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Corn Objective Yield: An Empirical Evaluation of the Use of 3, 4 or 5 Years Data to Develop Forecast Equations

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CORN OBJECTIVE YIELD: AN EMPIRICAL EVALUATION OF THE USE OF 3, 4 OR 5 YEARS' DATA TO DEVELOP FORECAST EQUATIONS.
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ABSTRACT

This study compares the level of forecast errors resulting from using data from the previous three, four and five years to develop forecast equations for corn yield. Forecast errors are tabulated for each state and the ten state region in the corn objective yield program for the years 1980-84. These tables provide a benchmark of the performance of the current corn objective yield forecast procedures.

Analysis of variance procedures are used to test for significant differences in the level of forecast errors resulting from using different numbers of years of data to estimate regression relationships. The stability of the estimated regression parameters is assessed and discussed.

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SUMMARY

For the ten-state region, the average absolute forecast error from 1980 through 1984 across all months is 0.15 bu./acre higher when five rather than three years' data are used to develop the forecast equations. This difference for the ten-state region is not statistically significant; neither are the differences for individual states.

In general, forecast errors decrease between August and September but do not change much between September and October. Forecast errors reported here pertain only to the samples which were not harvested before the end of the survey period for that month. Although forecast errors do not decrease between September and October, the error in the overall objective yield estimate does decrease as more samples are harvested.

For the five years included in this study, the forecasts were more than seven bushels per acre higher than final gross yield on the average. This upward bias in the forecasts appears to be due to forecast model insensitivity to weather conditions. Much of this average error is due to overestimating yields in 1980 and 1983. In both of these years, yields were substantially below average due to poor weather conditions.

The estimated parameters of the yield forecast regression models fluctuate considerably from year to year. Increasing the number of years of data used to estimate the regression relationships reduced these fluctuations slightly, but did not improve the accuracy or reliability of the forecasts for the years included in this study. Any further increase in the number of years of data used will likely decrease the sensitivity of the models to changes in cultural practices, agronomic technologies, weather and other factors.

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INTRODUCTION

The National Agricultural Statistics Service (NASS) of the U.S. Department of Agriculture (USDA) conducts monthly Corn Objective Yield (COY) surveys from August through November to forecast end-of-season yield of corn for grain for the ten major corn producing states. Sample level yield forecasts are computed from forecast equations applied to counts and measurements made in the sample plots during the current growing season. The forecast equations are derived by using data from previous years' COY surveys to estimate linear relationships between counts or measurements made during the growing season and counts or measurements obtained when the corn is mature. Prior to 1985, the regression relationships were estimated using data from the three previous years' surveys. In 1985 the procedure was changed; the previous five years' data were used to develop the forecast equations.

This study examines and compares the forecast errors resulting from the use of data from the previous three, four and five years to develop forecast equations for 1980 through 1984. The stability of parameter estimates is also addressed.

METHODOLOGY

A brief description of the COY sampling, data collection and forecasting methodologies is included here. More comprehensive discussions are contained in [7].

Sample units consisting of two plots, each containing two rows of corn fifteen feet long, are randomly located within a random sample of fields planted with corn for grain. Counts, measurements and observations of plant characteristics are made within these sample plots during the monthly survey periods.

When the corn reaches maturity, a count is made of the final number of ears in the sample plots, and the ears are harvested and weighed. A sample of ears is sent to a laboratory to determine an adjustment factor for converting field weight to grain weight at 15.5% moisture. This adjustment factor is applied to the weight of the ears harvested from the sample unit, and the result divided by the final number of ears to obtain the final average grain weight per ear. Final gross yield is calculated from the final number of ears, final average grain weight per ear, and the size of the sample plots. Post-harvest gleaning surveys are conducted to estimate the harvest loss. Estimated harvest loss is subtracted from final gross yield to obtain final net yield.

With data from the five previous years' COY surveys, simple linear regression models are used to estimate relationships between counts (or measurements) obtained during the growing season and counts made when the corn is mature. Forecasts of the final number of ears and average grain weight per ear are computed by applying these estimated regression relationships to counts and measurements made during the current growing season. Counts of stalks, stalks with ears, or number of ears are used as the predictor variable for final number of ears, depending on the stage of physiological development (maturity stage). Average kernel row length and average cob length over the husk are used to predict average grain weight per ear once the crop reaches a maturity stage sufficient to make these measurements. A historic average grain weight per ear is used prior to the development of kernels on ears. The yield forecast (bushels/acre) is computed by taking the product of the forecast number of ears, the forecast grain weight per ear and a multiplicative constant, divided by the area in the sample unit. Salient features of the forecasting procedures, beyond those described above, are:

a) generally speaking, forecasts for number of ears and average grain weight per ear are each a weighted average of two forecasts, with weights based on average R^2 values of the estimated regression relationships across maturity categories. In some maturity categories, historic averages or observed data are used instead of forecasts from models;

b) regression relationships are estimated using data for the same state, district, month and maturity category from the previous years;

c) automated outlier/leverage-point detection and removal procedures are used in developing the forecast equations [3];

d) if there are insufficient data from previous years within some maturity category to estimate the regression relationships, a forecast equation from another maturity category, month or year is used. In selecting the forecast equation to be substituted, equations from within the same month are considered first, then equations from other months, and finally equations from other years.

e) if the estimated intercept parameter is negative, the model is forced through the origin (zero intercept). If the slope parameter is negative, a regression equation from another maturity category, month or year is substituted following the procedures discussed in (d) above.

