major part of the year while it is highest about 85% during monsoon. Summers generally are full of gusty winds. The normal average rainfall is in the range of 600 to 900 mm with significant variation among the years. The major amount of rainfall in the region is received from South West Monsoon. Twenty one year's precipitation data has been collected for this study from 2000 to 2020 years from https://maharain.maharashtra.gov.in. Variations in the yearly precipitation for twenty one years from 2000 to 2020 are shown in Fig. 2.

3 Meteorological Drought

Meteorological drought is characterized as an absence of precipitation over a district for a while. Precipitation has been ordinarily utilized for meteorological dry spell investigation. Considering dry season as precipitation deficiency regarding normal qualities, a few examinations have dissected dry spells utilizing month to month precipitation information. Different methodologies investigate dry spell span and power corresponding to combined precipitation deficiencies. In any case, low precipitation occurs over a period of months to years due to barometric circumstances. High temperatures, high evaporation, low humidity, and desiccating winds can all make this worse [4].

4 Methodology

To get the necessary goals, the accompanying strategy was utilized for information Processing and examination as out recorded in the stream graph given. The rainfall anomalies were calculated to determine the trend change over time. Rainfall Anomaly Index, Palmer Drought Severity Index, Bhalme and Mooley Drought Index, Drought Severity Index, Standardized Precipitation Index, Effective Drought Index, and Reconnaissance Drought Index are a few of the more advanced and widely used meteorological drought indices [5]. Out of that here we are used only RAI & SPI for analysis of precipitation data for drought assessment.

4.1 Rainfall Anomaly Index (RAI)

The "Rainfall Anomaly Index" (RAI) (Van Rooy, 1965) was one the most popular and basic Meteorological drought index. It is totally reliant upon long haul meteorological precipitation perceptions. RAI demonstrates the connection between the actual evaluation of dry periods during rainy seasons and a regional humidity index. The fact that it only takes into account rainfall observations is a drawback of this index[5]. Rainfall of Jalna tehsil was collected for a period of 21 years (2000–2020) and annual rainfall anomaly of each year was calculated using long term average rainfall of study area with the help of R studio. The years with low precipitation esteems show negative takeoff from mean occasional precipitation which is additionally signified as dry season years. The formula is used for calculation of Rainfall Anomaly Index is:

$$RAI = (R-\mu)/\sigma$$

where,

RAI = Rainfall Anomaly Index, R = Rainfall, l = Long term average rainfall, r = Standard Deviation [3].

4.2 Standardized Precipitation Index (SPI)

Long term monthly rainfall data for 2000–2020 years were collected from https://mahrain.maharashtra.gov.in/and SPI was estimated to observe the spatio-temporal extent and intensity of meteorological drought event with the help of R Studio [3]. The SPI was planned by Tom McKee, Nolan Doesken, and John Kleist of the Colorado Climatic Center in 1993. SPI can be determined at various time scales and consequently can evaluate water shortages of various span. SPI was intended to show that it is feasible to at the same time encounter wet conditions on at least one time scales and dry conditions at some other time scale. Fitting historical precipitation data to a Gamma probability distribution function for a particular time period and location is used to calculate SPI. The Gamma distribution is then changed to a normal distribution with a mean of zero and a standard deviation of 1. The main premise of the current effort is that the use of a

