Analysis of rainfall variability and probability in Theni District, India

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ABSTRACT

Crop planning based probability analysis aids in increasing production. A crop planning research was conducted in the Theni district by examining probability analysis over a 40-year period (1982-2021) using weekly and monthly rainfall data. The mean annual rainfall in the Theni district was 1100.2 mm spread over 90 rainy days. The probability study revealed that obtaining 20mm rainfall per week received for 8 weeks (38 to 45th week), which is beneficial for sowing and planting. On the other side, October had the greatest mean monthly rainfall (191.8 mm), followed by November (147.9 mm). The main crops farmed in this area are rice, sugarcane, and bananas, but they should be replaced with maize, pulses, cowpea, sorghum, ragi, and minor millets since they can grow in a shorter time period and yield higher.

Key words: Rainfall, Markov chain analysis, initial and conditional probability and crop planning

INTRODUCTION

The primary crop farmed in Tamilnadu on 2.2 million acres is rice, which is the staple meal of India. The average agricultural production in the state is roughly 2.8 tonnes/ha, and rainfall is the main factor that limits crop yield (Agrawal and Singh, 2012). The region's agricultural practices are influenced by the frequency, timing, and regional variability of rainfall. Additionally, throughout the year, there are variations in the beginning, distribution, and cessation of rainfall, which has an impact on agricultural activities (Pradhan *et al.*, 2020). Rainfall fluctuation has significant effects on the economies of all nations, including India (Yadav *et al.*, 2014). Although the change in rainfall is difficult to quantify due to cloud formation and the unpredictable nature of rain, long-term rainfall analysis could be used to improve agricultural planning in rainfed areas (Rao *et al.*, 2010). Crop planning by using annual and seasonal rainfall variability and its probability analysis in Tamilnadu (Chattopadhyay and Ganesan, 1995). Weekly rainfall analysis helps in better crop planning in Madurai and Bhavanisagar in Tamilnadu suggested by Subbulakshmi *et al., (*2005).

Theni district is located in the southern zone of Tamilnadu which is sharing its border with Kerala state. Out of seven agro climatic zones of Tamilnadu, Southern zone occupies 24 percent of dry land area (Kannaiyan *et al.*, 2001, Kokilavani *et al.*, 2016). The uneven spatial and temporal distribution of rainfall affects the agricultural productivity in this region. In this context, the Markov chain model has been used to study the probabilities of rainfall occurrence (Gaberial and Newmam, 1962). Hence the analysis of occurrence of initial wet spell and dry spell as well as the conditional probability of wet spells may be utilized for minimizing risk factors due to weather conditions in crop production. Gupta *et al.* (1975) suggested that the rainfall at 50% probability is the medium limit for taking risks. In this paper, an attempt has been made to analyze the rainfall variability on a weekly, monthly, seasonal and annual basis to suggest crop planning in this region.

MATERIAL AND METHODS

The daily rainfall data of Theni district comprising of 10 raingauge stations for 40 years (1982-2021) had been collected from PWD, Vaigai dam, Periyar Vaigai Basin Division, Theni. Theni district raingauge stations were depicted in Fig. 1. and it was 303m elevation above sea level. The daily data were converted into weekly and monthly for analysis as per the India Meteorological Department (IMD) guidelines**.** The initial and conditional probabilities were estimated using the Markov Chain Analysis method of receiving 10mm, 20mm and 50mm of rainfall in a given week. Markov chain analysis is a universal method employed for rainfall analysis which helps to obtain specific information for crop planning and for carrying out agricultural operations (Sivakumar, 1992). Gupta *et al.*, (1975) suggested that 50 per cent probability is medium limit for taking risk. The weekly probability estimation results for initial and conditional probability of a wet week is given by the formula

$$P(W) = \frac{F(W)}{\mathrm{F(W)+F(D)}} \times 100 \quad \text{-- Equation 1}$$

$$\mathrm{P}\left(\frac{W_2}{W_1}\right) = \frac{\mathrm{F}(W_2 W_1)}{\mathrm{F}(W_1)} \quad \text{-- Equation 2}$$

Where in equation 1, P(W) is the probability of week being wet(%), F(W) and F(D) is frequency of wet and dry weeks in a data set and in equation 2, $P(W_2/W_1)$ is probability of second week being wet followed by preceding week wet and $F(W_2W_1)$ is frequency of wet week preceded by wet week.

