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EVALUATION OF THOMPSON-TYPE TREND AND MONTHLY WEATHER DATA MODELS FOR CORN YIELDS IN IOWA, ILLINOIA, AND INDIANA

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16. Abstract

An evaluation was made of Thompson-Type models which use trend terms (as a surrogate for technology), meteorological variables based on monthly average temperature, and total precipitation to forecast and estimate corn yields in Iowa, Illinois, and Indiana. Pooled and unpooled Thompson-type models were compared. Neither was found to be consistently superior to the other. Yield reliability indicators show that the models are of limited use for large area yield estimation. The models are objective and consistent with scientific knowledge. Timely yield forecasts and estimates can be made during the growing season by using normals or long range weather forecasts. The models are not costly to operate and are easy to use and understand. The model standard errors of prediction do not provide a useful current measure of modeled yield reliability.

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EVALUATION OF THOMPSON-TYPE TREND AND MONTHLY WEATHER DATA MODELS FOR CORN YIELDS IN IOWA, ILLINOIS AND INDIANA

by

Vikki French
Research Associate

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Evaluation of Thompson-type Trend and Monthly Weather Data Models for Corn Yields in Iowa, Illinois and Indiana

Vikki A. French

SUMMARY AND CONCLUSIONS

The Thompson-type models evaluated could be used to forecast and estimate corn yields in Iowa, Illinois, and Indiana. The variable year is used to develop surrogates for technological trend. Monthly average temperature and total precipitation are used to construct meteorological variables. Two methodologies were compared, pooled versus unpooled Thompson-type models. The pooled model first fitted the data for technological trend in each Crop Reporting District (CRD). Then the detrended CRd data within each state was pooled and the model fitted at the state level. For the unpooled models, separate models were developed for each of the nine CRDs within each state and for each of the treee states. Bootstrap tests were then run on the models to obtain indicators of yield reliability and current measures of modeled yield reliability.

Neither methodology is consistently better than the other. For many of the indicators, the pooled model outperforms the unpooled model, but the pooled model has a bias problem. The pooled model also requires more computer time and memory than does the unpooled model.

The yield reliability indicators generally show that the models have limited value for large area corn yield estimation. The models are objective and consistent with scienific knowledge. They could esily be developed to predict yields in other geographic areas. Timely yield forecasts and estimates can

be made during the growing season using normal or long-range forecast weather data. The models are not costly to operate and are easy to understand and use. The model standard errors of prediction do not provide a good current measure of modeled yield reliability.

DESCRIPTION OF THE MODELS

The corn yield models evaluated in this report are based on work by Louis M. Thompson (1969, 1980) at Iowa State University to study the relationship between weather and corn yields. In all models the basic historic weather variables are: (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. for each of these six variables the deviations from "normal" (DFN) values are computed and entered into each model, as are the squared DFN values. The latter are included because Thompson assumed that the DFN variables are related to yield in a curvilinear pattern resembling a parabola. Thompson used state level yield and weather data from five states (Iowa, Illinois, Indiana, Ohio and Missouri) to develop his models. Weather "normals" were regional averages of the weather variables.

In his early work, Thompson (1969) used a two-step pooling process with data from 1930-1967. In the first step, a "yield with normal weather" is estimated by setting all DFN values to zero and fitting a regression equation for each state using three linear trend terms as the only independent variable. The first time trend term (TREND 1) is the year minus 1929 for years from 1930 to 1960 and the value 31 for later years. The second trend term (TREND 2) is zero for years prior to 1961, and the year value minus 1960 for later years. The third year term (TREND 3) is the square of TREND 2. These trend terms are used as a surrogate for technology. Thompson (1969) assumed that technology was introduced gradually from 1930 to 1960 and adopted more rapidly after 1960. The basis of this assumption was the increased use of nitrogen fertilizer on corn to the five-state region. The independent variables are the DFN and squared DFN variables, and the detrended yields (for each state and year) calculated from the appropriate one of the five regression equations of the first step. Thompson used this regional model to study the relationship between corn yields and deviations from normal weather. Later, Thompson (1980) abandoned the two-step pooling approach in favor of a one-step approach. He developed five regression equations (one for each state) using the yield, twelve DFN and squared DFN variables, and the three trend terms. Unlike the first approach, both the trend and weather variables are included in the same equation.

The Modeling Center staff of the Yield Model Development (YMD) project in Columbia, Missouri decided to compare the results using both of Thompson's approaches before selecting models for evaluation. Although Thompson estimated only state level yields, the Staff also wanted to extend his method in order to estimate yields at the CRD level. For the two-step (pooled) approach, models for state level yield estimates were obtained by closely following Thompson's methodology (1969). The method differed only in that weather and yield values for three states (Iowa, Illinois, and Indiana) were pooled to develop the regional model, and that weather "normals" were based on three-state regional averages for the period from 1950-1980, rather than using Thompson's five states.

CRD level yield estimates using the two-step approach were obtained by applying Thompson's methodology at the state level. The first step, computing yield with normal weather, was performed separately for each CRD. Weather normals were based on individual state averages from 1950-1980. The DFN variables and estimated yield with normal weather for each year and each CRD were pooled within each state. Three state models were then developed. These state models were used to predict yields at the CRD level within each state.

For the one-step (unpooled) approach, state level corn yield estimates were obtained by closely following Thompson's methodology (1980), differing only in that weather normals were based on three-state regional averages from 1950-1980. For CRD level models, Thompson (1981) recommended fitting separate models for each CRD using the same weather and trend variables as used in the state level models. Weather "normals" used within each state were based on individual state averages from 1950-1980.

To develop CRD level data sets, published CRD level corn (for grain purposes only) yield data of the Statistical Reporting Service (SRS) and Climatic Division (CD) weather data of the National Oceanic and Atmospheric Administration (NOAA) were used. For Iowa, Illinois, and Indiana, CD boundaries exactly match those of CRDs. To develop state level data sets, weather variables and yields at the CRD level were weighted by harvested area and aggregated to the state level. To develop a regional level data set, weather variables at the state level were weighted by harvested area and aggregated to the three state regional level.

Weather and yield data from 1932 to 1980 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. 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. In this "special" data set, areas harvested for grain were estimated based on historic relationships between areas harvested for grain and areas harvested for all purposes. Iowa reported the corn for grain yields, but in Illinois the yields were corn for all purposes.

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 evaluation.

EVALUATION METHODOLOGY

Eight Model Characteristics to Be Discussed

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 measure of modeled yield reliability.

Each of these characteristics will be discussed as they pertain to the Thompson-type trend and monthly weather data corn yield models.

Bootstrap Technique Used to Generate Indicators of Yield Reliability for Comparison of Thompson Approaches and Evaluation of Selected Models

Indicators of yield reliability (reviewed below) require that the parameters of the regression mdoel be computed for a set of data and that a yield prediction be made based on the data for a given "test" year. The values required to generate indicators of yield reliability include the predicted yield, $\hat{Y}$, the actual (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, the "bootstrap" technique is used. Years from an earlier base period are used to generate parameter estimates for a prediction equation. Values of the independent variables in the test year following the base period are inserted into the equation to produce a predicted yield for that year. Then, the test year data is added to the base period and a new prediction equation and predicted yield are generated for the following test year. This process is continued over a ten year period (1971-1980) producing ten yield predictions independent of the data used to fit the model. The earliest year in the base period for Illinois is 1950, for Indiana 1932, and for Iowa, 1950. Thus, for example, in Illinois the data base period extended from 1950-1969 (20 years) for the development of the prediction model in test year 1971, from 1950-1969 and 1971 (21 years) for the development of the prediction model in test year 1972, etc.

It should be noted that the predicted yields are truly independent of the data base used to develop the regression coefficients. Thompson's original description of the model was published in 1970, prior to any of the test years, and his revision 10 years later did not affect the form of the model or the independent variables involved; they remain the same in each model for each test year.

Table 1 shows the average corn production and yields over the ten year test period for each state and CRD. The table also contains the percent production contributed to the state production total by each CRD and the percent production each CRD contributes to the three state region production total.

Along with the CRD, state, and regional models already described, predicted yields at the state level are also derived by obtaining a weighted average of the CRD level predicted yields. At the region level, predicted yields are obtained by calculating weighted averages both of the CRD model yields and of the state model yields. In every case the weighting factor used is harvested area. Results obtained by aggregating from the state models are identified as "state aggr." Results obtained by aggregating from the CRD models are identified as "CRDs 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.

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T[illegible]
AVERAGE [illegible]
F[illegible] 1981 [illegible]

IOWA, I[illegible]

STATE	CRD	PRODUCTION QUINTALS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
IOWA	10	46.539	183.1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	20	44.543	175.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	30	35.941	141.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	40	43.409	171.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	50	49.051	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	60	37.453	147.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	70	23.059	91.[illegible]	[illegible]	3.1	[illegible]	[illegible]
	80	13.333	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	90	25.974	[illegible]	8.1	[illegible]	[illegible]	[illegible]
STATE		319.304	1.257.[illegible]		[illegible]	[illegible]	[illegible]
ILLINOIS	10	50.811	[illegible]	17.7	[illegible]	[illegible]	[illegible]
	20	32.060	[illegible]	11.[illegible]	[illegible]	[illegible]	[illegible]
	30	28.847	113.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	40	47.942	188.7[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	50	44.044	173.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	60	33.595	132.[illegible]	11.7	[illegible]	[illegible]	[illegible]
	70	32.185	[illegible].711	11.[illegible]	[illegible]	[illegible]	[illegible]
	80	7.698	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
STATE		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
INDIANA	10	24.926	94.133	[illegible]	3.3	[illegible]	[illegible]
	20	19.683	77.481	13.3	[illegible]	[illegible]	[illegible]
	30	13.08[illegible]	51.531	[illegible]	1.7	[illegible]	[illegible]
	40	17.551	[illegible]	12.1	[illegible]	[illegible]	[illegible]
	50	32.569	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	60	10.486	[illegible]	7.1	[illegible]	[illegible]	[illegible]
	70	19.250	[illegible]	13.[illegible]	[illegible]	[illegible]	[illegible]
	80	5.436	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	90	4.559	[illegible]	3.1	[illegible]	[illegible]	[illegible]
STATE		147.636	[illegible]		[illegible]	[illegible]	[illegible]
REGION		753.302	[illegible]			[illegible]	[illegible]

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

From the d value, 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) are obtained.

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 value 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 would be close in value. For the purposes of this report, a model with bias 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 small observed actual yields and large differences often have the largest rd values. Several indicators are derived using relative differences. To calculate the proportion of years beyond a critical error limit, the number of years in which the absolute value of the relative difference exceeds a critical limit of 10 percent was counted. The initial limit of 10 percent was based on earlier investigations made by Sebaugh (1981). 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 Actual and Predicted Yields

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

Two indicators relate the change in direction of actual 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 actual 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).

Current Measure of Modeled Yield Reliability Defined By a Correlation Coefficient

One of the model characteristics to be evaluated is its ability to provide an accurate, current measure of modeled yield reliability. Although a specific statistic was not discussed in the paper, Crop Yield Model Test and Evaluation Criteria, (Wilson et al., 1980), it was stated that:

> This "reliability of the reliability" characteristic can be evaluated by comparing model generated reliability measures with subsequently determined deviation between modeled and "true" yield.

For regression models, this suggests the use of a correlation coefficient between two variables generated for reach test year. One variable is an indicator of the precision with which a prediction for the next year can be made, based on the model development base period. The other variable (obtained retrospectively) is an indicator of how close the predicted value for the next year actually is to the "true" value. The estimate of the standard error of a predicted value from the base period model, sy, is used for the first value, and the absolute value of the difference between the predicted and actual yield in the test year is used as the second variable, $|d|$.

A non-parametric (Spearman) correlation coefficient, r, is employed since the assumption of bivariate normality cannot be made. A positive value of $r(-1 \leq r \leq +1)$ indicates agreement between s_y and $|d|$, i.e., a smaller (larger) value of s_y is associated with a smaller (larger) value of $|d|$. An r value close to +1 is desirable since it indicates that a small standard error of prediction (and therefore a narrow prediction interval about the yield being predicted) is associated with small discrepancies between predicted and actual yields. If this were the case, one would have confidence in $s_{\hat{y}}$ as an indicator of the accuracy of $\hat{Y}$.

MODEL COMPARISON

Pooled and Unpooled Models Are Compared Using Statistical Tests and Ranked According to Performance

A statistical test has been constructed by considering that one model performs better than another if its predicted yields, $\hat{Y}$'s, are closer to the actual yields, Y's, than the other model. The reliability of each model is related to the absolute value of the discrepancy between actual and predicted yields. Thus, where $|d_1| = |\hat{Y}_1 - Y|$ and $|d_2| = |\hat{Y}_2 - Y|$, for model 1 (unpooled) and 2 (pooled), the statistic of interest is $D = |d_1| - |d_2|$. The null hypothesis to be tested is that there is no difference in the reliability of the two models over the ten test years. This hypothesis is rejected if it is unlikely that the true D is equal to zero.

Two types of paired-sample statistical tests are used: a parametric test using Student's "t" test statistic and a nonparametric test using the Wilcoxon signed rank test statistic. Both test statistics are used because the distribution of D may not be a normal distribution. Also, the nonparametric test will allow for the rejection of the null hypothesis if one model slightly, but consistently, outperforms the other model; the parametric test will only reject the null hypothesis if the average D value is large compared to its standard erro.

For the purpose of comparing pooled and unpooled Thompson-type models, the indicators of yield reliability are ranked. The model with the indicator value indicating the best performance is given a rank of one, and the other model is given a rank of two. In case of ties, both are given a rank of one.

Indicators of Yield Reliability and Statistical Tests Show Neither Model Outperforms the Other

The results of the parametric and nonparametric paired-sample statistical tests, shown in Table 2, are inconclusive. The pooled model generally is preferred at the CRD level, especially in those CRDs with higher corn production (Figure 1), but few of the differences are significant. At the state and regional level, the pooled models do not generally do as well as the unpooled models.

The rankings of indicators of yield reliability are equally inconclusive. Figures 2a - 3 show the preferred model in each CRD based on the different indicators. The bias indicators alone show a clear preference. The bias for the unpooled model is negative in almost every CRD indicating that the model is consistently underestmating the true yield (Table 3c). The values are also higher in general for the pooled model. If only the bias were considered, the clear choice would be the unpooled model. Many of the other indicators, however, tend to favor the pooled model.

At the state and regional levels, the unpooled model is frequently the better of the two. However, in Iowa, the most important state in terms of corn production, the pooled model is frequently better.

In summary, neither the pooled nor the unpooled models can produce consistently more reliable yield predictions at the CRD, state or region level. For this reason, both models will be evaluated in this report, and both models will be included in the evaluation tables.

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MODEL COMPARISON BASED ON
PAIRED-SAMPLE STATISTICAL TESTS
UNPOOLED MODEL WITH POOLED 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 AVERAGES|		% SMALLER |D| MODEL		|DIFFERENCE OF PERCENTAGE|	
STATE	CRD	THOMPS	POOL			THOMPS	POOL		
IOWA	10	11.8	10.9	1.0		40	60	20	
	20	11.3	9.8	1.5		40	60	20	
	30	11.6	7.1	4.5		20	80	60	*
	40	8.3	9.3	1.0		50	50	0	
	50	10.2	10.0	0.2		50	50	0	
	60	7.8	5.9	1.8		50	50	0	
	70	12.9	10.8	2.1		40	60	20	
	80	9.6	12.3	2.7		70	30	40	
	90	11.9	8.7	3.3		40	60	20	*
STATE MODEL		10.0	8.0	2.0		50	50	0	
CRDS AGGR.		7.8	7.9	0.1		60	40	20	
ILLINOIS	10	5.9	7.8	1.9		80	20	60	*
	20	8.4	7.1	1.3		30	70	40	
	30	8.2	7.8	0.4		60	40	20	
	40	7.8	7.7	0.1		50	50	0	
	50	10.6	9.5	1.1		50	50	0	
	60	9.6	5.4	4.2	*	30	70	40	**
	70	9.5	6.1	3.3		30	70	40	
	80	8.2	6.8	1.5		50	50	0	
	90	9.7	6.0	3.7	*	20	80	60	**
STATE MODEL		5.5	5.3	0.2		60	40	20	
CRDS AGGR.		5.7	6.0	0.3		50	50	0	
INDIANA	10	9.7	7.8	1.9		40	50	10	
	20	5.7	6.8	1.0		40	60	20	
	30	3.0	6.6	3.6	**	90	10	80	***
	40	9.0	9.1	0.1		60	40	20	
	50	6.2	5.9	0.3		50	50	0	
	60	6.6	5.9	0.6		50	50	0	
	70	3.1	6.7	3.6	**	90	10	80	***
	80	5.8	6.4	0.5		40	60	20	
	90	4.0	5.2	1.2		80	20	60	
STATE MODEL		5.1	5.4	0.2		60	40	20	
CRDS AGGR.		4.3	6.5	2.1	*	70	30	40	**
REGION MODEL									
CRDS AGGR.		4.0	6.0	1.9		90	10	80	**
STATES AGGR.		4.7	5.6	0.9		60	40	20	

Figure 1: Model with smaller average d value in each CRD.
U = unpooled Thompson-type model
P = pooled Thompson-type model

* = significant at .10 level
** = significant at .05 level
*** = significant at .01 level

(Darker shades indicate CRDs with higher production).

