Dry and wet spell probability by Markov chain model- a case study of North Lakhimpur (Assam), India

Parmendra Prasad Dabral*, Kuntal Purkayastha, Mai Aram

(*Department of Agricultural Engineering, North Eastern Regional Institute of Science & Technology* (*Deemed University*), *Nirjuli* (*Itanagar*)*-791109, Arunachal Pradesh, India*)

Abstract: For the purpose of crop planning and to carry out the agricultural practices, it is important to know the sequence of dry and wet periods. The present study was undertaken with the objectives to forecast dry and wet spell analysis using Markov chain model and also to find out the exact time of onset and termination of monsoon at study area for North Lakhimpur (Assam), India using weekly rainfall data for a period of 24 years. The results indicated that probability of occurrence of dry week is higher from week 1st to 14th and also from week 41st to 52nd. The range of probability of occurrence of dry week in these weeks varies from 41.67% to 100%. Probability of occurrence of wet week is higher from week 17th to 40th. The range of probability of wet week in these weeks varies from 66.67% to 100%. Week 1st to 4th and 43rd to 52nd of the year remains under stress on an average, as there are 50% to 95.83% chances of occurrence of two consecutive dry weeks. The analysis showed that monsoon starts effectively from week 23rd (4th June to 10th June) in North Lakhimpur. The week 25th (18th June to 24th June) is ideal time for initiation of wet land preparation for growing short duration rice variety. Pre-monsoon effectively starts from week 14th (2nd April to 8th April). On week 14th sowing of summer maize (rain fed) may be done. Week 15th (9th April to 15th April) is ideal time for initiation of wet land preparation for growing long duration rice variety.

Keywords: forecast, probability, dry and wet spell, Markov chain model, onset and withdrawal of monsoon

DOI: 10.3965/j.ijabe.20140706.002

Citation: Dabral P P, Purkayastha K, Aram M. Dry and wet spell probability by Markov chain model- a case study of North Lakhimpur (Assam), India. Int J Agric & Biol Eng, 2014; 7(6): 8－13.

1 Introduction

It is an established fact that the crop development will be affected if the dry spells coincide with the sensitive phonological stage of the crop. On the other hand, dry periods at the ripening stage of the crop are sometimes beneficial. Hence, for the purpose of crop planning and to carry out the agricultural practices, it is important to know the sequence of dry and wet periods[1]. Design of earthen dams and other soil conservation structures also necessitates the probability analysis of occurrence of wet and dry spells.

The Markov chain model is based on the transitional probability describing a situation that changes between two stages. The first stage occurs at time *t*-1 and the second stage takes place at time *t*. In other words, the current probability of certain state depends on the probability of the immediate preceding state only[2]. The Markov chain model has been extensively used to study spell distribution and other properties of rainfall occurrence[3], long term frequency behaviour of wet and dry weather[4] as well as for computation of probability of occurrence of daily precipitation[5]. Pandarinath[1] used the Markov chain model to study the probability of dry and wet spells in terms of the shortest period like week.

The date of onset of effective monsoon is the vital rainfall characteristics influencing rain fed farming.

Received date: 2014-03-18 **Accepted date:** 2014-11-07

Biographies: **Kuntal Purkayastha**, Bachelor of Technology, majoring in soil and water engineering; **Mai Aram,** Bachelor of Technology, majoring in soil and water engineering.

***Corresponding author: P. P. Dabral**, Ph.D., Professor, majoring in soil and water engineering. Mailing address: Department of Agricultural Engineering., NERIST, Nirjuli-791109, India. Email: ppdabral1962@gmail.com. Tel: +91-9436257602.

Agriculture operation in India starts with the onset of south-west monsoon. It is essential to forecast that of onset of effective monsoon since a slight delay in sowing of rain fed crops may adversely affect the next crop too. Generally, farmers opt for planting or broadcasting their seeds when a certain amount of rainfall has sufficiently moistened the top soil. If for a longer period, the weekly rainfall is summed forward or backward from the peak of dry season until certain amount is accumulated, then the probability of having received given amount of rainfall can be obtained for each time interval chosen. However, 75 mm accumulation of rainfall has been considered as the onset time for sowing of rain fed crop, and 200 mm accumulated rainfall for initiation of rice and for initiation of puddling time for wet land preparation of rice fields. Similarly, the end of wet season is determined by backward summing of rainfall data. It is considered that 500 and 300 mm accumulated rainfall values represent the week after which sufficient rain would be expected to sustain a second rice crop after monsoon crop assuming a fully charged soil profile at planting[6].

