

Evaluation of onset, cessation and length of rainy season for sustainable rainfed crop production in Bihar

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

Agrometeorology Division, Dr. Rajendra Prasad Central Agricultural University,

Pusa, Samastipur, Bihar – 848 125, India

** Department of Agril. Meteorology & Physics, Bidhan Chandra Krishi Viswavidyalaya,*

Mohanpur, Nadia, West Bengal – 741 252, India

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e mail : sattar.met@gmail.com

सार – कृषि जलवायविक अध्ययन बिहार के सभी 38 जिलों में पूर्वगामी और पश्चगामी वर्षा संचयन मापदंड पर आधारित है जिससे 50 प्रतिशत तक वर्षा ऋतु के आगमन, अवसान और वर्षा ऋतु की अवधि निर्धारित करने और 75 प्रतिशत तक उसकी संभावना को निर्धारित करने के लिए किया गया है। परिणामों से पता चला है कि जोन III बी (दक्षिण बिहार के जलोढ़ क्षेत्र) के अंतर्गत आने वाले जिलों में सबसे छोटी अवधि की और जोन II (पूर्वोत्तर जलोढ़ क्षेत्र) में सबसे लंबी अवधि की वर्षा ऋतु रही है। जोन II के अंतर्गत आने वाले जिलों में जहाँ 75 मि.मी. वर्षा पहले हो जाती है वहाँ खरीफ फसल की बुआई पहले हो जाती है और जोन III 'बी' में देर से बुआई होती है। रोपे हुए धान के पौधों के सुरक्षित विकास की अवधि की गणना 200 मि.मी. पूर्वगामी वर्षा और 50 मि.मी. पश्चगामी वर्षा के जल संचयन के मापदण्ड के आधार पर की गई है जो जोन I (पश्चिमोत्तर जलोढ़ क्षेत्र) में 13-17 सप्ताह की, जोन II में 14-19 सप्ताह की, जोन III ए (दक्षिण बिहार के जलोढ़ क्षेत्र) और जोन III बी के अंतर्गत आने वाले जिलों में 11 से 13 सप्ताह की रहने की 50 प्रतिशत संभावना पाई गई है जिससे पता चला है कि जल्दी पकने वाली चावल की किस्में (प्रभात, तुरंता) जोन III बी के अंतर्गत आने वाले जिलों में 100 वर्षों में से 50 वर्षों में सफलतापूर्वक उगाई गई। इस क्षेत्र में इस प्रकार की कम अवधि में तैयार होने वाली चावल की फसल के विकास करने की संभावना 75 प्रतिशत (अर्थात् 100 वर्षों में से 75 वर्षों में) से कम होगी। जोन I और जोन III ए के अंतर्गत आने वाले जिलों में छोटी अवधि से मध्यम अवधि में होने वाली चावल की किस्में (धनलक्ष्मी, रिछारिया, सरोज, राजेन्द्र भगवती, राजेन्द्र सुवासिनी, प्रभात, राजश्री) वर्षा प्रधान क्षेत्रों में लगाने के लिए उपयोगी होंगी। लंबी अवधि तक पानी की उपलब्धता के कारण जोन II अधिक उत्पादक क्षेत्र माना जा सकता है।

ABSTRACT. An agroclimatic study based on forward and backward rainfall accumulation criteria was conducted to determine the onset, cessation and length of rainy season at 50 and 75% probability levels for all 38 districts of Bihar. The results revealed that the districts under Zone IIIB (Part of south Bihar alluvial plains) recorded the shortest length of rainy season and the longest in Zone II (North east alluvial plains). The earliest sowing of rainfed crops based on 75 mm forward accumulated rainfall could be done in the districts under Zone II and delayed sowing in Zone IIIB. The length of safe growing period for rainfed transplanted rice calculated based on 200 mm forward and 50 mm backward accumulated rainfall criteria was found to prevail for 13-17 weeks in Zone I (North west alluvial plains), 14-19 weeks in Zone II, 13 to 15 weeks in Zone IIIA (part of south Bihar alluvial plains) and 11 to 13 weeks in the districts under Zone IIIB at 50 per cent probability level, which indicated that early maturing rice varieties (*Prabhat*, *Turanta*) could be successfully grown under rainfed condition in the districts under Zone IIIB in 50 out of 100 years. At 75 per cent probability level (*i.e.*, 75 out of 100 years), the length of rice growing season appeared to be too low to grow even such short duration rice in this Zone. In the districts under Zone I and Zone IIIA, short to medium duration rice varieties (*Dhanlaxmi*, *Richhariya*, *Saroj*, *Rajendra Bhagwati*, *Rajendra Suwasni*, *Prabhat*, *Rajshree*) could be considered for growing under rainfed condition. Zone II appeared to be the most productive in terms of longest duration of water availability.