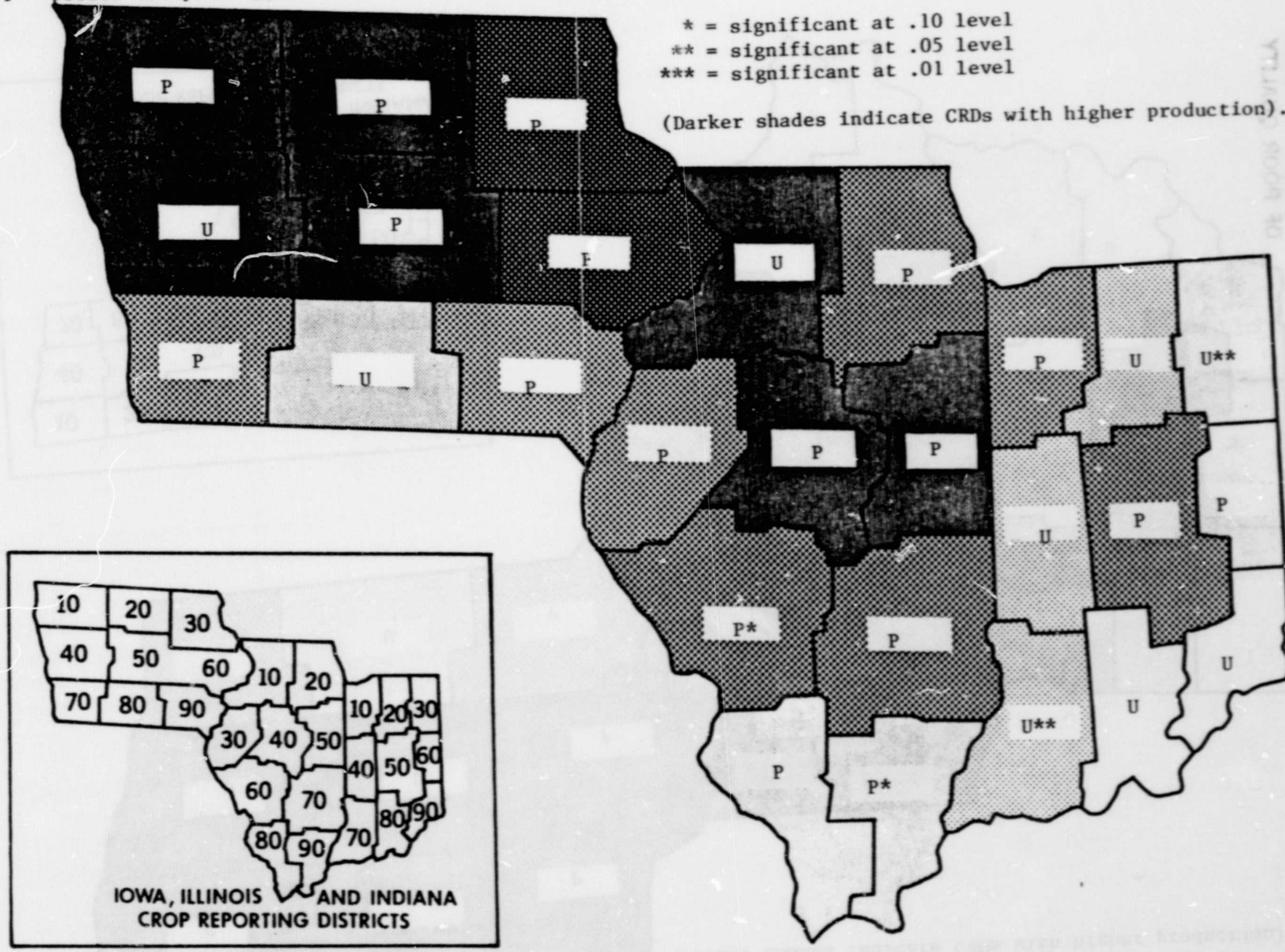


Figure 2. Model with smaller root mean square error (RMSE)
U = unpooled Thompson - type model
P = pooled Thompson - type model

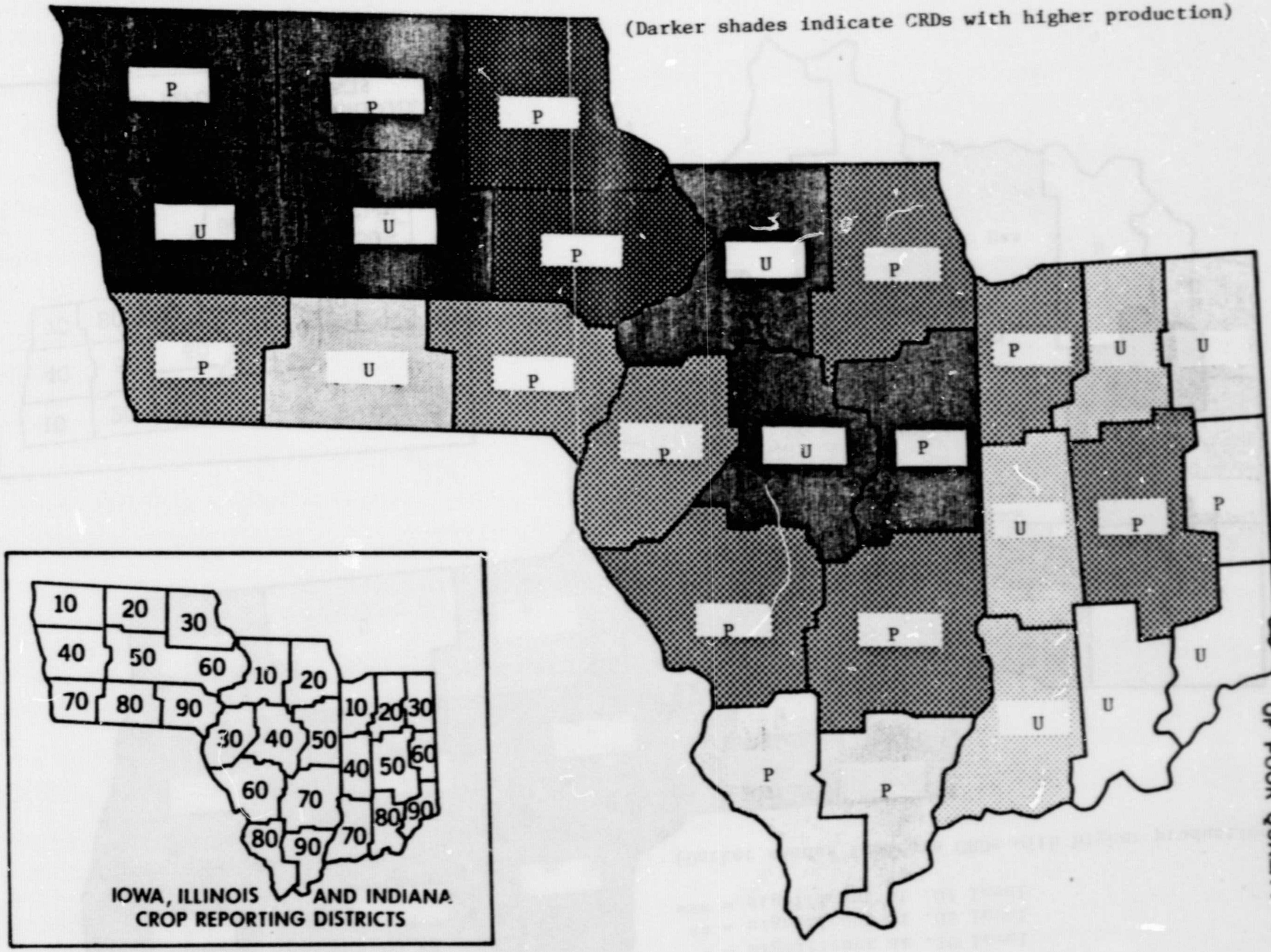


Figure 3: Model with smaller standard deviation (SD)
U = unpooled Thompson - type model
P = pooled Thompson - type model

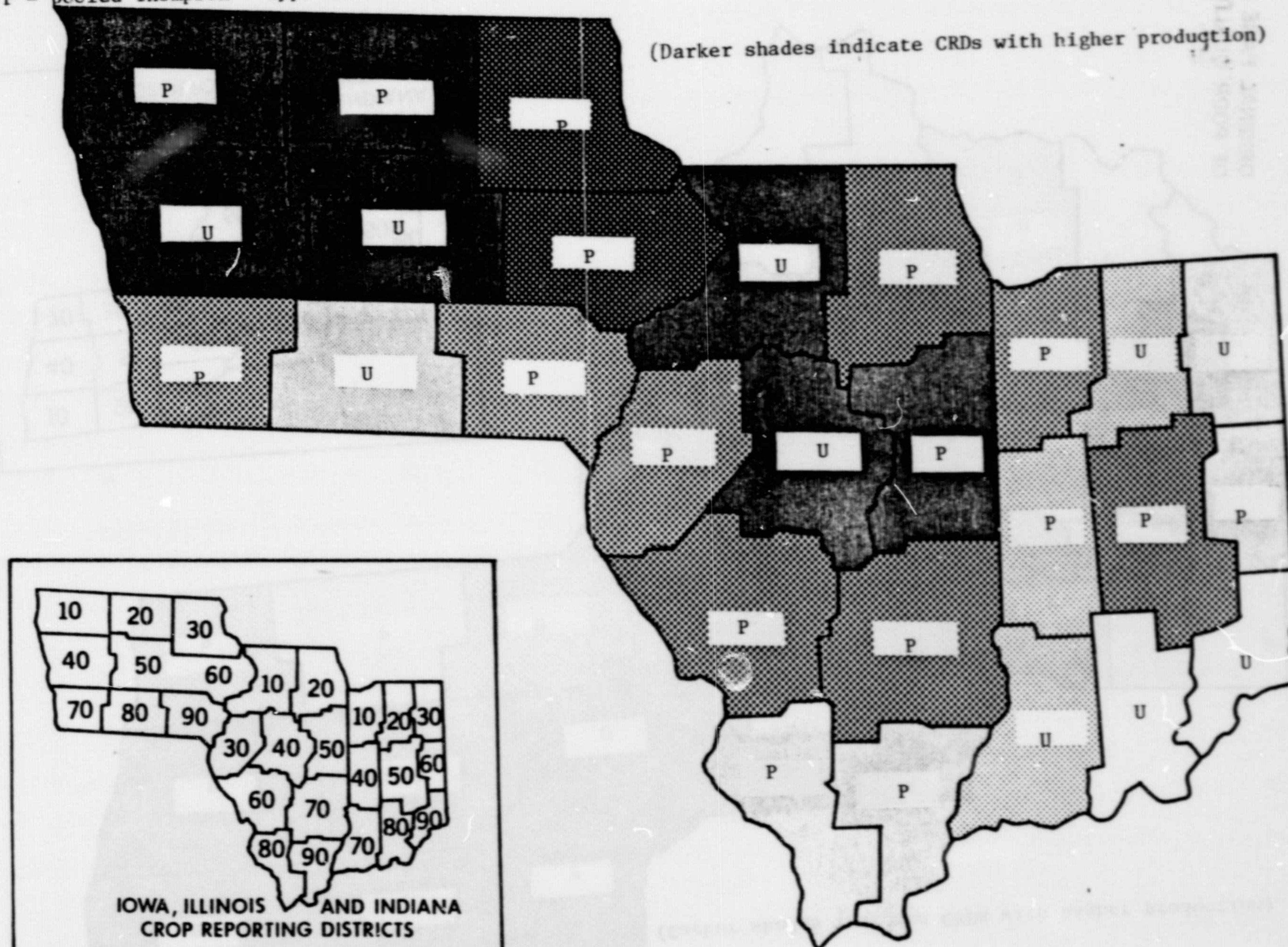


Figure 4. Model with smaller bias
U = unpooled Thompson - type model
P = pooled Thompson - type model

(Darker shades indicate CRDs with higher production)

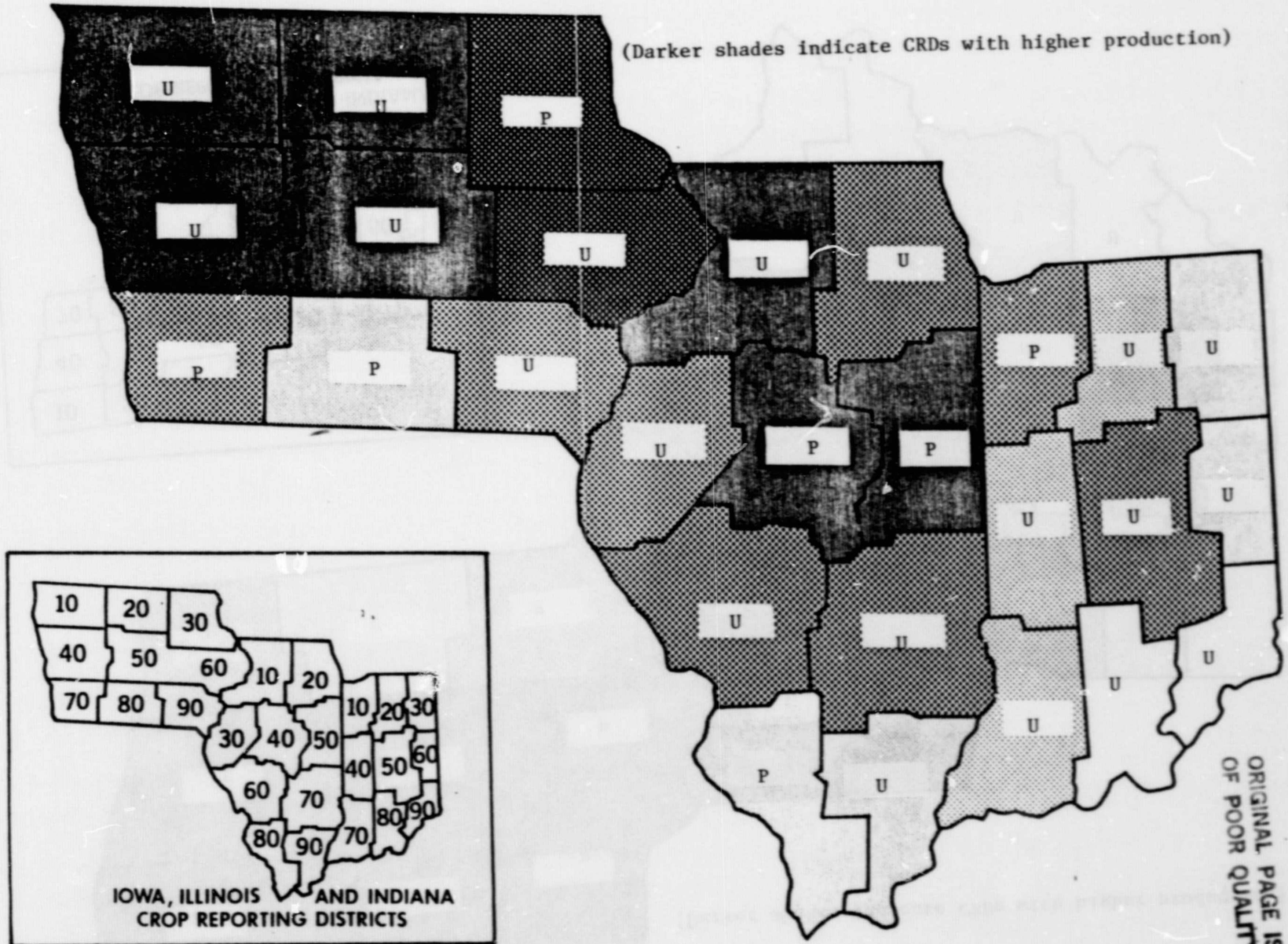
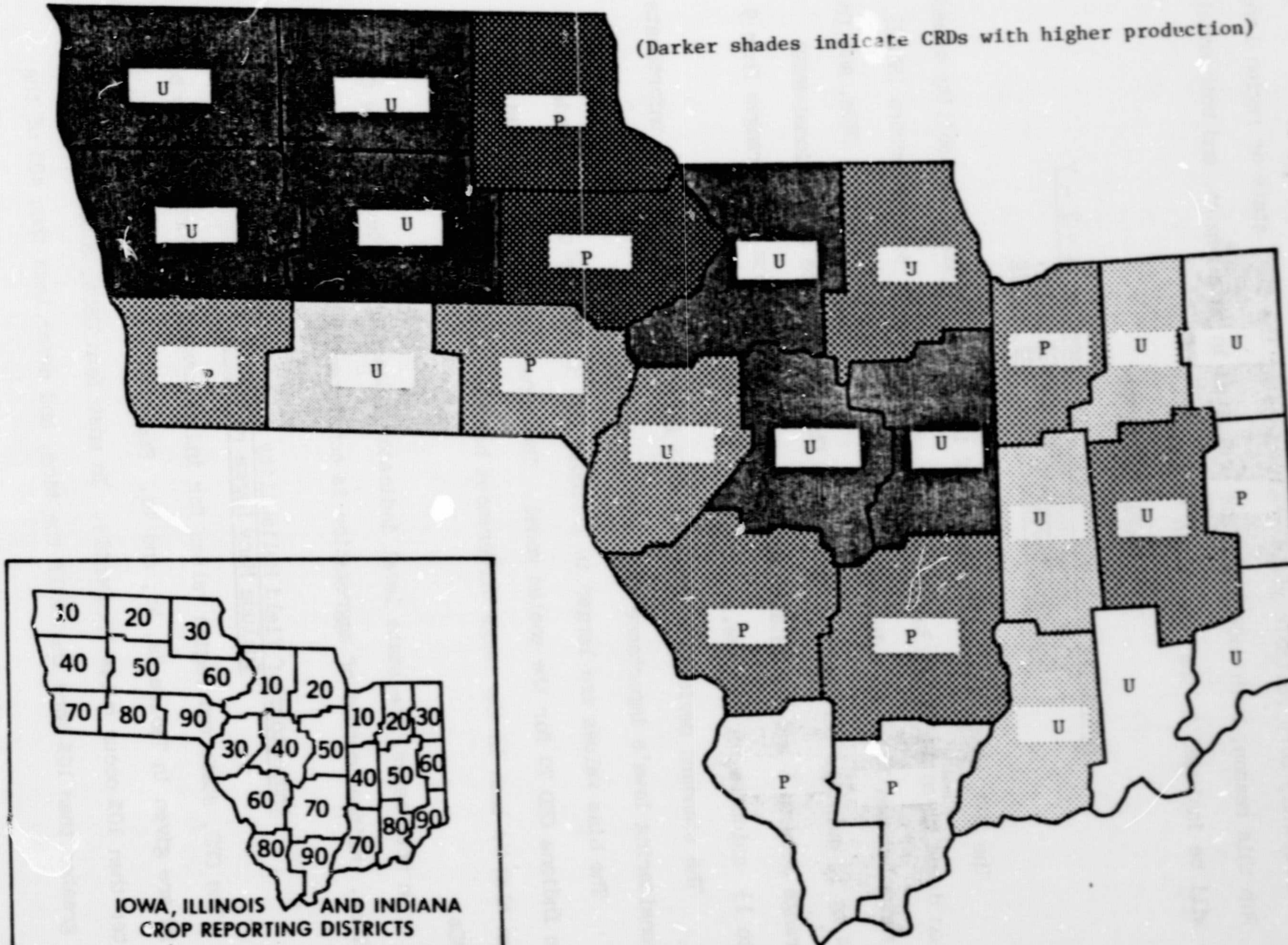


Figure 5. Model with largest correlation between actual and predicted yields.

U = unpooled Thompson - type model

P = pooled model



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consistently more reliable yield predictions at the CRD, state or region leve. For this reason, both models will be evaluated in this report, and both models will be included in the evaluation tables.

MODEL EVALUATION

Indicators of Yield Reliability Based on $d = \hat{Y} - Y$ Show Large Root Mean Square Error, Standard Deviation and Bias Values

The CRD, state and region values of indicators of yield reliability based on d are given in Tables 3a, 3b, and 3c. The root mean squares errors (RMSE) range between 7 and 17 quintals per hectare for Iowa and Illinois CRDs, and from 4 to 13 quintals per hectare for Indiana CRDs. The state and regional RMSE range between 6 and 8 quintals per hectare except for Iowa which ranges from 9 to 13 quintals per hectare.

The standard deviations (SD) are also larger in Iowa, which is unfortunate considering Iowa's importance as a corn-producing state.

The bias values are larger in Illinois CRD 50 for the unpooled model and in Indiana CRD 70 for the pooled model. The effect of these large bias values can also be seen in the large differences between SD and RMSE values for these CRDs.

In most cases, the state level indicator values are better than the CRL values. Neither method of aggregation is consistently better.

