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LARGE AREA CROP INVENTORY EXPERIMENT (LACIE)

LARGE AREA CROP INVENTORY EXPERIMENT

LACIE

LACIE PROJECT REVIEW MATERIAL

NASA NOAA USDA

LACIE THIRD INTERIM PHASE II ACCURACY ASSESSMENT REPORT

LACIE SENSITIVE INTERNAL USE ONLY

National Aeronautics and Space Administration

LYNDON B. JOHNSON SPACE CENTER

Houston, Texas

DECEMBER 1976

PROJECT WORKING DOCUMENT

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PHASE II ACCURACY ASSESSMENT REPORT

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
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NOTE: This report has been released as a "PROJECT WORKING DOCUMENT" to provide an expedited mechanism for making preliminary Accuracy Assessment results available within the Large Area Crop Inventory Experiment. Each interim report will be progressively modified to incorporate comments on the previous report or reports and will be expanded to incorporate the additional Accuracy Assessment results available during the crop year.

CONTENTS

ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS:

AA	Accuracy Assessment.
AA-01	LACIE Phase II AA Report for February 1976.
ACC	adjustable crop calendar.
Agromet	agricultural/meteorological.
Biowindow	biological window — a Landsat data acquisition period that is related to the biostages of wheat development. The LACIE approach is based on the judgment that wheat can be separated adequately from other crops by analysis of up to four acquisitions of Landsat data during the growing season. The biowindow may be updated if there is a significant lag or advancement in the current crop calendar. The sequence chosen includes acquisitions during the following biowindows: 1. Crop establishment — from 50 percent tillering to 50 percent jointing (biostage 2.3 to 3.0). 2. Green — from 50 percent jointing to 50 percent heading (biostage 3.1 to 4.0). 3. Heading — from 50 percent heading to 50 percent soft dough (biostage 4.1 to 5.0). 4. Mature — from 50 percent soft dough to 50 percent harvest (biostage 5.1 to 6.0).
Biostage or biophase	biological stage, biological phase — the specific stage of development of a crop which can be recognized by a major change in plant structure; i.e., emergence after germination, jointing, heading, soft dough, ripening, and harvest, which are represented by integers on the Robertson Biometeorological Time Scale.
Blind site	a LACIE sample segment chosen at random after normal analysis; used for testing classification performance.

BMTS	Biometeorological Time Scale.
CAMS	Classification and Mensuration Subsystem.
CAS	Crop Assessment Subsystem.
CCEA	Center for Climatological and Environmental Assessment — an organization of the National Oceanic and Atmospheric Administration, Columbia, Missouri.
Classification	in computer-aided analysis of remotely sensed data, the process of assigning data points to specified classes by a testing process in which the spectral properties of each unknown data point are compared with spectral properties typical of the subject being classified.
Classification error	a measure of the degree to which the LACIE CAMS overestimates or underestimates the wheat acreage in one or more LACIE samples.
CMR	CAS Monthly Report.
CRD	Crop Reporting District — a geographical area used by the U.S. Department of Agriculture for the collection and reporting of agricultural information; each district consists of several counties.
Crop calendar	a calendar depicting the biostages of the major crop types within a specified region during a calendar year.
Crop calendar adjustment	an adjustment made to the normal crop calendar on the basis of current meteorological data.
CUR	CAS Unscheduled Report.
CV	coefficient of variation (standard deviation divided by the mean).
DAPTS	Data Acquisition, Preprocessing, and Transmission Subsystem.
Group 2 segment	LACIE segment in a county that historically produces small quantities of wheat/small grains; samples are allocated with probability proportional to size.

IE	Information Evaluation.
IMR	IE Monthly Report.
ITS	intensive test site — a LACIE segment in the United States or Canada on which detailed crop information is collected by using ground and airborne equipment.
JSC	Lyndon B. Johnson Space Center of NASA, Houston, Texas.
LACIE	Large Area Crop Inventory Experiment.
Landsat	Land Satellite — formerly called ERTS (Earth Resources Technology Satellite); operates in a circular, Sun-synchronous, near-polar orbit of the Earth at an altitude of approximately 915 kilometers; orbits the Earth about 14 times a day and views the same scene approximately every 18 days.
LEC	Lockheed Electronics Company, Inc.
MSE	mean square error.
MSS	Multispectral Scanner System or multispectral scanner — the remote sensing instrument on Landsat that measures reflected sunlight in various spectral bands or wavelengths.
NASA	National Aeronautics and Space Administration.
NOAA	National Oceanic and Atmospheric Administration.
90-90 criterion	criterion that the LACIE U.S. Great Plains production estimate be 90 percent accurate, at harvest, 90 percent of the time (in comparison with the true value).
PPS	probability proportional to size.
Sample segment	a 5- by 6-nautical-mile area selected by stratified random sampling; information is recorded by the MSS and transformed into computer-compatible tapes and film products.
Sampling error	a measure of the degree to which the estimated wheat acreage in the LACIE sample segments does not represent the wheat acreage contained in the survey region being sampled.

USDA	U.S. Department of Agriculture.
USDA/ASCS	USDA Agricultural Stabilization and Conservation Service.
USDA/SRS	USDA Statistical Reporting Service.
U.S. Great Plains (USGP) (USSGP) (USNGP)	an area encompassing the nine states of Colorado, Kansas, Minnesota, Montana, Nebraska, North and South Dakota, Oklahoma, and Texas; it is divided geographically into (1) the U.S. southern Great Plains, which includes Colorado, Kansas, Nebraska, Oklahoma, and Texas, and (2) the U.S. northern Great Plains, which includes Minnesota, Montana, and North and South Dakota.

SYMBOLS:

$\hat{A}$	acreage estimate for the five-state area.
$\hat{A}_i$	acreage estimate for the *ith* state.
$\hat{A}_{ij}$	acreage estimate for the *ith* state and the *jth* CRD.
$CV(\hat{W})$	CV of production.
$CV'(\hat{W})$	$CV(\hat{W})$ without yield error.
$CV''(\hat{W})$	$CV(\hat{W})$ without acreage error.
$CV^*(\hat{W})$	$CV(\hat{W})$ without classification error.
$CV^{**}(\hat{W})$	$CV(\hat{W})$ without sampling error.
n	number of samples or observations.
$\hat{P}$	CAMS estimated proportion of wheat/small grains.
$\bar{\hat{P}}$	average $\hat{P}$.
$\hat{P}_i$	$\hat{P}$ for the *ith* state.
$\hat{P}_m$	$\hat{P}$ for the *mth* blind site.

P_{GT}	proportion of wheat/small grains based on identification of each field in the blind site or ITS by USDA/ASCS personnel.
$\overline{P}_{GT}$	average P_{GT}.
P_{GT_i}	P_{GT} for the *ith* state.
P_{GT_m}	P_{GT} for the m*th* blind site.
r	ratio of classification error to the sum of classification and sampling errors.
$\hat{V}$	estimated variance.
$\hat{W}$	production estimate for the five-state area.
$\hat{W}_i$	production estimate for the *ith* state.
$\hat{Y}$	yield estimate for the five-state area.
$\hat{Y}_i$	yield estimate for the *ith* state.
$\hat{Y}_{ij}$	yield estimate for the *ith* state and the j*th* CRD.
$\pm\sigma$	plus or minus one standard deviation — LACIE confidence interval.
$\hat{\sigma}_c^2$	estimate of classification error.
$\hat{\sigma}_s^2$	estimate of sampling error.

1. INTRODUCTION

The Large Area Crop Inventory Experiment (LACIE) is an interagency endeavor of the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Department of Agriculture (USDA). Its purposes are to demonstrate the economical importance of utilizing satellite remotely sensed data from the Land Satellite (Landsat) for agricultural applications; to test the capability of a system utilizing remote sensing in conjunction with climatological, meteorological, and conventional data to produce timely estimates of the production of a major world crop prior to harvest; and to validate the technology and procedures for such a system.

In accordance with the objectives of the LACIE, the Accuracy Assessment (AA) effort is designed to check the accuracy of the products from the experimental operations throughout the growing season and thereby determine if the procedures used are sufficient to accomplish the above objectives.

The original intent of this document was to evaluate the acreage, yield, and production estimates in the U.S. Great Plains (USGP) obtained through October 1976. However, since some previous assumptions, e.g., the assumption that yield estimates are correlated at the Crop Reporting District (CRD) level, have been invalidated, production statistics were calculated incorrectly. As a consequence, no coefficients of variation (CV's) will be reported in this document. These statistics are being recalculated and this evaluation must be delayed until the revised statistics are available. The results should appear in the Fourth Interim Accuracy Assessment Report. An outline of this report is presented in appendix A.

1.1 OBJECTIVES

The objectives of AA are as follows:

a. To determine how well LACIE is performing — in particular, to determine if LACIE is meeting the 90/90 criterion of being sufficiently accurate to estimate wheat production at harvest for the USGP region to within 10 percent of the true value 90 percent of the time.[1]

b. To study the sources of error in LACIE estimates and recommend procedures for reducing error.

1.2 GENERAL METHODOLOGY

Three groups of activities were required to implement the LACIE Phase II AA and satisfy its objectives:

a. Data requirements definition and acquisition monitoring

b. Data analysis and evaluation

c. Reporting

1.2.1 DATA REQUIREMENTS DEFINITIONS AND ACQUISITION MONITORING

The first group of the Phase II AA activities involved the identification of data requirements to support the accuracy evaluations of the various LACIE component products and the monitoring of data acquisitions by the LACIE operational organization and related NOAA and USDA functions. These activities involved the identification of LACIE operational data products to be used in AA, the definition of methods by which these products could be retrieved in a timely manner from LACIE operations for AA analyses, and identification of requirements for reference and control data from NOAA and USDA.

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[1] It should be understood that LACIE does make production estimates throughout the growing season but the valid basis for comparison is the at-harvest estimate.

AA Team members (1) selected blind-site data at random (approximately 40 sites for early- and late-season evaluations and approximately 136 sites for late-season evaluations) from segments which had at least one Landsat acquisition and which had been processed by the Classification and Mensuration Subsystem (CAMS) and forwarded to the Crop Assessment Subsystem (CAS) and (2) coordinated action with the Data Acquisition, Preprocessing and Transmission Subsystem (DAPTS) for acquiring ground truth from the blind sites and intensive test sites (ITS's) in the United States and for retrieving CAMS classification data for these sites from LACIE operations. The locations of the blind sites were withheld from the CAMS analysts so that these segments would be processed as regular operational segments.

Although AA data acquisition was largely accomplished by LACIE operations personnel, extensive coordination was required by AA in order to ensure the timely and accurate selection of blind sites and the gathering of adequate evaluation data.

1.2.2 DATA ANALYSIS AND EVALUATION

The second group of activities of Phase II AA concerned the analysis and evaluation of the basic data collected during the initial AA activities. Most of this analysis was for the U.S. Great Plains region.

In order to accomplish its objectives of determining the magnitude and components of error in LACIE estimates and of ascertaining whether or not the LACIE was satisfying the 90/90 criterion, AA:

a. Compared the LACIE and USDA/Statistical Reporting Service (SRS) estimates for production, acreage and yield throughout the season. This included calculating the CV's for the LACIE estimates in order to determine if the differences between the LACIE and USDA/SRS estimates were significant.

b. Established an error budget and compared the production CV's to the budgeted values to determine if the 90/90 criterion was being met.

c. Investigated classification error by comparing CAMS classification results with ground-truth data.

d. Investigated sampling error by regressing ground-truth proportions on the historical county wheat proportions.

e. Determined the contribution of errors in acreage, yield, classification and sampling to the CV for production, CV_P.

1.2.3 REPORTING

Reporting for Phase II AA consisted of the following three reporting methods:

1. Special AA management briefings and presentations
2. AA monthly quick-look reports
3. AA final report on Phase I and Phase II.

The monthly quick-look reports consist of technical comments on the current CAS Monthly Reports (CMR's). They discuss any problems indicated by the data presented in the CMR and the results of any investigations of these problem areas conducted by AA.

The AA final report is developed through a series of interim reports of which this is the third. This iterative building-block process of preparing the Phase II AA report has been developed to provide a timely communication of performance evaluation to project elements and a thorough review and critique of each report, with the technical comments being used to upgrade and improve the succeeding drafts of the report. It also provides for the analysis and addition of technical data that become available during the interim period between report drafts. The first interim report consisted of evaluations of early-season winter-wheat estimates in the U.S. southern Great Plains (USSGP). The second interim report examined early- and late-season winter-wheat estimates in the same area. The third interim report provides AA evaluations of at-harvest estimates of U.S. winter and spring wheat over the U.S. Great Plains. A fourth interim report will be developed to serve as a draft of the final AA report. It will cover Phase I as well as Phase II.

2. SUMMARY

Since the CV's for production were not available, a definitive determination of how well the LACIE is performing was not possible. However, the following general conclusions are based on current and previous investigations as well as observed relative differences[1] and limits on the corresponding coefficients of variation as determined from the error budget.

For winter wheat production, the relative difference between the October LACIE estimate and the corresponding USDA/SRS estimate was -6.4 percent for the USSGP region and -6.6 percent for the USGP region (USSGP plus the two mixed wheat states). The 90/90 criterion for the USGP level can be satisfied with an observed relative difference of this magnitude, if the corresponding coefficient of variation is 6.0 percent or less. However, underestimation problems still exist in Oklahoma. Preliminary indications are that this underestimate is partially due to drought conditions, which caused wheat signatures to differ significantly from those of normal wheat, and the resulting late "greening up" of the winter wheat crop, which caused the actual greening up of the crop to vary considerably from the crop calendar for "normal" winter wheat.

For spring wheat production, the relative difference between the October LACIE and USDA/SRS estimates for the USGP region was -25.7 percent due to underestimates in Minnesota, North Dakota, and Montana. Spring wheat blind site studies from Phase I and preliminary spring wheat blind site investigations

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[1] relative difference = $\frac{\text{LACIE} - \text{USDA/SRS}}{\text{LACIE}} \times 100\%$

from Phase II indicate that CAMS is accurately identifying small grains. Current investigations indicate that the underestimate of spring wheat production is due to sampling errors and incorrect estimates of the ratios used to calculate spring wheat proportions from small grain and spring small grain proportions. A new sampling strategy will be implemented in LACIE Phase III and a solution to the ratioing problem is being sought.

The relative difference between the October LACIE and USDA/SRS estimates of total wheat production in the USGP was -13.1 percent. With an observed relative difference of this magnitude, the 90/90 criterion for the USGP cannot be met even if the corresponding CV is 6.0 percent or less. However, the difference between the observed relative difference and the relative difference required to satisfy the 90/90 criterion, with a corresponding CV of 6.0 percent or less, is not large (less than 4.0 percent). It appears that some of the problems associated with the estimation of spring wheat production will have to be solved in order for the LACIE to meet its goals.

2.1 THE ERROR BUDGET AND THE 90/90 CRITERION

No evaluations were made since the statistics were not available.

2.2 ASSESSMENT OF PRODUCTION ESTIMATION

WINTER WHEAT

The winter wheat in the U.S. Great Plains region consists of the wheat in the five winter wheat states of the U.S. southern Great Plains plus the winter wheat in the two mixed wheat states of Montana and South Dakota.

The LACIE and USDA/SRS production estimates for the U.S. southern Great Plains are shown in plot 1 of figure 2-1. The LACIE estimates were lower than the corresponding USDA/SRS estimates for every month except June; they were lower than the USDA/SRS final estimate (October) for every month including June. The LACIE estimate in the April report (based on Landsat data acquired through February) was particularly low, due mainly to incomplete emergence. However, the LACIE estimate increased considerably in May, and again in June when the relative difference between it and the USDA/SRS final (October) estimate was only -2.1 percent. In June the LACIE estimate was considerably closer to the final SRS estimate than was the June USDA/SRS estimate. In September and October the LACIE estimate dropped to a relative difference of -6.4 percent.

The results for the individual states in the U.S. southern Great Plains (section 4.1) show that the largest relative differences in the latest production estimate (October) occurred in Oklahoma (a relative difference of -56.4 percent), Texas (a relative difference of -27.2 percent), and Nebraska (a relative difference of +13.5 percent). The LACIE estimates for Oklahoma have been consistently high and the estimates for Nebraska consistently low as compared to USDA/SRS estimates. The relative difference in Nebraska varied from +28.4 percent (for August) to +13.5 percent (for September and October). In both Oklahoma and Nebraska these differences are mainly due to errors in acreage estimation.

In the mixed wheat states, winter wheat production estimates are available only from June through October. Montana wheat production was consistently underestimated with relative differences that varied from -288.0 percent (June) to -75.0 percent (October). South Dakota was overestimated for every month except June, with relative differences that varied from 34.1 percent (July) to 55.8 percent (October). The relative differences for both

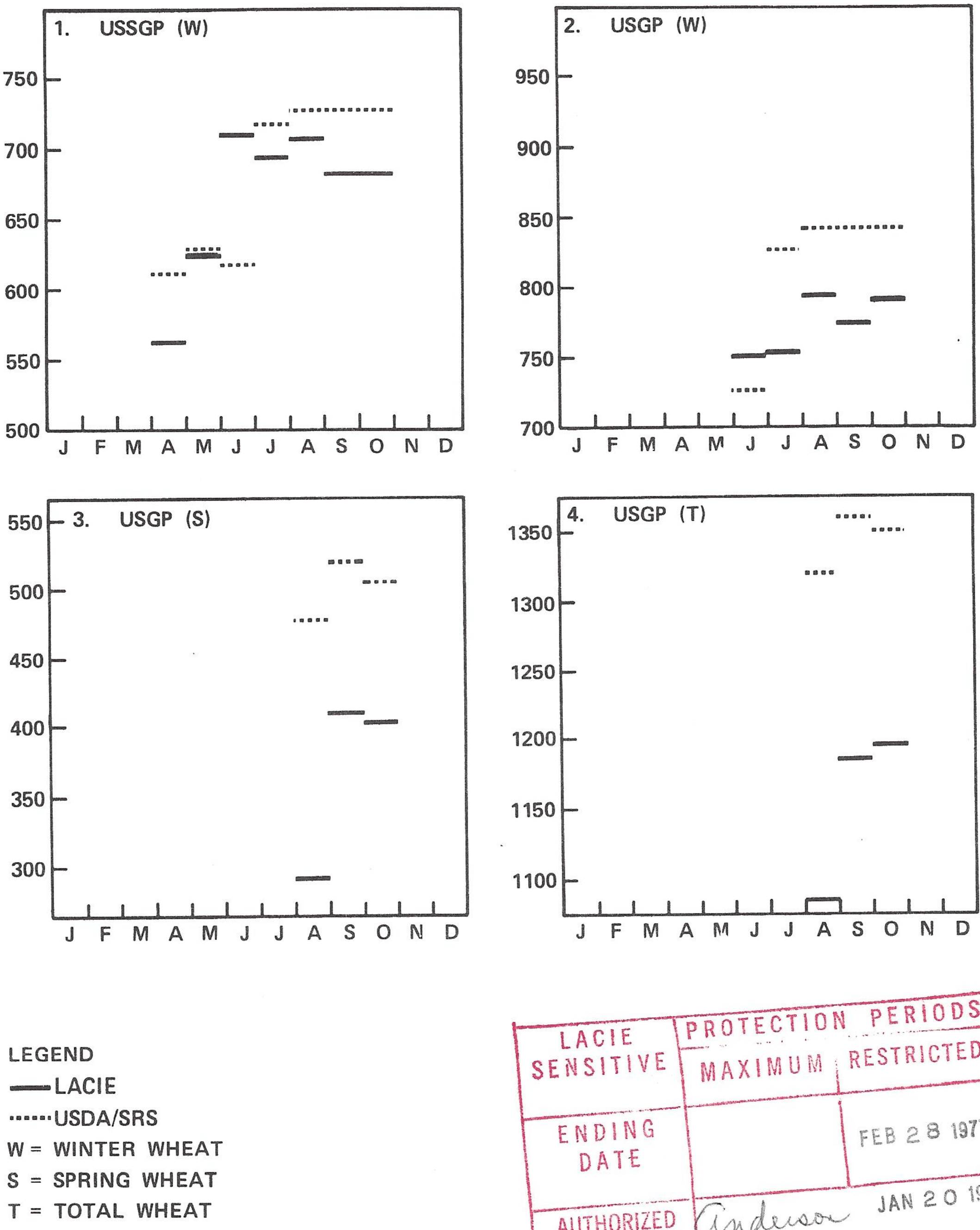


Figure 2-1.– LACIE and USDA/SRS production estimates.
[Bushels $\times 10^6$]

these states are large enough to indicate problems which should be further investigated.

When the winter wheat production estimates from the two mixed wheat states are added to the estimates for the USSGP (plot 1 of figure 2-1), one obtains the estimates for the total winter wheat production in the U.S. Great Plains region (plot 2 of figure 2-1). The addition of the estimates for the mixed wheat states to those for the USSGP region increased the magnitude of the relative difference between the LACIE estimates and the final USDA/SRS estimates for every month, especially June and July, where the relative differences changed from -2.1 percent and -4.5 percent to -11.8 percent and -11.4 percent, respectively. The relative difference for October was -6.6 percent.

SPRING WHEAT

The total spring wheat production for the U.S. Great Plains is shown in plot 3 of figure 2-1. There was consistent underestimation by LACIE compared to the USDA/SRS estimates. In October the LACIE estimate had a relative difference of -26.6 percent. Of the four states producing spring wheat, production was underestimated consistently in three of them (Minnesota, North Dakota and Montana) and was overestimated consistently in the fourth (South Dakota). The worst problems occurred in Minnesota and Montana. In October Minnesota had a relative difference of -90.3 percent and Montana had a relative difference of -65.4 percent. These underestimates in production were due to underestimates of spring wheat acreage.

