Vol. 44, No. 1, pp 37-43, 2016
Indian Journal of Soil Conservation
Online URL:http://indianjournals.com/ijor.aspx?target=ijor:ijsc&type=home

Assessing climatic water balance and growing period length for crop planning under rainfed condition

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ARTICLE INFO

Article history :
Received : May, 2014
Revised : September, 2015
Accepted : November, 2015

Key words :
Crop planning,
Length of growing period,
Probability distribution,
Rainfall,
Water balance

ABSTRACT

An agroclimatic study was conducted at Pusa, Samastipur region of Bihar using database of 45 years (1968-2012) to assess water balance and length of growing period for efficient crop planning under rainfed condition. The average annual rainfall computed was 1226.7 ± 388.9 mm. More than 30 mm rainfall week^{-1} was found to occur during 24 Standard Meteorological Weeks (SMW) to 39 SMW and more than 50 mm rainfall week^{-1} was available during 25-39 SMW, except 38 SMW. Total water surplus estimated was 487.3 mm during 24 to 43 SMW, as against the total annual water deficit of 75.4 mm during the corresponding period. Under average rainfall condition, actual evapotranspiration (AET) was more than 0.25 of potential evapotranspiration (PET) during the period from 18 to 50 SMW, whereas it was more than 50% of PET during 24 to 44 SMW. Chi-square test showed that Weibull distribution was the best fit distribution for annual and monsoon rainfall, whereas for non-monsoon season, Cauchy distribution was found to be appropriate. Out of annual average rainfall of 1227 mm, the surplus and effective rainfall were 39.7 and 60.3%, respectively. The average effective rainfall was 739.4 ± 89 mm. The effective rainfall, which was calculated by subtracting surplus water from rainfall, was equal to rainfall during 1 to 23 SMW and 44 to 52 SMW and lesser than rainfall during 24 to 43 SMW, which coincided with the surplus period. Year-wise lengths of growing periods (LGP) were worked out based on moisture adequacy index (I_{ma}). Mean LGP based on I_{ma}, was 217± 46 days, with 60% of the total years recording LGP ≥ 200 days. Crop planning based on LGP has been suggested for the region for sustainable crop production under rainfed condition.

1. INTRODUCTION

Crop production in an area under rainfed condition has a direct relation with amount and distribution of rainfall. It is a very important natural resource for crop production. Correct evaluation of water availability period is an important pre-requisite for crop planning under rainfed condition. The water balance is widely used method for determination of growing period length under rainfed condition. A number of workers have studied water balance technique to assess water availability, water deficiency and length of growing period for agricultural planning. Based on weekly climatic water balance parameters for the period from 1950 to 1987, Khan and Saha (1993) identified suitable crops and cropping patterns for drought prone district of Purulia in West Bengal. Dey (2008) studied climatological water balance for estimating soil moisture, AET, length of crop growing period and rainwater balance for determining effective rainfall, water surplus and deficit during different growth phases of transplanted *kharif* rice in West Bengal. Bannerjee *et al.* (2010) studied soil moisture based crop planning at Silai sub watershed of West Bengal and calculated length of growing period based on soil moisture in different land forms. The estimated LGPs in *tanr, baid, kanali and behal* lands were 145-155, 150-160, 155-165 and 170-180 days, respectively. They also suggested crop planning with suitable varieties of crops in respective land forms. Verma *et al.* (2012) studied monthly climatic water balance of selected locations of India and emphasized the need for proper crop selection with limited moisture. Kovilavani *et al.* (2012) studied variability of length of growing period in Coimbatore district and suggested growing of short duration crops such as sorghum

(*Sorghum vulgare*), bajra (*Pennisetum glaucum*), ragi (*Eleusine coracana*), maize (*Zea mays*), sunflower (*Helianthus annus)*, soybean (*Gycine max*), groundnut (*Arachis hypogaea*) or pulses like green gram (*Vigna radiata*), cowpea (*Vigna unguiculata*) successfully under rainfed condition.The research work involving evaluation of water balance for identifying the length of growing period has not yet been carried out in Bihar. Hence, an attempt has been made to assess the climatic water balance and length of growing period at Pusa under North West alluvium plain zone of Bihar for evaluation of effective crop management strategy in this region.