Indicators of Yield Reliability Based on rd - 100d/Y Include Many Large rd Values

The CRD, state and region values for indicators of yield reliability based on rd are given in Tables 4a, 4b, and 4c. Especially in Iowa, absolute rd values greter than 10% occur quite frequently. In most Iowa CRDs, absolute rd values are greater than 10% more than half the time, and never less than 40% of the

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TABLE 3a
INDICATORS OF YIELD RELIABILITY
BASED ON d = PREDICTED - ACTUAL YIELD
ROOT MEAN SQUARE ERROR (QUINTALS/HECTARE)
DERIVED FROM INDEPENDENT TEST YEARS

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

STATE	CRD	UNPOOLED		POOLED	
IOWA	10	13.52	(2)	[illegible]	(1)
	20	13.71	(2)	12.72	(1)
	30	13.12	(2)	[illegible]	(1)
	40	[illegible]	(1)	[illegible]	(2)
	50	11.54	(1)	12.13	(2)
	60	8.74	(2)	7.1[illegible]	(1)
	70	17.14	(2)	15.3[illegible]	(1)
	80	13.41	(1)	14.35	(2)
	90	13.23	(2)	9.91	(1)
STATE MODEL		12.54	(2)	10.14	(1)
CRDS AGGR.		9.44	(1)	10.24	(2)
ILLINOIS	10	8.51	(1)	5.95	(2)
	20	9.89	(2)	9.25	(1)
	30	9.41	(2)	9.50	(1)
	40	5.35	(1)	5.72	(2)
	50	14.34	(2)	10.43	(1)
	60	11.47	(2)	5.59	(1)
	70	10.88	(2)	7.56	(1)
	80	9.58	(2)	5.32	(1)
	90	10.57	(2)	7.2[illegible]	(1)
STATE MODEL		6.36	(1)	5.51	(2)
CRDS AGGR.		5.31	(1)	7.16	(2)
INDIANA	10	12.51	(2)	8.97	(1)
	20	7.74	(1)	8.52	(2)
	30	4.57	(1)	5.12	(2)
	40	10.50	(1)	10.50	(2)
	50	7.97	(2)	7.35	(1)
	60	8.49	(2)	5.95	(1)
	70	3.99	(1)	7.83	(2)
	80	5.86	(1)	8.08	(2)
	90	5.58	(1)	7.42	(2)
STATE MODEL		5.78	(1)	5.79	(2)
CRDS AGGR.		5.52	(1)	7.54	(2)
REGION MODEL					
CRDS AGGR.		6.18	(1)	7.45	(2)
STATES AGGR.		7.04	(2)	5.94	(1)

TABLE 3b
INDICATORS OF YIELD RELIABILITY
BASED ON d = PREDICTED - ACTUAL YIELD
STANDARD DEVIATION (QUINTALS/HECTARE)
DERIVED FROM INDEPENDENT TEST YEARS

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

STATE	CRD	UNPOOLED		POOLED	
		[illegible]	[illegible]	[illegible]	[illegible]
IOWA	10	13.91	(2)	[illegible]	(1)
	20	13.71	(2)	11.[illegible]	(1)
	30	12.[illegible]	(2)	[illegible]	(1)
	40	11.41	(1)	12.97	([illegible])
	50	11.21	(1)	11.[illegible]	(2)
	60	8.59	([illegible])	[illegible]	(1)
	70	15.30	(2)	15.[illegible]	(1)
	80	12.82	(1)	14.[illegible]	(2)
	90	13.2[illegible]	(2)	9.[illegible]	(1)
STATE MODEL		12.23	([illegible])	[illegible]	(1)
CRDS AGGR.		9.4[illegible]	(1)	[illegible]	(2)
ILLINOIS	10	8.35	(1)	[illegible]	(2)
	20	9.80	(2)	[illegible]	(1)
	30	9.75	(2)	9.17	(1)
	40	7.04	(1)	5.34	(2)
	50	11.78	(2)	1[illegible]	(1)
	60	11.17	(2)	5.5[illegible]	(1)
	70	10.77	(2)	7.[illegible]	(1)
	80	9.22	(2)	[illegible]	([illegible])
	90	11.53	(2)	5.76	([illegible])
STATE MODEL		5.21	(1)	5.35	(2)
CRDS AGGR.		5.12	(1)	5.45	(2)
INDIANA	10	12.42	(2)	5.57	(1)
	20	7.52	(1)	3.44	(2)
	30	4.53	(1)	7.45	(2)
	40	10.41	(2)	9.75	(1)
	50	7.91	(2)	5.91	(1)
	60	5.41	(2)	5.53	(1)
	70	3.32	(1)	4.31	(2)
	80	5.89	(1)	7.47	(2)
	90	5.47	(1)	5.11	(2)
STATE MODEL		5.78	(2)	5.3[illegible]	(1)
CRDS AGGR.		5.45	(1)	5.81	(2)
REGION MODEL					
CRDS AGGR.		5.09	(1)	7.01	(2)
STATES AGGR.		5.52	(2)	5.47	(1)

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TABLE 3c
INDICATORS OF YIELD RELIABILITY
BASED ON d = PREDICTED - ACTUAL YIELD
BIAS (QUINTALS/HECTARE)
DERIVED FROM INDEPENDENT TEST YEARS

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

STATE	CRD	UNPOOLED		POOLED	
		BIAS	RANK	BIAS	RANK
IOWA	10	-0.36	(1)	-2.4[illegible]	(2)
	20	-0.49	(1)	-4.47	(2)
	30	3.55	(2)	-2.43	(1)
	40	-1.49	(1)	-2.45	(2)
	50	2.75	(1)	-3.42	(2)
	60	0.95	(1)	-4.24	(2)
	70	5.31	(2)	-2.57	(1)
	80	3.91	(2)	-3.17	(1)
	90	0.97	(1)	-2.85	(2)
STATE MODEL		2.76	(1)	-3.39	(2)
CRDS AGGR.		1.20	(1)	-3.08	(2)
ILLINOIS	10	1.52	(1)	-2.48	(2)
	20	-1.36	(1)	-2.32	(2)
	30	-0.88	(1)	-2.04	(2)
	40	4.48	(2)	0.72	(1)
	50	3.51	(2)	0.33	(1)
	60	-2.51	(1)	-3.55	(2)
	70	1.51	(1)	-1.52	(2)
	80	-2.93	(2)	-0.53	(1)
	90	-0.94	(1)	-2.57	(2)
STATE MODEL		1.35	(1)	-1.81	(2)
CRDS AGGR.		1.59	(2)	-1.43	(1)
INDIANA	10	-3.45	(2)	-2.29	(1)
	20	1.39	(1)	-1.52	(2)
	30	0.54	(1)	-3.21	(2)
	40	-1.46	(1)	-3.82	(2)
	50	1.00	(1)	-2.43	(2)
	60	-1.22	(1)	-4.07	(2)
	70	-2.59	(1)	-5.54	(2)
	80	-0.78	(1)	-3.09	(2)
	90	-1.52	(1)	-4.21	(2)
STATE MODEL		0.20	(1)	-1.96	(2)
CRDS AGGR.		-0.77	(1)	-3.25	(2)
REGION MODEL					
CRDS AGGR.		1.07	(1)	-2.51	(2)
STATES AGGR.		1.75	(1)	-2.51	(2)

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TABLE 4a
INDICATORS OF YIELD RELIABILITY
BASED ON RD = 100 * (PREDICTED - ACTUAL YIELD)/ACTUAL YIELD
PERCENT OF YEARS |RELATIVE DIFFERENCE| > 10%
DERIVED FROM INDEPENDENT TEST YEARS

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

STATE	CRD	THOMPSON %	THOMPSON RANK	[illegible] %	[illegible] RANK
IOWA	10	30	(2)	70	(1)
	20	50	(1)	50	(1)
	30	[illegible]	(2)	50	(1)
	40	50	(2)	40	(1)
	50	50	(1)	50	(1)
	60	40	(1)	40	(1)
	70	70	(2)	50	(1)
	80	40	(1)	50	(2)
	90	70	(2)	60	(1)
STATE MODEL		50	(2)	40	(1)
CRDS AGGR.		50	(2)	40	(1)
ILLINOIS	10	30	(1)	50	(2)
	20	[illegible]	[illegible]	50	(2)
	30	[illegible]	[illegible]	60	(1)
	40	[illegible]	(2)	40	(1)
	50	50	(1)	70	(2)
	60	50	(2)	40	(1)
	70	50	(1)	50	(1)
	80	70	(2)	50	(1)
	90	[illegible]	(2)	60	(1)
STATE MODEL		40	(1)	40	(1)
CRDS AGGR.		30	(1)	40	(2)
INDIANA	10	[illegible]	(1)	60	(2)
	20	40	(1)	40	(1)
	30	10	(1)	40	(2)
	40	40	(1)	50	(2)
	50	40	(2)	30	(1)
	60	40	(1)	40	(1)
	70	10	(1)	50	(2)
	80	50	(2)	50	(1)
	90	30	(2)	20	(1)
STATE MODEL		30	(1)	30	(1)
CRDS AGGR.		20	(1)	30	(2)
REGION MODEL					
CRDS AGGR.		30	(1)	30	(1)
STATES AGGR.		30	(1)	40	(2)

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TABLE 4b
INDICATORS OF YIELD RELIABILITY
BASED ON RD = 100 * (PREDICTED - ACTUAL YIELD)/ACTUAL YIELD
LARGEST |RELATIVE DIFFERENCE|
DERIVED FROM INDEPENDENT TEST YEARS

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

STATE	CRD	THOMPSON RD	RANK	[illegible] RD	RANK
IOWA	10	-35.2	(1)	51.6	(2)
	20	35.4	(2)	-32.5	(1)
	30	39.1	(2)	-22.6	(1)
	40	[illegible]	(1)	51.5	(2)
	50	44.7	(2)	30.3	(1)
	60	23.2	(2)	-17.0	(1)
	70	121.3	(2)	121.0	(1)
	80	81.3	(2)	37.5	(1)
	90	35.9	(2)	-24.4	(1)
STATE MODEL		45.0	(2)	33.5	(1)
CRDS AGGR.		33.9	(1)	35.1	(2)
ILLINOIS	10	33.5	(2)	27.1	(1)
	20	32.9	(1)	37.3	(2)
	30	22.2	(1)	22.4	(2)
	40	21.2	(1)	27.4	(2)
	50	44.4	(2)	33.3	(1)
	60	-31.7	(2)	-14.0	(1)
	70	23.7	(2)	25.3	(1)
	80	42.2	(1)	52.7	(2)
	90	40.6	(2)	24.6	(1)
STATE MODEL		17.3	(1)	-14.1	(2)
CRDS AGGR.		20.3	(1)	21.6	(2)
INDIANA	10	34.9	(1)	[illegible]	(1)
	20	45.4	(2)	41.4	(1)
	30	34.5	(1)	34.9	(2)
	40	-32.4	(1)	41.8	(2)
	50	34.3	(2)	35.4	(1)
	60	-27.4	(2)	-19.8	(1)
	70	-14.9	(1)	-20.4	(2)
	80	23.5	(1)	-24.7	(2)
	90	-21.4	(1)	-24.3	(2)
STATE MODEL		27.7	(1)	27.9	(2)
CRDS AGGR.		25.5	(1)	27.7	(2)
REGION MODEL					
CRDS AGGR.		27.7	(1)	24.7	(2)
STATES AGGR.		32.9	(2)	26.1	(1)

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TABLE 4c
INDICATORS OF YIELD RELIABILITY
BASED ON RD = 100 * (PREDICTED - ACTUAL YIELD)/ACTUAL YIELD
NEXT LARGEST |RELATIVE DIFFERENCE|
DERIVED FROM INDEPENDENT TEST YEARS

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

STATE	CRD	THOMPSON RD	THOMPSON RANK	[illegible] RD	[illegible] RANK
IOWA	10	[illegible]	(2)	[illegible]	(1)
	20	-31.3	(2)	[illegible]	(1)
	30	[illegible]	(2)	21.3	(1)
	40	[illegible]	(1)	[illegible]	(2)
	50	[illegible]	(1)	-27.1	[illegible]
	60	[illegible]	(2)	[illegible]	(1)
	70	[illegible]	(2)	-24.9	(1)
	80	[illegible]	(2)	[illegible]	(1)
	90	[illegible]	(2)	24.1	(1)
STATE MODEL		[illegible]	(1)	[illegible]	(1)
CRDS AGGR.		[illegible]	(1)	-24.1	(2)
ILLINOIS	10	-13.9	(1)	-23.0	(2)
	20	-27.1	(2)	-21.3	(1)
	30	-21.5	(1)	[illegible]	[illegible]
	40	19.8	(2)	[illegible]	(1)
	50	41.3	(2)	[illegible]	(1)
	60	23.2	(2)	-11.6	(1)
	70	28.2	(2)	17.8	(1)
	80	29.7	(2)	-14.3	(1)
	90	33.3	(2)	[illegible]	(1)
STATE MODEL		-14.4	(1)	16.5	(2)
CRDS AGGR.		[illegible]	(1)	-15.5	(2)
INDIANA	10	-34.2	(2)	[illegible]	(1)
	20	15.3	(1)	[illegible]	(2)
	30	-5.3	(1)	-21.3	(2)
	40	-22.9	(1)	-23.7	(2)
	50	-15.5	(1)	-17.5	(2)
	60	24.1	(2)	19.5	(1)
	70	-7.3	(1)	-15.4	(2)
	80	-17.1	(1)	17.2	(2)
	90	14.1	(1)	-15.5	(2)
STATE MODEL		-22.5	(2)	-13.4	(1)
CRDS AGGR.		-11.9	(1)	-19.3	(2)
REGION MODEL					
CRDS AGGR.		-13.2	(1)	-17.3	(2)
STATES AGGR.		17.5	(2)	-14.5	(1)

time. In one of the test years Iowa CRD 70 has an rd of 121%. Indiana CRDs are better, having absolute rd values greater than 10% only between 10 and 60 percent of the time.

Again, state and regional models are slightly better, although the better aggregation method cannot be determined.

Indicators of Yield Reliability Based on Y and Y Show Poor Correspondence

Plots showing the actual and predicted yields using the state level models for the ten-year test period are shown in Figures 6a, 6b, 7a, 7b, 8a, and 8b. The CRD, state and region values for indicators of yield reliability based directly on actual and predicted yields are shown in Tables 5a, 5b, and 5c.

In several cases the change in direction of predicted yields agrees with the change in direction of actual yields from the previous year less than 50% of the time. This is not true as often for the change in direction from a three year base period. It can also be seen in the plots of the state models (Figures 6a -8b) that the pooled model is less sensitive to fluctuations in the previous year's actual yield than is the unpooled model and that neither are very good at predicting extreme values.

The Pearson correlation coefficients between actual and predicted yields would be significantly different from zero if they were greater than .549 (for = .05). Very few of the correlations are significantly different from zero.

Indicators of Base Period Precision Are Poor Predictors of Precision During Independent Tests

Certain ststistics generated from the regression analysis of the base period data are often used to provide some indication of expected yield reliability. However, these statistics only reflect how well the model describes the

Figure 6a

Iowa State Model, Actual and Predicted
Corn Yields for the test years 1971-1980
(Quintals/Hectare)

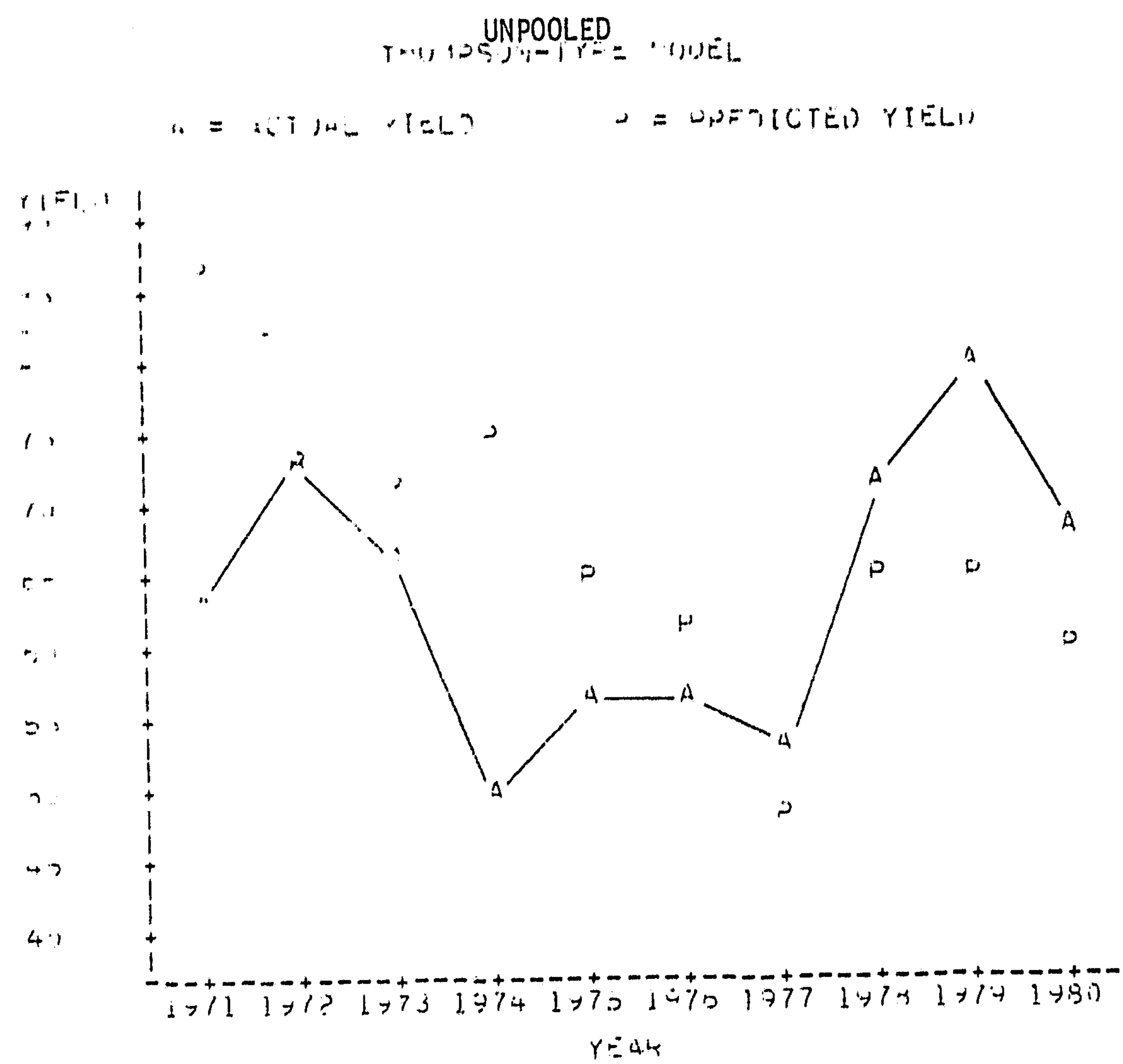

Figure 6b

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Iowa State Model, Actual and Predicted Corn Yields
for the test years 1971-1980
(Quintals/Hectare)

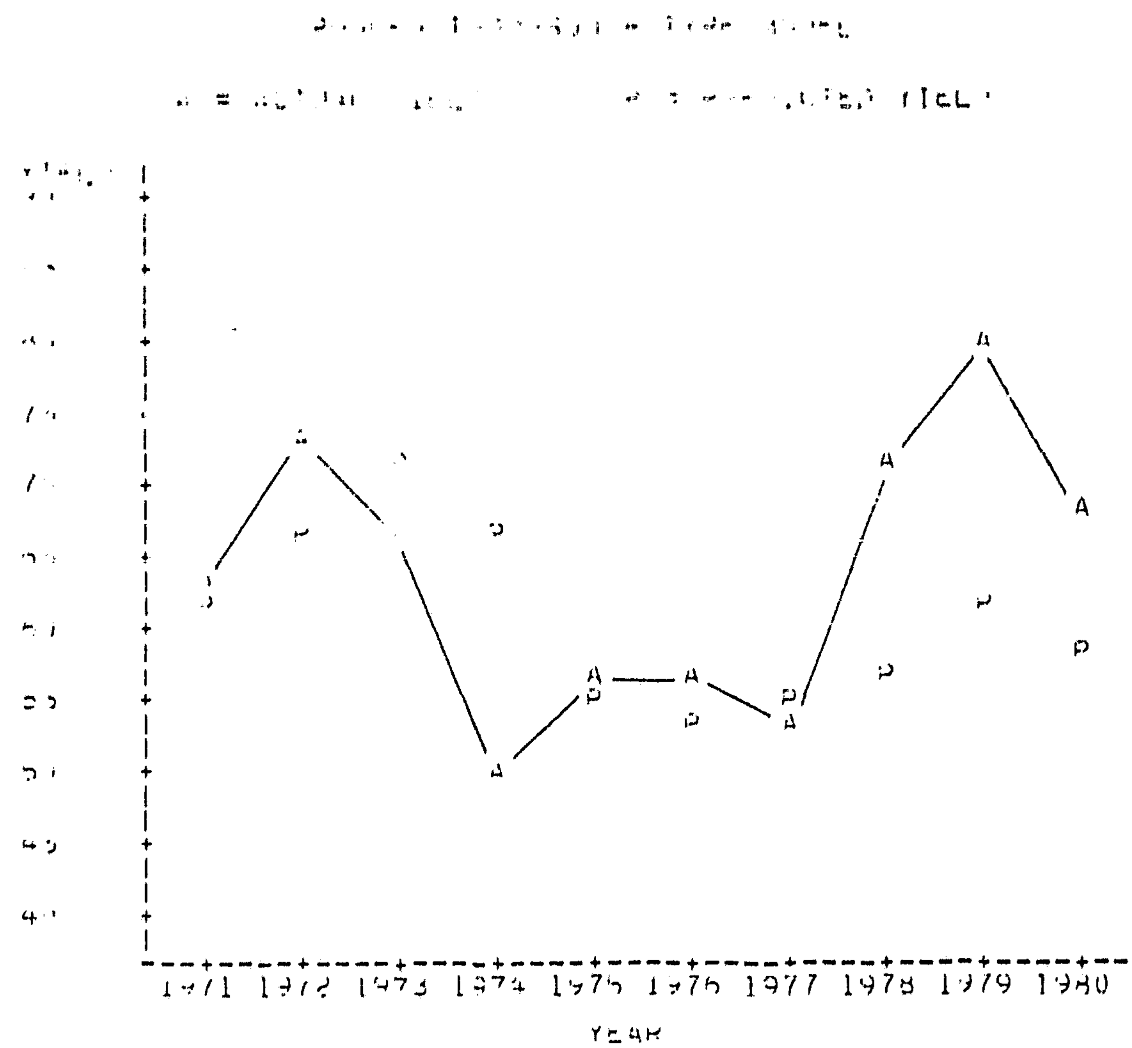

Figure 7a

Illinois State Model, Actual and Predicted
Corn Yields for the Test Years 1971-1980
(Quintals/Hectare)

