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Assessment of Drought Severity in Various Regions of Jharkhand State of India

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Abstract

Drought originates from the deficiency of precipitation over an extended period of time, resulting in a water shortage for some activity, group, or environmental sector. Drought affects virtually all climatic regions and more than one half of the earth is susceptible to drought each year. In India, around 68 percent of the country's area is prone to drought in varying degrees. There are 14 districts in the state of Jharkhand covering 100 blocks with an area of 34843 sq km (43.7 percent of the state area) which are covered under Drought Prone Area Programme (DPAP) implemented by Government of India. In rain fed agriculture scenario, which exist in the Jharkhand state of India, the rainfall occurrence is the prime deciding factor in evaluating the crop yields. Variability in the rainfall occurrence in the state primarily results due to interaction of various climatic parameters resulting in normal or erratic rainfall. Many parts of the state experiences agricultural drought like conditions during Kharif (monsoon) season. There are many indices for the evaluation of drought. In the present study drought severity assessment in various regions of Jharkhand state was attempted based on computation of select drought indices viz; Rainfall Anomaly Index (RAI), Aridity Index (Ia) and Departure Index (DI). Drought indices revealed that overall drought proneness is apparently high in Daltonganj and Chaibasa, although both of them have mild droughts in majority of the years. On the contrary in terms of moderate droughts, Dumka has the highest severity followed by Daltonganj, Jamshedpur and Dhanbad whereas Chaibasa and Ranchi has the least percentage.

Keywords: Rainfall, aridity index, rainfall anomaly index, departure index, humid regions.

Introduction

Drought is among the most important weather induced hazards resulting due to water deficit in a given area in a particular period of time. There was a sudden rise in the incidence as well as increase in the intensity of drought in Jharkhand during the 1991-2000 decade, which is attributed to urbanization, industrialization and climatic changes[1]. Due to apparent climate changes, during the last few years, the pattern of rainfall has become erratic. Frequent failures of monsoon in recent decades have also increased our dependency on groundwater for agricultural purpose[2]. This entails development of scientific approaches towards drought analysis and proper and sustainable utilization of water resources to combat drought in the state of Jharkhand.

Earlier workers dealing with drought prognosis developed a number of drought indices viz., Palmer Drought Severity Index (PDSI), Stochastic Component Time Series (SCTS), Rainfall Anomaly Index (RAI), Departure Index (DI), Percentiles, Deciles and Quartiles (PDQ), Drought Area Index (DAI), Drought Severity Index (DSI), Gumbel Recurrence Interval (GRI), Standardized Precipitation Index (SPI). RAI represent an effective drought index and its outcomes are similar to other drought indices such as PDSI and DAI[3].

The analysis of drought, which is based on the criterion of rainfall alone, is not adequate to explain drought conditions properly as drought is not a direct result of the shortage of rainfall alone but also depends upon soil and water need of a place[4]. India is leading towards a fresh water crisis mainly due to improper management of water resources[5]. In India, the monitoring of agricultural drought on a near real time is done for the entire country in the Kharif cropping season during June to October by the Indian Meteorological Department (IMD) based on Aridity Index. Yearly departures of aridity index from the median at a station when graphically plotted against the successive years yield the information about the years of drought and intensity[6].

Rainfall constitutes an important hydrological factor which is readily available meteorological measurement. It is therefore used in calculating various drought indices. It is better to utilize rainfall data of previous 20-30 years rather than using long term records for effective development planning[7]. Rainfall data comprising recent 30 years period is best suited for planning agricultural activities because such decisions are related to immediate past[8].

Some areas in drought prone regions in Palamu district of Jharkhand exhibits an increase in the rainfall over the years, yet the average water level is very deep indicating large water

losses due to runoff[9]. Therefore in the present study the drought characterization in Jharkhand was attempted based on aridity index as well as by employing rainfall based drought indices viz., Departure Index (DI) and Rainfall Anomaly Index (RAI). The climatic data pertaining to mean monthly temperatures and rainfall covering a period of 22 to 35 years was collected from Indian Meteorological Department (IMD), Pune for seven meteorological stations viz., Ranchi, Daltonganj, Dumka, Jamshedpur, Hazaribagh, Chaibasa and Dhanbad (figure 1).