TOTAL WHEAT IN THE U.S. GREAT PLAINS

The wheat production estimates for the nine-state U.S. Great Plains region are shown in plot 4 of figure 2-1. The LACIE estimate was consistently low but improved in September and in

October due to an improvement in acreage estimates. The October estimate had a relative difference of -13.3 percent due to an underestimate of 51×10^6 bushels (relative difference -6.6 percent) in the winter wheat crop and an underestimate of 103×10^6 bushels (relative difference -25.7 percent) in the spring wheat crop.

2.3 ASSESSMENT OF ACREAGE ESTIMATION

WINTER WHEAT

The LACIE and USDA/SRS winter wheat acreage estimates for the USSGP are shown in plot 1 of figure 2-2. The LACIE estimates for the USSGP region were lower than the corresponding USDA/SRS estimates for every month except June. The estimate for April was particularly low. However, the estimate made in April used Landsat data acquired from December 30 through February 25 and lower estimates are expected early in the season because a significant number of wheat fields have not yet "greened up" enough to have a characteristic wheat signature. In 1976 this effect was especially apparent in Kansas, Oklahoma and Texas, which were affected by drought in the winter and early spring. In May and June, the LACIE estimate for winter wheat acreage in the USSGP improved. In June, it was closer to the final USDA/SRS estimate (which held from July through October) than the June USDA/SRS estimate. Thereafter, however, the LACIE estimate decreased somewhat due to decreases in the Texas and Nebraska estimates. The final LACIE estimate (October) had a relative difference of -6.1 percent.

The results for the individual states (section 5.1) indicate that Colorado and Nebraska were consistently overestimated by LACIE, and Oklahoma was consistently underestimated. Current investigations indicate that the Colorado and Nebraska overestimates are related to the fact that these states have large

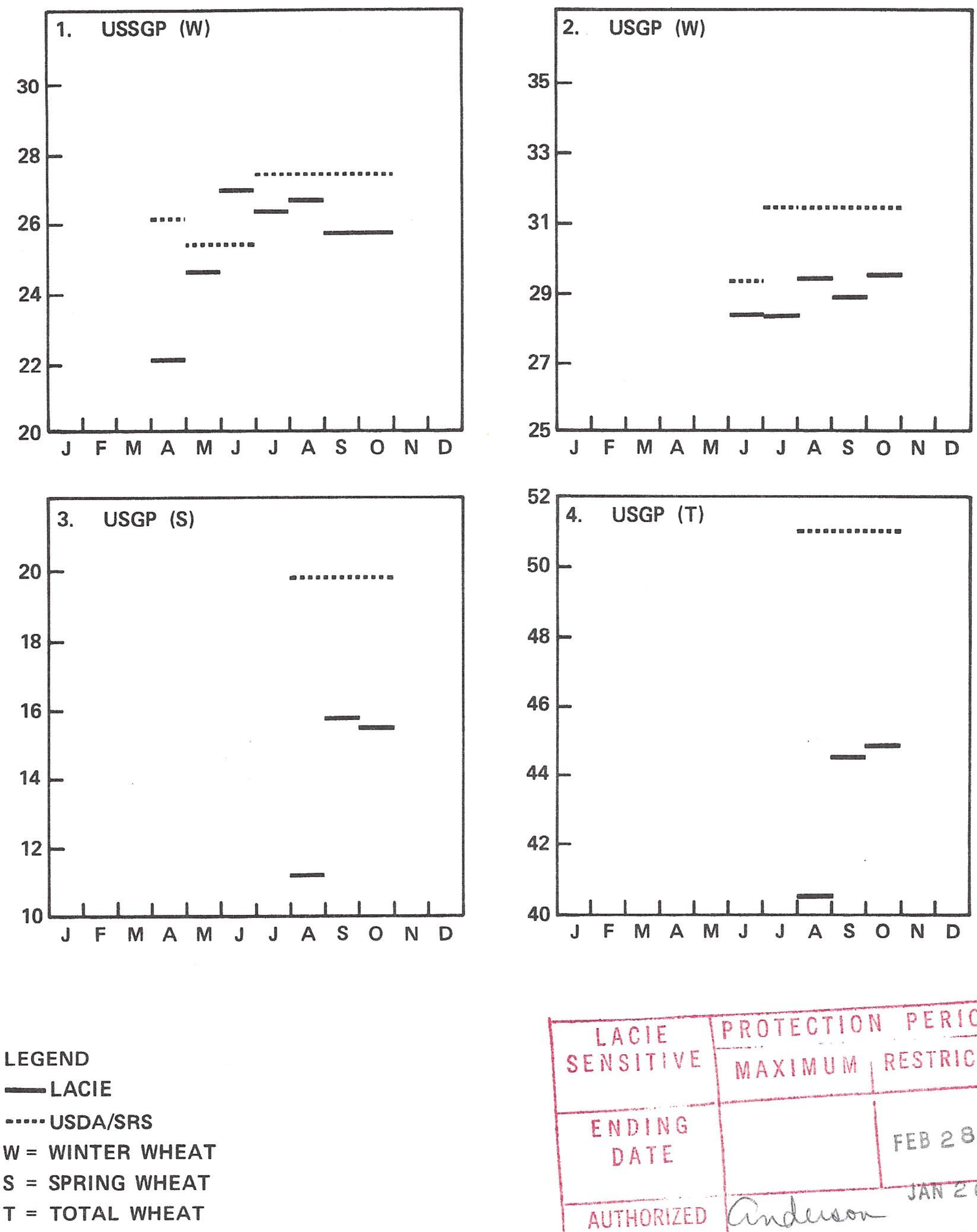


Figure 2-2.— LACIE and USDA/SRS acreage estimates. [acres $\times 10^6$]

acreages in crops whose spectral signatures may be confused with wheat when certain key acquisitions are not made by Landsat. The results of these investigations will appear in the Fourth Interim AA Report.

Blind site investigations (section 5.2.1) indicate a significant underestimation problem in Oklahoma and also in Kansas. The underestimate in Oklahoma appears to be partly due to drought effects, pests, and heavy grazing of cattle. In many cases the wheat was late in greening up and had signatures that were quite different from normal wheat. Further investigations of this problem will appear in the Fourth Interim AA Report. In Kansas the problem was due to one particular outlier, a segment with a large amount of wheat which was considerably underestimated. Omitting this outlier from the analysis would have resulted in no significant difference between CAMS wheat proportion estimates and the ground-truth wheat proportion. In Texas the blind site data showed no significant under- or overestimation. However, one blind site with very little wheat was considerably overestimated. Since this site had no other small grains, this indicates possible confusion with classes other than small grains. Also, omitting this blind site from the analysis would have resulted in a significant underestimate for Texas. The blind site results for Colorado and Nebraska did not indicate a significant difference between CAMS wheat proportion estimates and ground truth. These results imply that the consistent overestimation mentioned above is not significant. At the five-state USSGP level the CAMS wheat proportion estimates were significantly lower than the ground truth wheat proportions due mainly to the significant underestimate in Oklahoma.

In the mixed wheat states, Montana was consistently underestimated, with relative differences that varied from -261.0 percent in June to -42.0 percent in October, and South Dakota was underestimated in June (relative difference -69.0 percent), but the estimate increased to an overestimate (relative difference +26.5 percent) by October. Both these states, particularly Montana, have problems which should be investigated further.

The estimates for the total winter wheat acreage in the USGP region are shown in plot 2 of figure 2-2. The relative difference for October was -7.1 percent.

SPRING WHEAT

The monthly estimates for the total spring wheat acreage in the USGP region are shown in plot 3 of figure 2-2. The LACIE estimates are consistently below the USDA/SRS estimates. However, there is a considerable improvement from August to September, which was primarily due to improved spring-wheat-to-small-grains ratios in Minnesota, North Dakota, and South Dakota, and an increase in the number of sample segments in North Dakota (see section 5.1). Of the four states contributing to the total spring wheat estimate, only for one, South Dakota, is the spring wheat acreage not consistently underestimated. This indicates an underestimation problem for spring wheat. Preliminary blind site studies indicate that this is largely due to errors in the ratios of wheat to small grains that are used to calculate the wheat acreage.

TOTAL WHEAT IN THE U.S. GREAT PLAINS

Plot 4 of figure 2-2 shows the total wheat in the nine-state USGP region. The LACIE estimate is consistently low but improves as the season progresses. In October it has a relative difference of -14.3 percent due to an underestimate of 2.1×10^6 acres (relative difference -7.1 percent) in the winter wheat acreage and an underestimate of 4.3×10^6 acres (relative difference -28.0 percent) in the spring wheat acreage.

2.4 ASSESSMENT OF YIELD ESTIMATION

Accuracy assessment has identified possible error sources in yield estimation. Two of these error sources result from applying zone level yield models to the CRD's within the zone in order to estimate production at the CRD level and then aggregating these CRD production estimates to get state or higher level production estimates. The two error sources are:

a. Possible bias in yield estimates due to applying zone level yield models to CRD level weather data.

b. Error in estimating state and higher level production variances due to the correlation between CRD yield estimates within a yield model zone, a condition caused by using the same prediction equation for each CRD in a yield model zone.

A third error source not directly related to the above is the error due to omitting weather and yield data for some CRD's in a yield model zone from the development of the zone level yield model.

These error sources are currently being investigated and results of the investigations should appear in either the Fourth Interim or the Final AA Report. As a consequence of the above error sources, no evaluation of yield estimates were made for this document other than direct comparisons of monthly LACIE yield estimates with monthly USDA/SRS yield estimates, i.e., only relative differences are presented.

WINTER WHEAT

The LACIE and USDA/SRS monthly winter wheat yield estimates for the five-state U.S. southern Great Plains region are displayed in plot 1 of figure 2-3. Note that the LACIE estimates were very close to the USDA/SRS estimates for July through October, the

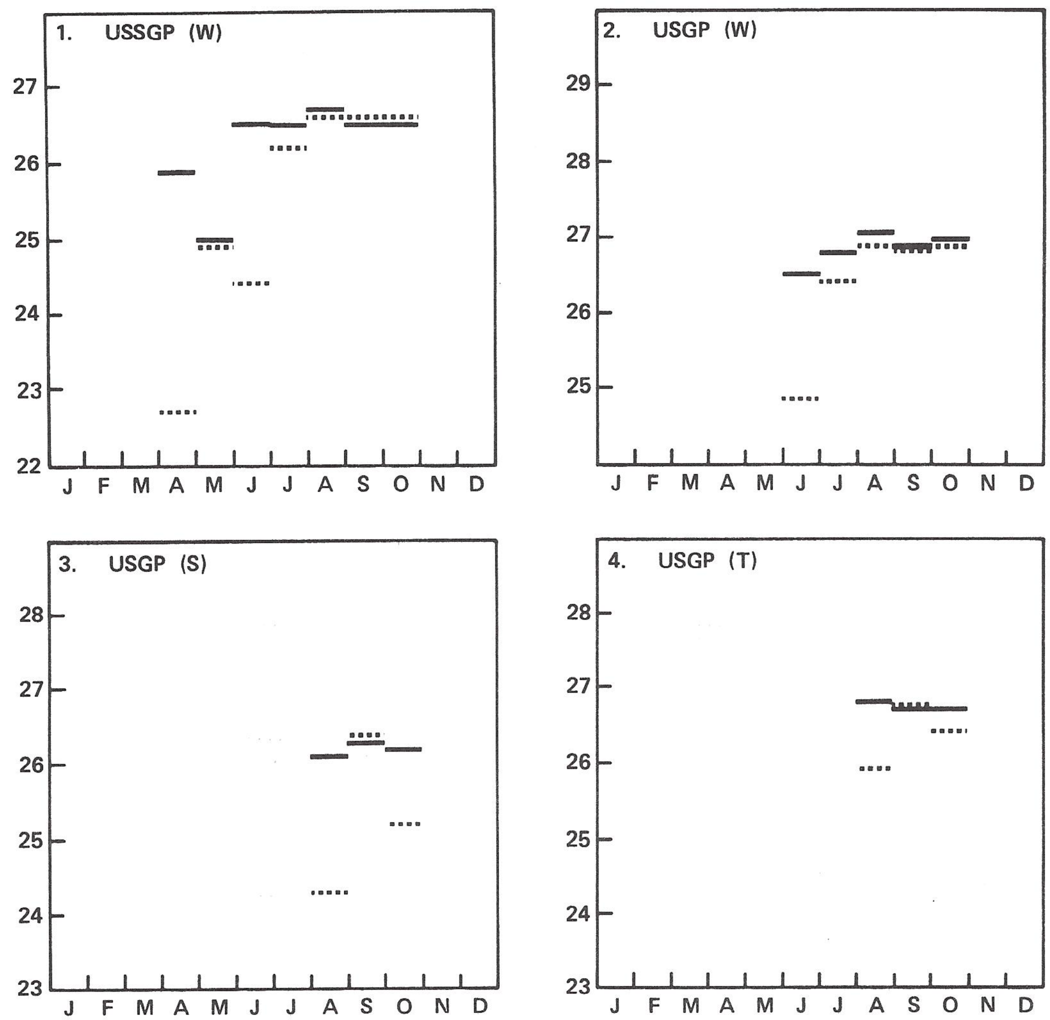


Figure 2-3.— LACIE and USDA/SRS yield estimates.
[Bushels/acre]

later months in the growing season. The relative difference between the two estimates in October was -0.4 percent.

For the earlier months of April, May, and June, the LACIE estimates did not agree as well with the corresponding USDA/SRS estimates, but they were much closer to the final USDA/SRS estimate for October than the USDA/SRS estimates. Also, the LACIE estimates leveled off in June, two months before the USDA/SRS estimates did. These results indicate that the LACIE estimates of winter wheat yield are more than satisfactory at the USSGP level.

Plot 2 of figure 2-3 gives the monthly winter wheat yield estimate by LACIE and USDA/SRS for the U.S. Great Plains. This region is made up of the five states in the USSGP and the two mixed wheat states, Montana and South Dakota. Montana yield estimates by LACIE were consistently lower than the corresponding USDA/SRS estimates, while South Dakota yield estimates were much higher than the corresponding USDA/SRS estimates. When these two were combined with the USSGP yield estimates, the resulting USGP level estimates by LACIE were very close to the USDA/SRS estimates, having a relative difference of +0.4 percent for the month of October.

SPRING WHEAT

The LACIE and USDA/SRS monthly spring wheat yield estimate for the U.S. Great Plains region are displayed in plot 3 of figure 2-3. Estimates were obtained only for the months of August, September, and October. The spring wheat region in the U.S. Great Plains consists of Minnesota, North Dakota, and the two mixed wheat states, Montana and South Dakota. Note that the LACIE estimates did not vary as much as the USDA/SRS estimates. The two estimates were very close in September, having a relative difference of -0.3 percent. However, in the other two months, the LACIE estimates were much higher, having a relative difference of +5.4 percent in August and a relative difference of +1.9 percent in October. The main reason for the four-state-level overestimate was the high overestimation by LACIE over USDA/SRS in South Dakota. Recall that this same situation occurred for the LACIE winter wheat yield estimate for this state. No explanation for this occurrence is apparent at this time.

TOTAL WHEAT IN THE U.S. GREAT PLAINS

The monthly total wheat yield estimates obtained by LACIE and USDA/SRS for all nine states in the U.S. Great Plains are exhibited in plot 4 of figure 2-3. At this level, the LACIE estimates agree very well with the USDA/SRS estimates for the three months reported. The relative differences were +3.0 percent, 0.0 percent, and 0.8 percent for August, September and October, respectively. This indicates that, at this level, the LACIE yield estimates are more than satisfactory and, in fact, are considerably more accurate (as compared to the USDA/SRS estimates) than the LACIE acreage estimates.

3. THE ERROR BUDGET AND THE 90/90 CRITERION

The 90/90 criterion specifies that the LACIE at-harvest production estimates for the USGP region be 90 percent accurate 9 years out of 10, or 90 percent of the time.

In principle, the evaluation of the LACIE production estimates against this criterion would require a comparison of the LACIE estimates to the "actual" production for a period of several years. This approach is obviously impractical to implement until data for several years of operational experience are obtained.

In practice, therefore, LACIE must estimate its performance parameters from data analysis experience acquired to date and draw inferences as to the performance of the technology if it were to be operated for a span of several years. Unfortunately, it is not possible to determine directly from the available data the manner in which the LACIE production estimates would distribute about the SRS national production estimate. To determine this distribution, the LACIE experiment would have to replicated and such replication would require excessive resources. In lieu of the required knowledge of this distribution, the 90/90 criterion is evaluated in terms of the estimated variance and bias of the production estimator, under the assumption that the estimator would produce normally distributed estimates in replicated trials. Under this assumption of normality, the probability that the LACIE national estimator will produce an estimate within ±10 percent of the SRS national estimate can be related to the computed variance and bias of the LACIE estimator.

Since the production estimator is the sum over the region under study of products of area estimates and yield estimates obtained for the coincident yield and area strata (e.g., U.S. CRD's), its statistical properties can be derived from a knowledge of the statistical properties of the area and yield estimators. The technique for doing this is described in appendix C.

In addition to normality, the following assumptions are made:

a. Acreage estimates are not correlated at the CRD level.

b. Yield estimates are not correlated at the CRD level.

c. Acreage and yield estimates are not correlated and are unbiased at the CRD level.

d. Yield variances supplied by the Center for Climatological and Environmental Assessment (CCEA) of the NOAA and acreage variances furnished by the CAS of the LACIE are correct.

Under these assumptions it is shown that the 90/90 criterion can be satisfied for a range of values of the coefficient of variation, CV_P, and bias of the LACIE production estimate. If the estimator is unbiased, CV_P can be as large as 6 percent and satisfy the 90/90 criterion. As the magnitude of the bias increases, there must be a corresponding decrease in CV_P to retain the 90/90 standard.

The bias of an estimator with respect to a particular data set is defined to be the average value of the differences between the estimates and the "true" value as determined from a set of replicated trials using the estimator. Thus, to compute directly the bias of the LACIE estimator, a multispectral and meteorological data set would need to be repeatedly analyzed to obtain replicated estimates of production. The average difference between the reference value and the set of estimates so obtained would provide an estimate of the bias attributable to the estimator.

Such an experiment on a large scale is obviously prohibitive; however, tests can be conducted to determine the probability that the estimator is biased as discussed below.

Since the production estimator is known to have a random error component with magnitude CV_P, replication of this experiment would produce observed relative differences with a distribution of values; most of these values would lie in an interval bounded by the average relative difference $\pm CV_P$. For example, 90 percent of them should be contained in the interval bounded by the average relative difference $\pm 1.645\ CV_P$. Thus, if it is assumed that the LACIE production estimator is unbiased; i.e., the average relative difference is zero, 90 percent of the observed relative differences should be between $\pm 1.645\ CV_P$. Therefore, for a particular value of the relative difference (given an unbiased estimator), there is less than a 10 percent chance that a particular relative difference would lie outside the interval $\pm 1.645\ CV_P$.

Thus, in LACIE, the CV of the production estimator is computed from the data as previously described. If the relative difference between the LACIE production estimate and the reference standard estimate is between $\pm 1.645\ CV_P$, the data are considered insufficient evidence to establish the existence of a bias. If the observed CV_P is 6 percent or less, then there is a reasonable expectation that the LACIE production estimator will satisfy the 90/90 criterion. As CV_P becomes smaller than 6 percent, it is known that some degree of bias can be tolerated and the confidence that the LACIE estimator will satisfy the 90/90 criterion is increased.

As stated earlier, the required statistics are not available, so the error budget analysis cannot be completed at the present time. It is expected that the revised statistics will be available in time to include this analysis in the fourth interim report.

4. ASSESSMENT OF PRODUCTION ESTIMATION

This section consists of two parts: a comparison of LACIE and USDA/SRS wheat production estimates (section 4.1) and an investigation of the contribution of various error sources to the production CV (section 4.2).

4.1 COMPARISON OF LACIE AND USDA/SRS PRODUCTION ESTIMATES

These comparisons are designed to monitor how well the LACIE is performing relative to the USDA/SRS estimates and to detect any problems that may exist.