UNPOOLED

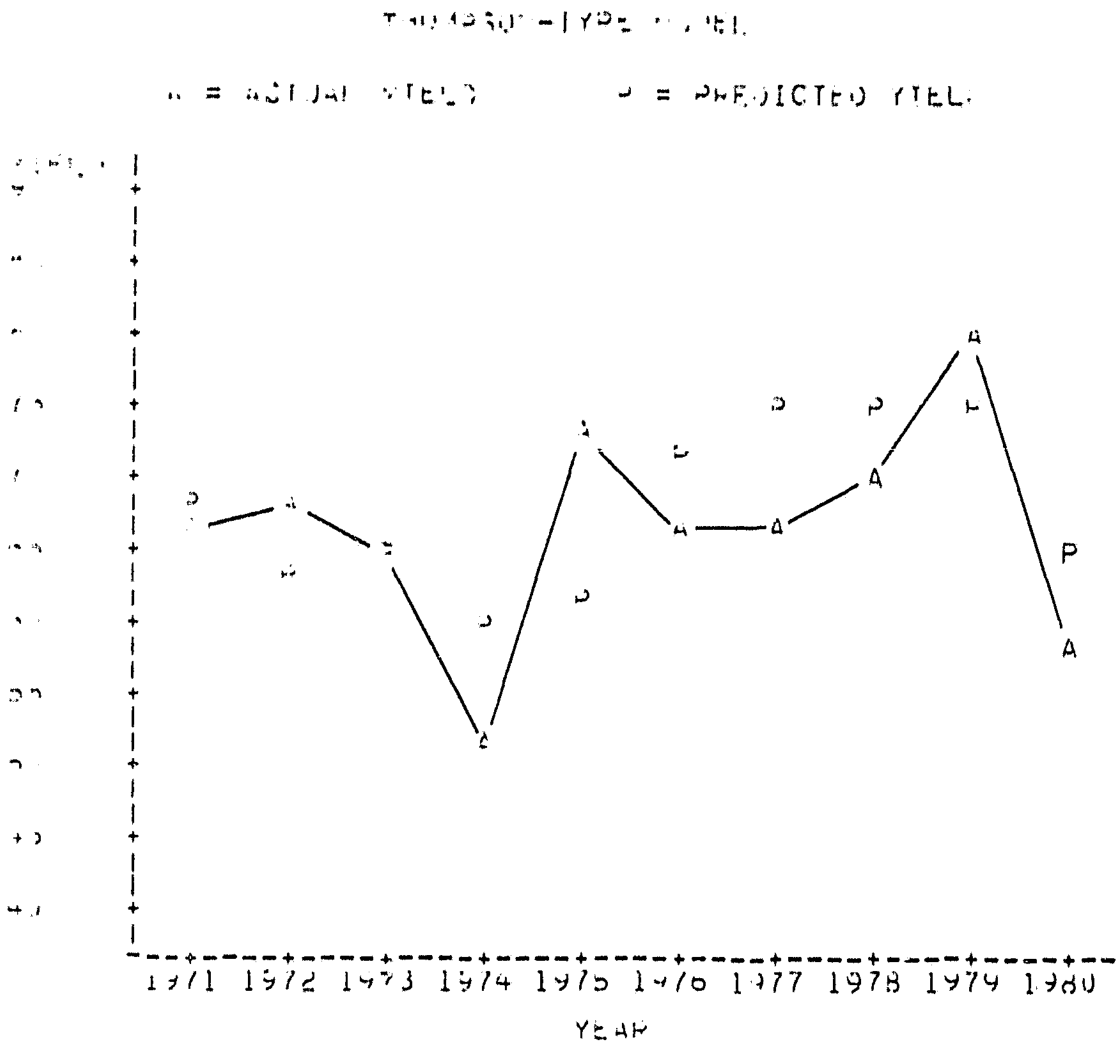

Figure 7b

Illinois State Model, Actual and Predicted
Corn Yields for the Test Years 1971-1980
Quintals/Hectare

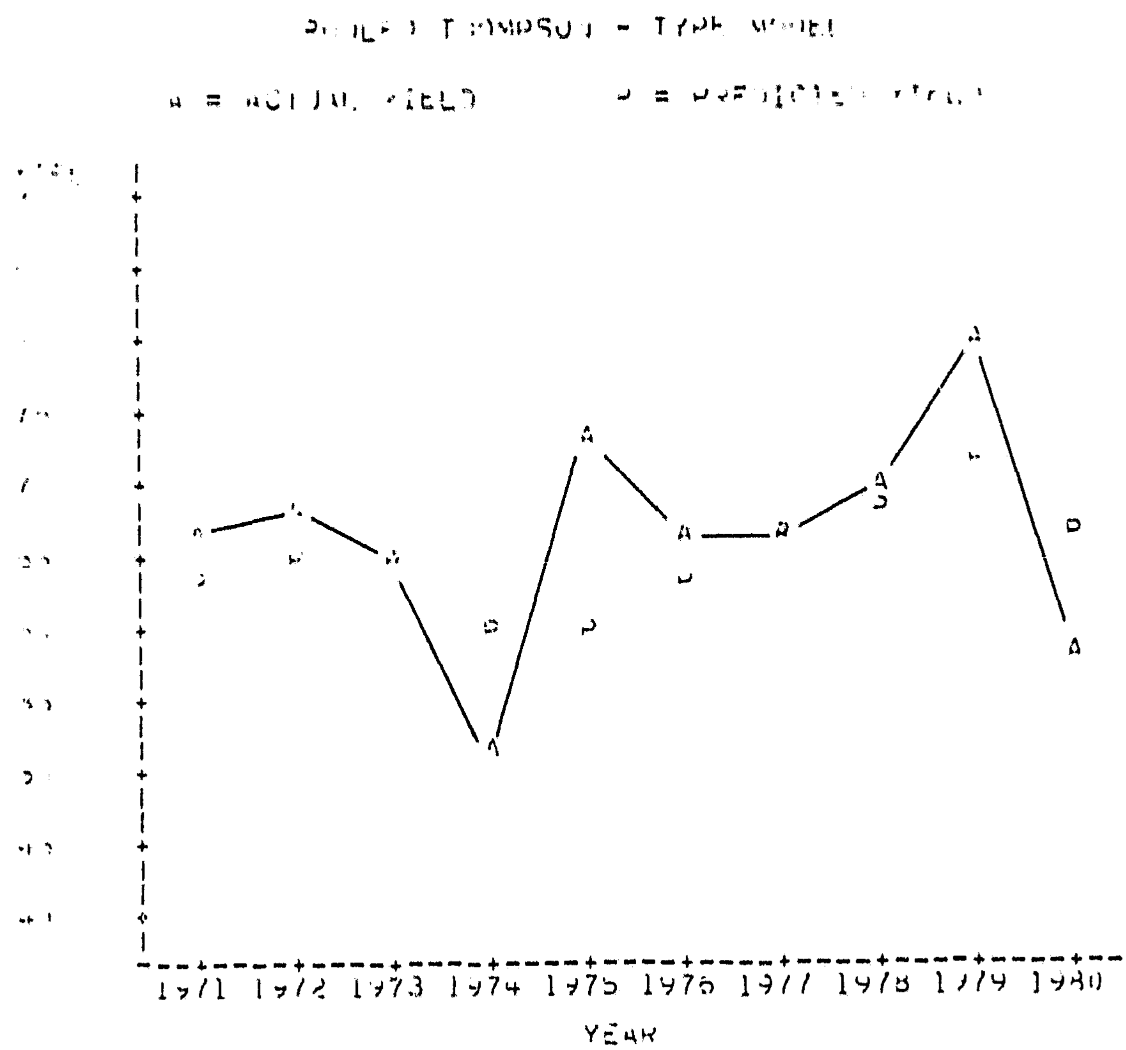

Figure 8a

Indiana State Model, Actual and Predicted
Corn Yields for the Test Years 1971-1980
Quintals/Hectare

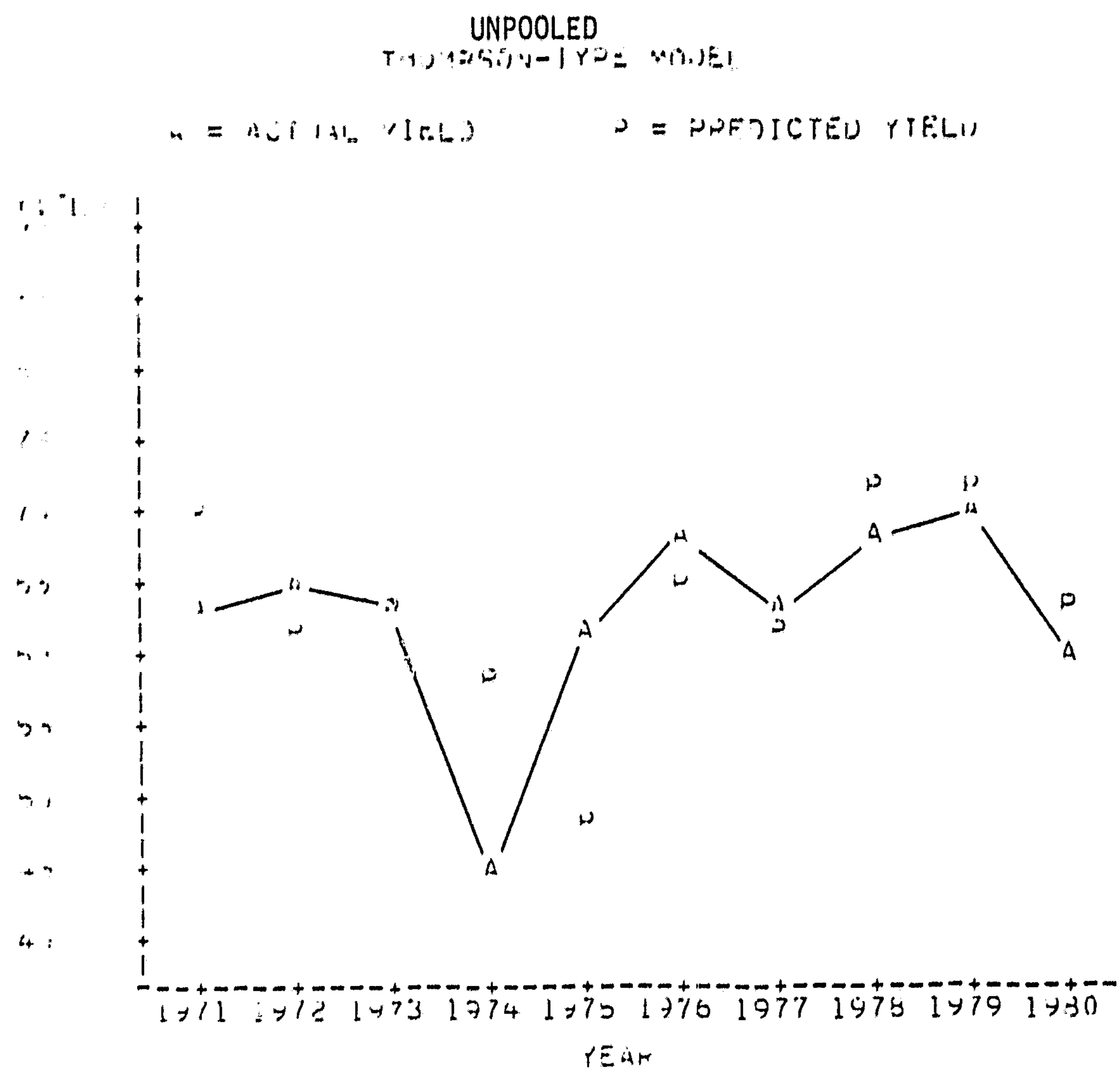

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Figure 8b

Indiana State Model, Actual and Predicted
Corn Yields for the Test Years 1971-1980
Quintals/Hectare

TABLE 5a
INDICATORS OF YIELD RELIABILITY
BASED ON ACTUAL AND PREDICTED YIELDS
PERCENT OF YEARS THE DIRECTION OF CHANGE
FROM THE PREVIOUS YEAR IS CORRECT
DURING INDEPENDENT TEST YEARS

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

STATE	CRD	UNPOOLED		POOLED	
		[illegible]	[illegible]	[illegible]	[illegible]
IOWA	10	33	(2)	44	(1)
	20	55	(1)	33	(2)
	30	33	(2)	57	(1)
	40	67	(1)	67	(1)
	50	44	(2)	57	(1)
	60	56	(2)	78	(1)
	70	33	(2)	56	(1)
	80	57	(1)	44	(2)
	90	55	(1)	56	(1)
STATE MODEL		44	(2)	56	(1)
CRDS AGGR.		44	(2)	57	(1)
ILLINOIS	10	55	(2)	57	(1)
	20	33	(2)	67	(1)
	30	78	(1)	44	(2)
	40	67	(1)	44	(2)
	50	55	(1)	33	(2)
	60	11	(2)	67	(1)
	70	44	(2)	[illegible]	(1)
	80	44	(2)	78	(1)
	90	56	(2)	67	(1)
STATE MODEL		44	(2)	67	(1)
CRDS AGGR.		56	(1)	56	(1)
INDIANA	10	44	(2)	56	(1)
	20	33	(2)	55	(1)
	30	78	(1)	56	(2)
	40	67	(1)	67	(1)
	50	78	(1)	56	(2)
	60	44	(1)	44	(1)
	70	67	(1)	67	(1)
	80	67	(1)	44	(2)
	90	44	(1)	44	(1)
STATE MODEL		56	(1)	56	(1)
CRDS AGGR.		78	(1)	56	(2)
REGION MODEL					
CRDS AGGR.		67	(1)	67	(1)
STATES AGGR.		44	(2)	56	(1)

TABLE 5b
INDICATORS OF YIELD RELIABILITY
BASED ON ACTUAL AND PREDICTED YIELDS
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

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STATE	CRD	UNPOOLED		POOLED	
IOWA	10	71	(1)	71	(1)
	20	71	(1)	[illegible]	(1)
	30	71	(1)	[illegible]	(1)
	40	86	(1)	[illegible]	(2)
	50	71	(1)	71	(1)
	60	57	(2)	71	(1)
	70	71	(1)	57	(2)
	80	57	(1)	57	(1)
	90	43	(2)	57	(1)
STATE MODEL		100	(1)	100	(1)
CRDS AGGR.		86	(1)	[illegible]	(1)
ILLINOIS	10	71	(1)	57	(2)
	20	71	(1)	57	(2)
	30	57	(1)	[illegible]	(2)
	40	57	(1)	43	(2)
	50	43	(2)	57	(1)
	60	14	(2)	57	(1)
	70	57	(1)	57	(1)
	80	57	(1)	57	(1)
	90	43	(2)	[illegible]	(1)
STATE MODEL		86	(1)	[illegible]	(1)
CRDS AGGR.		100	(1)	71	(2)
INDIANA	10	29	(2)	57	(1)
	20	57	(1)	43	(2)
	30	86	(1)	71	(2)
	40	57	(1)	57	(1)
	50	43	(2)	57	(1)
	60	71	(1)	71	(1)
	70	86	(1)	71	(2)
	80	57	(1)	57	(1)
	90	57	(1)	57	(1)
STATE MODEL		86	(1)	71	(2)
CRDS AGGR.		57	(1)	57	(1)
REGION MODEL					
CRDS AGGR.		57	(1)	43	(2)
STATES AGGR.		71	(1)	71	(1)

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TABLE 5c
INDICATORS OF YIELD RELIABILITY
BASED ON ACTUAL AND PREDICTED YIELDS
CORRELATION BETWEEN ACTUAL AND PREDICTED YIELDS
DURING INDEPENDENT TEST YEARS

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

STATE	CRD	UNPOOLED R		POOLED R	
IOWA	10	[illegible]	(1)	[illegible]	[illegible]
	20	[illegible]	(1)	[illegible]	(2)
	30	[illegible]	(2)	[illegible]	(1)
	40	[illegible]	(1)	[illegible]	[illegible]
	50	[illegible]	(1)	[illegible]	[illegible]
	60	[illegible]	[illegible]	[illegible]	(1)
	70	[illegible]	[illegible]	[illegible]	[illegible]
	80	0.41	(1)	[illegible]	[illegible]
	90	[illegible]	[illegible]	[illegible]	[illegible]
STATE MODEL		[illegible]	[illegible]	[illegible]	(1)
CRDS AGGR.		[illegible]	(1)	[illegible]	[illegible]
ILLINOIS	10	[illegible]	(1)	[illegible]	[illegible]
	20	[illegible]	(1)	[illegible]	[illegible]
	30	[illegible]	(1)	[illegible]	[illegible]
	40	0.71	(1)	[illegible]	[illegible]
	50	0.44	(1)	[illegible]	[illegible]
	60	[illegible]	(2)	[illegible]	(1)
	70	[illegible]	[illegible]	[illegible]	(1)
	80	[illegible]	[illegible]	[illegible]	(1)
	90	[illegible]	(2)	[illegible]	(1)
STATE MODEL		[illegible]	(1)	[illegible]	[illegible]
CRDS AGGR.		[illegible]	(1)	[illegible]	[illegible]
INDIANA	10	[illegible]	[illegible]	[illegible]	(1)
	20	0.23	(1)	[illegible]	[illegible]
	30	[illegible]	(1)	[illegible]	[illegible]
	40	[illegible]	(1)	[illegible]	[illegible]
	50	0.34	(1)	[illegible]	[illegible]
	60	[illegible]	(2)	[illegible]	(1)
	70	[illegible]	(1)	[illegible]	[illegible]
	80	[illegible]	(1)	0.11	[illegible]
	90	[illegible]	(1)	0.44	[illegible]
STATE MODEL		0.43	(1)	[illegible]	[illegible]
CRDS AGGR.		0.55	(1)	0.20	[illegible]
REGION MODEL					
CRDS AGGR.		[illegible]	(1)	[illegible]	[illegible]
STATES AGGR.		[illegible]	[illegible]	[illegible]	(1)

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data used to generate the model, i.e., fit of the model, rather than how well the model can predict given new data. Therefore, it is important to compare these indicators of fit of the model to the independent indicators of yield reliability discussed in the preceding sections. In this way, one can see how these base period indicators of fit of the model do or do not correspond to independent test indicators of yield reliability.

One indicator of yield reliability, the mean square error (MSE), is the sum of squared d values ($d = \hat{Y} - Y$) for the independent test years divided by the number of test years (Tables 3a - 3c). The direct analogue for the model development base period is the residual mean square. The residual mean square is obtained by first generating the usual least squares prediction equation using the base period years. Then instead of predicting the yield for the following test year, yields are predicted for each of the base period years. The residual mean square is the sum of squared d values for these base period years divided by the appropriate degrees of freedom (number of years minus number of parameters estimated in fitting the model). Whereas one value of MSE is generated for each geographic area over the entire test period, a value of the residual mean square is generated for each base period corresponding to a test year in that area. The low, high, and average of the base period values for each area are given in Tables 6a and 6b. The result of using models pooled to the state level are readily apparent in Table 6b.

The MSE values from Tables 3a, 3b and 3c are repeated in Tables 6a and 6b. The MSE values are all much larger than even the higher base period residual mean square values. Those models with larger base period residual mean squares do not necessarily have larger independent test MSE values.

