Modelling rainfall in different rainy Nakshatras: A Markov chain approach

Article · June 2019

CITATIONS
0

READS
37

5 authors, including:

Chandrashekhar Panchhayya Swami
Tuljaram Chaturchand College, Baramati
2 PUBLICATIONS **1** CITATION

Modelling rainfall in different rainy Nakshatras: A Markov chain approach

Pratiksha Shinde*, Vikas Kakade**, Chandrashekhar Swami**, Namrata Patil**, Trupti Doshi**,
Kantar, Mumbai, India

***Department of Statistics, Tuljaram Chaturchand College, Baramati, India*

Abstract

For studying rainfall the pattern of rainfall is more important than the total amount of rainfall within the entire period of time. Almost all the studies related to monsoon rainfall variations are based on monthly, seasonal or annual scale whereas our study attempts to use a smaller period of time scale based on rainy Nakshatras, which have an average period of 13-14 days. In this study, we consider the data for two dam regions (Bhatghar, Veer) and two non-dam regions (Baramati, Wadgaon). In this article, we study is there association in rainfall and the rainy Nakshatra to assess the time variability of rainfall using Markov chain approach and predict the rainfall for the few upcoming years. It is observed that, the analysis based on rainy Nakshatra gives fruitful results for the study of pattern of rainfall.

***Key words*:** Decadal fluctuations, Markovian property, Rainy Nakshatra, Stationary distribution, Transition probability matrices.

1. Introduction

India has a huge population of over 1.26 billion people. 60% of all the farms presently depend upon the rainfall for irrigation. Shimola K. and Krishnaveni M. (2014) have derived from the rainfall records (1935-2010) for various stations. The annual rainfall of the basin during 75 years of study shows a decrease in number of rainy days is observed in most of the stations. Rajendran V, Venkatasubramani R and Vijayakumar G (2016) carried out the frequency analysis of rainy days and studied the rainfall variation. Rainfall in much of the country is, on the other hand, often erratic and unreliable and rainfall variability and associated droughts have historically been major causes of food shortages and famine

Several researchers have shown that there is no significant trend in the all India rainfall. Also in these studies, they have not shown that their predictions are fruitful for farmers. The rainfall is predicted by the elderly people with their traditional knowledge about association in the rainy nakshatras.

In this article, we study is there association in rainfall and the rainy nakshatra to assess its time variability using Markov chain approach and predict the rainfall for the few upcoming years. The agricultural operations in the earlier years are mainly dependent on the seasons and nakshatra period. Farmers plan their agricultural activities as

per rainy nakshatras. India has a long tradition of using Panchang (Almanac). According to our ancestors out of twenty-seven nakshatras eleven nakshatras are affecting the cause of rainfall. These eleven nakshatras are Mruga, Ardra, Punarvasu, Pushya, Ashlesha, Magha, Purva, Uttara, Hasta, Chitra and Swati consecutively. Hence, we called these nakshatras as rainy nakshatras. These nakshatra are having a mean period of 13 or 14 days. U.S. DE, U. R. Joshi and G. S. Prakasa Rao (2004) have done Nakshatra based rainfall climatology for the entire maharashtra by dividing it into sub divisions.

In this study, we have considered the daily rainfall data for 39 years (1979 to 2017) from two dam regions (Bhatghar, Veer) and two non-dam regions (Baramati, Wadgaon) in Maharashtra. From the descriptive statistics the coefficient of variations for rainfall in each nakshatra were obtained for each region to check their consistencies. To identify the decadal fluctuations, the decadal descriptive statistics were calculated. The Nakshatra wise rainfall are categorized into 3 states low, medium and high and satisfied Markovian property. Transition probability matrices (tpm) are calculated for each Nakshatra in all stations and the stationary distributions are computed. From the tpm, we observe that in Bhatghar area the probabilities of the rainfall transiting from medium state to high state is noticeably increasing in the Nakshatra Ardra, Punarvasu, Pushya, Ashlesha, Uttara and Hasta respectively and similarly conclusion for the other three regions can be drawn. We observe in Pushya Nakshatra at dam region and Hasta Nakshatra at non-dam region rainfall can be found consistently in a good amount, so the farmers can plan their harvests accordingly. Simulation was done for the next decade and the rainfall in the rainy nakshatras was predicted.

