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RESEARCH ARTICLE

Dry and Wet Spell Probability by Markov Chain Model over Adilabad District of Telangana

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ABSTRACT

This research uses the Markov Chain Model to analyze dry and wet spells in Telangana, India's Adilabad district. The research intends to provide significant insights for agricultural planning in the region, which is critical considering that agriculture is the foundation of Indian economy. The study emphasizes the need to understand and effectively exploit natural resources, particularly rainfall, for the improvement and sustainability of rainfed agriculture. According to the calculation, there is a 70% chance of two consecutive wet weeks throughout the monsoon season (24th SMW to 40th SMW), resulting in about 17 weeks of monsoon rain in the Adilabad area. This enables the successful development of short-duration crops like rice. According to the study, the Markov Chain Model is effective for simulating the long-term frequency behavior of wet or dry spells, providing a comprehensive understanding of rainfall patterns and their impact on agriculture in the Adilabad District.

Keywords: *Rainfall Patterns, Dry and Wet Spells, Markov Chain Model, Rainfed Agriculture, Crop Planning, Standard Meteorological Weeks (SMW)*

INTRODUCTION

Agriculture is the backbone of the Indian economy, and it is important to ensure food and nutrition security. Rainfall is the most essential climatic component for farmers using rainfed agriculture (Wani*et al*., 2017). Understanding the amount and timing of rainfall is crucial for crop planning. Unfavorable weather conditions can disrupt the equilibrium and have major effects on lives and food production systems (Wakjira *et al*., 2021). Rainfed agriculture is an important source of agricultural productivity. Crop yield, particularly in rainfed settings, is determined by rainfall patterns (Habib *et al*., 2022). It is viable to enhance farm productivity by altering cropping patterns and agronomic procedures based on the weather. (Liliane and Charles., 2020) Many researchers have investigated the likely behavior of rainfall. (Salehyan.,2014). The study of wet and dry spells helps to characterize command area crops, plan cropping systems, and construct conservation structures (Srinivasarao *et al*., 2020). The Markov Chain Model has been widely used to investigate the distribution of spells and other aspects of rain events. The appropriate understanding and efficient use of natural resources, particularly rainfall, are critical for the improvement and sustainability of agriculture in rainfed areas (Gao *et al*., 2020).

The Markov Chain Model has shown to be effective in describing the long-term frequency behavior of wet or dry spells. The annual and seasonal rainfall study gives a broad overview of the region's rainfall pattern, whereas the weekly rainfall analysis is especially valuable for agricultural planning. The Markov chain probability model has been widely used to predict the long-term frequency of rainy and dry spells (Victor and Sastri, 1979).

Another part of crop planning is the forward and backward accumulation of rainfall to predict the start and end of the rainy season using precipitation data. Numerous studies have been conducted to examine daily, weekly, monthly, seasonal, and annual rainfall data for location-specific agricultural planning, and crop planning in particular. (Sharda and Bhushan,

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1985; Bhatt *et al*., 1996; Kumar, 1999; Mohanty *et al*., 2001). The Markov chain probability has also been used to calculate the likelihood of daily precipitation (Stern, 1982).Chand *et al*., (2011) studied historical rainfall data from Jhansi in Uttar Pradesh's Bundelkhand agro-climatic zone over 34 years (1975-2008) to calculate weekly, monthly, seasonal, and annual probabilities at various rainfall quantities for crop planning. The purpose of this study is to apply analogous analytical approaches to the Adilabad area, therefore offering important insights for regional agricultural planning.

MATERIALS AND METHODS

Study area

Adilabad district (Figure. 1), the gateway to South and Central India, is located in the northern part of Telangana, India, with the town of Adilabad as its seat. The district covers 4,153 square kilometers and has boundaries with Asifabad and Nirmal districts, as well as the Maharashtra state line. According to the 2011 census, the district has a population of 708,972, a population density of 170 per square kilometer, and a literacy rate of 63.46%. The district is divided into 18 Mandalas, and the economy is mostly concentrated on agriculture and forest goods. Rice, maize, cotton, and other pulses are the principal crops grown in the area. The district has a tropical climate, with the monsoons providing the most of the rainfall.

