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Water management for supplemental irrigation based on rainfall characteristics of Ranchi district, India

Ranjay Kumar Singh*, Ajita Gupta and Mukesh Kumar

ICAR-Central Institute of Agricultural Engineering, Bhopal, Madhya Pradesh.

*Corresponding author:
E-mail: ranjay_2005@rediffmail.com; rksinghiinrg@gmail.com (Ranjay Kumar Singh)*

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ABSTRACT

Rainfall and drought assessment is essential in identifying the water supply trends, detecting the probability of drought occurrence, and managing the irrigation water for assured crop growth. Forty two years (1971-2012) of daily point rainfall data were analyzed for Namkum, Ranchi station for assessment of basic rainfall characteristics, number of rainy days and distribution of rainfall across the seasons in a year to plan the supplemental irrigation for the *rabi* season crop. Trend analysis of rainfall amount and number of rainy days was done by non-parametric Mann-Kendall test and Sen's slope approaches. The drought analysis was done by using standardized precipitation index (SPI). The results showed a decreasing trend in annual rainfall for most of the months and significantly decreasing trend during February (-0.51 mm yr^{-1}) and July (-2.66 mm yr^{-1}) months. The annual and winter rainy day showed a statistically significant decreasing trend with the magnitude of -0.38 and -0.09 days yr^{-1}, respectively. The annual drought analysis revealed that out of forty two years of study duration, only one extremely severe drought occurred in this region in the year 2010. Thus, traditional water harvesting structures such as *Jalkunda* as well as farm pond should be constructed to harvest the excess rainfall in the rainy season. The harvested rainfall can be used to provide supplemental irrigation during *rabi* crop season as well as in the monsoon season during prolonged dry spells. The outcomes of this study would help in water management studies for providing supplemental irrigation to the crops at their critical stages.

1. INTRODUCTION

Rainfall, being an important hydro-meteorological parameter, has enormous role in the climatic studies of any region. Because of its practical and climatological implications, it is vital to place interest on its characteristics *e.g.* amounts, monthly and seasonal variations, percentage, intensity, and its spatio-temporal distribution (Awasthi, 1995).

In most parts of our country, rainfall is uneven, uncertain and erratic in nature. The knowledge of distribution of dry spells and amount of rainfall during wet spells is very much essential for successful management of agricultural practices. Various scientific studies have been carried out in the past by various investigators on rainfall analysis (Jana *et al.,* 2017; Alam *et al.,* 2016; Alam *et al.,* 2015a; Alam *et al.,* 2015b); Mohanty *et al.,* 2001; Jakhar *et al.,* 2011; Sharda and Bhushan, 1985; Ray *et al.,* 2012a; Ray *et al.,* 2012b; Ray *et al.,* 2014; Satapathy *et al.,* 1998).

Drought is an unexpected reduction in precipitation over period of time in an area which is not necessarily arid. Characterizing periods of deficit rainfall and drought have been an important aspect of planning and management of water resources systems for many decades (Nandeesha and Ramu, 2015). Rainfall deficits may result in low crop yields for agriculture, ground water deficit, depletion in lakes / reservoirs, shortage of drinking water and, reduced fodder availability etc., which have severe impact on local livelihood. Crops require regular irrigation during their growth cycles for the sustainability of agriculture (Rajput *et al.,* 2022). Sharma *et al.* (1979, 1987a and 1987b) analysed the rainfall using the definition of drought month as a month in which the actual rainfall is less than 50% of the average monthly rainfall. Sinha (1986) and Ray *et al.* (1987) used this definition to study the drought at Gopalpur, Odisha. Kamble *et al.* (2019) calculated the standardized precipitation index (SPI) values using monthly rainfall data to assess the meteorological drought. Kumar and Kumar (1989), Dabral (1996) and Ray *et al.* (2012b) analysed the weekly, monthly, seasonal and yearly rainfall of Pantnagar, Ranchi and Barapani, respectively for drought analysis; as per the procedure followed by Dhar *et al.* (1979), Sharma *et al.* (1979), IMD (1979), Ray *et al.* (2012b) and Singh *et al.* (2013). Climatic water balance assumes greater importance in rainfed regions like Ranchi where quantum and distribution of rainfall during the cropping season is highly variable and water availability strongly depends on geography and soil properties. In view of the above factors, knowledge of the interrelationship of the crop growth and productivity with the availability of water for crop growth, period of water deficiency and surplus water for water harvesting and their reuse is extremely important.

