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RS Sayyad
Subject Matter Specialist-Agrometeorology, Krishi Vigyan Kendra, Palghar, Maharashtra, India

VM Jadhav
Senior Scientist & Head, Krishi Vigyan Kendra, Palghar, Maharashtra, India

SV Phad
Subject Matter Specialist-Agrometeorology, Krishi Vigyan Kendra, Nandurbar, Maharashtra, India

Corresponding Author:
RS Sayyad
Subject Matter Specialist-Agrometeorology, Krishi Vigyan Kendra, Palghar, Maharashtra, India

Dry and wet spell probability by Markov chain model for agricultural planning at Palghar district, Maharashtra

RS Sayyad, VM Jadhav and SV Phad

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Abstract
Historical rainfall data of 26 years (1998 to 2023) of Palghar District were collected and analyzed with different statistical parameters like annual mean rainfall, standard deviation and coefficient of variation. The statistical analysis of rainfall revealed that the total mean annual rainfall of the district is 2665.3 mm. Annual maximum and minimum rainfall were received in Palghar district is 3603.7 mm (2019) & 1749.2 mm (2015) respectively. Standard deviation is 449.1 mm with coefficient of variation is 16.5 percent. Palghar receives 96.2% mean rainfall during south west *monsoon* season which is about 2564.4 mm, and only 3.08% (82.0 mm) rainfall during *post-monsoon* season. Weekly initial and conditional probabilities of dry and wet spell for monsoon and post-monsoon rainy season for 10, 20, 40, and 80 mm for the 22nd to 52nd SMW were determined, to obtain specific information essential for crop planning and for carrying out agricultural operations. The initial probability {P (W)} as well as conditional probability {P (W/W)} of getting 10 mm rainfall was more than 50% during 23rd to 26th SMW, Therefore, nursery preparation of rice can be done during this period. The initial {P (W)} as well as conditional probability {P (W/W)} of getting 20 mm rainfall was more than 50% in 24th to 26th SMW, this is more suitable for sowing of direct seeded low land rice and other kharif crops. this week is more suitable for sowing of crops. During 25th to 27th SMW probability of getting 80 mm rainfall was more than 50%. This period is suitable for transplantation of rice crops. Chance of dry week preceded by another dry week (PDD) were more than 40% during 40th, 41st and 42nd SMW. Therefore, during those dry weeks especially at the end of main rainy season, supplementary irrigation and moisture conservation practice such as mulching need to be undertaken. Since, 43th SMW (22 Oct - 28 Oct) & 45th to 52nd SMW was observed that there is possibility of (PDD) more than 90% Therefore, growing of high value *rabi* crops without supplementary irrigation would be very high risk during *rabi* season. Proper crop planning with suitable water conservation measures is need to be adopt to enhance the production of *kharif* as well as rabi crops of the district.

Keywords: Statistical rainfall analysis**,** Markov chain model, initial and conditional probability, crop planning

1. Introduction
Palghar district is the most North-Western district of the state of Maharashtra on the Arabian Sea coast. The district has a total 8 talukas, Jawhar, Mokhada, Talasari, Vasai, Vikramgad, Palghar, Dahanu and Wada. The Arabian Sea forms the western boundary, while net sown area of the district is 109291 which is 14.00% of the total geographical area of the district. Paddy is major crop grown in the district. While Nagali & Warai are the other cereals grown in the district. The total area under cereals was 90.00%. The total area under pulses is 7.00%. The Major pulses grown are green gram, black gram, red gram & bengal gram. Area under Oil seeds very low in compared to other districts. Topographically it has much diverse condition.ie. Hilly zone, saline zone, plateau zone and characterised by high iritic rainfall. In varied agricultural zones rainfall variability analysis aids to take farm decisions on times of sowing, inter culture operations, fertilizer application etc. Many studies have reported the advantages of working out weekly rainfall probabilities for a station or for an agroclimatic region (Subbulakshmi *et al.*, 2005 and Nemichandrappa *et al.*, 2010) [27, 18]. Probability analysis can be used for predicting the occurrence of future events of rainfall from the available data with the help of statistical methods