2. MATERIALS AND METHODS

The study was conducted at Pusa of Samastipur district, Bihar. Daily rainfall data from 1968 to 2012 were collected from Agromet Observatory, Pusa (latitudes: 25.98^0 N, longitudes: 85.67^{0}E, altitude: 52 m amsl). Daily rainfall data were summed up to obtain weekly total rainfall on standard meteorological week (SMW) basis. Based on particle size distribution and organic matter of soil of Pusa at various depths as surveyed and reported by NBSSLUP, ICAR, Nagpur and bulk density estimated from the equation (Saxton *et al.,* 1986), field capacity and wilting point were estimated following the methodologies given by Gupta and Larson (1979). Available water holding capacity (AWHC) per meter depth was estimated as the difference between filed capacity and permanent wilting point. The average water holding capacity so determined was 140 mm m^{-1} depth for the soil under study. Weekly total potential evapotranspiration (PET) data were collected from India Meteorological Department, Pune. Year-wise weekly water balance computation was carried out by using weekly total rainfall, normal total PET and AWHC following the procedure given by Thornthwaite and Mather (1955). Output components of water balance method were soil moisture storage (SMS), actual evapotranspiration (AET), and water surplus and water deficit. The derived parameters estimated from the water balance parameters were index of moisture adequacy index (I_{ma}), which is the ratio between AET and PET and soil moisture index (SMI) which is the ratio between SMS and AWHC. The water balance method considered that when rainfall was greater than PET, AET was taken as equal to PET and when rainfall was below the PET, the AET was calculated as the sum of rainfall and change in soil moisture storage between two successive weeks. The surplus water was determined in the present study. The effective rainfall was calculated by subtracting surplus water from rainfall (Chang, 1968).

For determining the length of growing period (LGP), which is also regarded as the water availability period under rainfed condition, the concept of index of moisture adequacy (I_{ma}), which is the ratio between AET and PET, has been considered. Since the study area falls under dry sub humid climatic condition, the onset of growing season was considered at a week when I_{ma} was greater than or equal to 0.75 (Gupta *et al.,* 2010), which is considered as the minimum moisture level for starting the sowing of crops like rainfed rice (*Oryza sativa*), maize (*Zea mays*), arhar (*Cajanus cajan*) and sunflower (*Helianthus annuus*). The termination of growing period was taken at a week from where I_{ma} is less than 0.25 (Krishnan *et al., 1980)*. From the results of water balance, LGP of each individual year during the period from 1968 to 2012 was determined and from this, the average LGP, standard deviation (SD) and coefficient of variation (CV) were calculated.

In order to identify the most appropriate probability distribution function in annual, monsoon, and non-monsoon rainfall, the test of goodness of fit through Chi-square test (Mishra *et al.,* 2013) was carried out with six probability distribution functions (Kumar *et al.,* 2007). Chi-square test statistic was computed from the following relationship:

$$\chi^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i}$$

Table: 1
Basic description of probability distribution functions considered in the study

Distribution type	Distribution function	Range	Parameters
Normal	$F(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$	$-\infty < x < \infty$	μ = mean, σ = standard deviation
Log-normal	$F(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{ln\,x-\mu}{\sigma}\right)^2}$	$0 < x < \infty$	μ = mean, σ = standard deviation
Gumbel Max	$F(x) = \frac{1}{\alpha} exp\left[-\frac{x-\mu}{\alpha} exp\left(-\frac{x-\mu}{\alpha}\right)\right]$	$-\infty < x < \infty$	μ = location parameter, ∞ = scale parameter
Gamma	$F(x) = \frac{1}{\Gamma(b)\,\theta^b} x^{b-1} e^{-x/\theta}$	$x>0$	b = shape parameter, θ = scale parameter
Weibull	$F(x) = \frac{k}{\lambda}\left(\frac{x}{\lambda}\right)^{k-1} e^{-\left(\frac{x}{\lambda}\right)^k}$	$x\geq0$	k = shape parameter > 0, λ = scale parameter > 0
Cauchy	$F(x) = \frac{1}{\Pi\theta}\left[\frac{\theta^2}{(x-\mu)^2+\theta^2}\right]$	$-\infty < x < \infty$	μ = location parameter, θ = scale parameter

Where, O_i and E_i = the observed and expected values in the i^{th} observation, respectively and k = number of observations.

