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Rainfall characterization and crop planning of scarcity Zone (Zone-II) for Maharashtra state

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■ **ABSTRACT :** The daily rainfall data of 30 years (1972-2002) of different 20 rain gauges stations form the scarcity zone of Maharashtra were collected considered for analysis. Weekly actual rainfall was considered for calculating Moisture Availability Index (MAI). The wet and dry spells were calculated by Markov Chain model. The onset and withdrawal of monsoon were decided by weekly rainfall frequency distribution method. It is suggested to grow grasses and dry land horticulture *viz*, custard apple, pomegranate etc. on shallow soil in addition to present cropping pattern. Similarly in medium and deep soils in *Kharif* season sunflower, pearmillet + pigeonpea, castor, groundnut etc. were suggested. In *Rabi* sunflower, safflower, *Rabi* sorghum, gram, etc. were suggested with the provision of supplemental irrigations. Fodder sorghum in *Kharif* and safflower in *Rabi*, pearlmillet in *Kharif* and gram in *Rabi*,black gram in *Kharif* and *Rabi* sorghum in *Rabi*, greengram in *Kharif* and sunflower in *Rabi*, cowpea for fodder in *Kharif* and sunflower in *Rabi* were suggested.

■ **KEY WORDS :** Rainfall characterization, Moisture Availability Index (MAI), Cropping system

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Advanced farm technology has a great potential to increase crop production. Climate is an important factor in decision making for crop planning, especially in dry land areas. Crop production in rainfed areas is risk prone to erratic behaviour of rainfall. The main reason for very low and highly unstable yields in these areas is the availability of adequate soil moisture during active growth period of the crops. Onset, progress, intensity, temporal and spatial distribution of monsoon rains decides the fate of dry land agriculture. The distribution of rainfall is the matter of more serious concern than the total amount of rainfall.

The farmers have adopted their farming system by experience of generations without proper knowledge of agro-climatic conditions, effective cropping pattern and importance of scheduling of irrigation. Hence, study of rainfall characteristics is very important in general and drought prone areas. This includes mean rainfall, its deviation and variability, withdrawal of monsoon, the duration, and frequency with their interaction with crop and soil so that this resources can be put to more efficient use in agricultural planning.

The cropping patterns are basically dependent on MAI. Hargreaves (1971) defined MAI is the ratio of assured rainfall expected at 75 per cent probability level and estimated potential evapotranspiration for the concerned period. Bhishnoi (1980) has defined MAI as

$$\mathbf{MAI} = \frac{\mathbf{AE}}{\mathbf{PE}}$$

where MAI = Moisture Adequacy Index, AE= Actual evapotranspiration, PE= Potential evapotranspiration

For crop planning knowledge of rainfall variability and MAI with the soil type of particular area is necessary. MAI is the prime factor for crop planning, especially in the tropics where it varies both in time and space. MAI were worked out on the basis of average monthly rainfall (Raman and Murthy, 1971) and crop planning was done. If there are dry spells in between, causing crop failure the monthly MAI at different risk levels for agricultural planning of majority of season's crops, the weekly MAI values will be more suitable.

■ METHODOLOGY

The meteorological data for scarcity zone of Maharashtra state were collected and rainfall variability, potential evapotranspiration (PET), Moisture Availability Index

(MAI), moisture availability periods etc. were computed and crop planning was done. The weekly rainfall data of some selected rain gauges stations in the scarcity zone of Maharashtra state were collected for the study. The data were collected form India Meteorological Department (IMD), Pune for 30 years (1972-2002) were analyzed. For MAI calculation actual weekly rainfall data were used. Weekly rainfall data from 1972-2002 were used for study of rainfall variability of the stations.

The Markov chain model was used to estimate the conditional probability of dry and wet spell. For determining dry and wet spell the limit of 15mm rainfall at initial growth stage of the crop and 30mm rainfall at active growth stage were considered. If the rainfall was equal to or grater than 15mm, in a particular meteorological week, that week was considered to be wet, otherwise it was considered as dry in initial growth stage. Similarly in active growth stage the rainfall was grater than or equal to 30mm in a particular meteorological week, that week was considered as wet, otherwise it was dry.