(Kumar and Kumar, 1989) [13]. Chattopadhyay and Ganesan (1995) [4] attempted to study the variability of annual and seasonal rainfall and its probability and suggested suitable cropping pattern for Tamil Nadu. Prakash and Rao (1986) [21] have suggested use of weekly rainfall data to predict the occurrence of rainy events and its amount for crop planning in Kota. Gupta *et al*. (1975) [12] suggested that the rainfall at 80 per cent probability can safely be taken as assured rainfall, while that of 50 per cent probability is the medium limit for taking dry risk. In order to stabilise the crop production at certain level, it is essential to plan agriculture on a scientific basis in terms of making best use of rainfall pattern of an area. This necessitates studying the sequences of dry and wet spells of an area so that necessary steps can be taken up to prepare crop plan in rainfed regions (Reddy *et al*. 2008) [22]. Prediction of wet and dry spell analysis for proper crop planning and agricultural operations may prove useful to farmers for improving productivity and cropping intensity. Markov chain probability model has been used previously for finding out the frequency of wet spells in Greece (Tolika and Maheras 2005) [28], dry spells in Croatia (Cindrić *et al*. 2010) [5] and computation of probability of occurrence of daily precipitation. Previous researchers (Pandarinath 1991; Banik *et al*. 2002; Barron *et al*. 2003; Deni *et al*. 2010) [19, 1, 2, 8] have used Markov chain model to study the probability of dry and wet spell analysis in terms of the shortest period like week and also demonstrated its practical utility in agricultural planning. Rainwater management and its optimum utilisation is a prime issue of present-day research for sustainability of rainfed agriculture. Increased climate variability has made rainfall patterns more inconsistent and unpredictable (Kumar *et al*. 2005) [14]. To meet the future food demands and growing competition for water among various sectors, a more efficient use of water in rainfed agriculture will be essential. Kothari *et al*. (2007) [15] opined that on the basis of water harvesting, water can be utilised for saving of crops during severe moisture stress. In order to address the issue, detailed knowledge of rainfall distribution can help in deciding the time of different agricultural operations and designing of water harvesting structures for providing round the year full irrigation (Srivastava 2001; Srivastava *et al*. 2009) [25, 26]. For sustainable crop planning, rainfall was characterised based on its variability and probability distribution by previous researchers (Mohanty *et al*. 2000; Bhakar *et al*. 2008; Jain and Kumar 2012) [17, 3, 9] for different regions of India. Manikandani *et al*., 2014 [16] analysed that the chance of getting 25 mm weekly rainfall with 50 per cent probability was noticed from 39th to 46th standard week covering eight weeks. Drought resistant short duration pulses and sorghum can be grown within the growing period from 39th to 46th standard weeks. Direct sowing of rabi crops just after harvest of kharif crops may also be tried to realize the advantage of residual moisture. Reddy *et al*., (2008) [23] studied on Markov Chain Model probability of dry, wet weeks and statistical analysis of weekly rainfall for agricultural planning at Bangalore. In this study Markov Chain Model has been extensively used to study spell distribution. Hence, present study has been undertaken to suggest the cropping plan for Palghar district of Maharashtra considering the rainfall amount at different probability levels.

2. Materials and Methodology

The daily rainfall data of Palghar district from 1998-2023 (26 years) were collected from Department of Agriculture, Maharashtra State (maharain.maharashtra.gov.in). The daily rainfall was grouped as week, month, seasonal and annual, and the statistical parameters like average (x), standard deviation (σ) and coefficient of variation (CV) for all groups were worked out. The daily rainfall was aggregated into weekly and used for analysis. Two types of probabilities i.e., Initial and Conditional probability indices were used for the study. Initial and conditional probabilities (Markov-Chain Model) simple criterion related to sequential phenomenon like dry and wet spell was used for analysing rainfall data to obtain specific information needed for crop planning and for carrying out agricultural operations. For the purpose of agricultural planning, we have applied Markov Chain model by choosing 10, 20, 40, and 80 mm/week as threshold limits. In this study, weekly rainfall values have been used to estimate consecutive dry and wet spell analysis based on "Markov Chain probability model". Initial, conditional probabilities and consecutive dry and wet spell analysis for 52 Standard meteorological weeks (SMW) are made by using equations from 1-8.

