Journal of Agrometeorology 21 (3) : 392-396 (September 2019)

Short communication

Precipitation probability and water budgeting for crop planning in central Gujarat

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The rainfed agriculture is highly inconsistent due to temporal distribution of precipitation during the critical stages of crop growth leading to crop failure. The large spatial and temporal variation in precipitation distribution is observed in central Gujarat (Vaidya *et al*., 2008). The precipitation in Gujarat varies from 300 mm in the north and north-west to gradually increasing to 2500 mm in the Southern districts (Priyan, 2015). The spatial and temporal variability of precipitation is compounded due to increase in frequency and intensity of extreme precipitation events due to global climate change (Ghosh *et al*., 2012). The analysis of daily, weekly, monthly and seasonal precipitation of a region is useful in designing of water harvesting structure, decision for agricultural operations like field preparation, sowing, irrigation, fertilizer application etc. (Sharma *et al*., 1979). To optimize agricultural productivity in any region, there is an urgent need to quantify temporal precipitation variability as a first step of combating extreme effects of persistent dry spells and crop failure (Kumar *et al*., 2014). The weekly water budget indirectly indicates the length of assured moisture availability for growing crops in the region (Singh *et al*., 2013). Therefore, keeping the above mentioned facts in mind, an attempt is made to analyze the daily precipitation data of sixty years at Vasad for initial, conditional and consecutive dry and wet week probability, weekly precipitation at different probability, monthly, seasonal, annual variations of precipitation and weekly soil water budget for crop planning in central Gujarat.

The meteorological data from 1957-2016 recorded at ICAR-IISWC, Research Centre-Vasad (22°27'23.90"N Latitude; 73°4'43.08"E Longitude and 43 m above mean sea level) is used for probability analysis of precipitation, weekly soil water budget for crop planning. The study area is in hot semi-arid eco-region, medium to deep coastal alluvium derived soils, low to medium soil water holding capacity, about 120-150 days length of growing period representing the climatic condition of central Gujarat (locally called as Charotar region). The annual reference evapotranspiration of central Gujarat is 2242.3 mm.

The initial, conditional, consecutive probability of dry and wet week is computed using Markov chain model (Robertson, 1976). The standard meteorological week receiving less than 20 mm precipitation is taken as dry week and a week receiving 20 mm or more precipitation as a wet week (Subash *et al*., 2009). The weekly precipitation at different probability levels is computed using incomplete gamma probability function (Swerling, 1960) and the weekly soil water budget is calculated using eq. 3 (Thornthwaite and Mather, 1955).

$$\Gamma(a,x) = \int_x^{\infty} t^{1-a}\bar{e}^{t}\,td \quad (1)$$

$$\Gamma(n,x) = (n-1)!\,e^{-x}e_{n-1}(x) \quad (2)$$

where, $\Gamma(a, x)$ is incomplete gamma function, a is an integer, t is the time.

$$STOR = AWC \times e^{\frac{(ACC(P-ET_0))}{AWC}} \quad (3)$$

Where, *STOR* is actual storage of soil moisture in mm, *AWC* is soil moisture storage capacity in mm, *ACC* is accumulated values, *P* is precipitation in mm, ET_o is the reference evapotranspiration in mm.

Annual, seasonal and monthly precipitation

The mean annual precipitation of 868.2 mm at Vasad is distributed over 36 rainy days with CV of 42.2 per cent is given in (Table 1). The annual precipitation trend analysis of 60 years shows slight increase in precipitation trend due to extraordinary precipitation during 2005. The annual precipitation of maximum 2132.9 mm and minimum of 323 mm is recorded in 2005 and 1986 with 43 and 18 rainy days, respectively. The wider variability of seasonal precipitation during *kharif* season with 824.2 mm (94.9 per cent), *rabi* season with 34.6 mm (3.99 per cent) and summer season with 9.3 mm (1.0 percent) is given in (Table 1). The CV of seasonal precipitation during *kharif* season is relatively less (58.7-99.9 per cent) owing to stable quantum of precipitation as compared to 213-554 per cent and 348-479 per cent in *rabi* and *summer* season, respectively as given in (Table 1). The 34 rainy days is limited to *kharif* season, 2 rainy days in *rabi* season and rarely one rainy day in summer season is given in

Table 1: Variation of monthly, seasonal and annual precipitation at Vasad, Gujarat

