SOYBEAN OBJECTIVE YIELD DESTRUCTIVE COUNTING STUDY

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ABSTRACT

This study examines the operational practicality of using a destructive counting procedure to obtain plant component counts for the soybean objective yield survey. The current procedure uses a nondestructive procedure to obtain these counts. The results presented here are based on the data collected in Illinois in 1978 and 1979, Arkansas in 1979, and Ohio in 1979. Comparisons of the plant component counts obtained from the two methods are made. The forecasting abilities of the two methods are also compared.

This report was prepared for ESS internal use and for distribution to the research community outside the U.S. Department of Agriculture.

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SUMMARY

This study examines the operational practicality of using a destructive counting procedure to obtain plant component counts for the soybean objective yield survey. The current procedure uses a nondestructive procedure to obtain these counts. The results presented here are based on the data collected in Illinois in 1978 and 1979, Arkansas in 1979, and Ohio in 1979.

Comparisons of the plant component counts obtained from the two methods indicate the nondestructive counts are lower than the destructive counts in Illinois for the mature samples. In Arkansas, the nondestructive counts are lower than the destructive counts throughout the season. There is no significant difference between the methods based on the counts in Ohio.

The forecasting abilities of the two methods are also compared. Early in the season, forecasting models which use the destructive counts perform as well as the current nondestructive models. However, later in the season the destructive forecast models do not perform at an acceptable level.

Soybean Objective Yield Destructive
Counting Study

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INTRODUCTION

A soybean objective yield destructive counting study was conducted by the Statistics Unit of the United States Department of Agriculture (USDA) Economics and Statistics Service (ESS). The study was conducted in conjunction with the 1978 soybean objective yield survey in Illinois and with the 1979 survey in Illinois, Arkansas and Ohio.

Illinois was selected as a test site in 1978. The states involved in the 1979 study were selected to give a cross-sectional view of such variables as soybean varieties and planting techniques. Arkansas provided samples of viny, southern determinate varieties, while Ohio provided samples with narrow row spacing; Illinois was a repeat from a 1978 study.

The expected advantage of the destructive counting procedure was the reduction of data collection difficulties and nonsampling errors. Under the destructive procedure, plants are removed from the field in order to count plant components. This method requires that a different set of plants be observed each month. The destructive counting procedure should reduce data collection difficulties encountered by enumerators in the field due to heavy vegetation and unfavorable field and weather conditions. In addition, nonsampling errors from two sources should be reduced. Counting plant components early in the season using the current objective yield (or nondestructive) procedures is a difficult task which may result in counting errors or incorrect identification of some plant components. With the destructive procedures, plants can be inspected more closely for more accurate counts, thus reducing counting errors. In addition, the effect of handling the plants monthly is eliminated with the destructive counting procedure. Repeated handling of plants, as is done in the current objective yield procedure, may cause the plant productivity of the sampled plants to no longer be representative of the productivity of the nonsampled plants. The change in productivity may be due to the direct effect of handling the sampled plants or damage to the surrounding competition.

The objective of the study was to examine the operational practicality of the destructive counting procedures. This examination included:

1. Evaluation of the efficiency and quality control effects of the study.

2. Comparison of the counts obtained during the destructive counting procedure with those obtained using the objective yield counting procedure.

3. Evaluation of the forecasting models using the destructive counting procedure data.

Data Collection

In 1978, one destructive plot per sample was located on each monthly visit. During each monthly visit in 1979, counts were obtained in two destructive plots per sample. Destructive plots were randomly located each month near the objective yield plots.

Each destructive plot was the same size as the objective yield detailed count section -- six inches by two rows (6-inch section). See Appendix 1 for a description of the soybean objective yield survey procedure. Plants from the destructive plots were removed from the field in plastic bags. Counting tasks were completed at the field entrance or at a convenient, nearby location. The same plant components were counted on plants in the destructive plots as in the objective yield plots. For further information on procedures, refer to the enumerator manuals for the objective yield survey and this study.

Evaluation of the Efficiency and Quality Control Effects

A numerical analysis of the operational efficiency or the data collection advantages of the destructive counting procedure was not possible. However, it is reasonable that the enumerators would be capable judges of the operational advantages of either procedure.

Enumerators were asked to evaluate the destructive counting procedure. See Appendix II for a complete summary of the evaluations. Enumerators strongly favored the destructive counting procedure. They had greater confidence in the accuracy of the counts and felt the counts were easier to complete. Enumerators reported no strong resistance from the farm operators to the removal of plants and did not expect an increase in the refusal rate. The major concern was the amount of material and equipment to be carried to and from the field. Four plant bags per unit or a total of eight bags per sample were required. Quality control on the detailed attribute counts for the destructive counting procedures would require the supervisory enumerator to accompany the enumerator to the field. Quality control on unit location, field location and field procedures could be completed by the supervisory enumerator without the enumerator present.

The destructive counting procedures required 15 to 30 minutes less time to complete than the nondestructive procedure. However, since the destructive counting procedure requires the location of an additional 6-inch section each month, minimal cost savings would be expected.

Comparison of Counts

A multiple paired t-test, also referred to as the Bonferroni method, was used to examine the data for consistent differences between counts obtained using the objective yield procedures and the counts using the destructive counting procedure. The multiple paired t-test was used because of the high correlations among the variables being tested, and because the interest was in making comparisons involving the mean of each variable. This test takes into account the fact that several tests are made concurrently, and that high correlations among variables affect the probability of obtaining significant results once one of the comparisons is found to be significant. It does not require that an overall multivariate test be performed. Because the data are paired, this test procedure results in a more powerful test of the mean differences.

The null hypothesis is H_o: $\bar{D} = \emptyset$ versus H_a: $\bar{D} \neq \emptyset$. The test statistic is:

$$t = (\bar{D} - U_D)/S_{\bar{D}} \text{ where } \bar{D} = \sum_i^n D_i/n$$

where

$U_D = \emptyset$ under the null hypothesis,

D_i = difference between the destructive and objective yield counts for the i^{th} plot,

$$S_{\bar{D}} = \sqrt{\frac{\sum_{i=1}^{n}(D_i - \bar{D})^2}{n-1}} \Big/ \sqrt{n}$$

n = number of paired plots,

t is distributed t $(1 - \alpha/2k,\ n-k)$,

k = number of comparisons being performed each month.

If $\left|\frac{\bar{D}}{S_{\bar{D}}}\right| > t(1-\alpha/2k, n-k)$ then the null hypothesis that the difference in counts for that variable is equal to zero is rejected. The multivariate hypothesis that the two counting procedures produce the same counts over all variables is rejected with a significance level less than or equal to α if at least one of the k individual comparisons is rejected. Consult the text, Multivariate Analysis with Applications in Education and Psychology, by Neil H. Timm (Brooks/Cole Publishing Co., 1975) for more information on this test.

A discussion of the results of these tests by state and year follows.

Illinois - 1978

The paired per plant count means for the two procedures, means of the differences, and observed multiple t-values are presented in Table 1 for August through November and for all mature samples. No significant differences were observed in the August 1 or September 1 surveys. In the October 1 survey, the destructive counts exceeded the objective yield counts by significant amounts (α = .05) for two variables, the number of pods on the mainstem and number of pods with beans per plant. For the November 1 survey, the destructive count of number of pods with beans per plant exceeded the objective yield count, but not significantly. However, only 44 units were observed in November since most units had previously been harvested. The destructive counts of number of pods with beans for all mature samples was significantly greater (α = .01) than the objective yield counts.

