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Comparison of the CEAS and Thompson-type Models for Corn Yields in Iowa, Illinois, and Indiana

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ABSTRACT

The CEAS and Thompson-type regression models compared in this report use the basic input variables of year and monthly average temperature and total precipitation to predict corn yields in Iowa, Illinois and Indiana. Individual CEAS models are developed for each CRD and State using stepwise methods, often including stress variables based on estimates of PET and ET. The Thompson-type models were constructed for each state and CRD using meteorological variables. The fixed weather variables consist of 12 linear and quadratic terms expressed as deviations from normal weather. The CEAS models outperform the Thompson-type models based on the comparisons according to eight model characteristics. The accuracy of the CEAS model's predictions is higher in Iowa and Illinois. Both models tend to underestimate in above-average yielding years and overestimate in below-average yielding years.

Key Words: Model comparison, crop yield modeling, regression models, corn yield models, pooled models.

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*AgRISTARS is an acronym for Agriculture and Resources Inventory Systems Through Aerospace Remote Sensing. It is a multi-agency research program to meet some current and new information needs for the U. S. Department of Agriculture.

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INTRODUCTION

The Yield Evaluation Section of the Statistical Reporting Service (SRS) located in the Modeling Center, Columbia, Missouri, along with NOAA (National Oceanic and Atmospheric Administration, Department of Commerce) has been identifying potential crop yield models, developing methodologies for model evaluation and comparison, and documenting the evaluation and comparison of particular models. The early emphasis has been focused on simple models for estimating the yields of corn and soybeans in Iowa, Illinois and Indiana and the yields of spring wheat and barley in North Dakota and Minnesota. This research has been conducted as part of the AgRISTARS Project.

Two yield/weather models were identified for each crop to be evaluated individually and then compared. The models included in this first group are simple in several ways. The basic weather variables, consisting of average monthly temperature and total precipitation, are calculated for a calendar month and, therefore, do not utilize year to year fluctuation in planting dates and crop development stages. These weather variables are calculated as an average over climatic districts which have the same boundaries as crop reporting districts in the above states. Both models handle trend by using linear and or quadratic trend terms which are a function of the year number. The models are inexpensive to use and can be applied to any area with sufficient yield and weather data. The documentation of these models provides a benchmark level of performance which more sophisticated models would be expected to exceed.

The purpose of this report is to compare the performance of Thompson-type and CEAS models for estimating end-of-season corn yields in Iowa, Illinois and Indiana. At this time, operational use of these models by SRS is not being considered.

DESCRIPTION OF THE MODELS

The corn models compared in this report were developed on the basis of the relationship between yield per harvested area, technology expressed as a function of the year number, and/or variables derived from monthly weather data. The "straw man," simple linear trend model, is also included in the comparison since, "Any candidate model which cannot substantially outperform a straw man model is of questionable value" (Sebaugh, 1981).

Thompson-Type Models

Louis M. Thompson developed corn models (1969, 1980) in order to study the influence of weather on corn yields. He used state level yield and weather data from five states (Iowa, Illinois, Indiana, Ohio, and Missouri). The weather variables include (1) cumulative rainfall from the previous September through June, (2) July monthly rainfall, (3) August monthly rainfall, (4) June average temperature, (5) July average temperature, and (6) August average temperature. Each of these variables expressed as a departure from the regional normal appears in a linear and squared form.

Thompson has used two approaches, "pooled" and "unpooled." Details about these approaches may be found in French (1982) who compared their yield prediction ability and concluded "neither the pooled nor the unpooled Thompson-type models are consistently better than the other. Neither the paired sample statistical tests nor the indicators of yield reliability provide a clear indication that one method is preferable. The pooled model is superior for many of the indicators but has a problem with bias, and also requires more computer time and memory than the unpooled model." Since performance appears to be about equal between the pooled and unpooled methods, the authors chose to include the unpooled model in this comparison because of the added computer time and memory required for the pooled model.

Weather normals were based on the three state regional normals (1950-1980) to obtain state level yield estimates. For crop reporting district (CRD) level estimates, separate models for each CRD were developed using the same weather variables used for the state level models. Weather normals at this level are computed for each individual state. Thompson defined three trend terms for model development. The first trend term is the year minus 1929 for years 1930-1960 and the value 31 for years beyond 1960. The second is defined to be zero before 1961 and the year minus 1960 for later years. The third trend term is the square of the second trend term.

CEAS Models

The models were developed by the Climatic and Environmental Assessment Services (CEAS) (LeDuc, 1980) to predict state and CRD level yields. CEAS is now known as the Assessment and Information Services Center (AISC). AISC is part of the National Oceanic and Atmospheric Administration (NOAA) within the U. S. Department of Commerce.

Separate models were developed for each CRD and state. Basic weather data input is average monthly temperature and total monthly precipitation. Other variables derived from these data include cumulative precipitation, departures from normal (DFN), and DFN squared. Also included are the agroclimatic variables based on estimates of monthly potential evapotranspiration (PET) and actual evapotranspiration (ET) which were developed by Thornthwaite (1948) and Palmer (1965). Iowa and Illinois have a single linear trend term, defined as year minus 1950. Three trend terms were defined for Indiana, only two of which were selected for any one model. One is a linear trend from 1930 to 1980, the second a linear trend from 1930 to 1951, and the third a linear increase from 1951 to 1980.

Pooled models were also developed for each state. Kestle (1982) compared the yield prediction ability of the pooled and unpooled models. Each state model may be used to predict yields at the CRD level which can be aggregated to a state level yield prediction. Kestle suggested that the unpooled models be used for the prediction of CRD yields rather than the pooled CRD models.

Straw Man Models

The straw man model is a simple linear regression of yield on year (1950=0). Kestle (1981) and Sebaugh (1981) used the previous twenty-three years of data to estimate the coefficients in the prediction equation for a given test year. These models were developed as an exercise in developing and applying procedures for model evaluation and comparison. They are considered to be simple, inexpensive, and objective but not necessarily optimum for yield prediction even among the class of models which do not incorporate weather.

COMPARISON METHODOLOGY

Eight Model Characteristics To Be Compared

The document, Crop Yield Model Test and Evaluation Criteria, (Wilson, *et al*., 1980), states:

> "The model characteristics to be emphasized in the evaluation process are: yield indication reliability, objectivity, consistency with scientific knowledge, adequacy, timeliness, minimum costs, simplicity, and accurate current measures of modeled yield reliability."

The models will be compared using these characteristics. Each characteristic is discussed individually without regard to the other characteristics. The present discussion makes no presumption as to the relative importance of the characteristics.

Bootstrap Technique Used to Generate Indicators of Yield Reliability for the End-of-Season Models

Indicators of yield reliability (reviewed below) require that the parameters of the regression model be computed for a set of data and that a yield prediction be made based on that data for a given "test" year. The values required to generate indicators of yield reliability include the predicted yield, $\hat{Y}$, the observed (reported) yield, Y, and the difference between them, $d=\hat{Y}-Y$, for each test year. It is desirable that the data used to generate the parameters for the model not include data from the test year.

To accomplish this, a "bootstrap" technique is used. Years from an earlier base period are used to fit the model and obtain a prediction equation. The values of the independent variables for the test year following the base period are inserted into the equation and a predicted yield is generated. Then, that test year is added to the base period and the process is repeated for the next sequential test year. Continuing in this way, ten (1971-1980) predictions of yield are obtained, each independent of the data used to fit the model. Data through 1969 are used to fit prediction models for 1971 (1970, the corn blight year, having been omitted), data through 1971 are used to fit prediction models for 1972, etc.

Even though the data used to estimate the regression coefficients do not include the test year, this procedure does not result in a predicted yield which is totally independent of the data from the test year. Data from the seventies were used to select the variables which are included in the CEAS models and to determine the break points for trend. It is unrealistic to require model developers to develop ten models for each CRD and state which truly use only data up to but not including each test year. Since the procedures used by CEAS for variable selection and break point determination include subjective decisions, the process cannot be simulated accurately by the model evaluator. Therefore, the bootstrap procedure described above neither tests how well these models can perform in the future if the variable selection procedure is repeated nor how well the model developer can incorporate future changes in trend using the present weather variables. However, the bootstrap test procedure does provide a valid independent test of the models in their current form.

Quantitative Model Comparisons Are Based on the Same Data

Direct quantitative comparisons between models will be made for two of the previously mentioned criteria: (1) yield indication reliability and (2) accurate current measures of modeled yield reliability. The quantities involved are derived from the observed yields and the model predicted yields and standard errors of prediction obtained from independent bootstrap tests for each of ten years (1971-1980).

Weather and yield data from 1932 to 1979 were used to develop Indiana models. For Iowa and Illinois, however, corn for grain yields are only published as far back as 1956 and 1954, respectively. In order to increase the number of years of data available for evaluation purposes, a "special" Iowa and Illinois corn for grain data set was used to extend the weather and yield data set for each state back to 1950 (Kestle, 1982). In this "special" data set, harvested-for-grain areas were estimated based on relationships between areas harvested-for-grain and areas harvested-for-all purposes. Iowa yields were for-grain yields, but in Illinois yields for all purposes were used. While CEAS model developers did not have access to these extended years of data when first developing the corn yield models, major differences between model development and model evaluation coefficients due to these extra years of data are not expected.

In all three states, the crop year of 1970 was eliminated from model development because of the effect of corn blight on yields. The 1970 crop year was, therefore, also eliminated during model evaluations. USDA reported yields for each state are shown in Figures 1, 2, and 3.

The average production and yield over the ten year period are listed in Table 1 for each geographic area. Also shown is the percent production each crop reporting district (CRD) contributes to its state and the three state region and the percent production each state contributes to the region. The percentage of regional production for each CRD is show graphically in Figure 4. Darker shades indicate higher production.

Figure 1

U.S.D.A. reported state corn yields for Iowa
1950-1980 (quintals/hectare)

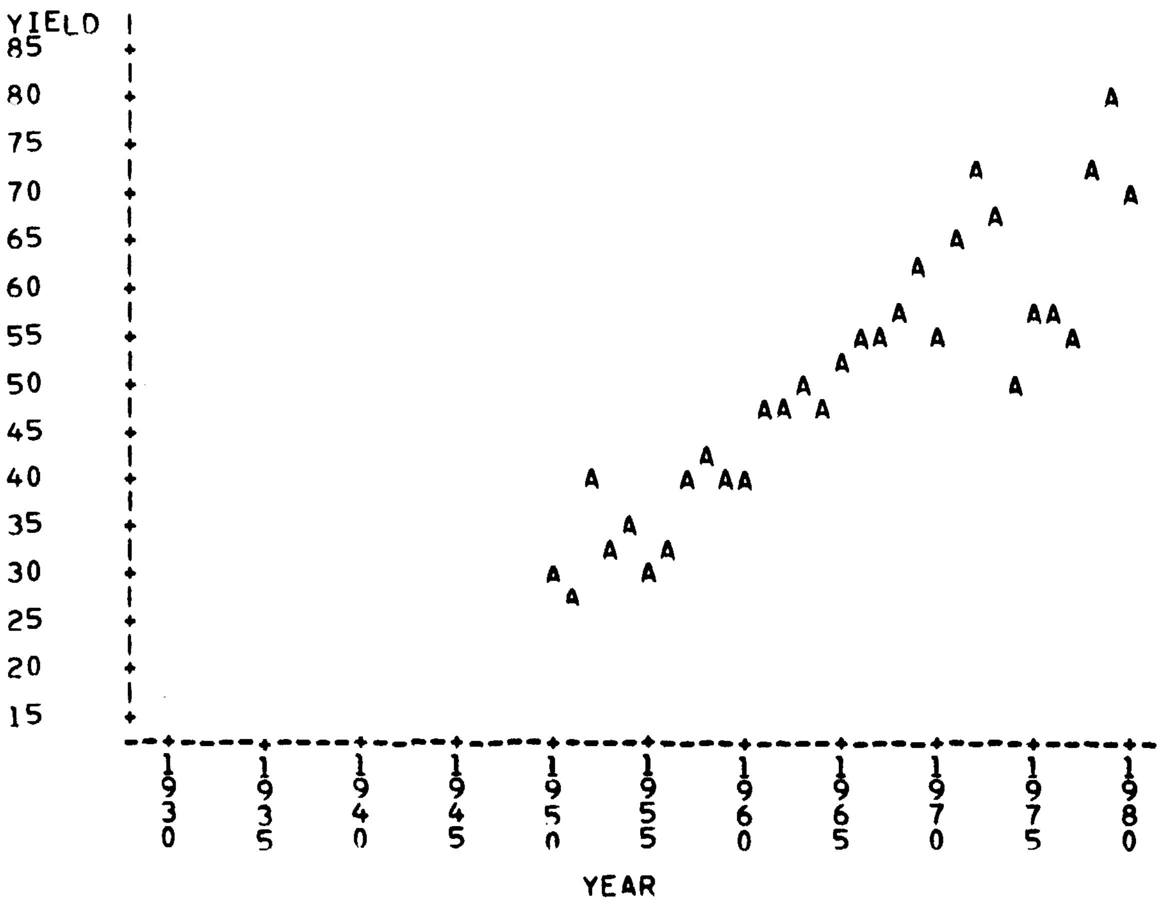


Figure 2

U.S.D.A. reported state corn yields for Illinois 1950–1980 (quintals/hectare)

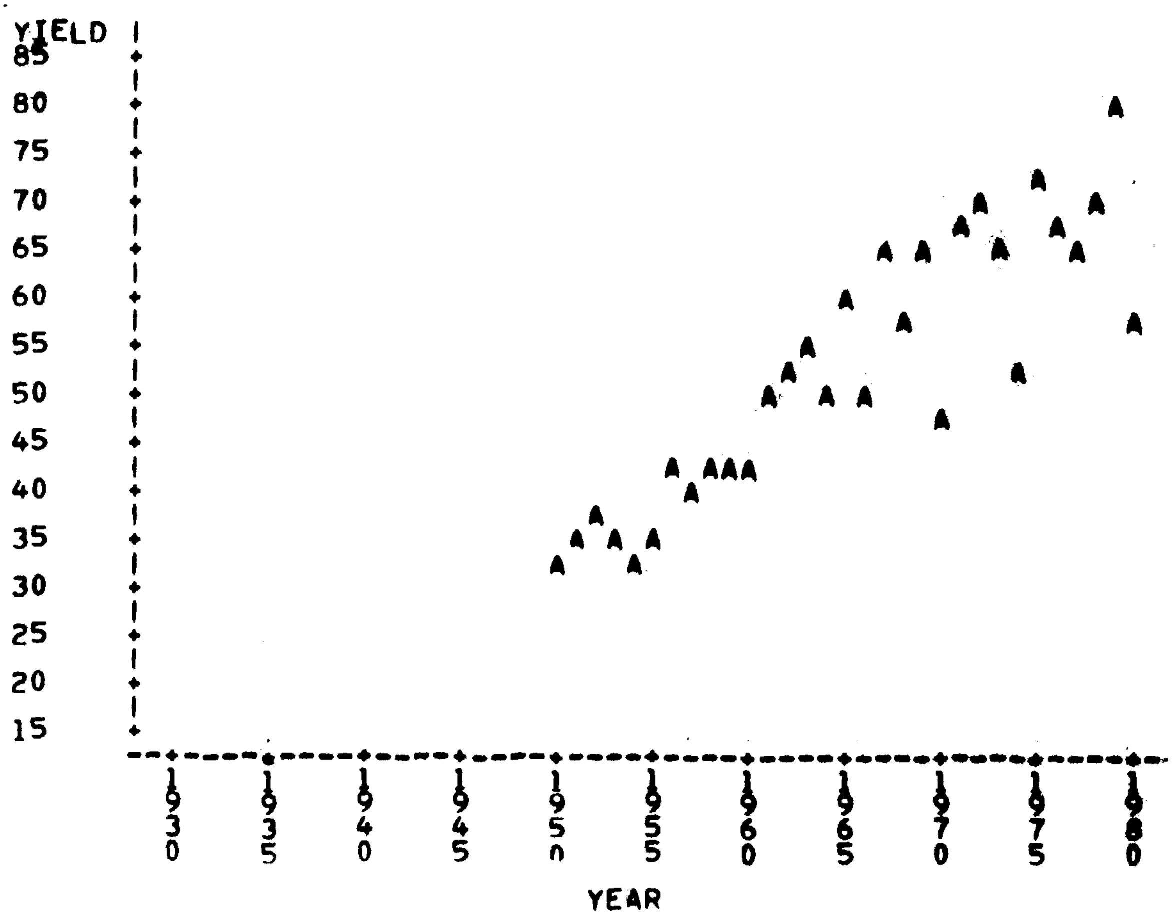


Figure 3

U.S.D.A. reported state corn yields for Indiana
1931-1980 (quintals/hectare)

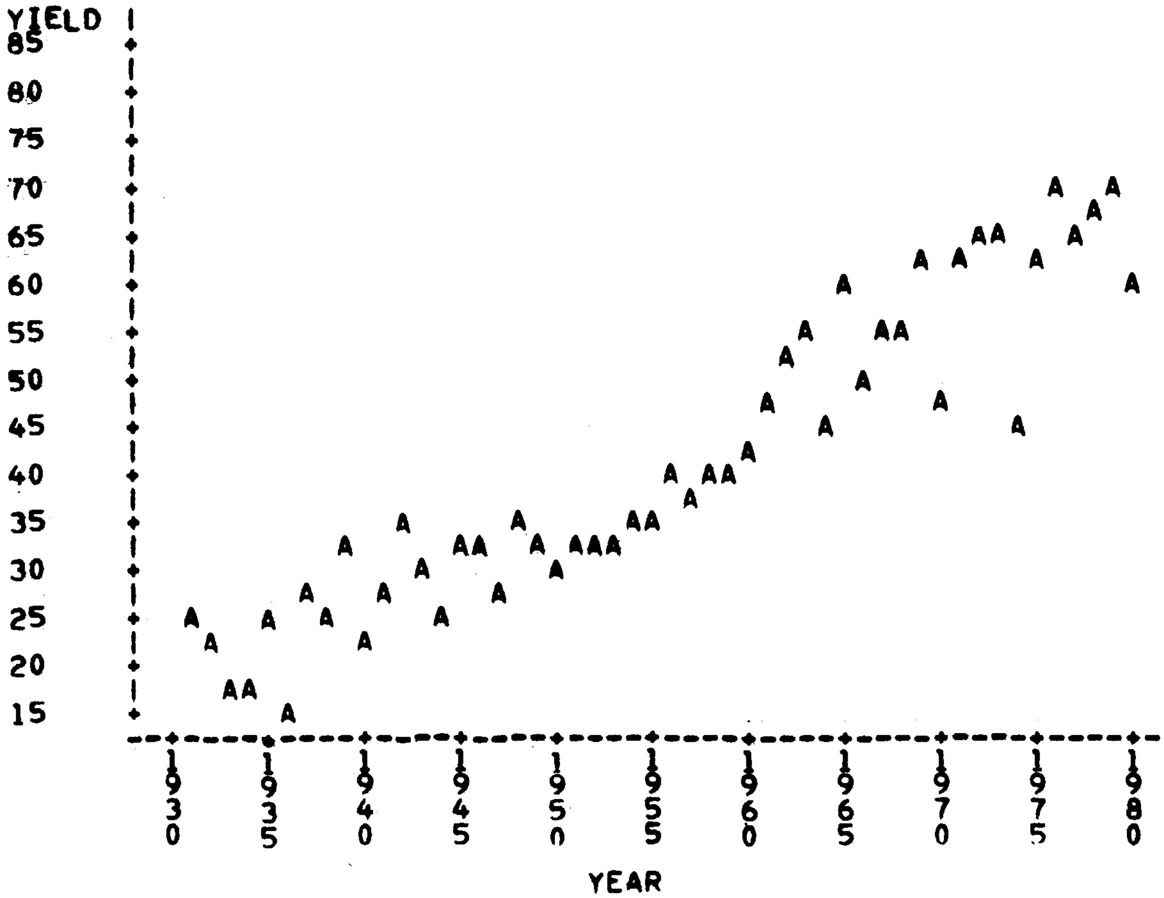
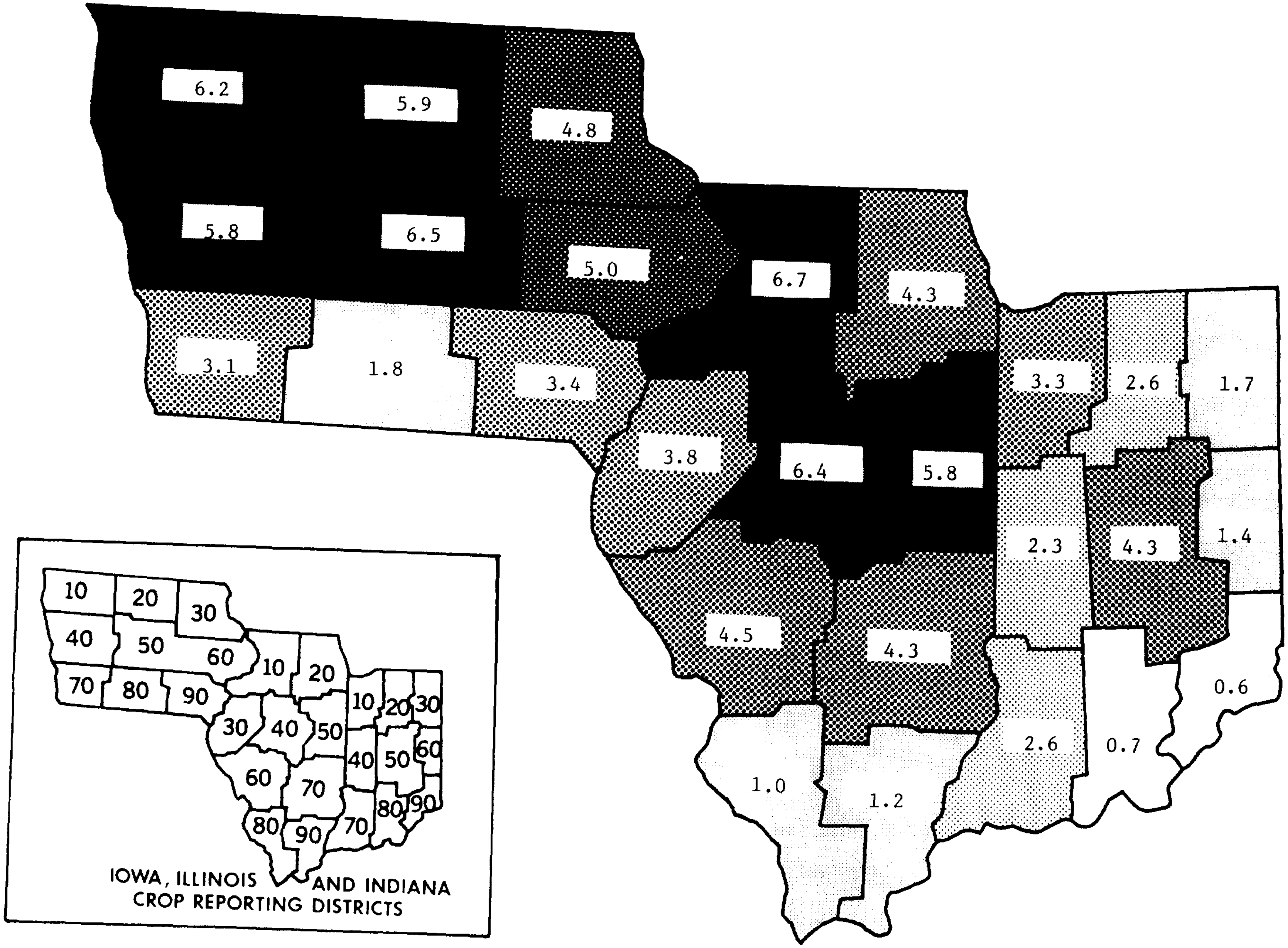


TABLE 1
AVERAGE PRODUCTION AND YIELD
FOR TEST YEARS 1971-80

CORN
IOWA, ILLINOIS, INDIANA

STATE	CRD	PRODUCTION (1,000) QUINTALS	PRODUCTION (1,000) BUSHELS	PERCENT OF STATE	PERCENT OF REGION	YIELD QNTL/HA	YIELD BU/ACRE
IOWA	10	46,530	183,190	14.6	6.2	64.2	102.3
	20	44,543	175,368	14.0	5.9	68.4	109.0
	30	35,941	141,501	11.3	4.8	66.7	106.3
	40	43,409	170,903	13.6	5.8	58.7	93.6
	50	49,051	193,114	15.4	6.5	67.6	107.7
	60	37,453	147,454	11.7	5.0	68.1	108.5
	70	23,069	90,822	7.2	3.1	57.2	91.1
	80	13,333	52,493	4.2	1.8	54.6	87.1
	90	25,974	102,258	8.1	3.4	66.1	105.4
STATE		319,304	1,257,101		42.4	64.3	102.4
ILLINOIS	10	50,811	200,042	17.7	6.7	67.9	108.1
	20	32,060	126,220	11.2	4.3	66.5	106.0
	30	28,847	113,570	10.1	3.8	67.5	107.6
	40	47,942	188,749	16.7	6.4	71.5	113.8
	50	44,044	173,400	15.4	5.8	70.1	111.7
	60	33,595	132,262	11.7	4.5	67.2	107.0
	70	32,185	126,711	11.2	4.3	64.3	102.4
	80	7,698	30,305	2.7	1.0	48.9	77.9
	90	9,182	36,150	3.2	1.2	49.6	79.0
STATE		286,362	1,127,410		38.0	66.6	106.1
INDIANA	10	24,926	98,133	16.9	3.3	64.8	103.2
	20	19,683	77,491	13.3	2.6	60.4	96.3
	30	13,089	51,531	8.9	1.7	58.0	92.5
	40	17,651	69,490	12.0	2.3	65.7	104.7
	50	32,569	128,224	22.1	4.3	66.7	106.2
	60	10,484	41,274	7.1	1.4	62.3	99.2
	70	19,250	75,786	13.0	2.6	63.6	101.3
	80	5,436	21,401	3.7	0.7	57.3	91.3
	90	4,550	17,915	3.1	0.6	56.9	90.7
STATE		147,636	581,245		19.6	63.1	100.6
REGION		753,302	2,965,756			64.9	103.5

Figure 4. Production of corn by CRD (1971-1980 average) as a percentage of the regional total. Darker shades indicate CRDs with higher production.



