A variance analysis of data collected in the 1970 State Farm Census in Wisconsin was made primarily to develop resource material that would be useful for training in sampling. Hence, most of the interpretation is left for students and instructors in sampling or readers with a background in sampling theory and agriculture. To illustrate applications of sampling theory numerous exercises for students can be formulated with reference to the tables. Also, much time can be spent profitably on studying the patterns of variation portrayed by the tables and on examining the effectiveness of various sample designs in relation to the patterns of variation.

One of the reasons for selecting Wisconsin was its wide geographic variation in agriculture. Secondly, the data happened to be conveniently available on magnetic tape and the variances could be computed for a modest cost. Third, as a farm in the annual census in Wisconsin is identified by a number that remains unchanged from year-to-year there was an attractive potential for taking another year's data and studying variances with reference to year-to-year changes, which could add a very important dimension for study.

Items were selected for this study primarily with reference to variability characteristics from the viewpoint of sample design. A major criterion for selection of items was percent reporting which ranges from less than one percent for potatoes and snap beans to 100 percent for farmland. Another criterion was geographic distribution. Some items selected are more uniformly distributed over the State than others. Population (number of persons living on a farm) was included because the variation from farm to farm is low and it is an item reported by nearly all farms.

The numbers in columns (2) thru (6) of tables 1 and 2 are not official estimates. They are totals as enumerated in the Wisconsin State Farm Census and may differ from official estimates for several reasons including, under or over enumeration, definitions, and dates to which the data relate.

All variances in the accompanying tables are expressed as relative variances on a single unit basis, i.e., a variance can be interpreted as applying to a sample of size "one"—one farm in tables 1, 2, 3, and 4 and one township in table 6. Variance formulas are presented in appendix A so there will be no misunderstanding of what the variances are arithmetically. Appendix A gives explanations by columns of the tables.

Crop Reporting Districts, CRD's, are subdivisions of the State which are used for various statistical purposes. They are relatively homogeneous groups of counties. See Figure 1 at the end of the tables for an outline of the State showing CRD's and counties.

Townships are subdivisions of counties. A few townships had only one or two farms. Townships with less than four farms were combined with adjacent townships, giving a total of 1,462 townships (or township combinations) for purposes of this study. The average number of farms per township was 69.5.

The system designed for processing the data involved two computer runs. The first run provided an output tape with the following results for each township, county, CRD, and the State:

For farmland: \( N, \Sigma Y, \Sigma Y^2, \) and \( S_Y^2 \)

where \( N \) is the number of farms,
\( Y \) is the number of acres of farmland, and
\( S_Y^2 \) is the variance of farmland

For each item other than farmland: \( N_x, \Sigma X, \Sigma X^2, \Sigma XY, S_X^2, S_X Y, \) and \( S^2(\bar{Y} \bar{X}) \)

where \( N_x \) is the number of farms reporting the item (that is, \( N_x \)

is the number with \( X > 0 \))
\( X \) represents any one of the selected items,
\( S_X^2 \) is the variance of \( X \),
\( S_X Y \) is the covariance of \( X \) and \( Y \), and
\[ S^2(\bar{Y} \bar{X}) = S_X^2 + (\frac{\Sigma X}{\Sigma Y})^2 S_Y^2 - 2(\frac{\Sigma X}{\Sigma Y}) S_X Y \]

which is the variance of \( \bar{Y} \bar{X} \)

Tables 1 and 2 were compiled from a printout of the CRD and State data on the output tape from the first run. The output tape from the first run was the input tape for the second run which gave results for the remaining tables.

A review of the variances indicated the possibility of an error for clover-timothy acres in Crop Reporting District No. 4 (See table 2). The data processing system provided for an output tape with township data on it
including variances within each township. A print out of the township data for CRD No. 4 showed one township that had an extremely large variance, so a print out of individual farm data for this township was called for. The record for one farm showed 5,000 acres of clover-timothy, a record that was clearly in error. The record could have been corrected and the results changed or clover-timothy could have been deleted from the tables. However, results as obtained from the computer output are shown in the tables to illustrate the impact of an error of this kind on the results. Also, it is of interest to consider the impact on sampling error and sample design if in fact one unusual farm did exist that had 5,000 acres of clover-timothy.
Table 1.—State Summary 1/

<table>
<thead>
<tr>
<th>Item</th>
<th>Total</th>
<th>Farms Reporting</th>
<th>Average Per Farm Reporting</th>
<th>Average Per Farm Reporting</th>
<th>Standard Deviation</th>
<th>Variance Design</th>
<th>Relative Variance</th>
<th>Estimator</th>
<th>Design</th>
</tr>
</thead>
<tbody>
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<td>Farmland (acres)</td>
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<td>175.3</td>
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<td>0.725</td>
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<td>0.450</td>
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<td>32.3</td>
<td>1.277</td>
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<td>All corn (acres)</td>
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<td>All pasture (acres)</td>
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<td>Milk cows (head)</td>
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<td>Clover and timothy (acres)</td>
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<td>Hay for silage (acres)</td>
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<td>Cattle Marketed (head)</td>
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<td>Soybeans (acres)</td>
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<td>Peas (acres)</td>
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<td>Stock sheep (head)</td>
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<td>Spring wheat (acres)</td>
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<td>Potatoes (acres)</td>
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<td>Snap beans (acres)</td>
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1/ See appendix for explanations keyed to column numbers.
Table 2.--Summary by Crop Reporting Districts 1/

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<th>Design Efficiency</th>
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Farmland

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Population

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1/ See appendix for explanations keyed to column numbers.
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<td>(11)</td>
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**Alfalfa**

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<td>Per Farm</td>
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<td>Deviation</td>
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1/ See appendix for explanations key to column numbers.
Table 2. Con't.--Summary by Crop Reporting Districts 1/

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<th>Average</th>
<th>Relative</th>
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1/ See appendix for explanations keyed to column numbers.
### Wisconsin State Farm Census - 1970

