LACIE-00439
JSC-11668

LARGE AREA CROP INVENTORY EXPERIMENT (LACIE)

7.9 10121
TM-79985

NASA NOAA USDA

(E79-10121) LARGE AREA CROP INVENTORY EXPERIMENT (LACIE). YES PHASE 1 YIELD FEASIBILITY REPORT (NASA) 42 p HC A03/MF A01 CSCL 02C

N79-19424

Unclas
G3/43 00121

YES PHASE I

YIELD FEASIBILITY REPORT

National Aeronautics and Space Administration
LYNDON B. JOHNSON SPACE CENTER
Houston, Texas

JANUARY 1977

YES PHASE I YIELD FEASIBILITY REPORT

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PREFACE

This document was prepared by the Earth Observations Division, Lyndon B. Johnson Space Center, Houston, Texas; by the Center for Climatic and Environmental Assessment, Columbia Missouri; and by the USDA-LACIE Project Office, Washington, D.C.; with the assistance of the Lockheed Electronics Company.

The purpose of this document is to present the results and conclusions of a yield feasibility study in which wheat yield models developed for the Great Plains States in the U.S. were evaluated. The models were developed by the National Oceanic and Atmospheric Administration Center for Climatic and Environmental Assessment.

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Section 0.0

SUMMARY OF RESULTS

The yield models which were developed prior to Phase II of the LACIE to predict crop reporting district (CRD) and state wheat yields in the nine Great Plains States in the U.S. were evaluated to determine whether or not country wheat predictions using these models could be made to within 10 percent of the SRS prediction 90 percent of the time (the so-called 90/90 criterion). This evaluation indicated that neither the yield predictions aggregated from state predictions nor those aggregated from CRD predictions did satisfy such a requirement. Moreover, there was no significant difference between state predictions, as obtained directly from the state models, and state predictions obtained by aggregating CRD predictions.

Each state model was separately evaluated to determine if a projected performance to the country level would statisfy a 90/90 criterion. All state models except the North Dakota and Kansas models satisfied that criterion both for district estimates aggregated to the state level and for state estimates directly from the models. In addition to the tests of the 90/90 criterion, the models were examined for their ability to adequately respond to fluctuations in weather. This portion of the analysis was based on a subjective interpretation of values of certain description statistics. As a result of this analysis, 10 of the 12 models were judged to respond inadequately to variations in weather-related variables.

SECTION 1.0

INTRODUCTION

The purpose of this study is to examine the feasibility of operating the yield models developed by CCEA (Center for Climatic and Environmental Assessment) in Phase II of the LACIE. These models were developed for the nine wheat-growing Great Plains States in the U.S. The current project goal for the LACIE is to be able to predict wheat production at harvest for a given country to within 10 percent of the true value 90 percent of the time. This is referred to as the 90/90 criterion. For this study, this requirement was interpreted for the U.S. to mean that the 90/90 criterion be met when comparing to the "end of the year" SRS predictions. In this study, an attempt has been made to statistically test the yield models with respect to their probable success in being able to predict yields with sufficient accuracy to satisfy this 90/90 requirement in future operation of the LACIE.

The study was input aimed at testing the ability of all the models, working as a unit, to accurately predict U.S. production, and input aimed at examining the individual performance of each model. This latter examination is intended to isolate potential problems in each model.

In order to test the ability of the models to predict production, a statistical test was devised using 10 years of yield prediction data. These data were obtained for each of the nine states for the period of 1965 through 1974. The predictions were computed for a given year by developing the yield models on previous years' data, not including the given year, and then predicting for that year. Thus, for example, the prediction for 1965 was obtained by regressing on yields and corresponding climatic data from 1964 and previous years and then computing the yield for 1965.

Yield predictions at two levels are considered in this study. The first is an average state yield prediction, and the second is an average CRD yield prediction. Both the state and CRD estimates are obtained through the use of the state yield model. The statistical tests, to determine if the 90/90 requirement was met, were made using both state level and CRD level estimates of yield.

SECTION 2.0

YIELD MODELS TESTED

The 10-year evaluation of the ability of the yield models to support the 90/90 criterion was based on yield predictions from the following models:

Colorado State Model - June Truncation (WW)

Kansas State Model - June Truncation (WW)

Montana Winter Wheat Model - June Truncation

Montana Spring Wheat Model - July Truncation

Nebraska State Model - June Truncation (WW)

North Dakota State Model - July Truncation (SW)

Oklahoma State Model - June Truncation (WW)

Red River (Minnesota) Model - July Truncation (SW)

South Dakota State Model - July Truncation (WW)

Texas State Model - June Truncation (WW)

Individual model evaluation was based on yield predictions from the above models and on predictions from the following additional models:

Badlands Model - July Truncation (WW)

Oklahoma - Texas Panhandle Model - June Truncation (WW)

SECTION 3.0

DISCUSSION OF STATISTICAL PROCEDURES

Statistical hypothesis testing methods to answer the question of whether or not the Great Plains yield models will support the 90/90 production criterion and the statistical estimation methods upon which the individual model evaluation is based are discussed in this section.

3.1 TEST PROCEDURE FOR EVALUATING THE 90/90 CRITERION

The probability statement of the 90/90 criterion can be written as follows:

$$\Pr\left(|\hat{P} - P| \leq .1P\right) \geq .9 \tag{3-1}$$

where $\hat{P}$ is the (CCEA) production estimator of the (SRS) value P. During Phase I of the LACIE, yield estimates were made only for the Great Plains states which account for only about 63 percent of the U.S. wheat production. Hence, to determine if those estimation methods would support the 90/90 criterion, which is for the whole U.S., an adjustment is needed to the probability statement in equation (3-1). To obtain this adjustment, we use the following model.

Let $R_1, R_2, \ldots, R_n$ be n regions and let $\hat{P}_i$ denote the production estimator for region i, $i = 1, 2, \ldots, n$. Assume these estimators are independent and identically distributed.

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Let $\hat{\bar{P}}_M = \sum_{i=1}^{M} \hat{P}_i$ for some $M \leq n$. Then

$$\sigma^2_{\hat{\bar{P}}_M} = M\sigma^2_{\hat{P}_1}$$

$$E(\hat{\bar{P}}_M) = ME(\hat{P}_1)$$

and

$$\frac{\sigma^2_{\hat{\bar{P}}_M}}{E(\hat{\bar{P}}_M)} = \frac{\sigma^2_{\hat{P}_1}}{E(\hat{P}_1)}$$

Thus, to compare the production variances for two subtotals of size M' and M'', we have

$$\frac{\sigma^2_{\hat{\bar{P}}_{M'}}}{\sigma^2_{\hat{\bar{P}}_{M''}}} = \frac{E(\hat{\bar{P}}_M)}{E(\hat{\bar{P}}_{M''})}$$

