Risk proof crop planning based on rainfall probability in Jagatsinghpur district of Odisha

A Baliarsingh, G Panigrahi, B Kamar, P Pattanaik, AKB Mohapatra, BS Rath and A Nanda

Abstract
The rainfall data of Jagatsinghpur district of Odisha for 20 years (1995-2014) were collected from Special Relief Commissioner (SRC), Government of Odisha, Bhubaneswar and were analyzed by Weather Cock software to estimate annual, seasonal, monthly and weekly rainfall probability with an objective to find out the risk proof crops based on rainfall probability analysis for the rainfed agriculture. The data revealed that the average annual rainfall during last 20 years of Jagatsinghpur district was 1495.3 mm. During monsoon (Jun-September) the district received about 1077.9 mm rainfall which contributes about 74.6 to its annual rainfall. During the post monsoon (October-November) winter (December-February) and summer (March-May) the district received about 223.5 mm (15.4%), 127 mm (0.8%) and 120.7 mm (8.0%) rainfall. Highest rainfall of 367.4 mm was received in the month of August. Rainfall probability analysis is one of the most important tools to predict the rainfall of an area. At 75% probability, the predication of annual, monsoon, winter & summer rainfall of Jagatsinghpur is 1210.7 mm, 850.1 mm, 78.3 mm, 68.9 mm, respectively. The Risk proof crop which can be best suitable for Kharif season are rice in the district in medium and low land and non-paddy crops like arhar, groundnut, green gram, black gram soybean can be taken. During winter season pulses like black gram, green gram and oil seeds like sesames can be grown. Taking the predicted rainfall of around more than 60 mm during summer fiber crop like jute can be grown in Jagatsinghpur.

Keywords: Rainfall distribution, rainfall probability, crop planning, Jagatsinghpur district

Introduction
Rainfall is the single most important factor in crop production in rainfed agriculture. Inter-annual variability of monsoon rainfall has considerable impact on agricultural production and water management. 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 success of rice crop depends upon not only the monsoon rainfall but also on the October rainfall which occurs due to cyclonic activity in the Bay of Bengal. Analysis of annual, seasonal and monthly rainfall of a region is useful to design water harvesting structure. Similarly weekly rainfall analysis give more useful information in crop planning (Sharma et al., 1979). Rainfall variation both in amount and distribution resulted in reduction of crop productivity especially in rice crop. The distribution of rainfall is the matter of more serious concern than the total amount of rainfall. Hence, study of rainfall characteristics is very important in drought prone areas.

Jagatsinghpur district is one of the coastal districts of east and south eastern coastal plain zone of Odisha comprising of 8 blocks namely, Biridi, Balikuda, Erasama, Jagatsinghpur, Kujanga, Nuagaon, Raghunathpur, Tritol. The mean annual and monsoon rainfall of Jagatsinghpur is 1514.6 and 1100.1 mm, respectively. However, occurrence of large variations was observed in block wise annual and monsoon rainfall. The Major food crop grown in Jagatsinghpur District is paddy, sugarcane, chilli during Kharif, sesamum, green gram, black gram groundnut and horse gram during rabi season are the major commercial crops. Condition of any region. Therefore, in this paper, an attempt has been made to analyze 20 years of rainfall (1995-2014) in Jagatsinghpur district of Odisha to find out the seasonal, monthly and weekly rainfall probability, risk proof crops for the rainfed agriculture and to select suitable cropping system based on rainfall probability analysis for the district.
Materials and Methods
Block wise daily rainfall data were collected from Special Relief Commissioner (SRC), Government of Odisha for the period from 1995 to 2014 (20 years) and processed by using Statistical Analysis Software (SAS, 2014).

Mean
The mean is computed as the sum of all the numbers in the series divided by the count of all numbers in the series.

Standard Deviation
Standard deviation is a measure of the dispersion of a set of data from its mean; more spread-apart data has a higher deviation. Standard deviation is calculated as the square root of variance. In finance, standard deviation is applied to the annual rate of return of an investment to measure the investment's volatility.

Coefficient of variation (CV): It is the ratio of standard deviation (σ) to mean (μ). The method of measuring the ratio of standard deviation to mean is also known as relative standard deviation often abbreviated as RSD. It only uses positive numbers in the calculation and expressed in percentage values.

\[
CV = \left( \frac{\text{Standard Deviation (σ)}}{\text{Mean (μ)}} \right) \times 100
\]

CV is important in the field of probability & statistics to measure the relative variability of the data sets on a ratio scale. In probability theory and statistics, it is also known as unitized risk or the variance coefficient.

