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Assessment of meteorological drought by standardized precipitation index for coastal agro-climatic zones of Odisha, India

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ABSTRACT

Drought is a recurring phenomenon in Indian agriculture. Every year, vast amount of crop areas are affected by drought in most parts of India causing heavy economic loss to the country. Drought forecasting and its mitigation measures are very important for boosting agricultural production, especially in rainfed areas. In this paper standardized precipitation index (SPI) was used to assess meteorological drought for 8 coastal districts coming under two coastal agro-climatic zones (CACZs) of Odisha. Monthly rainfall data of 115 years (1901-2015) for all 8 districts of Odisha were analyzed using SPI on 1, 3, 6, 9, and 12-month time scale. Results indicate that mild drought events have the highest frequencies of occurrence followed by moderate drought events for all time scales under analysis for different CACZs. Severe and extreme drought frequencies are comparatively lesser than mild and moderate drought frequencies. SPI analysis considering all the time scales shows that the frequency of occurrence of mild, moderate, severe and extreme droughts varies from 32.0% to 42.5%, 6.16% to 11.2%, 1.88% to 5.22% and 1.08% to 3.50%, respectively across all the districts in CACZs of Odisha. It was observed that 7 out of 8 districts (except Puri) had more number of drought years varying from 59 to 63 years (out of 115 years) in June, whereas all the 8 districts had more number of wet years in August varying from 59 to 67 years. The excess rainwater in August should be harvested for use in crops in subsequent months.

1. INTRODUCTION

Drought is a recurring feature of Indian climate. The drought history of India suggests that India is highly vulnerable to drought due to its monsoonal climate and the inherent spatial and temporal variability of rainfall. About 68% of the area is susceptible to drought in varying degrees. Of the entire area, 35% of the area, which receives precipitation between 750 mm and 1,125 mm, is considered drought-prone, whereas another 33%, which receives less than 750 mm of precipitation, is called chronically drought-prone. A drought is a period of below-average precipitation in a given region resulting in prolonged shortages in water supply. It has a substantial impact on the ecosystem and agriculture of the affected region, and harms the local economy. Difficulty in accurate prediction of its onset and uncertainty about its spread and severity render this phenomenon more harmful. Therefore, the study of drought and preparation of contingency plan based on its characteristics is very important for mankind in general, and for government in particular (Dash *et al.,* 2013; Panigrahi and Panda, 2001).

Drought indices are used to monitor and assess severity of drought for effective crop and water resources planning. A number of researchers have studied on identification and quantification of drought indices. Most of these drought indices are based either on meteorological or hydrological variables. Meteorological drought is defined usually on the basis of the degree of dryness in comparison to some normal or average amount of rainfall and the duration of the dry period. Definitions of meteorological drought must be considered as region specific. Other definitions may relate actual rainfall departures to average amounts on monthly, seasonal or annual time scales (Kumar *et al.*, 2018).

Some important drought indices include the Palmer

Drought Severity Index (PDSI; Palmer, 1965), the Rainfall Anomaly Index (RAI; Van Rooy, 1965), the Rainfall deciles (Gibbs and Maher, 1967), the National Rainfall Index (RI; Gommes and Petrassi, 1994), and the Standardized Precipitation Index (SPI; McKee *et al.,* 1993). Among these indices, SPI is widely used for assessment of meteorological drought in many countries of the world. The advantage of using SPI as an effective drought index is that it can be calculated for different time-scales and can be used to analyse different drought categories (Capra and Scicolone, 2012). Moreover, SPI is easier to calculate than more complex indices as it is based on a single data *i.e.* precipitation (Vicente-Serrano, 2006; Wu *et al.,* 2005). Guttman (1998) compared the SPI with PDSI and concluded that the SPI has statistical consistency advantages, and can describe both short-term and long-term drought impacts through different time scales of precipitation anomalies.

Agriculture in the state of Odisha, India is mainly rainfed, as only 35% of cultivated area of 62 lakh hectares has irrigation facilities from various sources (OSDMA, 2003). The state's population of 45 million resides mainly in rural areas (85%), with a large population of marginal farmers indicating high level of dependence on agriculture. The monsoonal behaviour across the state holds the key to agricultural productivity, and consequent food security. Nearly, 86% of annual rainfall in the state is contributed by the southwest monsoon (CGWB, 1999). A delayed / untimely monsoon, and / or less precipitation during the season are indicative of poor crop yield. Odisha has less experience of coping with droughts, in comparison to floods, resulting in poor preparedness. Hence, the impact of drought events may be more severe in the state. The coastal districts of Odisha are rich in agricultural production compared to other districts. The main economy of the state comes from agricultural production from these areas. With this in mind, the study was conducted with the objective of meteorological drought assessment using standardized precipitation index for all 8 districts covering the two CACZs of Odisha.

2. MATERIALS AND METHODS

Study Area

Odisha is located between 17°49' and 22°34'N latitudes and between 81°27' and 87°29'E longitudes. It is bounded by the Bay of Bengal on the east; Madhya Pradesh state on the west and Andhra Pradesh state on the south. It is spread over an area of 155,707 sq km accounting for about 4.87% of total area of India. It comprises 30 districts spreading over 10 different agro-climatic zones (ACZs). Out of 30 districts, 8 districts lie in the coastal belts, and they belong to two CACZs. Fig. 1 shows view of different ACZs of Odisha including the two CACZs (OMEGA, 2014). Table 1 shows the characteristics of various CACZs of Odisha.