Key words – Forward and backward accumulation of weekly rainfall, Rainy season, Crop planning, Probability.

1. Introduction

Rainfall is a very important natural resource for crop production under rainfed condition. To ensure better and efficient utilization of natural endowment of rainfall for

crop production, it is imperative to analyze the long term rainfall based on modern agroclimatic methods. Climatic factors such as seasonal rainfall, intra-seasonal rainfall distribution, and the dates of onset & termination of rainy season affect crop yields and determine the agricultural

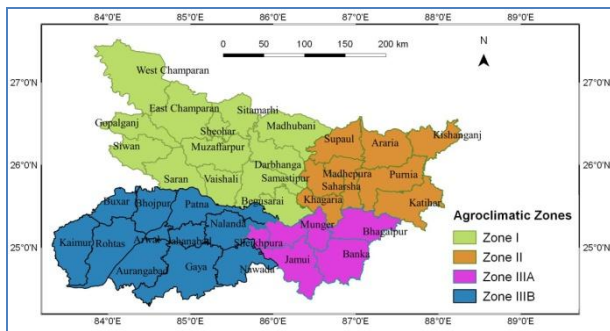


Fig. 1. Map showing various agroclimatic zones of Bihar

calendar of a region (Sivakumar, 1988; Maracchi *et al.*, 1993). More importantly, the onset of growing period based on onset of rainfall during rainy season is the most vital information (Barbier *et al.*, 2009; Marteau *et al.*, 2011) for agricultural management as it determines the sowing window of crops (Sivakumar, 1992; Omotosho *et al.*, 2000; Raes *et al.*, 2004). Traore *et al.* (2007) defined the onset of rains as the optimum planting time that ensures sufficient soil moisture during sowing and early growing periods to avoid crop failure after sowing (Sivakumar, 1988; Omotosho *et al.*, 2000). Traditional sowings are done with substantial earliest rain events (Bacci *et al.*, 1999), which on many occasions lead to sowing (crop) failures due to dry spell as a result of false start of monsoon. Mugalavi *et al.* (2008) identified rainfall onset, cessation and length of growing season of maize in western Kenya. Sattar and Khan (2016) employed agroclimatic approach for crop planning under rainfed condition in Darbhanga district of Bihar.

The economy of Bihar is dominated by agriculture and allied sectors. Almost 60 per cent of net cropped area in the state is rainfed. Rainfed agro-ecosystem has a distinct place in Indian agriculture having diverse farming systems with a large variety of crops, cropping systems and agroforestry practices (Venkateswarlu and Prasad, 2012). Thus, crop production under rainfed condition requires agroclimatic measures to slice down the climatic risks. Hence, precise evaluation of water availability period is an important pre-requisite for crop planning under rainfed condition.

Farmers in the state mainly rely on experience and traditional knowledge for deciding the time for planting of their crops and this leads to poor yield and on many occasions crop failure. Thus, it is necessary to determine the exact length, onset and cessation of the growing season for the entire state in view of looming danger of less crop production owing to erratic monsoon rainfall. This paper aims at evaluating the agroclimatic potential and determines the onset, cessation and length of rainy season based on forward and backward rainfall