ANALYSIS PROCEDURES

Forecast Errors

Forecasts and the corresponding forecast errors are computed for non-mature COY samples for the years 1980 through 1984, with forecast equations developed using COY survey data from the previous three, four and five years. The procedures used to develop the forecast equations and compute the forecasts are essentially the same as are used in the operational COY program. For the purposes of this analysis, forecast error is defined as the difference between the gross yield forecast and the final gross yield.

Subscripts used in the remainder of this report are:

i denotes treatment: 3, 4 or 5 years' data used to develop the forecast equations;

j denotes year: $j \in \{1\ (1980),\ 2\ (1981),\ \ldots\ ,\ 5\ (1984)\}$;

k denotes month: $k \in \{\ 1\ (\text{Aug}),\ 2\ (\text{Sept}),\ 3\ (\text{Oct})\}$;

l denotes state: $l \in \{1,2,\ldots 10\}$;

m denotes sample number: $m \in \{1,2,\ldots,n_{jkl}\}$.

The forecast error for the m^{th} sample, l^{th} state, k^{th} month and j^{th} year, using the i^{th} treatment, is:

$$E_{ijklm} = \hat{Y}_{ijklm} - Y_{jlm} \quad \text{where}$$

$\hat{Y}_{ijklm}$ is the gross yield forecast for the m^{th} sample; and

Y_{jlm} is the final gross yield. It does not vary as a function of the month within a year nor the number of years of data used to develop the forecast equations. Thus, the i and k subscripts are omitted.

In consideration of the self-weighted sampling plan used in the COY surveys, we define the state-level forecast error as the simple mean of the sample-level forecast errors. For the i^{th} treatment, j^{th} year, k^{th} month, and l^{th} state, the state-level forecast error is:

$$E_{ijkl.} = \sum_{m}^{n_{jkl}} E_{ijklm} / n_{jkl} \quad \text{where}$$

n_{jkl} is the number of samples for which forecasts were computed in the j^{th} year, k^{th} month, and l^{th} state. It does not vary as a function of the number of years of data used to develop the forecast equations.

The state-level forecast error as defined above excludes the effect of samples already harvested and samples for which data were not collected when the corn reached maturity. Samples already harvested were excluded since final gross yield is already observed; the forecast models are no longer used for these samples in the operational program. The inclusion of already harvested samples would only serve to mask any real differences which might exist in forecast error levels due to the numbers of years of data used to develop the forecast equations. Samples for which data were not collected when the corn reached maturity were excluded through necessity; the final gross yield is unknown for those samples, so forecast errors could not be computed. Some of the reasons data are not collected when the corn reaches maturity are: the farmer harvests the field before the enumerator is able to harvest the sample plots; the field is no longer intended to be harvested as corn for grain; the farm operator reneges on the permission granted to enter the field and conduct the survey.

State-level forecast errors are tabulated by month and year for the three treatments. The average absolute forecast error and the average squared forecast error are also tabulated for each month, and for all months combined across the five years.

The average absolute forecast error for the l^{th} state, k^{th} month, and i^{th} treatment is:

$$\overline{|E|}_{i.kl.} = \sum_{j=1}^{5} |\bar{E}_{ijkl.}| \ / \ 5 \qquad \text{and,}$$

$$\overline{|E|}_{i..l.} = \sum_{k=1}^{3} \overline{|E|}_{i.kl.} \ / \ 3$$

is the average absolute forecast error across the three months.

Replacing $|\bar{E}_{ijkl.}|$ with $(\bar{E}_{ijkl.})^2$, the average squared forecast errors are analogously defined.

Considering the ten-states in the COY survey as a region, regional level forecast errors are also tabulated by month and year for the three treatments. The regional level forecast error for the i^{th} treatment j^{th} year and k^{th} month, is defined as the weighted average of the state-level forecast errors:

$$\bar{E}_{ijk..} = \sum_{l=1}^{10} A_{jl}\bar{E}_{ijkl.} \ / \ \sum_{l=1}^{10} A_{jl} \qquad \text{where}$$

A_{jl} is the final harvested corn for grain acreage, which does not vary with months (k) nor treatments (i); and

$\bar{E}_{ijkl.}$ is the previously defined state-level forecast error for the l^{th} state, k^{th} month, j^{th} year and i^{th} treatment.