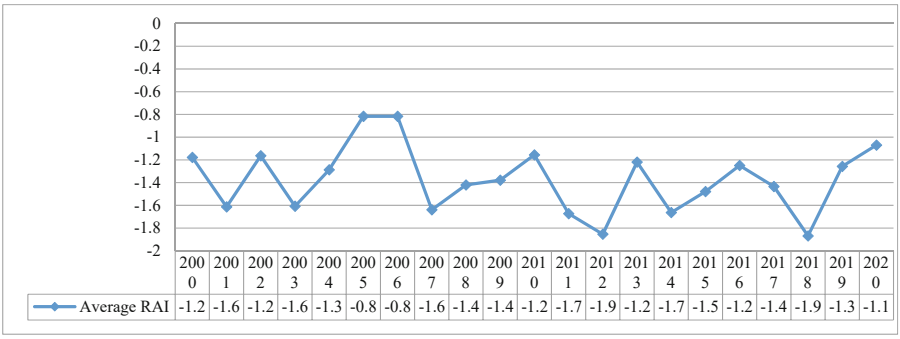

Fig. 3. Average annual RAI from 2000–2020

Table 1. Drought Category as per SPI value

SPI value	Drought category
2 and above	Extremely wet
1.50 to 1.99	Very wet
1 to 1.49	Moderately wet
−0.99 to 0.99	Near normal
−1 to −1.49	Moderately dry
−1.50 to −1.99	Severely dry
−2 and less	Extremely dry

drought index like SPI may lead to a more appropriate understanding of drought duration, magnitude, and spatial extent in semiarid areas. SPI is then given by the precipitation deviation from the mean of an equivalent normally distributed function with a zero mean and a standard deviation of 1 [4].

The use of SPI is standardized to a variety of time scales i.e. 3, 4, 6, 9, 12 months. SPI's positive values indicate wet conditions, while its negative values indicate dry conditions. The standardized numbers that fall between 0 and −2 and less are used to indicate the severity of the drought. The SPI also impose a time limit of one month or less. A meteorological drought index that can overcome the limitations of the most widely used meteorological drought index ever, SPI, has been the subject of extensive research [6].

4.3 Datasets Used: Meteorological Data

The meteorological data was obtained from https://maharain.maharashtra.gov.in/for Jalna tehsil. The meteorological data relating to daily rainfall ranges from 2000 to 2020 years. Interpolation method was used to calculate rainfall data, rainfall anomaly and standardized precipitation index [1]. Making the meteorological data compatible with other remote sensing data is required due to which daily rainfall data has been chosen for the research. These daily rainfall records have been used to identify the Meteorological drought seasons and rainfall deficient seasons. These have been also employed to generate Meteorological drought indicator and identify Meteorological drought over Jalna tehsil region [6].

4.4 Software Usage

The software used for the data processing and analyses are as follows:

- R Studio
- Microsoft Excel

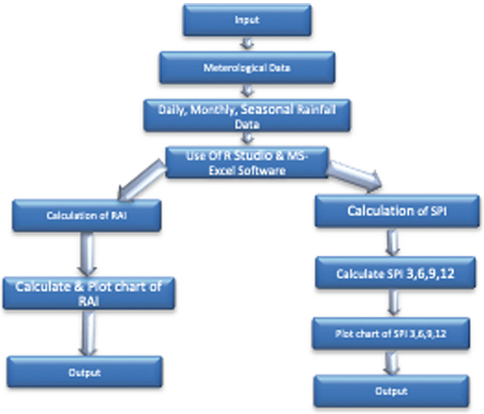

Fig. 4. Flow diagram of Calculation of SPI & RAI

5 Drought Monitoring Through SPI

SPI values over a 21-year period were used to identify drought risk. Because other pertinent data was only available for these years, SPI for the years 2003, 2007, 2012, 2014, and 2018 has been presented to illustrate the pattern of SPI during these years [1].

5.1 Calculation of SPI Average

The SPI that is acknowledged by the world climatic association as a kind of perspective drought indexlist for the depicting dry season.

$$SPI = (P_i - P)/S; S = \frac{\sqrt{\sum_1^i (P_i - P)^2}}{n}$$

where

P_i = the Rainfall of the given period
S = the Standard deviation
P = the average of the Period of the rainfall
n = the Number of data in a single period

Negative upsides of SPI file demonstrate dry spell, however the seriousness of the dry season and its characterization in various assets can be characterized by thinking about states of that district in a discretionary manner. According to the studies, it is preferable to consider -0.5 the beginning of the drought. Using the amount of rainfall, a diagram of the height-rainfall relationship for each period was created [2].