**Table 2. Con't.--Summary by Crop Reporting Districts 1/**

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1/ See appendix for explanations keyed to column numbers.
### Table 2. Con't.--Summary by Crop Reporting Districts 1/

| Crop Reporting District | Total | Farms Reporting | Average | Relative Variance | Design Efficiency | Per Farm | Number | Percent | Per Farm | Deviation | All Farms | Reporting | For Ratio | Estimator |
|-------------------------|-------|-----------------|---------|-------------------|------------------|----------|--------|---------|----------|-----------|----------|-----------|-----------|
|                         |       | (11)            | (2)     | (3)               | (4)              | (5)      | (6)    | (7)     | (8)      | (9)       |          | (10)      |           |           |
| **Hay for Silage**      |       |                 |         |                   |                  |          |        |         |          |           |          |           |           |           |
| 1                       | 48,982| 1,277           | 4.56    | 38.4              | 19.6             | 18.40    | 1.32   | .91     |          |           |          |           |           |           |
| 2                       | 52,497| 2,025           | 4.70    | 25.9              | 15.5             | 10.89    | 1.14   | .91     |          |           |          |           |           |           |
| 3                       | 26,414| 966             | 4.46    | 27.3              | 15.4             | 11.97    | 1.10   | .92     |          |           |          |           |           |           |
| 4                       | 81,787| 2,466           | 5.33    | 33.2              | 19.3             | 13.10    | 1.28   | .90     |          |           |          |           |           |           |
| 5                       | 36,245| 1,101           | 3.77    | 32.9              | 16.5             | 19.18    | 1.30   | .93     |          |           |          |           |           |           |
| 6                       | 91,650| 2,686           | 6.04    | 34.1              | 21.1             | 12.18    | 1.32   | .89     |          |           |          |           |           |           |
| 7                       | 90,332| 2,552           | 6.62    | 35.4              | 21.3             | 10.30    | 1.12   | .91     |          |           |          |           |           |           |
| 8                       | 100,219| 2,472          | 7.00    | 40.5              | 23.9             | 11.70    | 1.19   | .88     |          |           |          |           |           |           |
| 9                       | 23,474| 624             | 4.07    | 37.6              | 17.4             | 18.23    | 1.08   | .92     |          |           |          |           |           |           |
| **STATE**               | 551,600| 16,169         | 5.42    | 34.1              | 19.7             | 13.25    | 1.25   | .91     |          |           |          |           |           |           |
| **Cattle Marketed**     |       |                 |         |                   |                  |          |        |         |          |           |          |           |           |           |
| 1                       | 3,543 | 239             | .33     | 14.8              | 4.5              | 187.7    | 3.20   | .99     |          |           |          |           |           |           |
| 2                       | 1,660 | 129             | .15     | 12.9              | 3.4              | 534.1    | 5.20   | 1.00    |          |           |          |           |           |           |
| 3                       | 1,342 | 172             | .23     | 7.8               | 3.8              | 281.9    | 7.24   | .99     |          |           |          |           |           |           |
| 4                       | 14,603| 879             | .95     | 16.6              | 8.0              | 71.0     | 3.13   | .98     |          |           |          |           |           |           |
| 5                       | 13,709| 650             | 1.43    | 21.1              | 24.3             | 288.0    | 18.49  | .94     |          |           |          |           |           |           |
| 6                       | 16,999| 1,473           | 1.12    | 11.5              | 12.2             | 119.5    | 10.69  | .98     |          |           |          |           |           |           |
| 7                       | 44,341| 938             | 3.25    | 47.3              | 41.1             | 159.8    | 10.05  | .98     |          |           |          |           |           |           |
| 8                       | 76,664| 2,344           | 5.36    | 32.7              | 39.7             | 54.8     | 8.18   | .95     |          |           |          |           |           |           |
| 9                       | 15,536| 776             | 2.70    | 20.0              | 18.4             | 46.5     | 5.43   | .98     |          |           |          |           |           |           |
| **STATE**               | 188,397| 7,600          | 1.85    | 24.8              | 23.7             | 164.4    | 11.36  | .98     |          |           |          |           |           |           |

1/ See appendix for explanations keyed to column numbers.
**Wisconsin State Farm Census - 1970**

Table 2. Cont'd.—Summary by Crop Reporting Districts 1/

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| **Peas**                |       |                 |                  |                            |                   |                     |                        |                   |                |                     |           |
| 1                       | 2,396 | 74              | 0.7              | .22                        | 32.4              | 3.6                 | 254.1                 | 0.76             | .99            |                     |           |
| 2                       | 1,095 | 43              | 0.4              | .10                        | 25.5              | 2.2                 | 517.6                 | 1.00             | 1.00           |                     |           |
| 3                       | 2,621 | 66              | 1.1              | .44                        | 39.7              | 5.5                 | 153.5                 | 0.74             | .99            |                     |           |
| 4                       | 5,031 | 172             | 1.1              | .33                        | 29.2              | 5.4                 | 274.6                 | 2.07             | .99            |                     |           |
| 5                       | 7,517 | 175             | 1.8              | .78                        | 43.0              | 9.3                 | 142.8                 | 1.61             | .98            |                     |           |
| 6                       | 34,621| 1,185           | 7.8              | 2.28                       | 29.2              | 19.1                | 70.1                  | 4.54             | .90            |                     |           |
| 7                       | 3,466 | 135             | 1.0              | .25                        | 25.7              | 3.5                 | 189.9                 | 0.88             | .99            |                     |           |
| 8                       | 37,785| 1,128           | 7.9              | 2.64                       | 33.5              | 19.5                | 54.3                  | 3.35             | .94            |                     |           |
| 9                       | 7,082 | 202             | 3.5              | 1.23                       | 35.1              | 11.5                | 87.2                  | 2.10             | .98            |                     |           |
| STATE                   | 101,614| 3,180           | 3.1              | 1.00                       | 32.0              | 11.6                | 134.3                 | 3.24             | .97            |                     |           |