Model predicted yields are derived for each CRD in Iowa, Illinois, and Indiana and for each of the three states. Predicted yields at the state level are also obtained by using an aggregated weighted average of that state's CRD predicted yields. Predicted yields for the region are obtained both by aggregating the CRD predicted yields and the state level predicted yields. In all cases, the weighting factor used is corn harvested acreage. Results obtained by aggregating from the state level predicted yields are identified as "states aggr."

Review of Indicators of Yield Reliability

The Y, $\hat{Y}$ and d values for the ten-year test period at each geographic area may be summarized into various indicators of yield reliability. These indicators are considered to be descriptive statistics which are useful in characterizing model performance and are also discussed in Wilson and Sebaugh (1981). Formulas are given in an appendix (p. 51).

Indicators Based on the Difference Between $\hat{Y}$ and Y ($d=\hat{Y}-Y$) Demonstrate Accuracy, Precision and Bias

The d values provide estimates of the mean square error (root and relative root mean square error), the variance (standard deviation and relative standard deviation), and the bias (its square and the relative bias).

The root mean square error (RMSE) and the standard deviation (SD) indicate the accuracy and precision of the model and are expressed in the original units of measure (quintals/hectare). Assuming the d values are normally distributed, it is about 68% probable that the absolute values of d for a future year will be less than one RMSE and 95% probable that it will be less than twice the RMSE. So, accurate prediction capability is indicated by a small RMSE. A non-zero bias means the model is, on the average, overestimating the yield (positive bias) or underestimating the yield (negative bias). The SD is smaller than the RMSE when there is non-zero bias and indicates what the RMSE would be if there were no bias. If the bias is near zero, the SD and the RMSE will be close in value. A model whose bias is close to zero is preferred.

Indicators Based on Relative Differences Between $\hat{Y}$ and Y ($rd=100d/Y$) Demonstrate Worst and Best Performance

The relative difference, rd, is an especially useful indicator in years where a low actual yield is not predicted accurately. This is because years with samll observed actual yields and large differences often have the largest rd values.

Several indicators are derived using relative differences. In order to calculate the proportion of years beyond a critical error limit, we count the number of years in which the absolute value of the relative difference exceeds the critical limit of 10 percent. Values between 5 and 25 percent were investigated and a critical limit of 10 percent was found most useful in describing model performance. The worst and next to worst performance during the test period are defined as the largest and next to largest absolute value of the relative difference. The range of yield indication accuracy is defined by the largest and smallest absolute values of the relative difference.

Indicators Based on $\hat{Y}$ and Y Demonstrate Correspondence Between Observed and Predicted Yields

Another set of indicators demonstrates the correspondence between observed and predicted yields. It is desirable for increases in observed yield to be accompanied by increases in predicted yields. It is also desirable for large (small) predicted yields to correspond to large (small) observed yields.

Two indicators relate the change in direction of observed yields to the corresponding change in predicted yields. One looks at change from the previous year (nine observations) and the other at change from the average of the previous three years (seven observations). A base period of three years is used since a longer base period would further decrease the number of observations, while a shorter period would not be very different from the comparison to a single previous year.

Finally, the Pearson correlation coefficient, r, between the set of observed and predicted values for the test years is computed. It is desirable that $r(-1 \leq r \leq +1)$ be large and positive. A negative r indicates smaller predicted yields occurring with larger observed yields (and vice versa).

Models Are Ranked According to Performance

Models are ranked for each of the following indicators of yield reliability (order does not imply relative importance):

(1) the bias

(2) the root mean square error (RMSE)

(3) the standard deviation (SD)

(4) the percent of years the absolute value of the relative difference exceeds ten percent

(5) the largest absolute value of the relative difference

(6) the next largest absolute value of the relative difference

(7) the percent of years in which the direction of change from the previous year in the $\hat{Y}$'s agrees with the Y's

(8) the percent of years in which the direction of change from the average of the previous three years in the $\hat{Y}$'s agrees with the Y's and

(9) the Pearson correlation coefficient between the observed and predicted yields during the independent test years.

For most of the indicators (1-6), the model with the numeric value closest to zero exhibits the best performance in terms of yield reliability and is given a rank of one. For the remaining quantities, the model with the largest value exhibits the most desirable performance. If models have the same level of performance for an indicator, they are assigned the lower rank for which they are tied.

It should be remembered that the models are ranked only in relation to each other and not to an absolute standard. Therefore, saying that a particular model performs best or is superior to or more desirable than another model does not necessarily imply that the model is the best of all possible models. It is the best of only those with which it is currently being compared.

Models Are Compared Using Statistical Tests Based on $d=\hat{Y}-Y$

In cases where differences in philosophy or approach have led to the development of different models, it is particularly desirable to run a statistical test comparing the reliability of the competing models. A formal statistical test considers the variability of model performance over time and allows the user to specify an upper limit on the probability of incorrectly declaring one model better than another. This probability is known as α, the level of significance, or the Type I error.

However, although desirable, it is challenging to construct meaningful statistical tests comparing the reliability of two yield models. Only models with some acknowledged degree of success usually reach the stage of formal comparison with other competing models. Therefore, *a priori*, great differences between the reliability of the models are not expected. A powerful statistical procedure is needed which is able to detect small, although important, differences in reliability. Also, the test should be able to function well with relatively small samples of data for each model, say ten years.

The test should also perform well when only two models are being compared. Often only two models of a particular type, for example, two monthly weather data models or two daily weather data models, are competitive and available for testing. When models of different types are to be compared, it is unlikely that all possible model comparisons will be made. It is more likely that the best models of each type will be compared.

It would appear that an F test could be useful in comparing the mean square errors of two models. However, if the mean square errors are based on ten years of test data and $\alpha = .05$, then one model's mean square error must be four times larger than another's before the models can be declared different. This is an unreasonable requirement since models which are in the evaluation process will almost always be more competitive than this.

A test may be constructed by considering that one model is considered more reliable than another model if its predicted yields, $\hat{Y}$'s, are closer to the actual yields, Y's. No difference in the reliability of two models for a particular year means that the absolute value of the difference between their predicted yields and the observed yield is the same. The absolute value of the difference is used because in assessing yield indication reliability one is equally concerned with overestimates and with underestimates. The reliability of a model for that year is related to the amount of the discrepancy, not its direction. We may define $|d_1| = |\hat{Y}_1 - Y|$, $|d_2| = |\hat{Y}_2 - Y|$, and $D = |d_1| - |d_2|$. Then the models are equally reliable in a year for which D equals zero. If d is not equal to zero, one model is more reliable than the other for that year. In formal terms, we want to test the null hypothesis that there is no difference in the reliability of the models over all years. To do so the values of D from the ten test years may be used to compute a test statistic and a decision made whether or not to reject the null hypothesis. Since the results for the models are paired each year, paired-sample statistical tests are used.

Two types of paired-sample statistical tests are used: a parametric test using the student "t" test statistic and a nonparametric test using the Wilcoxon signed rank test statistic. One reason for applying both tests is that they require different assumptions. The parametric t-test assumes the D values are normally distributed while the nonparametric test does not. The d values may be considered to be approximately normally distributed. The $|d|$ values would then be folded normals rather than normally distributed. Although both models are folded at $|d| = 0$, their means may be different and the distribution of D has a possibility of not being normally distributed. The t-test is robust with respect to the normality assumption; however, this possible violation of the assumption is one reason for also running the nonparametric test. Formulas for these tests are given in an Appendix (p. 52).

The other reason for running both tests concerns the conditions under which the null hypothesis is rejected by each test. Using the parametric test, the basis for rejecting the null hypothesis is the average size of the D values as compared to their variability since the test statistic is the average of the sample D's divided by the sample standard error of the D's. The hypothesis will be rejected and and the model with the smaller $|d|$ values declared more reliable if t is large (either positive or negative). However, it is possible that one model could have a smaller $|d|$ value for each of the test years, in other words, be very consistent in outperforming the other model, and still the null hypothesis may not be rejected by the parametric test unless the average value of D is large enough. The parametric test implicitly requires that one model have more years with smaller $|d|$ values than the other model and explicitly requires that, on the average, the $|d|$ values be smaller by a sufficient amount before that model may be declared more reliable.

Using the nonparametric test, the null hypothesis will always be rejected if one model has smaller $|d|$ values for each of the test years, regardless of the magnitude of the D values. Therefore, if the models are very competitive in terms of the $|d|$ values each year, but one model consistently, although slightly outperforms the other model, the nonparametric test will still declare the consistent model to be more reliable.

The hypothesis of equal performance will only be rejected by the nonparametric test if one model has more years with smaller $|d|$ values than the other model. The model with more smaller $|d|$ values is considered the more reliable model in terms of consistency of performance. However, to reject the null hypothesis and declare one model clearly better than another, consistency of performance is not a sufficient requirement (although it is necessary). Consider the situation in which one model is more consistent than the other but the largest D values occur when the less consistent model performs better. In the few years the less consistent model performs better, it performs much better. A dilemma exists since one model is more consistent than the other, but the biggest differences between the models occur when the consistent model performs worse. The null hypothesis will not be rejected and the consistent model will not be declared better if this situation occurs. The null hypothesis will be rejected only if one model is more consistent and the biggest differences between the models occur when the consistent model performs better.

Model Performance Is Compared in Above Average Below Average, and Average Yielding Years

In yield modeling work, there is particular interest in the performance of models in unusual, particularly low yielding, years. Therefore, it is desirable to be able to identify unusually high and low yielding years and to compare the performance of the models in those years.

In order to identify different types of yielding years for each state, the following analysis was performed. The intercept, trend and weather coefficients were estimated using all data through 1980 for the three CEAS state models and for the three Thompson-type state models. Predicted yields for each model were then calculated at the state level for all years through 1980 using trend with normal (average) values for the weather variables. Each year, the average of these predicted values for the CEAS and Thompson-type models was calculated. The five years whose observed yields exceeded these predicted values the most were identified as above average yielding years and the five years whose observed yields were the furthest below these normal yields were identified as below average yielding years. The remaining years were identified as average yielding years. Since the data base in Iowa and Illinois begins in 1950, years from 1950 through 1980 in all three states (except 1970) are identified in terms of their yield level. An appendix shows the years identified as below average and above average for each state (p. 54).

The performance of the CEAS and Thompson-type models can then be examined for each type of yielding year. The predicted values calculated for each model from 1950 to 1980 are obtained using the same coefficients estimated above but with the actual, observed weather for each year. The average of the absolute value of the residual, and the lowest and highest residual are reported for below average, above average, and average years using the CEAS and the Thompson-type models in each state.

MODEL COMPARISON

Indicators of Yield Reliability Based on $d=\hat{Y}-Y$ Show the Thompson-Type Model Has the Smallest Bias But the CEAS Model Has the Smallest Root Mean Square Error and Standard Deviation

The model values and comparative ranks for the bias, the root mean square error (RMSE), and the standard deviation (SD) are given in Tables 2, 3, and 4. The Thompson-type model has the smallest bias more often at the CRD level (15 out of 27 times). It is ranked 1 at the state level in Illinois and Indiana, at the state level aggregated by CRDs, and at the regional level aggregated by CRDs in all three states.

However, the CEAS model demonstrates the most accuracy. It has the smallest root mean square error in 23 of the 27 CRDs (85%) at the state level in Iowa (both using the state level model and aggregating from the CRD models), using the state level model in Indiana, and at the regional level. The relative performance of the CEAS and Thompson-type models is the same for the standard deviation as for the root mean square error, except at the state level in

TABLE 2
MODEL COMPARISON BASED ON THE
BIAS (QUINTALS/HECTARE)
DERIVED FROM INDEPENDENT TEST YEARS

TREND AND MONTHLY WEATHER DATA MODELS
CORN
IOWA, ILLINOIS, INDIANA

STATE	CRD	STRAW MAN BIAS	STRAW MAN RANK	THOMPSON BIAS	THOMPSON RANK	CEAS BIAS	CEAS RANK
IOWA	10	1.29	(2)	-0.36	(1)	1.32	(3)
	20	2.21	(3)	-0.49	(1)	1.27	(2)
	30	-1.09	(1)	3.65	(3)	-1.44	(2)
	40	6.15	(3)	-1.99	(1)	4.44	(2)
	50	4.45	(3)	2.75	(2)	0.88	(1)
	60	2.51	(2)	0.95	(1)	2.63	(3)
	70	5.29	(2)	5.31	(3)	2.70	(1)
	80	4.64	(3)	3.91	(1)	3.93	(2)
	90	2.61	(3)	0.97	(1)	2.38	(2)
STATE MODEL		3.14	(3)	2.76	(2)	1.28	(1)
CRDS AGGR.		3.08	(3)	1.20	(1)	1.90	(2)
ILLINOIS	10	1.74	(2)	1.62	(1)	3.03	(3)
	20	1.03	(1)	-1.36	(2)	1.85	(3)
	30	2.92	(3)	-0.88	(1)	2.36	(2)
	40	5.31	(3)	4.48	(1)	4.88	(2)
	50	5.73	(2)	9.51	(3)	5.36	(1)
	60	4.84	(3)	-2.61	(2)	2.45	(1)
	70	4.84	(3)	1.51	(1)	2.14	(2)
	80	3.58	(3)	-2.93	(2)	1.58	(1)
	90	3.77	(3)	-0.94	(1)	1.10	(2)
STATE MODEL		3.78	(3)	1.35	(1)	3.74	(2)
CRDS AGGR.		3.79	(3)	1.89	(1)	3.17	(2)
INDIANA	10	6.28	(3)	-3.45	(1)	6.15	(2)
	20	2.16	(3)	1.39	(1)	1.59	(2)
	30	-0.24	(1)	0.64	(2)	-0.76	(3)
	40	4.21	(3)	-1.46	(1)	2.68	(2)
	50	1.81	(3)	1.00	(2)	-0.01	(1)
	60	-0.64	(1)	-1.22	(2)	-1.32	(3)
	70	4.41	(3)	-2.60	(2)	2.54	(1)
	80	3.16	(3)	-0.70	(1)	1.87	(2)
	90	3.27	(3)	-1.52	(2)	0.76	(1)
STATE MODEL		3.04	(3)	0.20	(1)	2.05	(2)
CRDS AGGR.		2.92	(3)	-0.77	(1)	1.77	(2)
REGION MODEL							
CRDS AGGR.		3.29	(3)	1.07	(1)	2.33	(2)
STATES AGGR.		3.33	(3)	1.75	(1)	2.36	(2)

TABLE 3
MODEL COMPARISON BASED ON THE
ROOT MEAN SQUARE ERROR (QUINTALS/HECTARE)
DERIVED FROM INDEPENDENT TEST YEARS

TREND AND MONTHLY WEATHER DATA MODELS
CORN
IOWA, ILLINOIS, INDIANA

STATE	CRD	STRAW MAN RMSE	STRAW MAN RANK	THOMPSON RMSE	THOMPSON RANK	CEAS RMSE	CEAS RANK
IOWA	10	11.11	(2)	13.52	(3)	8.73	(1)
	20	8.43	(2)	13.71	(3)	7.21	(1)
	30	7.09	(2)	13.12	(3)	6.04	(1)
	40	13.98	(3)	10.59	(2)	9.21	(1)
	50	13.37	(3)	11.54	(2)	6.59	(1)
	60	7.86	(2)	8.74	(3)	5.73	(1)
	70	15.89	(2)	17.14	(3)	12.24	(1)
	80	15.77	(3)	13.40	(1)	13.61	(2)
	90	11.06	(2)	13.23	(3)	10.58	(1)
STATE MODEL		10.13	(2)	12.59	(3)	6.60	(1)
CRDS AGGR.		10.13	(3)	9.48	(2)	7.21	(1)
ILLINOIS	10	7.60	(2)	8.51	(3)	5.05	(1)
	20	7.89	(2)	9.89	(3)	6.54	(1)
	30	9.59	(2)	9.80	(3)	7.86	(1)
	40	12.38	(3)	8.35	(1)	10.28	(2)
	50	13.41	(2)	14.38	(3)	10.51	(1)
	60	8.88	(2)	11.47	(3)	5.24	(1)
	70	9.92	(2)	10.88	(3)	6.70	(1)
	80	10.16	(3)	9.68	(2)	8.17	(1)
	90	8.83	(2)	10.57	(3)	5.85	(1)
STATE MODEL		8.86	(3)	6.36	(1)	7.02	(2)
CRDS AGGR.		8.89	(3)	6.30	(1)	6.34	(2)
INDIANA	10	11.57	(2)	12.51	(3)	10.16	(1)
	20	8.81	(3)	7.74	(2)	6.99	(1)
	30	7.81	(3)	4.57	(1)	5.15	(2)
	40	10.80	(3)	10.50	(2)	8.48	(1)
	50	7.80	(2)	7.97	(3)	6.38	(1)
	60	6.00	(2)	8.49	(3)	5.15	(1)
	70	6.71	(3)	3.99	(1)	5.10	(2)
	80	7.70	(3)	6.86	(2)	6.40	(1)
	90	6.48	(3)	5.68	(2)	4.85	(1)
STATE MODEL		7.83	(3)	6.78	(2)	6.19	(1)
CRDS AGGR.		7.79	(3)	5.52	(1)	5.81	(2)
REGION MODEL							
CRDS AGGR.		8.21	(3)	6.18	(2)	5.58	(1)
STATES AGGR.		8.22	(3)	7.04	(2)	5.80	(1)

TABLE 4
MODEL COMPARISON BASED ON THE
STANDARD DEVIATION (QUINTALS/HECTARE)
DERIVED FROM INDEPENDENT TEST YEARS

TREND AND MONTHLY WEATHER DATA MODELS
CORN
IOWA, ILLINOIS, INDIANA

STATE	CRD	STRAW MAN SD	STRAW MAN RANK	THOMPSON SD	THOMPSON RANK	CEAS SD	CEAS RANK
IOWA	10	11.03	(2)	13.51	(3)	8.63	(1)
	20	8.14	(2)	13.71	(3)	7.10	(1)
	30	7.00	(2)	12.60	(3)	5.87	(1)
	40	12.55	(3)	10.41	(2)	8.07	(1)
	50	12.61	(3)	11.21	(2)	6.53	(1)
	60	7.45	(2)	8.69	(3)	5.09	(1)
	70	14.98	(2)	16.30	(3)	11.94	(1)
	80	15.07	(3)	12.82	(1)	13.03	(2)
	90	10.75	(2)	13.20	(3)	10.31	(1)
STATE MODEL		9.63	(2)	12.29	(3)	6.48	(1)
CRDS AGGR.		9.65	(3)	9.40	(2)	6.95	(1)
ILLINOIS	10	7.39	(2)	8.35	(3)	4.05	(1)
	20	7.82	(2)	9.80	(3)	6.28	(1)
	30	9.14	(2)	9.76	(3)	7.50	(1)
	40	11.18	(3)	7.04	(1)	9.05	(2)
	50	12.13	(3)	10.78	(2)	9.16	(1)
	60	7.45	(2)	11.17	(3)	4.63	(1)
	70	8.66	(2)	10.77	(3)	6.35	(1)
	80	9.51	(3)	9.22	(2)	8.02	(1)
	90	7.98	(2)	10.53	(3)	5.74	(1)
STATE MODEL		8.01	(3)	6.21	(2)	5.95	(1)
CRDS AGGR.		8.04	(3)	6.02	(2)	5.49	(1)
INDIANA	10	9.71	(2)	12.02	(3)	8.09	(1)
	20	8.54	(3)	7.62	(2)	6.81	(1)
	30	7.81	(3)	4.53	(1)	5.10	(2)
	40	9.94	(2)	10.40	(3)	8.04	(1)
	50	7.59	(2)	7.91	(3)	6.38	(1)
	60	5.96	(2)	8.41	(3)	4.98	(1)
	70	5.06	(3)	3.02	(1)	4.42	(2)
	80	7.02	(3)	6.82	(2)	6.13	(1)
	90	5.60	(3)	5.47	(2)	4.79	(1)
STATE MODEL		7.22	(3)	6.78	(2)	5.85	(1)
CRDS AGGR.		7.22	(3)	5.46	(1)	5.53	(2)
REGION MODEL							
CRDS AGGR.		7.52	(3)	6.09	(2)	5.07	(1)
STATES AGGR.		7.51	(3)	6.82	(2)	5.30	(1)

Illinois. Figure 5 shows the best performing model in each CRD based on the root mean square error. The CEAS model generally performs better in the higher producing CRDs. The Thompson-type model actually performs worse than the straw man model in 16 of the 27 CRDs (59%).

Indicators of Yield Reliability Based on rd = 100d/Y Show the CEAS Model Performs Best

The model values and comparative ranks for the indicators of yield reliability based on the relative difference, rd, are shown in Tables 5, 6 and 7. These indicators are valuable for demonstrating the worst performance of a model. Therefore, the best performing model will have the smallest values for the percent of years the absolute value of the relative difference exceeds ten percent and for the largest and the next largest absolute value of the relative difference.

In 23 of 27 CRDs (85%), the CEAS model has the smallest (or is tied for the smallest) percent of years in which the absolute value of rd exceeds 10% (Figure 6). The CEAS model also performs better at the state and the regional level. The Thompson-type model performs worst, particularly in Illinois.

When considering the smallest values of the largest absolute relative difference (Figure 7), the Thompson-type model performs the best in Illinois and Indiana, and the CEAS model performs best in Iowa. Across the region, the CEAS model performs somewhat better in the higher production areas. The straw man model demonstrates the worst performance.

Considering the CEAS and Thompson models at the state level, the largest $|rd|$ for the CEAS model occurs in 1974 for Iowa and Indiana and in 1980 in Illinois. Also, 1974 had the largest $|rd|$ for the Thompson-type model in Iowa, but 1975 was the year with the largest $|rd|$ in Illinois and Indiana. All three states had low yields in 1974. In Illinois and Indiana 1980 was a below average year. In Iowa 1975 was a below average year and an above average year in Illinois. The section of the Appendix, Brief Description of Growing Conditions for Corn in the Bootstrap Test Years, provides information on individual test years.

In 16 of 27 CRDs (59%), the CEAS model has the smallest value of the next largest relative difference (Figure 8). Performance is mixed for the three models in the higher production areas. The CEAS model performs the best at the state level in Iowa and Indiana and at the regional level. The straw man model in general shows the worst performance.

Indicators of Yield Reliability Based on Y and $\hat{Y}$ Show the CEAS Model Performing Better

Plots of the observed and predicted yields over the ten year test period for each state model are displayed in Figures 9-11. The model values and the comparative ranks of the indicators of yield reliability based on Y and $\hat{Y}$ are given in Tables 8, 9, and 10. These indicators demonstrate the correspondence between observed and predicted yields.

Figure 5. Letter indicates the model with smallest root mean square error for corn yields based on test years 1971-1980. Darker shades indicate CRDs with higher production (C = CEAS, T = Thompson).

