The Pharma Innovation Journal 2018; 7(10): 635-638

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.03
TPI 2018; 7(10): 635-638

www.thepharmajournal.com
Received: 22-08-2018
Accepted: 23-09-2018

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Crop planning based on rainfall probability in rainfed areas of Khordha district in Odisha

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Abstract
The present study has been undertaken to determine the expected amount of rainfall in Khordha district at different probability levels (90%, 75% and 50%) using Incomplete Gamma Probability distribution in Weather Cock model. Rainfall data of 25 years (1993-2017) of Khordha district has been collected from Special Relief Commissioner (SRC), Govt. of Odisha to estimate annual, seasonal and monthly rainfall probabilities. The analysis of 25 years rainfall data revealed that the annual average rainfall of Khordha district is 1433 mm which is received in 94 rainy days. The average annual predicted rainfall at 90%, 75% and 50% probability levels are 1092.6 mm, 1238.7 mm and 1415.9 mm respectively. 31 SMW has the record of receiving highest amount of rainfall at all the three probability levels. From the onset of monsoon 23-25 SMW district receives a good amount of rainfall and it goes on increasing up to 40 SMW. At 75% of assured probability level monsoon period may receive 516 mm of rainfall and post monsoon period may receive 37.6 mm of rainfall. So, the best suitable crops in medium and lowlands are rice during *kharif* season and pulses like black gram, green gram, soybean, horse gram, rice bean and oil seeds like sesame, mustard can be taken up during *rabi* season.

Keywords: Incomplete gamma probability distribution, SMW, rainfall probability, risk proof crops and cropping sequence

Introduction
Rainfall is of most important concern for crop production and its better yield. Maximum population of Odisha is dependent on agriculture and most of the area is under rainfed agriculture where rainfall is the single most important factor for producing crops. Terminal drought is a recurring feature in Odisha. Intermittent dry spells make the crop operations delayed as 80 percent of the area in this region is under rainfed conditions. The agro ecology of the state is very much vulnerable as the agricultural operations depend upon the moisture availability due to rainfall pattern, amount, intensity and its uses for crop production (Deka and Nath, 2000) [3]. Odisha is always exposed to frequent floods and water logging conditions. Apart from cyclonic winds, heavy rainfall and long tides are experienced mainly during post monsoon period due to low pressure. It causes huge loss to human lives, properties and crop fields as well affecting the food security of the victims. Hence crop planning will certainly reduce the crop loss mainly in the coastal areas. Detailed knowledge of rainfall pattern helps in planning the cultivation of crops, their varieties, adoption of cultural operations, designing of different storage structures (Ray *et al*., 1987) [6] and harvesting of excess rain water of any region (Sinhababu 1977; Budhar *et al.*, 1987 and Kar, 2002) [7, 4, 5] to meet out irrigation requirement during moisture stress period. The distribution of rainfall influences the crop yield rather than the total amount of rainfall as studied by Bhargava *et al.*, 1974 [2]. Therefore, analysis of rainfall and determination of annual maximum daily rainfall would enhance the management of water resources applications as well as the effective utilization of water resources (Subudhi, 2007) [8]. Probability and frequency analysis of rainfall data enables us to determine the expected rainfall at various chances (Bhakar *et al.*, 2008) [1]. Hence, present study has been undertaken to suggest the cropping pattern for Khordha district of Odisha considering the rainfall amount at different probability levels using incomplete gamma probability distribution.

Materials and Methods
Study Area
The study has been conducted for Khordha district of Odisha which lies between $19^0$55' to $20^0$25'N Latitude and $84^0$55' to $86^0$5'E Longitude for estimating the expected amount of

rainfall at different probability levels. Khordha has normal rainfall of 1408 mm with maximum and minimum temperature of 42.2 and 11.1 degree Celsius respectively. The district comprises of 10 blocks namely Balianta, Balipatna, Banapur, Begunia. Bhubaneswar, Bolagarh, Chilika, Jatani, Khordha & Tangi. All the weather data including maximum temperature (T_{max}), minimum temperature (T_{min}), morning and evening relative humidity (RH_1, RH_2), bright sunshine hours (BSH), wind speed (WS) and evaporation (E) has been collected from the Department of Agricultural Meteorology, OUAT, BBSR for the period 1993-2017 (25 years). Block wise rainfall data of Khordha has been obtained from SRC site of Govt. of Odisha for the same period.