Ranchi region is the largest part of the chhota Nagpur Plateau having lateritic soil. This climate is considered to be Cwa according to the Köppen-Geiger climate classification. Under this classification summer season tends to be hot and wet and average temperature rises to more than 22^{0}C for at least one month. Winter season is normal and dry (Arnfield, 1997). Undulating terrain, shallow soil depth, low water retentive capacity and poor fertility of soils, fragmented holdings, high intensity (causing severe soil erosion) often erratically distributed (prolonged dry spells) rainfall and very meager irrigation potential (10-12%) are the most important constraints of the state (Wadood and Kumari, 2009). If the farmers have some idea of normal date of monsoon onset, its withdrawal and length of the rainy season, proper planning and scheduling of cropping activities in rainfed areas can effectively be done. The southwest monsoon normally advances over the state and adjoining areas by around 10 to 15 June and establishes firmly over the entire region by the end of June. It withdraws from the region mostly in the first to second week of October comprising 100 to 200 days of rainy season (Wadood and Kumari, 2009) with the normal duration of 140 days. Magnitude and intensity of rainfall is maximum during monsoon season. The time and duration of the seasons' high rainfall at a place or watershed is the most important factor for the planning and design of agriculture or water managements.

According to a study carried out by Wadood and Kumari (2009), it was observed that the frequency distribution in recent years has created a kind of uncertainty for the crops being grown in seasons other than monsoon season. Hence, raising crops in *rabi* season (post-monsoon) as well as in pre-monsoon seasons requires assured irrigation facilities. Hence, rainwater harvesting during its abundance and its re-use during its scarcity seems to be the only alternative for Jharkhand state. This will be helpful in growing successful crops in rain-scarce periods as well as in giving supplemental irrigations to standing crops raised in monsoon season in the events of prolonged dry spells. In view of the above, analysis of the rainfall amount, rainy days, onset and withdrawal of monsoon in Namkum station in Ranchi district has been dealt in the present paper by using suitable techniques. The analysis was correlated with harvesting of runoff water in the traditional structures as well as in the farm ponds at farmers' fields.

2. MATERIAL AND METHODS

Study Area and Data

Ranchi district is located between 22^{0}52″ to 23^{0}43″ north and between 84^{0}51″ to 85^{0}55″ east at an altitude of 650 m above mean sea level (amsl), covering an area of 5025 km^2 in Chota Nagpur plateau of Jharkhand state in India. The landscape of Ranchi district is formed of hills and undulating terrain of Ranchi plateau. The uplands of this plateau are known as *Tanrs* and the lowlands are locally known as *Dons*. In Ranchi district, 74% of the population lives in the villages and totally depends on agriculture and related activities. There is a scarcity of sufficient and dependable source of irrigation. There are no irrigation projects in this district, may be due to erratic rain and other unfavourable conditions.

Major Crop Production in Ranchi District

The net sown area of Ranchi District is 255 thousand hectares is still predominantly dependent on rainfall. Net irrigated area forms just 32,100 ha (12.5%) of net sown area and the vagaries of monsoon hit the economy hard. There are three main cropping seasons *viz. kharif, rabi,* and summer. Major *kharif* crops are rice, maize, *bajra*, vegetables etc. Major crops grown in the *rabi* season are wheat, gram, and mustard. Summer crops are rice, maize, groundnuts, vegetables, etc. Area under rice and wheat crop is 159.2 thousand hectares and 2.8 thousand hectares, respectively. In Ranchi district, rice is sown generally during second week of June to first week of July, while, wheat during second week of October to second week of November. The date of sowing other prominent crops like gram and mustard coincides with the wheat sowing date. For want of irrigational facilities the farmers are traditionally been doing mono cropping, resulting in poor economy. In the larger interest of the rural economy, agriculture needs to be strengthened and one of its most important inputs *i.e.,* irrigation facilities needs to be given due priority. Prevalence of undulating land results in high peak rate of runoff from barren slopes due to which major part of the water goes as a waste, which, otherwise could have been stored with the help of suitable water conservation structures for its use as a means of supplemental irrigation.

Water Management Practices in Ranchi District

Water resource management is the activity of planning, developing, distributing and managing the optimum use of water. A thorough understanding of rainfall patterns is essential for planning and developing various water conservation structures (Singh and Kumar, 2021). Ranchi, the capital of Jharkhand, like many other cities in the country, is reeling under severe water crisis. The land is irrigated by surface water, reservoirs, wells and natural streams, *etc.* (Source; State: Jharkhand Agriculture Contingency Plan for district: Ranchi, 2012). Managing the existing water bodies is one way of taking care of it. Ranchi has limited groundwater, considering its granitic rock system, which has poor water retention capacity. Water conservation practices are deep ploughing in summer, sowing across the major slope, shallow intercultural, compartmental bunding and short term of rainy season ploughing. Contour bunding and terracing will not only induce ground water recharge but will also help in conserving the soil moisture. Combination of leguminous crop may help in water conservation aspect, as these crops have the ability to fix the atmospheric nitrogen and increase soil organic matter content thereby improving soil structure. It enhances internal aeration and drainage and improves soil moisture storage. For conservation and management of water there are many water conservation techniques but the techniques that may be adopted will be based on climatological condition of the region and socio-economic condition of the people. Thus, water conservation structures should be cheap and at the same time it may serve the purpose.