Initial probability

P(D) = F(D)/N (Eq. 1)
P(W) = F(W)/N (Eq. 2)
Where, P(D) = probability of the week being dry
F(D) = frequency of dry weeks
P(W) = probability of the week being wet
F(W) = frequency of wet weeks
N = total number of years of data being used.

Conditional probabilities

P(DD) = F(DD)/F(D) (Eq. 3)
P(WW) = F(WW)/F(W) (Eq. 4)
P(WD) = 1 - P(DD) (Eq. 5)
P(DW) = 1 - P(WW) (Eq.6)

Where, P(DD) = probability of a week being dry preceded by another dry week
F(DD) = frequency of dry week preceded by another dry week
P(WW) = probability of a week being wet preceded by another wet week
F(WW) = frequency of a wet week preceded by another wet week
P(WD) = probability of a wet week preceded by a dry week
P(DW) = probability of a dry week preceded by a wet week.

Consecutive dry and wet week probabilities

P(2D) = P(DW1) × P(DDW2) (Eq. 7)
P(2W) = P(WW1) × P(WWW2) (Eq. 8)
Where,
P(2D) = probability of 2 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(2W) = probability of 2 consecutive wet 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

3. Results and Discussion

3.1 Variability in monthly, seasonal and annual rainfall

Mean, Standard Deviation (S.D.) and Coefficient of Variation (C.V.) for monthly, seasonally and annual rainfall over the study area, were calculated and are presented in (Tables 1). Table 1 shows that July was the wettest month having average rainfall of about 1001.8 mm with SD & CV was 306.8 mm and 30.6%

respectively. predominantly during the months of July, August, June and September received 1001.8, 673.2, 489.7 and 399.8 respectively. April was the driest month receiving average rainfall just 0.0 mm with SD & CV 0.1 mm & 379.3% respectively. Higher and longer values of coefficients of variation indicate the lesser rainfall and higher irregularity nature of rainfall. Whereas, out of twelve months Palghar district has received good amount of rainfall during June to September month only, but these months shows that the Standard deviation value is large which indicate there is larger variation in rainfall pattern.

In case of seasonal rainfall, South-west *Monsoon* season provides maximum contribution to the annual rainfall, Average *Monsoon* rainfall was found 2564.4 mm with SD & CV was 437.0 mm and 17.0% followed by *post-monsoon* season was received 82.0 mm rainfall with SD & CV was 67.0 mm, and 81.7%. Mean annual rainfall was 2665.3 mm with SD and CV 439.1 mm & 16.5% respectively. Maximum rainfall observed in 2019 (3603.7 mm) and minimum rainfall observed in 2015 (1749.2 mm)

Table 1: Variation of monthly rainfall at Palghar district during 1998-2023

Variables	Mean	SD	CV	% contribution to annual RF
Jan	0.1	0.3	394.1	0.00
Feb	0.4	2.2	500.0	0.02
Mar	1.1	2.8	248.8	0.04
Apr	0.0	0.1	379.3	0.00
May	14.0	38.2	273.3	0.52
Jun	489.7	236.3	48.3	18.37
Jul	1001.8	306.8	30.6	37.59
Aug	673.2	321.8	47.8	25.26
Sep	399.8	239.5	59.9	15.00
Oct	69.8	54.2	77.6	2.62
Nov	12.2	24.8	203.2	0.46
Dec	3.3	13.0	396.3	0.12
Pre -Monsoon	15.1	39.1	258.6	0.57
Monsoon	2564.4	437.0	17.0	96.21
Post-monsoon	82.0	67.0	81.7	3.08
Winter	3.4	13.3	395.6	0.13
Annual Rainfall	2665.3	439.1	16.5	100.00

