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Stochastic Modelling in Yearly Rainfall at Tirunelveli District, Tamil Nadu, India[1]

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Abstract

Rainfall is natural phenomenon and major component of the water cycle and is responsible for depositing most of the fresh water on the earth. Several methods have been proposed by various researchers for modelling rainfall data. This paper deals with the variations of annual rainfall in Tirunelveli based on stochastic method. The study is investigate the changes in rainfall model in present, past form the chronological rainfall chain used to calculate the rainfall amount for successive years in future using the stochastic model in the Tirunelveli district, Tamil Nadu. The data collected from the 24 rain fall station situated the study area for the period of 44 years among 1971 to 2015. Stochastic modelling method predicts the future rainfall in 2025. The main intention of the current study is to explain the make use of first order Markov chain modelling for annual basis of rainfall measurement of Tirunelveli District.

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Keywords: First order Markov chain, Annual rainfall, Rainfall prediction, Frequency distribution, Transition probability matrix.;

1. Introduction

Rain is a major component of the water cycle and is responsible for depositing most of the fresh water on the

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Earth through the hydrologic cycle process in environment. Rainfall is the main source of irrigation water in the southeast part of Tamilnadu. The amount of rainfall level is varying in time to time which are influenced by climatic situation of the local area. The average of annual rainfall is 752 mm in Tirunelveli District. The estimated rainfall in the year 2016 to 2025 is 193 mm to 1115 mm. Further estimated rainfall, 932 mm to 1115 mm is estimated probably in the year 2025. The rainfall model has been predicted from the 1971 to 2015 rainfall data using stochastic methods and be able to provide reliable result.

The transition probability matrix method preserves most of the characteristics of daily, monthly and annual characteristics shown to be the best performing model. Prediction the rainfall process have performed by amount of current months, Markov chain models are frequently propose to quickly obtain forecasts of the weather state at some future time using information given by the current state. The Markov chain method used to predict the precipitation on short period, the prediction performance of Markov chain model is related with the forecasting steps, little steps constantly receiving good performance. In this study, the Markov chain method was applied successfully to drawn the following process in prediction of rainfall probability.

2. Historical rainfall states and Study Area

Tirunelveli district is located in the southern part of Tamil Nadu. Tirunelveli district covers an area of 6,823 Km^2. It lies between 8°05' and 9°30' north latitude and 77°05' and 78°25' east longitude. The study area contains mountains and low land plains, including sandy soil and fertile alluvium and a variety of flora, fauna and protected wildlife, study area also has inland and mountainous forests.

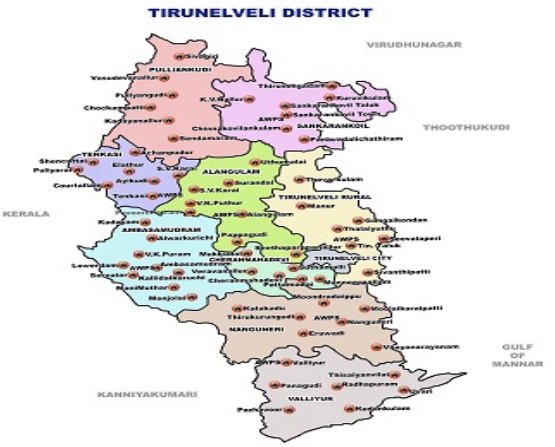

Fig. 1. Map of Tirunelveli district in Tamil Nadu showing 24 rainfall regions

The area is said to be the only to have all five types of ecological zones, hilly, forest, flat fertile land, seashore and dry dessert lands. Tirunelveli has rainfall in all seasons (953.1 mm in 2005 and 2006), and benefits from both the northeast and southwest monsoons. Most precipitation came from the northeast monsoon (548.7 mm) followed by the southwest monsoon (147.8 mm) and summer rains (184.2 mm). The district is irrigated by several rivers originating in the Western Ghats, such as the Pachiyar River which flows into the perennial Thamirabarani River. The Thamirabarani River provides consistent irrigation to a large agricultural area. The climate of study area is generally hot and humid. The average temperature during summer season ranges from 25 ^{o}C (77 ^{o}F) to 41 ^{o}C (106 ^{o}F) and 18 ^{o}C (64 ^{o}F) to 29 ^{o}C (84 ^{o}F) during the rest of the year. The average annual rainfall is 680 mm. Maximum precipitation occurs during northeast monsoon.

3. Materials and Methods

Historical rainfall data and climate data existed only at sparsely located weather stations with in the study area. The rainfall data were collected form 24 rainfall stations of Indian meteorological department, located across the area in Tirunelveli district. Meteorological data were collected yearly rainfall for year 1971 to 2015. Exposure data were linked with rainfall stations assigning it to 1 of 24 weather regions that have been delineated in Tirunelveli District in shown in Figure 1. The 24 rainfall region are Tirunelveli, Sanakarankovil, Sivagiri, Tenkasi,

Ambasamudram, Palayamkottai, Naguneri, Radhapuram, Ayikudi, Shencottai, Gadana dam, Manimuthar dam, Cheranmadevi, Karuppanathi, Kannadian dam, Nilaparai, Alangulam, Algiapandiapuram, Panagudi, Eruvadi, Vijayanarayanam, kalakkadu, Palavoor and Moolakaraipatti. The method used for data analysis in this study include Markov chain model. Stochastic model is used to analysis the long time series of rainfall data. This is a time series analysis of rainfall data. Time series analysis randomly distributed sample data for forecasting the future trends of variables of the sample area, the first order Markov chain model was used generate the sequence of rainfall occurrence using the method of transitional probability matrices while yearly rainfall amount was generated probability rainfall. In the study, transition matrix and Markov chain model were introduced to derive the rainfall changes and also forecast the probability of rainfall level in future.

