Int.J.Curr.Microbiol.App.Sci (2020) *9*(5): 57-66

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 9 Number 5 (2020)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2020.905.005

Weekly Rainfall Analysis by Markov Chain Model in Samastipur District of Bihar, India

Pappu Kumar Paswan[1*], Ved Prakesh Kumar[2], Andhale Anil Nanasaheb[3] and Abhishek Pratap Singh[4]

[1]Krishi Vigyan Kendra, Purnea, Bihar, India
[2]College of Agricultural Engineering, Dr.R.P.C.A.U, Pusa, Samastipur, India
[3]Department of Soil and Water Conservation Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, India

**Corresponding author*

Keywords

Weekly Rainfall, Markov Chain Model, Onset and Withdrawal of Rainfall

Article Info

Accepted:
05 April 2020
Available Online:
10 May 2020

A B S T R A C T

The historical rainfall data for the period of 22 years (19981-2019) of Samastipur district in Bihar were analyzed weekly rainfall data by using Markov chain model and initial and conditional probabilities were estimated for 10 mm and 20 mm rainfall amount. the initial probability of getting 10 mm rainfall during 23th to 42th SMW are more than 60% except 39th,41th and 42th SMW. Conditional probabilities of wet week preceded by another wet week of getting 10 mm rainfall during 23th to 40th SMW were 50% and more. initial probability of getting 20 mm rainfall during 23th to 38th SMW are more than 45% (Table 1.) whereas conditional probability of wet week preceded by another wet week of getting 20 mm rainfall during 23th to 38th SMW were 45% and more except 30th and 35th SMW. consecutive dry and wet week revealed that chances of occurrence of 10 mm and 20 mm 2 consecutive dry weeks are 0-54.55% and 0-59.09% respectively whereas 2 consecutive wet weeks are 0% - 86.36% and 0- 81.82% respectively from 23th to 42nd SMW respectively. The probability of 10 mm and 20 mm, 3 consecutive dry weeks are 0-54.55% and 0-59.09% respectively whereas 3 consecutive wet weeks are 0-72.73% and 0-63.64% respectively from 23rd to 42th SMW respectively

Introduction

Agriculture development in Bihar state is to a large extent dependent of water. A large portion of the water in Bihar state (both surface and ground water) is consumed by the agricultural sector for irrigation. The state has an area of 93.60 Lakh ha, the net area sown is 56.38 lakh ha and gross activated area is 79.46 lakh ha. The net sown area in Bihar is 60% of its geographical area. (Economic-Survey- 2012) Dynamic Ground Water Resources: Annual Replenishable Ground water Resource 29.19 BCM, Net Annual Ground Water Availability 27.42 BCM, Annual Ground Water Draft 10.77 BCM,

Stage of Ground Water Development 39%. The distribution of rainfall is very much erratic and uneven, so flood and droughts are occurring frequently in different regions of the state. Thus, the agricultural production is highly unstable.

Even during monsoon season, the state suffers from simultaneous problems of disposal of surplus water caused by heavy storms in some parts and water deficit due to lack of adequate rainfall in other parts. (Parthasarathy, 2009) The area is situated at the west of the college of Agricultural Engineering, Dr Rajendra Prasad Central Agricultural University, Pusa, Samastipur and falls under the jurisdiction of Gandak Command.

Pusa Farm is situated in Samastipur district of north Bihar on south of river Burhi-Gandak. It has a latitude of 250 29' North and a longitude of 830 48' East at an altitude of 52.92 meter above sea level. Coincidence of dry spells with the sensitive phenological stages of the crop causes damage to the crop development. Hence, simple criteria related to sequential phenomenon like dry and wet spells and prediction of probability of onset and termination of the wet season could be used to obtain specific information needed for crop planning and for canying out agricultural operations (Khichar *et al.*, 1991).

Markov Chain probability model has been extensively used to find the long term frequency behavior of wet and dry weather spells (Victor and Sastry, 1979). Pandarinath (1991) used Markov Chain model to study the probability of dry and wet spells in terms of the shortest period like week.