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TABLE 6a
RESIDUAL MEAN SQUARE AS AN
INDICATOR OF THE FIT OF THE MODEL
BASED ON THE MODEL DEVELOPMENT BASE PERIOD

UNPOOLED THOMPSON-TYPE MODEL - CORN
IOWA, ILLINOIS, INDIANA

STATE	CRD	BASE PERIOD RESIDUAL MEAN SQUARE LOW	HIGH	AVERAGE	INDEPENDENT TEST MSE
IOWA	10	10.62	30.83	16.61	182.78
	20	13.68	19.59	16.09	188.10
	30	10.56	21.82	15.49	172.00
	40	7.08	21.71	11.83	112.24
	50	2.71	25.18	9.68	133.11
	60	7.58	12.39	9.60	76.45
	70	15.64	44.86	30.43	293.75
	80	6.88	27.90	17.53	179.60
	90	4.61	25.05	12.36	175.15
STATE MODEL		2.73	20.67	10.42	156.59
ILLINOIS	10	1.39	9.68	7.00	72.39
	20	5.29	20.96	13.18	97.80
	30	4.77	15.58	11.02	96.05
	40	14.66	27.63	19.00	69.67
	50	16.16	25.31	21.44	206.73
	60	5.42	20.87	13.78	131.60
	70	5.46	12.97	8.08	118.33
	80	1.71	15.94	7.91	93.65
	90	12.03	19.89	15.69	111.80
STATE MODEL		2.71	7.15	4.78	40.44
INDIANA	10	11.09	21.40	17.20	156.46
	20	5.08	10.62	8.21	59.97
	30	8.38	9.90	9.09	20.92
	40	8.65	12.87	10.54	110.20
	50	10.17	12.54	11.33	63.57
	60	7.88	10.08	8.74	72.16
	70	9.06	10.75	9.89	15.83
	80	7.36	11.39	9.29	47.00
	90	6.61	9.39	7.81	32.24
STATE MODEL		7.14	9.86	8.59	45.95

TABLE 6b

RESIDUAL MEAN SQUARE AS AN INDICATOR OF THE FIT OF THE MODEL BASED ON THE MODEL DEVELOPMENT BASE PERIOD

POOLED THOMPSON-TYPE MODEL - CORN
IOWA, ILLINOIS, INDIANA

STATE	CRD	BASE PERIOD RESIDUAL MEAN SQUARE LOW	HIGH	AVERAGE	INDEPENDENT TEST [illegible]
IOWA	10	8.05	23.45	14.39	[illegible]
	20	8.05	23.45	14.39	[illegible]
	30	8.05	23.45	14.39	72.81
	40	8.05	23.45	14.39	154.11
	50	8.05	23.45	14.39	147.05
	60	8.05	23.45	14.39	57.43
	70	8.05	23.45	14.39	233.49
	80	8.05	23.45	14.39	204.07
	90	8.05	23.45	14.39	98.15
STATE MODEL		6.55	11.49	9.02	102.85
ILLINOIS	10	9.96	16.50	12.31	50.15
	20	9.96	16.50	12.31	86.18
	30	9.96	16.50	12.31	77.48
	40	9.96	16.50	12.31	75.45
	50	9.96	16.50	12.31	104.78
	60	9.96	16.50	12.31	44.81
	70	9.96	16.50	12.31	58.61
	80	9.96	16.50	12.31	59.24
	90	9.96	16.50	12.31	51.78
STATE MODEL		6.55	11.49	9.02	43.73
INDIANA	10	10.10	14.22	12.18	80.45
	20	10.10	14.22	12.18	74.31
	30	10.10	14.22	12.18	65.97
	40	10.10	14.22	12.18	110.25
	50	10.10	14.22	12.18	53.97
	60	10.10	14.22	12.18	45.29
	70	10.10	14.22	12.18	61.34
	80	10.10	14.22	12.18	55.30
	90	10.10	14.22	12.18	55.04
STATE MODEL		6.55	11.49	9.02	46.05

Another indicator of yield reliability is the Pearson correlation coefficient, r, between the observed and predicted yields for the independent test years (Tables 5a, 5b and 5c). It is desirable that r be close to +1, even though it can be negative. The analogue for the model development base period is the square root of R^2, the coefficient of multiple determination. The square root of R^2, (expressed as a proportion), R ($0 \leq R \leq 1$) may be interpreted as the correlation between observed and predicted values for the base period years. The low, high, and average values of R for each geographic area are shown in Tables 7a and 7b.

It can be readily seen that the base year correlation coefficients are extremely optimistic compared to the independent test year coefficients. It would be very difficult to estimate how well a model would predict future years based on the base period correlation coefficients.

Models are Objective

To predict the yield for a future year, the values for trend and any weather-related variables in the models would be calculated and used with the regression coefficients derived when the models were developed. This would be a completely objective process.

The models would probably be updated as new data were collected, and new trend terms might need to be specified. The specification of these trend terms as described by Thompson would be a subjective process in any updated models.

The original choice of variables to be included in the models was subjective judgment. If all future updated versions were to use the same variables, this judgment process would not need to be duplicated.

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TABLE 7a
CORRELATION BETWEEN OBSERVED AND PREDICTED YIELDS AS AN INDICATOR OF THE FIT OF THE MODEL BASED ON THE MODEL DEVELOPMENT BASE PERIOD

UNPOOLED THOMPSON-TYPE MODEL - CORN
IOWA, ILLINOIS, INDIANA

TEST STATE	CRD	BASE PERIOD CORRELATION COEFF. LOW	HIGH	AVERAGE	INDEPENDENT CORR. COEF.
IOWA	10	0.97	0.99	0.98	0.24
	20	0.95	0.99	0.98	0.06
	30	0.97	0.99	0.98	-0.06
	40	0.97	0.99	0.99	0.47
	50	0.97	1.00	0.99	0.35
	60	0.98	0.99	0.99	0.27
	70	0.95	0.99	0.97	0.05
	80	0.97	0.99	0.98	0.41
	90	0.97	1.00	0.99	-0.16
STATE MODEL		0.97	1.00	0.99	0.15
ILLINOIS	10	0.99	1.00	0.99	0.49
	20	0.96	0.99	0.98	0.25
	30	0.98	0.99	0.99	0.17
	40	0.98	0.99	0.98	0.71
	50	0.98	0.99	0.98	0.44
	60	0.98	1.00	0.99	-0.20
	70	0.99	1.00	0.99	0.32
	80	0.97	1.00	0.99	0.38
	90	0.97	0.99	0.98	-0.01
STATE MODEL		0.99	1.00	0.99	0.56
INDIANA	10	0.98	0.98	0.98	-0.23
	20	0.98	0.99	0.98	0.23
	30	0.97	0.98	0.98	0.89
	40	0.98	0.99	0.99	0.49
	50	0.98	0.99	0.98	0.34
	60	0.98	0.98	0.98	0.29
	70	0.98	0.99	0.99	0.30
	80	0.98	0.99	0.98	0.30
	90	0.98	0.99	0.99	0.30
STATE MODEL		0.98	0.99	0.99	0.48

[illegible] 7b

CORRELATION [illegible]
[illegible]
[illegible]

[illegible]

TEST STATE	GRD	[illegible]			[illegible]
IOWA	10	0.94	[illegible]	[illegible]	0.15
	20	0.94	0.93	0.95	-0.16
	30	0.94	[illegible]	0.95	0.33
	40	0.94	0.98	0.95	0.26
	50	0.94	[illegible]	0.95	0.25
	60	0.94	0.98	0.95	0.55
	70	0.94	0.98	0.90	0.13
	80	0.94	0.95	0.96	0.17
	90	0.94	0.98	0.96	0.15
STATE MODEL		0.96	0.95	0.98	0.24
ILLINOIS	10	0.95	0.97	0.97	0.22
	20	0.96	0.97	0.97	0.23
	30	0.95	0.97	0.97	-0.24
	40	0.96	0.97	0.97	0.45
	50	0.96	0.97	0.97	0.27
	60	0.96	0.97	0.97	0.50
	70	0.96	0.97	0.97	0.43
	80	0.96	0.97	0.97	0.42
	90	0.96	0.97	0.97	0.48
STATE MODEL		0.95	0.95	0.95	0.50
INDIANA	10	0.96	0.97	0.97	0.14
	20	0.96	0.97	0.97	0.07
	30	0.95	0.97	0.97	0.46
	40	0.96	0.97	0.97	0.03
	50	0.96	0.97	0.97	0.32
	60	0.95	0.97	0.97	0.52
	70	0.96	0.97	0.97	0.47
	80	0.95	0.97	0.97	0.11
	90	0.95	0.97	0.97	0.44
STATE MODEL		0.98	0.95	0.95	0.33

Models are Consistent With Scientific Knowledge

The Thompson-type corn yield models use two types of variables: (1) trend (year) as a surrogate for technology and (2) weather variables expressed as deviations from normal. The assumption is that changes in corn yields are primarily due to changes in these two types of variables (Thompson 1980).

In both the unpooled and pooled Thompson-type models, the trend terms used were the same. The assumption was that after 1930 corn yield began to increase due to the introduction of hybrid varieties. A linear trend term based on the year number was used to model this increase. Between 1960 and 1970 there was a sharp increase in corn yields apparently related to fertilizer use. During the seventies, this rapid increase slowed somewhat. A combination of linear and curvilinear trend terms were used to model this increase (Thompson 1980).

Figures 9a, 9b and 9c show the corn yields for each year in Iowa, Illinois, and Indiana, respectively. The plots for Indiana, which cover the longest time period, show that Thompson's assumptions about trend seem reasonable. The yields increase linearly until 1960 when a more rapid increase can be seen. This rapid increase continues until 1970 when a tapering-off seems to occur.

During the 1970s, yields seemed to be particularly variable, especially in Iowa. The year of the corn blight, 1970, can be seen to be a poor year in the plots for all three states. Other poor years in the region are 1974 and 1980. Possible reasons for these reductions from trend are included in Appendix A.

Monthly weather variables are used in the models. Monthly average temperature for a given year is not a very useful predictor of yield if the range of temperatures during the month is large. Total monthly precipitation may also be due to a moderate amount of precipitation several times during the month or to a single devastating flood. Monthly values although adequate in "average" years cannot reflect the possible extremes that would affect crops.

Both linear (DFN) and quadratic (SQDFN) departure from normal terms are used in the models. "Normal" was the average for each variable from 1932 to 1980 within each state. The variables used were cumulative precipitation from the previous September through June of the present year (DFNCUM and SQDFNCUM) June temperature (DFNT6 and SQDFNT6) July temperature (DFNT7 and SQDFNT7) August temperature (DFNT8 and SQDFNT8) July rainfall (DFNP7 and SQDFNP7) and August rainfall (DFNP8 and SQDFNP8). The August rainfall terms were not included in the original pooled model but were included in both the pooled and unpooled models in this study to make the models more comparable.

Both linear and quadratic terms were included due to the curviliear relationship between yields and departures from normal for the variables. These curvilinear relationships were explained and defended by Thompson (1969). They would seem to be intuitively appealing in terms of scientific knowledge.

As shown in Appendix C1 and C2 not all of the variables included in the model are statistically significant. The squared deviations from normal temperature terms for instance, seem to be important only in Indiana. Although it is stated that high corn yields are associated with June, July and August temperature and precipitation (Thompson, 1980) it is possible that a more parsimonious model could be obtained by eliminating certain of the less critical variables.

Figure 9a:

Iowa USDA Reported and Special Corn Yields, 1950-1980 (Quintals/Hectare)

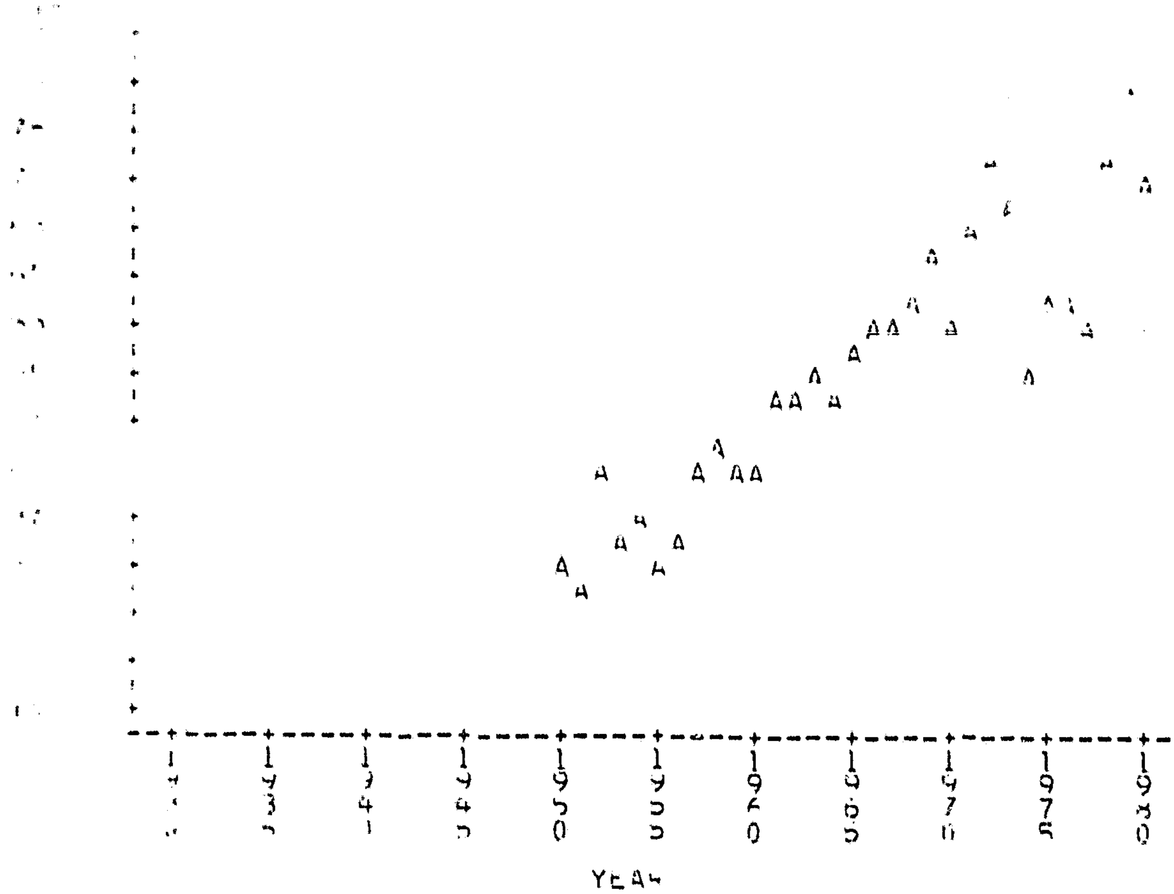


Figure 9b:

Illinois USDA Reported and Special Corn Yields, 1950-1980 (Quintals/Hectare)

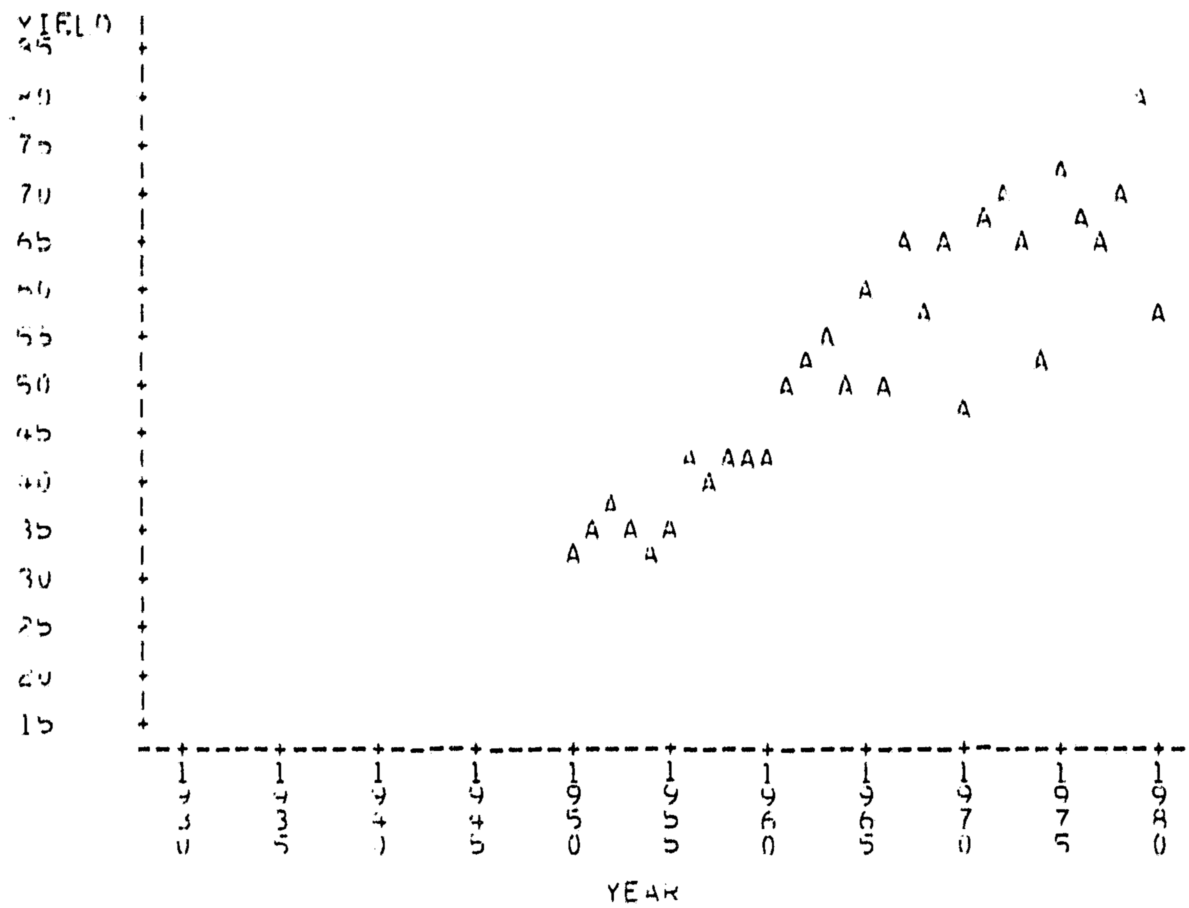
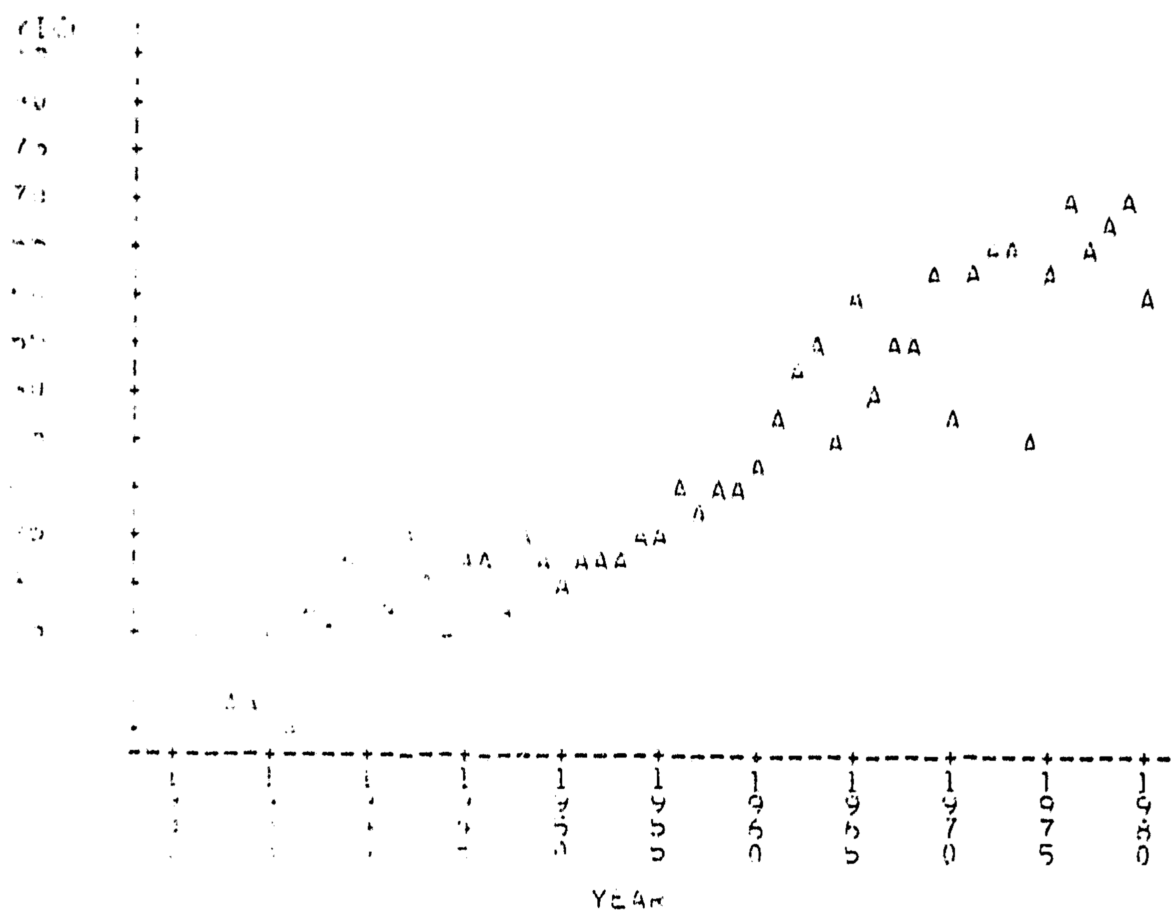


Figure 9c:

Indiana USDA Reported and Special
Corn Yields, 1931-1980 (Quintals/Hectare)



Thompson-Type Models Could Be Easily Developed to Predict Yields in Other Geographic Areas

These models were originally developed by Thompson to model yields on a five-state regional scale and have since been applied to state and CRD levels. They could be developed for any geographical region for which yearly yield and monthly weather data were available. Because of the large number of input variables involved, a long term time series of data would be necessary for adequate results. Using the Thompson approach to model development, no changes in model form would be necessary. The models evaluated here used climatic division weather data. The number of weather stations per division varies; in Indiana, for instance, the range is from seven to nineteen. Comparable results would be unlikely in areas with fewer number of stations.

