Vol. 15, No. 1, pp. 16-22 (2015)
Journal of Agricultural Physics
ISSN 0973-032X
http://www.agrophysics.in

Research Article

Analysis of Assured Rainfall for Crop Planning under Rainfed Condition in Drought-Prone Tract of Bihar

ABDUS SATTAR*, S.A. KHAN AND SAON BANERJEE

Department of Agril. Meteorology & Physics, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia-741 252, West Bengal

ABSTRACT

The agroclimatic zone III-B (part of south Bihar alluvial plains) of Bihar is considered as the dry region of the state, where rainfall is the limiting factor for successful raising of rainfed crops. It is, therefore, logical that agricultural planning needs to be drawn up based on the climatic potential of the area. For this purpose, the minimum assured weekly rainfall at different probability levels *viz.* 25, 50 and 75% has been computed for all 11 districts of the agroclimatic zone by employing weekly historical rainfall data for 30 to 55 years. Accumulated assured rainfall (AAR) calculated over 23 to 41 standard meteorological weeks (SMW) [4 June- 7 October] and the GIS map revealed that long duration crops (≥16 weeks) could be grown at potential rate in 5 out of 10 years. Considering 20 mm rainfall events in a week, the rainfall sufficiency prevailed for 8 to 11 weeks at 75% probability level. At 50% probability, sowing week with 20 mm threshold rainfall varied from 24 to 26 SMW (11 June - 1 July) and ending week extended from 38 to 39 SMW (17-30 September) across various districts. Gaya district recorded the highest water availability period of 16 weeks as against the lowest of 13 weeks in Arwal district. Six districts had water availability period of 14 weeks during which at least 20 mm of rainfall per week is assumed at 50% probability level. The duration of crop period and cropping plan have been suggested based on the probability of assured rainfall. Intercropping of pigeon pea (*Cajanus cajan*) with maize (*zea mays*) and sequential cropping of short-duration rice (*Oryza sativa*) followed by chickpea (*Cicer arietinum*) / lentil (*Lens culinaris*) could be the most efficient cropping systems in the drought-prone region of Bihar state.

Key words: Rainfall probability, Assured rainfall, Crop planning

Introduction

Rainfall is the prime natural resource which determines the fate of crop production under rainfed condition, where almost all agricultural operations are dependent upon the probability of receiving certain amount of rainfall. As compared to other weather elements, the amount and distribution of rainfall in a given location during cropping season vary greatly across weeks and years. Hence, a comprehensive idea regarding the probability of having certain amount of rainfall during a certain period is essential in view of its economic implications of weather sensitive operations for production (Virmani *et al.,* 1982). Water stress for a few days during sensitive phases of crop growth could be disastrous for crop production. A number of risks are involved in crop production in the rainfed regions due to uncertainty of rainfall and occurrence of recurrent droughts (Misra, 2005). Moisture regime is therefore an important determinant of crop growth

*Corresponding author,
Email: sattar.met@gmail.com

and development and thus, it plays a vital role in food sufficiency of any region (Mwale *et al*., 2007). In rainfed and low-productive region, rainfall being the only water resource, crop planning must be based on potentially high rain water utilization technology. This calls for a better understanding of rainfall pattern through modern approach of rainfall probability analysis to work out agro-climatologically sound and efficient cropping system (Singandhupe *et al.,* 2002). Many workers emphasized the utility of cropping plan based on rainfall amount estimated at different probability levels (Sarker *et al*., 1982; Srivastava *et al*., 1998; Deka and Nath, 2000; Mahale and Dhane, 2003; Manorama *et al.,* 2007; Manikandan *et al*., 2014).