Months	Precipitation (mm)	Contribution to total (%)	Standard Deviation	Standard Error ±	Coefficient of Variation (%)	Rainy Days
March	1.6	17.3	7.7	1.0	479.4	0.1
April	2.0	22.2	7.2	0.9	348.1	0.1
May	5.6	60.4	22.8	2.9	404.7	0.2
***Summer season* (MAM)**	9.3	1.0	25.2	3.2	270.5	0.5
June	126.0	15.2	125.8	16.2	99.8	4.6
July	298.9	36.2	175.3	22.6	58.6	12.2
August	263.2	31.9	161.5	20.8	61.3	11.5
September	136.0	16.5	123.7	15.9	90.9	5.8
***Kharif season* (JJAS)**	824.2	94.9	367.3	47.4	44.5	34.2
October	19.4	55.9	41.3	5.3	212.9	0.9
November	11.0	31.7	39.6	5.1	360.6	0.5
December	1.5	4.5	5.4	0.7	343.3	0.1
January	2.2	6.4	7.0	0.9	317.8	0.1
February	0.4	1.2	2.4	0.3	554.3	0.0
***Rabi season* (ONDJS)**	34.6	3.9	54	6.9	155.7	1.8
Grand Total	868.2	100.0	367.0	47.3	42.2	36.6

(Table 1). The July is the highest precipitation receiving month with 299 mm followed by August with 263 mm is given in (Table 1). The February is least precipitation contributing month with less than 2 per cent of annual precipitation. The June to September is the most probable period of receiving precipitation with least CV from 99.9-58.7 per cent. The month of February to May is most likely to go dry with CV from 554-479 per cent.

Probability analysis of dry and wet weeks

The weekly precipitation starts with 14.9 mm in 26th SMW and traces maximum to 77.10 mm in 32nd SMW (Fig. 1). The weekly precipitation starts decreasing from 55.6 mm in 33rd SMW and reaches to minimum of 1.4 mm in 44th SMW. The higher value of CV in all weeks in (Fig. 1) indicates that the precipitation in the region is highly erratic in nature. However, the precipitation variation was higher in pre monsoon (22nd to 28th SMW) and post monsoon weeks (40th to 44th SMW), which shows uncertainty in precipitation during these weeks. The weekly precipitation at different probability of 10, 25, 50, 75 and 90 per cent is shown in (Fig. 2). The mean weekly precipitation in (Fig. 2) shows a sharp increase in weekly precipitation from 22nd to 27th SMW ranging from 0 to 63 mm. The oscillating pattern from 27th to 32th SMW as shown in (Fig. 2) receives weekly precipitation from 63 mm to 77 mm, respectively. The steep decline in weekly precipitation from 32nd to 34th SMW varies from 77 mm to 46 mm, respectively which continues to decline till 44th SWM to 1.4 mm except for some slight increase during 35th SMW. The weekly precipitation in (Fig. 2) is more uncertain from 39th to 44th SMW ranging from 20 mm to 1.4 mm per week. The probability of occurrence of dry week (Fig. 3) is as high as 100 per cent during first 22 SMWs. Thereafter, the probability of dry week falls rapidly from 80 to 38 per cent during 23rd to 27th SMW as shown in (Fig. 3). The probability of dry week fluctuates from 20 to 43 per cent during 27th to 35th SMW and continues to increase rapidly from 38 to 100 per cent during 35th to 45th SMW. The probability of consecutive two, three and four dry week follows more or less same pattern as identified for single dry week. The probability of wet week rises rapidly from 23rd to 27th SMW ranging from 13 to 59 per cent and follows oscillating pattern to reach at peak 70 per cent by 31st-32nd SMW as shown in (Fig. 4). The probability of wet week ranging from 50 to 1.6 per cent decrease rapidly from 35th to 44th SMW, respectively and thereafter remains negligible. The two, three and four consecutive wet weeks as shown in (Fig. 4) also follows the same pattern with lesser probability. The mean probability of dry week followed by dry week as shown in (Fig. 5) remains 100 per cent during first 22nd SMWs. It starts declining rapidly during 23rd to 27th SMW from 87 to 36 per cent respectively and continues to increase persistently with some sudden increase in probability of during 29, 31, 34 and 36, 39 SMW with values ranging from 44 to 90.5 per cent. However, the mean probability of dry week followed by wet week increases abruptly from 0 to 87.5 per cent during 23rd to 24th SMW and again decreases to 23.81 per cent as shown in (Fig. 5). The mean probability of dry week followed by wet week increases suddenly during 27th, 30th, 34th, 38th and 40th SMW to 36, 35, 42, 70, 100 per cent, respectively as shown in (Fig. 6). There is 100 per cent probability of getting wet week