Climate of the study area is characterised as tropical monsoon type. By early June, the southwest monsoon announces its arrival and departs by the middle of October. 80% of annual rainfall is received during the monsoon season that starts from 1st June and continues upto 15th October. Remaining amount is received throughout the year. *Kharif* is the main cropping season, and rice (*Oryza sativa)* is the principal crop during this season. Cropping during *rabi* season is mainly confined to irrigated areas and areas with residual moisture. Other important crops produced in the state are pulses, oil seeds, fibres (jute, mesta, cotton), sugarcane and vegetables. Mango, banana, coconut and cashew nut are the main horticultural crops of the state.

Data Used

Rainfall data required for the study were collected from India Meteorological Department (IMD) and Indian Water Portal for a period of 115 years (1901-2015) for all 8 districts under 2 CACZs of Odisha.

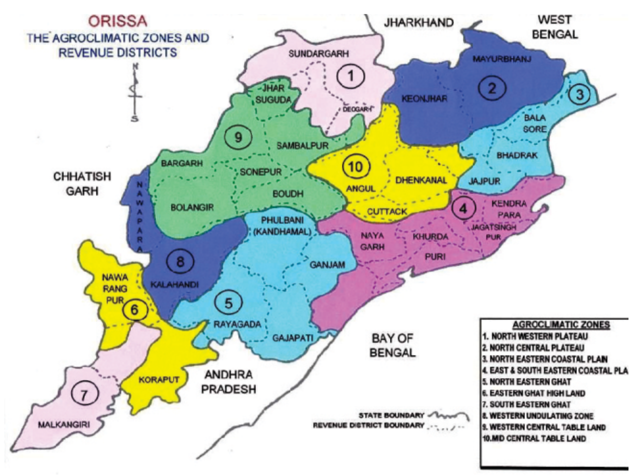

Fig. 1. Various agro-climatic zones of Odisha, India

Table: 1
Characteristics of various coastal agro-climatic zones of Odisha (OMEGA, 2014)

Coastal agro-climatic zone	Districts	Climate	Mean annual rainfall*(mm)	Soil group
North Eastern Coastal Plain	Balasore, Bhadrak, Jajpurand part of Keonjhar	Hot and Moist	1568	Red, Lateritic, Deltaic Alluvial and Coastal Alluvial
East and South Eastern plain	Kendrapara, Khorda, Jagatsinghpur, Puri, Nayagarh, part of Cuttack, part of Ganjam	Hot and Moist	1449	Saline, Lateritic, Alluvial, Red and Mixed Red

**Mean calculated with 115 years data*

Calculation of Standardized Precipitation Index (SPI)

In the present study, SPI was used to quantify the severity and characteristic of drought at 1, 3, 6, 9 and 12-months timescales. As suggested by Edwards and McKee (1997) for any location, long term precipitation over a desired period is used to compute SPI. This long-term record is then 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. Positive SPI values indicate greater than median precipitation whereas negative values indicate less than median precipitation. McKee *et al*. (1993) used the SPI classification system along with the range of values of SPI which is shown in Table 2.

Calculation of SPI involves the following steps:

Step1: Mean for the normalized precipitation values of the log-normal (ln) rainfall series is calculated and the shape and scale parameter β and α, respectively are computed by eqn's. (1) to (4).

$$\text{Log mean: } \bar{X}_{ln} = \frac{\sum \ln X}{N} \qquad ...(1)$$

$$\text{Shape parameter: } \beta = \frac{1}{4\,U}\left[1 + \sqrt{\frac{4U}{3}}\right] \qquad ...(2)$$

$$\text{Scale parameter: } \alpha = \frac{\bar{X}}{\beta} \qquad ...(3)$$

$$\text{Where, } U \text{ is the constant, } U = \ln \bar{X} - \bar{X}_{ln} \qquad ...(4)$$

Step 2: The resulting parameters are then used to estimated the cumulative probability of an observed precipitation event for the given month and time scale for the station. The gamma distribution is found to fit well to the climatic data of precipitation time series (Kumar *et al.,* 2018; Edwards and Mckee, 1997) and so, in this study, computation of SPI has been done fitting gamma probability density function to the series of monthly precipitation data of each station. The cumulative probability as given by Gamma distribution is as follows:

$$G(x) = \frac{1}{\alpha^{\beta}\Gamma\beta}\int_0^x x^{\beta-1} e^{\frac{-x}{\alpha}}\,dx \qquad ...(5)$$

Letting $t = \frac{-x}{\alpha}$, this equation becomes the incomplete gamma function.

Table: 2
SPI classification and their values

Category	SPI range
Extremely wet	2.00 or more
Severely wet	1.50 to 1.99
Moderately wet	1.00 to 1.49
Mildly wet	0 to 0.99
Mildly dry	0 to - 0.99
Moderately dry	-1.00 to - 1.49
Severely dry	-1.5 to - 1.99
Extremely dry	-2.00 or less

Since the gamma function is undefined for $x = 0$ and a precipitation distribution may contain zero, the cumulative probability becomes,

$$H(x) = q + 1 - q\,(x) \qquad ...(7)$$

Where, q is the probability of zero events.

If m is the number of zeros in a precipitation time series, then q can be estimated by m/N. Tables of the incomplete gamma function can be used to determine the cumulative probability G(x). McKee *et al.* (1993) used an analytic method to determine the cumulative probability. The cumulative probability, H(x), is then transformed to the standard normal random variable "Z" with mean zero and variance one, which is the value of the SPI. The Z or SPI values is more easily obtained computationally using an approximation that converts cumulative probability to the standard normal random variable Z (eqn's. 8 to 11).

$$Z = SPI = -\left[t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right] \text{ for } 0 < H(x) \leq 0 \qquad ...(8)$$

$$Z = SPI = +\left[t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right] \text{ for } 0.5 < H(x) \leq 1.0 \qquad ...(9)$$

$$\text{Where, } t = \sqrt{\frac{1}{(H(x))^2}} \text{ for } 0 < H(x) \leq 0.5 \qquad ...(10)$$

$$t = \sqrt{\frac{1}{(1.0 - H(x))^2}} \text{ for } 0.5 < H(x) \leq 1.0 \qquad ...(11)$$

Where, $c_0 = 2.515517$, $c_1 = 0.802853$, $c_2 = 0.010328$, $d_1 = 1.432788$, $d_2 = 0.189269$ and $d_3 = 0.001308$.