RESULTS AND DISCUSSION

Monthly and weekly rainfall

The mean monthly rainfall was higher in October (191.8mm) with the CV of 48.3 per cent followed 147.9 mm of rainfall with 74 per cent of CV in the month of November. The lowest mean monthly value was observed in January (13.9 mm) with CV of 106.6 per cent. The maximum amount of rainfall was received during August month as 476.2 mm and the higher minimum rainfall was received during April month with 16.8 mm The coefficient of variation was lower than the threshold level (<100%) between the months from April to November which clearly showed that the rainfall during these months were highly dependable (Table 1).

The mean weekly rainfall was higher during 44th standard week (29 Oct – 04 Nov) which received 51.7 mm of rainfall with the CV of 90.8 per cent. The stable rainfall period was found between 16 to 46th standard week (April 16 to November 18) with the corresponding CV of less than 150 per cent (Fig. 2). Thus, the total average growing period at Theni district was for 32 weeks. This showed that the successful crop production can be done during these weeks with an assured moisture regime.

Weekly rainfall probabilities

The occurrence of hard pans at shallow depth is the most prevailing soil physical constraint in this region. The agricultural crops are denied of the full benefits of soil fertility and nutrient use due to this constraint. The sub-soil hard pans are characterized by high bulk density which in turn lowers infiltration, water storage capacity, available water and movement of air and nutrients, with related adverse effects on the yield of crops (Rai and Singh, 2009). This problem was predominantly occuring in Theni particularly under rainfed farming. To mitigate this, atleast 10mm of rainfall was required for cultural practices like land preparation and sowing. The probability of getting 10mm or more rainfall exceeded 50 per cent for 30 weeks between 16 to 46th week except 25th week. For successful crop production the normal requirement of rainfall was considered as 20 mm/week and 50mm/week in particular for rice crops. The probability of receiving 20 mm rainfall per week with more than 50 per cent were between 38 to 45th week (for 8 weeks) respectively. When the probability was fixed as 50 mm of rainfall with more than 50 per cent was achieved during 44th week (Table 2). After the onset of monsoon, 22nd standard week (June 2) can be considered for final land preparation and sowing of kharif crops. Maize can be sown in between 18 to 20th standard week with low risk, as rainfall of 10 mm or more exceeds 50 per cent probability. The conditional probability of getting 10 mm rainfall with above 50 per cent was received during 16-48th week and it was essential for cultural operations like ploughing, land preparation, weeding, etc. For successful crop production, 20mm of rainfall was necessary. In this region, 20mm of rainfall was occurred during 27-46th week (02 Jul – 18 Nov). The samba rice was predominantly sown during June month in this region. The probability of getting 50mm of rainfall with above 50 per cent was intermittent during 32-45th week (Aug- Nov) is used for recharging the ground water and rain water harvesting in ponds.

Crop Planning

Farmers in this area cultivate rice more than any other crop. However, some farmers cultivate sugarcane and bananas as wetland crops, which require a lot of water and should be replaced with crops that use less water, such as maize, cumbu, sorghum, pulses, ragi, and other small millets, as well as vegetable crops like onion, chilli, and tomato. The current cropping pattern has to be changed in order to lessen the monsoon anomaly. Farmers can grow green gram, black gram, horse gram, cowpea, maize, and minor millets such as finger millet, foxtail millet, proso millet, and others are drought resistant and may be grown with little soil moisture suitable for weather prevailed by switching from a double crop of rice to a single crop area and soon after the harvest of rice crop. In this area, it is best to intercrop or combine maize with other crops including cowpeas, green gram, and black gram. To increase plant population from 50 to 60 hills per m^2, paddy can be replanted with 3–4 seedlings per hill. Pruning and thinning of paddy seedlings may be helpful for improved germination and the best plant stand. Therefore, the cropping method, including the variety, should be changed. To lower risks in food production in this area, cropping patterns, crop choices, cultivars, and management techniques need to be reviewed. Growing crops that require no more than 13 or 14 weeks of crop length is advised because all agriculture depends on rainfall patterns (Sagar *et al.,* 2022).