1/ See appendix for explanations keyed to column numbers.
### Table 2. Con't.—Summary by Crop Reporting Districts

<table>
<thead>
<tr>
<th>Crop Reporting District</th>
<th>Total</th>
<th>Farms Reporting</th>
<th>Average Per Farm</th>
<th>Average Reporting</th>
<th>Standard Deviation</th>
<th>Relative Variance</th>
<th>Design Farms Reporting</th>
<th>Efficiency Ratio Estimator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stock Sheep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
<td>(7)</td>
<td>(8)</td>
</tr>
<tr>
<td>1</td>
<td>7,100</td>
<td>220</td>
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<td>.66</td>
<td>32.3</td>
<td>7.9</td>
<td>142.3</td>
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<td>.20</td>
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<td>174.8</td>
<td>1.08</td>
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<tr>
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<td>13,881</td>
<td>405</td>
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<td>.91</td>
<td>34.3</td>
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<td>101.4</td>
<td>1.69</td>
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<td>5,003</td>
<td>207</td>
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<td>.52</td>
<td>24.2</td>
<td>5.1</td>
<td>95.4</td>
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<tr>
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<td>4,106</td>
<td>211</td>
<td>1.4</td>
<td>.27</td>
<td>19.5</td>
<td>3.8</td>
<td>198.0</td>
<td>1.77</td>
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<tr>
<td>7</td>
<td>18,600</td>
<td>627</td>
<td>4.6</td>
<td>1.36</td>
<td>29.7</td>
<td>13.6</td>
<td>100.2</td>
<td>3.65</td>
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<tr>
<td>8</td>
<td>20,934</td>
<td>717</td>
<td>5.0</td>
<td>1.46</td>
<td>29.2</td>
<td>13.7</td>
<td>88.4</td>
<td>3.46</td>
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<td>9</td>
<td>4,965</td>
<td>180</td>
<td>3.1</td>
<td>.86</td>
<td>27.6</td>
<td>8.2</td>
<td>90.6</td>
<td>1.85</td>
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<tr>
<td>STATE</td>
<td>77,679</td>
<td>2,742</td>
<td>2.7</td>
<td>.76</td>
<td>28.3</td>
<td>9.0</td>
<td>138.3</td>
<td>2.76</td>
</tr>
</tbody>
</table>

| Spring Wheat           |       |                |                  |                   |                   |                   |                         |                            |
|                        |       | (2)            | (3)              | (4)               | (5)               | (6)               | (7)                     | (8)                        |
| 1                      | 482   | 29             | 0.3              | .04               | 16.6              | 1.6               | 1236                    | 2.34                       |
| 2                      | 176   | 16             | 0.1              | .02               | 11.0              | .6                | 1442                    | 1.06                       |
| 3                      | 137   | 15             | 0.3              | .02               | 9.1               | .7                | 947                     | 1.42                       |
| 4                      | 643   | 53             | 0.3              | .04               | 12.1              | 1.4               | 1040                    | 2.66                       |
| 5                      | 1,610 | 53             | 0.6              | .17               | 30.4              | 8.5               | 2617                    | 13.40                      |
| 6                      | 2,663 | 293            | 1.9              | .18               | 9.1               | 1.6               | 86                      | 0.67                       |
| 7                      | 338   | 23             | 0.2              | .02               | 14.7              | .8                | 1008                    | 0.69                       |
| 8                      | 1,546 | 147            | 1.0              | .11               | 10.5              | 1.4               | 175                     | 0.81                       |
| 9                      | 7,686 | 565            | 9.8              | 1.33              | 13.6              | 6.8               | 26                      | 1.69                       |
| STATE                  | 15,281| 1,194          | 1.2              | .15               | 12.8              | 3.3               | 490                     | 4.75                       |

1/ See appendix for explanations keyed to column numbers.
Table 2. Con't.--Summary by Crop Reporting Districts 1/

<table>
<thead>
<tr>
<th>Crop Reporting District</th>
<th>Total Farms Reporting</th>
<th>Average Farms Reporting</th>
<th>Average Standard Deviation</th>
<th>Relative Variance</th>
<th>Farms Efficiency Estimator</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percent</td>
<td>Per Farm</td>
<td>Reporting</td>
<td>Per Farm</td>
</tr>
<tr>
<td>(11)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
</tr>
<tr>
<td>1</td>
<td>1,737</td>
<td>27</td>
<td>0.3</td>
<td>.16</td>
<td>64.3</td>
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<td>2</td>
<td>5,524</td>
<td>87</td>
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<td>.50</td>
<td>63.5</td>
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<tr>
<td>3</td>
<td>7,826</td>
<td>134</td>
<td>2.3</td>
<td>1.32</td>
<td>58.4</td>
</tr>
<tr>
<td>4</td>
<td>698</td>
<td>26</td>
<td>0.2</td>
<td>.05</td>
<td>26.8</td>
</tr>
<tr>
<td>5</td>
<td>16,820</td>
<td>245</td>
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<td>1.75</td>
<td>68.7</td>
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<td>1,213</td>
<td>43</td>
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<td>7</td>
<td>642</td>
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<td>.05</td>
<td>64.2</td>
</tr>
<tr>
<td>8</td>
<td>1,032</td>
<td>31</td>
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<td>.07</td>
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<td>9</td>
<td>4,587</td>
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<td>.80</td>
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<td>40,079</td>
<td>741</td>
<td>0.7</td>
<td>.39</td>
<td>54.1</td>
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</table>

Potatoes

Snap Beans

1/ See appendix for explanations keyed to column numbers.
### Table 3 - Relative Variances for Stratified Random Sampling