In this study, the SPI_SL_6 program developed by the National Drought Mitigation Centre, University of Nebraska-Lincoln was used to compute time SPI for the selected station and for each month of the year at different time scales. Values of SPI for different time scales for all months of the year for entire 115 years for all the districts coming under different CACZs were calculated. Thereafter, its frequency of occurrence of drought for different districts for various time scales were calculated.

3. RESULTS AND DISCUSSION

Drought Assessment

North Eastern Coastal Plain (NECP)

Bhadrak, Balasore, Jajpur and part of Keonjhar districts come under NECP ACZ. Since only one division of Keonjhar falls under this ACZ, only the first three districts are taken for assessment of drought. The highest frequency of drought occurrence was found in Bhadrak (37.31%) under mild drought condition in NECP ACZ. Balasore has high frequency of drought of 9.56% under moderately drought conditions. As for severe drought, Bhadrak gives the highest frequency of 4.34% and Jajpur gives the highest frequency (3.33%) under extreme drought category (Table 3). Edwards and Mckee (1997) has suggested that for agricultural crop planning, SPI values at 1-month time is to be considered. Hence, we have presented the SPI values of all the12-months at 1-month time scale for all the districts of NECP ACZ in Fig's. 2 to 13. At 1-month time scale, the highest drought intensity in NECP ACZ occurred in Balasore in January, February, April, June, September and December with values of -1.31 (1911), -2.11 (2006), -2.42 (1999), -2.48 (1905), -1.94 (2013) and -0.40 (1955), respectively. The highest drought intensity in this ACZ at 1-

Table: 3

Frequency (percentage) of occurrence of drought in SPI series of 1, 3, 6, 9 and 12 months in North Eastern Coastal Plain agro-climatic zone of Odisha

Districts	1-month				3-month				6-month				9-month				12-month			
	Mild	Mod	Sev	Ext	Mild	Mod	Sev	Ext	Mild	Mod	Sev	Ext	Mild	Mod	Sev	Ext	Mild	Mod	Sev	Ext
Balasore	34.0	9.0	4.2	2.53	32.0	8.26	4.42	2.9	32.0	8.47	4.1	3.1	36.6	7.68	3.7	2.55	35.3	9.56	4.05	1.88
Bhadrak	35.1	8.76	4.34	2.02	33.9	7.75	4.27	2.8	34.2	7.39	3.6	3.2	35.9	8.26	3.1	2.39	37.3	9.05	3.04	1.95
Jajpur	32.4	9.50	3.40	2.17	32.5	8.76	4.27	2.9	32.7	9.20	2.6	3.3	36.9	8.91	2.7	2.46	34.8	9.49	3.47	2.02