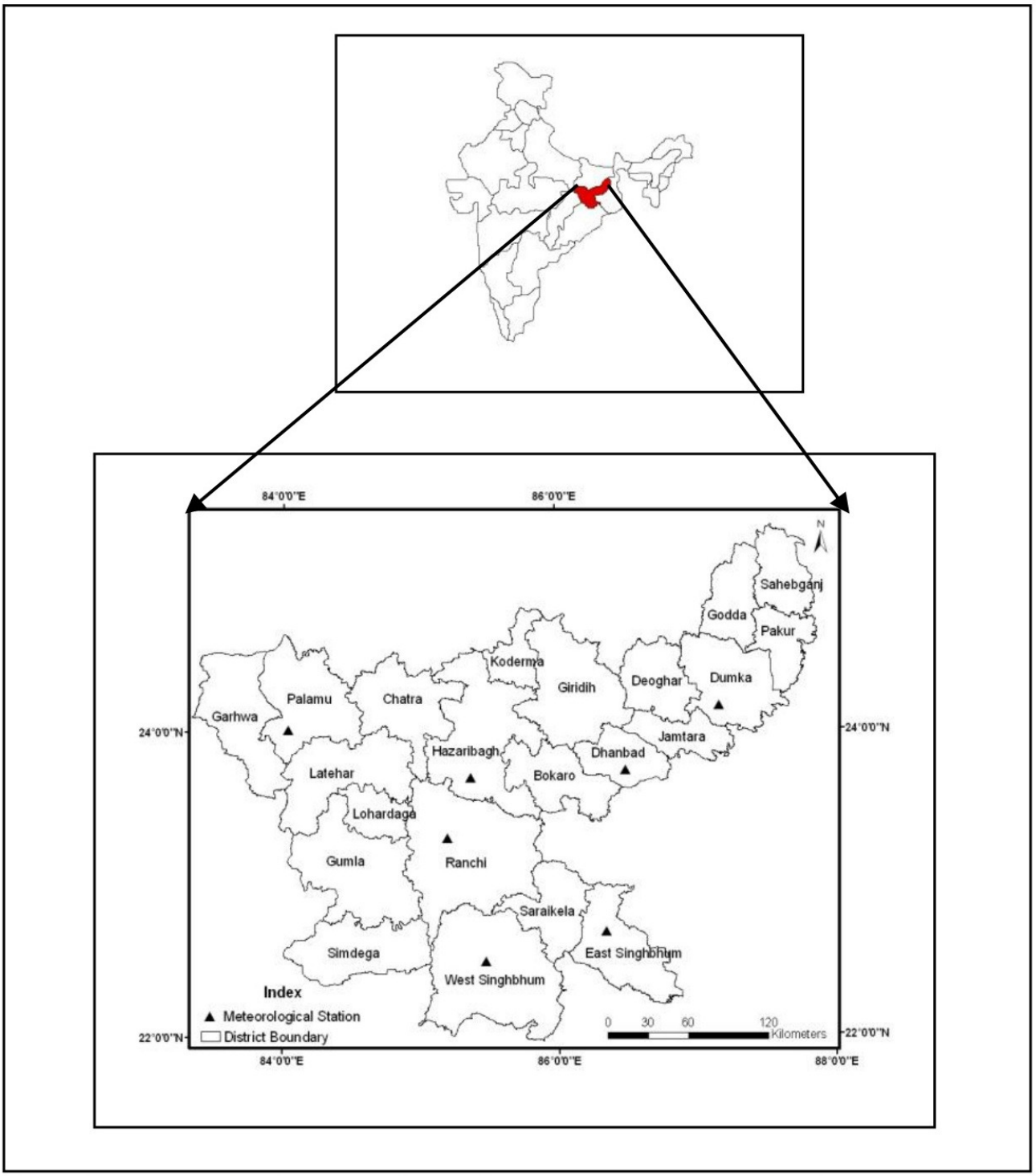

Figure-1
Location map of Jharkhand state with sites of seven meteorological stations

Material and Methods

Aridity Index (I_a): Aridity index (I_a) is used for the analytical study of drought situation and represent the percentage ratio of water deficit to water need. It is computed as $I_a = \frac{PE - AE}{PE} * 100$, where *PE* is the potential evapotranspiration, *AE* is the actual evapotranspiration and *(PE-AE)* gives the water deficit.