Sample Allocation Proportioned to Number of Farms 1/

<table>
<thead>
<tr>
<th>Item</th>
<th>Mean Estimator (12)</th>
<th>Stratification (14)</th>
<th>Ratio Estimator (13)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crop Reporting:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>District : County :</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Township : Zero :</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Township : None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farmland</td>
<td>0.725</td>
<td>0.711</td>
<td>0.698</td>
</tr>
<tr>
<td>Population</td>
<td>0.450</td>
<td>0.447</td>
<td>0.441</td>
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<td>Alfalfa</td>
<td>1.277</td>
<td>1.178</td>
<td>1.134</td>
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<tr>
<td>All corn</td>
<td>3.33</td>
<td>3.11</td>
<td>2.98</td>
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<tr>
<td>All pasture</td>
<td>3.04</td>
<td>2.81</td>
<td>2.75</td>
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<tr>
<td>Milk cows</td>
<td>1.34</td>
<td>1.33</td>
<td>1.28</td>
</tr>
<tr>
<td>Beef cattle</td>
<td>16.07</td>
<td>15.74</td>
<td>15.52</td>
</tr>
<tr>
<td>Clover and timothy</td>
<td>15.76</td>
<td>14.41</td>
<td>14.00</td>
</tr>
<tr>
<td>Hay for silage</td>
<td>13.20</td>
<td>13.16</td>
<td>13.07</td>
</tr>
<tr>
<td>Cattle marketed</td>
<td>163.9</td>
<td>163.0</td>
<td>162.3</td>
</tr>
<tr>
<td>Soybeans</td>
<td>73.4</td>
<td>71.9</td>
<td>69.1</td>
</tr>
<tr>
<td>Peas</td>
<td>134.2</td>
<td>133.3</td>
<td>132.0</td>
</tr>
<tr>
<td>Stock sheep</td>
<td>138.2</td>
<td>137.8</td>
<td>137.4</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>488</td>
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<td>478</td>
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<tr>
<td>Potatoes</td>
<td>789</td>
<td>787</td>
<td>777</td>
</tr>
<tr>
<td>Snap beans</td>
<td>1501</td>
<td>1498</td>
<td>1484</td>
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1/ See appendix for explanations keyed to column numbers.
Table 3A - Design Efficiencies for Stratified Random Sampling
Sample Allocation Proportioned to Number of Farms

<table>
<thead>
<tr>
<th>Item</th>
<th>Mean Estimator (12)</th>
<th>Ratio Estimator (13)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Stratification (14)</td>
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</tr>
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<td></td>
<td>None</td>
<td>Crop Reporting:</td>
</tr>
<tr>
<td></td>
<td>District</td>
<td>County</td>
</tr>
<tr>
<td>Farmland</td>
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<td>0.981</td>
</tr>
<tr>
<td>Population</td>
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<td>0.993</td>
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<td>All-pasture</td>
<td>1.000</td>
<td>0.924</td>
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<td>Milk cows</td>
<td>1.000</td>
<td>0.992</td>
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<tr>
<td>Beef cattle</td>
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<td>0.979</td>
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<td>Hay for silage</td>
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<td>Soybeans</td>
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<td>0.980</td>
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<td>Peas</td>
<td>1.000</td>
<td>0.993</td>
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<td>Stock sheep</td>
<td>1.000</td>
<td>0.997</td>
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<tr>
<td>Spring wheat</td>
<td>1.000</td>
<td>0.992</td>
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<tr>
<td>Potatoes</td>
<td>1.000</td>
<td>0.997</td>
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<tr>
<td>Snap beans</td>
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<td>0.998</td>
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<tr>
<td>Average for all items</td>
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<td>0.974</td>
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1/ See appendix for explanations keyed to column numbers.
### Wisconsin State Farm Census - 1970

Table 4 - Relative Variances and Design Efficiencies for Alternative Sample Allocations to Crop Reporting Districts

<table>
<thead>
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<th>Item</th>
<th>Relative Variance</th>
<th>Design Efficiency</th>
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<td>Ratio Estimator (13)</td>
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<td></td>
<td>Allocation Proportional to</td>
<td>Allocation</td>
</tr>
<tr>
<td></td>
<td>Number of Farms (1)</td>
<td>Item (11)</td>
</tr>
<tr>
<td>Farmland</td>
<td>0.711</td>
<td>---</td>
</tr>
<tr>
<td>Population</td>
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<td>0.447</td>
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<tr>
<td>Alfalfa</td>
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<td>1.228</td>
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<tr>
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<td>3.11</td>
<td>2.66</td>
</tr>
<tr>
<td>All pasture</td>
<td>2.81</td>
<td>2.56</td>
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<td>1.33</td>
<td>1.33</td>
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<td>Beef cattle</td>
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<td>Clover and timothy</td>
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<td>21.90</td>
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<td>13.06</td>
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<td>112.6</td>
</tr>
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<td>Spring wheat</td>
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<td>451</td>
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<tr>
<td>Potatoes</td>
<td>784</td>
<td>535</td>
</tr>
<tr>
<td>Snap beans</td>
<td>1498</td>
<td>740</td>
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1/ See appendix for explanations keyed to column numbers.
Table 5 - Sample Allocation to Crop Reporting Districts for the Mean Estimator 1/

