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Determination of the Optimal Level for Combining Area and Yield Estimates

by M.M. Hixson and C.D. Jobusch

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Technical Report

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16. Abstract
Since the eventual aim of crop inventory studies is production estimation, the stratification for area and yield estimates must be coordinated so that acceptable variances are obtained. The objective of this study was to determine the optimal level for combining area and yield estimates of corn and soybeans. Several levels of obtaining both area and yield estimates were considered: county, refined strata, refined/split strata, crop reporting district and state.

Using the CCEA model form and smoothed weather data, regression coefficients at each level were derived to compute yield and its variance. Within stratum area variances were also computed.

The variance of the yield estimates was largest at the state and smallest at the county level for both crops. The refined strata had somewhat larger variances than those associated with the refined/split strata and CRD.

For production estimates, the difference in standard deviations among levels was not large for corn, but for soybeans the standard deviation at the state level was more than 50% greater than for the other levels. The refined strata had the smallest standard deviations. The county level was not considered in evaluation of production estimates due to lack of county area variances. Further studies should consider: (1) bias introduced using estimation at any of the levels, (2) the cost of computation of area and yield estimates at the varying levels, and (3) additional crops of interest.

17. Key Words (Suggested by Author(s))
optimal level, sampling, aggregation, production, precision, Iowa, corn, soybeans

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1. Introduction

The eventual aim of crop inventory studies is production estimation, not area or yield estimates alone. Production estimates can be made only at a level where area and yield strata intersect. The variance of the production estimates is dependent upon the means and variances of both area and yield in the stratum. Thus, it is important that the stratifications for area and yield estimation be coordinated, and that the levels for aggregation be selected so that acceptable variances are obtained.

In the AgRISTARS Foreign Commodity Production Forecasting (FCPF) Project, estimates are to be made for corn and soybeans area and yield in the United States as well as in Brazil and Argentina.

To make production estimates, NASA provides area estimates based on analysis of remotely sensed data and the USDA provides yield estimated from a regression model. In order to obtain the most precise production estimates, the levels of estimation must be coordinated. Thus, a study to determine the precision at several possible levels of aggregation was proposed.

2. Objectives

The overall objective of this study was to determine the optimal level for combining area and yield estimates of corn and soybeans. Production estimates and their variances were computed for several levels of area and yield estimates, and the resulting estimates were compared.

3. Approach

Iowa was selected to study the optimal level for combining area and yield estimates of corn and soybeans. This state was selected for study as it is included in the 1981 AgRISTARS pilot experiment. The year selected for evaluation ("current year") was 1978.

The level at which aggregation of area and yield to obtain production should occur is dependent upon the technology being utilized for estimation. If, for example, area or yield estimates made at a given level are biased or unreliable, then aggregation at that level would most likely be undesirable regardless of any potential gains in precision. A change in the technology utilized for estimation, however, might produce reliable estimates at the same level and be a viable candidate for aggregation. This investigation assessed the optimal level with respect to the current technology. Current technology utilizes digital analysis of Landsat MSS data on sample segments to provide area estimates; regression models are developed from historical data and used with current weather data to provide yield estimates. Several levels of obtaining both area and yield estimates were considered: county, refined stratum, refined/split stratum, crop reporting district, and state.

The model form and variables included in the regression used by CCEA for yield estimation of corn and soybeans in Iowa were obtained. A weather data base with historical (at least 30 years) and "current year" weather data were needed for all the cooperative meteorological stations in Iowa. Historical and "current year" county area and yield estimates made by USDA/SRS in Iowa were acquired for the same time period.

Coefficients for the regression equations were derived to predict yield using the historical weather and yield data at each of the levels of aggregation. A weather smoothing function was utilized to provide estimates of meteorological variables for the various strata studied. Using the 1978 weather data, "current year" yield estimates were made for corn and soybeans in Iowa.

The yield estimate ($\hat{Y}$) and its variance were computed based on the regression equations. The yield estimate was then aggregated to the state level using area weights. The aggregated yield variance was used to determine which stratification systems were candidates for precise estimation methods.

For those levels of aggregation which appeared to be improvements over the currently used method, a further investigation into the effects of using the current area estimation methodology was conducted. Within stratum variances for the area of the crops of interest were obtained. The production estimate ($\hat{P}$) and its variance ($V(\hat{P})$) were computed for all the candidate aggregations. Evaluations compared the variances with one another.

3.1 Data Set Utilized

For development of regression models for yield, a historical series of yield estimates and meteorological data were required. The USDA/SRS county level statistics for yield of corn and soybeans were obtained from the Iowa state office for 1932-78. The 1932-77 data were used in computing the regression coefficients, and the 1978 data were acquired for results comparison.

Daily observations of temperature and precipitation for all the cooperative meteorological stations in the state of Iowa were purchased from the Iowa Geological Survey (1900-74) and some were supplied by another task (1975-78).

3.2 Levels of Aggregation

During the Large Area Crop Inventory Experiment (LACIE), aggregation of area and yield estimates to production was done at the state level. Thus, this would be one level for investigation.

For the state of Iowa, yield estimates will be made at the state level and one other level during the 1981 AgRISTARS pilot experiment. NASA/JSC requested that this level be the refined strata in the state (Figure 1). The yield modeling group, however, thinking that these strata were too broad, suggested a subdivision of them (Figure 1). This subdivision will be referred to as the refined/split strata in this report. Both of these levels are being considered for evaluation.

An additional level which seems to be natural to include is the crop reporting district level (Figure 2) as this has traditionally been a standard unit for the reporting of agricultural statistics. Also, the county level is included as the smallest possible unit using current yield estimation technology, as this is the smallest level for which historical yield estimates are available.

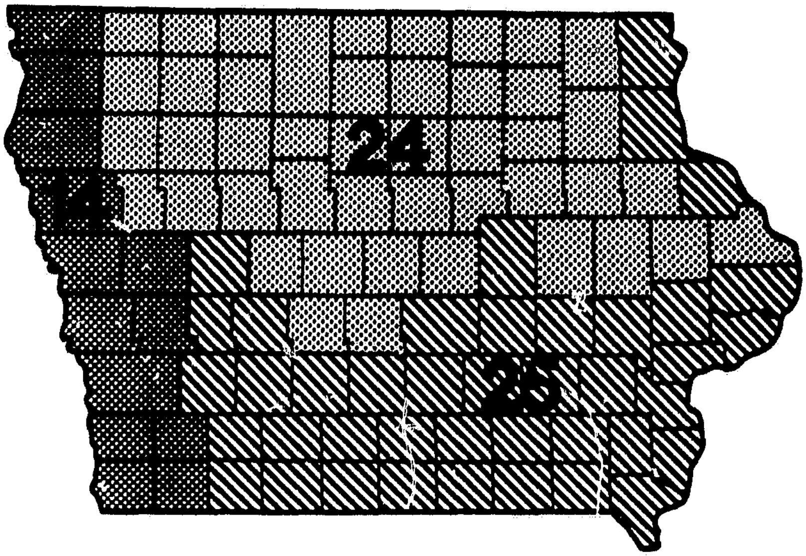
Some characteristics of the strata are presented in Tables 1-3. Means and variability between counties within the strata are described.

3.3 Meteorological Data Estimation

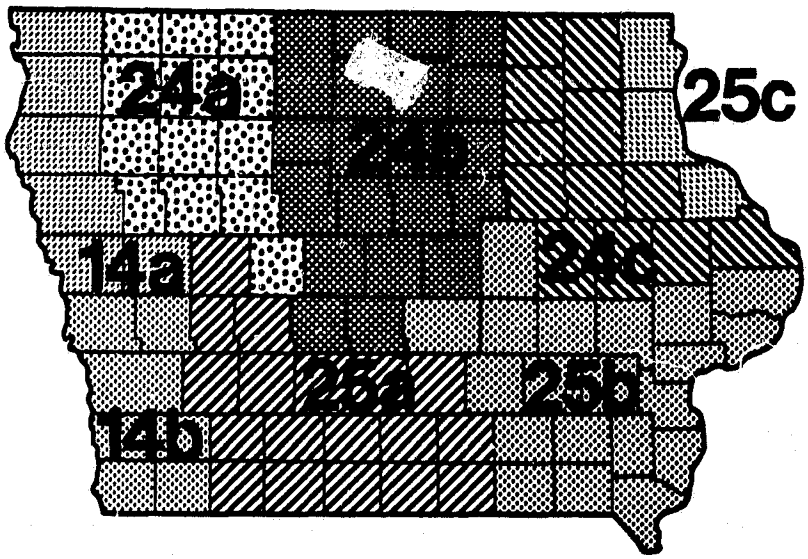
In order to study the various levels of aggregation, yield estimates were needed at each of the levels. To make yield estimates using current technology, meteorological data were needed for each stratum. Not all counties contain weather stations; besides, weighting by nearby weather stations may provide a better estimate of the overall weather of a county than the use of one weather station alone (Figure 3).

For this reason, a weather smoothing routine was utilized. Wagner (1971) devised an objective analysis technique which incorporates a low pass filter and provides a good analysis in sparse data areas or with data containing significant noise. Furthermore, the characteristics of the applied filter function are easily calculated and the analysis technique is quite forgiving in terms of the sensitivity of choosing a filter function for a given data set. This technique was initially devised to remove high frequency fluctuations in the initial condition fields used for numerical weather forecasting. However, the consistency and speed of the technique make it a viable technique for our purposes.

Odell (1975) compared ten techniques for interpolation for irregularly spaced sparse data: composite average, nearest neighbor, least squares linear regression, least squares convex hull, average



REFINED STRATA



REFINED/SPLIT STRATA

Figure 1. Maps of the refined strata developed at NASA/JSC (top) and the refined/split strata as subdivided for the yield modeling effort (bottom).

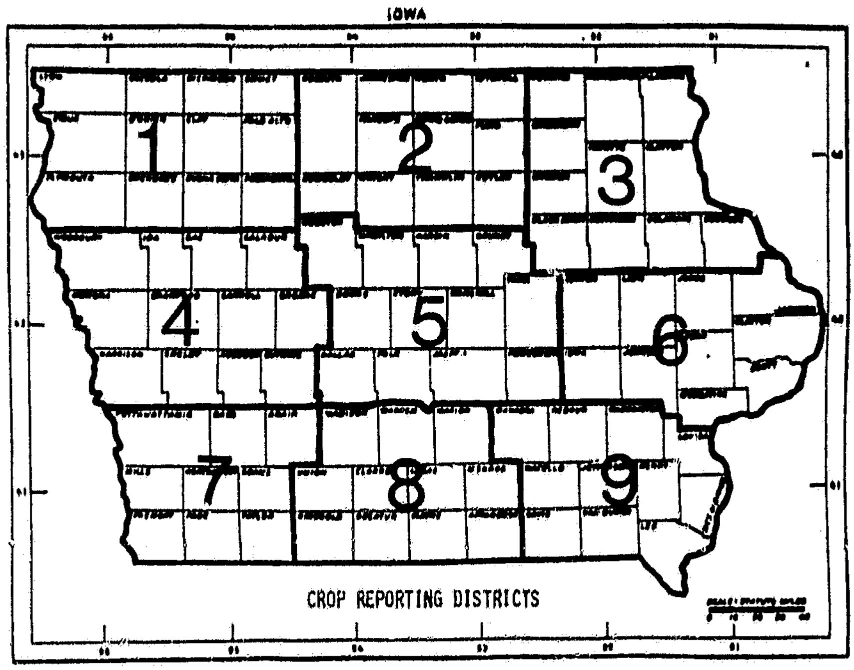


Figure 2. Map of the crop reporting districts in Iowa.

Table 1. Some characteristics of the refined strata. Means and variability are described for corn and soybeans proportions and yields.

DESCRIPTION OF PROPORTIONS FOR REFINED STRATA

	CORN			SOYBEANS			
Stratum	Mean	Standard Deviation	C.V.	Mean	Standard Deviation	C.V.	No. of Counties
14	37.0	4.3	11.6	16.7	3.8	22.6	13
24	37.7	9.0	35.4	25.5	9.0	35.4	45
25	25.7	8.7	33.7	13.3	5.0	37.3	41

DESCRIPTION OF YIELDS FOR REFINED STRATA

	CORN			SOYBEANS			
Stratum	Mean	Standard Deviation	C.V.	Mean	Standard Deviation	C.V.	No. of Counties
14	85.1	23.4	27.5	32.3	3.9	12.1	13
24	99.6	15.7	15.8	32.6	4.0	12.3	45
25	94.7	18.2	19.2	31.0	4.6	14.8	41

Table 2. Some characteristics of the refined/split strata. Means and variability are described for corn and soybeans proportions and yields.

DESCRIPTION OF PROPORTIONS FOR REFINED/SPLIT STRATA

	CORN			SOYBEANS			
Stratum	Mean	Standard Deviation	C.V.	Mean	Standard Deviation	C.V.	No. of Counties
14A	39.3	2.9	7.5	14.1	2.6	18.7	6
14B	35.0	4.4	12.6	19.0	3.1	16.4	7
24A	39.7	2.0	5.1	29.7	6.6	22.1	13
24B	39.7	3.2	8.1	29.3	5.4	18.4	20
24C	32.3	5.2	16.1	14.6	7.1	48.9	12
25A	21.3	8.8	41.1	12.4	3.5	28.4	18
25B	22.2	5.7	25.8	0.9	0.2	20.2	3
25C	30.2	6.7	22.2	16.0	2.9	18.0	20

DESCRIPTION OF YIELDS FOR REFINED/SPLIT STRATA

	CORN			SOYBEANS			
Stratum	Mean	Standard Deviation	C.V.	Mean	Standard Deviation	C.V.	No. of Counties
14A	81.7	22.9	28.0	32.2	4.8	14.9	6
14B	88.0	23.7	26.9	32.4	3.1	9.6	7
24A	97.5	18.5	19.0	33.5	4.1	12.2	13
24B	103.6	14.1	13.6	33.0	3.8	11.5	20
24C	95.4	13.2	13.8	30.8	3.9	12.7	12
25A	85.6	20.4	23.8	29.1	4.3	14.8	18
25B	102.4	12.5	12.2	32.9	4.2	12.8	20
25C	98.6	8.4	8.5	30.0	2.8	9.3	3

Table 3. Some characteristics of the crop reporting districts. Means and variability are described for corn and soybeans proportions and yields.

DESCRIPTION OF PROPORTIONS FOR CROP REPORTING DISTRICTS

	CORN			SOYBEANS			
Stratum	Mean	Standard Deviation	C.V.	Mean	Standard Deviation	C.V.	No. of Counties
North West	39.5	2.3	5.7	26.8	8.5	31.7	12
North Central	39.9	2.1	5.2	30.7	5.4	17.5	11
North East	30.2	7.1	23.5	11.7	8.9	75.7	11
West Central	38.3	4.7	12.4	19.3	8.3	43.1	12
Central	37.6	4.9	13.1	25.1	6.5	25.9	12
East Central	33.1	5.3	16.0	13.5	5.4	40.1	10
South West	29.7	5.8	19.6	17.5	4.0	22.8	9
South Central	16.3	4.8	29.3	10.6	2.3	22.0	11
South East	27.0	6.9	25.7	16.5	3.1	18.7	11

DESCRIPTION OF YIELDS FOR CROP REPORTING DISTRICTS

	CORN			SOYBEANS			
Stratum	Mean	Standard Deviation	C.V.	Mean	Standard Deviation	C.V.	No. of Counties
North West	93.1	21.0	22.6	33.8	4.3	12.7	12
North Central	99.8	14.1	14.1	32.2	3.5	10.9	11
North East	95.9	12.7	13.2	29.8	3.5	11.7	11
West Central	89.9	21.0	23.4	31.8	3.9	12.3	12
Central	106.8	12.8	12.0	33.9	3.8	11.2	12
East Central	100.5	12.7	12.6	33.8	3.6	10.7	10
South West	85.7	25.1	29.3	31.2	3.4	10.9	9
South Central	86.0	18.7	21.7	28.2	4.7	16.7	11
South East	101.9	12.8	12.6	31.7	4.4	13.9	11

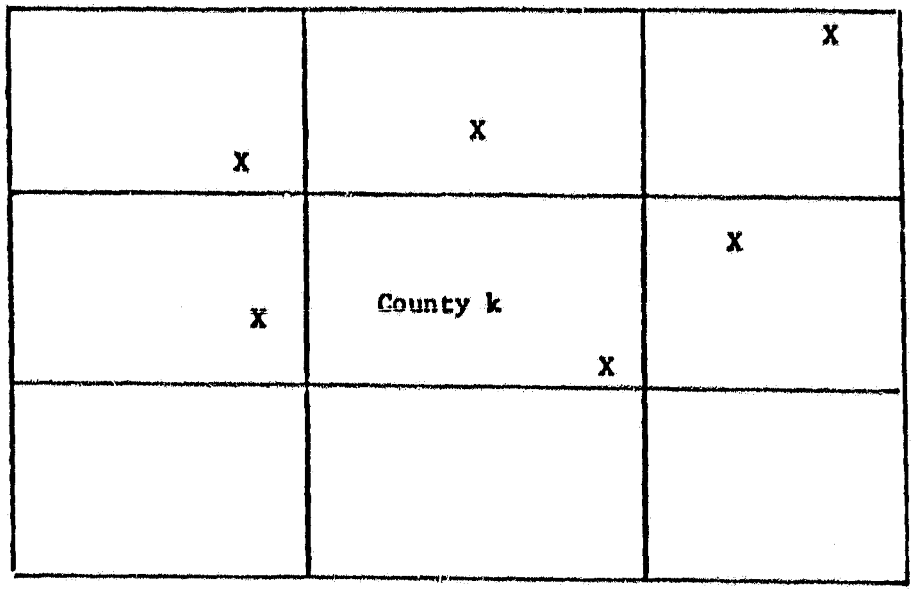


Figure 3. An example of a situation when weighting by weather stations in adjacent counties may be beneficial in providing good estimates of weather for county k. Each x represents a meteorological station.

linkage, average linkage with directional correlation, Wagner's objective analysis, modified linkage, and modified least squares. These techniques were tested in terms of their ability to interpolate five years of wheat yield data across the state of North Dakota (45 data points) based on seven stations of wheat yield data. The weighted linear regression technique appeared to be the best technique with the objective analysis, least squares linear regression, and the modified average linkage coming in close behind. However, the weighted linear regression is computationally time consuming, the least squares linear regression is not well behaved on the boundaries, and the modified linkage does not reflect directional trends in the data. The objective analysis approach provides a smooth well-behaved surface and is computationally fas . Its major deficiency is that the original data points are not fit exactly. However, if noise exists in the input data, this can be advantageous. And, use of the cooperative meteorological station data makes this a reasonable assumption.

