ANNUAL REPORT OF HAIL STUDIES

BY

NEIL G. TOWERY AND RANDI OLSON

Report of Research Conducted
15 May 1976 - 14 May 1977

For
The Country Companies

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INTRODUCTION

In 1974, the Illinois State Water Survey began a research project for the Country Companies related to remote sensing of crop-hail damage. The results of the research in the May 1974 - May 1976 period are contained in two previous annual reports (Towery, et al. 1976; Towery, et al. 1975). The primary objective of developing a technique to quantify field losses based on aerial photography could not be fulfilled for several reasons. A secondary objective of developing methods by which adjusters could use aerial photography to improve their procedures was much more successful. As a result, the Country Companies formed an Aerial Survey Department to photograph areas of severe crop damage.

A computer mapping program was developed as part of the primary objective (quantifying field losses). The mapping program was necessary to determine areas of damage, field average, and final adjustment figures. The mapping program was used to perform some initial evaluation of the most optimum sample size and sampling method necessary to obtain a reasonably accurate assessment of field loss. The ability to use the mapping program to obtain field loss based on adjuster values and to evaluate optimum sampling procedures formed the basis of the 1976-1977 research.

RESEARCH OBJECTIVES

The objective of the May 15, 1976 - May 14, 1977 research was to develop a computer mapping system suitable for mapping crop-hail losses within a field based on loss assessments of an adjuster. The development of this
system included: 1) testing of the number of assessments necessary from a field to obtain an accurate field loss; 2) adapting the program to map irregular shaped fields and, 3) comparisons of field losses obtained from several different sampling methods. The basic question to be answered was: "What is the best way to obtain an accurate field loss?".

COMPUTER MAPPING

The computer mapping routine used in this research is based upon a multiquadric equation in which a series of cones are mathematically fitted to the map surface. In using the multiquadric equation and input data (adjuster loss assessment values) points a value for each cell in the map is obtained through interpolation. In other words, the map produced represents an exact fit of the input and interpolated values. Once a value has been established mathematically, it is converted to a symbol to be displayed visually. Conversion of the values to symbols is based upon the classification scheme desired, e.g. 5 or 10% class intervals in which each class has its own symbol: 10 symbols for 10% classes or 20 symbols for 5% classes.

Calculation of the area occupied by each class is accomplished by summing the number of map symbols that fall into the class. The frequency obtained represents a percentage of the area of the entire map and is determined from the length, width, and scale variables entered.

Calculation of the average damage or loss is accomplished by summing all values of damage determined at each map point by the multiquadric equation and then dividing by the total number of map points. It is thus a true weighted
mean value. For example, consider a map that is 12 inches wide and 10 inches long. The number of map values that would go into the mean would be 7200:

$$12 \times 10 = 120 \text{ [computer prints 10 cols/inch for the width]}$$

$$\times$$

$$10 \times 6 = 60 \text{ [computer prints 6 cols/inch for the length]}$$

$$120 \times 60 = 7200$$

The mean field loss is therefore based on many loss values and a pattern of the damage is visually displayed. A sample map is shown in Figure 1.

DATA

The data used as the basis of this research were fields from which loss assessments had been obtained over the past three years. There were a total of 219 fields from which loss assessments had been obtained. However, only 72 fields met the criteria designed for this study. Those criteria were as follows: 1) the field had to be larger than 10 acres; 2) more than eight assessments had to be taken for each field, 3) the field had to be of a rectangular shape, 4) the average loss of yield for the field had to be greater than 5%, and 5) the loss assessments obtained by the adjusters had to be well distributed throughout the field. Twenty-five additional fields were slightly modified to meet the above criteria. This modification consisted of removing ends of fields to obtain an even areal distribution of adjuster assessments or to make the field rectangular (the original mapping routine was designed to handle only rectangular shaped fields). These modifications were generally
Figure 1. Computer map evaluated using a multi-quadric equation.
minor but they did improve the data set. Therefore, a total of 97 fields was used as the data base.

The 97 fields were almost equally divided between corn (49 fields) and beans (48 fields). Ten fields came from data collected in 1974, 36 fields came from 1975 data, and 51 came from one storm in 1976. The 97 fields represented 14 stages of corn and 9 stages of beans. Crop stages for corn ranged from 8 leaf to soft dough and bean stages ranged from V-1 to R-7. A wide variety of crop stages throughout the growing season reflected the different storm dates of the past three years. Loss of yield ranged from 5% to 100%. The number of loss assessments in each field ranged from 8 to 33 and the average number of assessments per field was 14. Fields ranged in size from 10 to 250 acres, however, 84% of the fields were between 2C and 80 acres. The average field size was 54 acres and the median size was 41 acres.

DATA MANIPULATION

For each of the 97 fields, a map and weighted average loss for each field was produced using all of the adjusters assessments. The loss pattern map (with 5% class intervals) and weighted average of yield loss were considered correct. All field losses obtained by various sampling methods and techniques were compared against the weighted average of yield loss. The use of the weighted average as the correct value computed in this manner seemed appropriate because it was based on many adjuster-obtained assessments and the mapping routine generated additional loss assessments which were used to obtain the weighted average for the field.
Consultation with Country Companies personnel had revealed that it would be almost impossible, because of economic constraints, for adjusters to take many losses within a field as part of their normal procedures. The initial research in 1975-1976 had indicated that an 8 point sample provided reasonable accuracy and that an 8 point sample was significantly better than a 6 or 4 point sample. It was decided that sampling would continue in a similar fashion. Hopefully, the earlier analyses would be confirmed. The earlier analyses had been based on a sample size of 44 fields as compared to sample size of 97 fields used for this study.

Each of the 97 fields was systematically sampled for 8, 6, or 4 points according to the method exhibited in Figure 2. The locations were designed to represent equal area for a given sampling method. The loss values used at these locations were obtained from the map produced for the field using all of the adjusters loss assessments. The loss value used at a given location was the mid-point value of the class interval at that location. For instance, if the location of a loss assessment was in the 20-25% class interval then 22.5% was the loss value used at that location. These locations and losses were then used to generate a map and weighted average for each sample size for a given field. In other words, for each field, 4 maps and weighted averages were produced: for all points, and an 8 point, 6 point, and 4 point systematic sample. These maps and averages were labelled SYST (SURF) because the samples were systematically chosen and surface fitted maps of the data were prepared. The 8, 6, and 4 point values were also averaged in the normal fashion to obtain a straight average called SYST (AVG). The purpose of obtaining the SYST (AVG) was to compare it against the SYST (SURF) in tests to determine how much more (or less) accurate the weighted average is compared to a simple straight average.
Figure 2. 8, 6, and 4 point 2-line systematic samples.
After the initial mapping and averages for the entire data set of 97 fields were completed, the data was then stratified in several ways: by crop type and field size. For the former, stratification was based on a corn and bean discrimination. For the latter, the field sizes were stratified into two groups: 10-40 acres and 41-80 acres. After the maps and averages were produced and various stratifications done the data had to be statistically tested. The statistical tests are described in the next section.

**STATISTICAL TESTING**

The only statistic that can be tested to see if there is a difference between the average percent losses derived using a differing number of data points (8, 6, 4) is the measure of dispersion (σ) or spread of the average percent damages about the mean. The standard deviation difference test utilizes the measure of dispersion, i.e., the standard deviation, and was thus the primary statistic chosen to analyze the data. The objective of the testing was to find the number of points (loss assessments) which has the least dispersion or standard deviation (and hence reduces the error) and is significantly different from other numbers of sample points. The statistical formula necessary for this test are contained in Table 1.