The SPI is an extremely well known meteorological dry spell file which has been every now and again involved by decision makers for estimating and checking the power of meteorological dry season occasions. Except these, SPI is useful for identifying spatio-temporal extent of long-term historical droughts. This tool was used to identify the frequency and intensity of the meteorological dry season in this analysis. During the months of July and August, the SPI values ranged from -1 to -2, indicating that the

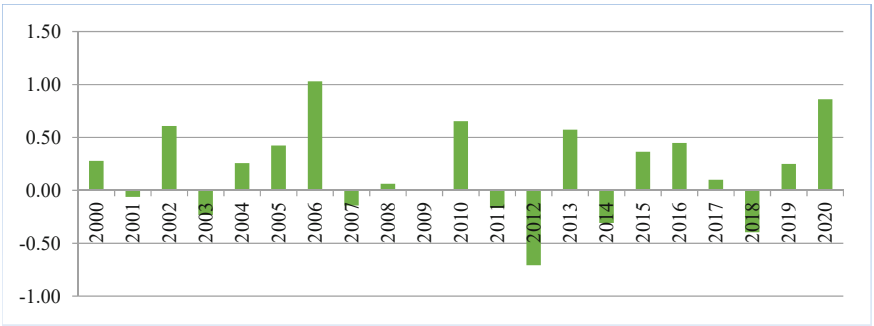

Fig. 5. Graphical representation of SPI3 (2000–2020) values

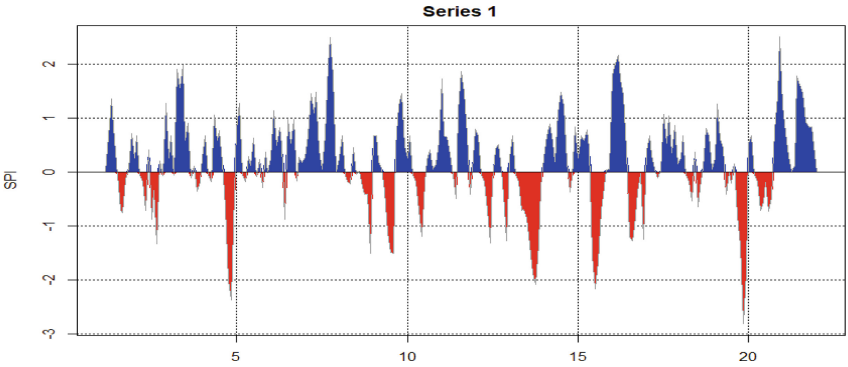

Fig. 6. Graphical representation of SPI3 values By R Studio

region is experiencing moderate to extreme dryness [3]. After calculation, SPI was categorized according to Table 1 and analyzed in the monthly (SPI-1) and annual (SPI-12) scales. In order to calculate the SPI index, software R version 3.4.21 (R Development Core Team, 2017) library SCI package was used [9].

5.2 Computation of SPI

SPI is an index of probability that only takes into account precipitation over a given time period. It was created using historical data to keep track of and evaluate the drought at any rainfall station. McKee and others In order to define drought intensities, they proposed the SPI as a drought monitoring index (Table 1). SPI was calculated for the years 2000 to 2020 in the study. Positive SPI values are above normal precipitation, whereas negative SPI values are below normal precipitation. McKee et al.'s seven-category classification system 1993, 1995) for the SPI to be specific incredibly wet (>2.0), exceptionally wet (1.5–1.99), modestly wet (1.0–1.49), close to typical (−0.99 to 0.99), decently dry (−1.00 to −1.49), seriously dry (−1.5 to −1.99), and very dry (<−2.0) was followed to arrange the SPI in the review (Fig. 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18 and 19).