Rainfall variability:

Studies of the variability of annual and seasonal rainfall, frequency of dry spell on monthly and weekly basis provided useful information for knowing the climatic potential of agricultural production. Mean weekly standard deviation (SD) and co-efficient of variation (CV) were computed for the period of 1972 to 2002. The weekly rainfall data of that period from scarcity zone of Maharashtra were used. The measure of variability of distribution about the mean is the coefficient of variation, which can be expressed as

$$CV = \frac{100 * \pm}{\overline{X}}$$

where as σ = Standard deviation of weekly rainfall and $\overline{X}$ = mean weekly rainfall

Onset and withdrawal of monsoon:

The frequency analysis of weekly rainfall was carried out on the basis of weekly data of 30 years. For deciding the onset and withdrawal of monsoon, frequency of weekly rainfall of 21 mw to 25mw and 38 mw to 44mw was considered. During this period (21 mw to 25mw), the week which showed sudden rise in the frequency of rainfall was considered as onset of monsoon and 38 mw to 44mw the week which showed sudden drop in the frequency of rainfall value considered as withdrawal of monsoon.

Computation of weekly PET :

It is assumed in all agrometeorological studies that potential evapotranspiration express the maximum demand of the atmosphere, while actual evapotranspiration may sometimes be higher than PET covering the soil surface completely. It has been found that early stage of crop growth (3 to 4 weeks), actual evapotranspiration is about a quarter of potential rate due to small. India Meteorology Department, Pune has installed 35 lysimeters in various soils and climatic zones of the country to find out the water requirement of different crops. Venkatraman *et al.* (1976) found that the cumulative seasonal ET is about 70 per cent of the cumulative PE. It has, therefore, been considered for this study that the difference between weekly averages rainfall and PE of the corresponding period will go into stored soil moisture and plants can use it even after the end of rainy season.

Moisture availability periods :

The MAI for 50,100 and 200 mm available water holding capacity were calculated which represented shallow, medium and deep soils. The growth period was considered as the period during which the MAI was more than 0.5 at the time of sowing and active vegetative growth period and more than 0.3 at the time of maturity. All the periods during active vegetative growth for which MAI was less than 0.5 were considered as stress period. The earliest date of sowing *Kharif* crops was assumed to be the day of when rainfall received along with the stored soil moisture, meet half the PET during moist period a sub-humid period. The date of *Rabi* sowing crops was assumed to be the day when soil moisture was sufficient to meet the full evaporation demand of the atmosphere. The crop growth periods or dry spells were worked out for different stations.

Computation of dry and wet spells:

The Markov chain model property can be utilized to understand the time evolutionary processes in the atmospheric system since metrological events occur in sequence. Markov chains can be used to answer and analyze similar problems involving dynamic system. Markov chain and geometrical distribution of sequences of dry and wet events are related. For example, the distribution of wet spells of length k is given by:

$$P(w=k)=(1-P1)P1^{k}\ P1=P(w/w)$$

and probability of wet sequences with length greater than k is

$$P(w=k)=P1^{k}$$

Crop planning:

Crop planning as per soil moisture storage and its variability with efficient moisture conservation and fertilizer use coupled with better management inputs leads to increase and stabilize yields of crop production. For planning suitable cropping pattern for different parts of scarcity zone of Maharashtra, it is necessary to delineate the districts and thesils into homogenous regions of similar agro-climate conditions. Soil and climate are usually fixed entities, which could not be demarketing areas of uniform cropping.

RESULTS AND DISCUSSION

The scarcity zone of Maharashtra comprised of 114 tahasils of 18 districts of the state. This zone covers Ahmednagar and Solapur districts. Eastern part covers Sangli, Satara, Pune, Dhule, Nasik, Nandurbar, Jalgoan, district. Western part covers Aurangabad, Jalana, Beed, Latur and Osmanabad districts. The total geographical area under the scarcity zone in the state is 10.8 million ha. Out of which 8.6 million ha area is under cultivation. The proportion of total area under scarcity zone of the state is total 37 per cent indicating that scarcity zone covers one third area of the state. General topography of the zone is rolling with slope ranging from 1-3 per cent and hilly areas it much higher. The soils of scarcity zone are characterized as very shallow soils (10 %), shallow soils (26%), medium deep (47%), and deep soils (17%). Soils were reddish brown to dark brown in colour and vary in texture and structure depending upon clay content. The soils were low in organic carbon and available N content, low to medium in available P and high in available K content. The shallow and medium deep soils are classified as Lithic Ustorthents and Vertic Ustrochrepts(Entisol and Inceptisol) and generally suited for *Kharif* cropping, while deep soils the Typic Haplusterts (Vertisols) are sited for *Rabi* crops.