**PRIMARY RESULTS**

The use of stratified and unstratified data has produced some interesting results, the most important will be discussed in this section. These primary results pertain to the following issues or questions: 1) the
Table 1. Statistical Formula used in 1976-1977 Research

Mean ($\bar{x}$):

\[
\bar{x} = \frac{\Sigma x}{N}
\]

where:  
$\Sigma x$ = total number of observations  
$N$ = assumed counter  
$j = 1$

Standard Deviation ($\sigma$):

(sampe) \[ \sigma_s = \sqrt{\frac{\Sigma x^2}{N} - \frac{\Sigma (x)^2}{N}} \]

(population estimate) \[ \sigma_p = \sigma_s \sqrt{\frac{N}{N-1}} \]

Standard Error of the Standard Deviation ($\sigma_\sigma$):

\[ \sigma_\sigma = \frac{\hat{\sigma}_p}{\sqrt{2N}} \]

Unpooled Estimate of the Standard Error of the
Difference of Standard Deviations ($\sigma_{\sigma-\sigma}$):

\[ \sigma_{\sigma-\sigma} = \sqrt{\frac{\sigma_1^2}{\sigma_1^2} + \frac{\sigma_2^2}{\sigma_2^2}} \]

where the standard error of the standard deviations ($\sigma_1$ and $\sigma_2$) are derived from independent samples.

t-Statistic for Standard Deviations Difference Test:

\[ t = \frac{\sigma_1 - \sigma_2}{\sqrt{\frac{\sigma_1^2}{\sigma_1^2} + \frac{\sigma_2^2}{\sigma_2^2}}} \]
number of sample points necessary to obtain an accurate estimate of the damage; 2) are the number of sample points significantly different from each other; 3) how much error occurs when the number of assessments varies; 4) does the computer mapping routine increase the accuracy of the field loss over a simple straight average; and 5) is the field loss obtained from computer mapping significantly different from that obtained by a simple straight average. The results will be presented with the use of a series of tables and/or graphs.

Table 2 presents results for the unstratified data (97 fields) comparing various number of sample points for two different sampling methods. For the SYST (SURF) method (computer mapping) the number of sample points are all significantly different from each other; in the case of the SYST (AVG) all are significantly different except when comparing 8 versus 6 points. However, this case approaches significance since the T-test value is 1.6955 and a value greater than 1.9600 is needed for significance. In testing methods, i.e. SYST (SURF) versus SYST (AVG), no significance was found using either an 8 point or 6 point sample size.

The data was then stratified by crop type for similar testing of the number of sample points and method of testing. The results are contained in Tables 3 and 4. For SYST (SURF) and SYST (AVG) 8 points are not different from 6 but both 6 and 8 points are significantly different from the 4 point sample. Again, we find no significant difference between the method of sampling for either crop, however, significance is approached in the case of the corn fields, especially for the 8 point samples. In the case of the 6 point samples no significant difference between sampling methods was found.
<table>
<thead>
<tr>
<th>Sampling Method</th>
<th># of points</th>
<th>Std. Dev. Difference</th>
<th>Unpooled Std. Error</th>
<th>t-table 0.05 level</th>
<th>t-test 0.05 level</th>
<th>Significant at 0.05 level</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYST (SURF)</td>
<td>8 points vs 6 points</td>
<td>0.3022</td>
<td>0.1341</td>
<td>1.9600</td>
<td>2.2534</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>8 points vs 4 points</td>
<td>1.9559</td>
<td>0.2394</td>
<td>1.9600</td>
<td>8.1713</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>6 points vs 4 points</td>
<td>1.6537</td>
<td>0.2478</td>
<td>1.9600</td>
<td>6.6737</td>
<td>yes</td>
</tr>
<tr>
<td>SYST (AVG)</td>
<td>8 points vs 6 points</td>
<td>0.2432</td>
<td>0.1434</td>
<td>1.9600</td>
<td>1.6955</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td>8 points vs 4 points</td>
<td>1.4171</td>
<td>0.2153</td>
<td>1.9600</td>
<td>6.5823</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>6 points vs 4 points</td>
<td>1.1739</td>
<td>0.2234</td>
<td>1.9600</td>
<td>5.2558</td>
<td>yes</td>
</tr>
<tr>
<td>SYST (SURF) vs SYST (AVG)</td>
<td>8 points vs 8 points</td>
<td>0.1243</td>
<td>0.1243</td>
<td>1.9600</td>
<td>1.000</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td>6 points vs 6 points</td>
<td>0.0653</td>
<td>0.1518</td>
<td>1.9600</td>
<td>0.4302</td>
<td>no</td>
</tr>
</tbody>
</table>
Table 3. Standard Deviation Difference T-Test:
48 Bean Fields
To Test the Number of Sample Points and Method of Sampling

<table>
<thead>
<tr>
<th>Sampling Method</th>
<th># of points</th>
<th>Std. Dev. Difference</th>
<th>Unpooled Std. Error</th>
<th>t-table at 0.05 level</th>
<th>t-test</th>
<th>Significant at 0.05 level</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYST (SURF)</td>
<td>8 points vs 6 points</td>
<td>0.3101</td>
<td>0.1907</td>
<td>1.9900</td>
<td>1.6260</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td>8 points vs 4 points</td>
<td>2.4373</td>
<td>0.3877</td>
<td>1.9900</td>
<td>6.2872</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>6 points vs 4 points</td>
<td>2.1272</td>
<td>0.3986</td>
<td>1.9900</td>
<td>5.3372</td>
<td>yes</td>
</tr>
<tr>
<td>SYST (AVG)</td>
<td>8 points vs 6 points</td>
<td>0.2977</td>
<td>0.2033</td>
<td>1.9900</td>
<td>1.4642</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td>8 points vs 4 points</td>
<td>1.7956</td>
<td>0.3378</td>
<td>1.9900</td>
<td>5.3152</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>6 points vs 4 points</td>
<td>1.4979</td>
<td>0.3506</td>
<td>1.9900</td>
<td>4.2727</td>
<td>yes</td>
</tr>
<tr>
<td>SYST (SURF) vs SYST (AVG)</td>
<td>8 points vs 8 points</td>
<td>0.1836</td>
<td>0.1737</td>
<td>1.9900</td>
<td>1.0568</td>
<td>no</td>
</tr>
<tr>
<td>SYST (AVG) vs SYST (AVG)</td>
<td>6 points vs 6 points</td>
<td>0.0812</td>
<td>0.2181</td>
<td>1.9900</td>
<td>1.3723</td>
<td>no</td>
</tr>
</tbody>
</table>

Corn and Bean: Comparison

<table>
<thead>
<tr>
<th>Sampling Method</th>
<th># of points</th>
<th>Std. Dev. Difference</th>
<th>Unpooled Std. Error</th>
<th>t-table at 0.05 level</th>
<th>t-test</th>
<th>Significant at 0.05 level</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYST (SURF) vs SYST (AVG)</td>
<td>8 points vs 8 points</td>
<td>0.0212</td>
<td>0.1674</td>
<td>1.9900</td>
<td>0.1267</td>
<td>no</td>
</tr>
<tr>
<td>SYST (SURF) vs SYST (AVG)</td>
<td>8 points vs 8 points</td>
<td>0.0737</td>
<td>0.1849</td>
<td>1.9900</td>
<td>0.3986</td>
<td>no</td>
</tr>
</tbody>
</table>
Table 4. Standard Deviation Difference T-Test:
49 Corn Fields
To Test the Number of Sample Points and Method of Sampling

<table>
<thead>
<tr>
<th>Sampling Method</th>
<th># of points</th>
<th>Std. Dev. Difference</th>
<th>Unpooled Std. Error</th>
<th>t-table 0.05 level</th>
<th>t-test</th>
<th>Significant at 0.05 level</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYST (SURF)</td>
<td>8 points vs 6 points</td>
<td>0.2917</td>
<td>0.1903</td>
<td>1.9900</td>
<td>1.5332</td>
<td>no</td>
</tr>
<tr>
<td>SYST (AVG)</td>
<td>8 points vs 4 points</td>
<td>1.3576</td>
<td>0.2835</td>
<td>1.9900</td>
<td>4.7888</td>
<td>yes</td>
</tr>
<tr>
<td>SYST (SURF)</td>
<td>6 points vs 4 points</td>
<td>1.0659</td>
<td>0.2972</td>
<td>1.9900</td>
<td>3.5863</td>
<td>yes</td>
</tr>
<tr>
<td>SYST (AVG)</td>
<td>8 points vs 6 points</td>
<td>0.1792</td>
<td>0.2025</td>
<td>1.9900</td>
<td>0.8849</td>
<td>no</td>
</tr>
<tr>
<td>SYST (AVG)</td>
<td>8 points vs 4 points</td>
<td>0.9312</td>
<td>0.2651</td>
<td>1.9900</td>
<td>3.5133</td>
<td>yes</td>
</tr>
<tr>
<td>SYST (AVG)</td>
<td>6 points vs 4 points</td>
<td>0.7520</td>
<td>0.2747</td>
<td>1.9900</td>
<td>2.7377</td>
<td>yes</td>
</tr>
<tr>
<td>SYST (SURF)</td>
<td>8 points vs 8 points</td>
<td>0.3461</td>
<td>0.1789</td>
<td>1.9900</td>
<td>1.9343</td>
<td>no</td>
</tr>
<tr>
<td>SYST (AVG)</td>
<td>6 points vs 6 points</td>
<td>0.0036</td>
<td>0.2126</td>
<td>1.9900</td>
<td>0.1580</td>
<td>no</td>
</tr>
</tbody>
</table>
A stratification of the data by field size was performed. The data were divided into two groups of field sizes: 10-40 acres and 41-80 acres. The results are contained in Table 5. For fields in the 10-40 acre size both sampling methods using an 8 point sample are not significantly different from the 6 point sample. There is no significant difference between the sampling methods for either 8 or 6 point samples.

