Original Research Paper

Volume-8 | Issue-9 | September-2018 | PRINT ISSN No 2249-555X

Agricultural Science

MARKOV CHAIN MODEL OF WEEKLY RAINFALL PROBABILITY AND DRY AND WET SPELLS FOR AGRICULTURAL PLANNING IN KANDHAMAL DISTRICT OF ODISHA

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ABSTRACT This study was done at CAET, OUAT, Bhubaneswar during 2018 under post graduation programme to obtain crop planning for Kandhamal district of Odisha, India with its large population is facing unique challenges of water scarcity due to diverse geographical, climatic and geo-environmental conditions apart from unequal spatio-temporal distribution of fresh water resources. Therefore efficient and effective water management strategies are essential for meeting the increasing water needs of agricultural, domestic, industrial and environmental sectors. Considering the current water resources problems and rapid increase in its demand, the importance of effective utilization of water resources cannot be underestimated if India has to remain self-reliant in food production. Agriculture is the major user of water, improving agricultural water management is essential. Generally, yield decreased by 50% due to water stress. Daily rainfall Data of 25 years (1992– 2016) were collected for the study. The dry and wet spell analysis was carried out using weekly rainfall based on Markov Chain Model considering less than 20 mm rainfall in a week as a dry week and 20 mm or more as a wet week. The effective monsoon period districts for Kandhamal are from 24th to 39th SMW. From 75 mm forward accumulation it is concluded that the ploughing operation may be started from 17th SMW and from 200 mm forward accumulation it is concluded that puddling operation may be started from 24th for Kandhamal district. Different SMWs were obtained by using 100 mm, 200 mm, 300 mm, 400 mm and 500 mm from backward accumulation for different districts and crop planning were made accordingly. Also, different SMWs were obtained by using combination of rainfall (100 mm, 200 mm, 300 mm, 400 mm and 500 mm) and irrigation(0, 100 mm, 200 mm, 300 mm, 400 mm and 500 mm) and crop planning were made accordingly.

KEYWORDS :

INTRODUCTION:

Agriculture is the back bone of Indian economy as well as our food and nutritional security. Adverse weather conditions tilt the balance and badly affect the livelihood and food production system. India with its large population is facing unique challenges of water scarcity due to diverse geographical, climatic and geo-environmental conditions apart from unequal spatio-temporal distribution of fresh water resources. Therefore efficient and effective water management strategies are essential for meeting the increasing water needs of agricultural, domestic, industrial and environmental sectors. Considering the current water resources problems and rapid increase in its demand, the importance of effective utilization of water resources cannot be underestimated if India has to remain self-reliant in food production. Agriculture is the major user of water, improving agricultural water management is essential. Generally, yield decreased by 50% due to water stress. The state of Odisha extends from 17.49^0 N latitude to 22.34^0 N latitude and from 81.27^0 E longitudes to 87.29^0 E longitudes. It is, having geographical area of 155.4 lakh hectares, about 63 lakh hectares of land have been put under cultivation. About 60 percent of cultivated area is coming under rainfed and this is also decreasing day by day due to variation in production. The yield of crops particularly in dry land condition depends on the rainfall pattern. Dry spells occur due to inadequate rainfall throughout the rainy season. More than 70 percent of net sown area of India is rain fed.

The yield of crops, particularly in rain fed condition depends on the rainfall pattern. The probable behavior of rainfall was studied by many researchers (Chakravorthy and Mandal, 2008; Jat et al, 2010; Chand et al, 2011; Jakhar et al, 2011; Kumar et al, 2007). The wet and dry spell analysis will help in characterization of command area crop, cropping system planning and design of conservation structures. The concept of probability is usually used to study the dry and wet spells for agricultural planning (Shrivastav et al, 2004). The Markov Chain Model has been used extensively to study the spell distributions and other properties of rain occurrences. The proper understanding and efficient utilization of the natural resources especially rainfall is of great concern for the improvement and sustainability of agriculture in rainfed areas. So, Markov Chain Model has been found suitable to describe the long term frequency behavior of wet or dry spells. The annual and seasonal analysis of rainfall will give general idea about the rainfall pattern of the region, whereas the weekly analysis of rainfall will be of much use as far as agricultural planning is concerned. Markov chain probability model has been used extensively to find the long-term frequency behavior of wet and dry weather spells (Victor and Sastri 1979). Another aspect of crop planning is forward and backward accumulation of rainfall to determine the onset and termination of wet season based on precipitation data. A number of studies have been conducted for location specific agricultural planning in general and crop planning in particular by analyzing daily, weekly, monthly, seasonal and annual rainfall data.