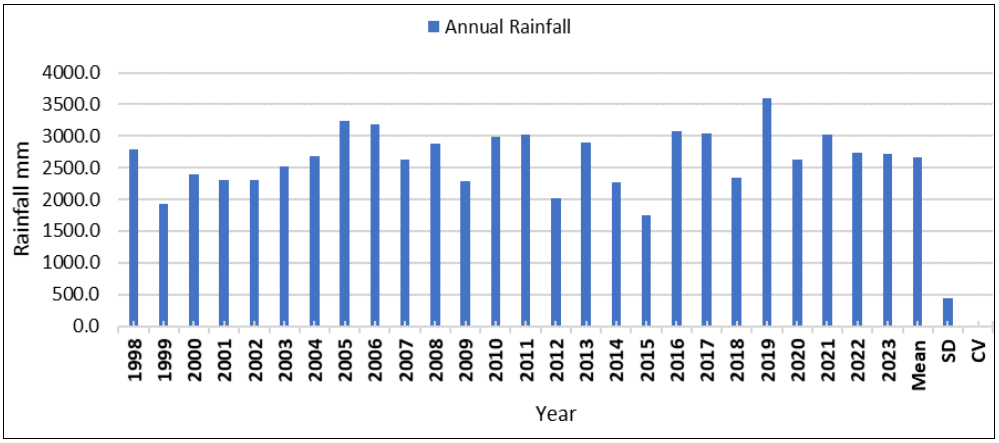

Fig 1: Variation of annual rainfall at Palghar district during 1998-2023

3.2 Weekly rainfall probabilities

The initial {P (W)} and conditional probability {P (W/W)} approach would be relatively good method for rainfall analysis, especially in the regions like Palghar, it comes under heavy rainfall region but it found erratic or short dry periods can be expected during monsoon & post-monsoon season. The initial rainfall probability {P (W)} of wet week getting 10 mm rainfall per week was >40% during 23 SMW (Table 2) at Palghar district and hence, field preparation should be done during this period. The initial probability {P (W)} as well as conditional probability of wet week followed by wet week {P (W/W)} of getting 10 mm rainfall was more than 50% during 23 to 26 SMW (Table 2). Therefore, nursery sowing of rice can be planned during this period. Further delay in sowing may cause very low productivity and even crop failure. The conditional probability {P (W/W)} of getting 10 mm rainfall with above 50 per cent was received during 23rd -38th week and it was essential for maintain adequate moisture in kharif crop land, it is sufficient for vegetative development of pulses, cereals and newly planted fruit orchard, cultural operations like ploughing, land preparation, weeding, intercultural operations etc.

For successful crop production the normal requirement of rainfall was considered as 20 mm per week for all crops. Probability of receiving 20 mm rainfall per week with > 50 per cent were found between 24th & 26th week. This is more suitable for sowing of direct seeded low land rice and other kharif crops. Nachni, Warai, green gram, black gram, red gram sowing operations can carry out at 24th SMW (11 Jun - 17 Jun) helps for good germination of seeds and helps in avoiding moisture stress for germination period.

Initial probability of getting 40mm of rainfall with above 50 per cent was received during 30th -32nd (23 July -12 Aug). Therefore, it is enough for puddling & transplanting of rice. Due to the availability of sufficient rainfall, transplantation of paddy should be completed within July and 1st fortnight of August as high rainfall exists during this period in Palghar district. 36th (03 Sep - 09 Sep) & 38th week (17 Sep - 23 Sep). The conditional probability {P (W/W)} of getting 40 mm rainfall with above 50 per cent was received during 26th-38th week (3 September - 23rd September) which is essential for vegetative development of Rice crop. If vegetative phase of rice received good amount of rainfall it will enhance yield automatically.

The initial probability of wet week followed by wet week {P (W/W)} of getting 80 mm rainfall was more than 50% during 31 (30 Jul - 05 Aug) to 32 (6 July - 12 Aug) & 38 (17 Sep - 23 Sep) SMW (Table 5). Farmers whose adapt rainfed rice based cropping system, they should prefer to grow early & medium duration rice varieties. They should harvest rain water during 31st, 32nd and 38th SMW, So, it may useful as protective life saving irrigation from harvested rain water.

3.3 Consecutive dry and wet week probabilities

During monsoon season, the probability of dry week (PD) getting 10 mm rainfall is more than 50% was observed during

37th and 39th to 42nd SMW and also chance of dry week preceded by another dry week (PDD) were more than 40% during 40th, 41st and 42nd SMW. Therefore, during those dry weeks especially at the end of main rainy season, supplementary irrigation and moisture conservation practice such as mulching need to be undertaken. 43th SMW (22 Oct - 28 Oct) & 45th to 52nd SMW was observed that chance of dry week preceded by another dry week (PDD) more than 90% for getting10 mm. Therefore, growing of high value *rabi* crops without supplementary irrigation would be very high risk during 45th to 52nd SMW. Probability of dry week preceded by another dry week regarding getting 20 mm was found during 39th (24 Sep - 30 Sep) & 41st SMW (08 Oct - 14 Oct). Farmers should make arrangement of irrigation for fruit crops which are in vegetative growth stage.