For the fields in 41-80 acre class all sample sizes were significantly different from each other. As for the 10-40 acre sample the sampling methods were not significantly different from each other.

The above tests were used to determine if there was any significant difference in sampling method or sample sizes. They did not give any indication as to the difference in accuracy of one method or sample size as compared to the others. That information is contained in Table 6. This table indicates the average error ($\bar{x}$) and standard deviation ($\sigma$) between the weighted average of all the values and the values obtained for the two sampling methods using different sample size. For instance, for all 97 fields when comparing the all weighted values against an 8 point SYST (SURF) sample we find that the SYST (SURF) sample overplays by 0.7912% and has a standard deviation of 1.1540. The SYST (AVG) sample underplays by 0.6678% and has a standard deviation of 1.2783. Inspection of 6 and 4 point samples shows an increase in the average error ($\bar{x}$) and standard deviation. This is generally true whether the samples are stratified by crop type or field size. Furthermore, the standard deviation is usually larger for the SYST (AVG) than the SYST (SURF). This is an indication that the SYST (AVG) has more of a tendency to have large errors in it than the SYST (SURF) because the standard deviation is a
<table>
<thead>
<tr>
<th>Sampling Method</th>
<th># of points</th>
<th>Std. Dev. Difference</th>
<th>Unpooled Std. Error</th>
<th>t-table</th>
<th>t-test</th>
<th>Significant at 0.05 level</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>10 - 40 Acres: 46 Fields</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SYST (SURF)</td>
<td>8 points vs 6 points</td>
<td>0.0404</td>
<td>0.2337</td>
<td>1.9900</td>
<td>0.1729</td>
<td>no</td>
</tr>
<tr>
<td>SYST (AVG)</td>
<td>8 points vs 6 points</td>
<td>0.0274</td>
<td>0.2457</td>
<td>1.9900</td>
<td>0.1115</td>
<td>no</td>
</tr>
<tr>
<td>SYST (SURF)</td>
<td>8 points vs 8 points</td>
<td>0.0571</td>
<td>0.1991</td>
<td>1.9900</td>
<td>0.2868</td>
<td>no</td>
</tr>
<tr>
<td>SYST (AVG)</td>
<td>6 points vs 6 points</td>
<td>0.0701</td>
<td>0.1940</td>
<td>1.9900</td>
<td>0.3613</td>
<td>no</td>
</tr>
<tr>
<td><strong>41 - 80 Acres: 39 Fields</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>SYST (SURF)</td>
<td>8 points vs 6 points</td>
<td>0.5844</td>
<td>0.2253</td>
<td>1.9930</td>
<td>2.5937</td>
<td>yes</td>
</tr>
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<td>SYST (AVG)</td>
<td>8 points vs 6 points</td>
<td>0.6459</td>
<td>0.2304</td>
<td>1.9930</td>
<td>2.8034</td>
<td>yes</td>
</tr>
<tr>
<td>SYST (SURF)</td>
<td>8 points vs 8 points</td>
<td>0.0051</td>
<td>0.1724</td>
<td>1.9930</td>
<td>0.0296</td>
<td>no</td>
</tr>
<tr>
<td>SYST (AVG)</td>
<td>6 points vs 6 points</td>
<td>0.2072</td>
<td>0.2722</td>
<td>1.9930</td>
<td>0.2072</td>
<td>no</td>
</tr>
<tr>
<td><strong>10 - 40 Acres, 41 - 80 Acres</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>SYST (SURF)</td>
<td>8 points vs 8 points</td>
<td>0.2413</td>
<td>0.1841</td>
<td>1.9900</td>
<td>1.3107</td>
<td>no</td>
</tr>
<tr>
<td>SYST (AVG)</td>
<td>8 points vs 8 points</td>
<td>0.3035</td>
<td>0.1883</td>
<td>1.9900</td>
<td>1.6116</td>
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</tbody>
</table>
Table 6. Summary Statistics for Various Sampling Methods
Based on Unstratified and Stratified Data

<table>
<thead>
<tr>
<th>Statistic</th>
<th>All vs 8</th>
<th>All vs 6</th>
<th>All vs 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\bar{X}$</td>
<td>$\sigma$</td>
<td>$\bar{X}$</td>
</tr>
<tr>
<td>All Fields</td>
<td>SYST (SURF)</td>
<td>-0.7912</td>
<td>1.1540</td>
</tr>
<tr>
<td></td>
<td>SYST (AVG)</td>
<td>0.6678</td>
<td>1.2783</td>
</tr>
<tr>
<td></td>
<td>N = 97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>SYST (SURF)</td>
<td>-0.7784</td>
<td>1.1644</td>
</tr>
<tr>
<td></td>
<td>SYST (AVG)</td>
<td>0.7649</td>
<td>1.3105</td>
</tr>
<tr>
<td></td>
<td>N = 49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beans</td>
<td>SYST (SURF)</td>
<td>-0.8044</td>
<td>1.1432</td>
</tr>
<tr>
<td></td>
<td>SYST (AVG)</td>
<td>0.5687</td>
<td>1.2368</td>
</tr>
<tr>
<td></td>
<td>N = 48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10-40 Acres</td>
<td>SYST (SURF)</td>
<td>-0.8396</td>
<td>1.3068</td>
</tr>
<tr>
<td></td>
<td>SYST (AVG)</td>
<td>0.8672</td>
<td>1.3639</td>
</tr>
<tr>
<td></td>
<td>N = 46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>41-80 Acres</td>
<td>SYST (SURF)</td>
<td>-0.7574</td>
<td>1.0655</td>
</tr>
<tr>
<td></td>
<td>SYST (AVG)</td>
<td>0.4544</td>
<td>1.0604</td>
</tr>
<tr>
<td></td>
<td>N = 39</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$\bar{X}$ = Mean

$\sigma$ = Standard Deviation
statistic that reflects extreme values. This is very important when one considers that the adjuster's goal is accuracy in every field.

A graphical display of the variations in the means and errors are shown in Figures 3 through 5. Figure 3 shows the percent difference from a weighted average for all points as compared to 8, 6, and 4 point samples for two sampling methods. The computer mapping routine [SYST (SURF)] has a tendency to overpay and the straight average [SYST (AVG)] to underpay. The important thing to note is the change in the width of the percent difference as the number of sample points is reduced. For the 8 point sample approximately 57% (55 of the 97 samples) are within 2% of the correct value. Only about 27% of the 4 point samples are within 2% of the true value. There are no cases of 6% errors for the 8 point samples and both the 6 and 4 point samples indicate some errors larger than 6%.

Figures 4 and 5 show the number of cases versus the absolute percent error for computer mapping [SYST (SURF)] and straight average [SYST (AVG)]. These figures simply show that more cases of small error occur with the larger sample sizes and more cases of large error occur with the smaller sample size.

PRIMARY RECOMMENDATIONS

Considerable analyses have been performed using the computer mapping and statistical tests to determine the best sampling methods to be used by the adjuster. Some of the results have been somewhat contradictory. After careful assessment of all the results the following sampling procedures are recommended:

1) systematic samples as indicated in Figure 2 are recommended.

2) Four point samples are not recommended except in extremely small fields.
Figure 3.
PERCENT DIFFERENCE FROM A WEIGHTED AVERAGE OF ALL THE POINTS AS COMPARED TO 8, 6, AND 4 POINT SAMPLES

- Weighted Average
- Straight Average
- Field Sampling Method

Sample size was 97 fields
Figure 4. The number of cases versus absolute percent error for 8, 6, and 4 point samples (weighted average).
Figure 5. The number of cases versus absolute percent error for 8, 6, and 4 point samples (straight average).
3) Six point samples are recommended for fields in the 10-40 acre size.
4) Eight point samples should be used for fields in the 41-80 acre size,
5) There were few fields larger than 80 acres and firm conclusions can not be made concerning large fields, however, it would seem appropriate to have at least one loss assessment per 10 acres.
6) If aerial photography is available and a high degree of variability in the damage is indicated more assessments should be taken than those recommended above.
7) Computer mapping of the fields will increase the overall accuracy and is therefore recommended. However, experience with the program might indicate that some discretion could be used. For instance, if after the assessments have been taken and very little variability in the damage is indicated then mapping might not be necessary.