Timely Estimates Can Be Made Using Approximated Weather Data And/Or Assumed Normal Weather

End-of-year yields could be predicted as early as September in the harvest year, but this would be dependent on the availability of the weather data. It normally takes about three months after the end of a month to receive that month's average temperature and total precipitation at the climatic division level from the National Climatic Center in Asheville, N.C. Estimates of these climatic division values can be prepared earlier and these approximations could be used.

If within-season yield forecasts were needed, a combination of monthly data estimates for past months and assumed normal weather for months yet to come could be used for predictions of yield.

Thompson-Type Yield Models Are Not Costly to Operate

Operational costs of running these models for Iowa, Illinois and Indiana would not be high. The monthly data (average temperature and total rainfall) obtained on a timely basis are currently developed for other users on a routine basis, so possibly the cost could be shared. To obtain the yield estimates, the weather data would need to be obtained, and the regression equation calculations performed. The pooled models require greater memory and time values than the unpooled models which might be a problem for some computer systems.

The more expensive part of the process is the maintenance of the historic agricultural and meteorological data bases. The maintenance of the data bases requires the part-time efforts of persons familiar with meteorological data, agricultural data, and the computer system being used. The re-development of the models in future years, incorporating recent yield and weather data, would require someone skilled in regression methodology.

It is difficult to say how expensive it would be to develop a model for a geographic area other than Iowa, Illinois, and Indiana. The availability and form of the weather and yield data would be determining factors.

The Models Are Easy to Understand and Use

The variables contained in these models are very simple and straightforward, both to understand and use, as the variables in the models are always the same. Calculating the departures from normal is perhaps the most difficult task, but this can be done easily with a simple computer program. Once the historic weather and yield data bases are created, they can be saved and used repeatedly to re-calculate departures from normal and to update models in future years.

Standard Errors of Prediction Provide Poor Current Measures of Modeled Yield Reliability

The CRD, state and region values for the Spearman correlation coefficient between the estimate of the standard error of a predicted yield value and the absolute value of the difference between the predicted and actual yield are shown in Table 8. Many of the coefficients are low or even negative, indicating that $s_{\hat{Y}}$ does not provide a good measure of the closeness of the predicted values to the actual values.

CONCLUSIONS

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.

The indicators of yield reliability reveal these models to be of limited value for large area corn yield estimation. The models are objective and consistent with scientific knowledge. They could easily be developed for predicting yields in other geographic areas. Timely yield estimates and forecasts can be made during the growing season. The models are not costly to operate and are easy to understand and use. The model standard errors of prediction provide poor current measures of modeled yield reliability.

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TABLE 8
CURRENT INDICATION OF MODELED YIELD RELIABILITY
BASED ON THE CORRELATION COEFFICIENT BETWEEN
BASE PERIOD PREDICTED AND TEST YEAR ACTUAL ACCURACY

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

STATE	CRD	UNPOOLED		POOLED	
IOWA	10	[illegible]	[illegible]	[illegible]	[illegible]
	20	[illegible].31	[illegible]	[illegible]	[illegible]
	30	[illegible]	[illegible]	[illegible]	[illegible]
	40	[illegible]	(2)	[illegible]	1
	50	[illegible]	(2)	[illegible]	[illegible]
	60	[illegible]	[illegible]	[illegible]	[illegible]
	70	[illegible]	(1)	[illegible]	[illegible]
	80	[illegible]	(2)	[illegible]	[illegible]
	90	[illegible]	[illegible]	[illegible]	[illegible]
STATE MODEL		[illegible]	(1)	[illegible]	[illegible]
ILLINOIS	10	[illegible]	[illegible]	[illegible]	[illegible]
	20	[illegible]	(2)	[illegible]	[illegible]
	30	[illegible]	[illegible]	[illegible]	1
	40	[illegible]	[illegible]	[illegible]	[illegible]
	50	[illegible]	[illegible]	[illegible]	[illegible]
	60	[illegible]	(1)	[illegible]	[illegible]
	70	[illegible]	[illegible]	[illegible]	[illegible]
	80	[illegible]	[illegible]	[illegible]	[illegible]
	90	[illegible].27	[illegible]	[illegible]	[illegible]
STATE MODEL		[illegible]	2	[illegible]	[illegible]
INDIANA	10	[illegible]	[illegible]	[illegible]	[illegible]
	20	[illegible]	(2)	[illegible]	[illegible]
	30	[illegible]	(1)	[illegible]	[illegible]
	40	[illegible]	(1)	[illegible]	[illegible]
	50	[illegible]	(1)	[illegible]	[illegible]
	60	0.37	(1)	[illegible]	[illegible]
	70	-0.11	(1)	[illegible]	[illegible]
	80	-0.01	(2)	[illegible]	[illegible]
	90	0.15	(2)	[illegible]	[illegible]
STATE MODEL		0.42	(1)	[illegible]	[illegible]

References

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APPENDIX A

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 A

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 A

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 A

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 A

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 B1
BOOTSTRAP TEST RESULTS
FOR CORN YIELDS IN
IOWA, ILLINOIS, AND INDIANA
USING A THOMPSON-TYPE MODEL

UNPOOLED

STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	PRED.	D	RD	S.E. PRED.
IOWA	10	1971	61.6	75.6	14.0	22.7	21.22
		1972	72.8	79.1	6.3	8.7	7.83
		1973	69.1	79.5	10.4	15.1	5.63
		1974	47.1	61.4	14.3	30.4	10.32
		1975	55.0	47.9	-7.1	-12.9	9.56
		1976	45.9	58.3	12.4	27.0	8.21
		1977	64.6	49.7	-14.9	-23.1	9.10
		1978	75.0	73.4	-1.6	-2.1	9.98
		1979	77.8	50.4	-27.4	-35.2	8.63
		1980	73.3	63.3	-10.0	-13.6	7.57
	20	1971	67.0	90.7	23.7	35.4	13.33
		1972	73.8	79.0	5.2	7.0	15.24
		1973	68.9	72.4	3.5	5.1	13.22
		1974	55.7	70.1	14.4	25.9	8.35
		1975	59.9	64.1	4.2	7.0	8.35
		1976	58.5	61.5	3.0	5.1	9.99
		1977	64.3	52.2	-12.1	-18.8	9.38
		1978	75.9	69.7	-6.2	-8.2	8.22
		1979	81.6	65.6	-16.0	-19.6	16.28
		1980	78.6	54.0	-24.6	-31.3	14.91
	30	1971	60.9	84.7	23.8	39.1	14.82
		1972	68.9	71.9	3.0	4.4	12.71
		1973	65.0	81.8	16.8	25.8	10.60
		1974	55.3	69.1	13.8	25.0	10.73
		1975	58.1	65.9	7.8	13.4	6.89
		1976	56.9	63.4	6.5	11.4	7.38
		1977	70.0	59.9	-10.1	-14.4	13.29
		1978	74.1	58.6	-15.5	-20.9	5.38
		1979	81.9	67.6	-14.3	-17.5	11.52
		1980	76.2	80.9	4.7	6.2	8.71
	40	1971	57.8	57.6	-0.2	-0.3	21.05
		1972	72.7	60.8	-11.9	-16.4	9.83
		1973	66.7	67.5	0.8	1.2	9.14
		1974	44.5	66.5	22.0	49.4	8.22
		1975	53.2	57.8	4.6	8.6	6.44
		1976	44.3	48.6	4.3	9.7	7.69
		1977	46.6	42.7	-3.9	-8.4	5.94
		1978	72.2	57.1	-15.1	-20.9	4.84
		1979	74.7	63.2	-11.5	-15.4	6.03
		1980	54.5	45.5	-9.0	-16.5	6.30

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APPENDIX B1:
BOOTSTRAP TEST RESULTS FOR CORN YIELDS IN IOWA, ILLINOIS, AND INDIANA USING A THOMPSON-TYPE MODEL

STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	PRED.	D	RD	UNPOOLED S.E. PRED.
IOWA	50	1971	68.3	80.0	11.7	17.1	8.07
		1972	78.2	74.6	-3.6	-4.6	5.53
		1973	71.1	81.5	10.4	14.6	3.84
		1974	59.9	67.5	7.6	12.7	5.83
		1975	61.8	78.5	16.7	27.0	5.67
		1976	65.0	59.0	-6.0	-9.2	8.76
		1977	41.2	59.6	18.4	44.7	6.45
		1978	72.9	69.5	-3.4	-4.7	6.09
		1979	84.9	67.5	-17.4	-20.5	5.07
		1980	72.8	65.9	-6.9	-9.5	7.42
	60	1971	69.2	85.0	15.8	22.8	13.92
		1972	71.6	67.3	-4.3	-6.0	10.04
		1973	53.8	58.9	5.1	9.0	6.02
		1974	53.9	65.4	12.5	23.2	6.15
		1975	62.8	73.1	10.3	16.4	9.01
		1976	64.0	61.5	-2.5	-3.9	6.43
		1977	64.4	60.1	-4.3	-6.7	10.48
		1978	73.9	67.2	-6.7	-9.1	5.10
		1979	83.0	73.4	-9.6	-11.6	4.55
		1980	74.0	67.2	-6.8	-9.2	4.83
	70	1971	61.5	78.4	16.9	27.5	13.41
		1972	70.1	72.6	2.5	3.6	10.93
		1973	66.1	49.3	-16.8	-25.4	16.84
		1974	30.0	66.4	36.4	121.3	9.12
		1975	42.8	50.0	7.2	16.8	16.04
		1976	61.8	60.1	-1.7	-2.8	12.95
		1977	42.9	70.8	27.9	65.0	21.07
		1978	65.7	65.3	-0.4	-0.6	10.27
		1979	75.3	62.2	-13.1	-17.4	8.71
		1980	55.3	49.5	-5.8	-10.5	9.48
	80	1971	59.9	60.2	0.3	0.5	11.06
		1972	68.3	62.1	-6.2	-9.1	7.21
		1973	61.5	76.1	14.6	23.7	7.39
		1974	38.4	69.8	31.4	81.8	7.85
		1975	45.3	45.9	0.6	1.3	13.72
		1976	59.5	55.2	-4.3	-7.2	9.25
		1977	25.2	43.6	18.4	73.0	26.67
		1978	62.6	64.9	2.3	3.7	7.55
		1979	69.3	56.2	-13.1	-18.9	6.43
		1980	55.5	50.6	-4.9	-8.8	7.63

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APPENDIX B1:

BOOTSTRAP TEST RESULTS FOR CORN YIELDS IN IOWA, ILLINOIS, AND INDIANA USING A THOMPSON-TYPE MODEL

UNPOOLED

STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	YIELD (Q/H) PRED.	D	RD	S.E. PRED.
IOWA	90	1971	59.7	64.5	-5.2	-7.5	9.63
		1972	74.1	61.9	-12.2	-16.5	5.77
		1973	66.2	82.3	16.1	24.3	6.45
		1974	56.6	71.7	15.1	26.7	7.50
		1975	58.5	67.7	9.2	15.7	8.65
		1976	67.1	69.4	2.3	3.4	7.02
		1977	47.8	64.0	16.2	33.9	9.20
		1978	66.9	72.4	5.5	8.2	6.15
		1979	83.5	67.1	-16.4	-19.6	5.26
		1980	70.9	50.0	-20.9	-29.5	4.95
STATE MODEL		1971	64.0	86.8	22.8	35.6	11.45
		1972	72.8	73.2	0.4	0.5	7.41
		1973	67.2	71.9	4.7	7.0	5.08
		1974	50.2	74.3	24.1	48.0	4.66
		1975	56.5	64.4	7.9	14.0	7.73
		1976	57.1	60.9	3.8	6.7	9.45
		1977	54.0	48.4	-5.6	-10.4	11.63
		1978	72.2	65.7	-6.5	-9.0	6.33
		1979	79.7	64.2	-15.5	-19.4	5.20
		1980	69.0	60.5	-8.5	-12.3	6.10
CRDS AGGR.		1971	64.0	76.1	12.1	18.9	
		1972	72.8	70.9	-1.9	-2.6	
		1973	67.2	73.6	6.4	9.5	
		1974	50.2	67.2	17.0	33.9	
		1975	56.5	62.5	6.0	10.6	
		1976	57.1	59.2	2.1	3.7	
		1977	54.0	55.4	1.4	2.6	
		1978	72.2	66.5	-5.7	-7.9	
		1979	79.7	63.8	-15.9	-19.9	
		1980	69.0	59.5	-9.5	-13.8	

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APPENDIX B1
BOOTSTRAP TEST RESULTS FOR CORN YIELDS IN IOWA, ILLINOIS, AND INDIANA USING A THOMPSON-TYPE MODEL

UNPOOLED

STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	PRED.	D	RD	S.E. PRED.
ILLINOIS	10	1971	66.3	83.6	22.3	33.6	4.02
		1972	68.7	71.7	3.0	4.4	7.45
		1973	62.8	63.7	0.9	1.4	7.20
		1974	49.1	55.4	6.3	12.8	6.53
		1975	72.2	62.2	-10.0	-13.9	7.43
		1976	63.5	64.6	1.1	1.7	6.20
		1977	72.5	66.3	-6.2	-8.6	4.94
		1978	71.7	74.8	3.1	4.3	4.29
		1979	79.5	74.3	-5.2	-6.5	4.19
		1980	72.5	73.4	0.9	1.2	3.81
	20	1971	63.1	71.5	8.4	13.3	14.51
		1972	66.8	61.1	-5.7	-8.5	8.05
		1973	61.5	66.9	5.4	8.8	11.99
		1974	45.9	60.5	14.7	32.0	4.51
		1975	69.4	50.6	-18.8	-27.1	7.37
		1976	65.4	60.5	-4.9	-7.5	9.38
		1977	71.9	57.7	-14.2	-19.7	7.82
		1978	71.1	73.7	2.6	3.7	8.50
		1979	80.2	75.0	-5.2	-6.5	7.97
		1980	69.9	74.0	4.1	5.9	6.01
	30	1971	69.5	54.5	-15.0	-21.6	6.58
		1972	72.6	57.0	-15.6	-21.5	7.09
		1973	65.9	64.6	-1.3	-2.0	13.09
		1974	57.9	59.9	2.0	3.5	9.56
		1975	73.8	77.6	3.8	5.1	7.15
		1976	66.7	76.5	9.8	14.7	6.70
		1977	54.4	66.5	12.1	22.2	10.91
		1978	69.2	67.7	-1.5	-2.2	5.47
		1979	82.7	70.6	-12.1	-14.6	4.54
		1980	62.4	71.4	9.0	14.4	6.15
	40	1971	74.7	83.5	8.8	11.8	24.71
		1972	76.5	72.5	-4.0	-5.2	11.47
		1973	72.3	64.5	-7.8	-10.8	17.99
		1974	54.7	66.3	11.6	21.2	11.87
		1975	81.9	87.5	5.6	6.8	9.54
		1976	78.2	82.1	3.9	5.0	8.19
		1977	66.0	79.1	13.1	19.8	8.16
		1978	72.7	83.0	10.3	14.2	5.98
		1979	83.3	78.7	-4.6	-5.5	6.36
		1980	54.2	62.1	7.9	14.6	7.74

APPENDIX B1
BOOTSTRAP TEST RESULTS FOR CORN YIELDS IN IOWA, ILLINOIS, AND INDIANA USING A THOMPSON-TYPE MODEL

STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	YIELD (Q/H) PRED.	D	RD	UNPOOLED S.E. PRED.
ILLINOIS	50	1971	75.3	91.5	16.2	21.5	16.02
		1972	75.2	79.0	3.8	5.1	12.81
		1973	67.9	66.5	-1.4	-2.1	13.16
		1974	52.8	74.6	21.8	41.3	9.27
		1975	78.8	83.0	4.2	5.3	11.59
		1976	75.6	72.8	-2.8	-3.7	10.15
		1977	64.7	96.0	31.3	48.4	21.87
		1978	75.0	83.9	7.9	10.4	8.25
		1979	84.6	83.1	-1.5	-1.8	7.04
		1980	49.8	65.4	15.6	31.3	4.12
	60	1971	65.7	58.7	-7.0	-10.7	10.37
		1972	69.4	47.4	-22.0	-31.7	7.15
		1973	69.1	65.1	-4.0	-5.8	10.88
		1974	57.9	74.2	16.3	28.2	8.36
		1975	71.6	59.3	-12.3	-17.2	9.35
		1976	61.5	74.1	12.6	20.5	11.26
		1977	68.0	64.8	-3.2	-4.7	6.40
		1978	66.7	71.1	4.4	6.6	5.61
		1979	82.1	69.5	-12.6	-15.3	5.33
		1980	59.9	61.6	1.7	2.8	7.38
	70	1971	63.1	80.9	17.8	28.2	11.73
		1972	62.9	65.7	2.8	4.5	10.36
		1973	63.4	51.3	-12.1	-19.1	5.54
		1974	47.8	51.4	3.6	7.5	7.75
		1975	70.0	75.0	5.0	7.1	6.08
		1976	67.3	74.0	6.7	10.0	8.05
		1977	67.3	53.8	-13.5	-20.1	8.15
		1978	69.8	73.6	3.8	5.4	4.29
		1979	78.3	64.1	-14.2	-18.1	5.13
		1980	52.9	68.1	15.2	28.7	5.95
	80	1971	44.4	39.3	-5.1	-11.5	9.04
		1972	49.9	36.6	-13.3	-26.7	3.31
		1973	44.6	41.5	-3.1	-7.0	5.09
		1974	41.5	41.6	0.1	0.2	5.86
		1975	53.2	46.0	-7.2	-13.5	4.58
		1976	42.9	55.2	12.3	28.7	5.28
		1977	55.0	39.5	-15.5	-28.2	4.64
		1978	56.2	53.1	-3.1	-5.5	5.26
		1979	67.6	59.1	-8.5	-12.6	5.54
		1980	33.4	47.5	14.1	42.2	7.85

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APPENDIX B1
BOOTSTRAP TEST RESULTS
FOR CORN YIELDS IN
IOWA, ILLINOIS, AND INDIANA
USING A THOMPSON-TYPE MODEL