3. RESULTS AND DISCUSSION

Water Balance

The results on average rainfall, PET, AET, water surplus, water deficit, soil moisture and SMI for the period 1968-2012, presented in Table 2 and Fig. 1, revealed that average rainfall was more than 20 mm during 23 SMW to 40 SMW, more than 30 mm rainfall week^{-1} during 24 SMW to 39 SMW and more than 50 mm rainfall week^{-1} was available during 25-39 SMW, excepting 38 SMW. The period during

Table: 2
Average water balance parameters for Pusa, Samastipur (Database: 1968- 2012)

SMW	Rainfall (mm)	PET (mm)	AET (mm)	Water surplus (mm)	Water deficit (mm)	SMS (mm)	SMI	Effective rainfall (mm)
1	1.5	10.5	3.0	0.0	7.5	28.8	0.21	1.5
2	2.7	10.5	3.4	0.0	7.1	28.2	0.20	2.7
3	2.0	11.2	3.3	0.0	7.9	26.8	0.19	2
4	3.2	11.9	4.0	0.0	7.9	26.1	0.19	3.2
5	3.4	12.6	4.0	0.0	8.6	25.5	0.18	3.4
6	3.2	14	3.9	0.0	10.1	24.7	0.18	3.2
7	4.6	16.1	5.4	0.0	10.7	24.0	0.17	4.6
8	2.8	18.2	5.0	0.0	13.2	21.7	0.16	2.8
9	1.7	19.6	4.2	0.0	15.4	19.2	0.14	1.7
10	0.6	21.7	3.3	0.0	18.4	16.5	0.12	0.6
11	1.1	21	3.2	0.0	17.8	14.3	0.10	1.1
12	1.4	25.9	3.7	0.0	22.2	12.0	0.09	1.4
13	1.3	28.7	3.5	0.0	25.2	9.9	0.07	1.3
14	2.5	30.1	3.9	0.0	26.2	8.4	0.06	2.5
15	2.7	32.9	4.3	0.0	28.6	6.8	0.05	2.7
16	6.3	34.3	7.3	0.0	27.0	5.8	0.04	6.3
17	7.0	35	7.0	0.0	28.0	5.8	0.04	7
18	9.7	37.1	9.8	0.0	27.3	5.7	0.04	9.7
19	13.6	37.8	12.0	0.0	25.8	7.3	0.05	13.6
20	17.2	39.2	13.3	0.0	25.9	11.2	0.08	17.2
21	25.2	39.9	18.7	0.0	21.2	17.7	0.13	25.2
22	15.1	39.9	16.1	0.0	23.8	16.7	0.12	15.1
23	26.8	36.4	18.1	0.0	18.3	25.4	0.18	26.8
24	31.5	34.3	20.7	2.0	13.6	34.1	0.24	29.5
25	54.0	36.4	29.9	3.2	6.5	55.1	0.39	50.8
26	67.2	34.3	27.7	17.3	6.6	77.2	0.55	49.9
27	77.6	32.9	29.5	30.5	3.4	94.9	0.68	47.1
28	78.4	34.3	30.6	34.9	3.7	107.8	0.77	43.5
29	83.2	31.5	30.0	44.9	1.5	116.1	0.83	38.3
30	66.1	30.1	28.8	32.2	1.3	121.2	0.87	33.9
31	63.3	30.1	28.4	33.6	1.7	122.5	0.87	29.7
32	60.5	29.4	28.7	31.8	0.7	122.5	0.88	28.7
33	75.2	28.7	27.3	47.2	1.4	123.2	0.88	28
34	73.0	28.7	27.9	42.5	0.8	125.8	0.90	30.5
35	51.9	29.4	28.1	25.4	1.3	124.2	0.89	26.5
36	62.1	28.7	27.2	35.9	1.5	123.2	0.88	26.2
37	55.7	28.7	27.3	29.0	1.4	122.6	0.88	26.7
38	39.7	28.7	26.7	18.1	2.0	117.4	0.84	21.6
39	54.7	25.2	23.5	30.6	1.7	118.0	0.84	24.1
40	29.6	28	23.9	16.1	4.1	107.7	0.77	13.5
41	16.9	25.9	20.5	4.9	5.4	99.3	0.71	12
42	15.1	24.5	17.6	7.0	6.9	89.8	0.64	8.1
43	2.5	25.9	16.0	0.2	9.9	76.1	0.54	2.3
44	2.4	24.5	13.3	0.0	11.2	65.3	0.47	2.4
45	2.5	21.7	10.4	0.0	11.3	57.3	0.41	2.5
46	0.6	20.3	8.1	0.0	12.2	49.8	0.36	0.6
47	0.7	18.2	6.5	0.0	11.7	44.0	0.31	0.7
48	2.3	16.8	5.8	0.0	11.0	40.5	0.29	2.3
49	0.0	15.4	4.2	0.0	11.2	36.3	0.26	0
50	1.6	14	4.1	0.0	9.9	33.8	0.24	1.6
51	0.5	9.8	2.6	0.0	7.2	31.7	0.23	0.5
52	2.6	9.8	3.6	0.0	6.2	30.7	0.22	2.6