4. Result and Discussions

The average rainfall for a specific month is the average of 44 monthly values for the period 1971 to 2015. The calculation requires the existence of all the monthly rainfall data. Since rainfall is highly variable from month to month.

4.1. Average Annual Rainfall (AAR)

Average annual rainfall is calculated from the rainfall data set 1971 to 2015 in 24 rainfall stations. The average annual rainfall is given by,

(1)

where MRf is sum of a monthly rainfall and NM is number of months.

Table 1: Average Annual Rainfall in Tirunelveli, 1971 – 2016

S. No	Name of Rain gauge station in Tirunelveli	Average Annual Rainfall 1971 -2016	Average Annual Rainfall states 1971-2016
1.	Tirunelveli	51.32	B
2.	Sanakarankovil	54.31	B
3.	Sivagiri	69.06	C
4.	Tenkasi	58.49	C
5.	Ambasamudram	84.16	D
6.	Palayamkottai	59.98	C
7.	Naguneri	57.19	C
8.	Radhapuram	53.24	B
9.	Ayikudi	60.14	C
10.	Shencottai	119.95	F
11.	Gadana dam	92.38	E
12.	Manimuthar dam	104.01	E
13.	Cheranmadevi	52.41	B
14.	Karuppanathi	44.51	B
15.	Kannadian dam	74.33	D
16.	Nilaparai	46.56	B
17.	Alangulam	32.44	A
18.	Algiapandiapuram	19.35	A
19.	Panagudi	78.36	D
20.	Eruvadi	24.62	A
21.	Vijayanarayanam	38.18	B
22.	Kalakkadu	34.35	A
23.	Palavoor	21.22	A
24.	Moolakaraipatti	32.95	A

4.2. Class Interval

Average annual rainfall value is calculated in equation (2), the number of class interval for the rainfall stations was calculated by substituting the value N, as class interval K is 5.5.

(2)

Where *K* is number of class interval and *N* is total number of rainfall station.

Class interval (K) = 5.5.

4.3. Range in Rainfall Frequency

The range in rainfall frequency was calculated by given equation (3).

(3)

where minimum value is 19.35, maximum value is 119.95 and class interval (k) value is 5.5.

frequency (f) = 18.35.

4.4. Frequency Distribution of Average Annual Rainfall

The frequency distribution of average annual rainfall data between the period 1971 to 2015, adding the minimum value and class interval. Similarly other annual average rainfall values are calculated up to the last value by using the maximum value. The state A, B, C, D, E, F and G are given for the range of class interval of rainfall. The frequencies for each class interval are calculated and shown in Table 2. It is shown that highest rainfall amount is 111.56 mm to 129.85 mm is having frequency value is 1 and is mention state G. The smallest amount of rain fall 19.35 mm to 37.64 mm is having frequency value is 6 and is mention state A.

Table 1. Frequency distribution of Average Annual Rainfall 1971 to 2015

Class Interval of Rainfall (mm)	States	Frequency
19.35 – 37.64	A	6
37.65 – 55.94	B	7
55.95 – 74.24	C	5
74.25 – 93.25	D	3
93.26 – 111.55	E	2
111.56 – 129.85	F	1

4.5. Markov Chain Model

A Markov chain named after Andrey Markov is a random process that undergoes transitions from one state to another on a state space. The stochastic process is called a Markov chain, if, for the outcomes are called the states of the Markov chain, if has the outcome , the process is said to be state *j* at n^{th} trial. To a pair of states (j, k) at the two successive trials say, n^{th} and $(n+1)^{th}$ trials. The transition probabilities are basic to the structure of the Markov chain.

The transition probability may or may not be dependent of n. If the transition probability is independent of n, the markov chain is said to be homogeneous. If it is dependent on n, the chain is said to be non-homogeneous. Here we shall confine to homogeneous chains. The transition probability refers to the states *(k, k)* at two successive trials; the transition is one-step and is called one step transition probability. In the more general case, we are concerned with the pair of states *(j, k)* at two non-successive trials, state *j* at the n^{th} trial and state *k* at the $(n+m)^{th}$ trial. The corresponding transition probability is the called *m*-step transition probability and is denoted by. The structure of transition probability matrix is

$$P_{n,\,n+1} = \quad P_{n,\,n+1} =$$

$P_{n,\ n+1} =$ $P_{n,\ n+1} =$

In the above transition probability matrix, the probability of rainfall of states i at time *(n)* and the state *j* at time *(n+1)* can be estimated using the equation given below.