Although the average annual rainfall in the state is of around 1,200 mm, only a fifth of it is utilized. The state's 2010-11 economic survey indicated that surface water for agriculture was not sufficient because of inadequate storage facilities. Ninety percent of the state's rainwater is wasted as untapped runoff due to poor management practices. Jharkhand agriculture is largely rainfed, with only 10-12% of the cultivated area under assured irrigation (Wadood and Kumari, 2009).

Daily rainfall data for Namkum, Ranchi district, was collected for a period of 42 years from 1971-2012 from the Agrometeorology Station, ICAR-Indian Institute of Natural Resins and Gums, Ranchi maintained by India Meteorological Department (IMD), Government of India. The location and boundary of study area are shown in Fig.1.

Rainfall Analysis

By analysing the data, annual and monthly pattern and magnitude of rainfall in a given year for the period were calculated and the average monthly, seasonal and yearly rainfall values were worked out. The variation of rainfall for each month, season and year from the mean was determined

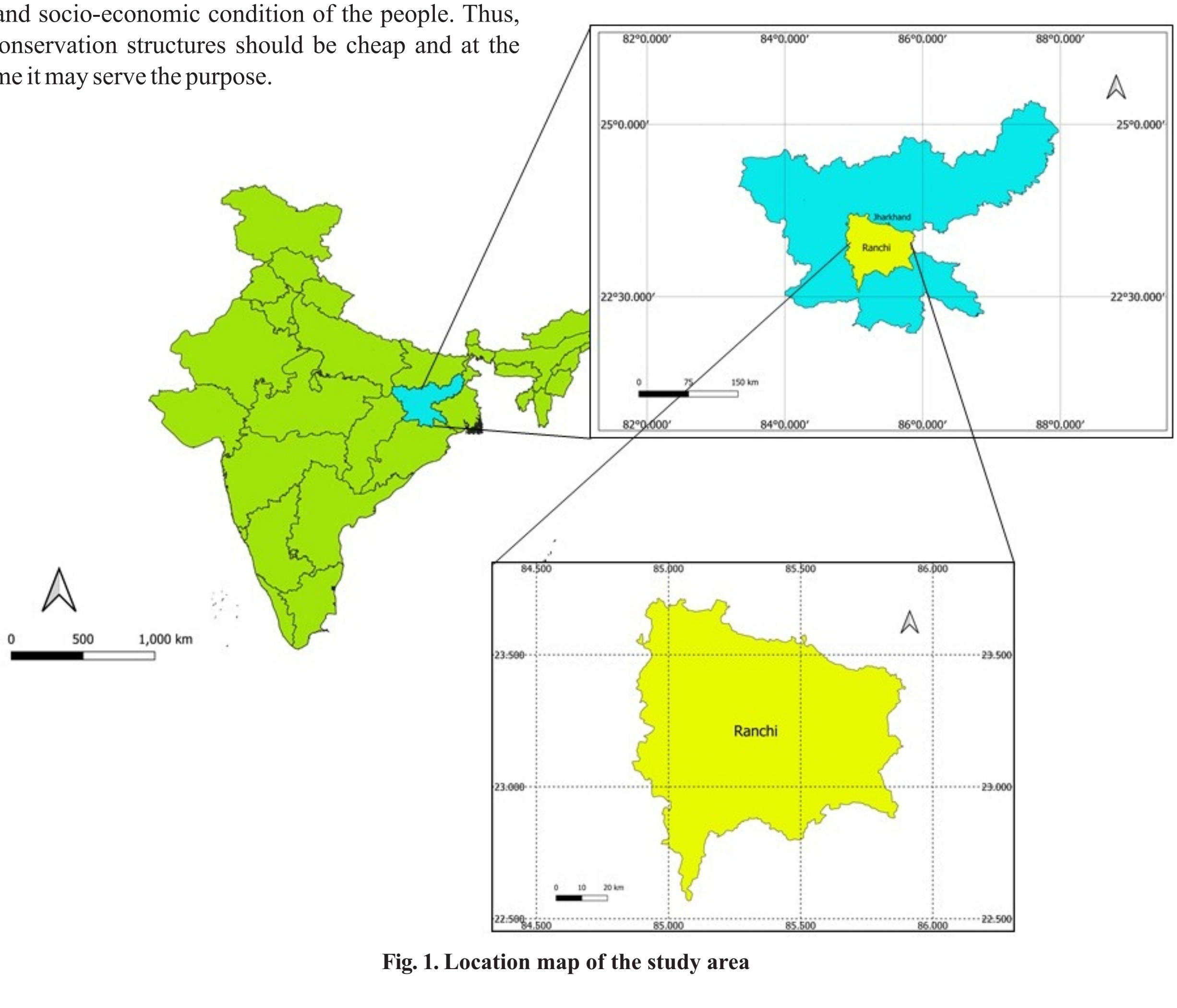

Fig. 1. Location map of the study area

and the mean deviation for the seasons was calculated. Trend analysis of annual rainfall amount and number of rainy days were calculated using Mann-Kendall and Sen's slope estimation method at 5% significant level. The non-parametric Mann-Kendall test is used to detect the trend present in the time series (Mann 1945; Kendall 1975). The Sen's slope test, also a nonparametric technique, is used for determining the trend magnitude (Sen, 1968).

Standard Precipitation Index (SPI)

Today, drought indices are indispensable tools to detect, monitor and evaluate drought events (Khan *et al.,* 2008). One of the most commonly used indices is the SPI (Guttman 1999), distinguished by simplicity and temporal flexibility, due to which the index can be used over different time scales. SPI was developed by McKee *et al.* (1993) as an index that could be used to assess whether there was an excess or shortfall of precipitation. The computation of SPI requires long-term data on precipitation to determine the probability distribution function (gamma distribution) which is then transformed to a normal distribution with zero as mean and standard deviation of one. For each region where precipitation data series are available, we can also determine the frequency of severely wet or dry episodes using SPI for a specific time scale (Moreira *et al.,* 2008). In 2010, World Meteorological Organization (WMO) selected the SPI as a key meteorological drought indicator for operational purposes. The standards for establishing the start and end of a drought episode were set by McKee *et al.*, 1993. When the SPI is consistently negative and drops to a value of -1 or less, a drought event starts. The calculation and analysis of SPI compute through SPI program developed by National Drought Mitigation Centre (University of Nebraska).