Rainfall Probability
The probability of rainfall enable us to determine the expected rainfall at various chances. It is estimated using WEATHER COCK software which is developed by CRIDA, Hyderabad for weather data analysis.

Analysis of Annual and Weekly Rainfall Probability
Annual and weekly rainfall probabilities were calculated through the module named as “Incomplete Gamma Probabilities.exe”. Block wise weekly rainfall data is 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 Rainfall
The mean annual rainfall of Jagatsinghpur was recorded 1443 mm with average of 81 rainy days (Table 1). It is clear from the table that rainfall was slightly erratic. The annual rainfall and annual rainy days oscillated around the mean. However, during last twenty years the mean rainfall received was decreased by 4.7% as against the normal.

Table 1: Yearly Rainfall Distribution of Jagatsinghpur district

<table>
<thead>
<tr>
<th>Year</th>
<th>Rainfall</th>
<th>Rainy days</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>1769.1</td>
<td>95</td>
<td>Normal</td>
</tr>
<tr>
<td>1996</td>
<td>824.7</td>
<td>65</td>
<td>Drought</td>
</tr>
<tr>
<td>1997</td>
<td>1812.4</td>
<td>80</td>
<td>Excess</td>
</tr>
<tr>
<td>1998</td>
<td>1898.9</td>
<td>104</td>
<td>Excess</td>
</tr>
<tr>
<td>1999</td>
<td>1395.3</td>
<td>83</td>
<td>Normal</td>
</tr>
<tr>
<td>2000</td>
<td>754.5</td>
<td>80</td>
<td>Drought</td>
</tr>
<tr>
<td>2001</td>
<td>1609.3</td>
<td>75</td>
<td>Normal</td>
</tr>
<tr>
<td>2002</td>
<td>1609.3</td>
<td>75</td>
<td>Normal</td>
</tr>
<tr>
<td>2003</td>
<td>1702.6</td>
<td>97</td>
<td>Normal</td>
</tr>
<tr>
<td>2004</td>
<td>1203.3</td>
<td>73</td>
<td>Drought</td>
</tr>
<tr>
<td>2005</td>
<td>1621.7</td>
<td>82</td>
<td>Normal</td>
</tr>
<tr>
<td>2006</td>
<td>1609.3</td>
<td>75</td>
<td>Normal</td>
</tr>
<tr>
<td>2007</td>
<td>1452.7</td>
<td>83</td>
<td>Normal</td>
</tr>
<tr>
<td>2008</td>
<td>1688.5</td>
<td>85</td>
<td>Normal</td>
</tr>
<tr>
<td>2009</td>
<td>1480.1</td>
<td>73</td>
<td>Normal</td>
</tr>
<tr>
<td>2010</td>
<td>1208.8</td>
<td>76</td>
<td>Drought</td>
</tr>
<tr>
<td>2011</td>
<td>1320.6</td>
<td>77</td>
<td>Normal</td>
</tr>
<tr>
<td>2012</td>
<td>1093.2</td>
<td>81</td>
<td>Drought</td>
</tr>
<tr>
<td>2013</td>
<td>1278.5</td>
<td>83</td>
<td>Normal</td>
</tr>
<tr>
<td>2014</td>
<td>1530.0</td>
<td>87</td>
<td>Normal</td>
</tr>
<tr>
<td>Mean</td>
<td>1443.2</td>
<td>81.5</td>
<td></td>
</tr>
</tbody>
</table>

During the period of analysis, in 13 years rainfall were normal, five years were drought and two excess rainfall years. Highest rainfall of 1898 mm with 104 rainy days occurred in 1998 (Table 1). The lowest rainfall of 754 mm with 80 rainy days occurred in 2000. However the numbers of rainy days were more (104) in excess year in 1998 and less (65) during a drought year in 1996.

Mean Weekly Rainfall
The mean weekly rainfall data indicated that the rainfall amount was within 10 mm upto 18th week ranging from 0.51 mm in 9th week to 9.25 mm in 14th week. From 19th SMW the rainfall amount was more than 20 mm up to 23rd week (Table 2). Within the range of 27.1 mm to 109.3 mm per SMW and continued up to 43 SMW. The total rainfall received during this period from 19 to 43 week was 1350.9 mm representing 93.5% of the annual rainfall. The CV recorded in 12 Meteorological weeks are within 100 and were distributed from July to September. The mean weekly rainfall increased to more than 30 mm start will from 24th week (39.2 mm) to 43 week (33.97 mm) highest rainfall of 109.39 mm was revealed in 31st week. From 44th week the rainfall amount decreased and to below 20 mm upto 51st week and the 52nd week was dry. The coefficient of variation of rainfall raised from 58.4 in 25th week to 447.2 in 50 and 52nd week. However it was less than 100 during the period from 25th week to 36th week.

