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Long term trends in rainfall and its probability for crop planning in two districts of Bundelkhand region

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ABSTRACT

Annual and weekly rainfall data for the period of 69 years (1942-2008) of Datia and (1939-2007) of Jalaun districts of Bundelkhand region were analyzed. The overall mean annual rainfall was 778.8 mm with 27.3% variability for Jalaun and 831.8 mm with 30.3 % variability for Datia region. Mann-Kendall rank statistics and Gaussian low pass filter revealed the long-term a decreasing trend in total amount of annual rainfall at Jalaun. However, in past 13 years (1996 to 2008), both regions exhibited significant decreasing trend in total amount of annual rainfall. At Datia, the probability more than 10 mm during 26^{th} (25 June-1 July) and 27^{th} (2-7, July) standard meteorological week (SMW) suggested to initiate field preparation operation for *Kharif* crop and sowing in subsequent week due to assured probability (70%) of more than 20 mm rainfall. The 27^{th} and 28^{th} (8-15, July) SMW is also an ideal time for the crop fertilization. Overall expected rainfall for getting more than 20 mm rainfall at 60% probability level is for 10 weeks at Datia suggesting that short duration varieties of various crops can be ideal in the region. At Jalaun, the trend analysis showed that field operation may be a week delay than Datia due to late onset on monsoon. Therefore, the ideal combination of crops of the regions may be sorghum for the grain purpose intercropped with cowpea for the fodder purpose as livestock is an integral part of rainfed rural economy.

***Key words* :** Rainfall trend analysis, crop planning, rainfall probability, rainfed regions

Rainfall is the single most important factor in crop production planning in rainfed ecologies. The information on annual, seasonal (monthly and weekly) rainfall of a region is useful to design water harvesting structure for agricultural operations field preparation, seeding, irrigation, fertilizer application and overall in field crop planning (Sharma *et al*, 1979). Around 60% of the Indian agriculture is rain-dependent, diverse, complex, under-invested, risky, distress prone and vulnerable. Uncertainties and seasonal migrations have been further compounded due to high frequency of the extreme rainfall and weather events like droughts due to global warming. Historically, Bundelkhand region of UP and MP used to have one drought in 16 years in 19^{th} century which increased by three times during the period 1968 to 2000 and in last 10 years region have witnessed five drought years. The Jalaun and Datia districts of Bundelkhand region are categorized as rainfed region with low, erratic and uncertain rainfall pattern with frequent dry spells during the monsoon season. Hence monsoon cropping is a tricky operation in the region as well as sudden crop failures during *kharif* season is a common phenomenon due to early withdrawal of monsoon. Rainfall probability pattern has been studied by many scientists in India (Gupta *et al*. 1975; Hundal and Kaur 2002, Suchit and Singh 2009; Ahmed *et al*. 2009, Ravindrababu *et al*. 2010) and concluded that rainfall occurrence is certain at greator than or equal to 80%probability, while 50% probability is the medium limit of certainty and may involve dry spell risk. Taking into account these climatic and probability factor, the current study was conducted to two rainfed districts of Bundelkhand region namely Jalaun and Datia for interlinking the rainfall probability and intensity factor with the crop planning pattern in the region.

MATERIALS AND METHODS

Weekly rainfall data for the period 1939 to 2008 i.e. for 69 years pertaining to Datia (25^{o} .31'N, 78^{o} 33'E, 224 m msl), and Jalaun (25^{o} .31'N, 78^{o} 33'E, 224 m msl) were obtained from India Meteorological Department (IMD), Pune. Weekly, annual and seasonal rainfall distribution patterns were critically examined and analyzed adopting procedure suggested by Panse and Sukhatme (1985). In order to apply appropriate statistical test the frequency distribution of annual and seasonal rainfall series have been tested for normality by Fisher's statistics. Trends were examined by Cramer's test, Mann-Kendall rank statistics and Gaussian low-pass (WMO, 1966). An initial and conditional probability of weekly rainfall at different threshold limits (10, 20 and 40 mm) were computed using