Table 2: Initial and conditional rainfall probability of 10 mm rainfall in Palghar district

Week	P(W)	P (D)	P (W/W	P (D/W	P (D/D)	P (D/W)	P 2W	P 2D
22	0.18	0.82	1.00	0.00	0.90	0.10	0.09	0.45
23	0.45	0.55	0.50	0.50	0.56	0.44	0.27	0.18
24	0.64	0.36	0.60	0.40	0.33	0.67	0.45	0.27
25	0.55	0.45	0.71	0.29	0.75	0.25	0.36	0.18
26	0.64	0.36	0.67	0.33	0.40	0.60	0.36	0.09
27	0.64	0.36	0.57	0.43	0.25	0.75	0.36	0.09
28	0.64	0.36	0.57	0.43	0.25	0.75	0.64	0.09
29	0.91	0.09	1.00	0.00	0.25	0.75	0.64	0.00
30	0.73	0.27	0.70	0.30	0.00	1.00	0.64	0.18
31	0.73	0.27	0.88	0.13	0.67	0.33	0.73	0.00
32	1.00	0.00	1.00	0.00	0.00	1.00	0.55	0.00
33	0.55	0.45	0.55	0.45	0.00	0.00	0.27	0.09
34	0.64	0.36	0.50	0.50	0.20	0.80	0.55	0.27
35	0.64	0.36	0.86	0.14	0.75	0.25	0.36	0.09
36	0.64	0.36	0.57	0.43	0.25	0.75	0.36	0.27
37	0.45	0.55	0.57	0.43	0.75	0.25	0.45	0.09
38	0.91	0.09	1.00	0.00	0.17	0.83	0.18	0.09
39	0.18	0.82	0.20	0.80	1.00	0.00	0.00	0.36
40	0.45	0.55	0.00	1.00	0.44	0.56	0.18	0.45
41	0.27	0.73	0.40	0.60	0.83	0.17	0.09	0.45
42	0.36	0.64	0.33	0.67	0.63	0.38	0.00	0.64
43	0.00	1.00	0.00	1.00	1.00	0.00	0.00	0.91
44	0.09	0.91	0.00	0.00	0.91	0.09	0.00	0.82
45	0.09	0.91	0.00	1.00	0.90	0.10	0.00	0.82
46	0.09	0.91	0.00	1.00	0.90	0.10	0.00	0.91
47	0.00	1.00	0.00	1.00	1.00	0.00	0.00	0.91
48	0.09	0.91	0.00	0.00	0.91	0.09	0.09	0.91
49	0.09	0.91	1.00	0.00	1.00	0.00	0.09	0.91
50	0.09	0.91	1.00	0.00	1.00	0.00	0.09	0.91
51	0.09	0.91	1.00	0.00	1.00	0.00	0.09	0.91
52	0.09	0.91	1.00	0.00	1.00	0.00		

Table 3: Initial and conditional rainfall probability of 20 mm rainfall in Palghar district