The yield of crops in rain-fed condition depends on the rainfall pattern. Dry and wet spells could be used for analyzing rainfall data, for crop planning and for carrying out agricultural operations (Sharma *et al.*, (1979).

Materials and Methods

Description of the problem area

The present study is based on a time series daily rainfall data of 22 years (1998-2019) observed at Samastipur located in Bihar State of India. Pusa Farm is situated in Samastipur district of north Bihar on south of river Burhi-Gandak. It has a latitude of 25^{o} 29' North and a longitude of 83^{o} 48' East at an altitude of 52.92 meter above sea level. Samastipur faces adverse climatic conditions in summer months with temperature ranging from 35^{0}C to 40^{0}C.

In the winter months, temperature ranges from 10^{0}C to 12^{0}C. The average rainfall is 1200 mm. various factors such as its proximity to the sea influence the weather of Samastipur. The rainfall in this region mostly starts from 23^{rd} SMW with total duration of 20 weeks till 42^{nd} SMW. Thereafter rainfall amount is meagre for rest of the SMW. Therefore the period from 23^{rd} to 42^{rd} SMW is considered for rainfall analysis.

Onset and withdrawal of rainy season

The onset of rainy season is computed from weekly rainfall data using Morris and Zandestra, (1979) method using of 75 mm accumulation as the threshold (Rath *et al.*, 1996, Panigrahi and Panda, 2002; Jat *et al.*, 2003; Deora, 2005), if any week having nil rainfall then restart accumulation of rainfall from SMW.

The withdrawal of rainy season is determined by backward accumulation of rainfall from 52^{nd} SMW accounting to an amount of 10 mm (Singh and Hazara, 1999; Jat *et al.*, 2005). In the present study backward accumulation of rainfall is considered from 47^{th} SMW instead of 52^{nd} SMW because post monsoon season is not considered for withdrawal of rainy season.

If for a longer period (at least 25 years) the weekly rainfall is summed forward and backward from the peak of dry season, until the certain amount calculated, then the probability of given amount of rainfall can be obtained for each time interval chosen. (Dash and Senapati, 1992). Years with respective weeks of onset and withdrawal of rainy season were assigned with the rank number. The probability of each rank was calculated by the following Weibull's formula.

$$P = \frac{m}{N+1} \qquad \text{..... 1}$$

Where, m is the rank number and N is the number of years. For forward accumulation, the rank order and probability level were arranged in ascending order and the corresponding week numbers were arranged in the same manner. Similarly for backward accumulation the rank order and the probability level were arranged in descending order and the corresponding week numbers were arranged in the same way.

Rainfall probabilities by markov chain model

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)] ; and the probability of next week being wet, if this week is dry [P(W/D)] are very important and are called "Conditional probabilities". Analogously, initial and conditional probabilities for a dry week were defined. These initial and conditional probability approaches would help in determining the relative chance of receiving a given amount of rainfall. This becomes the basis for the analysis of rainfall using Markov Chain model.

Initial probability

The parameters estimated for the analysis were as follows. According to Markov probability model the initial probability is the probability that a particular week of the year is dry or wet under the assumption that the weather of previous week (dry or wet) is not taken into consideration. The initial probability of a week being dry and wet are defined as

$$P_D = F_D/n \qquad \text{.....2}$$
$$P_W = F_W/n \qquad \text{.....3}$$

Where,

P_D = Probability of the week being dry,
P_W = Probability of the week being wet,
F_D = Number of dry weeks,
F_W = Number of wet weeks,
n = Number of years of data

Conditional probabilities

A conditional probability is the probability that a particular week of the year is dry or wet under the assumption that, the weather of the previous week (dry or wet) is taken into consideration. It indicates the probability of changes in weather from one week to the next week. The conditional probability of a week being dry preceded by another dry week is given by

$$P_{DD} = F_{DD}/F_D \text{.....4}$$
$$P_{WW} = F_{WW}/F_W \text{.....5}$$
$$P_{WD} = 1\text{-}P_{DD} \text{.....6}$$
$$P_{DW} = 1\text{-}P_{WW} \text{.....7}$$

