APPENDIX
<table>
<thead>
<tr>
<th>Sample size</th>
<th>Factors for control limits</th>
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<tbody>
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<td>2</td>
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<tr>
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<td>23</td>
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<td>24</td>
<td>0.612</td>
</tr>
<tr>
<td>25</td>
<td>0.600</td>
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</tbody>
</table>
This is to certify that Mr. K.Kiran Premosh, Dept. of Statistics, 

of A.P. College, Akasaghat, Khammam, has participated in the National Seminar on 

'Suicides in Post-Modern India' held during 22nd & 23rd October, 2010 at Sri Krishnadevaraya 

University, Anantapur and Presented a paper on 'Statistical Analysis: Andhra St.

means'.
PREDICTION OF RAIN FALL THROUGH THE MOVING AVERAGES MODEL

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ABSTRACT
Earlier authors proposed (Kiran Prakash et al 2010) a preliminary statistical analysis to study the behavior of the rainfall in three Mandals namely (1) Sathupally, (2) Vemsoor and (3) Aswaraopet. Further, they proposed a Markov Chain model for the rainfall data by considering '0' as no-rainy day and '1' as a rainy day and obtained Steady state solutions (Kiran Prakash et al 2010), for the above three Mandals. In this paper a new approach for prediction of rainfall in these three Mandals is considered using Moving Average (M.A) Model. A time series \((X_t, t \in T)\) is called time series data and daily rainfall can be considered as a time series. For this data a Moving Average process of order \(p\) can be fitted and predictions can be made based on the fitted model by putting \(p = 3\). To fit the model, we have used method of 'Least Squares' (Gupta and Kapoor 2005) and obtained Mean Square Error (M.S.E) (Gupta and Kapoor 2003; Medhi 1984). These M.S.E. of different Mandals of M.A.(3) Process are compared and conclusions are drawn based on the results obtained.

Key words: Moving Average, Least Square, Mean Square Error.

1. INTRODUCTION

Water is the most important one and it embrace of all spear of human activity. It plays very crucial role in the development of mankind in all sectors. The growth of any country or area certainly depends on the availability of water resources. In view of these the present study is concentrated on the prediction of rainfall for three Mandals namely (1) Sathupally, (2) Vemsoor and (3) Aswaraopet of Khammam District in A.P. The three Mandals are mainly depending on ground water and rain water resources, a ground water level intern depend on rain fall. For the purpose of analysis daily rainfall data is collected in rainy seasons that are from 1st June to 31st October (5 months per season) from 1990 to 2009, collected from the three Mandals separately. The model proposed by us in this paper is explained in the following section.
2. MOVING AVERAGE (MA) PROCESS (Medhi 1984, Sharma 2003)

A time series \( \{X_t, t \in T\} \) is called a Moving Average process of order \('p'\) if it can be expressed in the form

\[
X_t = a_0 e_t + a_1 e_{t-1} + \ldots + a_p e_{t-p},
\]

\( t = 0, 1, 2, 3, \ldots, p \) \( l = t, t-1, t-2, \ldots, t-p \).

Where, \( a_0 \) are constants, and \( (e_t) \) is a white noise with \( E(e_t) = 0 \) and \( V(e_t) = \sigma^2 \).

In particular when \( p = 3 \) (2.1) reduces as follows

\[
X_t = a_1 X_{t-1} + a_2 X_{t-2} + a_3 X_{t-3}.
\]

Where \( a_1, a_2, a_3 \) are unknown constants, which are to be estimated from the collected data. To do this, Normal equations using method of Least squares are formed as follows for the model given in equation (2.2), are given as follows,

\[
a_1 \sum X_{t-1}^2 + a_2 \sum X_{t-2} + a_3 \sum X_{t-3} = \sum X_t X_{t-1}
\]

\[
a_1 \sum X_{t-2} + a_2 \sum X_{t-3} + a_3 \sum X_{t-3} = \sum X_t X_{t-2}
\]

\[
a_1 \sum X_{t-3} + a_2 \sum X_{t-3} + a_3 \sum X_{t-3} = \sum X_t X_{t-3}
\]

(2.3)

Solving these normal equations we will get estimates unknown constants.

Therefore the fitted 3-season moving average model to the data is

\[
\hat{X}_t = a_1 \hat{X}_{t-1} + a_2 \hat{X}_{t-2} + a_3 \hat{X}_{t-3}
\]

After fitting the M.A(3) process to the collected data, control charts for M. Average are drawn to determine "Outlier". To draw control charts, the following Control limits are used.