While there were no significant differences between the number of plants per plot for any of the monthly visits, it should be noted that the differences in plant population may be affecting the significance levels at which the other plant count differences are observed. This is due to a negative correlation between the per plant counts and plant population. For the August 1 and September 1 surveys, the mean number of plants in the destructive plots exceeded the objective yield mean. This positive difference in number of plants may be introducing a negative affect on the per plant differences. This would reduce any positive per plant count differences and could cause a difference to be incorrectly bypassed as not significant for a fixed α. Conversely, for the October 1 and November 1 surveys, the number of plants in the destructive plots was less than the objective yield plots. The negative difference in number of plants could be artificially increasing positive differences in per plant counts and creating significance for a fixed α where it does not exist. This may be a problem for those differences that are very close to the selected level of significance, such as the number of pods with beans in October which was barely significant at α = .05.

Illinois - 1979

The per plant count means for the two procedures, means of the differences, and observed multiple t-values are presented in Table 2 for August through November and for all mature samples. No significant differences were observed in the August 1, September 1 or November 1 surveys. In the October 1 survey, the destructive counts exceeded the objective yield counts by a significant amount for two variables, the number of mainstem nodes with pods per plant and the number of pods with beans per plant. The destructive counts of number of pods on the mainstem per plant and number of pods with beans per plant exceeded the objective yield counts by significant amounts for the mature samples. In both cases, the significance level for the differences in number of pods with beans per plant variable is at an α = .01 level.

There were no significant differences encountered in number of plants in any of the monthly visits, but significance levels for the differences in per plant counts may be affected. The only result that may be affected by this problem is the October 1 test of number of pods on the mainstem per plant. This difference was not declared significant at the $\alpha = .05$ level, but it may in reality be significant at this level.

Ohio - 1979

The per plant count means for the two procedures, means of differences, and observed multiple t-values are presented in Table 3 for the August 1 through November 1 surveys and for all mature samples. No significant differences were observed during the year.

Approximately 20 percent of the samples analyzed in Ohio had a 7-inch row width. It was expected that the samples with narrow row width would exhibit a greater handling effect than was observed in the samples with wider row spacings. Per plant count analysis to examine differences in counting methods was performed using only the narrow row samples. No significant differences were observed and the data have not been presented.

There were no significant differences encountered in number of plants in any of the monthly visits. While significance levels for the per plant tests may be affected, this problem would not affect the results in Ohio.

Arkansas - 1979

The per plant count means for the two procedures, means of the differences, and observed multiple t-values are presented in Table 4 for the September 1 through November 1 surveys and for all mature samples. Significant differences were observed from the onset through the end of the season; virtually all of the destructive procedure counts exceeded the objective yield procedure counts. In the September 1 survey, three of the nine variables showed a significant difference. In the October 1 survey, five of the six variables showed a significant difference. The difference in the number of lateral branches was not significant, but the differences of the two variables on the lateral branches, number of nodes with pods and number of pods, were significant. Since Arkansas soybeans are viny, these results may indicate an undercounting of plant parts because of the difficulty in identifying plant parts while in the field when vegetation is heavy. The data presented for November 1 and for all mature samples are almost identical because only two samples were mature at the October 1 survey. During the November 1 survey, when the samples were mature, the only significant differences were in the number of mainstem nodes with pods and the number of pods on mainstem.

There were no significant differences encountered in number of plants in any of the monthly visits. However, because differences in plant population may still affect the significance levels of the per plant tests, two results may be affected. In the September 1 survey, the difference in number of mainstem nodes with fruit was not declared significant at the α=.05 level when the difference may be significant. In October, the difference in number of pods on the mainstem was declared significant at the α = .05 level when it may not be significant at this level.

FORECASTING ABILITY

One of the major objectives of the Soybean Objective Yield Survey is to provide early-season forecasts of soybean yield. The forecasts are based upon the relationship between early-season plant components and end-of-season yield. The current objective yield program uses a stepwise regression procedure to derive the "best" forecasting models for number of pods with beans per plant and number of plants per 18-square feet by maturity category. Data from the previous three seasons are used in deriving the models.

The models for forecasting number of plants per 18-square feet include the plant count from both the 6-inch and 3-foot sections. These models are not presented, since analysis indicates that use of the plant count from the 6-inch destructive plot or the objective yield plot has very little impact on the forecast of plants per 18-square feet.

The independent variables considered for models to forecast number of pods with beans per plant are listed in Appendix III. Except for the variable, plants per 18-square feet (which includes the plant count from both the 6-inch and 3-foot sections), the independent variables are from the 6-inch section. The current objective yield program uses the number of pods with beans per plant at maturity in the 6-inch section as the dependent variable. An advantage of the dependent variable from the 6-inch section is that relatively strong relationships can be developed for forecasting purposes since the same plants are counted throughout the season. A disadvantage is that if the number of pods with beans has been reduced due to plant handling, both the early-season forecasts, which use historic models, and the end-of-season estimates will tend to be biased downward. With the destructive procedure no opportunity exists to use a dependent variable from the same plants counted early in the season. The logical source of the dependent variable, number of pods with beans per plant, is the 3-foot section counts.

Four sets of regression models were developed to compare the forecasting capabilities of the two procedures:

1. Model 1: Destructive early-season counts regressed on the dependent variable from the 3-foot section.

2. Model 2: Objective yield early-season counts regressed on the dependent variable from the 3-foot section.

3. Model 3: Objective yield early-season counts regressed on the dependent variable from the 6-inch section.

4. Model 4: Counts from the paired research and objective yield 6-inch units combined and regressed on the dependent variable from the 3-foot section.

The models are presented in Appendix V.

Objective yield procedures were followed in developing the models. Both the destructive and objective yield units were stratified by maturity category. Stratification by maturity categories is based upon two factors -- the enumerator's observed maturity stage and the relationship between plant components. Maturity categories and stages are defined in Appendix IV.

One method for comparison of the forecasting ability of models is the R^2 value obtained from the models. The R^2 values and number of observations from the four models for each survey are presented in Tables 5 through 8 by month and maturity category. Table 9 presents the R^2 values and number of observations from the four models obtained when the Illinois data sets for the two years are combined.

When using the dependent variable from the 3-foot section, the destructive and the objective yield models produced a similar level of R^2 values across all maturity categories. These results may indicate that the destructive procedures do not produce sufficiently different counts to improve the relationship to productivity in the 3-foot section. However, it may also be that the relatively low relationship in per plant productivity between the 6-inch and 3-foot sections has resulted in an insensitivity to the differences in counts. This model comparison is not critical and was done primarily to evaluate differences in the data.

A more important comparison is the forecasting ability of the destructive models using a dependent variable from the 3-foot section and the objective yield models using a dependent variable from the 6-inch section (Model 1 vs. Model 3). The use of the 6-inch dependent variable corresponds to the current procedure, except that the data come from at most two seasons instead of three seasons. If the destructive procedure is to be operationally feasible, the forecast models must give a similar level of accuracy as models obtained with the objective yield procedure.

For the lower maturity categories (1 through 4) the destructive models are at least as good as the objective yield models. However, in the higher maturity categories, R^2 values from the destructive models are below those observed from the objective yield models. The data for higher maturity categories contained significant within-row variation which was not expected when the study was designed. Since this variability does exist, the advantage of observing the same plants throughout the season becomes much more important. It is, therefore, not surprising that the R^2 values for the destructive models differ from the R^2 values for the objective yield models.

Model 4 used independent variables aggregated from both the destructive and objective yield data. The data then are from two feet of row rather than one foot. It was hoped that an increased sampling of plants for the early-season counts would improve the relationship with the 3-foot dependent variable by reducing the variability of the independent variables. The R^2 values do not show a significant improvement when using this procedure. Thus, sampling more plants did not improve the forecasting ability of the destructive models.

