

Original Research Article

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## Weekly Rainfall and Rainy Days Trend Analysis for Crop Planning in Baramati Tehsil of Pune District

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### ABSTRACT

#### Keywords

Wet spells, Dry spells, Rainfall and rainy days trend, Mann-kendall test, Sen's slope method, Markov-chain initial, Conditional and consecutive probability, Baramati, Pune

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Rainfall analysis would enhance the management and effective utilization of water resources. Knowledge of wet spells, dry spells and trend in rainfall can be useful for crop planning in a particular area. The present study has been undertaken to study weekly rainfall and rainy days using Mann Kendall test and Sen's slope method. Based on Markov-chain initial, conditional and consecutive dry and wet weeks probability, more probability of getting wet week is observed in Baramati tehsil from 23<sup>rd</sup>, 24<sup>th</sup>, 36<sup>th</sup> to 40<sup>th</sup> SMWs. The sowing week of Pigeon pea in Baramati has changed to 27<sup>th</sup> SMW. So, the probability of getting 20 mm rainfall to at least one or two critical growth stages of the crop is more.

### Introduction

Pune district lies in the Maharashtra state which lies on Deccan plateau. It has a hot semi-arid climate bordering with tropical wet and dry. The Sahyadri Mountain is located in the North-South direction of the district.

According to the classification of National Agricultural Research Project (NARP), as a geographical structure Pune district is classified as the western part of Mulshi and Vadgaon Maval come under Ghat zone and Bhor, Velhe's eastern part, Junnar, Khed, Ambegaon tehsils western part is under sub-

mountain zone whereas, central parts of Bhor, the eastern part of Maval, Khed, Ambegaon and Junnar consist Plain zone. The scarcity zone consists of Purandar, Haveli, Indapur, Baramati, Shirur and Daund tehsils.

Mann Kendall test (Mann, 1945 and Kendall, 1975) is one of the commonly used non-parametric tests for determining a trend (increasing or decreasing) in hydrologic time series, whereas Sen's slope method is used to determine the magnitude of rainfall and rainy days trend. Various researches has been carried out on trend analysis of different areas such as Murumkar and Arya (2014); Chinchorkar *et al.*, (2015); Pandit (2016); Upadhye *et al.*, (2016); Kalunge (2018) and Wale *et al.*, (2020).

Crop planning and management has their application to ensure the yield of the crop. Dry spell coincidence with sensitive phenological stages of crop is very likely to affect the crop development. Hence, it is very important to analyze the sequence of dry and wet weeks for crop planning purpose. Various researches has been carried out on crop planning such as Singh *et al.*, (2008); Chand *et al.*, (2011); Chinchorkar *et al.*, (2012); Pali *et al.*, (2013) and Joshi (2019). Soil and climatic characteristics affect crops, any variation in agro-meteorological factors has implications on agriculture (Awasthi and Kamble, 2013). The monsoon characteristics relating to its time of onset, withdrawal and distribution controls (weekly or monthly) agricultural production and in turn the livelihood of the people. Hence, crop planning based on trend analysis is important.

## **Materials and Methods**

### **Study area**

Baramati tehsil is lies in Pune district of state of Maharashtra in India. Baramati tehsil lies

at 18°15' north latitudes and 74° 57' East longitudes. It is located at an altitude of 550 meters above means sea level. Area of Baramati tehsil is 1382 sq. km. Baramati tehsil is bounded by Phaltan tehsil towards south, Daund tehsil towards north, Malshiras tehsil towards east, Indapur tehsil towards east and Purandar tehsil to west side.

The climate of the Baramati tehsil is slightly different in irrigated and non-irrigated area. The winter season is from December to about the middle of February followed by summer season which last up to May. June to September is the south-west monsoon season, whereas October and November constitute the post-monsoon season. The mean minimum temperature is about 12°C and means temperature is about 39°C.

### **Software used for study**

Microsoft office sub-module MS-Excel was used for data analysis. The formulation and conditional statements were also executed in MS-excel.

The Weather Cock software developed by CRIDA, Hyderabad was used for the analysis of initial, conditional and consecutive probabilities. MAKESENS excel template was used for trend detection and estimation of the magnitude of trend (Salmi *et al.*, 2002).