TABLE 1

Earliest sowing weeks of rainfed crops in different districts of Bihar

District	Earliest sowing week (SMW)	District	Earliest sowing week (SMW)
Zone I			
		Saharsa	16
Darbhanga	18	Khagaria	18
Samastipur	18	Zone IIIA	
Begusarai	19	Banka	20
Madhubani	17	Bhagalpur	18
Sitamarhi	17	Munger	18
Sheohar	17	Lakhisarai	20
Muzaffarpur	18	Sheikhpura	20
Vaishali	20	Jamui	20
Saran	20	Zone IIIB	
Siwan	19	Patna	19
Gopalganj	19	Nalanda	21
E. Champaran	17	Nawada	22
W. Champaran	15	Gaya	22
Zone II		Jahanabad	22
Katihar	16	Arwal	22
Purnia	15	Aurangabad	22
Kishanganj	15	Rohtas	20
Araria	15	Bhojpur	22
Supaul	16	Buxar	22
Madhepura	15	Kaimur	22

accumulation method to achieve sustainable crop production through efficient agroclimatic resource utilization across various districts of the state.

2. Materials and method

2.1. Study area

The study was conducted for all 38 districts located under different agroclimatic zones of Bihar. The State is located between 24°17' and 27°31' N latitudes and between 83°19' and 88°17' E longitudes covering an area of 9.38 million hectares. It is broadly divided into three agro-climatic zones *viz.*, Zone I (North-west alluvial plains), Zone II (North east alluvial plains) and Zone III (South Bihar alluvial plains). Zone III is further subdivided into Zone IIIA and Zone IIIB on the basis of rainfall variability, cropping pattern and topography. The map showing different agroclimatic zones of the state is presented in Fig. 1.

2.2. Rainfall data

Historical weekly rainfall data for a period of 30 to 55 years were collected from the India Meteorological

TABLE 2

Onset of rainy season during SMWs based on 75 and 200 mm forward accumulated rainfall and termination of rainy season with 50, 100 and 300 mm rainfall still to receive by backward accumulation at 50 and 75% probability levels

Zone/District	Forward accumulation				Backward accumulation					
	75 mm		200 mm		50 mm		100 mm		300 mm	
	50% Prob.	75% Prob.	50% Prob.	75% Prob.	50% Prob.	75% Prob.	50% Prob.	75% Prob.	50% Prob.	75% Prob.
Zone I (North west alluvial plains)										
Darbhanga	24	25	26	28	39	37	38	36	34	33
Samastipur	23	25	26	28	40	39	39	37	35	33
Begusarai	25	25	27	27	39	37	38	36	34	32
Madhubani	23	24	26	27	39	38	38	37	34	33
Sitamarhi	22	23	25	27	39	38	38	37	34	33
Sheohar	22	23	25	27	39	38	38	37	34	33
Muzaffarpur	23	25	26	27	40	39	38	37	35	33
Vaishali	25	26	27	29	39	37	38	36	34	32
Saran	25	26	27	28	40	38	38	37	35	33
Siwan	25	26	27	28	39	37	38	36	34	33
Gopalganj	25	26	27	27	39	38	38	37	34	33
East Champan	23	25	26	27	40	38	39	37	35	33
West Champan	20	23	24	25	40	39	39	38	35	34
Zone II (North east alluvial plains)										
Katihar	21	22	24	26	40	39	39	38	36	34
Purnia	20	21	23	25	40	39	39	38	37	35
Kishanganj	19	20	22	24	40	39	39	39	36	35
Araria	19	21	23	24	41	39	39	38	36	35
Supaul	21	23	24	26	40	38	39	37	35	33
Madhepura	20	22	24	25	40	38	39	37	35	34
Saharsha	23	24	26	28	39	38	38	37	35	32
Khagaria	23	25	26	27	39	38	38	37	35	32
Zone IIIA (South Bihar alluvial plains)										
Banka	24	25	27	28	40	39	39	38	34	34
Bhagalpur	23	24	26	27	40	39	39	38	35	33
Munger	24	25	26	27	39	39	38	38	35	34
Lakhisarai	25	25	27	28	39	37	38	36	34	32
Sheikhpura	25	25	27	28	39	37	38	36	34	32
Jamui	25	26	27	28	40	38	39	28	35	34
Zone IIIB (South Bihar alluvial plains)										
Patna	25	26	28	28	39	38	38	37	34	33
Nalanda	26	27	28	29	38	37	37	36	33	31
Nawada	26	27	28	29	40	38	39	37	34	32
Gaya	26	26	28	29	39	38	38	37	34	33
Jahanabad	26	27	28	30	39	37	38	36	33	32
Arwal	26	27	29	30	39	37	38	36	34	32
Aurangabad	25	27	28	29	39	37	38	36	34	33
Rohtas	25	26	27	29	38	37	37	36	34	33
Bhojpur	26	27	28	29	38	37	37	36	34	33
Buxar	26	27	28	29	39	38	38	37	34	33
Kaimur	26	27	28	29	39	37	38	36	34	33