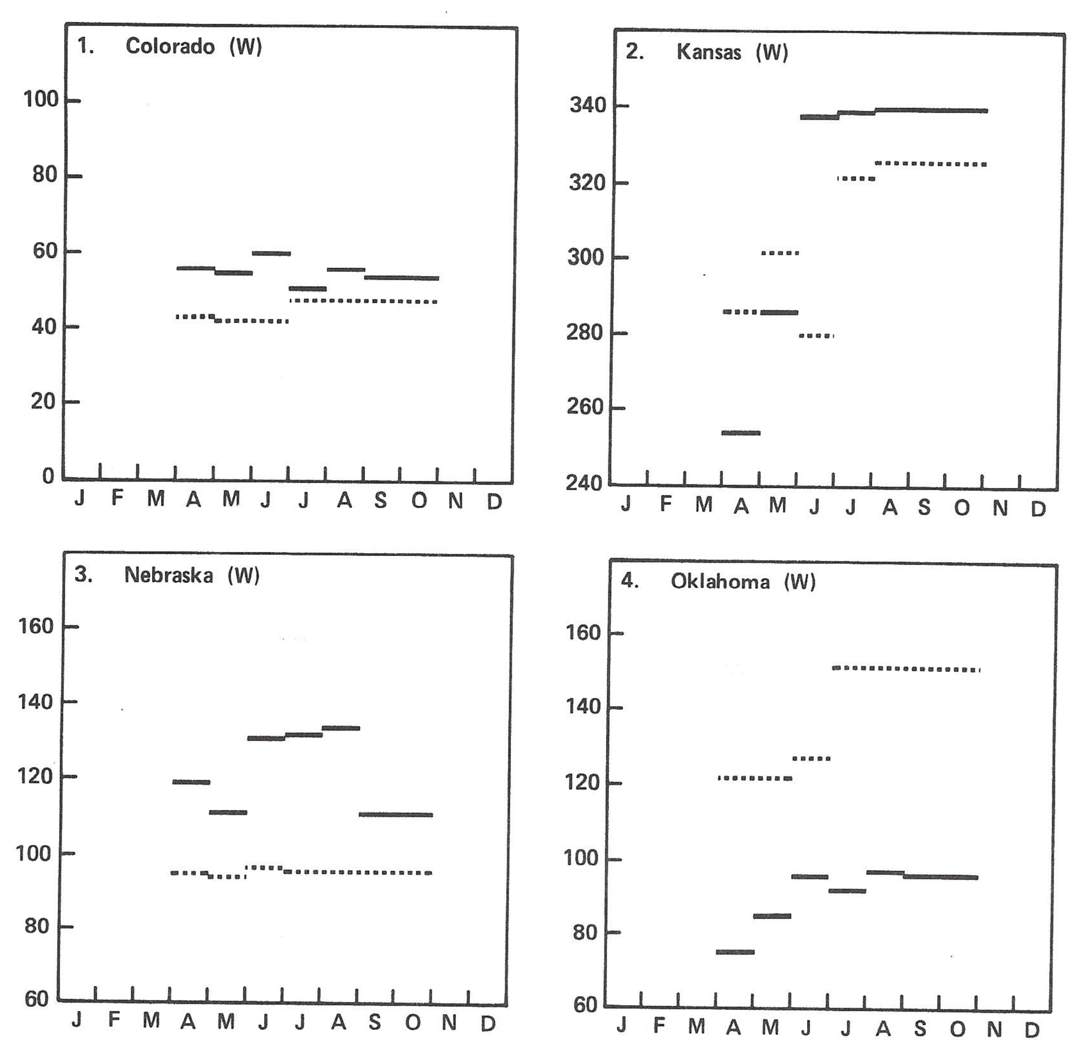
The LACIE and USDA/SRS production estimates are shown in figure 4-1 and table 4-1. Estimates are given for each state in the nine-state USGP region and for the following regions:

a. The U.S. southern Great Plains States (USSGP) — This region consists of Colorado, Kansas, Nebraska, Oklahoma and Texas. These states have winter wheat only and therefore could also be called the "winter wheat states". LACIE estimates of wheat production are available for the USSGP from February through October.

b. The Spring Wheat States (SW states, Minnesota and North Dakota) — These states have spring wheat only. LACIE estimates of wheat production are available from August through October.

c. The Mixed Wheat States (MW states, Montana and South Dakota) — These states have both spring and winter wheat. LACIE estimates of wheat production are available from August through October for the spring wheat and from June through October for the winter wheat.

d. The U.S. northern Great Plains States (USNGP) made up of the four spring and mixed wheat states.



LEGEND
—— LACIE
••••• USDA/SRS
W = WINTER WHEAT
S = SPRING WHEAT
T = TOTAL WHEAT

Figure 4-1.— LACIE and USDA/SRS production estimates [Bushels × 10^6].

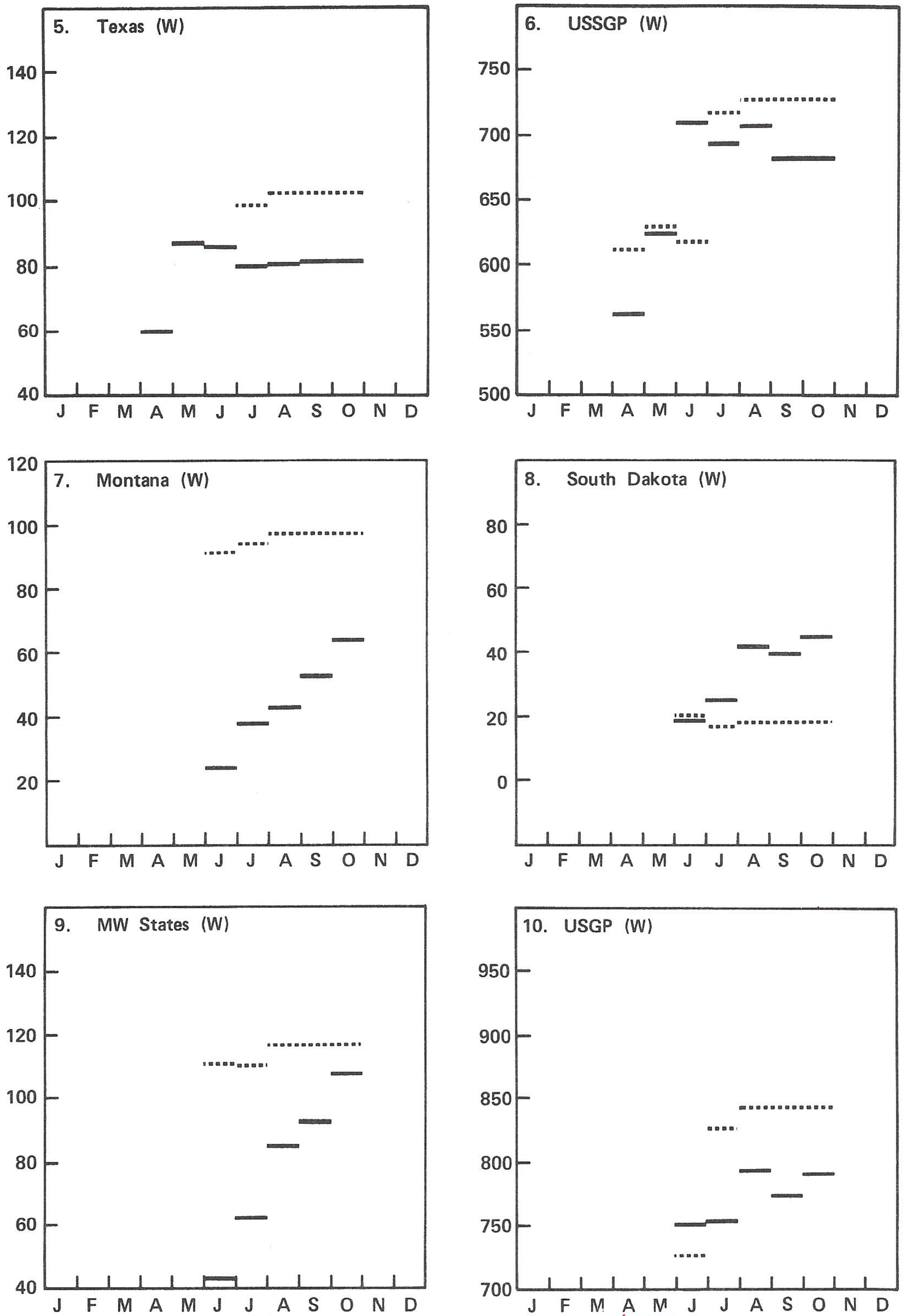


Figure 4-1.— Continued.

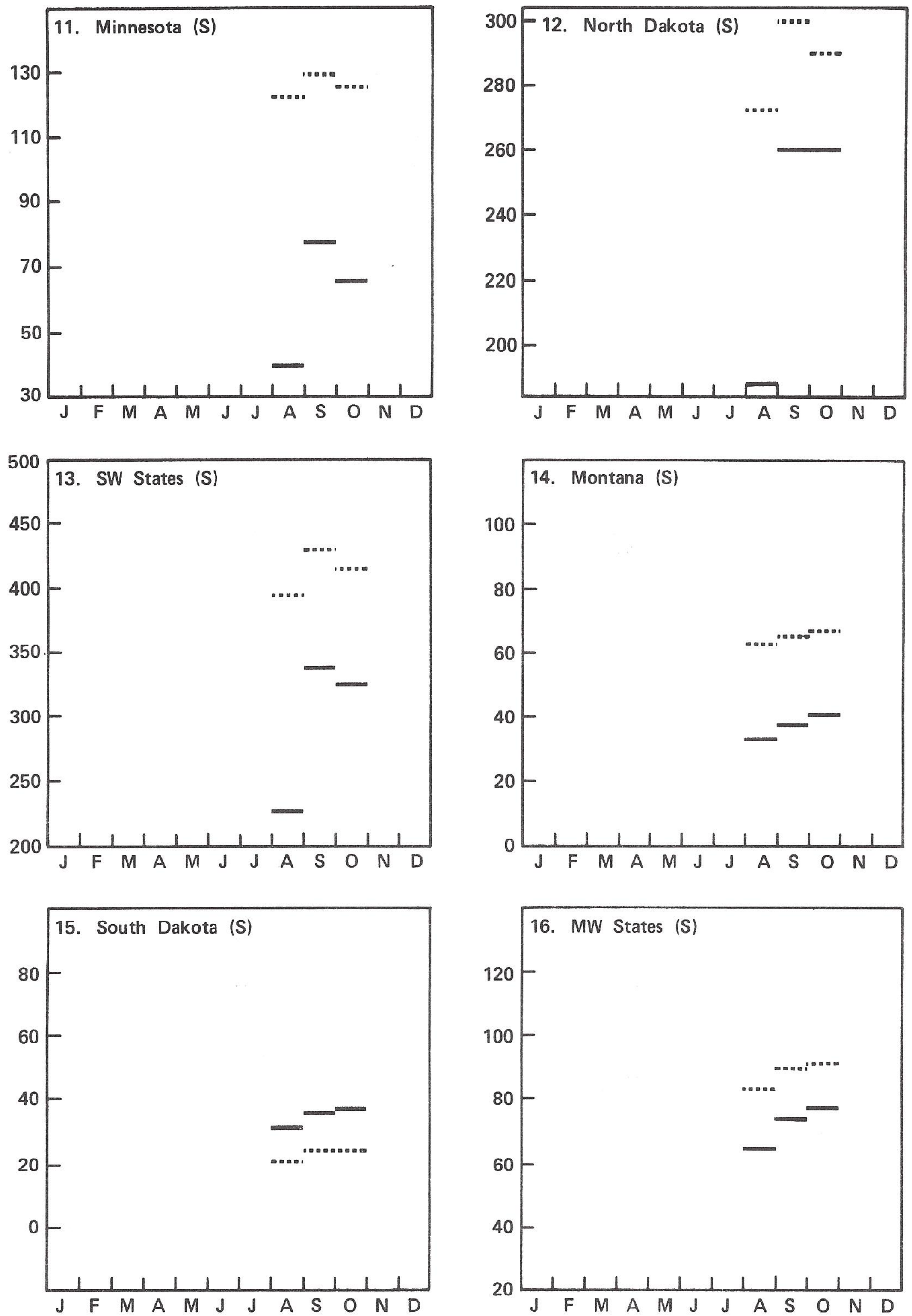


Figure 4-1.— Continued.

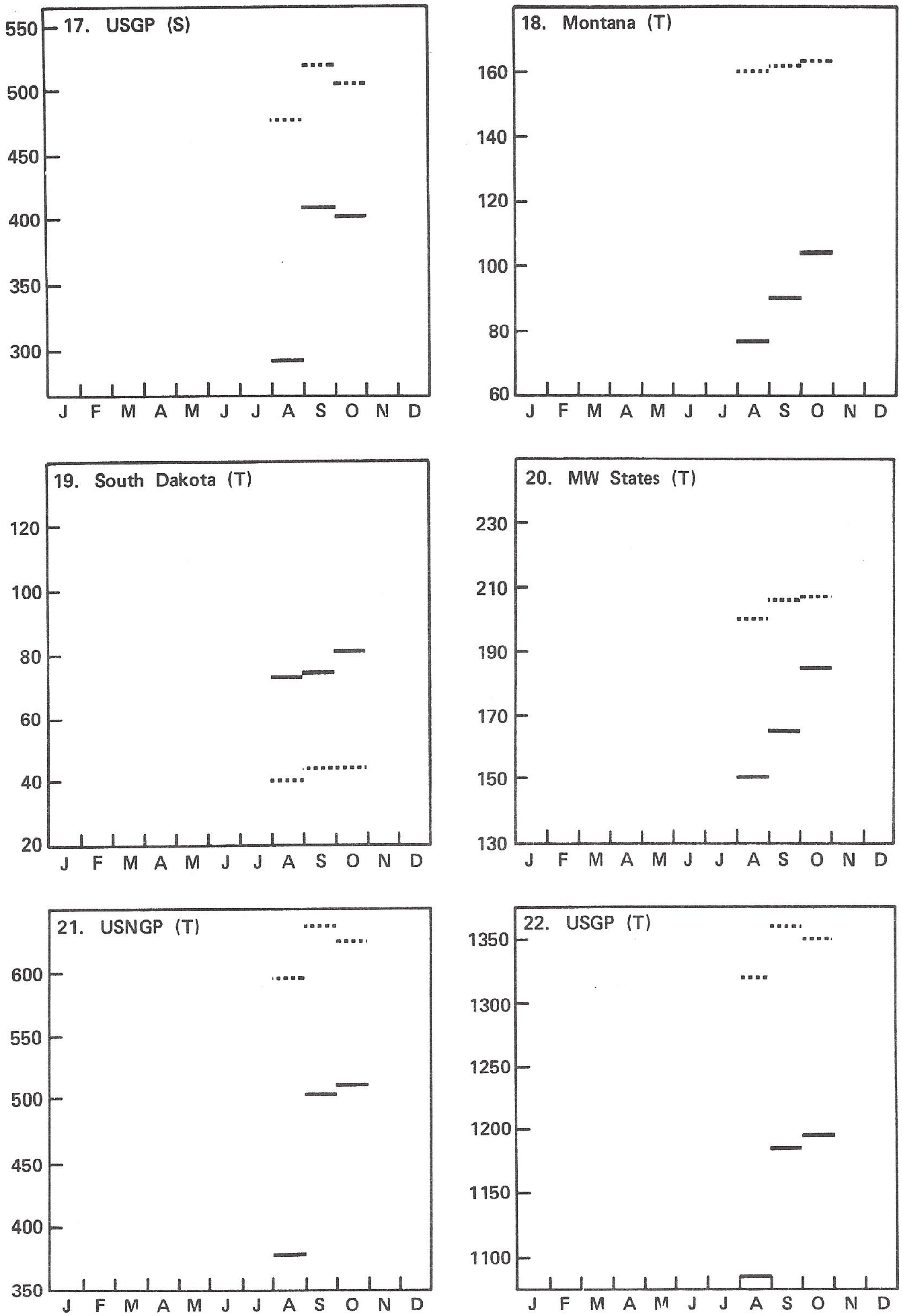


Figure 4-1.— Concluded.

TABLE 4-1.— COMPARISON OF USDA/SRS AND LACIE PRODUCTION AGGREGATION ESTIMATES

[Bushels × 10^3]

State	USDA/SRS	LACIE	Relative difference %	Standard deviation	CV
April					
Winter Wheat					
Colo.	42 840	55 570	22.9		
Kans.	286 000	253 930	-12.6		
Nebr.	95 200	119 359	20.2		
Okla.	121 800	74 809	-62.8		
Tex.	66 300	60 011	-10.5		
USSGP[a]	612 140	563 679	-8.6		
May					
Winter Wheat					
Colo.	41 800	54 697	23.6		
Kans.	302 400	286 309	-5.6		
Nebr.	94 400	111 280	15.2		
Okla.	121 800	84 671	-43.9		
Tex.	70 200	87 383	19.7		
USSGP[a]	630 600	624 340	-1.0		

[a]The five-state U.S. southern Great Plains Region

TABLE 4-1.— Continued.

State	USDA/SRS	LACIE	Relative difference %	Standard deviation	CV
June					
Winter Wheat					
Colo.	41 800	60 501	30.9		
Kans.	279 500	338 398	17.4		
Nebr.	97 350	131 216	25.8		
Okla.	127 600	95 645	-33.4		
Tex.	70 200	85 738	18.1		
USSGP	616 450	711 498	13.4		
Mont.	90 600	23 341	-288.2		
S. Dak.	20 800	18 941	-9.8		
MW States[b]	111 400	42 282	-163.5		
USGP[c]	727 850	753 780	3.4		
July					
Winter Wheat					
Colo.	48 400	51 290	5.6		
Kans.	321 900	338 940	5.0		
Nebr.	96 000	132 322	27.4		
Okla.	151 200	92 214	-64.0		
Tex.	98 700	79 817	-23.7		
USSGP	716 200	694 583	-3.1		
Mont.	93 620	36 953	-153.3		
S. Dak.	16 640	25 236	34.1		
MW States	110 260	62 189	-77.3		
USGP	826 460	756 772	-9.2		

[b]The mixed wheat states Montana and South Dakota.

[c]The nine-state U.S. Great Plains Region.

TABLE 4-1.— Continued.

State	USDA/SRS	LACIE	Relative difference %	Standard deviation	CV
August					
Winter Wheat					
Colo.	48 400	55 697	13.1		
Kans.	327 450	340 092	3.7		
Nebr.	96 000	134 040	28.4		
Okla.	151 200	97 663	-54.8		
Tex.	103 400	80 798	-28.0		
USSGP	726 450	708 290	-2.6		
Mont.	96 640	43 528	-122.0		
S. Dak.	19 760	41 858	52.8		
MW States	116 400	85 386	-36.3		
USGP	842 850	793 676	-6.2		
Spring Wheat					
Minn.	122 518	39 361	-211.3		
N. Dak.	272 700	188 083	-45.0		
SW States[d]	395 218	227 444	-73.8		
Mont.	63 095	33 411	-88.8		
S. Dak.	20 350	31 236	34.9		
MW States	83 409	64 647	-29.0		
USGP	478 663	292 093	-63.9		
Total[e] Wheat					
Mont.	159 735	76 939	-107.6		
S. Dak.	40 110	73 097	45.1		
MW States	199 845	150 036	-33.2		
USNGP[f]	595 063	377 480	-57.6		
USGP	1 321 513	1 085 769	-21.7		

[d]The spring wheat states Minnesota and North Dakota.

[e]Spring wheat plus winter wheat.

[f]The four-state U.S. northern Great Plains Region.

TABLE 4-1.— Continued.

State	USDA/SRS	LACIE	Relative difference %	Standard deviation	CV
September					
Winter Wheat					
Colo.	48 400	53 536	9.6		
Kans.	327 450	339 728	3.6		
Nebr.	96 000	110 970	13.5		
Okla.	151 200	96 645	-56.4		
Tex.	103 400	81 310	-27.2		
USSGP	726 450	682 189	-6.5		
Mont.	96 640	53 260	-81.4		
S. Dak.	19 760	39 117	49.5		
MW States	116 400	92 377	-26.0		
USGP	842 850	774 566	-8.8		
Spring Wheat					
Minn.	130 256	78 200	-66.6		
N. Dak.	300 040	259 815	-15.5		
SW States	430 296	338 015	-27.3		
Mont.	65 410	37 406	-74.8		
S. Dak.	24 300	35 417	31.4		
MW States	89 710	72 823	-23.2		
USGP	520 006	410 838	-26.6		
Total Wheat					
Mont.	162 050	90 666	-78.7		
S. Dak.	44 060	74 534	40.9		
MW States	206 110	165 200	-24.8		
USNGP	636 406	503 215	-26.5		
USGP	1 362 856	1 185 404	-15.0		

TABLE 4-1.— Concluded.

State	USDA/SRS	LACIE	Relative difference %	Standard deviation	CV
October					
Winter Wheat					
Colo.	48 400	53 534	9.6		
Kans.	327 450	339 974	3.7		
Nebr.	96 000	110 972	13.5		
Okla.	151 200	96 670	-56.4		
Tex.	103 400	81 312	-27.2		
USSGP	726 450	682 462	-6.4		
Mont.	96 640	63 666	-51.8		
S. Dak.	19 760	44 722	55.8		
MW States	116 400	108 388	-7.4		
USGP	842 850	790 850	-6.6		
Spring Wheat					
Minn.	126 344	66 404	-90.3		
N. Dak.	290 320	260 198	-11.6		
SW States	416 664	326 602	-27.6		
Mont.	66 658	40 240	-65.4		
S. Dak.	24 300	36 765	33.9		
MW States	90 958	77 005	-18.1		
USGP	507 532	403 607	-25.7		
Total Wheat					
Mont.	163 208	103 906	-57.1		
S. Dak.	44 060	81 481	46.0		
MW States	207 268	185 387	-11.8		
USNGP	623 932	511 995	-21.9		
USGP	1 350 382	1 194 457	-13.1		

5. The U.S. Great Plains States (USGP) made up of the nine states of the USSGP and the USNGP.

In the following discussion winter wheat is treated first, followed by spring wheat and total wheat (winter wheat plus spring wheat). Figure 4-1 and table 4-1 are arranged in this order. Each plot in figure 4-1 corresponds to a line in table 4-1, in the same order. For the months April through July, table 4-1 does not have a line corresponding to every plot in figure 4-1 since all the production estimates were not available for these months. In considering the plots in figure 4-1, it is instructive to compare these results with the results for acreage and yield in figures 5-1 and 6-1, respectively. In most cases, the pattern of the production results is similar to that of the acreage results, being only slightly modified by yield differences.

WINTER WHEAT

Plots 1 through 10 in figure 4-1 show the estimates for winter wheat. Plots 1 through 6 are for the USSGP winter wheat region and plots 7 through 9 show the winter wheat in the two mixed wheat states. Plot 10 is the total winter wheat in the USGP region.