CONCLUSION

Agriculture is the most climate-sensitive sector, with temperature and rainfall variations having a direct impact. The main cropping season in this region is from June to November for single crop rice and June to February for double crop rice, which coincides with the Southwest and Northeast monsoon seasons. Dry spells may occur during the cropping period, affecting crop growth and maturity stages by shortening the growing period. According to the findings, farmers can grow short-season crops such as pulses, sorghum, maize, and millets during the summer to produce a high yield while using less water and surviving drought conditions.As a result, in the face of significant climate variability, crops like maize, pulses and millets production and consumption need to be encouraged.

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Table 1. Monthly Mean rainfall (mm), Maximum and Minimum rainfall (mm) along with Standard Deviation and Coefficient of Variation (%) in Theni district

Month	Mean Rainfall (mm)	Standard Deviation	Coefficient of Variation (%)	Maximum (mm)	Minimum (mm)
January	13.9	14.8	106.6	63.8	0
February	14.1	18.0	127.1	70.2	0
March	38.6	54.1	140.0	309.6	3
April	75.6	47.9	63.3	219.7	16.8
May	98.0	45.7	46.7	216.9	0
June	80.4	51.5	64.0	216.3	0
July	108.4	78.0	72.0	275.7	0
August	142.0	111.1	78.3	476.2	0
September	135.2	86.4	63.9	322.8	0
October	191.8	92.6	48.3	367.4	0.0
November	147.9	109.4	74.0	360.0	0
December	54.2	54.8	101.0	223.4	0

Table 2. Initial and Conditional probability (%) of receiving weekly 10, 20 and 50 mm of rainfall in Theni district

Week	Mean Rainfall (mm)	CV (%)	Initial Probability (%)			Conditional Probability (%)		
			10mm	20mm	50mm	10mm	20mm	50mm
15	16.7	147.6	38.5	25.6	7.7	40.0	25.0	0.0
16	21.8	102.4	56.4	43.6	10.3	60.0	60.0	33.3
17	21.5	68.6	76.9	43.6	2.6	77.3	58.8	0.0
18	27.0	79.9	79.5	51.3	12.8	76.7	35.3	0.0
19	23.9	99.1	71.8	38.5	10.3	74.2	40.0	20.0
20	20.9	97.0	61.5	43.6	10.3	60.7	40.0	25.0
21	17.7	96.9	56.4	38.5	7.7	70.8	47.1	0.0
22	21.0	85.4	61.5	38.5	7.7	68.2	40.0	0.0
23	20.1	101.0	61.5	33.3	7.7	66.7	46.7	33.3
24	22.8	114.2	59.0	38.5	12.8	75.0	46.2	0.0

25	14.4	100.7	48.7	30.8	0.0	65.2	40.0	0.0
26	15.1	107.7	51.3	30.8	5.1	57.9	33.3	0.0
27	23.1	126.3	51.3	33.3	12.8	60.0	58.3	0.0
28	25.7	104.0	59.0	51.3	12.8	75.0	69.2	20.0
29	28.0	105.7	66.7	53.9	15.4	87.0	75.0	20.0
30	25.1	111.7	56.4	46.2	20.5	73.1	66.7	16.7
31	30.5	123.0	53.9	46.2	25.6	63.6	72.2	37.5
32	33.9	95.6	66.7	51.3	33.3	85.7	72.2	70.0
33	32.2	129.7	66.7	43.6	23.1	69.2	55.0	46.2
34	33.6	106.9	69.2	48.7	30.8	76.9	58.8	66.7
35	26.7	108.1	66.7	46.2	18.0	77.8	73.7	25.0
36	26.7	113.7	56.4	46.2	20.5	65.4	72.2	57.1
37	26.3	144.1	56.4	41.0	18.0	63.6	55.6	25.0
38	32.5	97.9	69.2	61.5	23.1	86.4	75.0	57.1
39	40.1	88.7	74.4	66.7	33.3	88.9	83.3	66.7
40	42.1	89.8	74.4	66.7	35.9	86.2	84.6	61.5
41	39.9	83.9	79.5	64.1	30.8	89.7	65.4	35.7
42	44.5	90.8	74.4	64.1	46.2	80.7	80.0	58.3
43	44.9	96.9	76.9	66.7	33.3	82.8	80.0	55.6
44	51.7	90.8	69.2	64.1	51.3	76.7	73.1	61.5
45	47.0	114.3	71.8	61.5	38.5	85.2	76.0	50.0
46	31.2	146.6	56.4	43.6	20.5	71.4	50.0	33.3
47	27.4	165.3	38.5	33.3	20.5	50.0	47.1	25.0
48	19.4	142.6	48.7	38.5	10.3	73.3	61.5	12.5
49	20.9	163.8	41.0	28.2	12.8	47.4	40.0	0.0