Singh et al (2008) analyzed daily rainfall data of fifty two years (1952-2004 for establishing the long term averages of weekly, monthly, seasonal and annual rainfall and its variability. The annual rainfall at Pusa was 1222.3 mm and coefficient of variability indicated that rainfall was more or less stable over the years. The stable rainfall period was of 9 weeks, which spread over 27 to 37th standard meteorological weeks (SMW) except 32nd and 34th SMW. Summer crops (cowpea, black gram, green gram, maize and direct sown rice etc) could also be grown successfully in this region with supplemental irrigation. Rains at 75% probability level can be utilized for seedbed preparation for raising rice seedlings of short duration (100 days) or direct sown rice. The transplanting of kharif rice in first week of July will have additional advantage of almost assured water supply through rain during August and September. However, wheat can be grown only with assured irrigation during rabi season starting from first week of November. Green gram, Cowpea, black gram could be grown during summer in upland areas. Less water demanding short duration smaller millets (finger millet, fox tail millet, kodon etc) can be raised during summer season. Maize can be sown in the 22nd week with low risk, as rainfall at 50 % probability is 8.8 mm.

Vaidya et al (2008) analyzed the daily rainfall data of different districts of Gujarat to study the rainfall characteristics, onset and withdrawal of monsoon rains and also the duration of getting assured rainfall. The mean annual rainfall analysis on agro-climatic zone basis revealed that the highest rainfall (1651 mm) was received in South Gujarat region while, lowest rainfall (442.3 mm) was observed in North-west zone. The frequency analysis (at ≥50% probability) of weeks getting assured rainfall of either ≥10 mm or ≥20 mm rainfall revealed that in Kutch district there was not a single week while, it was maximum (16 weeks) in Valsad and Dangs districts.

Subash et al (2009) studied Markov chain model to know the initial and conditional probability of having a dry or a wet week and also the occurrence of consecutive dry or wet periods of 2 or 3 weeks for selected stations of Bihar State representing different agro-ecological zones. Average annual rainfall is 1222.4, 1538.0, 1162. 7 and 1134.5 mm were received at Pusa, Purnia, Bhagalpur and Patna districts, respectively. This indicates that among the different zones, zone-II

gets more annual rainfall followed by zone I, but the annual variability is lower for zone-IIIB followed by zone-I. Under the ideal situation, rice crop of medium to long duration transplanted during the end of June will have its flowering period during the middle of September to early October. In lowlands of Zone-II a successful rainfed crop is possible with medium to long duration varieties and timely planting by 26th week.

Chand (2011) analyzed the historical rainfall data for the period of 34 years (1975-2008) of Jhansi in Bundelkhand agro climatic zone of U.P to know weekly, monthly, seasonal and annual probabilities at different levels of rainfall for suitable crop planning. The Kharif season crops and their varieties may be chosen with the growing period to avoid moisture stress as well as In-situ moisture conservation practices like mulching, use of anti- transpirants, control of weeds, adequate plant stands should be adopted and to mitigate the effect of dry spell during critical crop growth stages provide live saving or supplemental irrigation through use of sprinkler system. It is also indicated that the pulses and oilseeds whose average water requirements are 300 mm could successfully be cultivated during rabi season. It is also advisable to plant early short duration, recommended and drought resistant varieties of groundnut, maize, pearl millet and jowar between 25 to 27 SMW while in case of late condition black gram, green gram, sesame, intercropping with pigeon pea should be planted by 29 to 30 SMW .

Dey et al (2011) determined the water deficit pattern in the lower Gangetic plains of West Bengal by taking historical rainfall data for fifteen years from thirty meteorological stations located within the study area. Rainfall data was analyzed for calculation of probability of receiving critical amount of rainfall for rice transplanting. It was observed that an assured amount of 50 mm rainfall can be received in all over the study area in 28th SMW (standard meteorological week). The GIS maps were then prepared showing the variation of water deficit based on 29th, 31st and 33rd SMW as transplanting week. From this GIS maps, high, moderate and low water deficit zones were identified and pertinent zone specific recommendations were prepared. Second fortnight of July is the most suitable time for transplanting rainfed rice.