Table 1 : Statistical parameters of annual and seasonal rainfall in two districts of central India

Rainfall	Mean	SD	CV (%)	Highest (mm)	Lowest (mm)	% C	CS	CK	g_1/SE (g_1)	g_2/SE (g_2)
Jalaun										
Annual	778.8	217.4	27.3	1385.8	357.3	-	0.46	0.11	1.43*	0.2*
Monsoon	706.9	192.3	27.2	1260.0	313.9	89.0	0.99	0.07	1.71*	1.0*
Pre-monsoon	18.6	18.3	98.4	71.3	0	2.3	0.99	0.07	3.05	0.11*
Post-monsoon	37.5	53.6	142.8	212.1	0	4.7	1.67	2.17	5.10	3.4
Winter	31.6	33.0	104.3	170.0	0	4.0	1.89	4.79	5.8	7.4
Datia										
Annual	831.8	252.4	30.3	1527.4	438.4	0	0.54	0.15	1.67*	0.2*
Monsoon	767.7	234.9	31.0	1447.6	190.0	91.3	0.33	0.34	1.03*	0.5*
Pre-monsoon	35.3	63.6	180.0	298.2	0	4.2	2.57	6.57	7.94	10.1
Post-monsoon	24.7	31.1	126	137.6	0	2.9	2.04	4.32	6.28	6.6
Winter	13.5	20.5	151.8	112.9	0	1.6	2.65	9.31	8.17	14.3

* Significant at 5% level, %C: Contribution in annual rainfall (%), CS: Coefficient of skewness, CK: Coefficient kurtosis, $g_1/SE(g_1)$ and $g_2/SE(g_2)$: Fisher statistics

Table 2 : Expected weekly rainfall amount (mm) at different probability level (%)

SMW	Jaluan				Datia			
	Mean	**50**	**60**	**70**	**Mean**	**50**	**60**	**70**
24	11.5	2.2	0.5	0.0	10.3	1.2	0.0	0.0
25	17.2	6.4	2.8	1.2	17.3	8.0	3.3	1.0
26	30.8	12.0	8.6	4.5	38.3	20.3	7.6	3.0
27	37.2	26.2	16.1	5.4	48.5	37.0	26.6	21.0
28	46.6	34.2	29.2	14.2	45.9	30.0	25.0	18.0
29	61.6	50.0	39.2	28.0	64.6	55.6	42.2	30.4
30	48.0	42.0	27.6	17.2	65.8	50.0	29.5	20.0
31	54.6	45.4	32.3	24.6	65.6	57.1	42.2	29.6
32	82.0	55.2	45.7	31.0	75.5	63.2	39.6	25.2
33	74.9	66.8	55.3	37.6	75.0	66.0	48.0	35.2
34	49.1	48.1	26.6	12.5	50.3	43.6	25.0	12.0
35	53.1	37.8	19.8	15.3	49.6	42.6	30.0	22.1
36	31.5	27.8	15.0	7.6	57.5	30.6	21.4	11.0
37	14.0	39.4	23.6	9.5	53.2	30.0	15.0	9.9
38	18.0	15.2	7.4	0.0	34.4	9.6	2.0	0.0
39	12.0	0.0	0.0	0.0	11.8	0.0	0.0	0.0

first order Markov chain process (Robertson, 1976). Expected amount of rainfall at a given probability level was computed using Weibull's distribution (Chow, 1964).

RESULTS AND DISCUSSION

Variability in annual and seasonal rainfall

The average annual rainfall is 794.8 at Jalaun and it varied from 357.3 to 1385.8 mm with coefficient of variation (CV) of 27.3%, (Table 1). About 89% of annual rainfall is received from the southwest monsoon. The annual and monsoon rainfall series were normally distributed. The pre-monsoon, post monsoon and winter season rainfall contributed 2.3, 4.7 and 4 % rainfall to the annual rainfall respectively. The rainfall during the season are highly variable. At Datia, the average annual rainfall of 831.8 mm