Integration of data fields (raster form) produced by the objective analysis routine is sometimes required in order to obtain averages of meteorological (or other) data over some polygonal area. In order to accomplish this, the subroutines of Rios (1979) were utilized. A driver program was written to enable averages, mean square errors, and variances to be calculated for polygonal areas with 39 or fewer vertices. The polygon may contain both convex and concave features. This capability enables averages for a farmer's field, or an entire political subdivision or stratum to be calculated.

The general procedure utilized by the objective analysis technique is illustrated by Figure 4. A grid of a user-selected density is placed over the area of interest. Then the available met station data are used to specify the values at the nearest grid intersection points. The objective analysis procedure then uses gradient and Laplacian weights to specify the values at all grid intersections (Wagner, 1971). Finally, an estimate of the smoothed variable can be made over any polygon of interest by averaging over the grid points within that polygon.

The objective analysis technique was found to perform well in interpolating maximum temperature, minimum temperature, and precipitation on both a monthly and a daily basis for a case study in May 1977 in Oklahoma (Pitts, 1980).

Based upon the favorable results obtained by other investigators, the FORTRAN coded programs for objective analysis were obtained from Dr. David E. Pitts of NASA/JSC. The programs were modified to fit our specific needs; the resulting listings are presented in Appendix A.

A meteorological data smoothing experiment was conducted to determine how the objective function should be utilized. One month of daily data (June 1974) for all met stations in Iowa was used in the study. There were several factors in the experiment: grid size (25 x

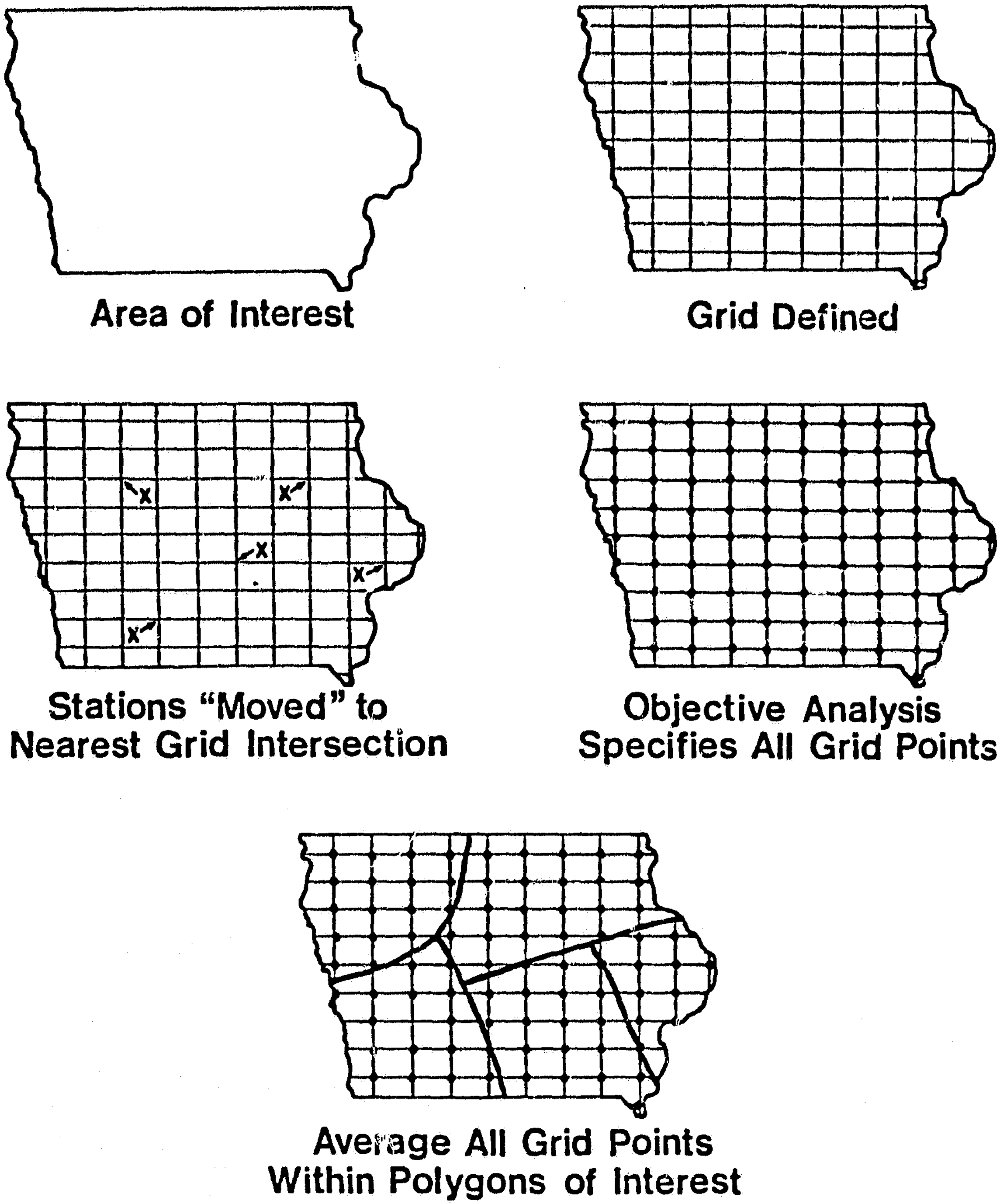


Figure 4. Schematic diagram of the steps in the meteorological data smoothing routine used to obtain meteorological estimates for polygons of interest in Iowa.

25, 32 x 32, 64 x 64), level of smoothing (daily vs. monthly), gradient weight (1,10), and Laplacian weight (1,10). The results were evaluated by examining the mean square error of fit to station data and the maximum change in specified values.

The first observation from this experiment was that using gradient and Laplacian weights of 10 caused too much change in the specified values. A difference of up to about one inch of precipitation was observed. Thus, the remainder of the experiment was analyzed using weights of one only.

The maximum absolute deviation from specified values was examined for the three grid sizes (Table 4). The 64 x 64 grid provided estimates much closer to the specified values than the other two grid sizes. The root mean square error was examined for daily vs. monthly averaging (Table 5). It was found that averaging met data to monthly values and then smoothing the monthly averages performed significantly better than smoothing daily values and then averaging the smoothed values to obtain a monthly estimate.

The parameters selected for use in our study were: grid size 64 x 64 over Iowa, gradient and Laplacian weights of 1.0, and smoothing of monthly average values.

3.4 Yield and Yield Variance Estimation

Estimates of yield at all the levels of aggregation were required for this study. To do this, the variables used in the CCEA state level model were utilized (Table 6). Regression coefficients were developed for each set of strata utilizing 1931-77 meteorological data and 1932-77 USDA/ESCS estimates of county level yields. Data from 1970 were not used in the derivation of regression coefficients for corn due to the corn blight which occurred during that year. The meteorological data inputs were daily reports of minimum temperature, maximum temperature, and precipitation for the strata as computed by the Wagner variational analysis technique.

The programs used to compute the yield and the yield variances were written in SAS. A sample program for each crop is given in Appendix B.

The variance of the yield estimates was computed from the regressions by:

$$V(\hat{Y}) = \sigma^2_{y|x}\,(1 + x'\,(x'(X'X)^{-1}x).$$

Using this formula, a variance was computed for each of the strata in each of the candidate stratification systems.

Table 4. Some results from the meteorological data smoothing experiment. The table shows daily maximum absolute deviations of smoothed values from the specified station values.

Weather Variable	Grid Size		
	25 x 25	32 x 32	64 x 64
Maximum Temperature	2.93	2.45	0.77
Minimum Temperature	2.08	1.39	0.63
Precipitation	0.06	0.04	0.01

Table 5. Some results from the meteorological data smoothing experiment. The table shows the root mean square error of smoothed values from the specified station values.

Weather Variable	Grid Size	RMS Error	
		Daily Smooth	Monthly Smooth
Temperature	32 x 32	4.88	0.52
	64 x 64	NA*	0.17
Precipitation	32 x 32	6.67	0.92
	64 x 64	NA	0.17

* NA - Not Available

Table 6. Model variables for the regressions predicting yield of corn and soybeans in Iowa.

Corn	Soybeans
Linear trend 1941-60	Linear trend 1932-74
Linear trend 1961-72	Cumulative precipitation October - April DFN
May temperature x precipitation interaction	May temperature x precipitation interaction
June temperature x precipitation interaction	June temperature DFN *
June temperature $(DFN)^2$	July precipitation DFN
July precipitation DFN	July temperature DFT
July temperature DFT	August precipitation DFN
July temperature $(DFT)^2$	August precipitation $(DFN)^2$
August temperature DFT	August temperature DFT

* DFN = Departure From Normal
DFT = Departure From Trend

To compare the precision of the several levels, a yield estimate aggregated to the state level was computed. The variance of the aggregated estimates must account for both the variance and covariances of the estimates. Thus, if

$$\hat{Y}_L = \sum_i W_i \hat{Y}_i,$$

then its variance can be computed by:

$$V(\hat{Y}_L) = \sum_i W_i^2 V(\hat{Y}_i) + 2 \sum_{i<j} \text{Cov}(\hat{Y}_i, \hat{Y}_j) W_i W_j$$

where $\hat{Y}_L$ is the aggregated state yield estimate, W_i is the area weight for stratum i, and $\hat{Y}_i$ is the regression yield estimate for stratum i.

3.5 Area and Area Variance Estimation

The area estimates used in the study were the 1978 final area harvested estimates made by the USDA/SRS for the Iowa counties. The variance of these estimates is not computed due to the complex estimation methodology employed. More importantly, the variance of the USDA estimates would most likely differ from that obtained utilizing the AgRISTARS "current technology" of estimating crop areas based on analysis of Landsat data over sample segments.

The variance of the area estimates was computed using the methods described by Chhikara and Perry (1980). The number and distribution of agricultural segments in a region were obtained from NASA. For regions without Landsat imagery, the unobserved potential segments were assigned the same distribution of percent agricultural as the observed segments in that county.

Two methods (Chhikara and Perry, 1980) were available to fit the model:

$$\hat{\sigma}_x^2 = Ax^B,$$

one method based on field sizes and the other a pixel-based method. Both methods were used for comparison and verification.

In the field size model:

$$\sigma_{x_0}^2 = \frac{4}{9} \tilde{P} (1 - \tilde{P})$$

was computed. The field size estimates were obtained from Pitts (1980) data base. Counties were assigned an average field size equal to that of any sample segments within the county. Counties without segments were assigned the field size of a county with similar farm size in geographic proximity.

The second computational method, based on pixels, used the equation:

$$\sigma^2_{x_o} = \alpha_1(1-\tilde{P}) + \alpha_2\tilde{P}^2 + \alpha_3(0.3682 - \tilde{P} + \tilde{P}^2).$$

The programs which were utilized to estimate area variances are presented in Appendix C.

3.6 Aggregation Methodology

For each of the strata in each stratification system, the production was computed as:

$$\hat{P}_i = \hat{A}_i \times \hat{Y}_i$$

where $\hat{P}_i$, $\hat{A}_i$, and $\hat{Y}_i$ are the estimates of production, area, and yield, respectively, in stratum i.

The state-level aggregated production estimate was computed using the methods of stratified estimation presented in Cochran (1963).

For each stratum, the variance of production was computed as:

$$V(\hat{P}_i) = V(\hat{A}_i \times \hat{Y}_i) = V(\hat{A}_i)\mu^2_{\hat{Y}_i} + V(\hat{Y}_i)\mu^2_{\hat{A}_i} + V(\hat{A}_i)V(\hat{Y}_i)$$

For the aggregated state estimate,

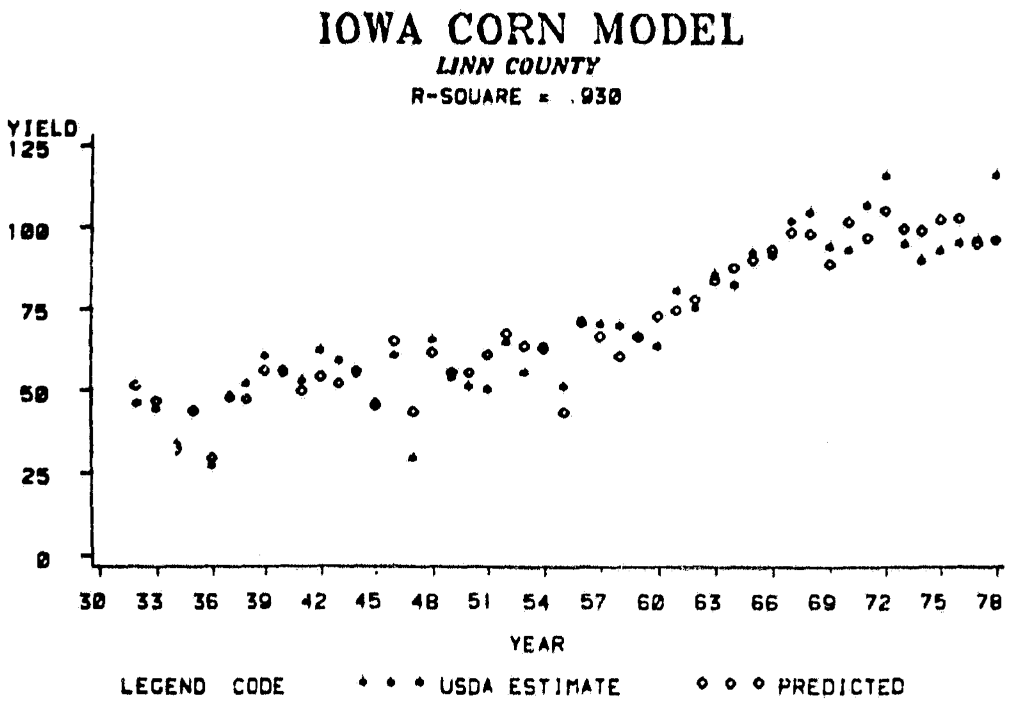
$$V(\hat{P}_L) = V(\sum_i \hat{P}_i) = \sum_i V(\hat{P}_i) + 2\sum_{i<j} \mathrm{Cov}(\hat{P}_i, \hat{P}_j).$$

4. Results and Discussion

4.1 Regression Analysis

A selection of results from the regression analyses are illustrated in Figures 5-9. At the county level, the correlations between values predicted by the regression and USDA observed values had a substantial range. Linn County, with r-square values of 0.93 and 0.92 for corn and soybeans, respectively, is fairly representative of a high correlation situation. Lyon County (r-squares of 0.78 and 0.76) is representative of a lower correlation.

In estimating the yield of corn and soybeans at the crop reporting district level, the correlations between estimated and observed values did not have such a large range as for counties. This is due (at least in part) to the smoothing effects achieved by the consideration of a larger geographic region. The results for the state are illustrated also.



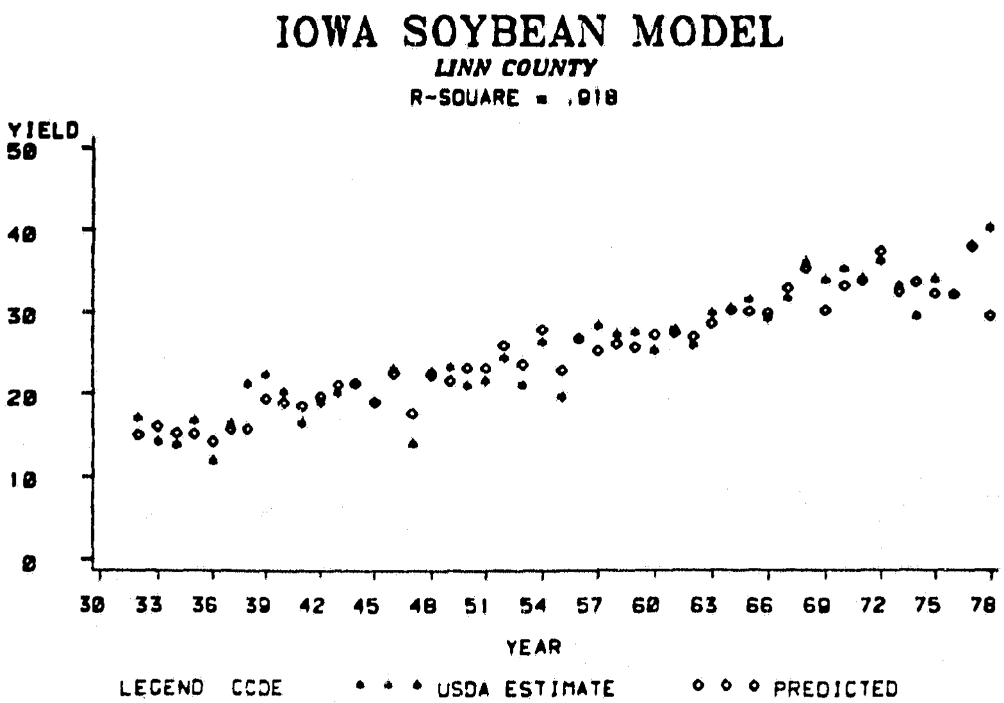
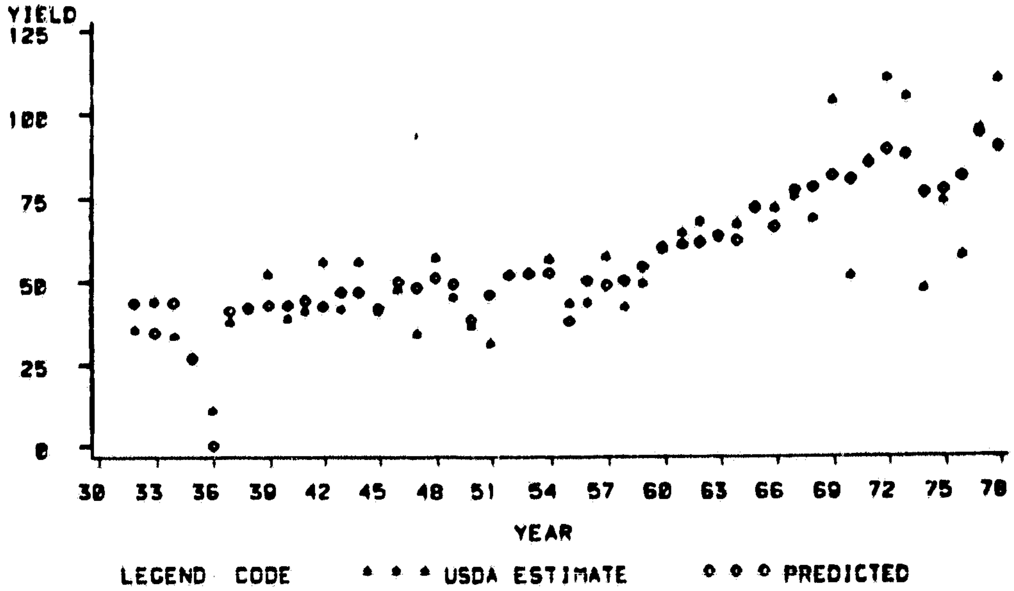


Figure 5. Comparison of corn and soybean yields predicted by the regression equations with USDA/SRS estimates for Linn County, Iowa.