Mod = Moderate, Sev = Severe, Ext = Extreme

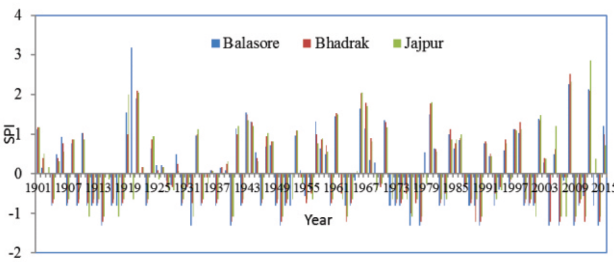

Fig. 2. 1-month SPI for North Eastern Coastal Plain for the month of January

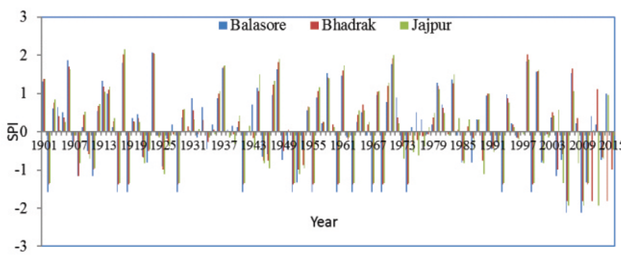

Fig. 3. 1-month SPI for North Eastern Coastal Plain for the month of February

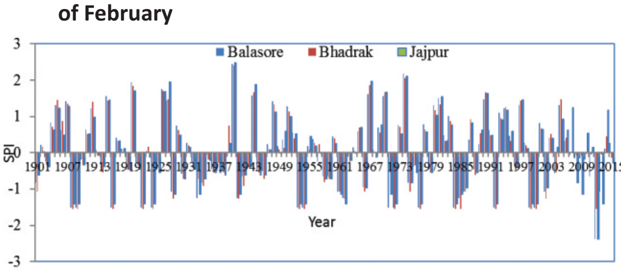

Fig. 4. 1-month SPI for North Eastern Coastal Plain for the month of March

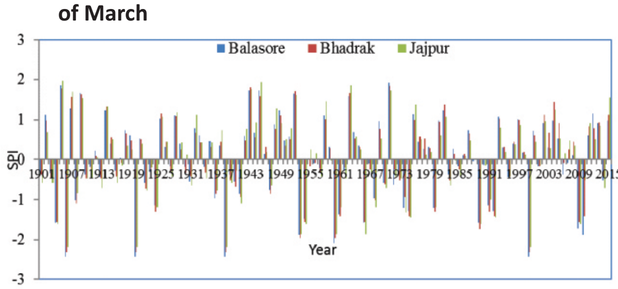

Fig. 5. 1-month SPI for North Eastern Coastal Plain for the month of April

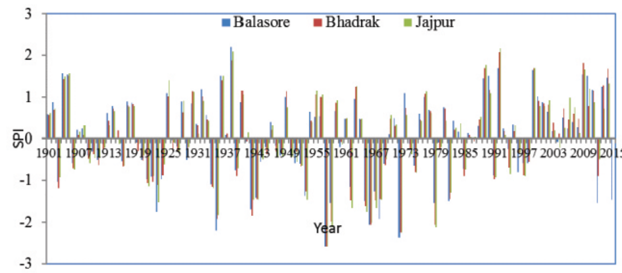

Fig. 6. 1-month SPI for North Eastern Coastal Plain for the month of May

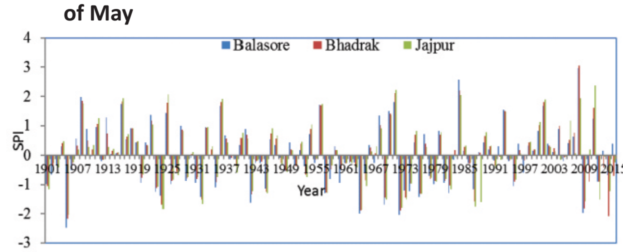

Fig. 7. 1-month SPI for North Eastern Coastal Plain for the month of June

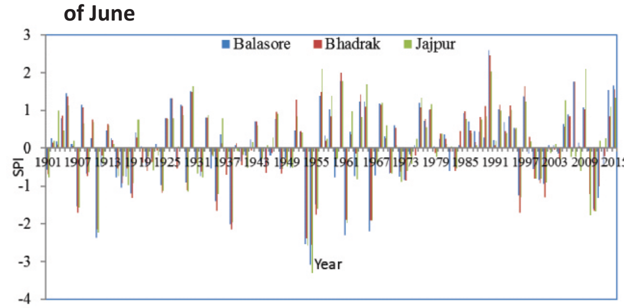

Fig. 8. 1-month SPI for North Eastern Coastal Plain for the month of July

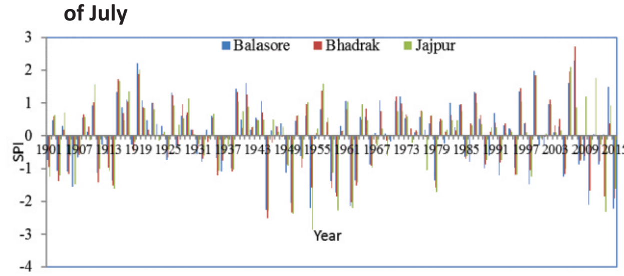

Fig. 9. 1-month SPI for North Eastern Coastal Plain for the month of August

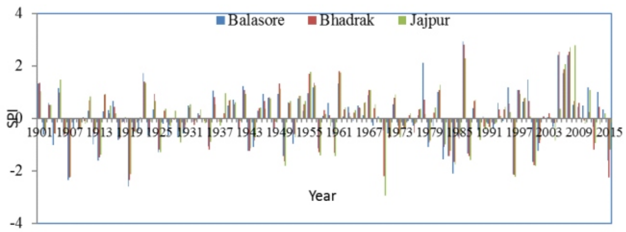

Fig. 10. 1-month SPI for North Eastern Coastal Plain for the month of September

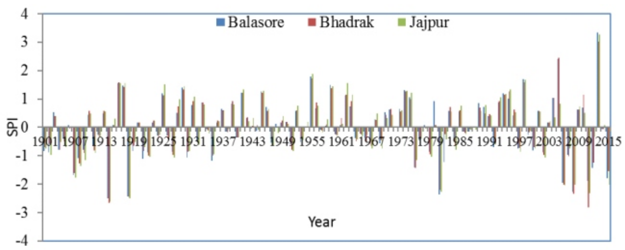

Fig. 11. 1-month SPI for North Eastern Coastal Plain for the month of October

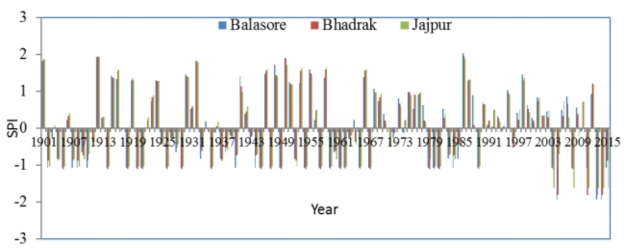

Fig. 12. 1-month SPI for North Eastern Coastal Plain for the month of November

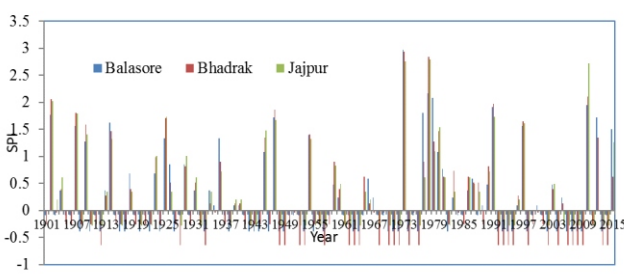

Fig. 13. 1-month SPI for North Eastern Coastal Plain for the month of December

month time scale occurred in Bhadrak in August, October and May with SPI value of -2.51(1945), -2.81 (2011) and -2.59 (1957), respectively. Similarly, the highest drought intensity in this ACZ at 1-month time scale occurred in Jajpur in July, September and March with SPI value of -3.32 (1954), -2.95 (1970) and -2.38 (2012), respectively. Thus, the study reveals that the highest drought intensity at 1-month time scale occurs in Balasore for more number of months (six). The 3-months SPI result of the month of June shows that the highest drought intensity occurred in 1945 with Bhadrak giving SPI value of -2.35. The 6-month SPI result shows that the highest drought intensity occurred in 1935 with Bhadrak having SPI value of -2.92. The 9 and 12-months SPI result shows that the highest drought intensity occurred in 1908 with Jajpur giving value of -2.75 and -2.96, respectively. The results of 1-month SPI values of June, July, August and September revealed that the highest drought intensity occurred in 1905, 1954, 1945, 1970, respectively in NECP ACZ with values of SPI of -2.48, -3.32, -2.51 and -2.95, respectively. Highest values of SPI in the above mentioned 4-months ranged from -2.03 to -2.48 in 1-month time scale, -2.76 to -3.24 in 3-month time scale, -2.67 to -3.19 in 6-month time scale, -2.80 to -3.10 in 9-month time scale and -2.53 to -3.06 in 12-month time scale in various districts of this ACZ.

An analysis for drought affected years shows that Bhadrak has the highest number of drought years followed by Jajpur. Balasore has the least number of years affected by drought.

East and South Eastern Coastal Plain (ESECP)