Mean Seasonal Rainfall

Table 2: Mean seasonal rainfall Distribution of Jagatsinghpur

<table>
<thead>
<tr>
<th>District Name</th>
<th>Season</th>
<th>Rainfall</th>
<th>Rainy Days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Amount</td>
<td>C.V.</td>
</tr>
<tr>
<td>Jagatsinghpur</td>
<td>Winter</td>
<td>14.2</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Summer</td>
<td>127.4</td>
<td>8.8</td>
</tr>
<tr>
<td></td>
<td>Monsoon</td>
<td>1077.9</td>
<td>74.7</td>
</tr>
<tr>
<td></td>
<td>Post Monsoon</td>
<td>223.6</td>
<td>15.5</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1443.2</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The daily rainfall data of 20 years were divided into 4 seasons: Monsoon, Post Monsoon, Winter, Summer. June, July, August and September are the Monsoon months; October, and November are the Post Monsoon; December, January and February are the Winter months and March, April and May are the summer months.

The analysis of mean seasonal rainfall (Table 3) reevaluated that in Jagatsinghpur district during monsoon reevaluated 1077 mm, in post monsoon 223 mm, in summer 127 mm while in winter it was recorded 14 mm rainfall. The percentage contribution of the seasonal rainfall to the total rainfall of Jagatsinghpur is as follows. In winter 0.99%, in summer 8.83%, %, in post monsoon 15.49% whereas maximum percent was recorded in monsoon. i.e. 74.69%.

The seasonal co-efficient of variation (CV) in monsoon 74%, in post monsoon 83%, in summer 82, while in winter it was recorded 102%.

### Mean Monthly Rainfall

<table>
<thead>
<tr>
<th>Month</th>
<th>Total Rainfall</th>
<th>Mean Rainfall</th>
<th>Contribution</th>
<th>S.D</th>
<th>C.V</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>141.3</td>
<td>6.5</td>
<td>0.5</td>
<td>9.8</td>
<td>150.9</td>
</tr>
<tr>
<td>February</td>
<td>144.9</td>
<td>7.7</td>
<td>0.5</td>
<td>12.1</td>
<td>157.4</td>
</tr>
<tr>
<td>March</td>
<td>145.6</td>
<td>6.5</td>
<td>0.5</td>
<td>13.7</td>
<td>210.3</td>
</tr>
<tr>
<td>April</td>
<td>543.7</td>
<td>20.2</td>
<td>1.4</td>
<td>32.1</td>
<td>158.5</td>
</tr>
<tr>
<td>May</td>
<td>2138.1</td>
<td>100.6</td>
<td>7.0</td>
<td>111.6</td>
<td>110.9</td>
</tr>
<tr>
<td>June</td>
<td>3101.1</td>
<td>156.8</td>
<td>10.9</td>
<td>76.7</td>
<td>48.9</td>
</tr>
<tr>
<td>July</td>
<td>5908.4</td>
<td>294.4</td>
<td>20.4</td>
<td>140.3</td>
<td>47.6</td>
</tr>
<tr>
<td>August</td>
<td>7394.7</td>
<td>367.4</td>
<td>25.5</td>
<td>178.3</td>
<td>48.5</td>
</tr>
<tr>
<td>September</td>
<td>4906.7</td>
<td>259.2</td>
<td>18.0</td>
<td>119.9</td>
<td>46.2</td>
</tr>
<tr>
<td>October</td>
<td>3665.7</td>
<td>184.9</td>
<td>12.8</td>
<td>166.3</td>
<td>89.9</td>
</tr>
<tr>
<td>November</td>
<td>696.5</td>
<td>34.8</td>
<td>2.4</td>
<td>59.5</td>
<td>171.1</td>
</tr>
<tr>
<td>December</td>
<td>77.8</td>
<td>3.8</td>
<td>0.3</td>
<td>9.9</td>
<td>256.4</td>
</tr>
</tbody>
</table>