SECONDARY RESULTS AND RECOMMENDATIONS

One of the goals of the project was to make a 3-way comparison of loss values obtained by the Illinois State Water Survey assigned adjuster, an audit adjuster, and the settling adjuster who used the aerial photography. The intent was to determine what effect, if any, the photography had on the final adjustment. This goal could not be accomplished because 80% of the fields selected for audit were settled by the same team of adjusters. This completely biased the sample and made it unuseable.

In addition to taking systematic samples of 8, 6, and 4 points another method of selecting sample location was attempted. The purpose of this test
was to determine if aerial photography could be used to determine the sampling location to obtain an accurate loss of yield for the field. The principal investigator looked at the photography and decided where the loss assessments should be taken. The values for 33 of the 97 fields were mapped [PHOTO (SURF)] and a straight average by [PHOTO (AVG)] obtained. SYST (SURF) and SYST (AVG) values had already been computed for the original data and the results of all 4 methods were compared. The results when using photography (Tables A and B, Appendix) were much worse than the systematic samples. Therefore, using the photography alone to determine assessment locations is not recommended. However, for fields with extreme variability, a combination of a systematic sample and use of the photographs is recommended.

An attempt was made to determine what changes would occur if 8 or 6 point samples obtained from 3 or 4 lines through the field were used instead of the two line samples. Some of the research and knowledge of how the mapping routine works had indicated that more accuracy might be obtained by having an 8 or 6 point sample obtained from 3 or 4 line samples through the field. This revolved mainly around trying to control "edge effects" that occur with any kind of mapping routine. Edge effects occur when there aren't enough control points at the edges of fields or areas being mapped. A three or four line sample essentially had the effect of moving sample points closer to the edges of the field. Also, re-sampling according to 3 or 4 line samples would give some indication as to the importance of adjuster location in the field (i.e. how critical is it that his sample be chosen from an exact location). There were 9 fields selected for this test. They were chosen because of the high number of loss assessments (average of 22) per field and the excellent
areal distribution of the assessments. Figure A in the Appendix displays various methods of obtaining the 3 and 4 line systematic samples. The results contained in Table C in the Appendix, showed that very little difference occurred. For example, using 3 variations of 8 point - 3 line samples, the maximum average difference for any method was 1.67% and the minimum average difference was 0.81%, the absolute maximum difference was 4.73%. The 2 line samples provided more values close to the true value than any of the 3 or 4 line samples. Although the results are based on a small sample of fields it is probably fair to conclude that not much accuracy is gained by using a method different than the 8 point systematic sample illustrated in Figure 2. Also, accurate location of the adjuster is not extremely critical. In other words, it is not necessary for the adjuster to accurately measure distances to his locations; however, he should attempt to be close to the locations.

The original computer mapping routine had the capability of mapping only rectangular fields. It is been modified to map irregular shaped areas provided the area boundaries are supplied to it. A revised version of the program and instructions can be found in the Appendix (Figure B).

The capability to map irregular boundaries makes it ideal for mapping entire storm areas. It would require that the boundaries be provided along with many sample points. A sample map of an entire storm is shown in Figure 6. The map could be prepared soon after the storm, prior to actual field loss settlement, by having personnel obtain losses at many locations throughout the storm. The mapping routine would compute an average loss for the storm. This weighted average combined with the company knowledge of the percent of
Figure 6. Computer map for an entire storm utilizing the irregular border option of the mapping routine.
acres covered in the storm and approximate insured value per acre could be used to predict the total cost of the storm. This would be extremely valuable to hail managers who must make an estimate of the funds necessary to cover loss payments. These funds are withdrawn from investment or savings accounts which are accruing a great deal of interest on a daily basis. An overestimate of funds withdrawn could be very expensive in lost interest.

SUMMARY

The objectives of this research were to develop a computer mapping system suitable for mapping crop hail losses. This development included: 1) testing of the number of assessment points necessary from a field to obtain an accurate field loss; 2) adapting the mapping program to map irregular shaped fields and 3) comparison of fielded loss obtained from several different sampling methods.

The results and recommendation contained in the previous sections concluded that six to eight point systematic samples, depending on field size, are sufficient to obtain a reasonably accurate loss assessment for a field. Computer mapping of the field is not necessary but will likely increase the accuracy. The combined use of aerial photography and computer mapping would be advisable in fields where a high degree of loss variability is indicated, either from the photography or from actual loss assessments.

The computer mapping routine has been developed for mapping regular or irregular shaped fields. The flexibility of using it for any shaped field makes the routine much more useful than the original routine.
The computer mapping routine can be used to map an entire storm if the necessary input values are provided. The entire storm mapping and weighted average can be valuable to crop-hail claims managers in several ways. One way is to combine the average storm loss with company knowledge of insured acreage to determine the amount of funds to be withdrawn from savings accounts or investments to pay losses. Another possible use would be to use the storm map as a pre-audit of the adjusters. For instance, if an adjuster determines a field loss to be 70% and the field lies in a 20% area according to the storm map supervisory personnel might want to have this field re-checked.

The 1977-78 research consists of performing some final checks on the computer mapping routine and training selected personnel within The Country Companies to use the program. This work will be completed during the summer of 1977. The principal investigator will be available 20% time from August 1977 to May 1978 for consultation with The Country Companies. The consultation will be related to areal photography of crop damage, the computer mapping system, and associated subjects.

REFERENCES


ACKNOWLEDGEMENTS

This research was performed under the general supervision of William C. Ackermann, Chief of the Illinois State Water Survey and Stanley A. Changnon, Head of the Atmospheric Sciences Section of the Illinois State Water Survey.

Roy Whiteman, Louis Rediger, and Donald Bradshaw of The Country Companies have offered suggestions concerning the project and made decisions related to the continued funding of the project. John Williams, Carroll Kries, and Robert Weiser of The Country Companies obtained the loss assessments from the fields.
APPENDIX
Table A. Statistical Summary for 33 Selected Corn and Bean Fields

<table>
<thead>
<tr>
<th>Statistic</th>
<th>$\bar{X}$</th>
<th>$\sigma$</th>
<th>$\bar{X}$</th>
<th>$\sigma$</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYST (SURF)</td>
<td>-1.1618</td>
<td>1.2605</td>
<td>-1.2773</td>
<td>1.5902</td>
</tr>
<tr>
<td>SYST (AVG)</td>
<td>0.7367</td>
<td>1.4588</td>
<td>1.5673</td>
<td>1.5970</td>
</tr>
<tr>
<td>PHOTO (SURF)</td>
<td>-1.7642</td>
<td>2.5211</td>
<td>-2.5445</td>
<td>2.4801</td>
</tr>
<tr>
<td>PHOTO (AVG)</td>
<td>-0.1370</td>
<td>3.2114</td>
<td>-0.4152</td>
<td>2.6392</td>
</tr>
</tbody>
</table>

Sample Size = 33
Table B. Standard Deviation Difference T-Test:
33 Selected Fields
To Test the Number of Points and Method of Sampling