In the present study the annual water balance was estimated for each station followed by computation of aridity index (I_a). Median and standard deviation was computed by considering all the values of I_a. Departure of individual I_a value from the median were observed so as to find out the drought intensity at each station in a particular year following the general scheme of drought categorization[6] (table 1).

Table-1
General scheme of drought categorization based on Aridity Index

Departure of I_a from Median	Drought Intensity
Less than 0	**No**
Below ½ σ	Moderate
½ σ to σ	Large
σ to 2 σ	Severe
Over 2σ	Disastrous

Departure Index (DI): Indian Meteorological Department and National Commission on Agriculture classified the droughts on the basis of annual rainfall deficiency[10, 11]. The criteria is based upon the percentage of rainfall departure from its long term mean and is computed as

$$DI = \left[\frac{RF - M_{RF}}{M_{RF}}\right] * 100$$

where, *DI* is the percentage of departure from long term mean, *RF* is the annual rainfall in mm and M_{RF} is the long term mean of annual rainfall in mm.

The percentage of departure from normal rainfall and corresponding intensity of meteorological drought is shown in table 2.

Table-2
Intensity of meteorological drought based on Departure Index

Departure Index	Intensity of meteorological drought	Code
0.0 or above	No drought	M_o
00.0 to –25.0	Mild drought	M_1
-25.0 to –50.0	Moderate drought	M_2
-50.0 or above	Severe drought	M_3

Rainfall Anomaly Index (RAI): Rainfall anomaly index calculates the annual rainfall variability[12]. It is used for the purpose of assessing the degree of droughts and their management. This technique incorporates the rainfall measurements for a given area during a particular time period. The rainfall data were arranged in descending order of intensity in which higher rainfall values are ranked first and the lowest rainfall values are ranked last. Further the average value of the ten highest rainfall measurements comprising the maximal average of ten extrema and the ten lowest rainfall measurements comprising the minimal average of ten extrema was computed for the period under consideration. These values represent the positive and negative anomalies respectively based on average rainfall values of ten extrema.

RAI is calculated for positive anomalies and negative anomalies as given in equation 1 and 2 below.

$$RAI = +3\left[\frac{RF - M_{RF}}{M_{H10} - M_{RF}}\right] \quad (1)$$

$$RAI = -3\left[\frac{RF - M_{RF}}{M_{L10} - M_{RF}}\right] \quad (2)$$

In above equations RAI is the annual RAI, *RF* represent total rainfall obtained during a particular year whereas M_{RF} constitute the mean rainfall recorded during the study period. The mean value of the 10 highest and 10 lowest rainfall values is given by M_{H10} and M_{L10} respectively.

Results and Discussion

Aridity Index: Aridity index provide the information about the intensity of each drought event. The drought intensity has been categorized as moderate, large, severe and disastrous based on departure of yearly Ia values from the median value computed for the entire observation period[6]. Drought severity based on aridity index for various stations in Jharkhand is given in table 3. Drought proneness was also calculated to asses relative vulnerability of regions to various intensity of drought using the formula

$$Drought\ proneness = \frac{Number\ of\ droughts\ under\ each\ category}{Total\ number\ of\ droughts} * 100$$

It is imperative that overall drought proneness is highest in Daltonganj (61%) followed by Jamshedpur (54%) and equal proneness in Dumka (52%) and Chaibasa (52%), whereas least in Ranchi (51%) and Dhanbad (50%). In terms of drought proneness under each drought intensity category highest percentage of moderate drought occurrences was found in Chaibasa and Ranchi followed by Jamshedpur and Dumka and least in both Dhanbad and Daltonganj. In terms of large drought Daltonganj, Jamshedpur, Dhanbad and Ranchi have similar occurrences, whereas Dumka and Chaibasa have the least proneness. Although disastrous droughts are rare in Jharkhand the occurrence of severe droughts are highest in Daltonganj and Dumka followed by Chaibasa, Ranchi and Dhanbad and least in Jamshedpur.

Figures in parenthesis indicate drought proneness with reference to a particular drought category.