### **Data collection**

The daily rainfall data of 39 years of Baramati tehsil in Pune district from the month of January to December were collected from; Department of Agricultural Meteorology, College of Agriculture, Pune; State Agriculture Department, Pune; India Meteorological Department, Pune and Downloaded from [www.maharain.gov.in](http://www.maharain.gov.in) ([www.krishi.maharashtra.gov.in](http://www.krishi.maharashtra.gov.in)).

**Rainfall and rainy days trend analysis**

Trend analysis (increase or decrease) of all the independent weather parameters (e.g. annual rainfall and rainy days) was statistically examined by the non-parametric Mann-Kendall test and Sen’s slope method (Choudhury *et al.*, 2012). The Mann Kendall test applied to the detection of a monotonic trend of rainfall and rainy days’ time series and Sen’s slope method was used to determine the magnitude of rainfall and rainy days trend. The negative values of results indicated a decreasing trend and positive values indicated the increasing trend.

**Mann-Kendall method**

The Mann-Kendall test statistic (S) is calculated using the formula that follows (Mann, 1945);

$$S = \sum_{k=1}^n \sum_{j=k-1}^n \text{sign} (X_j - X_k) \sum_{k=1}^n \sum_{j=k-1}^n \text{sign} (X_j - X_k)$$

Where,  $X_j$  and  $X_k$  are the annual values in year’s  $j$  and  $k$ ,  $j > k$  respectively and  $X_k$  represent the data point at time  $k$ .

The value of sign ( $x_j - x_k$ ) is computed as number follows

$$\text{Sign} = \begin{cases} +1 & \text{if } x_j - x_k > 0 \\ 0 & \text{if } x_j - x_k = 0 \\ -1 & \text{if } x_j - x_k < 0 \end{cases}$$

This statistic represents the number of positive differences minus the number of negative differences for all the differences considered. For large samples ( $N > 10$ ), the test is conducted using a normal approximation (Z statistics) with the mean and the variance as follows:

$$\text{Variance (S)} = \frac{(n(n-1)(2n+5) - \sum_{p=1}^{p-1} (tp(tp-1)(2tp+5)))(n(n-1)(2n+5) - \sum_{p=1}^{p-1} (tp(tp-1)(2tp+5)))}{18}$$

Where,  $n$  = number of years,  $g$  = number of tied groups (A tied group is a set of sample data having the same value) and  $t_p$  = number of items in the tied group

Calculate a normalized test statistic  $Z$  by the following equation

$$z = \frac{(S + 1)}{\sqrt{\text{Variance}(S)}} \quad \text{If } S > 0$$

$$z = 0 \quad \text{If } S = 0$$

$$z = \frac{(S - 1)}{\sqrt{\text{Variance}(S)}} \quad \text{If } S < 0$$

Where,  $S = p - q$ ,  $p$  = number of (+1) values and  $q$  = number of (-1) values

The statistic  $Z$  has a normal distribution. In the present study, at confidence level of 99, 95 and 90 per cent the positive or negative trends is determined by the test statistic.

**Sen’s slope method**

Sen’s slope method has been used for predicting the magnitude of hydro meteorological time series data. This method uses a linear model for the trend analysis by using a simple non-parametric procedure developed by Sen (1968).

To derive an estimate of the slope  $Q_t$ , the slope of all data pairs was calculated;

$$Q_t = \frac{X_j - X_k}{j - k}, \quad i = 1, 2, 3, N, j > k$$

If there are  $n$  values of  $X_j$  in the time series then as many as  $N = n(n-1)/2$  slope estimates,  $Q_t$  are to be computed. The Sen’s estimator of slope is the median of these  $N$  values of  $Q_t$ . The  $N$  values of  $Q_t$  were ranked from the smallest to the largest and the Sen’s estimate was calculated as;

$$Q_t = \begin{cases} Q^{\frac{N+1}{2}} & \text{if } N \text{ is odd} \\ \frac{1}{2} (Q^{\frac{N}{2}} + Q^{\frac{N+2}{2}}) & \text{if } N \text{ is even} \end{cases}$$

The median of all slope values gives Q, which is the magnitude of trend. A positive value indicates increasing and negative values indicates decreasing trend of rainfall and rainy days.