Control Limits for Moving Average Chart (Duncan 1970)

Let \( \bar{X}_i \) = Moving Average of \( i^{th} \) month and

\( R_i \) = Moving Range or \( i^{th} \) month then the control limits for moving average charts are given by

Upper Control Limit (U.C.L) = \( \bar{X} + A_2 \bar{R} \) \( \ldots \) (2.5)

Central Line (C.L) = \( \bar{X} \) \( \ldots \) (2.6)

Lower Control Limit (L.C.L) = \( \bar{X} - A_2 \bar{R} \) \( \ldots \) (2.7)

Where \( \bar{X} = \frac{\sum \bar{X}_i}{k} \)

\( \bar{R} = \frac{\sum R_i}{k} \), \( k \) = number of months.

In order to judge the validity of the fitted model to the collected data, one has to calculate Mean Square Error which is explained as follows.

The Mean Square Error (Cochran 1997, Murthy 1967)

In order to compare a biased estimator with an unbiased estimator, or two estimators with different amounts of bias, a useful criterion is the Mean Square Error.
PREDICTION OF RAIN FALL THROUGH THE MOVING AVERAGES MODEL

(M.S.E) of the estimate, measured from the population value that is being estimated. Formally,

\[ \text{MSE}(\hat{X}_t) = E((\hat{X}_t - X)^2) = \frac{1}{n} \sum_{i=1}^{n} (\hat{X}_i - X)^2 \]  

Use of MSE as a criterion of accuracy of an estimator amounts to regarding two estimates that have the same MSE as equivalent. This is not strictly correct because the frequency distribution of errors \((\hat{X}_i - X)\) of different size will not be the same for the two estimates if they have different amounts of bias (Medhi 1984).

3. CALCULATIONS

By using the data collected from the three Mandals, various intermediary results are obtained and given in the following table (3.1).

Table 3.1 : Control limits for 3 season Moving Average for three Mandals

<table>
<thead>
<tr>
<th>Name of the Mandal</th>
<th>UCL</th>
<th>CL</th>
<th>LCL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sathupally</td>
<td>417.6</td>
<td>206.56</td>
<td>-4.511</td>
</tr>
<tr>
<td>Vemsoor</td>
<td>341.47</td>
<td>171.30</td>
<td>1.13</td>
</tr>
<tr>
<td>Aswaraopet</td>
<td>333.19</td>
<td>161.61</td>
<td>-9.97</td>
</tr>
</tbody>
</table>

Table 3.2):Rearranged data for 3-season Moving Average model for three Mandals.

<table>
<thead>
<tr>
<th></th>
<th>Sathupally</th>
<th>Vemsoor</th>
<th>Aswaraopet</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \sum X_i )</td>
<td>19753261.27</td>
<td>19181383.03</td>
<td>18711244.27</td>
</tr>
<tr>
<td>( \sum X_i^2 )</td>
<td>18546730.47</td>
<td>18221697.02</td>
<td>18027446.79</td>
</tr>
<tr>
<td>( \sum X_i X_{i-1} )</td>
<td>18311857.67</td>
<td>18311857.67</td>
<td>18038730.42</td>
</tr>
<tr>
<td>( \sum X_i X_{i-2} )</td>
<td>17745887.78</td>
<td>17745887.78</td>
<td>17745887.78</td>
</tr>
</tbody>
</table>

Substitute values in the table (3.2) in the normal equations given in (2.3) for each Mandal separately we get, the following normal equations for each Mandal.

For Sathupally Mandal,

\[ a_1 19753261.27 + a_2 18546730.47 + a_3 18221697.02 = 18311857.67 \]
\[ a_1 18546730.47 + a_2 19181383.03 + a_3 18027446.79 = 18038730.42 \]  
\[ a_1 18221697.02 + a_2 18027446.79 + a_3 18711244.27 = 17745887.78 \]  

solving the above equations we get the estimates of unknown constants.

Therefore the fitted equation to the data for 3-seasons Moving Average model is

\[ X_t = 0.351603579 X_{t-1} + 0.327096935 X_{t-2} + 0.290859936 X_{t-3} \]  

For Vemsoor Mandal,

<table>
<thead>
<tr>
<th></th>
<th>Sathupally</th>
<th>Vemsoor</th>
<th>Aswaraopet</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \sum X_i )</td>
<td>19753261.27</td>
<td>19181383.03</td>
<td>18711244.27</td>
</tr>
<tr>
<td>( \sum X_i^2 )</td>
<td>18546730.47</td>
<td>18221697.02</td>
<td>18027446.79</td>
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<tr>
<td>( \sum X_i X_{i-1} )</td>
<td>18311857.67</td>
<td>18311857.67</td>
<td>18038730.42</td>
</tr>
<tr>
<td>( \sum X_i X_{i-2} )</td>
<td>17745887.78</td>
<td>17745887.78</td>
<td>17745887.78</td>
</tr>
</tbody>
</table>

101
solving the above equations we get the estimates of unknown constants.