SMW: Standard met week, 1 SMW: 1-7 January, PET: Potential evapotranspiration. AET: Actual evapotranspiration, SMS: Soil moisture storage, SMI: Soil moisture index.

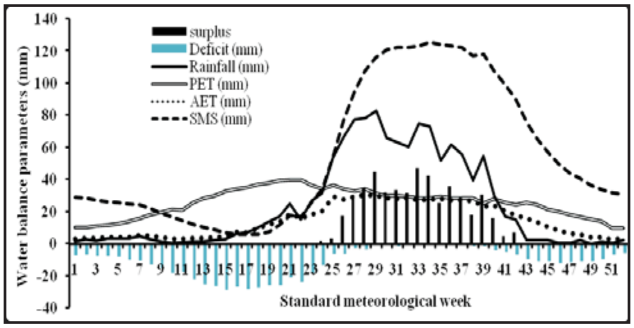

Fig. 1. Average weekly water balance parameters at Pusa, Bihar

25-37 SMW, where weekly rainfall was greater than 50 mm week^{-1} for consecutive period, could be identified as the period for growing low land rice crop grown within 120 days. The highest weekly rainfall (83.2 mm) was found to occur in 29 SMW, whereas the lowest rainfall was found to occur in 49 SMW.

Weekly total PET was greater than 20 mm during the period from 10 to 46 SMW, whereas it was greater than 30 mm week^{-1} during 14-31 SMW. During December to February, PET was lesser than 20 mm week^{-1}. Water surplus, which includes runoff and deep drainage, was found to prevail from 24 to 43 SMW and this information provides scope for identification of suitable low land rice varieties to match with the period of water surplus. The total annual surplus was computed as 487.3 mm during 24 to 43 SMW as against the total water deficit 75.4 mm during the corresponding period. However, annual deficit determined was 591.4 mm. The 50% of AWHC value prevailed during the period from 26 SMW to 43 SMW, indicating that under average rainfall condition, crops growing during this period would be able to produce at potential level. Similar variation was also observed in soil moisture index, where SMI > 0.5 was found to occur during the period from 26-43 SMW.

Annual Rainfall, Surplus, Deficit, AET and Effective Rainfall

The lowest annual rainfall (498 mm) was recorded in 1992, whereas the highest rainfall (2431 mm) was occurred in 2007. The average annual rainfall computed was 1226.7 ± 388.9 mm (Table 3). Out of 45 years (1968-2012), 51.1% years recorded below normal rainfall and 48.9% years recorded above normal rainfall. The lowest annual water surplus, which was nil, was recorded in 1992 and 2005, whereas the highest surplus (1311 mm) was recorded in 1974. The average surplus was 487.3 ± 341.2 mm. Out of 45 years, 55.6% years recorded above average surplus. The results suggest that in most of the years, annual surplus water was more than 400 mm, which can be harvested in pond and other surface water structures for future use for life saving irrigation.