<table>
<thead>
<tr>
<th>Item</th>
<th>Allocations to Crop Reporting Districts</th>
<th>Sample Allocations to Crop Reporting Districts</th>
<th>Design Efficiency, Mean Estimator</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Propotional to (1)</td>
<td>(37) (38) (38) (38) (38) (38) (38) (38) (38) (38)</td>
<td>(39)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 2 3 4 5 6 7 8 9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number of Farms</td>
<td>106 110 58 151 95 149 134 141 57</td>
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</tr>
<tr>
<td>Population</td>
<td>Item Total</td>
<td>110 105 56 172 95 120 159 133 50</td>
<td>1.000</td>
</tr>
<tr>
<td></td>
<td>Optimum</td>
<td>95 104 55 145 94 147 139 156 65</td>
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<td>Item Total</td>
<td>81 37 52 183 73 187 189 145</td>
<td>1.042</td>
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<td>114 70 56 167 88 158 147 139 60</td>
<td>.981</td>
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<td>All corn</td>
<td>Item Total</td>
<td>51 38 33 138 79 144 168 257 91</td>
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<td>Optimum</td>
<td>60 41 34 116 120 143 136 257 92</td>
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<td>All pasture</td>
<td>Item Total</td>
<td>166 134 33 173 67 58 243 103 22</td>
<td>.911</td>
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<td>Item Total</td>
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<td>1.000</td>
</tr>
<tr>
<td></td>
<td>Optimum</td>
<td>99 98 53 149 81 154 134 163 67</td>
<td>.985</td>
</tr>
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<td>Item Total</td>
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<td>.827</td>
</tr>
<tr>
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<td>Optimum</td>
<td>73 50 36 155 73 82 243 236 54</td>
<td>.807</td>
</tr>
<tr>
<td>Clover and timothy</td>
<td>Item Total</td>
<td>236 411 81 81 99 43 17 13 18</td>
<td>1.520</td>
</tr>
<tr>
<td></td>
<td>Optimum</td>
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<td>.656</td>
</tr>
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<td>Hay for silage</td>
<td>Item Total</td>
<td>89 95 48 148 66 166 164 182 43</td>
<td>.992</td>
</tr>
<tr>
<td></td>
<td>Optimum</td>
<td>106 87 46 149 80 161 147 173 51</td>
<td>.981</td>
</tr>
</tbody>
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1/ See appendix for explanations keyed to column numbers.
Wisconsin State Farm Census - 1970

Table 5 - Con't. - Sample Allocation to Crop Reporting Districts for the Mean Estimator 1/

<table>
<thead>
<tr>
<th>Item</th>
<th>Allocations Proportional to (37)</th>
<th>Sample Allocations to Crop Reporting Districts</th>
<th>Design Efficiency, Mean Estimator (39)</th>
</tr>
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<td></td>
<td>1 2 3 4 5 6 7 8 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Farms</td>
<td>106 110 58 151 95 149 134 141 57</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cattle Marketed</td>
<td>Item Total</td>
<td>18 9 7 78 73 90 235 407 82</td>
<td>.684</td>
</tr>
<tr>
<td></td>
<td>Optimum</td>
<td>26 20 12 65 124 98 297 301 56</td>
<td>.615</td>
</tr>
<tr>
<td>Soybeans</td>
<td>Item Total</td>
<td>40 4 0 250 38 78 38 263 290</td>
<td>.698</td>
</tr>
<tr>
<td></td>
<td>Optimum</td>
<td>93 14 3 195 56 121 66 237 216</td>
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</tr>
<tr>
<td>Peas</td>
<td>Item Total</td>
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<tr>
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<td>Optimum</td>
<td>40 26 34 88 94 394 50 293 70</td>
<td>.772</td>
</tr>
<tr>
<td>Stock sheep</td>
<td>Item Total</td>
<td>91 25 15 179 64 53 239 269 64</td>
<td>.817</td>
</tr>
<tr>
<td></td>
<td>Optimum</td>
<td>104 44 19 172 60 71 229 242 58</td>
<td>.794</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>Item Total</td>
<td>31 12 9 42 105 174 22 101 503</td>
<td>.932</td>
</tr>
<tr>
<td></td>
<td>Optimum</td>
<td>75 30 19 92 363 109 48 90 174</td>
<td>.452</td>
</tr>
<tr>
<td>Potatoes</td>
<td>Item Total</td>
<td>43 138 195 17 420 30 16 26 114</td>
<td>.682</td>
</tr>
<tr>
<td></td>
<td>Optimum</td>
<td>77 155 140 32 329 71 60 63 73</td>
<td>.516</td>
</tr>
<tr>
<td>Snap beans</td>
<td>Item Total</td>
<td>0 13 35 5 15 304 4 92 532</td>
<td>.494</td>
</tr>
<tr>
<td></td>
<td>Optimum</td>
<td>0 61 48 16 28 344 14 175 315</td>
<td>.351</td>
</tr>
</tbody>
</table>

1/ See appendix for explanations keyed to column numbers.
Table 6.—Relative Variances Among Townships

<table>
<thead>
<tr>
<th>Item</th>
<th>Among Townships Within the State</th>
<th>Among Townships Within CRD's</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Estimator</td>
<td>Ratio Estimator</td>
</tr>
<tr>
<td></td>
<td>EPS</td>
<td>PPS</td>
</tr>
<tr>
<td>(1)</td>
<td>(40)</td>
<td>(41)</td>
</tr>
<tr>
<td>Number of farms</td>
<td>0.508</td>
<td></td>
</tr>
<tr>
<td>Farmland</td>
<td>0.516</td>
<td></td>
</tr>
<tr>
<td>Population</td>
<td>0.590</td>
<td>0.036</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>0.987</td>
<td>0.356</td>
</tr>
<tr>
<td>All Corn</td>
<td>1.245</td>
<td>0.681</td>
</tr>
<tr>
<td>All pasture</td>
<td>1.757</td>
<td>1.291</td>
</tr>
<tr>
<td>Milk cows</td>
<td>0.841</td>
<td>0.211</td>
</tr>
<tr>
<td>Beef cattle</td>
<td>2.079</td>
<td>1.668</td>
</tr>
<tr>
<td>Clover and timothy</td>
<td>4.184</td>
<td>4.031</td>
</tr>
<tr>
<td>Hay for silage</td>
<td>1.543</td>
<td>0.931</td>
</tr>
<tr>
<td>Cattle marketed</td>
<td>8.66</td>
<td>8.22</td>
</tr>
<tr>
<td>Soybeans</td>
<td>10.05</td>
<td>9.83</td>
</tr>
<tr>
<td>Peas</td>
<td>9.56</td>
<td>8.94</td>
</tr>
<tr>
<td>Stock sheep</td>
<td>4.16</td>
<td>3.86</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>29.1</td>
<td>28.9</td>
</tr>
<tr>
<td>Potatoes</td>
<td>36.1</td>
<td>36.4</td>
</tr>
<tr>
<td>Snap beans</td>
<td>84.3</td>
<td>84.3</td>
</tr>
</tbody>
</table>