Saxena and Tiwari[7], Agnihotri[8], Rath et al.[9], Singh and Bhandari[10], Panigrahi and Panda[11], Jat et al.[12], Dabral and Jhajharia[13], Dingre[14] and Subash et al.[15] had carried out analysis on dry and wet spell probability using Markov chain model and onset/withdrawal of monsoon and pre-monsoon for different agro-climatological zone of India. For tropical humid region of India, study carried out by Dabral and Jhajharia[13] is only study available on these aspects. Since, no systematic information is available about dry/wet spell analysis and regarding onset/withdrawal of monsoon for north Lakhimpur (Assam) in India the present study was undertaken with the following objectives:

1) To find out the initial and transitional probability of dry and wet spell weeks and also the probability of two and three consecutive dry and wet spell weeks using Markov chain model.

2) To find out the exact time of onset and termination of monsoon at study area.

2 Methods and material

2.1 Study area

Lakhimpur is an administrative district in the state of Assam in India. The district headquarters are located at North Lakhimpur. The district is bounded by Siang and Papumpare districts of Arunachal Pradesh (India) and on east by Demaji district and Subansiri River. It comes under tropical humid region of northeast India. Average rainfall is 5 043 mm of the said area. Over the year, temperature and relative humidity varies 10 to 32℃ and 70% to 93%. Main water resources of the north Lakhimpur are shallow/deep tube wells, water harvesting ponds and discharge from small streams.

Daily rainfall data recorded at the Regional Agricultural Research Station (Assam Agricultural University), North Lakhimpur (Assam) in India (27°19′N latitude, 97°07′E longitude and 102 m above mean sea level) for a period of 24 years (1981-2004) have been used in this analysis (Figure 1).

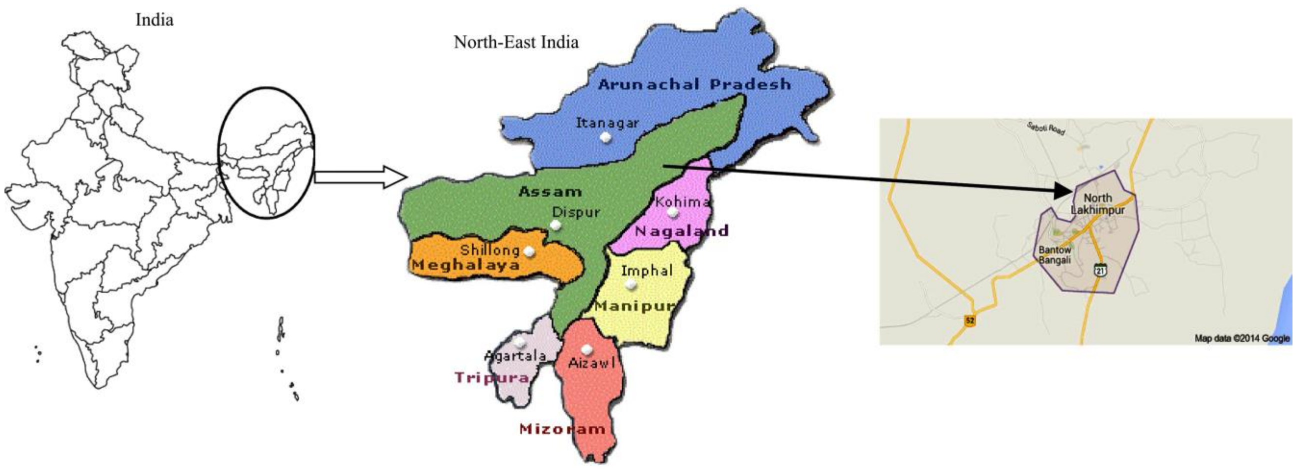

Figure 1 Location map of the study area

The daily data, in a particular year, have been converted to weekly data. Maximum, minimum, mean, standard deviation and coefficient of variation values of weekly rainfall are given in Figure 2.