To apply this model we assume that the U.S. can be divided into these "statistically equivalent" regions $R_1, R_2, \ldots, R_n$, and that any given Great Plains state is a subset of these regions. Let σ^2_s

denote the variance in the production estimate $\hat{P}_s$ for a given state and σ_T^2 the total variance in the U.S. production estimate $\hat{P}_T$. Then

$$\frac{\sigma_{\hat{P}_s}^2}{\sigma_{\hat{P}_T}^2} = \delta_s$$

where

$$\delta_s = \frac{E(\hat{P}_s)}{E(\hat{P}_T)}$$

We will apply the model to a given state. The expansion to the nine Great Plains States can be obtained by simply replacing any state by the nine Great Plains States. If P_s and P_T are the SRS values being estimated, respectively, by $\hat{P}_s$ and $\hat{P}_T$, and $\hat{P}_s$ and $\hat{P}_T$ are unbiased estimates, then

$$\frac{\sigma_{\hat{P}_s}}{P_s} = \frac{1}{\sqrt{\delta_s}} \frac{\sigma_{\hat{P}_T}}{P_T} \tag{3-2}$$

The probability statement in equation (3-1) (using $\hat{P}_T$ and P_T in place of $\hat{P}$ and P) can be written as

$$\Pr\left(\frac{|\hat{P}_T - P_T|}{\sigma_{\hat{P}_T}} \leq 0.1 \frac{P_T}{\sigma_{\hat{P}_T}}\right) \geq 0.90$$

In view of equation (3-2)

$$\Pr\left(\frac{|\hat{P}_T - P_T|}{\sigma_{\hat{P}_T}} \leq \frac{.1}{\sqrt{\delta_s}} \frac{P_s}{\sigma_{\hat{P}_s}}\right) \geq 0.90$$

and assuming that $\frac{\hat{P}_T - P_T}{\sigma_{\hat{P}_T}}$ and $\frac{\hat{P}_s - P_s}{\sigma_{\hat{P}_s}}$ are both standard normal random variables, we have

$$\Pr\left(\frac{|\hat{P}_s - P_s|}{\sigma_{\hat{P}_s}} \leq \frac{.1}{\sqrt{\delta_s}} \frac{P_s}{\sigma_{\hat{P}_s}}\right) \geq 0.90$$

or

$$\Pr\left(|\hat{P}_s - P_s| \leq \frac{.1}{\sqrt{\delta_s}} P_s\right) \geq 0.90 \qquad (3\text{-}3)$$

Next we consider an additional adjustment to the probability statement in equation (3-3) to account for errors in acreage estimation. For brevity in the remaining development, we write $\hat{P}$ for $\hat{P}_s$, P for P_s, and δ for δ_s.

Let A_i denote the harvested wheat acreage at the i^{th} region and Y_i the yield at that region. By region we mean either a state or a crop reporting district (or climatic district), and not the regions, R_i, as considered above. Let $\hat{A}_i$, $\hat{Y}_i$ denote the respective LACIE estimator of those quantities. Define

$$P = \sum_i A_i Y_i \tag{3-4}$$

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

and

$$\hat{P}_1 = \sum_i A_i \hat{Y}_i \tag{3-5}$$

$$\hat{P}_2 = \sum_i \hat{A}_i Y_i$$

Here P denotes the true production and $\hat{P}$ its LACIE estimator. $\hat{P}_1$ denotes a production estimator where true acreages (SRS values) are used in place of estimated acreages and $\hat{P}_2$ denotes the reverse situation, i.e., true yields in place of yield estimates.

The error in the production estimate can now be expressed as

$$\hat{P} - P = \sum_i \hat{A}_i \hat{Y}_i - P$$

$$= \sum_i (\hat{A}_i - A_i)(\hat{Y}_i - Y_i) + (\hat{P}_1 - P) + (\hat{P}_2 - P)$$

If we assume $\sum_i (\hat{A}_i - A)(\hat{Y}_i - Y_i) \leq \varepsilon \min(\hat{P}_1 - P, \hat{P}_2 - P)$

for some small ϵ and $E\ ((\hat{P}_1 - P)\ (\hat{P}_2 - P)) = 0$, then, as an approximation, we have

$$E(\hat{P} - P)^2 \doteq E(\hat{P}_1 - P)^2 + E(\hat{P}_2 - P)^2$$

This expression estimates the total production as a sum of a production error due to errors in the yield estimates and a production error due to errors in the acreage estimates.

If we assume that these error components are equal,[1] then

$$E(\hat{P} - P)^2 = 2E(\hat{P}_1 - P)^2$$

and, if we assume $\hat{P}$ and $\hat{P}_1$ are both unbiased estimates of P, then

$$\sigma_{(\hat{P} - P)} = \sqrt{2}\,\sigma_{(\hat{P}_1 - P)} \tag{3-6}$$

where

$$\sigma_{(\hat{P} - P)} \triangleq \sqrt{E(\hat{P} - P)^2}$$

$$\sigma_{(\hat{P}_1 - P)} \triangleq \sqrt{E(\hat{P}_1 - P)^2}$$

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[1] In the current LACIE "error budget" estimates, this assumption is made.

Usirg the probability statement in equation (3-3),

$$\Pr\left(\frac{|\hat{P} - P|}{\sigma(\hat{P} - P)} \leq \frac{.1P}{\sigma(\hat{P} - P)} \sqrt{\delta}\right) \geq 0.90$$

Again, since

$$\frac{\hat{P} - P}{\sigma(\hat{P} - P)} \quad \text{and} \quad \frac{\hat{P}_1 - P}{\sigma(\hat{P}_1 - P)}$$

are both standard normal random variables, and, using equation (3-6), we have

$$\Pr\left(\frac{|\hat{P}_1 - P|}{\sigma(\hat{P}_1 - P)} \leq 0.707 \frac{.1}{\sqrt{\delta}} \frac{P}{\sigma(\hat{P}_1 - P)}\right) \geq 0.90$$

or

$$\Pr\left(\frac{|\hat{P}_1 - P|}{P} \leq \frac{.0707}{\sqrt{\delta}}\right) \geq 0.90 \qquad (3\text{-}7)$$

In other words, if we consider $\hat{P}_1$ as an estimator of production which neglects acreage estimation errors, and we assume that the production errors due to acreage errors and yield errors are unbiased and have equal variance, then to account for acreage error in considering the yield estimator, we can consider the probability statement in equation (3-7) in place of the one in equation (3-3).

To devise a test to determine if the probability statement in equation (3-7) is satisfied, we can proceed as follows.

Let

$$\psi(x) = \begin{cases} 1, & x \leq 0 \\ 0, & x > 0 \end{cases}$$

and define the random variable

$$Z = |\hat{P}_1 - P| - \frac{.0707P}{\sqrt{\delta}}$$

Then we want to test the null hypothesis

$$H_o: \; E(\psi(Z)) \geq 0.90$$

If $z(t)$, $t=1, 2, \ldots$ denote independent observations on Z, then the test can be based on the binominally distributed statistic

$$\hat{p}_n = \frac{1}{n} \sum_{t=1}^{n} \psi(z(t))$$

3.2 DESCRIPTIVE YIELD MODEL ANALYSIS

In the preceeding section, statistics were derived to test the performance of the models relative to the 90/90 criterion. In this section, statistics are considered which will provide insight into primarily the weather-related behavior of the models. This analysis is intended to be a descriptive statistical summary of potential problems in the models, and, therefore the conclusions are subject to individual interpretations.