### Crop planning and management

Crop calendar can be considered as a key or tool for crop management information when it is superimposed over dry and wet weeks sequence. Accordingly, from where the initial probability of week being wet increases land preparation starts and where the conditional probability of week being wet i.e. occurrence of rainfall at 20 mm per week is above 50 per cent, is the right week of planting. Supplementary irrigation and moisture conservation practices need to be undertaken if at a 20 mm threshold the probability of dry week and dry week followed by dry week exceeds 50 per cent (Admasu *et al.*, 2014). The irrigation can be withheld for some time if there is a probability of wet week or apply irrigation during the dry week in a very sensitive phenological or critical growth stage of crop (Singh *et al.*, 2014).

### Markov chain modelling of dry and wet weeks

The concept of estimating probabilities of dry and wet spells with respect to a given amount of rainfall is extremely useful for successful crop planning and the design of soil conservation structures. The probability of dry and wet spells may also be obtained by applying Markov chain analysis. The Markov method is applicable when dependence exists between sequential events in a random process and the dependence is such that the

next step depends only on the present state and not on the preceding past states. In general, a Markov process describes only step-by-step dependence, called a first-order process. The probability relationships for a Markov process must provide for the conditional probabilities of the process moving from any state at period (t) to any subsequence state at period (t+1). Thus, the relation  $P(X_{t+1} = j / X_t = i)$  expresses conditional probability of transitioning from state i to state j at a time (t+1). Two conditions must be defined to describe the process completely. One is the initial state and the other is the complete matrix of transition probabilities. In the present study, weekly rainfall data have been used to establish drought frequency during week period considering less than 20 mm rainfall as dry week and more than 20 mm as a wet week as suggested by Pandarinath (1991) and Dash and Senapati (1992).

### Initial probability of dry and wet weeks

Based on historical data of weekly rainfall and following the above mentioned criteria of dry and wet week, the initial probabilities can be calculated as:

$$P(D) = F(D)/N$$

$$P(W) = F(W)/N$$

Where,

P(D) is the probability of occurrence of dry week,

P(W) is the probability of occurrence of wet week,

F(D) is the frequency of occurrence of dry week,

F(W) is the frequency of occurrence of wet week,

N is the total number of years

### **Conditional probability of dry and wet weeks**

$$P(D/D) = F(DD)/F(D)$$

$$P(W/W) = F(WW)/F(W)$$

$$P(W/D) = 1-P(D/D)$$

$$P(D/W) = 1-P(W/W)$$

where,

P(D/D) = probability of a week being dry preceded by another dry week,

F(DD) = frequency of dry week preceded by another dry week,

P(W/W) = probability of a week being wet preceded by another wet week,

F(WW) = frequency of a wet week preceded by another wet week,

(W/D) = probability of a wet week preceded by a dry week, and

P(D/W) = probability of a dry week preceded by a wet week.

### **Consecutive Probability of Dry and Wet Weeks**

$$P(2D) = P(DW1) \times P(DDW2)$$

$$P(3D) = P(DW1) \times P(DDW2) \times P(DDW3)$$

$$P(2W) = P(WW1) \times P(WWW2)$$

$$P(3W) = P(WW1) \times P(WWW2) \times P(WWW3)$$

where,

P(2D) = probability of two consecutive dry weeks starting with the week,

P(DW1) = probability of the first week being dry,

P(DDW2) = probability of the second week being dry, given the preceding week being

dry,

P(3) = probability of three consecutive dry weeks starting with the week,

P(DDW3) = probability of the third week being dry, given the preceding week dry,

P(2W) = probability of two consecutive dry weeks starting with the week,

P(WW1) = probability of the first week being wet,

P(WWW2) = probability of the second week being wet, given the preceding week being wet,

P(3W) = probability of three consecutive wet weeks starting with the week and

P(WWW3) = probability of the third week being wet, given the preceding week wet.

### **Crop calendar**

The following crop calendar has been used as a key tool for crop planning which is recommended by Mahatma Phule Krishi Vidyapeeth, Rahuri in its University publication Krishidarshani (2020) (Table 1).