IOWA CORN MODEL

LYON COUNTY

R-SQUARE = .777



IOWA SOYBEAN MODEL

LYON COUNTY

R-SQUARE = .761

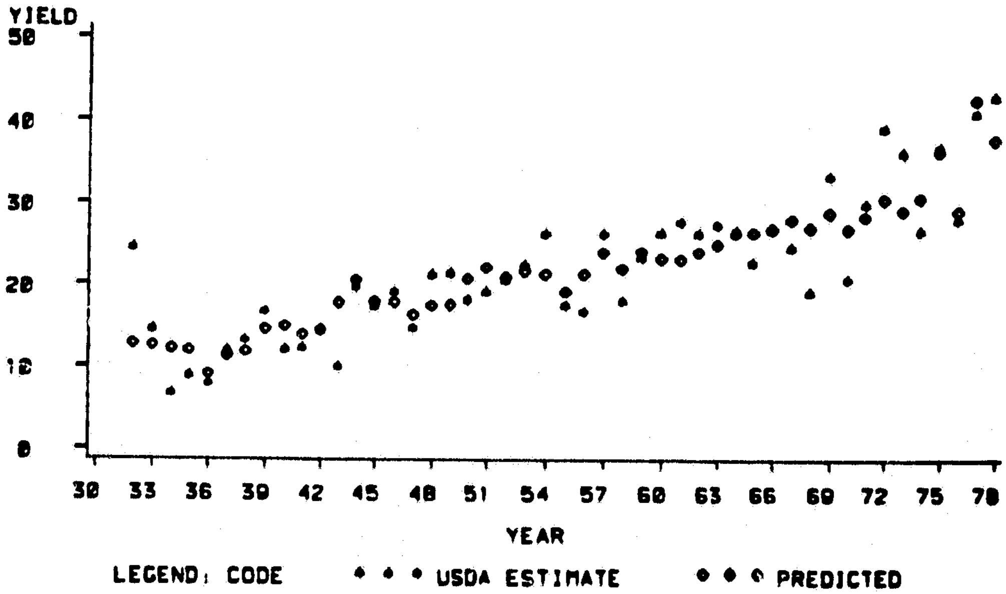
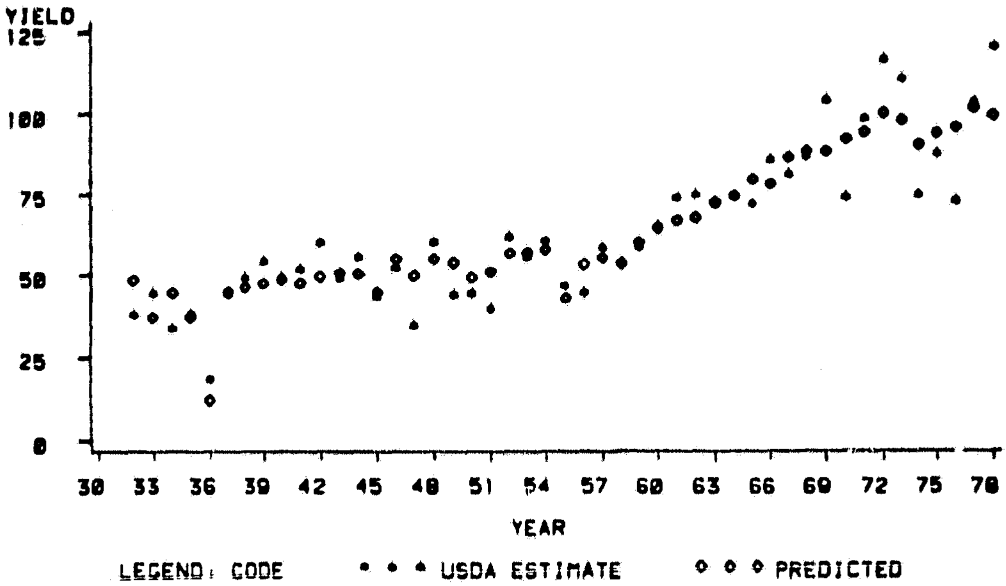


Figure 6. Comparison of corn and soybean yields predicted by the regression equations with USDA/SRS estimates for Lyon County, Iowa.

IOWA CORN MODEL

NORTH WEST CROP REPORTING DISTRICT

R-SQUARE = 866



IOWA SOYBEAN MODEL

NORTH WEST CROP REPORTING DISTRICT

R-SQUARE = 845

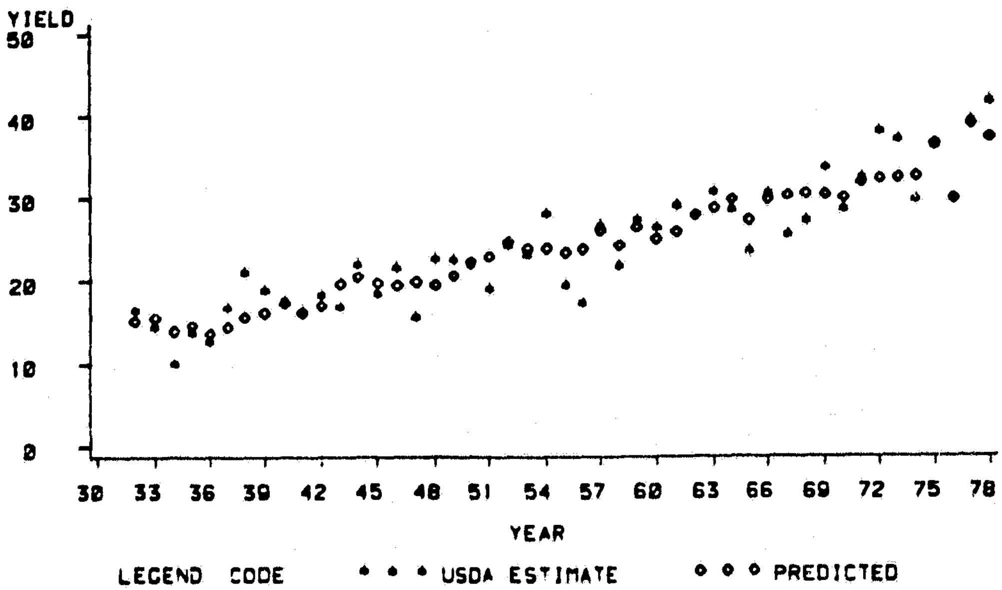
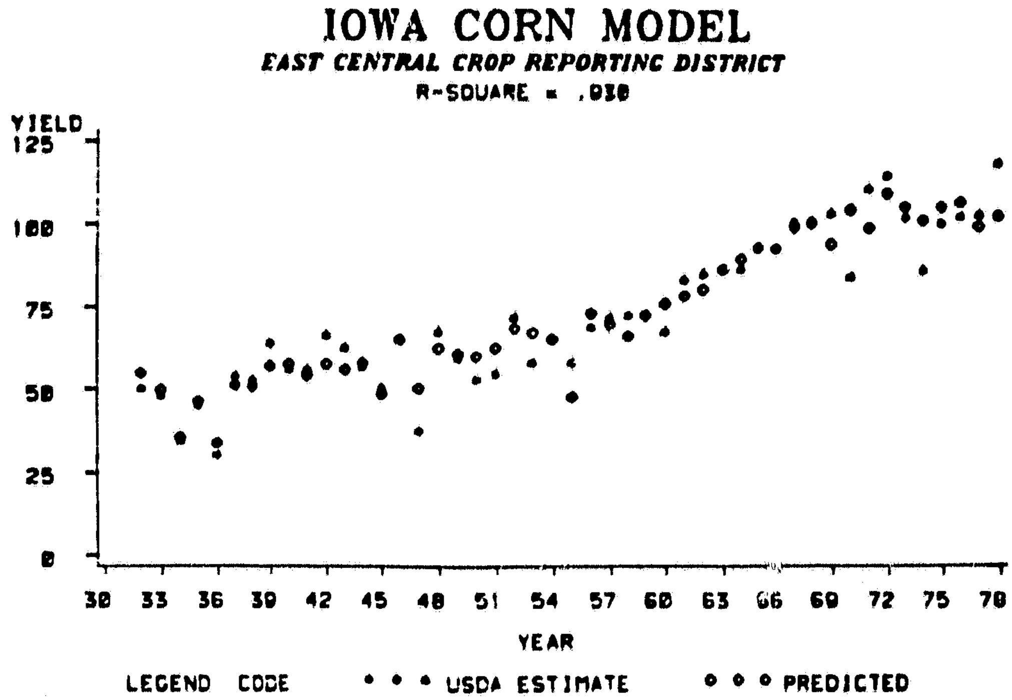


Figure 7. Comparison of corn and soybean yields predicted by the regression equations with USDA/SRS estimates for the North West Crop Reporting District in Iowa.



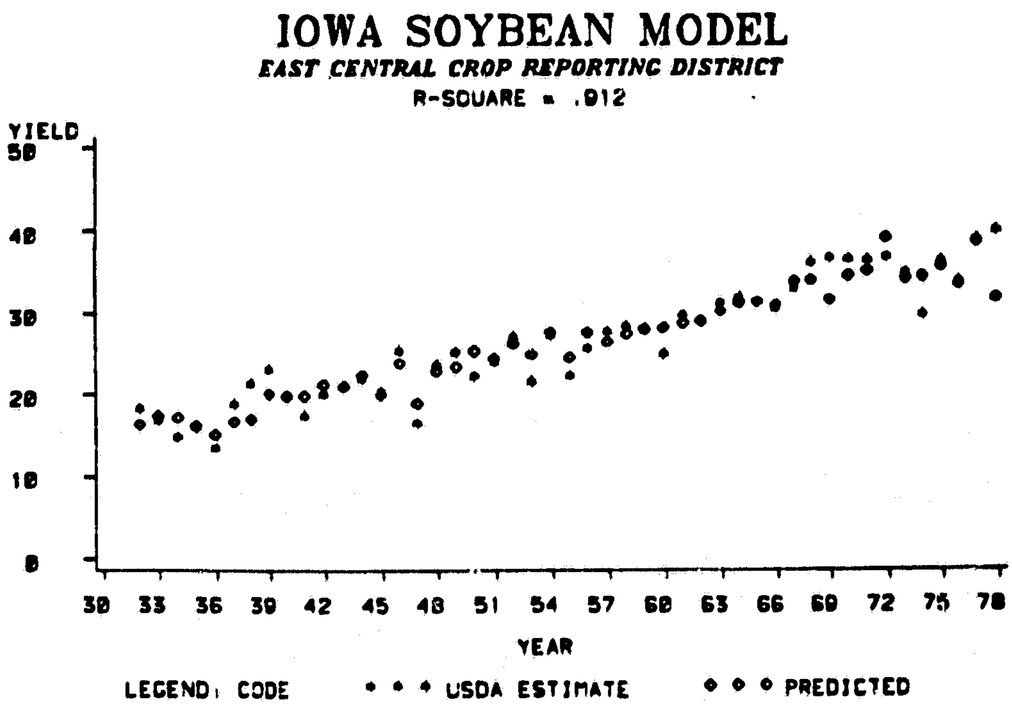
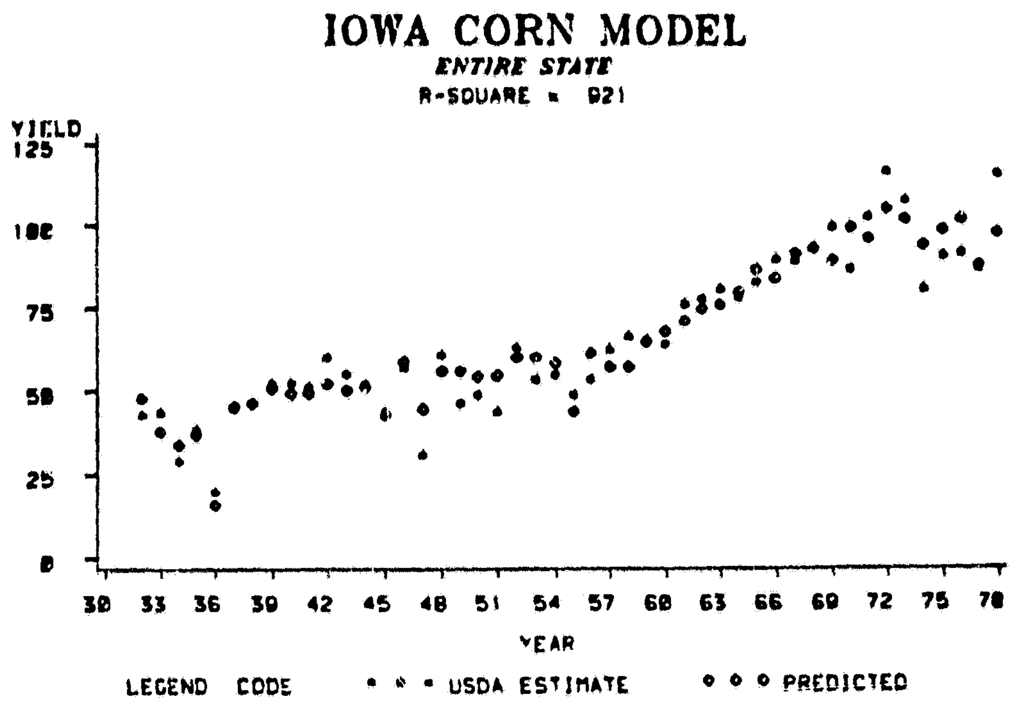


Figure 8. Comparison of corn and soybean yields predicted by the regression equations with USDA/SRS estimates for the East Central Crop Reporting District in Iowa.



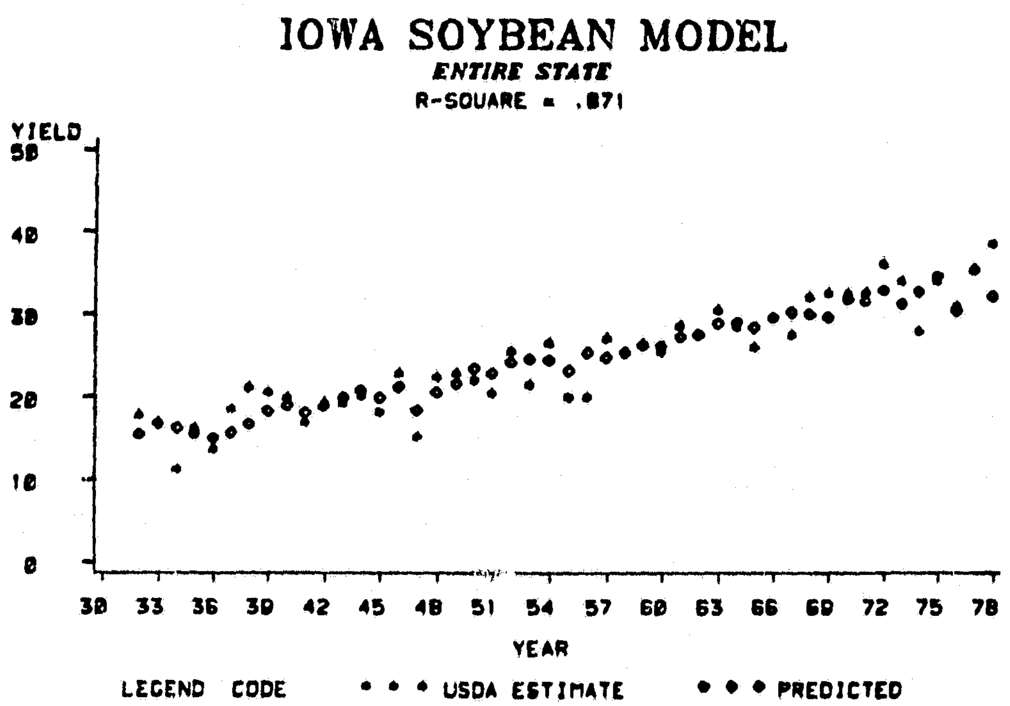


Figure 9. Comparison of corn and soybean yields predicted by the regression equations with the USDA/SRS estimates for the state of Iowa.

4.2 Variance of Yield Estimates

The variance of the yield estimates was computed for each stratum in each of the stratification systems from the regression equations. The aggregate of these results to the state level is shown in Table 7 and illustrated in Figure 10.

For both crops, the state level had the largest variance, and the county level had the smallest variance. The refined strata had somewhat larger variances than those associated with the refined/split strata. The variances for the CRD and the refined/split strata are about the same.

4.3 Variance of Production Estimates

The variance of the production estimates, computed based on the preceeding results, is shown in Table 8 and is illustrated in Figures 11 and 12. There were only small differences between the values computed using the field size and pixel size methods for computing area variances. Thus, the same discussion applies no matter which method is selected.

For corn, the difference in the standard deviations among levels is not great. The differences for soybeans are quite apparent, however, with the standard deviation at the state level being more than 50% greater than for the other levels. For both crops, the refined strata had the smallest standard deviations.

This result is somewhat surprising since the aggregated yields had shown this method to be of slightly lower precision. What is probably being illustrated, however, is the precision gained by having fewer strata. There are only three refined strata compared with eight refined/split strata and nine crop reporting districts. Due to the strata correlations, relatively more precision was obtained with the fewer refined strata.

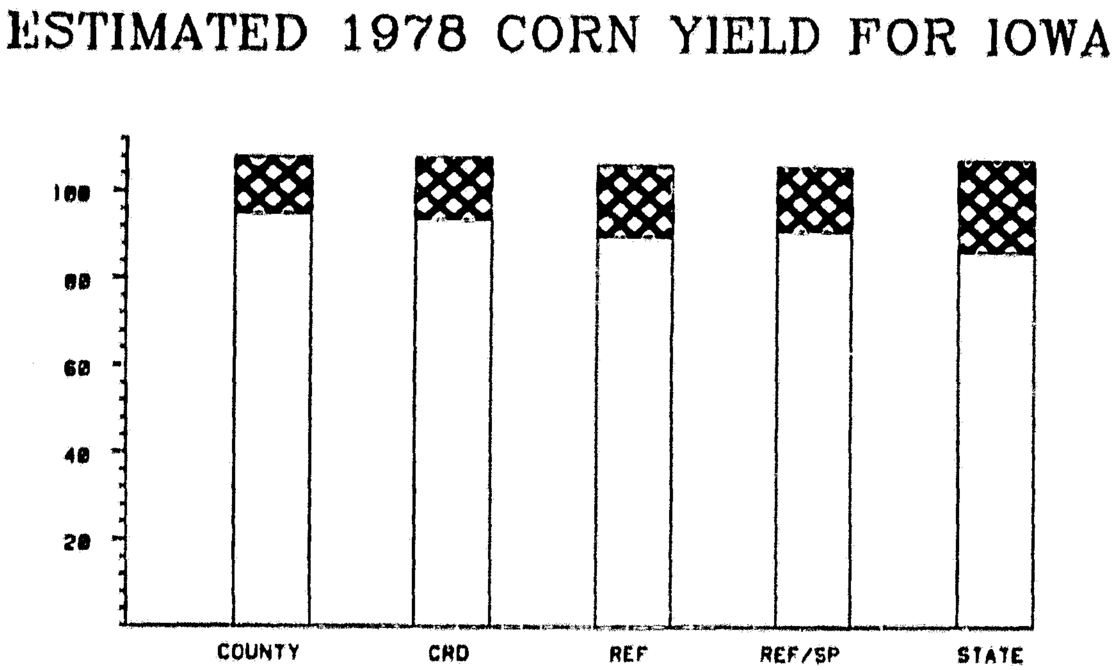
5. Summary and Conclusions

Aggregation of area and yield to production at the state level was the least precise of the methods examined. The crop reporting district, refined strata, and refined/split strata had similar levels of precision of production estimates.