Weather data

For the current study, daily rainfall data from Adilabad district were gathered from the IMD New Delhi from 1981 to 2023, analyzed, and converted to weekly rainfall.

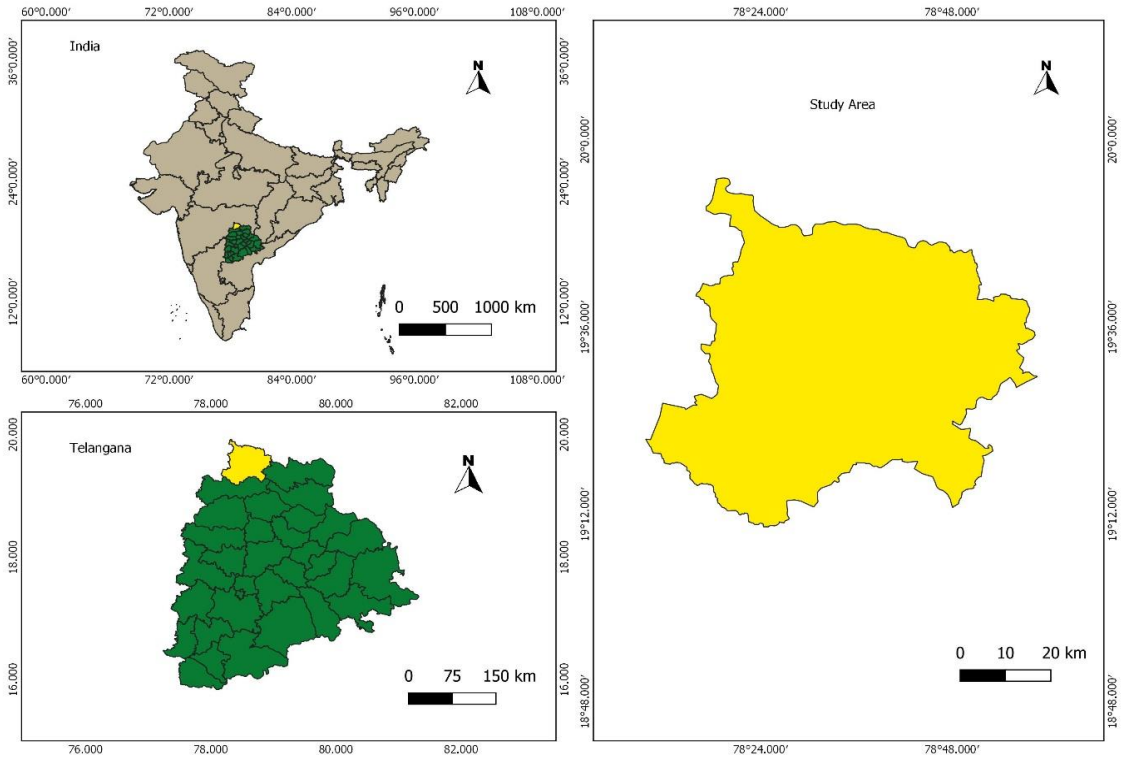
Markov chain probability model

A wet week (or dry week) is defined by the Indian Meteorological Department as having more than 5 mm of rainfall or less than 5 mm. As a result, weeks alternate between rainy and dry spells. Furthermore, if the occurrence of a wet or dry week is simply influenced by the weather conditions of the previous week, the process of occurrence of wet and dry weeks may be described by a two-state Markov chain, with wet and dry weeks acting as the states. The transition probability matrix, which defines the two-state Markov chain model, is given by,

$$P = \begin{bmatrix} P_{D/D} & P_{D/W} \\ P_{W/D} & P_{W/W} \end{bmatrix}$$

with PD/D+PD/W=1 and PW/D+PW/W=1, where PD/D, PD/W, PW/D, and PW/W represent transition probabilities. Specifically, they are the odds of