<table>
<thead>
<tr>
<th>Sampling Method</th>
<th># of points</th>
<th>Std. Dev. Difference</th>
<th>Unpooled Std. Error</th>
<th>t-table 0.05 level</th>
<th>t-test</th>
<th>Significant at 0.05 level</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYST (SURF)</td>
<td>8 points vs 6 points</td>
<td>0.3297</td>
<td>0.2537</td>
<td>2.0000</td>
<td>1.2996</td>
<td>no</td>
</tr>
<tr>
<td>SYST (AVG)</td>
<td>8 points vs 6 points</td>
<td>0.1382</td>
<td>0.2703</td>
<td>2.0000</td>
<td>0.5112</td>
<td>no</td>
</tr>
<tr>
<td>PHOTO (SURF)</td>
<td>8 points vs 6 points</td>
<td>0.0410</td>
<td>0.4420</td>
<td>2.0000</td>
<td>0.0928</td>
<td>no</td>
</tr>
<tr>
<td>PHOTO (AVG)</td>
<td>8 points vs 6 points</td>
<td>0.5222</td>
<td>0.5235</td>
<td>2.0000</td>
<td>0.9975</td>
<td>no</td>
</tr>
<tr>
<td>S (S) vs S (A)</td>
<td>8 points vs 8 points</td>
<td>0.1983</td>
<td>0.2410</td>
<td>2.0000</td>
<td>0.8229</td>
<td>no</td>
</tr>
<tr>
<td>S (S) vs P (S)</td>
<td>8 points vs 8 points</td>
<td>1.2606</td>
<td>0.3523</td>
<td>2.0000</td>
<td>3.5780</td>
<td>yes</td>
</tr>
<tr>
<td>S (S) vs P (A)</td>
<td>8 points vs 8 points</td>
<td>1.9509</td>
<td>0.4312</td>
<td>2.0000</td>
<td>4.5240</td>
<td>yes</td>
</tr>
<tr>
<td>S (A) vs P (S)</td>
<td>8 points vs 8 points</td>
<td>1.0623</td>
<td>0.3640</td>
<td>2.0000</td>
<td>2.9181</td>
<td>yes</td>
</tr>
<tr>
<td>S (A) vs P (A)</td>
<td>8 points vs 8 points</td>
<td>1.7526</td>
<td>0.4409</td>
<td>2.0000</td>
<td>3.9754</td>
<td>yes</td>
</tr>
<tr>
<td>P (S) vs P (A)</td>
<td>8 points vs 8 points</td>
<td>0.6903</td>
<td>0.5103</td>
<td>2.0000</td>
<td>1.3527</td>
<td>no</td>
</tr>
</tbody>
</table>

S (S) = SYST (SURF)
S (A) = SYST (AVG)
P (S) = PHOTO (SURF)
P (A) = PHOTO (AVG)
Figure A. 8 and 6 point systematic samples using 3 and 4 lines through the field.
Table C. Weighted Average Losses Using a Variety of Systematic Sampling Methods

<table>
<thead>
<tr>
<th>Field #</th>
<th>Crop</th>
<th>Acres</th>
<th># Counts</th>
<th>All Points</th>
<th>8 pt. sample</th>
<th>6 pt. sample</th>
<th>4 pt. sample</th>
<th>Change from 2 to 3 line (8 pt. sample)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC 10</td>
<td>Bean</td>
<td>124</td>
<td>20</td>
<td>11.47</td>
<td>11.53*</td>
<td>11.01</td>
<td>11.58</td>
<td>0.13</td>
</tr>
<tr>
<td>NC 17</td>
<td>Corn</td>
<td>80</td>
<td>33</td>
<td>42.91</td>
<td>45.00</td>
<td>41.74</td>
<td>49.39</td>
<td>0.26</td>
</tr>
<tr>
<td>NC 64</td>
<td>Bean</td>
<td>75</td>
<td>16</td>
<td>10.59</td>
<td>10.66*</td>
<td>10.79</td>
<td>11.57</td>
<td>0.0</td>
</tr>
<tr>
<td>NC 35</td>
<td>Corn</td>
<td>36</td>
<td>17</td>
<td>80.53</td>
<td>81.11</td>
<td>82.74</td>
<td>85.53</td>
<td>0.61</td>
</tr>
<tr>
<td>NC 22</td>
<td>Bean</td>
<td>68</td>
<td>16</td>
<td>10.73</td>
<td>11.43</td>
<td>11.96</td>
<td>13.07</td>
<td>0.16</td>
</tr>
<tr>
<td>SO 2</td>
<td>Corn</td>
<td>80</td>
<td>21</td>
<td>33.21</td>
<td>33.58*</td>
<td>32.71</td>
<td>35.01</td>
<td>3.13</td>
</tr>
<tr>
<td>SO 5</td>
<td>Bean</td>
<td>119</td>
<td>32</td>
<td>28.89</td>
<td>30.21</td>
<td>32.71</td>
<td>35.92</td>
<td>3.43</td>
</tr>
<tr>
<td>DO 4</td>
<td>Corn</td>
<td>33</td>
<td>14</td>
<td>60.21</td>
<td>60.85</td>
<td>60.23*</td>
<td>63.81</td>
<td>1.64</td>
</tr>
<tr>
<td>C 4</td>
<td>Bean</td>
<td>116</td>
<td>29</td>
<td>87.98</td>
<td>88.63*</td>
<td>89.47</td>
<td>89.67</td>
<td>0.58</td>
</tr>
</tbody>
</table>

* Value closest to all point value.
Figure B. Complete listing of the computer mapping program including a list of instructions.
FIVE CONTROL CARDS ARE NECESSARY TO RUN THIS PROGRAM:

CARD1: MAP CARD TO IDENTIFY, NUMBER OF MAPS TO BE RUN
CARD2: TITLE CARD
CARD3: VARIABLE FORMAT CARD FOR X & Y COORDINATES AND ASSOCIATED
LOSS VALUES
CARD4: FIELD INFORMATION CARD SET UP AS FOLLOWS:
FI= FIELD NAME....A-FORMAT (COLS 1-4)
PH1, PH2= PHOTON NUMBER....A-FORMAT (COLS 5-9)
IA= ALTIMETER.....I-FORMAT....RIGHT, JUSTIFY (COLS 11-14)
FT= FUEL TYPE....A-FORMAT (COLS 16-17)
SA= SCALE 1 INCH = FEET....F-FORMAT (COLS 19-24)
CR= CRNRP TYPE....A-FORMAT (COLS 25-28)
SC= CRNRP SCALE....A-FORMAT (COLS 29-33)
NP= NUMBER OF COUNTS....I-FORMAT....RIGHT, JUSTIFY (COLS 35-36)
XMIN= 0....F-FORMAT (COLS 40-49)
XMAX= WIDTH OF FIELD IN INCHES....F-FORMAT (COLS 50-59)
YMIN= 0....F-FORMAT (COLS 60-69)
YMAX= LENGTH OF FIELD IN INCHES....F-FORMAT (COLS 70-79)
NC= BLANK (COL 80)

CARD5: POINT CARD SET UP AS FOLLOWS:
NUM= ENTER A 1 IN AS MANY COLUMNS AS THERE ARE COUNTS (COLS 1-50)
XSIZE= DESIRED WIDTH OF MAP IN INCHES—LENGTH AUTOMATICALLY SCALLED
TO WIDTH....F-FORMAT (COLS 51-70)
ADJ= INSURED VALUE OF EACH ACRE (F-FORMAT)
NRD= 1 IF IRREGULAR BOUNDARY; 0 IF REGULAR SHAPED FIELD (COL 80)

 THESE 5 CARDS FOLLOW THE PROGRAM AND ARE IN TURN FOLLOWED BY DATA
CARDS—1 PAIR OF X & Y COORDINATES AND ASSOCIATED LOSS
VALUE PER CARD. IF NRD=0, THEN INCLUDE X & Y COORDINATES
FOR NON-BOUNDARY POINTS. IF NRD=0 AND NO POINTS ARE NEEDED
REPEAT CARDS 2-5 FOR EACH ADDITIONAL MAP DESIRED INCCLUDING
APPROPRIATE DATA CARDS

DIMENSION XX(50), YY(50), ZZ(50)
DIMENSION NUM(50), NV(50)
DIMENSION XX(50), YY(50), ZZ(50), CCM(66)
DIMENSION ID(20), FORM(20)
DIMENSION XMPC(10), NX(10)
COMMON TOTA X, WA
REAL*8 CCM

NMAPS=NUMBER OF MAPS TO BE EVALUATED FROM 01 TO 99
NSW=SWITCH: 1=OF; 2=TRENDS SURFACE USE 1
NDD=DEGREE OF TRENDS SURFACE (0-9); USE 0