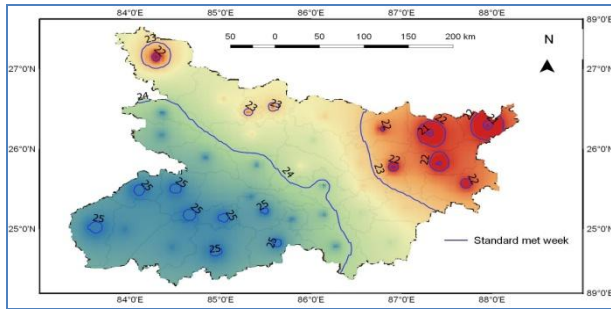


Fig. 2. Onset of rainy season based on forward accumulation of 75 mm rainfall at 50% probability level

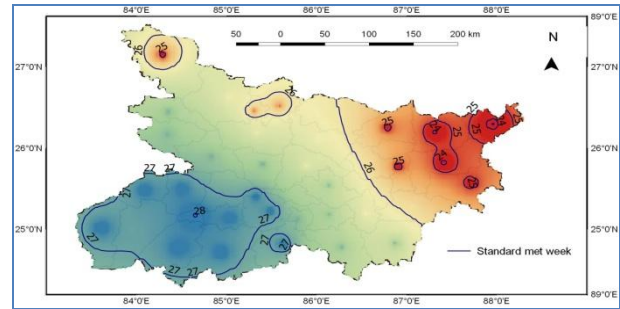


Fig. 4. Starting week of puddling operation for rice transplanting at 50% probability level in Bihar

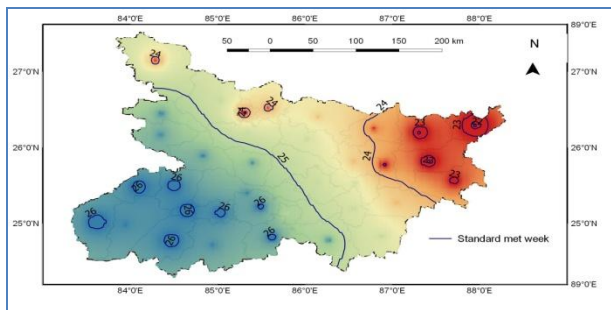


Fig. 3. Onset of rainy season based on forward accumulation of 75 mm rainfall at 75% probability level

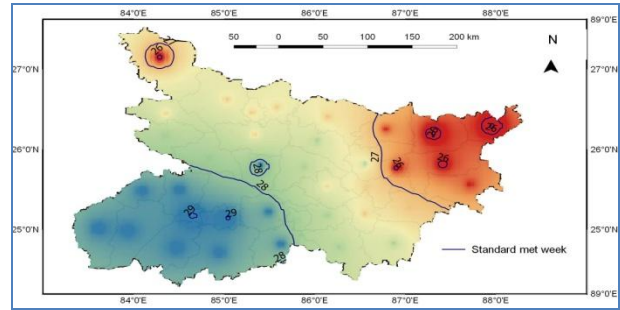


Fig. 5. Starting week of puddling operation for rice transplanting at 75% probability level in Bihar

Department, Pune and Agrometeorology Division, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar. Altogether, rainfall data of 110 rain-gauge stations were utilized for the study.