Therefore the fitted equation to the data for 3-seasons Moving Average model is

\[ X_t = 0.257661863X_{t-1} + 0.244315443X_{t-2} + 0.519585423X_{t-3} \]  \hspace{1cm} (3.4)

For Aswaraopet Mandal,

\[ a_1 11934295.87 + a_2 11217761.91 + a_3 11190979.38 = 11103148.66 \]
\[ a_1 11217761.91 + a_2 11471596.6 + a_3 11074205.23 = 10873721.24 \]
\[ a_1 11190979.38 + a_2 11074205.23 + a_3 11627310.91 = 11109006.28 \]  \hspace{1cm} (3.5)

solving the above equations we get the estimates of unknown constants.

Therefore the fitted equation to the data for 3-seasons Moving Average model is

\[ X_t = 0.31223582X_{t-1} + 0.085503864X_{t-2} + 0.573468308X_{t-3} \] \hspace{1cm} (3.6)

Now we proceed to above M.A. Control charts for 3-Mandals, in the following section.

4. CONTROL CHARTS:

Fig 4.1 : Control limit 3 months Moving Average chart Sathupally Mandal

Fig 4.2 : Control limit 3 months Moving Average chart Vemsoor Mandal
Using fitted models given in equation (3.2), (3.4) and (3.6), now we proceed to predict the rainfall in the 3-mandsals separately in the following section.

5. PREDICTION:

For calculation of predictions, total rainfall in the rainy season of each year is calculated and are denoted by ‘t’. Let \( X_{t-1}, X_{t-2} \) and \( X_{t-3} \) values as previous season totals of previous \( t-1, t-2 \) and \( t-3 \) years, and substituting these totals in fitted equations we obtain predictions for the year ‘t’ rainfall. These predictions are denoted by \( \hat{a}_t \). To determine the appropriateness of the fitted model \( a_t \)’s are to be compared with \( e_t \). This is done by mean square error given in equation (2.8). The observed (\( a_t \)), predicted (\( e_t \)) and M.S.E.’s for the three Mandalas under consideration are given in the following tables.

Table 5.1: Observed, Predicted and Mean Square Error (M.S.E.) for 3-season Moving Average Model of different Mandalas.

<table>
<thead>
<tr>
<th>Years/Seasons</th>
<th>Sathupally</th>
<th>Vemsoor</th>
<th>Aswaraopet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Observed (m)</td>
<td>Expected (m)</td>
<td>Observed (m)</td>
</tr>
<tr>
<td>2009</td>
<td>619.0</td>
<td>1105.4871</td>
<td>588.8</td>
</tr>
<tr>
<td>2008</td>
<td>1316.8</td>
<td>1175.2311</td>
<td>1086.6</td>
</tr>
<tr>
<td>2007</td>
<td>1142.6</td>
<td>1162.0504</td>
<td>919.4</td>
</tr>
<tr>
<td>2006</td>
<td>924.0</td>
<td>1222.0051</td>
<td>953.2</td>
</tr>
<tr>
<td>2005</td>
<td>1620.2</td>
<td>926.7427</td>
<td>1125.1</td>
</tr>
<tr>
<td>2004</td>
<td>1056.2</td>
<td>828.1956</td>
<td>909.3</td>
</tr>
<tr>
<td>2003</td>
<td>1055.0</td>
<td>839.1463</td>
<td>1115.2</td>
</tr>
<tr>
<td>2002</td>
<td>723.0</td>
<td>939.5412</td>
<td>579.5</td>
</tr>
<tr>
<td>2001</td>
<td>759.0</td>
<td>1081.7634</td>
<td>669.4</td>
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<tr>
<td>2000</td>
<td>1157.5</td>
<td>1018.7438</td>
<td>895.8</td>
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<tr>
<td>1999</td>
<td>1011.0</td>
<td>1140.8737</td>
<td>653.1</td>
</tr>
<tr>
<td>1998</td>
<td>1183.0</td>
<td>1113.6473</td>
<td>874.6</td>
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<td>1997</td>
<td>950.0</td>
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<td>1996</td>
<td>1424.0</td>
<td>837.0081</td>
<td>927.9</td>
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<tr>
<td>1995</td>
<td>1079.0</td>
<td>784.1749</td>
<td>1036.9</td>
</tr>
<tr>
<td>1994</td>
<td>847.3</td>
<td>850.3094</td>
<td>866.5</td>
</tr>
<tr>
<td>1993</td>
<td>620.5</td>
<td>960.92</td>
<td>485.0</td>
</tr>
</tbody>
</table>