Where,

P_{DD} = Probability (conditional) of a dry week preceded by a dry week,
P_{WW} = Probability (conditional) of a dry week preceded by a wet week,
P_{WD} = Probability (conditional) of a wet week preceded by a dry week,

P_{DW} = Probability (conditional) of a dry week preceded by a wet week,
F_{DD} = Number of dry weeks preceded by another dry week
F_{WW} = Number of dry weeks preceded by another wet week,

Consecutive dry and wet week probabilities

$2D = P_{Dw1}.P_{DDw2}$ …….8
$2W = P_{Ww1}.P_{WWw2}$ ……..….9
$3D = P_{Dw1}.P_{DDw2}.P_{DDw3}$ …….10
$3W = P_{Ww1}.P_{WWw2}.P_{WWw3}$ …….11

Where,
2D = Probability of 2 consecutive dry weeks starting with the week,
2W = Probability of 2 consecutive wet weeks starting with the week,
3D = Probability of 3 consecutive dry weeks starting with the week,
3W = Probability of 3 consecutive wet weeks starting with the week,
P_{Dw1} = Probability of the week being dry (first week),
P_{DDw2} = Probability of the second week being dry, given the preceding week dry,
P_{DDw3} = Probability of the third week being dry, given the preceding week dry,
P_{Ww1} = Probability of the week being wet (first week),
P_{WWw2} = Probability of the second week being wet, given the preceding week wet,
P_{WWw3} = Probability of the third week being wet, given the preceding week wet,

Results and Discussion

Estimation of dry and wet weekly probability by using markov chain model

Markov Chain model is used to find out long term frequency behaviour of wet and dry rainfall spells. In the Markov chain model, the probability of an event that would occur on any week depends only on the conditions during the preceding weeks and is dependent of the events of future weeks. Initial probabilities of occurrence of dry weeks during the different stages of crop growth and conditional probabilities (taking into account the sequential events) provide the basic information on rainfall distribution characteristics necessary for agricultural operations such as irrigation scheduling, fertilizer application. The weekly rainfall data of 22 years (1998-2019) were analyzed to find out initial and conditional probabilities of receiving assured rainfall of 10 and 20 mm using Markov chain model (Table 1.).

Results revealed that the initial probability of getting 10 mm rainfall during 23th to 42th SMW are more than 60% except 39th,41th and 42th SMW (Table 1.) whereas conditional probability of wet week preceded by another wet week of getting 10 mm rainfall during 23th to 40th SMW were 50% and more. Conditional probability of dry week preceded by another dry week of getting 10 mm rainfall during 31th to 42th SMW are more than 20% except 32th and 34th SMW.

Conditional probability of dry week preceded by another wet week of getting 10 mm rainfall during 23th to 42th SMW are more than 10% except 32th and 33th SMW. Conditional probabilities of wet week preceded by another dry week of getting 10 mm rainfall during 23th to 40th SMW are more than 50% except 33th SMW.

Results revealed that the initial probability of getting 20 mm rainfall during 23th to 38th SMW are more than 45% (Table 1.) whereas conditional probability of wet week preceded by another wet week of getting 20 mm rainfall during 23th to 38th SMW were 45% and more except 30th and 35th SMW. Conditional probability of dry week preceded by another dry week of getting 20 mm rainfall during 23th to 42th SMW are more than 25%

except 28th,30th and 32th SMW. Conditional probability of dry week preceded by another wet week of getting 20 mm rainfall during 23th to 42th SMW are more than 20% except 32th,33th and 38th SMW. Conditional probability of wet week preceded by another dry week of getting 20 mm rainfall during 23th to 40th SMW are more than 40% except 33th and 37th SMW. The analysis of consecutive dry and wet week revealed that chances of occurrence of 10 mm and 20 mm 2 consecutive dry weeks are 0-54.55% and 0-59.09% respectively whereas 2 consecutive wet weeks are 0% - 86.36% and 0- 81.82% respectively from 23th to 42nd SMW respectively Table (2). The probability of 10 mm and 20 mm, 3 consecutive dry weeks are 0-54.55% and 0-59.09% respectively whereas 3 consecutive wet weeks are 0-72.73% and 0-63.64% respectively from 23rd to 42th SMW respectively. Similar results were obtained by Vanitha and Ravi (2017).