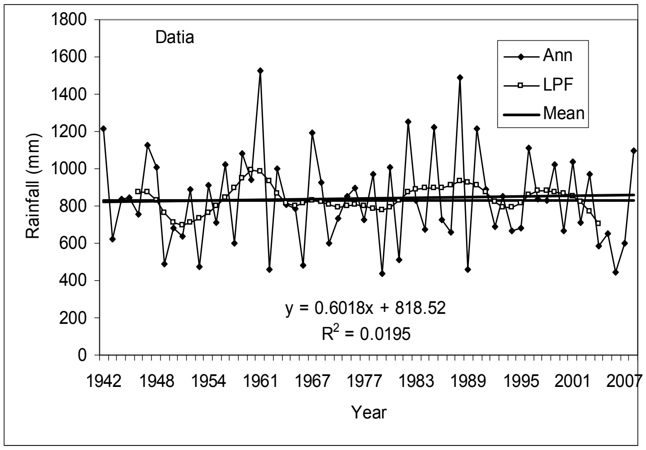

Fig. 1 : Gaussian low pass filter curves of annual rainfall at Datia

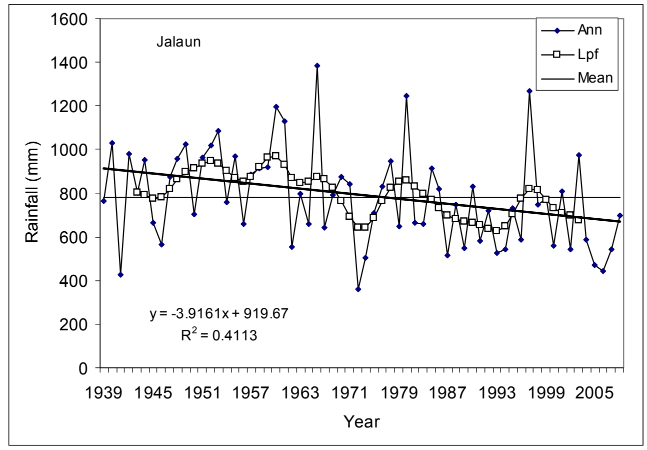

Fig. 2 : Gaussian low pass filter curves of annual rainfall at Jalaun

with CV (30.3%) indicated that the rainfall is more or less stable over the years. The highest and lowest rainfall recorded was 1527.4 mm (1961) and 438.4 mm, respectively (Table1). The potential evapotranspiration was estimated to be 1457.2 mm and 1476.7 mm for Jalaun and Datia respectively indicating annual water deficit by 658.8 mm and 634.9 mm for respective locations. Fisher statistics (g_1/SE(g_1) and g_2/SE(g_2)) were computed to test the normality at 95% level of significance.

Trend analysis

To understand the nature of trend, the annual series was subjected to "Gaussion low pass filter'(GLPF) analysis" i.e. a 9-point Gaussian lowpass filter/weights (WMO, 1966) were used to give a smoothed curve (Hingane *et al*. 1985, Rupakumar and Hingane 1988). The smoothed curve is drawn as the time series in addition to the trend line. The low pass filter for annual rainfall series for both the locations has been shown in Fig. 1 and 2. At Datia, the long term trend over GLPF showed slightly increasing trend though statistically non-significant (Fig.1). It can be seen from the figure that GLPF curves indicated a non-linear trend but oscillatory i.e. time series increase or decrease in nature consisting for a period of 6 to 12 years. An increasing trend is noticed from year 1948 to 1961, whereas the rainfall during the period from 1962 to 1983 did not show any trend and rainfall is more or less stable during this period. Similarly, Jalaun also showed significantly decreasing long-term trend in annual rainfall series (Fig. 2).

The Mann-Kendal rank (MK_t) statistics revealed a significant ($P<0.05$) decreasing trend in monsoon (MK_t= -0.214*) and annual (MK_t= 0.231**) rainfall series of Jalaun. The rainfall during winter season at Jalaun also indicated a decreasing trend but not statistically significant. At Datia, rainfall showed a increasing trend in all seasons except winter season but it was not statistically significant.