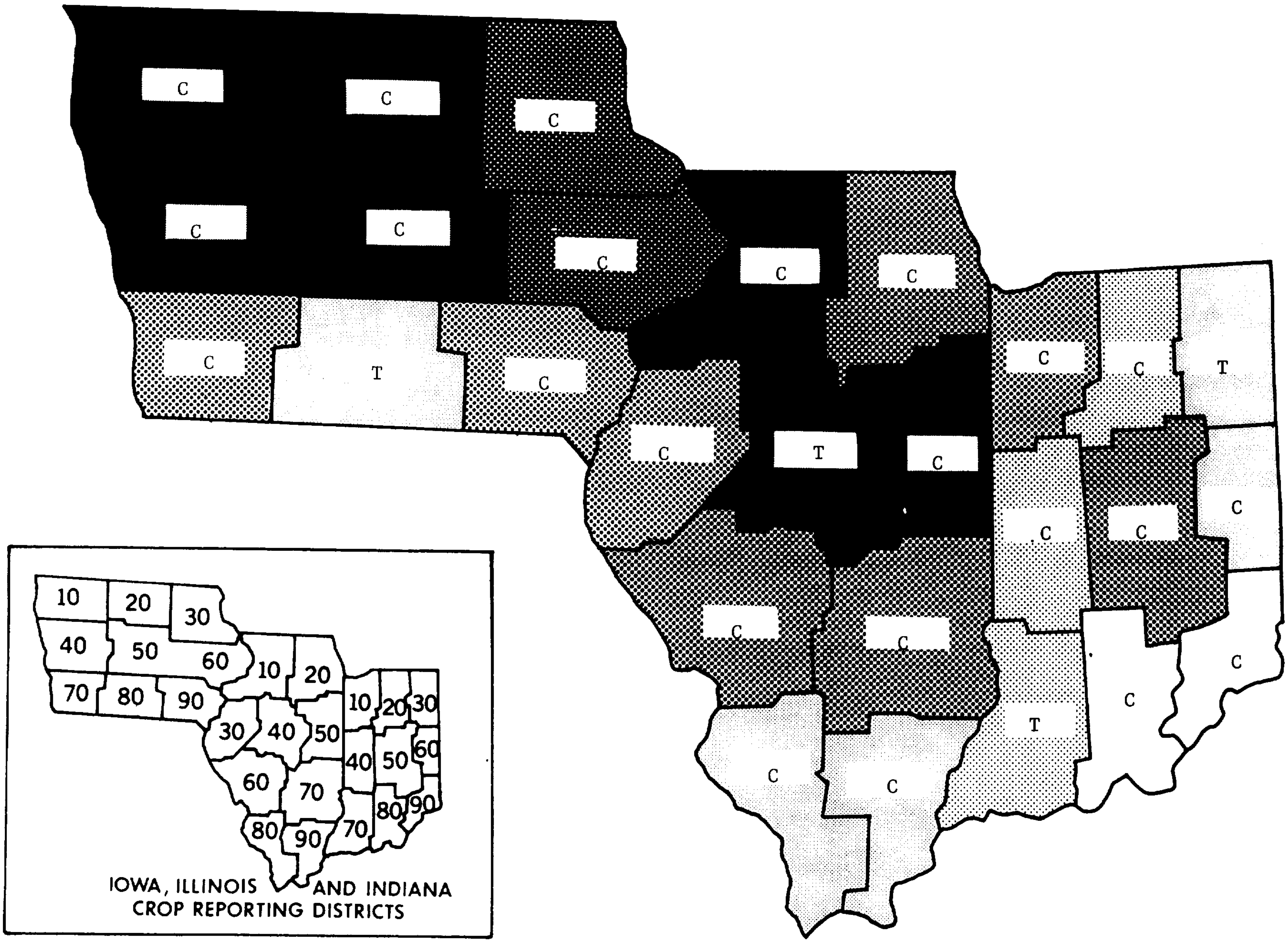


TABLE 5
MODEL COMPARISON BASED ON THE
PERCENT OF YEARS |RELATIVE DIFFERENCE| > 10%
DERIVED FROM INDEPENDENT TEST YEARS

TREND AND MONTHLY WEATHER DATA MODELS
CORN
IOWA, ILLINOIS, INDIANA

		MODEL					
		STRAW MAN		THOMPSON		CEAS	
STATE	CRD	%	RANK	%	RANK	$\bar{x}$	RANK
IOWA	10	60	(2)	80	(3)	50	(1)
	20	40	(2)	50	(3)	30	(1)
	30	50	(2)	80	(3)	40	(1)
	40	80	(3)	50	(1)	50	(1)
	50	60	(2)	60	(2)	40	(1)
	60	40	(2)	40	(2)	30	(1)
	70	60	(2)	70	(3)	50	(1)
	80	50	(3)	40	(1)	40	(1)
	90	60	(1)	70	(3)	60	(1)
STATE MODEL		60	(2)	60	(2)	20	(1)
CRDS AGGR.		60	(3)	50	(2)	30	(1)
ILLINOIS	10	20	(1)	30	(3)	20	(1)
	20	20	(2)	40	(3)	10	(1)
	30	40	(2)	60	(3)	30	(1)
	40	30	(1)	60	(3)	30	(1)
	50	40	(2)	50	(3)	30	(1)
	60	50	(2)	60	(3)	30	(1)
	70	20	(1)	50	(3)	20	(1)
	80	60	(1)	70	(3)	60	(1)
	90	60	(2)	90	(3)	40	(1)
STATE MODEL		20	(1)	40	(3)	20	(1)
CRDS AGGR.		20	(1)	30	(3)	20	(1)
INDIANA	10	30	(2)	50	(3)	20	(1)
	20	20	(1)	40	(3)	20	(1)
	30	20	(3)	10	(1)	10	(1)
	40	30	(2)	40	(3)	20	(1)
	50	20	(2)	40	(3)	10	(1)
	60	10	(1)	40	(3)	20	(2)
	70	20	(2)	10	(1)	20	(2)
	80	30	(1)	60	(3)	40	(2)
	90	30	(1)	30	(1)	40	(3)
STATE MODEL		20	(2)	30	(3)	10	(1)
CRDS AGGR.		20	(1)	20	(1)	20	(1)
REGION MODEL							
CRDS AGGR.		30	(2)	30	(2)	10	(1)
STATES AGGR.		30	(2)	30	(2)	10	(1)

TABLE 6
MODEL COMPARISON BASED ON THE
LARGEST |RELATIVE DIFFERENCE|
DERIVED FROM INDEPENDENT TEST YEARS

TREND AND MONTHLY WEATHER DATA MODELS
CORN
IOWA, ILLINOIS, INDIANA

		MODEL					
		STRAW MAN		THOMPSON		CEAS	
STATE	CRD	RD	RANK	RD	RANK	RD	RANK
IOWA	10	43.5	(3)	-35.2	(1)	36.7	(2)
	20	29.1	(2)	35.4	(3)	26.0	(1)
	30	18.8	(2)	39.1	(3)	18.4	(1)
	40	53.5	(3)	49.4	(2)	41.1	(1)
	50	80.1	(3)	44.7	(2)	18.6	(1)
	60	32.5	(3)	23.2	(2)	16.3	(1)
	70	122.3	(3)	121.3	(2)	111.7	(1)
	80	144.4	(3)	81.8	(1)	115.5	(2)
	90	49.4	(3)	33.9	(1)	44.8	(2)
STATE MODEL		38.2	(2)	48.0	(3)	33.3	(1)
CRDS AGGR.		38.2	(3)	33.9	(2)	29.9	(1)
ILLINOIS	10	41.5	(3)	33.6	(2)	23.6	(1)
	20	46.4	(3)	32.0	(1)	40.1	(2)
	30	34.9	(3)	22.2	(1)	34.2	(2)
	40	48.9	(3)	21.2	(1)	44.5	(2)
	50	61.2	(3)	48.4	(2)	48.2	(1)
	60	27.0	(2)	-31.7	(3)	13.5	(1)
	70	42.9	(3)	28.7	(1)	31.0	(2)
	80	72.2	(3)	42.2	(1)	46.7	(2)
	90	49.5	(3)	40.6	(2)	20.8	(1)
STATE MODEL		36.1	(3)	17.3	(1)	28.0	(2)
CRDS AGGR.		36.5	(3)	20.8	(1)	26.8	(2)
INDIANA	10	52.5	(3)	34.9	(1)	45.8	(2)
	20	58.1	(3)	46.9	(2)	43.6	(1)
	30	57.4	(3)	34.5	(1)	36.9	(2)
	40	66.6	(3)	-32.4	(1)	51.2	(2)
	50	43.5	(3)	34.3	(2)	31.4	(1)
	60	29.3	(3)	-27.4	(2)	16.7	(1)
	70	29.4	(3)	-14.9	(1)	25.6	(2)
	80	42.0	(3)	23.8	(1)	28.2	(2)
	90	26.3	(3)	-21.4	(2)	19.2	(1)
STATE MODEL		46.3	(3)	27.7	(1)	39.3	(2)
CRDS AGGR.		46.1	(3)	26.6	(1)	35.2	(2)
REGION MODEL							
CRDS AGGR.		39.0	(3)	27.7	(1)	29.7	(2)
STATES AGGR.		39.0	(3)	32.9	(2)	32.3	(1)

TABLE 7
MODEL COMPARISON BASED ON THE
NEXT LARGEST (RELATIVE DIFFERENCE)
DERIVED FROM INDEPENDENT TEST YEARS

TREND AND MONTHLY WEATHER DATA MODELS
CORN
IOWA, ILLINOIS, INDIANA

STATE	CRD	STRAW MAN RD	STRAW MAN RANK	THOMPSON RD	THOMPSON RANK	CEAS RD	CEAS RANK
IOWA	10	42.3	(3)	30.4	(1)	31.6	(2)
	20	20.3	(2)	-31.3	(3)	14.5	(1)
	30	-14.3	(2)	25.8	(3)	-11.5	(1)
	40	47.9	(3)	-20.9	(1)	33.4	(2)
	50	24.0	(2)	27.0	(3)	-15.0	(1)
	60	-12.9	(1)	22.8	(3)	15.3	(2)
	70	47.0	(2)	65.0	(3)	31.1	(1)
	80	63.8	(1)	73.0	(3)	64.6	(2)
	90	23.7	(2)	-29.5	(3)	23.4	(1)
STATE MODEL		25.4	(2)	35.6	(3)	12.6	(1)
CRDS AGGR.		25.4	(3)	-19.9	(2)	16.5	(1)
ILLINOIS	10	10.4	(1)	-13.9	(3)	12.1	(2)
	20	-11.2	(2)	-27.1	(3)	8.9	(1)
	30	21.4	(2)	-21.6	(3)	15.0	(1)
	40	40.6	(3)	19.8	(1)	32.2	(2)
	50	43.9	(3)	41.3	(2)	38.3	(1)
	60	23.8	(2)	28.2	(3)	11.9	(1)
	70	41.0	(3)	28.2	(2)	21.9	(1)
	80	24.0	(2)	28.7	(3)	22.1	(1)
	90	23.0	(2)	38.3	(3)	16.6	(1)
STATE MODEL		28.6	(3)	-14.4	(1)	25.7	(2)
CRDS AGGR.		28.4	(3)	13.9	(1)	21.2	(2)
INDIANA	10	47.1	(3)	-34.2	(1)	43.1	(2)
	20	22.3	(3)	16.5	(1)	21.2	(2)
	30	-11.0	(3)	-6.8	(1)	-7.7	(2)
	40	28.1	(3)	-22.9	(2)	19.3	(1)
	50	12.0	(2)	-16.5	(3)	-10.0	(1)
	60	-9.0	(1)	24.1	(3)	-12.2	(2)
	70	15.1	(3)	-7.3	(1)	10.9	(2)
	80	25.1	(3)	-17.1	(2)	16.0	(1)
	90	23.4	(3)	14.1	(2)	10.6	(1)
STATE MODEL		17.2	(2)	-22.8	(3)	9.5	(1)
CRDS AGGR.		17.1	(3)	-11.9	(2)	10.4	(1)
REGION MODEL							
CRDS AGGR.		14.5	(3)	-13.2	(2)	7.3	(1)
STATES AGGR.		14.7	(2)	17.6	(3)	8.4	(1)

Figure 6. Letter indicates the corn yield model(s) with smallest percent of test years (1971-1980) having absolute value of the relative difference greater than ten percent. Darker shades indicate CRDs with greater production (S = Straw man, T = Thompson, C = CEAS).

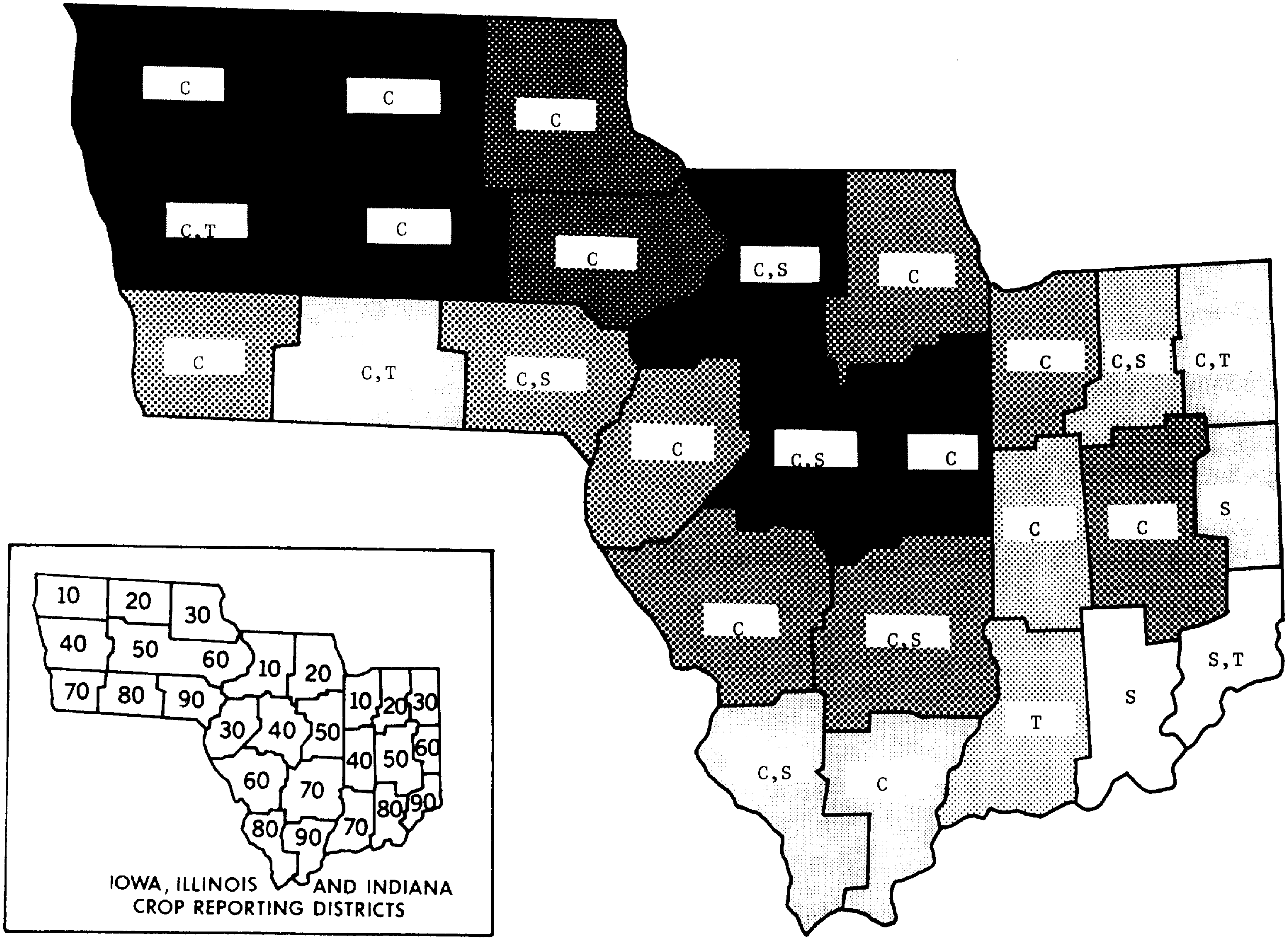


Figure 7. Letter indicates the corn yield model with smallest value of the largest absolute relative difference during the test years 1971-1980. Darker shades indicate CRDs with higher production (T = Thompson, C = CEAS).

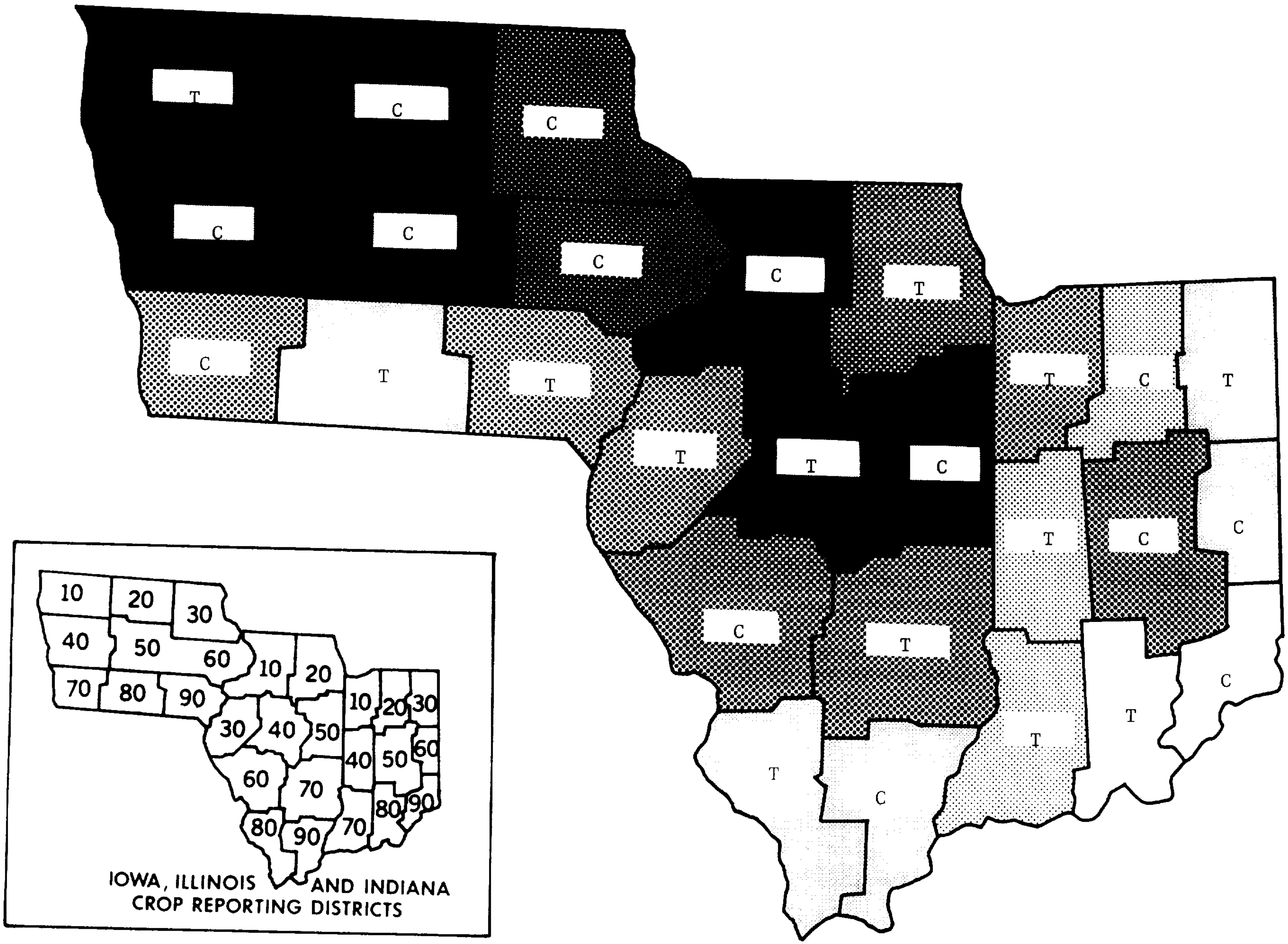


Figure 8. Letter indicates the corn yield model with smallest value of the next largest absolute relative difference during the test years 1971-1980. Darker shades indicate CRDs with higher production (S = Straw man, T = Thompson, C = CEAS).

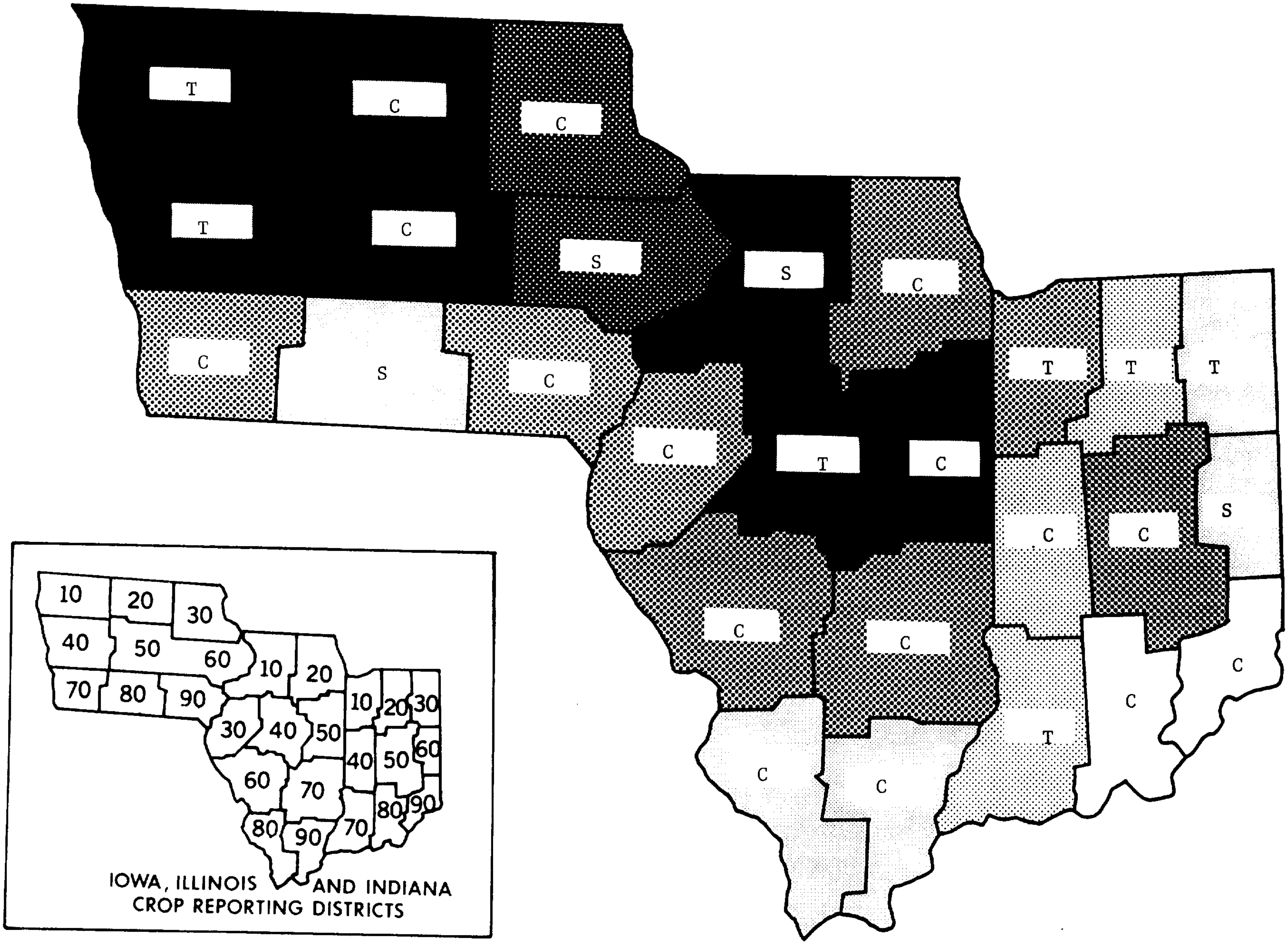


Figure 9

Iowa state model, reported and predicted corn yields
for the test years 1971-1980 (quintals/hectare)