2.3. Methodology

2.3.1. Forward and backward accumulation of weekly rainfall

The forward and backward methods of rainfall accumulation as developed by Morris and Zandstra (1979) were employed to determine the onset and termination of rainy season. As suggested by them, 75 mm accumulated rainfall was considered as onset time for sowing of rainfed crops and 200 mm accumulated rainfall as onset time for puddling operation for transplanted rice. For forward accumulation, 75 and 200 mm rainfall from the earliest sowing week before which sowing is not possible was considered. The cessation of rainy season was determined by backward summing of weekly rainfall from 52 standard meteorological (SMW) to attain different magnitudes of accumulated rainfall amounting to 50, 100 and 300 mm. The earliest sowing weeks used in the calculation of forward and backward accumulation of rainfall were determined for each district based on earliest sowing rain calculated as 20 mm rainfall received in a week (Virmani, 1975) at 10% probability level (Table 1). The difference of period between onset and termination of

rainy season as per these criteria was considered as length of rainy season. The weeks when the accumulations (forward and backward) reached in each year between the start and end of the database year for each district, were ranked from the earliest to the latest (in case of onset) and from the latest to the earliest (in case of termination) to find out the empirical probability of the onset and termination at different times of the year.

2.3.2. 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. Then output data pertaining to onset, termination and length of rainy season, and crop growing period were linked to the district polygon map. Thematic maps pertaining to these parameters were generated using QGIS 2.2 software.

3. Results and discussion

3.1. Sowing/transplanting window based on forward rainfall accumulation

The sowing window is a range of time for sowing of crops and such windows are narrower for rainfed crops than those grown with irrigation. In areas with limited or

no irrigation facilities, identification of sowing windows is necessary for guiding the farmers to sow their crops at appropriate times. Results of forward and backward accumulation of weekly rainfall presented in Table 2 showed that at 50 per cent probability level, 75 mm forward accumulation of rainfall (onset of rainy season) was observed between 20-25 SMW and 200 mm accumulation (initiation of puddling operation for rice) during 24-27 SMW in Zone I. Thus, in one out two years, rainfed crops could be sown during 20-25 SMW in different districts under Zone I and puddling operation for rice transplantation could be initiated as early as in 24 SMW and the latest by 27 SMW over various districts of Zone I. In the districts under Zone II, 75 mm forward accumulation of weekly rainfall was observed during 19-23 SMW, with majority of the districts showing forward accumulated rainfall within 21 SMW and 22 SMW at 50 per cent and 75 per cent probability level, respectively. At 50% probability, 200 mm rainfall could be accumulated during 22-26 SMW, with the earliest accumulation being recorded in Kishanganj, whereas the latest in Saharsha and Khagaria districts. At lower level of risk (75 per cent probability), 75 mm forward accumulation was recorded during 20-25 SMW and 200 mm accumulation during 24-28 SMW, with the earliest accumulation being observed in Kishanganj and Araria districts and the latest occurring in Saharsha and Khagaria districts (Table 2). Many authors used 75 mm forward accumulation for deciding the start of growing season of rainfed crops (Morris and Zandstra 1979; Olerderman and Frere 1982; Dey, 2008; Ghosh, 2014; Sattar, 2015).

In the districts under Zone IIIA, at 50 per cent probability level, the earliest accumulation of 75 mm rainfall was observed in Bhagalpur during 23 SMW and the latest (25 SMW) happened in Jamui, Lakhisarai and Sheikhpura districts. The forward accumulation of 200 mm rainfall was recorded during 26-27 SMW, with Bhagalpur and Munger having this level of accumulation during 26 SMW and the rest of the districts had their accumulation of 200 mm during 27 SMW. At higher probability level, *i.e.*, 75 per cent probability level, 75 mm forward accumulated rainfall was observed during 24-26 SMW and 200 mm during 27-28 SMW (Table 2).

The districts under Zone IIIB recorded 75 mm accumulated rainfall during 25-26 SMW (Table 2). Patna and Aurangabad districts registered 75 mm forward accumulation during 25 SMW, while the remaining 9 districts showed this level of accumulation (75 mm) for starting the sowing of rainfed during 26 SMW. In case of 200 mm forward accumulation, the earliest accumulation occurred in Rohtas district during 27 SMW, whereas the last accumulation was observed in Arwal district during 29 SMW. However, the remaining 9 districts of this

agroclimatic zone recorded 200 mm accumulation for initiation of puddling operation during 28 SMW at 50 per cent probability level. At higher probability level (75 per cent), these districts reached the week of accumulation of 75 mm during 26-27 SMW and 200 mm during 28-30 SMW.