It could be suggested that despite the lower R^2 values when regressing on the 3-foot dependent variable, all of the models may produce similar forecasted values if used on a new set of data. A rebuttal to this suggestion is possible when the "best" set of independent variables in the models are compared (see Appendix V). Plant population is by far the most dominating variable in the destructive models. The objective yield models with the 6-inch dependent variable contain more of the plant component variables. The models containing plant component variables could be expected to be more sensitive to late-season changes in yield potential than would the models based primarily on plant population.

CONCLUSIONS

The destructive counting procedure is operationally efficient. The enumerators are able to collect the data, and quality control procedures are available.

Comparisons have shown the objective yield counts to be lower than the destructive counts for Illinois in the mature samples and for Arkansas throughout the season. No significant differences in counts were found in Ohio. No definite statements which explain the results in each state can be made since the study was not designed to identify the possible sources of nonsampling errors. The large difference in October for Arkansas may support the assumption that using the objective yield procedure causes an incorrect identification and undercounting of plant components when vegetation is heavy. The Illinois data may support the assumption of reduction in plant component parts due to handling. The Ohio data may support the assumption that the handling affect is compensated by the destruction of the surrounding competition.

Regardless of the differences in counts obtained by the two procedures, the real question is, "Can the destructive procedure forecast the crop at least as well as the current objective yield procedure?" Early in the season, the destructive procedure does forecast the crop as well as the current objective yield procedure. As the season progresses, however, the destructive procedure does not appear to forecast the crop at a level acceptable to the standards of the Statistics Unit of ESS/USDA.

Data collection using the destructive procedure is being completed in Illinois during the 1980 season. Unless methods of improving the forecasting performance of the destructive procedure are developed, the study should be terminated and the objective yield procedures not changed.

T A B L E S

Table 1: Paired Comparison of Destructive and Objective Yield Counts, Illinois, 1978

Variable	AUGUST: Mean Value: Destructive	AUGUST: Mean Value: Objective Yield	AUGUST: Mean Difference	AUGUST: Paired t-Value n=80	SEPTEMBER: Mean Value: Destructive	SEPTEMBER: Mean Value: Objective Yield	SEPTEMBER: Mean Difference	SEPTEMBER: Paired t-Value n=149
Mainstem nodes per plant	12.99	12.75	0.24	1.00	16.08	15.78	0.30	1.05
Lateral branches per plant	1.13	1.18	- .05	- .38	1.76	1.80	- .04	- .40
Lateral branch nodes w/fruit per plant 1/	3.18	3.09	.09	.20	7.08	6.71	.37	.67
Fruit on lateral branches per plant 1/	7.71	8.16	- .45	- .35	14.42	13.65	.77	.57
Mainstem nodes with fruit per plant 1/	5.91	5.48	.43	1.87	11.93	11.55	.38	1.31
Fruit on mainstem per plant 1/	21.78	19.53	2.25	1.96	36.46	36.01	.45	.39
Blooms per plant	10.51	10.02	.49	.58	.30	.32	- .02	- .33
Nodes with fruit buds only per plant	3.85	3.44	.45	2.14	.13	.18	- .05	-1.67
Pods with beans per plant	1.32	1.30	.02	.13	36.58	34.58	2.00	1.19
Plants	6.23	5.56	.67	1.77	5.99	5.60	.39	1.50

Variable	OCTOBER: Mean Value: Destructive	OCTOBER: Mean Value: Objective Yield	OCTOBER: Mean Difference	OCTOBER: Paired t-Value n=151	NOVEMBER: Mean Value: Destructive	NOVEMBER: Mean Value: Objective Yield	NOVEMBER: Mean Difference	NOVEMBER: Paired t-Value n=44
Lateral branches per plant	1.85	1.67	0.18	1.64	1.77	1.69	0.08	.50
Lateral branch nodes with pods per plant	6.34	5.52	.82	1.78	5.80	4.96	.84	1.06
Pods on lateral branches per plant	10.38	9.22	1.16	1.41	10.27	8.17	2.10	1.36
Mainstem nodes with pods per plant	10.79	10.09	.70	2.41	9.97	9.03	.94	1.62
Pods on mainstem per plant	28.72	25.83	2.91	3.16*	27.05	23.63	3.42	2.34
Pods with beans per plant	36.18	32.19	3.99	2.71*	34.81	29.37	5.44	2.37
Plants	5.38	5.50	- .12	- .46	4.84	5.50	- .66	-1.18

Variable	ALL MATURE SAMPLES: Mean Value: Destructive	ALL MATURE SAMPLES: Mean Value: Objective Yield	ALL MATURE SAMPLES: Mean Difference	ALL MATURE SAMPLES: Paired t-Value n=144
Lateral branches per plant	1.84	1.67	0.17	1.55
Lateral branch nodes with pods per plant	6.37	5.51	.86	1.79
Pods on lateral branches per plant	10.53	9.05	1.48	1.76
Mainstem nodes with pods per plant	10.84	9.87	.97	3.13 *
Pods on mainstem per plant	28.87	25.39	3.48	3.78 **
Pods with beans per plant	36.82	31.89	4.93	3.29 **
Plants	5.35	5.62	- .27	-1.00

1/ Fruit defined as blooms, dried flowers and pods.
* Paired means differ significantly at the overall multiple-t significance level of $\alpha = .05$.
** Paired means differ significantly at the overall multiple-t significance level of $\alpha = .01$.

Table 2: Paired Comparison of Destructive and Objective Yield Counts, Illinois, 1979

Variable	AUGUST Mean Value Destructive	AUGUST Mean Value Objective Yield	AUGUST Mean Value Mean Difference	AUGUST Paired t-Value n=146	SEPTEMBER Mean Value Destructive	SEPTEMBER Mean Value Objective Yield	SEPTEMBER Mean Value Mean Difference	SEPTEMBER Paired t-Value n=293
Mainstem nodes per plant	13.18	13.32	- .14	- .86	16.45	16.07	.38	2.05
Lateral branches per plant	1.07	1.08	- .01	- .07	1.64	1.66	- .02	.29
Lateral branch nodes w/fruit per plant 1/	3.85	3.54	.31	.91	6.58	6.34	.24	.67
Fruit on lateral branches per plant 1/	9.66	8.93	.73	.81	15.15	14.40	.75	.76
Mainstem nodes with fruit per plant 1/	7.37	7.52	- .15	- .84	12.07	11.71	.36	2.09
Fruit on mainstem per plant 1/	25.16	23.91	1.25	1.59	39.91	39.23	.68	.80
Blooms per plant	9.94	9.56	.38	.78	.69	.90	- .22	-1.68
Nodes with fruit buds only per plant	2.87	2.77	.10	.60	.18	.23	- .05	-1.64
Pods with beans per plant	1.99	1.42	.57	2.64	36.08	34.34	1.74	1.57
Plants	6.45	6.15	.30	1.02	5.70	5.76	- .06	- .32

Variable	OCTOBER Mean Value Destructive	OCTOBER Mean Value Objective Yield	OCTOBER Mean Value Mean Difference	OCTOBER Paired t-Value n=302	NOVEMBER Mean Value Destructive	NOVEMBER Mean Value Objective Yield	NOVEMBER Mean Value Mean Difference	NOVEMBER Paired t-Value n=65
Lateral branches per plant	1.58	1.59	- .01	- .01	2.07	2.03	.04	.19
Lateral branch nodes with pods per plant	5.73	5.23	.50	1.40	6.69	6.73	- .04	- .04
Pods on lateral branches per plant	9.95	8.60	1.35	1.73	12.03	11.81	.22	.10
Mainstem nodes with pods per plant	10.91	10.37	.54	2.73*	9.58	8.68	.90	1.95
Pods on mainstem per plant	29.22	27.25	1.97	2.68	25.54	22.82	2.72	1.53
Pods with beans per plant	36.60	32.24	4.36	3.73**	33.89	28.51	5.38	2.08
Plants	5.98	5.76	.22	1.16	5.46	5.40	.06	.15