The average absolute forecast error and average squared forecast error for the ten-state region are defined in the same manner as the corresponding state-level estimators.

Test for Treatment Differences

Analysis of variance (ANOVA) procedures are used to test for differences in the level of forecast errors between treatments. Treatments correspond to the use of data from the previous three, four or five years to develop the forecast equations. Although sample sizes are not the same from month to month nor year to year, we assume that for a given state, the impact of a state-level forecast error of a given magnitude is the same regardless of the month or year in which it occurs. Under this assumption, unweighted least squares is appropriate. Furthermore, the design is balanced with three treatments, five years, three months within each year, and one observation per cell. All three treatments are applied to the same set of samples so we effectively have the requisite randomization. Treatments, years, and months within years are considered fixed effects.

Two dependent variables, or responses, are considered: the absolute value of the state-level forecast error $|E_{ijkl.}|$; and the squared state-level forecast error $(E_{ijkl.})^2$. A separate ANOVA is performed for each state. The assumed model for the l^{th} state (l fixed), with absolute error as the response, is:

$|\bar{E}_{ijkl.}| = \mu + \alpha_i + \beta_j + \delta_{jk} + \epsilon_{ijkl}$ where

- α_i is the effect of the use of three, four or five years data to develop the forecast equations;
- β_j is the effect of the j^{th} year;
- δ_{jk} is the effect of the k^{th} month within the j^{th} year; and
- ϵ_{ijkl} are assumed to be normal, independent, identically distributed random variables (l is fixed).

The model is analogously defined for the squared forecast error response. The same model is also used for the regional level absolute and squared forecast errors, with appropriate modification of the response variable and assumptions.

The hypothesis of interest is H_0: $\alpha_1=\alpha_2=\alpha_3$; there is no difference in the level of the forecast errors due to the number of years of data (3, 4 or 5) used. Rejection of this hypothesis will lead to the conclusion that the level of the absolute (or squared) forecast errors is not the same for all treatments if the underlying assumptions are satisfied. Hypothesis tests are performed with a testwise type I error rate of α=.05.

There are inter-dependencies between treatments since forecast equations based on data from the previous three, four and five years are not independent. Likewise, inter-dependencies exist between years and months within years. Although the assumed model should largely eliminate these inter-dependencies, the residuals are examined to assess the validity of the normality, independence and homoscedasticity (equal variance) assumptions.

Stability of Parameter Estimates

One of the primary reasons for changing from the use of three years to the use of five years of data to develop the forecast equations was the instability of the parameter estimates. As a gross, overall measure of the stability of the parameter estimates, a statistic similar to a coefficient of variation (CV) is computed for the intercept and slope parameters of each of the four models - two models for final number of ears, and two for average grain weight per ear. We define this measure of stability of the estimated parameter p, for the h^{th} parameter of the g^{th} model using the i^{th} treatment (3, 4 or 5 years' data) as:

$$STAB_{ghi} = 100 * \sqrt{\hat{\sigma}^2(\delta_{ghi})} \; / \; \bar{p}_{ghi....} \qquad \text{where}$$

$\hat{\sigma}^2(\delta_{ghi})$ is the estimated component of variance between years for the h^{th} parameter of the g^{th} model under the i^{th} treatment; and

$\bar{p}_{ghi....}$ is the average parameter estimate across all maturity categories, state/districts, months and years, weighted by the number of samples forecasts were computed for using this model. These means are essentially equal for 3, 4 or 5 years', so it has a negligible effect on the measure of stability.

As a computational convenience in estimating the between year variance component of an estimated parameter (for a particular model, parameter and treatment, with associated g, h and i subscripts omitted for simplicity), we adopt a nested linear model of the form:

$$p_{jklmq} = \mu + \alpha_k + \beta_{kl} + \Gamma_{klq} + \delta_{klqj} + \epsilon_{jklmq} \qquad \text{where}$$

α_k is the effect of the k^{th} month ;

β_{kl} is the effect of the l^{th} state/district within the k^{th} month;

Γ_{klq} is the effect of the q^{th} maturity category within the l^{th} state/district and k^{th} month;

δ_{klqj} is the effect of the j^{th} year within the q^{th} maturity category, l^{th} state/district and k^{th} month;

ϵ_{jklmq} is the random error; and

p_{jklmq} is the parameter estimate for the m^{th} sample within the j^{th} year, the q^{th} maturity category, l^{th} state/ district and k^{th} month.