Thus, it is evident from the results that at 50 and 75 per cent probability levels, 75 and 200 mm accumulated rainfall by forward method occurs first in the districts under Zone II and the last in the districts under Zone IIIB. Based on the results, it could be inferred that at 50 per cent probability level, the sowing of rainfed crops could be undertaken at the earliest (19 SMW) in Kishanganj and Araria districts and the latest sowing (26 SMW) under the districts of Zone IIIB. At the same probability level (50 per cent), the initiation of puddling operation for rice transplanting could be started as early as in 22 SMW in Kishanganj district located in the extreme north eastern part of the state (Zone II) and the most delayed puddling operation being started during 29 SMW in Arwal district located in south Bihar under agroclimatic Zone IIIB. Maps depicting weeks of achieving 75 mm rainfall through forward accumulation (onset of rainy season) and 200 mm rainfall (starting week of puddling operation for rice transplantation) at both 50 and 75 per cent probability levels presented in Figs. (2-5) indicated the progress of onset of rainy season (in terms of SMW) for sowing of rainfed crops and for start of puddling operation for transplanted rice across various regions of the state. Das and Datar (1998) employed forward and backward accumulation method for evaluation of double cropping in Coastal and *Terai* zones of West Bengal. The information on sowing/transplanting window would be useful guidelines for the farmers to take up sowing of rainfed upland crops and transplanting of low land rice in appropriate times, according to actual sowing window, as it is one of the key factors, which strongly affect crop production (Ati *et al.*, 2002). Moreover, late sowings of crops in an area shorten the length of crop growing period and increase the infestation of weeds (Vaksmann *et al.*, 1996), leading to significant reduction in productivity.

3.2. Cessation of rainy season based on backward rainfall accumulation

Considering 50 mm backward accumulated rainfall, the rainy season ended during 39-40 SMW in Zone I, 39-41 SMW in Zone II, 39-40 SMW in Zone IIIA and 38-40 SMW in Zone IIIB at 50 per cent probability level (Table 2). The result further revealed that comparatively earlier cessation of rainy season occurs in the districts under Zone I and Zone III. The termination of rainy season with 100 mm accumulated rainfall is delayed by 1-2 weeks. When 300 mm backward accumulated rainfall

TABLE 3

Length of rainy season (weeks) in various districts of Bihar based on forward and backward accumulation of weekly rainfall

Zone/District	75 mm forward and 100 mm backward accumulation		75 mm forward and 300 mm backward accumulation		200 mm forward and 50 mm backward accumulation	
	50% Prob.	75% Prob.	50% Prob.	75% Prob.	50% Prob.	75% Prob.
Zone I (North west alluvial plains)						
Darbhanga	15	12	11	8	14	10
Samastipur	17	13	13	9	15	12
Begusarai	14	12	10	8	13	11
Madhubani	16	14	12	8	14	12
Sitamarhi	17	15	13	11	15	12
Sheohar	17	16	13	12	15	12
Muzaffarpur	16	13	13	9	15	13
Vaishali	14	11	10	7	13	9
Saran	14	11	11	8	14	11
Siwan	14	11	10	8	13	10
Gopalganj	14	12	10	8	13	12
E. Champaran	17	13	13	9	15	12
W. Champaran	20	16	16	12	17	15
Zone II (North east alluvial plains)						
Katihar	19	17	16	13	17	14
Purnia	20	18	18	15	18	15
Kishanganj	21	20	18	16	19	16
Araria	21	18	18	15	19	16
Supaul	19	15	15	11	17	13
Madhepura	20	16	16	13	17	14
Saharsha	16	14	13	9	14	11
Khagaria	16	13	13	8	14	12
Zone IIIA (South Bihar alluvial plains)						
Banka	16	14	12	10	14	12
Bhagalpur	17	13	13	10	15	13
Munger	15	14	12	10	14	13
Lakhisarai	14	12	10	8	13	10
Sheikhpura	14	12	10	8	13	10
Jamui	15	12	11	9	14	11
Zone IIIB (South Bihar alluvial plains)						
Patna	14	12	10	8	12	11
Nalanda	12	10	8	5	11	9
Nawada	14	11	9	6	13	10
Gaya	13	12	9	8	12	10
Jahanabad	13	10	8	6	12	8
Arwal	13	10	9	6	11	8
Aurangabad	14	10	10	7	12	9
Rohtas	13	11	10	8	12	9
Bhojpur	12	10	9	7	11	9
Buxar	13	11	9	7	12	10
Kaimur	13	10	9	7	12	9