Week	P(W)	P (D)	P (W/W	P (D/W	P (D/D)	P (D/W)	P 2W	P 2D
22	0.18	0.82	0.00	0.00	0.82	0.18	0.09	0.55
23	0.36	0.64	0.50	0.50	0.67	0.33	0.18	0.27
24	0.55	0.45	0.50	0.50	0.43	0.57	0.27	0.27
25	0.45	0.55	0.50	0.50	0.60	0.40	0.36	0.27
26	0.64	0.36	0.80	0.20	0.50	0.50	0.36	0.18
27	0.55	0.45	0.57	0.43	0.50	0.50	0.18	0.27
28	0.36	0.64	0.33	0.67	0.60	0.40	0.27	0.27
29	0.64	0.36	0.75	0.25	0.43	0.57	0.27	0.00
30	0.64	0.36	0.43	0.57	0.00	1.00	0.55	0.18
31	0.73	0.27	0.86	0.14	0.50	0.50	0.73	0.00
32	1.00	0.00	1.00	0.00	0.00	1.00	0.18	0.00
33	0.18	0.82	0.18	0.82	0.00	0.00	0.09	0.55
34	0.36	0.64	0.50	0.50	0.67	0.33	0.27	0.45
35	0.45	0.55	0.75	0.25	0.71	0.29	0.18	0.09
36	0.64	0.36	0.40	0.60	0.17	0.83	0.36	0.27
37	0.45	0.55	0.57	0.43	0.75	0.25	0.45	0.09
38	0.91	0.09	1.00	0.00	0.17	0.83	0.09	0.09
39	0.09	0.91	0.10	0.90	1.00	0.00	0.00	0.45
40	0.45	0.55	0.00	1.00	0.50	0.50	0.09	0.55
41	0.09	0.91	0.20	0.80	1.00	0.00	0.00	0.64
42	0.27	0.73	0.00	1.00	0.70	0.30	0.00	0.73

43	0.00	1.00	0.00	1.00	1.00	0.00	0.00	0.91
44	0.09	0.91	0.00	0.00	0.91	0.09	0.00	0.82
45	0.09	0.91	0.00	1.00	0.90	0.10	0.00	0.82
46	0.09	0.91	0.00	1.00	0.90	0.10	0.00	0.91
47	0.00	1.00	0.00	1.00	1.00	0.00	0.00	1.00
48	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.91
49	0.09	0.91	0.00	0.00	0.91	0.09	0.09	0.91
50	0.09	0.91	1.00	0.00	1.00	0.00	0.09	0.91
51	0.09	0.91	1.00	0.00	1.00	0.00	0.09	0.91
52	0.09	0.91	1.00	0.00	1.00	0.00		

Table 4: Initial and conditional rainfall probability of 40 mm rainfall in Palghar district

Week	P(W)	P (D)	P (W/W	P (D/W	P (D/D)	P (D/W)	P 2W	P 2D
22	0.18	0.82	0.00	0.00	0.82	0.18	0.00	0.73
23	0.09	0.91	0.00	1.00	0.89	0.11	0.09	0.73
24	0.27	0.73	1.00	0.00	0.80	0.20	0.09	0.55
25	0.27	0.73	0.33	0.67	0.75	0.25	0.09	0.55
26	0.27	0.73	0.33	0.67	0.75	0.25	0.09	0.64
27	0.18	0.82	0.33	0.67	0.88	0.13	0.00	0.73
28	0.09	0.91	0.00	1.00	0.89	0.11	0.09	0.55
29	0.45	0.55	1.00	0.00	0.60	0.40	0.18	0.18
30	0.55	0.45	0.40	0.60	0.33	0.67	0.36	0.27
31	0.55	0.45	0.67	0.33	0.60	0.40	0.36	0.09
32	0.73	0.27	0.67	0.33	0.20	0.80	0.00	0.18
33	0.09	0.91	0.00	1.00	0.67	0.33	0.00	0.64
34	0.27	0.73	0.00	1.00	0.70	0.30	0.09	0.45
35	0.36	0.64	0.33	0.67	0.63	0.38	0.18	0.27
36	0.55	0.45	0.50	0.50	0.43	0.57	0.36	0.36
37	0.45	0.55	0.67	0.33	0.80	0.20	0.27	0.18
38	0.64	0.36	0.60	0.40	0.33	0.67	0.00	0.36
39	0.00	1.00	0.00	1.00	1.00	0.00	0.00	0.64
40	0.36	0.64	0.00	0.00	0.64	0.36	0.00	0.64
41	0.00	1.00	0.00	1.00	1.00	0.00	0.00	0.82
42	0.18	0.82	0.00	0.00	0.82	0.18	0.00	0.82
43	0.00	1.00	0.00	1.00	1.00	0.00	0.00	1.00
44	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.91
45	0.09	0.91	0.00	0.00	0.91	0.09	0.00	0.82
46	0.09	0.91	0.00	1.00	0.90	0.10	0.00	0.91
47	0.00	1.00	0.00	1.00	1.00	0.00	0.00	1.00
48	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00
49	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00
50	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00
51	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.91
52	0.09	0.91	0.00	0.00	0.91	0.09		