As a straightforward extension of results presented by Searle [4] for two-way and three-way nested classification models, the analysis of variance estimator of the between-year component of variance is:

$$\hat{\sigma}^2(\delta) = \frac{\left[\sum_{klqj}\sum\sum\sum p^2_{jkl.q}/n_{jklq} - \sum_{klq}\sum\sum p^2_{.kl.q}/n_{.klq} - (d_{...} - c_{..})\hat{\sigma}^2(e)\right]}{\left[N - \sum_{klqj}\sum\sum\sum n^2_{jklq}/n_{.klq}\right]}$$

where:

$\hat{\sigma}^2(e)$ is the mean squared error from the above model; its value is zero since all samples within a maturity category, state/district, month and year have the same parameter estimate. Specification of the model without the year-term would result in the MSE being the ANOVA estimator of the between-year component of variance with identical results;

$d_{...} - c_{..}$ is the degrees of freedom for the between-years sums of squares;

N is the total number of samples forecasts were computed for using estimates of this parameter;

n_{jklq} is the number of samples forecasts were computed for using the estimated parameter for the q^{th} maturity category, l^{th} state/district, k^{th} month and j^{th} year.

The dot subscript notation denotes the customary summation over the indicated subscript.

Caution should be exercised in interpreting this measure of stability. As previously defined, $\hat{\sigma}^2(\delta)$ is a biased estimate of the variance. The bias arises as a result of the lack of independence in parameter estimates from year to year. Assuming parameter estimates are positively correlated between years within a maturity category, month and state, $\hat{\sigma}^2(\delta)$ will understate the true variance of the parameters. As the number of years used to estimate the parameters is increased, this bias will increase substantially unless there is some strong periodic relationship in the parameter estimates. It is beyond the scope of this study to develop and compute unbiased estimates of the variance for the parameters.

RESULTS

Forecast Errors

Regional level forecast errors are presented in Table 1. Results for individual states are contained in the Appendix, Tables A-1 through A-10.

There are three notable patterns in the tables. First, within any month and year, the forecast errors are almost the same, regardless of the number of years used to develop the forecast equations. Second, although there is generally an improvement in the accuracy of the forecasts from August to September, there is no substantial gain between September and October. In the operational program, the forecasts do converge toward the final gross yield in October, but apparently this is due to the inclusion of data from samples which have already been harvested. Third, the forecast procedures are upward biased. A preponderance of the forecast errors are positive, and the positive forecast errors are an order of magnitude larger than the negative errors. On the average, forecasts were more than seven bushels per acre higher than final gross yield. Much of this error is due to overestimating yields in 1980 and 1983. Yields were substantially below average during both of these years due to poor weather conditions.

These observations are based solely on the data from these five years. Extreme care should be exercised in extrapolating conclusions beyond this time period. Generally speaking, the patterns observed for the ten-state region also hold for the individual states.

TABLE 1: Ten-State Region Corn Objective Yield Forecast Errors

			Forecast Error (Bu/Acre)		
Year	Month	N	3 Years in Model	4 Years in Model	5 Years in Model
80	August	723	14.43	11.06	8.97
	September	1131	6.80	4.61	4.48
	October	566	7.31	5.54	4.37
81	August	708	-5.04	-5.64	-7.54
	September	1124	-0.90	-0.78	-2.09
	October	968	0.40	-0.31	-1.51
82	August	735	4.00	3.84	3.51
	September	1155	5.72	5.41	4.98
	October	906	6.45	5.84	5.64
83	August	679	30.68	32.51	32.11
	September	1354	23.20	24.50	23.98
	October	449	21.05	22.29	22.26
84	August	733	-0.88	-0.66	2.49
	September	1471	0.53	1.34	3.76
	October	848	2.40	2.04	4.33
80-84	Average				
	August	3578	8.64	8.22	7.91
	September	6235	7.07	7.02	7.02
	October	3737	7.52	7.08	7.02
	All Months	13550	7.74	7.44	7.32
80-84	Average Absolute				
	August	3578	11.00	10.74	10.92
	September	6235	7.43	7.33	7.86
	October	3737	7.52	7.20	7.62
	All Months	13550	8.65	8.42	8.80
80-84	Average Squared				
	August	3578	238.27	245.18	237.39
	September	6235	123.60	130.67	127.70
	October	3737	108.83	113.20	113.47
	All Months	13550	156.90	163.02	159.52

Test for Treatment Differences

ANOVA tables for the ten-state region are presented below. Table 2 contains the results for the absolute forecast error response; Table 3, the results for the squared forecast error response.

TABLE 2: ANOVA Table - Ten State Region
Absolute Forecast Error as the Response Variable

Source	df	Sum of Squares	Mean Square	F	PR>F
Treatment	2	1.08	0.54	0.36	0.70
Years	4	3500.97	875.24	577.85	
Months(Years)	10	299.09	29.91	19.75	
Error	28	42.41	1.51		
TOTAL (CFM)	44	3843.55			

TABLE 3: ANOVA Table - Ten State Region
Squared Forecast Error as the Response Variable

Source	df	Sum of Squares	Mean Square	F	PR>F
Treatment	2	282.51	141.25	0.18	0.83
Years	4	3139812.52	785953.13		
Months(Years)	10	508437.39	50843.74		
Error	28	21400.89	764.32		
TOTAL (CFM)	44	3669933.31			

The hypothesis tests for equality of treatment means, both for the ten-state region and for the individual states, do not detect any significant differences between treatments for either the average absolute forecast error or the average squared forecast error. For treatment differences to be significant at the α=.05 level, differences in average absolute forecast errors of 1.2 bu/acre for the ten-state region, and 0.9 to 2.8 bu/acre for individual states would be required. For average squared forecast errors, differences of 26 at the regional level, and 14 to 187 for the states, would have been required for them to be declared significant. The significance levels reported above depend on the underlying assumptions being satisfied.