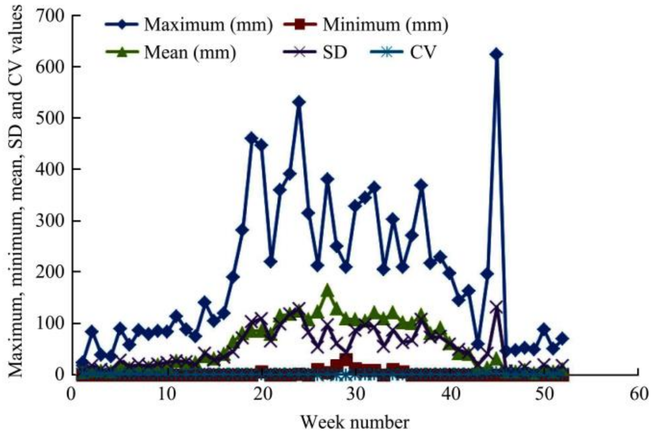

Figure 2 Maximum, minimum, mean, standard deviation and coefficient of variation values of weekly rainfall of North Lakhimpur, Assam, India (1981-2004)

2.2 Forecasting of dry and wet spells using Markov chain model

The concept of estimating probabilities with respect to a given amount of rainfall is extremely useful for agricultural planning. In a crop growing season, many times decisions have to be taken based on the probability of receiving certain amount of rainfall during a given week [$P(W)$], which are called "initial probabilities". Then the probability of rain next week, if we had rain this week [$P(W/W)$] etc. are very important and are called "conditional probabilities". These initial and conditional probability becomes the basis for the analysis of rainfall using Markov chain process.

The following definitions have been employed:

1) A day receiving at least 2.5 mm or more rainfall from 08:30 to 08:30 IST the next day is defined as a wet day. Otherwise, the day is counted as a dry day (Agarwal et al.[16]).

2) A week is wet if it receives 20 mm or more rainfall, otherwise dry (Pandarinath[1]).

The initial probability of a week being dry is defined by:

$$P(D) = F(D)/N \tag{1}$$

where, $P(D)$ is probability of the week being dry; $F(D)$ is frequency of dry weeks; N is the total number of years of data being used.

Thus initial probability of the week being wet is given as:

$$P(W) = F(W)/N \tag{2}$$

where, $P(W)$ is probability of the week being wet; $F(W)$ is frequency of dry weeks.

The transitional probability of week being dry preceded by another dry week is:

$$P(D/D) = \mathrm{F}(DD)/F(D) \tag{3}$$

where, $P(D/D)$ is probability of the week being dry preceded by another dry week; $F(D/D)$ is frequency of dry weeks preceded by another dry week.

The transitional probability of week being wet preceded by another wet week is:

$$P(W/W) = F(WW)/F(W) \tag{4}$$

where, $P(W/W)$ is probability of the week being wet preceded by another wet week; $F(WW)$ is frequency of wet weeks preceded by another wet week; $F(W)$ is frequency of wet weeks.

The transitional probability of week being dry preceded by another wet week is:

$$P(D/W) = 1 - P(W/W) \tag{5}$$

The transitional probability of week being wet preceded by another dry week is:

$$P(W/D) = 1 - P(D/D) \tag{6}$$

where, $P(D/W)$ is probability of week being dry preceded by another wet week; $P(W/D)$ is probability of week being wet preceded by another dry week.

The consecutive dry probabilities are computed as follow:

$$P(2D) = P(Dw_1) \times P(DDw_2) \tag{7}$$

$$P(3D) = P(Dw_1) \times P(DDw_2) \times P(DDw_3) \tag{8}$$

where, $P(2D)$ is probability of two consecutive dry weeks; $P(Dw_1)$ is probability of the first week being dry; $P(DDw_2)$ is the probability of the 2^{nd} consecutive dry week given the preceding week being dry; $P(3D)$ is the probability of three consecutive dry weeks; $P(DDw_3)$ is probability of 3^{rd} week being dry given that preceding week dry.