Oduwole et al (2011) used Markov Chain Model to select the best planting date by avoiding the period of high risk of long dry period near the beginning of the rainy season always experienced in Northern Nigeria. Wet and dry spell were derived from a period of 20 years to predict the length of dry spell and wet spell during the rainy season at Gyawana meteorological station in Yola, North Eastern Nigeria.

Kar et al. (2014) analysed weekly rainfall data of Kandhamal district during the period of 1965 to 2010 was taken for analysis purpose. Monsoon starts effectively from 24th SMW (11 – 17th June) and remains active up to 39th SMW (30th November). Therefore, mean length of rainy season was found to be 15 weeks (105days. It indicates that seedbed preparation and sowing of kharif crops can be initiated in the 11th week. During the winter season (31st week onwards), negligible rainfall is recorded at 0.55 probability level. So the surface soil would become dry with rare chances of getting adequate soil-moisture in the seeding zone. Hence, surface moisture conservation would be essential for germination of seed and plant establishment and, if possible, water harvesting should be done to ensure a pre-sowing irrigation. It was also revealed that the rabi crops have to be raised under moisture stress conditions. The crops should be able to use residual soil profile moisture more judiciously as reliability of getting adequate weekly rainfall is low. If irrigation facilities are available, then early sown varieties may be grown with the application of pre-sowing irrigation.

Ray et al (2018) used Markov chain probability model to calculate the chances of occurrences of dry and wet spells was applied for Mayurbhanj using 20 years (1997 to 2016) weekly rainfall. Monsoon starts on the 24th standard meteorological week (SMW) (11th – 17th June) and remains active up to 43rd SMW 22-28th October) with a total length of 20 weeks (140 days). Initial, conditional and consecutive dry and wet week probabilities showed that chances of occurrence of a week getting wet are high during from 24th week onwards up to 40th week**.** Hence, agricultural operations like planting/sowing can be undertaken successfully during this period with assured irrigation.

Ganjam district is located at 19.35^{0}N 84.98^{0}E, it has an average elevation of. The geographical area of the Ganjam district is 8070.6 sq. km. The population of Ganjam district is 3,520,151. The study was under taken with the objectives

1. To analyze rainfall data for drought forecasting by Markov chain model.
2. To obtain the mean, standard deviation and co-efficient of variation of weekly rainfall

MATERIALS AND METHODS

Daily rainfall data of 25 years were collected from district headquarters. The dry and wet spell analysis was carried out using weekly rainfall based on Markov Chain Model considering less than 20 mm rainfall in a week as a dry week and 20 mm or more as a wet week (Dash and Senapati, 1992; Pandharinath, 1991). Generally, dry spells occur due to inadequate rainfall throughout the rainy season. The evaporative demand of the atmosphere varies from 40 mm per week during the beginning of the season and decreased to 30 mm per week during the active rainy season. A week receiving rainfall of about 20 mm will be able to meet 0.5 to 0.75 times the evaporative demand. Therefore, a week with rainfall less than 20 mm was considered as a dry week. However, during a dry week, the crop may meet its water requirement through the moisture available in the soil. If the rainfall is less than 20 mm per week for two or more consecutive weeks, the crops are likely to be subjected to moisture stress in the absence of adequate stored soil moisture.

The different notations followed in the Markov Chain Analysis are given below:

Initial Probability:

$$P_d = {}^{F_w}/_{n}, P_{w=} {}^{F_w}/_{n}$$

Conditional Probabilities:

$$P_{dd} = {}^{F_{dd}}/_{F_d}, P_{ww} = {}^{F_{ww}}/_{F_w}$$

$$P_{wd} = 1 - P_{dd}, P_{dw} = 1 - P_{ww}$$

Consecutive Dry and Wet Week Probabilities:

$$P_{2d} = P_{d_1} * P_{dd_2}, P_{2w} = P_{w_1} * P_{ww_2}$$

$$P_{3d} = P_{d_1} * P_{dd_2} * P_{dd_3}, P_{3w} = P_{w_1} * P_{ww_2} * P_{ww_3}$$

Where,
Pd is the probability of the period considered being dry.