Of all the agroclimatic zones of Bihar, Zone III-B (part of South Bihar alluvial plains) is considered as a chronically drought-prone region because of low and uneven distribution of rainfall. This zone is traditionally called as the dry zone of Bihar. Apparently, the primary agroclimatic constraint for crop production in this zone is the limited and variable moisture supply to the crops. Due to scanty and variable rainfall, water stress is experienced during different phases of crop growth and consequently low crop productivity becomes a common feature in this region. Studies involving estimation of assured rainfall over weeks should provide useful information for evaluating climatic potential for agricultural development and evolving suitable cropping patterns (Sarker *et al,* 1982). In this paper, a comprehensive study has been made to compute assured weekly rainfall, and thereby to identify water availability period at different probability levels to enhance and stabilize rainfed crop production through rational crop planning in the entire chronically drought-prone agroclimatic zone of Bihar.

Materials and Methods

Data and methodology

The study was conducted for the agroclimatic zone III-B (part of south Bihar alluvial plains) (Fig.1). Historical weekly rainfall data of three locations from each of eleven districts for different time periods were utilized for district-level analysis (Table 1).

By employing the database on standard meteorological week (SMW) basis, the assured

Fig. 1. Map showing various agroclimatic zones of Bihar state

Table 1. Rainfall database of the districts under Zone III-B of Bihar state utilized in the study

Sl No	Districts	Rainfall stations	Data base (years)
1.	Gaya	Gaya, Attri, Sherghati	1959-2013
2.	Auranagabd	Aurangabad, Daudnagar, Deo	1975-2012
3.	Jahanabad	Jahanabad, Makdampur, Kako	1984-2013
4.	Kaimur	Bhabua, Mohania, Kudra	1972-2013
5.	Nalanda	Asthwa, Biharsharif, Nursarai	1974-2013
6.	Nawada	Gobindpur, Sirdala, Hisua	1982-2013
7.	Rohtas	Bikramganj, Dehri, Sasaram	1974-2012
8.	Bhojpur	Koilwar, Jagdishpur, Sahar	1977-2013
9.	Buxar	Buxar, Brahampur, Dumrao	1974-2012
10.	Arwal	Arwal. Karpy, Kurtha	1983-2013
11.	Patna	Barh, Patna sadar, Paliganj	1964-2012

weekly rainfall amounts at different probability levels *viz.* 25, 50 and 75%, were computed through incomplete gamma distribution technique developed by Thom (1958) and adopted by Sarker and Biswas (1986, 1988). The assured weekly rainfall estimated at different probability levels constitutes a series of data that may be expected in different years and hence, risk involved in getting a certain amount of rainfall during a particular period may be obtained from this analysis. The equations which were given by Sarker *et al.* (1982), Sarker and Biswas (1986) were used for computation of minimum assured rainfall at different probability levels.

The weekly values of rainfall so determined at different probability levels *viz*. 25, 50 and 75% is termed as minimum assured rainfall at respective levels (Sarker *et al.,* 1982). The accumulated assured rainfall (AAR) during the period from 23 to 41 SMW were computed at 25, 50 and 75% probability levels for all districts under the study. Water availability period based on weekly threshold rainfall of 20 and 50 mm per week was identified for rainfed crop production. Based on the threshold rainfall of 20 mm, sowing weeks in each individual district were worked out (Virmani, 1975; Ramana Rao *et al*., 1983).

GIS mapping

QGIS 2.2, which is an open source and widely used GIS software in research and development purposes, was employed in this study. Geo-referencing of administrative map of Bihar and digitization of district boundaries were carried out in the GIS environment. Data pertaining to assured rainfall at 25, 50 and 75% probability levels were then linked to the district polygon map. Thematic maps pertaining to these parameters were generated using QGIS 2.2 software.

Results and Discussion

The accumulated assured rainfall (AAR) for eleven districts of zone III-B at 25, 50 and 75% probability levels presented in Table 2 revealed that at 25% probability (2.5 out of 10 yrs.), the AAR during the period from 23 to 41 SMW (4 June-7 October) was the highest (1389.3 mm) in Buxar district and the lowest (1075.4 mm) in district of Nalanda. Thematic map generated with GIS helped to identify high and low rainfall districts at 25% probability level (Fig. 2). At this probability, most of the districts had 1200-1300 mm accumulated assured rainfall. At 50% probability (in 5 out of 10 yrs.), the AAR varied from as low as 548.9 mm in Nalanda to as high as 695.9 mm in Aurangabad district. GIS map indicated that less than 600 mm AAR took place during 23 to 41 SMW in the districts of Nawada, Nalanda, Jahanabad and Arwal (Fig. 3). The AAR between 600-700 mm during the period 23-41 SMW was obtained at all probability levels tested in six of out eleven districts *viz.* Gaya, Aurangabad, Rohtas, Kaimur, Bhojpur and Patna. Only Buxar district recorded an AAR> 700 mm.