Departure Index (DI): Departure index (DI) given by India Meteorological Department and National Commission on Agriculture provide measure of percentage of rainfall departure from normal rainfall and corresponding meteorological drought intensity[10,11] (table 2). It shows that all the stations have experienced only mild and moderate drought (table 4, figure 2). Combining all drought years to deduce overall drought proneness, it is apparent that Daltonganj (61%) experienced the highest followed by Chaibasa (56%), Dumka (52%), Ranchi (51%), Jamshedpur (50%) and Dhanbad (45%) during the respective observation periods.

The overall drought proneness is apparently high in Daltonganj and Chaibasa, although both of them have mild droughts in majority of the years. On the contrary in terms of moderate droughts, Dumka has the highest severity followed by Daltonganj, Jamshedpur and Dhanbad whereas Chaibasa and Ranchi has the least percentage.

Figures in parenthesis indicate drought proneness with reference to a particular drought category.

Table-3
Drought severity during different years in various stations in Jharkhand based on Aridity Index

Stations (observation years)	Overall Drought Proneness	Mod. Drought Year	Large Drought Year	Severe Drought Year	Disastrous. Drought Year
Ranchi (35)	18 (51%)	72, 74, 76, 79, 80, 82, 84, 86, 89, 2000, 2002 (61%)	85, 99, 2004 (17%)	92, 96, 2001 (17%)	88 (5%)
Daltonganj (23)	14 (61%)	72, 73, 76, 83, 85, 89 (43%)	69, 84, 96 (21%)	74, 75, 79, 81 (29%)	88 (7%)
Dumka (23)	12 (52%)	74, 75, 76, 79, 80, 86, 88 (59%)	84 (8%)	72, 82, 85, 87 (33%)	0 (0%)
Jamshedpur (26)	14 (54%)	74, 76, 77, 80, 84, 87, 88, 90 (58%)	69, 75, 79 (21%)	72 (7%)	86, 89 (14%)
Chaibasa (23)	12 (52%)	69, 75, 76, 80, 82, 84, 89, 93 (68%)	87 (8%)	72, 74, 79 (24%)	0 (0%)
Dhanbad (22)	11 (50%)	70, 74, 75, 77, 81 (46%)	69, 72, 79 (27%)	76, 84 (18%)	82 (9%)

Table-4
Drought severity during different years in various stations in Jharkhand based on Departure Index

Stations (observation years)	Overall Drought Proneness	Mild Drought Year	Moderate Drought Year	Severe Drought Year
Ranchi (35)	18 (51%)	72, 74, 80, 82, 83, 84, 85, 86, 88, 92, 93, 96, 99, 2000, 2001, 2002, 2004 (95%)	79 (5%)	0 (0%)
Daltonganj (23)	14 (61%)	69, 72, 73, 74, 76, 83, 84, 85, 89, 96 (72%)	75, 79, 81, 88 (28%)	0 (0%)
Dumka (23)	12 (52%)	70, 74, 75, 76, 80, 88 (50%)	72, 79, 82, 85, 86, 87 (50%)	0 (0%)
Jamshedpur (26)	13 (50%)	69, 70, 74, 76, 80, 87, 88, 90, 98 (69%)	72, 79, 86, 89 (31%)	0 (0%)
Chaibasa (23)	13 (56%)	69, 70, 73, 74, 76, 80, 82, 85, 86, 87, 93 (85%)	72, 79 (15%)	0 (0%)
Dhanbad (22)	10 (45%)	69, 70, 74, 79, 86, 88 (60%)	72, 76, 80, 82 (40%)	0 (0%)

Rainfall Anomaly Index: The value of RAI for different stations in Jharkhand (figure 3) shows the occurrence of dry years (negative values) as well as wet years (positive values). However values of the RAI less than minus three normally correlate with severe drought[13]. It was observed that number of dry years computed for different stations was same as computed through Departure Index. However during the period when RAI was less than minus three, Ranchi experienced severe droughts in the years 72, 79, 82, 88 and 92, Daltonganj 75, 79, 81 and 88, Jamshedpur 72, 79, 86 and 89, Dumka 72, 75, 79, 82, 85, 86 and 87, Dhanbad 72, 76, 80 and 82 and Chaibasa with 2 events 72 and 79. Highest drought severity occurred in Jamshedpur when RAI was less than minus six. The overall drought proneness percentage deduced from RAI is same as obtained through DI.