### **Results and Discussion**

#### **Trend analysis of weekly rainfall and rainy days at Baramati tehsil**

Weekly rainfall and rainy trends at Baramati tehsil are presented in Table 2. Baramati tehsil during 22, 25-27, 30-32, 34-36, and 42 MWs exhibit increasing trend in rainfall and rainy days whereas, MWs 21, 24, 28, 33, 37-41 and 43-46 showed decreasing trend in rainfall and rainy days. MW 23 exhibit increasing trend in rainfall while decreasing trend in rainy days. MW 29 exhibit

decreasing trend in rainfall while increasing trend in rainy days. MW 20 didn't exhibit any trend. MW 34 (20 August to 26 August) exhibited a statistically significant increasing rainfall trend ( $Z= 2.04$ ) at a 95 per cent confidence level and MW 35 (27 August and 2 September) exhibited a statistically significant increasing rainfall trend ( $Z= 2.73$ ) at a 99 per cent confidence level.

Rainy days trend at Baramati tehsil during MW 35 (27 August and 2 September) showed a statistically significant increasing trend ( $Z= 2.40$ ) at a 95 per cent level of significance.

**Markov-chain initial, conditional and consecutive probabilities dry and wet weeks**

The initial, conditional and consecutive probability of dry and wet week at threshold limit 20 mm of rainfall during the crop growth period (SMW 23<sup>rd</sup> to 42<sup>th</sup>) is calculated using 'Weather Cock' software developed by CRIDA, Hyderabad and the results obtained are discussed below.

**Table.1** Crop calendar as suggested by M.P.K.V., Rahuri

| Season | Crop                  | Sowing Window                               |             | Critical Growth Stages | Period |       | Total Water Requirement (cm) |
|--------|-----------------------|---|-------------|------------------------|--------|-------|------------------------------|
|        |                       | Date  | SMW         |                        | DAS    | SMW   |                              |
| Kharif | Pearl Millet          | 15 <sup>th</sup> June-15 <sup>th</sup> July | 25-28       | Panicle Emergence      | 25-30  | 29-30 | 25-30                        |
|        |                       |   |             | Booting                | 50-55  | 33-35 |                              |
|        | Pigeon Pea (Red Gram) | 15 <sup>th</sup> - 30 <sup>th</sup> June    | 25-26       | Branching              | 35-40  | 30-31 | 40-45                        |
|        |                       |   |             | Flowering              | 65-70  | 35    |                              |
|        |                       |   | Pod Filling | 90-95                  | 39     |       |                              |

**Table.2** Weekly rainfall and rainy days trend analysis at Baramati tehsil

| Time Series | First year | Last Year | N  | Rainfall |           |       | Rainy days |           |   |
|-------------|------------|-----------|----|----------|-----------|-------|------------|-----------|---|
|             |            |           |    | Test Z   | Signific. | Q     | Test Z     | Signific. | Q |
| MW 20       | 1980       | 2018      | 39 | 0        |           | 0     | 0          |           | 0 |
| MW 21       | 1980       | 2018      | 39 | -0.07    |           | 0     | -0.16      |           | 0 |
| MW 22       | 1980       | 2018      | 39 | 1.27     |           | 0     | 1.19       |           | 0 |
| MW 23       | 1980       | 2018      | 39 | 0.42     |           | 0     | -0.10      |           | 0 |
| MW 24       | 1980       | 2018      | 39 | -1.43    |           | -0.31 | -0.77      |           | 0 |
| MW 25       | 1980       | 2018      | 39 | 0.46     |           | 0     | 0.99       |           | 0 |
| MW 26       | 1980       | 2018      | 39 | 0.30     |           | 0     | 0.51       |           | 0 |
| MW 27       | 1980       | 2018      | 39 | 1.29     |           | 0.10  | 1.28       |           | 0 |
| MW 28       | 1980       | 2018      | 39 | -1.17    |           | -0.04 | -0.80      |           | 0 |
| MW 29       | 1980       | 2018      | 39 | -0.17    |           | 0     | 0.07       |           | 0 |
| MW 30       | 1980       | 2018      | 39 | 0.08     |           | 0     | 0.28       |           | 0 |
| MW 31       | 1980       | 2018      | 39 | 0.40     |           | 0     | 0.62       |           | 0 |