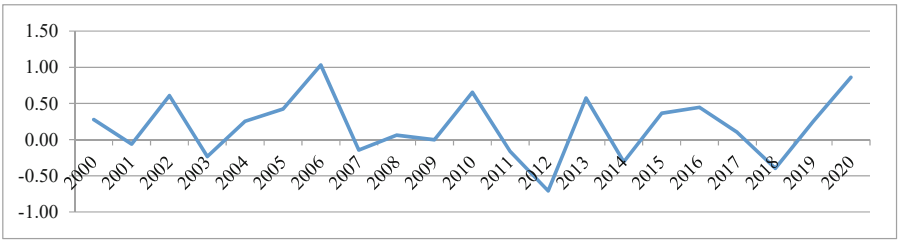

Fig. 7. Graphical representation of SP13 using Microsoft Excel

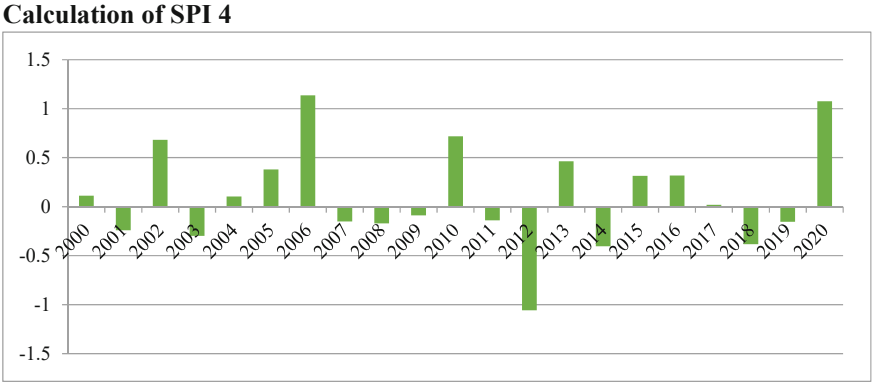

Fig. 8. Graphical representation of SPI4 values

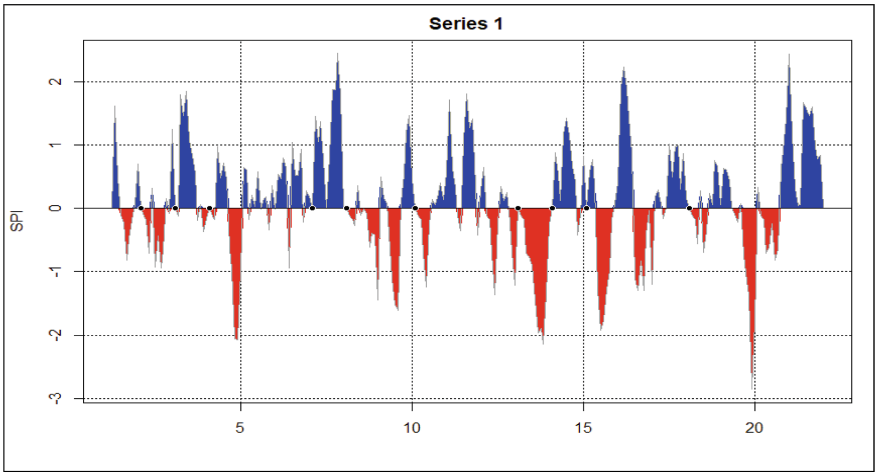

Fig. 9. Graphical representation of SPI4 values By R Studio

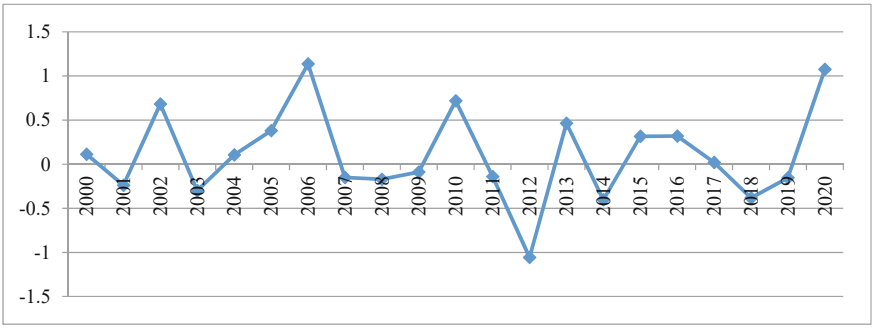