Variable	ALL MATURE SAMPLES Mean Value Destructive	ALL MATURE SAMPLES Mean Value Objective Yield	ALL MATURE SAMPLES Mean Value Mean Difference	ALL MATURE SAMPLES Paired t-Value n=277
Lateral branches per plant	1.56	1.57	.01	.13
Lateral branch nodes with pods per plant	5.75	5.22	.53	1.38
Pods on lateral branches per plant	9.89	8.57	1.32	1.47
Mainstem nodes with pods per plant	10.93	10.38	.55	2.67
Pods on mainstem per plant	29.25	27.14	2.11	2.70 *
Pods with beans per plant	36.50	32.10	4.40	3.48 **
Plants	5.87	5.71	.16	.85

1/ Fruit defined as blooms, dreid flowers, and pods.
* Paired means differ significantly at the overall multiple-t significance level of $\alpha = .05$.
** Paired means differ significantly at the overall multiple-t significance level of $\alpha = .01$.

Table 3: Paired Comparison of Destructive and Objective Yield Counts, Ohio, 1979

Variable	AUGUST 2/ Mean Value: Destructive	Objective Yield	Mean Difference	Paired t-Value n=93	SEPTEMBER 2/ Mean Value: Destructive	Objective Yield	Mean Difference	Paired t-Value n=176
Mainstem nodes per plant	12.70	12.58	.12	.53	16.31	15.71	.60	2.43
Lateral branches per plant	1.25	1.17	.08	.80	2.10	2.14	- .04	- .38
Lateral branch nodes w/fruit per plant 1/	3.21	3.20	.01	.03	7.74	6.90	.84	1.34
Fruit on lateral branches per plant 1/	7.83	7.61	.22	.30	15.36	14.01	1.35	.97
Mainstem nodes with fruit per plant 1/	6.19	5.80	.39	1.72	11.16	10.60	.56	2.22
Fruit on mainstem per plant 1/	19.37	17.62	1.75	2.23	30.94	30.29	.65	.69
Blooms per plant	8.51	8.02	.49	.89	.90	.95	- .05	- .65
Nodes with fruit buds only per plant	2.30	1.96	.34	1.82	.39	.42	- .03	- .25
Pods with beans per plant	.44	.25	.19	2.02	29.95	27.60	2.35	1.70
Plants	5.24	5.31	- .07	- .26	4.86	4.94	- .08	- .41

Variable	OCTOBER 2/ Mean Value: Destructive	Objective Yield	Mean Difference	Paired t-Value n=179	NOVEMBER 2/ Mean Value: Destructive	Objective Yield	Mean Difference	Paired t-Value n=109
Lateral branches per plant	1.77	1.99	- .22	-2.28	1.89	2.16	-.27	-1.90
Lateral branch nodes with pods per plant	5.11	5.68	- .57	-1.20	5.46	5.83	-.37	- .65
Pods on lateral branches per plant	7.68	8.16	- .48	- .53	7.92	8.36	-.44	- .49
Mainstem nodes with pods per plant	9.67	9.42	.25	1.04	9.62	9.08	.54	1.52
Pods on mainstem per plant	22.18	21.48	.70	1.06	21.13	20.68	.45	.42
Pods with beans per plant	27.20	26.88	.32	.26	27.05	26.58	.47	.28
Plants	5.08	4.89	.19	.92	4.91	4.53	.38	1.47

Variable	ALL MATURE SAMPLES 2/ Mean Value: Destructive	Objective Yield	Mean Difference	Paired t-Value n=176
Lateral branches per plant	1.88	2.01	-.13	-1.34
Lateral branch nodes with pods per plant	5.44	5.64	-.20	- .47
Pods on lateral branches per plant	7.70	7.97	-.27	- .40
Mainstem nodes with pods per plant	9.84	9.40	.44	1.65
Pods on mainstem per plant	22.14	21.32	.82	1.09
Pods with beans per plant	27.60	26.81	.79	.65
Plants	4.97	4.81	.16	.75

1/ Fruit is defined as blooms, dried flowers, and pods.
2/ No significant differences in paired means at the overall multiple-t significance level of α = .05.

Table 4: Paired Comparison of Destructive and Objective Yield Counts, Arkansas, 1979

Variable	AUGUST Mean Value: Destructive	Objective Yield	Mean Difference	Paired t-Value	SEPTEMBER Mean Value: Destructive	Objective Yield	Mean Difference	Paired t-Value n=221
Mainstem nodes per plant	---	---	---	---	13.27	12.92	.35	2.31
Lateral branches per plant	---	---	---	---	3.96	3.66	.30	2.39
Lateral branch nodes w/fruit per plant 1/	---	---	---	---	10.06	8.54	1.52	3.97**
Fruit on lateral branches per plant 1/	---	---	---	---	52.85	44.02	8.83	3.63**
Mainstem nodes with fruit per plant 1/	---	---	---	---	7.18	6.80	.38	2.73
Fruit on mainstem per plant 1/	---	---	---	---	48.39	47.30	1.09	.78
Blooms per plant	---	---	---	---	14.77	14.26	.51	.60
Nodes with fruit buds only per plant	---	---	---	---	1.42	1.33	.09	1.03
Pods with beans per plant	---	---	---	---	18.72	15.45	3.27	3.01*
Plants	---	---	---	---	7.59	7.33	.26	1.03

Variable	OCTOBER Mean Value: Destructive	Objective Yield	Mean Difference	Paired t-Value n=231	NOVEMBER Mean Value: Destructive	Objective Yield	Mean Difference	Paired t-Value n=198
Lateral branches per plant	4.41	4.24	.17	1.17	3.56	3.85	- .29	-1.92
Lateral branch nodes with pods per plant	11.24	9.20	2.04	3.93**	9.42	8.22	1.20	2.22
Pods on lateral branches per plant	29.26	25.15	4.11	3.15*	22.37	19.22	3.15	2.05
Mainstem nodes with pods per plant	6.56	5.81	.75	4.92**	5.81	5.16	.65	4.64**
Pods on mainstem per plant	20.58	18.91	1.67	2.70*	17.20	15.40	1.80	2.80*
Pods with beans per plant	42.26	36.71	5.55	3.56**	35.57	30.98	4.59	2.52
Plants	6.91	7.02	- .11	- .44	6.93	6.97	- .04	- .16

Variable	ALL MATURE SAMPLES Mean Value: Destructive	Objective Yield	Mean Difference	Paired t-Value n=200
Lateral branches per plant	3.57	3.88	- .31	-2.09
Lateral branch nodes with pods per plant	9.44	8.27	1.17	2.20
Pods on lateral branches per plant	22.44	19.40	3.04	1.99
Mainstem nodes with pods per plant	5.84	5.19	.65	4.65 **
Pods on mainstem per plant	17.29	15.50	1.79	2.79 *
Pods with beans per plant	35.76	31.28	4.48	2.47
Plants	6.96	7.02	- .06	- .24

1/ Fruit is defined as blooms, dried flowers, and pods.
* Paired means differ significantly at the overall multiple-t significance level of $\alpha = .05$.
** Paired means differ significantly at the overall multiple-t significance level of $\alpha = .01$.