Plot 6 shows that the LACIE estimates for the USSGP region were lower than the USDA/SRS estimates for every month except June; they were lower than the USDA/SRS final estimate (October) for every month including June. The LACIE estimate was particularly low in April, due mainly to low acreage estimates in Kansas, Oklahoma and Texas which were affected by drought (see section 5.1). However, the LACIE estimate improved considerably in May and again in June when the relative difference between it and the USDA/SRS estimate was only -2.1 percent. In June, the LACIE estimate was considerably better than the USDA/SRS estimate. In September and October, the LACIE estimate fell to a relative difference of -6.4 chiefly because of a drop in the estimate for Nebraska.

The plots for the individual states (plots 1 through 5) show that Colorado and Nebraska were consistently overestimated and Oklahoma was consistently underestimated, as compared with USDA/SRS estimates. These effects are mainly due to similar over- and underestimates of acreage, which are discussed in section 5-1.

Plots 7 and 8 show the winter wheat production estimates for the mixed wheat states of Montana and South Dakota. In Montana, the LACIE estimates were consistently low but increased as the season progressed due to increasing wheat acreage estimates. In South Dakota, the June estimate was very close to the final USDA/SRS estimate. This was the result of an overestimate in the yield and an underestimate in the acreage. As the season progressed, the yield estimate remained high and the acreage estimate increased, resulting in a considerable overestimate in wheat production by October.

The production estimates for the winter wheat in the two mixed wheat states are shown in plot 9. They were very low in June but increased throughout the season and had a relative difference of -7.4 percent in October.

Plot 10 shows the estimates for the total winter wheat in the USGP region. The addition of the estimates for the mixed wheat states to those for the USSGP region increases the relative difference between the LACIE estimates and the final USDA/SRS estimates for every month, especially June and July. The relative difference for October is -6.6 percent.

SPRING WHEAT

Plots 11 through 17 show the estimates for spring wheat production. Plots 11 through 13 are for the spring wheat states and plots 14 through 16 are for the spring wheat in the mixed wheat states. The estimates for the total spring wheat in these four states are shown in plot 17.

Plots 11, 12 and 13 show that both Minnesota and North Dakota were consistently underestimated. However, there was a considerable improvement in the LACIE estimate in September due to the processing of new data by CAMS and the use of revised confusion-crop ratios.

Plots 14, 15 and 16 show that the spring wheat estimates for the mixed wheat states have the same pattern as the winter wheat estimates for these states (plots 7 through 9) during August through October, i.e., consistent underestimation in Montana, consistent overestimation in South Dakota, and consistent underestimation in the total for the two states. The mixed wheat states total for October had a relative difference of -18.1 percent.

The estimates for the total spring wheat in the U.S. Great Plains states, i.e., the sum of the estimates in plots 13 and 16, are shown in plot 17. The pattern is similar to that in plot 13 due to the relatively small contribution of the mixed wheat states. The LACIE estimates are consistently below the USDA/SRS estimates. Of the four states contributing to the total spring wheat estimate, only for one, South Dakota, is the spring wheat production not consistently underestimated. This indicates a serious underestimation problem for spring wheat production. These underestimates in production are due to underestimates of spring wheat acreage since the yields are overestimated by LACIE except for September, when they are slightly less (0.3 percent) than the USDA/SRS estimate (see plot 17 in figure 5-1). This problem is discussed further in section 5-1.

<u>TOTAL WHEAT IN THE MIXED WHEAT STATES</u>

Plots 18 through 20 show estimates for total wheat (spring plus winter) for the mixed wheat states. The total wheat is underestimated in Montana, overestimated in South Dakota and underestimated in the two-state region shown in plot 20. The October estimate for the two-state total was 11.8 percent below the USDA/SRS estimate.

TOTAL WHEAT IN THE U.S. NORTHERN GREAT PLAINS

Plot 21 shows the total wheat in the four-state U.S. northern Great Plains region obtained by adding the estimates in plots 13 and 20. In August, the LACIE estimate was very low relative to the SRS estimate, but increased considerably in September, mainly due to the increases in the spring wheat estimates for Minnesota and North Dakota. The LACIE estimate further increased in October but it still has a relative difference of -21.9 percent. Most of the difference was due to the underestimates in Minnesota and North Dakota.

TOTAL WHEAT IN THE U.S. GREAT PLAINS

The wheat production estimates for the nine-state U.S. Great Plains region are shown in plot 22. They are obtained by adding the estimates for the U.S. southern Great Plains (plot 6) and the U.S. northern Great Plains (plot 21). The LACIE estimate was consistently low but improved in September and in October. The October estimate had a relative difference of -13.1 percent due to an underestimate of 51×10^6 bushels (relative difference -6.6 percent) in the winter wheat crop and an underestimate of 103×10^6 bushels (relative difference -25.7 percent) in the spring wheat crop.

4.2 PRODUCTION ERROR SOURCES

This section describes an investigation of the contribution of errors in acreage and yield estimates to the CV for production, CV_p. The contributon from acreage error is further subdivided into contributions from errors in classification and sampling.

The method employed in calculating these contributions is described in appendix C. Using equations 37, 38, and 39 of appendix C, values for CV_P can be calculated for the following cases:

- Case 1: There is acreage error but no yield error.
- Case 2: There is yield error but no acreage error.

The results of computations for these two cases for the USSGP are listed in table 4-2 (columns 3 and 5) along with the respective reductions in the production CV as a result of omitting yield error (column 5) or acreage error (column 6) — to be completed when the CV's are available.

(Discussion of results to be completed when revised estimates are available.)

The acreage estimation error can be further subdivided into two secondary components:

a. Sampling error, which arises from the fact that the LACIE does not examine all the wheat acreage in the United States but only that which is within the LACIE sample segments. If all wheat acreage were surveyed, there would be no sampling error.

b. Classification error, which comprises all errors from the LACIE acreage estimation process. There would be no error if all the wheat proportions for the sample segments could be perfectly determined.

The method for estimating the classification error σ_c^2 and the sampling error σ_s^2 is discussed in section 5.2. Estimates for these quantities were obtained for April through August and are listed in table 5-7.

TABLE 4-2.— ESTIMATED PRODUCTION COEFFICIENTS OF VARIATION FOR THE U.S. SOUTHERN GREAT PLAINS SHOWING RESPECTIVE CONTRIBUTIONS OF ACREAGE AND YIELD

Month	Total CV	Case 1: Acreage but no yield error		Case 2: Yield but no acreage error	
		CV	Reduction from total, %	CV	Reduction from total, %
(1)	(2)	(3)	(4)	(5)	(6)
April					
May					
June					
July					
August					

From this information, the fraction of the error variance caused by the classification error and that caused by sampling error were ascertained. Then, using equations 40, 41, and 42 of appendix C, estimates of the production CV for the USSGP for April through August were obtained for the following cases:

- Case 3: There is classification error but no sampling error.
- Case 4: There is sampling error but no classification error.

The results listed in table 4-3 indicate that ··· (to be completed when the revised CV's are available).

TABLE 4-3.— ESTIMATED PRODUCTION COEFFICIENTS OF VARIATION FOR THE U.S. SOUTHERN GREAT PLAINS SHOWING CLASSIFICATION AND SAMPLING ERROR COMPONENTS

Month	Total CV	Case 3: Classification but no sampling error		Case 4: Sampling but no classification error	
		CV	Reduction from total, %	CV	Reduction from total, %
April					
May					
June					
July					
August					

5. ASSESSMENT OF ACREAGE ESTIMATION

This section consists of two major subsections: a comparison of LACIE and USDA/SRS wheat acreage estimates (section 5.1) and a number of investigations of acreage error sources (section 5.2).

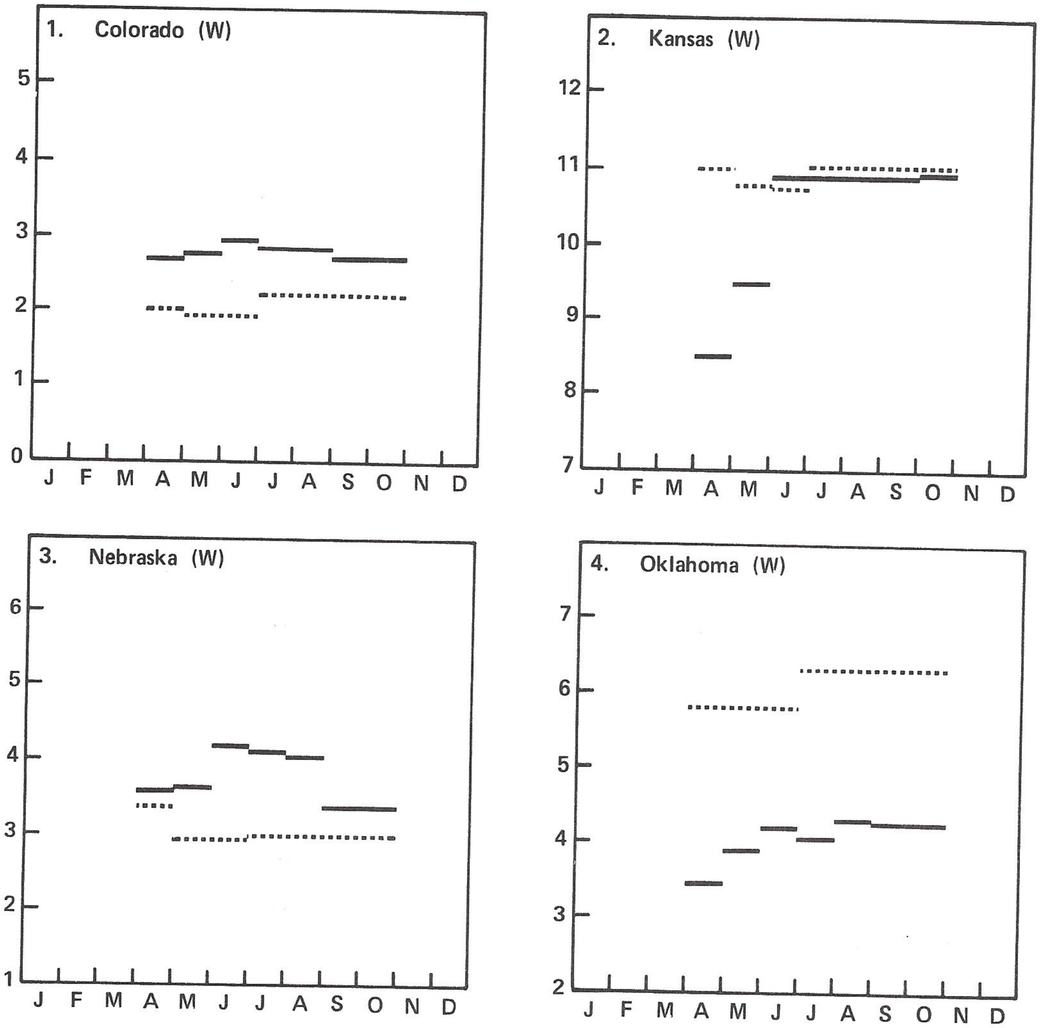
5.1 COMPARISON OF LACIE AND USDA/SRS ACREAGE ESTIMATES

The USDA/SRS and LACIE acreage estimates are shown in table 5-1 and figure 5-1. These are in the same format as table 4-1 and figure 4-1 except that the estimates are for acreage rather than production.

WINTER WHEAT

Plots 1 to 10 in figure 5-1 show the acreage estimates for winter wheat. Plots 1 to 6 are for the USSGP winter wheat region and plots 7 to 9 show the winter wheat in the two mixed wheat states. Plot 10 is the total winter wheat in the USGP region.

Plot 6 shows that the LACIE estimates for the USSGP region were lower than the USDA/SRS estimates for every month except June. The estimate for April is particularly low due to low estimates in Kansas, Oklahoma and Texas. However, these lower estimates are expected early in the season, because a significant number of wheat fields have not yet "greened up" enough to have a characteristic wheat signature. In 1976 this effect was especially apparent in Kansas, Oklahoma and Texas which were affected by drought. In May and June, the LACIE estimate for the USSGP improved. In June, it was close to the final USDA/SRS estimate (which held from July through October) than the June USDA/SRS estimate. Thereafter, however, the LACIE estimate decreased somewhat due to decreases in the Texas and Nebraska estimates. The final LACIE estimate (Oct.) had a relative difference of -6.1 percent.



LEGEND
—— LACIE
------ USDA/SRS
W = WINTER WHEAT
S = SPRING WHEAT
T = TOTAL WHEAT

Figure 5-1.— LACIE and USDA/SRS acreage estimates [Acres × 10^6].

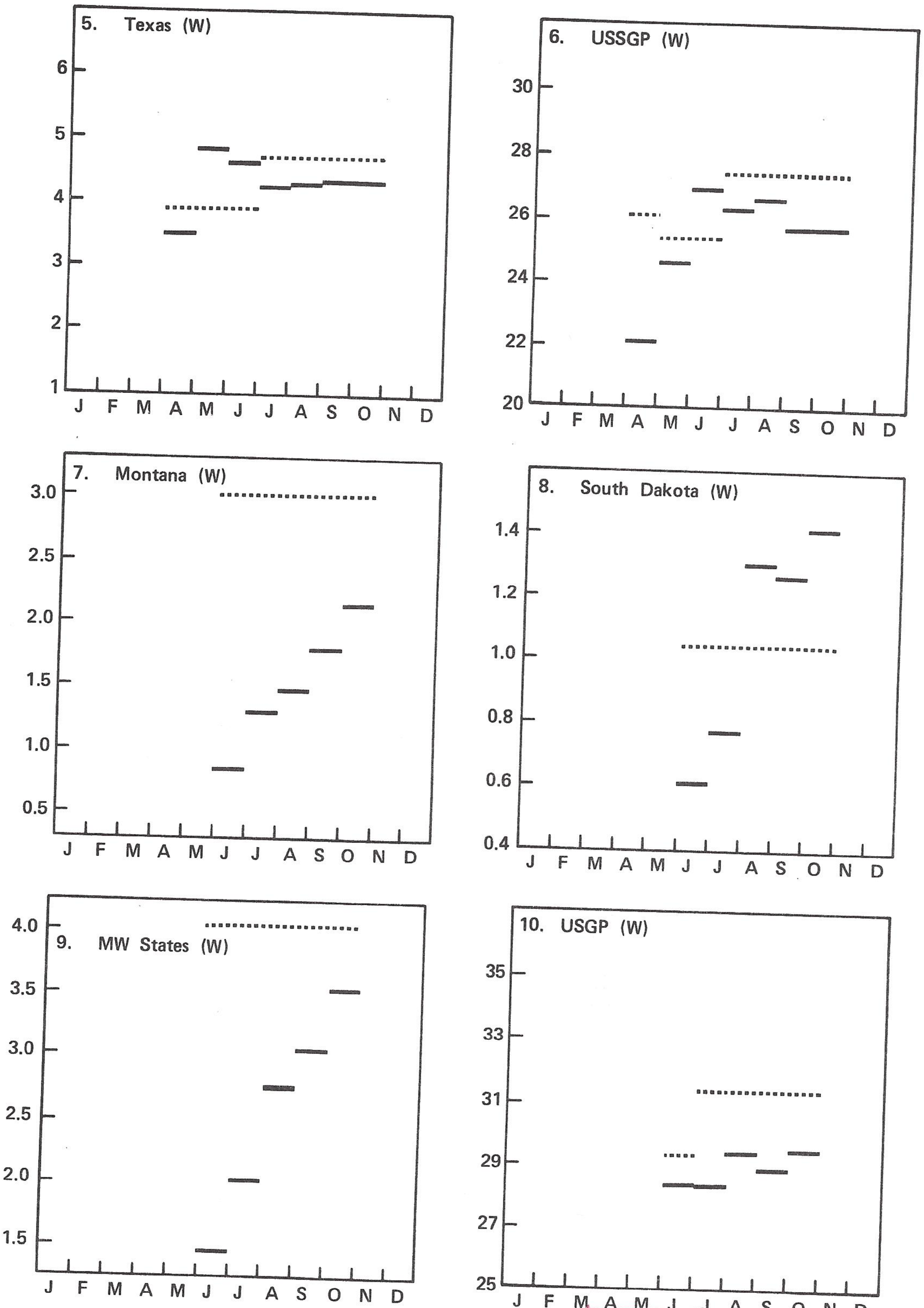


Figure 5-1.— Continued.

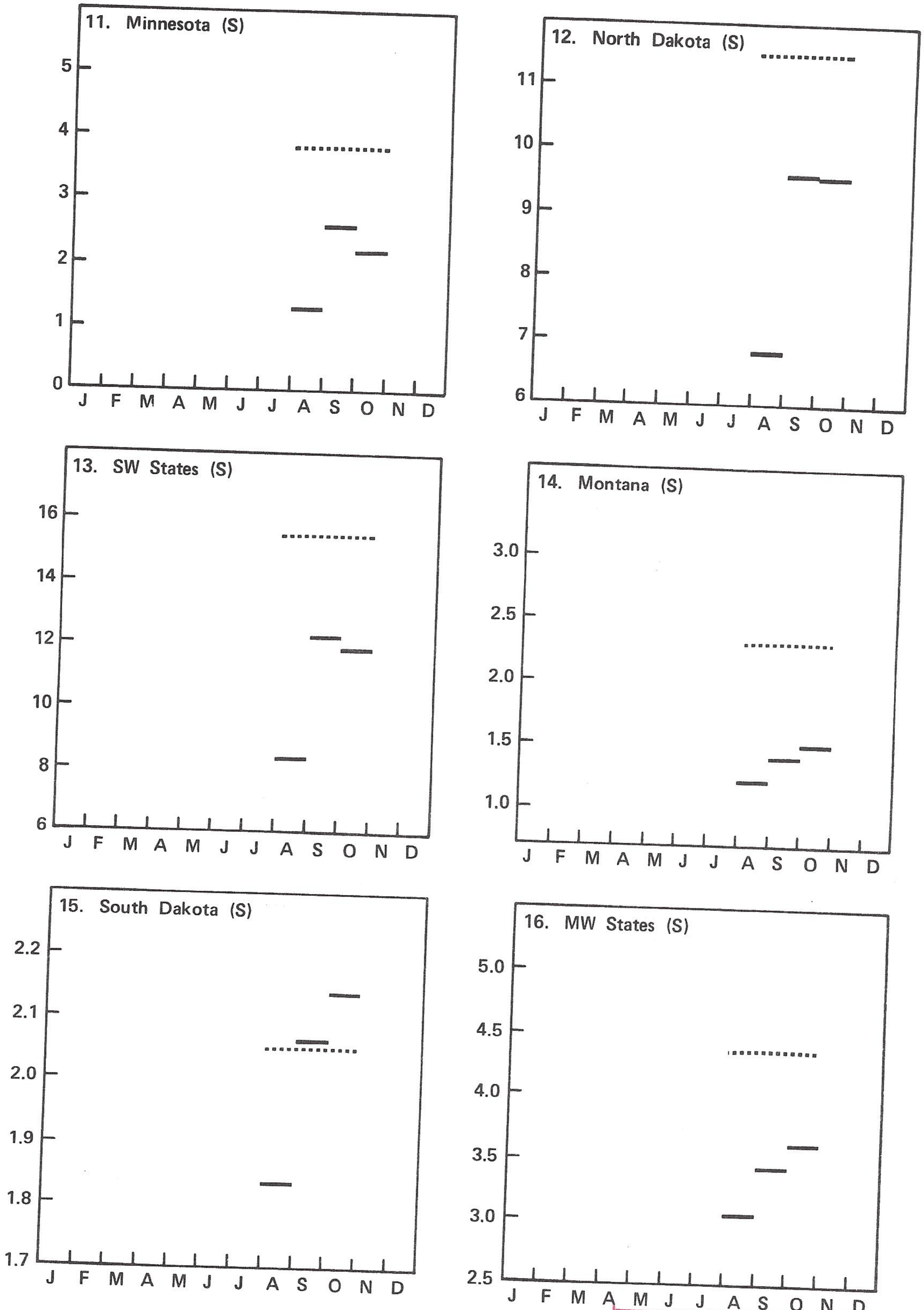


Figure 5-1.— Continued.