Pw is the probability of the period considered being wet.
Fd is the number of dry weeks observed.
Fw is the number of wet weeks observed.
n is the number of years of data used.

Pdd is the probability of dry week preceded by another dry week (conditional).

Fdd is the number of dry weeks preceded by another dry week.
Pwd is the probability of wet week preceded by another dry week.
Pdw is the probability of dry week preceded by another wet week.
P2d is the probability of two consecutive dry weeks.
P3d is the probability of three consecutive dry weeks.
P2w is the probability of two consecutive wet weeks.
P3w is the probability of three consecutive wet weeks.
Pd_1 is the probability of the period being dry (1st week).

Pdd_2 is the probability of the second consecutive dry week, given that the preceding week being dry.

Pdd_3 is the probability of the third consecutive dry week, given that the preceding week being dry.

Pw_1 is probability of the period being wet (1st week).

Pww_2 is the probability of the second consecutive wet week, given that the preceding week being wet.

Pww_3 is the probability of the third consecutive wet week, given that the preceding week being wet.

RESULT AND DISCUSSION

Weekly rainfall Data of 25 years (1992– 2016) indicated that the monsoon starts effectively from 23rd SMW and remains active up to

43rd SMW .(Fig 1). Pww is more than 50 % during these weeks. Therefore, mean length of rainy season was found to be 15 weeks (105 days). The winter seasons weeks (between 40th and 52nd) weeks received very less rainfall. It was also observed that within a normal month there were weekly rainfall variations causing temporary dry spells. When these dry spells coincide with the critical stage of crop growth, there will be considerable reduction in the yield of standing field crops. Therefore, appropriate moisture conservation measures such as mulching and water harvesting should be adopted to save crops from damaging action of drought.

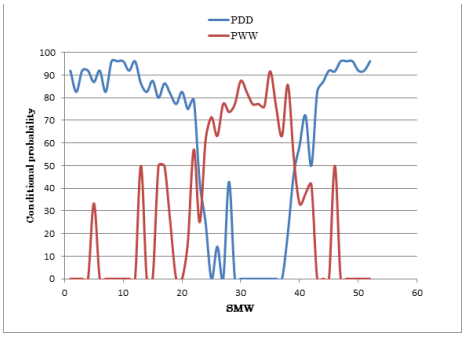

Fig 1 PDD and PDD calculation of Kandhamal district in different weeks and probabilities.

Table 1: SMW of forward and backward accumulation at 70% probability for Kandhamal district

Rank	Forward Accumulatio		Backward Accumulation					Probability
	75 mm	200 mm	100 mm	200 mm	300 mm	400 mm	500 mm	
1	26	29	35	33	32	30	28	3.703704
2	26	27	36	35	32	31	29	7.407407
3	25	27	36	35	33	31	29	11.11111
4	25	27	36	35	33	32	30	14.81481
5	24	27	37	35	33	32	30	18.51852
6	24	27	38	35	34	32	30	22.22222
7	23	26	38	35	35	33	31	25.92593
8	23	25	38	35	35	33	32	29.62963
9	22	25	38	36	35	33	32	33.33333
10	22	25	38	36	35	33	32	37.03704
11	21	25	38	37	35	34	32	40.74074
12	21	25	38	37	36	35	33	44.44444
13	21	25	39	37	36	35	33	48.14815
14	19	25	40	38	36	35	33	51.85185
15	19	25	40	38	36	35	34	55.55556
16	18	24	40	38	36	35	34	59.25926
17	18	24	40	38	37	35	35	62.96296
18	17	24	41	38	37	35	35	66.66667
19	17	24	41	38	37	36	35	70.37037
20	16	24	41	38	37	36	35	74.07407
21	14	24	41	38	37	36	35	77.77778
22	14	23	41	39	38	36	35	81.48148
23	11	22	42	40	38	36	35	85.18519
24	9	19	42	40	38	36	35	88.88889
25	2	19	43	40	39	37	36	92.59259
26	2	17	44	42	39	38	37	96.2963

The 17th week received 75mm of rainfall in 70% probability level and 24th week received 200mm of rainfall which is suitable for puddling operation for paddy and sowing operatuion for other crops.(Table 1)