Table 5: Illinois R^2 Values Obtained from Forecasting Models, 1978

Monthly Maturity Category	Model 1 Obs.	Model 1 R^2	Model 2 Obs.	Model 2 R^2	Model 3 Obs.	Model 3 R^2	Model 4 Obs.	Model 4 R^2
Aug								
1	18	.47	12	.49	12	.38	12	.68
2	14	.63	22	.50	22	.38	22	.50
3	10	.62	16	.31	16	.63	16	.41
4	21	.28	15	.38	15	.88	15	.41
5	8	.48	5	.63	5	.92	5	.41
Sept								
7	13	.45	19	.61	19	.94	18	.70
8	68	.53	73	.60	74	.80	72	.64
9	62	.63	54	.28	54	.70	54	.42
Oct								
9	15	.46	18	.49	18	.98	17	.75
10	31	.28	30	.38	31	.86	29	.46

Table 6: Illinois R^2 Values Obtained from Forecasting Models, 1979

Monthly Maturity Category	Model 1 Obs.	Model 1 R^2	Model 2 Obs.	Model 2 R^2	Model 3 Obs.	Model 3 R^2	Model 4 Obs.	Model 4 R^2
Aug								
1	20	.54	16	.69	16	.19	16	.74
2	11	.38	17	.80	17	.93	17	.75
3	14	.91	36	.50	31	.30	36	.41
4	60	.47	44	.47	44	.46	44	.51
5	17	.76	14	.64	14	.79	15	.67
Sept								
7	31	.50	35	.28	32	.88	35	.41
8	161	.51	158	.52	154	.83	161	.52
9	65	.36	58	.51	58	.95	60	.55
Oct								
9	27	.34	28	.61	27	.96	28	.55
10	38	.11	38	.08	35	.94	38	.08

Model 1: Independent variables from destructive 6-inch plot, dependent variable from 3-foot section.
Model 2: Independent variables from objective yield 6-inch plot, dependent variable from 3-foot section.
Model 3: Independent variables and dependent variable from objective yield 6-inch plot.
Model 4: Independent variables from combined destructive and objective yield 6-inch plots, dependent variable from 3-foot section.

Table 7: Ohio R^2 Values Obtained from Forecasting Models, 1979

Monthly Maturity Category	Model 1 Obs.	Model 1 R^2	Model 2 Obs.	Model 2 R^2	Model 3 Obs.	Model 3 R^2	Model 4 Obs.	Model 4 R^2
Aug								
1	20	.77	19	.36	18	.68	20	.66
2	8	.90	14	.38	14	.72	14	.31
3	12	.72	24	.57	24	.48	24	.59
4	38	.40	21	.74	20	.71	22	.62
5	6	.89	6	.71	6	.68	7	.75
Sept								
7	31	.49	43	.44	42	.83	46	.38
8	87	.57	73	.36	72	.83	75	.48
9	44	.51	47	.37	46	.56	50	.44
Oct								
9	36	.27	36	.22	36	.96	38	.22
10	66	.81	65	.40	65	.96	70	.69

Model 1: Independent variables from destructive 6-inch plot, dependent variable from 3-foot section.

Model 2: Independent variables from objective yield 6-inch plot, dependent variable from 3-foot section.

Model 3: Independent variables and dependent variable from objective yield 6-inch plot.

Model 4: Independent variables from combined destructive and objective yield 6-inch plots, dependent variable from 3-foot section.

Table 8: Arkansas R^2 Values Obtained from Forecasting Models, 1979

Monthly Maturity Category	Model 1 Obs.	Model 1 R^2	Model 2 Obs.	Model 2 R^2	Model 3 Obs.	Model 3 R^2	Model 4 Obs.	Model 4 R^2
Sept								
3	8	.85	15	.34	15	.24	15	.66
4	18	.19	17	.42	18	.71	17	.34
5	81	.69	82	.65	82	.62	83	.70
6	20	.20	13	.48	13	.56	13	.42
7	43	.52	49	.41	47	.72	49	.54
8	7	.79	6	.90	6	.99	6	1.00
Oct								
8	24	.69	24	.88	22	.88	25	.83
9	160	.54	155	.50	154	.80	157	.52
10	14	.90	13	.83	14	.97	14	.84

Model 1: Independent variables from destructive 6-inch plot, dependent variable from 3-foot section.

Model 2: Independent variables from objective yield 6-inch plot, dependent variable from 3-foot section.

Model 3: Independent variables and dependent variable from objective yield 6-inch plot.

Model 4: Independent variables from combined destructive and objective yield 6-inch plots, dependent variable from 3-foot section.

Table 9: Illinois R^2 Values Obtained from Forecasting Models, 1978 and 1979 Combined

Monthly Maturity Category	Model 1 Obs.	Model 1 R^2	Model 2 Obs.	Model 2 R^2	Model 3 Obs.	Model 3 R^2	Model 4 Obs.	Model 4 R^2
Aug								
1	39	.35	29	.49	21	.34	38	.34
2	26	.67	40	.64	25	.68	55	.63
3	25	.73	54	.39	37	.36	66	.48
4	82	.43	60	.48	50	.49	70	.42
5	26	.57	20	.31	15	.77	26	.37
Sept								
7	45	.43	54	.34	34	.86	55	.40
8	230	.53	232	.55	176	.82	238	.56
9	128	.52	113	.37	74	.94	117	.50
Oct								
9	44	.51	47	.56	33	.97	47	.57
10	70	.17	69	.19	49	.92	69	.23

Model 1: Independent variables from destructive 6-inch plot, dependent variable from 3-foot section.

Model 2: Independent variables from objective yield 6-inch plot, dependent variable from 3-foot section.

Model 3: Independent variables and dependent variable from objective yield 6-inch plot.

Model 4: Independent variables from combined destructive and objective yield 6-inch plots, dependent variable from 3-foot section.

A P P E N D I X I

Operational Soybean Objective Yield
Survey Procedure

The present soybean objective yield model is used to make monthly forecasts and a final estimate of soybean yield, in bushels per acre, for 17 states. Separate forecasts of gross yield are computed for each sample field selected in a state, by averaging gross yield forecasts determined from two 3 1/2-foot by 2-row plots (called "units") laid out at random in the field. Net yield is forecast for the sample field by subtracting a state historical value of average harvest loss. A simple average of the sample forecasts is the state forecast of soybean yield.

The forecast of gross yield in a unit is determined by multiplying three values: the forecast number of plants, the forecast number of pods per plant, and a five-year historical average weight of soybeans per pod. The number of plants is forecast by either a quadratic/curvilinear or linear regression equation, depending on the maturity of the soybeans. The regression parameters are estimated by analyzing pooled data from the previous three years for each maturity category. All plants are counted in the units to make the forecast. The number of pods per plant is forecast by a multiple regression equation whose parameters are also estimated from the previous three years' pooled data; a separate set of parameters is determined for each of twelve maturity categories and for each forecast date. For this forecast, counts of such items as number of mainstem nodes, number of lateral branches with fruit, number of pods, and so on, are obtained only from plants in two adjacent six-inch row sections of each unit. In all, nine attributes of the soybean plants are counted in the two six-inch sections. Just before harvest, all pods with beans are removed from a three-foot row section of one of the units and counted; at this stage of maturity, this is the only count used in the multiple regression forecast.

Plant and attribute counts are made at each enumerator visit, which occurs during the last week of each month preceding a first-of-the-month forecast. The same pair of six-inch row sections is used each time.