Table 2. Accumulated assured rainfall (AAR) at different probability levels in Agroclimatic Zone III-B of Bihar state

District	AAR (mm) during 23-41 SMW (4 June-7 October)		
	25% probability	50% probability	75% probability
Gaya	1247.6	671.8	320.3
Aurangabad	1299.1	695.9	332.5
Jahanabad	1152.2	577.8	246.1
Kaimur	1284.0	659.3	293.5
Nalanda	1075.4	548.9	240.6
Nawada	1197.6	598.5	252.1
Rohtas	1269.5	686.3	331.5
Bhojpur	1300.0	666.3	292.9
Buxar	1389.3	720.2	322.3
Arwal	1170.7	577.3	238.9
Patna	1298.4	666.2	293.2

At 75% probability (in 7.5 out of 10 yrs.), the AAR ranged from a minimum of 240.6 mm in Nalanda district to a maximum of 332.5 mm in Aurangabad district. Thematic map shows that Nalanda, Jahanabad and Arwal districts recorded < 250 mm AAR during 23-41 SMW and greater than 300 mm AAR in Gaya, Aurangabad, Rohtas and Buxar districts (Fig. 4). Rainfall ranging from 250 to 300 mm was observed for the districts of Kaimur, Bhojpur, Patna and Nawada at 75% probability level. Under rainfed condition, a short-duration crop (10-12 weeks) requires about 250 mm rainfall during its growing period. Similarly, a medium-duration crop of 12 to 16 weeks would require nearly 350 mm and a long-duration crop of 16 weeks or more would require > 400 mm rainfall (Sarker *et al.,* 1982). Accordingly, as per results of AAR in the present study, long-duration crops like pigeon pea (*Cajanus cajan*) and maize (*Zea mays*) would be able to produce at potential rate in 5 out of 10 years *i.e.,* at 50% probability. In 7.5 out 10 years (75% probability level), it would be safe to grow only less water requiring and short-duration crops like maize (*Zea mays*), urd (*Vigna mungo*), sesame (*Sesamum indicum*), sunflower (*Helianthus annuus*), groundnut (*Arachis hypogaea*), castor (*Ricinus communis*) during *kharif* (rainy) season with AAR varying from 241 to 333 mm in various districts during 23-41 SMW.

The rainfall amount of 20 mm per week should provide sufficient moisture for sowing of an upland crop (Virmani, 1975; Ramana Rao *et al*., 1983; Sattar and Singh, 2014). Since rainfall amounting to 20 mm per week was almost