1/ See appendix for explanations keyed to column numbers.
Table 6A.—Design Efficiencies for the Township As a Sampling Unit 1/

<table>
<thead>
<tr>
<th>Item</th>
<th>Among Townships Within the State</th>
<th>Among Townships Within CRD's</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Estimator : Ratio Estimator</td>
<td>Mean Estimator : Ratio Estimator</td>
</tr>
<tr>
<td></td>
<td>EPS : EPS</td>
<td>EPS : EPS</td>
</tr>
<tr>
<td>Farmland</td>
<td>1.00 : .16</td>
<td>1.00 : .05</td>
</tr>
<tr>
<td>Population</td>
<td>1.00 : .06</td>
<td>1.00 : .05</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>1.00 : .36</td>
<td>1.00 : .27</td>
</tr>
<tr>
<td>All corn</td>
<td>1.00 : .55</td>
<td>1.00 : .48</td>
</tr>
<tr>
<td>All pasture</td>
<td>1.00 : .74</td>
<td>1.00 : .45</td>
</tr>
<tr>
<td>Milk cows</td>
<td>1.00 : .25</td>
<td>1.00 : .20</td>
</tr>
<tr>
<td>Beef cattle</td>
<td>1.00 : .80</td>
<td>1.00 : .58</td>
</tr>
<tr>
<td>Clover and timothy</td>
<td>1.00 : .96</td>
<td>1.00 : .64</td>
</tr>
<tr>
<td>Hay for silage</td>
<td>1.00 : .60</td>
<td>1.00 : .47</td>
</tr>
<tr>
<td>Cattle marketed</td>
<td>1.00 : .95</td>
<td>1.00 : .78</td>
</tr>
<tr>
<td>Soybeans</td>
<td>1.00 : .98</td>
<td>1.00 : .94</td>
</tr>
<tr>
<td>Peas</td>
<td>1.00 : .94</td>
<td>1.00 : .94</td>
</tr>
<tr>
<td>Stock sheep</td>
<td>1.00 : .93</td>
<td>1.00 : .93</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>1.00 : .99</td>
<td>1.00 : .93</td>
</tr>
<tr>
<td>Potatoes</td>
<td>1.00 : 1.01</td>
<td>1.00 : 1.24</td>
</tr>
<tr>
<td>Snap beans</td>
<td>1.00 : 1.00</td>
<td>1.00 : 1.14</td>
</tr>
<tr>
<td>Average for all items</td>
<td>1.00 : .74</td>
<td>1.00 : .69</td>
</tr>
<tr>
<td>except farmland</td>
<td>1.00 : .67</td>
<td>1.00 : .65</td>
</tr>
</tbody>
</table>

1/ See appendix for explanations keyed to column numbers.
### Table 6B.--Design Efficiency of Stratification When the Township Is the Sampling Unit
and Design Efficiency of the Township As a Sampling Unit Compared to Individual Farms 1/

<table>
<thead>
<tr>
<th>Item</th>
<th>Design Efficiency of Stratification by CRD's</th>
<th>Design Efficiency of the Township</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Estimator (EPS) : Ratio Estimator (EPS) : Mean Estimator (PPS)</td>
<td>No Stratification : Mean Estimator (EPS) : No Stratification : Mean Estimator (PPS)</td>
</tr>
<tr>
<td>Population</td>
<td>.92 : 1.08 : .97</td>
<td>91.1 : 4.6 : 4.5</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>.80 : .64 : .64</td>
<td>53.7 : 14.5 : 10.0</td>
</tr>
<tr>
<td>All corn</td>
<td>.72 : .63 : .64</td>
<td>26.0 : 11.0 : 7.6</td>
</tr>
<tr>
<td>All pasture</td>
<td>.88 : .72 : .73</td>
<td>40.2 : 21.5 : 17.0</td>
</tr>
<tr>
<td>Milk cows</td>
<td>.92 : .95 : .94</td>
<td>43.6 : 8.3 : 7.9</td>
</tr>
<tr>
<td>Beef cattle</td>
<td>.78 : .72 : .79</td>
<td>9.0 : 5.2 : 4.2</td>
</tr>
<tr>
<td>Clover and timothy</td>
<td>.76 : .50 : .50</td>
<td>18.5 : 13.3 : 7.3</td>
</tr>
<tr>
<td>Hay for silage</td>
<td>.92 : .96 : 1.01</td>
<td>8.1 : 3.5 : 3.5</td>
</tr>
<tr>
<td>Cattle marketed</td>
<td>.87 : .87 : .98</td>
<td>3.7 : 2.5 : 2.5</td>
</tr>
<tr>
<td>Soybeans</td>
<td>.86 : .83 : .86</td>
<td>9.5 : 7.4 : 6.5</td>
</tr>
<tr>
<td>Peas</td>
<td>.86 : .87 : 1.07</td>
<td>5.0 : 4.9 : 5.3</td>
</tr>
<tr>
<td>Stock sheep</td>
<td>.88 : .88 : .98</td>
<td>2.1 : 1.9 : 1.9</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>.89 : .83 : .78</td>
<td>4.1 : 3.7 : 2.9</td>
</tr>
<tr>
<td>Potatoes</td>
<td>.96 : .94 : .84</td>
<td>3.2 : 4.5 : 3.8</td>
</tr>
<tr>
<td>Snap beans</td>
<td>.96 : .96 : .93</td>
<td>3.9 : 4.6 : 4.2</td>
</tr>
<tr>
<td>Average for all items</td>
<td>.86 : .83 : .84</td>
<td></td>
</tr>
</tbody>
</table>

1/ See appendix for explanations keyed to column numbers.
APPENDIX A

Explanations of Tables

Numbers in parenthesis are keyed to columns in the tables. In the formula, upper case letters refer to the population and lower case letters to a sample.

(1) The items are listed in order of decreasing percent reporting, column (4), primarily because sampling variance and variability patterns are closely related to percent reporting.