Figure 1. Study area Map of Adilabad



the following conditional events: ED/D: A week is considered dry if the week prior to it was also dry. EW/D: A week is wet if the previous week was dry. ED/W: A week is dry if the previous week was wet. EW/W: A week is considered wet if the week before it was also wet. Assume that each week from January to December is categorized based on the occurrence of the four occurrences ED/D, ED/W, EW/D, and EW/W, so that the first week corresponds to the 52nd week of December. The frequency of event occurrences is then counted by repeating this method year after year. Let the observed frequencies be labeled as a, b, c, and d for the relevant occurrences, where $a + b = n_0$ and $c + d = n_1$. The highest likelihood estimates of the unknown probabilities PD/D, PD/W, PW/D, and PW/W, i.e., model parameters, are calculated as

$$\widehat{P}_{D/D} = P_{D/D} = \frac{a}{n_0}, \widehat{P}_{D/W} = P_{D/W} = \frac{b}{n_0}$$

$$_{W/D} = P_{W/D} = \frac{c}{n_1}, \widehat{P}_{W/W} = P_{W/W} = \frac{d}{n_1}$$

The transition probabilities are conditional. However, the chance of a dry week (PD) and the likelihood of a wet week (PW) are computed using the observed frequencies of the conditional events as follows:

$$\widehat{P_D} = p_D = \frac{a + c}{n_0 + n_1} \text{ and } \widehat{P_W} = p_W = \frac{b + d}{n_0 + n_1}$$

These unconditional probabilities, also known as binomial probabilities, consider a rainy week as successful and a dry week as unsuccessful.

RESULTS AND DISCUSSION

According to the descriptive data of weekly rainfall in Adilabad district, rainfall ranged from 25.0mm (23rd SMW) to 87.9mm (29th SMW) each SMW beginning with the 23rd SMW and ending with 13.2mm in the 42nd SMW. The 29th SMW got the most rainfall (87.9mm), while the 49th had the least (0.4mm). The coefficient of variance was lowest (78.5%) during the 27th SMW and highest (549.9%) during the 49th SMW. This data gives a detailed overview of the Adilabad district's rainfall trends. These patterns are critical for planning agricultural operations and managing water resources in the district. TheMean weekly rainfall distribution of Adilabad district from 1981 to 2023 is represented in the figure 2.

Probabilities of Wet and Dry spell

The daily rainfall data was converted to a Standard Meteorological Week (SMW) based on the amount of rainfall (5mm), and the SMWs were classed as dry or wet spells to investigate the rainfall pattern. A two-state Markov chain model was used to assess the marginal and conditional probability of dry and wet spells, with less than 5 mm of rainfall in a week classified as dry and 5 mm or more as wet.Table 2 shows the marginal probabilities of wet weeks P(W), dry weeks P(D), conditional probabilities of wet week followed by dry week P(W/D), dry week followed by wet week P(D/W), wet week followed by wet week P(W/W), and dry week followed by dry week P(D/D) for the period 1981–2023.

The likelihood of a rainy week during the pre-monsoon season (18th SMW to 23rd SMW) in Adilabad

Figure 2. Mean weekly rainfall distribution of Adilabad district (1981 – 2023)