A P P E N D I X II

Enumerator Evaluations

Enumerator Evaluations

Question	ILL '78	ILL '79	Ohio	Ark
	percent			
1. Which method do you feel gives more accurate counts in the 6-inch section?				
Destructive	57	53	68	86
Objective yield	17	17	5	7
No difference	26	30	27	7
2. Were there any destructive methods or instructions that you found difficult or hard to carryout?				
Yes	11	9	0	0
No	89	91	100	100
3. Do you recall any farm operator who refused or was reluctant to cooperate on Soybean Objective Yield Destructive Counting Procedure Study once permission had been obtained to lay out Objective Yield units?				
Yes	10	6	9	7
No	90	94	91	93
4. If the destructive procedure were adopted, do you think the refusal rate would: Increase	20	8	4	14
Decrease	3	6	9	7
Stay the same	77	86	87	79
5. If the destructive procedure were adopted, would it take more, less or the same amount of time to make your counts?				
More	20	22	13	36
Less	50	39	35	28
Same	30	39	52	36
Number of respondents	30	36	23	14

6. What did you like most about the destructive method?
   Ill. '78 -- Comfort and what they felt was the greater accuracy of counts from the destructive procedure.
   Ill. '79 -- Getting out of field; extra time earned.
   Ohio -- Getting out of field.
   Arkansas -- Getting out of field.

7. What did you like least about the destructive method?
   Ill '78 -- The amount of material to carry from field.
   Ill '79 -- Carrying bags and equipment from field.
   Ohio -- Carrying bags from the field.
   Arkansas-- Carrying bags and equipment from field.

8. What destructive methods or instructions did you find difficult or hard to carry out?
   Ill '78 -- Coordination of destructive work with the objective yield work.
   Ill '79 -- Recording time.
   Ohio -- No comment.
   Arkansas-- No comment.

A P P E N D I X III

Regression Independent Variables

Variables Considered when Selecting "Best" Set of Predicting Variables

Variable	Maturity Category 1/	Description
X15	1-11	Number of plants in both 3-ft and 6-inch sections, adjusted to 18 square feet.
X8	1-11	$(X15)^2$
X12	1-11	Pods with beans, per plant.
X9	1-3	Mainstem nodes per plant.
	4-11	$(X12)^2$
X4	1-3	Nodes with fruit buds only per plant.
	4-11	Pods and dried flowers per plant.
X10	1-11	Blooms, pods and dried flowers per plant, August and September only
X13	1-11	Mainstem nodes with fruit, per plant.
X14	1-11	Lateral branches per plant.
X16	1-11	Lateral branch nodes with fruit per plant.

1/ See Appendix IV for a description of maturity categories.

A P P E N D I X IV

Maturity Categories

Maturity categories are calculated by unit. The purpose of the categories is to group units by maturity with the intention of improving the forecasting models. Calculation of the maturity categories is based on an enumerator observed maturity stage and per plant counts. Maturity stage is observed in the three-foot section. Listed below are the maturity stage and maturity category descriptions. Additional information can be found in the Objective Yield Survey Enumerators Manual and the Objective Yield Supervising and Editing Manual.

Soybean Objective Yield Maturity Stages Determined by Enumerators

Maturity Stage	Description
1	Plants still in bloom stage. Any pods found are still green with little or no seed development.
2	Very few blooms. Most pods still filling and leaves are still green.
3	Leaves turning yellow. Almost all pods filled and some ripening.
4	All leaves have turned yellow and some have fallen. Pods full sized and changing from green to brown color. Beans not yet firm.
5	Pods brown and easily opened. Beans brown and have shrunken. Most leaves have been shed.
6	Pods brown and ready to combine. Beans very hard.

Soybean Objective Yield Assigned Maturity Categories

Maturity Category	Description 1/
0	No plants were present in either row of the two 6-inch row sections per unit.
1	No pods are present and less than 60% of the plants in the 6-inch row sections have blooms.
2	At least 60% of the plants in the 6-inch row sections have some blooms but no pods were counted. Also, the ratio of blooms to nodes is not greater than one.
3	a) If pods were counted, the number of pods was not larger than the number of blooms. b) If no pods were counted, the ratio of blooms to nodes is larger than one.
4	The ratio of pods to total fruit (blooms plus pods) is between .50 and .75, and the ratio of pods with bean (if any) to fruit is less than or equal to .01.
5	The ratio of pods to total fruit is larger than .75, or the ratio of pods with beans to total fruit is between .01 and .10.
6	The ratio of pods with beans to total fruit is between .10 and .30.
7	The ratio of pods with beans to total fruit is between .30 and .50.
8	The ratio of pods with beans to total fruit is larger than .50 and the leaves have not yet started to turn yellow.
9	Leaves have started to turn yellow but no leaves have been shed (Maturity State 3).
10	Leaves have all turned yellow and are starting to fall from the plants (Maturity Stage 4).
11	At least half of the leaves have been shed by the plants. (Maturity Stages 5 and 6).

1/ Brief approximation of each category determination.

APPENDIX V

Regression Models

August 1979, Ohio

Maturity Category = 1

Model 1: -0.09 - 0.1093(X15) + 3.1539(X9) + 13.4468(X16)
Model 2: 20.59 + 53.1730(X14)
Model 3: 15.88 + 2.0697(X4) + 69.0777(X14)
Model 4: -6.48 + 2.8867(X9) + 5.9372(X10)

Maturity Category = 2

Model 1: -28.77 + 51.4047(X4)
Model 2: -25.55 + 4.6420(X9)
Model 3: -5.84 - 0.0012(X8) + 2.8579(X9)
Model 4: 19.35 + 5.7438(X4)

Maturity Category = 3

Model 1: 39.64 - 0.0013(X8) - 1.0549(X9) + 2.9986(X4)
Model 2: 116.61 - 2.8737(X15) + 0.0164(X8) + 10.8723(X4)
Model 3: 11.06 + 8.4657(X14)
Model 4: 196.79 - 3.8477(X15) + 0.0224(X8) - 1.0412(X10)

Maturity Category = 4

Model 1: 32.47 - 0.2041(X15) + 4.0036(X14)
Model 2: 24.37 - 0.3672(X15) + 22.9885(X12) - 7.4597(X9) + 2.1078(X13)
Model 3: 30.32 + 1.0763(X4) - 5.3740(X13)
Model 4: 75.36 - 1.3581(X15) + 0.0067(X8) + 4.3553(X12)

Maturity Category = 5

Model 1: 193.00 - 1.6518(X15) - 9.2472(X13)
Model 2: 99.40 - 1.7258(X15)
Model 3: 23.85 + 1.2675(X16)
Model 4: 105.74 - 1.8546(X15)

September 1979, Ohio

Maturity Category = 7

Model 1: 60.57 - 5.6338(X13) + 3.5101(X16)
Model 2: 39.48 - 0.8243(X15) + 0.0046(X8) + 1.1716(X13)
Model 3: 2.99 + 0.0116(X9) + 0.2043(X4) + 0.4539(X16)
Model 4: 30.86 - 0.2178(X15) + 0.7547(X16)

Maturity Category = 8

Model 1: 65.36 - 1.2257(X15) + 0.0067(X8) + 0.2640(X16)
Model 2: 92.99 - 2.0276(X15) + 0.0118(X8)
Model 3: 4.46 - 0.0004(X8) + 0.3042(X12)
Model 4: 106.03 - 1.6538(X15) + 0.0090(X8) - 3.2309(X13) + 6.0899(X14)

Maturity Category = 9

Model 1: 36.51 - 0.2584(X15) + 6.1136(X14)
Model 2: 67.31 - 0.9305(X15) + 0.0041(X8)
Model 3: 15.02 + 0.7756(X4) - 1.3352(X13)
Model 4: 33.12 - 0.1910(X15) + 1.5344(X16)