The consecutive wet probabilities are computed as follow:

$$P(2W) = P(Ww_1) \times P(WWw_2) \tag{9}$$

$$P(3W) = P(Ww_1) \times P(WWw_2) \times P(WWw_3) \tag{10}$$

where, $P(2W)$ is probability of two consecutive wet weeks; $P(Ww_1)$ is probability of the first week being wet and $P(WWw_2)$ is the probability of the 2^{nd} consecutive wet week given the preceding week being wet; $P(3W)$ is the probability of three consecutive wet weeks; $P(WWw_3)$ is probability of 3rd week being wet given that preceding week wet.

2.3 Time for onset and termination of monsoon

In the present study onset of rainy season was computed from weekly rainfall data. A 75 mm accumulated of rainfall (forward accumulation starting from week 22nd) is considered the time for onset of monsoon and 200 mm accumulated rainfall (backward accumulation starting from week 52nd) is considered the time for termination of monsoon. For the calculation of forward as well as backward accumulation the weekly rainfall are arranged in columns and the years are arranged in rows. In this method, weekly rainfall was summed by forward accumulation of (22+23+24+…+52 weeks) until a certain amount of rainfall i.e 75 mm is accumulated. Backward accumulation of rainfall (52+51+…+41 weeks) was used for termination or withdrawal of rainy season. Accumulation of 200 mm rainfall was chosen for the termination of rainy season. For each year, the week number, and the forward and backward accumulated rainfall (actual) were noted as per case and assigned with rank number. The probability of each rank is calculated by the Weibull's formula:

$$P = \{M/(N+1)\} \times 100$$

where, P is probability; M is rank number; N is the number of years observation.

For finding out the onset of pre monsoon, 75 mm accumulation of rainfall (starting from week 9th) is considered in this study. For finding out the probability, Weibull's method has been used.

3 Results and discussion

3.1 Weekly dry and wet spells

3.1.1 Initial and transitional dry and wet week probability analysis

Probability of occurrence of dry week is higher from week 1st to 14th, and also from week 41st to 52nd (Figure 3). The range of probability of occurrence of dry week in these weeks varies from 41.67% to 100%. The probability of occurrence of dry week preceded by another dry week is higher from week 1st to 18th and also from week 40th to 52nd. The range of probability of occurrence of dry week in these weeks is varying from 33.33% to 95.83%. Probability of occurrence of dry week preceded by wet week is 100% for week 1st, 3rd, 4th and 44th to 51st excluding 50th weeks.

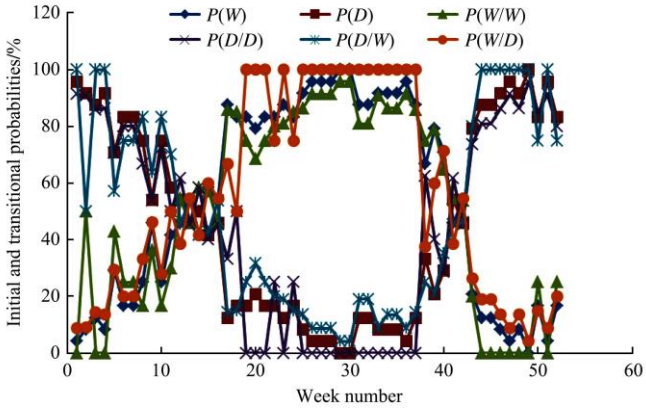

Figure 3 Initial and transitional probabilities of dry and wet week for North Lakhimpur, Assam, India

Probability of occurrence of wet week is higher from week 17th to 40th. The range of probability of wet week varies from 66.67% to 100%. The probability of occurrence of wet week preceded by another wet week is higher from week 17th to 40th. The probability of occurrence of wet week in these weeks ranged from 64.71% to 95.83%. Probability of wet week preceded by dry week is higher in week 15th, 17th, and 19th to 40th. The range of probability of occurrence of wet week in these weeks varies from 60% to 100% (Figure 3).

3.1.2 Consecutive dry and wet week probability analysis

The analysis of consecutive dry and wet spells (Figure 4) reveals that there is 20.83% to 95.83% probability that two consecutive dry weeks will occur from week 1st to 14th and 43rd to 52nd. Similarly, the probability of occurrence of three consecutive dry weeks is very low varying from 0 to 31.94% in most of the weeks.