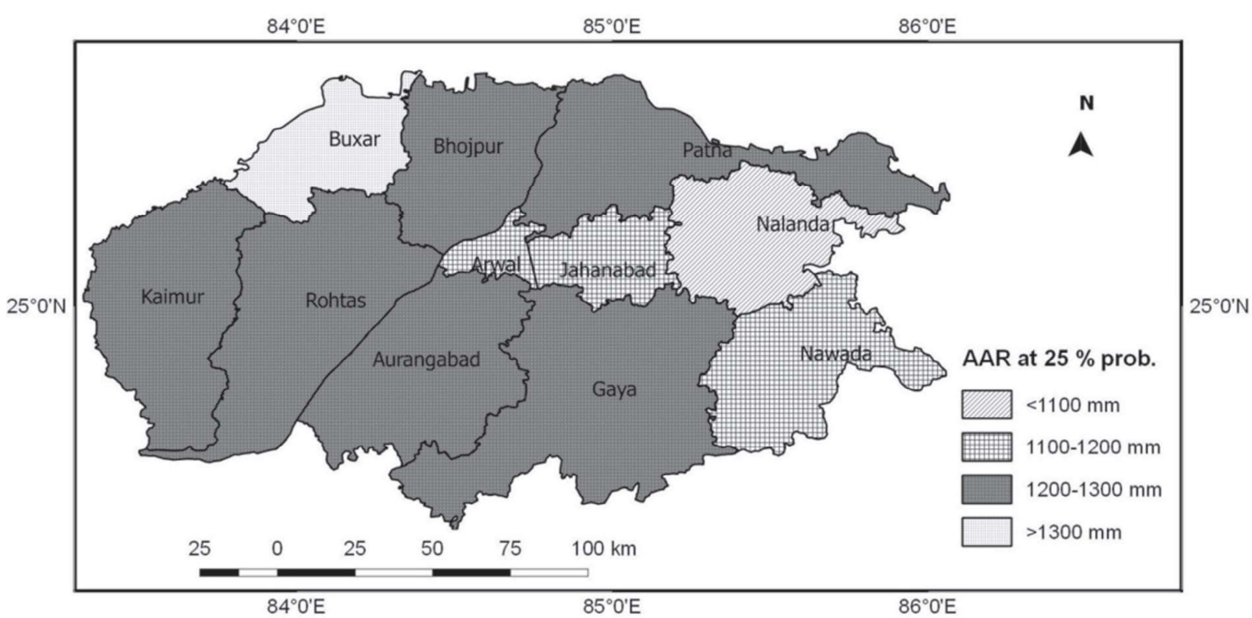

Fig. 2. Thematic map of accumulated assured rainfall (AAR) during 23-41 SMW at 25% probability in the districts of Zone III-B of Bihar state

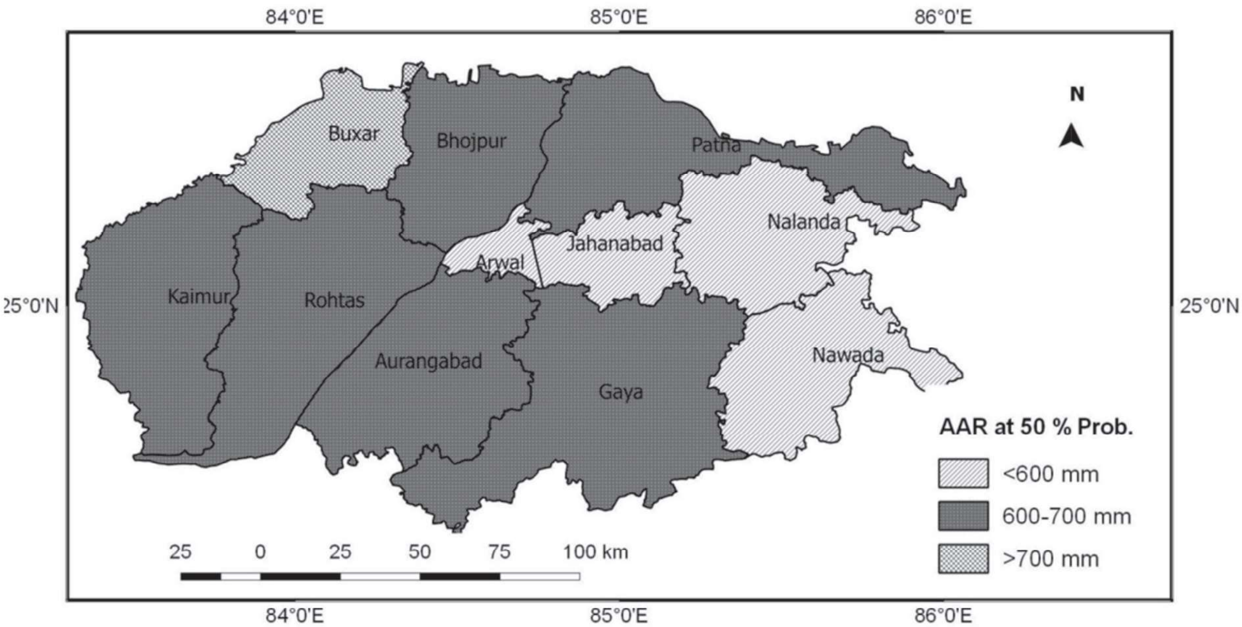

Fig. 3. Thematic map of accumulated assured rainfall (AAR) during 23-41 SMW at 50% probability in the districts of Zone III-B of Bihar state