Vivek Kumar Garg and Jai Bhagwan Singh (2010) studied the pattern of rainfall at Pantnagar for daily rainfall data of 42 years (1961-2002) using a three-state Markov chain model. They divided each year into three periods and calculated transition probability matrices for seasons of dry, wet and rainy for each of the period.

2. Materials and Methods

For the study, the data was being recorded at the irrigation department, Baramati. The data is classified into eleven rainy nakshatra discussed in Section-1. The coefficient of variations for rainfall in each nakshatra was obtained for each region to check their consistencies. Transition probability matrices (tpm) are calculated for each Nakshatra in all stations and the stationary distributions are computed.

For the transition probability matrix random variable is defined as

X_n: the amount of rainfall in n^{th} year

We classified the rainfall into 3 states as low=0, medium=1 and high=2 where 0, 1 and 2 are defined as,

0: Total amount of rainfall between 0 mm to 34.99mm,

1: Total amount of rainfall between 35.00 mm to 70.99 mm and

2: Total amount of rainfall between 71.00 mm and above

We compute the transition probability matrix to each nakshatras and verified the Markovian property. The next step after this was evaluating the order of the Markov chains. After this we calculated stationary distributions with the help of transition probability matrix to find the long run proportion of the Markov chain being in any state. The irreducibility and aperiodicity of the Markov chain was verified to check if their stationary distributions are unique. These related things are discussed in the next section.

2.1 Markovian Property

In this section, we test the sequence of the level of rainfall in each rainy nakshatras follows the Markovian property. We developed macro in R software using the Package "markovchain" for testing Markovian property. We observe that, all the sequence of the level of rainfall in all eleven nakshatras from all the stations follows the Markovian property.

2.2 Estimated Transition Probability Matrices for each Nakshatra

In this section, we propose the estimated transition probability matrices for all the nakshatras corresponding to each station using the method of maximum likelihood estimation. The transition probability matrices for the Bhatghar region are as follows:

Table-1: Transition Probability Matrix of Nakshatra

Pushya			
	0	1	2
0	0.000	0.000	1.000
1	0.333	0.000	0.666
2	0.062	0.093	0.843

Ashlesha			
	0	1	2
0	0.000	0.000	1.000
1	0.000	0.200	0.800
2	0.062	0.125	0.812

Uttara			
	0	1	2
0	0.500	0.071	0.428
1	0.000	0.200	0.800
2	0.368	0.157	0.473

Hasta			
	0	1	2
0	0.272	0.090	0.636
1	0.000	0.400	0.600
2	0.318	0.136	0.545

From these tpm, it is observed that in Bhatghar region the probability of rainfall transiting from medium to high level are increasing with magnitudes 0.545 for Ardra, 0.6 for Punarvasu, 0.84 for Pushya, 0.81 for Ashlesha , 0.47 for Uttara and 0.54 for Hasta nakshatra.

The remaining transition probability matrices for the other nakshatra are prepared for the other three stations.

A three-state Markov chain was employed by M.A. Raheem,W.B. Yahya, K.O. Obisesan. (2015) to examine the pattern and distribution of daily rainfall in Uyo metropolis of Nigeria using 15 years (1995-2009) rainfall data obtained from University of Uyo meteorological centre. A day was regarded as a dry day if the rainfall was not more than 2.50mm, as a wet day if the rainfall was between 2.51mm to 5.00mm and as a rainy day if rainfall was above 5.00mm. Based on the three conditions of rainfall (dry, wet and rainy) and the statistical techniques were applied and the expected length (duration) of dry, wet and rainy days were observed.

2.3 Testing Irreducibility and Aperiodicity of Markov Chain

As per theory, if the transition probability matrix is irreducible as well as aperiodic then we can say that the corresponding sequence have the unique stationary distribution. Stationarity is the long run proportion of the Markov chain which remains in the same state after a long period of time. We developed macro in R software for testing Irreducibility and Aperiodicity of Markov chain.