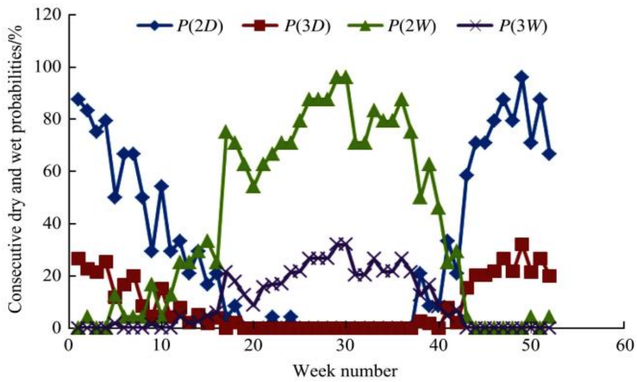

Figure 4 Consecutive dry and wet week probability analysis for North Lakhimpur, Assam, India

Consecutive probability of two wet weeks is varying from 25% to 95.83% for week 12nd to 42nd. Consecutive probability of three wet weeks is varying from 1.79% to 31.94% for week 5th to 42nd. The study reveals that week 1st to 4th and 43rd to 52nd of the year remain under stress on an average as there are 50% to 95.83% chances of occurrence of two consecutive dry weeks.

The results reported above are different from Dabral and Jhajharia[13] who had carried out the similar study for tropical humid climate of the northeast India at Doimukh (Itanagar), Arunachal Pradesh, India.

3.2 Analysis of forward and backward accumulation of rainfall for determining the onset and termination of monsoon

3.2.1 Forward and backward accumulation (starting from week 22nd) of rainfall

The results of forward and backward accumulation starting from week 22nd of rainfall reveals that there is 96% chance of getting 75 mm cumulative rainfall in week 23rd (4th June to 10th June), considering forward accumulation of rainfall into account. Similarly, the results of backward accumulation starting from week 52nd of rainfall reveals that there is 96% chance of getting 200 mm cumulative rainfall in week 42nd (15th October to 21st October) (Table 1). The results reported above are similar as Dabral and Jhajharia[13].

The analysis reveals that monsoon starts effectively, from week 23rd (4th June to 10th June) in North Lakhimpur, Assam (India) and remains active up to week 42nd (15th October to 21st October). One can therefore, accept good monsoon shower for about 19 weeks in the region. The week 25th (18th June to 24th June) is ideal time for initiation of wet land preparation of rice field for short duration rice variety. This short duration rice can be harvested before the monsoon terminates from the region and so the chances of reduction of the yield of rice due to water stress will be low. Moreover, the residual soil moisture after the harvest of rice can be utilized for raising another short duration crop in winter.

Table 1 Probability of having 75 mm cumulative rainfall (Forward accumulation from 22nd week) and 200, 300 and 500 mm cumulative rainfall (Backward accumulation from 52nd week)

Forward accumulation (From 22nd week)				Backward accumulation (From 52nd week)					
# 75 mm (OEM)	Probability (%)	+ 200 mm	Probability (%)	*200 mm (TEM)	Probability (%)	** 300 mm	Probability (%)	** 500 mm	Probability (%)
22nd week	92.00	22nd week	66.67	39th week	88.00	36th week	66.67	34th week	60.00
23rd week	96.00	23rd week	83.33	41st week	92.00	37th week	75.00	36th week	64.00
		24th week	91.67	42nd week	96.00	38th week	83.33	37th week	68.00
		25th week	95.83			39th week	91.67	38th week	76.00

Note: # 75 mm accumulation of rainfall is considered as the onset time of sowing of rainfed crop.
+ 200 mm accumulated rainfall for initiation of puddling time of wet land preparation of rice field.
*200 mm accumulated rainfall (Back ward accumulation starting from 52nd week) is the time for termination of monsoon.
** It is considered that 500 and 300 mm accumulated rainfall values represents the week after which sufficient rain would be expected to sustain a second rice crop after monsoon crop assuming fully charged soil at planting.

3.2.2 Forward accumulation of rainfall

The results of forward accumulation (starting from week 9th) of rainfall show that there is 97.67% chance of getting 75 mm cumulative rainfall in week 14th (2nd April to 8th April) and also 92% chance of getting 200 mm cumulative rainfall in week 15th (9th April to 15th April) (Table 2). The results reported above are different from Dabral and Jhajharia[13]. Results reveal that pre-monsoon effectively starts from week 14th (2nd April to 8th April). On week 14th, the sowing of summer maize (rainfed) may be done. Week 15th is the ideal time for initiation of wet land preparation of rice field for long duration rice variety.