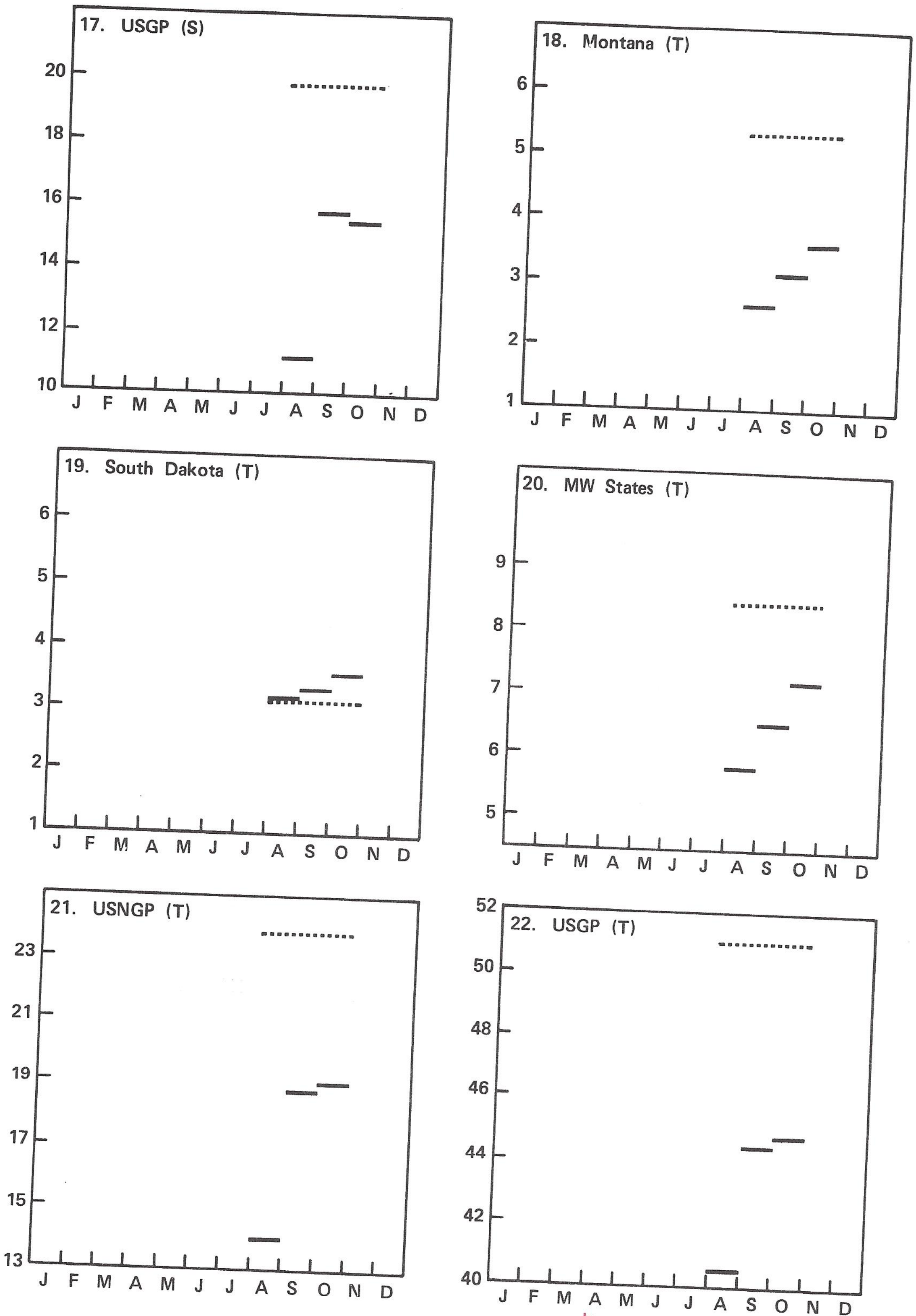


Figure 5-1.— Concluded.

TABLE 5-1.— COMPARISON OF USDA/SRS AND LACIE ACREAGE AGGREGATION ESTIMATES

[Acres × 10^3]

State	USDA/SRS	LACIE	Relative difference %	Standard deviation	CV
			April		
Winter Wheat					
Colo.	2 040	2 743	25.6		
Kans.	11 000	8 499	-29.4		
Nebr.	3 400	3 610	5.8		
Okla.	5 800	3 449	-68.2		
Tex.	3 900	3 506	-11.2		
USSGP[a]	26 140	21 807	-11.9		
			May		
Winter Wheat					
Colo.	1 900	2 782	31.7		
Kans.	10 800	9 487	-13.8		
Nebr.	2 950	3 679	19.8		
Okla.	5 800	3 899	-48.8		
Tex.	3 900	4 831	19.3		
USSGP[a]	25 350	24 678	-2.7		

[a]The five-state U.S. southern Great Plains Region

TABLE 5-1.— Continued.

State	USDA/SRS	LACIE	Relative difference %	Standard deviation	CV
June					
Winter Wheat					
Colo.	1 900	2 960	35.8		
Kans.	10 750	10 886	1.3		
Nebr.	2 950	4 184	29.5		
Okla.	5 800	4 181	-38.7		
Tex.	3 900	4 643	16.0		
USSGP	25 300	26 854	5.8		
Mont.	3 020	836	-261.2		
S. Dak.	1 040	613	-69.7		
MW States[b]	4 060	1 449	-180.2		
USGP[c]	29 360	28 303	-3.7		
July					
Winter Wheat					
Colo.	2 200	2 856	23.0		
Kans.	11 100	10 937	-1.5		
Nebr.	3 000	4 140	27.5		
Okla.	6 300	4 031	-56.3		
Tex.	4 700	4 266	-10.2		
USSGP	27 300	26 230	-4.1		
Mont.	3 020	1 233	-144.9		
S. Dak.	1 040	776	-34.0		
MW States	4 060	2 009	-102.1		
USGP	31 360	28 239	-11.1		

[b] The mixed wheat states Montana and South Dakota.

[c] The nine-state U.S. Great Plains Region.

TABLE 5-1.— Continued.

State	USDA/SRS	LACIE	Relative difference %	Standard deviation	CV
		August			
Winter Wheat					
Colo.	2 200	2 851	2.2		
Kans.	11 100	10 956	-1.3		
Nebr.	3 000	4 092	26.7		
Okla.	6 300	4 311	-46.1		
Tex.	4 700	4 313	-9.0		
USSGP	27 300	26 523	-2.9		
Mont.	3 020	1 448	-108.6		
S. Dak.	1 040	1 305	25.5		
MW States	4 060	2 753	-47.5		
USGP	31 360	29 276	-7.1		
Spring Wheat					
Minn.	3 826	1 300	-194.3		
N. Dak.	11 540	6 835	-68.8		
SW States[d]	15 366	8 135	-88.9		
Mont.	2 315	1 205	-92.1		
S. Dak.	2 050	1 837	-11.6		
MW States	4 365	3 042	-43.5		
USGP	19 731	11 177	-73.3		
Total[e] Wheat					
Mont.	5 335	2 653	-101.1		
S. Dak.	3 090	3 142	1.7		
MW States	8 425	5 795	-45.1		
USNGP[f]	23 791	13 930	-70.7		
USGP	51 091	40 453	-25.4		

[d]The spring wheat states Minnesota and North Dakota.

[e]Spring wheat plus winter wheat.

[f]The four-state U.S. northern Great Plains Region.

TABLE 5-1.— Continued.

State	USDA/SRS	LACIE	Relative difference %	Standard deviation	CV
September					
Winter Wheat					
Colo.	2 200	2 735	19.6		
Kans.	11 100	10 969	-1.2		
Nebr.	3 000	3 399	11.7		
Okla.	6 300	4 267	-47.6		
Tex.	4 700	4 344	-8.2		
USSGP	27 300	25 714	-6.2		
Mont.	3 020	1 783	-69.4		
S. Dak.	1 040	1 263	17.7		
MW States	4 060	3 046	-33.3		
USGP	31 360	28 760	-9.0		
Spring Wheat					
Minn.	3 826	2 583	-48.1		
N. Dak.	11 540	9 598	-20.2		
SW States	15 366	12 181	-26.1		
Mont.	2 315	1 382	-67.5		
S. Dak.	2 050	2 063	0.6		
MW States	4 365	3 445	-26.7		
USGP	19 731	15 626	-26.3		
Total Wheat					
Mont.	5 335	3 165	-68.6		
S. Dak.	3 090	3 326	7.1		
MW States	8 425	6 491	-29.8		
USNGP	23 791	18 672	-27.4		
USGP	51 091	44 386	-15.1		

TABLE 5-1.— Concluded.

State	USDA/SRS	LACIE	Relative difference %	Standard deviation	CV
October					
Winter Wheat					
Colo.	2 200	2 735	19.6		
Kans.	11 100	10 989	-1.0		
Nebr.	3 000	3 399	11.7		
Okla.	6 300	4 268	-47.6		
Tex.	4 700	4 344	-8.2		
USSGP	27 300	25 735	-6.1		
Mont.	3 020	2 128	-41.9		
S. Dak.	1 040	1 415	26.5		
MW States	4 060	3 543	-14.6		
USGP	31 360	29 278	-7.1		
Spring Wheat					
Minn.	3 826	2 192	-74.5		
N. Dak.	11 540	9 600	-20.2		
SW States	15 366	11 792	-30.3		
Mont.	2 315	1 487	-55.7		
S. Dak.	2 050	2 140	4.2		
MW States	4 365	3 627	-20.3		
USGP	19 731	15 419	-28.0		
Total Wheat					
Mont.	5 335	3 615	-47.6		
S. Dak.	3 090	3 555	-13.1		
MW States	8 425	7 170	-17.5		
USNGP	23 791	18 962	-25.5		
USGP	51 091	44 697	-14.3		

The plots for the individual states indicate that Colorado and Nebraska were consistently overestimated by LACIE and Oklahoma was consistently underestimated. Consistent under- or over-estimation generally indicates a problem that should be investigated. The Colorado and Nebraska overestimates may be related to the fact that these states have large amounts of alfalfa and hay whose spectral signatures may be confused with wheat when certain key acquisitions are not made by Landsat. This is being investigated and the results will appear in the Fourth Interim AA Report. Blind site investigations (section 5.2.1) indicate that the underestimate in Oklahoma is at least partly due to drought effects, pests, and heavy grazing of cattle. In many cases, the wheat was late in greening up and had signatures that were quite different from normal wheat. Further investigations of this problem will appear in the Fourth Interim AA Report.

Plots 7 and 8 display the winter wheat estimates in the mixed wheat states of Montana and South Dakota. In Montana the LACIE estimate was consistently low but increased as the season progressed, primarily due to the processing of more segments. In South Dakota the estimates of wheat area were low in June and July but increased markedly in August. Thereafter, they remained above the USDA/SRS estimate. A possible explanation for the relatively higher LACIE estimates in South Dakota is that this state has large amounts of alfalfa and hay that can be confused with wheat when key Landsat acquisitions are missed. Also, there were computer software problems for the aggregations in both Montana and South Dakota which may have contributed to the differences observed.

The winter wheat acreage estimates for the two mixed wheat states are shown in plot 9. These estimates were very low in June but increased throughout the season. The relative difference in October was -14.6 percent.

Plot 10 shows the total USGP winter wheat estimates by month obtained by adding the monthly acreage estimates from plots 6 and 9. The LACIE estimates are somewhat lower than for the USSGP due to the underestimates in the mixed wheat states. The October results show a relative difference of -7.1 percent.

SPRING WHEAT

Plots 11 through 17 show the acreage estimates for spring wheat. Plots 11 through 13 are for the spring wheat states and plots 14 through 16 are for the spring wheat in the mixed wheat states. The estimates for total spring wheat in these four states are shown in plot 17.

Plots 11, 12 and 13 show that both Minnesota and North Dakota were consistently underestimated. However, there was a considerable improvement in the LACIE estimate in September. A change in the small-grains-to-wheat ratio accounted for 48 percent of the improvement in North Dakota and 53 percent of the improvement in Minnesota. In North Dakota a further 36 percent of the impovement was due to the addition of 21 new segments. These new segments were added to North Dakota to correct a sampling problem identified during Phase I. It is also expected that there is a sampling problem in Minnesota since the acreage has increased from 829 000 acres in 1969 (the year that was used for the sampling allocation) to 2 844 000 acres in 1976.

Plots 14, 15 and 16 display the spring wheat estimates for the two mixed wheat states, Montana and South Dakota. They exhibit the same pattern as plots 1 through 9 for the winter wheat in these same states, i.e., consistent underestimation in Montana, initial underestimation followed by overestimation in South Dakota, and consistently low estimates in the total that improve as the season progresses. The improvement in the South Dakota estimates from August to September was due entirely to improved spring-wheat-to-small-grains ratios. The total spring wheat estimate for the mixed wheat states in October had a relative difference of -20.3 percent.

The monthly estimates for the total spring wheat in the U.S. Great Plains region, i.e., the sum of the estimates shown in plots 13 and 16, is shown in plot 17. Note that the pattern is similar to that in plot 13 due to the relatively small contribution of the mixed wheat states. The LACIE estimates are consistently below the USDA/SRS estimates. Of the four states contributing to the total spring wheat estimate, only for one, South Dakota, is the spring wheat acreage not consistently underestimated. As pointed out earlier, this indicates a serious underestimation problem for spring wheat. Preliminary blind site studies, which will be reported in the Fourth Interim AA Report, indicate that this is largely due to errors in the ratios of wheat to small grains that are used to calculate the wheat acreage. For spring wheat, CAMS normally determines only small grains proportions and the wheat proportions are then calculated by multiplying these by the historical wheat-to-small-grains ratios for the county in which the segment is located. The preliminary blind site studies indicate that on the average the LACIE small grains proportions are not significantly different from the ground observed proportions, while the ratioed LACIE estimates of spring wheat are significantly lower than the ground observed proportions of spring wheat.

TOTAL WHEAT IN THE MIXED WHEAT STATES

Plots 18 through 20 show acreage estimates for total wheat (spring plus winter) for the mixed wheat states. The total acreage is underestimated in Montana, overestimated in South Dakota, and underestimated in the two-state region (plot 20). The October estimate for the two-state total had a relative difference of -17.5 percent.

TOTAL WHEAT IN THE U.S. NORTHERN GREAT PLAINS

Plot 21 shows the total wheat in the four-state U.S. Northern Great Plains obtained by adding the estimates in plots 13 and 20. It is consistently underestimated but improves as the season progresses. The October estimate has a relative difference of -25.5 percent due to underestimates of spring wheat in Montana, Minnesota and North Dakota and of winter wheat in Montana. Both spring and winter wheat were overestimated in South Dakota.

TOTAL WHEAT IN THE U.S. GREAT PLAINS

Plot 22 shows the total wheat in the nine-state USGP region. The LACIE estimate is consistently low but improves as the season progresses. In October it has a relative difference of -14.3 percent due to an underestimate of 2.1×10^6 acres (relative difference -7.1 percent) in the winter wheat acreage and an underestimate of 4.3×10^6 acres (relative difference of -28.0 percent) in the spring wheat acreage.

5.2 ACREAGE ERROR SOURCES

The main components of acreage error are classification error and sampling error. The investigations of classification error described below consist of (1) a routine comparison of LACIE classification results with ground-truth data for the blind sites (section 5.2.1), and (2) an investigation of two special effects related to classification accuracy, namely the accuracy of the adjustable crop calendar and the dependence of classification accuracy on biophase selection (section 5.2.2). The investigation of sampling error is described in section 5.2.3.

5.2.1 BLIND SITE INVESTIGATIONS OF CLASSIFICATION ERROR

Blind site investigations for winter and spring wheat are discussed separately. Winter wheat investigations are discussed in section 5.2.1.1 and spring wheat investigations are discussed in section 5.2.1.2.

5.2.1.1 Winter Wheat Blind Site Investigations

The winter wheat blind site investigation consisted of three different investigations: (1) an early-season investigation for April, (2) a mid-season investigation extending from April to August, and (3) a late-season investigation for October. Each used a different set of blind sites and each is described separately below.

EARLY SEASON INVESTIGATION

The LACIE Phase II examination of early-season acreage estimation involved evaluations of acquisitions acquired after emergence and through February; these acquisitions were classified by the CAMS and passed to CAS. Forty blind sites were randomly selected from these acquisitions, and aircraft photography was obtained. Field overlays were prepared and then used by the USDA/ASCS to acquire ground-truth land-use information. Classification and ground-truth data were obtained for 29 of the 40 blind sites and for six intensive test sites. This was the basic data set used in the early-season acreage estimation evaluations, the results of which are reported in table 5-2. A review of table 5-2 shows that the average of LACIE estimates over the 35 sites in the five states of the U.S. southern Great Plains was less (-9.17 percent) than the average of ground-observed proportions in these states. More detailed investigations were then conducted over a subset (20) of the blind sites, where comparisons of analyzed Landsat and aircraft imagery could be made. These assessments showed:

a. Visual interpretations of Landsat and aircraft color infrared signatures were very similar when acquisition dates were within 10 days.

TABLE 5-2.– ESTIMATES OF EARLY-SEASON SMALL-GRAIN PERCENTAGES FOR 29 BLIND SITES AND 6 INTENSIVE TEST SITES IN THE U.S. SOUTHERN GREAT PLAINS

State	Number of segments	$\bar{\hat{P}}$, %	$\bar{P}_{GT}$, %	$\bar{\hat{P}}-\bar{P}_{GT}$, %
Colorado	2	2.30	10.15	-7.85
Kansas	14	22.50	29.80	-7.30
Texas	10	9.80	19.58	-9.78
Nebraska	3	13.43	21.76	-8.33
Oklahoma	6	21.48	35.06	-13.58
Overall 5-state	35	16.50	25.97	-9.17

b. Overall, many wheatfields had little, if any, wheat signatures (pink) on either aircraft or Landsat color infrared products, which indicated that the thin stands of wheat were not being detected.

c. Many reasons for thin (undetectable) wheat stands were identified - most stemming from drought effects; i.e.,

- Eight of the twenty segments showed drought effects.
- Six of the twenty segments were damaged by mosaic virus, army worms, or greenbugs.
- Heavy grazing of cattle was also identified as a cause, inasmuch as it was a common practice in some areas until mid-March, regardless of drought conditions.

The drought effects were further studied over a representative ITS in the fall drought area (Rice County, Kansas). Acquisitions and classifications over this site showed no significant change until after favorable weather occurred late in the spring (March). At that time, a significant improvement in detectable wheat signatures was noted, and the LACIE estimates began to approach ground-truth estimates ($\hat{p}$ = 47 percent wheat, P_{GT} = 50 percent wheat). Because of the problems encountered in early-season acreage estimation, it was felt that further tracking and monitoring of these effects over the blind sites was necessary. As a result, the recommendation to rephotograph and remeasure the ground truth over the 40 blind sites was made and approved by LACIE project management.

MID-SEASON INVESTIGATION

After the blind sites were remeasured, a new set of 30 blind sites, slightly different from the previous set, was selected for the mid-season investigation. The distribution of these 30 sites by state was as follows: Colorado, 2; Kansas, 8; Nebraska, 5; Oklahoma, 8; and Texas 7.

Evaluation of the LACIE acreage estimates utilizing this remeasured ground-truth data was conducted. An examination of the remeasured ground truth revealed that approximately 10 percent of the wheat previously observed in these sites was not harvested. This reduced the mean differences ($\overline{D}$) between LACIE estimates and ground observations from the -9.17 percent observed in the early season (table 5-2) to approximately -6 percent as shown in table 5-3.

In addition, table 5-3 shows a steady decline in the MSE from April through July with a slight increase in August, which appears to be caused by the change in one outlying segment in Oklahoma. Similar patterns or trends can also be noted in the RMD's and in $\overline{D}$; namely, larger differences between LACIE estimates and ground truth were noted early in the season, with the differences becoming smaller as the season progressed.

Another study of the LACIE underestimation trend was conducted by determining the percentage of the blind sites that were underestimated during this period. The results of this study (table 5-4) suggest that a significant number (90 percent) of the segments were being underestimated during the early season. This percentage became less as the season progressed, but a tendency toward underestimation was still apparent, even in August (71 percent were underestimated.

In summary, these blind site investigations disclosed a potential early-season acreage underestimation problem, as well as general underestimation bias, which required further consideration and investigation by AA personnel.

LATE SEASON INVESTIGATION

The early and midseason investigations were conducted with only 30 blind sites, because when those studies were begun, ground

TABLE 5-3.— MEASUREMENTS OF CLASSIFICATION ERROR (LACIE ESTIMATES VERSUS GROUND-OBSERVED SMALL-GRAIN PROPORTIONS) OVER 30 BLIND SITES IN THE U.S. SOUTHERN GREAT PLAINS

Month	MSE (a)	RMD (b)	$\overline{D}$ (c)
April	114.71	-0.31	-5.79
May	84.61	-.22	-4.10
June	61.21	-.16	-3.06
July	50.09	-.13	-2.47
August	53.09	-.15	-2.70

[a] $MSE = \frac{\sum\left[\hat{P}_i - P_{GT_i}\right]^2}{n}$, where $\hat{P}_i$ is the wheat/small-grain proportion estimate for the *ith* segment, P_{GT_i} is the ground-observed, harvested, wheat/small-grain proportion for the *ith* segment, and n is the number of segments.

[b] $RMD = \frac{\overline{\hat{P}} - \overline{\hat{P}}_{GT}}{\overline{P}_{GT}}$.

[c] $\overline{D} = \frac{\sum\left[\hat{P}_i - P_{GT_i}\right]}{n} = \overline{\hat{P}} - \overline{P}_{GT}$.

TABLE 5-4.— PERCENTAGE OF BLIND SITE SEGMENTS IN WHICH THE SMALL-GRAIN PROPORTIONS WERE UNDERESTIMATED

April	May	June	July	August
90	77	77	73	71

truth was available for only a limited number of blind sites. However, by October, ground truth had been obtained for many more blind sites in the five-state winter wheat region. As a result, a new investigation was performed using 103 blind sites and the CAMS classification results for these blind sites corresponding to the October LACIE estimates.

The results are shown in figure 5-2 and table 5-5. Figure 5-2 shows plots of the proportion error $\hat{P} - P_{GT}$ as a function of P_{GT}, where $\hat{P}$ is the CAMS wheat or porportion estimate and P_{GT} is the ground truth wheat proportion. These plots are for the five individual states and the total USSGP five-state region. Points lying above the horizontal line $\hat{P} - P_{GT} = 0$ correspond to overestimation of wheat proportions by CAMS and points lying below the line correspond to underestimation.

The plots in figure 5-2 indicate that there is an overall trend toward negative values of $\hat{P} - P_{GT}$ as P_{GT} increases for the five-state region and for each of the individual states except Colorado. In other words, for these regions, CAMS tends to underestimate the true wheat proportion when the true wheat proportion is large. In fact, for $P_{GT} > 28$ percent, there is only one blind site out of 26 in the five-state region for which the CAMS result is not an underestimate relative to ground truth. Also, figure 5-2 indicates that there is a tendency to underestimate in Oklahoma and Texas for all true wheat proportions. In Oklahoma, 17 of 20 *85 percent) of the blind sites were underestimated and in Texas 15 of 19 (79 percent) of the blind sites were underestimated. A statistical analysis of this data follows.