The following statistics are defined.

A. Standard deviations. Let

$$S_y(i) = \left(\frac{1}{n-1}\sum_{j=1}^{n}\left(Y_i(j) - \bar{Y}_i\right)^2\right)^{1/2}$$

$$S_{\hat{y}}(i) = \left(\frac{1}{n-1}\sum_{j=1}^{n}\left(\hat{Y}_i(j) - \bar{\hat{Y}}_i\right)^2\right)^{1/2}$$

where $\hat{Y}_i(j)$, $Y_i(j)$ are the ith yearly LACIE yield estimators and yearly SRS yields for the ith model, respectively, and where

$$\bar{Y}_i = \frac{1}{n}\sum_{j=1}^{n} Y_i(j)$$

$$\bar{\hat{Y}}_i = \frac{1}{n}\sum_{j=1}^{n} \hat{Y}_i(j)$$

Let

$$S_d(i) = \left(\frac{1}{n-1}\sum_{j=1}^{n}\left(d_i(j) - \bar{d}_i\right)^2\right)^{1/2}$$

where

$$d_i(j) = \hat{Y}_i(j) - Y_i(j)$$

$$\bar{d}_i = \frac{1}{n} \sum_{j=1}^{n} d_i(j)$$

B. Correlation coefficient. Let

$$\hat{r}_i = \frac{\frac{1}{n} \sum_{j=1}^{n} \left(\hat{Y}_i(j) - \bar{\hat{Y}}_i\right)\left(Y_i(j) - \bar{Y}_i\right)}{S_y(i)\ S_{\hat{y}}(i)}$$

The practical significance of these individual statistics is described below:

1. The coefficient of correlation $(\hat{r}_i)$ is a measure of how well the year-to-year deviations from a grand mean[1] in the CCEA predictions correspond to proportional deviations from a grand mean in the USDA estimates. A high coefficient of correlation does not, of itself, guarantee that the predicted yields will not underestimate or overestimate changes indicated by the USDA estimates, since either the CCEA or SRS estimates can be changed by a multiplicative constant without changing $\hat{r}_i$. Hence, in addition to $\hat{r}_i$, other statistics need to be considered.

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[1]The grand mean is the average over the 10-year period.

2. The standard deviation over years of the predicted yields should equal the standard deviation of the USDA estimates. If the standard deviation of the predicted yields is smaller, this indicates that, in the past, the model has tended to underestimate USDA deviations from a grand mean. A possible explanation is that the monthly totals used by CCEA to estimate the climatic values in the model "smooth" the temporal distribution of precipitation and of temperature. It could also be because the use of a single model for a state ignores the spatial distribution of these values.

On the other hand, if the standard deviation of the predicted yields is higher, this probably indicates that extreme precipitation was experienced during some monthly period in the past in conjunction with a positive regression coefficient for the quadratic function. Again, this may be traced back to the use of variables which smooth distribution.

3. The standard deviations of the differences $(S_d(i))$ between the CCEA predictions and the USDA estimates is a function of correlation, of the relative sizes of the standard deviations of the USDA estimates and the CCEA predictions, and of any bias built into the CCEA predictions. For the model to be any good at all, $S_d(i)$ must be smaller than the standard deviation of the USDA estimates. To be effective, $S_d(i)$ probably should be no larger than 0.6 times the standard deviation of the USDA estimates.

Besides the above summary statistics, three other statistics are computed. These are estimators of the standard variance, the variance of prediction, and the prediction error. The standard error is the standard deviation of the SRS predictions about the regression plane. Its estimate is defined as

$$\hat{\sigma}_y(i) \triangleq \sqrt{\frac{1}{n - P} \sum_{k}^{n} \left(Y_i(k) - \hat{Y}_i(k)\right)^2}$$

where n is the number of years over which the yield model was regressed and p is the number of variables in the regression model. The standard deviation of prediction is the standard deviation of the yield estimator, $\hat{Y}(i)$, about the regression plane. The estimator of this parameter is defined as for a given x[1,2]

$$\hat{\sigma}_{\hat{y}}(i) \triangleq \hat{\sigma}_y(i) \sqrt{x'(XX')^{-1}x}$$

where x is a vector of variable values for the variables used in the yield model and X is a $p \times n$ matrix whose columns are the values of

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[1]For a discussion of these estimators, see the Phase I LACIE production feasibility report.

[2]For a discussion of NOAA/CCEA yield models, see the NOAA memorandum entitled "CCEA Crop/Weather Models for the Great Plains Region."

the variable vectors used for the n years over which the model was regressed. Notice that the standard deviation of prediction depends upon the vector of variable values x that are used for a given prediction. In particular, if the weather for a given year is normal, which means that $x'(XX')^{-1}x$ should be small, then the standard deviation of the prediction for that year is less than σ_y. On the other hand, abnormal weather causes $x'(XX')^{-1}x$ to be large, and hence $\sigma_{\hat{y}}$ exceeds σ_y. In other words, normal weather increases our confidence in the prediction, and abnormal weather decreases it. Finally, the prediction error is the square root of the sum of the standard error squared and the variance of prediction. Its estimator is defined as

$$\hat{\sigma}_{(y-\hat{y})}(i) = \sqrt{\hat{\sigma}_y^{\,2}(i) + \hat{\sigma}_{\hat{y}}^{\,2}(i)}$$

The derivation of this statistic uses the fact that the yield model is derived by regressing over n years of SRS yield data and assumes that the $n + 1^{st}$ SRS yield prediction is independent of the past years, and, in addition, assumes that both the LACIE and SRS estimates unbiasedly estimate the same quantity. The prediction error is then the mean square error between the SRS and LACIE estimates.

SECTION 4.0

DISCUSSION OF RESULTS

Tables 4-I and 4-II

Tables 4-I and 4-II present the computations that enter into the test of the 90/90 criterion as discussed in section 3.1. The entries in the year-state matrix in the tables are relative differences. In Table 4-I, the relative differences are defined at $(\hat{P}_1 - P)/P$ where P is defined in equation (3-4) and $\hat{P}_1$ is defined in equation (3-5). When the relative difference applies to state estimates, $P = AY$, where A is the harvested state wheat acreage for the year indicated and Y is the state yield. When the relative difference applies to the Great Plains estimate, $P = \sum_{i=1}^{9} A_i Y_i$ where A_i are again harvested state wheat acreages and Y_i are the state yields. Similarly, $\hat{P}_1 = A\hat{Y}$ for individual states, and $\hat{P}_1 = \sum_{i=1}^{9} A_i \hat{Y}_i$ for the Great Plains estimate. In this case, $\hat{Y}$ and $\hat{Y}_i$ are LACIE estimated yields.