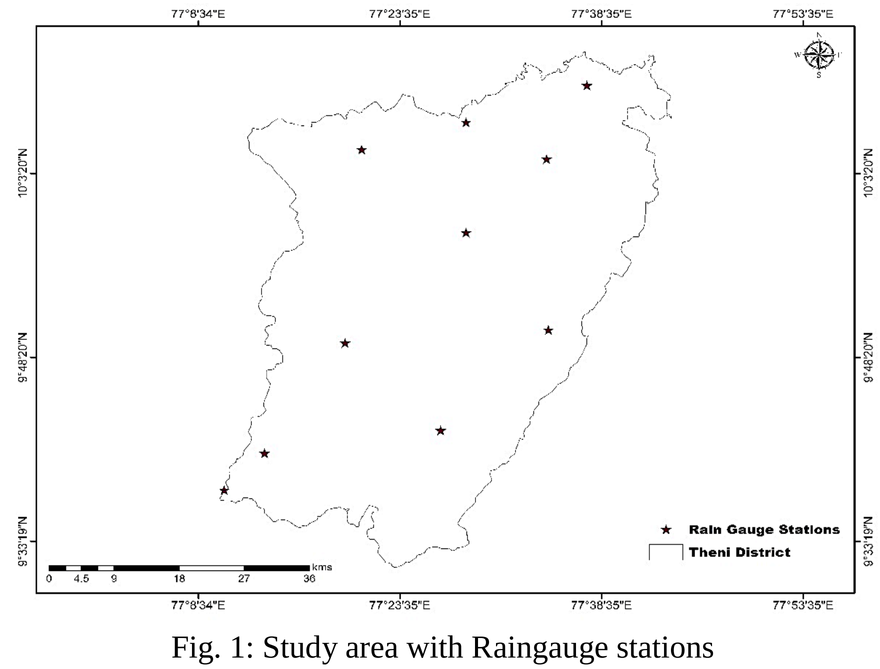

Fig. 1: Study area with Raingauge stations

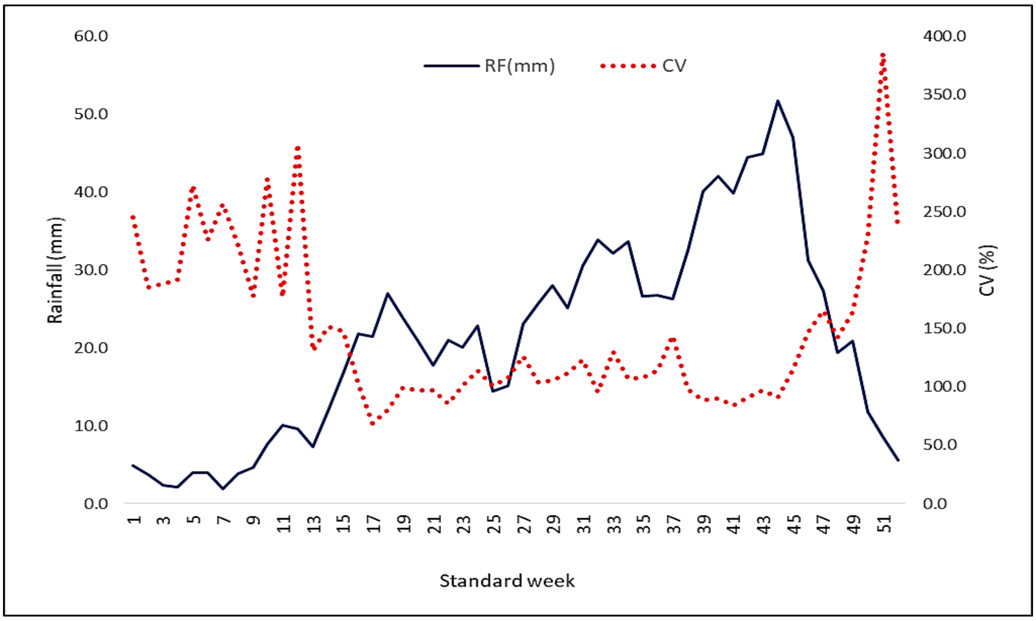

Fig. 2. Variation in mean weekly rainfall (mm) and Coefficient of Variation (%)