Characteristics of rainy season

Onset, withdrawal and length of rainy season are worked out by forward and backward accumulation of weekly rainfall data.

Table.1 Initial and Conditional Probabilities of rainfall (10 and 20 mm) at Samastipur (1998-2019)

SMW	10 mm					20 mm				
	P(W)	P(D/D)	P(D/W)	P(W/W)	P(W/D)	P(W)	P(D/D)	P(D/W)	P(W/W)	P(W/D)
23	68.18	42.86	26.67	73.33	57.14	50.00	50.00	50.00	50.00	50.00
24	68.18	28.57	33.33	66.67	71.43	45.45	54.55	54.55	45.45	45.50
25	81.82	14.29	20.00	80.00	85.71	72.73	25.00	30.00	70.00	75.00
26	86.36	25.00	11.11	88.89	75.00	63.64	50.00	31.25	68.75	50.00
27	77.27	0.00	26.32	73.68	100.00	72.73	25.00	28.57	71.43	75.00
28	81.82	0.00	23.53	76.47	100.00	72.73	16.67	31.25	68.75	83.30
29	68.18	50.00	27.78	72.22	50.00	63.64	50.00	31.25	68.75	50.00
30	68.18	0.00	46.67	53.33	100.00	63.64	0.00	57.14	42.86	100.00
31	81.82	28.57	13.33	86.67	71.43	59.09	50.00	35.71	64.29	50.00
32	95.45	0.00	5.56	94.44	100.00	90.91	0.00	15.38	84.62	100.00
33	86.36	100.00	9.52	90.48	0.00	81.82	100.00	10.00	90.00	0.00
34	86.36	0.00	15.79	84.21	100.00	72.73	50.00	22.22	77.78	50.00
35	68.18	33.33	31.58	68.42	66.67	45.45	50.00	56.25	43.75	50.00
36	81.82	28.57	13.33	86.67	71.43	45.45	75.00	30.00	70.00	25.00
37	68.18	25.00	33.33	66.67	75.00	50.00	66.67	30.00	70.00	33.30
38	81.82	28.57	13.33	86.67	71.43	77.27	27.27	18.18	81.82	72.70
39	54.55	25.00	50.00	50.00	75.00	36.36	60.00	64.71	35.29	40.00
40	63.64	30.00	41.67	58.33	70.00	31.82	57.14	87.50	12.50	42.90
41	31.82	75.00	64.29	35.71	25.00	13.64	86.67	85.71	14.29	13.30
42	31.82	66.67	71.43	28.57	33.33	27.27	68.42	100.00	0.00	31.60

Table.2 Consecutive Dry and Wet Probability

SMW	Consecutive dry probability (%)				Consecutive wet probability (%)			
	2D		3D		2W		3W	
	10 mm	20 mm	10 mm	20 mm	10 mm	20 Mm	10 mm	20 mm
23	9.09	27.27	1.30	6.82	45.45	22.73	36.36	15.91
24	4.55	13.64	1.14	6.82	54.55	31.82	48.48	21.88
25	4.55	13.64	0.00	3.41	72.73	50.00	53.59	35.71
26	0.00	9.09	0.00	1.52	63.64	45.45	48.66	31.25
27	0.00	4.55	0.00	2.27	59.09	50.00	42.68	34.38
28	9.09	13.64	0.00	0.00	59.09	50.00	31.52	21.43
29	0.00	0.00	0.00	0.00	36.36	27.27	31.52	17.53
30	9.09	18.18	0.00	0.00	59.09	40.91	55.81	34.62
31	0.00	0.00	0.00	0.00	77.27	50.00	69.91	45.00
32	4.55	9.09	0.00	4.55	86.36	81.82	72.73	63.64
33	0.00	9.09	0.00	4.55	72.73	63.64	49.76	27.84
34	4.55	13.64	1.30	10.23	59.09	31.82	51.21	22.27
35	9.09	40.91	2.27	27.27	59.09	31.82	39.39	22.27
36	4.55	36.36	1.30	9.92	54.55	31.82	47.27	26.03
37	9.09	13.64	2.27	8.18	59.09	40.91	29.55	14.44
38	4.55	13.64	1.36	7.79	40.91	27.27	23.86	3.41
39	13.64	36.36	10.23	31.52	31.82	4.55	11.36	0.65
40	27.27	59.09	18.18	40.43	22.73	4.55	6.49	0.00
41	45.45	59.09	36.36	48.01	9.09	0.00	0.00	0.00
42	54.55	59.09	54.55	59.09	0.00	0.00	0.00	0.00