The normality assumption appears reasonable with the absolute forecast error response but not with the squared error response based upon a test that the residuals are a random sample from a normal distribution using the Shapiro-Wilk statistic [5]. Moderate departures from the equal variance assumption were observed for both responses. Sample intraclass correlation coefficients computed between all pairs of residuals within treatments were not significantly different from zero, lending credibility to the independence assumption.

The extent of violation of the underlying assumptions would be of major concern if a significant or nearly significant result were obtained from the tests. However, it is doubtful that any test would be capable of detecting the small observed differences between treatments, either for the average absolute or average squared forecast error.

Stability of Parameter Estimates

As expected, the parameter estimates are more stable between years as the number of years of data used to develop the forecast equations is increased. The measure of stability, STAB, is presented in Table 4. It is a gross measure of the relative change in parameter estimates from year to year. Models 1 and 2 are the regression models for number of ears; models 3 and 4, for average grain weight per ear [7,p.15B-5].

Table 4: Stability of Estimated Parameters

	3 Years		4 Years		5 Years	
MODEL	Int.	Slope	Int.	Slope	Int.	Slope
1	232	33	207	29	166	24
2	280	136	245	132	244	131
3	211	109	193	95	167	81
4	779	64	794	48	783	42

Model 2 is not actually a regression model; it is a ratio estimator, the denominator of which is a forecast from an estimated regression relationship. The stability shown above for model 2 pertains to the stability of the estimated parameters for the regression model used in the denominator.

CONCLUSIONS AND DISCUSSION

There is no appreciable difference in the level of forecast errors when the forecast equations are developed from the previous three, four or five years' data. In years with average or high yields - 1981, 1982 and 1984 - the forecast errors are quite reasonable. However, in years with low yields, especially 1983, the forecast errors are very large. Furthermore, forecast errors do not change much between September and October forecasts. These two factors indicate that the variables being used in the models are not sensitive to changes in conditions and/or that the models are incorrect, i.e. the relationships being estimated are not the same from year to year. There is considerable evidence of the latter, judging from the amount the parameter estimates change from year to year.

Changing to the use of five years' data does make the parameter estimates more stable. Changing to the use of 10 or 20 years would make them more stable. A logical extension would be the use of constant forecast equations, instead of estimating the parameters each year. The dangers of doing this should be apparent. If the relationship is not the same from year to year, but we force stability in the parameter estimates by increasing the number of years of data used, the large positive covariances between years could easily increase the true variance of the parameter estimates, resulting in less accurate forecasts. In other words, the greater the number of years of data used to estimate the forecast equations, the less sensitive the forecast equations will be to changes in crop technologies, weather and other factors. It's important to bear in mind that the purpose of the yield models is not to estimate parameters, but to produce forecasts of yield. Increasing the number of years of data used did not increase the accuracy of the forecasts for the years included in this empirical study. This change in procedures only serves to mask the the very real problems which exist with the current yield forecast models - namely insensitivity to weather and other factors changing between years.

RECOMMENDATIONS

The number of years of data used to develop the forecast equations should not be further increased without sound theoretical or empirical evidence that the accuracy of the forecasts will be improved.

The tables in this report provide a benchmark of the performance of the operational objective yield forecast models. When substantive changes in the operational program are recommended, the impact of these changes on the level of the forecasts should be computed and, when appropriate, compared against this benchmark. Furthermore, the Crop Reporting Board should be informed of the level of change in forecasts, or forecast errors, which will result from the proposed change in procedures.

Development and examination of empirical or theoretical estimates of the variance/covariance structure of the components of the sample-level forecasts would shed considerable light on the major strengths and weaknesses of the current forecast models. This variance/covariance structure should include appropriate terms for interactions between estimated parameters which arise through the use of the multiplicative yield model. This topic should receive high priority.

Alternative modeling techniques and variables need to be examined to develop better forecasts. Some techniques currently being explored such as production models [1], probability models [2], improved grain weight per ear models [6], and computer intensive data fitting methods should receive strong emphasis.