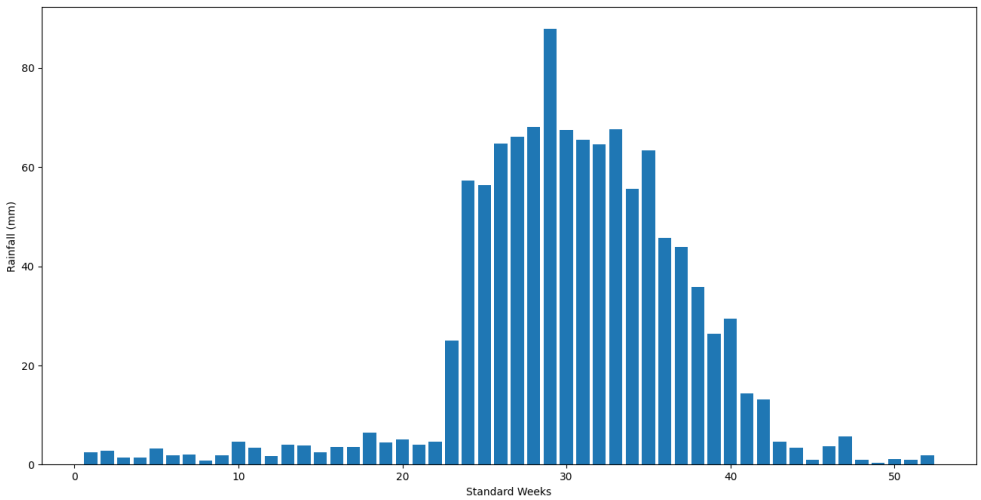


Table. 1. Descriptive statistics of standard metrological weekly rainfall in adilabad district from 1981-2023

SMW	Mean (mm)	SD (mm)	CV (%)	SMW	Mean (mm)	SD (mm)	CV (%)
1	2.6	7.3	285.0	27	66.1	51.9	78.5
2	2.9	8.2	285.0	28	68.2	65.1	95.5
3	1.4	4.4	317.8	29	87.9	86.1	98.0
4	1.4	5.4	392.0	30	67.4	57.5	85.3
5	3.3	16.5	499.3	31	65.5	63.7	97.3
6	1.8	5.9	316.6	32	64.6	69.9	108.3
7	2.1	7.0	330.7	33	67.7	62.7	92.6
8	0.8	2.8	370.7	34	55.7	62.6	112.5
9	1.9	5.4	285.8	35	63.4	66.0	104.2
10	4.7	12.1	256.7	36	45.7	44.7	97.9
11	3.4	6.5	194.6	37	43.9	47.5	108.2
12	1.7	4.2	242.3	38	35.9	42.1	117.1
13	4.0	12.7	318.7	39	26.4	36.4	137.7
14	3.8	5.8	151.3	40	29.5	39.2	132.8
15	2.5	5.5	221.1	41	14.3	20.3	141.3
16	3.6	6.6	185.6	42	13.2	54.8	415.7
17	3.5	11.5	329.8	43	4.6	10.1	220.0
18	6.4	14.3	223.6	44	3.4	7.7	225.6
19	4.5	12.3	270.8	45	1.0	3.7	358.7
20	5.2	8.8	171.4	46	3.8	13.2	349.3
21	4.0	6.5	161.3	47	5.8	19.2	332.2
22	4.7	9.9	211.0	48	1.1	5.0	474.5
23	25.0	31.4	125.3	49	0.4	2.4	549.9
24	57.4	60.9	106.2	50	1.2	4.0	340.0
25	56.4	57.3	101.6	51	1.0	3.1	322.7
26	64.8	63.6	98.1	52	1.8	5.3	288.6