### Mean Monthly Rainy days of Jagatsinghpur

<table>
<thead>
<tr>
<th>Month</th>
<th>Total Rainy days</th>
<th>Mean</th>
<th>Contribution</th>
<th>S.D</th>
<th>C.V</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>16.0</td>
<td>0.8</td>
<td>1.0</td>
<td>1.3</td>
<td>165.2</td>
</tr>
<tr>
<td>February</td>
<td>15.0</td>
<td>0.8</td>
<td>0.9</td>
<td>0.9</td>
<td>113.4</td>
</tr>
<tr>
<td>March</td>
<td>10.0</td>
<td>0.5</td>
<td>0.6</td>
<td>1.0</td>
<td>189.2</td>
</tr>
<tr>
<td>April</td>
<td>33.0</td>
<td>1.7</td>
<td>2.0</td>
<td>2.0</td>
<td>121.7</td>
</tr>
<tr>
<td>May</td>
<td>122.0</td>
<td>6.1</td>
<td>7.5</td>
<td>4.5</td>
<td>73.7</td>
</tr>
<tr>
<td>June</td>
<td>215.0</td>
<td>10.8</td>
<td>13.2</td>
<td>3.7</td>
<td>34.3</td>
</tr>
<tr>
<td>July</td>
<td>340.0</td>
<td>17.0</td>
<td>20.9</td>
<td>3.1</td>
<td>18.1</td>
</tr>
<tr>
<td>August</td>
<td>380.0</td>
<td>19.0</td>
<td>23.3</td>
<td>2.3</td>
<td>12.1</td>
</tr>
<tr>
<td>September</td>
<td>283.0</td>
<td>14.2</td>
<td>17.4</td>
<td>4.4</td>
<td>31.4</td>
</tr>
<tr>
<td>October</td>
<td>170.0</td>
<td>8.5</td>
<td>10.4</td>
<td>5.4</td>
<td>64.0</td>
</tr>
<tr>
<td>November</td>
<td>39.0</td>
<td>2.0</td>
<td>2.4</td>
<td>2.2</td>
<td>114.6</td>
</tr>
<tr>
<td>December</td>
<td>6.0</td>
<td>0.3</td>
<td>0.4</td>
<td>0.8</td>
<td>267.1</td>
</tr>
</tbody>
</table>

The data on mean monthly rainfall of Jagatsinghpur district (Table 4) revealed during the month of August highest rainfall (367.4 mm) was recorded contributing about 22.1% to the total annual rainfall followed by July (294.4 mm and 20.1%). The least rainfall of (3.8 mm) was recorded in the month of December contributing only 0.24%. It is clear from the data that after May there was a sudden rise in rainfall amount, which increased linearly from June to August and thereafter, then started decreasing. But after September the rainfall was observed to be reduced drastically. However the rainy season is confined between June to October. The co-efficient variation due to monthly rainfall range from 46.2% (July) to 256.4% (December), occurrence of rainfall the month of June, July, August and September were the most reliable as it showed less CV value of 48.9, 47.6, 48.5 and 46.2, respectively. The CV value of December, March and November were much higher. The relationship between CV and average monthly rainfall (Table 4) revealed that CV had an inverse relationship with the rainfall, i.e. CV decreased as the month tends to wet and increased for dry months.

The mean annual rainy days in Jagatsinghpur district was 81.6 (Table 5). It ranged from 0.3 day in December to 19 days in August. The coefficient of variation of monsoon months were less raising from (18.11 during July to 34.26% during June) as compare to winter (Rabi) months raising from 113.43 during February to 267.1 during December.

### Mean Annual Weekly Rainfall Probability

The total annual predicted rainfall of the district at 90%, 75%, and 50% probability are 1041.5 mm, 1210.7 mm and 1419.5 mm respectively (Table 6). At 75% probability the district received very less rainfall (<6mm) before the onset of monsoon. All SMW received very less rainfall (<6mm) before the onset of monsoon that is before 24th Standard Meteorological Weak (SMW). But at the beginning of monsoon in SMW 25, 26 and 28 a very good amount of rainfall maybe received up to 30 mm. At 75% probability the district may receive highest rainfall in all the three districts may received highest rainfall above 30 mm. At 75% probability are 1041.5 mm, 1210.7 mm and 1419.5 mm respectively (Table 6). But at the beginning of monsoon in SMW 25, 26 and 28 a very good amount of rainfall maybe received up to 30 mm.
Seasonal probability was calculated based on rainfall data of the districts for four seasons namely monsoon (SMW 23 to 39), post monsoon (SMW 40 to 48), winter (SMW 49 to 52 and 1 to 8) and summer (SMW 9 to 22). At 75% probability during monsoon Jagatsinghpur, may receive highest of rainfall amount of 850.1, in post monsoon 74.5, in summer 68.9 and 44.1 and in winter (Table 7). At 75% probability level during monsoon season Jagatsinghpur district received about 850.1 mm rainfall. It is distributed, with the period from 25th to 40th weeks giving rise to or length of growing season 120 days or 17 weeks. So the non-paddy crops like groundnut, sunflower, short duration arhar of 120 days can be taken in upland during kharif season. The rainfall at 75% assured level should be utilized for growing rainy-season crops like maize, cowpea, groundnut, blackgram and direct-seeded rice in second fortnight of June with the commencement of monsoon. Senapati et al. (2009), revealed that the duration of monsoon period is 92 days and short duration crops of 90 - 95 days should be preferred to be grown in rain fed uplands. In medium land rice can be taken with a duration of maximum up to 130 days or short duration rice of 100 to 120 days can be taken to accommodate vegetables like cole crops as a second crops, sowing of which can be made early to best utilize the soil moisture. In low land, long duration rice of 150 days may be grown as the altitude of the coastal district like Jagatsinghpur is low.