On an average, annual AET varied from 525 mm in 1992 to 898 mm in 2003. The average annual AET is 739.1 ± 83.0 mm. Although the lowest rainfall year 1992 was associated with lowest ET, the highest rainfall year of 2007 gave AET of 785 mm, which was lower than highest AET (898 mm) recorded in 2003.This anomaly was due to the differences in distribution of rainfall between two years. Annual water deficit over different years showed that it was the lowest (433 mm) in 2003 as against the highest (806 mm) in 1992. The yearly deficit

Table: 3
Year wise rainfall (mm), water surplus (mm), actual evapotranspiration (mm), water deficit (mm) and effective rainfall (mm) during 1968-2012 at Pusa

Year	Rainfall (mm)	Water surplus (mm)	AET (mm)	Water deficit (mm)	Effective rainfall (mm)
1968	791.9	179.7	619.1	711.6	612.2
1969	1563.9	698.1	848	482.7	865.8
1970	768.4	32.1	743.5	587.2	736.3
1971	1534	662.2	864.7	466	871.8
1972	791.1	216.1	562	768.7	575
1973	1226.1	428.2	804.4	526.3	797.9
1974	2078.7	1310.5	760.4	570.3	768.2
1975	1014.4	288.1	737.4	593.3	726.3
1976	1836.8	1028.3	821.9	508.8	808.5
1977	1133.3	293.3	820.1	510.6	840
1978	1134.9	310	835.7	495	824.9
1979	1228	479	717.4	613.3	749
1980	1320.2	571.8	787.1	543.6	748.4
1981	1787.4	1064.9	724.6	606.1	722.5
1982	773.8	159	616.7	714	614.8
1983	946.1	251.3	691.2	639.5	694.8
1984	1406.4	628.8	779.2	551.5	777.6
1985	1439.9	646.6	773.5	557.2	793.3
1986	951.4	178.7	761.6	569.1	772.7
1987	1625.5	998.5	656.8	673.9	627
1988	1169.3	501.5	665.8	664.9	667.8
1989	1413.6	637.4	763.1	567.6	776.2
1990	1157.6	461.6	709	621.7	696
1991	954	226.6	711.3	619.4	727.4
1992	497.7	0	524.5	806.2	497.7
1993	1150.2	374	740.3	590.4	776.2
1994	753.1	136.3	639.3	691.4	616.8
1995	1338.5	649.1	666.7	664	689.4
1996	712.5	109	637.9	692.8	603.5
1997	1298.7	552.8	721.4	609.3	745.9
1998	1527.1	714.4	811.9	518.8	812.7
1999	1365.2	587.2	777.7	553	778
2000	1303.9	486.6	835.7	495	817.3
2001	1655	803.8	841.2	489.5	851.2
2002	1129	397.3	743.1	587.6	731.7
2003	1400.5	472.3	897.7	433	928.2
2004	1164.5	445.8	759.1	571.6	718.7
2005	636.7	0	631.8	698.9	636.7
2006	1062.8	372.2	680.4	650.3	690.6
2007	2430.9	1626	785	545.7	804.9
2008	1558.6	775.8	798	532.7	782.8
2009	903.3	171.2	740.1	590.6	732.1
2010	958	263.9	690.8	639.9	694.1
2011	1428.5	547.8	865.1	465.6	880.7
2012	880.2	189.4	699	631.7	690.8
Mean	1226.7	487.3	739.1	591.6	739.4
SD(±)	388.9	341.2	83.0	83.0	89.0
CV (%)	31.6	70.0	11.2	14.0	12.0

occurring in 1992 and that in 2007 showed inverse relationship with AET during the corresponding years. The average annual AET was 739.1 ± 83.0 mm.

Out of the average annual rainfall of 1227 mm, the surplus and effective rainfall were 39.7 and 60.3%, respectively. The effective rainfall, which was observed to be the highest (50.8 mm) in 25 SMW and the lowest (0 mm) in 49 SMW, was equal to rainfall during 1 to 23 SMW and 44 to 52 SMW and lesser than rainfall during 24 to 43 SMW being coincided with the surplus period (Table 2). The latter period could effectively be utilized as period of crop growing for potential productivity evaluation under average rainfall condition. The average annual effective rainfall was 739.4 ± 89.0 mm. The highest effective rainfall (928.2 mm) was recorded in 2003 and the lowest (497.7 mm) was observed in 1992 (Table 3).