|       |      |      |    |       |    |       |       |   |      |
|-------|------|------|----|-------|----|-------|-------|---|------|
| MW 32 | 1980 | 2018 | 39 | 0.06  |    | 0     | 0.58  |   | 0    |
| MW 33 | 1980 | 2018 | 39 | -0.22 |    | 0     | -0.57 |   | 0    |
| MW 34 | 1980 | 2018 | 39 | 2.04  | *  | 0.06  | 1.43  |   | 0    |
| MW 35 | 1980 | 2018 | 39 | 2.73  | ** | 0.40  | 2.40  | * | 0.03 |
| MW 36 | 1980 | 2018 | 39 | 0.74  |    | 0.05  | 0.51  |   | 0    |
| MW 37 | 1980 | 2018 | 39 | -0.54 |    | -0.25 | -0.18 |   | 0    |
| MW 38 | 1980 | 2018 | 39 | -0.68 |    | -0.30 | -0.60 |   | 0    |
| MW 39 | 1980 | 2018 | 39 | -1.26 |    | -0.54 | -1.54 |   | 0    |
| MW 40 | 1980 | 2018 | 39 | -0.67 |    | -0.16 | 0.51  |   | 0    |
| MW 41 | 1980 | 2018 | 39 | -0.39 |    | 0     | -0.02 |   | 0    |
| MW 42 | 1980 | 2018 | 39 | 0.35  |    | 0     | 0.56  |   | 0    |
| MW 43 | 1980 | 2018 | 39 | -1.34 |    | 0     | -1.62 |   | 0    |
| MW 44 | 1980 | 2018 | 39 | -1.02 |    | 0     | -0.94 |   | 0    |
| MW 45 | 1980 | 2018 | 39 | -0.75 |    | 0     | -0.75 |   | 0    |
| MW 46 | 1980 | 2018 | 39 | -0.24 |    | 0     | -0.23 |   | 0    |

\* Significance at 95 per cent confidence level, \*\* Significance at a 99 per cent confidence level and + Significance at 90 per cent confidence level