In examining the variance of yield estimates, the aggregated results from estimation at a county level showed a high precision.

Table 7. The variance of yield estimates obtained using each level of estimation. The individual stratum results were aggregated to the state level for comparison.

Stratification System	No. of Strata	CORN		SOYBEANS	
		Variance	Standard Deviation	Variance	Standard Deviation
STATE	1	109.6	10.5	14.2	3.8
CRD	9	49.0	7.0	6.2	2.5
COUNTY	99	39.9	6.3	4.3	2.1
REFINED	3	66.4	8.1	9.0	3.0
REF/SPLIT	8	51.4	7.2	6.5	2.5



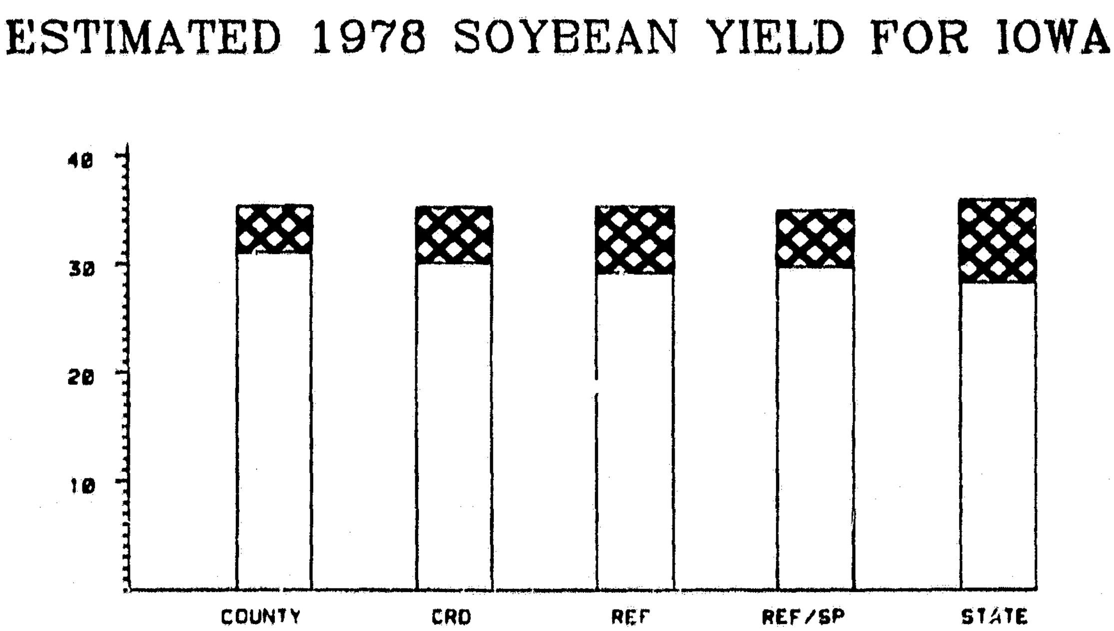
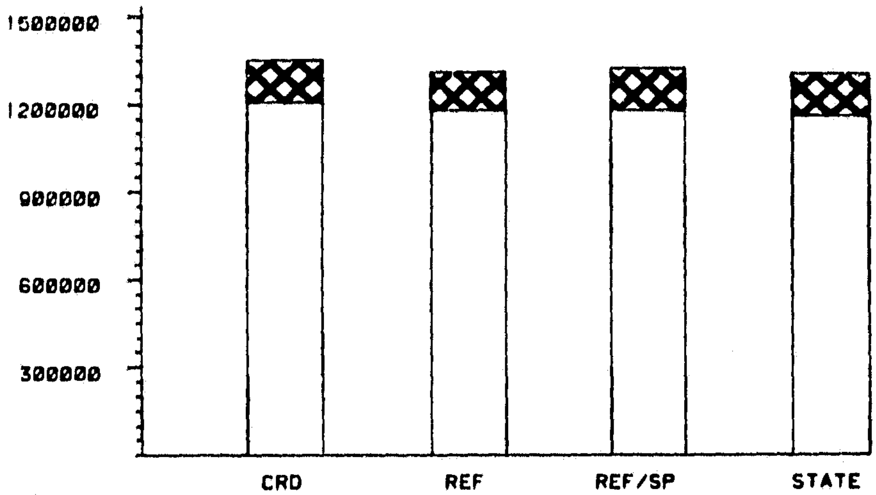


Figure 10. The estimated yield of corn and soybeans at the state level for each of the stratification systems. The shaded area is the estimated yield plus and minus one standard deviation.

Table 8. Standard deviation of state-level production estimates made at several levels of aggregation. Units are in thousands of bushels.

Level of Aggregation	Field Size Method		Pixel Size Method	
	Corn	Soybeans	Corn	Soybeans
CRD	72.2	14.8	72.2	14.8
Refined	63.8	13.8	63.3	13.6
Refined/Split	71.1	14.2	71.0	14.1
State	71.5	22.5	69.2	22.2

ESTIMATED 1978 CORN PRODUCTION FOR IOWA
FIELD SIZE VARIANCE ESTIMATION METHOD



ESTIMATED 1978 SOYBEAN PRODUCTION FOR IOWA
FIELD SIZE VARIANCE ESTIMATION METHOD

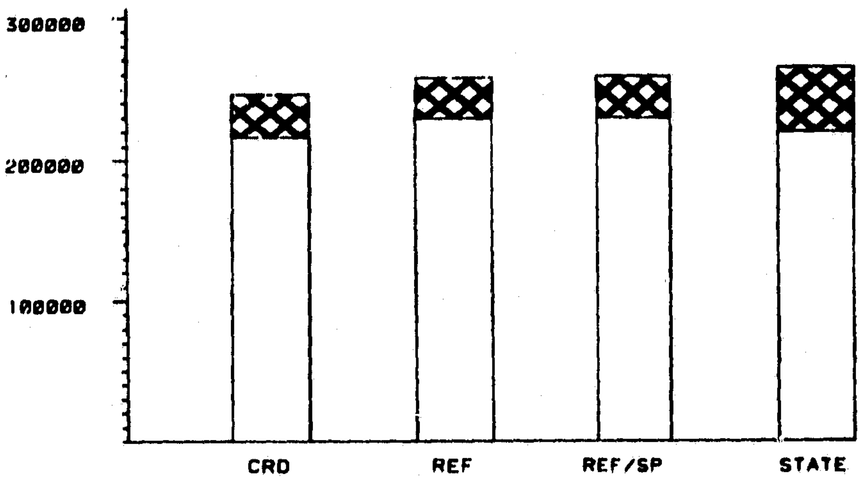
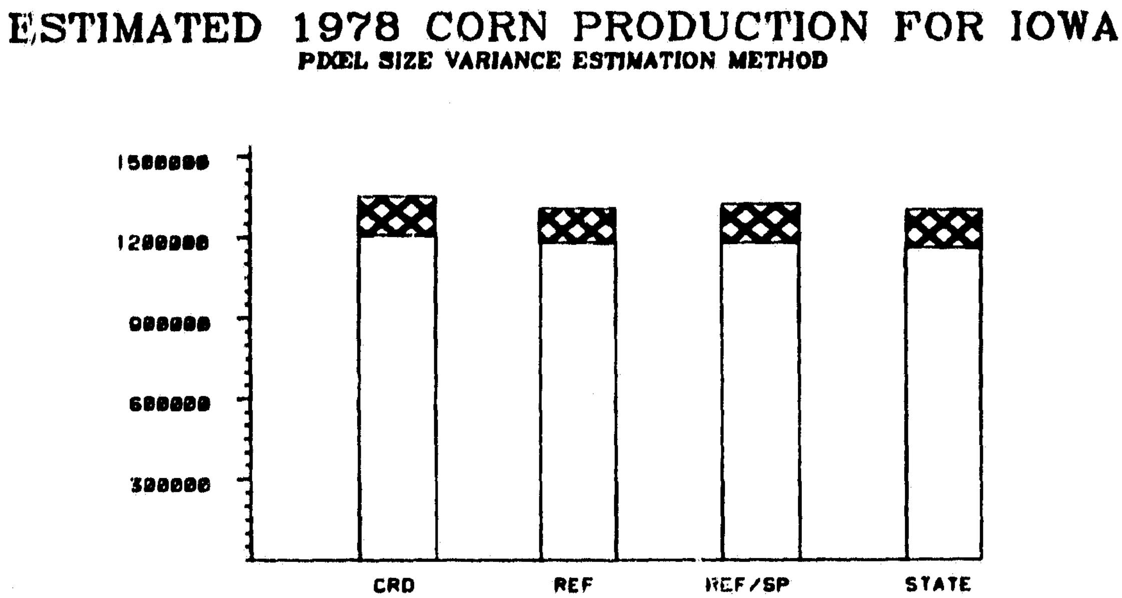


Figure 11. Estimated corn and soybean production for Iowa using the field size variance estimation method. Shaded area is estimated production plus and minus one standard deviation.



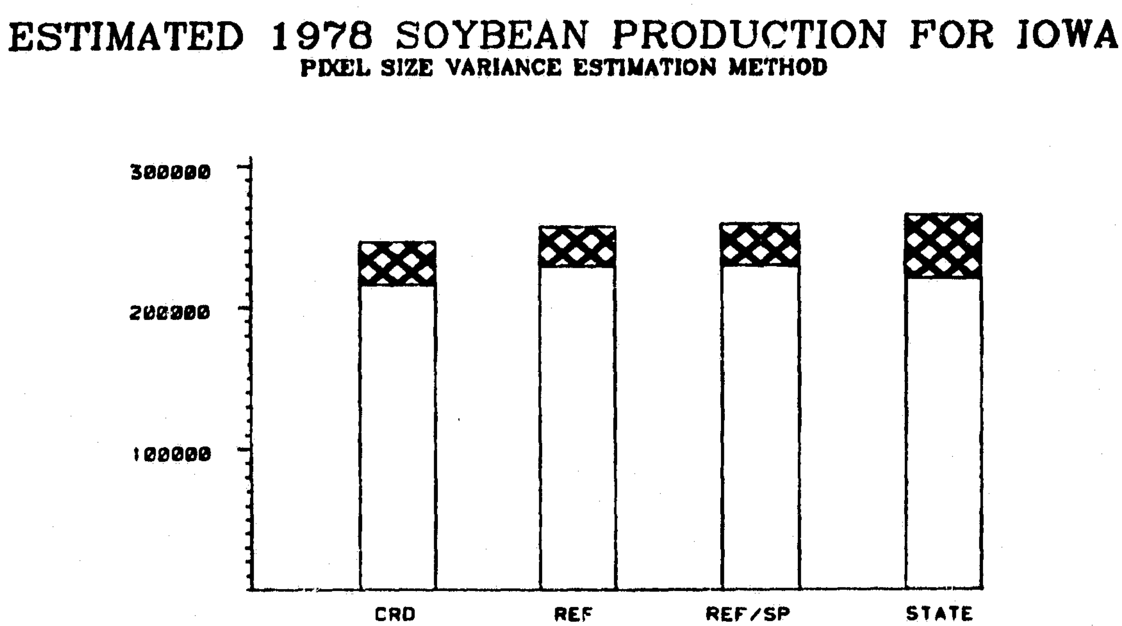


Figure 12. Estimated corn and soybean production for Iowa using the pixel size variance estimation method. Shaded area is estimated production plus and minus one standard deviation.

Unfortunately, we did not have a mechanism for estimation of area variances at the county level. This level for estimation should be considered, however, because of its high precision for yield.

The results of this study provide a first step in determination of the optimum level for combining area and yield estimates to obtain production. Two aspects not considered in this study should be part of a further analysis: (1) bias introduced using area or yield estimation at any of the levels, (2) the cost of computation of area and yield estimates at the varying levels, and (3) differences in the optimal level due to the crop of interest.

The bias of estimates was considered in this study only to the extent that it did not appear that any of the estimates were biased with respect to the estimates made using any other level of estimation. It may be, however, that either area estimates, yield estimates, or both may have a bias when estimated at one of the levels. The area estimates are currently made at a refined stratum level; no information is available on the potential bias introduced by estimating areas on any smaller geographic region. The yield estimates are now made generally at the state level. Biases may be introduced due to the density of weather stations available for estimating the parameters of the regression equation. A technique such as was utilized in this study may be one possible solution to this problem. However, it is possible that the resulting yields should be smoothed rather than the input meteorological data since the relationship between the input data and predicted values is not linear in the input variables.

The costs of computing the area and yield components must also be considered before a final recommendation can be made. The basis for the decision will consist of consideration of the variances and standard deviations computed as a part of this investigation coupled with cost information for computation of area and yield estimates at each of the potential levels of aggregation. The analysis can be carried out based on sample survey design theory such as described by Cochran (1963).

The results for corn and soybeans were substantially different, with the level at which corn is aggregated making less difference than the level at which soybeans are aggregated. Thus, additional crops of interest such as small grains should be examined.

In summary, the results of this study indicate that aggregations should be performed at a level below the entire state. Selection of the most appropriate level, however, requires further study of bias, cost, and crop-dependent differences.

6. References

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7. Wagner, K.K. 1971. Variational Analysis Using Observation and Low-Pass Filtering Constraints. Master's Thesis, Dept. of Meteorology, University of Oklahoma, Norman, Oklahoma.