Kendrapara, Khurda,Jagatsinghpur, Puri, Nayagarh, part of Cuttack and part of Ganjam come under ESECP ACZ. Since, a small portion of the districts of Cuttack and Ganjam comes under this ACZ, only the first five districts are taken for assessment of drought. District Puri is found to have the highest frequency of occurrence of mild drought whereas Kendrapara has the lowest frequency of occurrence of mild drought, at each time scale (Table 4). The frequency of occurrence of the mild drought at 1, 3, 6, 9 and 12-month time scale in Puri are 39.8%, 34.6%, 36.3%, 39.9% and 42.5%, respectively. The frequency of occurrence of the mild drought at 1, 3, 6, 9 and 12-month time scale in Kendrapara are 33.6, 32.7, 34.5, 35.6 and 36.9%, respectively. The 1-month results show that Jagatsinghpur has the highest number of drought frequency under moderate category, and Khorda shows the highest frequency under extreme category. The 3-month SPI analysis shows that Nayagarh is affected the most by moderate drought (9.13% of time) whereas Khorda is affected the most by severe drought (5.22%) and Kendrapara is affected the most by extreme drought (2.7%) (Table 4). The 6-month SPI gives the highest moderate drought frequency of 8.69% in Jagatsinghpur district, severe drought of 3.8% frequency in Nayagarh and extreme drought frequency of 3.5% in Kendrapada. As for 9-month SPI analysis, the result shows that highest frequency of moderate, severe and extreme are found in Puri (8.91%), Nayagarh (3.33%) and Khorda (2.75%), respectively. 12-month SPI results also give highest frequency of drought in the moderate category for Puri district (8.98%) whereas, the highest number of severe and extreme drought is found in Kendrapada district having values of 2.97% and 2.53%, respectively (Table 4).

SPI values of all the12-months starting from January to December at 1-month time scale for all the districts of ESECP ACZ are depicted in Fig's. 14 to 25.

The highest drought intensity at 1 month time scale in

Table: 4
Frequency (percentage) of occurrence of drought in SPI series of 1, 3, 6, 9 and 12-months in East and South Eastern Coastal Plain agro-climatic zone of Odisha

Districts	1-month				3-month				6-month				9-month				12-month			
	Mild	Mod	Sev	Ext	Mild	Mod	Sev	Ext	Mild	Mod	Sev	Ext	Mild	Mod	Sev	Ext	Mild	Mod	Sev	Ext
Balasore	34.0	9.0	4.2	2.53	32.0	8.26	4.42	2.9	32.0	8.47	4.1	3.1	36.6	7.68	3.7	2.55	35.3	9.56	4.05	1.88
Kendrapara	33.6	8.98	3.40	1.23	32.7	8.76	4.20	2.7	34.5	7.89	3.0	3.5	35.6	8.62	2.5	2.68	36.9	7.31	2.97	2.53
Jagatsigpur	37.4	11.2	3.62	1.15	33.9	8.62	4.56	2.5	35.4	8.69	3.5	3.0	38.5	8.33	2.3	2.68	40.3	7.89	2.53	2.17
Khorda	33.7	7.68	2.89	1.66	33.3	7.46	5.22	2.6	34.8	7.25	3.7	3.1	38.2	8.04	2.2	2.75	41.3	7.75	1.88	2.46
Puri	39.8	6.95	3.18	1.08	34.6	8.91	3.98	2.4	36.3	8.33	3.4	2.5	39.9	8.91	2.0	2.18	42.5	8.98	1.59	1.95
Nayagarh	36.4	6.16	3.04	1.38	33.9	9.13	4.06	2.4	36.0	6.67	3.8	2.9	38.4	7.25	3.3	2.40	40.4	8.77	2.83	2.03

Mod = Moderate, Sev = Severe, Ext = Extreme

ESECP ACZ occurred in Jagatsinghpur in January, February, March, April, October and December with values of -1.12 (1911), -1.82 (2005), -2.38 (2010), -2.38 (2009), -3.36 (1914) and -1.05 (1912), respectively. The highest drought intensity in this ACZ at 1-month time scale occurred in Khorda in June, September and November with SPI value of -2.51 (1988), -4.13 (1970) and -1.94 (2004), respectively. Similarly, the highest drought intensity in this ACZ at 1-month time scale in Nayagarh occurred in July and August with SPI value of -3.39 (1954) and -3.41 (1954), respectively and in Puri it occurred in May with SPI value of -2.83 (1957). Thus, the study reveals that the highest drought intensity at 1-month time scale occurred in Jagatsinghpur for more number of months (six).