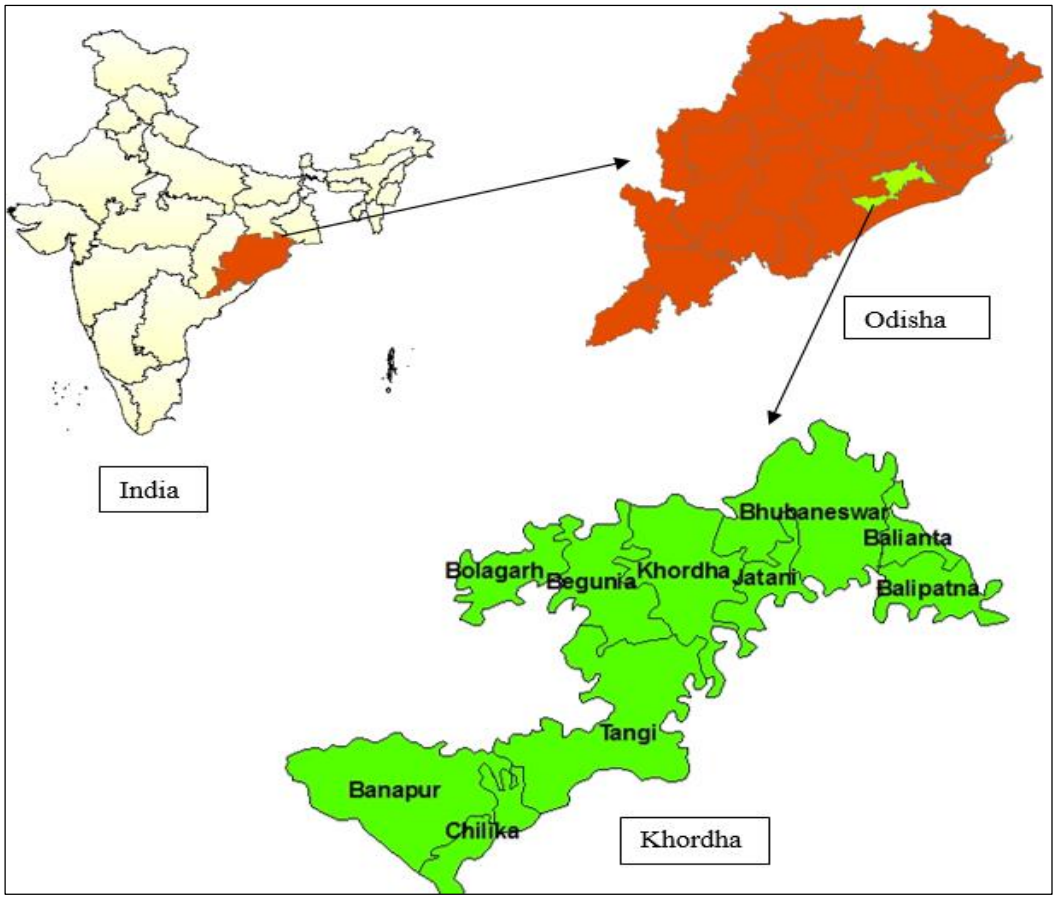

Fig 1: District Map- Khordha

Rainfall Probability

The probability analysis of rainfall helps to determine the expected amount of rainfall at different levels (50%, 75%, 90%). Twenty five years of rainfall data has been collected from Special Relief Commissioner (SRC), Govt. of Odisha to determine the weekly, monthly and seasonal rainfall probability. It is estimated using WEATHER COCK software which is developed by CRIDA, Hyderabad for weather data analysis.

Some attention is needed to be given before going for weather data analysis by using Weather Cock software which is as follows.

1. NEVER rename the Weather Cock folder.
2. All Data files should be either created in Notepad or as. csv file (comma separated values) of excel.
3. Kindly examine the data file structure in the SAMPLE DATA folder for any analysis before creating the new data file.
4. While analysing data with. csv file if any error occurs then open the. csv file in Notepad and delete all the last commas in every data line.
5. Data for every day Date structure- mm/dd/yyyy.
6. The possible errors in data are like 12.8.0 or 12..8 or 12.8. instead of 12.8. Data may be typed as a non-numeric symbols (space, _, +).

Analysis of annual and weekly rainfall probability

Annual and Weekly rainfall probabilities have been calculated through the module named as "Incomplete Gamma Probabilities.exe". Block wise weekly rainfall data has been used as an input to obtain the annual and weekly probability of rainfall at a level of 90%, 75%, and 50%. The amount of rainfall at three probability level has been computed for each standard week by fitting Incomplete Gamma Distribution model.