### Monthly Rainfall Probability

Table 7: Monthly Rainfall Probability of Jagatsinghpur

<table>
<thead>
<tr>
<th>Month</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>90%</td>
</tr>
<tr>
<td>January</td>
<td>0.3</td>
</tr>
<tr>
<td>February</td>
<td>0.4</td>
</tr>
<tr>
<td>March</td>
<td>0.1</td>
</tr>
<tr>
<td>April</td>
<td>0.6</td>
</tr>
<tr>
<td>May</td>
<td>23.1</td>
</tr>
<tr>
<td>June</td>
<td>61.7</td>
</tr>
<tr>
<td>July</td>
<td>128.0</td>
</tr>
<tr>
<td>August</td>
<td>202.4</td>
</tr>
<tr>
<td>September</td>
<td>98.0</td>
</tr>
<tr>
<td>October</td>
<td>26.6</td>
</tr>
<tr>
<td>November</td>
<td>0.6</td>
</tr>
<tr>
<td>December</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Maximum amount of rainfall is expected in three months of the year, namely July, August and September with more than150 mm rainfall at 75% probability (Table 7). Highest rainfall of 279.0 mm is predicted in the month of August. The period of six months from November to April the district may get negligible amount of rainfall (below 5 mm). About 813.3 mm is received in rest six month period from May to October.

During the winter season (40th week onwards), negligible rainfall is recorded at 0.75 probability level. So the surface soil would become dry with rare chances of getting adequate soil-moisture in the seedling 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

### Mean Seasonal Probability

Table 6: Mean seasonal rainfall probability of Jagatsinghpur

<table>
<thead>
<tr>
<th>District</th>
<th>Season</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>90%</td>
</tr>
<tr>
<td>Jagatsinghpur</td>
<td>Monsoon</td>
<td>699.8</td>
</tr>
<tr>
<td></td>
<td>Post monsoon</td>
<td>26.0</td>
</tr>
<tr>
<td></td>
<td>summer</td>
<td>36.7</td>
</tr>
<tr>
<td></td>
<td>Winter</td>
<td>0.8</td>
</tr>
</tbody>
</table>
application of pre-sowing irrigation. Bhadoria et al. (2013) analysed the rainfall in the rainy season. August was the highest rainfall contributing month (33.4%) followed by July (28.9%) mean weakly, precipitation amount and its assurance reaches the peak (>50mm/week) during 26th SMW (Standard Meteorological Week) to 38th SMW and again declined thereafter. The earliest onset of rainy season occurred in 24th SMW. The normal onset of rainy season was observed as 26th SMW with CV of 5.8 percent. 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.

**Risk Proof Crops and Cropping System**

During summer season Jagatsinghpur likely to get 68.9 mm rainfall at 75% probability so that cash crop like jute can be taken in low land during April that is on 17th week onwards and will be harvested within 30 to 31 week so that rice crop of medium duration can be taken as second crop. During post monsoon (October, November) season, Jagatsinghpur district likely get 74.5 mm rainfall at 75% probability level. The pre rabi crops like green gram, black gram, hors gram and sesami can be taken in upland and vegetables like cucurbits, lady’s finger, cowpea, cole crops can be grow in medium land as second crop.

After harvest of medium duration rice in medium land non paddy short duration crops like pulses such as green gram, black gram, lathyrus, oilseeds like sesami can be grown for effective utilisation of soil moisture recharge by predicted post monsoon rainfall. Wheat, potato, mustard, lentil, chickpea, onion, cabbage, cauliflower etc. Jute, ladies finger can also be taken after harvesting of the transplanted rice at the beginning of October. The cropping patterns are based on rice. farmers can grow those crops provided the stored moisture after rice is utilized through immediate land preparation (by the middle of October).

As there is very little chances of rainfall occurrence after 47th week, no crop is advised to take up after 48th week in upland and medium land unless there is provision of irrigation facilities. There was continuous dry spell at the end of October which could be utilized for harvesting of rainy season crops and field preparations for winter season. High value winter crops could be grown only with supplemental irrigation during winter season, starting from November.

**References**