UNPOOLED

STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	PRED.	D	RD	S.E. PRED.
ILLINOIS	90	1971	43.8	61.5	17.8	40.6	20.60
		1972	53.2	40.5	-12.7	-23.9	6.80
		1973	44.0	35.2	-8.8	-20.0	9.20
		1974	42.2	46.8	4.6	10.9	9.95
		1975	53.8	44.5	-9.3	-17.3	6.58
		1976	54.5	50.3	-4.2	-7.7	9.73
		1977	53.6	46.8	-6.8	-12.7	6.60
		1978	46.5	53.2	6.7	14.4	5.57
		1979	65.7	54.3	-11.4	-17.4	5.59
		1980	38.4	53.1	14.7	38.3	10.62
STATE MODEL		1971	66.5	67.6	1.1	1.7	5.60
		1972	69.0	63.8	-5.2	-7.5	3.59
		1973	64.6	64.3	-0.3	-0.5	5.98
		1974	51.5	60.4	8.9	17.3	3.96
		1975	72.8	62.3	-10.5	-14.4	5.09
		1976	67.2	70.9	3.7	5.5	5.27
		1977	65.9	74.8	8.9	13.5	5.00
		1978	69.7	74.5	4.8	6.9	3.94
		1979	80.3	75.5	-4.8	-6.0	3.73
		1980	58.4	65.3	6.9	11.8	3.91
CRDS AGGR.		1971	66.5	75.3	8.8	13.2	
		1972	69.0	64.0	-5.0	-7.2	
		1973	64.6	61.5	-3.1	-4.8	
		1974	51.5	62.2	10.7	20.8	
		1975	72.8	69.4	-3.4	-4.7	
		1976	67.2	70.6	3.4	5.1	
		1977	65.9	68.3	2.4	3.6	
		1978	69.7	74.2	4.5	6.5	
		1979	80.3	72.8	-7.5	-9.3	
		1980	58.4	66.5	8.1	13.9	

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APPENDIX B1
BOOTSTRAP TEST RESULTS FOR CORN YIELDS IN IOWA, ILLINOIS, AND INDIANA USING A THOMPSON-TYPE MODEL

UNPOOLED

STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	YIELD (Q/H) PRED.	D	RD	S.E. PRED.
INDIANA	10	1971	71.6	47.1	-24.5	-34.2	8.60
		1972	69.6	65.2	-4.4	-6.3	6.96
		1973	67.5	66.3	-1.2	-1.8	7.11
		1974	47.8	64.5	16.7	34.9	5.74
		1975	65.2	60.6	-4.6	-7.1	6.75
		1976	70.6	50.8	-19.8	-28.0	7.10
		1977	65.7	58.6	-7.1	-10.9	6.91
		1978	66.1	67.2	1.1	1.7	6.33
		1979	73.6	69.4	-4.2	-5.7	6.34
		1980	49.9	63.4	13.5	27.1	6.90
	20	1971	62.8	56.3	-6.5	-10.4	6.77
		1972	61.8	60.5	-1.2	-1.9	4.07
		1973	62.3	58.9	-3.4	-5.5	4.02
		1974	40.1	58.9	18.8	46.9	3.60
		1975	62.3	64.8	2.5	4.0	8.72
		1976	67.5	58.3	-9.2	-13.6	5.35
		1977	62.4	63.8	1.4	2.2	5.42
		1978	61.7	65.6	3.9	6.3	4.86
		1979	68.6	67.2	-1.4	-2.0	4.17
		1980	54.7	63.7	9.0	16.5	4.12
	30	1971	55.1	57.8	2.7	4.9	9.83
		1972	59.3	57.1	-2.2	-3.7	5.23
		1973	58.1	60.0	1.9	3.3	4.87
		1974	37.1	49.9	12.8	34.5	5.34
		1975	52.5	51.8	-0.7	-1.3	6.72
		1976	62.9	58.6	-4.3	-6.8	5.84
		1977	63.8	61.2	-2.5	-4.1	4.89
		1978	59.9	60.2	0.3	0.5	4.33
		1979	67.3	65.4	-1.9	-2.8	3.95
		1980	64.1	64.5	0.4	0.6	3.81
	40	1971	67.7	74.3	6.6	9.7	7.43
		1972	69.6	64.8	-4.8	-6.9	5.32
		1973	67.5	60.8	-6.7	-9.9	5.07
		1974	42.8	50.1	7.3	17.1	5.92
		1975	69.3	53.4	-15.9	-22.9	5.41
		1976	71.1	74.7	3.6	5.1	6.12
		1977	64.5	43.6	-20.9	-32.4	10.25
		1978	72.5	79.6	7.1	9.8	5.64
		1979	74.0	70.1	-3.9	-5.3	5.96
		1980	58.1	71.1	13.0	22.4	5.68

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APPENDIX B1
BOOTSTRAP TEST RESULTS FOR CORN YIELDS IN IOWA, ILLINOIS, AND INDIANA USING A THOMPSON-TYPE MODEL

UNPOOLED

STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	YIELD (Q/H) PRED.	D	RD	S.E. PRED.
INDIANA	50	1971	65.9	75.8	9.9	15.0	8.27
		1972	67.3	62.0	-5.3	-7.9	5.84
		1973	68.5	72.7	4.2	6.1	5.78
		1974	48.1	64.6	16.5	34.3	6.45
		1975	64.6	65.7	1.1	1.7	5.19
		1976	72.7	75.3	2.6	3.6	6.20
		1977	64.7	54.0	-10.7	-16.5	8.90
		1978	74.5	64.7	-9.8	-13.2	5.52
		1979	73.9	74.8	0.9	1.2	7.14
		1980	66.4	67.0	0.6	0.9	4.76
	60	1971	57.9	62.0	4.1	7.1	7.51
		1972	62.1	53.8	-8.3	-13.4	5.40
		1973	61.7	65.3	3.6	5.8	5.20
		1974	47.8	59.3	11.5	24.1	6.01
		1975	55.8	58.9	3.1	5.6	4.45
		1976	65.6	69.5	3.9	5.9	4.92
		1977	59.9	50.9	-9.0	-15.0	5.30
		1978	69.7	67.6	-2.1	-3.0	4.34
		1979	71.1	51.6	-19.5	-27.4	9.14
		1980	71.1	71.6	0.5	0.7	4.68
	70	1971	60.1	58.9	-1.2	-2.0	6.69
		1972	65.8	56.0	-9.8	-14.9	5.23
		1973	61.5	59.4	-2.1	-3.4	4.92
		1974	52.3	51.1	-1.2	-2.3	9.82
		1975	63.4	58.8	-4.6	-7.3	4.62
		1976	70.2	66.7	-3.5	-5.0	5.28
		1977	65.6	62.7	-2.9	-4.4	4.45
		1978	68.1	67.8	-0.3	-0.4	4.21
		1979	65.8	63.0	-2.8	-4.3	5.67
		1980	62.8	65.2	2.4	3.8	4.81
	80	1971	52.8	58.4	5.6	10.6	6.14
		1972	60.5	53.8	-6.7	-11.1	4.87
		1973	57.3	54.9	-2.4	-4.2	4.52
		1974	48.7	53.9	5.2	10.7	7.48
		1975	42.9	53.1	10.2	23.8	4.18
		1976	64.9	54.1	-10.8	-16.6	5.25
		1977	62.5	51.8	-10.7	-17.1	5.41
		1978	64.5	64.3	-0.2	-0.3	4.70
		1979	61.8	59.9	-1.9	-3.1	5.51
		1980	57.3	62.0	4.7	8.2	5.33

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APPENDIX B1
BOOTSTRAP TEST RESULTS FOR CORN YIELDS IN IOWA, ILLINOIS, AND INDIANA USING A THOMPSON-TYPE MODEL

UNPOOLED

STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	PRED.	D	RD	S.E. PRED.
INDIANA	90	1971	54.5	59.3	4.8	8.8	5.57
		1972	56.5	53.4	-3.1	-5.5	4.84
		1973	50.8	51.4	0.6	1.2	4.86
		1974	47.5	54.2	6.7	14.1	5.12
		1975	48.3	48.1	-0.2	-0.4	4.13
		1976	64.4	50.6	-13.8	-21.4	4.07
		1977	61.9	55.2	-6.7	-10.8	4.67
		1978	63.6	60.7	-2.9	-4.6	4.22
		1979	62.3	61.5	-0.8	-1.3	4.18
		1980	59.7	59.9	0.2	0.3	4.52
STATE MODEL		1971	63.4	69.9	6.5	10.3	7.62
		1972	65.3	61.6	-3.7	-5.7	5.29
		1973	64.0	63.3	-0.7	-1.1	4.71
		1974	45.8	58.5	12.7	27.7	4.87
		1975	61.5	47.5	-14.0	-22.8	6.63
		1976	69.0	64.9	-4.1	-5.9	5.59
		1977	64.0	61.8	-2.2	-3.4	6.02
		1978	67.8	71.7	3.9	5.8	4.60
		1979	70.3	71.0	0.7	1.0	4.95
		1980	60.3	63.2	2.9	4.8	4.18
CRDS AGGR.		1971	63.4	62.2	-1.2	-1.9	
		1972	65.3	60.3	-5.0	-7.7	
		1973	64.0	63.5	-0.5	-0.8	
		1974	45.8	58.0	12.2	26.6	
		1975	61.5	59.5	-2.0	-3.3	
		1976	69.0	63.9	-5.1	-7.4	
		1977	64.0	56.4	-7.6	-11.9	
		1978	67.8	67.0	-0.8	-1.2	
		1979	70.3	67.1	-3.2	-4.6	
		1980	60.3	65.8	5.5	9.1	

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APPENDIX B1
BOOTSTRAP TEST RESULTS
FOR CORN YIELDS IN
IOWA, ILLINOIS, AND INDIANA
USING A THOMPSON-TYPE MODEL

UNPOOLED

STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	PRED.	D	RD	S.E. PRED.
REGION CRDS	AGGR.	1971	64.8	73.0	8.2	12.7	
		1972	69.9	66.2	-3.7	-5.3	
		1973	65.6	67.1	1.5	2.3	
		1974	49.8	63.6	13.8	27.7	
		1975	63.6	64.5	0.9	1.4	
		1976	63.3	64.4	1.1	1.7	
		1977	60.5	60.4	-0.1	-0.2	
		1978	70.3	69.5	-0.8	-1.1	
		1979	78.1	67.8	-10.3	-13.2	
		1980	63.3	63.4	0.1	0.2	
STATES	AGGR.	1971	64.8	76.2	11.4	17.6	
		1972	69.9	67.4	-2.5	-3.6	
		1973	65.6	67.4	1.8	2.7	
		1974	49.8	66.2	16.4	32.9	
		1975	63.6	60.3	-3.3	-5.2	
		1976	63.3	65.5	2.2	3.5	
		1977	60.5	61.0	0.5	0.8	
		1978	70.3	70.2	-0.1	-0.1	
		1979	78.1	69.7	-8.4	-10.8	
		1980	63.3	62.8	-0.5	-0.8	

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APPENDIX B2
BOOTSTRAP TEST RESULTS FOR CORN YIELDS IN IOWA, ILLINOIS, AND INDIANA USING A POOLED THOMPSON-TYPE MODEL

STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	YIELD (Q/H) PRED.	D	RD	S.E. PRED.
IOWA	10	1971	61.6	68.4	6.8	11.0	3.09
		1972	72.8	66.9	-5.9	-8.1	2.97
		1973	69.1	73.8	4.7	6.8	2.98
		1974	47.1	71.4	24.3	51.6	3.18
		1975	55.0	56.6	1.6	2.9	4.17
		1976	45.9	50.8	4.9	10.7	4.21
		1977	64.6	47.8	-16.8	-26.0	4.16
		1978	75.0	59.7	-15.3	-20.4	4.52
		1979	77.8	61.0	-16.8	-21.6	4.49
		1980	73.3	61.8	-11.5	-15.7	4.94
	20	1971	67.0	72.0	5.0	7.5	3.20
		1972	73.8	71.7	-2.1	-2.8	3.00
		1973	68.9	72.5	3.6	5.2	3.01
		1974	55.7	71.1	15.4	27.6	3.12
		1975	59.9	62.6	2.7	4.5	4.10
		1976	58.5	58.3	-0.2	-0.3	4.09
		1977	64.3	52.4	-11.9	-18.5	4.25
		1978	75.9	63.3	-12.6	-16.6	4.50
		1979	81.6	55.0	-26.6	-32.6	5.88
		1980	78.6	60.6	-18.0	-22.9	5.36
	30	1971	60.9	65.7	4.8	7.9	3.18
		1972	68.9	66.1	-2.8	-4.1	3.02
		1973	65.0	65.9	0.9	1.4	3.05
		1974	55.3	67.1	11.8	21.3	3.14
		1975	58.1	62.4	4.3	7.4	4.07
		1976	56.9	58.4	1.5	2.6	4.05
		1977	70.0	54.6	-15.4	-22.0	4.35
		1978	74.1	66.3	-7.8	-10.5	4.50
		1979	81.9	69.5	-12.4	-15.1	4.55
		1980	76.2	67.0	-9.2	-12.1	5.01
	40	1971	57.8	61.7	3.9	6.7	3.05
		1972	72.7	61.8	-10.9	-15.0	2.94
		1973	66.7	68.5	1.8	2.7	3.00
		1974	44.5	67.4	22.9	51.5	3.14
		1975	53.2	54.9	1.7	3.2	4.09
		1976	44.3	48.5	4.2	9.5	4.14
		1977	46.6	44.0	-2.6	-5.6	4.14
		1978	72.2	47.2	-25.0	-34.6	4.49
		1979	74.7	56.8	-17.9	-24.0	4.43
		1980	54.5	51.9	-2.6	-4.8	4.94

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APPENDIX B2
BOOTSTRAP TEST RESULTS FOR CORN YIELDS IN IOWA, ILLINOIS, AND INDIANA USING A POOLED THOMPSON-TYPE MODEL

STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	PRED.	D	RD	S.E. PRED.
IOWA	50	1971	68.3	67.3	-1.0	-1.5	3.13
		1972	78.2	70.0	-8.2	-10.5	3.00
		1973	71.1	76.0	4.9	6.9	2.99
		1974	59.9	70.9	11.0	18.4	3.17
		1975	61.8	66.4	4.6	7.4	4.12
		1976	65.0	61.7	-3.3	-5.1	4.11
		1977	41.2	53.7	12.5	30.3	5.10
		1978	72.9	55.8	-17.1	-23.5	4.49
		1979	84.9	60.2	-24.7	-29.1	4.46
		1980	72.8	59.9	-12.9	-17.7	4.94
	60	1971	69.2	69.5	0.3	0.4	3.13
		1972	71.6	69.6	-2.0	-2.8	3.03
		1973	63.8	66.8	3.0	4.7	3.09
		1974	53.9	59.1	5.2	9.6	3.30
		1975	62.8	59.9	-2.9	-4.6	4.06
		1976	64.0	58.2	-5.8	-9.1	4.05
		1977	64.4	56.2	-8.2	-12.7	4.68
		1978	73.9	64.3	-9.6	-13.0	4.50
		1979	83.0	68.9	-14.1	-17.0	4.52
		1980	74.0	65.7	-8.3	-11.2	4.98
	70	1971	61.5	58.0	-3.5	-5.7	3.05
		1972	70.1	64.2	-5.9	-8.4	2.96
		1973	66.1	65.0	-1.1	-1.7	3.23
		1974	30.0	66.3	36.3	121.0	3.33
		1975	42.8	47.7	4.9	11.4	4.23
		1976	61.8	43.3	-18.5	-29.9	4.05
		1977	42.9	40.9	-2.0	-4.7	6.34
		1978	65.7	49.7	-16.0	-24.4	4.54
		1979	75.3	56.7	-18.6	-24.7	4.45
		1980	55.3	54.0	-1.3	-2.4	5.09
	80	1971	59.9	50.1	-9.8	-16.4	3.03
		1972	68.3	60.7	-7.6	-11.1	2.95
		1973	61.5	62.3	0.8	1.3	3.29
		1974	38.4	61.7	23.3	60.7	3.16
		1975	46.3	50.8	4.5	9.7	4.13
		1976	59.5	48.9	-10.6	-17.8	4.04
		1977	25.2	42.2	17.0	67.5	5.34
		1978	62.6	42.2	-20.4	-32.6	4.53
		1979	69.3	47.5	-21.8	-31.5	4.45
		1980	55.5	48.4	-7.1	-12.8	5.04

APPENDIX B2
BOOTSTRAP TEST RESULTS FOR CORN YIELDS IN IOWA, ILLINOIS, AND INDIANA USING A POOLED THOMPSON-TYPE MODEL

STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	PRED.	D	RD	S.E. PRED.
IOWA	90	1971	69.7	58.6	-11.1	-15.9	3.13
		1972	74.1	67.7	-6.4	-8.6	2.97
		1973	66.2	68.7	2.5	3.8	3.27
		1974	56.6	67.3	10.7	18.9	3.15
		1975	58.5	62.8	4.3	7.4	4.15
		1976	67.1	61.6	-5.5	-8.2	4.04
		1977	47.8	59.3	11.5	24.1	4.35
		1978	66.9	59.9	-7.0	-10.5	4.51
		1979	83.5	63.1	-20.4	-24.4	4.45
		1980	70.9	63.8	-7.1	-10.0	5.16
STATE MODEL.		1971	64.0	62.1	-1.9	-3.0	3.32
		1972	72.8	66.8	-6.0	-8.2	2.75
		1973	67.2	72.3	5.1	7.5	2.72
		1974	50.2	67.0	16.8	33.5	3.09
		1975	56.5	54.4	-2.1	-3.7	3.64
		1976	57.1	53.6	-3.5	-6.1	3.59
		1977	54.0	55.1	1.1	2.0	5.01
		1978	72.2	56.8	-15.4	-21.3	3.31
		1979	79.7	61.6	-18.1	-22.7	3.37
		1980	69.0	59.1	-9.9	-14.3	3.97
CRDS AGGR.		1971	64.0	65.0	1.0	1.6	
		1972	72.8	66.9	-5.9	-8.1	
		1973	67.2	69.9	2.7	4.0	
		1974	50.2	67.8	17.6	35.1	
		1975	56.5	59.1	2.6	4.6	
		1976	57.1	54.9	-2.2	-3.9	
		1977	54.0	50.6	-3.4	-6.3	
		1978	72.2	57.4	-14.8	-20.5	
		1979	79.7	60.5	-19.2	-24.1	
		1980	69.0	59.8	-9.2	-13.3	

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APPENDIX B2
BOOTSTRAP TEST RESULTS FOR CORN YIELDS IN IOWA, ILLINOIS, AND INDIANA USING A POOLED THOMPSON-TYPE MODEL

STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	PRED.	D	RD	S.E. PRED.
ILLINOIS	10	1971	66.3	70.9	4.6	6.9	3.27
		1972	68.7	71.2	2.5	3.6	3.38
		1973	62.8	69.1	6.3	10.0	3.31
		1974	49.1	62.4	13.3	27.1	3.56
		1975	72.2	55.6	-16.6	-23.0	3.58
		1976	63.5	56.6	-6.9	-10.9	3.84
		1977	72.5	61.5	-11.0	-15.2	4.08
		1978	71.7	66.5	-5.2	-7.3	4.00
		1979	79.5	70.7	-8.8	-11.1	4.05
		1980	72.5	69.5	-3.0	-4.1	4.26
	20	1971	63.1	64.8	1.7	2.7	3.32
		1972	66.8	66.5	-0.3	-0.4	3.66
		1973	61.5	66.0	4.5	7.3	3.33
		1974	45.9	63.0	17.1	37.3	3.45
		1975	69.4	54.5	-14.8	-21.3	3.58
		1976	65.4	57.5	-7.9	-12.1	3.78
		1977	71.9	58.4	-13.5	-18.8	4.01
		1978	71.1	69.4	-1.7	-2.4	4.00
		1979	80.2	71.3	-8.9	-11.1	4.07
		1980	69.9	70.5	0.6	0.9	4.21
	30	1971	69.5	61.8	-7.7	-11.1	3.32
		1972	72.6	67.2	-5.4	-7.4	3.24
		1973	65.9	73.5	7.6	11.5	3.38
		1974	57.9	66.8	8.9	15.4	3.43
		1975	73.8	63.3	-10.5	-14.2	3.59
		1976	66.7	66.0	-0.7	-1.0	3.77
		1977	54.4	66.6	12.2	22.4	4.43
		1978	69.2	62.5	-6.7	-9.7	3.98
		1979	82.7	64.4	-18.3	-22.1	3.89
		1980	62.4	62.6	0.2	0.3	4.24
	40	1971	74.7	70.1	-4.6	-6.2	3.38
		1972	76.5	73.9	-2.6	-3.4	3.29
		1973	72.3	73.7	6.4	8.9	3.37
		1974	54.7	69.7	15.0	27.4	3.48
		1975	81.9	69.2	-12.7	-15.5	3.60
		1976	78.2	70.8	-7.4	-9.5	3.78
		1977	66.0	74.7	8.7	13.2	4.05
		1978	72.7	74.0	1.3	1.8	4.00
		1979	83.3	75.7	-7.6	-9.1	3.92
		1980	54.2	64.9	10.7	19.7	4.26