(2) This column shows State totals, table 1, and totals by CRD's, table 2. The data are totals as enumerated in the Wisconsin State Farm Census for 1970 and are not official estimates.

(3) The term "farms reporting" denotes the number of farms having the item. If \( X_i \) is the value of item \( X \) for the \( i \)th farm, then the number of "farms reporting" this item is the number of farms having a value of \( X_i \) greater than zero. All farms have some farmland so the number of farms reporting farmland is the total number of farms. The number of farms reporting population is less than the number of farms because there are no farm families living on some farms.

(4) This column shows the number of farms reporting as a percent of all farms. It is column (3) divided by the total number of farms 101,685 and expressed in percent.

(5) This is column (2) divided by the total number of farms.

(6) Column (6) is column (2) divided by column (3).

(7) The standard deviation is:

\[
S_X = \sqrt{\frac{\sum (X_i - \bar{X})^2}{N-1}}
\]

where \( X_i \) is the value of the variable \( X \) for the \( i \)th farm and \( N \) is the total number of farms.
In Table 1 the standard deviation measures the variation among all farms in the State. In Table 2 the standard deviation among farms within each crop reporting district is shown. The last line for each commodity in Table 2 is for the whole State and is the same as the data shown in Table 1.

\[(8) \quad \text{Relative variance is } \frac{S^2_x}{\overline{x}^2} \quad \text{It is the variance, square of the standard deviation, divided by the square of the average per farm.}\]

One may derive column (8) by taking the square of each entry in column 7 and dividing by the square of the corresponding entry in column (5).

\[(9) \quad \text{Relative variance for farms reporting is analogous to the relative variance for all farms. It is the relative variance among farms in a subset of farms reporting. For example, for soybeans it is the variance among the 4,125 farms reporting soybeans divided by 30.7^2 which is the square of the average number of acres of soybeans on the 4,125 farms.}\]

\[(10) \quad \text{Design efficiency denotes the ratio of two variances for the purpose of showing the size of the variance for one method in comparison to another. In Table 1, column (10) is the ratio of the variance for the ratio estimator } \left( \sum \frac{X_i}{Y_i} \right) \text{ to the variance for the mean estimator } \bar{X} \text{ assuming simple random sampling, where } \bar{X} \text{ is the sample average for the item, } \bar{Y} \text{ is the sample average for farmland, } N \text{ is the total number of farms, and } \sum \gamma \text{ is total farmland. In Table 2 the comparison is made for each Crop Reporting District.}\]
(11) See figure 1 for a definition of Crop Reporting Districts. As can be seen to some extent from table 2, there is a substantial difference in agriculture between the northern and southern parts of the State.

(12) For simple random sampling the mean estimator is \( \bar{X} \). For stratified random sampling the mean estimator is \( \sum N_h \bar{x}_h \) where \( N_h \) is the total number of farms in stratum \( h \) and \( \bar{x}_h \) is the sample average per farm for stratum \( h \).

(13) For simple random sampling the ratio estimator is \( \frac{\sum x_i}{\sum y_i} \). For stratified random sampling the ratio estimator is \( \frac{\sum N_h x_i}{\sum N_h y_i} \).

(14) There were four levels of geographic stratification: None, Crop Reporting Districts, Counties, and Townships. There were 9 CRD's, 72 counties, and 1,462 townships. Table 3 presents average within stratum variances which are applicable for stratified random sampling of individual farms when the sample is selfweighting, that is, allocated to strata in proportion to the total number of farms. The relative variances recorded in table 3 are \( \frac{N \sum (\sum N_h S_h^2)}{(\sum x_i)^2} = \frac{\sum N_h x_i}{(R)^2} \) where \( h \) denotes a stratum,

\( N_h \) is the number of farms in stratum \( h \),
\( N = \sum N_h \) the total number of farms in the State,
\( S_h^2 \) is the variance within stratum \( h \), and
\( \sum x_i \) = State total of the item. \( \frac{N_h \sum (X_{hi} - \bar{x}_h)^2}{N_h - 1} \)

For the mean estimator, \( S_h^2 = \frac{N_h \sum (X_{hi} - \bar{x}_h)^2}{N_h - 1} \)

For the ratio estimator, \( S_h^2 = \frac{N_h \sum (X_{hi} - R Y_i)^2}{N_h - 1} \) where \( R = \frac{\sum x_i}{\sum y_i} \).
$y^2$ is the relative variance among individual farms within strata and may be thought of as the variance for a sample of one farm even though it is impossible to select a stratified random sample of one farm. The variance for another ratio estimator \( \sum y_h \frac{\bar{x}_h}{y_h} \) was also computed, where \( y_h \) is the total farmland in stratum \( h \). Its variance was either identical to or differed by a trivial amount from the variance of 
\[
\left( \sum y_h \right) \frac{\sum N_h \bar{x}_h}{\sum N_h y_h}.
\]

(15) See (14).

(16) See (14).

(17) This column in table 3 is of interest in comparison with columns (8) and (9). It shows what the relative variance for a mean estimator would be if one had proportionate representation between two strata: farms reporting, and farms having none of the item. These two strata differ from item to item and no geographic stratification is assumed.

Mathematically, the mean estimator and its relative variance are as follows:

The estimator is \( N_0 \bar{x}_0 + N_r \bar{x}_r = N_r \bar{x}_r \)

where \( N_r \) = number of farms reporting the item

\( \bar{x}_r \) = average per farm reporting

\( N_0 \) = number of farms not having the item

\( \bar{x}_0 \) = zero

The relative variance column (17) is \( \frac{N N_h \sigma_r^2}{(\sum x_r)^2} \) where \( r \) refers to the stratum of farms reporting.

Excepting rounding error, column (17) of table 3 can be derived by dividing the entries in column (9) of table 1 by the corresponding entries in column (4) of table 1.
(18) See (14).
(19) See (14).
(20) See (14).
(21) See (14).