Table 5: Initial and conditional rainfall probability of 80 mm rainfall in Palghar district

Week	P(W)	P (D)	P (W/W	P (D/W	P (D/D)	P (D/W)	P 2W	P 2D
22	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.91
23	0.09	0.91	0.00	0.00	0.91	0.09	0.09	0.82
24	0.18	0.82	1.00	0.00	0.90	0.10	0.09	0.82
25	0.09	0.91	0.50	0.50	1.00	0.00	0.00	0.73
26	0.18	0.82	0.00	1.00	0.80	0.20	0.00	0.73
27	0.09	0.91	0.00	1.00	0.89	0.11	0.00	0.82
28	0.09	0.91	0.00	1.00	0.90	0.10	0.00	0.91
29	0.00	1.00	0.00	1.00	1.00	0.00	0.00	0.82
30	0.18	0.82	0.00	0.00	0.82	0.18	0.09	0.55
31	0.36	0.64	0.50	0.50	0.67	0.33	0.18	0.64
32	0.18	0.82	0.50	0.50	1.00	0.00	0.00	0.82
33	0.00	1.00	0.00	1.00	1.00	0.00	0.00	1.00
34	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.91
35	0.09	0.91	0.00	0.00	0.91	0.09	0.00	0.82
36	0.09	0.91	0.00	1.00	0.90	0.10	0.00	0.55
37	0.36	0.64	0.00	1.00	0.60	0.40	0.18	0.64
38	0.18	0.82	0.50	0.50	1.00	0.00	0.00	0.82
39	0.00	1.00	0.00	1.00	1.00	0.00	0.00	0.91
40	0.09	0.91	0.00	0.00	0.91	0.09	0.00	0.91
41	0.00	1.00	0.00	1.00	1.00	0.00	0.00	1.00

42	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00
43	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00
44	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00
45	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00
46	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00
47	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00
48	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00
49	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00
50	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00
51	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00
52	0.00	1.00	0.00	0.00	1.00	0.00		

3.4 Crop Planning

Farmers in this area cultivate rice more than any other crop during June to November and November to February cultivate Rice, Pulses, vegetables and flowers. However, some farmers cultivate Sapota, Coconut, Cashew nut and bananas as wetland crops, which require a lot of water. The current cropping pattern has to be changed in order to lessen the monsoon anomaly. it is best to take intercrop with fruit crops during Kharif & Rabi crop. To lower risks in Rice production farmers advised to change cropping patterns, crop choices, cultivars, and management techniques. Soil and water conservation activities should encourage to check the soil erosion and promoting water harvesting. Farmers can grow cowpea; chick pea and oilseed crops on residual soil moisture after harvesting of Rice crop. Farmers are advised to grow multiple crops to reduce the risk of total crop failure due to fluctuations of rainfall. Adopt improved irrigation system, like drip and sprinkler irrigation to conserve water. Follow weather forecasts and early warning systems to plan agricultural activities and avoid crop loss.

4. Conclusion

This study provides a valuable framework for sustainable agriculture areas like Palghar district. Annual average rainfall is 2665.3 mm, with significant variability (CV: 16.5%). Most rainfall (96.2%) occurs during the southwest monsoon season (June-September). July is the wettest month, while April is the driest. High CV observed in winter season (395.6%) followed by pre-monsoon season (258.6%), with contribution 0.13% & 0.57% in annual rainfall. Therefore, farmers can grow short-season crops such as pulses, cucurbits, and millets during the winter to produce a high yield while using less water and surviving drought conditions. The Markov Chain Model effectively identifies rainfall patterns for optimizing crop schedules. Initial and conditional probabilities were high of wet spells (10 mm) occur during 23rd-26th standard meteorological weeks (SMW), suitable for rice nursery preparation and sowing of kharif crops. From 40th to 42nd SMW found possibility of getting (PDD) for getting 10 mm rainfall. Therefore, during those dry weeks, supplementary irrigation and moisture conservation practice such as mulching need to be undertaken

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