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TABLE A-1: Illinois Corn Objective Yield Forecast Errors

			Forecast Error (Bu/Acre)		
Year	Month	N	3 Years in Model	4 Years in Model	5 Years in Model
80	August	108	29.43	29.14	27.93
	September	222	10.01	8.36	9.02
	October	30	16.59	15.75	14.22
81	August	103	-12.86	-13.36	-13.13
	September	216	-8.90	-9.00	-10.53
	October	115	-7.10	-8.01	-8.94
82	August	109	8.40	7.04	7.27
	September	212	2.48	1.36	1.23
	October	71	9.62	7.55	7.12
83	August	95	37.52	41.29	40.83
	September	193	23.38	24.47	23.50
	October	59	17.52	20.62	20.12
84	August	111	8.63	6.39	11.64
	September	222	7.32	6.13	9.57
	October	92	1.47	0.48	4.81
80-84	Average				
	August	526	14.22	14.10	14.91
	September	1065	6.86	6.26	6.56
	October	367	7.62	7.28	7.47
	All Months	1958	9.57	9.21	9.64
80-84	Average Absolute				
	August	526	19.37	19.44	20.16
	September	1065	10.42	9.87	10.77
	October	367	10.46	10.48	11.04
	All Months	1958	13.42	13.26	13.99
80-84	Average Squared				
	August	526	516.79	564.55	561.62
	September	1065	157.18	157.82	167.53
	October	367	145.52	158.94	152.13
	All Months	1958	273.16	293.77	293.76

TABLE A-2: Indiana Corn Objective Yield Forecast Errors

			Forecast Error (Bu/Acre)		
Year	Month	N	3 Years in Model	4 Years in Model	5 Years in Model
80	August	84	12.98	13.35	10.67
	September	172	8.96	8.94	9.19
	October	47	10.93	10.82	10.33
81	August	85	-6.42	-5.68	-5.11
	September	162	-0.69	-0.34	-3.20
	October	135	0.82	-0.38	-0.44
82	August	85	-8.88	-9.49	-7.78
	September	174	-8.03	-7.26	-7.83
	October	40	-10.30	-9.77	-10.29
83	August	76	40.66	41.77	41.26
	September	155	21.25	22.60	23.08
	October	42	22.10	22.18	22.34
84	August	80	-12.83	-13.08	-10.23
	September	165	-12.50	-13.17	-10.36
	October	95	-12.87	-16.19	-14.29
80-84	Average				
	August	410	5.10	5.37	5.76
	September	828	1.80	2.15	2.18
	October	359	2.14	1.33	1.53
	All Months	1597	3.01	2.95	3.16
80-84	Average Absolute				
	August	410	16.35	16.67	15.01
	September	828	10.29	10.46	10.73
	October	359	11.40	11.87	11.54
	All Months	1597	12.68	13.00	12.43
80-84	Average Squared				
	August	410	421.21	443.26	401.52
	September	828	150.65	163.36	159.22
	October	359	176.09	193.30	183.21
	All Months	1597	249.32	266.64	247.98

TABLE A-3: Iowa Corn Objective Yield Forecast Errors

Year	Month	N	Forecast Error (Bu/Acre) 3 Years in Model	4 Years in Model	5 Years in Model
80	August	100	3.73	0.87	-1.52
	September	203	1.41	0.00	-0.67
	October	35	4.45	2.88	0.12
81	August	107	-5.37	-10.74	-11.14
	September	210	-0.94	-1.21	-1.37
	October	118	-1.82	-2.30	-3.26
82	August	105	13.00	12.52	9.02
	September	209	14.70	14.04	13.07
	October	169	16.31	15.59	14.95
83	August	94	40.06	41.32	41.40
	September	186	33.01	34.03	33.58
	October	25	30.86	33.00	32.90
84	August	97	1.03	4.90	7.72
	September	194	7.79	10.32	12.94
	October	64	8.01	7.27	10.22
80-84	Average				
	August	504	10.49	9.77	9.10
	September	1002	11.19	11.44	11.51
	October	411	11.56	11.29	10.99
	All Months	1917	11.08	10.83	10.53
80-84	Average Absolute				
	August	504	12.64	14.07	14.16
	September	1002	11.57	11.92	12.33
	October	411	12.29	12.21	12.29
	All Months	1917	12.17	12.73	12.92
80-84	Average Squared				
	August	504	363.56	400.80	396.26
	September	1002	273.84	292.60	293.64
	October	411	261.09	279.70	284.17
	All Months	1917	299.50	324.37	324.69