TABLE 2: Weekly rainfall pattern at Kandhamal district

SMW	Mean	Max	Min	SD	CV
1	2.9	64	0	12.6	439.5
2	6.9	78	0	18.9	274.3
3	2.2	54	0	10.6	478.6
4	3.8	61.4	0	12.4	326.8
5	3.8	37	0	9.4	249.4
6	2.5	35	0	7.3	294.5
7	4.0	27	0	8.0	201.2
8	1.5	13	0	3.8	261.2
9	1.7	16.2	0	4.3	249.1
10	0.1	2.6	0	0.5	509.9
11	2.3	29	0	5.9	262.7
12	0.0	0	0	0.0	-
13	6.1	56	0	14.2	233.0
14	9.4	70	0	18.2	192.9
15	3.7	41	0	9.9	268.2
16	6.5	35	0	11.2	173.4
17	7.2	46.6	0	13.5	188.2
18	8.8	52	0	15.4	176.2
19	14.3	146	0	38.3	267.1
20	11.5	128	0	25.5	221.0
21	13.8	75	0	20.9	152.0
22	9.6	40	0	12.1	126.4
23	25.4	137	0	33.5	131.9
24	54.4	235	0	59.0	108.5
25	57.2	205	0	48.3	84.5
26	57.5	359.6	2	70.4	122.4
27	79.9	429.2	6	87.7	109.7
28	69.5	401.8	0	91.6	131.8
29	93.3	348.8	8	87.6	93.9
30	101.3	573.4	15	118.8	117.3
31	106.1	325.8	0	90.7	85.6
32	82.4	342	1	84.4	102.5
33	87.5	332.4	2	92.3	105.5
34	55.6	222	2	55.4	99.8
35	99.4	361.6	2	84.5	85.0
36	74.5	218.2	0	61.4	82.4
37	58.4	346	0	69.4	118.9
38	68.8	307.6	0	68.5	99.7
39	31.6	133	0	35.7	113.0
40	25.4	153	0	39.4	155.0
41	23.4	114.4	0	35.7	152.3
42	24.3	129	0	34.6	142.5
43	9.7	103.8	0	23.2	238.4
44	5.3	24	0	8.5	159.5
45	2.6	24	0	6.0	233.1
46	2.8	25	0	6.9	244.7
47	0.0	1.2	0	0.2	509.9
48	0.2	5	0	1.0	509.9
49	0.4	8	0	1.6	416.5
50	2.8	54	0	10.7	387.6
51	1.7	40	0	7.8	453.3
52	0.5	8.8	0	1.8	396.8

We are receiving more than 20 mm rainfall from 23rd to 43rd SMW. The weekly rainfall attributes showing mean, maximum, minimum, standard deviation, coefficient of variation and percentage of weekly rainfall contribution towards annual rainfall (Table 2).

The results reveal that, there are total of 14 weeks (23rd to 43rd SMW) where rainfall exceeds more than 20 mm. harvesting excess runoff water for future supplemental irrigations and also drives attention towards soil erosion measures to be taken up for soil erosion control. During rainy season the mean weekly rainfall is found to be more than the weekly contribution of rainfall towards annual average rainfall is found to be highest during 23rd to 43rd SMW.

CONCLUSION

The effective monsoon period districts for Kandhamal are from 24th to 39th SMW. From 75 mm forward accumulation it is concluded that the ploughing operation may be started from 17th SMW and from 200 mm forward accumulation it is concluded that puddling operation may be started from 24th for Kandhamal district. Different SMWs were obtained by using 100 mm, 200 mm, 300 mm, 400 mm and 500 mm from backward accumulation for different districts and crop planning were made accordingly. Also, different SMWs were obtained by using combination of rainfall (100 mm, 200 mm, 300 mm, 400 mm and 500 mm) and irrigation(0, 100 mm, 200 mm, 300 mm, 400 mm and 500 mm) and crop planning were made accordingly.

If drought , flood or cyclone occurs on or before 35th week, the farmers may grow crops or may be given crops like Cauliflower, Radish, Mustard, Coriander, Knol Khol, Green gram, Maize, Black gram, Horse gram, Sesamum from Govt if there is no irrigation in Kandhamla district of Odisha.

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