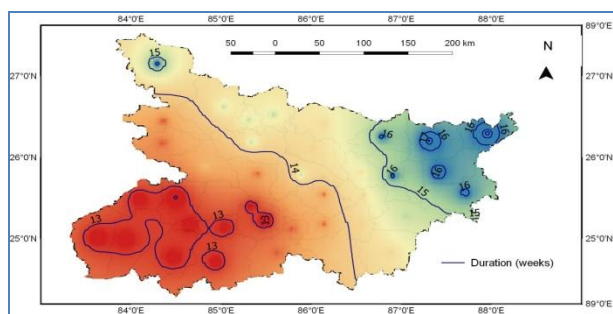


Fig. 6. Duration of rice growing season in weeks based on 200 mm forward accumulation and 50 mm backward accumulation of weekly rainfall at 50% probability level in Bihar

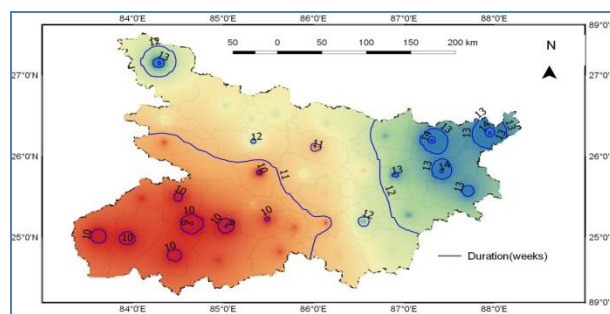


Fig.7. Duration of rice growing season in weeks based on 200 mm forward accumulation and 50 mm backward accumulation of weekly rainfall at 75% probability level in Bihar

was considered, the rainy season over different districts ended during 34-35 SMW in Zone I and Zone IIIA, 35-37 SMW in Zone I and 33-34 SMW in Zone IIIB at 50 per cent probability level, whereas at 75 per cent probability level, the rainy season terminates 1-2 weeks earlier than at 50 per cent probability level. As compared to other zones, the rainy season lasts longer in Zone II in the state.

3.3. Length of rainy season

The length of rainy season with 75 mm forward accumulation and 100 mm backward accumulation criteria (Morris and Zandstra, 1979; Dey, 2008) varies from 14 to 20 weeks at 50 per cent probability level in the districts under Zone I (Table 3). The shortest duration of 14 weeks was recorded in Begusarai, Vaishali, Saran, Siwan and Gopalganj districts, whereas the longest duration of 20 weeks was recorded in West Champaran district. At 75 per cent probability level, cropping durations ranging from 11 to 16 weeks was observed across various districts under Zone I. In Zone II, length of rainy season ranged from 16 to 21 weeks at 50 per cent probability and 13 to 20 weeks at 75 per cent probability. The districts under Zone IIIA have lengths of rainy season varying from 14 to 17 weeks at 50 per cent probability and 12 to 14 weeks at lower risk level (75 per cent probability). The length of rainy season determined for the districts under Zone IIIB was much lower than those for the districts under the remaining zones at both 50 and 75 per cent probability levels. Such duration in Zone IIIB varied from 12 to 14 weeks at 50 per cent probability and 10 to 12 weeks at 75 per cent probability. Thus, in the districts under Zone IIIB, only short to medium duration rainfed crops could be grown.