Table 2 Probability of having 75 and 200 mm cumulative rainfall (forward accumulation from 9th week)

Forward Accumulation from the 9th week			
75 mm (OEM)	Probability/%	200 mm	Probability/%
13th week	83.33	14th week	68.00
14th week	97.67	15th week	92.00

4 Conclusions

Probability of occurrence of two consecutive dry weeks from 22nd October to 1st December and 1st January to 28th January varies from 50% to 95.83%. Probability of occurrence of dry week from 1st January to 8th April varies from 41.67% to 100%. Therefore, there is need of supplement irrigation for the major crops grown in the study area from 22nd October to 8th April. Pre monsoon rain also starts in between 9th April to 15th April which is ideal time for sowing maize(rain fed) crop. Period from 9th April to 15th April is ideal time for initiation of wet land preparation for growing long duration rice variety. From 23rd April to 7th October probability of occurrence of wet week varies from 66.67% to 100% during that period supplement irrigation is not required for the crops grown in the study area. Monsoon starts effectively from 4th June to 10th June in the study area. Period of 18th June to 24th June is ideal time for initiation of wet land preparation for growing short duration rice variety. Results obtained in this study will be useful for the farmers/growers of the region for better water management planning.

[References]

[1] Pandarinath N. Markov chain model probability of dry and wet weeks during monsoon period over Andhra Pradesh. Mausam, 1991; 42(4): 393–400.

[2] Gerald E T. Management science: An introduction to modern quantitative analysis and decision making. New York: McGrawHill, 1976.

[3] Gabriel K R, Newmann J A. Markov chain model for daily rainfall occurrence at Tel Aviv. J. R. Met. Soc., 1962; 88: 90–95.

[4] Victor U S, Sastry P S N. Dry spell probability by Markov chain model and its application to crop development stage. Mausam, 1979; 30: 479–484.

[5] Stern R D. Computing a probability distribution for the start of rains from a Markov chain model for precipitation. J. Applied Meteorology, 1982; 21(3): 420–423.

[6] WMO. Technical Note No. 179. 1982, pp 149–158.

[7] Saxena A K, Tiwari K N. Water harvesting ponds- Capacity calculation and design-II. Indian J. Power and River Valley Development, 1988; 38(1/2): 12–16

[8] Agnihotri A. Study on occurrence of wet/dry spells and weather cycles at Chandhigarh using Markov chain model. Indian J. Soil Cons., 1993; 21(1): 71–79.

[9] Rath Haripriya, Jena G N, Senapati P C. Forecasting of dry and wet spells at Boudh for agricultural planning. Indian J. Soil Cons., 1996; 24(1): 28–36.

[10] Singh Mohan, Bhandari A R. Wet and dry spells analysis using Markov chain model for mid hill region of Himachal Pradesh. Indian J. Soil Cons., 1998; 26(2): 147–152.

[11] Panigrahi B, Panda S N. Dry spell probability by Markov chain model and its application to crop planning in Kharaghpur. Indian J. Soil Cons., 2002; 30(1): 95–100.

[12] Jat M L, Singh R V, Baslyan J K, Jain L K. Dry and wet spells for agricultural planning at Bhilwara. Indian J. Soil Cons., 2003; 31(3): 291–294.

[13] Dabral P P, Jhajharia D. Dry and wet spell probability by Markov chain model and its application to crop planning in Doimukh (Itanagar), Arunachal Pradesh. J. Soil & Water Conservation, India, 2003; 2(1/2): 32–39.

[14] Dingre S. Markov chain model of probability for dry spell and its application to crop planning in Kashmir valley. J. Soil and Water Conservation, 2007; 6(4): 194–199.

[15] Subash N, Sikka, A K, Haris A. Markov chain approach: dry and wet spell rainfall probabilities for rice-wheat planning. Indian J. Soil Cons., 2009; 37(2): 91–99.

[16] Agarwal A, Singh R V, Chauhan H S. Probability of sequence of wet and dry days in Nainital Tarai region. J. Agril. Engineering (ISAE), 1984; 21(4): 61–70.