C IIPUN=SWITCH FOR PUNCHING COEFFICIENTS FOR TRENDS SURFACE: 0=NO; 1=YES
READ(5,10) NMAPS, NSW, NDD
10 FORMAT(2I1) READ(5,11) ID(J), J=1,20
11 FORMAT(2I1) READ(5,12) FORM(J), J=1,20
12 READ(5,21) FI, PH1, PH2, IA, FT, SA, CR, SC, NP, XMIN, XMAX, YMIN, YMAX, NC
13 READ(5,24) IF
14 READ(5,25) FI, PH1, PH2, IA, FT, SA, CR, SC, NP, XMIN, XMAX, YMIN, YMAX, NC
15 READ(5,26) (NUM(J), J=1,50), XSIZE, ADJ, NRD
16 READ(5,27) (NUM(J), J=1,50), XSIZE, ADJ, NRD
17 FORMAT(25) 26 FORMAT(25I1, 2F10.2, 2E10.2)
18 WRITE(6,41) I, J, I
19 DO 30 J=1, 50, I=1, 20
30 WRITE(6,41) I, J, I
40 WRITE(6,41) I, J, I
41 WRITE(6,42) I, J, I
42 WRITE(6,43) I, J, I
43 WRITE(6,44) I, J, I
*FILE TYPE: 'A2/1X,' 'SCALE: 1"= 'F6.1/1X,' 'CROP: 'A4/1X,' 'CROP STAG
*E: 'A4/1X,' 'N.' NRS: 'J2/1X,' 'XMIN: 'F10.2/1X,' 'XMAX: 'F10.2/1X,'
*YMIN: 'F10.2/1X,' 'YMAX: 'F10.2/1X,' 'Z-COORDINATE (X-COORDINATE)
*MATE
*Z-VALUE: 1

0024 IF(NC.EQ.0) GO TO 59
0025 IF(NC.EQ.1) MC=10
0026 READ(5,52)(XMPC(J),J=1,MC)
0027 52 FORMAT(10F8.2)
0028 DO 54 J=1,NP
0029 N=Z(J)
0030 54 Z(J)=XMPC(N)
0031 59 K=0
0032 DO 110 J=1,50
0033 IF(SUM(J).EQ.1) GO TO 100
0034 GO TO 110
0035 100 K=K+1
0036 NV(K)=J
0037 110 CONTINUE
0038 XNP=NP
0039 110 SUMZ=0.
0040 NORS=K
0041 DO 120 J=1,NORS
0042 X(J)=X(NV(J))
0043 Y(J)=Y(NV(J))
0044 Z(J)=Z(NV(J))
0045 120 SUMZ=SUMZ+Z(J)
0046 AVGZ=SUMZ/XNP
0047 DO 60 J=1,NORS
0048 60 WRITE(6,61) X(J),Y(J),Z(J)
0049 61 FORMAT(3X,F8.2,9X,F8.2,AX,F8.2)
0050 IF(NWS.EQ.2) GO TO 65
0051 CALL MAESLV(X,Y,Z,CCM,NORS)
0052 GO TO 69
0053 65 IIPUN=0
0054 DO 68 J=1,10
0055 68 NX(J)=0
0056 NX(NDD)=1
0057 CALL POLYM(X,Y,Z,NORS,IIPUN,NX,CCM)
0058 69 CALL MAP(CCM,10,X,Y,XMIN,XMAX,YMIN,YMAX,NORS,SUM,SA,ADJ,NV,XSIZE,NDD,..NSW,NORO)
0059 WRITE(6,70)AVGZ
0060 70 FORMAT(1X,'AVERAGE OF % DAMAGE FOR ENTIRE FIELD BASED ON IN
*PUT MAP POINTS= 'F6.2,' 'F1)
0061 1000 CONTINUE
0062 STOP
0063 END
SUBROUTINE MOESLV(X, Y, Z, CCI, NR)

DIMENSION X(50), Y(50), Z(50), AA(50, 50), CCI(66), ZA(50)

INTEGER*4 IDUM(50)

REAL*8 AA, DSORT, XX1, YY1, XX2, YY2, CCI, ZA

DO 10 I = 1, NR

YY2 = Y(I)

DO 10 J = 1, NR

XX1 = X(J)

YY1 = Y(J)

10 AA(I, J) = DSORT((XX1 - XX2)**2 + (YY1 - YY2)**2)

DO 20 I = 1, NR

20 ZA(I) = Z(I)

IER = 1

CALL GAUSZ(AA, NR, 50, ZA, CCI, IDUM, IER)

RETURN

END
SUBROUTINE MAP(CCI, ID, X, Y, XMIN, XMAX, YMIN, YMAX, NP, SA, ADJ, NV, XSIZE,
  * NDD, NSH, NRDR)

DIMENSION NC1(20), NC2(20), PT(20), AA(20)

DIMENSION X(50), Y(50), CCI(66), TD(20), MCOUNT(20), MAP1(130), MAP2(130,
  *) MAP3(130), IX(120), ISX2(120), ISX3(120)

DIMENSION NV(50), NX(50), NY(50)

DIMENSION NSF(10), NBR(1000), NRC(1000)

REAL*8 CCI

COMMON TOTAR, WA

DATA MINUS(/) / DATA IAD(/) / DATA NSF(/)

DATA ISX1(/) / DATA ISX2(/) / DATA ISX3(/)

DATA IAD(/) / DATA ISX1(/) / DATA ISX2(/) / DATA ISX3(/)

DATA NCOLS=XSIZ*10. XDI=XM=XMIN

YDIF=YMAX-YMIN

XNY=(XDI/XDI*NCOLS)*.8+.5

YI=YDIF/(XNY-1.)

XI=XDI/(NCOLS-1)

NYY=XNY

DIF=(130-NCOLS)/2.

NDIF=DIF

IF(NRDR.EQ.0) GO TO 20

CALL BORDER(NBR, NRC, NEWRS, XMIN, XMAX, YMIN, YMAX, NCOLS)

DO 10 J=1, NP

NX(J)=(X(J)-XMIN)/XI+1.5

10  NY(J)=(Y(J)-YMIN)/YI+1.5

DO 25 J=1, 10

25  NCOUNT(J)=0

WRITE(6, 31) (ID(J), J=1, 20)

31  FORMAT('ID, 20A4')

DO 300 J=1, 130

300  MAP1(J)=ISX1(1)

DO 310 J=1, NCOLS

310  MAP1(K)=MINUS

WRITE(6, 58) (MAP1(K), K=1, 130)

L1=I

L2=O

CT=0.

DO 55 K=1, NYY

55  IF(NRDR.EQ.0) GO TO 80

DO 42 J=1, 130

42  MAP1(J)=ISX1(I)

MAP2(J)=ISX1(I)

MAP3(J)=ISX1(I)

44  IF(K.GT.NBR(NEWRS)) GO TO 90

45  IF(K.LT.NBR(1)) GO TO 90

48  L1=L1+2

L2=L2+2

N1=NRC(L1)

N2=NRC(L2)