Under double cropping situation (75 mm forward and 300 mm backward accumulation) if a farmer completes his first rainfed upland crop in a week after which still there is a probability of receiving 300 mm rainfall for the subsequent crop, then at 50 per cent probability, the lengths of rainy season available for the

first crop was 10-16 weeks across various districts under Zone I, 13-18 weeks in Zone II, 10-13 weeks in Zone IIIA and 8-10 weeks in Zone IIIB (Table 3). At much higher probability (75 per cent), such periods were 8 to 12 weeks in Zone I, 8-16 weeks in Zone II, 8-10 weeks in Zone IIIA and only 5-8 weeks in Zone IIIB. These durations in different agroclimatic zones represent the length of cropping period. Accordingly, upland crops and their varieties should be selected. Considering the case of rice transplanting, if a farmer fails to transplant or is unable to grow rice crop due to poor monsoon, then by following the criterion of 300 mm backward accumulation, he has a chance of growing second rainfed crop during 34-35 SMW in Zone I and Zone IIIA, 35-37 SMW in Zone II and 33-34 SMW in Zone IIIB with the probability of still receiving 300 mm rainfall after sowing at 50 per cent probability level. It is considered that 300 mm accumulated rainfall by backward method represents the week after which sufficient rain would be expected to sustain a second crop after monsoon crop (Morris and Zandstra, 1979) assuming a fully charged soil profile at planting (WMO, 1982).

3.4. Growing period of transplanted rice under rainfed condition

Considering 200 mm rainfall by forward accumulation and 50 mm rainfall by backward accumulation criteria, the length of rainy season was found to be 13-17 weeks in Zone I, 14-19 weeks in Zone II, 13 to 15 weeks in Zone IIIA and 11 to 13 weeks in the districts under Zone IIIB at 50 per cent probability level (Table 3). However, at 75 per cent probability, the length of rainy season reduced to 9-15 weeks in Zone I, 11 to 16 weeks in Zone II, 10-13 weeks in Zone IIIA and 9-11 weeks in Zone IIIB. Considering the availability of rainy season length, only early maturing varieties of rice (*Prabhat*, *Turanta*) could be grown under rainfed condition in the districts under Zone IIIB in 50 out of 100 years. However, at 75 per cent probability level (*i.e.*, 75 out of 100 years), the length of rainy season appears to be

too low to grow even such short duration rice varieties. Dey *et al.* (2011) also evaluated the duration of transplanted rice in the plains of Gangetic West Bengal based on 200 mm forward and 50 mm backward accumulated rainfall. In the districts under Zone I and Zone IIIA, short to medium duration rice varieties (*Dhanlaxmi, Richhariya, Saroj, Rajendra Bhagwati, Rajendra Suwasni, Prabhat, Rajshree*) could be considered for growing under rainfed condition. However, there is a possibility of growing medium (*Rajendra Bhagwati, Rajendra Suwasni, Prabhat, Rajshree*) to long (*Rajendra sweta, Santosh, Rajshree, Rajendra Mansuri, Satyam, Kishori*) duration varieties of rice in West Champaran (Zone I), Katihar, Purnia, Kishanganj, Araria, Supaul and Madhepura (Zone II) districts of Bihar. Thematic maps depicting the homogeneous duration of rice growing season based on 200 mm forward accumulation and 50 mm backward accumulation criteria at 50 and 75 per cent probability levels have been presented in Figs. 6 and 7. Olderman and Frere (1982) employed forward and backward accumulation method to evaluate the homogenous rice growing season in Thailand.

4. Conclusions

The information generated in this paper could serve as useful guidelines for the farmers to take up sowing of rainfed crops and transplanting of low land rice based on rainfall accumulation criteria. Correct evaluation of agroclimatic potential in terms of water availability, sowing window and growing period length will help policy makers and farmers to achieve the scope of identifying suitable crops and to amend the existing limitations to cropping, to avoid moisture stress during crop growing season, as well as to chalk out tactical and strategic plans for rainfed crop production under climate change scenarios.

Disclaimer : The views expressed in this research paper are those of the authors' and do not necessarily reflect the views of the organization to which they are affiliated.

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