Let $\pi_s = \Pr\left(|\hat{P}_1 - P|/P \leq \frac{.0707}{\sqrt{\delta_s}}\right)$. Tests of the 90/90 criterion at the state and Great Plains level reduce to tests of the form

$$H_o: \ \pi_s \geq .9$$

vs.

$$H_a: \ \pi_s < .9$$

The statistic for this test as discussed in section 3.1 is $\hat{p}_n$. Using the fact that $n\hat{p}_n$ has a binomial distribution, a one tail test of H_o at the .07 level for $n = 10$ is

$$\text{accept } H_o \text{ if } 10\hat{p}_{10} \geq 8$$

$$\text{reject } H_o \text{ otherwise}$$

Table 4-I presents the relative difference by year, from 1965 to 1974, and by state. The last column represent the aggregated Great Plains estimated relative differences where the aggregation is over state yield estimates. The tolerance limits, as discussed in section 3.1, are given in the lower part of the table. The last row in the table, which is labeled $10\hat{p}_{10}$, contains the number of relative differences in a given column which is within the column tolerance limits. It is seen from the entries in this row that for North Dakota, Kansas, and the Great Plains, H_o is rejected.

To interpret the null hypothesis, H_o for a given state one assumes that the entire country is made up of states which have the same yield estimator distribution, where the yield estimator is defined by the given state yield model. Thus, accepting H_o for a given state is the same as saying that the state yield model performance is acceptable, provided that all state models are "statistically equivalent" to that state.

Table 4-II is similar to Table 4-I, except that, here, the relative differences are computed from district estimates aggregated to the state level or to the Great Plains level. The district estimates, in this case, are computed using the state model with district values for the weather variables. It is seen in Table 4-II that, again, H_o is rejected for North Dakota, Kansas, and the Great Plains.

Table 4-III

In Table 4-III the state-aggregated and CRD-aggregated estimates are compared directly. According to the paired t-value, both estimators are estimating the same quantity (at the 10% level of significance).

Tables 4-IV and 4-V

Tables 4-IV and 4-V present the state model evaluations as discussed in section 3.2. The conclusions obtained from the data in Tables 4-IV and 4-V are subjective in the sense that no attempt has been made to statistically test hypotheses. A breakdown of the conclusions by yield model is as follows:

BADLANDS

This model was developed for winter wheat in South Dakota and in the Nebraska Panhandle (CRD No. 1). The coefficient of correlation for the 10-year study period, 1965 to 1974, was only 0.62. With only eight degrees of freedom, this would be not quite significant at the 5-percent level of probability. A ratio value of 0.92 of the standard deviations of predicted to USDA yields probably is acceptably close to 1.0, but the ratio of the standard deviation of the differences to the USDA estimates (0.84) is larger than desired.

COLORADO

The coefficient of correlation for the 11-year period, 1965 to 1975, is 0.53. A coefficient of correlation of 0.53 with nine degrees of freedom is not significantly different from zero. In addition, the standard deviation of the differences between the USDA and predicted yields is larger than for the USDA yields alone.

KANSAS

The Kansas data presents an object lesson in the possible unreliability of correlation coefficients. The CCEA prediction for 1973 was obviously in error (and would never have passed CCEA quality control), an 18.8-bushel overestimate (see Table 4-VII (k)) occasioned by heavy rainfall during March and a positive regression coefficient for the square of the March precipitation function. The coefficient of correlation over the 1965 to 1975 period including 1973 is 0.685. Excluding 1973, it is only 0.631. Both correlations are significantly different from zero at the 5-percent level of probability. The ratio of the standard deviation of predicted to USDA yields of 0.90 would indicate that the CCEA model would tend to underestimate changes from normal by a factor of about 10 percent.

MONTANA (winter wheat)

The coefficient of correlation of 0.09 for the years 1965 to 1975 inclusive indicates that, for these recent years, a randon number generator based upon the proper parameters could have been almost as effective in predicting the USDA estimates. Further, the standard deviation of the CCEA predictions is 55 percent greater than for the USDA estimates, and the standard deviation of the differences is 77 percent greater.

MONTANA (spring wheat)

In marked contrast to the winter wheat model, the spring wheat model predictions for Montana were highly correlated with the USDA estimates; the standard deviations of the predicted yields were almost exactly equal to that of the USDA estimates.

NEBRASKA

The CCEA predictions for Nebraska were highly correlated ($r = 0.83$) with the 1965 to 1975 USDA estimates. However, the CCEA estimates were about 20 percent more variable than the USDA estimates, and an examination of the actual estimates shows that the CCEA model overestimated USDA for the 1965 to 1968 seasons and underestimated USDA from 1972 to 1975 inclusive. This may be happenstance, or it may reflect a change in the distribution of wheat acreage in the state. For example, the two largest wheat-producing climatic districts in the state, the Panhandle and the Southwest, had 23 and 29 percent, respectively, of the total wheat area in 1969 (not shown in tables). By 1975, the proportion of wheat area in the Panhandle had increased from 23 to 31 percent. In the Southwest, the proportion of wheat area had decreased from 29 to 23 percent. This could be taken as an indication that either:

A. District weather information for each year should be aggregated by the proportion of the state acreage that year, or

B. Individual forecast models should be established for each district.

NORTH DAKOTA

The correlation between USDA estimates and CCEA predictions was significant at the 5-percent level of probability. However, the standard deviation of the CCEA predictions was 55 percent larger than for the USDA estimates, and the standard deviation of the differences was 22 percent larger.

OKLAHOMA

The correlation between the CCEA predictions and the USDA estimates was highly significant. While the standard deviation of the CCEA predictions was 26 percent larger than for the USDA estimates, this was due to one bad estimate, for 1973 (see Table 4-VIII(j)). Disregarding this one year brings the two standard deviations acceptably close. The ratio of the standard deviations of the differences to the standard deviation for the USDA estimates at 0.83 is larger than it should be.

OKLAHOMA-TEXAS PANHANDLE

This model was developed for the Oklahoma Panhandle and the High Plains of Texas. The correlation between CCEA predictions and the USDA estimates (r = 0.61, 8 degrees of freedom) is not quite significant at the 5-percent level of probability. The standard deviation of the CCEA predictions was 17 percent smaller than that for the USDA estimates. This would indicate that the CCEA model would tend to underestimate changes from normality by about 17 percent.

RED RIVER VALLEY

This model was developed from districts 3 and 6 of North Dakota and districts 1 and 4 of Minnesota for the predictions of yield in Minnesota. The correlation is poor, the standard deviation of the predicted yields is 27 percent smaller than for the USDA estimates, and the standard deviation of the differences is larger than either.

SOUTH DAKOTA (spring wheat)

The correlation between the CCEA and the USDA estimates was higher for this model than for any of the others. However, the standard deviation of the predicted yields is only 63 percent as large as the standard deviation of the USDA estimates. This indicates that the CCEA model would tend to underestimate changes from normality by about 37 percent.

TEXAS

The so-called Texas model really is only for climatic divisions 2 and 3 (USDA crop reporting districts 2, 3 and 4). For these districts, the correlation between the CCEA predictions and the USDA estimates is significantly high, but the standard deviation of the predicted yields is only 39 percent as large as for the USDA estimates. This indicates that the CCEA model would greatly underestimate any changes from average yields.