The average rainfall in the zone varies between 500mm to 750mm. monthly variability of the scarcity zone of Maharashtra is highly erratic. Even in the rainiest month of July the coefficient of variation of monthly rainfall recorded is as high 40 to 50 per cent. The relative proneness to drought is due to macro and micro variations in the soils. Based on the variations, the scarcity zone of Maharashtra is divided into highly, moderately and slightly drought prone zones.

Agro-climate of the scarcity zone:

The agro-climate of the sub region is characterized by hot, semi-arid (dry) with dry summers and milt winter. The annual temperature (MAT) ranges from 26 to 27^{0}C. It rises to a maximum of 35 to 40^0 C during the hottest months of April and May, whereas it drops to a minimum of 10 to 15^{0}C in the coldest months of December and January. The area receives SW monsoon in the late of June with erratic and scanty rainfall. The monsoon season extends till the first week of October in most of the years. The mean rainfall ranging from 600-750mm meets 40-42 per cent of mean PET demand ranging from 1500 and 1800 mm. the total monsoon rainfall ranges between 590 and 652 mm covering 87 to 88 per cent of mean rainfall in the sub region. The length of growing period in the sub region varies from 90-120 days in a year. The water balance indicates that SMCS of the area remains dry for more than 90 cumulative days in a year. For crop planning purpose rainfall zones were considered as basis. The crop planning and formation of crop planning pattern depends upon (Anonymous, 1976) two factors, climate and soil.

Crop planning for rainfall zone-II of scarcity zone:

The rainfall distribution (mean S.D.and C.V.) of the zone is given in Table 1.

Rainfall of scarcity zone:

The grouping of scarcity zone of Maharashtra based on climatic parameters. The different stations/tahsils in scarcity zone were grouped into four rainfall zones.

Rainfall zone-II:

Rahuri, Sangamner. The rainfall distribution (mean S.D.and C.V.) of the zone is given in Table 1 and Fig. 1.

The rainfall zone-II covers the different stations of scarcity zone of Maharashtra which covers Rahuri and Sangamner.

Rahuri :

The mean annual rainfall of Rahuri is 550.0 mm with SD of 209.8 and CV covers 38.1 per cent (Table 1). The distribution of annual rainfall in different season's *viz.,* pre-monsoon, monsoon and post-monsoon was 17.8, 410.4 and 121.8 mm, respectively with SD of 18.9, 166.8 and 111.7 mm, respectively with CV of 105.6, 40.6 and 93.8 per cent.

The distribution of Rahuri is shown in Fig. 1 which indicates that onset of monsoon was in 23 mw and withdrawal was in 40 mw. There was low frequency of rainfall distribution in 32 and high frequency from 37 to 39 mw.

The MAI values for the meteorological weeks from 22 to 44 in three types of soils are reported in Table.3. For deciding the water availability periods, the number of weeks having MAI values $\geq$ 0.3 and $\geq$ 0.5 were counted.

The water availability period for MAI $\geq$ 0.3 was 22 weeks in shallow and medium soil, 21 weeks in deep soils. While for MAI $\geq$ 0.5 it was 15 weeks in shallow and 18 weeks in medium and 19 weeks in deep soils. Hence, period of 15to 22 weeks

Table 1 : The rainfall distribution (mean S.D.and C.V.) of the zone II

Rainfall zone	Annual rainfall			Pre-monsoon			Monsoon			Post-monsoon		
	Mean (mm)	S.D (mm)	C.V. (%)	Mean (mm)	S.D (mm)	C.V. (%)	Mean (mm)	S.D (mm)	C.V. (%)	Mean (mm)	S.D (mm)	C.V. (%)
II												
Rahuri	550.0	209.8	38.1	17.8	18.9	105.6	410.4	166.8	40.6	121.8	111.7	93.8
Sangamner	398.0	169.8	42.7	19.1	30.5	159.3	306.5	147.8	48.2	72.4	56.3	79.1