Table.3 Onset and withdrawal of rainy season at Junagadh

Year	Onset	Withdrawal
	75 mm	10 mm
1998	26	46
1999	25	42
2000	21	40
2001	22	43
2002	19	40
2003	23	43
2004	22	38
2005	25	43
2006	23	42
2007	24	45
2008	23	40
2009	19	41
2010	21	42
2011	22	42
2012	26	41
2013	22	41
2014	23	42
2015	21	42
2016	18	40
2017	22	38
2018	20	40
2019	27	50

Table.4 Characteristics of the rainy season at Junagadh

Onset of rainy season (week)		Withdrawal of rainy season (week)		Length of rainy season (week)	
Early	Late	Early	Late	Maximum	Minimum
18	27	38	50	23	15

Table.5 Probability of the onset of rainy season during standard week

SMW	18	19	20	21	22	23	24	25	26	27
Probability of onset of rainy season (%)	9.09	18.18	27.28	36.37	45.46	54.55	63.64	81.82	88.20	90.91

Onset of rainy season

In the beginning of the rainy season, there should be adequate rainfall for land preparation and sowing of crops. The onset of the rainy season is considered as the week by which the rainfall accumulates to 75 mm after 20th week. If any week having nil rainfall than restart accumulation of rainfall.

The standard meteorological week during which rainy season started in respective year is shown in Table 3. Considerable variation in the onset of rainy season occurs during the years. From Table 4, it is evident that early onset of rainy season is at 18th week and maximum delay is up to 27th week. The percentage probabilities for onset of rainy season during different standard meteorological weeks are presented in Table 5. Probability at 25th week is found to be 81.82% which may be supposed as mean standard week of onset of rainy season.

Withdrawal of rainy season

Withdrawal of rainy season is determined by backward accumulation of rainfall from 52th week accounting to an amount of 10 mm rainfall as suggested by Morris and Zandestra, (1979) are presented in Table 3. Table-3 shows the withdrawal of rainy season in different years and Table 2.Shows early and late weeks of withdrawal of rainy season.

From these tables it can be seen that earliest withdrawal of rainy season is in 38th week, late withdrawal of rainy season in 50th week. Probabilities of onset of rainy season are shown in Table 5. Probability in 25th week is found to be 81.25%, which may be considering onset of rainy season.

The results revealed that the determined withdrawal of monsoon is observed in 35 SMW during the year 1987 and 2009, while the crop growth period terminates in 47th SMW considering the observed onset of monsoon (28th SMW) and groundnut crop having maximum length of growing season of 18 weeks.

Therefore, it is observed that rainfall during whole post monsoon season considered for withdrawal of rainy season is not justified. Therefore backward accumulation of rainfall should be considered from 47th SMW rather than 52nd SMW. Similar results were obtained by Singh *et al.*, (2014).

Length of rainy season

The length of rainy season is the period between onset and withdrawal of the rainy season. Length of rainy season for Samastipur shown in Table 4. Minimum length of rainy season is found to be 15 week during 2012 and maximum length of raining season is found 23 weeks in 2019.

The initial and conditional probability of getting 20 mm per week in 25 SMW is 81.82%. Therefore sowing should be carried out in this week.

The probability of two and three consecutive dry weeks having 10 mm per week threshold limit is more than 27% and 54% respectively after 39th SMW. Hence irrigation should be applied to the crops during these periods.