Probability Distribution

Chi-square test carried out to test the goodness of fit for selection of suitable probability distribution functions revealed that Weibull distribution was the best fit distribution for annual and monsoon season rainfall; whereas for non monsoon season, Cauchy distribution was found to be appropriate (Table 4). Mishra *et al.* (2013) also fitted the best probability function using Chi-square test for annual, monsoon and non monsoon season rainfall of Tawa canal command of Madhya Pradesh, India.

Water Availability Period

Under average rainfall condition, the period during which AET was greater than 0.25 of PET prevailed from 18 to 50 SMW, whereas the period during which AET became more than 50% of PET existed during the period from 24 to 44 SMW (Fig. 2). Thus, it was evident that under average rainfall condition, LGP would be as high as 231 days extending from 18 to 50 SMW. On the other hand, under average rainfall condition, deficit occurred during 1to 23 SMW and from 44 to 52 SMW, whereas surplus during 24 to 43 SMW.

Table: 4
Chi square values of various probability distribution functions for annual, monsoon and non monsoon season rainfall

Period	Chi-square values					
	Normal	Log normal	Gambel Max	Weibull	Gamma	Cauchy
Yearly	0.96	1.62	1.50	0.18	1.61	2.45
MW	1.38	3.45	6.45	0.08	4.48	1.75
NMW	20.42	3.77	15.89	3.59	7.74	0.32

MW: Monsoon week (23-43 SMW), NMW: Non-monsoon week

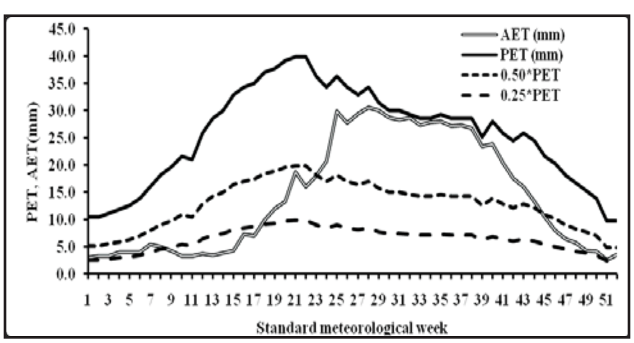

Fig. 2. Water availabiity period at Pusa, Bihar

LGP on the Basis of I_{ma}

The results on LGP along with standard deviation (SD) and coefficient of variation (CV) presented in Table 5 showed that the earliest start of LGP occurred in 16 SMW in

Table: 5
Start, end and duration of length of growing period (LGP) at Pusa during 1968-2012

Year	Start	End	LGP (weeks)	LGP (days)
1968-69	22	44	23	161
1969-70	21	50	30	210
1970-71	21	48	28	196
1971-72	20	50	31	217
1972-73	27	12	38	266
1973-74	24	3	32	224
1974-75	23	7	37	259
1975-76	25	9	37	259
1976-77	19	47	29	203
1977-78	16	13	50	350
1978-79	19	50	32	224
1979-80	24	13	42	294
1980-81	19	47	29	203
1981-82	21	46	26	182
1982-83	23	46	24	168
1983-84	21	45	25	175
1984-85	22	46	25	175
1985-86	24	2	31	217
1986-87	20	5	36	252
1987-88	23	50	28	196
1988-89	24	45	22	154
1989-90	20	1	34	238
1990-91	25	48	24	168
1991-92	24	6	34	238
1992-93	28	43	26	182
1993-94	26	11	38	266
1994-95	26	49	24	168
1995-96	25	10	38	266
1996-97	23	44	22	154
1997-98	25	11	39	273
1998-99	25	2	30	210
1999-2000	24	6	35	245
2000-01	20	47	28	196
2001-02	18	51	34	238
2002-03	22	46	25	175
2003-04	23	10	40	280
2004-05	21	42	22	154
2005-06	23	44	22	154
2006-07	19	48	29	203
2007-08	24	6	35	245
2008-09	23	50	28	196
2009-10	19	47	29	203
2010-11	21	1	33	231
2011-12	20	11	44	308
2012-13	25	52	28	196