Results and Discussion

Mean Annual and Weekly Rainfall Probability

The expected amount of annual rainfall for the district at 90%, 75% and 50% are 1092.6 mm, 1238.7 mm and 1415.9 mm respectively (Table 1). The rainfall amount is expected to be less than 5 mm in the weeks before the onset of monsoon at 75% probability level. Whereas, after the onset of monsoon, i.e. from 23 SMW till 40 SMW the rainfall amount is very high. The district may receive a fair amount of rainfall during 25 to 38 SMWs at 75% probability. Highest rainfall has been estimated in 31 SMW at all the probability levels. The amount of rainfall again decreases gradually after 40 SMW (during cessation of monsoon) and so water stress condition prevails during that period for *rabi* season crops.

Table 1: Annual and Weekly rainfall probability of Khordha district

Week	Probability levels			Mean(mm)
	90%	75%	50%	
1	0.2	0.6	1.5	1.2
2	0.2	0.8	2.3	2.6
3	0.2	0.8	2.2	2.5
4	0.3	0.8	1.8	1.5
5	0.4	0.8	1.5	0.9
6	0	0	2.3	2.3
7	0	0	4.1	4.1
8	0	0	4.6	4.6
9	0.2	0.8	2.1	2.3
10	0.2	1	3.4	5.2
11	0.3	1	2.8	3.6
12	0.3	0.9	2.2	2.2
13	0.4	1	2.6	2.9
14	0.3	1.2	4	6.4
15	0.4	1	2.5	2.6
16	0.5	1.6	4.4	5.9
17	0.4	1.9	6.8	11.5
18	0.4	1.4	4.3	6
19	0.6	3.6	14.5	28.7
20	0.8	3.5	12.3	21.7
21	1.1	4.4	14.2	24.1
22	1.1	3.3	8.8	12.6
23	3.5	8.3	18.2	23.7
24	4.5	13	32.9	47.9
25	9.9	20.3	39.3	48.5
26	17.2	29.1	47.9	54.4
27	14	30.2	60.5	77.1
28	7	19.3	46.8	66.9
29	25.8	41.3	65	72.5
30	23	36.2	56.4	62.4
31	28.7	46.7	74.6	84
32	17.5	31.3	54.1	63.1
33	21.6	39.4	69.3	81.9
34	22.3	36.3	57.9	64.9
35	29.3	47.6	76.1	85.6
36	22.5	35.7	55.7	61.7
37	13	24.6	44.5	53.1
38	25.8	41.5	65.7	73.5
39	6.2	15.2	33.5	44.9
40	6.8	17.5	40.4	55.8
41	1.5	6.7	22.7	40.1
42	1.3	5.7	19.8	35.5
43	0.3	2.2	11.9	28.7
44	0.2	1.9	10.4	25.1
45	0.2	1.4	6	11.9
46	0.1	0.8	3.6	7.1
47	0.2	0.6	1.7	1.7
48	0.6	0.8	1.1	0.2
49	0.1	0.6	2.1	2.8
50	0.2	0.6	1.5	1.2
51	0.3	0.6	1.4	1
52	0.5	0.7	0.9	0
Annual	1092.6	1238.7	1415.9	1432.6

Mean Seasonal Rainfall Probability

The Indian weather system has been categorised into four seasons: Winter (49-52 SMW and 1-8 SMW), Summer (9-22 SMW), South West monsoon (23-39 SMW) and North East monsoon (40-48 SMW). At 75% probability the district may receive 6.3 mm of rainfall in winter season, 26.6 mm in summer season, 516 mm during monsoon and 37.6 mm of rainfall during post monsoon period (Table 2). This amount of rainfall provides 17 weeks or 120 days of growing period during monsoon season (23-39 SMW).

Table 2: Mean seasonal rainfall probability for Khordha district

Season	Probability levels		
	90%	75%	50%
Winter	2.4	6.3	26.2
Summer	7	26.6	84.9
South West	291.8	516	898.4
North East	11.2	37.6	117.6

Mean Monthly Rainfall Probability

Monthly rainfall probability for Khordha district has been estimated at three different probability levels, i.e. 90%, 75% and 50%. 75% is known as the assured rainfall and is of more concern for producing crops. Highest amount of rainfall is expected in the month of August (170 mm) at 75% probability (Table 3). Three months namely, July, August and September receives maximum amount of rainfall. Six months period of November to April may receive negligible amount of rainfall.