Fig. 10. Graphical representation of SPI4 values By Microsoft Excel

Calculation of SPI 6

Fig. 11. Graphical representation of SPI6 values

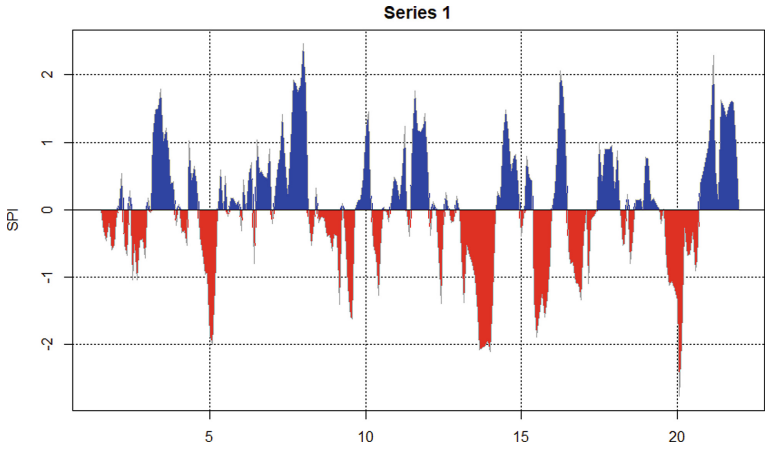

Fig. 12. Graphical representation of SPI6 values By R Studio

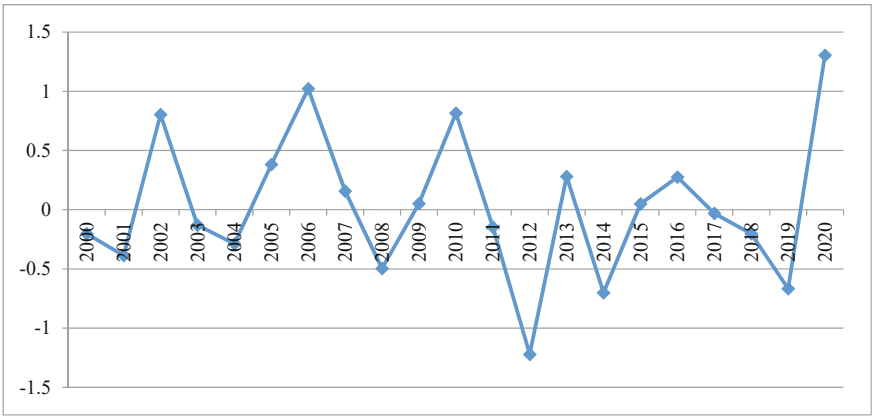

Fig. 13. Graphical representation of SPI6 values By Microsoft Excel

Calculation of SPI 9.