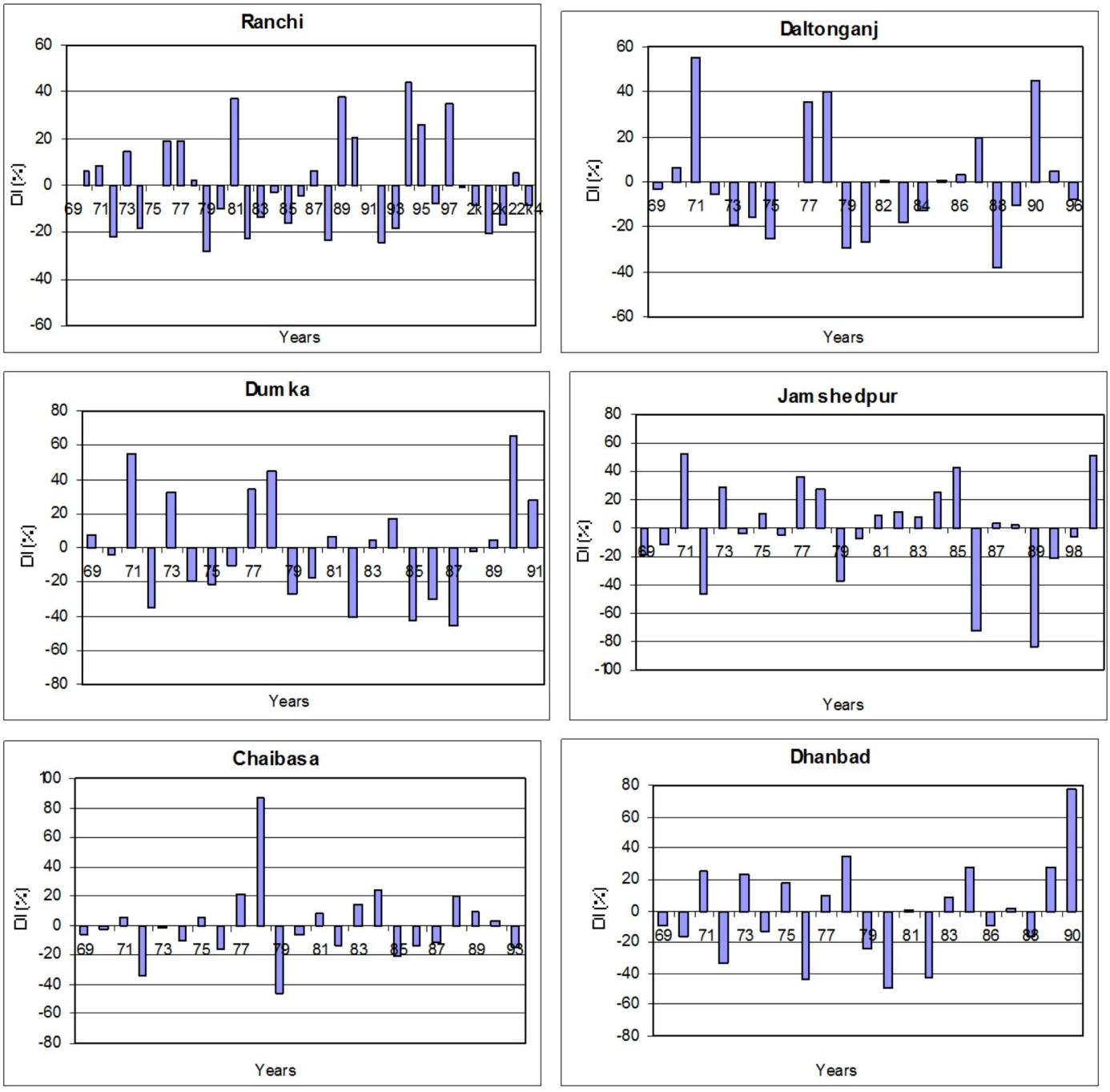

Figure-2
Departure Index at different stations of Jharkhand

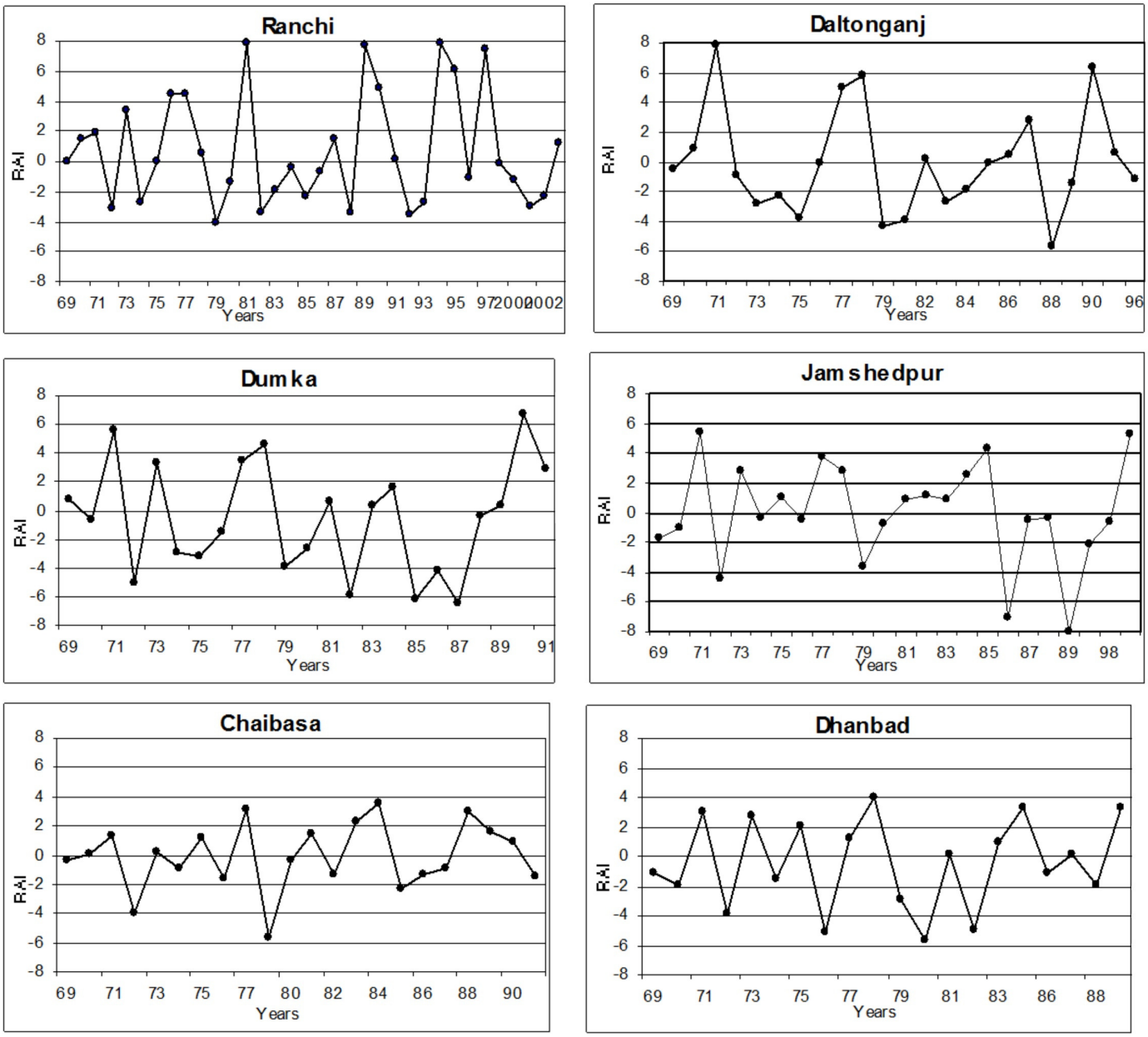

Figure-3
Rainfall Anomaly Index at different stations of Jharkhand

It is to remark that although comparatively less but still higher drought proneness apparent in Ranchi under all the methods is attributed to the occurrence of drought in the years 2000, 2001, 2002 and 2004 in various parts of Jharkhand for which the rainfall data was available only at Ranchi station. If we ignore these four drought years from the data the overall drought proneness of Ranchi comes further down to 40% under each (Ia, DI and RAI) method.