Appendix A. FORTRAN programs used to carry out the meteorological smoothing routine.

```
C
C=====================================================================
C
C     SMOOTH FORTRAN
C     WRITTEN BY DAVE PITTS (J.S.C.)
C     MODIFIED BY  KEVIN MCCULLEN (L.A.R.S.)  06/09/80
C
C     SMOOTH FORTRAN IS THE INITIAL CALLING PROGRAM FOR A WEATHER DATA
C     SMOOTHING FUNCTION
C
C=====================================================================
C
C     VARIABLES
C
C     MAXLAT        MAXIMUM LATITUDE ON MAP
C     MINLAT        MINIMUM LATITUDE ON MAP
C     MAXLNG        MAXIMUM LONGITUDE ON MAP
C     MINLNG        MINIMUM LONGITUDE ON MAP
C     ISIZE         NUMBER OF GRID IN NORTH-SOUTH DIRECTION
C     JSIZE         NUMBER OF GRID IN EAST-WEST DIRECTION
C     L             NUMBER OF PAIRS OF VERTICES OF POLYGON
C     IDEBUG        EQUALS L IF EXTRA PRINTOUT IS NEEDED FOR DEBUGGING
C     IBUF(2)       NUMBER OF PSEUDOZONE OR FIELD DESCRIBED BY POLYGON
C     IPOLY         NUMBER OF PLOYGONS TO BE PLACED OVER THE FUNCTION U
C
C     ISIZE, MAXLAT, AND MINLAT MUST BE ADJUSTED SO THAT ISCALE IS AN
C     INTEGER.
C     JSIZE, MAXLNG, AND MINLNG MUST BE ADJUSTED SO THAT JSCALE IS AN
C     INTEGER.
C
C=====================================================================
C
      IMPLICIT INTEGER*4 (I-N), REAL*8 (A-H, O-Z)
      REAL*8 XLAT(500),XLONG(500),TMAX(500),TMIN(500),PREC(500)
      REAL*8 P(64,64),U(64,64),DIFF(64,64)
      REAL*8 MAXLAT,MINLAT,MAXLNG,MINLNG
      INTEGER*4 IBUF(80),IX6(512)
      INTEGER*4 NTIMES
C
C==== BEGIN ==========================================================
C
    5 READ (5,101,END=9200) MAXLAT,MINLAT,MAXLNG,MINLNG,ISIZE,JSIZE,K,
     +AA,ALF2,ALF4,ERR,MAXPAS
  101 FORMAT(F9.3,3F10.3,3I5,/,4F10.3,I5)
      ISIZE = 64
      JSIZE = 64
      NTIMES = 64
      ISCALE=(FLOAT(ISIZE-1))/(MAXLAT-MINLAT)
      JSCALE=(FLOAT(JSIZE-1))/(MAXLNG-MINLNG)
```

```
C
C==== READ IN LOW DENSITY MAP DATA =====================================
C
      CALL IN(XLAT,XLONG,TMAX,TMIN,PREC,L,MAXLAT,MINLAT,MAXLNG,MINLNG)
      DO 104 I=1,NTIMES
      DO 104 J=1,NTIMES
  104 P(I,J)=0.0
      DO 102 M=1,L
      XI=(MAXLAT-XLAT(M))*ISCALE+1
      XJ=(MAXLNG-XLONG(M))*JSCALE+1
      I=XI
      IF (XI-FLOAT(I).GE.0.5) I=I+1
      J=XJ
      IF (XJ-FLOAT(J).GE.0.5) J=J+1
      IF (K.EQ.2) P(I,J)=TMAX(M)
      IF (K.EQ.0) P(I,J)=TMIN(M)
  102 IF (K.EQ.1) P(I,J)=PREC(M)
C
C==== WRITE FIELD, DO OBJECTIVE ANALYSIS, PRINTOUT CONTOURED RESULTS ===
C
      WRITE(6,3)
    3 FORMAT(1H1,'64 X 64 GRID')
      WRITE (6,2) ((P(I,J),J=1,16),I=1,NTIMES)
      WRITE (6,2) ((P(I,J),J=17,NTIMES),I=1,NTIMES)
    2 FORMAT (32(16(1X,F7.3),/))
      CALL ANAL(ISIZE,JSIZE,AA,ALF2,ALF4,MAXPAS,ERR,P,U)
      WRITE(6,3)
      WRITE (6,2) ((U(I,J),J=1,16),I=1,NTIMES)
      WRITE (6,2) ((U(I,J),J=17,NTIMES),I=1,NTIMES)
      DO 9999 I=1,64
      DO 9999 J=1,64
      DIFF(I,J)=P(I,J)-U(I,J)
 9999 IF (P(I,J).EQ.0.0) DIFF(I,J)=0.0
      WRITE (6,3)
      WRITE (6,2) ((DIFF(I,J),J=1,16),I=1,NTIMES)
      WRITE (6,2) ((DIFF(I,J),J=17,NTIMES),I=1,NTIMES)
      WRITE (16, 4)
4     FORMAT('GRID SMOOTHED, ANALYSIS BEGUN ')
      MIN = 0
      INT = 0
      SCALE = 0.0
      CALL BONTUR (P,ISIZE,JSIZE,MIN,INT,SCALE)
      MIN = 0
      INT = 1
      SCALE = 1.0
      CALL BONTUR (U,ISIZE,JSIZE,MIN,INT,SCALE)
C
C==== BEGINNING OF READ HIGH DENSITY MAP DATA ==========================
C
      DO 609 JJJ=1,JSIZE
      DO 609 III=1,ISIZE
  609 P(III,JJJ)=-1.0
      CALL IN(XLAT,XLONG,TMAX,TMIN,PREC,L,MAXLAT,MINLAT,
     *MAXLNG,MINLNG)
```

```
      IF (L.LT.5) GO TO 503
      DO 502 M=1,L
      XI=(MAXLAT-XLAT(M))*ISCALE+1
      XJ=(MAXLNG-XLONG(M))*JSCALE+1
      I=XI
      IF (XI-FLOAT(I).GE.0.50) I=I+1
      J=XJ
      IF(XJ-FLOAT(I).GE.0.5) J=J+1
      IF (K.EQ.2) P(I,J)=TMAX(M)
      IF (K.EQ.0) P(I,J)=TMIN(M)
  502 IF (K.EQ.1) P(I,J)=PREC(M)
  503 CONTINUE
C
C==== BEGINNING OF INTEGRATION OVER A POLYGON ON THE MAP ===============
C
      READ (5,108,END=9200) IPOLY
      DO 268 INUM=1,IPOLY
      IBUF(2)=INUM
      READ (5,108,END=9200) L,IDEBUG
  108 FORMAT (2I2)
      NO=1+L*2
      M=3
  702 READ (5,100,END=9200) XLAT(M),XLONG(M)
  100 FORMAT (F9.3,4F10.3,A5)
      XI=(MAXLAT-XLAT(M))*ISCALE+1
      XJ=(MAXLNG-XLONG(M))*JSCALE+1
      I=XI
      J=XJ
      IF (XI-FLOAT(I).GE.0.5) I=I+1
      IF (XJ-FLOAT(J).GE.0.5) J=J+1
      IBUF(M)=J
      IBUF(M+1)=I
      IF (M.EQ.3) GO TO 703
      IF (IBUF(M).NE.IBUF(M-2).OR.IBUF(M+1).NE.IBUF(M-1)) GO TO 703
      M=M-2
      NO=NO-2
  703 IF (M.GE.NO) GO TO 701
      M=M+2
      GO TO 702
  701 CALL POLYG(NO,IBUF,IDEBUG,IX6,J,IYMIN,IYMAX)
C
C==== PAINTING OF INTERIOR OF POLYGON WILL COMMENCE ====================
C
      I=IYMIN
      SUM=0.0
      ICNT=0
      SS=0.0
      SS1=0.0
      ICOUNT=0
      K=1
  206 CONTINUE
      K1=IX6(K)
      IF (IX6(K).GT.5000) K1=K1-5000
      K2=IX6(K+1)
      IF(K2.GT.JSIZE) WRITE (16,285)
```

```
  286 FORMAT (' POLYGON EXTENDS OUTSIDE OBJECTIVE FIELD IN LONGITUDE ')
      IF (K2.GT.JSIZE) CALL EXIT
      DO 107 JJ=K1,K2
      ICOUNT=ICOUNT+1
      IF(L.LT.5) GO TO 107
      IF(P(I,JJ).LT.-1.0E-10) GO TO 107
      ICNT=ICNT+1
      SS=SS+U(I,JJ)-P(I,JJ)
      SS1=SS1+(U(I,JJ)-P(I,JJ))**2
  107 SUM=SUM+U(I,JJ)
      IF(I.GT.ISIZE) WRITE (16,296)
  296 FORMAT (' POLYGON EXTENDS OUTSIDE OBJECTIVE FIELD IN LATITUDE ')
      IF (I.GT.ISIZE) CALL EXIT
      IF (IX6(K+2).GT.5000) I=I+1
      K=K+2
      IF(K.LT.J) GO TO 206
      SUM=SUM/FLOAT(ICOUNT)
      WRITE(7,267) IBUF(2),SUM,ICNT
  267 FORMAT (' AVERAGE OVER AREA ',I4,'  EQUALS ',F9.5,2X,
     *'NUMBER OF OBS=',I5)
      IF(L.LT. 5) GO TO 268
      SM=SS/(FLOAT(ICNT))
      WRITE (7,362) SM
  362 FORMAT (' SAMPLE BIAS = ', F9.5)
      SM=DSQRT((SS1-(SS**2)/(DFLOAT(ICNT)))/(DFLOAT(ICNT-1)))
      SS1=SS1/(FLOAT(ICNT))
      WRITE (7,363) SM,SS1
  363 FORMAT (' STANDARD DEVIATION = ', F9.5, ' MSE = ', F10.5,//)
  268 CONTINUE
      IF (L.LT.5) GO TO 5
      GO TO 5
 9200 STOP
      END
      SUBROUTINE IN(XLAT,XLONG,TMAX,TMIN,PREC,L,MAXLAT,MINLAT,
     *MAXLNG,MINLNG)
      IMPLICIT INTEGER*4 (A-Q, S-Z), REAL*8 (R)
      REAL*8 XLAT(500),XLONG(500),TMAX(500),TMIN(500),PREC(500)
      REAL*8 MAXLAT,MINLAT,MAXLNG,MINLNG
      L=0
    1 L=L+1
      READ(5,100,END=9200)XLAT(L),XLONG(L),TMAX(L),TMIN(L),PREC(L),AAA,
     * AAB
  100 FORMAT (F8.3,4F10.3,2A4)
      IF (XLAT(L).LT.-90.0) GO TO 40
      ITEST=0
      IF (XLAT(L).GT.MAXLAT.OR.XLAT(L).LT.MINLAT.OR.XLONG(L).GT.MAXLNG
     1.OR.XLONG(L).LT.MINLNG) ITEST=1
      IF (ITEST.EQ.1) L=L-1
      GO TO 1
   40 CONTINUE
      L=L-1
      WRITE (7,106) L
  106 FORMAT (' NUMBER OF STATIONS READ IN = ',I10,//)
 9200 RETURN
      END
```

```
C
C=======================================================================
C
C     POLYG FORTRAN
C     WRITTEN BY DAVE PITTS (J.S.C.)
C     MODIFIED BY KEVIN MCCULLEN (L.A.R.S.)  06/09/80
C
C     POLYG IS A SUBROUTINE TO THE MAINV WEATHER DATA SMOOTHING
C     ALGORITHIM
C
C=======================================================================
C
C     VARIABLES
C
C     NO             LENGTH OF INPUT, BUF
C     BUF            INPUT DATA STRING
C     X6             OUTPUT STRING
C     J              LENGTH OF OUPUT, X6
C     BUF(1)         UNUSED
C     BUF(2)         NUMBER IDENTIFYING CRD OR PSEUDOZONE
C
C     NO = 1 + L * 2 (L = NUMBER OF PAIRS OF DATA POINTS)
C     IF IDEBUG IS 1 THEN EXTRA DEBUG OUTPUT IS GENERATED
C
C=======================================================================
C
      SUBROUTINE POLYG(INO,IBUF,IDEBUG,IX6,IJ,IYMIN,IYMAX)
      IMPLICIT INTEGER*4 (A-Q, S-Z),  REAL*8 (R)
      INTEGER*4 IBUF(80),IX6(512)
      COMMON /STUFF/X6(512),NPRT,BUF(80),NO,X1(50),Y1(50),N1,YMIN,YMAX,
     *X2(55),Y2(55),N2,X3(70),Y3(70),N3,X4(512),Y4(512),N4,X5(200,11),J
      NPRT=16
      NO=INO
      DO 30 I=1,80
   30 BUF(I)=IBUF(I)
  102 FORMAT (2I4)
      CALL S01(IDEBUG)
      CALL S12(IDEBUG)
      CALL S23(IDEBUG)
      CALL S34(IDEBUG)
      CALL S45(IDEBUG)
      CALL S55(IDEBUG)
      CALL S56(IDEBUG)
      IJ=J
      DO 31 I=1,512
   31 IX6(I)=X6(I)
      IYMIN=YMIN
      IYMAX=YMAX
      RETURN
      END
```

```
C
C=======================================================================
C
C     S01 FORTRAN
C     WRITTEN BY DAVE PITTS (J.S.C.)
C     MODIFIED BY KEVIN MCCULLEN (L.A.R.S.)  06/09/80
C
C     S01 IS A SUBROUTINE IN THE MAINV WEATHER SMOOTHING ALGORITHIM
C
C=======================================================================
C
C     DEBUG SHOULD BE SET TO 1 TO GET EXTRA PRINTOUT OF WORKING ARRAYS
C     INPUT IS THRU DATA STRING BUF CONTAINING X AND Y COORDINATES
C     READS BUF INTO X1 AND Y1 AND FINDS YMIN AND YMAX
C     BUF(I) CONTAINS X(I) IN ODD I STARTING WITH 3
C     THE FOLLOWING IS AN EXAMPLE RUN WITH INPUT
C     1 3
C     2 1
C     4 3
C     6 1
C     5 6
C     WITH OUTPUT AS FOLLOWS (FIRST LINE IS FOR YMIN)
C     (LAST LINE IS FOR YMAX)
C     5002    2    6    6
C     5002    3    5    6
C     5001    4    4    6
C     5002    5
C     5004    5
C     5005    5
C     BUF(I) CONTAINS Y(I) IN EVEN I STARTING WITH 4, X(3),Y(4) IS A
C     PAIR, BUF(2) IS A FIELD OR PSEUDOZONE NUMBER, BUF(1) IS BLANK.
C     OUTPUT IS A DATA STRING X6  FROM SUBROUTINE S56 .....
C     TYPICAL CALLING ROUTINE IS AS FOLLOWS
C           CALL S01
C           CALL S12
C           CALL S23
C           CALL S34
C           CALL S45
C           CALL S55
C           CALL S56
C     BUF AND X6 ARE IMPLICIT INTEGERS
C
C=======================================================================
C
      SUBROUTINE S01(DEBUG)
      IMPLICIT INTEGER*4 (A-Q, S-Z),  REAL*8 (R)
      COMMON /STUFF/X6(512),NPRT,BUF(80),NO,X1(50),Y1(50),N1,YMIN,YMAX,
     *X2(55),Y2(55),N2,X3(70),Y3(70),N3,X4(512),Y4(512),N4,X5(200,11),J
      YMIN=10000
      YMAX=-10000
      J=1
```

```
      DO 1 I=3,NO,2
      X=BUF(I)
      Y=BUF(I+1)
      IF (Y.LT. YMIN) YMIN=Y
      IF (Y.GT.YMAX) YMAX=Y
      J=J+1
      X1(J)=X
    1 Y1(J)=Y
      N1=J
C
C==== MAKE OUTLINE OVERLAP AT BOTH ENDS ================================
C
      X1(1)=X1(J)
      Y1(1)=Y1(J)
      J=J+1
      X1(J)=X1(2)
      Y1(J)=Y1(2)
      IF (J.GT.50) WRITE (16,102) BUF(2)
  102 FORMAT ('  FIELD  ',I5,'  EXCEEDS THE SIZE ALLOWED FOR X1 AND Y1')
      RETURN
      END
```

```
C
C=========================================================================
C
C     S12 FORTRAN
C     WRITTEN BY DAVE PITTS (J.S.C.)
C     MODIFIED BY KEVIN MCCULLEN (L.A.R.S.)  06/09/80
C
C     S12 FORTRAN IS PART OF MAINV WEATHER DATA SMOOTHING ALGORITHIM,
C     S12 REMOVES REDUNDANT POINTS FROM X1 AND Y1 SO THAT THERE ARE
C     AT MOST 2 CONTIGUOUS POINTS ON A LINE.
C
C=========================================================================
C
      SUBROUTINE S12(DEBUG)
      IMPLICIT INTEGER*4 (A-Q, S-Z),  REAL*8 (R)
      COMMON /STUFF/X6(512),NPRT,BUF(80),N0,X1(50),Y1(50),N1,YMIN,YMAX,
     *X2(55),Y2(55),N2,X3(70),Y3(70),N3,X4(512),Y4(512),N4,X5(200,11),J
      J=1
      DO 1 I=2,N1
      IF (Y1(I).NE.Y1(I-1)) GO TO 2
      IF (Y1(I).NE.Y1(I+1)) GO TO 2
C
C==== POINT I IS A REDUNDANT POINT =======================================
C
      GO TO 1
    2 CONTINUE
C
C==== POINT IS NOT A REDUNDANT POINT =====================================
C
      J=J+1
      X2(J)=X1(I)
      Y2(J)=Y1(I)
    1 CONTINUE
      N2=J
C
C==== MAKE OUTLINE OVERLAP AT BOTH ENDS ==================================
C
      X2(1)=X2(J)
      Y2(1)=Y2(J)
      J=J+1
      X2(J)=X2(2)
      Y2(J)=Y2(2)
      J=J+1
      X2(J)=X2(3)
      Y2(J)=Y2(3)
      IF(J.GT.55) WRITE (NPRT,102) BUF(2)
  102 FORMAT ('  FIELD  ',I5,'  EXCEEDS THE SIZE ALLOWED FOR X2 AND Y2')
      RETURN
      END
```

```
C
C=======================================================================
C
C     S23 FORTRAN
C     WRITTEN BY DAVE PITTS (J.S.C.)
C     MODIFIED BY KEVIN MCCULLEN (L.A.R.S.)  06/09/80
C
C     S23 IS PART OF THE MAINV WEATHER DATA SMOOTHING ALGORITHIM, S23
C     INSERTS REDUNDANT POINTS AT MAXIMA, MINIMA, AND INFLECTION POINTS
C
C=======================================================================
C
      SUBROUTINE S23(DEBUG)
      IMPLICIT INTEGER*4 (A-Q, S-Z),  REAL*8 (R)
      COMMON /STUFF/X6(512),NPRT,BUF(80),NO,X1(50),Y1(50),N1,YMIN,YMAX,
     *X2(55),Y2(55),N2,X3(70),Y3(70),N3,X4(512),Y4(512),N4,X5(200,11),J
      J=0
      DO 1 I=2,N2
      YY1=Y2(I-1)
      YY2=Y2(I)
      YY3=Y2(I+1)
      YY4=Y2(I+2)
      D12=YY2-YY1
      D23=YY3-YY2
C
C==== CHECK TO SEE IF POINTS I AND (I+1) ARE POINTS OF INFLECTION ======
C
      IF(D23.EQ.0) GO TO 2
C
C==== CHECK TO SEE IF POINTS I AND (I-1) ARE A TWO-POINT MAX OR MIN ====
C
      IF(D12.EQ.0) GO TO 3
C
C==== CHECK TO SEE IF POINTS I AND (I-1) ARE A ONE-POINT MAX OR MIN ====
C
      IF ((D12.GT.0).AND.(D23.GT.0)) GO TO 3
      IF((D12.LT.0).AND.(D23.LT.0)) GO TO 3
C
C==== POINT I AIS A MAXIMUM OR MINIMUM =================================
C
      J=J+1
      X3(J)=X2(I)
      Y3(J)=Y2(I)
      GO TO 3
    2 CONTINUE
C
C==== POINTS I AND (I+1) MIGHT BE POINTS OF INFLECTION =================
C
      D34=YY4-YY3
      IF((D12.GT.0).AND.(D34.LT.0)) GO TO 3
      IF((D12.LT.0).AND.(D34.GT.0)) GO TO 3
```

```
C                                                                       SMS02230
C==== POINTS I AND (I+1) ARE POINTS OF INFLECTION =====================SMS02240
C                                                                       SMS02250
      J=J+1                                                             SMS02260
      Y3(J)=Y2(I)                                                       SMS02270
      IF(X2(I+1).LT.X2(I)) GO TO 4                                      SMS02280
C                                                                       SMS02290
C==== PUT A REDUNDANT POINT TO RIGHT OF POINT I AND TAG BY ADDING 5000 =SMS02300
C                                                                       SMS02310
      X3(J)=X2(I)+5001                                                  SMS02320
      GO TO 3                                                           SMS02330
    4 CONTINUE                                                          SMS02340
C                                                                       SMS02350
C==== PUT A REDUNDANT POINT TO LEFT OF POINT I AND TAG BY ADDING 5000 ==SMS02360
C                                                                       SMS02370
      X3(J)=X2(I)+4999                                                  SMS02380
    3 CONTINUE                                                          SMS02390
      J=J+1                                                             SMS02400
      X3(J)=X2(I)                                                       SMS02410
      Y3(J)=Y2(I)                                                       SMS02420
    1 CONTINUE                                                          SMS02430
      J=J+1                                                             SMS02440
      X3(J)=X3(1)                                                       SMS02450
      Y3(J)=Y3(1)                                                       SMS02460
      N3=J                                                              SMS02470
      IF (J.GT.70) WRITE (NPRT,102) BUF(2)                              SMS02480
  102 FORMAT ('  FIELD  ',I5,'  EXCEEDS THE SIZE ALLOWED FOR X3 AND Y3')SMS02490
      RETURN                                                            SMS02500
      END                                                               SMS02510
```

```
C
C=======================================================================
C
C     S34 FORTRAN
C     WRITTEN BY DAVE PITTS (J.S.C.)
C     MODIFIED BY KEVIN MCCULLEN (L.A.R.S.)  06/09/80
C
C     S34 IS PART OF THE MAINV WEATHER DATA SMOOTHING ALGORITHIM, S34
C     FILLS IN MISSING LINES IN THE DATA SET
C
C=======================================================================
C
      SUBROUTINE S34(DEBUG)
      IMPLICIT INTEGER*4 (A-Q, S-Z),  REAL*8 (R)
      COMMON /STUFF/X6(512),NPRT,BUF(80),NO,X1(50),Y1(50),N1,YMIN,YMAX,
     *X2(55),Y2(55),N2,X3(70),Y3(70),N3,X4(512),Y4(512),N4,X5(200,11),J
      N3=N3-1
      J=0
      DO 1 I=1,N3