**M.S.E.**

1687250.37  830188.34  795928.20

98250.02  48834.61  46813.42
Observed and predicted values for the three Mandals are represented graphically in the following figures (5.1), (5.2) and (5.3)

**Fig.(5.1): Sathupally Mandal**

![Graph for Sathupally Mandal]

**Fig.(5.2): Vemsoor Mandal**

![Graph for Vemsoor Mandal]

**Fig.(5.3): Aswaraopet Mandal**

![Graph for Aswaraopet Mandal]
6. CONCLUSIONS

Critically comparing three season M.A. control chart given in (3.1) to (3.3) we can observed that August 2005 and July 2008 are out layer commonly in all the three Mandals. Out layers of each Mandals:


7. OBSERVED AND EXPECTED VALUES:

Comparing $\alpha_i$ and $e_i$ values in the fig (5.1), (5.2) and (5.3) we conclude that M.S.E. is higher in Sathupally and is lower in Aswaraopet. Thus predictions in Aswaraopet are tallying with Actual values more closely than other Mandals. The fitted equation M.A. (3) is more appropriate for Aswaraopet Mandal than Sathupally and Vemsoor. This fact is exhibited clearly in the fig (5.3). one can observe that more closely associated with $\alpha_i$ and $e_i$ in Aswaraopet (5.3).

REFERENCES


Assured Rainfall Estimation Through Percentiles

Key words: Assured rainfall, Dependeable rainfall

Classification was done based on the average rainfall. (White and Perry 1988, Driggs and Lemin Jr 1992 and Kulkarni and Reddy 1994). Rainfall recorded over a period of time generally exhibits considerable year-to-year variation and is therefore inconsistent. Hence the choice of average rainfall would be appropriate only for summarizing the characteristics, but in appropriate for agricultural planning. The most suitable approach would be to obtain a classification based on "assured" availability of rainfall. Hence, an attempt has been made to obtain a classification of the mandals of Khammam district, Andhra Pradesh, which accounts for the "assured" availability of rainfall.

Suppose there are 'm' mandals for which "n" years of monthly data are available. Let X(i) be the observation vector corresponding to the i-th mandal (i = 1, 2, m). Let X(i) represents the estimates of assured rainfall of k months of the seasons. Now, based on X(i), the 'm' regions are to be classified into homogeneous groups, as described below:

Estimates of Assured Rainfall: The assured rainfall which is also referred as 'dependable Precipitation' (DP) in the context of measuring the Moisture Availability Index (MAI), is the largest possible rainfall that can occur in a period (week/month/season) at a given probability. The assured rainfall X(p) at p-th level of probability can be expressed with a probabilistic expression:

\[ P(X > X(p)) = \int f(x) \, dx = p \]

Or, alternatively

\[ P(X > X(p)) = 1 - p \, P(X > X(p)) = (1-p) = q \]

i.e., X(p) is the (1-p)th percentile of the frequency distribution f(x) of the rainfall variable X. It is thus obvious that as the level of q increases, the magnitude of X(p) also increases. However, the values at the higher percentiles are less frequent and therefore not "likely" to represent the assured rainfall. Hence, the choice of X(p) is corresponding to the lower percentiles. In this context, Viramani(1975) and Hargreaves (1975) advocated p = 0.75 as the acceptable level for estimating the rainfall on-monthly basis; whereas

Biwas and Sarkar(1978) and Sarkar, et al.,(1982) considered 50 percent probabilistic rainfall as the dependable as the precipitation for rainfall measured on weekly basis. Since the present study involves monthly rainfall data, the dependable rainfall X(p) was estimated at p = 0.75.

The estimate of assured rainfall X(p) can be conveniently obtained from the percentile of the distribution f(x). X(p) is the (1-p)th percentile of f(x). The percentiles of the rainfall distribution are generally obtained by fitting statistical distribution to the yearly rainfall data. These distributions are either Gamma or normal distribution (Hillel and Morgan 1981). A less restrictive approach, which do not assume any statistical distribution, was proposed by Davy, et al.(1978). The approach involves empirically determining the percentiles from the array of rainfall data as follows: The "n" years of rainfall data (corresponding to month) can be arranged in an ascending order of magnitude. Now, if q = (1-p) is any chosen level of proportion, the (100 x q)th percentile which is the estimate X(p), is represented by the (n x q)th value of the array.