The SPI programme was downloaded from https://drought.unl.edu/Monitoring/SPI/SPIProgram.aspx. When the SPI value turns positive, the event is over. SPI values were calculated for three different time scales: monthly (June, July, August, September), monsoon season, and twelve-month, *i.e.* annual (SPI-12) time scales for the entire observation period of Ranchi district. The wet conditions and dry conditions corresponding threshold for SPI can be classified based on SPI categories respectively as given in Table (Mckee *et al.* 1993).

SPI values	Drought / Wetness condition
2 and above	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2.0 and less	Extremely dry

3. RESULTS AND DISCUSSION

Rainfall Analysis

Forty-two years (1971-2012) of daily point rainfall data were analysed for Namkum station, Ranchi. Descriptive statistical analysis of monthly and annual rainfall was done for Ranchi station (Table 1). The average annual rainfall of Namkum is 1456.7 mm with 76 number of rainy days. The maximum annual rainfall recorded as 2335.34 mm corresponding to the year 1994 and the minimum recorded as 746.75 mm corresponding to the year 2010. Highest mean rainfall (351.83 mm) was observed in July month, while lowest mean rainfall (9.52 mm) was observed in December month. The coefficient of variation was more than 100% for the months of January, March, November and December. The standard deviation varies from 16.37 mm to 133.96 mm. Lowest coefficient of variation (38%) was observed in

Table: 1
Statistical analysis of rainfall

Month	Minimum (mm)	Maximum (mm)	Mean (mm)	Standard deviation (n-1)	Variation coefficient (n-1)	Skewness (Pearson)	Kurtosis (Pearson)	% contribution
Jan	0.00	127.75	19.81	25.10	1.27	2.34	6.64	1.35
Feb	0.00	72.08	22.69	21.01	0.93	0.59	-0.88	1.55
Mar	0.00	129.93	21.93	28.57	1.30	2.01	4.11	1.50
Apr	0.00	111.14	27.95	26.62	0.95	1.40	1.63	1.89
May	0.72	147.37	58.38	42.80	0.73	0.32	-1.09	4.00
Jun	37.20	553.51	247.87	133.96	0.54	0.65	-0.40	17.01
Jul	194.87	884.00	351.83	132.59	0.38	1.63	4.19	24.15
Aug	99.42	748.96	342.90	131.17	0.38	0.63	0.64	23.53
Sep	96.50	651.08	266.09	107.34	0.40	1.30	2.40	18.26
Oct	0.00	286.86	74.62	67.40	0.90	1.44	1.97	5.12
Nov	0.00	97.48	13.11	20.61	1.57	2.12	5.01	0.89
Dec	0.00	68.20	9.52	16.37	1.72	2.12	4.16	0.65
Annual	746.75	2335.34	1456.70	294.29	0.20	0.40	0.94	100