The SPI values for 1-month time scale in June indicates that the years 1901, 1924, 1935, 1945 and 1954 were affected by severe drought during the period of 1901-2015 (Fig. 19). Highest values of SPI in June, July, August and September at 1-month time scale ranged from -2.18 to -2.51, -2.01 to -3.39, -2.25 to -3.41 and -3.31 to -4.13, respectively.

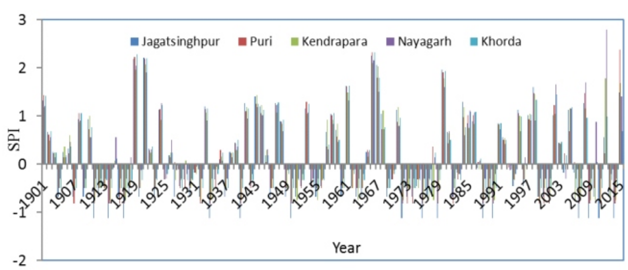

Fig. 14. 1-month SPI for East and South Eastern Coastal Plain for the month of January

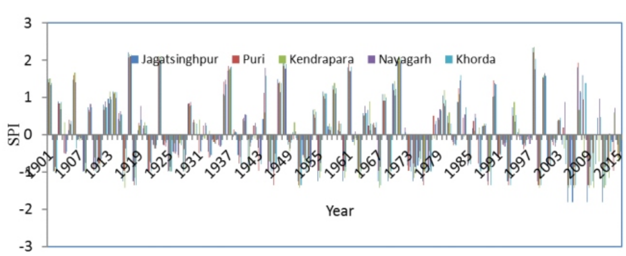

Fig. 15. 1-month SPI for East and South Eastern Coastal Plain for the month of February

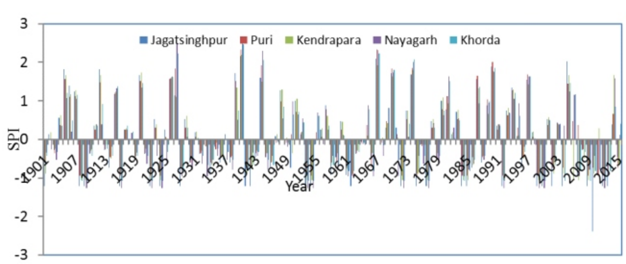

Fig. 16. 1-month SPI for East and South Eastern Coastal Plain for the month of March

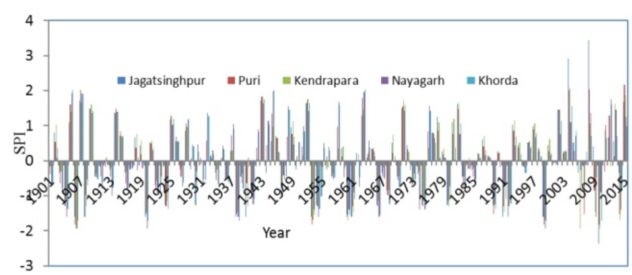

Fig. 17. 1-month SPI for East and South Eastern Coastal Plain for the month of April

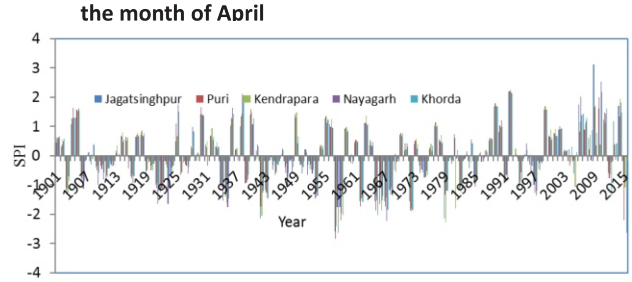

Fig. 18. 1-month SPI for East and South Eastern Coastal Plain for the month of May

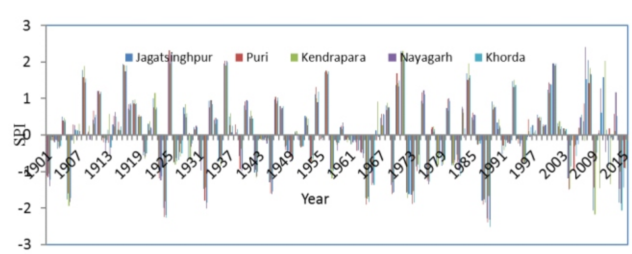

Fig. 19. 1-month SPI for East and South Eastern Coastal Plain for the month of June

Crop Planning

Agriculture is the main source of people's livelihood in the coastal belts of the state of Odisha. Agricultural activities in this region are dominated by rainfed rice and rice based cropping system. It suffers from water stress due to long breaks of monsoon (dry spells) during the crop growing season, and erratic distribution of rainfall at different crop growth stages. The 4 *kharif* months (June-September) are crucial since most of the water supplied for crop cultivation (mainly rice) comes from these 4-months. Out of these 4-months, June and July rains are crucial for rice crop cultivation, and hence droughts in these months severely affect crop production in Odisha (Behera and Panigrahi, 2010). Further, it is reported that SPI values of 1-month time scale are generally used for crop planning (Edwards and Mckee (1997). Keeping this in mind the 1-month SPI values for the four monsoon months (June, July, August and September) of both the two CACZs are discussed for effective crop planning.