Table 3: Mean monthly rainfall probability of Khordha district

Months	Probability levels			Mean (mm)
	90%	75%	50%	
January	1	3.2	8.8	8.1
February	0.4	0.9	12.9	12.6
March	1.3	4.4	12.1	15.1
April	1.6	5.7	17.7	26.4
May	3.5	14.7	49.8	87
June	35.6	72.2	142.5	180.6
July	81.1	148.3	263	318.9
August	99.1	170	287.6	327.2
September	76.5	127	209.5	245.5
October	10	32.8	99.6	170.1
November	1	4.6	17.6	36
December	1.3	2.7	6.3	5

At 75% probability level negligible amount of rainfall is predicted to be received by the district during the winter months. So, it has been revealed that the *rabi* crops are always grown under moisture stress condition. The soil condition remains dry due to unavailability of required amount of rainfall which is detrimental for seed germination and crop growth. So, it is quite necessary to conserve and store excess of rain water in harvesting structures to utilise it efficiently during water stress condition and provide pre-sowing irrigation whenever necessary. The early varieties can be grown if pre sowing irrigation facility is provided. The *rabi* crops mainly utilise the residual soil moisture as there is deficiency of rain water during their critical growth phases.

Risk Proof Crops and Crop Planning

Khordha is likely to get 516 mm of rainfall at 75% probability level and it is not sufficient for growing long duration rice varieties. So, the major thrust should be on rain water management through *in situ* conservation and water harvesting through on-farm reservoirs/ capturing runoff from local catchments/ flash flood water from local streams to recycle at the time of need. Bhadoria *et al*., 2013 analysed the rainfall in the rainy season and revealed that there is an ample scope for rain water harvesting from July to September which can be utilized as crop saving irrigation as well as pre-sowing irrigation for succeeding *rabi* crops which are generally sown on residual soil moisture.

In medium and low lands, usually short duration rice varieties should be preferred because of less amount of predicted rainfall during monsoon. Varieties like Lalat, Sahabhagi,

Mandakini, Shatabdi etc. of 110-125 days duration are suitable for Khordha region. It has been observed that from 2013 onwards Odisha is hit by severe cyclones in between 10-15 October and keeping that in view it is advised to grow short duration rice varieties so that it can be harvested before 10th of October and thus no yield loss. The direct seeded rice is mainly sown after the first shower of monsoon, i.e. 24-25 SMW for better seed germination. The dry seed beds are prepared for nursery rising in 26-27 SMW so that rice can be transplanted during 31-33 SMW. Hence, cash crops like jute etc. can be grown during summer season from 17th SMW onwards which will be harvested in 30-31 SMW making the field free for transplanting rice.

Medium duration rice varieties in medium lands are harvested mostly after withdrawal of the monsoon at around 39-41 SMW. So, after harvest of rice in medium lands non paddy short duration crops like pulses such as green gram, black gram, lathyrus, oilseeds like sesame can be grown for effective utilisation of soil moisture recharge by predicted post monsoon rainfall. Wheat, potato, mustard, lentil, chickpea, onion, cabbage, cauliflower, okra can also be taken up after harvesting of the transplanted rice at the beginning of October.

No crops are advised to take up after 47-48 SMW as there is very little chance of getting rainfall in medium and uplands. Low lands can store moisture for a little more time than medium and uplands due to water stagnation.

Cropping Sequence

Uplands: Paddy is not preferred mostly in rainfed uplands because of predicted moisture deficit at reproductive stage. Instead drought resistant non paddy crops like pulses such as black gram, green gram, cowpea, short duration arhar, oilseed crops like sesame, short duration groundnut can be grown during *kharif* season followed by pre-rabi crops like horse gram, sesame, etc. in the month of October. Cropping sequence can be:

Green gram-horse gram
Black gram/Groundnut-horse gram

Medium and Low lands: Short or medium duration rice varieties with less than 120 days can be cultivated in kharif season up to 40-41 SMW and then pulses like black gram, green gram, green pea, lathyrus, cowpea, sesame, soybean, mustard, rice bean, fodder crops can be grown. Following sequences can be followed:

Rice-black gram/ green gram
Rice-sesame/ soybean
Rice-mustard

Low land: Long duration rice varieties with more than 145 days duration followed by pulses, oilseeds and vegetables in *rabi* season can be taken up. Cropping sequences can be:

Rice-black gram/green gram
Rice-cabbage/cauliflower

Conclusion

Rainfall probability analysis through Incomplete Gamma distribution model predicts the amount of rainfall of the district at different probability levels, i.e. 90%, 75% and 50%. Weekly, seasonal and monthly predicted amount of rainfall will help the farmers in carrying out different agricultural operations in the field and deciding the cropping system for the same area. Time of sowing of *kharif* and *rabi* crops are also decided according to the availability of water. *Rabi* crops are mainly sown during winter season when rain water availability is very less and so they take up the water from residual soil moisture. Rain water need to be stored in water harvesting structures for efficient utilisation during water stress condition in critical stages of crop growth. Rice can be cultivated in *kharif* season in medium and low lands followed by pulses in *rabi* season. In uplands pulses can be grown during *kharif* season and vegetables in *rabi* season.

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