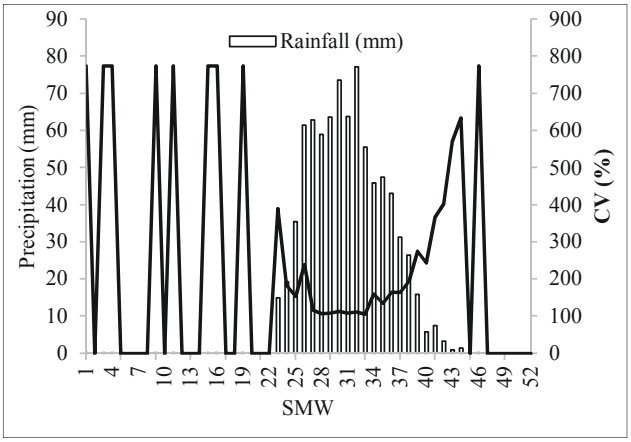

Fig. 1: Mean weekly precipitation distribution and its variation

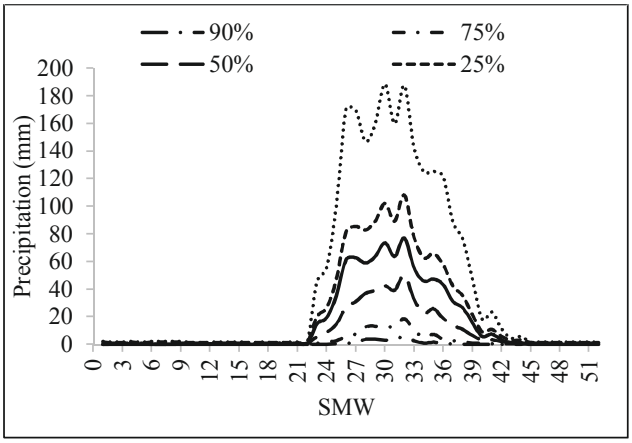

Fig. 2: Mean weekly precipitation at different probability levels

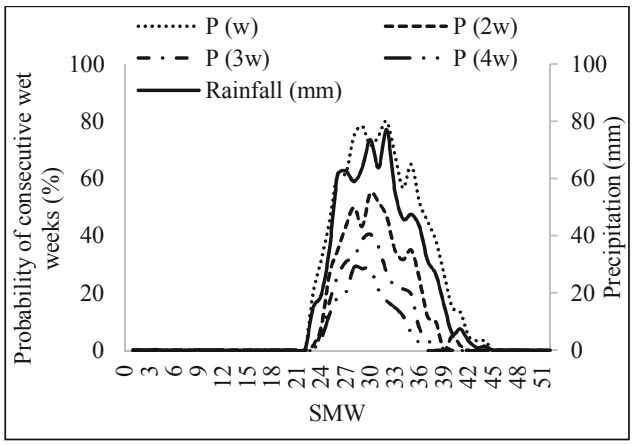

Fig. 4: Mean weekly precipitation and probability of consecutive wet week

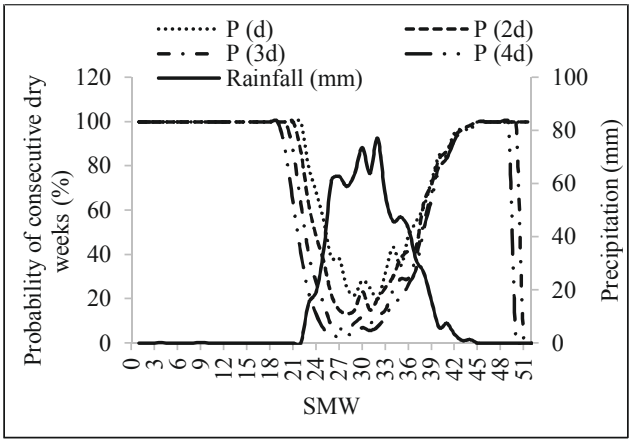

Fig. 3: Mean weekly precipitation and probability of consecutive dry week

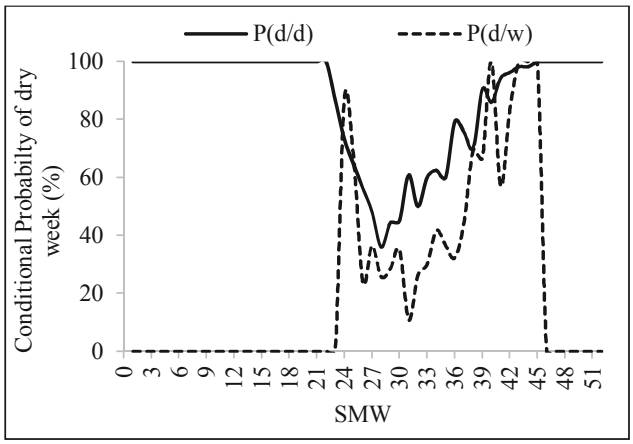

Fig. 5: Conditional probability of dry week

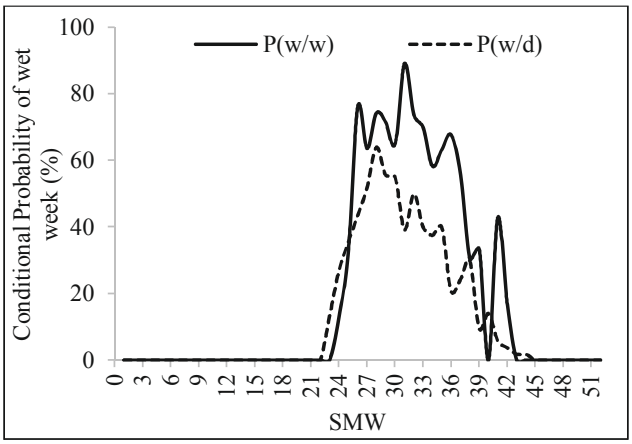

Fig. 6: Conditional probability of wet week

after dry week from 43rd to 45th SMW. The probability of wet week followed by wet week increases from 23rd to 26th SMW ranging from 0 to 76 per cent and reaches maximum probability of 89 per cent at 31st SMW. The probability of wet week preceded by wet week starts decreasing from 31st SMW and reaches minimum in 40th and 43rd SMW with sudden increase of probability to 43 per cent during 41st SMW. The probability of wet week preceded by dry week probability increases steeply from 13 per cent to 67 per cent during 23rd to 25th SMW and continues to decrease continuously up to 45th SMW with sudden rises during 30, 32, 35, 38 and 40th SMW is shown in (Fig 6).

Table 2: Weekly water budgeting for Vasad, Gujarat

SMW	RF	PE	ASM	AET	S	D	MAI	SMI
23	14.9	56.0	0	14.9	0	41.1	0.27	0
24	19.4	51.6	0	19.4	0	32.2	0.38	0
25	35.4	44.3	0	35.4	0	8.8	0.80	0
26	61.4	38.4	23.0	38.4	0	0	1	0.21
27	62.8	30.4	55.4	30.4	0	0	1	0.50
28	59.0	27.9	86.6	27.9	0	0	1	0.79
29	63.7	22.7	110.0	22.7	17.6	0	1	1
30	73.6	21.2	110.0	21.2	52.3	0	1	1
31	63.8	19.2	110.0	19.2	44.6	0	1	1
32	77.1	18.5	110.0	18.5	58.6	0	1	1
33	55.6	22.1	110.0	22.1	33.5	0	1	1
34	45.9	21.6	110.0	21.6	24.2	0	1	1
35	47.5	22.6	110.0	22.6	24.9	0	1	1
36	43.2	24.2	110.0	24.2	19.0	0	1	1
37	31.3	25.5	110.0	25.5	5.8	0	1	1
38	26.5	27.1	109.4	27.1	0	0	1	0.99
39	15.9	25.0	100.7	24.6	0	0.4	0.98	0.92