Tables 4-VI to 4-VII(1)

Tables 4-VI to 4-VII(1) present the 1965 through 1975 LACIE yield predictions along with the values of the statistics discussed in section 3.2. These predictions are state predictions (except for the Badlands and Panhandle predictions) and are for the last monthly truncation of each yield model. One purpose for presenting these tables is simply to show some of the data that were used in the feasibility analysis and to display examples of values of the standard variance, variance of prediction, and the prediction error, which will be available in the operational printout from these models. The last column in these tables are 90-percent confidence intervals about the CCEA predictions. With the exception of North Dakota and Kansas, the confidence intervals for each state cover the USDA prediction at least 8 out of 10 times, and on the average 9.2 times out of 10, which indicates that these intervals are about the right size. In Kansas, the intervals cover the USDA values only 6 out of 10 times; and in North Dakota, only 7 out of 10 times. It is signicicant to note that, in Kansas, three of the "bad years" (i.e., the years for which the CCEA predictions and the USDA predictions are not within one-half the width of the confidence interval) coincide with the years that contribute to the nonacceptance of the 90/90 hypothesis for state aggregated estimates (see table 4-I). In North Dakota, similar "bad years" are 1966 and 1974.

TABLE 4-I.- RELATIVE DIFFERENCES OF STATE AND GREAT PLAINS YIELD ESTIMATES (STATE AGGREGATED ESTIMATES)

Year	N. Dakota	Texas	Kansas	Colorado	Nebraska	Oklahoma	Minnesota	S. Dakota	Montana	G. Plains
1965	.09585	-.24545	-.00425	-.26566	-.11499	-.12499	.17539	.05515	-.00184	-.02891
1966	.25952	-.23999	.36410	.37553	-.24285	.04285	.42653	-.02473	-.17357	.09848
1967	-.24015	.0625	0	-.00264	-.30188	.20588	-.04746	-.13278	-.16554	-.08870
1968	-.00578	-.26817	-.05769	-.04499	-.0125	-.02608	-.11940	-.13405	-.04205	-.06044
1969	.22414	-.27916	.03225	.08843	.06666	0	.18265	.50663	.08642	.08167
1970	-.12196	-.18749	-.08484	.07583	-.06842	.13846	-.57832	-.18901	-.12611	-.10283
1971	-.03039	-.18570	-.15362	-.19925	-.13809	.08500	-.07560	.13937	-.04870	-.07540
1972	.11833	-.27272	-.10447	-.14923	.016211	-.06521	.05150	.03626	.06062	-.02149
1973	-.08213	-.30689	.50810	.24430	.06285	.23666	-.06896	.11720	.08093	.16519
1974	.29204	.1	.28727	-.22112	.03529	.195238	.24044	.24123	.00691	.181047
Tolerance limits[1]	±.2091	±.4120	±.1676	±.3635	±.3015	±.2582	±.3329	±.3939	±.2732	±.0889
[2] $10\hat{p}_{10}$	6	10	7	9	9	10	8	9	10	6

[1] Tolerance limits are computed from $.0707/\sqrt{\delta_s}$, where δ_s is defined in section 3.0.

[2] $10\hat{p}_{10}$ = number of years for which yield estimates are within tolerance limits.

TABLE 4-II.- RELATIVE DIFFERENCES OF STATE AND GREAT PLAINS YIELD ESTIMATES (CROP REPORTING DISTRICT AGGREGATED ESTIMATES)

Year	N. Dakota	Texas	Kansas	Colorado	Nebraska	Oklahoma	Minnesota	S. Dakota	Montana	G. Plains
1965	.104	-.168	.013	.414	-.185	-.132	.223	.028	-.004	-.008
1966	.244	-.187	.369	.372	-.291	.024	.467	-.087	-.218	.119
1967	-.093	.238	-.015	-.031	-.268	.229	-.003	-.179	-.163	-.077
1968	-.004	.605	-.038	-.085	-.013	-.035	-.116	.132	-.032	.015
1969	.208	-.138	.023	.088	-.010	-.007	.173	0	.045	.049
1970	.314	-.113	-.103	-.112	-.011	.104	.076	-.054	-.127	-.068
1971	-.016	-.152	-.162	-.196	-.195	.055	-.061	-.123	-.038	-.094
1972	.138	-.118	-.110	-.058	.014	-.065	.088	.060	-.056	-.017
1973	.022	-.090	.516	.273	-.060	.210	-.062	-.117	.067	.186
1974	.387	.069	.273	-.235	-.006	.157	.253	.255	.004	.185
Tolerance limits[1]	±.2091	±.4120	±.1676	±.3635	±.3015	±.2582	±.3329	±.3939	±.2732	±.0889
[2] $_{10}\hat{p}_{10}$	7	9	7	8	10	10	9	10	10	7

[1] Tolerance limits are computed from $.0707/\sqrt{\delta_s}$ where δ_s is defined in section 3.0.

[2] $_{10}\hat{p}_{10}$ = number of years for which yield estimates are within tolerance limits.

TABLE 4-III.- COMPARISON OF DISTRICT YIELD WITH STATE YIELD ESTIMATES

Year	State yield converted to production P'[1] (X1000)	District yield converted to production P"[1] (X1000)	P' - P" (X1000)
1965	838296	858051	-19755
1966	904524	897624	10900
1967	814681	849594	-34913
1968	975202	969115	6087
1969	1061600	1049823	11777
1970	872342	862574	9768
1971	1004852	1002685	2167
1972	998167	997625	542
1973	1479392	1518897	-39505
1974	1342155	1346064	-3909
Mean			-5684
St. dev.			19023
t			-.9448

[1]The conversion to production is $P = \sum_{i=1}^{9} A_i \hat{Y}_i$, where A_i are the SRS state wheat area estimates for the given year and $\hat{Y}_i$ are the LACIE estimated state yields.

TABLE 4-IV.- MEANS AND STANDARD DEVIATIONS OF USDA ESTIMATES AND OF CCEA FINAL TRUNCATION PREDICTIONS, UNITED STATES, 1965 to 1975[3]

Model	USDA		CCEA		$d_i = Y_i - Y_i$	
	Mean ($\bar{Y}$)	S.D. (s_y)	Mean ($\bar{Y}$)	S.D. (s_y)	Mean ($\bar{d}$)	S.D. (s_d)
	bu./A.	bu./A.	bu./A.	bu./A.	bu./A.	bu./A.
Winter wheat						
Badlands	29.98	6.24	28.08	5.77	1.90	5.22
Colorado	22.41	4.11	22.30	4.84	.11	4.38
Kansas[1]	27.85	5.41	28.54	4.88	- .69	4.45
Kansas[2]	28.68	5.83	31.02	9.44	-2.34	6.84
Montana	28.95	2.04	27.91	3.16	1.05	3.60
Nebraska	33.00	5.89	31.25	7.18	1.75	4.05
Oklahoma	23.77	4.01	24.82	5.05	-1.05	3.32
Okla.-Texas	21.42	4.44	22.22	3.69	-.80	3.67
Texas	19.17	3.63	17.62	1.41	1.55	2.84
Spring wheat						
Montana	22.74	3.19	22.25	3.18	0.48	2.22
N. Dakota	26.18	3.45	27.17	5.34	- .99	4.19
Red River	30.58	3.74	33.09	2.74	-2.47	4.02
S. Dakota	20.82	3.88	21.22	2.46	- .40	2.10

[1]Excluding 1973 data.