APPENDIX B2
BOOTSTRAP TEST RESULTS FOR CORN YIELDS IN IOWA, ILLINOIS, AND INDIANA USING A POOLED THOMPSON-TYPE MODEL

STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	YIELD (Q/H) PRED.	D	RD	S.E. PRED.
ILLINOIS	50	1971	75.3	65.5	-9.8	-13.0	3.38
		1972	75.2	73.1	-2.1	-2.8	3.30
		1973	67.9	77.4	9.5	14.0	3.39
		1974	52.8	67.7	14.9	28.2	3.45
		1975	78.8	65.8	-13.0	-16.5	3.63
		1976	75.6	66.2	-9.4	-12.4	3.80
		1977	64.7	73.0	8.3	12.8	4.63
		1978	76.0	71.7	-4.3	-5.7	3.99
		1979	84.6	77.2	-7.4	-8.7	4.00
		1980	49.8	66.4	16.6	33.3	4.21
	60	1971	65.7	62.8	-2.9	-4.4	3.31
		1972	69.4	61.9	-7.5	-10.8	3.25
		1973	69.1	68.6	-0.5	-0.7	3.36
		1974	57.9	62.8	4.9	8.5	3.44
		1975	71.6	63.7	-7.9	-11.0	3.60
		1976	61.5	59.6	-1.9	-3.1	3.79
		1977	68.0	60.7	-7.3	-10.7	3.85
		1978	66.7	64.9	-1.8	-2.7	3.99
		1979	82.1	67.3	-14.8	-18.0	3.90
		1980	59.9	64.1	4.2	7.0	4.35
	70	1971	63.1	63.3	0.2	0.3	3.35
		1972	62.9	60.3	-2.6	-4.1	3.25
		1973	63.4	63.8	0.4	0.6	3.37
		1974	47.8	56.3	8.5	17.8	3.47
		1975	70.0	59.2	-10.8	-15.4	3.59
		1976	67.3	58.4	-8.9	-13.2	3.77
		1977	67.3	61.3	-6.0	-8.9	3.87
		1978	69.8	68.9	-0.9	-1.3	4.03
		1979	78.3	69.3	-9.0	-11.5	4.07
		1980	52.9	66.8	13.9	26.3	4.27
	80	1971	44.4	50.2	5.8	13.1	3.25
		1972	49.9	47.6	-2.3	-4.6	3.21
		1973	44.6	46.3	1.7	3.8	3.39
		1974	41.5	39.2	-2.3	-5.5	3.42
		1975	53.2	47.5	-5.7	-10.7	3.60
		1976	42.9	47.4	4.5	10.5	3.79
		1977	55.0	44.4	-10.6	-19.3	3.88
		1978	56.2	51.3	-4.9	-8.7	4.01
		1979	67.6	55.5	-12.1	-17.9	3.92
		1980	33.4	51.0	17.6	52.7	4.74

APPENDIX B2
BOOTSTRAP TEST RESULTS FOR CORN YIELDS IN IOWA, ILLINOIS, AND INDIANA USING A POOLED THOMPSON-TYPE MODEL

STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	YIELD (Q/H) PRED.	D	RD	S.E. PRED.
ILLINOIS	90	1971	43.8	42.6	-1.0	-2.3	3.23
		1972	53.2	44.1	-9.1	-17.1	3.21
		1973	44.0	44.8	0.8	1.8	3.35
		1974	42.2	40.2	-2.0	-4.7	3.44
		1975	53.8	46.7	-7.1	-13.2	3.62
		1976	54.5	46.9	-7.6	-13.9	3.81
		1977	53.6	49.9	-3.7	-6.9	3.90
		1978	46.5	51.6	5.1	11.0	4.00
		1979	65.7	53.3	-12.4	-18.9	3.95
		1980	38.4	49.7	11.3	29.4	4.66
STATE MODEL		1971	66.5	62.5	-4.0	-6.0	3.04
		1972	69.0	65.5	-3.5	-5.1	2.84
		1973	64.6	65.4	0.8	1.2	3.12
		1974	51.5	60.0	8.5	16.5	3.13
		1975	72.8	59.6	-13.2	-18.1	3.35
		1976	67.2	62.7	-4.5	-6.7	3.39
		1977	65.9	66.2	0.3	0.5	4.10
		1978	69.7	67.8	-1.9	-2.7	3.31
		1979	80.3	71.7	-8.6	-10.7	3.34
		1980	58.4	66.4	8.0	13.7	3.68
CRDS AGGR.		1971	66.5	64.5	-2.0	-3.0	
		1972	69.0	66.5	-2.5	-3.6	
		1973	64.6	69.5	4.9	7.6	
		1974	51.5	62.6	11.1	21.6	
		1975	72.8	60.7	-12.1	-16.6	
		1976	67.2	61.1	-6.1	-9.1	
		1977	65.9	64.2	-1.7	-2.6	
		1978	69.7	67.2	-2.5	-3.6	
		1979	80.3	70.0	-10.3	-12.8	
		1980	58.4	65.3	6.9	11.8	

APPENDIX B2
BOOTSTRAP TEST RESULTS FOR CORN YIELDS IN IOWA, ILLINOIS, AND INDIANA USING A POOLED THOMPSON-TYPE MODEL

STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	YIELD (Q/H) PRED.	D	RD	S.E. PRED.
INDIANA	10	1971	71.6	62.8	-8.8	-12.3	3.30
		1972	69.6	66.4	-3.2	-4.6	3.34
		1973	67.5	68.9	1.4	2.1	3.30
		1974	47.8	64.5	16.7	34.9	3.31
		1975	65.2	56.1	-9.1	-14.0	3.62
		1976	70.6	58.6	-12.0	-17.0	3.66
		1977	65.7	59.9	-5.8	-8.8	3.87
		1978	66.1	63.3	-2.8	-4.2	3.78
		1979	73.6	64.8	-8.8	-12.0	3.75
		1980	[illegible].9	59.4	9.5	19.0	3.79
	20	1971	62.8	59.0	-3.8	-6.1	3.31
		1972	61.8	60.9	-0.9	-1.5	3.29
		1973	62.3	63.9	1.6	2.6	3.27
		1974	40.1	56.9	16.8	41.9	3.33
		1975	62.3	48.7	-13.6	-21.8	3.76
		1976	67.5	55.7	-11.8	-17.5	3.65
		1977	62.4	57.0	-5.4	-8.7	3.97
		1978	61.7	62.3	0.6	1.0	3.78
		1979	68.6	62.6	-6.0	-8.7	3.74
		1980	54.7	62.0	7.3	13.3	3.75
	30	1971	55.1	52.6	-2.5	-4.5	3.29
		1972	59.3	53.7	-5.6	-9.4	3.26
		1973	58.1	60.1	2.0	3.4	3.55
		1974	37.1	51.9	14.8	39.9	3.35
		1975	52.5	43.8	-8.7	-16.6	3.75
		1976	62.9	49.5	-13.4	-21.3	3.67
		1977	63.8	53.6	-10.2	-16.0	3.88
		1978	59.9	58.1	-1.8	-3.0	3.79
		1979	67.3	61.3	-6.0	-8.9	3.74
		1980	64.1	63.4	-0.7	-1.1	3.74
	40	1971	67.7	58.9	-8.8	-13.0	3.30
		1972	69.6	61.3	-8.3	-11.9	3.27
		1973	67.5	68.2	0.7	1.0	3.31
		1974	42.8	60.7	17.9	41.8	3.38
		1975	69.3	52.9	-16.4	-23.7	3.61
		1976	71.1	56.9	-14.2	-20.0	3.64
		1977	64.5	60.8	-3.7	-5.7	4.33
		1978	72.5	65.5	-7.0	-9.7	3.79
		1979	74.0	67.7	-6.3	-8.5	3.99
		1980	58.1	66.0	7.9	13.6	3.75

APPENDIX B2
BOOTSTRAP TEST RESULTS FOR CORN YIELDS IN IOWA, ILLINOIS, AND INDIANA USING A POOLED THOMPSON-TYPE MODEL

STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	YIELD (Q/H) PRED.	D	RD	S.E. PRED.
INDIANA	50	1971	65.9	62.2	-3.7	-5.6	3.29
		1972	67.3	61.3	-6.0	-8.9	3.29
		1973	68.5	68.0	-0.5	-0.7	3.29
		1974	48.1	62.7	14.6	30.4	3.37
		1975	64.6	57.7	-6.9	-10.7	3.58
		1976	72.7	60.0	-12.7	-17.5	3.64
		1977	64.7	63.9	-0.8	-1.2	3.94
		1978	74.5	68.7	-5.8	-7.8	3.88
		1979	73.9	68.6	-5.3	-7.2	3.98
		1980	66.4	68.7	2.3	3.5	3.75
	60	1971	57.9	56.1	-1.8	-3.1	3.30
		1972	62.1	53.3	-8.8	-14.2	3.31
		1973	61.7	61.5	-0.2	-0.3	3.28
		1974	47.8	57.1	9.3	19.5	3.40
		1975	55.8	51.6	-4.2	-7.5	3.60
		1976	65.6	52.6	-13.0	-19.8	3.65
		1977	59.9	54.8	-5.1	-8.5	3.90
		1978	69.7	61.8	-7.9	-11.3	3.79
		1979	71.1	66.3	-4.8	-6.8	4.24
		1980	71.1	66.9	-4.2	-5.9	3.74
	70	1971	60.1	54.0	-6.1	-10.1	3.28
		1972	65.8	55.8	-10.0	-15.2	3.23
		1973	61.5	58.2	-3.3	-5.4	3.32
		1974	52.3	53.0	0.7	1.3	4.10
		1975	63.4	53.8	-9.6	-15.1	3.62
		1976	70.2	55.9	-14.3	-20.4	3.64
		1977	65.6	60.6	-5.0	-7.6	3.93
		1978	68.1	63.6	-4.5	-6.6	3.83
		1979	65.8	55.0	-10.8	-16.4	4.48
		1980	62.8	60.3	-2.5	-4.0	3.85
	80	1971	52.8	57.6	4.8	9.1	3.27
		1972	60.5	52.6	-7.9	-13.1	3.22
		1973	57.3	57.1	-0.2	-0.3	3.33
		1974	48.7	52.7	4.0	8.2	3.74
		1975	42.9	50.3	7.4	17.2	3.63
		1976	64.9	46.3	-18.6	-28.7	3.62
		1977	62.5	53.1	-9.4	-15.0	4.00
		1978	64.5	59.6	-4.9	-7.6	3.84
		1979	61.8	55.6	-6.2	-10.0	4.09
		1980	57.3	57.4	0.1	0.2	3.75

APPENDIX B2
BOOTSTRAP TEST RESULTS FOR CORN YIELDS IN IOWA, ILLINOIS, AND INDIANA USING A POOLED THOMPSON-TYPE MODEL

STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	YIELD (Q/H) PRED.	D	RD	S.E. PRED.
INDIANA	90	1971	54.5	55.9	1.4	2.6	3.27
		1972	56.5	51.4	-5.1	-9.0	3.23
		1973	50.8	53.6	2.8	5.5	3.35
		1974	47.5	48.3	0.8	1.7	3.54
		1975	48.3	43.7	-4.6	-9.5	3.59
		1976	64.4	45.5	-18.9	-29.3	3.62
		1977	61.9	51.7	-10.2	-16.5	3.88
		1978	63.6	58.6	-5.0	-7.9	3.84
		1979	62.3	61.4	-0.9	-1.4	3.80
		1980	59.7	57.3	-2.4	-4.0	3.79
STATE MODEL		1971	63.4	59.8	-3.6	-5.7	2.90
		1972	65.3	59.8	-5.5	-8.4	2.90
		1973	64.0	63.5	-0.5	-0.8	2.94
		1974	45.8	58.6	12.8	27.9	3.12
		1975	61.5	54.0	-7.5	-12.2	3.49
		1976	69.0	56.3	-12.7	-18.4	3.35
		1977	64.0	60.8	-3.2	-5.0	3.68
		1978	67.8	65.2	-2.6	-3.8	3.33
		1979	70.3	69.3	-1.0	-1.4	3.79
		1980	60.3	64.5	4.2	7.0	3.60
CRDS AGGR.		1971	63.4	58.7	-4.7	-7.4	
		1972	65.3	59.5	-5.8	-8.9	
		1973	64.0	64.3	0.3	0.5	
		1974	45.8	58.5	12.7	27.7	
		1975	61.5	52.6	-8.9	-14.5	
		1976	69.0	55.7	-13.3	-19.3	
		1977	64.0	59.0	-5.0	-7.8	
		1978	67.8	63.7	-4.1	-6.0	
		1979	70.3	63.6	-6.7	-9.5	
		1980	60.3	63.3	3.0	5.0	

APPENDIX B2.
BOOTSTRAP TEST RESULTS FOR CORN YIELDS IN IOWA, ILLINOIS, AND INDIANA USING A POOLED THOMPSON-TYPE MODEL

STATE	CRD	YEAR	YIELD (Q/H) ACTUAL	YIELD (Q/H) PRED.	D	RD	S.E. PRED.
REGION CRDS	AGGR.	1971	64.8	63.5	-1.3	-2.0	
		1972	69.9	65.3	-4.6	-6.6	
		1973	65.6	68.6	3.0	4.6	
		1974	49.8	64.1	14.3	28.7	
		1975	63.6	58.4	-5.2	-8.2	
		1976	63.3	57.4	-5.9	-9.3	
		1977	60.5	57.4	-3.1	-5.1	
		1978	70.3	62.3	-8.0	-11.4	
		1979	78.1	64.6	-13.5	-17.3	
		1980	63.3	62.5	-0.8	-1.3	
STATES	AGGR.	1971	64.8	61.8	-3.0	-4.6	
		1972	69.9	64.9	-5.0	-7.2	
		1973	65.6	68.0	2.4	3.7	
		1974	49.8	62.8	13.0	26.1	
		1975	63.6	56.3	-7.3	-11.5	
		1976	63.3	57.6	-5.7	-9.0	
		1977	60.5	60.4	-0.1	-0.2	
		1978	70.3	62.6	-7.7	-11.0	
		1979	78.1	66.8	-11.3	-14.5	
		1980	63.3	62.9	-0.4	-0.6	

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Appendix C1

Significance of Variables in Unpooled Model

x = p < .10   xx = p < .05   xxx = p < .01

		Intercept	TREND 1	TREND2	TREND 3	DENCUM 6	SQDENCUM 6	DENP 7	SQDENP 7	DENP 8	SQDENP 8	DENT 6	DENT 7	DENT 8	SQDENT 6	SQDENT 7	SQDENT 8	RSQ
Iowa	10		xx	x				xx	xx									.93
	20		xxx	xxx	x		x	xxx	xx									.96
	30			xxx				xx	x									.95
	40			xx		x	xx	xxx	xx		x			xx				.94
	50		xx	xxx		xx	xxx	x			xx	xx						.95
	60		xxx	xx		xx	xxx	xx		xx		xx						.96
	70					xx	xx	xxx	xxx									.92
	80		x	xx		x	xx	xxx	xx		xx	xxx						.94
	90			xx			xx	x										.93
	State		xx	xx			xx	xxx										.95
Illinois	10		xxx	xxx			xxx	xxx		xx						xx		.98
	20		xx	x		x												.95
	30	xx		xxx	xx		x				xx							.95
	40		xxx	xxx	x		x	xx	xx		x							.96
	50		xxx	xxx	x		x	xx	xx			x						.95
	60		x	xxx	x		x	xx										.96
	70		x	xxx	x		x	xx										.97
	80		xx			xx	xx	x	xx									.94
	90								x									.93
	State		xxx	xxx	xx	x	xx	xxx	x	x								.98
Indiana	10	xxx	xxx	xxx	xxx			xxx					xxx					.95
	20	xxx	xxx	xxx	xxx	x	xx	xxx		x			xxx		xxx		x	.96
	30	xxx	xxx	xxx		xx		xxx	xxx					x				.97
	40	xxx	xxx	xxx	xxx	xx	xx	xxx	xxx			x	xxx		x			.97
	50	xxx	xxx	xxx		xx		xxx	xxx				x		xx			.97
	60	xxx	xxx	xxx				xxx			xx		xx	xx	x			.97
	70	xxx	xxx	xxx	xxx		xx	xx										.98
	80	xxx	xxx	xxx			xxx	xxx					xx					.97
	90	xxx	xxx	xxx			xxx	xxx										.97
	State	xxx	xxx	xxx	xxx			xxx	xxx				xx		x			.98

Appendix C2

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Significance of Variable in Pooled Model

Step 1

x = $p \leq .10$ xx = $p \leq .05$ xxx = $p \leq .01$

		Intercept	Trend 1	Trend 2	Trend 3	RSQ
Iowa	10		x	xx		.79
	20		xx	xxx		.88
	30		xx	xx		.88
	40		xx	xx		.68
	50		xx	xx		.77
	60		xxx	xxx		.87
	70		x	x		.62
	80		x	xx		.64
	90		xx	xxx		.82
	State		xx	xxx		.83
Illinois	10		xxx	xx		.85
	20		xxx	xx		.87
	30		xx	xxx	xx	.84
	40		xx	xxx	xx	.81
	50		xx	xxx	xx	.79
	60		xx	xxx	xx	.82
	70		xx	xxx	x	.82
	80		xx	xx		.71
	90		xx	xx		.76
	State		xxx	xxx	xx	.86
Inidana	10	xxx	xxx	xxx	xxx	.90
	20	xxx	xxx	xxx		.86
	30	xxx	xxx	xx		.86
	40	xxx	xxx	xxx	xxx	.89
	50	xxx	xxx	xxx	x	.90
	60	xxx	xxx	xx		.89
	70	xxx	xxx	xxx	xxx	.94
	80	xxx	xxx	xxx	xxx	.91
	90	xxx	xxx	xxx	xx	.92
	State	xxx	xxx	xxx	xxx	.92

Appendix C2 (cont)

Significance of Variable in Pooled Model

Step 2

		Intercept	Ŷ from Trend	DENCUM6	SQDENCUM6	DENP7	SQDENP7	DENP8	SQDENP8	DENT6	DENT7	DENT8	SQDENT6	SQDENT7	SQDENT8	RSQ
Iowa	10		XXX			XXX	XX					XX				.93
	20		XXX			XXX	XX									.96
	30		XXX			X										.94
	40	X	XXX	XX	XX	XXX	XX					XX				.94
	50		XXX	XX	XXX				XX	X				X		.93
	60		XXX	XXX	XXX	XX		XX	X	XX						.96
	70		XXX	XX	XXX	XXX	XXX			X						.92
	80		XXX	XX	XX	XXX	X		XX	XX	XXX					.92
	90		XXX		XX	X										.92
	State		XXX	XXX	XXX	XXX	XXX		XXX	XXX	XXX	XXX			XX	.89
Illinois	10	XX	XXX			XX					XX					.94
	20	XXX	XXX		X	XXX					XX		XX			.95
	30	XXX	XXX	X		XXX	XXX		X			XX				.96
	40	XXX	XXX	X	XX	XXX	XX			X	XX		X			.96
	50	XXX	XXX			XXX	XX						X			.96
	60		XXX			XXX										.95
	70	XXX	XXX			XXX	XX									.97
	80	XXX	XXX			XXX	XX					XX				.96
	90	XXX	XXX		X	XXX	XXX	XX								.97
	State	XXX	XXX	XXX	XXX	XXX	XXX	XXX		XXX	XXX	X	X		XXX	.92
Indiana	10	XX	XXX		XXX	XXX		XX		X						.97
	20		XXX	X					X					XX		.95
	30		XXX		X				X							.95
	40		XXX		X	XX	XX		X							.96
	50		XXX		X	XX	XX			X		X				.94
	60	X	XXX		X	XXX										.96
	70	XX	XXX		XX	XXX	XX									.96
	80	XXX	XXX	XXX	XXX	XX	XX									.94
	90	XXX	XXX			X	XX									.93
	State	XXX	XXX		XX	XXX	XXX	XXX		XXX	XXX	XX	XXX			.95