n = number of years

July and August months. Perusal of Table 1 also points out that July and August are the wettest month contributing more than 47.7% of annual rainfall. Yearly variations of annual and seasonal rainfall, *i.e.,* pre monsoon (Feb to May), monsoon (June to Sep), post monsoon (Oct to Nov) and winter (Dec to Jan) were analysed (Fig. 2). From the figure it is evident that contribution of monsoon rainfall is the maximum (82.9%) in annual rainfall component. It also suggests that monsoon, annual and seasonal rainfall follow the same trend with high inter-annual rainfall variation, observed during the study period.

According to IMD for defining the 'rainy days' *i.e.* the day with at least 2.5 mm rain is called a rainy day (Ashokraj, 1979). Hence, average number of rainy days was calculated using same criteria for all standard meteorological weeks (SMW) (Fig. 3). The average number of rainy days per week was more than 3 from 25 to 37 SMW. Total rainy days, quantum of rainfall and evapotranspiration are presented on weekly basis in Fig. 3. The annual rainy days were more than 10 for June to September month (25-37 SMW).

Annual and Seasonal Rainfall Trend Analysis

The non-parametric Mann-Kendall (MK) test was applied for trend detection and trend magnitude analysis of annual and seasonal rainfall amount and number of rainy days (Table 2). Table shows the decreasing trend in annual rainfall for most of the months and significant decreasing trend during February (-0.51 mm yr^{-1}) and July (-2.66 mm yr^{-1}) months. As July is agriculturally important month for this region, it will affect agricultural practices of the region. Table also shows the decreasing trend in seasonal rainfall. The MK test applied to the number of rainy days series, too, showed decreasing trend for all months and seasons, but the

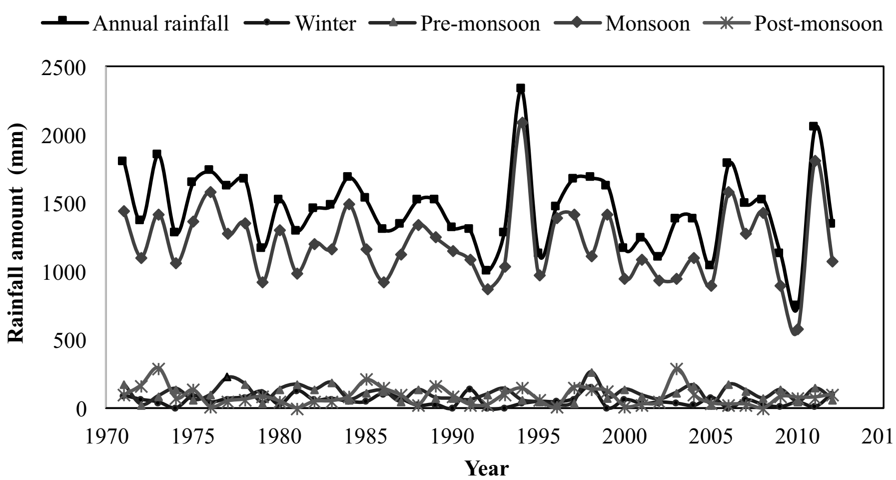

Fig. 2. Variation of annual and seasonal rainfall of Ranchi district from 1971 to 2012