October 1979, Ohio

Maturity Category = 9

Model 1: 36.33 - 0.2581(X15)
Model 2: 37.26 - 0.2812(X15)
Model 3: 1.20 + 0.5090(X12) + 0.0059(X9) + 0.7022(X13)
Model 4: 35.50 - 0.2460(X15)

Maturity Category = 10

Model 1: 47.85 - 0.8235(X15) + 0.0050(X8) + 0.0062(X9)
Model 2: 82.86 - 1.9565(X15) + 0.0120(X8) + 3.3246(X14)
Model 3: -2.33 + 1.1427(X12) - 0.0024(X9)
Model 4: 52.50 - 0.1590(X15) + 0.0260(X9) - 3.4311(X13) - 4.1119(X14)

September 1979, Arkansas

Maturity Category = 3

Model 1: 72.08 - 0.6274(X15) - 5.9957(X4)
Model 2: 38.77 - 6.4582(X4)
Model 3: 37.78 - 0.0038(X8)
Model 4: 89.73 - 6.6757(X9) + 8.6673(X14)

Maturity Category = 4

Model 1: 31.30 - 0.0031(X8)
Model 2: 21.02 - 1.3909(X13) + 1.3884(X16)
Model 3: 8.10 + 3.1777(X16)
Model 4: 79.50 - 1.8565(X15) + 0.0134(X8)

Maturity Category = 5

Model 1: 55.29 - 1.1910(X15) + 0.0077(X8) + 0.0779(X4) + 0.5139(X16)
Model 2: 51.88 - 0.4173(X15) - 1.6322(X13) + 1.5209(X16)
Model 3: -1.43 + 0.1837(X4) + 1.5931(X16)
Model 4: 35.13 - 0.4344(X15) - 0.0147(X9) + 3.9723(X14) + 0.6839(X16)

Maturity Category = 6

Model 1: 13.16 + 3.4963(X14)
Model 2: 16.28 + 0.0124(X9)
Model 3: 0.82 + 0.2711(X4)
Model 4: 18.49 + 0.0051(X9)

Maturity Category = 7

Model 1: 105.00 - 2.2952(X15) + 0.0185(X8) - 1.9965(X13) + 1.3965(X14)
Model 2: 49.09 - 0.5081(X15) + 1.7682(X14)
Model 3: 15.76 - 0.9938(X12) + 0.0107(X9) + 0.1790(X4) + 1.9553(X16)
Model 4: 55.74 - 0.3829(X15) + 0.4365(X12) - 2.3240(X13)

Maturity Category = 8

Model 1: 64.79 - 1.3019(X15) + 4.3444(X14)
Model 2: 111.66 - 1.3102(X15) - 0.2513(X4)
Model 3: -38.38 + 2.4324(X12) - 0.0141(X9)
Model 4: 91.13 - 0.0150(X9) - 11.4928(X13) + 5.4635(X16)

October 1979, Arkansas

Maturity Category = 8

Model 1: 84.94 - 1.7823(X15) + 0.0109(X3)
Model 2: 96.48 - 2.5870(X15) + 0.0188(X8) + 2.3907(X14)
Model 3: 2.23 + 0.7290(X12)
Model 4: 124.89 - 3.2478(X15) + 0.0239(X8)

Maturity Category = 9

Model 1: 64.21 - 1.4523(X15) + 0.0098(X8) + 0.2968(X12) - 0.0004(X9)
Model 2: 44.61 - 0.3944(X15) - 1.0298(X13) + 1.3138(X16)
Model 3: 4.32 + 0.6921(X12) + 0.0018(X9)
Model 4: 50.33 - 1.0822(X15) + 0.0070(X8) + 0.3836(X12)

Maturity Category = 10

Model 1: 79.09 - 2.1967(X15) + 0.0169(X8) + 2.9218(X14)
Model 2: 108.39 - 2.5597(X15) + 0.0174(X8)
Model 3: 0.46 + 0.9205(X12)
Model 4: 103.96 - 2.4046(X15) + 0.0159(X8)

August 1978, Illinois

Maturity Category = 1

Model 1: 35.11 - 0.3097(X15) + 2.1079 (X10)
Model 2: 47.37 - 0.5412(X15)
Model 3: 10.02 + 2.6094(X4)
Model 4: 38.52 + 35.5340(X14) - 0.2091(X15)

Maturity Category = 2

Model 1: 72.82 - 1.0126(X15)
Model 2: 79.82 - 1.7973(X15) + 0.0112(X8)
Model 3: 24.29 + 9.4651(X14)
Model 4: 79.24 - 1.0054(X15) + 0.0036(X8)

Maturity Category = 3

Model 1: 48.81 - 0.0080(X8)
Model 2: 45.57 - 0.0074(X8)
Model 3: 56.64 - 3.6954(X9) + 0.7022(X10)
Model 4: 47.44 - 0.0027(X8)

Maturity Category = 4

Model 1: 49.34 - 0.5029(X15)
Model 2: 46.07 - 0.4051(X15)
Model 3: 15.89 - 0.0055(X8) + 0.5409(X10)
Model 4: 45.70 - 0.2271(X15)

Maturity Category = 5

Model 1: 50.02 - 0.4422(X15)
Model 2: 64.38 - 7.8228(X14)
Model 3: 16.81 - 0.5541(X12) + 0.2897(X10)
Model 4: 25.96 + 0.2353(X4)

September 1978, Illinois

Maturity Category = 7

Model 1: 41.63 - 0.4506(X15)
Model 2: 26.94 - 0.0033(X16) + 0.0029(X9)
Model 3: 9.95 + 1.5752(X12) - 0.1085(X15) - 0.3659(X4)
Model 4: 5.06 + 5.2490(X14) + 0.1803(X4)

Maturity Category = 8

Model 1: 78.11 - 1.9308(X15) + 0.0147(X8) + 0.0037(X9)
Model 2: 113.36 - 3.4890(X15) + 0.0329(X8)
Model 3: 4.39 + 0.7589(X12) + 0.6377(X13) - 0.1684(X15)
Model 4: 103.04 - 1.5922(X15) - 0.4667(X4) + 0.0085(X8) + 0.0130(X9)

Maturity Category = 9

Model 1: 65.91 - 2.2970(X15) + 0.0216(X8) + 0.7840(X12) - 0.0048(X9)
Model 2: 83.14 - 2.0241(X15) + 0.0181(X8)
Model 3: 6.14 + 1.6400(X12) - 0.7796(X4)
Model 4: 53.80 + 0.4580(X12) - 0.9147(X15) + 0.0052(X8)

October 1978, Illinois

Maturity Category = 9

Model 1: 22.05 - 0.003(X8) + 0.343(X12)
Model 2: 105.50 + 0.0326(X8) - 3.4151(X15)
Model 3: 0.70 + 0.8348(X12) + 0.5085(X13) - 0.0008(X8)
Model 4: 15.06 - 3.7984(X16) + 0.0346(X9)

Maturity Category = 10

Model 1: 45.17 - 0.4134(X15)
Model 2: 34.54 - 0.2879(X15) + 4.0683(X14)
Model 3: 5.01 + 0.7490(X4)
Model 4: 17.80 + 2.5965(X16)

August 1979, Illinois

Maturity Category = 1

Model 1: 84.88 - 1.6771(X15) + 0.0106(X8)
Model 2: 91.88 - 1.8756(X15) + 0.0118(X8) - 16.7979(X13)
Model 3: 8.62 + 1.5912(X9)
Model 4: 93.86 - 1.8451(X15) + 0.0112(X8) - 11.3745(X10)