      XB=X3(I)
      YB=Y3(I)
      XN=X3(I+1)
      YN=Y3(I+1)
      J=J+1
      X4(J)=XB
      Y4(J)=YB
      INC=YN-YB
      IF(INC.EQ.0) GO TO 1
C
C=======================================================================
C
C     MISSING LINES MUST BE FILLED IN.
C     CHECK TO SEE IF EITHER I OR (I+1) HAS BEEN TAGGED AS POINT OF
C     INFLECTION.
C
C=======================================================================
C
      IF(XB.GT.3000) XB=XB-5000
      IF(XN.GT.3000) XN=XN-5000
      RDX=DFLOAT(XN-XB)
      RDY=DFLOAT(YN-YB)
      RS=RDX/RDY
      RXB=DFLOAT(XB)+0.5
      INC=1
      IF(RDY.LT.0.0) INC=-1
      Y=YB
C==== FILL IN LINES BETWEEN (BUT NOT INCLUDING) POINTS I AND (I+1) =====
C
    3 CONTINUE
```

```
      J=J+1
      Y=Y+INC
      RY=DFLOAT(Y-YB)
      RX=RXB+RS*RY
      X4(J)=RX
      Y4(J)=Y
      IF(Y.NE.YN) GO TO 3
      J=J-1
    1 CONTINUE
      N4=J
      IF(J.GT.511) WRITE (NPRT,102) BUF(2)
  102 FORMAT('  FIELD  ',I5,'  EXCEEDS THE SIZE ALLOWED FOR X4 AND Y4')
      RETURN
      END
```

```
C
C=======================================================================
C
C     S45 FORTRAN
C     WRITTEN BY DAVE PITTS (J.S.C.)
C     MODIFIED BY KEVIN MCCULLEN (L.A.R.S.)  06/09/80
C
C     S34 IS PART OF THE MAIV WEATHER DATA SMOOTHING ALGORITHIM, S45
C     COLLECTS ALL OF THE INTERCEPTS WITHIN GIVEN LINES
C
C=======================================================================
C
      SUBROUTINE S45(DEBUG)
      IMPLICIT INTEGER*4 (A-Q, S-Z),  REAL*8 (R)
      COMMON /STUFF/X6(512),NPRT,BUF(80),NO,X1(50),Y1(50),N1,YMIN,YMAX,
     *X2(55),Y2(55),N2,X3(70),Y3(70),N3,X4(512),Y4(512),N4,X5(200,11),J
      YOFF=YMIN-1
      YEND=YMAX-YOFF
      IF (YEND.GT.200) WRITE (NPRT,102) BUF(2)
  102 FORMAT ('  FIELD  ',I5,'  HAS TOO MANY LINES')
      IF (YEND.GT.200) STOP
      DO 1 I=1,200
      X5(I,11)=0
    1 CONTINUE
      IF (N4.GT.512) WRITE (NPRT,200) N4
  200 FORMAT (' N4 = ',I5)
      IF (N4.GT.512) STOP
      DO 2 I=1,N4
      S=X4(I)
      L=Y4(I)-YOFF
      IF (L.GT.200) WRITE (NPRT,201) L
  201 FORMAT (' L= ',I5)
      IF (L.GT.200) STOP
      N=X5(L,11)
      N=N+1
      IF (N.GT.10) WRITE (NPRT,103) L,BUF(2)
  103 FORMAT (' -LINE ',I5,'  OF FIELD  ',I5,'  HAS TOO MANY INTERSECTIO
     *NS ')
      IF (N.GT.10) STOP
      X5(L,11) = N
      X5(L,N)=S
    2 CONTINUE
      DO 3 L=1,YEND
      NEND=X5(L,11)
    3 CONTINUE
      RETURN
      END
```

```
C
C===========================================================================
C
C     S55 FORTRAN
C     WRITTEN BY DAVE PITTS (J.S.C.)
C     MODIFIED BY KEVIN MCCULLEN (L.A.R.S.)  06/09/80
C
C     S55 IS PART OF THE MAINV WEATHER DATA SMOOTHING ALGORITHIM, S55
C     SORTS THE INTERCEPTS INTO ASCENDING ORDER
C
C===========================================================================
C
      SUBROUTINE S55(DEBUG)
      IMPLICIT INTEGER*4 (A-Q, S-Z),  REAL*8 (R)
      COMMON /STUFF/X6(512),NPRT,BUF(80),NO,X1(50),Y1(50),N1,YMIN,YMAX,
     *X2(55),Y2(55),N2,X3(70),Y3(70),N3,X4(512),Y4(512),N4,X5(200,11),J
      YEND=YMAX-YMIN+1
      DO 1 L=1,YEND
      NEND=X5(L,11)
      NODD=NEND-2*(NEND/2)
      IF (NODD.EQ.0) GO TO 6
C
C==== AN ODD NUMBER OF INTERSECTIONS IS NOT PERMITTED ==================
C
      LINE=L+YMIN-1
  102 FORMAT ( ' ODD NUMBER OF VERTICES ON LINE ',I5,'  OF FIELD  ',I5)
    6 CONTINUE
      DO 2 I=1,NEND
      XMIN=30000
      DO 3 J=1,NEND
      X=X5(L,J)
C
C===========================================================================
C
C     IF THE POINT HAS BEEN USED BEFORE (AND TAGGED AS 31000) JUMP OVER
C     IT
C
C===========================================================================
C
      IF (X.EQ.31000) GO TO 3
C
C==== IF THE POINT IS TAGGED AS POINT OF INFLECTION SUBTACT 5000 =======
C
      IF (X.GT.3000) X=X-5000
      IF (X.GT.XMIN) GO TO 3
      XMIN=X
      JMIN=J
    3 CONTINUE
C
C==== POINT STORED AT JMIN HAS THE SMALLEST REMAINING X-VALUE ==========
C
      X1(I)=X5(L,JMIN)
```

```
C                                                                       SMS04140
C==== TAG POINT AT JMIN AS HAVING BEEN USED ============================SMS04150
C                                                                       SMS04160
      X5(L,JMIN)=31000                                                  SMS04170
    2 CONTINUE                                                          SMS04180
      DO 4 I=1,NEND                                                     SMS04190
      X=X1(I)                                                           SMS04200
      IF (X.LT.3000) GO TO 5                                            SMS04210
C                                                                       SMS04220
C==== THIS POINT IS A NECESSARY REDUNDANT POINT OF INFLECTION ==========SMS04230
C                                                                       SMS04240
      J=I/2                                                             SMS04250
      SW=I-2*J                                                          SMS04260
C                                                                       SMS04270
C==== POINT IN EVEN POSITION SHOULD BE MOVED TO RIGHT ==================SMS04280
C                                                                       SMS04290
      IF(I.EQ.NEND) GO TO 969                                           SMS04300
      IF (SW.EQ.0) X5(L,I)=X1(I+1)                                      SMS04310
C                                                                       SMS04320
C==== POINT IN ODD POSITION SHOULD BE MOVED TO LEFT ====================SMS04330
C                                                                       SMS04340
      IF(I.EQ.1) GO TO 5                                                SMS04350
  969 IF (SW.NE.0) X5(L,I)=X1(I-1)                                      SMS04360
      GO TO 4                                                           SMS04370
    5 CONTINUE                                                          SMS04380
      X5(L,I)=X1(I)                                                     SMS04390
    4 CONTINUE                                                          SMS04400
      DO 970 I=1,NEND                                                   SMS04410
      IF (X5(L,I).EQ.31000) X5(L,I)=X1(I)                               SMS04420
      IF (X5(L,I).GT.5000) X5(L,I)=X5(L,I)-5000                         SMS04430
  970 CONTINUE                                                          SMS04440
    1 CONTINUE                                                          SMS04450
      RETURN                                                            SMS04460
      END                                                               SMS04470
```

```
C
C=========================================================================
C
C     S56 FORTRAN
C     WRITTEN BY DAVE PITTS (J.S.C.)
C     MODIFIED BY KEVIN MCCULLEN (L.A.R.S.)  06/09/80
C
C     S56 IS PART OF THE MAINV WEATHER DATA SMOOTHING ALGORITHIM, S56
C     PACKS THE INTERCEPTS INTO A ONE-DIMENSIONAL BUFFER
C
C=========================================================================
C
      SUBROUTINE S56(DEBUG)
      IMPLICIT INTEGER*4 (A-Q, S-Z),  REAL*8 (R)
      COMMON /STUFF/X6(512),NPRT,BUF(80),NO,X1(50),Y1(50),N1,YMIN,YMAX,
     *X2(55),Y2(55),N2,X3(70),Y3(70),N3,X4(512),Y4(512),N4,X5(200,11),J
      YEND=YMAX-YMIN+1
      J=0
      DO 1 L=1,YEND
C
C==== TAG THE FIRST X-VALUE IN EACH LINE BY ADDING 5000 ================
C
      X5(L,1)=X5(L,1)+5000
      NEND=X5(L,11)
  905 IQEND=NEND-3
      IF (NEND.LT.4) GO TO 903
      DO 902 I=1,IQEND,2
      IF (X5(L,I+1).NE.X5(L,I+2)) GO TO 902
      X5(L,I+1)=X5(L,I+3)
      IBEG=I+2
      IEND=IQEND+1
      NEND=NEND-2
      IF (IBEG.GT.IQEND) GO TO 902
      DO 904 IX=IBEG,IEND
  904 X5(L,IX)=X5(L,IX+2)
      GO TO 905
  902 CONTINUE
  903 CONTINUE
      DO 2 I=1,NEND
      J=J+1
      X6(J)=X5(L,I)
    2 CONTINUE
    1 CONTINUE
      IF (J.GT.511) WRITE (NPRT,102) BUF(2)
  102 FORMAT ('  FIELD',2X,I5,'  EXCEEDS THE SIZE ALLOWED FOR X6  ')
      N6=J
      X6(512)=N6
      RETURN
      END
```

```
C
C=======================================================================
C
C     BONTUR FORTRAN
C     WRITTEN BY DAVE PITTS (J.S.C.)
C     MODIFIED BY KEVIN MCCULLEN (L.A.R.S.)  06/09/80
C
C     BONTUR IS PART OF THE MAINV WEATHER DATA SMOOTHING ALGORITHIM,
C     BONTUR PRINTS A STANDARD NI BY NJ GRID WITH CONTURING BETWEEN
C     LINES
C
C=======================================================================
C
C     VARIABLES
C
C     MIN            MINIMUM VALUE
C     INT            CONTOURING INTERVAL
C     SCALE          SCALING FACTOR FOR PRINTING
C
C     IF INT = 0 THEN THERE WILL BE NO CONTOURS OR DATA PRINTED
C     IF NJJ IS GREATER THAN 26 2 GRIDS ARE PRINTED;
C        FROM 1 TO 26
C        FROM 26 TO NJJ
C
C=======================================================================
C
      SUBROUTINE BONTUR(Z,NI,NJJ,MIN,INT,SCALE)
      IMPLICIT INTEGER*4(I-N), REAL*8(A-H, O-Z)
      INTEGER*4 IZ(64,64)
      INTEGER*4 KALP(16),LINE(127),LIN(27)
      REAL*8 Z(64,64)
      DATA KALP/1H ,1HA,1H ,1HB,1H ,1HC,1H ,1HD,1H ,1HE,1H ,1HF,1H ,
     1  1HG,1H ,1HH/
      LTOT=INT*16
      NTEMP = NJJ
      NJJ = 51
      NJ=NJJ
C
C==== 360 ==============================================================
C
      J1=1
      IF(NJJ.GT.26) NJ=26
      DO 10 I=1,NI
      DO 10 J=1,NJJ
   10 IZ(I,J)=Z(I,J)*SCALE
      IF (INT) 51,50,51
   51 NIM=NI-1
   60 NJM=NJ-J1
      WRITE(6,910)
910   FORMAT(1H1)
      NUM=5*NJM+1
      WRITE(6,900)(IZ(1,J),J=J1,NJ)
900   FORMAT(3X,26I5)
```

```
      DO 1 IR=2,NI
      DO 2 JD=1,2
      IF(J1.NE.1) GO TO 20
      DO 3 L=1,NJ
    3 LIN(L)=((IZ(IR,L)-IZ(IR-1,L))*JD)/3+IZ(IR-1,L)
      GO TO 30
   20 DO 40 L=26,NJJ
   40 LIN(L-25)=((IZ(IR,L)-IZ(IR-1,L))*JD)/3+IZ(IR-1,L)
   30 K=1
      DO 4 J=1,NJM
      LINJ=LIN(J)
      LINE(K)=LINJ
      NDZ=LIN(J+1)-LINJ
      DO 5 L=1,4
      K=K+1
    5 LINE(K)=(NDZ*L)/5+LINJ
      K=K+1
    4 CONTINUE
      LINE(K)=LIN(NJM+1)
      DO 6 L=1,NUM
      JDF=LINE(L)-MIN
      IF(JDF)8,9,9
    8 JDF=JDF-LTOT*((JDF+1)/LTOT-1)
    9 J=JDF/INT
      IF(J-16)6,26,26
   26 J=J-(J/16)*16
    6 LINE(L)=KALP(J+1)
      WRITE(6, 901) (LINE(L),L=1,NUM)
  901 FORMAT(7X,126A1)
    2 CONTINUE
      WRITE(6,900)(IZ(IR,J),J=J1,NJ)
    1 CONTINUE
      IF(NJ.NE.NJJ) GO TO 2234
      NJJ = NTEMP
      RETURN
2234  CONTINUE
      NJ=NJJ
      J1=26
      GO TO 60
50    CONTINUE
      IF (NJ.NE.NJJ) GO TO 2235
      NJJ = NTEMP
      RETURN
2235  CONTINUE
      NJ=NJJ
      J1=26
      GO TO 50
      END
```

```
C
C=========================================================================
C
C     ANAL FORTRAN
C     WRITTEN BY DAVE PITTS (J.S.C.)
C     MODIFIED BY KEVIN MCCULLEN (L.A.R.S.)  06/09/80
C
C     ANAL IS PART OF THE MAINV WEATHER DATA SMOOTHING ALGORITHIM, ANAL
C     PERFORMS VARIATIONAL ANALYSIS BY THE 'KIT WAGNER 2ND DERIVATIVE
C     FILTERING' METHOD.
C     ANAL MINIMIZES THE INTEGRAL...
C        SQUARES OF THE DIFFERENCES + THS SQUARES OF THE GRADIENT*ALF2 +
C        THE SQUARES OF THE LAPLACIAN*ALF4
C
C=========================================================================
C
C     VARIABLES
C
C     UO          INPUT DATA
C     U           ANALYSIS
C     AA          FILTER WEIGHTS (SEE NOTE BELOW)
C     ALF2        FILTER WEIGHT
C     ALF4        FILTER WEIGHT
C     MAXPAS      MAXIMUM NUMBER OF ITERATIONS
C     ERR         APROXIMATION CRITERIA
C
C     ARRAY DIMENSIONS
C
C     U(NI,NJ)
C     UO(NI,NJ)
C     WA(NI,NJ)
C     YA(NI+2,NJ+2)
C
C     NOTE: FOR FILTER WEIGHTS REFERENCE K. WAGNER THESIS
C
C     FOR MESOSCALE ANALYSIS OF MAGNITUTE 10, TYPICAL PARAMETERS ARE:
C        AA = 100.0
C        ALF2 = 1.0
C        ALF4 = 1.0
C        MAXPAS = 99
C        ERR = .01
C
C     INCREASING ALF2 AND/OR ALF4 REDUCES HIGHER FREQUENCYS
C     TYPICAL MAXIMUMS ARE:
C        ALF2 = 10.0
C        ALF4 = 10.0
C        AA = 100.0
C     VALUES FOR ALF2 AND ALF4 ARE USUALLY .1, 1.0, 10.0
C
C=========================================================================
C
```

```
      SUBROUTINE ANAL(NI,NJ,AA,ALF2,ALF4,MAXPAS,ERR,UO,U)
      IMPLICIT INTEGER*4 (I-N),  REAL*8 (A-H,O-Z)
      DIMENSION U(NI,NJ),UO(NI,NJ),YA(66,66),WA(66,66)
      EQUIVALENCE (YA(1,1),WA(1,1))
      IO=16
      NJP2=NJ+2
      NIP2=NI+2
      NIM1=NI-1
      NIM2=NI-2
      NJM1=NJ-1
      NJM2=NJ-2
      NJP1=NJ+1
      NIP1=NI+1
      BETA=2.0
C
C==== INITIALIZE GUESS FIELD BY AVERAGING ================================
C
      DO 16 J=1,NJ
      DO 16 I=1,NI
   16 U(I,J)=UO(I,J)
      DO 10 J=1,NJP2
      DO 10 I=1,NIP2
   10 YA(I,J)=0.0
      DO 9997 J=1,NJ
      DO 9997 I=1,NI
      IF (U(I,J) .NE. 0) GO TO 9998
 9997 CONTINUE
      DO 9996 J=1,NJ
      DO 9996 I=1,NI
      UO(I,J)=0.0
 9996 U(I,J)=0.0
      RETURN
 9998 KNT=1
  201 CONTINUE
C
C==== CHECK FOR NUMBER OF NO GUESS =======================================
C
      IF (KNT) 15,200,15
   15 KNT=0
      DO 12 J=2,NJP1
      DO 12 I=2,NIP1
   12 YA(I,J)=U(I-1,J-1)
      DO 99 J=2,NJP1
      DO 99 I=2,NIP1
      IF (YA(I,J)) 86,98,86
   98 SUM=0.0
      CNT=0.0
C
C==== AVERAGE NINE POINTS ================================================
C
```

```
   24 DO 97 JK=1,3
      DO 97 IK=1,3
      II=I-2+IK
      JJ=J-2+JK
      IF (YA(II,JJ)) 96,97,96
   96 SUM=SUM+YA(II,JJ)
      CNT=CNT+1.
   97 CONTINUE
      IF (CNT) 93,92,93
   93 IF (SUM) 95,94,95
C
C==== USE .0001 INSTEAD OF ZERO AVERAGE ================================
C
   94 U(I-1,J-1)=.0001
      GO TO 99
   95 U(I-1,J-1)=SUM/CNT
      GO TO 99
   92 KNT=KNT+1
      GO TO 99
   86 U(I-1,J-1)=YA(I,J)
   99 CONTINUE
  200 CONTINUE
      WRITE(IO,100) KNT
  100 FORMAT(I5,29H POINTS UNSPECIFIED THIS PASS)
      IF (KNT) 201,79,201
   79 CONTINUE
C
C==== SMOOTH FIELD OF AVERAGES =========================================
C
      DO 31 J=2,NJM1
      DO 31 I=2,NIM1
   31 WA(I,J)=(4.*U(I,J)+U(I-1,J-1)+U(I+1,J-1)+U(I+1,J+1)+U(I-1,J+1)
     1+2.*(U(I,J-1)+U(I+1,J)+U(I,J+1)+U(I-1,J)))/16.
      DO 32 J=2,NJM1
      WA(1,J)=(8.*U(1,J)+2.*(U(2,J)+U(1,J-1)+U(1,J+1))+U(2,J-1)+U(2,J+1
     1))/16.
   32 WA(NI,J)=(8.*U(NI,J)+2.*(U(NIM1,J)+U(NI,J-1)+U(NI,J+1))+U(NIM1,J-1
     1)+U(NIM1,J+1))/16.
      DO 33 I=2,NIM1
      WA(I,1)=(8.*U(I,1)+2.*(U(I,2)+U(I-1,1)+U(I+1,1))+U(I-1,2)+U(I+1,2
     1))/16.
   33 WA(I,NJ)=(8.*U(I,NJ)+2.*(U(I,NJM1)+U(I-1,NJ)+U(I+1,NJ))+U(I-1,NJM1
     1)+U(I+1,NJM1))/16.
      WA(1,NJ)=(3.*U(1,NJ)+2.*(U(2,NJ)+U(1,NJM1))+U(2,NJM1))/8.
      WA(NI,NJ)=(3.*U(NI,NJ)+2.*(U(NIM1,NJ)+U(NI,NJM1))+U(NIM1,NJM1))/8.
      WA(NI,1)=(3.*U(NI,1)+2.*(U(NIM1,1)+U(NI,2))+U(NIM1,2))/8.
      WA(1,1)=(3.*U(1,1)+2.*(U(2,1)+U(1,2))+U(2,2))/8.
      DO 36 J=1,NJ
      DO 36 I=1,NI
   36 U(I,J)=WA(I,J)
   39 CONTINUE
```

```
C
C==== 2 DIMENSIONAL ANALYSIS OF INTERIOR POINTS AND WEIGHTS ============
C
      GRD=(NI-4)*(NJ-4)
      ALF4B=ALF4*BETA
      UIJO=4.*ALF2+20.*ALF4
      UI1J1=-ALF2-8.*ALF4
      WRITE(7,500) AA,ALF2,ALF4,UIJO,UI1J1
C
C==== ITERATIVE SCHEME ================================================
C
      DO 41 IT=1,MAXPAS
      IA=1
      SUM=0.0
      DO 42 J=3,NJM2
      DO 42 I=3,NIM2
      UIJ=UIJO
C
C==== CHECK FOR OBSERVATION ===========================================
C
      IF (UO(I,J)) 43,44,43
   44 AL=0.0
      GO TO 45
   43 AL=AA
      UIJ=UIJ+AL
C
C==== EQUATION FOR RESIDUAL ===========================================
C
   45 RES=-AL*UO(I,J)+UIJ*U(I,J)+UI1J1*(U(I+1,J)+U(I-1,J)+U(I,J+1)+U(I,J
     1-1))+ALF4B*(U(I-1,J-1)+U(I-1,J+1)+U(I+1,J-1)+U(I+1,J+1))
      RES=RES+ALF4*(U(I,J+2)+U(I,J-2)+U(I+2,J)+U(I-2,J))
      RLAXP=1./UIJ
C
C==== CORRECT GUESS OF U ==============================================
C
      U(I,J)=U(I,J)-RLAXP*RES
C
C==== CHECK FOR APPROXIMATION SATISFIED AT ALL POINTS =================
C
      IF (DABS(RES)-ERR) 46,46,47
   47 IA=2
   46 SUM=SUM+RES*RES
   42 CONTINUE
      STD=DSQRT(SUM/GRD)
      GO TO (41,41),IA
   41 CONTINUE
      WRITE (7,510)IT,STD
    9 WRITE(7,511) IT
  510 FORMAT(1X,I3,E12.5)
  511 FORMAT(1X,17HNO. OF ITERATIONS,I5)
  500 FORMAT(8H WEIGHTS/5E15.2/28H  STD DEVIATION OF RESIDUAL )
      RETURN
      END
```