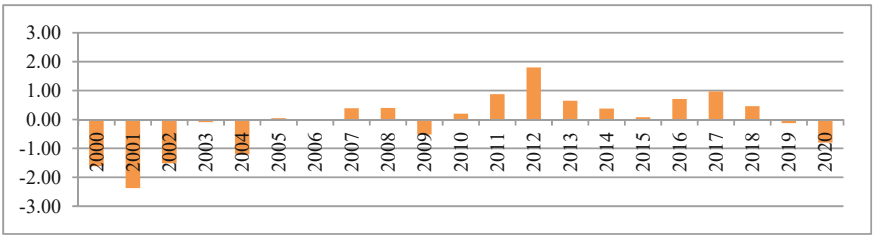

Fig. 14. Graphical representation of SPI values

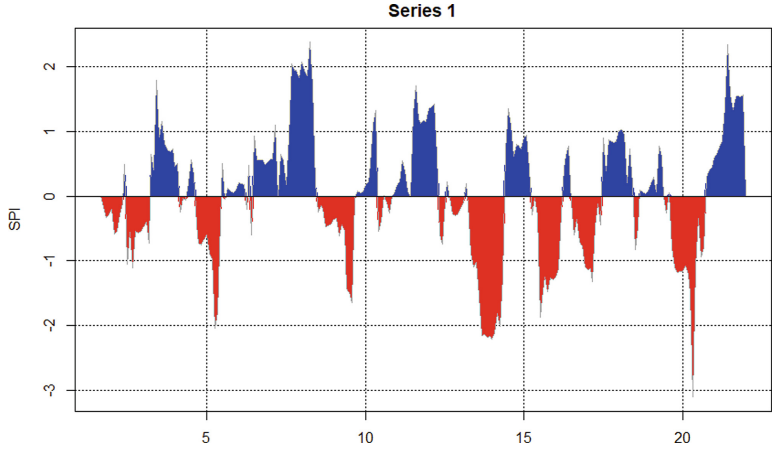

Fig. 15. Graphical representation of SPI9 values by R Studio

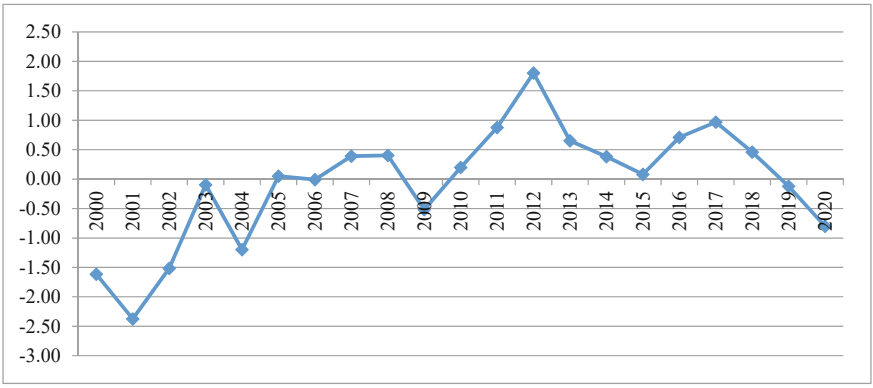

Fig. 16. Graphical representation of SPI9 values By Microsoft Excel

Calculation of SPI 12.

Fig. 17. Graphical representation of SPI12 values

6 Analysis and Observation

The SPI data for the period of 2000–2020 of Jalna tehsil was calculated. According to the SPI data, there was a very wet period from 2006 to 2020, followed by a less wet period from 2002 to 2012. SPI values over a 21-year period were used to identify drought risk. In order to comprehend the intra-seasonal variability of drought intensity, an analysis of the 3-month SPI for the years 2000 to 2020 reveals that 2012 was dry and 2006 was wet. This data was used to validate the IDMI of wet (2006) and dry (2012) years. In order to comprehend the intra-seasonal variability of drought intensity, an analysis of the 6-month SPI for the years 2000 to 2020 reveals that 2012 was dry and 2019 was wet. The IDMI of wet (2019) and dry (2012) years was used to validate these years. The 6-month SPI analysis for the years 2000 to 2020 reveals that 2012, 2014, and 2019 were dry, while 2020 was wet. This information was used to validate the IDMI of wet (2020) and dry (2012, 2014, and 2019) years in order to comprehend the intra-seasonal variation in drought intensity. The 9-month SPI analysis for the years 2000 to 2020 reveals that the years 2000, 2001, 2002, and 2004 were dry, while 2012 was wet. The