Table-2: Test of Irreducibility and Aperiodicity of Markov chain for various Nakshatras in four regions

Sr.No.	Nakshatras	Bhatghar		Veer		Wadgaon		Baramati	
		Irreducibility	Period	Irreducibility	Period	Irreducibility	Period	Irreducibility	Period
1	Mruga	True	1	True	1	True	1	True	1
2	Ardra	True	1	True	1	True	1	True	1
3	Punarvasu	True	1	True	1	True	1	True	1
4	Pushya	True	1	True	1	True	1	True	1
5	Ashlesha	True	1	True	1	True	1	True	1
6	Magha	True	1	True	1	True	1	True	1
7	Purva	True	1	True	1	True	1	True	1
8	Uttara	True	1	True	1	True	1	True	1
9	Hasta	True	1	True	1	True	1	True	1
10	Chitra	True	1	True	1	True	1	True	1
11	Swati	True	1	True	1	True	1	True	1

In the given sequence, transition probability matrix corresponding to each sequence of nakshatra is irreducible and aperiodic. From the table, it is observed that the each sequence of nakshatra has a unique stationary distribution.

The transition probability matrices corresponding to each sequence of nakshatra are irreducible and aperiodic.

2.4 Transition probability matrices for consecutive nakshatras

In this section, we propose the transition probability matrices for consecutive nakshatras. We denote

notations: 0: (0-34.99mm) 1: (35-70.99mm) 2: (71-1000mm)

	Ardra		
	0	1	2
Mruga			
0	0.200	0.200	0.600
1	0.428	0.142	0.428
2	0.136	0.227	0.636

The transition probability matrices for consecutive nakshatras are as follows:

	Punarvasu		
	0	1	2
Ardra			
0	0.125	0.25	0.625
1	0.375	0.125	0.125
2	0.043	0.217	0.739

	Pushya		
	0	1	2
Punarvasu			
0	0.000	0.000	1.000
1	0.125	0.125	0.750
2	0.076	0.076	0.846

	Ashlesha		
	0	1	2
Pushya			
0	0.333	0.000	0.666
1	0.000	0.000	1.000
2	0.030	0.151	0.818

	Magha		
	0	1	2
Ashlesha			
0	0.000	0.500	0.500
1	0.400	0.000	0.600
2	0.156	0.250	0.593

	Purva		
	0	1	2
Magha			
0	0.142	0.428	0.428
1	0.222	0.333	0.444
2	0.391	0.086	0.521

	Uttara		
	0	1	2
Purva			
0	0.25	0.25	0.5
1	0.25	0.125	0.625
2	0.473	0.052	0.473

	Hasta			
Uttara		0	1	2
	0	0.214	0.071	0.714
	1	0.4	0.2	0.4
	2	0.3	0.2	0.5

From these tpm, we obtain the dependent probabilities of occurrence of rainfall. For instance consider the 1st tpm 0.136 is the probability that if in Mruga nakshatra the rainfall lies between 71-1000mm, then in Ardra nakshatra it will occur in the range 0-34.99mm. Similarly, for the remaining probabilities.

2.5 Stationary Distribution for consecutive nakshatras:

In this section, we propose the analyze the stationary distribution in the following table:

Table-3: Stationary Distribution for consecutive nakshatras

Consecutive pairs	**Bhatghar**		
	0	1	2
Mruga- Ardra	0.333	0.333	0.333
Ardra- Punarvasu	0.362	0.215	0.421
Punarvasu- Pushya	0.333	0.333	0.333
Pushya- Ashlesha	0.333	0.333	0.333
Ashlesha- Magha	0.333	0.333	0.333
Magha- Purva	0.333	0.333	0.333
Purva- Uttara	0.25	0.354	0.395
Uttara- Hasta	0.333	0.333	0.333

0: low state ; 1:medium state; 2: high state

Stationary distributions give the long run proportions of the Markov chain being in any state initially. So we consider the pair of Ardra- Punarvasunakshatra, 0.362 is the proportion that the Markov chain will stay in low state (i.e. for 36 out of 100 time periods), similarly 0.215 is the proportion that it will stay in medium state (i.e. for 21 out of 100 time periods) and so on. The stationary distributions for the consecutive rainy nakshatras give the long run proportions of the Markov chain being in any state. The simulation study for the prediction of rainfall is discussed in the next section.

3. Simulation of total rainfall data for the next ten years

Prediction of rainfall for next 10 years

We developed macro using the package “markovchain” in R software to prediction of rainfall for the next ten years. Simulation technique may be used in stochastic experiment and also in other areas in significant uncertainties. We used simulation techniques to generate the pseudo random numbers (ex. Prediction).