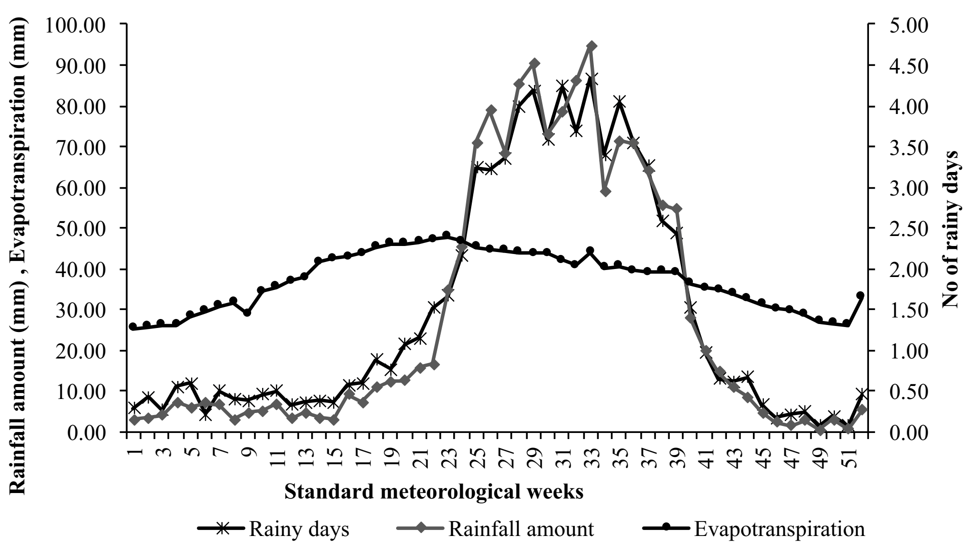

Fig. 3. Weekly average rainy days, rainfall amount and evapotranspiration

Table: 2
Trend analysis of rainfall amount and number of rainy days

Time series	Rainfall amount			No of rainy days		
	Test Z (Kendell trend)	p-value	Sen slope value (Q) mm yr^{-1}	Test Z (Kendell trend)	p-value	Sen slope value (Q) days yr^{-1}
Jan	-1.16	0.24	-0.13	-0.90	0.36	0.00
Feb	-2.16	0.03*	-0.51	-0.93	0.35	0.00
Mar	0.07		0.00	-0.12	0.90	0.00
Apr	-0.82	0.41	-0.16	-0.86	0.38	0.00
May	-0.43	0.66	-0.25	0.02	0.98	0.00
Jun	0.33	0.74	0.78	-0.36	0.71	0.00
Jul	-2.04	0.04*	-2.66	-2.31	0.02*	-0.14
Aug	-1.08	0.28	-1.73	-0.34	0.73	0.00
Sep	0.00	1	0.05	-1.51	0.13	-0.07
Oct	-0.74	0.45	-0.66	-0.99	0.32	-0.03
Nov	-0.70	0.48	0.00	-0.47	0.63	0.00
Dec	-0.27	0.78	0.00	-1.60	0.10	0.00
Annual	-1.84	0.06	-7.39	-2.56	0.01*	-0.38
Winter (Dec-Feb)	-1.90	0.05	-0.91	-2.06	0.03*	-0.09
Pre-monsoon	-0.87		-0.58	-0.28	0.77	0.00
Monsoon	-1.63		-5.44	-1.86	0.06	-0.18
Post-monsoon	-0.89		-0.79	-0.49	0.62	0.00

**represents the significant trend at 5% significance level*

significant decreasing trend was observed in July (-0.14 days yr^{-1}). The annual and winter rainy day showed statistically significant decreasing trend with the magnitude of -0.38 and -0.09 days yr^{-1}, respectively.

Drought Analysis

The analysis of dry period is important for sustainable irrigation water management. As frequency of dry period increases, the agriculture production decreases. From agriculture point of view, July is more critical month because of its influence on crop sowings. The dryness in the month of June affects the crop sowing to some extent, particularly to the early sown crops. The dryness and its variability in the month of August which represents the active crop growing period has more deleterious effect on the performance of crops. Dryness in September if not preceded by dryness in the August has less bearing on the crops, but has huge impact on water harvesting. Thus, the uncertainty in rainfall during July month has more effect on agriculture yield when compared to other months. Therefore, drought analysis was carried out for each month (June, July, August and September), monsoon season and annual time scale. SPI values during 1971-2012 time period for the months of June, July, August and September separately are presented in Fig. 4.

The extensive dry years in June month include 1987,1993, 1992, 2002, 2003, and 2010. The year 2002 (SPI value -2.16) was observed as the extreme dry year. In the month of July, the dry years include 1982, 1992,1993, 2002, 2003, 2009 and 2010. Of these years, 2002 (SPI value -2.75) was the extreme dry year. While 1992, 2009, and 2010 were reported under severe dryness. In general, more area under July dryness was observed only during recent years. As compared to earlier years, the dryness in July is higher in the recent years.

The years under dryness was detected in the August month of 1992, 1993, 2002, 2005, 2009, and 2010. Of these years, in 2002 (SPI value -2.12) and 2010 (SPI value -2.32) falls under the extreme dryness condition. In the month of September less drought years were observed compared to preceding months. In September month the dryness was observed mostly under moderate category. The years with moderate dryness include 1991, 1992, 2002, 2005, and 2009. The year under extreme dry category include 2010 (SPI value -2.93).

In monsoon season, moderate dryness was observed in the years 1975, 1976, 1992, 1993, 2006, 2009 and 2012 at Ranchi district. Severe dryness was occurred only in 2011. Extreme drought occurred in 2010 with the lowest SPI value (-2.64). The occurrence of monsoon drought is found to be a precursor of the drought occurring at the annual time-scale in the Ranchi district. Rice being an important *kharif* crop (June-Oct) in Jharkhand, the decreasing trend of rainfall is observed to delay / affect the transplanting / vegetative phase of the crop, for which assured irrigation is very much needed to tackle the drought situation (Jharkhand Action Plan on Climate Change, 2014).