A = Reported Yield
S = Straw man, C = CEAS, T = Thompson-type

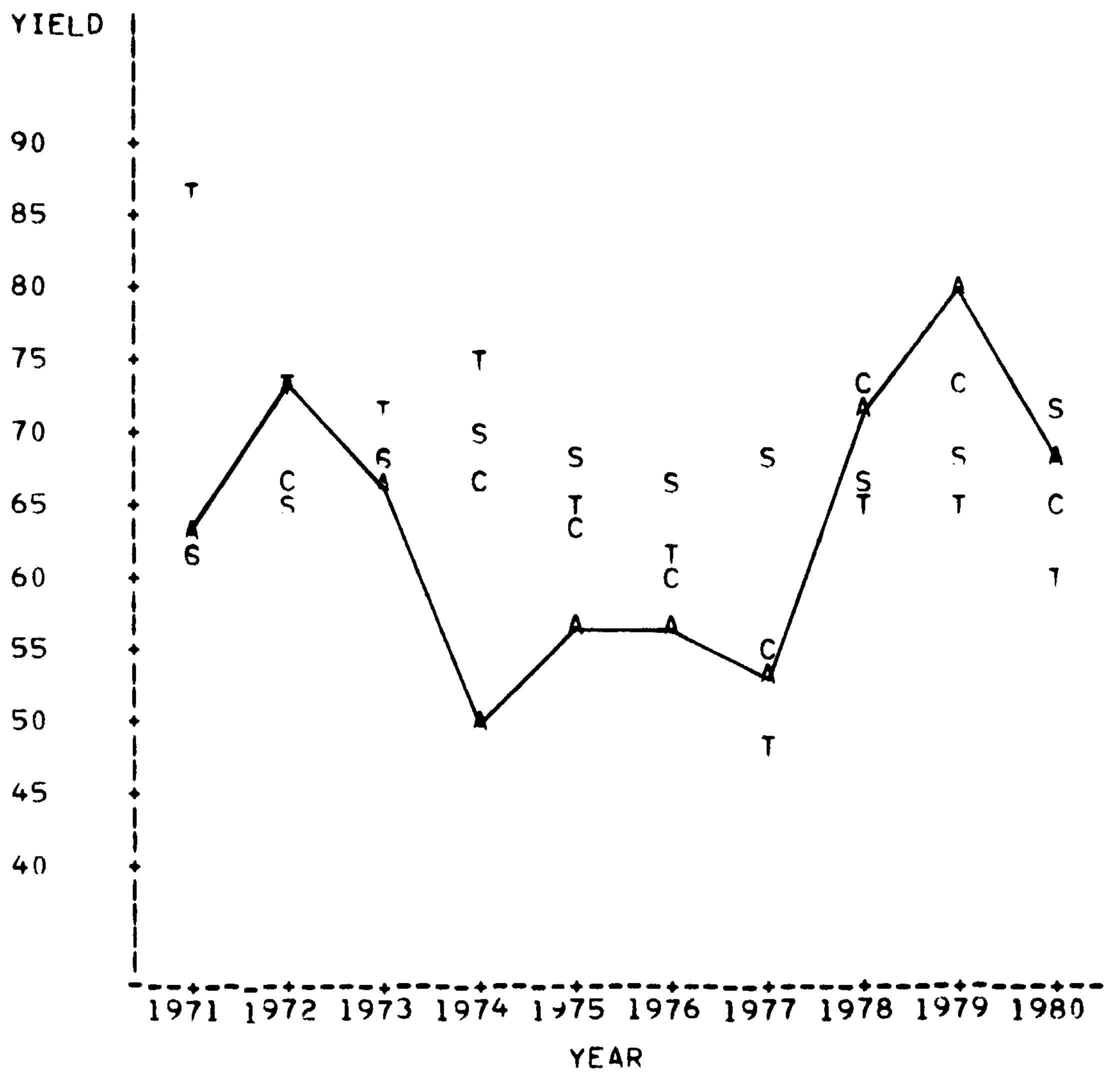


Figure 10

Illinois state model, reported and predicted corn yields
for the test years 1971-1980 (quintals/hectare)

A = Reported Yield
S = Straw man, C = CEAS, T = Thompson-type

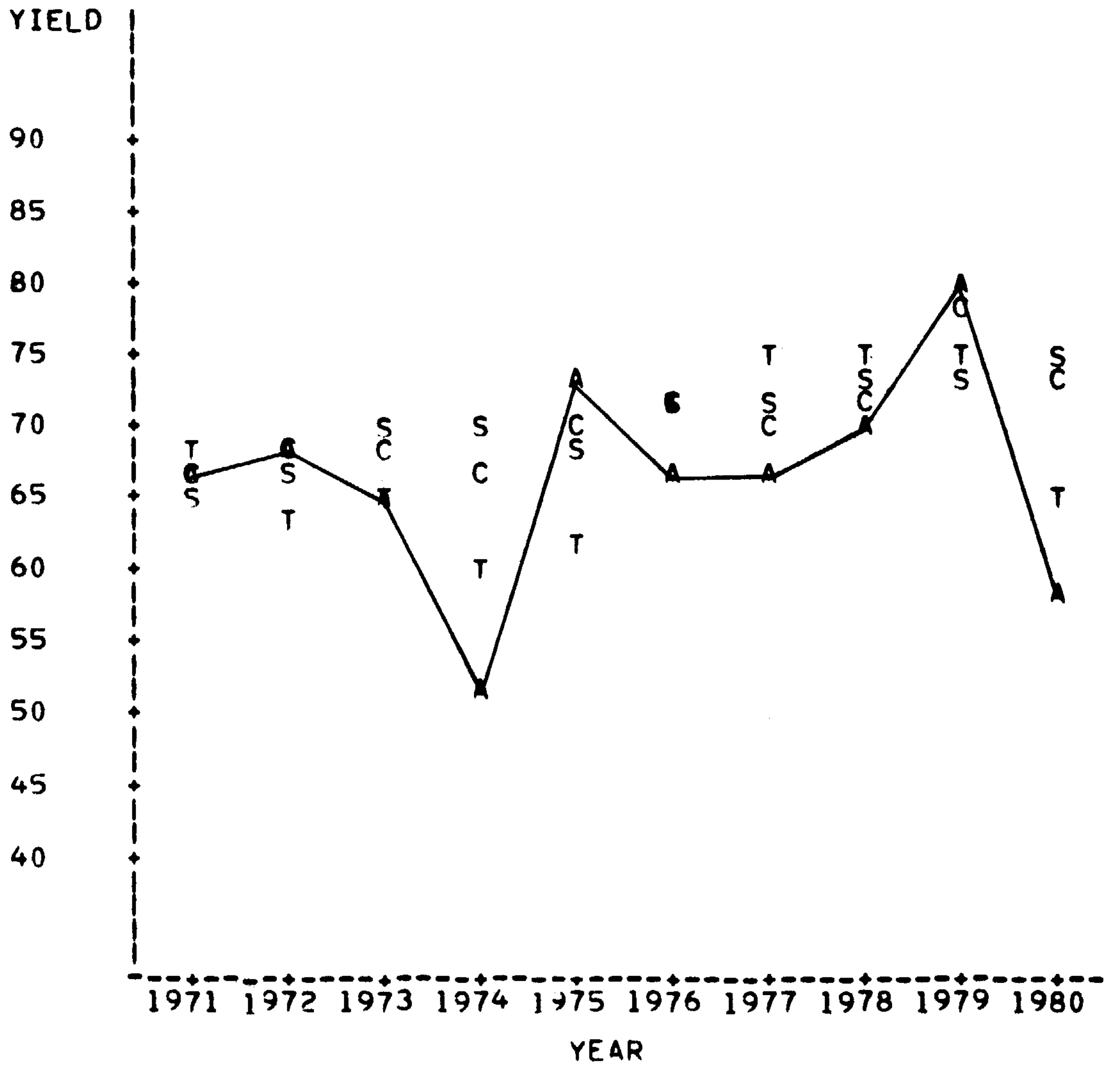


Figure 11

Indiana state model, reported and predicted corn yields
for the test years 1971-1980 (quintals/hectare)

A = Reported Yield
S = Straw man, C = CEAS, T = Thompson-type

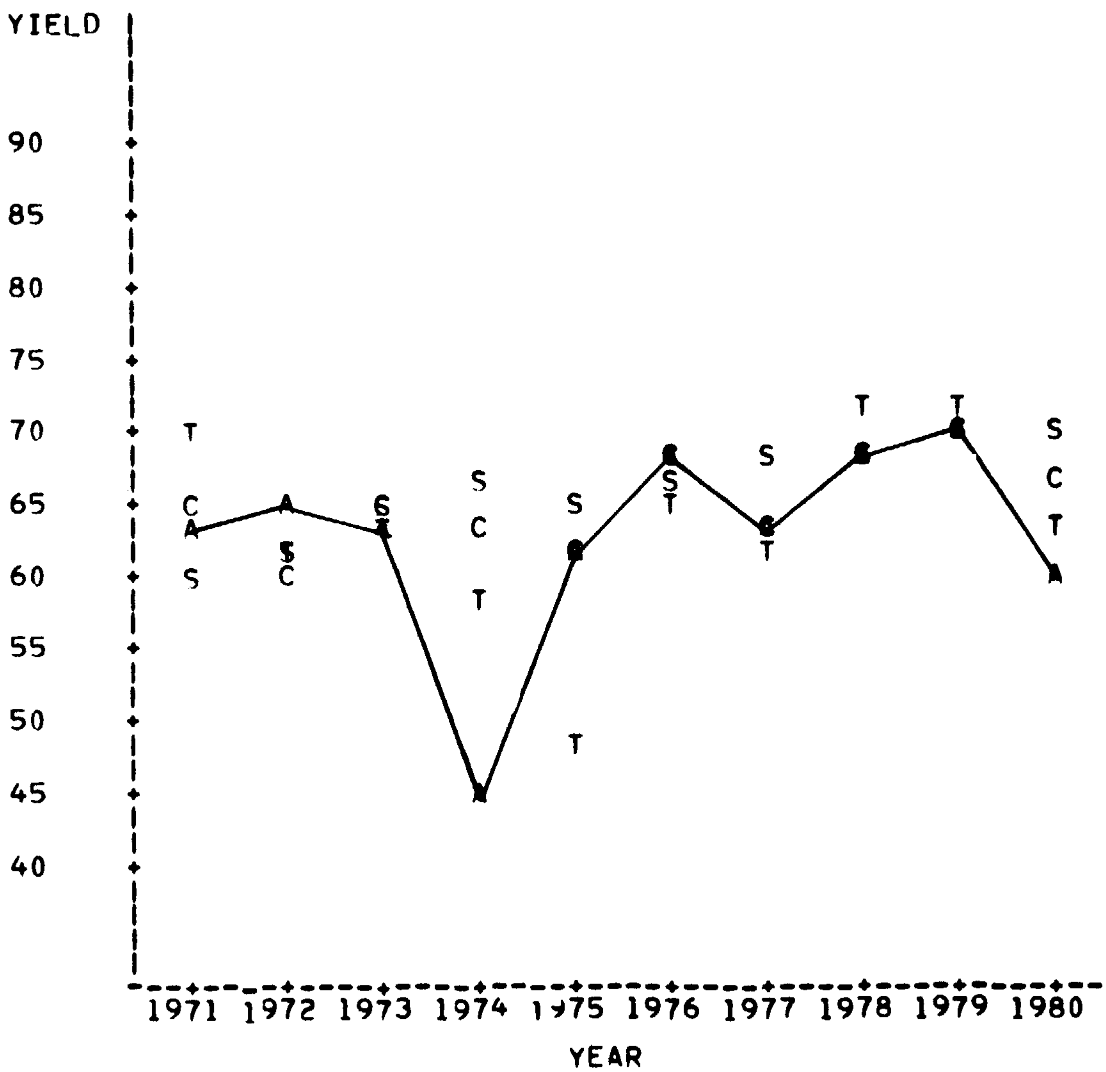


TABLE 8
MODEL COMPARISON BASED ON THE
PERCENT OF YEARS THE DIRECTION OF CHANGE
FROM THE PREVIOUS YEAR IS CORRECT
DURING INDEPENDENT TEST YEARS

TREND AND MONTHLY WEATHER DATA MODELS
CORN
IOWA, ILLINOIS, INDIANA

STATE	CRD	STRAW MAN %	STRAW MAN RANK	THOMPSON %	THOMPSON RANK	CEAS %	CEAS RANK
IOWA	10	44	(2)	33	(3)	67	(1)
	20	44	(3)	56	(1)	56	(1)
	30	56	(2)	33	(3)	67	(1)
	40	33	(3)	67	(1)	67	(1)
	50	22	(3)	44	(2)	89	(1)
	60	33	(3)	56	(2)	78	(1)
	70	22	(3)	33	(2)	78	(1)
	80	22	(3)	67	(1)	67	(1)
	90	22	(3)	56	(2)	78	(1)
STATE MODEL		22	(3)	44	(2)	67	(1)
CRDS AGGR.		22	(3)	44	(2)	67	(1)
ILLINOIS	10	33	(3)	56	(2)	89	(1)
	20	33	(2)	33	(2)	78	(1)
	30	22	(3)	78	(1)	67	(2)
	40	22	(3)	67	(2)	78	(1)
	50	11	(3)	56	(2)	67	(1)
	60	22	(2)	11	(3)	67	(1)
	70	33	(3)	44	(2)	56	(1)
	80	33	(3)	44	(2)	67	(1)
	90	44	(3)	56	(2)	67	(1)
STATE MODEL		33	(3)	44	(2)	89	(1)
CRDS AGGR.		33	(3)	56	(2)	89	(1)
INDIANA	10	22	(3)	44	(2)	78	(1)
	20	33	(2)	33	(2)	78	(1)
	30	44	(2)	78	(1)	44	(2)
	40	44	(3)	67	(1)	67	(1)
	50	44	(3)	78	(1)	67	(2)
	60	44	(2)	44	(2)	56	(1)
	70	33	(3)	67	(1)	56	(2)
	80	22	(3)	67	(1)	67	(1)
	90	22	(3)	44	(1)	44	(1)
STATE MODEL		44	(3)	56	(2)	67	(1)
CRDS AGGR.		44	(3)	78	(1)	67	(2)
REGION MODEL							
CRDS AGGR.		22	(3)	67	(2)	78	(1)
STATES AGGR.		22	(3)	44	(2)	67	(1)

TABLE 9
MODEL COMPARISON BASED ON THE PERCENT OF YEARS THE DIRECTION OF CHANGE FROM A THREE YEAR BASE PERIOD IS CORRECT DURING INDEPENDENT TEST YEARS

TREND AND MONTHLY WEATHER DATA MODELS
CORN
IOWA, ILLINOIS, INDIANA

STATE	CRD	STRAW MAN %	STRAW MAN RANK	MODEL THOMPSON %	MODEL THOMPSON RANK	CEAS $\bar{\%}$	CEAS RANK
IOWA	10	57	(3)	71	(1)	71	(1)
	20	57	(2)	71	(1)	57	(2)
	30	57	(3)	71	(1)	71	(1)
	40	43	(3)	86	(2)	100	(1)
	50	14	(3)	71	(2)	86	(1)
	60	71	(1)	57	(3)	71	(1)
	70	43	(3)	71	(2)	86	(1)
	80	14	(3)	57	(1)	57	(1)
	90	29	(3)	43	(1)	43	(1)
STATE MODEL		57	(3)	100	(1)	71	(2)
CRDS AGGR.		57	(2)	86	(1)	57	(2)
ILLINOIS	10	57	(3)	71	(2)	86	(1)
	20	57	(3)	71	(1)	71	(1)
	30	29	(3)	57	(2)	71	(1)
	40	29	(3)	57	(2)	71	(1)
	50	43	(2)	43	(2)	100	(1)
	60	29	(2)	14	(3)	57	(1)
	70	57	(2)	57	(2)	86	(1)
	80	57	(2)	57	(2)	71	(1)
	90	43	(2)	43	(2)	86	(1)
STATE MODEL		57	(3)	86	(2)	100	(1)
CRDS AGGR.		57	(3)	100	(1)	100	(1)
INDIANA	10	29	(2)	29	(2)	57	(1)
	20	29	(3)	57	(2)	71	(1)
	30	57	(3)	86	(1)	86	(1)
	40	57	(2)	57	(2)	100	(1)
	50	71	(1)	43	(3)	71	(1)
	60	71	(2)	71	(2)	100	(1)
	70	57	(2)	86	(1)	57	(2)
	80	29	(3)	57	(2)	71	(1)
	90	29	(3)	57	(1)	57	(1)
STATE MODEL		71	(2)	86	(1)	57	(3)
CRDS AGGR.		57	(2)	57	(2)	86	(1)
REGION MODEL							
CRDS AGGR.		71	(2)	57	(3)	86	(1)
STATES AGGR.		71	(1)	71	(1)	43	(3)

TABLE 10
MODEL COMPARISON BASED ON THE
CORRELATION BETWEEN ACTUAL AND PREDICTED YIELDS
DURING INDEPENDENT TEST YEARS

TREND AND MONTHLY WEATHER DATA MODELS
CORN
IOWA, ILLINOIS, INDIANA

STATE	CRD	STRAW MAN R	STRAW MAN RANK	THOMPSON R	THOMPSON RANK	CEAS R	CEAS RANK
IOWA	10	0.14	(3)	0.29	(2)	0.65	(1)
	20	0.27	(2)	0.00	(3)	0.55	(1)
	30	0.59	(2)	-0.06	(3)	0.78	(1)
	40	-0.51	(3)	0.47	(2)	0.81	(1)
	50	-0.47	(3)	0.35	(2)	0.84	(1)
	60	0.22	(3)	0.27	(2)	0.80	(1)
	70	-0.59	(3)	0.05	(2)	0.48	(1)
	80	-0.67	(3)	0.41	(1)	0.21	(2)
	90	-0.31	(3)	-0.16	(2)	-0.12	(1)
STATE MODEL		-0.11	(3)	0.15	(2)	0.71	(1)
CRDS AGGR.		-0.12	(3)	0.29	(2)	0.70	(1)
ILLINOIS	10	0.33	(3)	0.49	(2)	0.87	(1)
	20	0.39	(2)	0.28	(3)	0.59	(1)
	30	-0.29	(3)	0.17	(2)	0.28	(1)
	40	-0.36	(3)	0.71	(1)	0.36	(2)
	50	-0.40	(3)	0.44	(2)	0.60	(1)
	60	-0.10	(2)	-0.20	(3)	0.75	(1)
	70	0.06	(3)	0.32	(2)	0.65	(1)
	80	-0.04	(3)	0.38	(2)	0.51	(1)
	90	0.02	(2)	-0.01	(3)	0.71	(1)
STATE MODEL		-0.05	(3)	0.56	(2)	0.60	(1)
CRDS AGGR.		-0.07	(3)	0.58	(2)	0.71	(1)
INDIANA	10	-0.53	(3)	-0.23	(2)	0.26	(1)
	20	-0.20	(3)	0.23	(2)	0.46	(1)
	30	0.29	(3)	0.89	(1)	0.82	(2)
	40	-0.23	(3)	0.49	(1)	0.41	(2)
	50	0.14	(3)	0.34	(2)	0.52	(1)
	60	0.54	(2)	0.29	(3)	0.75	(1)
	70	0.30	(3)	0.80	(1)	0.42	(2)
	80	0.17	(3)	0.30	(2)	0.49	(1)
	90	0.39	(3)	0.50	(2)	0.63	(1)
STATE MODEL		-0.01	(3)	0.48	(1)	0.44	(2)
CRDS AGGR.		-0.01	(3)	0.55	(1)	0.53	(2)
REGION MODEL							
CRDS AGGR.		-0.05	(3)	0.48	(2)	0.74	(1)
STATES AGGR.		-0.04	(3)	0.35	(2)	0.67	(1)

The best performing model will have the largest value for the percent of years in which the direction of change from the previous year and from the average of the previous three years in the $\hat{Y}$'s agrees with the Y's and for the correlation coefficient between the observed and predicted yields.

Based on correctness of direction of change from the previous year, the CEAS model performs best in Iowa and Illinois and at the regional level. Results at the CRD and state level in Indiana are mixed for the CEAS and Thompson-type models. Figure 12 shows the highest ranking model(s) for each CRD.

Rankings based on correctness of direction of change from the average of the three previous years again show mixed results for the CEAS and Thompson-type models with the straw man model generally performing the worst (Figure 13).

The Pearson correlation coefficient is closest to +1 for the CEAS model in 22 of 27 CRDs (81%) (Figure 14). The CEAS model also ranks first at the state level in Iowa and Illinois and at the regional level. The straw man model performs worst at all levels.

Statistical Tests Based on $d=\hat{Y}-Y$ Favor the CEAS Model

The results of the parametric and nonparametric paired-sample statistical tests are given in Tables 11, 12 and 13. The results for the comparison of the straw man model with the Thompson-type model are shown in Table 11.

The parametric test results show significant differences at the CRD level between the straw man and Thompson-type model two times, with each model performing better in one of those instances. No significant differences were found at state or regional levels. State model results are close in Indiana with somewhat more difference favoring the straw man model in Iowa and the Thompson-type model in Illinois. The more reliable model in each CRD according to the average value of $|d|$ is presented in Figure 15. The straw man model performs better in 19 of 27 CRDs (70%).

The nonparametric test results show five significant differences at the CRD level, three favoring the Thompson-type model. Significant results at the regional level favor the Thompson-type model. The better model in each CRD according to the percent of years with smaller $|d|$ is presented in Figure 16. The straw man model performs better in 11 of 27 CRDs (41%), including many higher production CRDs, the Thompson-type model performs better in 5 of 27 CRDs (19%) and the models are tied in 11 (41%).

In summary, the results of the statistical tests for yield reliability indicate that the straw man model performs somewhat better than the Thompson-type model at the CRD level. The Thompson model performs somewhat better at the state level in Illinois, the straw man model performs somewhat better at the state level in Iowa, with the results being close in Indiana.

The results of the comparison of the straw man model with the CEAS model are given in Table 12. Here there is more evidence of statistically significant differences between the two models.

Figure 12. Letter indicates the model(s) with largest percent of test years (1971-1980) having agreement in direction of change from the previous year between predicted and observed corn yields. Darker shades indicate CRDs with higher production (T = Thompson, C = CEAS).

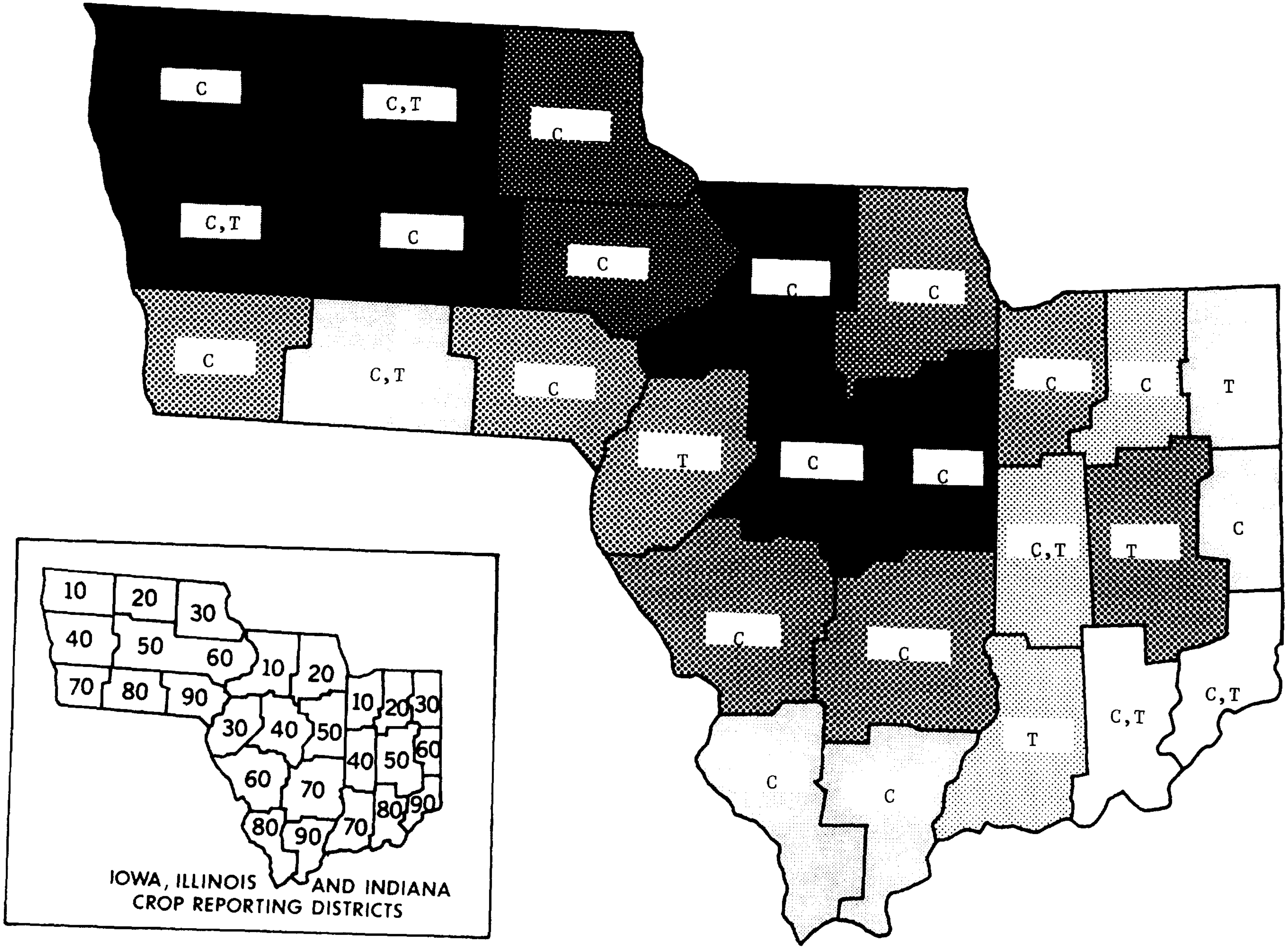


Figure 13. Letter indicates the model(s) with largest percent of test years (1971-1980) having agreement in the direction of change from the previous three year average between predicted and observed corn yields. Darker shades indicate CRDs with higher production (S = Straw man, T = Thompson, C = CEAS).