Table 5-5 displays the average ground-truth wheat proportions, $\overline{P}_{GT}$, and the average CAMS wheat proportions, $\hat{P}$, as determined for the blind sites data given in figure 5-2 for each of the five

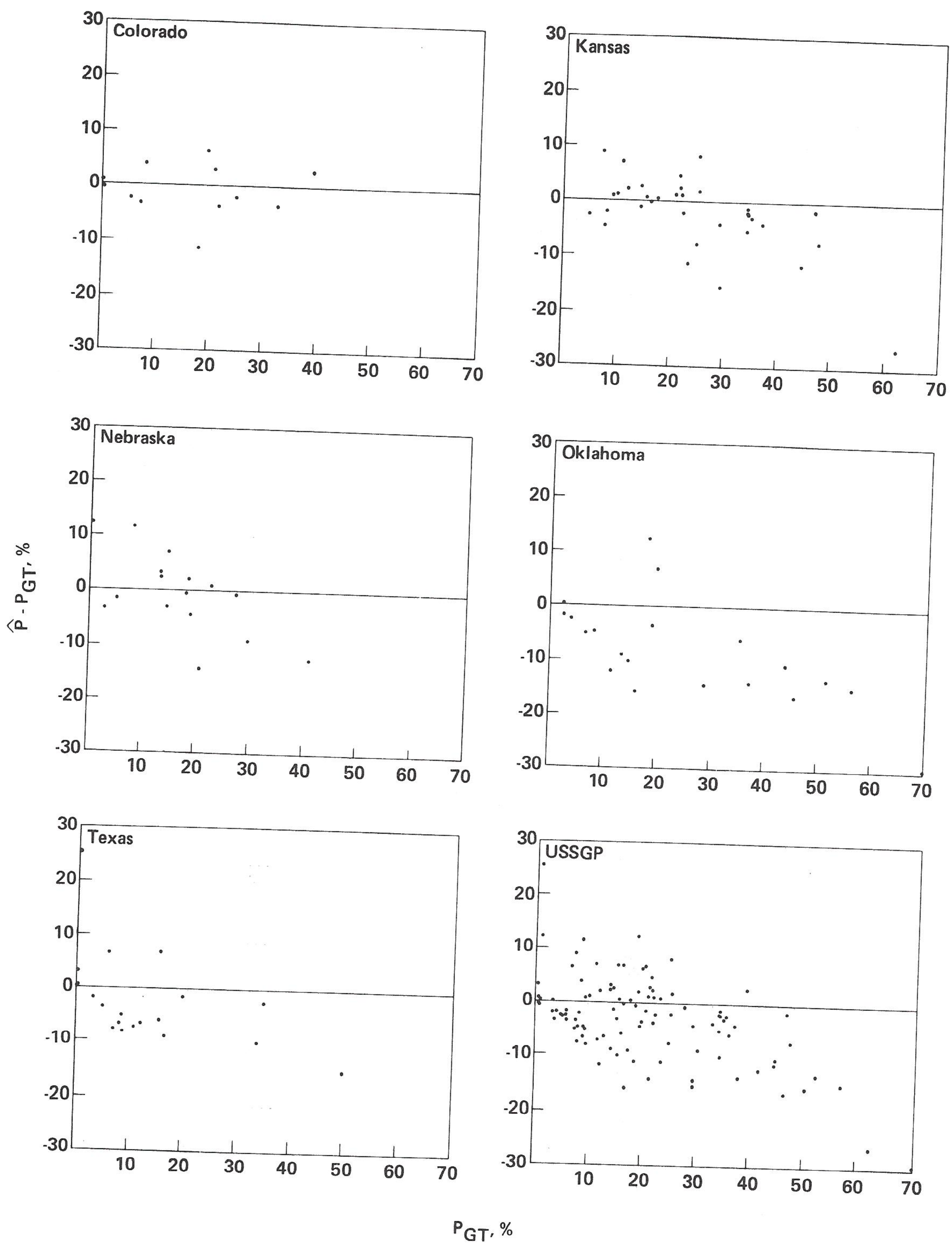


Figure 5-2.- Plot of wheat proportion estimation errors versus ground truth wheat proportion for blind sites in the USSGP.

TABLE 5-5.– BLIND SITE RESULTS FOR THE USSGP

State	n (a)	N (b)	$\bar{P}_{GT}$	$\hat{\bar{P}}$ (c)	$\bar{D}$	$S_{\bar{D}}$	95% C. L. for $\bar{D}$
Colorado	13	32	14.62	14.54	-.08	1.06	(-2.39, 2.23)
Kansas	34	84	23.89	22.00	-1.89	0.91	(-3.74, -0.04)
Nebraska	18	35	14.12	14.78	0.65	1.15	(-1.78, 3.08)
Oklahoma	20	40	24.19	17.60	-6.58	1.51	(-9.74, -3.42)
Texas	18	49	12.61	11.83	-0.78	1.58	(-4.11, 2.55)
USSGP	103	240	19.10	17.17	-1.93	0.58	(-3.08, -0.78)

[a] Number of blind sites.

[b] Number of segments allocated.

[c] Wheat estimates from the October CMR.

states in the USSGP and the five-state region. Also presented in this table for each of these regions are the average difference, $\bar{D}$, between CAMS and ground truth wheat proportions and the standard error, $S_{\bar{D}}$, of this average difference. Assuming that the differences, $\hat{P}_i - P_{GT_i}$, are normally distributed, where i refers to the *ith* blind site, 95 percent confidence limits may be obtained for $\bar{D}$, and these are also presented in table 5-5 for each of the regions.

For instructive purposes, the formulas for each of the above quantities are given. Let N be the number of segments allocated to a region (state or higher level) and let n be the number of blind sites selected randomly from these N segments. For a region, let $\hat{P}_i$ represent the CAMS estimate of the proportion of wheat in the *ith* blind site and let P_{GT_i} represent the ground truth proportion of wheat in the *ith* blind site, where $i = 1, \ldots, n$. Then, the average difference, $\bar{D}$, is given by

$$\bar{D} = \frac{1}{n} \sum_{i=1}^{n} \left(\hat{P}_i - P_{GT_i} \right)$$

or

$$\bar{D} = \frac{1}{n} \sum_{i=1}^{n} d_i ,$$

where $d_i = \hat{P}_i - P_{GT_i}$. An estimate of the variance of the differences, d_i, is given by

$$S_D^2 = \frac{1}{n-1} \sum_{i=1}^{n} (d_i - \bar{D})^2$$

It follows from elementary sampling theory that an estimate of the variance of the average difference is given by

$$S_{\bar{D}}^2 = \frac{S_D^2}{n} \left(1 - \frac{n}{N} \right)$$

where $\frac{n}{N}$ is the sampling fraction. The standard error of the average difference is then given by

$$S_{\overline{D}} = \sqrt{S_{\overline{D}}^2} = \frac{S_D}{\sqrt{n}}\sqrt{1 - \frac{n}{N}}$$

Lower and upper confidence limits for the population average difference are given by

$$\overline{D}_L = \overline{D} - tS_{\overline{D}} \ , \ \overline{D}_U = \overline{D} + tS_{\overline{D}}$$

where t is the value of the percentage point, from the Student's t distribution with (n-1) degrees of freedom, corresponding to the desired confidence probability. The 95 percent confidence limits for the population average difference are presented in table 5-5. It should be pointed out that the population here is those segments allocated to the region under consideration.

In order to determine whether or not the average difference for a particular region is significantly different from zero, we need only observe whether or not the corresponding confidence interval contains zero. If it does, then the average difference is not significantly different from zero. If it does not, then we are 95 percent confident that the average difference is significantly different from zero. For example, the 95 percent confidence interval for Oklahoma is given by (-9.74, -3.42). This interval does not contain zero. Hence, we conclude that the average difference is significantly different from zero; i.e., the CAMS estimates of the wheat proportions in those segments allocated to Oklahoma are significantly lower than the ground truth for those segments. This underestimate has since been determined to be due to drought conditions that existed in Oklahoma.

In table 5-5 it is also observed that a significant difference occurs for the state of Kansas. Inspection of the data plotted in figure 5-2 reveals one outlier, a difference of -25.56 percent corresponding to a ground truth of 61.56 percent wheat. Omitting this one outlier would result in an average difference not significantly different from zero. However, further invetigation revealed this to be actually what was recorded for this segment. No cause for this extreme underestimation is apparent at this time.

Recall that it was stated earlier in this section that 79 percent of the blind sites in Texas were underestimated. However, the 95 percent confidence interval contains zero indicating that there is insufficient evidence to state that the average difference is significantly different from zero. Inspection of the data plotted in figure 5-2 for Texas reveals an outlier - a difference of +25.31 percent corresponding to a ground truth of .69 percent, i.e., an extreme overestimate of a trace of wheat. Omitting this outlier would result in an average difference significantly different from zero agreeing with the previous statement. As in Kansas, however, further investigation revealed this to be actually what was recorded for this particular blind site. No cause for this extreme overestimation is apparent, especially since ground truth revealed that the .69 percent wheat to be the only small grain in the segment. That is, something other than small grains has been confused by the analyst as wheat.

Neither of the average differences for the other two states, Colorado and Nebraska, are significantly different from zero. Also, closer inspection of the data shown in figure 5-2 reveals no apparent outliers. The analysts in CAMS are apparently having some success in identifying wheat for these two states.

At the USSGP five-state level, there is sufficient evidence to conclude that the CAMS wheat proportion estimates are significantly different from the ground wheat proportions at the 95 percent level. The average difference at this level is

-1.93 percent with a standard error of .58 percent. So, the significant underestimation in Kansas and Oklahoma was enough to cause a significant underestimation at the USSGP level.

5.2.1.2 Spring Wheat Blind Site Investigations of Classification Error.

These investigations are currently being performed and will be reported in the Fourth Interim AA Report.

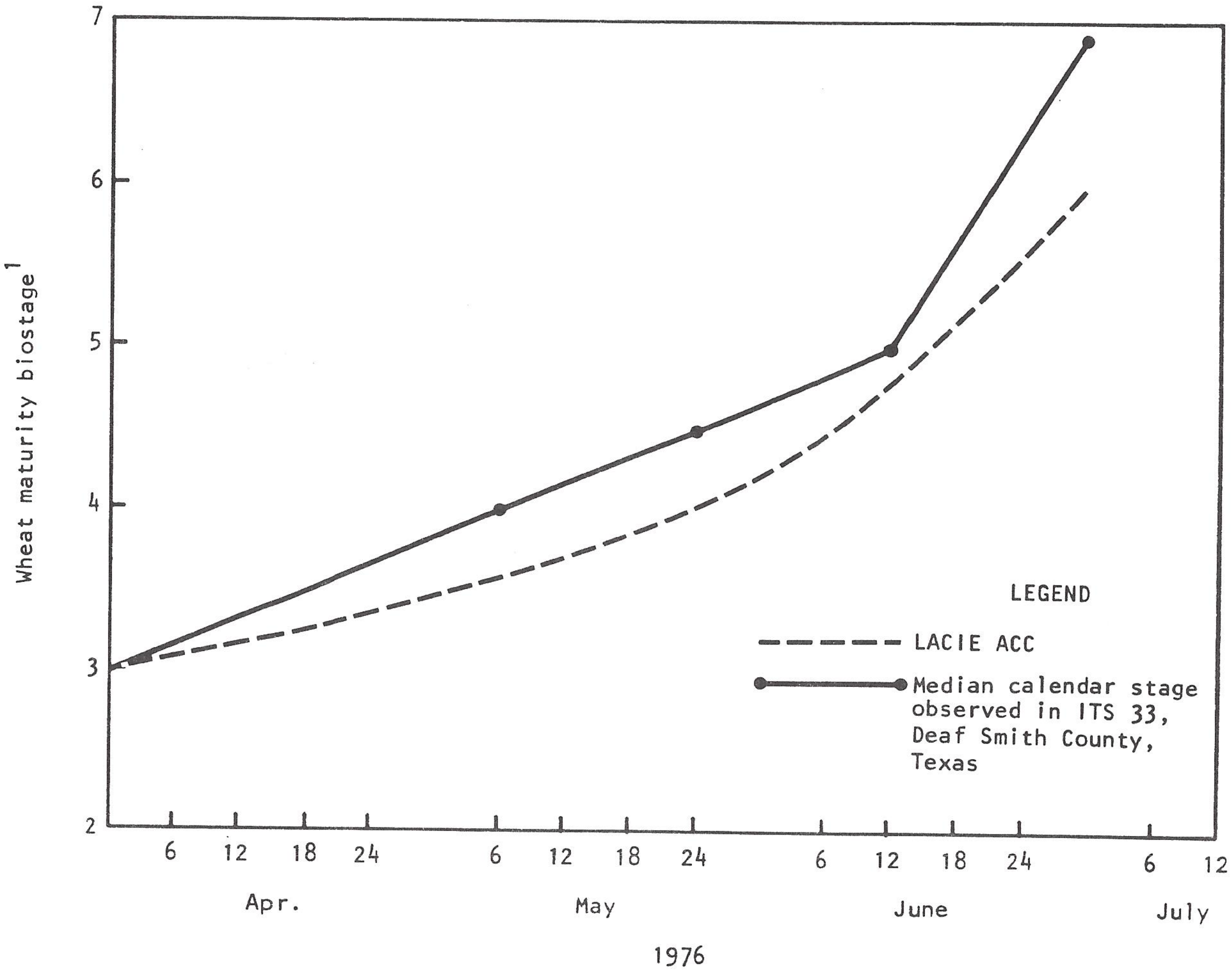
5.2.2 SPECIAL STUDIES RELATED TO CLASSIFICATION ERROR

This section contains a discussion of two special studies related to proportion estimation that were carried out in Phase II. One was an investigation of the accuracy of the adjustable crop calendar and the other an investigation of the effect of the biophase of Landsat acquisitions on proportion estimation.

5.2.2.1 Adjustable Crop Calendar

The adjustable crop calendar (ACC) is designed to indicate to the CAMS analyst the growth stage of wheat and other crops in the segments he is analyzing. It is therefore expected to have a considerable impact on the accuracy of the CAMS estimates. A study was performed to determine the accuracy of the ACC by comparing it with ground-observed growth-stage data.

Ground-observed growth-stage data were collected by USDA/ASCS personnel and reported on the standard forms, examples of which are presented in appendix D. These data were collected over eight ITS's in Texas and Kansas during the months of April through June. These ground-observed data were plotted along with comparable LACIE ACC-predicted wheat development data. An example of these plots from Deaf Smith County, Texas, is presented in figure 5-3.



[1]According to the Robertson Biometeorological Time Scale, the numbered biostages are: 1 = planting, 2 = emergence, 3 = jointing, 4 = heading, 5 = soft dough, 6 = ripening, and 7 = harvest.

Figure 5-3.— Plot of observed and predicted progression of crop calendar stages for Deaf Smith County, Texas, intensive test site.

These plots were analyzed, and the results are listed in table 5-6. On the 6th of each month, data were taken from plots, and the differences were recorded in Biometeorological Time Scale (BMTS) units of the Robertson scale. A review of this test shows that crop calendar stages predicted by the LACIE ACC were temporally behind the stages observed in all ITS's except Oldham County, Texas, and Morton County, Kansas. Also, the $\overline{D}$ between the ACC stages and the ground-truth stages increased as the season progressed, with all ITS ACC stage predictions falling behind the ground-truth stages in the June time frame.

At present no specific reason for this ACC error is evident. However, potential causes may be associated with the starting of the ACC model.

5.2.2.2 Effect of Biophase on Proportion Estimation

A test was made to determine whether proportion estimation errors for biophase 4 were significantly different than the errors for biophase 1. Since there were not enough paired data per state for biophases 1 and 4 for reliable comparison, the data for the five southern Great Plains states was merged (i.e., for 23 blind sites) and a comparison of biophase data was made on this basis.

The Wilcoxon matched-pairs signed-rank test[1] was employed, applied to the differences $x = \hat{P}_1 - P_{GT}$ and $y = \hat{P}_4 - P_{GT}$, where $\hat{P}$ is the proportion of small grains estimated in a given blind site for biophase 1, $\hat{P}_4$ is a corresponding estimate for biophase 4, and P_{GT} is the small-grain proportions observed. The signed-rank test as applied here assumes that the differences x-y can be ordered in terms of a greater than or less than

[1] R.P. Runyon and A. Haber, "Fundamentals of Behavioral Statistics", and ed. Addison-Wesley Publishing Co., Reading, Mass., 1971, pp. 263-265.

TABLE 5-6.— COMPARISON OF LACIE ADJUSTABLE CROP CALENDAR WITH OBSERVED STAGES IN THE EIGHT INTENSIVE TEST SITES IN THE U.S. SOUTHERN GREAT PLAINS

[$\bar{D}$ in the BMTS units of the Robertson scale]

Site		Date		
County	State	April 6	May 6	June 6
Randall	Texas	-0.12	-0.33	-0.28
Deaf Smith	Texas	-.08	-.42	-.39
Oldham	Texas	.01	0	-.08
Ellis	Kansas	0	-.42	-.51
Rice	Kansas	0	-.44	-.38
Phinney	Kansas	-.17	-.04	-.38
Saline	Kansas	-.18	-.51	-.42
Morton	Kansas	-.16	0	-.08
Average		-.12	-.27	-.32

relation. Each rank is assigned the same algebraic sign as the corresponding difference x-y so that the direction as well as the magnitude of x-y is utilized in the test. The null hypothesis is made that the sums T of positive and negative ranks are equal with an assigned level of significance, that is, positive and negative ranks of the same magnitudes are equally likely. Critical values of T are to be found in tables prepared by Wilcoxon[2] for various numbers N of samples (here N=23).

Upon applying the test described, for a 10 percent level of significance, it was found that the null hypothesis could not be rejected. It follows that LACIE estimates made using data from biophase 4 could not be said to be either better or worse than estimates made on the basis of data derived from biophase 1.

5.2.3 SAMPLING ERROR

An estimate of the sampling error ($\hat{\sigma}_S^2$) for the blind sites used in the mid-season investigation (section 5.2.1.1) was determined by regressing the proportion of wheat obtained from ground truth in the blind site segments to the corresponding county wheat proportions during 1969 and calculating the mean squared error (MSE) of the residual terms. These estimates were obtained for April through August and are listed in table 5-7 with the classification error estimate ($\hat{\sigma}_C^2$) from table 5-3, the total error $\hat{\sigma}_C^2 + \hat{\sigma}_S^2$ and the percent of the total error contributed by each component.

[2] Ibid, table J, p. 308.

TABLE 5-7.– COMPARISON OF CLASSIFICATION AND SAMPLING ERROR BASED ON BLIND SITE DATA

Month	Error components		Total error, $\hat{\sigma}_c^2+\hat{\sigma}_s^2$	Error contributed by classification, % (a)	Error contributed by sampling, % (b)
	$\hat{\sigma}_c^2$	$\hat{\sigma}_s^2$			
April	151.0	150.0	301.0	50	50
May	84.6	42.4	127.0	67	33
June	61.2	42.4	103.6	59	41
July	50.1	42.4	92.5	54	46
August	53.1	42.4	95.5	56	44

[a]The ratio of classification error to total error is calculated by $r = \dfrac{\hat{\sigma}_c^2}{\hat{\sigma}_c^2 + \hat{\sigma}_s^2}$.

[b]The ratio of sampling error is calculated by $1 - r = \dfrac{\hat{\sigma}_s^2}{\hat{\sigma}_c^2 + \hat{\sigma}_s^2}$.

6. ASSESSMENT OF YIELD ESTIMATION

Accuracy Assessment has identified possible error sources that result from applying zone level yield models to each crop reporting district (CRD) within the zone and then estimating production at the state level by the LACIE method of aggregating from the CRD level. These error sources are currently being investigated and are listed below:

a. Possible bias in yield estimates due to applying zone level yield models to CRD level weather data.

b. Possible error in estimating the state production variance due to the correlation between CRD yield estimates within a yield model zone, a condition caused by using the same prediction equation for each CRD in a yield model zone.

c. A third possible error source that is also being investigated is error due to omitting weather and yield data for some CRD's in a zone from the development of the zone level yield model areas.