The yearly SPI-12 was also analysed and presented in Fig. 4. The moderate dry year include only in 2009. The

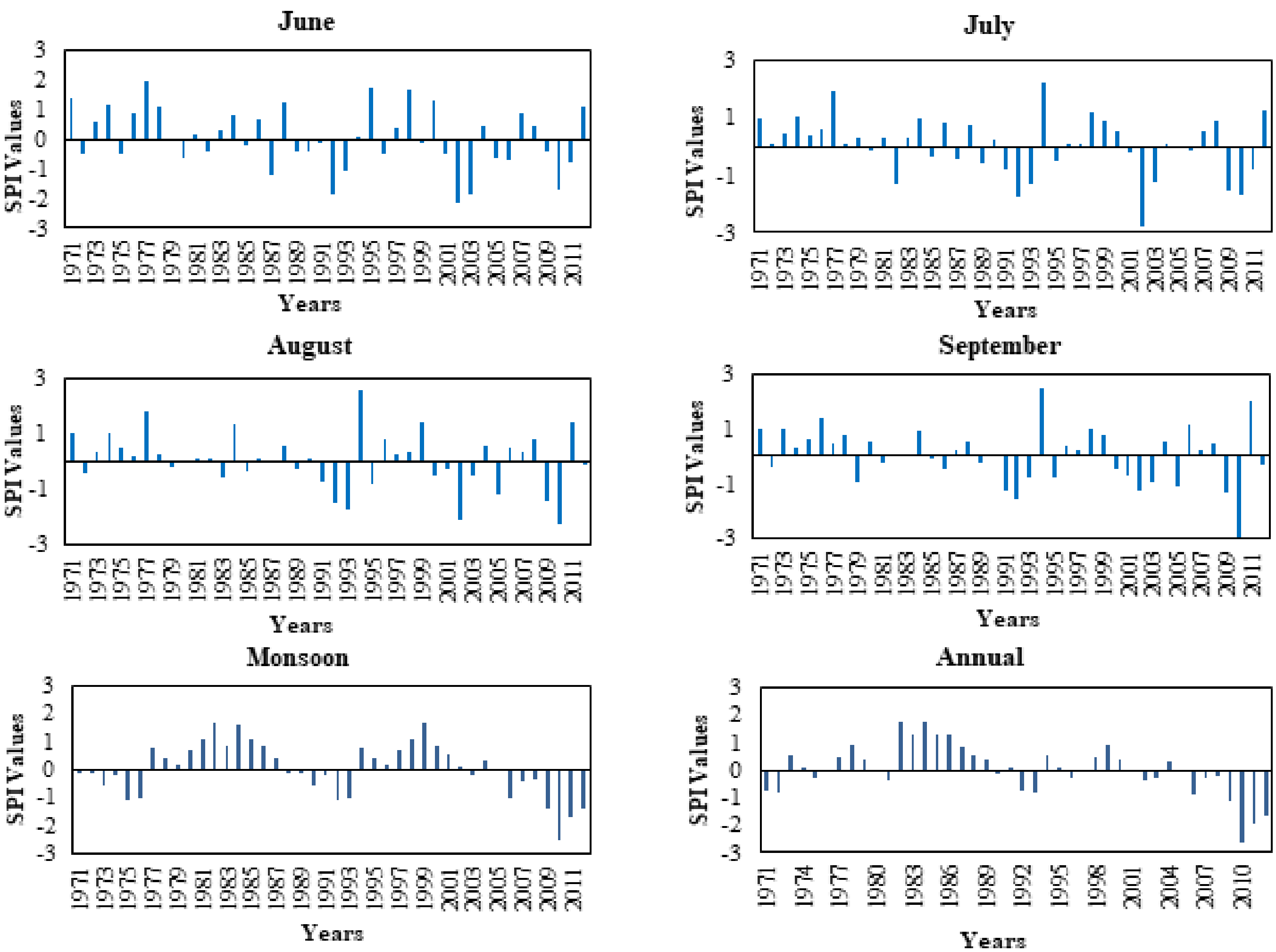

Fig. 4. Standard Precipitation Index (SPI) values at monthly (June, July, August and September), monsoon and annual time scale

severe dryness was observed in the year 2011 and 2012. Out of 42 years of study period the extreme drought condition was observed only in 2010 with the lowest SPI value -2.64. In the year 2010, whole Jharkhand state was affected by severe drought condition (Disaster Management Department, Jharkhand, http://disaster.jharkhand.gov.in/drought. php).