Conditional probability of wet week preceded by wet week having 20 mm threshold limit is more than 60% in 25th to 38th SMW. Therefore it is the optimal time for water harvesting for supplementary irrigation to crops in moisture deficit period.

Minimum length of rainy season is found to be 15 week during 2012 and maximum length of raining season is found 23 weeks in 2019.

Abbreviation and symbol

cm Centimeter
h Hour
m meter
% Percentage
& And
mm millimeter
° Degree
T Return Period
°C Degree Celsius
Mha Million hectares
MCM Million Cubic Meter
SMW Standard Metrological Week
2D Two consecutive dry weeks
2W Two consecutive wet weeks
P(W) Probability of wet weeks
P(D) Probability of dry weeks

Application of research

Weekly rainfall analysis by markov chain model for crop playing in Samastipur district of Bihar

References

Dash, M. K. and Senapati, P. C. (1992). Forecasting of dry and wet spell at Bhubaneswar for Agricultural planning. *Indian Journal of Soil Conservation*, 20(142):75-82

Jat, L, Singh, R. V., Balyan, J. K. and Jain, L. K. (2005). Analysis of Weekly Rainfall for Crop Planning in Udaipur Region, *Journal of Agricultural Engineering*, 42(2): 166-169.

Jat, M. L., Singh, R. V., Kumpawat, B. S. and Balyan, J. K. (2003). Rainy season and its variability for crop planning in Udaipur region. *Journal of Agrometrology*, 5(2):82-86.

Khichar, M. L., Singh, R. and Rao. V. D. M. (1991). Water availability periods for crop planning in Haryana. *International Journal of Tropical Agriculture*, 1(4):301-305.

Morris, R. A. and Zandstra, H. G. (1979). Land and climatic in relation to cropping patterns. In rainfed low land rice, selected papers from 1970. *International Rice Research Conference.IRRI*, 255-274.

Pandatinath, N. (1991). Markov chain model probability of Dry and wet weeks during monsoon periods over Andhra Pradesh. *Mausam*, 42 (4):393-400.

Panigrahi, B. and Panda, S. N. (2002) Analysis of weekly rainfed for crop planning in rainfed region. Journal of Agricultural Engineering, (ISAE), 38(4): 47-57.

Parthasarathy, R. (2009). State level water section interventions - Gujarat State, International Water Management Institute -TATA Water Policy Research Program.

Rath, H., Jena, G. N. and Senapati, P. C. (1996) Forecasting of dry and wet spells at Boudh for agricultural planning. *Indian Journal of Soil Conservation*, 24(1):28-36.

Sharma, H. C., Chauhan, H. S. and Ram, S. (1979). Probability analysis of rainfall for crop planning. *Journal of Agricultural Engineering*, 14: 87-94.

http://finance.bih.nic.in/Budget/Economic-Survey-2012

Singh, R. S., Patel, C.,Yadav, M. K., Singh, P. K. and Singh, K. K. (2014). Weekly Rainfall Analysis and Markov Chain Model Probability of Dry and Wet Weeks at Varanasi in Uttar Pradesh. *Journal of Environment & Ecology*, 32 (3): 885-890,

Vanitha, S. and Ravikumar, V. (2017). Weekly Rainfall Analysis for Crop Planning Using Markov's Chain Model for Kumulur. International *Journal of Agriculture Sciences*, 9(42):4679-4682.

Victor, U. S. and Sastri., P. S. N. (1979). Dry

spell probability by Markov chain model and its application to crop development stages. *Indian Journal of Meteorology, Hydrologyand Geophysics.* 30(4):479-489.

How to cite this article:

Pappu Kumar Paswan, Ved Prakesh Kumar, Andhale Anil Nanasaheb and Abhishek Pratap Singh[4]. 2020. Weekly Rainfall Analysis by Markov Chain Model in Samastipur District of Bihar. *Int.J.Curr.Microbiol.App.Sci.* 9(05): 57-66.
doi: https://doi.org/10.20546/ijcmas.2020.905.005