Classification of mandals: The mandal wise rainfall data on the observation vector X(i) (i=1, 2, m) which represents the vector of assured rainfall of the rainfall months obtained at p = 0.75 can be subjected to Cluster Analysis. Among the various methods of clustering, those based on Hierarchical approach and in particular, the Ward's Minimum Variance method can be applied due to its several advantages over the other approaches (Everitt 1974).

The approach outlined above was applied for obtaining the rainfall-based classification of three mandals of Khammam district. Classification was obtained by using 20 years of monthly rainfall data for the three mandals were considered.

The three mandals were considered as a cluster and taking the 5 rainfall variables in the observation vector. These variables were the monthly rainfall of June to October. Classification was done on the basis of two criteria: i.e. mean rainfall and the estimates of assured rainfall. Statistical data was collected at Mandal Revenue Office's of each mandal.
Table 1. Characteristic of three mandals rainfall (mm) during 1980-2009

<table>
<thead>
<tr>
<th>Mandal</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>October</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sathupally</td>
<td>145.23</td>
<td>270.87</td>
<td>296.05</td>
<td>180.05</td>
<td>130.14</td>
</tr>
<tr>
<td>C.V(%)</td>
<td>51.21</td>
<td>41.96</td>
<td>41.95</td>
<td>76.05</td>
<td>52.52</td>
</tr>
<tr>
<td>Estimate</td>
<td>73.8</td>
<td>191.4</td>
<td>214.8</td>
<td>90</td>
<td>77.8</td>
</tr>
<tr>
<td>Vemsoor</td>
<td>122.04</td>
<td>242.10</td>
<td>235.09</td>
<td>133.44</td>
<td>125.79</td>
</tr>
<tr>
<td>C.V(%)</td>
<td>51.03</td>
<td>34.16</td>
<td>45.45</td>
<td>56.31</td>
<td>59.81</td>
</tr>
<tr>
<td>Estimate</td>
<td>66.4</td>
<td>195.2</td>
<td>167.5</td>
<td>72.4</td>
<td>65.8</td>
</tr>
<tr>
<td>Aswaracopet</td>
<td>121.41</td>
<td>221.56</td>
<td>204.34</td>
<td>160.73</td>
<td>111.86</td>
</tr>
<tr>
<td>C.V(%)</td>
<td>61.25</td>
<td>47.03</td>
<td>49.00</td>
<td>80.70</td>
<td>62.72</td>
</tr>
<tr>
<td>Estimate</td>
<td>59.5</td>
<td>116.2</td>
<td>127.8</td>
<td>112.4</td>
<td>38</td>
</tr>
</tbody>
</table>

Table 2. Rainfall based classification of three mandals

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Mandal</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Classification with Mean rainfall</th>
<th>Classification with Dependable rainfall estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sathupally</td>
<td>121</td>
<td>222</td>
<td>204</td>
<td>133</td>
<td>112</td>
<td>Sathupally</td>
<td>60</td>
</tr>
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The rainfall characteristics of the mandals are presented in Table 1. In general, it can be observed that July and August are "peak" as well as the consistent rainfall months. The inconsistent nature of rainfall for agricultural planning. The most suitable choice would be the estimates of dependable, i.e., assured rainfall which is generally obtained at 0.75 level of probability.

The estimates of assured rainfall are obviously less than the corresponding mean values. If the distribution of the rainfall variable were symmetric, the mean values would represent the median or the 50th percentile of the data; while the estimate of assured rainfall (or, the dependable rainfall) would represent the 25 percentile of the data. However, the frequency of occurrence of rainfall less than the estimate is sufficiently greater than with the mean values, i.e., at least a "minimum" possible rainfall represented by the estimate is "assured" with a probability of 0.75.

In light of these limitations of the mean values, and the results of cluster analysis, which are represented in table 2. Classification is done based on the estimates of assured rainfall among the three mandals. The dependable rain fall in the month of July and August is very high comparing to the June, September and October.

The mean values of the rainfall variables are always at higher level and also inconsistent. Hence, it is obvious that for agricultural planning, the classification based on the mean values would be misleading and may lead to heavy crop losses. With this effort the agriculturist effectively utilizing the assured rainfall data and accordingly plan his crop and prevent the heavy crop losses.
LITERATURE CITED


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