Wet Year Analysis

Surface water bodies and groundwater levels are certainly affected by the rainfall condition in a particular year. A realistic assessment of demand for crop water during *rabi* season, its total availability and management of supply is extremely important to provide supplemental irrigation to the crops in *rabi* season. The rainfall received during the wet years can be harvested into the local water harvesting structures for its future use. For Ranchi district (Fig. 4) most of the years fall under the category of near normal with the SPI values ranges from -0.99 to 0.99. The highest SPI-12 value was obtained in the year 1982 (SPI value 1.75), and 1984 (SPI value 1.75). Out 42 years of study period, only four years (2009, 2010, 2011 and 2012) face the drought conditions of varying levels. Thus this region doesn't face much rainfall deviation and a scientific water harvesting planning may benefit the farmers.

Water Management Planning for Ranchi District

The main agricultural season namely *kharif* season extends from June to October / November and depends largely on the rainfall from south-west monsoon. July month represents the peak sowing period, August represents the active growing period of crops and September represents the maximum vegetative phase or early reproductive phase of rainfed crops. Rainfall in the month of June is essential in triggering sowings in the country. Therefore, rainfall during July month is very critical for timely completion of crop sowings as well as for the sustenance of early sown crops. Similarly, from the water harvesting point of view the rainfall of the months of August / September plays an indispensable role. More the wetness obtained in these months, more water can be harvested for the supplemental irrigation in subsequent *rabi* season.

This runoff water can be captured in the water harvesting structures to meet the crop water requirement during *rabi* season. The crop water budgets will have to be kept in view of the limited supplemental irrigation. For example, during the *rabi* season, wheat crop requires 4-5 irrigations based on soil and climatic condition. Total water requirement of the wheat crop ranges from 400-600 mm (Pal *et al.,* 2001). Since the most critical crop water requirement stages for wheat crop are crown root initiation and flowering requires approximately 120-160 mm irrigation, thus, to provide lifesaving irrigation for 2800 ha of area sown under wheat crop in Ranchi would require 3920 Million litres of irrigation water.

Traditional *Jalkunda* (water catch pits) with dimensions (L × W × D) of 8.0 m × 6.0 m × 1.5 m, can harvest 72,000 litres of water. In order to provide supplemental irrigation during most critical stages of wheat crop approximately 54,000 *Jalkundas* (Small water harvesting structure at farm level) are required. The construction of additional *Jalkundas* depends on the number of available *Jalkundas* in the region. Similarly, *Dobhas* are indigenous structures for water conservation which were prevalent in the region 20 to 30 years back, regaining popularity during this ongoing water crisis. The potential *Dobha* sites were identified in low-lying areas where the rainwater could accumulate, and *Dobhas* of dimensions 3.04 m × 3.04 m × 3.04 m were dug up. These *Dobhas* can store up to 25,000 to 30,000 liters of rainwater, enough to meet farmers' water needs during non-monsoon season. A total of 500,000 operational *Dobhas* will collectively save 12.5 million cubic meters of rainwater. For efficient utilization of limited water and also for getting full advantage of rainwater, field should be properly levelled and graded, wherever it is necessary. Direct rainfall collection through *Jalkundas* can be highly beneficial to the farmers for providing irrigations to the crops under moisture scarcity conditions during the dry season. Photographs of *Jalkunda* have been shown in Fig. 5 (a & b).

Fig. 5 (a). Polythene lined *Jalkunda*

Fig. 5 (b). Water filled *Jalkunda*

4. CONCLUSIONS

Forty-two years (1971-2012) of daily point rainfall data were analysed for the Namkum station, Ranchi. The average annual rainy days were 76 and the annual rainy days were more than 10 for June to September month. About 83% rainfall is received during monsoon period (June-September). Since non-rainy seasons receive only 17% of total rainfall, that too sporadic, it becomes imperative to construct water harvesting structures for storing excess water during rainy season, which can be utilized as a life-saving irrigation for cereals and horticultural crops, during non-rainy season.

The drought analysis shows that out of forty-two years there was only one severe drought occurrence in this region in the year 2010. Total 22 years were found with no drought condition for the study area. Therefore, for rice cultivation farmers of this region may depend on monsoon. Since the post monsoon seasonal rainfall is very less, for growing winter season crops, arrangement may be made for assured irrigation with proper rainwater harvesting methods. Although larger size *Jalkundas* can be constructed as per the area need to be irrigated but smaller size *Jalkundas* require low cost and are easy in maintenance. As such, smaller size polythene lined *Jalkundas* are recommended which are more affordable and useful to the small and marginal farmers. The findings of this study may be helpful for farmers in irrigation water management which will help them to adopt diversified cropping from existing mono cropping system as well as bringing more area under cultivation. Surplus water harvested during the rainy season will also help in providing supplemental irrigation to the crops during non-rainy season alongside during rainy season with prolonged dry spells.

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