Mean LGP: 217.2, SD (±): 45.5, CV (%): 21.0

1977, whereas the delayed start of sowing week appeared in 27 SMW in 1972. From the values of the ends of LGP during different years, it was apparent that the earliest withdrawal of LGP occurred in 42 SMW during 2004-05, whereas the latest end of LGP was found to occur in 13 SMW in 1977-78 and 1979-80. Total length of LGP which was calculated over the period between start and end of LGP for each individual year revealed that the lowest LGP of 154 days was recorded in 1988-89 as against the highest LGP of 350 days in 1977-78. When averaged over 1968-2012, it was observed that mean LGP accounts for 217±46 days with CV of 21%. Thus, it is obvious that there was a lot of year to year variation in LGP as evidenced by higher CV values. Out of 45 years, 48.9% years recorded LGP being above the mean value (217± 46 days) and 51.1% years being below mean LGP. Out of the total number of years under study, 60% of the years recorded LGP ≥ 200 days, where double cropping with maize (*Zea mays*) in the *kharif* season followed by short duration rapeseed (*Brassica campestris*) in *rabi* season would be better choice under rainfed condition.

The frequency of start of LGP at various SMWs was calculated which showed that frequency of occurring of start of sowing week varied from 2.3% in 18 SMW to 15.9% in 23 and 24 SMWs. It was observed that the sowing could be feasible by 22 SMW in 45 years out of 100 years and by 23 SMW in 61 years out of 100 years. Thus, it is concluded that that the sowing window in the district could be fixed during 19-23 SMW and hence, the farmers of the region could be alerted for undertaking sowing of rainfed crops during this period through agromet advisories.

Cropping Plan

The information on LGP estimated through the water balance could be of immense help for crop planning under rainfed condition because of its utility in selection of crops or a variety under a crop in agreement with the duration of water availability period. The results revealed that in most of the years, the adoption of double cropping under rainfed condition could be feasible. In Bihar, particularly in the study area, usually long duration rice (*Oryza sativa*), maize (*Zea mays*), arhar (*Cajanus cajan) and sunflower* (*Helianthus annus*) during *kharif* season followed by rapeseed (*Brassica campestris*), chick pea (*Cicer arietinum*) and lentil (*Lens culinaris*) during *rabi* season are grown under rainfed condition and they mostly experience moisture stress at different phases of growth and produce lesser yield. Presently, before selection and sowing of a crop, the information on duration of water availability period matching with duration of a given crop is not considered. Instead of adopting long duration varieties, emphasis should be given for selection of appropriate short duration varieties for making the sequential cropping during *kharif* and *rabi* seasons more successful. As compared to arhar (*Cajanus cajan*) and long duration rice (*Oryza sativa*), upland rice (*Oryza sativa*) and maize (*Zea mays*) are of shorter duration and the choice of improved short duration varieties of the latter crops is required to ensure the growing of subsequent crops. Following the harvest of *kharif* crops, short duration varieties of *rabi* oil seeds and pulses could be grown with greater success. In this way, the LGP of 217± 46 days could be effectively utilized for rainfed crop production. Changes in sowing of crop with early maturing varieties offer scope for enhancing crop production under rainfed condition (Krishnan, 1983).

4. CONCLUSIONS

Under average rainfall condition, the LGP could be as high as 231 days extending from 18 to 50 SMW. When averaged over 1968-2012, the mean LGP becomes 217± 46 days with CV of 21%. Appropriate crops and varieties under a crop matching with water availability period for making the sequential cropping during *kharif* and *rabi* seasons more successful should be selected under rainfed condition. The double cropping with maize (*Zea mays*) in the *kharif* season followed by the short duration rapeseed (*Brassica campestris*) and pulses in *rabi* season could be better choice for potential productivity evaluation under rainfed condition in the region. About 56% of the years under study recorded greater than 487.3 mm water surplus, which could be harvested in pond and other surface water structures for use as supplemental irrigations for both *kharif* and *rabi* crops. The sowing period identified in the district lies during 19-23 SMW during which the sowing of rainfed crops could be recommended for farmers through agromet advisory services.

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