Appendix B. Listing of SAS programs which carried out the estimation of yield and yield variances for corn and soybeans. The programs given are for the county level. Other levels were estimated in a similar manner. An example program for computation of covariances is also given.

```
*  SAS PROGRAM FOR CORN YIELD ESTIMATION FOR EACH COUNTY IN IOWA.
*  BASED ON A USDA YIELD MODEL, WHICH USES LINEAR REGRESSION TECHNIQUES
*  AND METEOROLOGICAL PREDICTOR VARIABLES.
*  PROGRAM IS USED TO PREDICT 1978 YIELDS WITH A MODEL DEVELOPED USING
*  YIELD DATA FROM 1932 TO 1977, AND MET DATA FROM 1932 TO 1978.
*  WRITTEN BY CAROL JOBUSCH AT LARS, 1981.
*  ;
DATA YLDMET; SET METCROP2. CTY ;
   DROP SACRES SPROD SYIELD;
   IF STRATUM = QQ
   CYLD = CYIELD;
   IF YEAR = 70 OR YEAR = 78 THEN CYLD = . ;
   TREND1=0;   TREND2=0;
   IF YEAR > 40 THEN TREND1=YEAR-40;
   IF YEAR > 60 THEN TREND1=20;
   IF YEAR > 60 THEN TREND2=YEAR-60;
   IF YEAR > 72 THEN TREND2=12;
   PCP_TMP5=PCP5*TMP5;
   PCP_TMP6=PCP6*TMP6;
   JUN_T_SQ=TMP6*TMP6;
   JUL_P=PCP7;
   JUL_T_SQ=JUL_T_DT*JUL_T_DT;
   LABEL TREND1=LINEAR TREND 1941-1960;
   LABEL TREND2=LINEAR TRENC 1961-1972;
   LABEL PCP_TMP5=MAY TEMP*PRECIP INTERACTION;
   LABEL PCP_TMP6 = JUNE TEMP*PRECIP INTERACTION;
   LABEL JUN_T_SQ = JUNE TEMP DFN SQUARED;
   LABEL JUL_P = JULY PRECIPITATION DFN;
   LABEL JUL_T_DT = JULY TEMP DEPARTURE FROM TREND;
   LABEL JUL_T_SQ = JULY TEMP DFT SQUARED;
   LABEL AUG_T_DT =AUGUST TEMP DEPARTURE FROM TREND;
PROC REG  DATA=YLDMET OUTSSCP=SSYX OUTEST=BDATA;
 TITLE1 ***************************************************************;
 TITLE2 *******  IOWA CORN MODEL - COUNTY  QQ  **********************;
 TITLE3 ***************************************************************;
 TITLE4  ;
 TITLE5 PREDICTION OF IOWA CORN YIELDS BASED ON 1932-1977 (EXCEPT 1970);
   MODEL CYLD=TREND1 TREND2 PCP_TMP5 PCP_TMP6 JUN_T_SQ JUL_P JUL_T_DT
   JUL_T_SQ AUG_T_DT/ P ;
   OUTPUT OUT=YLDMET PREDICTED=CPYIELD RESIDUAL=CRESID;
PROC PRINT DATA=YLDMET;   VAR YEAR CYIELD  CPYIELD CRESID;
PROC PLOT DATA=YLDMET;
   TITLE5 'ACTUAL(*) VS PREDICTED(P) CORN YIELDS (1932-78)';
   PLOT CYIELD*YEAR='*' CPYIELD*YEAR='P' / OVERLAY ;
*
*  PREPARE TO CALCULATE THE VARIANCE OF THE PREDICTED YIELD FOR 1978
*  ;
DATA X78; SET YLDMET;
   KEEP TREND1 TREND2 PCP_TMP5 PCP_TMP6 JUN_T_SQ JUL_P JUL_T_DT JUL_T_SQ
   AUG_T_DT;
   IF YEAR=78;
```

```
DATA VSAVE; SET YLDMET;
   KEEP SYSTEM STRATUM CSIZE CYIELD CPYIELD CACRES CPROD;
   IF YEAR=78;
DATA XPX; SET SSYX;
   IF _N_ =2 THEN DELETE;
PROC MATRIX ;
   TITLE4 *******                                                  *******;
   TITLE5 *******          X''X MATRIX FOR THE 1978 ESTIMATE      *******;
   TITLE6 *******                                                  *******;
   TITLE7 *****************************************************************;
   FETCH XPX DATA=XPX(KEEP=INTERCEP TREND1 TREND2 PCP_TMP5 PCP_TMP6
       JUN_T_SQ JUL_P JUL_T_DT JUL_T_SQ AUG_T_DT) COLNAME=XNAMES;
   FETCH X78 DATA=X78(KEEP=TREND1 TREND2 PCP_TMP5 PCP_TMP6 JUN_T_SQ
       JUL_P JUL_T_DT JUL_T_SQ AUG_T_DT) COLNAME=X78NAMES;
   ONE=1;
   X78=ONE || X78;
   NAMEONE = 'INTERCEP' ;
   X78NAMES = NAMEONE || X78NAMES ;
   PE=X78*INV(XPX)*(X78)';
   FETCH SIGMA DATA=BDATA (KEEP=_SIGMA_);
   SIGMASQ = SIGMA*SIGMA ;
   VARCORN = SIGMASQ*PE ;
   IVARCORN = SIGMASQ*(1+PE);
   FETCH VSAVE
      DATA=VSAVE(KEEP=SYSTEM STRATUM CSIZE CYIELD CPYIELD CACRES CPROD)
      COLNAME=VNAMES;
   VSAVE = VSAVE || VARCORN ;
   VSAVE = VSAVE || IVARCORN ;
   NVARCORN = 'VARCORN' 'IVARCORN';
   VNAMES = VNAMES || NVARCORN ;
   PRINT XPX COLNAME=XNAMES ROWNAME=XNAMES;
   PRINT X78 COLNAME=X78NAMES;
   PRINT PE SIGMA ;
   PRINT VSAVE COLNAME=VNAMES;
   OUTPUT VSAVE OUT=SASOUT. CTYQQ COLNAME=VNAMES ;
*
*  SAVE RESIDUALS FOR LATER CALCULATION OF THE COVARIANCE OF THE
*  PREDICTED YIELD FOR EACH STRATIFICATION SYSTEM.
*  ;
DATA CRESIDX. CTYQQ ;  SET YLDMET;
   KEEP SYSTEM STRATUM YEAR CRESID CPYIELD ;
```

```
*   SAS PROGRAM FOR SOYBEAN YIELD ESTIMATION FOR EACH COUNTY IN IOWA.
*   BASED ON A USDA YIELD MODEL, WHICH USES LINEAR REGRESSION TECHNIQUES
*   AND METEOROLOGICAL PREDICTOR VARIABLES.
*   PROGRAM IS USED TO PREDICT 1978 YIELDS WITH A MODEL DEVELOPED USING
*   YIELD DATA FROM 1932 TO 1977, AND MET DATA FROM 1931 TO 1978.
*   WRITTEN BY CAROL JOBUSCH AT LARS, 1981.
*   ;
DATA YLDMET; SET METCROP2. CTY ;
   DROP CACRES CPROD CYIELD;
   IF STRATUM = QQ ;
   SYLD = SYIELD;
   IF YEAR = 78 THEN SYLD = . ;
   TREND=YEAR-31;
   IF YEAR > 74 THEN TREND=43;
   PCP_TMP5=PCP5*TMP5;
   AUG_P_SQ=PCP8*PCP8;
   LABEL TREND=LINEAR TREND 1932-1974;
   LABEL CUM_PCP=CUMULATIVE PRECIP OCT-APR DFN;
   LABEL PCP_TMP5=MAY TEMP*PRECIP INTERACTION;
   LABEL TMP6 = JUNE TEMPERATURE DFN;
   LABEL PCP7 =JULY PRECIPITATION DFN;
   LABEL JUL_T_DT = JULY TEMP DEPARTURE FROM TREND;
   LABEL PCP8 = AUGUST PRECIPITATION DFN;
   LABEL AUG_P_SQ = AUGUST PRECIPITATION DFN SQUARED;
   LABEL AUG_T_DT =AUGUST TEMP DEPARTURE FROM TREND;
PROC REG  DATA=YLDMET OUTSSCP=SSYX OUTEST=BDATA;
   TITLE1 ****************************************************************;
   TITLE2 *******  IOWA SOYBEAN MODEL - COUNTY  QQ  ******************;
   TITLE3 ****************************************************************;
   TITLE4  ;
   TITLE5 BOOTSTRAP TEST FOR THE YEAR 1978;
   MODEL SYLD=TREND CUM_PCP PCP_TMP5 TMP6 PCP7 JUL_T_DT PCP8 AUG_P_SQ
         AUG_T_DT;
   OUTPUT OUT=YLDMET PREDICTED=SPYIELD RESIDUAL=SRESID;
PROC PRINT DATA=YLDMET;   VAR YEAR SYIELD  SPYIELD ;
   TITLE5 PREDICTION OF IOWA SOYBEAN YIELDS BASED ON YEARS 1932-1977;
PROC PLOT DATA=YLDMET;
   TITLE5 'ACTUAL(*) VS PREDICTED(P) SOYBEAN YIELDS (1932-78)';
   PLOT SYIELD*YEAR='*' SPYIELD*YEAR='P' / OVERLAY ;
*
*   PREPARE TO CALCULATE VARIANCE OF THE PREDICTED YIELD FOR 1978.
*   ;
DATA X78; SET YLDMET;
   KEEP TREND CUM_PCP PCP_TMP5 TMP6 PCP7 JUL_T_DT PCP8 AUG_P_SQ AUG_T_DT;
   IF YEAR=78;
DATA VSAVE; SET YLDMET;
   KEEP SYSTEM STRATUM SYIELD SPYIELD SACRES SPROD;
   IF YEAR=78;
DATA XPX; SET SSYX;
   IF _N_ =2 THEN DELETE;
```

```
PROC MATRIX ;
   TITLE4 *******                                                      *******;
   TITLE5 *******          X''X MATRIX FOR THE 1978 ESTIMATE         *******;
   TITLE6 *******                                                      *******;
   TITLE7 *******************************************************************;
   FETCH XPX DATA=XPX(KEEP=INTERCEP TREND CUM_PCP PCP_TMP5 TMP6 PCP7
       JUL_T_DT PCP8 AUG_P_SQ AUG_T_DT) COLNAME=XNAMES;
   FETCH X78 DATA=X78(KEEP= TREND CUM_PCP PCP_TMP5 TMP6 PCP7 JUL_T_DT
         PCP8 AUG_P_SQ AUG_T_DT) COLNAME=X78NAMES;
   ONE=1;
   X78=ONE || X78;
   NAMEONE = 'INTERCEP' ;
   X78NAMES = NAMEONE || X78NAMES ;
   PE=X78*INV(XPX)*(X78)';
   FETCH SIGMA DATA=BDATA (KEEP=_SIGMA_);
   SIGMASQ = SIGMA*SIGMA ;
   VARSOY = PE*SIGMASQ ;
   IVARSOY = SIGMASQ*(1+PE) ;
   FETCH VSAVE
         DATA=VSAVE (KEEP=SYSTEM STRATUM SYIELD SPYIELD SACRES SPROD)
         COLNAME=VNAMES;
   VSAVE = VSAVE || VARSOY ;
   VSAVE = VSAVE || IVARSOY ;
   NVARSOY = 'VARSOY' 'IVARSOY';
   VNAMES = VNAMES || NVARSOY ;
   PRINT XPX COLNAME=XNAMES ROWNAME=XNAMES;
   PRINT X78 COLNAME=X78NAMES;
   PRINT PE SIGMA ;
   PRINT VSAVE COLNAME=VNAMES;
   OUTPUT VSAVE OUT=SOYOUT. ZZZ COLNAME=VNAMES ;
*
*  SAVE RESIDUALS FOR LATER CALCULATION OF THE COVARIANCE OF THE
*  PREDICTED YIELD FOR EACH STRATIFICATION SYSTEM.
*  ;
DATA SRESIDX. CTYQQ ;  SET YLDMET;
   KEEP SYSTEM STRATUM YEAR SRESID SPYIELD ;
```

```
*  SAS PROGRAM TO CALCULATE THE COVARIANCE OF THE YIELD ESTIMATION
*  FOR A GIVEN STRATIFICATION SYSTEM.
*  THE ACRES OF CORN AND SOYBEANS FOR EACH STRATUM ARE USED AS WEIGHTS.
*  WRITTEN BY CAROL JOBUSCH AT LARS, AUGUST 1981.
*  ;
DATA WTEMP0;  SET METCROP2. XXX ;
   IF YEAR = 78 ;
PROC SUMMARY DATA=WTEMP0 ;
   CLASS  STRATUM;  VAR CACRES SACRES;
   OUTPUT OUT=WTEMP1  SUM=CACRES SACRES;
DATA WTEMP2;  SET WTEMP1;   RETAIN CTOT STOT;
   IF _TYPE_=0 THEN DO;
      CTOT = CACRES;  STOT = SACRES;   DELETE;   END;
   CWT = CACRES/CTOT;  SWT = SACRES/STOT;  SYSTEM = ZZ ;
   KEEP SYSTEM STRATUM CWT SWT;
PROC SORT DATA=RESID. XXX  OUT=TEMP; BY YEAR;
DATA TEMP2;
   KEEP SYSTEM YEAR CRESID1-CRESIDQQ
                    SRESID1-SRESIDQQ ;
   ARRAY CRESIDS (STRATUM) CRESID1-CRESIDQQ ;
   ARRAY SRESIDS (STRATUM) SRESID1-SRESIDQQ ;
   DO OVER CRESIDS;
      SET TEMP; BY YEAR;
      CRESIDS = CRESID ;
      SRESIDS = SRESID ;
      IF LAST.YEAR THEN RETURN;  END;
   TITLE DATA SET TEMP;
PROC CORR NOCORR COV OUT=CYTEMP (TYPE=COV) DATA=TEMP2;
   VAR CRESID1-CRESIDQQ ;
   TITLE DATA SET CVCORNY. XXX ;
DATA CYTEMP2 (TYPE=COV); SET CYTEMP;
   IF _TYPE_ = 'COV' ;
PROC TRANSPOSE DATA=WTEMP2 OUT=CORNWT  PREFIX=CWT;  VAR CWT;
PROC MATRIX ;
   FETCH COVM DATA=CYTEMP2 (KEEP=CRESID1-CRESIDQQ ) COLNAME=CNAMES;
   FETCH CWT DATA=CORNWT  (KEEP=CWT1-CWTQQ );
   CWTD = DIAG(CWT);
   COVM = CWTD * COVM * CWTD;
   OUTPUT COVM OUT=CYTEMP3 COLNAME=CNAMES;
DATA CYTEMP4;  SET CYTEMP3;
   SYSTEM = ZZ ;
DATA CVCORNY. XXX ; SET CYTEMP4;  BY SYSTEM;
   KEEP SYSTEM COVCY;
   ARRAY CY(I) CRESID1-CRESIDQQ ;
   I = 1;
   DO WHILE (I LT _N_);
      COVCY + CY;
      I + 1;
      END;
   IF LAST.SYSTEM THEN OUTPUT;
PROC PRINT;
```

```
PROC CORR NOCORR COV OUT=SYTEMP (TYPE=COV) DATA=TEMP2;
   VAR SRESID1-SRESIDQQ ;
   TITLE DATA SET CVSOYY. XXX ;
DATA SYTEMP2;  SET SYTEMP;
   IF _TYPE_ = 'COV';
PROC TRANSPOSE DATA=WTEMP2 OUT=SOYWT  PREFIX=SWT;  VAR SWT;
PROC MATRIX ;
   FETCH COVM DATA=SYTEMP2 (KEEP=SRESID1-SRESIDQQ ) COLNAME=SNAMES;
   FETCH SWT DATA=SOYWT  (KEEP=SWT1-SWTQQ );
   SWTD = DIAG(SWT);
   COVM = SWTD * COVM * SWTD;
   OUTPUT COVM OUT=SYTEMP3 COLNAME=SNAMES;
DATA SYTEMP4;  SET SYTEMP3;
   SYSTEM = ZZ ;
DATA CVSOYY. XXX ;  SET SYTEMP4;  BY SYSTEM;
   KEEP SYSTEM COVSY;
   ARRAY SY(I) SRESID1-SRESIDQQ ;
   I = 1;
   DO WHILE (I LT _N_);
      COVSY + SY;
      I + 1;
      END;
   IF LAST.SYSTEM THEN OUTPUT;
PROC PRINT;
```