GO TO 43
0055  80  N1=1
0056  40  M2=MNCOLS
0057  43  YR=YMIN+(K-1)*YI
0058  50  DO  50  J=N1,N2
0059   XR=XMIN+(J-1)*XI
0060  60  IF(NSW.EQ.2)GO TO 372
0061  61  ZC=0
0062  370  DO  370 L=1,NSP
0063  370  ZC=ZC+CCI(L)*SORT((X(L)-XR)**2+(Y(L)-YR)**2)
0064  372  GO TO 373
0065  373  ZC=ZP(CCI,XR,YR,NSP)
0066  374  IF(ZC.GT.100.0) ZC=100.0
0067  375  IF(ZC.LT.0.0) ZC=0.0
0068  376  SUM=SUM+ZC
0069  377  CT=CT+1
0070  378  NSPP=ZC/5+1
0071  379  IF(NSPP.LT.1) NSPP=1
0072  380  IF(NSPP.GT.20) NSPP=20
0073  381  NSP=ZC/10+1
0074  382  IF(NSP.LT.1) NSP=1
0075  383  IF(NSP.GT.10) NSP=10
0076  384  NCOUNT(NSP)=NCOUNT(NSP)+1
0077  385  I=I+NDIF
0078  386  MAP1(I)=ISX1(NSP)
0079  387  MAP2(I)=ISX2(NSP)
0080  388  MAP3(I)=ISX3(NSP)
0081  389  L3=L3+1
0082  390  IF(NNR(I,2).EQ.NRR(L3)) GO TO 48
0083  391  CONTINUE
0084  392  N2=NCOLS+1+NDIF
0085  393  MAP1(N2)=1
0086  394  MAP1(NSP)=1
0087  395  DO  51 L=1,NSP
0088  51  IF(NY(L).EQ.K) GO TO 52
0089  52  GO TO 51
0090  53  IF(NY(L).LT.10) GO TO 53
0091  54  NF=NY(L)/10
0092  55  NS=NY(L)-NF*10
0093  56  IF(NS.EQ.0) NS=10
0094  57  GO TO 54
0095  58  NF=NY(L)
0096  59  KL=NX(L)+NDIF
0097  60  IF(NX(L).EQ.NCNO NCOLS.AND.* NY(L).GT.10) KL=NCOLS-1
0098  61  MAP1(KL)=NSF(NF)
0099  62  MAP2(KL)=ISX1(I)
0100  63  MAP3(KL)=ISX1(I)
0101  64  IF(NY(L).LT.10) GO TO 51
0102  65  KL=KL+1
0103  66  MAP1(KL)=NSF(NS)
0104  67  MAP2(KL)=ISX1(I)
0105  68  MAP3(KL)=ISX1(I)
0106  69  CONTINUE
0107  70  WRITE(*,58)(MAP1(J),J=1,130)
0108  71  WRITE(*,59)(MAP2(J),J=1,130)
0109  72  WRITE(*,59)(MAP3(J),J=1,130)
0110  73  FORMAT(1X,130A1)
0111  74  FORMAT(1X,130A1)
0112  75  WRITE(*,58)(NX(J),J=1,130)
0113  76  WRITE(*,59)(NX(J),J=1,130)
0114  77  WRITE(*,59)(NX(J),J=1,130)
01108            DO 210 J=1, NCOLS
01109            K=J+MDIF
01110            210 MAP1(K)=MINUS
01111            WRITE(6,58)(MAP1(K),K=1,130)
01112            TOTFRE=0.
01113            DO 150 J=1,10
01114            150 TOTFRE=TOTFRE+NCOUNT(J)
01115            TOTAR=CT/(NCOLS*NYY)*XDIFF*YDIFF*SA**2)/43560.
01116            DO 122 J=1,10
01117            NC1(J)=(J-1)*10
01118            MC2(J)=NC1(J)+10
01119            PT(J)=NCOUNT(J)/TOTFRE*100.
01120            AA(J)=PF(J)/TOTAR
01121            151 XNC1=NC1(J)
01122            WRITE(6,66)
01123            66 FORMAT(1X,'/*40X,SYMBO*, 8X,'CLASS',7X,'FREQUENCY',9X,'AREA',/51
01124            *X, '(% DAMAGE)',8X,'(% AREA)',11X,(ACRES)*,')
01125            DO 100 J=1,10
01126            100 WRITE(6,60)ISX1(J),ISX1(J),ISX1(J)
01127            IF(II.EQ.2)GO TO 71
01128            WRITE(6,61)ISX2(J),ISX2(J),ISX2(J)
01129            GO TO 72
01130            71 WRITE(6,62)ISX2(J),ISX2(J),ISX2(J),MC1(J),NC2(J),PT(J),AA(J)
01131            72 WRITE(6,63)ISX3(J),ISX3(J),ISX3(J)
01132            CONTINUE
01133            WRITE(6,77)
01134            77 FORMAT(1X,+)
01135            CONTINUE
01136            WA=(SUM/CT)*TOTAR/WA/100.
01137            WRITE(6,63) TOTAR
01138            63 FORMAT(16,82X,F10.2,* = TOTAL ACREAGE*)
01139            WRITE(6,64) WA
01140            64 FORMAT(16,82X,F10.2,AVG)*
01141            111 FORMAT(1X, 'AVERAGE OF % DAMAGE FOR ENTIRE FIELD BASED ON AL
01142            *L EVALUATED MAP POINTS= ',F6.2,'%*)
01143            112 FORMAT(1X,'AVERAGE OF % DAMAGE FOR ENTIRE FIELD BASED ON ALL
01144            *L EVALUATED MAP POINTS= ',F6.2,'%')
01145            1148 FORMAT(1X, 'INSURED VALUE OF EACH ACRE= ',F6.2,' TOTAL
01146            * ADJUSTMENT= ',F6.2,' ADJ')
01147            1150 FORMAT(1X,'+'*40X,3A1,9X,12, '*'*13,8X,F6.2,9X,F8.2)
01148            RETURN
01149            END
SURROUTINE POLYM(X,Y,Z,NDT,NIPX,NI,NG0,NC,LX)

C C
C GENERALIZED MULTIPLE CURVILINEAR CORRELATION ANALYSIS REGRESSION
C ONE DEPENDENT, TWO INDEPENDENT VARIABLES, UP TO TEN DEGREES

DIMENSION X(NDT),Y(NDT),Z(NDT),AA(66,66),BA(66,66),C(66,66),ISX(10),
* A(66),CC(66),ND(10),ZP(200),R(200),NC(66),NX(10)
R=1.08 ARX=ARY XX=YY A=ZZ G=CI CCI
REAL*8 ARX=ARY XX=YY A=ZZ G=CI CCI
REAL*8 XMAX,XMIN,XTEST
INTEGER*4 INUM(66)
LOGICAL*1 LASTPT
DATA ISX/3,5,10,15,21,28,36,45,55,66/
L=0 DO 42 J=1,10
K=11-J IF(NX(K).EQ.1) GO TO 45
GO TO 42
L=L+1 KD(J)=K NF=L
CONTINUE NDD=ND(1) NTT=ISX(NDD)
DO 46 L=1,NTT
DO 46 K=1,NTT
AA(L,K)=0.
DO 48 K=1,NTT
G(K)=0.
J=1
CONTINUE L=2 DO 60 NJ=1,NDD
N=NJ+1 DO 60 K=1,N
XX=X(J)
XX=XX
YY=Y(J)
IF(XX.EQ.0. AND JX2.EQ.0) GO TO 82
ARX=XX**JX2
GO TO 84
IF(YY.EQ.0. AND JX2.EQ.0) GO TO 86
ARY=YY**JX2
GO TO 88
ARY=1.
A(L)=ARY
L=L+1 CONTINUE A(1)=1.
DO 70 K=1,NTT
Zz=Z(J)
G(K)=G(K)+Zz*A(K)
DO 100 L=1,NTT
DO 100 K=1,NTT
AA(L,K)=AA(L,K)+A(L)*A(K)
J=J+1 IF(J.GT.NDT) GO TO 110
GO TO 50 CONTINUE
GO TO 110
ZMEAN=(1)/NDT
WRITE(6,163)
163 FORMAT(11,1)** POLYNOMIAL MULTIPLE CURVILINEAR REGRESSION PROGRAM
* **, //IX BASIC STATISTICS FOR THIS RUN, //)
WRITE(6,61) NDF,NFX L
61 FORMAT(11,1)'TOTAL # DATA POINTS= ',I3,'/IX', '# OF FITS= ',I2,'/IX,'
** # OF TERMS IN HIGHEST DEGREE= ',I3,'/IX,'
WRITE(6,62)(ND(II),I,II=1,ND)
62 FORMAT(1X,'EQUATIONS TO BE FITTED',1A(12,1X),//)
DO 1000 MM=1,ND
1000 IER=1.
NDF=ND(ND)
N1=1SX(NDF)
D(I11I,J)=1,N1
D(I11I,J)=1,N1
111 B(I,J)=A(I,J)
CALLGAUS(P,B,R,N1,66,G,C1,INDN,IER)
SUMA=0.
SUMT=0.
DO 130 J=1,NDF
XX=X(J)
YY=Y(J)
ZP(J)=ZP(J)
R(J)=Z(J)-ZP(J)
SUMR=SUMR+R(J)**2
130 SUMT=SUMT+(ZMEAN-Z(J)**2
EXPV=SUMT-SUMR
COREL=SUMR/EXPV
ND=NDT-1.
TMSS=SUMT/ND
CDEF=COREL**2
NDFX=ISX(NDF)-1.
NDFUN=NDT-NDFX-1.
EMSS=EXPV/NDFX
MSUM=SUMR/NDFUN
FTEST=EMSS/UNMS
WRITE(6,132)ND
132 FORMAT(1X,'THIS IS A LEAST-SQUARES FIT OF THE',1X,12,'DEGREE',//)
WRITE(6,133)
133 FORMAT(3X,'X-VALUE',1X,'6X',1X,'Y-VALUE',1X,'5X',1X,'Z-VALUE',1X,'5X','PREDICTED',1X,'5X','RESIDUAL',1X,'//)
WRITE(6,140)(X(J),Y(J),Z(J),ZP(J),R(J),J=1,NDT)
140 FORMAT(3X,1X,F10.3,1X,F10.3,1X,F10.3,1X,F10.3,1X,F10.3,1X,F10.3)
WRITE(6,150)ND
150 FORMAT(1X,'COEFFICIENTS FOR',1X,12,'DEGREE EQUATION',//)
DO 160 J=1,N1
160 NC(J)=J-1.
DO 165 J=1,N1
165 WRITE(6,170)NC(J),C1(J)
160 170 FORMAT(1X,'13,1X,1F25.15)
170 IF(I11PUN.EQ.0)60 TO 181
60 175 J=1,N1
181 WRITE(6,180)NC(J),C1(J)
180 180 FORMAT(11,'ANALYSIS OF VARIANCE MEASURES',//31X,'SUM',11X,'DEGR
* FES',8X,'MEAN SUM',8X,'OF SQUARES',6X,'OF FREEDOM',5X,'OF SQUARE
* S',1X,1X,1X)
WRITE(6,171)SUM,ND,TMSS,EXPV,NDFX,EMSS,MSUM,NDFUN,UNMS
171 FORMAT(9X,'TOTAL VARIATION',1X,F13.4,8X,F13.4,8X,F13.4,8X)/5X,'EXPLAINED
FUNCTION ZIP(C,A,X,Y,NND)
DIMENSION C(100)
REAL*8 C,X,Y
X=A
Y=AY
Z=C(1)+C(2)*X+C(3)*Y
IF(NND.GT.4) GO TO 10
Z=Z+C(4)*X**2+C(5)*X*Y+C(6)*Y**2
IF(NND.EQ.2) GO TO 10
Z=Z+C(7)*X*Y+C(8)*X**2+C(9)*Y**2+C(10)*Y**3
IF(NND.EQ.3) GO TO 10
Z=Z+C(11)*X**4+C(12)*X**3*Y+C(13)*X**2*Y**2+C(14)*X*Y**3+C(15)*Y**4
IF(NND.EQ.4) GO TO 10
Z=Z+C(16)*X**5+C(17)*X**4*Y+C(18)*X**3*Y**2+C(19)*X**2*Y**3+C(20)*X*Y**4+C(21)*Y**5
IF(NND.EQ.5) GO TO 10
Z=Z+C(22)*X**6+C(23)*X**5*Y+C(24)*X**4*Y**2+C(25)*X**3*Y**3+C(26)*X**2*Y**4+C(27)*X*Y**5+C(28)*Y**6
IF(NND.EQ.6) GO TO 10
Z=Z+C(29)*X**7+C(30)*X**6*Y+C(31)*X**5*Y**2+C(32)*X**4*Y**3+C(33)*X**3*Y**4+C(34)*X**2*Y**5+C(35)*X*Y**6+C(36)*Y**7
Z=Z+C(37)*X**8+C(38)*X**7*Y+C(39)*X**6*Y**2+C(40)*X**5*Y**3+C(41)*X**4*Y**4+C(42)*X**3*Y**5+C(43)*X**2*Y**6+C(44)*X*Y**7+C(45)*Y**8
IF(NND.EQ.8) GO TO 10
Z=Z+C(46)*X**9+C(47)*X**8*Y+C(48)*X**7*Y**2+C(49)*X**6*Y**3+C(50)*X**5*Y**4+C(51)*X**4*Y**5+C(52)*X**3*Y**6+C(53)*X**2*Y**7+C(54)*X*Y**8+C(55)*Y**9
IF(NND.EQ.9) GO TO 10
Z=Z+C(56)*X**10+C(57)*X**9*Y+C(58)*X**8*Y**2+C(59)*X**7*Y**3+C(60)*X**6*Y**4+C(61)*X**5*Y**5+C(62)*X**4*Y**6+C(63)*X**3*Y**7+C(64)*X**2*Y**8+C(65)*X*Y**9+C(66)*Y**10
10 ZIP=7
RETURN
END
SUBROUTINE BORDER(NBR, NRC, NEWBRS, XMIN, XMAX, YMIN, YMAX, NCOL5)