(22) thru (30). These columns, table 3A, correspond to columns in table 3. Table 3A shows design efficiencies for the mean estimator which are obtained by dividing columns (8), (11), (15), (16), and (17) by column (8); and design efficiencies for the ratio estimator which are obtained by dividing columns (18), (19), (20), and (21) by column (18). If the ratio estimator had been more efficient relative to the mean estimator, the reduction in variance due to stratification probably would have been quite different for the two estimators.

(31) This column shows the relative variances for stratified random sampling and the mean estimator when the sample is allocated to Crop Reporting Districts in proportion to the item total. The relative variances recorded are

\[
\frac{1}{(\bar{X})^2} \left[ \sum \frac{N_h^2 S_h^2}{P_h} \right]
\]

where \( P_h \) is the proportion of the item in stratum h. The allocation differs for every item. Table 5 shows allocations assuming a sample of 1,000 farms, even though the variances in table 4 are expressed on a unit basis and can be interpreted as variances for a hypothetical sample of one farm.

(32) For the mean estimator and stratification by CRD's the sampling variance is a minimum when the sample is allocated so

\[ m_h \propto N_h S_h \]

where \( m_h \) is the sample size for stratum h. The relative variance for this allocation is
recorded in column (32). It is \[
\frac{1}{(\Xi X)^2} \sum \frac{N_h S_h^2}{P_h'} \text{ where } P_h' = \frac{N_h S_h}{\Xi N_h S_h}.
\]
In this case \[
\frac{1}{(\Xi X)^2} \sum \frac{N_h S_h^2}{P_h'} \text{ reduces to } \left( \frac{\Xi N_h S_h}{\Xi X} \right)^2.
\]
(33) The optimum allocation for the ratio estimator is analogous to the optimum for the mean estimator. Simply substitute in (32) the values of \( S_h^2 \) for the ratio estimator. Optimum allocations for the ratio estimator are not shown in table 5 because they are very close to the optimum allocations for the mean estimator.

(34) Column (34) is column (31) divided by column (11).

(35) Column (35) is column (32) divided by column (11).

(36) Column (36) is column (33) divided by column (19).

(37) This column shows the basis for allocation. See (31) and (32).

(38) For the various items and criteria for allocation, the columns identified as (38) show sample sizes by CRD's (i.e. strata) for a total sample size of 1,000.

(39) The numbers in this column come from columns (34) and (35) of table 4. This column facilitates looking at differences in the sample allocations and observing the impact on sampling variance.

(40) EPS denotes "equal probability of selection." Hence, the relative variances in this column are for an unstratified random sample of townships using equal probability of selection and a mean estimator. The mean estimator in this case is the average per township multiplied by the total number of townships. Let \( T \) represent a township total for one of the items. The relative variance in column (40) is \[
V_T = \frac{M^2}{(\Xi T)^2} \left[ \frac{\Xi (T-\bar{T})^2}{M-1} \right] \text{ where } M \text{ is the total number of townships and } \Xi T \text{ is the State total for the item.} \]
Note from the formula for $V_T^2$ that the relative variances in table 6 are expressed in terms of one township, that is, the township is the sampling unit and is enumerated completely. The average number of farms in a township is 69.5. The variances in table 6 must be multiplied by 69.5 to express them on a per farm basis and to make them comparable with the variances in tables 1, 2, 3, and 4.

(41) The specifications are the same as for (40) except that a ratio estimator is used. There are two possible ratio estimators: $N \frac{\sum \bar{y}}{m}$ or $\sum \gamma \frac{\sum \bar{y}}{\sum y}$ where $N$ is the total number of farms in the State, 

$\sum \bar{y}$ is the sample total, 

$n$ is the total number of farms in the sample. (Note that $n$ is a random variable in this case.) 

$\sum \gamma$ is the total farmland in the State, and 

$\sum \gamma$ is the total farmland in the sample. 

The variances for these two estimators were very close to being the same so only the relative variances for $N \frac{\sum \bar{y}}{m}$ are presented, column (41).

(42) PPS denotes "probability proportional to size." Size in this case was number of farms. For a sample of $m$ townships selected with replacement, the mean estimator involves a weighted mean. It is $\frac{N}{m} \sum \frac{t}{P}$ where $t$ is the township total for a township in the sample and $P$ is its probability of selection. The relative variances recorded in this column are $\frac{\sum P_i [\frac{T_i}{P_i} - L_i]^2}{(\sum L_i)^2}$ where $i$ refers to township, $T$ is the township total for an item, and $P_i = \frac{N_i}{N}$ where $N_i$ equals the number of farms in the $i$th township.
(43), (44), and (45) These columns correspond, respectively, to columns (40), (41), and (42). The only difference is that stratification by CRD's is imposed.

(46) thru (51) These columns correspond to columns (40) thru (45) of table 6. They show design efficiencies for alternative methods of estimation and probabilities of selection. Columns (46), (47), and (48) are equal to columns (40), (41), and (42) divided by column (40). Columns (49), (50), and (51) are equal to columns (43), (44), and (45) divided by column (43).

(52), (53), and (54) These columns show the design efficiency attributable to stratification by crop reporting districts. Column (52) is column (43) divided by column (40); (53) is (44) divided by (41); and (54) is (45) divided by (42). One of many comparisons of interest is the comparison of columns (52), (53), and (54) with columns (23) and (28) in table 3A.

(55) This column illustrates the loss of efficiency (or increase in sampling variance) owing to variation in the size of township and intraclass correlation when the sampling units are townships instead of individual farms. The average township had 69.5 farms. Column (55) is 69.5 times Col. (40). To illustrate, the 26.0 for corn means, if a township is used as a sampling, that the number of farms must be 26 times larger to have the same sampling error.

(56) This column is 69.5 Col. (42) Col. (18). Selection of townships with probability proportional to number of farms has the effect of reducing the variation among townships which is associated with variation in number of farms.
This column is \( \frac{\text{Col. (45)}}{\text{Col. (11)}} \). It is analogous to column (56). The entries in column (57) tend to be less than the entries in column (56) because stratification has a greater impact on the variation among townships than on the variation among farms.