Validation of drought intensity in Ranchi in the year 2009, when all parts of the state experienced drought conditions was done using the daily observations of rainfall, temperature and evaporation recorded at meteorological observatory, BIT, Ranchi. It was analyzed that as per I_a, the drought severity at Ranchi during 2009 was classified as severe, whereas DI shows moderate drought, which confirm the validity of these methods in classifying drought accurately.

Conclusion

Comparative study of number of drought years obtained through various drought indices clearly revealed that all the methods yielded similar results, although at places marginal differences were observed in the number of drought years. This indicates

suitability of any of these methods in deducing the drought years. Among the three methods employed, Aridity Index (Ia) seems to be the most accurate method for drought severity assessment as it is based on the computation of various parameters of water balance. Comparatively, the Departure Index (DI) is rather simple in computation and sees only the annual rainfall variation to asses drought severity. Rainfall Anomaly Index (RAI) although doesn't quantify drought severity but only the dry years, still it is similar in approach as DI and therefore yields similar results as DI. Drought indices revealed that overall drought proneness is apparently high in Daltonganj and Chaibasa, although both of them have mild droughts in majority of the years. On the contrary in terms of moderate droughts, Dumka has the highest severity followed by Daltonganj, Jamshedpur and Dhanbad whereas Chaibasa and Ranchi has the least percentage. Therefore to combat drought situation supplementary irrigation facilities should be made available in high drought prone regions. The crop selection in these regions should be directed towards adoption of crops which require low moisture conditions.

References

1. Hema Malini B. and Anuja T., Trends in the incidence of droughts in Jharkhand state, India, *The Eastern Geographer***,** 13(1)**, 51-57 (2007)**

2. Mushini V.S.R., Vaddi D.R. and Bethapudi S.A.A., Assessment of Quality of Drinking Water at Srikurmam in Srikakulam District, Andhra Pradesh, India, *Int. Res. J. Environment Sci.*, **1(2)**, 13-20 **(2012)**

3. Oladipo E.O., A comparative performance analysis of three meteorological drought indices, *Journal of Climatology*, **5**, 655-664 **(1985)**

4. Gibbs W.J. and Mather J.V., Rainfall deciles as drought indicators, Bull. No. 48, Melbourne Bureau of Met., Melbourne **(1967)**

5. Ramesh K. and Bhuvana Jagadeeswari P., Hydrochemical Characteristics of Groundwater for Domestic and Irrigation Purposes in Periyakulam Taluk of Theni District, Tamil Nadu, *Int. Res. J. Environment Sci*., **1(1)**, 19-27 **(2012)**

6. Subrahmanyam V.P. and Subramaniam, A.R., Some characteristicts and frequency of occurrence of droughts in the dry climatic zones of India, *Bull. Internat. Assn. Sci. Hydro*., XC, Annes, **3,** 31-37 **(1965)**

7. Dennett M.D., Elston J. and Rodgers J.A., A reappraisal of rainfall trends in the Sahel, *Journal of Climatology*, **5**, 353-361 **(1985)**

8. Todorov A.V., Sahel: the changing rainfall regime and the "Normals" used for its assessment, *Journal of Climate and Applied Meteorology*, **24(2)**, 97-107 **(1985)**

9. Tirkey Anamika Shalini, Pandey A.C. and Nathawat M.S., Groundwater Level and Rainfall Variability Trend Analysis using GIS in parts of Jharkhand state (India) for Sustainable Management of Water Resources, *Int. Res. J. Environment Sci*., **1(4)**, 24-31**(2012)**

10. Indian Meteorological Department, Rainfall and Drought in India, Indian Meteorological Department, Government of India, Poona, India **(1971)**

11. National Commission on Agriculture, Agricultural commission report, National Commission on Agriculture, Ministry of Agriculture, Government of India, New Delhi, **(1976)**

12. Van Rooy M.P., A rainfall anomaly index independent of time and space, **Notos**, **14**, 43 **(1965)**

13. Tilahun K., Analysis of rainfall climate and evapo-transpiration in arid and semi-arid regions of Ethiopia using data over the last half a century, *Journal of Arid Environments*, **64**, 474-487 **(2006)**