Initial and conditional rainfall probability analysis

The long-term rainfall data analysis revealed that at Jalaun, initial {P (W)} and conditional {P (W/W) i.e. wet week followed by wet week} probabilities of getting 10 mm rainfall per week was 57% to 64% during 26th and 67% to 73% during 27th standard meteorological week (SMW), respectively (Fig. 3). An amount of 10 mm rainfall per week can be taken as the minimum requirement for seedbed preparation/sowing of rainfed *kharif* crops (Ahmed *et al*. 2009). The data analysis further revealed that 20 mm rainfall probability of 59% to 64% was observed during the 27th SMW. The probability of getting 40 mm rainfall during the period 28th to 33rd SMW ranged from 46% to 70%. During 32nd and 33rd SMW as the probability of getting rainfall of 40 mm is more than 70% at Jalaun and it would be a ideal time for fertilizer application in the region.

During 38th SMW the initial probability of getting rainfall of 20 mm reduced to 32%, clearly indicating that supplemental irrigation is required for long duration varieties. Short duration varieties should be selected in the above mentioned regions, where, rainfall starts receding within 38th SMW.

At Datia, the long-term weekly initial and conditional rainfall probability analysis revealed that during 26th SMW the probability of getting 10 mm rainfall

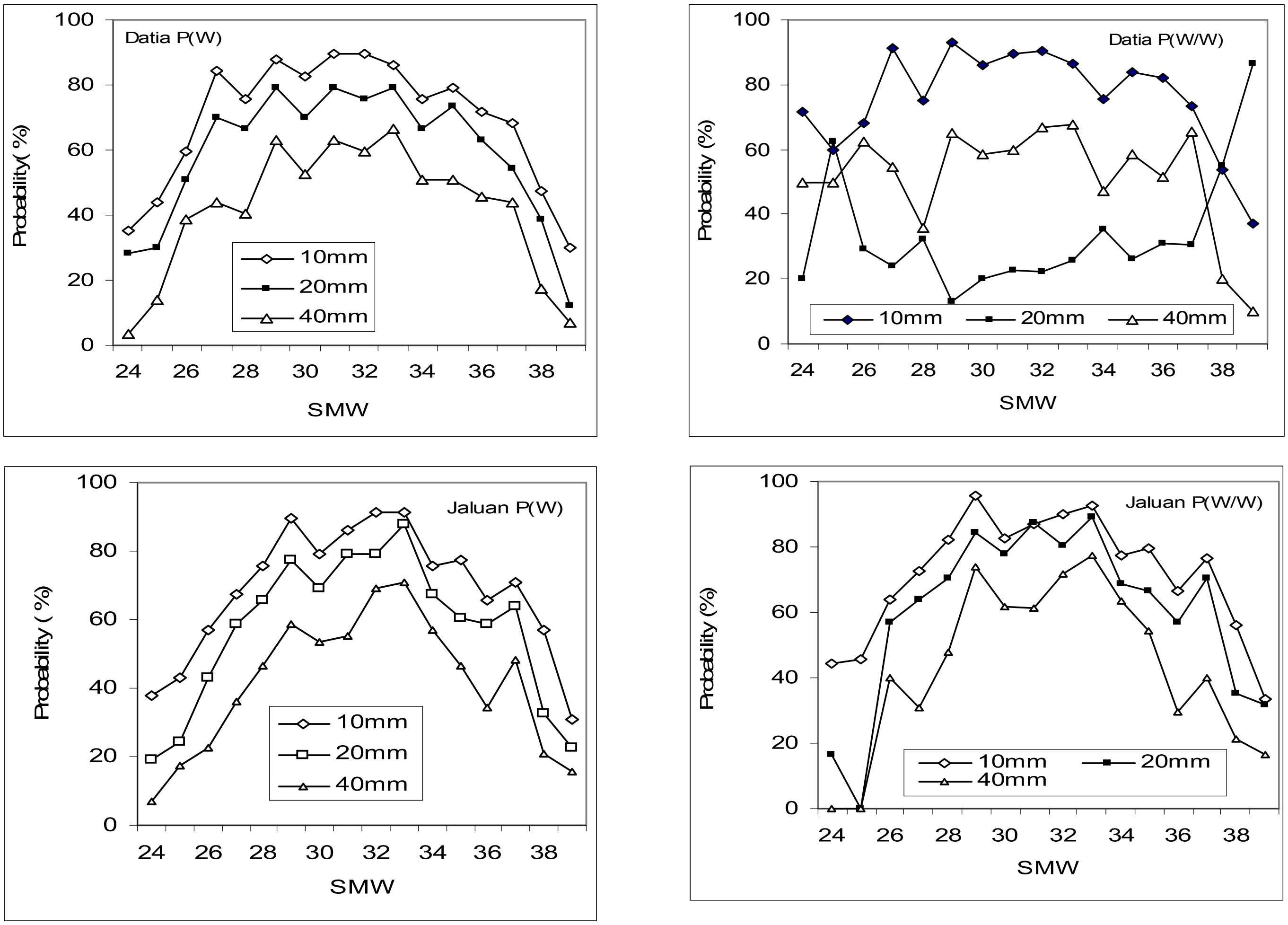

Fig. 3 : Initial and conditional probabilities of weekly rainfall at different threshold limit at Datia and Jaluan

per week is 60% and 68 %. Therefore, farmers should initiate the tillage and bed preparation field operations during that 26th SWM as well as sowing of the rainfed crop may also be initiated during the same as the higher rainfall probability is increasing during the upcoming months. During the 27th to 33rd week probability of receiving 20 mm rainfall is 40% to 64%, whereas probability of 40 mm rainfall is above 50% except during 28th week, where probability is 43%. Therefore these subsequent weeks are ideal for integrated field operations like sowing, fertilizer application etc. in the Datia region.

Expected rainfall amount and sustainable crop production strategies