TABLE A-4: Michigan Corn Objective Yield Forecast Errors

Year	Month	N	Forecast Error (Bu/Acre) 3 Years in Model	4 Years in Model	5 Years in Model
80	August	47	0.70	-3.05	-4.11
	September	47	2.99	0.84	1.35
	October	90	0.85	-2.86	-3.45
81	August	42	-0.63	0.56	-2.52
	September	42	2.29	1.97	-0.33
	October	64	2.38	2.53	0.26
82	August	46	-4.77	-6.72	-5.52
	September	46	2.32	3.45	1.92
	October	71	2.71	2.28	2.23
83	August	40	7.00	7.66	5.73
	September	77	10.23	11.75	10.15
	October	59	8.44	8.85	8.00
84	August	43	19.97	20.88	21.87
	September	84	10.77	11.60	12.98
	October	63	8.37	9.12	10.37
80-84	Average				
	August	218	4.45	3.87	3.09
	September	296	5.72	5.92	5.21
	October	347	4.55	3.98	3.48
	All Months	861	4.91	4.59	3.93
80-84	Average Absolute				
	August	218	6.61	7.78	7.95
	September	296	5.72	5.92	5.34
	October	347	4.55	5.12	4.86
	All Months	861	5.63	6.28	6.05
80-84	Average Squared				
	August	218	94.26	109.86	112.99
	September	296	48.04	57.83	55.40
	October	347	31.00	36.23	37.69
	All Months	861	57.77	67.97	68.70

TABLE A-5: Minnesota Corn Objective Yield Forecast Errors

Year	Month	N	Forecast Error (Bu/Acre) 3 Years in Model	4 Years in Model	5 Years in Model
80	August	78	3.19	-4.30	-7.05
	September	147	-0.74	-2.82	-2.91
	October	121	-5.37	-6.42	-5.77
81	August	69	-8.00	-6.89	-11.59
	September	135	-4.01	-4.06	-4.99
	October	107	-0.92	-0.87	-1.27
82	August	70	-3.57	-2.60	-1.35
	September	148	-1.24	-1.33	-1.45
	October	134	0.09	-0.06	0.06
83	August	60	31.47	28.82	29.33
	September	134	25.89	24.37	24.24
	October	64	18.48	16.47	16.24
84	August	79	2.11	3.30	2.73
	September	161	0.55	1.42	1.06
	October	141	7.56	8.84	7.72
80-84	Average				
	August	356	5.04	3.67	2.41
	September	725	4.09	3.52	3.19
	October	567	3.87	3.59	3.40
	All Months	1648	4.37	3.59	3.00
80-84	Average Absolute				
	August	356	9.67	9.18	10.41
	September	725	6.48	6.80	6.93
	October	567	6.49	6.53	6.21
	All Months	1648	7.55	7.50	7.85
80-84	Average Squared				
	August	356	216.44	182.79	210.67
	September	725	137.72	124.40	124.81
	October	567	85.69	78.27	71.61
	All Months	1648	146.62	128.49	135.70

TABLE A-6: Missouri Corn Objective Yield Forecast Errors

			Forecast Error (Bu/Acre)		
Year	Month	N	3 Years in Model	4 Years in Model	5 Years in Model
80	August	47	38.64	33.03	31.04
	September	78	14.72	12.40	10.08
	October	3	25.04	21.85	20.55
81	August	48	-31.82	-30.45	-30.41
	September	104	-16.27	-16.31	-17.92
	October	17	3.61	-0.87	-2.94
82	August	61	10.45	8.57	4.44
	September	106	10.98	10.08	8.38
	October	30	16.37	13.70	12.23
83	August	53	41.32	53.27	53.30
	September	86	29.07	32.57	31.53
	October	6	17.38	14.25	16.99
84	August	57	5.57	-1.17	6.92
	September	108	11.88	8.90	15.64
	October	19	8.98	8.00	13.28
80-84	Average				
	August	266	12.83	12.65	13.06
	September	482	10.08	9.53	9.54
	October	75	14.28	11.39	12.02
	All Months	823	12.40	11.19	11.54
80-84	Average Absolute				
	August	266	25.56	25.30	25.22
	September	482	16.58	16.05	16.71
	October	75	14.28	11.73	13.20
	All Months	823	18.81	17.70	18.38
80-84	Average Squared				
	August	266	870.63	986.13	959.39
	September	482	317.66	332.31	346.37
	October	75	258.17	186.61	209.17
	All Months	823	482.15	501.68	504.98

TABLE A-7: Nebraska Corn Objective Yield Forecast Errors

Year	Month	N	Forecast Error (Bu/Acre) 3 Years in Model	4 Years in Model	5 Years in Model
80	August	82	38.14	29.78	27.90
	September	83	24.03	17.19	17.25
	October	23	10.61	5.45	5.33
81	August	88	-1.27	0.84	-5.45
	September	89	1.99	3.70	0.73
	October	105	4.88	3.84	-0.09
82	August	84	1.40	4.51	5.26
	September	84	14.10	13.69	14.07
	October	151	15.41	15.16	14.99
83	August	94	20.85	24.15	26.76
	September	187	17.63	22.14	21.35
	October	20	32.46	35.24	35.35
84	August	94	-5.50	-10.57	-5.61
	September	183	-4.29	-3.92	-0.78
	October	75	3.85	3.32	6.36
80-84	Average				
	August	442	10.72	9.74	9.77
	September	626	10.69	10.56	10.52
	October	374	13.44	12.60	12.39
	All Months	1442	11.62	10.97	10.89
80-84	Average Absolute				
	August	442	13.43	13.97	14.20
	September	626	12.41	12.13	10.84
	October	374	13.44	12.60	12.42
	All Months	1442	13.09	12.90	12.49
80-84	Average Squared				
	August	442	384.56	320.59	316.63
	September	626	221.90	200.42	190.51
	October	374	288.42	305.40	308.67
	All Months	1442	298.30	275.47	271.93