Table-4: Simulation of total rainfall data for the next ten years for Bhatghar station

BHATGHAR	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Mruga	H	H	H	M	M	H	L	L	L	H
Ardra	H	H	H	H	L	L	M	H	L	H
Punarvasu	H	M	H	H	L	H	M	H	H	H
Pushya	H	H	H	H	M	H	H	H	H	H
Ashlesha	H	H	M	H	H	H	L	H	H	H
Magha	H	H	M	H	H	H	L	H	L	H
Purva	L	M	L	H	L	L	L	M	L	H
Uttara	H	H	M	H	L	L	L	M	H	H
Hasta	L	L	H	H	L	H	H	H	H	H
Chitra	L	M	L	L	H	H	M	L	L	L
Swati	L	M	L	L	L	L	L	M	L	L

H: high M: medium L: low

4. Results and Discussion:

- The highest average rainfall is 221.1mm in Pushya nakshatra at Bhatghar, 81.474mm in Hasta nakshatra at Veer, 86.11mm and 108.77mm in Uttaranakshatra at Wadgaon and Baramati respectively. The least standard deviations are being observed in Swati nakshatra for all the stations.

- At Bhatghar in Pushya nakshatra the highest average rainfall is 221.1mm, 81.474mm in Hasta nakshatra at Veer, 86.11mm and 108.77mm in Uttara nakshatra at Wadgaon and Baramati respectively. The least standard deviations are being observed in Swati nakshatra for all the stations.

- MMaximum rainfall at Bhatgharis 963mm in 2007,at Veer it is 415mm in 2007, at Wadgaon it is 411mm in 1979 and at Baramati it is 835mm in 2014.

- AAt Veer region Purva to Chitra nakshatra shows more consistency in the rainfall, for Wadgaon Uttara and Hasta are consistent and similarly Purva, Uttara and Chitra are consistent for Baramati region.

- At Bhatghar in the first decade the average rainfall is maximum between the nakshatras Ardra to Purva while for the next three decades the highest average rainfall is in Uttara nakshatra.

- For Veer area in the first decade the average rainfall is maximum in Pushya nakshatra, whereas for the other three decades the average rainfall is found to be almost constant in all the nakshatras.

- For Wadgaon region the average rainfall increases and decreases sharply first in Mruga to Punarvasu and again in Pushya to Maghain the first decade. There is no such sharp variation in the average rainfall for the next three decades.

- In the Baramati region the average maximum rainfall is highest in the Pushya nakshatra then it goes down decreasing gradually. For the fourth most decade the average rainfall increases sharply to maximum in Magha nakshatra. For the middle two decades there is no such distinct fluctuation.

- From the transition probability matrix of rainfall for each nakshatra we observe that,
  - In Bhatghar region rainfall transiting from medium to high level is increasing with probability 0.5454 for Ardra, 0.6 for Punarvasu, 0.84 for Pushya, 0.81 for Ashlesha , 0.47 for Uttara and 0.54 for Hasta nakshtra.
  - In Veer region rainfall level transiting from low to medium state probability is decreasing while from medium to high increases for Mruga, Ardra, Punarvasu, Pushya and Ashlesha.
  - In Wadgaon region, the probability of rainfall transiting from medium to high state is increasing for Mruga, Pushya, Purva and Uttara.
  - In Baramatiregion, the probability of rainfall transiting from medium state to high state is increasing for Punarvasu, Pushya, Ashlesha, Magha, Purva, Uttara, Hasta and Chitra.

- By simulating method the prediction of the future occurrences of rainfall nakshatras wise may be possible.

5. References

1. U.S. DE, U. R. Joshi and G. S. Prakasa Rao.(2004): Nakshatra based rainfall climatology, *MAUSAM*, 55, 305-312.

2. Vivek Kumar Garg and Jai Bhagwan Singh (2010): Three – State Markov Chain Approach On the Behavior of Rainfall, *New York Science Journal*, 3(12), 76-81.
   *

3. Shimola K. and Krishnaveni M. (2014): A Study on Rainfall variability and its pattern in Semi Arid Basin, Tamil Nadu, India, *Disaster Advances*, 7(5),65-75.

4. M.A. Raheem,W.B. Yahya, K.O. Obisesan (2015): A Markov Chain Approach On Pattern Of Rainfall Distribution, *Journal of Environmental Statistics*, 7(1),1-13.

5. Rajendran V, Venkatasubramani R and Vijayakumar G (2016): Rainfall variation and frequency analysis study in Dharmapuri district (India). Indian J. Geo. Mar. Sci. 45(11) 1560-5.