The minimum weekly rainfall amount expected at 50, 60 and 70% probability level is presented in Table 2 for both locations along with their weekly long-term mean. As discussed above rainfall at 70% probability is assured rainfall at 50 % probability is the median limit for taking risk. At Datia, the probability of more than 10 mm from 26th SMW is above 50%, and farmers can initiate their field preparation operations from 26th week and in subsequent weeks i.e. 27th (July, 2-8) onwards probability of receiving more the 20 mm rainfall is more than 70%, which is ideal week of the seeding of the *kharif* crops in the region. The 27th and 28th (July 2-15) is also an ideal time for the crop fertilization based upon the rainfall pattern and intensity. At Datia, above 60 mm rainfall is expected from 29th to 33rd week (July 16-Aug.19). Overall expected rainfall days are more than 60 at Datia suggesting that short duration varieties of various crops can be ideal in the region Similarly, for Jalaun region too, tillage and dry seeding, in 27th and 28th SMW may be preferred as during these SMW more than 10 mm rainfall probability is 50% and whereas in 28th SMW probability is more than 70%. The intermittent rains of more than 20 mm rainfall was also expected at 70 % level during 36th to 33rd SMW, but thereafter probability of getting even 20 mm rainfall per week is not 70%, suggested that short duration varieties may be more suitable or supplemental irrigation must be ensured if long duration varieties are to be grown in the region.

The prevalent *kharif* season crops of the region include green gram, black gram sorghum and maize depending upon the soil type. In view of the above studies, it is suggested that the *kharif* rainfed crops such as groundnut, blackgram, greengram and seasmum should be sown during 27th SMW in both Datia and Jalaun region. The ideal combination of crops of the regions can be sorghum for the grain purpose intercropped with cowpea for the fodder purpose. Livestock integrated with the agricultural/food production systems is the cornerstone for rural economy of the farmers, therefore, the current suggested cropping systems integrating food-fodder system with rainfall probabilities may fetch an additional green fodder of 150-200 q ha^{-1} to the farmers apart from the sorghum grain yield and improve their livelihood. Therefore, overall the current study reveals that past rainfall record analysis may be handy tool for future rainfall probability projections, which alternatively can be of immense importance in the crop and other field operation planning in rainfed agricultural system as well as improving their livelihood.

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