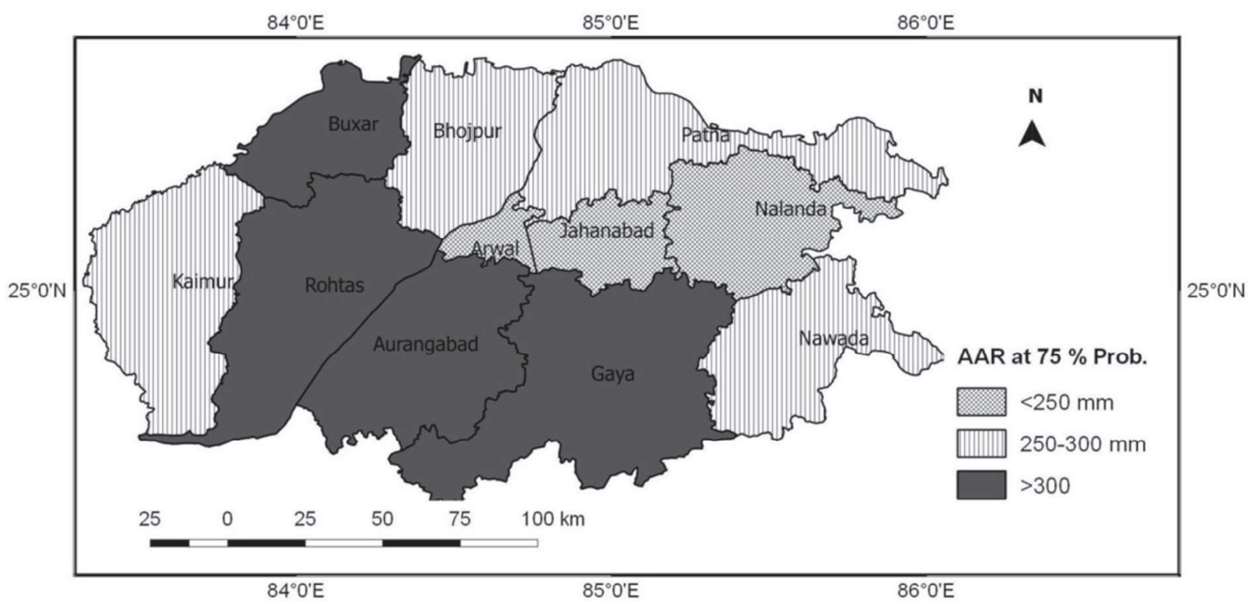

Fig. 4. Thematic map of accumulated assured rainfall (AAR) during 23-41 SMW at 75% probability in the districts of Zone III-B of Bihar state

adequate at all the growth stages of rainfed upland crops (Subramanium and Rao, 1989; Chattopadhyay and Ganesan, 1995), duration in weeks with assured rainfall ≥ 20 mm were considered to determine the length of cropping period. Accordingly, length of growing period was worked out for various districts under study (Table 3). It was observed that at 50% probability level, starting week with 20 mm threshold rainfall (sowing week) varied from 24 to 26 SMW and ending week from 38 to 39 SMW across the districts. Hence, on the basis of availability of sowing rain, the earliest sowing of rainfed crops could be possible in Gaya district during 24 SMW

Table 3. Water availability period with 20 and 50 mm threshold weekly rainfall in Agroclimatic Zone III-B of Bihar state