40	5.9	29.3	81.3	25.3	0	4.0	0.86	0.74
41	7.5	30.0	66.2	22.6	0	7.4	0.75	0.60
42	3.3	29.6	52.1	17.5	0	12.2	0.59	0.47
43	1.0	28.6	40.5	12.6	0	16.0	0.44	0.37
44	1.4	28.8	31.5	10.4	0	18.5	0.36	0.29
45	0	27.6	24.5	0.7	0	20.6	0.25	0.22
46	0.1	25.4	19.4	5.2	0	20.2	0.20	0.18

Crop planning based on precipitation probability and water budgeting

The dry spells during *kharif* season entails lifesaving irrigation at critical stages of the crop, as 30-40 per cent of the precipitation is lost through runoff (Sheoran *et al.*, 2008) which otherwise may be utilized through harvested rainwater. The sowing of *kharif* crops (maize, tobacco, pearl millet, hybrid and *desi* cotton etc.) must be completed by 26th SMW (25 June-01 July) for normal monsoon. However, for delayed monsoon by 29th SMW (16 July-22 July) sowing of short duration pulse crop (pigeon pea, green gram, black gram, cow pea etc.) and oilseeds (castor, soybean etc.) are recommended for remunerative crop yield. The intercropping of pearl millet + pigeon pea (2:1), maize + pigeon pea (1:1), pigeon pea + black gram (1:2) at a row spacing of 50-60 cm with mulching during *kharif* is found suitable in this region (Prasad *et al.*, 2012). The weekly water surplus and deficit, moisture availability index and soil moisture index used for crop planning is given in (Table 2). The precipitation received during 43rd to 44th SMW is only 2-3 per cent of annual precipitation which is not enough for sowing of *rabi* crop. Therefore, rain water harvesting of surplus water is essentially required from 26th to 35th SMW to provide lifesaving irrigation to *kharif* crop at critical stages during dry spell and early sowing of *rabi* crop (mustard, wheat, fennel, rajgira etc.) by 46th SMW considering surplus water of 280.5 mm being utilized with 65-70% efficiency owing to inevitable losses given in (Table 2).

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Received : February 2019 : Accepted : August 2019