Crop Planning in North Eastern Coastal Plain Agro-Climatic Zone

The study revealed that district Balasore had 59 years of drought (out of total 115 years) of varying intensity, both in June and September, whereas in the month of July and August, there were 53 and 54 years of drought (Fig's. 7 to 10). This implies that for saving the crop from drought, supplemental irrigation must be arranged in June and September. Since the months July and August had less drought chances as more number of years had wet condition, the excess rainwater in these two months may be collected in water harvesting structures, which may be used as supplemental irrigation to rice in September. District Bhadrak was found to have drought for more number of years in June and July (60 and 59 years out of 115 years) whereas in August and September, it was less with values of 48 and 56 years (Fig's. 7 to 10). The surplus water in the month of August and September may be harvested and used in *rabi* crops. District Jajpur had drought only in month of June (59 years out of 115 years), and in other three months (July to September) more number of years had wet condition . The excess rain water in these three months may be harvested for use in raising *rabi* crops (Fig's. 7 to 10).

Crop Planning in East and South Eastern Coastal Plain Agro-Climatic Zone

The study revealed that district Jagatsinghpur had 59,

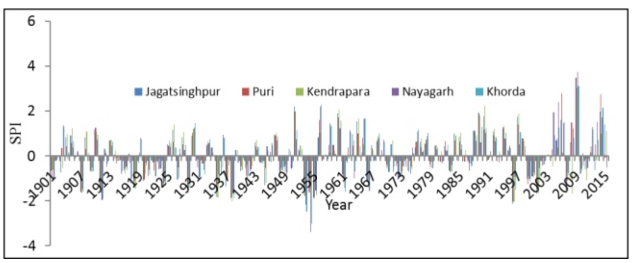

Fig. 20. 1-month SPI for East and South Eastern Coastal Plain for the month of July

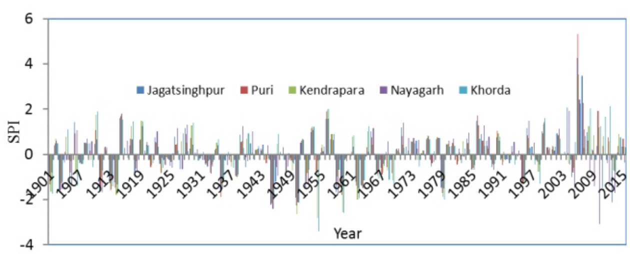

Fig. 21. 1-month SPI for East and South Eastern Coastal Plain for the month of August

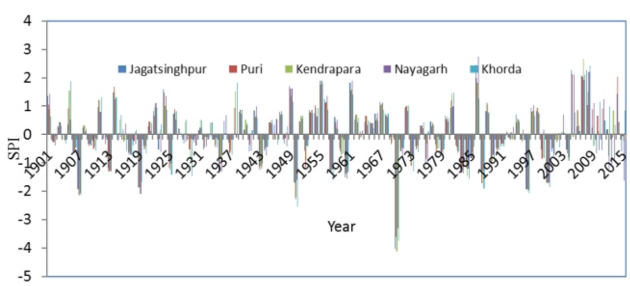

Fig. 22. 1-month SPI for East and South Eastern Coastal Plain for the month of September

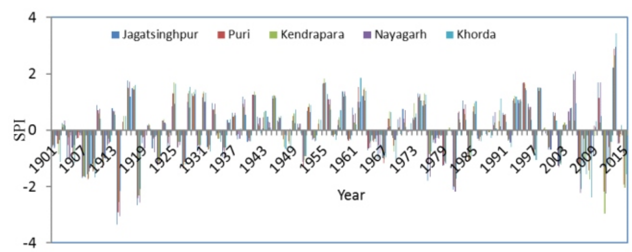

Fig. 23. 1-month SPI for East and South Eastern Coastal Plain for the month of October

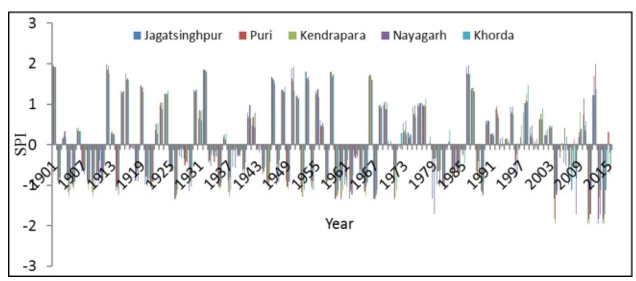

Fig. 24. 1-month SPI for East and South Eastern Coastal Plain for the month of November

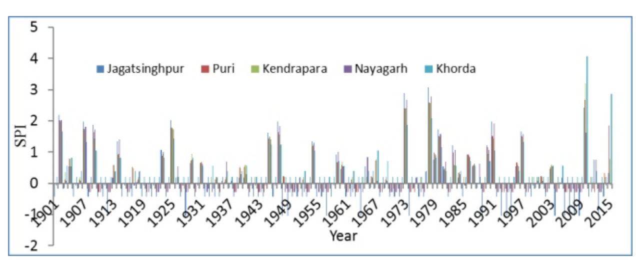

Fig. 25. 1-month SPI for East and South Eastern Coastal Plain for the month of December