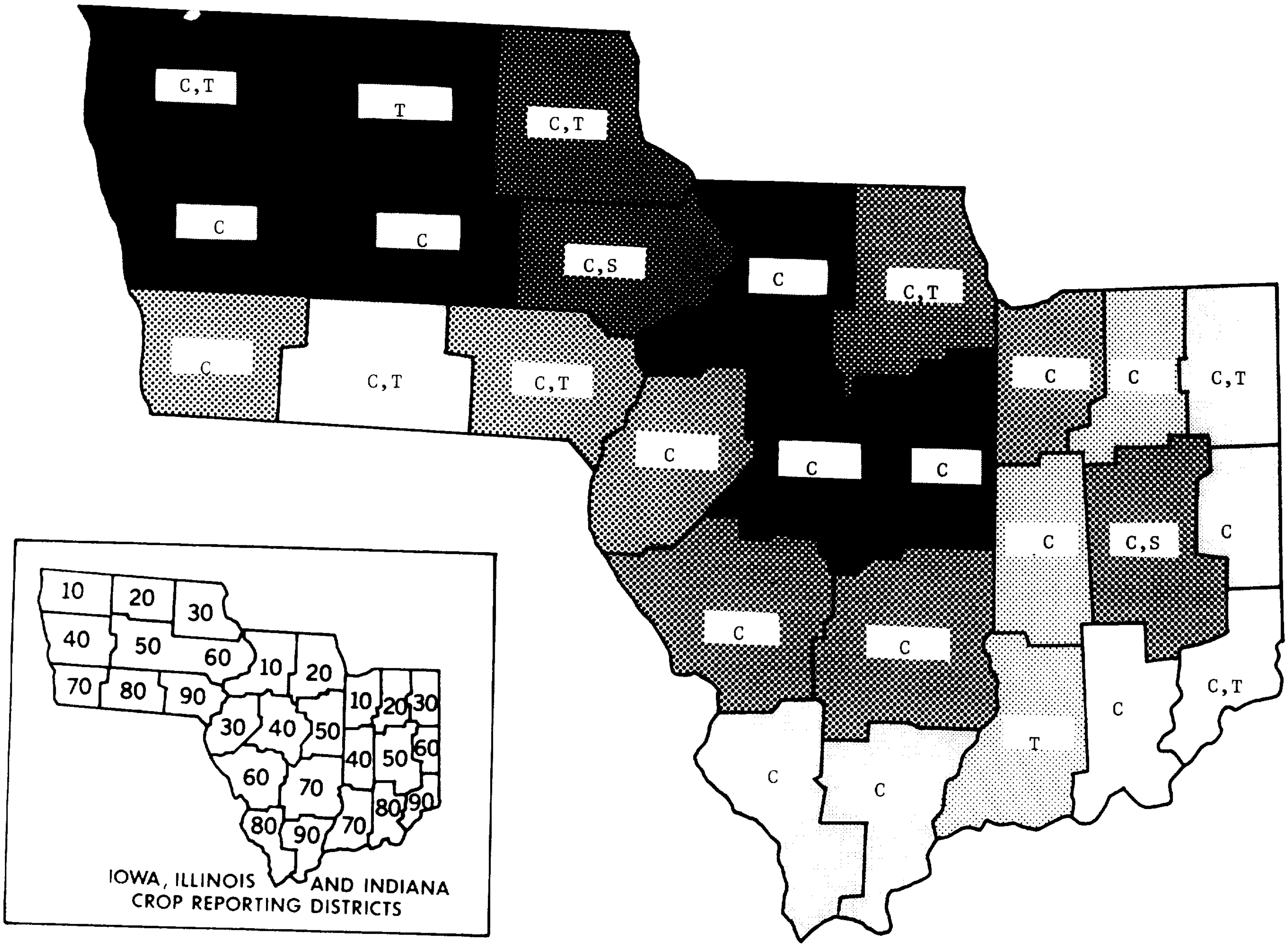


Figure 14. Letter indicates the model with the largest correlation coefficient between observed and predicted corn yields over the test years (1971-1980). Darker shades indicate CRDs with higher production (T = Thompson, C = CEAS).

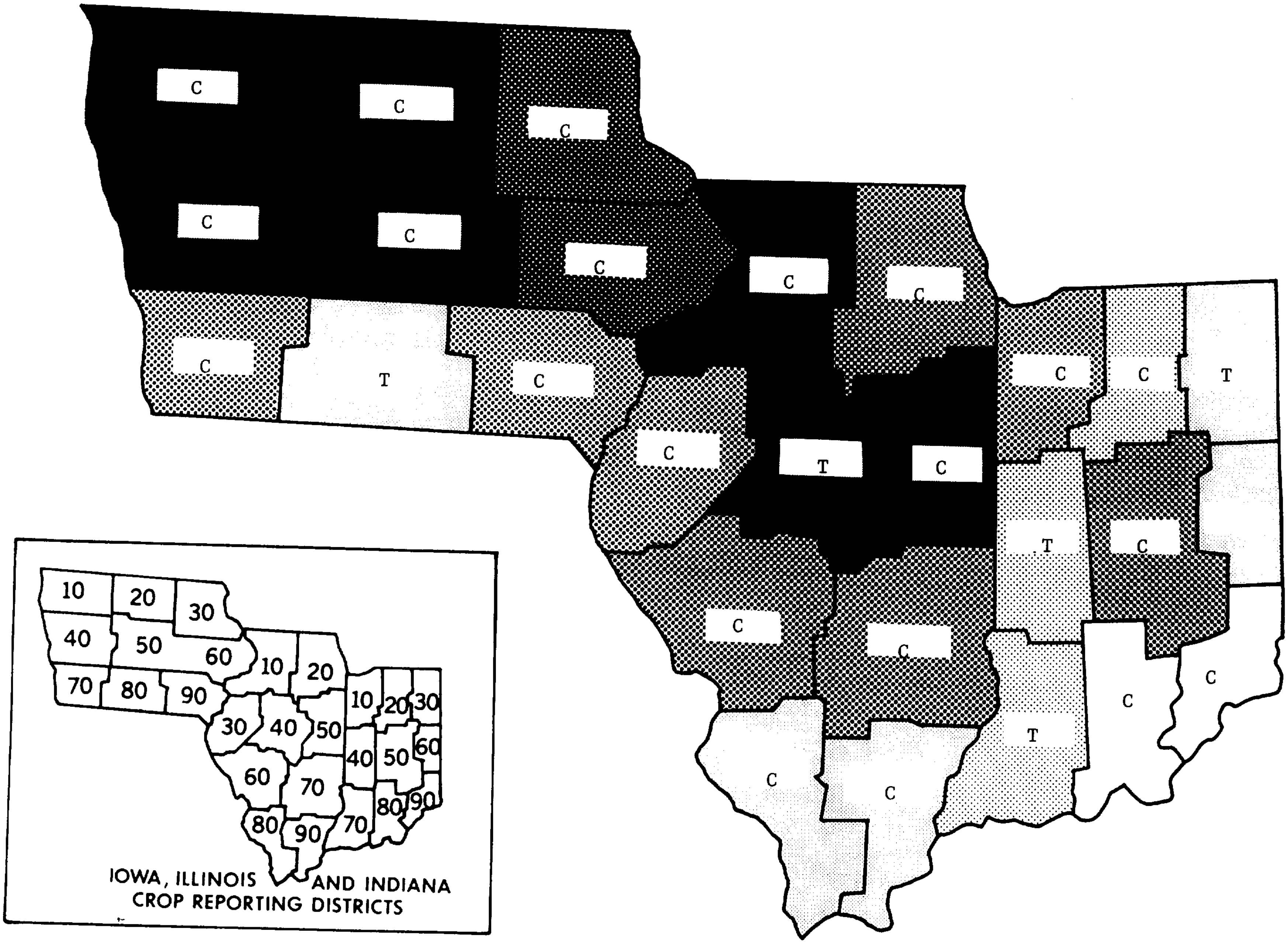


TABLE 11
MODEL COMPARISON BASED ON
PAIRED-SAMPLE STATISTICAL TESTS
STRAW MAN MODEL WITH THOMPSON MODEL
(*=P<.10, **=P<.05, ***=P<.01)

TREND AND MONTHLY WEATHER DATA MODELS
CORN
IOWA, ILLINOIS, INDIANA

STATE	CRD	PARAMETRIC T-TEST: AVERAGE IDI MODEL STRMAN	THOMPS	DIFFERENCE OF AVERAGES		NONPARAMETRIC RANK TEST: % SMALLER IDI MODEL STRMAN	THOMPS	DIFFERENCE OF PERCENTAGE	
IOWA	10	8.9	11.8	3.0		50	50	0	
	20	7.1	11.3	4.2		60	40	20	
	30	6.2	11.6	5.4	*	80	20	60	**
	40	12.2	8.3	3.9		40	60	20	*
	50	9.8	10.2	0.5		60	40	20	
	60	6.4	7.8	1.4		50	50	0	
	70	11.8	12.9	1.0		40	60	20	
	80	11.5	9.6	1.9		50	50	0	
	90	8.8	11.9	3.1		60	40	20	
STATE MODEL		8.4	10.0	1.6		60	40	20	
CRDS AGGR.		8.4	7.8	0.6		50	50	0	
ILLINOIS	10	5.1	5.9	0.8		50	50	0	
	20	5.3	8.4	3.1		80	20	60	*
	30	8.2	8.2	0.1		40	60	20	
	40	9.1	7.8	1.4		60	40	20	
	50	9.5	10.6	1.1		50	50	0	
	60	6.8	9.6	2.8		70	30	40	
	70	6.7	9.5	2.8		70	30	40	
	80	7.5	8.2	0.7		60	40	20	
	90	7.0	9.7	2.7		70	30	40	
STATE MODEL		6.8	5.5	1.3		40	60	20	
CRDS AGGR.		6.8	5.7	1.1		30	60	30	
INDIANA	10	7.8	9.7	1.9		50	50	0	
	20	5.8	5.7	0.1		50	50	0	
	30	5.2	3.0	2.2	**	30	70	40	**
	40	6.5	9.0	2.4		80	20	60	
	50	5.6	6.2	0.6		50	50	0	
	60	5.0	6.6	1.5		50	50	0	
	70	5.3	3.1	2.2		40	60	20	*
	80	5.6	5.8	0.3		50	50	0	
	90	4.8	4.0	0.8		50	50	0	
STATE MODEL		5.0	5.1	0.1		50	50	0	
CRDS AGGR.		5.0	4.3	0.7		50	50	0	
REGION MODEL									
CRDS AGGR.		6.4	4.0	2.4		20	80	60	*
STATES AGGR.		6.4	4.7	1.7		20	80	60	*

TABLE 12
MODEL COMPARISON BASED ON
PAIRED-SAMPLE STATISTICAL TESTS
STRAW MAN MODEL WITH CEAS MODEL
(*=P<.10, **=P<.05, ***=P<.01)

TREND AND MONTHLY WEATHER DATA MODELS
CORN
IOWA, ILLINOIS, INDIANA

STATE	CRD	PARAMETRIC T-TEST: AVERAGE |D| MODEL STRMAN	CEAS	DIFFERENCE OF AVERAGES	NONPARAMETRIC RANK TEST: % SMALLER |D| MODEL STRMAN	CEAS	DIFFERENCE OF PERCENTAGE
IOWA	10	8.9	6.9	2.0	20	80	60 *
	20	7.1	6.1	1.0	30	70	40 *
	30	6.2	5.1	1.1	20	80	60 *
	40	12.2	8.0	4.2 ***	10	90	80 ***
	50	9.8	5.8	4.0	40	60	20
	60	6.4	4.8	1.5	30	70	40
	70	11.8	7.9	4.0 **	10	90	80 ***
	80	11.5	9.7	1.8 *	30	70	40 **
	90	8.8	8.7	0.1	40	60	20
STATE MODEL		8.4	4.9	3.6 **	30	70	40 **
CRDS AGGR.		8.4	5.7	2.7 **	20	80	60 ***
ILLINOIS	10	5.1	3.7	1.4	50	50	0
	20	5.3	4.1	1.2	20	80	60 **
	30	8.2	6.4	1.7 **	20	80	60 **
	40	9.1	7.3	1.8 **	10	90	80 ***
	50	9.5	7.2	2.3 **	20	80	60 ***
	60	6.8	4.5	2.3	30	70	40 *
	70	6.7	5.0	1.7	30	70	40
	80	7.5	6.8	0.7	40	60	20
	90	7.0	4.9	2.2	30	60	30
STATE MODEL		6.8	4.9	1.9 **	10	90	80 ***
CRDS AGGR.		6.8	4.6	2.2 ***	10	90	80 ***
INDIANA	10	7.8	6.6	1.2 **	20	80	60 **
	20	5.8	4.6	1.2 *	10	90	80 ***
	30	5.2	3.5	1.7 *	20	80	60 **
	40	6.5	5.9	0.7	50	50	0
	50	5.6	5.2	0.4	50	40	10
	60	5.0	4.4	0.7	60	40	20
	70	5.3	3.2	2.1 *	20	80	60 *
	80	5.6	5.2	0.4	40	60	20
	90	4.8	4.2	0.6	60	40	20
STATE MODEL		5.0	3.3	1.7 **	10	90	80 ***
CRDS AGGR.		5.0	3.6	1.4 *	20	80	60 *
REGION MODEL							
CRDS AGGR.		6.4	4.0	2.5 ***	10	90	80 ***
STATES AGGR.		6.4	3.9	2.5 ***	10	90	80 ***

TABLE 13
MODEL COMPARISON BASED ON
PAIRED-SAMPLE STATISTICAL TESTS
THOMPSON MODEL WITH CEAS MODEL
(*=P<.10, **=P<.05, ***=P<.01)

TREND AND MONTHLY WEATHER DATA MODELS
CORN
IOWA, ILLINOIS, INDIANA

		PARAMETRIC T-TEST			NONPARAMETRIC RANK TEST		
		AVERAGE |D| MODEL		DIFFERENCE OF	% SMALLER |D| MODEL		DIFFERENCE OF
STATE	CRD	THOMPS	CEAS	AVERAGES	THOMPS	CEAS	PERCENTAGE
IOWA	10	11.8	6.9	4.9 *	40	60	20 *
	20	11.3	6.1	5.2	40	60	20 *
	30	11.6	5.1	6.5 **	20	80	60 **
	40	8.3	8.0	0.4	50	50	0
	50	10.2	5.8	4.4 *	30	70	40 **
	60	7.8	4.8	3.0	20	80	60 *
	70	12.9	7.9	5.0	30	70	40
	80	9.6	9.7	0.1	50	50	0
	90	11.9	8.7	3.2	40	60	20
STATE MODEL		10.0	4.9	5.1 **	10	90	80 **
CRDS AGGR.		7.8	5.7	2.1	40	60	20
ILLINOIS	10	5.9	3.7	2.2	50	50	0
	20	8.4	4.1	4.3 *	20	80	60 **
	30	8.2	6.4	1.8	40	60	20
	40	7.8	7.3	0.5	30	70	40
	50	10.6	7.2	3.5	20	80	60 *
	60	9.6	4.5	5.1 *	20	80	60 **
	70	9.5	5.0	4.4 *	10	90	80 **
	80	8.2	6.8	1.4	50	50	0
	90	9.7	4.9	4.8 ***	10	90	80 ***
STATE MODEL		5.5	4.9	0.6	40	60	20
CRDS AGGR.		5.7	4.6	1.1	30	70	40
INDIANA	10	9.7	6.6	3.1	40	50	10
	20	5.7	4.6	1.2	30	70	40 *
	30	3.0	3.5	0.5	60	40	20
	40	9.0	5.9	3.1	30	70	40 *
	50	6.2	5.2	0.9	50	50	0
	60	6.6	4.4	2.2	30	70	40
	70	3.1	3.2	0.1	40	60	20
	80	5.8	5.2	0.7	40	60	20
	90	4.0	4.2	0.2	50	50	0
STATE MODEL		5.1	3.3	1.8	40	60	20
CRDS AGGR.		4.3	3.6	0.8	40	60	20
REGION MODEL							
CRDS AGGR.		4.0	4.0	0.1	70	30	40
STATES AGGR.		4.7	3.9	0.8	50	50	0

Figure 15. Comparison of Straw man and Thompson models to predict corn yields based on the average of $|d| = |\hat{Y}-Y|$ for 1971-1980. Letter indicates model with smaller average $|d|$. Blank denotes tie. Stars indicate the level of significance, none ($P > 0.10$), * ($0.05 < P < 0.10$), ** ($0.01 < P < 0.05$), *** ($P < 0.01$). Darker shades indicate CRDs with higher production (S = Straw man, T = Thompson).

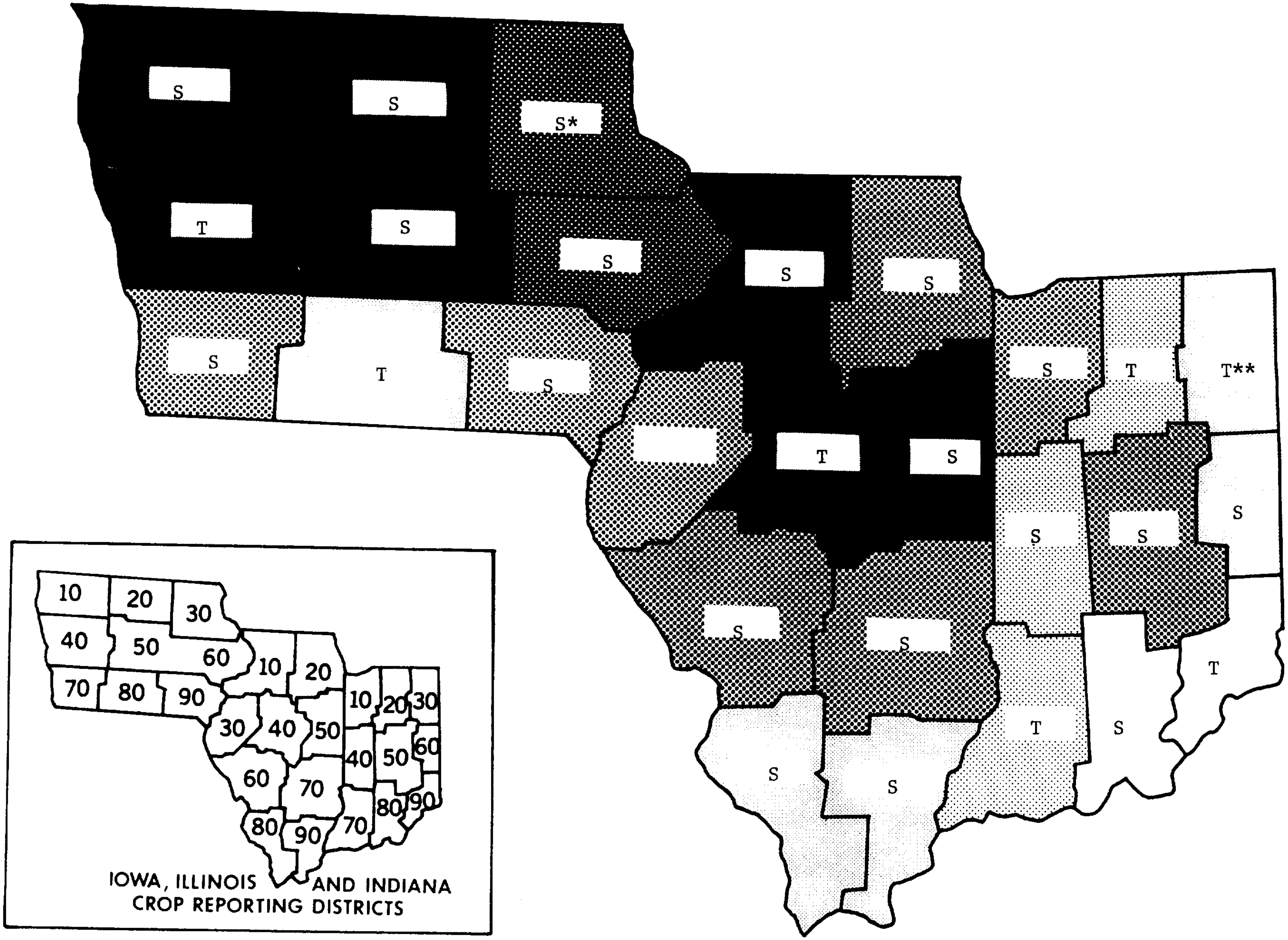
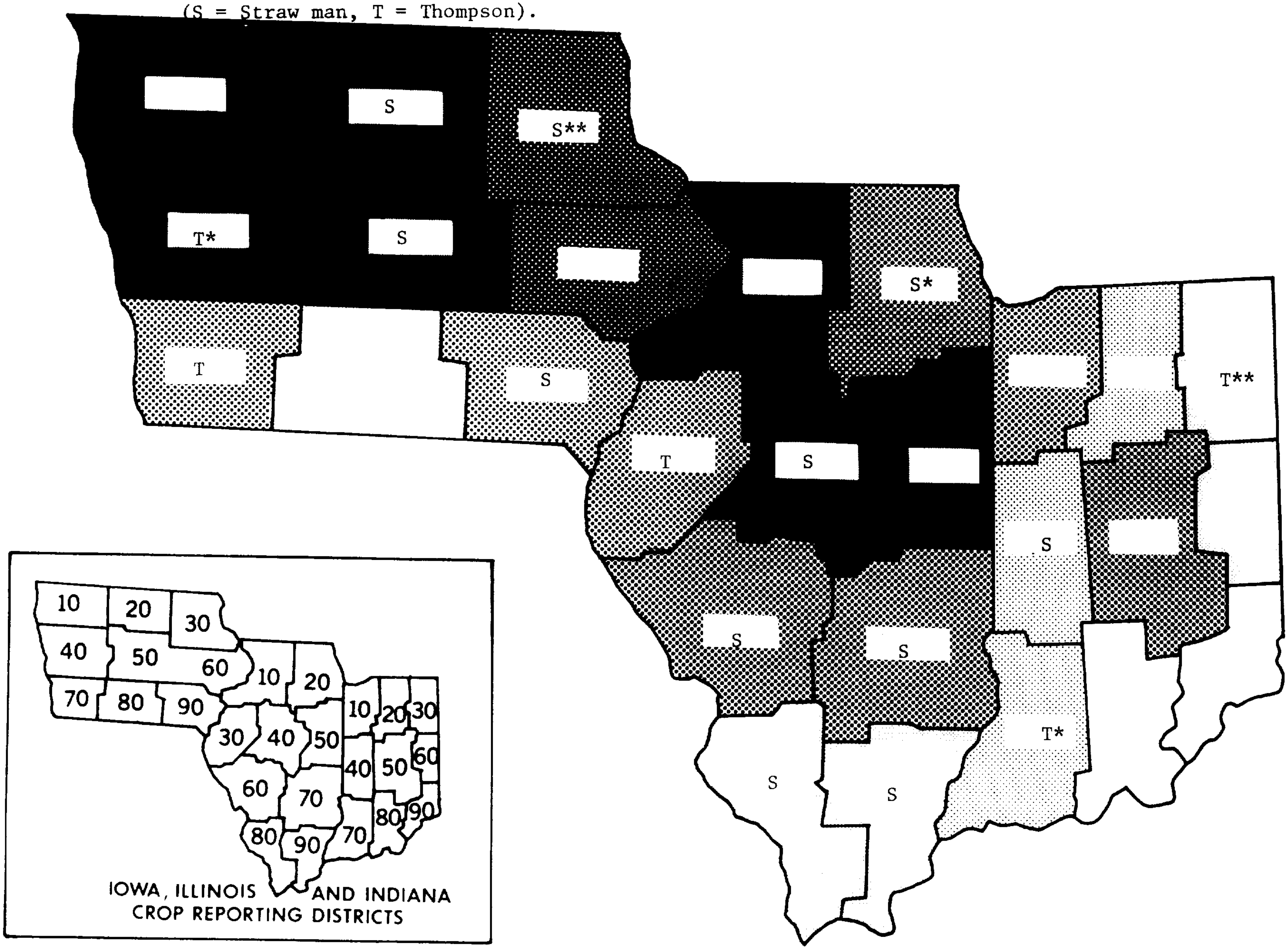


Figure 16. Comparison of Straw man and Thompson models to predict corn yields based on the percent of test years (1971-1980) with smaller $|d| = |\hat{Y}-Y|$. Letter indicates model with larger percent. Blank denotes tie. Stars indicate the level of significance, none ($P > 0.10$), * ($0.05 < P < 0.10$), ** ($0.01 < P < 0.05$), *** ($P < 0.01$). Darker shades indicate CRDs with higher production (S = Straw man, T = Thompson).



The parametric test results shows significant differences in 10 of 27 CRDs (37%), all favoring the CEAS model. The statistically significant differences at the state and regional level favor the CEAS model. The better model in each CRD according to the average value of $|d|$ is displayed in Figure 17. The CEAS model performs better than the straw man model in all 27 CRDs.