(4)

where is state of average annual rainfall, *i* is row value and *j* is column value.

The is the rainfall frequency of transition probability from the state row i and state j and *C* is the maximum number of state. The state of rainfall at *i* and *j* up to state *n*, the probabilities are validated probability accurately between zero to one, it is represented as, $0 < < 1$ where *i, j* is state *1, 2, 3,….,C*. Successive multiplications of state in all elements $(P_{n,\ n+1})$ of matrix performed by itself until complete transition probabilities for given time series using markov chain model. The relative transition probability values in row *i* and column *j* at the state *k* are useful to calculate the cumulative probability (P_{ik}) with the following formula expressed as. The relative probability parameters within the cumulative probability transition matrix are complied with the definition, in that the value of each row ends with 1. Hence, cumulative summation of values within each row leads to generate the synthetic series of rainfall in states between the ranges of uniform random number (0 to 1) with the help of random number generator.

(5)

4.6. Variation of Average Annual Rainfall

Average annual rainfall for 44 years was derived from the long time rainfall data of all rain gauge stations and the rate of annual changes was interpolated in figure 2. In the middle of the period of 2016 to 2025, the locations of rainfall namely received highest and least amount of rainfall **(A)** kalakkadu, Palavoor, Moolakaraipatti, Eruvadi, Algiapandiapuram, Alangulam, Naguneri, Ayikudi and Panagudi. **(B)** Sanakarankovil, Radhapuram, Tirunelveli, Cheranmahadevi, Karuppanathi, Nilaparai, Vijayanarayanam. **(C)** Sivagiri, Tenkasi, Palayamkottai. **(D)** Ambasamudram and Kannadian dam. **(E)** Manimuthar dam and Gadana dam. The result of transition matrix was produced cumulative probability rainfall for each state and the uniform random numbers were derived between the range of 0 and 1 using random number generator. The cumulative probability values are segmented to different classes according to the derived random uniform numbers within the random number range and the states are assigned to corresponding random uniform number, then rainfall probability values each year was assumed range of class interval of annual rainfall. Hence, the synthetic series of random rainfall pattern composed by both uniform random number and state (shown in Table 3). The series of uniform random numbers are represented by subsequent years in future and the rainfall patterns of these years are predicted form the corresponding state's frequency annual rainfall which is given in (Table 1). The uniform random numbers, states with its rainfall frequency are represented in (Table 4). From the table, the random numbers denoted state A for 2016 and 2017 and the predicted that the range of rainfall frequency is 19.35 – 37.64. The random numbers denoted state B for 2019 and the predicted that the range of rainfall frequency is 37.65 – 55.94. The random numbers denoted state C for 2021, 2023, 2024 and 2025 the predicted that the range of rainfall frequency is 55.95 – 74.24. The random numbers denoted state D for 2020 and the predicted that the range of rainfall frequency is 74.25 – 93.25. The random numbers denoted state E for 2022 and the predicted that the range of rainfall frequency is 93.26 – 111.55

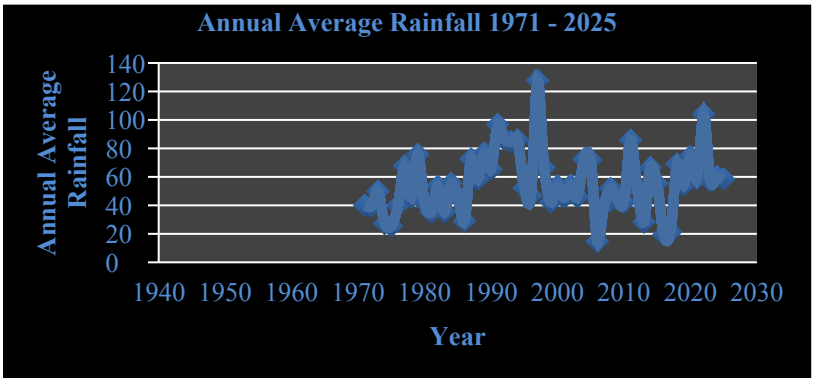

Fig. 2. Annual Average Rainfall 1971 – 2025

Table 2. Rainfall Level Prediction for Future

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Uniform Random Numbers	0.17	0.29	0.54	0.33	0.70	0.55	0.97	0.52	0.57	0.60
State	A	A	C	B	D	C	E	C	C	C
Probability Rainfall (mm)	19.35 – 37.64	19.35 – 37.64	55.95 – 74.24	37.65 – 55.94	74.25 – 93.25	55.95 – 93.25	93.26 – 111.55	55.95 – 74.24	55.95 – 74.24	55.95 – 74.24

5. Conclusion

This study has examined the relative efficiency of the use of rainfall amount in the determination of generated rainfall at Tirunelveli district. The transition probability matrix represents the rainfall model in which the trend of the following year is estimated. The analysis of extreme yearly rainfall shows that markov chain approach provides one alternative of modelling future variation in rainfall. Markov modelling is one of the tools that can be utilized to assist the planners in assessing the rainfall.

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