[2]Including 1973 data.

[3]1965 to 1974 only for the Badlands, Oklahoma-Texas, and Red River models.

TABLE 4-V.- STATISTICS COMPUTED FOR EVALUATION OF CCEA WHEAT YIELD PREDICTIONS, UNITED STATES

Model	[1]$S_{\hat{y}} \div S_y$	[2]$S_d \div S_y$	[3]r	Years
<u>Winter wheat</u>				
Badlands	0.92	0.84	0.62	1965-74
Colorado	1.16	1.06	.53	1965-75
Kansas	.90	.82	.63	1965-72, 1974-75
Montana	1.55	1.76	.09	1965-75
Nebraska	1.22	.69	.83	1965-75
Oklahoma	1.26	.83	.76	1965-75
Okla.-Texas	.83	.83	.61	1965-74
Texas	.39	.78	.69	1965-75
<u>Spring wheat</u>				
Montana	0.996	0.70	0.76	1965-75
North Dakota	1.55	1.21	.62	1965-75
Red River	.73	1.07	.26	1965-74
South Dakota	.63	.54	.88	1965-75

[1]$S_{\hat{y}}$ is the standard deviation of the CCEA yields predicted for indicated years. S_y is the standard deviation of comparable USDA estimates.

[2]S_d is the standard deviation of the individual year differences between the CCEA predictions and the USDA estimates.

[3]r is the coefficient of correlation between the CCEA predictions and the USDA estimates for the years indicated.

TABLE 4-VI.- 1975 YIELD PREDICTIONS

State model	Truncation	Year	USDA estimated yield	CCEA predicted yield	Standard error	Standard variance	$X_o'CX_o$	Standard deviation of prediction	Prediction error	90% Confidence interval about CCEA predictions
Badlands	July	1975		27.6	4.0632	16.5099	0.5908	3.1230	5.1248	(18.9, 36.3)
Colorado	June	1975	22.0	24.9	3.0809	9.4919	0.3042	1.6994	3.5185	(19.0, 30.8)
Kansas	June	1975	29.0	34.1	2.4568	6.0358	0.3046	1.3558	2.8061	(29.4, 38.8)
Montana Winter Wheat	June	1975	32.0	30.9	2.4553	6.0283	1.1803	2.6674	3.6254	(24.8, 37.0)
Montana Spring Wheat	July	1975	27.3	27.5	2.2115	4.8908	0.2300	1.0606	2.4527	(23.4, 31.6)
Nebraska	June	1975	32.0	34.2	3.2086	10.2954	0.2771	1.6889	3.6260	(28.1, 40.3)
North Dakota	July	1975	26.7	24.4	2.6274	6.9033	1.8979	3.6196	4.4727	(16.8, 32.0)
Oklahoma	June	1975	24.0	20.7	2.1213	4.4997	0.8752	1.9844	2.9048	(15.8, 25.6)
Panhandle	May	1975		25.9	2.4340	5.9243	0.5336	1.7780	3.0142	(20.8, 31.0)
Red River (Minn.)	July	1975		30.2	3.0855	9.5206	0.4971	2.1754	3.7753	(23.8, 36.6)
South Dakota	July	1975	18.9	21.0	2.0950	4.3892	0.7354	1.7967	2.7600	(16.3, 25.7)
Texas	June	1975	23.0	19.4	1.9381	3.7562	0.5497	1.4370	2.4127	(15.3, 23.5)

TABLE 4-VII.- TEN-YEAR YIELD PREDICTIONS

(a) Badlands State Model July Truncation

Year	USDA yield	CCEA predicted yield	Standard error	Standard variance	$X_o'CX_o$	Standard deviation of prediction	Prediction error	90% Confidence interval about CCEA Prediction
1965	15.4	19.9	4.0158	16.1269	0.5521	2.9838	5.0030	(11.4, 28.4)
1966	31.6	20.1	4.0008	16.0062	0.6224	3.1563	5.0959	(11.5, 28.7)
1967	30.5	26.5	4.3024	18.5107	0.6344	3.4269	5.5004	(17.2, 35.8)
1968	32.7	29.7	4.2670	18.2077	0.4770	2.9470	5.1858	(20.9, 38.5)
1969	25.7	25.4	4.2165	17.7786	0.4346	2.7800	5.0503	(16.9, 33.9)
1970	32.4	33.8	4.1426	17.1615	0.6930	3.4487	5.3903	(24.7, 42.9)
1971	37.8	30.9	4.0774	16.6250	0.3992	2.5761	4.8230	(22.7, 39.1)
1972	36.0	37.4	4.1450	17.1807	0.5642	3.1134	5.1840	(28.6, 46.2)
1973	30.1	24.7	4.0839	16.6786	1.1806	4.4374	6.0307	(14.5, 34.9)
1974	27.6	32.4	4.0666	16.5368	0.4415	2.7021	4.8824	(24.1, 40.7)

(b) Texas State Model June Truncation

Year	USDA yield	CCEA predicted yield	Standard error	Standard variance	$X_o'CX_o$	Standard deviation of prediction	Prediction error	90% Confidence interval about CCEA Prediction
1965	16.5	16.6	1.7526	3.0717	1.2941	1.9937	2.6546	(12.1, 21.1)
1966	19.0	17.1	1.7187	2.9538	0.9560	1.6804	2.4037	(13.0, 21.2)
1967	14.4	17.0	1.7024	2.8981	0.6648	1.3881	2.1966	(13.3, 20.7)
1968	19.9	16.1	1.7127	2.9335	0.9170	1.6401	2.3714	(12.1, 20.1)
1969	21.5	17.3	1.7627	3.1070	0.7907	1.5674	2.3588	(13.3, 21.3)
1970	22.7	19.5	1.8249	3.3304	0.5842	1.3548	2.2969	(15.6, 23.4)
1971	13.5	17.1	1.8450	3.4040	0.6823	1.5240	2.3931	(13.1, 21.3)
1972	18.5	16.0	1.8769	3.5226	0.8849	1.7656	2.5768	(11.6, 20.4)
1973	24.8	20.1	1.8741	3.5122	0.4545	1.2635	2.2602	(16.3, 23.9)
1974	17.1	17.6	1.9652	3.8621	0.4068	1.2535	2.3309	(13.7, 21.5)