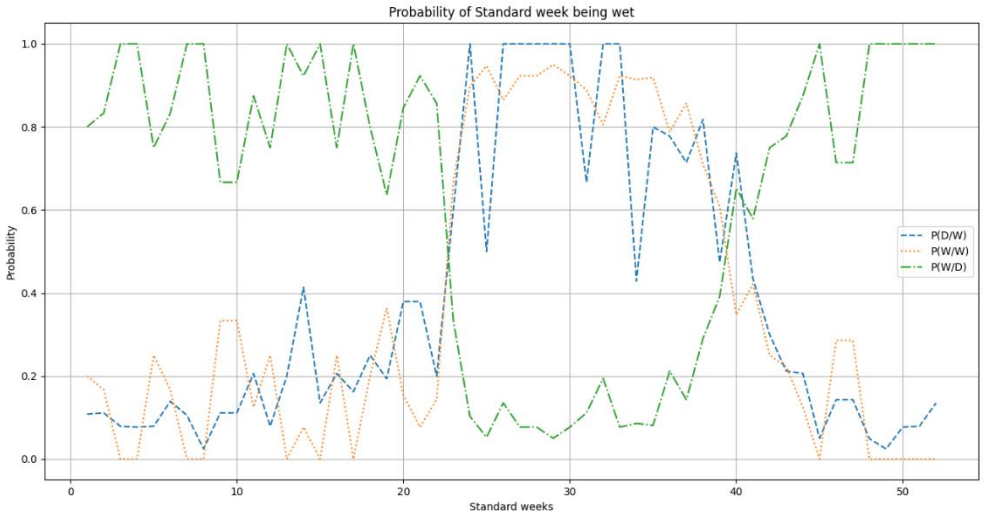
district is approximately 30%. However, during the monsoon season (from the 24th to the 40th SMW), the likelihood rises to over 70%, and from the 41st to the 43rd SMW, it is around 45%. The conditional chance of a wet week followed by another wet week, P(W/W), is equivalent to the marginal likelihood of wet weeks. During the pre-monsoon season (18th to 23rd SMW), the conditional probability of a wet week given wet weeks, P(W/W), is around 30%. However, during the monsoon season, it climbs to more than 85% (24th to 37th SMW), and from the 38th to 43rd SMW, it is approximately 60%. However, from the 44th to the 48th SMW, it is lower to around 25%.

The conditional probability of a wet week followed by a dry week, P(W/D), is shown to be less than 25% during the pre-monsoon season and more than 60% during the monsoon season. Figure 3 depicts the likelihood of normal weeks being wet. The difference between P(W/D) and P(W/W) reduces as the monsoon season proceeds, showing that the chances of having a wet week become less reliant on the preceding week's conditions as the rains grow more consistent. Similarly, the difference between P(D/D) and P(W/D) declines as the monsoon season proceeds, supporting the observation that the likelihood of having a wet week becomes less reliant on the preceding week's conditions as the rains become more consistent. However, the difference between P(D/D) and P(D/W) grows throughout the monsoon season, indicating that

Table. 2. Marginal and Conditional probabilities of Rainfall during 1981- 2023 (Limit = 5mm/ week)