District	20 mm threshold rainfall at 50% probability			20 mm threshold rainfall at 75% probability			50 mm rainfall at 50% probability		
	Start week	End week	Duration (week)	Start week	End week	Duration (week)	Start week	End week	Duration (week)
Gaya	24	39	16	26	36	11	28	34	7
Aurangabad	25	38	14	27	37	11	27	34	8
Jahanabad	25	39	15	-	-	-	-	-	-
Kaimur	25	38	14	28	36	9	28	34	7
Nalanda	25	38	14	27	34	8	-	-	-
Nawada	26	39	14	26	34	9	28	29	2
Rohtas	25	38	14	27	34	8	28	34	7
Bhojpur	25	38	14	27	37	11	28	33	6
Buxar	25	39	15	27	37	11	28	34	7
Arwal	26	38	13	27	36	10	27	30	4
Patna	25	39	15	27	37	11	28	34	7

(11-17 June) and the latest during 26 SMW (25 June-1 July) in the district of Arwal. The highest water availability period of 16 weeks (24-39 SMW) was in Gaya, and the lowest of 13 weeks (26-38 SMW) in Arwal district. At higher level of probability i.e., 75% probability level, the starting week was delayed by 2 to 3 weeks and large variability in ending week from 34 to 37 SMW could be observed across the districts of Zone III-B.

Considering evapotranspiration and percolation losses from rice fields at 3-4 mm d^{-1}, water requirement of rice (*Oryza sativa*) without stress is about 50 mm $week^{-1}$, which is sufficient for stable rice cultivation (Singh and Singh, 2000). Based on this, the stable rainfall periods at 50% probability level over various districts of Bihar were worked out (Table 3). Dey *et al.* (2011) also computed weekly assured rainfall (50 mm) at 50% probability by fitting incomplete gamma distribution to evaluate transplanted rice cultivation in the lower Gangetic plains of West Bengal. Results of the present study indicated that stable rainfall period at 50% probability started during 27 to 28 SMW (2-15 July) across various districts and ended earliest at 29 SMW (16-22 July) and delayed by 34 SMW (20-26 August). Thus, the duration of such weeks varied from 2 to 8 weeks across the districts of zone III-B. It is worth mentioning that the districts of Jahanabad and Nalanda did not show any stable rainfall period at 50% probability level. Considering 20-25 days period for the seedling stage and 25-30 days for the maturity, growing of short-duration rice (*Oryza sativa*) varieties (cv. *Prabhat, Dhanlaxmi, Richhariya, Turanta, Saroj*) maturing in 90-110 days could be recommended in Gaya, Aurangabad, Kaimur, Rohtas, Buxar and Patna districts with stable rainfall period in one in two years. The results revealed that the vast geographical part of this zone is not conducive for growing rice as rainfed crop. Even short-duration varieties of rice (*Oryza sativa*) would face severe moisture stress at various growth phases and hence, it may not be able to produce at potential rate in the districts like Nalanda, Jahanabad, Nawada and Arwal during *kharif* season under rainfed condition. Pigeon pea (*Cajanus cajan*) is regarded as the potential component crop of the intercropping system in the drought-prone region (Singh *et al.,* 1981). So, introduction of intercropping with pigeon pea (*Cajanus cajan*) and maize (*Zea mays*) or sequential cropping with short-duration rice (*Oryza sativa*) followed by chickpea (*Cicer arietinum*) / lentil (*Lens culinaris*) could be promising with regard to total productivity under rainfed drought prone zone of Bihar.

Conclusions

The findings indicated that information on assured rainfall at different probability levels could be a reliable guide in framing cropping plan to harness the climatic potential of the area. The problem of low rainfall and consequently low production under rainfed condition may be overcome by tailoring the crop plan on a rational basis with available rainfall resource to enhance the agricultural production.

References

Chattopadhyay, N. and Ganesan, G.S. 1995. Probability studies of rainfall and crop production in coastal Tamil Nadu. *Mausam* **46** (3): 263- 274.