Maturity Category = 2

Model 1: 46.45 - 0.448(X15)
Model 2: 88.67 - 2.5489(X15) + 0.0156(X8) + 3.8994(X13)
Model 3: 67.55 - 0.7018(X15) - 3.3297(X9) +2.9039(X4)
+ 3.3639(X13) - 26.1055(X14) + 14.5761(X16)
Model 4: 43.52 - 0.4952(X15) + 8.2955(X16)

Maturity Category = 3

Model 1: 134.88 - 4.2315(X15) + 0.0383(X8)
Model 2: 42.08 - 0.3477(X15) + 0.8518(X16)
Model 3: 22.31 + 8.4400(X14)
Model 4: 49.42 - 0.4411(X15)

Maturity Category = 4

Model 1: 55.12 - 0.6052(X15) + 4.3996(X14)
Model 2: 74.77 - 0.9185(X15)
Model 3: 20.59 - 0.2745(X15) + 0.5064(X4)
Model 4: 52.69 - 0.7334(X15) + 0.3204(X4)

Maturity Category = 5

Model 1: 84.23 - 1.0126(X15) - 17.8066(X14) + 3.3523(X16)
Model 2: 105.83 - 2.5669(X15) + 0.0210(X8)
Model 3: -24.75 + 5.1875(X13) + 5.3899(X14)
Model 4: 119.58 - 3.1944(X15) + 0.0277(X8)

September 1979, Illinois

Maturity Category = 7

Model 1: 19.69 + 0.0073(X9)
Model 2: 38.81 + 0.0100(X9) - 1.9021(X13)
Model 3: 2.08 + 0.7874(X12) + 0.6180(X16)
Model 4: 19.33 + 0.0072(X9)

Maturity Category = 8

Model 1: 99.48 - 3.0286(X15) + 0.0267(X8) + 0.6691(X12)
- 0.2025(X4) + 3.4108(X14) - 1.4036(X16)
Model 2: 67.18 - 1.8058(X15) + 0.0149(X8) + 0.4977(X12) - 0.7694(X16)
Model 3: 7.18 - 0.6906(X15) + 0.0066(X8) + 0.8216(X12)
- 0.0034(X9) + 1.0388(X13) + 2.7837(X14)
Model 4: 72.83 - 2.5611(X15) + 0.0232(X8) + 1.0111(X12)
- 0.0039(X9) - 1.1375(X16)

Maturity Category = 9

Model 1: 96.53 - 2.1613(X15) + 0.0157(X8)
Model 2: 85.13 - 2.3401(X15) + 0.0193(X8) + 0.9835(X13)
Model 3: -1.76 + 1.0273(X12) - 0.4198(X16)
Model 4: 83.47 - 2.4463(X15) + 0.0205(X8) + 1.3044(X13)

October 1979, Illinois

Maturity Category = 9

Model 1: 17.34 + 0.3910(X4)
Model 2: 30.33 - 0.2599(X15) - 0.0042(X9) + 2.7484(X16)
Model 3: -1.29 + 1.0570(X12) - 0.4929(X16)
Model 4: 9.92 - 0.2075(X15) - 0.0061(X9) + 1.0961(X4)

Maturity Category = 10

Model 1: 24.39 + 0.2991(X12) - 3.0890(X14)
Model 2: 26.09 + 0.0029(X9)
Model 3: 3.37 + 1.0348(X12) - 0.6302(X13) + 0.3700 (X16)
Model 4: 15.61 + 1.3920(X13)

August 1978 and 1979, Illinois

Maturity Category = 1

Model 1: 60.11 - 1.0124(X15) + 0.0060(X8)
Model 2: 68.97 - 1.2884(X15) + 0.00081(X8) - 6.1767(X10)
Model 3: 18.21 - 0.1798(X15) + 1.4125(X9)
Model 4: 57.39 - 0.9903(X15) + 0.0063(X8)

Maturity Category = 2

Model 1: 75.52 - 1.9118(X15) + 0.0131(X8) + 0.8387(X9)
Model 2: 100.08 - 2.1989(X15) + 0.0145(X8) - 1.9178(X4)
Model 3: 33.34 - 0.4111(X15) + 1.9443(X4) + 4.7326(X16)
Model 4: 88.61 - 2.3561(X15) + 0.0160(X8) - 1.1021(X12) + 1.6435(X13)

Maturity Category = 3

Model 1: 116.31 - 3.1490(X15) + 0.0252(X8)
Model 2: 50.79 - 0.4612(X15)
Model 3: -6.98 + 2.2316(X9) + 6.1683(X14)
Model 4: 65.85 - 0.4537(X15) - 1.3064(X9) + 0.6375(X16)

Maturity Category = 4

Model 1: 50.50 - 0.6096(X15) + 0.2265(X4)
Model 2: 63.37 - 0.7645(X15) + 0.7710(X4) - 0.6548(X10)
Model 3: 23.98 - 0.3222(X15) + 0.4686(X10)
Model 4: 54.25 - 0.5919(X15) - 0.4488(X14) + 1.1623(X16)

Maturity Category = 5

Model 1: 27.31 - 0.0058(X8) + 0.1083(X9) + 0.2996(X4)
Model 2: 58.08 - 0.4824(X15)
Model 3: -26.90 + 5.4801(X13) + 4.6873(X14)
Model 4: 55.55 - 0.5071(X15) + 0.8667(X12)

September 1978 and 1979, Illinois

Maturity Category = 7

Model 1: 19.69 + 0.0074(X9)
Model 2: 54.68 - 1.2667(X15) + 0.0104(X8) + 0.0035(X9)
Model 3: 1.34 + 0.9518(X12)
Model 4: 10.24 + 0.5419(X12)

Maturity Category = 8

Model 1: 85.16 - 2.3301(X15) + 0.0190(X8) + 0.8220(X12) - 14.9063(X4) + 14.5320(X10) - 0.3811(X13) + 2.5088(X14) - 1.542(X16)
Model 2: 89.42 - 2.6098(X15) + 0.0238(X8) + 0.5614(X12) + 5.4779(X4) - 5.7119(X10)
Model 3: 6.55 - 0.7215(X15) + 0.0070(X8) + 0.8103(X12) - 0.0032(X9) + 1.1204(X13) + 2.8299(X14)
Model 4: 84.82 - 2.9829(X15) - 0.0043(X9) - 0.2725(X4) - 0.6515(X16) + 0.0278(X8) + 1.2473(X12)

Maturity Category = 9

Model 1: 84.16 - 2.4286(X15) + 0.0205(X8) + 1.2956(X12) - 0.0029(X9) - 0.6532(X4) - 0.3680(X13)
Model 2: 77.56 - 1.9626(X15) + 0.0163(X8) + 0.6383(X13)
Model 3: -1.44 + 1.0132(X12) - 0.4185(X16)
Model 4: 55.59 - 1.7641(X15) + 0.0154(X8) + 0.9003(X12) - 0.0065(X9)

October 1978 and 1979, Illinois

Maturity Category = 9

Model 1: 45.96 - 1.3935(X15) + 0.0119(X8) + 0.5297(X12)
Model 2: 56.09 - 1.4073(X15) + 0.0105(X8) - 0.0045(X9) + 2.8438(X16)
Model 3: -3.77 + 0.8717(X12) + 0.6030(X13)
Model 4: 32.45 - 1.4444(X15) + 0.0121(X8) + 1.3684(X12) - 0.0073(X9)

Maturity Category = 10

Model 1: 50.83 - 0.7934(X15) + 0.0056(X8)
Model 2: 51.04 - 0.7818(X15) + 0.0053(X8)
Model 3: 4.77 + 0.9754(X12) - 0.6596(X13) + 0.3738(X16)
Model 4: 21.29 - 0.1533(X15) + 1.1230(X13) + 1.7753(X16)