TABLE A-8: Ohio Corn Objective Yield Forecast Errors

Year	Month	N	Forecast Error (Bu/Acre) 3 Years in Model	4 Years in Model	5 Years in Model
80	August	72	-0.26	0.67	-2.299
	September	73	5.48	5.96	3.85
	October	43	4.57	4.87	3.90
81	August	66	18.09	19.40	20.65
	September	66	18.13	18.71	19.52
	October	120	14.11	15.07	15.97
82	August	79	1.53	2.92	3.23
	September	80	5.39	7.04	6.84
	October	55	-10.14	-8.65	-7.32
83	August	74	24.84	23.59	24.22
	September	151	20.75	21.89	22.24
	October	51	6.32	6.65	7.28
84	August	75	-21.98	-16.97	-14.96
	September	148	-21.46	-17.97	-15.87
	October	112	-11.00	-10.26	-9.78
80-84	Average				
	August	366	4.44	5.92	6.17
	September	518	5.66	7.13	7.32
	October	381	0.77	1.53	2.01
	All Months	1265	3.62	4.86	5.17
80-84	Average Absolute				
	August	366	13.34	12.71	13.07
	September	518	14.24	14.31	13.66
	October	381	9.23	9.10	8.85
	All Months	1265	12.27	12.04	11.86
80-84	Average Squared				
	August	366	285.87	245.97	250.60
	September	518	255.81	247.39	237.78
	October	381	96.75	95.03	94.54
	All Months	1265	212.81	196.13	194.31

TABLE A-9: South Dakota Corn Objective Yield Forecast Errors

Year	Month	N	Forecast Error (Bu/Acre) 3 Years in Model	4 Years in Model	5 Years in Model
80	August	40	13.04	4.73	1.93
	September	39	2.94	-6.07	-4.37
	October	52	1.97	0.94	-1.04
81	August	41	-0.10	1.48	-4.26
	September	42	7.14	6.61	2.64
	October	64	3.70	1.61	1.23
82	August	40	-2.72	-3.01	-2.68
	September	41	1.25	0.43	0.75
	October	74	0.42	0.63	1.68
83	August	35	12.53	15.58	14.83
	September	67	17.00	18.35	17.36
	October	13	17.38	19.58	19.82
84	August	40	-4.35	-5.15	-2.21
	September	87	-4.85	-4.08	-2.17
	October	71	2.53	3.38	4.18
80-84	Average				
	August	196	3.68	2.71	1.52
	September	276	4.70	3.04	2.84
	October	274	5.20	5.23	5.17
	All Months	746	4.53	3.67	3.18
80-84	Average Absolute				
	August	196	6.55	5.99	5.18
	September	276	6.64	7.11	5.46
	October	274	5.20	5.23	5.59
	All Months	746	6.13	6.11	5.41
80-84	Average Squared				
	August	196	70.66	60.55	50.76
	September	276	74.76	86.80	66.51
	October	274	65.28	79.71	83.18
	All Months	746	70.24	75.68	66.82

TABLE A-10: Wisconsin Corn Objective Yield Forecast Errors

			Forecast Error (Bu/Acre)		
Year	Month	N	3 Years in Model	4 Years in Model	5 Years in Model
80	August	65	-7.03	-11.66	-13.03
	September	67	-6.98	-6.95	-6.87
	October	122	-2.21	-5.70	-6.27
81	August	58	5.25	5.95	0.29
	September	58	4.81	4.38	5.16
	October	123	5.99	5.75	3.08
82	August	56	9.94	7.69	8.50
	September	55	7.21	5.99	5.42
	October	111	4.49	3.38	3.42
83	August	58	6.22	7.74	-2.16
	September	118	11.80	12.00	11.04
	October	110	8.42	8.87	8.24
84	August	57	-6.64	-3.69	-1.94
	September	119	-0.78	2.73	3.25
	October	116	5.50	8.55	9.66
80-84	Average				
	August	294	1.55	1.20	-1.67
	September	417	3.21	3.63	3.60
	October	582	4.44	4.17	3.63
	All Months	1293	3.07	3.00	1.85
80-84	Average Absolute				
	August	294	7.02	7.35	5.18
	September	417	6.32	6.41	6.35
	October	582	5.32	6.45	6.14
	All Months	1293	6.22	6.74	5.89
80-84	Average Squared				
	August	294	51.71	60.81	50.10
	September	417	52.75	50.96	47.13
	October	582	32.41	45.75	44.35
	All Months	1293	45.62	52.51	47.19