TABLE 4-VII.- Continued

(c) South Dakota State Model June Truncation

Year	USDA yield	CCEA predicted yield	Standard error	Standard variance	$X_o'CX_o$	Standard deviation of prediction	Prediction error	90% Confidence interval about CCEA Prediction
1965	18.3	18.4	2.2[illegible]34	5.0329	0.5207	1.6189	2.7665	(13.7, 23.1)
1966	15.3	17.0	2.[illegible]81	4.8317	0.7127	1.8557	2.8767	(12.1, 21.9)
1967	24.3	23.3	2.1699	4.7086	0.5293	1.5737	2.6834	(18.8, 27.8)
1968	23.4	21.0	2.1353	4.5596	0.4524	1.4362	2.5734	(16.7, 25.3)
1969	20.[illegible]	22.3	2.1305	4.5390	0.8626	1.9788	2.9077	(17.4, 27.2)
1970	19.5	20.4	2.1120	4.4605	0.3972	1.3311	2.4965	(16.2, 24.6)
1971	27.0	24.3	2.0807	4.3294	0.3384	1.2103	2.4071	(20.2, 28.4)
1972	24.1	24.9	2.0896	4.3666	0.5144	1.4987	2.5715	(20.6, 29.2)
1973	23.1	21.8	2.0603	4.2448	0.3761	1.2636	2.4169	(17.7, 25.9)
1974	14.9	19.0	2.0380	4.1535	0.[illegible]113	1.3071	2.4212	(14.9, 23.1)

(d) Red River Valley Model June Truncation

Year	USDA yield	CCEA predicted yield	Standard error	Standard variance	$X_o'CX_o$	Standard deviation of prediction	Prediction error	90% Confidence interval about CCEA Prediction
1965	29.8	31.4	2.7682	7.6627	0.5532	2.0590	3.4500	(25.6, 37.2)
1966	25.0	32.7	2.7531	7.5796	0.6565	2.2307	3.5434	(26.7, 38.7)
1967	30.1	30.6	2.9363	8.6221	0.4355	1.9377	3.5181	(24.7, 36.5)
1968	32.4	29.0	2.8847	8.3214	0.5395	2.1188	3.5792	(23.0, 35.0)
1969	32.5	35.5	2.8808	8.2993	0.3842	1.7856	3.3894	(29.8, 41.2)
1970	27.5	29.6	2.8695	8.2341	0.4265	1.8740	3.4272	(23.8, 35.4)
1971	36.8	35.0	2.8404	8.0678	0.2970	1.5479	3.2348	(29.5, 40.5)
1972	31.8	34.6	2.8102	7.8971	0.3090	1.5621	3.2152	(29.2, 40.0)
1973	34.2	36.2	2.7997	7.8384	0.2570	1.4194	3.1390	(30.9, 41.5)
1974	25.7	35.9	2.7750	7.7004	0.4706	1.9036	3.3651	(30.2, 41.6)

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TABLE 4-VII.- Continued

(e) Montana State Model June Truncation: winter wheat

Year	USDA yield	CCEA predicted yield	Standard error	Standard variance	$X_o'CX_o$	Standard deviation of prediction	Prediction error	90% Confidence interval about CCEA Prediction
1965	29.0	27.4	2.3108	5.3398	0.5268	1.6772	2.8553	(22.6, 32.2)
1966	30.0	25.3	2.2777	5.1879	0.4591	1.5433	2.7513	(20.7, 29.9)
1967	30.0	22.7	2.3570	5.5555	1.0423	2.4064	3.3684	(17.0, 28.4)
1968	31.5	30.8	2.5000	6.2500	0.3332	1.4432	2.8866	(25.9, 35.7)
1969	26.0	30.6	2.4587	6.0450	1.1620	2.6503	3.6151	(24.5, 36.7)
1970	27.0	22.6	2.4872	6.1859	0.8293	2.2650	3.3639	(16.9, 28.3)
1971	30.0	30.1	2.5107	6.3034	0.4168	1.6208	2.9864	(25.0, 35.2)
1972	27.0	30.6	2.4705	6.1036	0.3352	1.4303	2.8547	(25.8, 35.4)
1973	26.5	28.6	2.4955	6.2276	0.3211	1.4142	2.8684	(23.8, 33.4)
1974	29.5	27.4	2.4749	6.1253	0.6511	1.9970	3.1801	(22.0, 32.8)

(f) Colorado State Model June Truncation

Year	USDA yield	CCEA predicted yield	Standard error	Standard variance	$X_o'CX_o$	Standard deviation of prediction	Prediction error	90% Confidence interval about CCEA Prediction
1965	15.5	11.5	2.9875	8.9252	6.6734	7.7176	8.2757	(-2.5, 25.5)
1966	18.0	24.8	2.9412	8.6508	0.9173	2.8170	4.0726	(17.9, 31.7)
1967	19.5	19.5	3.0411	9.2482	0.5992	2.3541	3.8458	(13.0, 26.0)
1968	20.0	19.1	2.9842	8.9057	0.6458	2.3981	3.8284	(12.5, 25.6)
1969	21.0	24.2	2.9332	8.6036	0.5631	2.2010	3.6672	(18.0, 30.4)
1970	28.5	25.2	2.9222	8.5394	0.4750	2.0140	3.5490	(19.2, 31.2)
1971	28.0	22.4	2.9078	8.4553	0.4514	1.9537	3.5032	(16.5, 28.3)
1972	24.0	23.3	2.9810	8.8864	0.3166	1.6773	3.4205	(17.5, 29.1)
1973	24.5	30.5	2.9359	8.6196	0.4912	2.0576	3.5852	(24.4, 36.6)
1974	25.5	19.9	3.0156	9.0937	0.3903	1.8839	3.5557	(13.9, 25.9)

TABLE 4-VII.- Continued

(g) Montana State Model June Truncation; spring wheat

Year	USDA yield	CCEA predicted yield	Standard error	Standard variance	$X_o'CX_o$	Standard deviation of prediction	Prediction error	90% Confidence interval about CCEA Prediction
1965	20.8	22.8	2.3169	5.3682	0.5077	1.6512	2.8451	(18.0, 27.5)
1966	22.0	17.5	2.2955	5.2692	0.4535	1.5458	2.7674	(12.8, 22.2)
1967	18.0	18.4	2.3600	5.5695	0.4291	1.5460	2.8213	(13.6, 23.2)
1968	21.7	20.0	2.3199	5.3820	0.3103	1.2924	2.6556	(15.5, 24.5)
1969	27.5	25.7	2.2964	5.2737	0.6430	1.8414	2.9436	(20.7, 30.7)
1970	23.5	21.4	2.2739	5.1706	0.3124	1.2709	2.6050	(17.0, 25.8)
1971	23.0	20.7	2.2611	5.1127	0.2748	1.1853	2.5530	(16.4, 25.0)
1972	26.3	26.1	2.2556	5.0878	0.3183	1.2726	2.5900	(21.7, 30.5)
1973	21.0	22.8	2.2224	4.9391	0.2676	1.1496	2.5021	(18.6, 27.0)
1974	19.0	21.9	2.2068	4.8698	0.5341	1.6127	2.7332	(17.3, 26.5)