SMW	Marginal Probability		Conditional Probability				SMW	Marginal Probability		Conditional Probability			
	P(D)	P(W)	P(D/D)	P(D/W)	P(W/W)	P(W/D)		P(D)	P(W)	P(D/D)	P(D/W)	P(W/W)	P(W/D)
1	0.88	0.12	0.89	0.11	0.20	0.80	27	0.07	0.93	0.00	1.00	0.92	0.08
2	0.86	0.14	0.89	0.11	0.17	0.83	28	0.07	0.93	0.00	1.00	0.92	0.08
3	0.90	0.10	0.92	0.08	0.00	1.00	29	0.05	0.95	0.00	1.00	0.95	0.05
4	0.93	0.07	0.92	0.08	0.00	1.00	30	0.07	0.93	0.00	1.00	0.92	0.08
5	0.90	0.10	0.92	0.08	0.25	0.75	31	0.14	0.86	0.33	0.67	0.89	0.11
6	0.86	0.14	0.86	0.14	0.17	0.83	32	0.14	0.86	0.00	1.00	0.81	0.19
7	0.90	0.10	0.89	0.11	0.00	1.00	33	0.07	0.93	0.00	1.00	0.92	0.08
8	0.98	0.02	0.98	0.02	0.00	1.00	34	0.17	0.83	0.57	0.43	0.91	0.09
9	0.86	0.14	0.89	0.11	0.33	0.67	35	0.12	0.88	0.20	0.80	0.92	0.08
10	0.86	0.14	0.89	0.11	0.33	0.67	36	0.21	0.79	0.22	0.78	0.79	0.21
11	0.81	0.19	0.79	0.21	0.13	0.88	37	0.17	0.83	0.29	0.71	0.86	0.14
12	0.90	0.10	0.92	0.08	0.25	0.75	38	0.26	0.74	0.18	0.82	0.71	0.29
13	0.83	0.17	0.80	0.20	0.00	1.00	39	0.45	0.55	0.53	0.47	0.61	0.39
14	0.69	0.31	0.59	0.41	0.08	0.92	40	0.45	0.55	0.26	0.74	0.35	0.65
15	0.88	0.12	0.86	0.14	0.00	1.00	41	0.55	0.45	0.57	0.43	0.42	0.58
16	0.81	0.19	0.79	0.21	0.25	0.75	42	0.71	0.29	0.70	0.30	0.25	0.75
17	0.88	0.12	0.84	0.16	0.00	1.00	43	0.79	0.21	0.79	0.21	0.22	0.78
18	0.76	0.24	0.75	0.25	0.20	0.80	44	0.81	0.19	0.79	0.21	0.13	0.88
19	0.74	0.26	0.81	0.19	0.36	0.64	45	0.95	0.05	0.95	0.05	0.00	1.00
20	0.69	0.31	0.62	0.38	0.15	0.85	46	0.83	0.17	0.86	0.14	0.29	0.71
21	0.69	0.31	0.62	0.38	0.08	0.92	47	0.83	0.17	0.86	0.14	0.29	0.71
22	0.83	0.17	0.80	0.20	0.14	0.86	48	0.98	0.02	0.95	0.05	0.00	1.00
23	0.36	0.64	0.40	0.60	0.67	0.33	49	0.98	0.02	0.98	0.02	0.00	1.00
24	0.07	0.93	0.00	1.00	0.90	0.10	50	0.93	0.07	0.92	0.08	0.00	1.00
25	0.10	0.90	0.50	0.50	0.95	0.05	51	0.90	0.10	0.92	0.08	0.00	1.00
26	0.12	0.88	0.00	1.00	0.86	0.14	52	0.88	0.12	0.86	0.14	0.00	1.00

Figure 3. Probability of Standard week being wet for Adilabad District



conditional reliance on dry weeks occurs even during the monsoon season in the Adilabad district, which lasts from June to October. Summer crops (cowpea, black gram, green gram, maize, and directly planted rice, among others) may be efficiently cultivated in this region with sufficient irrigation. Rains with a 75% chance can be used to prepare seedbeds for short-duration (100-day) rice seedlings or direct-sown rice. The transplanting of *kharif* rice in the first week of July will have the added benefit of nearly certain water supplies from rain in August and September. Green gram, cowpea, and black gram may all be produced in highland locations throughout the summer. Smaller millets (finger millet, foxtail millet, etc.) that use less water and have a shorter growing season can be produced in the summer (Shilpashree*et al*., 2019). Maize can be seeded in the 22nd week with a low risk because rain is expected at 50% chance. This study clearly shows that cereal crops like rice, maize, and jowar may be readily grown during the monsoon season, while pulse crops such as green gram, Bengal gram, black gram, and others can be grown utilizing residual moisture and post-monsoon rainfall. This research provides thorough knowledge of rainfall patterns and their influence on agriculture in the Adilabad District.

CONCLUSION

According to Adilabad district research, the consecutive dry and wet periods during the pre-monsoon season (18th SMW to 23rd SMW) were around 30%. The monsoon season predicted a 70% risk of two consecutive wet weeks between the 24th and 40th SMW, as well as a 45% chance between the 41st and 43rd SMW. As a result, we may expect a good monsoon rain in the Adilabad area for approximately 17 weeks (24th SMW to 43rd SMW). As a result, short-duration crops like rice, which last roughly 100 to 110 days, may be easily produced in the region. Short-duration rice can be harvested before the monsoon leaves the region, reducing the likelihood of rice crop loss owing to water stress. Furthermore, leftover moisture may be used to cultivate pulse crops such as Bengal gram and black gram. This research provides thorough knowledge of rainfall patterns and their influence on agriculture in the Adilabad District.

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