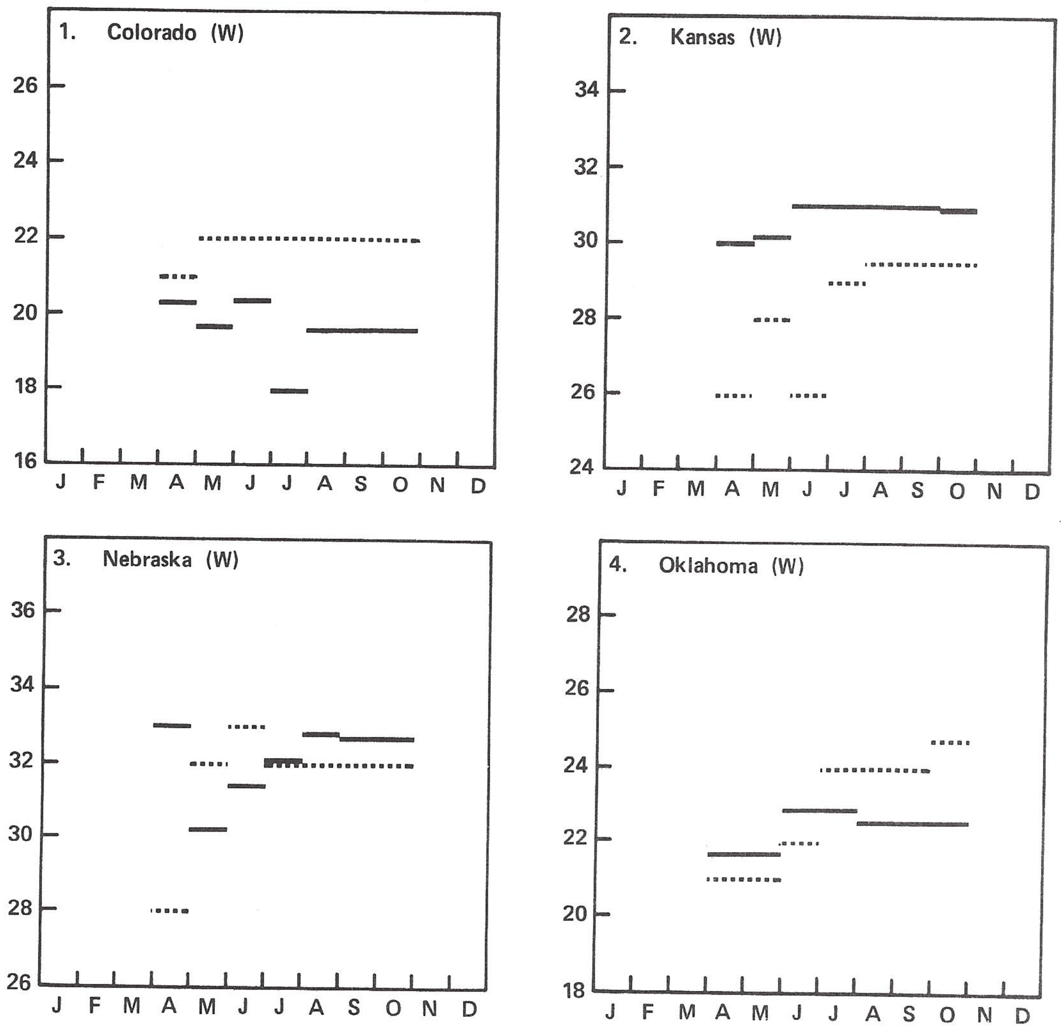
As a consequence of the above, no evaluation of yield estimates will be made other than direct comparisons of monthly LACIE yield estimates with monthly USDA/SRS yield estimates at the state and higher levels. As in the production and acreage sections, only relative differences will be reported; no coefficients of variation will be presented. In comparing these yield estimates for state and higher levels, certain observations will be made, but no speculation as to why these observations have occurred will be given. However, in the final AA report, possible explanations for these discrepancies will be presented.

WINTER WHEAT YIELD

The LACIE and USDA/SRS monthly winter wheat yield estimates for each of the five states in the U.S. southern Great Plains are displayed in plots 1 through 5 of figure 6-1. The total yield estimates for these five states are presented in plot 6. The corresponding relative differences for these estimates are presented in table 6-1. Note that at the five-state level, the LACIE estimates of winter wheat yield are very close to the USDA/SRS estimates for the month of May and for July through October. Also, the LACIE estimates leveled off in June, two months before the USDA/SRS estimates did.

Upon examination of the individual state estimates, it is seen that the LACIE estimates were consistently underestimated relative to the USDA/SRS estimates in Kansas. In the other three states, consistent under- or overestimation did not occur until July. An interesting observation is that the consistent overestimation in Nebraska and the consistent underestimation in Oklahoma and Texas all began in July and continued through October. However, this is probably purely coincidental. It should be pointed out, though, that the LACIE estimates appear to be more stable from month to month than the USDA/SRS estimates for each state except Colorado.

The winter wheat yield estimates by LACIE and USDA/SRS for the two mixed wheat states, Montana and South Dakota, are exhibited in plots 7 and 8. The winter wheat yield estimates for the two-state region are given in plot 9. The corresponding relative differences for these plots are listed in table 6-1. The LACIE yield estimates were consistently lower than the USDA/SRS yield estimates in Montana and consistently higher in South Dakota. Combining the two resulted in a consistent overestimation by LACIE over USDA/SRS for the two-state total. As pointed out earlier, no speculation as to why this occurred will be given in this report.



LEGEND
—— LACIE
······ USDA/SRS
W = WINTER WHEAT
S = SPRING WHEAT
T = TOTAL WHEAT

Figure 6-1.— LACIE and USDA/SRS yield estimates [Bushels/acre].

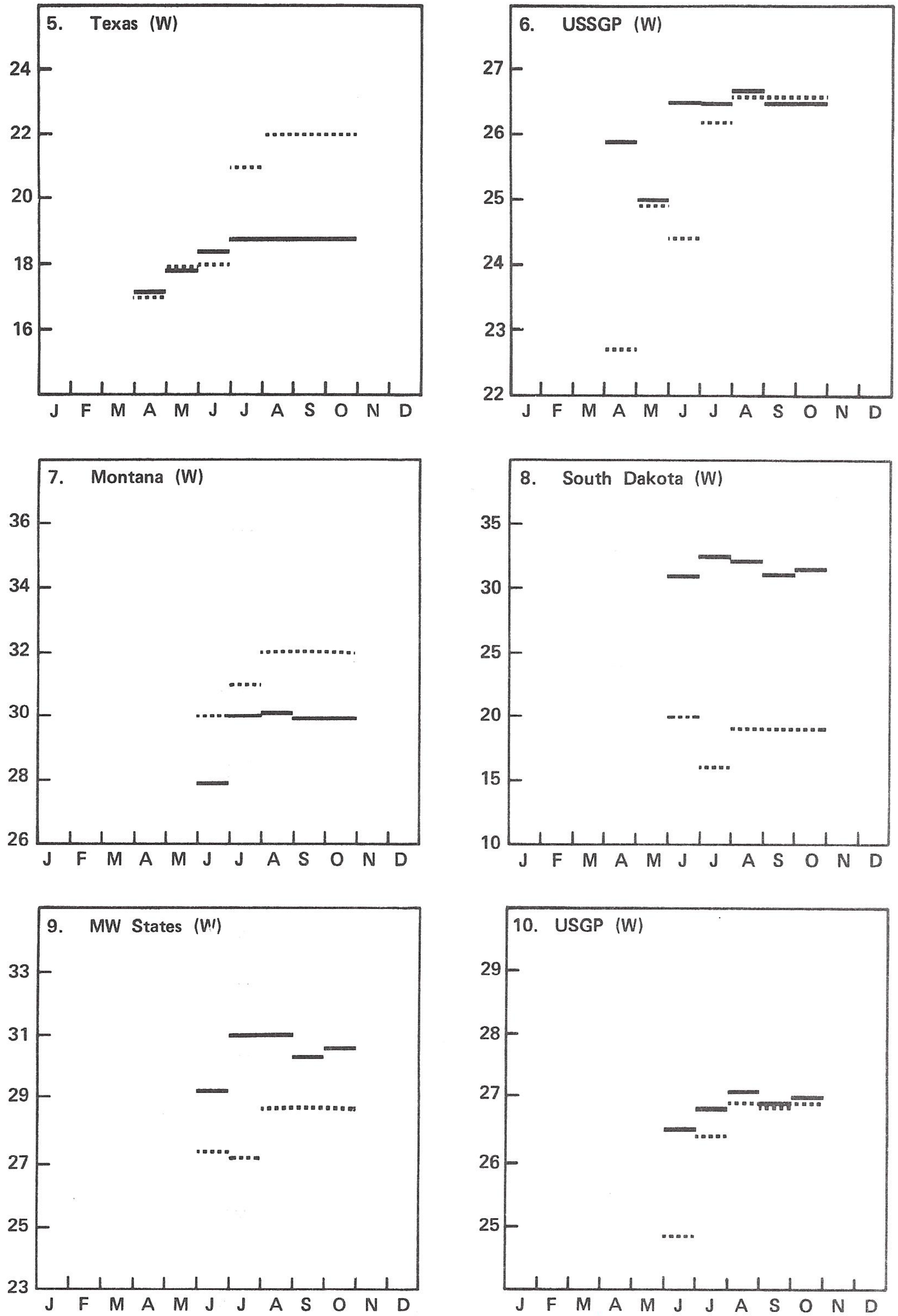


Figure 6-1.— Continued.

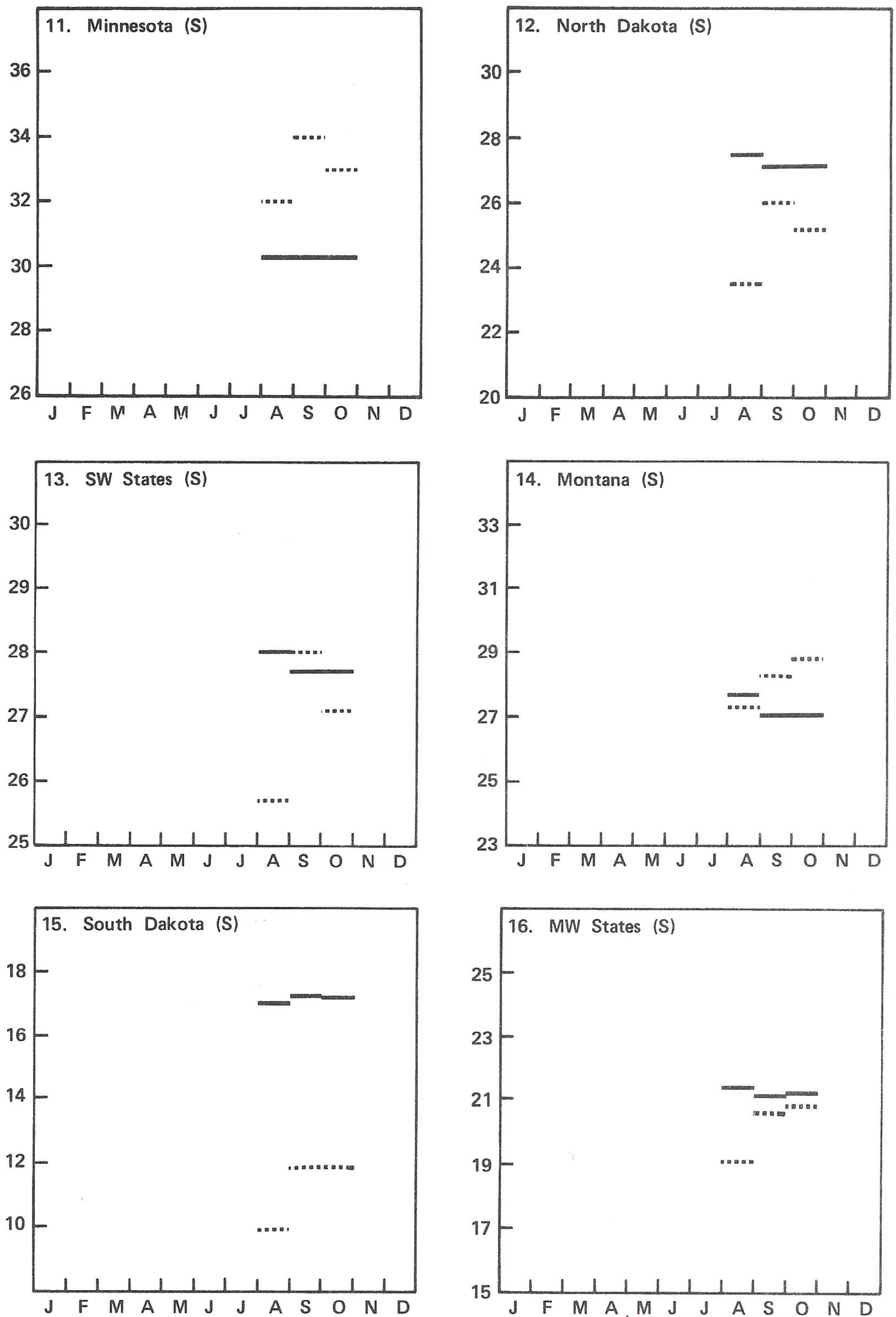


Figure 6-1.— Continued.

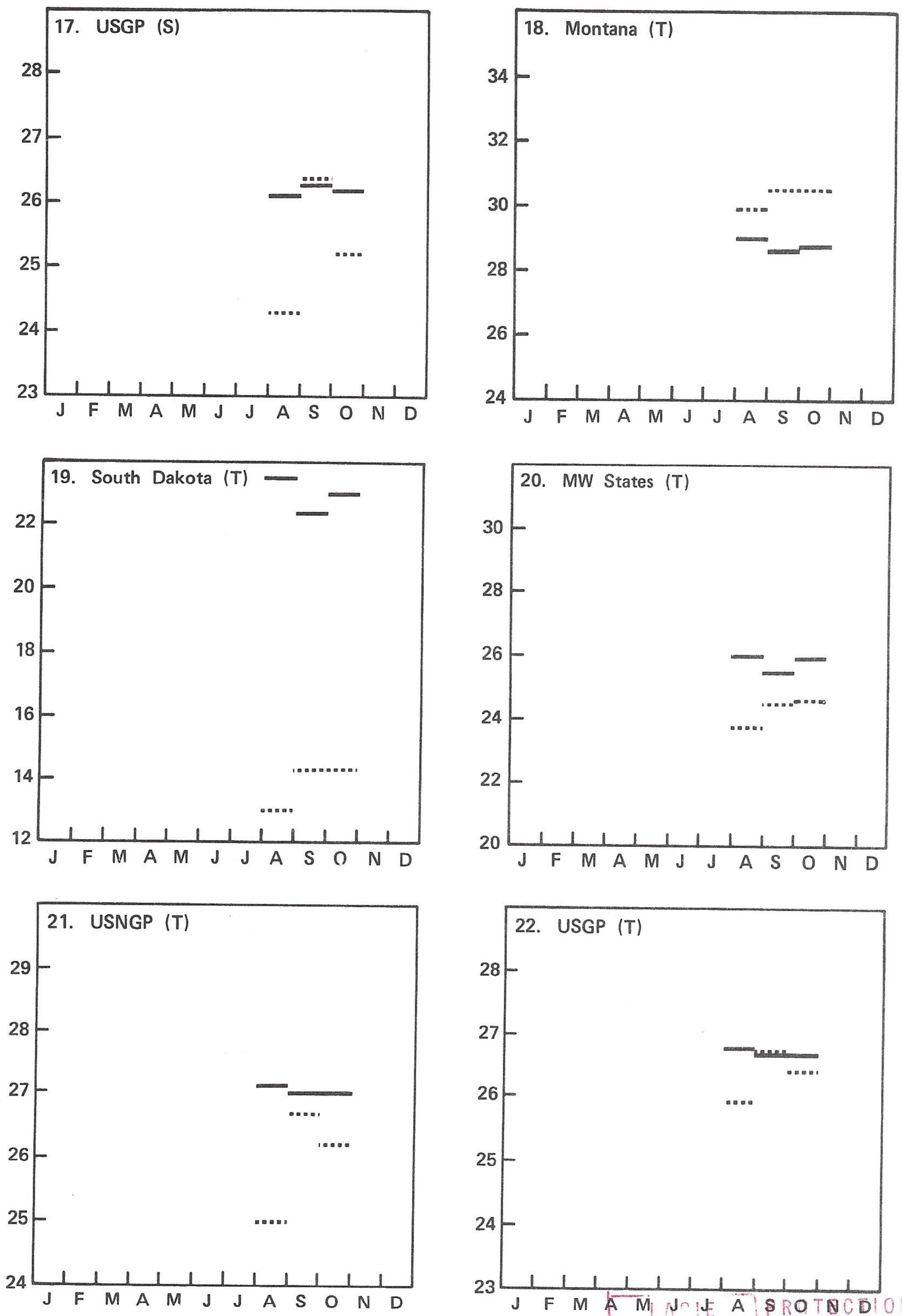


Figure 6-1.— Concluded.

TABLE 6-1.— COMPARISON OF USDA/SRS AND LACIE YIELD AGGREGATION ESTIMATES

[Bushels/acre]

State	USDA/SRS	LACIE	Relative difference %	Standard deviation	CV
April					
Winter Wheat					
Colo.	21.0	20.3	-3.4		
Kans.	26.0	29.9	13.0		
Nebr.	28.0	33.1	15.4		
Okla.	21.0	21.7	3.2		
Tex.	17.0	17.1	.6		
USSGP[a]	22.7	25.9	12.2		
May					
Winter Wheat					
Colo.	22.0	19.7	-11.7		
Kans.	28.0	30.2	7.3		
Nebr.	32.0	30.2	-6.0		
Okla.	21.0	21.7	3.2		
Tex.	18.0	17.9	-.6		
USSGP[a]	24.9	25.0	0.4		

[a]The five-state U.S. southern Great Plains Region

TABLE 6-1.— Continued.

State	USDA/SRS	LACIE	Relative difference %	Standard deviation	CV
June					
Winter Wheat					
Colo.	22.0	20.4	-7.3		
Kans.	26.0	31.0	16.1		
Nebr.	33.0	31.4	-5.0		
Okla.	22.0	22.9	3.9		
Tex.	18.0	18.4	2.2		
USSGP	24.4	26.5	7.9		
Mont.	30.0	27.9	-7.5		
S. Dak.	20.0	30.9	35.3		
MW States[b]	27.4	29.2	6.2		
USGP[c]	24.8	26.6	6.8		
July					
Winter Wheat					
Colo.	22.0	18.0	-22.2		
Kans.	29.0	31.0	6.5		
Nebr.	32.0	32.0	0		
Okla.	24.0	22.9	-4.8		
Tex.	21.0	18.7	-12.3		
USSGP	26.2	26.5	1.1		
Mont.	31.0	30.0	-3.3		
S. Dak.	16.0	32.5	50.8		
MW States	27.2	31.0	12.3		
USGP	26.4	26.8	1.5		

[b]The mixed wheat states Montana and South Dakota.

[c]The nine-state U.S. Great Plains Region

TABLE 6-1.— Continued.

State	USDA/SRS	LACIE	Relative difference %	Standard deviation	CV
August					
Winter Wheat					
Colo.	22.0	19.5	-12.8		
Kans.	29.5	31.0	4.8		
Nebr.	32.0	32.8	2.4		
Okla.	24.0	22.7	-5.7		
Tex.	22.0	18.7	-17.6		
USSGP	26.6	26.7	0.4		
Mont.	32.0	30.1	-6.3		
S. Dak.	19.0	32.1	40.8		
MW States	28.7	31.0	7.4		
USGP	26.9	27.1	0.7		
Spring Wheat					
Minn.	32.0	30.3	-5.6		
N. Dak.	23.6	27.5	14.2		
SW States[d]	25.7	28.0	8.2		
Mont.	27.3	27.7	1.4		
S. Dak.	9.9	17.0	41.8		
MW States	19.1	21.3	10.3		
USGP	24.3	26.1	5.4		
Total[e] Wheat					
Mont.	29.9	29.0	-3.1		
S. Dak.	13.0	23.5	44.7		
MW States	23.7	26.0	8.8		
USNGP[f]	25.0	27.1	7.7		
USGP	25.9	26.8	3.0		

[d]The spring wheat states Minnesota and North Dakota.

[e]Spring wheat plus winter wheat.

[f]The four-state U.S. northern Great Plains Region.

TABLE 6-1.– Continued.

State	USDA/SRS	LACIE	Relative difference %	Standard deviation	CV
September					
Winter Wheat					
Colo.	22.0	19.6	-12.2		
Kans.	29.5	31.0	4.8		
Nebr.	32.0	32.7	2.1		
Okla.	24.0	22.7	-5.7		
Tex.	22.0	18.7	-17.6		
USSGP	26.6	26.5	-0.4		
Mont.	32.0	29.9	-7.0		
S. Dak.	19.0	31.0	38.7		
MW States	28.7	30.3	5.3		
USGP	26.9	26.9	0.0		
Spring Wheat					
Minn.	34.1	30.3	-12.5		
N. Dak.	26.0	27.1	4.1		
SW States	28.0	27.7	-1.1		
Mont.	28.3	27.1	-4.4		
S. Dak.	11.9	17.2	30.8		
MW States	20.6	21.1	2.4		
USGP	26.4	26.3	-0.3		
Total Wheat					
Mont.	30.4	28.6	-6.3		
S. Dak.	14.3	22.4	36.2		
MW States	24.5	25.5	3.9		
USNGP	26.7	27.0	1.1		
USGP	26.7	26.7	0.0		

TABLE 6-1.— Concluded.

State	USDA/SRS	LACIE	Relative difference %	Standard deviation	CV
October					
Winter Wheat					
Colo.	22.0	19.6	-10.6		
Kans.	29.5	30.9	4.5		
Nebr.	32.0	32.7	2.1		
Okla.	24.7	22.7	-5.7		
Tex.	22.0	18.7	-17.6		
USSGP	26.6	26.5	-0.4		
Mont.	32.0	29.9	-7.0		
S. Dak.	19.0	31.6	39.9		
MW States	28.7	30.6	12.1		
USGP	26.9	27.0	0.4		
Spring Wheat					
Minn.	33.0	30.3	-8.9		
N. Dak.	25.2	27.1	7.0		
SW States	27.1	27.7	2.2		
Mont.	28.8	27.1	-6.3		
S. Dak.	11.9	17.2	30.8		
MW States	20.8	21.2	1.9		
USGP	25.7	26.2	1.9		
Total Wheat					
Mont.	30.6	28.7	-6.6		
S. Dak.	14.3	22.9	37.6		
MW States	24.6	25.9	5.0		
USNGP	26.2	27.0	3.0		
USGP	26.4	26.7	0.8		

The monthly total winter wheat yield estimates for these seven states in the U.S. Great Plains are given in plot 10. The corresponding relative differences are shown in table 6-1. At this level, the LACIE estimates were consistently over the USDA/SRS estimates; however, the two were very close for the last three months plotted.