The nonparametric test results show 15 CRDs (56%) with significant differences, all in favor of the CEAS model. Significant differences are found when aggregating CRD results to the state and regional levels. The better model in each CRD based on the percent of years with smaller $|d|$ is presented in Figure 18. The CEAS model performs better than the straw man model in 22 of 27 CRDs (81%), the straw man model performs better in only 3 of 27 CRDs, and there are 2 ties.

To summarize, the CEAS model performs better than the straw man model at the CRD, state and regional levels. Significant differences are found at all levels.

The results for the comparison of the Thompson-type model with the CEAS model are given in Table 13. The parametric test results show a significant difference in 7 of 27 CRDs (26%), all favoring the CEAS model. There are no significant differences in Indiana. The CEAS state level model for Iowa performs significantly better. The better model in each CRD according to the average value of $|d|$ is shown in Figure 19. The CEAS model performs better than the Thompson model in 23 of 27 CRDs (85%). The four CRDs in which the Thompson-type model performs better are not high producing CRDs.

The nonparametric test results show 12 CRDs with significant differences, all of which favor the CEAS model. Again, the CEAS state level model performs significantly better in Iowa. The better model in each CRD, according to the percent of years with smaller $|d|$, is presented in Figure 20. The CEAS model performs better in 20 of 27 CRDs (74%), the Thompson model performs better in only 1 CRD, and the models are tied in 6 CRDs. The CEAS model tends to do better in the Iowa and Illinois CRDs with higher production.

In summary, the CEAS model performs better at the CRD level, particularly in Iowa and Illinois. State level model results are significantly different in Iowa. The CEAS model performs only slightly better at the regional level with no significant differences resulting.

Models Perform Worse in Below and Above Average Yielding Years

Results of the comparison in performance between below average, above average and average yielding years for the CEAS and Thompson-type state level models are presented in Table 14. Referring to the column labeled as average of absolute value of the base period residuals (AAVR), both models demonstrate larger AAVRs in the below average years as compared to the average years. The AAVRs for the above average years are also larger than those for the average years, although the difference is not as pronounced as for the below average years. It is disappointing that the performance of these models is worse in the unusual years, the years for which assistance in estimating yield levels is most desired. From examining the lowest and highest residual values, it can be seen that there is a tendency for the below average yields to be overestimated and for the above average years to be underestimated. There are, however,

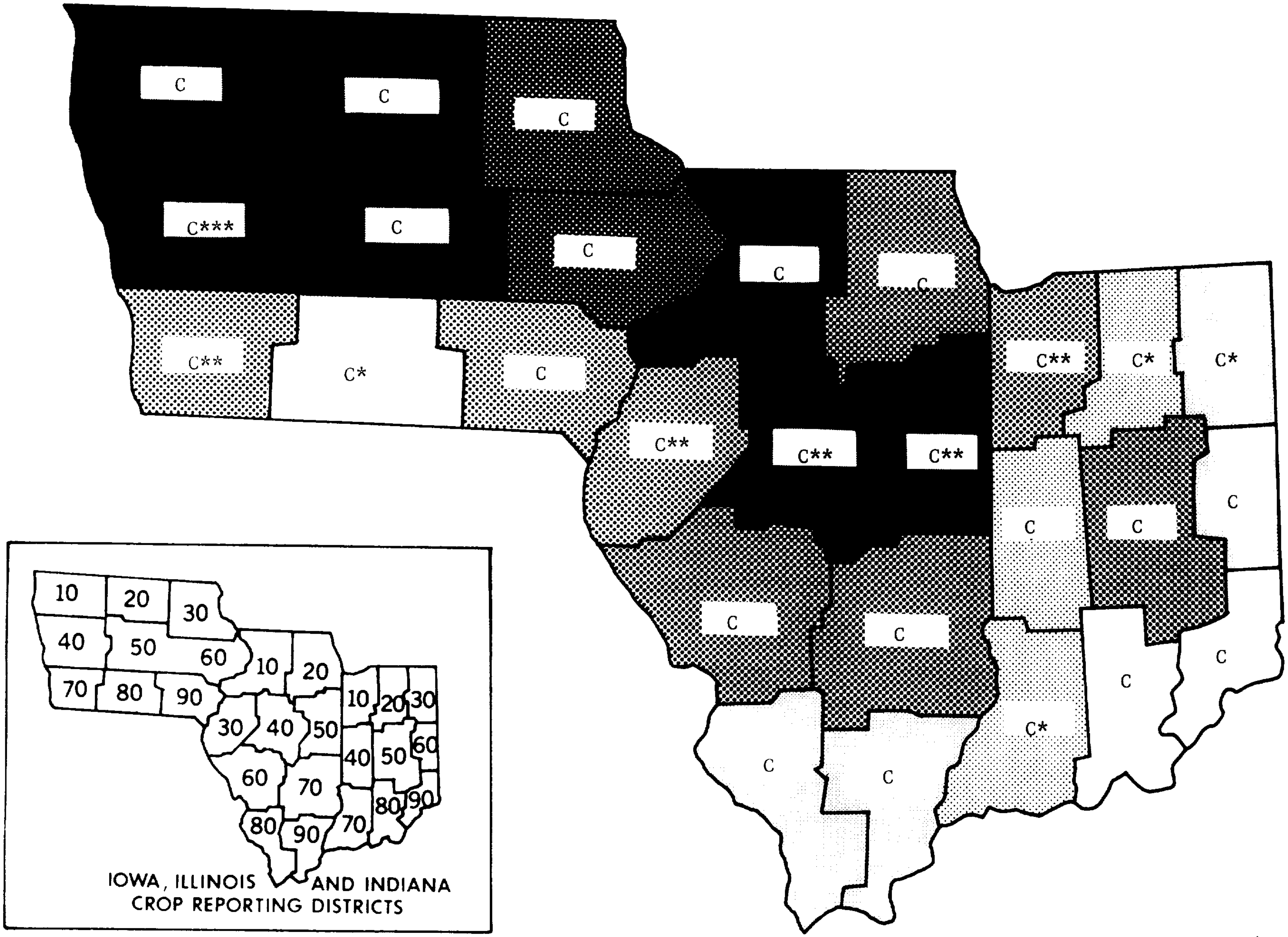


Figure 17. Comparison of Straw man and CEAS models to predict corn yields based on the average of $|d| = |\hat{Y}-Y|$ for 1971-1980. Number indicates model with smaller average $|d|$. Blank denotes tie. Stars indicate the level of significance, none ($P > 0.10$), * ($0.05 < P < 0.10$), ** ($0.01 < P < 0.05$), *** ($P < 0.01$). Darker shades indicate CRDs with higher production (C = CEAS).

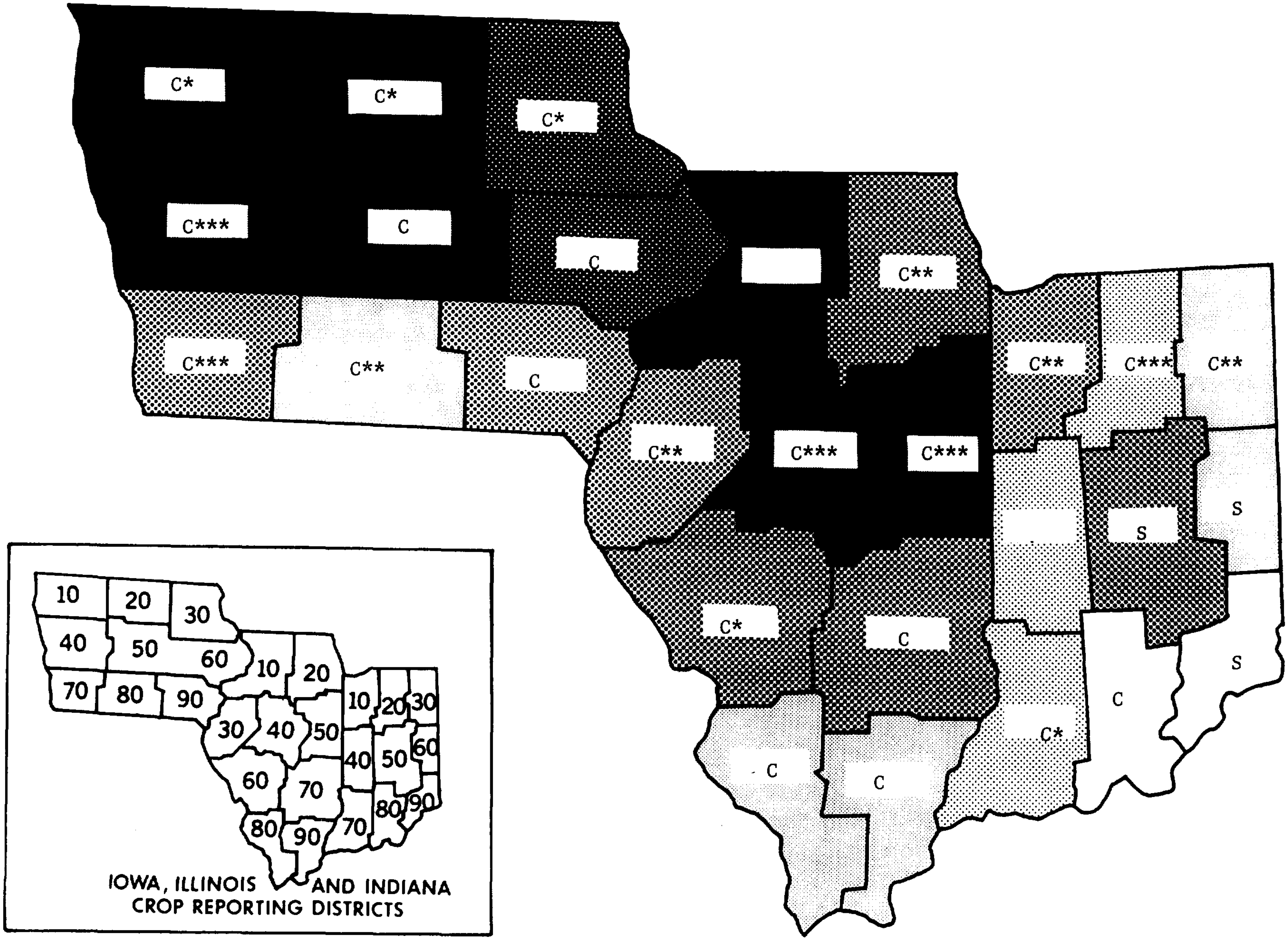


Figure 18. Comparison of Straw man and CEAS models to predict corn yields based on the percent of test years (1970-1980) with smaller $|d| = |\hat{Y}-Y|$. Letter indicates model with larger percent. Blank denotes tie. Stars indicate the level of significance, none ($P > 0.10$), * ($0.05 < P < 0.10$), ** ($0.01 < P < 0.05$), *** ($P < 0.01$). Darker shades indicate CRDs with higher production (S = straw man, C = CEAS).

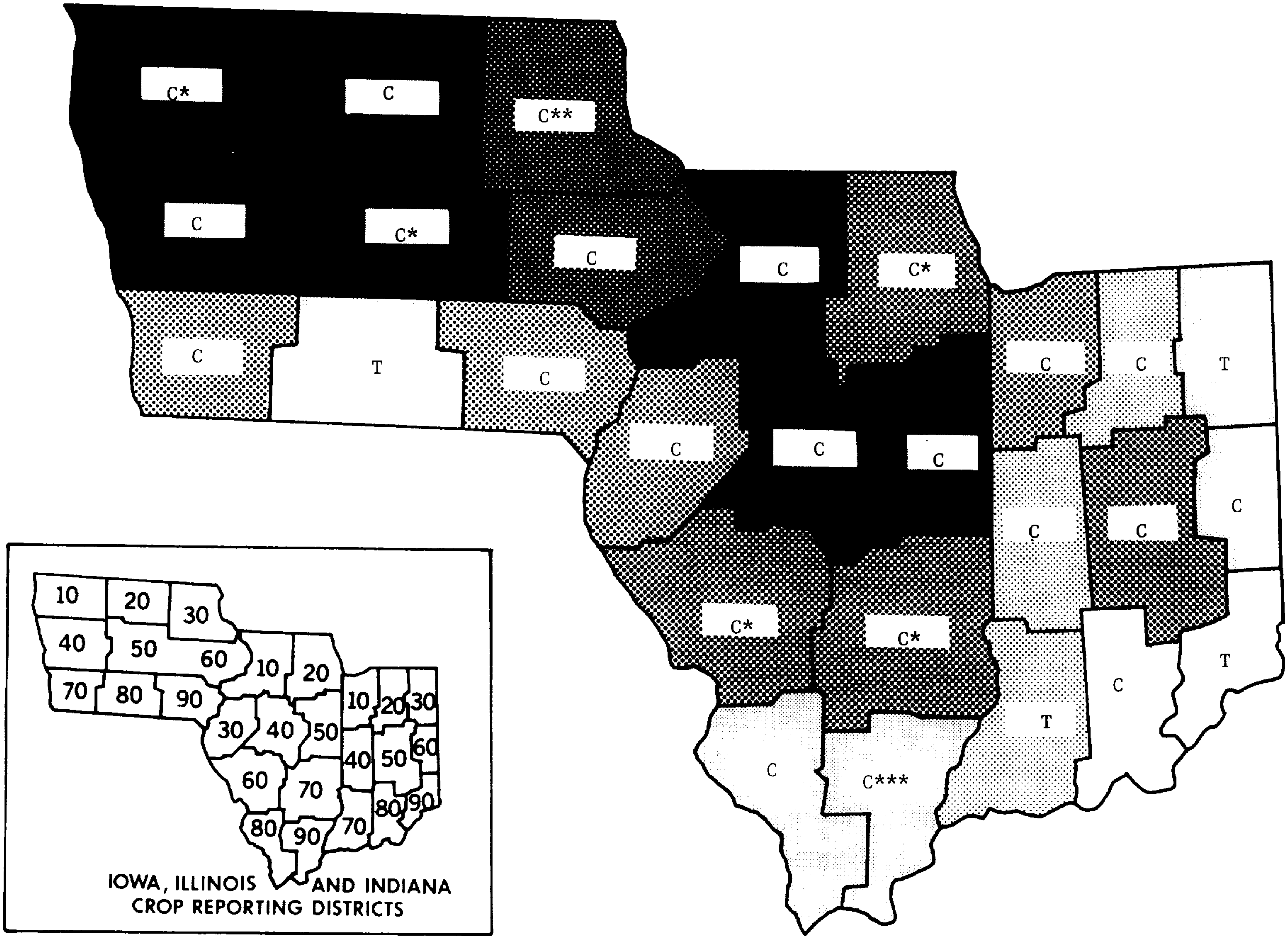


Figure 19. Comparison of Thompson and CEAS models to predict corn yields based on the average of $|d| = |\hat{Y}-Y|$ for 1971-1980. Number indicates model with smaller average $|d|$. Blank denotes tie. Stars indicate the level of significance, none ($P > 0.10$), * ($0.05 < P < 0.10$), ** ($0.01 < P < 0.05$), *** ($P < 0.01$). Darker shades indicate CRDs with higher production (T = Thompson, C = CEAS).

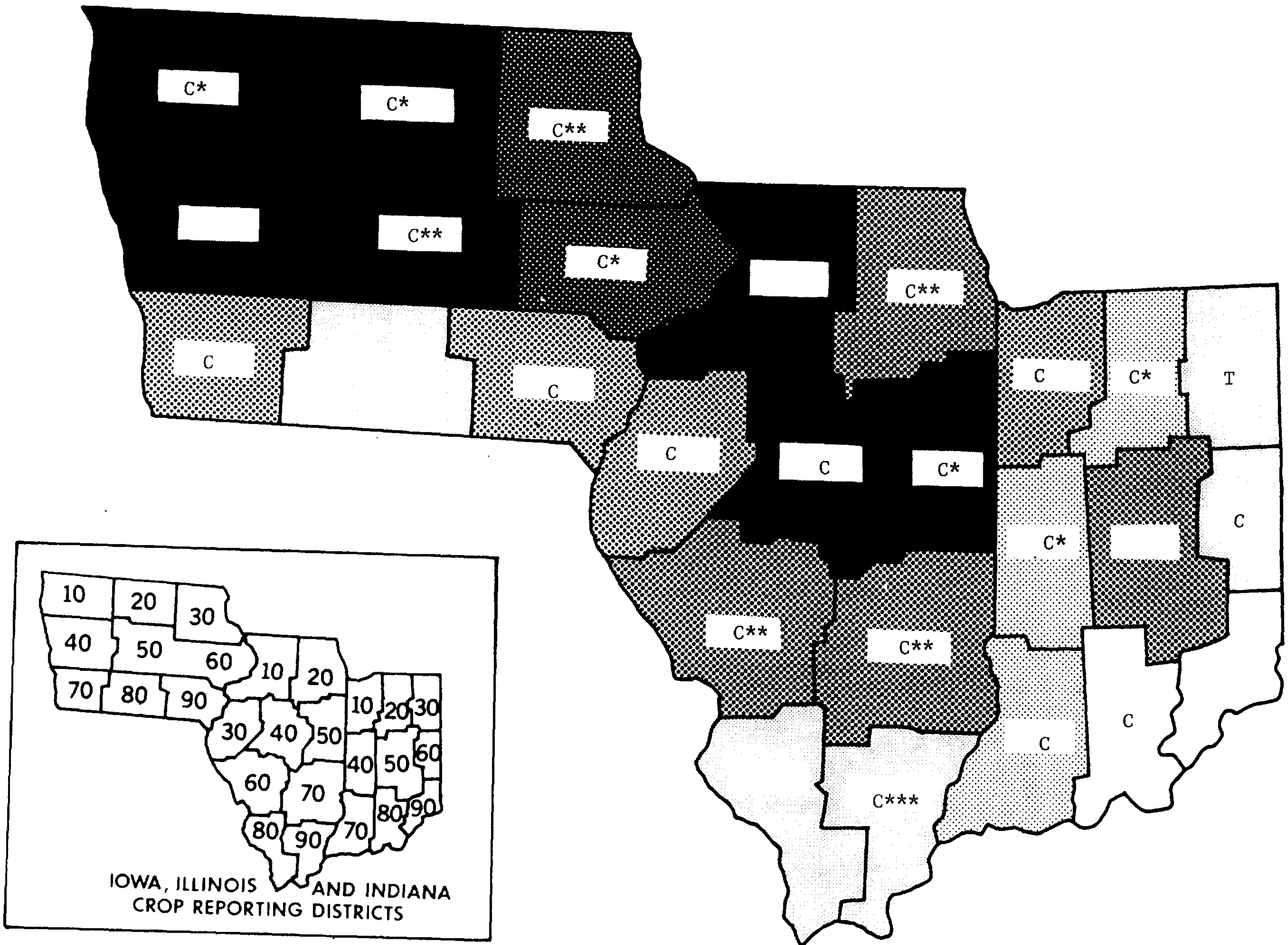


Figure 20. Comparison of Thompson and CEAS models to predict corn yields based on the percent of test years (1971-1980) with smaller $|d| = |\hat{Y}-Y|$. Letter indicates model with larger percent. Blank denotes tie. Stars indicate level of significance, none ($P < 0.10$), * ($0.05 < P < 0.10$), ** ($0.01 < P < 0.05$), *** ($P < 0.01$). Darker shades indicate CRDs with higher production (T = Thompson, C = CEAS).

Table 14. Performance of state level models in below average, above average, and average yielding years

State	Type of year	Model	Base period residuals ($\hat{Y}$-Y) Average of absolute value	Lowest value	Highest value
Iowa	Below average	CEAS	4.5	-2.1	11.3
		Th-type	3.2	0.8	5.0
	Above average	CEAS	3.7	-6.6	-0.1
		Th-type	3.2	-5.5	-2.1
	Average	CEAS	2.6	-4.3	7.3
		Th-type	2.4	-7.0	-4.5
Illinois	Below average	CEAS	5.3	-4.4	11.0
		Th-type	1.5	-2.2	3.2
	Above average	CEAS	3.5	-4.4	-2.8
		Th-type	1.8	-4.1	0.3
	Average	CEAS	2.6	-6.4	8.0
		Th-type	1.4	-2.6	4.2
Indiana	Below average	CEAS	5.8	2.2	14.3
		Th-type	4.2	-3.0	6.9
	Above average	CEAS	5.6	-7.5	-3.2
		Th-type	2.7	-4.1	-0.2
	Average	CEAS	1.6	-3.4	5.2
		Th-type	1.6	-2.9	3.6

exceptions which make it difficult to adequately adjust for this pattern of bias. The base period residuals should not be used to make direct comparisons in the performance of the models for the same type of year. The independent bootstrap test results are more appropriate for that purpose. More information on the below and above average years may be found in a section of the Appendix entitled "Below Average and Above Average Yielding Years for Each State and Associated Model Performance Data."

Neither Model Provides a Current Measure of Modeled Yield Reliability

This criterion for model evaluation asks whether the model can provide any indication of its accuracy in the current year. For example, one might speculate that the accuracy of a model's prediction is related to how unusual the weather is in a given year, as compared to an average year. A measure of the distance from a model's independent variable values for a given year to the average values is provided by the standard error of prediction for the given year. However, previous work (French, 1982; Kestle, 1982) has shown that this distance is not related to the model's accuracy. Also, inspection of the appendix on below-average and above-average yielding years shows that the relative size of the standard error of prediction for the CEAS and Thompson-type models in a given year does not indicate the relative accuracy of their prediction.

Models Are Equally Timely

It takes about three months after the end of a month to obtain published values for that month's average temperature and total precipitation for the climatic divisions in Iowa, Illinois, and Indiana from the National Climatic Data Center (NCDC) in Asheville, North Carolina. Estimates of these climatic division values could be prepared earlier based on first-order weather station values+ available on the NOAA computer system on a real-time basis or based on arrangements made with a sample of the cooperative stations which submit their data to NCDC. These weather data approximations could be calculated during the first week of the month following the month for which weather data pertains. The accuracy of the approximations would need to be monitored.

A combination of monthly data estimates for past months and assumed normal weather for months yet to come could be used to predict yield with the Thompson-type model. His model provides an end-of-season estimate at the end of August. Truncated CEAS models have been developed for use at the end of April through the end of August.

Neither Model Is Costly to Operate

Operational costs associated with each of the models are not high. The monthly weather data for the climatic divisions in Iowa, Illinois, and Indiana are currently prepared for other users. In the past, these weather data values have been telephoned to NOAA's Assessment and Information Services Center in Columbia, Missouri from the USDA World Agriculture Outlook Board and NOAA's Climatic Assessment Branch in Washington, D.C. Recently, only the latter source has been used, and the timeliness of the reporting has been quite variable (during March 1982 through February 1983, from six to thirty-six days after the end of the month for which the data pertained).

Maintenance of the historic agricultural and meteorological data bases is the most expensive part in the operation of these models, requiring the efforts of a part-time person who is familiar with these data and the computer system used. All that is required to obtain yield estimates is to have someone responsible for acquiring the weather data estimates and performing the regression equation calculations. The necessary computer programs are written in SAS and could be run on a computer having that capability. The redevelopment of the models in the future years, incorporating a larger data base, would require the skills of a person familiar with statistical regression methodology and agronomic modeling using meteorologically derived variables.

The Thompson-type Models Are Somewhat Easier to Understand and Use

The variables found in the Thompson-type models are very simple and straightforward both to understand and use as the variables in the model are always the same. The weather variables are simple derivations of the monthly temperature and precipitation values. A program is necessary for the calculation of the agronomic variables and for the departures from normal in the CEAS model. The soil moisture budget contents can be saved from the previous year for use in the next year, or the budget can be assumed to be filled to capacity each winter.

Both Models Are Based on Historic, Statistical Relationships Between Monthly Weather Values and Yield

The evaluation reports for each model (French 1982; Kestle 1982) discuss the model's consistency with scientific knowledge. Both the CEAS and Thompson-type models are based on the historical, statistical relationships between crop yields and weather. The weather values used by both models are averaged over calendar months and large area (CRDs or states), so both would be subject to the limitations implied by such averaging.

Three trend terms are available for inclusion in the Thompson model. A linear trend over the entire range of years is used to capture the increase due to the introduction of hybrid varieties. A combination of linear and curvilinear trend terms is used to model a rapid rise and subsequent slower rise in yields apparently related to fertilizer use. A single linear trend term is used in Iowa and Illinois by the CEAS model. In Indiana, three trend terms were defined, only two of which were selected for any one model. One allows for a linear increase in yields from 1930 to 1980, the second a linear increase from 1930 to 1951, and the third a linear increase from 1951 to 1980.

The CEAS model developers use weather data to construct agroclimatic variables. These variables are constructed based on algorithms for estimating potential evapotranspiration (PET) and actual evapotranspiration (ET). Thompson used weather data to construct variables which were deviations and squared deviations from normal.

Models Are Equally Objective

As presently defined, both models are equally objective in their application to the current year. To predict yields in a future year with either model, the value of the trend term and any weather-related variables would be calculated and used with the regression coefficients obtained during model development. This is an objective procedure and calls for no intervention by the model user. The CEAS model also requires the specification of two soil moisture budget values for each location. These values relate to the available water capacity, (1) in the surface layer and (2) in the underlying layer. The CEAS model developers have specified values to use in each state and CRD which, presumably, would not change.