62 and 59 years of drought (out of total 115 years) of varying intensity in June, July and September, whereas in the month of August, there was 55 years of drought (Fig's. 19 to 22). The excess water received in August may be used in rice crop in September to save it from drought. District Puri had alternate dry and wet conditions in *kharif* months with more number of drought years in July and August. The excess rainwater in June and August should be harvested and used as supplemental irrigation in July and September. In months of June and July, Khorda had 59 and 58 years of drought, whereas in August and September, number of drought years were less with values of 55 and 57 (Fig's. 19 to 22). Effective crop planning requires provision of supplemental irrigation in June and July. On the other hand, the excess rainwater in August and September may be stored in water harvesting structures for use in *rabi* crops. It is revealed from the study that the district Kendrapara had drought for more number of years in all the *kharif* months, except August. The number of drought years in June, July and September were 59, 60 and 58, respectively, whereas in August it was 53 (Fig's. 19 to 22). So there should be arrangement of irrigation in these three months. District Nayagarh had more drought years in June and July (63 and 61, respectively) and less drought years in August and September (54 and 55 years, respectively) (Fig,s. 19 to 22). So surplus rainwater in August and September should be harvested and used for successfully raising a second crop in *rabi.*

The study reveals that all the 8 districts had more number of wet years in August varying from 59 to 67. The excess rainwater in August should be harvested for use in crops in subsequent months. Earlier studies by Panigrahi and Panda (2001) and Panigrahi *et al.* (2002) also indicate that there is ample scope of rainwater harvesting in on-farm reservoirs in August month in the state of Odisha which receives more rainfall than crop water requirement, which may be used as supplemental irrigation in rice crops.

4. CONCLUSIONS

Drought indices are helpful to monitor and assess severity of drought for effective crop and water resources planning. They are helpful to study the impact of climate change and its variability, and various anomalies study related to climate change. Moreover, drought indices are helpful to identify and locate places suffering from deficiency of available water resources, which may affect the effective use of crop production and productivity. In this study, drought of various intensities in terms of SPI in 1, 3, 6, 9 and 12-month time scales were calculated for 8 coastal districts comprising 2 CACZs of Odisha. Results indicate that the frequency of occurrence of mild, moderate, severe and extreme droughts varies from 32.0% to 42.5%, 6.16% to 11.2%, 1.88% to 5.22% and 1.08% to 3.50%, respectively across all the districts in CACZs of Odisha. It was observed that 7 out of 8 districts (except Puri) had more number of drought years varying from 59 to 63 years (out of 115 years) in June, whereas all the 8 districts had more number of wet years in August varying from 59 to 67. The excess rainwater in August should be harvested for use in crops in subsequent months.

REFERENCES

Behera, B.P. and Panigrahi, B. 2010. Water management practices for producing more crops with less water with special reference to Orissa state. *Indian J. Power River Valley Dev.,* 95-101.

Capra, A. and Scicolon, B. 2012. Spatiotemporal variability of drought on a short–medium time scale in the Calabria Region (Southern Italy). *Theoretical Appl. Climat.*, 3: 471–488.

Central Ground Water Board (CGWB). 1999. Ground water year book: 1998-99. South Eastern Region, Bhubaneshwar.

Dash, B.K., Panigrahi, B., Paul, J.C. and Sahu, A.P. 2013. Forecasting dry and wet spell for agricultural planning in South Odisha. *J. Soil Water Cons.,* 12(4): 327-332.

Edwards, D.C. and McKee, T.B. 1997. Characteristics of 20th century drought in the United States at multiple scales. *J. Atmos. Sci.,* 634.

Gibbs, W. and Maher, J. 1967. Rainfall deciles as drought indicators. *Theor. Appl. Climatol.*, 48: 117.

Gommes, R. and Petrassi, F. 1994. Rainfall variability and drought in Sub-Saharan Africa since 1960. Agro-meteorology series working paper 9, Food and Agriculture Organization, Rome.

Guttman, N.B.1998. Comparing the Palmer drought severity index and the standardized precipitation Index. *J. Am. Water Resour. Asso.,* 34: 113–121.

Kumar, N., Chandrawanshi, S.K. and Radadia, G.G. 2018. Reconnaisance of meteorological drought by using standardized precipitation index and India Meteorological department criteria for five districts of south Gujarat. *Indian J. Soil Cons.,* 46(3): 293-304.

McKee, T.B., Doesken, N.J. and Kleist, J. 1993. The Relationship of Drought Frequency and Duration to Time Scales. *Proc. of the Ninth Conference on Applied Climatology.* American Meteorological Society, Boston, 179–184.

OMEGA. 2014. Basket of Projects for various Agro-Climatic Zones of Odisha, Government of Orissa.

OSDMA, 2003. Annual Report on Natural Calamities. 2003. Special Relief Commissioner, Revenue Department, Orissa State Disaster Mitigation Authority, Government of Orissa.

Palmer, W.C.1965. Meteorological drought. Research Paper, U.S. Weather Bureau, Washington, D.C. 45: 58.

Panigrahi, B. and Panda, S.N. 2001. Analysis of weekly rainfall for crop planning in rainfed region. *J. Agric. Eng.,* 38(4): 47-57.

Panigrahi, B., Panda, S.N. and Mull, R. 2002. Prediction of hydrological events for planning rainfed rice. *Hydrologic. Sci. J.,* 47(3): 435-448.

Van Rooy, M.P. 1965. A rainfall anomaly index independent of time and space. *Notos,* 4:43–48.

Vicente-Serrano, S.M. 2006. Differences in spatial patterns of drought on different time sales. An analysis of the Iberian Peninsula. *Water Resour. Manage.*, 20: 37–60.

Wu, H., Hayes, M.J., Wilhite, D.A. and Svoboda, M.D. 2005. The effect in the length of record in the Standardized Precipitation Index calculation. *Int. J. Climatol.*, 25: 505–520.