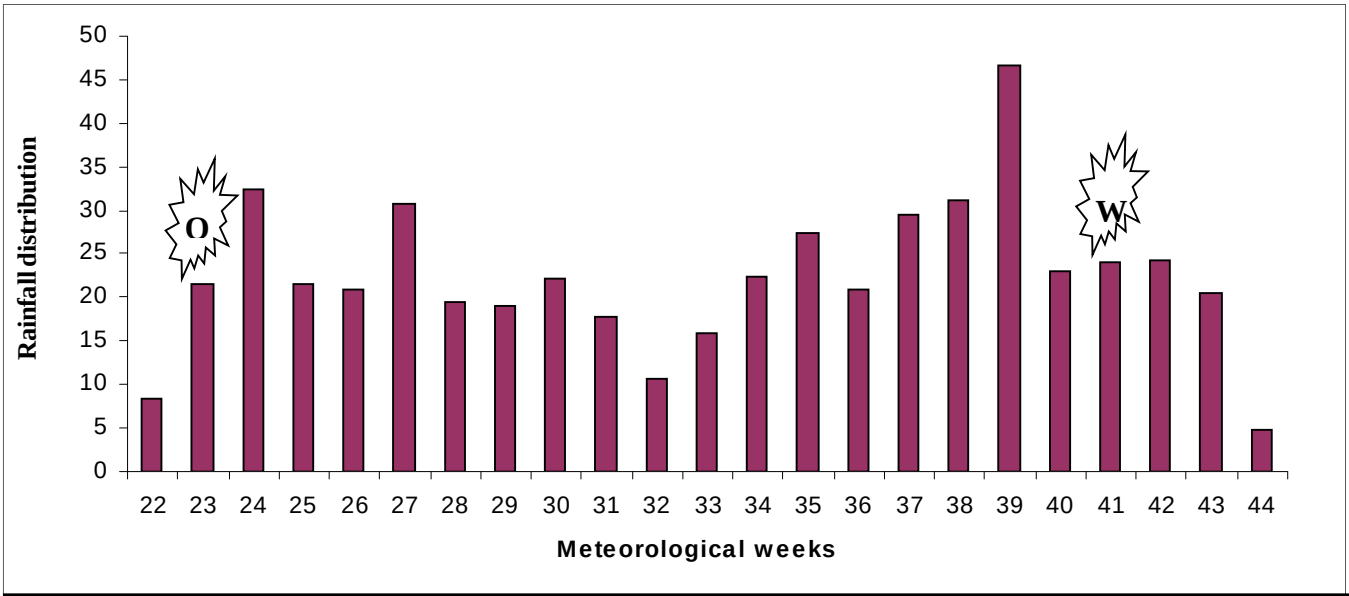

Fig. 1 : Rainfall distribution showing normal onset and withdrawal of monsoon at Rahuri

Table 2 : MAI in various type of soils at Rahuri

mw	PET(mm)	At actual rainfall(mm)			
		P	Shallow soil	Medium soil	Deep soil
22	52.5	8.3	0.22	0.15	0.12
23	48.3	21.5	0.44	0.33	0.29
24	43.4	32.5	0.66	0.58	0.53
25	37.8	21.6	0.54	0.49	0.46
26	34.3	21.0	0.49	0.47	0.46
27	31.5	30.7	0.51	0.53	0.52
28	31.4	19.4	0.51	0.55	0.54
29	29.4	19.1	0.55	0.57	0.54
30	28.7	22.2	0.53	0.57	0.58
31	27.3	17.8	0.52	0.58	0.61
32	27.2	10.6	0.52	0.57	0.59
33	27.3	16.0	0.46	0.53	0.57
34	28.7	22.3	0.42	0.53	0.57
35	27.3	27.4	0.55	0.61	0.67
36	28.0	20.9	0.57	0.59	0.61
37	30.1	29.6	0.53	0.62	0.65
38	29.4	31.1	0.69	0.74	0.78
39	29.5	46.7	0.74	0.74	0.77
40	29.4	23.1	0.76	0.78	0.81
41	30.1	24.1	0.64	0.69	0.74
42	29.4	24.3	0.40	0.59	0.66
43	29.4	20.4	0.39	0.54	0.65
44	26.6	4.9	0.36	0.45	0.57