As the yield/weather data base grows, model redevelopment will become necessary in order to make use of the new data. This, of course, introduces subjectivity. Trend terms may need to be respecified for both models. The weather variables included in the Thompson-type model are fixed, whereas the weather variables included in the CEAS models are chosen by variable selection procedures. This would involve some subjective decisions to be made regarding the inclusion of variables.

Model Redevelopment Would Be Required to Use the CEAS Models in Other Areas

Because of the number of variables in the Thompson-type model (twelve weather variables plus trend) and the stepwise procedures used to select variables to be included in CEAS models, both require a rather lengthy time series of yield and weather data (at least twenty-five years) for application in a new area. A CEAS model would require a complete model development effort, including specification of the available water capacities in the surface and underlying layers. The models have the same requirements in terms of trend specification.

CONCLUSION

The CEAS models outperform the Thompson-type models for all of the indicators of yield reliability with the exception of bias. The CEAS model's yield predictions are more accurate in all three states, but particularly in Iowa and Illinois. Both models tend to overestimate in below-average yielding years and underestimate in above-average yielding years. The use of the agroclimatic variables in the CEAS models appears advantageous and merits further investigation.

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Wilson, Wendell W. and Sebaugh, Jeanne L., 1981. Established Criteria and Selected Methods for Evaluating Crop Yield Models in the AgRISTARS Program. Anerican Statistical Association 1981 Proceedings of the Section on Survey Research Methods, 24-31.

APPENDIX - STATISTICAL FORMULAS

Measures of Model Performance

Definition of Terms:

Y_i = Yield as reported by U.S.D.A. for year i ("true" or "actual" yield).

$\hat{Y}_i$ = Yield as predicted by a model for year i.

$d_i = \hat{Y}_i - Y_i$ = difference between predicted and actual yield for year i.

$rd_i = 100\ d_i/Y_i$ = relative difference for year i.

s_{Y_i} = Standard error of regression = (Residual or Error Mean Square from Model Development Base Period $)^{1/2}$ for year i.

$s_{\hat{Y}_i}$ = Standard error of a predicted value for year i = $s_{Y_i}(1 + \underline{x}_0'(\underline{X}'\underline{X})^{-1}\underline{x}_0)^{1/2}$, where $\underline{X}$ is the regression design matrix of independent variable values and $\underline{x}_0$ is the vector of independent variable values for the year the prediction is being made.

i = 1, ..., n = number of test years and $\Sigma = \sum_{i=1}^{n}$ = summation over the test years.

$\bar{Y} = 1/n\ \Sigma\ Y_i$ = average actual yield.

Measures:

Bias = B = $1/n\ \Sigma\ d_i = \bar{d}$.

Relative Bias = RB = $100\ B/\bar{Y}$.

Mean Square Error = MSE = $1/n\ \Sigma\ d_i^2$.

Root Mean Square Error = RMSE = $(MSE)^{1/2}$.

Relative Root Mean Square Error = RRMSE = $100\ RMSE/\bar{Y}$.

Variance = Var = $1/n\ \Sigma\ (d_i - \bar{d})^2$.

Standard Deviation = SD = $(Var)^{1/2}$.

Relative Standard Deviation = RSD = $100\ SD/(\bar{Y} + \bar{d})$.

Mean Square Error = Variance + $(\text{Bias})^2$.

Pearson r between $\hat{Y}_i$ and Y_i:

$$r = \left[\Sigma\hat{Y}_i Y_i - \frac{(\Sigma\hat{Y}_i)\ (\Sigma Y_i)}{n}\right]\left[\left(\Sigma\hat{Y}_i^{\,2} - \frac{(\Sigma\hat{Y}_i)^2}{n}\right)\left(\Sigma Y_i^{\,2} - \frac{(\Sigma Y_i)^2}{n}\right)\right]^{-\frac{1}{2}}$$

Paired-Sample Statistical Tests Comparing the Performance of Two Crop Yield Models

Definition of Terms:

$\hat{Y}_{1_i}$ = Yield as predicted by model 1 for year i.

$\hat{Y}_{2_i}$ = Yield is predicted by model 2 for year i.

$|d_{1_i}| = |\hat{Y}_{1_i} - Y_i|$ = Absolute value of the difference between model 1 predicted and actual yield for year i.

$|d_{2_i}| = |\hat{Y}_{2_i} - Y_i|$ = Absolute value of the difference between model 2 predicted and actual yield for year i.

$D_i = |d_{1_i}| - |d_{2_i}|$.

Rank $(|D_i|)$ = Ranks of the absolute values of D_i assigned in ascending order (smallest value of $|D_i|$ = rank 1, ..., largest value of $|D_i|$ = rank n). If two or more years have the same value for $|D_i|$, assign each year the average of the ranks.

Parametric Test - Student t:

H_0: $\mu_D = 0$

H_a: $\mu_D \neq 0$

Test Statistic = $t = \frac{\overline{D}}{s_{\overline{D}}}$, where

$\overline{D} = 1/n\ \Sigma D_i$,

$s_{\overline{D}} = (s_D^2/n)^{1/2}$, and

$s_D^2 = [\Sigma D_i^2 - 1/n(\Sigma D_i)^2]/(n-1)$.

Reject H_0 if $|t| > t_{\alpha,\ (n-1)}$.

Nonparametric Test - Wilcoxon Signed Rank:

H_0: There is no difference in the performance of the models.

H_a: There is a difference in the performance of the models.

Procedure to compute test statistic, T:

1. Compute the D_i.
2. Assign ranks to $|D_i|$.
3. Assign signs to Rank ($|D_i|$) corresponding to the signs of D_i.
4. Let T = the absolute value of the sum of the ranks with the less frequent sign.

Reject H_0 if $T \leq T_{\alpha(1\ \text{tailed}),\ n}$.

APPENDIX

Below Average and Above Average Yielding Years (1950-69, 1971-80) for Each State and Associated Model Performance Data*

State	Year and Type	Obs. Yield (bu/Ha) (Y)	CEAS Model			Thompson-type Model		
			Pred. Yield ($\hat{Y}$)	$\hat{Y}$-Y	$s_{\hat{y}}$	Pred. Yield ($\hat{Y}$)	$\hat{Y}$-Y	$s_{\hat{y}}$
Iowa	Below average							
	1974	50.2	61.5	11.3	1.09	53.9	3.7	3.79
	1977	54.0	55.8	1.8	2.29	59.0	5.0	3.79
	1976	57.1	59.2	2.1	1.62	61.5	4.4	3.46
	1975	56.5	61.7	5.2	1.21	58.8	2.3	3.71
	1955	30.4	28.3	-2.1	1.78	31.2	0.8	4.26
	Above average							
	1972	72.8	66.2	-6.6	1.38	70.4	-2.4	3.01
	1979	79.7	74.9	-4.8	1.61	74.2	-5.5	3.04
	1952	39.2	34.0	-5.2	1.32	37.1	-2.1	3.30
	1969	62.1	62.0	-0.1	1.28	59.3	-2.8	3.78
	1973	67.2	65.4	-1.8	1.18	63.8	-3.4	4.03
Illinois	Below average							
	1974	51.5	58.5	7.0	2.69	52.5	1.0	2.55
	1980	58.4	69.4	11.0	2.25	61.6	3.2	2.10
	1966	50.2	47.8	-2.4	1.59	50.2	0.0	2.32
	1954	31.7	33.4	1.7	1.93	32.6	0.9	1.98
	1955	35.1	30.7	-4.4	2.20	32.9	-2.2	2.60
	Above average							
	1979	80.3	77.2	-3.1	1.99	76.9	-3.4	1.95
	1967	65.3	61.1	-4.2	1.50	65.6	0.3	2.38
	1975	72.8	68.4	-4.4	1.31	68.7	-4.1	1.75
	1972	69.0	65.9	-3.1	1.34	67.8	-1.2	1.96
	1965	59.0	56.2	-2.8	1.01	58.8	-0.2	1.95
Indiana	Below average							
	1974	45.8	60.1	14.3	1.08	52.7	6.9	1.97
	1980	60.3	64.6	4.3	1.92	61.8	1.5	2.07
	1964	45.2	50.0	4.8	0.72	51.3	6.1	1.35
	1952	31.4	34.6	3.2	1.50	28.4	-3.0	1.57
	1953	32.3	34.5	2.2	1.18	35.7	3.4	1.40
	Above average							
	1965	59.0	51.6	-7.4	1.41	54.9	-4.1	1.47
	1963	54.6	51.4	-3.2	1.01	52.2	-2.4	1.78
	1969	62.8	55.3	-7.5	0.80	59.9	-2.9	1.72
	1962	51.5	48.3	-3.2	0.84	51.3	-0.2	1.35
	1972	65.3	58.5	-6.8	1.18	61.2	-4.1	1.85

*Predicted yields ($\hat{Y}$) and standard errors of the predicted yield ($s_{\hat{y}}$) are computed using data through 1980 (except for 1970).

APPENDIX

Brief Description of Growing Conditions for Corn in the Bootstrap Test Years*

Year	State	Description
1971	Iowa	Record yield up 19%, production up 36%. Early planting due to cool and dry spring. June very hot, but July very cool. August very dry. Early harvest with excellent conditions. Nitrogen rate/acre down 6%.
	Illinois	Record yield up 27%, production up 30%. Planting completed early. Crop growth and development continue ahead of schedule. Early harvest with excellent conditions. Nitrogen rate/acre down 5%.
	Indiana	Record yield (up 33%) and production (up 49%). Planting completed early due to cool temperatures. June warm, but July-mid August cool. Harvest completed early with excellent conditions. Nitrogen rate/area down 11%.
1972	Iowa	Record yield up 14%, production up 4%. Frequent rains delay planting. Growing and harvest season very cool and wet. Some hail and flood losses occur. Harvest delayed beyond end of year by rain. Nitrogen rate/acre unchanged from 1971.
	Illinois	Record yield up 4%, production down 5%. Planting delayed by wet weather. Harvest also delayed into 1973 by rains. Nitrogen rate/acre up 12%.
	Indiana	Record yield up 3%, production down 9%. Wet, cool spring delays planting. Cool July, with dry weather in south. Harvest delayed by cool, wet weather. Nitrogen rate/acre up 12%.
1973	Iowa	Yield down 8%, production down 2%. Planting delayed by frequent rains. Growing season very wet and warm. Harvest also delayed by rains, but excellent weather in October allowed an early finish. Nitrogen rate/acre down 1%.

APPENDIX

Brief Description of Growing Conditions for Corn in the Bootstrap Test Years*

Year	State	Description
	Illinois	Yield down 6%, production down 3%. Planting delayed by spring rains. Summer growing conditions good. Harvest occurred on time with excellent conditions. Nitrogen rate/acre down 4%.
	Indiana	Yield down 2%, production up 5%. Planting behind schedule due to rains. Summer moisture mostly adequate. Normal harvest timing. Nitrogen rate/acre down 10%.
1974	Iowa	Yield down 25%, production down 20%. Heavy rains in May, early June delay planting. Hot, dry late June, July. Early frost in September. Excellent harvest conditions once begun. Nitrogen rate/acre down 7%.
	Illinois	Yield down 20%, production down 17%. Excess rain and late freeze delay planting. Wet fields and early freezes delay maturity. Larger than usual abandonment and cut for silage. Harvest delayed by wet weather. Nitrogen rate/acre down 8%.
	Indiana	Yield down 28%, production down 27%. Heavy May rains delay planting. Most of spring wet and cool, stalling development. July very hot and dry. Early freeze and heavy fall rains hurt harvest. Nitrogen rate/acre down 11%.
1975	Iowa	Yield up 13%, production up 15%. Excellent May weather ideal for planting. Flooding, heavy rains in June. Hot, dry July and August. Harvest conditions very good. Nitrogen rate/acre up 1%.
	Illinois	Record yield (up 41%) and production (up 54%). Planting completed on schedule. Ideal summer weather conditions. Harvesting completed on time. Nitrogen rate/acre up 3%.

APPENDIX

Brief Description of Growing Conditions for
Corn in the Bootstrap Test Years*

Year	State	Description
	Indiana	Yield up 34%, production up 42%. Excellent spring planting conditions. Warm temperatures and rainfall in June and August give excellent growing season conditions. Harvesting completed normally. Nitrogen rate/acre up 3½%.
1976	Iowa	Yield up 1%, production up 5%. Planting delayed due to rains. June and July warm and dry. Harvest completed early. Nitrogen rate/acre up 23%.
	Illinois	Yield down 8%, production down 1%. Planting completed ahead of schedule. Dry growing season reduces crop prospects. Dry fall allows early harvest completion. Nitrogen rate/acre up 21%.
	Indiana	Record yield (up 12%) and production (up 26%). Cold, dry weather for planting. Heavy rains in June, but long dry spells July-September. Near normal or cool temperatures all season. Near normal harvest schedule. Nitrogen rate/acre up 22½%.
1977	Iowa	Yield down 2%, production down 7%. Warm spring, planting completed early. Hot, dry June and July - much crop stress with long drought in central areas. Cool, wet fall weather delays harvest. Nitrogen rate/acre up 1½%.
	Illinois	Yield down 2%, production down 4%. Planting completed early. Dry summer weather. Harvest ahead of schedule through October, then slowed by rains. Nitrogen rate/acre down 8%.

APPENDIX

Brief Description of Growing Conditions for Corn in the Bootstrap Test Years*

Year	State	Description
	Indiana	Yield down 7%, production down 9%. Warm spring - planting completed early. Hot and dry late June through July - some crop stress. Wet, warm fall - harvest delayed. Nitrogen rate/acre up 8%.
1978	Iowa	Record yield (up 36%) and production (up 35%). Above normal spring rains - planting on normal schedule. Warm, muggy June and July, rains in late August. Excellent growing season conditions. Harvest completed very early. Nitrogen rate/acre up 1%.
	Illinois	Yield up 6%, production up 5%. Planting a little later than usual. Weather generally cool and dry. Harvest completed ahead of normal. Nitrogen rate/acre up 7%.
	Indiana	Yield up 6%, production up 6%. Planting delayed slightly by freeze in early May. Warm, moist summer weather-excellent conditions. September warm - helped crop maturity. Harvest completed early due to dry conditions. Nitrogen rate/acre down 6½%.
1979	Iowa	Record yield (up 8%) and production (up 13%). Planting delayed by cool, rainy weather. Favorable June and cooler July weather help crop. Warm, dry September brings early harvest. Nitrogen rate/acre up 6%.
	Illinois	Record yield (up 15%) and production (up 14%). Planting begins late but finishes ahead of normal. Dry, cooler weather June to July - good growing conditions. Excellent harvest conditions allow early completion. Nitrogen rate/acre up 4½%.
	Indiana	Record yield up 6%, production up 1%. Planting delayed by cold, wet April. Summer cool and moist with heavy rains in some areas. Harvest period cool and dry, with early freeze. Nitrogen rate/acre up 14½%.

APPENDIX

Brief Description of Growing Conditions for
Corn in the Bootstrap Test Years*

Year	State	Description
1980	Iowa	Yield down 13%, production down 12%. Planting over on schedule. Heavy June rains, some hail. July hot dry; August hot, humid. Harvest completed earliest ever. Nitrogen rate/acre down 3%.
	Illinois	Yield down 27% (lowest since 1974), production down 25%. Excellent spring weather allows early planting. Very hot, dry in southern 2/3 of state hampers growth during early summer. Good fall weather allows very early harvest. Nitrogen rate/acre up ½%.
	Indiana	Yield down 16%, production down 11%. Planting completed early. June cool, wet with some hail and flooding. Very hot, dry July stresses crop. Fall weather very favorable - harvest completed early. Nitrogen rate/acre down 1%.

* The following references served as source for the growing condition data described in this Appendix:

Illinois Agricultural Statistics, Bulletin No.'s 72-1 to 81-1, Illinois Cooperative Crop Reporting Service, USDA and Illinois Dept. of Agriculture.

Iowa Weather and Field Crops from Planting to Harvest, reports for years 1970 to 1977 and 1979, Iowa Crop and Livestock Reporting Service, USDA and Iowa Dept. of Agriculture.

Iowa Agricultural Statistics, 1979 and 1981, Iowa Crop and Livestock Reporting Service, USDA and Iowa Dept. of Agriculture.

Indiana Annual Crop and Livestock Summary, Bulletin No.'s A75-1 to A81-1, USDA and Purdue University, Agricultural Experiment Station.

Weekly Weather and Crop Bulletin, Volumes 58, 59, and 60, USDA Statistical Reporting Service and USDC National Oceanic and Atmospheric Administration.

Fertilizer Situation, reports for years 1971 to 1980, USDA Statistical Reporting Service.

APPENDIX
BOOTSTRAP TEST RESULTS FOR CORN YIELDS IN IOWA, ILLINOIS, AND INDIANA COMPARING TREND AND MONTHLY WEATHER DATA MODELS

STMAN=STRAW MAN THOMP=THOMPSON-TYPE CEAS=CEAS MODEL

STATE	CRD	YEAR	ACTUAL YIELD (Q/H)	PREDICTED YIELD (Q/H) STMAN	THOMP	CEAS	D= PREDICTED-ACTUAL STMAN	THOMP	CEAS
IOWA	10	1971	61.6	59.0	75.6	61.9	-2.6	14.0	0.3
		1972	72.8	61.2	79.1	63.6	-11.6	6.3	-9.2
		1973	69.1	65.1	79.5	65.6	-4.0	10.4	-3.5
		1974	47.1	67.6	61.4	64.4	20.5	14.3	17.3
		1975	55.0	65.9	47.9	60.6	10.9	-7.1	5.6
		1976	45.9	65.3	58.3	60.4	19.4	12.4	14.5
		1977	64.6	64.1	49.7	65.4	-0.5	-14.9	0.8
		1978	75.0	65.8	73.4	77.6	-9.2	-1.6	2.6
		1979	77.8	69.2	50.4	69.5	-8.6	-27.4	-8.3
		1980	73.3	71.9	63.3	66.4	-1.4	-10.0	-6.9
	20	1971	67.0	65.1	90.7	64.4	-1.9	23.7	-2.6
		1972	73.8	67.2	79.0	66.5	-6.6	5.2	-7.3
		1973	68.9	70.3	72.4	68.1	1.4	3.5	-0.8
		1974	55.7	71.9	70.1	70.2	16.2	14.4	14.5
		1975	59.9	70.9	64.1	68.6	11.0	4.2	8.7
		1976	58.5	70.4	61.5	66.4	11.9	3.0	7.9
		1977	64.3	70.4	52.2	68.6	6.1	-12.1	4.3
		1978	75.9	70.9	69.7	77.3	-5.0	-6.2	1.4
		1979	81.6	73.4	65.6	74.2	-8.2	-16.0	-7.4
		1980	78.6	75.8	54.0	72.6	-2.8	-24.6	-6.0
	30	1971	60.9	59.3	84.7	59.5	-1.6	23.8	-1.4
		1972	68.9	61.0	71.9	61.6	-7.9	3.0	-7.3
		1973	65.0	64.0	81.8	63.2	-1.0	16.8	-1.8
		1974	55.3	65.7	69.1	65.5	10.4	13.8	10.2
		1975	58.1	65.2	65.9	63.1	7.1	7.8	5.0
		1976	56.9	65.0	63.4	60.1	8.1	6.5	3.2
		1977	70.0	65.3	59.9	68.8	-4.7	-10.1	-1.2
		1978	74.1	67.4	58.6	70.4	-6.7	-15.5	-3.7
		1979	81.9	70.2	67.6	72.5	-11.7	-14.3	-9.4
		1980	76.2	73.3	80.9	68.2	-2.9	4.7	-8.0
	40	1971	57.8	62.1	57.6	61.4	4.3	-0.2	3.6
		1972	72.7	62.9	60.8	66.0	-9.8	-11.9	-6.7
		1973	66.7	66.5	67.5	70.0	-0.2	0.8	3.3
		1974	44.5	68.3	66.5	62.8	23.8	22.0	18.3
		1975	53.2	66.4	57.8	61.4	13.2	4.6	8.2
		1976	44.3	65.5	48.6	59.1	21.2	4.3	14.8
		1977	46.6	63.9	42.7	53.9	17.3	-3.9	7.3
		1978	72.2	62.1	57.1	66.2	-10.1	-15.1	-6.0
		1979	74.7	64.5	63.2	69.7	-10.2	-11.5	-5.0
		1980	54.5	66.5	45.5	61.1	12.0	-9.0	6.6

APPENDIX
BOOTSTRAP TEST RESULTS
FOR CORN YIELDS IN
IOWA, ILLINOIS, AND INDIANA
COMPARING TREND AND MONTHLY WEATHER DATA MODELS
STMAN=STRAW MAN   THOMP=THOMPSON-TYPE   CEAS=CEAS MODEL

STATE	CRD	YEAR	ACTUAL YIELD (Q/H)	PREDICTED YIELD (Q/H) STMAN	THOMP	CEAS	D= PREDICTED-ACTUAL STMAN	THOMP	CEAS
IOWA	50	1971	68.3	67.1	80.0	68.5	-1.2	11.7	0.3
		1972	78.2	69.1	74.6	71.1	-9.1	-3.6	-7.1
		1973	71.1	72.7	81.5	69.2	1.6	10.4	-1.9
		1974	59.9	74.3	67.5	65.0	14.4	7.6	5.1
		1975	61.8	73.8	78.5	73.3	12.0	16.7	11.5
		1976	65.0	73.4	59.0	73.8	8.4	-6.0	8.8
		1977	41.2	74.2	59.6	35.0	33.0	18.4	-6.2
		1978	72.9	70.1	69.5	80.5	-2.8	-3.4	7.6
		1979	84.9	71.5	67.5	78.5	-13.4	-17.4	-6.3
		1980	72.8	74.4	65.9	69.8	1.6	-6.9	-3.0
	60	1971	69.2	66.7	85.0	68.5	-2.5	15.8	-0.7
		1972	71.6	68.8	67.3	69.5	-2.8	-4.3	-2.1
		1973	63.8	71.0	68.9	68.0	7.2	5.1	4.2
		1974	53.9	71.4	66.4	62.7	17.5	12.5	8.8
		1975	62.8	69.8	73.1	72.4	7.0	10.3	9.6
		1976	64.0	69.7	61.5	72.2	5.7	-2.5	8.2
		1977	64.4	70.6	60.1	69.4	6.2	-4.3	5.0
		1978	73.9	70.6	67.2	75.4	-3.3	-6.7	1.5
		1979	83.0	72.3	73.4	76.9	-10.7	-9.6	-6.1
		1980	74.0	74.8	67.2	71.9	0.8	-6.8	-2.1
	70	1971	61.5	58.8	78.4	61.3	-2.7	16.9	-0.2
		1972	70.1	61.1	72.6	61.9	-9.0	2.5	-8.3
		1973	66.1	64.6	49.3	63.5	-1.5	-16.8	-2.5
		1974	30.0	66.7	66.4	63.5	36.7	36.4	33.5
		1975	42.8	62.9	50.0	56.1	20.1	7.2	13.3
		1976	61.8	60.5	60.1	61.1	-1.3	-1.7	-0.7
		1977	42.9	62.8	70.8	49.0	19.9	27.9	6.1
		1978	65.7	60.8	65.3	64.3	-4.9	-0.4	-1.4
		1979	75.3	61.9	62.2	67.7	-13.4	-13.1	-7.6
		1980	55.3	64.3	49.5	50.1	9.0	-5.8	-5.2
	80	1971	59.9	54.5	60.2	55.0	-5.4	0.3	-4.9
		1972	68.3	57.2	62.1	57.0	-11.1	-6.2	-11.3
		1973	61.5	61.1	76.1	61.4	-0.4	14.6	-0.1
		1974	38.4	62.9	69.8	63.2	24.5	31.4	24.8
		1975	46.3	61.1	46.9	59.3	14.8	0.6	13.5
		1976	59.5	59.7	55.2	60.4	0.2	-4.3	0.9
		1977	25.2	61.6	43.6	54.3	36.4	18.4	29.1
		1978	62.6	56.6	64.9	58.3	-6.0	2.3	-3.8
		1979	69.3	57.9	56.2	64.0	-11.4	-13.1	-5.3
		1980	55.5	60.3	50.6	51.9	4.8	-4.9	-3.6

APPENDIX
BOOTSTRAP TEST RESULTS FOR CORN YIELDS IN IOWA, ILLINOIS, AND INDIANA COMPARING TREND AND MONTHLY WEATHER DATA MODELS