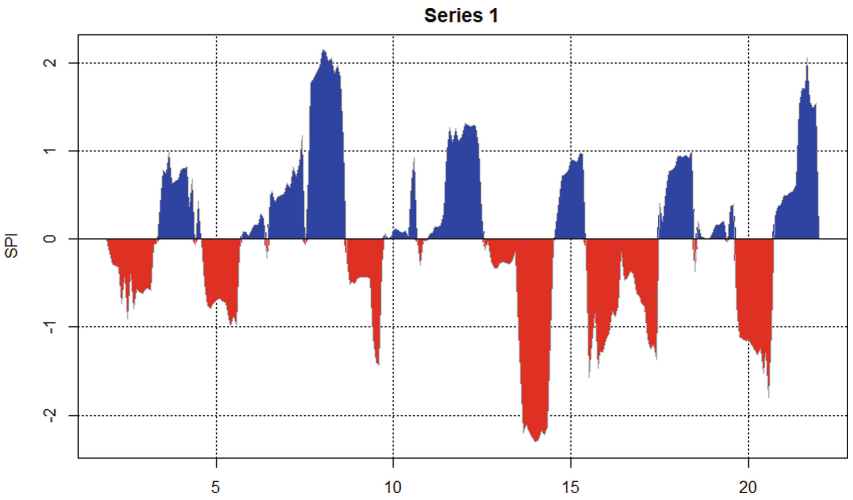

Fig. 18. Graphical representation of SPI12 values By R Studio

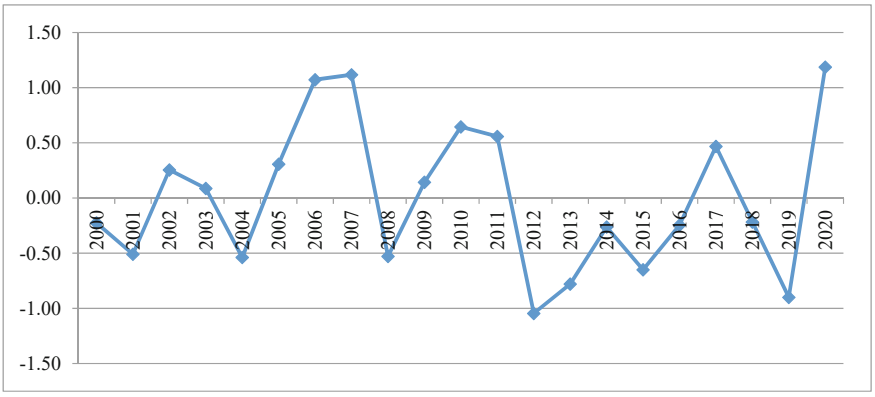

Fig. 19. Graphical representation of SPI12 values By Microsoft Excel

IDMI of wet (2012) and dry (2000, 2001, 2002, and 2004) years was used to validate the intra-seasonal variability of drought intensity. In a region prone to drought and low rainfall, the SPI values of various years are compared to actual rainfall and rainfall variation from normal. The RAI data were used to identify droughts between the years 2000 and 2020.

7 Conclusion

The objective is to determine whether SPI can be used as a better indicator for assessing drought intensity than the conventional rainfall deviation-based approach. The 12-month SPI analysis for the years 2000 to 2020 reveals that 2012, 2013, 2015, and 2019 were

dry years, while 2006, 2007, and 2020 were wet years. This information was used to validate the IDMI of wet (2006, 2007, and 2020) and dry (2012, 2013, and 2019) years in order to comprehend the intra-seasonal variability of drought intensity. Therefore, SPI assisted in determining the medium-term precipitation trend and, as a result, the years in which Jalna tehsil was more susceptible to drought risk. The results of applying RAI indices to rainfall data show that moderately dry years occurred in 2001, 2002, 2003, 2007, 2011, 2012, 2014, and 2018. Therefore, RAI assisted in determining which years Jalna tehsil was more susceptible to drought risk. In order to provide a more accurate assessment of the situation during the dry season, SPI values should accept a larger area to account for the level of wetness or dryness. According to the findings of this study, SPI as a stand-alone indicator should be interpreted with caution when assessing drought intensity, particularly in low rainfall regions that are more susceptible to droughts.

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