Deka, R.L. and Nath, K.K. 2000. Rainfall analysis for rainfed crop production in the upper Brahamaputa valley zone of Assam. *J. Agrometeorol.* **2**(1): 47-53.

Dey, S., Banerjee, S and Saha, A. 2011. Water Deficit Patterns for Cultivation of Rainfed Rice in the Lower Gangetic Plains of West Bengal. *J. Agril. Physics* **11**: 79-83.

Mahale, D. and Dhane, S.S. 2003. Rainfall analysis in relation to paddy crop in coastal saline soils at Panvel. *J. Agrometeorol*. **5**: 89-92.

Manikandan, N., Arthi Rani, B. and Sathyamoorthi, K. 2014. Weekly rainfall variability and probability analysis for Coimbatore in respect of crop planning. *Mausam* **65**: 353-356.

Manorama, K., Ravichandran, G. And Joseph, T.A. 2007. Rainfall analysis and crop planning for the Nilgiris. *J. Agrometeorol.* **9**: 209-215.

Misra, A.K. 2005. Contingency planning for feeding and management of livestock during drought. In: K.D. Sharma and K.S. Ramasastri (Eds), Allied Publishers Pvt. Ltd., New Delhi. pp. 276-286.

Mwale, S.S., Azam-Ali, S.N. and Massawe J.J. 2007. Growth and development of bambara groundnut in response to soil moisture: 2. Resource capture and conversion. *Euro. J. Agron*. **26**: 354-362.

Ramana Rao, B.V., Rao, G.G.S.N., Gupta, B.S. and Malakar, A.R. 1983. Influence of commencement of sowing rains on crop production in some dry district of Rajasthan. *Mausam* **34**: 335-342.

Sarker, R.P., Biswas, B.C. and Khambete, N.N. 1982. Probability analysis of short period rainfall in dry farming tract of India. *Mausam* **33**: 269-284.

Sarker R.P. and Biswas, B.C. 1986. Agroclimatic classification for assessment of crop potential and its application to dry farming tract. *Mausam* **37**: 27-38.

Sarker, R.P. and Biswas, B.C. 1988. A new approach for agroclimatic classification to find out crop potential. *Mausam* **39**(4): 343-358.

Sattar, A and Singh, V.P. 2014. Drought: Agricultural aspect, vulnerability assessment and strategic appraisal in Bihar. RAU, Pusa (Samastipur), pp.71.

Singandhupe, R.B., Anand, P.S.B. and Kannan, K . 2002. Effect of rainfall pattern on rice productivity in state of Orissa. *Crop Res.* **20**: 360-366.

Singh, R.P., De, R., Malik, D.S., Hedge, B.R., Umrani,N.K. and Singh, R.K. 1981. Dryland Agriculture In: Prasad, R., Parashar, K.S., Singh, R.P. (Eds.), Quarter Centuries of Agronomic Research in India (1955-1980), Indian Soc. Agron., IARI, New Delhi-110012, pp.61-78.

Singh, V.P. and Singh, R.K. (Ed.) 2000. Rainfed rice: A source book of best practices and strategies in eastern India. IRRI, Manila, Philippines. 292 p.

Srivastava, S.K., Mishra, S.K., Sahu, A.K. and Ahmed, A. 1998. Probability analysis of rainfall for crop planning at N. Lakhimpur, Assam. *Ind. J. Soil Cons*. **24**: 162-165.

Subramanium, A.R. and Rao, P.S. 1989. Dry spell sequence in south coastal Andhra. *Mausam* **40**(1): 57-60.

Thom, H.C.S. (1958). A note on gamma distribution. *Mont. Weather Rev*. **86**: 117-122.

Virmani, S.M. 1975. The agricultural climate of Hyderabad region in relation to agricultural planning, ICRISAT, Patancheru, Andhra Pradesh, pp.54.

Virmani, S.M. Sivakumar, M.V.K. and Reddy, S.J. 1982. Rainfall probability estimates for selected locations of semi arid India. ICRISAT Centre, Patancheru, India, pp.170.

Received: March 17, 2015; Accepted: June 7, 2015