STMAN=STRAW MAN   THOMP=THOMPSON-TYPE   CEAS=CEAS MODEL

STATE	CRD	YEAR	ACTUAL YIELD (Q/H)	PREDICTED YIELD (Q/H) STMAN	THOMP	CEAS	D= PREDICTED-ACTUAL STMAN	THOMP	CEAS
IOWA	90	1971	69.7	61.7	64.5	62.4	-8.0	-5.2	-7.3
		1972	74.1	65.1	61.9	66.5	-9.0	-12.2	-7.5
		1973	66.2	68.6	82.3	63.3	2.4	16.1	-2.9
		1974	56.6	70.0	71.7	69.4	13.4	15.1	12.8
		1975	58.5	69.9	67.7	72.2	11.4	9.2	13.7
		1976	67.1	69.5	69.4	71.7	2.4	2.3	4.6
		1977	47.8	71.4	64.0	69.2	23.6	16.2	21.4
		1978	66.9	68.7	72.4	69.8	1.8	5.5	2.9
		1979	83.5	69.6	67.1	70.8	-13.9	-16.4	-12.7
		1980	70.9	72.9	50.0	69.7	2.0	-20.9	-1.2
STATE MODEL		1971	64.0	62.4	86.8	61.8	-1.6	22.8	-2.2
		1972	72.8	64.4	73.2	66.3	-8.4	0.4	-6.5
		1973	67.2	67.8	71.9	68.2	0.6	4.7	1.0
		1974	50.2	69.4	74.3	66.9	19.2	24.1	16.7
		1975	56.5	68.1	64.4	63.6	11.6	7.9	7.1
		1976	57.1	67.4	60.9	59.8	10.3	3.8	2.7
		1977	54.0	67.7	48.4	55.8	13.7	-5.6	1.8
		1978	72.2	66.7	65.7	73.6	-5.5	-6.5	1.4
		1979	79.7	68.8	64.2	73.7	-10.9	-15.5	-6.0
		1980	69.0	71.4	60.5	65.8	2.4	-8.5	-3.2
CRDS AGGR.		1971	64.0	62.3	76.1	63.3	-1.7	12.1	-0.7
		1972	72.8	64.3	70.9	65.6	-8.5	-1.9	-7.2
		1973	67.2	67.6	73.6	66.6	0.4	6.4	-0.6
		1974	50.2	69.4	67.2	65.2	19.2	17.0	15.0
		1975	56.5	68.0	62.5	65.8	11.5	6.0	9.3
		1976	57.1	67.4	59.2	65.3	10.3	2.1	8.2
		1977	54.0	67.7	55.4	58.9	13.7	1.4	4.9
		1978	72.2	66.7	66.5	72.7	-5.5	-5.7	0.5
		1979	79.7	68.7	63.8	72.3	-11.0	-15.9	-7.4
		1980	69.0	71.4	59.5	66.0	2.4	-9.5	-3.0

APPENDIX
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IOWA, ILLINOIS, AND INDIANA
COMPARING TREND AND MONTHLY WEATHER DATA MODELS
STMAN=STRAW MAN THOMP=THOMPSON-TYPE CEAS=CEAS MODEL

STATE	CRD	YEAR	ACTUAL YIELD (Q/H)	PREDICTED YIELD (Q/H) STMAN	THOMP	CEAS	D= PREDICTED-ACTUAL STMAN	THOMP	CEAS
ILLINOIS	10	1971	66.3	66.3	88.6	64.7	0.0	22.3	-1.6
		1972	68.7	67.7	71.7	70.9	-1.0	3.0	2.2
		1973	62.8	69.3	63.7	64.9	6.5	0.9	2.1
		1974	49.1	69.5	55.4	60.7	20.4	6.3	11.6
		1975	72.2	67.1	62.2	72.1	-5.1	-10.0	-0.1
		1976	63.5	68.9	64.6	71.2	5.4	1.1	7.7
		1977	72.5	69.6	66.3	72.4	-2.9	-6.2	-0.1
		1978	71.7	71.1	74.8	76.8	-0.6	3.1	5.1
		1979	79.5	72.4	74.3	78.2	-7.1	-5.2	-1.3
		1980	72.5	74.3	73.4	77.2	1.8	0.9	4.7
	20	1971	63.1	63.5	71.5	64.1	0.4	8.4	1.0
		1972	66.8	64.9	61.1	65.1	-1.9	-5.7	-1.7
		1973	61.5	66.7	66.9	65.5	5.2	5.4	4.0
		1974	45.9	67.2	60.6	64.3	21.3	14.7	18.4
		1975	69.4	64.6	50.6	65.9	-4.8	-18.8	-3.5
		1976	65.4	66.5	60.5	65.0	1.1	-4.9	-0.4
		1977	71.9	67.8	57.7	71.6	-4.1	-14.2	-0.3
		1978	71.1	69.6	73.7	70.1	-1.5	2.6	-1.0
		1979	80.2	71.2	75.0	76.0	-9.0	-5.2	-4.2
		1980	69.9	73.5	74.0	76.1	3.6	4.1	6.2
	30	1971	69.5	63.8	54.5	65.7	-5.7	-15.0	-3.8
		1972	72.6	66.5	57.0	67.0	-6.1	-15.6	-5.6
		1973	65.9	69.3	64.6	66.8	3.4	-1.3	0.9
		1974	57.9	70.3	59.9	66.6	12.4	2.0	8.7
		1975	73.8	70.0	77.6	69.2	-3.8	3.8	-4.6
		1976	66.7	72.5	76.5	71.7	5.8	9.8	5.0
		1977	54.4	73.4	66.5	73.0	19.0	12.1	18.6
		1978	69.2	71.4	67.7	72.7	2.2	-1.5	3.5
		1979	82.7	72.1	70.6	76.4	-10.6	-12.1	-6.3
		1980	62.4	75.0	71.4	69.6	12.6	9.0	7.2
	40	1971	74.7	70.5	83.5	73.2	-4.2	8.8	-1.5
		1972	76.5	73.2	72.5	73.5	-3.3	-4.0	-2.9
		1973	72.3	75.7	64.5	74.5	3.4	-7.8	2.2
		1974	54.7	76.9	66.3	72.3	22.2	11.6	17.6
		1975	81.9	74.8	87.5	76.1	-7.1	5.6	-5.8
		1976	78.2	77.8	82.1	76.3	-0.4	3.9	-1.9
		1977	66.0	79.8	79.1	75.0	13.8	13.1	9.0
		1978	72.7	79.0	83.0	77.1	6.3	10.3	4.4
		1979	83.3	79.2	78.7	86.9	-4.1	-4.6	3.6
		1980	54.2	80.7	62.1	78.3	26.5	7.9	24.1

APPENDIX
BOOTSTRAP TEST RESULTS
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IOWA, ILLINOIS, AND INDIANA
COMPARING TREND AND MONTHLY WEATHER DATA MODELS
STMAN=STRAW MAN THOMP=THOMPSON-TYPE CEAS=CEAS MODEl

STATE	CRD	YEAR	ACTUAL YIELD (Q/H)	PREDICTED YIELD (Q/H) STMAN	THOMP	CEAS	D= PREDICTED-ACTUAL STMAN	THOMP	CEAS
ILLINOIS	50	1971	75.3	70.0	91.5	72.6	-5.3	16.2	-2.7
		1972	75.2	73.0	79.0	73.1	-2.2	3.8	-2.1
		1973	67.9	75.4	66.5	73.7	7.5	-1.4	5.8
		1974	52.8	76.0	74.6	73.0	23.2	21.8	20.2
		1975	78.8	73.7	83.0	75.9	-5.1	4.2	-2.9
		1976	75.6	76.3	72.8	76.7	0.7	-2.8	1.1
		1977	64.7	77.9	96.0	73.6	13.2	31.3	8.9
		1978	76.0	77.1	83.9	78.6	1.1	7.9	2.6
		1979	84.6	78.3	83.1	83.3	-6.3	-1.5	-1.3
		1980	49.8	80.3	65.4	73.8	30.5	15.6	24.0
	60	1971	65.7	66.2	58.7	71.2	0.5	-7.0	5.5
		1972	69.4	67.9	47.4	68.0	-1.5	-22.0	-1.4
		1973	69.1	70.1	65.1	67.5	1.0	-4.0	-1.5
		1974	57.9	71.7	74.2	65.7	13.8	16.3	7.8
		1975	71.6	71.7	59.3	72.4	0.1	-12.3	0.8
		1976	61.5	74.0	74.1	68.6	12.5	12.6	7.1
		1977	68.0	74.1	64.8	66.5	6.1	-3.2	-1.4
		1978	66.7	74.9	71.1	73.1	8.2	4.4	6.4
		1979	82.1	73.6	69.5	76.2	-8.5	-12.6	-5.9
		1980	59.9	76.1	61.6	67.0	16.2	1.7	7.1
	70	1971	63.1	64.0	80.9	66.5	0.9	17.8	3.4
		1972	62.9	65.8	65.7	63.8	2.9	2.8	0.9
		1973	63.4	67.1	51.3	57.1	3.7	-12.1	-6.3
		1974	47.8	68.3	51.4	62.6	20.5	3.6	14.8
		1975	70.0	66.7	75.0	66.1	-3.3	5.0	-3.9
		1976	67.3	69.4	74.0	69.1	2.1	6.7	1.8
		1977	67.3	70.9	53.8	68.5	3.6	-13.5	1.2
		1978	69.8	72.1	73.6	72.0	2.3	3.8	2.2
		1979	78.3	72.3	64.1	74.0	-6.0	-14.2	-4.3
		1980	52.9	74.6	68.1	64.5	21.7	15.2	11.6
	80	1971	44.4	49.2	39.3	52.5	4.8	-5.1	8.1
		1972	49.9	49.6	36.6	51.0	-0.3	-13.3	1.1
		1973	44.6	51.1	41.5	47.5	6.5	-3.1	2.9
		1974	41.5	51.3	41.6	46.4	9.8	0.1	4.9
		1975	53.2	51.2	46.0	51.7	-2.0	-7.2	-1.5
		1976	42.9	53.2	55.2	52.4	10.3	12.3	9.5
		1977	55.0	52.8	39.5	46.4	-2.2	-15.5	-8.6
		1978	56.2	54.1	53.1	51.8	-2.1	-3.1	-4.4
		1979	67.6	54.5	59.1	55.8	-13.1	-8.5	-11.8
		1980	33.4	57.5	47.5	49.0	24.1	14.1	15.6

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COMPARING TREND AND MONTHLY WEATHER DATA MODELS
STMAN=STRAW MAN THOMP=THOMPSON-TYPE CEAS=CEAS MODEL

STATE	CRD	YEAR	ACTUAL YIELD (Q/H)	PREDICTED YIELD (Q/H) STMAN	THOMP	CEAS	D= PREDICTED-ACTUAL STMAN	THOMP	CEAS
ILLINOIS	90	1971	43.8	49.8	61.6	52.9	6.0	17.8	9.1
		1972	53.2	50.0	40.5	51.4	-3.2	-12.7	-1.8
		1973	44.0	52.0	35.2	46.2	8.0	-8.8	2.2
		1974	42.2	51.9	46.8	49.2	9.7	4.6	7.0
		1975	53.8	52.0	44.5	48.6	-1.8	-9.3	-5.2
		1976	54.5	54.0	50.3	55.5	-0.5	-4.2	1.0
		1977	53.6	55.4	46.8	52.6	1.8	-6.8	-1.0
		1978	46.5	56.0	53.2	50.9	9.5	6.7	4.4
		1979	65.7	54.9	54.3	54.9	-10.8	-11.4	-10.8
		1980	38.4	57.4	53.1	44.5	19.0	14.7	6.1
STATE MODEL		1971	66.5	65.2	67.6	67.0	-1.3	1.1	0.5
		1972	69.0	67.1	63.8	67.7	-1.9	-5.2	-1.3
		1973	64.6	69.2	64.3	67.5	4.6	-0.3	2.9
		1974	51.5	70.1	60.4	65.9	18.6	8.9	14.4
		1975	72.8	68.5	62.3	69.8	-4.3	-10.5	-3.0
		1976	67.2	71.0	70.9	71.2	3.8	3.7	4.0
		1977	65.9	72.1	74.8	70.3	6.2	8.9	4.4
		1978	69.7	72.5	74.5	71.7	2.8	4.8	2.0
		1979	80.3	72.9	75.5	78.8	-7.4	-4.8	-1.5
		1980	58.4	75.1	65.3	73.4	16.7	6.9	15.0
CRDS AGGR.		1971	66.5	65.2	75.3	67.2	-1.3	8.8	0.7
		1972	69.0	67.2	64.0	67.8	-1.8	-5.0	-1.2
		1973	64.6	69.4	61.5	66.0	4.8	-3.1	1.4
		1974	51.5	70.3	62.2	65.3	18.8	10.7	13.8
		1975	72.8	68.6	69.4	70.0	-4.2	-3.4	-2.8
		1976	67.2	70.9	70.6	70.2	3.7	3.4	3.0
		1977	65.9	72.1	68.3	70.1	6.2	2.4	4.2
		1978	69.7	72.3	74.2	72.9	2.6	4.5	3.2
		1979	80.3	72.8	72.8	77.3	-7.5	-7.5	-3.0
		1980	58.4	75.0	66.5	70.8	16.6	8.1	12.4

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IOWA, ILLINOIS, AND INDIANA
COMPARING TREND AND MONTHLY WEATHER DATA MODELS
STMAN=STRAW MAN THOMP=THOMPSON-TYPE CEAS=CEAS MODEL

STATE	CRD	YEAR	ACTUAL YIELD (Q/H)	PREDICTED YIELD (Q/H)			D= PREDICTED-ACTUAL		
				STMAN	THOMP	CEAS	STMAN	THOMP	CEAS
INDIANA	10	1971	71.6	65.9	47.1	69.3	-5.7	-24.5	-2.3
		1972	69.6	68.6	65.2	69.5	-1.0	-4.4	-0.1
		1973	67.5	71.3	66.3	70.2	3.8	-1.2	2.7
		1974	47.8	72.9	64.5	69.7	25.1	16.7	21.9
		1975	65.2	70.3	60.6	69.8	5.1	-4.6	4.6
		1976	70.6	70.9	50.8	71.5	0.3	-19.8	0.9
		1977	65.7	72.3	58.6	69.8	6.6	-7.1	4.1
		1978	66.1	72.2	67.2	71.9	6.1	1.1	5.8
		1979	73.6	72.6	69.4	76.0	-1.0	-4.2	2.4
		1980	49.9	73.4	63.4	71.4	23.5	13.5	21.5
	20	1971	62.8	58.0	56.3	59.9	-4.8	-6.5	-2.9
		1972	61.8	59.7	60.6	60.0	-2.1	-1.2	-1.8
		1973	62.3	61.8	58.9	61.5	-0.5	-3.4	-0.8
		1974	40.1	63.4	58.9	57.6	23.3	18.8	17.5
		1975	62.3	60.4	64.8	60.7	-1.9	2.5	-1.6
		1976	67.5	61.8	58.3	62.3	-5.7	-9.2	-5.2
		1977	62.4	63.9	63.8	61.5	1.5	1.4	-0.9
		1978	61.7	64.5	65.6	63.4	2.8	3.9	1.7
		1979	68.6	65.4	67.2	66.9	-3.2	-1.4	-1.7
		1980	54.7	66.9	63.7	66.3	12.2	9.0	11.6
	30	1971	55.1	53.8	57.8	54.3	-1.3	2.7	-0.8
		1972	59.3	54.5	57.1	55.5	-4.8	-2.2	-3.8
		1973	58.1	56.9	60.0	57.3	-1.2	1.9	-0.8
		1974	37.1	58.4	49.9	50.8	21.3	12.8	13.7
		1975	52.5	55.8	51.8	49.1	3.3	-0.7	-3.4
		1976	62.9	56.0	58.6	60.9	-6.9	-4.3	-2.0
		1977	63.8	58.1	61.2	58.9	-5.7	-2.6	-4.9
		1978	59.9	59.8	60.2	59.1	-0.1	0.3	-0.8
		1979	67.3	61.1	65.4	62.5	-6.2	-1.9	-4.7
		1980	64.1	63.3	64.5	64.0	-0.8	0.4	-0.1
	40	1971	67.7	63.5	74.3	67.8	-4.2	6.6	0.1
		1972	69.6	66.1	64.8	64.6	-3.5	-4.8	-5.0
		1973	67.5	69.4	60.8	63.8	1.9	-6.7	-3.7
		1974	42.8	71.3	50.1	64.7	28.5	7.3	21.9
		1975	69.3	68.0	53.4	64.4	-1.3	-15.9	-4.9
		1976	71.1	69.9	74.7	68.8	-1.2	3.6	-2.3
		1977	64.5	71.6	43.6	67.5	7.1	-20.9	3.0
		1978	72.5	71.8	79.6	73.0	-0.7	7.1	0.5
		1979	74.0	73.2	70.1	80.0	-0.8	-3.9	6.0
		1980	58.1	74.4	71.1	69.3	16.3	13.0	11.2

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BOOTSTRAP TEST RESULTS FOR CORN YIELDS IN IOWA, ILLINOIS, AND INDIANA COMPARING TREND AND MONTHLY WEATHER DATA MODELS

STMAN=STRAW MAN THOMP=THOMPSON-TYPE CEAS=CEAS MODEL

STATE	CRD	YEAR	ACTUAL YIELD (Q/H)	PREDICTED YIELD (Q/H) STMAN	THOMP	CEAS	D= PREDICTED-ACTUAL STMAN	THOMP	CEAS
INDIANA	50	1971	65.9	61.4	75.8	62.7	-4.5	9.9	-3.2
		1972	67.3	63.6	62.0	60.6	-3.7	-5.3	-6.7
		1973	68.5	66.7	72.7	64.7	-1.8	4.2	-3.8
		1974	48.1	69.0	64.6	63.2	20.9	16.5	15.1
		1975	64.6	67.0	65.7	60.5	2.4	1.1	-4.1
		1976	72.7	68.4	75.3	67.9	-4.3	2.6	-4.8
		1977	64.7	70.4	54.0	67.5	5.7	-10.7	2.8
		1978	74.5	70.9	64.7	70.9	-3.6	-9.8	-3.6
		1979	73.9	72.9	74.8	80.8	-1.0	0.9	6.9
		1980	66.4	74.4	67.0	67.7	8.0	0.6	1.3
	60	1971	57.9	55.4	62.0	55.3	-2.5	4.1	2.6
		1972	62.1	57.0	53.8	54.5	-5.1	-8.3	-7.6
		1973	61.7	59.8	65.3	59.1	-1.9	3.6	-2.6
		1974	47.8	61.8	59.3	55.8	14.0	11.5	8.0
		1975	55.8	60.8	58.9	56.0	5.0	3.1	0.2
		1976	65.6	61.3	69.5	59.2	-4.3	3.9	-6.4
		1977	59.9	62.8	50.9	59.4	2.9	-9.0	-0.5
		1978	69.7	63.4	67.6	64.4	-6.3	-2.1	-5.3
		1979	71.1	65.9	51.6	78.1	-5.2	-19.5	7.0
		1980	71.1	68.1	71.6	67.7	-3.0	0.5	-3.4
	70	1971	60.1	60.7	58.9	64.0	0.6	-1.2	3.9
		1972	65.8	62.7	56.0	63.0	-3.1	-9.8	-2.8
		1973	61.5	66.1	59.4	62.8	4.6	-2.1	1.3
		1974	52.3	67.7	51.1	65.7	15.4	-1.2	13.4
		1975	63.4	67.2	58.8	64.3	3.8	-4.6	0.9
		1976	70.2	68.8	66.7	69.6	-1.4	-3.5	-0.6
		1977	65.6	70.8	62.7	65.8	5.2	-2.9	0.2
		1978	68.1	71.5	67.8	68.5	3.4	-0.3	0.4
		1979	65.8	71.9	63.0	73.0	6.1	-2.8	7.2
		1980	62.8	72.3	65.2	64.3	9.5	2.4	1.5
	80	1971	52.8	54.5	58.4	58.2	1.7	5.6	5.4
		1972	60.5	56.1	53.8	54.6	-4.4	-6.7	-5.9
		1973	57.3	59.4	54.9	57.5	2.1	-2.4	0.2
		1974	48.7	60.9	53.9	56.5	12.2	5.2	7.8
		1975	42.9	60.9	53.1	55.0	18.0	10.2	12.1
		1976	64.9	59.6	54.1	60.2	-5.3	-10.8	-4.7
		1977	62.5	61.6	51.8	56.7	-0.9	-10.7	-5.8
		1978	64.5	63.0	64.3	65.1	-1.5	-0.2	0.6
		1979	61.8	63.9	59.9	70.9	2.1	-1.9	9.1
		1980	57.3	64.9	62.0	57.2	7.6	4.7	-0.1

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STATE	CRD	YEAR	ACTUAL YIELD (Q/H)	PREDICTED YIELD (Q/H) STMAN	THOMP	CEAS	D= PREDICTED-ACTUAL STMAN	THOMP	CEAS
INDIANA	90	1971	54.5	55.8	59.3	58.2	1.3	4.8	3.7
		1972	56.5	57.5	53.4	54.9	1.0	-3.1	-1.6
		1973	50.8	59.7	51.4	56.2	8.9	0.6	5.4
		1974	47.5	60.0	54.2	56.5	12.5	6.7	9.1
		1975	48.3	59.6	48.1	53.2	11.3	-0.2	4.9
		1976	64.4	58.9	50.6	58.7	-5.5	-13.8	-5.7
		1977	61.9	60.8	55.2	55.6	-1.1	-6.7	-6.3
		1978	63.6	62.4	60.7	61.2	-1.2	-2.9	-2.4
		1979	62.3	63.3	61.5	64.1	1.0	-0.8	1.8
		1980	59.7	64.2	59.9	58.4	4.5	0.2	-1.3
STATE MODEL		1971	63.4	60.3	69.9	64.4	-3.1	6.5	1.0
		1972	65.3	62.4	61.6	60.5	-2.9	-3.7	-4.8
		1973	64.0	65.2	63.3	64.8	1.2	-0.7	0.8
		1974	45.8	67.0	58.5	63.8	21.2	12.7	18.0
		1975	61.5	64.9	47.5	62.3	3.4	-14.0	0.8
		1976	69.0	65.9	64.9	67.7	-3.1	-4.1	-1.3
		1977	64.0	67.7	61.8	63.8	3.7	-2.2	-0.2
		1978	67.8	68.3	71.7	68.2	0.5	3.9	0.4
		1979	70.3	69.4	71.0	70.4	-0.9	0.7	0.1
		1980	60.3	70.7	63.2	66.0	10.4	2.9	5.7
CRDS AGGR.		1971	63.4	60.2	62.2	62.4	-3.2	-1.2	-1.0
		1972	65.3	62.3	60.3	61.5	-3.0	-5.0	-3.8
		1973	64.0	65.1	63.5	63.2	1.1	-0.5	-0.8
		1974	45.8	66.9	58.0	61.9	21.1	12.2	16.1
		1975	61.5	64.7	59.5	61.1	3.2	-2.0	-0.4
		1976	69.0	65.7	63.9	66.1	-3.3	-5.1	-2.9
		1977	64.0	67.5	56.4	64.5	3.5	-7.6	0.5
		1978	67.8	68.2	67.0	67.8	0.4	-0.8	0.0
		1979	70.3	69.4	67.1	74.0	-0.9	-3.2	3.7
		1980	60.3	70.6	65.8	66.6	10.3	5.5	6.3

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STATE	CRD	YEAR	ACTUAL YIELD (Q/H)	PREDICTED YIELD (Q/H) STMAN	THOMP	CEAS	D= PREDICTED-ACTUAL STMAN	THOMP	CEAS
REGION CRDS	AGGR.	1971	64.8	62.9	73.0	64.5	-1.9	8.2	-0.3
		1972	69.9	65.0	66.2	65.5	-4.9	-3.7	-4.3
		1973	65.6	67.8	67.1	65.7	2.2	1.5	0.1
		1974	49.8	69.2	63.6	64.5	19.4	13.8	14.8
		1975	63.6	67.6	64.5	66.5	4.0	0.9	2.9
		1976	63.3	68.4	64.4	67.3	5.1	1.1	4.0
		1977	60.5	69.3	60.4	64.2	8.8	-0.1	3.7
		1978	70.3	69.0	69.5	71.7	-1.3	-0.8	1.4
		1979	78.1	70.4	67.8	74.5	-7.7	-10.3	-3.6
		1980	63.3	72.5	63.4	67.9	9.2	0.1	4.6
STATES	AGGR.	1971	64.8	63.0	76.2	64.3	-1.8	11.4	-0.5
		1972	69.9	65.0	67.4	65.7	-4.9	-2.5	-4.2
		1973	65.6	67.8	67.4	67.3	2.2	1.8	1.7
		1974	49.8	69.2	66.2	65.9	19.4	16.4	16.1
		1975	63.6	67.6	60.3	65.7	4.0	-3.3	2.1
		1976	63.3	68.4	65.5	65.7	5.1	2.2	2.4
		1977	60.5	69.3	61.0	62.9	8.8	0.5	2.4
		1978	70.3	69.2	70.2	71.8	-1.1	-0.1	1.5
		1979	78.1	70.4	69.7	74.9	-7.7	-8.4	-3.2
		1980	63.3	72.6	62.8	68.6	9.3	-0.5	5.3