(h) Oklahoma - Texas Panhandle State Model June Truncation

Year	USDA yield	CCEA predicted yield	Standard error	Standard variance	$X_o'CX_o$	Standard deviation of prediction	Prediction error	90% Confidence interval about CCEA Prediction
1965	24.6	20.7	2.3508	5.5260	1.2687	2.6478	3.5407	(14.7, 26.7)
1966	21.4	19.5	2.3624	5.5808	1.0650	2.4380	3.3948	(13.8, 25.2)
1967	15.7	23.4	2.3292	5.4253	0.8848	2.1910	3.1978	(18.0, 28.8)
1968	20.8	22.0	2.5320	6.4112	0.7689	2.2203	3.3676	(16.3, 27.7)
1969	20.5	25.0	2.4912	6.2061	0.9496	2.4277	3.4784	(19.1, 30.9)
1970	23.2	22.9	2.5205	6.3531	0.8079	2.2656	3.3891	(17.2, 28.6)
1971	21.5	18.5	2.4771	6.1361	0.4634	1.6863	2.9966	(13.4, 23.6)
1972	22.9	21.7	2.4764	6.1327	0.6576	2.0082	3.1883	(16.3, 27.1)
1973	29.8	30.6	2.4418	5.9623	1.1467	2.6147	3.5776	(24.6, 36.6)
1974	13.8	17.9	2.4053	5.7856	0.5886	1.8453	3.0316	(12.8, 23.0)

TABLE 4-VII.- Continued

(i) Nebraska State Model June Truncation

Year	USDA yield	CCEA predicted yield	Standard error	Standard variance	$X_o'CX_o$	Standard deviation of prediction	Prediction error	90% Confidence interval about CCEA Prediction
1965	20.0	17.7	3.1551	9.9546	1.0057	3.1641	4.4683	(10.1, 25.3)
1966	35.0	26.5	3.1088	9.6649	0.4265	2.0302	3.7131	(20.2, 32.8)
1967	26.5	18.5	3.3526	11.2398	1.8388	4.5462	5.6487	(9.0, 28.0)
1968	32.0	31.6	3.4137	11.6531	0.634[illegible]	2.7190	4.3642	(24.2, 39.0)
1969	31.5	33.6	3.3528	11.2409	0.5127	2.4006	4.1236	(26.6, 40.6)
1970	38.0	35.4	3.3096	10.9534	0.6993	2.7677	4.3143	(28.1, 42.7)
1971	42.0	36.2	3.2743	10.7208	0.3572	1.9568	3.8144	(29.8, [illegible])
1972	37.0	37.6	3.3413	11.1640	0.256[illegible]	1.6936	3.7460	(31.3, 43.9)
1973	35.0	37.2	3.2900	10.8241	0.8062	2.9541	4.4216	(29.7, 44.7)
1974	34.0	35.2	3.2526	10.5792	0.4652	2.2184	3.9371	(28.5, 41.9)

(j) Oklahoma State Model June Truncation

Year	USDA yield	CCEA predicted yield	Standard error	Standard variance	$X_o'CX_o$	Standard deviation of prediction	Prediction error	90% Confidence interval about CCEA Prediction
1965	28.0	24.5	2.0182	4.0733	1.3806	2.3714	3.1140	(19.2, 29.8)
1966	21.0	21.9	2.0299	4.1207	1.4374	2.4337	3.1692	(16.5, 27.3)
1967	17.0	20.5	1.9921	3.9685	0.8756	1.8641	2.7283	(15.9, 25.1)
1968	23.0	22.4	2.0181	4.0729	0.8475	1.8579	2.7432	(17.8, 27.0)
1969	28.5	28.0	1.9819	3.9281	1.0325	2.0140	2.8256	(23.2, 32.8)
1970	26.0	29.6	1.9473	3.7919	1.0844	2.0278	2.8114	(24.8, 34.4)
1971	20.0	21.7	1.9678	3.8721	0.5532	1.4636	2.4524	(17.6, 25.8)
1972	23.0	21.5	1.9515	3.8085	0.4738	1.3433	2.3692	(17.5, 25.5)
1973	30.0	37.1	1.9333	3.7376	1.4779	2.3503	3.0433	(32.0, 42.2)
1974	21.0	25.1	2.0636	4.2586	0.3498	1.2206	2.3976	(21.0, 29.2)

TABLE 4-VII.- Concluded

(k) Kansas State Model June Truncation

Year	USDA yield	CCEA predicted yield	Standard error	Standard variance	$X_o'CX_o$	Standard deviation of prediction	Prediction error	90% Confidence interval about CCEA Prediction
1965	24.0	23.4	1.9485	3.7968	1.0987	2.0424	2.8228	(18.6, 28.2)
1966	19.5	26.6	1.9095	3.6460	1.5088	2.3454	3.0244	(21.5, 31.7)
1967	20.0	20.0	2.0788	4.3213	1.0782	2.1585	2.9967	(14.9, 25.1)
1968	26.0	24.5	2.0390	4.1576	0.5478	1.5091	2.5367	(20.2, 28.8)
1969	31.0	32.0	2.0144	4.0579	0.5484	1.4918	2.5067	(27.8, 36.2)
1970	33.0	30.2	1.9833	3.9336	0.4007	1.2555	2.3473	(26.2, 34.2)
1971	34.5	29.2	1.9978	3.9913	0.2893	1.0746	2.2685	(25.4, 33.0)
1972	33.5	30.0	2.1379	4.5705	0.3024	1.1756	2.4398	(25.9, 34.1)
1973	37.0	55.8	2.1745	4.7286	19.1218	9.5089	9.7543	(39.3, 72.3)
1974	28.0	35.4	2.2664	5.1367	0.5645	1.7029	2.8349	(30.6, 40.2)

(l) North Dakota State Model July Truncation

Year	USDA yield	CCEA predicted yield	Standard error	Standard variance	$X_o'CX_o$	Standard deviation of prediction	Prediction error	90% Confidence interval about CCEA Prediction
1965	26.0	28.5	2.5289	6.3952	0.6487	2.0368	3.2471	(25.0, 32.0)
1966	23.4	29.5	2.5057	6.2784	0.8633	2.3281	3.4203	(25.5, 33.5)
1967	22.6	17.2	2.6179	6.8535	2.7672	4.3549	5.0812	(9.8, 24.6)
1968	26.8	26.6	2.6240	6.8852	0.5219	2.3650	3.2371	(22.6, 30.6)
1969	29.8	36.5	2.5729	6.6200	0.8649	2.3928	3.5136	(32.4, 40.6)
1970	23.5	20.7	2.6766	7.1644	1.5995	3.3852	4.3156	(14.9, 26.5)
1971	31.8	30.8	2.6486	7.0149	1.2275	2.9344	3.9529	(25.8, 35.8)
1972	28.8	32.3	2.6041	6.7814	0.9910	2.5924	3.6745	(27.9, 36.7)
1973	28.3	26.0	2.5997	6.7586	0.7694	2.2804	3.4582	(22.1, 29.9)
1974	20.3	26.4	2.5751	6.6312	1.4884	3.1417	4.0622	(21.1, 31.7)