**Table.3** Dry and wet week probability during crop growth period in Baramati tehsil

| SMW | Initial Probability (%) |      | Conditional Probability (%) |        |        |        | Consecutive Probability (%) |       |       |       |
|-----|-------------------------|------|-----------------------------|--------|--------|--------|-----------------------------|-------|-------|-------|
|     | P(W)                    | P(D) | P(W/W)                      | P(D/W) | P(D/D) | P(W/D) | P(2D)                       | P(3D) | P(2W) | P(3W) |
|     |                         |      |                             |        |        |        |                             |       |       |       |
| 23  | 63.2                    | 36.8 | 86.7                        | 13.3   | 52.2   | 47.8   | 15.4                        | 8.7   | 38.5  | 11.7  |
| 24  | 60.5                    | 39.5 | 62.5                        | 37.5   | 42.9   | 57.1   | 23.1                        | 15.7  | 18.0  | 6.4   |
| 25  | 34.2                    | 65.8 | 30.4                        | 69.6   | 60.0   | 40.0   | 43.6                        | 25.2  | 12.8  | 4.9   |
| 26  | 34.2                    | 65.8 | 38.5                        | 61.5   | 68.0   | 32.0   | 38.5                        | 20.1  | 12.8  | 4.8   |
| 27  | 42.1                    | 57.9 | 38.5                        | 61.5   | 56.0   | 44.0   | 30.8                        | 19.6  | 15.4  | 8.1   |
| 28  | 44.7                    | 55.3 | 37.5                        | 62.5   | 50.0   | 50.0   | 35.9                        | 26.1  | 23.1  | 14.9  |
| 29  | 42.1                    | 57.9 | 52.9                        | 47.1   | 66.7   | 33.3   | 41.0                        | 28.0  | 28.2  | 10.0  |
| 30  | 44.7                    | 55.3 | 68.8                        | 31.3   | 72.7   | 27.3   | 38.5                        | 31.1  | 15.4  | 5.9   |
| 31  | 34.2                    | 65.8 | 35.3                        | 64.7   | 66.7   | 33.3   | 53.9                        | 42.7  | 12.8  | 5.1   |
| 32  | 26.3                    | 73.7 | 38.5                        | 61.5   | 80.0   | 20.0   | 59.0                        | 40.7  | 10.3  | 6.2   |
| 33  | 23.7                    | 76.3 | 40.0                        | 60.0   | 82.1   | 17.9   | 51.3                        | 34.2  | 15.4  | 9.2   |
| 34  | 39.5                    | 60.5 | 66.7                        | 33.3   | 69.0   | 31.0   | 41.0                        | 20.5  | 23.1  | 13.6  |
| 35  | 44.7                    | 55.3 | 60.0                        | 40.0   | 65.2   | 34.8   | 28.2                        | 14.1  | 25.6  | 19.5  |
| 36  | 55.3                    | 44.7 | 58.8                        | 41.2   | 47.6   | 52.4   | 23.1                        | 8.2   | 41.0  | 31.2  |
| 37  | 65.8                    | 34.2 | 76.2                        | 23.8   | 47.1   | 52.9   | 12.8                        | 4.7   | 48.7  | 33.1  |
| 38  | 71.1                    | 29.0 | 76.0                        | 24.0   | 38.5   | 61.5   | 10.3                        | 2.4   | 48.7  | 37.5  |
| 39  | 65.8                    | 34.2 | 66.7                        | 33.3   | 36.4   | 63.6   | 7.7                         | 5.1   | 51.3  | 18.8  |
| 40  | 76.3                    | 23.7 | 76.0                        | 24.0   | 23.1   | 76.9   | 15.4                        | 11.7  | 28.2  | 8.1   |
| 41  | 36.8                    | 63.2 | 37.9                        | 62.1   | 66.7   | 33.3   | 48.7                        | 0.0   | 10.3  | 0.0   |
| 42  | 26.3                    | 73.7 | 28.6                        | 71.4   | 75.0   | 25.0   | 64.1                        | 0.0   | 10.3  | 0.0   |

**Table.4** Contingency crop planning for Baramati tehsil

| Tehsil-Baramati       |        |                                |     |              |                 |        |                       |             |
|-----------------------|--------|--------------------------------|-----|--------------|-----------------|--------|-----------------------|-------------|
| Crop                  | Sowing | Protective Irrigation Planning |     |              |                 |        |                       | Hoing (SMW) |
|                       |        | Water Requirement Stages       | SMW | Mean RF (mm) | Probability (%) |        | Protective Irrigation |             |
|                       |        |                                |     |              | P(W)            | P(W/W) |                       |             |
| Pearl Millet          | SMW 26 | Panicle Emergence              | 30  | 15.67        | 44.7            | 68.8   | Yes                   | 30, 33      |
|                       |        | Booting                        | 34  | 20.12        | 39.5            | 66.7   | No                    |             |
| Pigeon Pea (Red gram) | SMW 27 | Branching                      | 32  | 10.47        | 26.3            | 38.5   | Yes                   | 29, 32      |
|                       |        | Flowering                      | 36  | 40.45        | 55.3            | 58.8   | No                    |             |
|                       |        | Pod Filling                    | 40  | 44.35        | 76.3            | 76.0   | No                    |             |