DIMENSION X(200), Y(200)
DIMENSION NC(200), NRC(1000), NBR(1000), MAP(130)

LOGICAL LAST

READ(5, 111) X(K), Y(K), LAST
IF(LAST) GO TO 120
K = K + 1
GO TO 110

DUPLICATE LAST BORDER POINT

X(NBRS+1) = X(1)
Y(NBRS+1) = Y(1)
NBRS = NBRS + 1

CONVERSION TO ROW AND COLUMN

RX = XMAX - XMIN
RY = YMAX - YMIN
XLP = 8
YNY = RY / RX * NCOL5 * XLP + .5
NY = YNY
XI = RX / (NCOL5 - 1)
YI = RY / (YNY - 1)

DO 250 I = 1, NBRS
NC(I) = (XI - XMIN) / XI + 1.5
.END 250

ROW INTERPOLATION

L = 0
DO 1000 J = 1, NBRS
K2 = K + 1
C CHECK FOR DIFFERENCE BETWEEN ROWS
NDIF = NR(K2) - NR(J)\nNADIF = IABS(NDIF)
L = L + 1
NRRL = NR(J)
NCC(L) = NC(J)
IF(NADIF .LE. 1) GO TO 1000
DIF = NADIF
COLD = NC(K2) - NC(J)
COLI = COLD / DIF
NT = NADIF - 1
DO 400 KL = 1, NT
KK = KL
IF(NDIF .LT. 0) KK = -KK
L = L + 1
NRRL = NR(J) + KK
XINT = NC(J) + COLI * (KL + .5)
NCC(L) = XINT
400 CONTINUE
1000 CONTINUE
NEWBRS = L
L = 0
II = 0
I2 = 1
NTO = 0
II = II + 1
I2=I2+1
NTOT=NTOT+1
IF(I2.GT.NEWOBS) GO TO 1250
IF(NRR(I2)*EQ.NKR(I1)) GO TO 1200

1250 N1=I2-NTOT
N2=I1
C CHECK FOR LOCAL TWO POINT MIN OR MAX
NS1=N1-1
IF(NS1.LT.1) NS1=NEWOBS
NS2=N2+1
IF(NTOT.EQ.1) GO TO 1450
IF(NRR(NS1).LT.NRR(N1)).AND.NRR(NS2).LT.NRR(N2)) .OR. (NRR(NS1).GT.N
*RR(N1)) .AND. NRR(NS2).GT.NRR(N2)) GO TO 1300
C ASSUME TWO POINTS OR MORE ARE INFLECTION POINTS
L=1+1
NBR(L)=NRR(N1)
NC(L)=(NCC(N1)+NCC(N2))/2
GO TO 1460

1300 L=1+1
NBR(L)=NRR(N1)
NC(L)=NCC(N1)
L=1+1
NBR(L)=NRR(N2)
NC(L)=NCC(N2)
C CHECK FOR ONE POINT MIN OR MAX—DUPLICATE POINT
GO TO 1460

1450 N=0
IF((NRR(NS1).LT.NRR(N2)).AND.(NRR(NS2).LT.NRR(N2)) .OR. (NRR(NS1).GT.N
*RR(N2)) .AND. NRR(NS2).GT.NRR(N2)) N=2
DO 3000 KK=1,N
3000 L=1+1
NBR(L)=NRR(N2)
NC(L)=NCC(N2)
IF(N2.LT.NEWOBS) GO TO 1100
NEWOBS=L
C ORDER THE NBR ARRAY IN ASCENDING ORDER—PREERVE THE NBC ARRAY
DO 4000 I=1,NEWOBS
3000 NINC=999999
DO 3900 J=1,NEWOBS
IF(NBR(J).LT.NINC) GO TO 3700
GO TO 3900
3700 NINC=NBR(J)
3900 CONTINUE
NRR(I)=NRR(JX)
NCC(I)=NBC(JX)
NBR(JX)=999999
C ORDER THE NCC ARRAY IN ASCENDING ORDER—PREERVE THE NRR ARRAY
4000 CONTINUE
I1=0
I2=1
I2=I2+1
NTOT=NTOT+1
IF(I2.GT.NEWOBS) GO TO 4250
IF(NRR(I2).EQ.NKR(I1)) GO TO 4200
N1=I2-NTOT
N2=I1
0106      DO 4500 J=N1,N2
0107      NCI=999999
0108      DO 4400 J=N1,N2
0109      IF(NCC(J) .LE. NCI) GO TO 4300
0110      GO TO 4400
0111      4300      NCI=NCC(J)
0112      JX=J
0113      4400      CONTINUE
0114      NBR(I)=NRR(JX)
0115      NBC(I)=NCC(JX)
0116      NCC(JX)=999999
0117      4500      CONTINUE
0118      IF(N2 .LT. NEWOBS) GO TO 4100
0119      RETURN
0120      END