Appendix C. FORTRAN programs used for estimation of the area variances. Both the pixel size (msefs3) and the field size (msefs) estimation programs are presented.

msefs3 fortran

```
      IMPLICIT REAL*8 (A-H,O-Z)
      REAL*8 Y(100),YP(100),YPC(100),YW(100),
     *       E(100),YGPC(100),PE(100),RE(100),Z(100),
     *       NEWPC,XXX(100),YYP(100),YAG(100),FLD(100)
      INTEGER*4 JCNT(100),STRATM,STRATO,COUNTY,SYSNUM,SNOLD
      REAL*8 CTYNAM,CNAME(100)
      IEOF=0
      I=0
      KKK=0
      READ(1,100,END=99) SYSTEM,SYSNUM,STRATM,COUNTY,CTYNAM,FLDACR,IGPC,
     *   IPC,AGRI,CPACRE,CROP
      SYSOLD = SYSTEM
      SNOLD = SYSNUM
      STRATO = STRATM
      IF (IPC .NE. 0) GO TO 2
    1 READ(1,100,END=99) SYSTEM,SYSNUM,STRATM,COUNTY,CTYNAM,FLDACR,IGPC,
     *   IPC,AGRI,CPACRE,CROP
  100 FORMAT(A8,2I3,I5,1X,A8,F4.0,2I3,2F8.0,2X,A8)
      IF(IPC.EQ.0) GO TO 1
      IF((SYSNUM.NE.SNOLD).OR.(STRATM.NE.STRATO)) GO TO 3
    2 I=I+1
      CNAME(I) = CTYNAM
      JCNT(I)=COUNTY
      Y(I)=CPACRE
      YAG(I)=CPACRE/AGRI
      YPC(I)=IPC
      YGPC(I)=IGPC
      FLD(I) = FLDACR
      GO TO 1
   99 IEOF=1
    3 CONTINUE
      KKK=KKK+1
      IF(I.EQ.1) GO TO 7
      SUM=0.0D00
      FLDSUM=0.0
      SUMPC=0.0D00
      SUMGPC=0.0D00
      DO 4 J=1,I
      IF(YPC(J).GT.0.0) SUM=SUM+Y(J)
      SUMPC=SUMPC+YPC(J)
      SUMGPC=SUMGPC+YGPC(J)
      FLDSUM=FLDSUM+FLD(J)
    4 CONTINUE
      IF(SUM.EQ.0.0) GO TO 7
      P=SUM/(SUMPC*25426.56D00)
      DO 55 J=1,I
      IF(YPC(J).GT.0.0) YP(J)=Y(J)/(YPC(J)*25426.56D00)
      YW(J)=YPC(J)/SUMPC
      E(J)=(P-YP(J))**2
   55 CONTINUE
```

```
      FLDSIZ = FLDSUM/I
      A = P * (1.0-P) * 4.0 / 9.0
      NN=0
      DO 54 J=1,I
      IF(YPC(J).EQ.0.0) GO TO 54
      NN=NN+1
      XXX(NN)=YPC(J)
      YYP(NN)=E(J)
   54 CONTINUE
      WRITE(2,225) CROP,SYSOLD,STRATO
  225 FORMAT('1 CROP = ',A8,2X,'SYSTEM =',A8,2X,'STRATUM =',I3)
      DO 227 J=1,NN
  227 XXX(J)=XXX(J)*(25426.0/FLDSIZ)
      CALL FITB(NN,XXX,YYP,A,B)
      A=A/((FLDSIZ*(22932.0/25426.0))**B)
      SF=22932.0D00**B
      VAR = A*SF
      WRITE(2,200) I,P,A,B,SF,VAR
  200 FORMAT(//' NUMBER OF COUNTIES IN STRATUM = ',I3/' P =',F16.9
     *  //' A =',F16.9 /' B =',F16.9
     *  /' SF =',F15.9 /' VAR =',F14.9)
      DO 11 J=1,I
      IF(YPC(J).GT.0.0) PE(J)=A*(YPC(J)*22932.0D00)**B
      IF(YPC(J).EQ.0.0) PE(J)=0.0D00
      IF(YPC(J).GT.0.0) RE(J)=(PE(J)-E(J))
      IF(YPC(J).EQ.0.0) RE(J)=0.0D00
   11 CONTINUE
      M=0
      X=0.0D00
      SX=0.0D00
      DO 13 J=1,I
      IF(YPC(J).EQ.0.0) GO TO 13
      M=M+1
      X=X+RE(J)
      SX=SX+RE(J)**2
   13 CONTINUE
      IF(M.GT.1)GO TO 14
      WRITE(2,500)
  500 FORMAT(//,1X,'DEGREES OF FREEDOM=0',//)
      GO TO 7
   14 XM=M
      SD=SX-X**2/XM
      SD=SD/(XM-1.0D00)
      SD=DSQRT(SD)
      BAR=X/XM
      DO 17 J=1,I
      IF(YPC(J).GT.0.0) Z(J)=(RE(J)-BAR)/SD
      IF(YPC(J).EQ.0.0) Z(J)=0.0D00
   17 CONTINUE
      WRITE(2,400)
  400 FORMAT(//,1X,'CNTY   GPC       PC      ACRES        PI        WI',
     *  '     (PI-P)**2     PROJECTED     ERROR          ',
     *  '       Z VALUE       CNTY')
```

```
      DO 6 J=1,I
      WRITE(2,300)JCNT(J),YGPC(J),YPC(J),Y(J),YP(J),YW(J),E(J),
     *  PE(J),RE(J),Z(J),CNAME(J)
  300 FORMAT(1X,I3,2(3X,F4.0),3X,F8.0,2(3X,F7.4),2(3X,F10.7),
     1(3X,F10.7),(3X,F10.4),6X,A8)
    6 CONTINUE
      DO 21 J=1,I
      PC=YPC(J)
      IF(YAG(J).GE.1.0) GO TO 180
      IF((DABS(Z(J)).LE.3.0).OR.(PC.LE.0.0).OR.
     *     (YPC(J).GT.0.5*YGPC(J))) GO TO 21
      YPC(J)=0.0
      WRITE(2,700) JCNT(J),Z(J)
  700 FORMAT(//,1X,'COUNTY',I5,5X,'REJECTED',5X,'Z=',F10.3)
      GO TO 21
  180 CONTINUE
      YPC(J)=0.0
      WRITE(2,780) JCNT(J),YAG(J)
  780 FORMAT(//,1X,'COUNTY',I5,5X,'CROP TO AG RATIO=',F10.3)
   21 CONTINUE
      NEWPC=0.0
      DO 22 J=1,I
   22 NEWPC=NEWPC+YPC(J)
      III=NEWPC
      JJJ=SUMPC
      WRITE(3,1000) CROP,SYSOLD,STRATO,KKK,SUMGPC,SUMPC,
     *  A,B,SF,P,VAR,I
 1000 FORMAT(2A8,2I3,2F7.0,5F8.4,I4)
      IF((III.LT.JJJ).AND.(KKK.LE.3)) GO TO 3
      WRITE(4,1000) CROP,SYSOLD,STRATO,KKK,SUMGPC,SUMPC
     6,A,B,SF,P,VAR,I
    7 CONTINUE
      SYSOLD=SYSTEM
      SNOLD = SYSNUM
      STRATO=STRATM
      I=0
      KKK=0
      IF(IEOF.EQ.0) GO TO 2
      STOP
      END
```

```
      SUBROUTINE FITB(N,X,Y,A,B)
      IMPLICIT REAL*8 (A-H,O-Z)
      REAL*8 X(100),Y(100),MAX
      EPS=0.000001D00
      I=0
      K=10
      XK=K
      B1=-0.90
      B2=-0.10
      WRITE(2,200)
    1 CONTINUE
      DELTA=(B2-B1)/XK
      MAX=F(X,Y,A,B1,N)
      DO 9 J=1,K
      B=B1+J*DELTA
      FB=F(X,Y,A,B,N)
      IF(MAX.LT.FB) GO TO 9
      MAX=FB
      BB=B
    9 CONTINUE
      I=I+1
      WRITE(2,100)I,BB,MAX,DELTA
      IF(I.GT.20) GO TO 99
      IF(DELTA.LT.EPS) GO TO 99
      B1=BB-DELTA
      B2=BB+DELTA
      GO TO 1
  200 FORMAT(//,T6,'K',T23,'B(K)',T41,'F(B(K))',T64,'DELTA')
  100 FORMAT(1X,I5,6(1X,F20.15))
   99 CONTINUE
      B=BB
      FB=MAX
      RETURN
      END

      REAL FUNCTION F*8 (X,Y,A,B,N)
      IMPLICIT REAL*8(A-H,O-Z)
      REAL*8 X(100),Y(100),A,B,S,Y1,XB
      S=0.0D00
      DO 1 J=1,N
      XB=1.0
      Y1=Y(J)
      IF((X(J).EQ.0.0).OR.(B.EQ.0.0)) GO TO 10
      XB=X(J)**B
   10 S=S+(Y1-A*XB)**2
    1 CONTINUE
      F=S/N
      RETURN
      END
```

msefs fortran

```
      IMPLICIT REAL*8 (A-H,O-Z)
      GENERIC
      REAL*8 Y(100),YP(100),YPC(100),YW(100),
     *       E(100),YGPC(100),PE(100),RE(100),Z(100),
     *       NEWPC,XXX(100),YYP(100),YAG(100),FLD(100)
      INTEGER*4 JCNT(100),STRATM,STRATO,COUNTY,SYSNUM,SNOLD
      REAL*8 CTYNAM,CNAME(100)
      IEOF=0
      I=0
      KKK=0
      READ(1,100,END=99) SYSTEM,SYSNUM,STRATM,COUNTY,CTYNAM,FLDACR,IGPC,
     *   IPC,AGRI,CPACRE,CROP
      SYSOLD = SYSTEM
      SNOLD = SYSNUM
      STRATO = STRATM
      IF (IPC .NE. 0) GO TO 2
    1 READ(1,100,END=99) SYSTEM,SYSNUM,STRATM,COUNTY,CTYNAM,FLDACR,IGPC,
     *   IPC,AGRI,CPACRE,CROP
  100 FORMAT(A8,2I3,I5,1X,A8,F4.0,2I3,2F8.0,2X,A8)
      IF(IPC.EQ.0) GO TO 1
      IF((SYSNUM.NE.SNOLD).OR.(STRATM.NE.STRATO)) GO TO 3
    2 I=I+1
      CNAME(I) = CTYNAM
      JCNT(I)=COUNTY
      Y(I)=CPACRE
      YAG(I)=CPACRE/AGRI
      YPC(I)=IPC
      YGPC(I)=IGPC
      FLD(I) = FLDACR
      GO TO 1
   99 IEOF=1
    3 CONTINUE
      KKK=KKK+1
      IF(I.EQ.1) GO TO 7
      SUM=0.0D00
      FLDSUM=0.0
      SUMPC=0.0D00
      SUMGPC=0.0D00
      DO 4 J=1,I
      IF(YPC(J).GT.0.0) SUM=SUM+Y(J)
      SUMPC=SUMPC+YPC(J)
      SUMGPC=SUMGPC+YGPC(J)
      FLDSUM=FLDSUM+FLD(J)
    4 CONTINUE
      IF(SUM.EQ.0.0) GO TO 7
      P=SUM/(SUMPC*25426.56D00)
      DO 55 J=1,I
      IF(YPC(J).GT.0.0) YP(J)=Y(J)/(YPC(J)*25426.56D00)
      YW(J)=YPC(J)/SUMPC
      E(J)=(P-YP(J))**2
   55 CONTINUE
```

```
      FLDSIZ = FLDSUM/I
      AA = P * (1.0-P)
      XP = FLDSIZ * 22932. / 25426.56
      NN=0
      DO 54 J=1,I
      IF(YPC(J).EQ.0.0) GO TO 54
      NN=NN+1
      XXX(NN)=YPC(J) * 22932.
      YYP(NN)=E(J)
   54 CONTINUE
      WRITE(2,225) CROP,SYSOLD,STRATO
  225 FORMAT('1 CROP = ',A8,2X,'SYSTEM =',A8,2X,'STRATUM =',I3)
      A1 = P*(SQRT(XP)-1.2732)**2/XP
      A3 = P*(SQRT(XP)+1.2732)**2/XP - A1
      A2 = 1. - A1 - A3
      A = A1*(1.-P)**2 + A2*P**2 + A3*(0.3682-P+P**2)
      CALL FITB(NN,XXX,YYP,A,B)
      SF=22932.0D00**B
      VAR = A*SF
      WRITE(2,200) I,P,A,B,SF,VAR
  200 FORMAT(//' NUMBER OF COUNTIES IN STRATUM = ',I3/' P =',F16.9
     *  //' A =',F16.9 /' B =',F16.9
     *  /' SF =',F15.9 /' VAR =',F14.9)
      DO 11 J=1,I
      IF(YPC(J).GT.0.0) PE(J)=A*(YPC(J)*22932.0D00)**B
      IF(YPC(J).EQ.0.0) PE(J)=0.0D00
      IF(YPC(J).GT.0.0) RE(J)=(PE(J)-E(J))
      IF(YPC(J).EQ.0.0) RE(J)=0.0D00
   11 CONTINUE
      M=0
      X=0.0D00
      SX=0.0D00
      DO 13 J=1,I
      IF(YPC(J).EQ.0.0) GO TO 13
      M=M+1
      X=X+RE(J)
      SX=SX+RE(J)**2
   13 CONTINUE
      IF(M.GT.1)GO TO 14
      WRITE(2,500)
  500 FORMAT(//,1X,'DEGREES OF FREEDOM=0',//)
      GO TO 7
   14 XM=M
      SD=SX-X**2/XM
      SD=SD/(XM-1.0D00)
      SD=DSQRT(SD)
      BAR=X/XM
      DO 17 J=1,I
      IF(YPC(J).GT.0.0) Z(J)=(RE(J)-BAR)/SD
      IF(YPC(J).EQ.0.0) Z(J)=0.0D00
   17 CONTINUE
```

```
      WRITE(2,400)
  400 FORMAT(//,1X,'CNTY  GPC      PC      ACRES        PI        WI',
     *  '     (PI-P)**2     PROJECTED     ERROR        ',
     *  '       Z VALUE       CNTY')
      DO 6 J=1,I
      WRITE(2,300)JCNT(J),YGPC(J),YPC(J),Y(J),YP(J),YW(J),E(J),
     *  PE(J),RE(J),Z(J),CNAME(J)
  300 FORMAT(1X,I3,2(3X,F4.0),3X,F8.0,2(3X,F7.4),2(3X,F10.7),
     1(3X,F10.7),(3X,F10.4),6X,A8)
    6 CONTINUE
      DO 21 J=1,I
      PC=YPC(J)
      IF(YAG(J).GE.1.0) GO TO 180
      IF((DABS(Z(J)).LE.3.0).OR.(PC.LE.0.0).OR.
     *      (YPC(J).GT.0.5*YGPC(J))) GO TO 21
      YPC(J)=0.0
      WRITE(2,700) JCNT(J),Z(J)
  700 FORMAT(//,1X,'COUNTY',I5,5X,'REJECTED',5X,'Z=',F10.3)
      GO TO 21
  180 CONTINUE
      YPC(J)=0.0
      WRITE(2,780) JCNT(J),YAG(J)
  780 FORMAT(//,1X,'COUNTY',I5,5X,'CROP TO AG RATIO=',F10.3)
   21 CONTINUE
      NEWPC=0.0
      DO 22 J=1,I
   22 NEWPC=NEWPC+YPC(J)
      III=NEWPC
      JJJ=SUMPC
      WRITE(3,1000) CROP,SYSOLD,STRATO,SNOLD,SUMGPC,SUMPC,
     *  A,B,SF,P,VAR,I
 1000 FORMAT(2A8,2I3,2F7.0,5F8.4,I4)
      IF((III.LT.JJJ).AND.(KKK.LE.3)) GO TO 3
      WRITE(4,1000) CROP,SYSOLD,STRATO,SNOLD,SUMGPC,SUMPC
     6,A,B,SF,P,VAR,I
    7 CONTINUE
      SYSOLD=SYSTEM
      SNOLD = SYSNUM
      STRATO=STRATM
      I=0
      KKK=0
      IF(IEOF.EQ.0) GO TO 2
      STOP
      END
```

```
      SUBROUTINE FITB(N,X,Y,A,B)
      IMPLICIT REAL*8 (A-H,O-Z)
      REAL*8 X(100),Y(100),MAX
      EPS=0.000001D00
      I=0
      K=10
      XK=K
      B1=-0.90
      B2=-0.10
      WRITE(2,200)
    1 CONTINUE
      DELTA=(B2-B1)/XK
      MAX=F(X,Y,A,B1,N)
      DO 9 J=1,K
      B=B1+J*DELTA
      FB=F(X,Y,A,B,N)
      IF(MAX.LT.FB) GO TO 9
      MAX=FB
      BB=B
    9 CONTINUE
      I=I+1
      WRITE(2,100)I,BB,MAX,DELTA
      IF(I.GT.20) GO TO 99
      IF(DELTA.LT.EPS) GO TO 99
      B1=BB-DELTA
      B2=BB+DELTA
      GO TO 1
  200 FORMAT(//,T6,'K',T23,'B(K)',T41,'F(B(K))',T64,'DELTA')
  100 FORMAT(1X,I5,6(1X,F20.15))
   99 CONTINUE
      B=BB
      FB=MAX
      RETURN
      END

      REAL FUNCTION F*8 (X,Y,A,B,N)
      IMPLICIT REAL*8(A-H,O-Z)
      REAL*8 X(100),Y(100),A,B,S,Y1,XB
      S=0.0D00
      DO 1 J=1,N
      XB=1.0
      Y1=Y(J)
      IF((X(J).EQ.0.0).OR.(B.EQ.0.0)) GO TO 10
      XB=X(J)**B
   10 S=S+(Y1-A*XB)**2
    1 CONTINUE
      F=S/N
      RETURN
      END
```