### Probability distribution of Baramati tehsil

The initial, conditional and consecutive dry and wet week probability observed in Baramati tehsil during crop growth period (SMW 23<sup>rd</sup> to 42<sup>nd</sup>) is given in table 3. The initial probability of getting wet and dry week P(W) and P(D), respectively ranges from 23.7 to 76.3 and 23.7 to 76.3 per cent and P(W) more than 50 per cent is observed in 23<sup>rd</sup>, 24<sup>th</sup> and 36<sup>th</sup> to 40<sup>th</sup> SMW and in the remaining weeks during crop growth period P(D) is greater than 50 per cent. The conditional probability of wet and dry weeks, P(W/W), P(D/W), P(D/D) and P(W/D) ranges from 28.6 to 86.7, 13.3 to 71.4, 23.1 to 82.1 and 17.9 to 76.9 per cent respectively. P(W/W) greater than 50 per cent was observed in 23<sup>rd</sup>, 24<sup>th</sup>, 29<sup>th</sup>, 30<sup>th</sup> and 34<sup>th</sup> to 40<sup>th</sup> SMWs. The probability of two and three consecutive dry and wet weeks i.e. P(2D), P(3D), P(2W) and P(3W) ranges from 7.7 to 64.1, 0 to 42.7, 10.3 to 51.3 and 0 to 37.5 per cent during crop growth period respectively. The probability of getting two consecutive wet weeks greater than 30 per cent is observed in 23<sup>rd</sup> and 36<sup>th</sup> to 38<sup>th</sup> SMW and P(3W) greater than 20 per cent is observed in 36<sup>th</sup> to 38<sup>th</sup> SMW. The greater probability of being wet weeks was observed in 23<sup>rd</sup>, 24<sup>th</sup> and 36<sup>th</sup> to 40<sup>th</sup> SMWs. So, there will be less moisture stress to crops in *kharif* season during these weeks and there will be

more chances of dry weeks during remaining weeks. The more chances of water harvesting are likely to get in these wet weeks for the upcoming dry weeks, thus appropriate measures of water harvesting should be carried out in this period in Baramati tehsil.

### Contingency crop management and planning based on rainfall analysis

Tehsil-wise crop management and planning work based on rainfall analysis is necessary to assure sustainable crop production. The sowing time is nothing but the mean time of onset of effective monsoon which is the SMW between 21 to 26 SMW which shows sudden rise in the rainfall assuring sufficient moisture for crop germination. The major *Kharif* crops viz. Pearl millet and Pigeon pea are considered for planning in Baramati tehsil. For any particular area the crop irrigation planning should be based on the date of OEM. Then the rescheduling of protective irrigation should be carried out accordingly. Study on coincidence of critical growth stages of these crops and initial and conditional wet weeks probabilities are considered as a tool for protective irrigation planning. Supplementary irrigation and moisture conservation practices need to be undertaken if at 20 mm threshold the probability of dry week and dry week followed by dry week exceeds 50 per cent

(Admasuet *et al.*, 2014). The irrigation can be withheld for some time if there is probability of wet week and apply irrigation during dry week in very sensitive phenological or critical growth stage of crop (Singh *et al.*, 2014). On the basis of initial, conditional and consecutive dry and wet weeks probability SMWs with adequate rainfall availability are found out. Baramati tehsil there are chances of water harvesting in SMWs 23<sup>rd</sup>, 24<sup>th</sup> and 36<sup>th</sup> to 40<sup>th</sup>. Based on mean rainfall, initial and conditional probability at different critical growth stages of selected *Kharif* crops contingency measures viz. MW for sowing, protective irrigation and hoeing operation is given in table 4.

In conclusion baramati tehsil during 22, 25-27, 30-31, 34-36, and 42 MWs exhibit increasing trend in rainfall and rainy days whereas, MWs 21, 24, 28, 33, 37-41 and 43-46 showed decreasing trend in rainfall and rainy days. MW 23 exhibit increasing trend in rainfall while decreasing trend in rainy days. MW 29 exhibit decreasing trend in rainfall while increasing trend in rainy days. The Markov-chain probability analysis showed that probability of getting more wet weeks is observed during SMWs 23<sup>rd</sup>, 24<sup>th</sup> and 36<sup>th</sup> to 40<sup>th</sup> for Baramati tehsil.

Sowing week of Pigeon pea in Baramati tehsil has changed to 27<sup>th</sup> SMW so, that probability of getting 20 mm rainfall to atleast one or two critical growth stages of crop is more. The dry and wet week initial, conditional and consecutive probabilities are helpful for crop management planning in different tehsils of Pune district. Thus, chances of rainwater harvesting in wet weeks is more and judicious use of harvested water in dry spells as protective irrigation is beneficial for the sustainable yield.

**Abbreviation:** SMW: Standard Meteorological Week; OEM: Onset of Effective Monsoon; RF: Rainfall; IMD: India

Meteorological Department; *et al.*: *et alli* (and others); Fig: Figure; Km<sup>2</sup>: Kilometre square; mm: Millimetre; °C: Degree Celsius and %: Per cent

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