Table 3 : Conditional rainfall probability (%) of Rahuri

mw	Rainfall probability (%)							
	At ? 15 mm				At ? 30 mm			
	W	W/W	D/W	W/D	W	W/W	D/W	W/D
22	23	71	43	29	10	33	30	67
23	47	64	69	36	30	33	43	67
24	67	40	60	60	40	42	22	58
25	43	23	41	77	30	22	24	78
26	33	50	40	50	23	57	22	43
27	43	23	41	77	30	22	24	78
28	33	30	40	70	23	29	22	71
29	37	64	32	36	23	43	17	57
30	43	38	29	62	23	43	22	57
31	33	20	30	80	27	0	9	100
32	27	25	23	75	7	50	14	50
33	23	29	22	71	17	40	12	60
34	23	57	39	43	17	60	28	40
35	43	54	24	46	33	20	5	80
36	37	55	32	45	10	33	30	67
37	40	67	50	33	30	33	38	67
38	57	59	54	41	37	73	32	27
39	57	41	54	59	47	29	38	71
40	43	31	18	69	33	30	10	70
41	23	29	17	71	17	40	8	60
42	20	50	25	50	10	67	22	33
43	30	22	10	78	27	0	9	100
44	13	0	15	10	7	0	7	100

will be available for crop growth in shallow, medium and deep soil. Hence, long period crop of 110 to 130 days can be grown in this. For good germination and emergence of crop, the chances of getting rainfall $\geq$ 15 mm at more than 50 per cent probability in 24, 38 and 39 (Table 3).

For growth and development, probability of getting rain $\geq$ 30mm is given in Table 3. The probability of getting rain $\geq$ 30 is given in (Table 3). No week is observed in which the probability of getting rainfall if $\geq$ 30mm is more than 50 per cent.

From 38 to 39 mw, the probability of getting rainfall $\geq$ 15 mm was more than 50 per cent. In 38 mw, the probability of getting rainfall in subsequent week (w/w) was also more than 50 per cent. Therefore, sowing of *Rabi* crops should be undertaken during the period of these weeks.

Suggested cropping pattern in zone II:

The zone covers Rahuri and Sangamner. The rainfall distribution (Mean S.D. and C.V) of this zone is given in Table 1. For both season life savings irrigations are needed. In addition to present cropping pattern, the intercropping (Pearmillet+ Pigeonpea) and horticultural crops *viz*., dry land horticulture crops suggested. Pearl millet, *Kharif* sorghum, and fruit crops are common in this rainfall zone. It is suggested to grow grasses and dry land horticulture *viz.*, custard apple, pomegranate etc. on shallow soil in addition to present cropping pattern. Similarly in medium and deep soils in *Kharif* season sunflower, pearmillet + pigeonpea, castor, groundnut etc. are suggested. In *Rabi* sunflower, safflower, *Rabi* sorghum, gram, etc. are suggested with the provision of supplemental irrigations. Fodder sorghum in *Kharif* and safflower in *Rabi*, pearlmillet in *Kharif* and gram in *Rabi*,black gram in *Kharif* and *Rabi* sorghum in *Rabi*, greengram in *Kharif* and sunflower in *Rabi*, cowpea for fodder in *Kharif* and sunflower in *Rabi* are suggested.

In order to suggest the suitable and viable cropping pattern for the sub montane zone, the stations have been grouped into four units by considering rainfall pattern (Zone II). By considering the overall situation of the moisture availability period, onset and withdrawal of monsoon, assured rainfall, dry and wet spell and different soil moisture conditions, the cropping pattern is suggested for scarcity zone of Maharashtra. Rainfall is highly variable at all stations in this zone. Most of the soils are medium and deep, derived from

rocks namely desalt commonly known as Deccan trap. Soils are generally radish brown to dark gray in colour, vary in texture and structure depending upon the clay content. From the total rainfall it is clear that maximum rainfall is received in the month of July and September from 37 to 40 mw.

Conclusion :

It is suggested to grow grasses and dry land horticulture *viz.*, custard apple, pomegranate etc. on shallow soil in addition to present cropping pattern. Similarly in medium and deep soils in *Kharif* season sunflower, pearmillet + pigeonpea, castor, groundnut etc. are suggested. In *Rabi* sunflower, safflower, *Rabi* sorghum, gram, etc. are suggested with the provision of supplemental irrigations. Fodder sorghum in in *Kharif* and safflower in *Rabi*, pearlmillet in *Kharif* and gram in *Rabi*,black gram in *Kharif* and *Rabi* sorghum in *Rabi*, greengram in *Kharif* and sunflower in *Rabi*, cowpea for fodder in *Kharif* and sunflower in *Rabi* are sugggested

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