SPRING WHEAT YIELD

The LACIE and USDA/SRS spring wheat yield estimates for the two spring wheat states, Minnesota and North Dakota, are given in plots 11 and 12. Plot 13 contains the yield estimates for the two-state total. The corresponding relative differences are reported in table 6-1. The monthly LACIE estimates of yield for Minnesota did not change for the three months reported and were consistently lower than the USDA/SRS estimates. On the other hand, the LACIE estimates of yield for North Dakota were consistently higher than the USDA/SRS estimates. As a result, the LACIE two-state total estimates were very close to the USDA/SRS estimates. Note again that the LACIE estimates in each case were more stable from month to month than the USDA/SRS estimates.

Plots 14 and 15 show the monthly estimates of spring wheat yield by LACIE and USDA/SRS for the two mixed wheat states. The two-state total for the yield estimates is displayed in plot 16. Table 6-1 contains the corresponding relative differences for these plots. The LACIE estimates of yield for South Dakota are considerably higher than the USDA/SRS estimates. Recall that the same situation occurred for the winter wheat yield estimates for this state. The LACIE yield estimates for Montana, however, were lower but much closer to the corresponding USDA/SRS estimates except for August when the LACIE estimate was slightly higher. The two-state total spring wheat yield estimates by LACIE were, as a result, higher but very comparable to the USDA/SRS estimates, especially for the last two months reported, September and October. As before, the LACIE estimates appear more stable for the period reported than do the USDA/SRS estimates.

The total spring wheat yield estimates for the states in the U.S. northern Great Plains are given in plot 17. Table 6-1 shows the corresponding relative differences. In plot 17, it is seen that the LACIE estimates are very stable while the USDA/SRS estimates varied considerably. The two September estimates were very close with the USDA/SRS estimate being higher, while for both August and October the LACIE estimates were higher.

TOTAL WHEAT YIELD IN THE MIXED WHEAT STATES

Plots 18 through 20 display the LACIE and USDA/SRS monthly estimates of yield of total wheat (spring and winter combined) for the two individual mixed wheat states and the two mixed wheat states combined, respectively. The corresponding relative differences are shown in table 6-1. Note the huge difference between the two estimates for South Dakota. This, of course, was a reflection of the LACIE estimates of both spring and winter wheat yields being considerably higher than the corresponding USDA/SRS estimates. The LACIE estimates of total wheat yield for Montana were just the opposite. They were lower than the USDA/SRS estimates and much closer. As a result, the LACIE estimates of the two-state total for these mixed wheat states were consistently higher than the USDA/SRS estimates for all three months reported.

TOTAL WHEAT YIELD IN THE U.S. NORTHERN GREAT PLAINS

The LACIE and USDA/SRS monthly total wheat yield estimates for the U.S. northern Great Plains are displayed in plot 21. The relative differences corresponding to this plot are shown in table 6-1. The LACIE estimates are consistently higher than the USDA/SRS estimates for all three months and are much more stable.

TOTAL WHEAT IN THE U.S. GREAT PLAINS

The monthly total wheat yield estimates obtained by LACIE and USDA/SRS for all nine states in the U.S. Great Plains are displayed in plot 22. The corresponding relative differences are given in table 6-1. Note that these estimates were very close in September and October. In August, the estimates were not as close, but they were only one bushel/acre apart. This indicated that the LACIE yield estimates, at this level, were considerably more accurate (as compared to USDA/SRS estimates) than the LACIE acreage estimates.

APPENDIX A

OUTLINE OF THE FOURTH INTERIM ACCURACY ASSESSMENT REPORT

OUTLINE OF THE FOURTH INTERIM
ACCURACY ASSESSMENT REPORT

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1.2 GENERAL METHODOLOGY (I and II)

1.2.1 DATA REQUIREMENTS DEFINITIONS AND ACQUISITION MONITORING (I and II)

1.2.2 DATA ANALYSIS AND EVALUATION (I and II)

1.2.3 REPORTING (I and II)

2. SUMMARY (I and II)

2.1 THE ERROR BUDGET AND THE 90/90 CRITERION (I and II)

2.2 ASSESSMENT OF PRODUCTION ESTIMATION (I and II)

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5.2.1 SPECIAL STUDIES RELATED TO CLASSIFICATION ERROR (I and II)

5.2.1.1 Fourteen-AI Analysis (I)

5.2.1.2 Four-AI Analysis (I)

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[1] I indicates the section contains material relevant to Phase I and II indicates the section contains material relevant to Phase II.

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5.2.1.6 Spring Wheat Blind Site Investigations (II)

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5.2.1.8 Segment-Level Comparisons of CAMS Estimates with USDA/SRS County Estimates (I)

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5.2.1.10 Adjustable Crop Calendar (II)

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APPENDIX B — OUTLINE OF THE FINAL AA REPORT

APPENDIX B

USDA/ASCS INSTRUCTIONS FOR LACIE SEGMENT INVENTORY

INSTRUCTIONS

FOR

LACIE SEGMENT INVENTORY

June 7, 1976

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I. Introduction

A. Background

The LACIE (Large Area Crop Inventory Experiment) is an interagency experiment in the use of Landsat (formerly called Earth Resources Technology Satellite) and meteorological data to identify and inventory crop production. Participating agencies include the Department of Agriculture, the National Aeronautics and Space Administration, and the National Oceanic and Atmospheric Administration. Within the Department of Agriculture, participating agencies are the Agricultural Stabilization and Conservation Service, Economic Research Service, Foreign Agricultural Service, Agricultural Research Service, Soil Conservation Service, and Statistical Reporting Service. The overall general objectives of the LACIE are to determine utility and cost effectiveness of satellite and surface derived data sources to monitor large area crop (wheat) production and assess the impact of agricultural and meteorological conditions on production estimates. The utility of the information produced will be evaluated on the basis of its objectivity, timeliness, accuracy, and its expected value for policy and program decision making.

LACIE reports are based on data extracted from 5 x 6 mile segments that have been randomly placed throughout the wheat producing region of the United States. In order to determine our accuracy, it is necessary that we know what is actually in our sample segment. The information requested for the segment that has been identified and forwarded to you is essential for a successful evaluation of the project. The enclosed color prints have been obtained only over the selected site in your county to support ground data collection.

B. Authority

The USDA LACIE Project Manager has requested that the Agricultural Stabilization and Conservation Service provide this function and they have accepted the assignment. You should have already gotten an authorization from your State office concerning this task. If you have not, you should contact them at once.

C. Requirements of the ASCS County Office

You are being asked to do the following:

1. Review the set of instructions.
2. Visit the segment location and identify the land uses, even if the segment falls outside your county.
3. Check over your work and return the completed inventory as soon as possible.

II. Data Collection Procedures

A. Supplies

1. Color infrared print or prints.
2. Mylar overlay.
3. Topographic map with segment location.

4. Standard crop key.

5. Crop stage development key.

6. Evaluation form.

7. Return post card and return mailing tube label.

B. In some cases, all of the segment will not be covered by the photo. Complete the survey for that portion outlined on the photo.

C. Procedures

1. You are required to identify all fields within the segment boundaries using codes as indicated on the attached crop key (see attached LACIE segment for classification).

2. Use ball point pen for all coding directly on the mylar.

3. The photos are provided as a base for field pattern and references.

   a. All field identification should be based on actual ground conditions on the day that you visit the segment.

   b. If there are any differences between the photo and the ground, then footnote each field that is different and explain on evaluation form.

   c. If any fields have been harvested at the time of your visit, place a __/H after the crop code.

   d. If any fields have not been harvested at the time of your visit, and from your observations appear to be abandoned, place a __/A after the crop code, footnote, and explain.

4. Use the evaluation form for all comments on any unusual crop condition or practice (irregular, replanting, drought, etc.).

5. If there are any crops in the segment for which there is no code, select an unused symbol and indicate its meaning on the evaluation form.

6. Assess the average wheat crop stages while completing the segment inventory and enter it on the evaluation form upon completion.

III. JSC Contact

A. If there are any problems, contact the person listed below.

B. Review procedures and crop key before going into the field and contact the Johnson Space Center if there are any questions.

Bobby E. Spiers, TF4
U.S. Department of Agriculture/ASCS
NASA - Johnson Space Center
Large Area Crop Inventory Experiment
Houston, TX 77058

Phone: Commercial - A/C 713-483-4623
FTS - 525-4623

IV. Due Date and Mailing Procedures

A. Upon receipt of data from the Johnson Space Center, complete the enclosed post card and return it to JSC.

B. Field information should be collected within 10 days after receipt of material by your office, if at all possible.

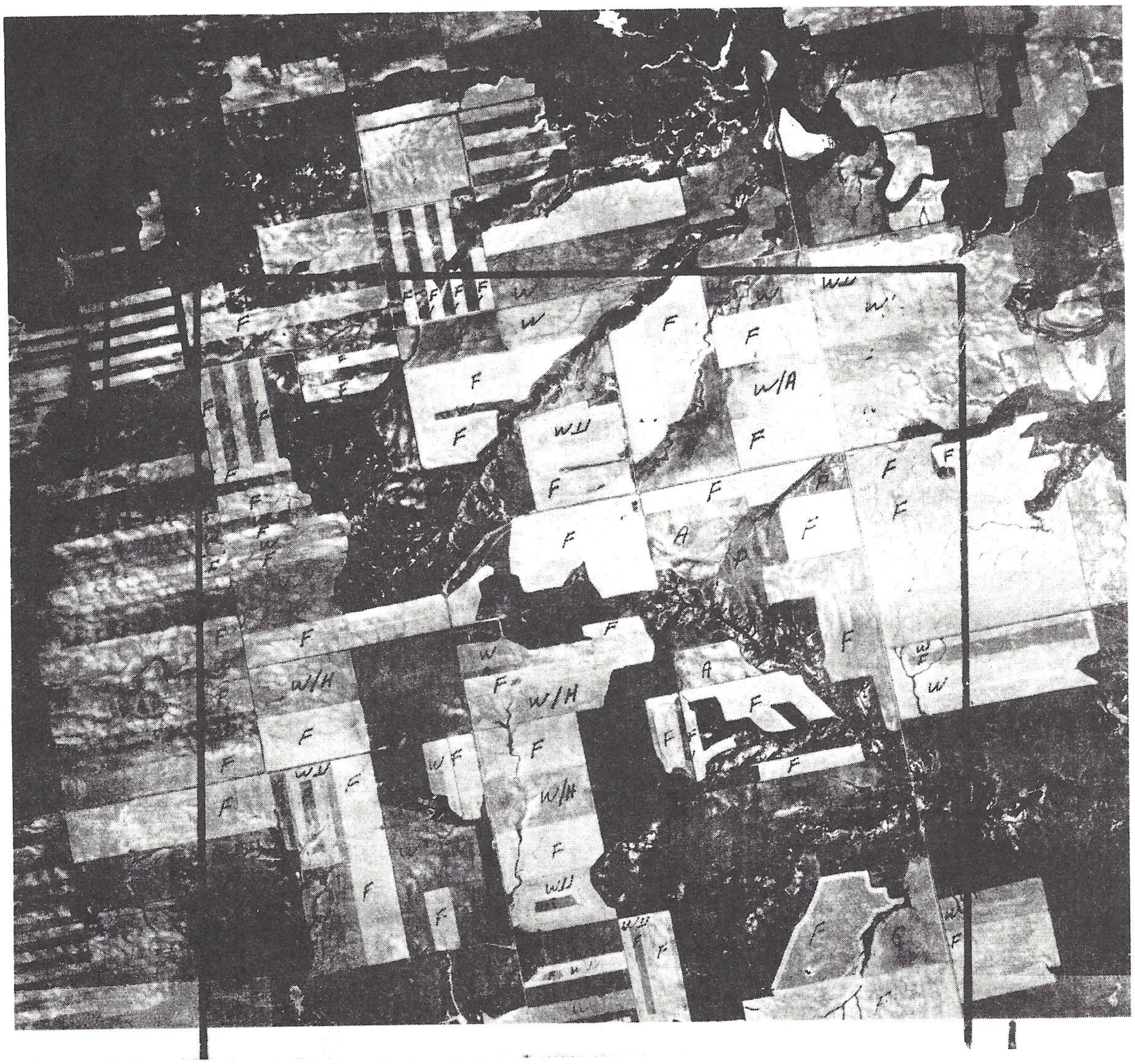
1. Upon completion of field survey, fill out evaluation form and return with photos.

2. Return all material (maps and photos) in the same mailing tube you received data in, using the provided return label.

C. Thank you for your cooperation and effort in assisting LACIE in this vital area of the experiment.

<u>SAMPLE SEGMENT</u>

With Photo and Mylar
(Not to Scale)



<u>Sample</u>: W/A These were winter wheat fields but are currently being plowed under due to the effects of drought.

STANDARD CROP KEY

KEY	CROP TYPE
W	Winter Wheat
SW	Spring Wheat
F	Fallow
G	Grass (not cut for hay and no fence)
H	Hay (any visible signs of hay activities)
A	Alfalfa
P	Pasture
C	Corn
SF	Safflower
SU	Sunflower
SG	Sudan grass
SR	Sorghum
SY	Soybeans
SB	Sugar beets
FX	Flax
T	Trees
R	Rye
B	Barley
X	Homestead - nonag, lakes, ponds, etc.
BN	Beans
O	Oats
(Crop)/H	Crop has been harvested
(Crop)/A	Crop has been abandoned; footnote and explain

1. If there are crops in segment for which there is no code, select an unused symbol and indicate its use on the evaluation form.
2. Use standard key for all identification.
3. Use ball point pen for all coding on mylar.

CROP STAGE KEY

CROP STAGE KEY	STAGE	DESCRIPTION
1.0	Planted	Seed was put in the ground.
2.0	Emerged	When one leaf per plant is visible.
3.0	Jointed	Defined as when the first node of the stem is visible.
4.0	Heading	Defined as the stage when the base of the rachis (or head) reached the same height as the ligule (or base of the shot leaf).
5.0	Soft Dough	At this stage the crop is starting to turn color. The kernals can be easily deformed when pressed between the fingers, but no "milk" or liquid should exude under such pressure.
6.0	Hard Dough	The kernals readily part from the head. The grain is firm and though it may be dented by pressure of the thumbnail, it is not easily crushed. The characteristic color of the grain has become more distinct. The leavers are brown, dry, and shrunken. Wheat in this stage may be swathed in some areas.
7.0	Harvested or Harvestable	Straw is brittle and dull yellow at this stage. The grain (if not harvested yet) is hard and breaks into fragments when crushed.

EVALUATION FORM

Segment No.: ______ County: ______________ State: ____________

Name: ________________________________ Date: ____________

Man-Hours Required to Complete Survey: ________________________

I. Based on your assessment of the development of wheat in the segment while completing the survey, what is the average wheat stage for the segment? See attached Crop Stage Key. Is the crop development this year in the segment normal, ahead, or behind as compared to previous years? Explain. Enter Crop Stage: ________________________

II. Comments, footnotes, and additional crop key used:

III. Comments on the effects of drought and/or winterkill:

IV. Comments and recommendations for improving these procedures for future surveys:

APPENDIX C

ACCURACY ASSESSMENT METHODOLOGY

NOTE: This appendix is being rewritten to incorporate revised methods of computing variances and CV's. The new version will appear in the Fourth Interim Report.

APPENDIX C

ACCURACY ASSESSMENT METHODOLOGY

CONTENTS

SYMBOLS

A_j	true wheat acreage in the *jth* CRD.
B	bias.
b_i	blind-site wheat proportions from ground truth.
C_α	percentage point of the standard normal distribution at the α-level of significance.
COV	covariance.
CV	coefficient of variation.
$\hat{}$	estimate.
$E\left(\varepsilon_{c_j}\right)$	expected value of ε_{c_j}.
$E\left(\varepsilon_{s_j}\right)$	expected value of ε_{s_j}.
$\Rightarrow$	implied statement.
n	number of samples.
N	total number of CRD's in the zone.
Pr	probability.
V	variance.
W	true wheat production.
W_0	USDA/SRS value for wheat production.
$\hat{W}_j$	production estimate for the *jth* CRD.
X_i	county wheat proportions from the 1969 Agricultural Census.
Y	true wheat yield.
Y_i'	LACIE wheat proportion estimate from the *ith* blind site.

Y_j	true wheat yield in the *jth* CRD.
Z	$\frac{\hat{W} - (W + B)}{\sigma_{\hat{W}}}$
α	level of significance.
ε_{c_j}	error resulting from classification.
ε_{s_j}	error resulting from sampling.
ε_{W_j}	production estimation error.
ε_{Y_j}	yield estimation error.
σ_c^2	true variance of classification error.
$\sigma_{c_j}^2$	true variance of classification error in the *jth* CRD.
σ_s^2	true variance of sampling error.
$\sigma_{s_j}^2$	true variance of sampling error in the *jth* CRD.
$\sigma_{W_j}^2$	true variance of production estimation error in the *jth* CRD.
$\sigma_{Y_j}^2$	true variance of yield estimation error in the *jth* CRD.

1. INTRODUCTION

This appendix contains a description of methods to be used in (i) determining if the LACIE production estimate is meeting the 90-90 criterion and (ii) estimating various error components.

In section 3, it is shown that the 90-90 criterion will be satisfied if the CV for the production estimate at the U.S. Great Plains level, $CV(\hat{W})$, is less than a certain upper bound. This is the method used by AA to determine if the 90-90 criterion is being met. The models and assumptions used in the calculation of $CV(\hat{W})$ are described in section 2 of this appendix.

The methods of estimating error components are set out in section 4, and the effects of various error components on the production estimate are described in section 5.

The general statistical models proposed in this report express merely the functional relationship among the estimates, the true values of the estimates, and the error components of the estimates. The detailed description of the LACIE operational models and methodologies, such as acreage aggregation and yield prediction, may be obtained from the CAS and YES requirements documents (refs. 1, 2).

The assumptions made in the models are those which have been made in the LACIE Phase II operational system. The models are subject to modification to incorporate the new algorithms when they become officially available for the LACIE operational system.

2. GENERAL STATISTICAL MODELS

In this section, the statistical models for the acreage and yield estimates are presented, and these estimates are then incorporated into a model for the production estimate. The variance (V) and CV of each estimate are derived in a general form based on each formulated model and the corresponding assumptions.

2.1 ACREAGE

The statistical model for the estimate of wheat acreage is formulated as follows. Let N be the total number of CRD's in the zone under investigation and let $\hat{A}_j$ be the estimate of the true wheat acreage, A_j, in the *jth* CRD. Then the general statistical model for the acreage estimate in the *jth* CRD is given by

$$\hat{A}_j = A_j + \varepsilon_{c_j} + \varepsilon_{s_j} \tag{1}$$

for $j = 1,2,\cdots,N$, where ε_{c_j} and ε_{s_j} are the errors resulting from classification and sampling, respectively. The following assumptions are made concerning these errors.

1. ε_{c_j} is a random variable with mean zero and unknown variance $\sigma^2_{c_j}$; that is,

$$E\left(\varepsilon_{c_j}\right) = 0 \quad \text{and} \quad V\left(\varepsilon_{c_j}\right) = \sigma^2_{c_j} \tag{2}$$

   where $E\left(\varepsilon_{c_j}\right)$ = expected value of ε_{c_j}.

2. ε_{c_j} and ε_{c_i} are uncorrelated, $i \neq j$, so that $COV\left(\varepsilon_{c_j}, \varepsilon_{c_i}\right) = 0$, where $COV\left(\varepsilon_{c_j}, \varepsilon_{c_i}\right)$ is the covariance of ε_{c_j} and ε_{c_i}.

3. ε_{s_j} is also a random variable with mean zero and unknown variance $\sigma^2_{s_j}$; that is,

$$E\left(\varepsilon_{s_j}\right) = 0 \qquad \text{and} \qquad V\left(\varepsilon_{s_j}\right) = \sigma^2_{s_j} \tag{3}$$

4. ε_{s_j} and ε_{s_i} are uncorrelated, $i \neq j$, so that $COV\left(\varepsilon_{s_j}, \varepsilon_{s_i}\right) = 0$.

Thus, $E(\hat{A}_j) = A_j$ ($\Rightarrow \hat{A}_j$ is an unbiased estimator of A_j),

$$V(\hat{A}_j) = \sigma^2_{s_j} + \sigma^2_{c_j} \qquad \text{for } j = 1,2,\cdots,N \tag{4}$$

and

$$COV(\hat{A}_i, \hat{A}_j) = 0 \qquad \text{for all } i \neq j \tag{5}$$

Consequently, the CV of the acreage estimate, $CV(\hat{A}_j)$, for the *jth* CRD is given by

$$CV^2(\hat{A}_j) = \frac{V(\hat{A}_j)}{A_j^2}$$

$$= \frac{\sigma^2_{c_j}}{A_j^2} + \frac{\sigma^2_{s_j}}{A_j^2}$$

$$= \frac{\sigma^2_{c_j}}{\sigma^2_{c_j} + \sigma^2_{s_j}} CV^2(\hat{A}_j) + \frac{\sigma^2_{s_j}}{\sigma^2_{c_j} + \sigma^2_{s_j}} CV^2(\hat{A}_j)$$

$$= CV^2(\hat{A}_j|c) + CV^2(\hat{A}_j|s) \tag{6}$$

where

$CV(\hat{A}_j|c)$ = the CV of the acreage estimate resulting from classification error.

$CV(\hat{A}_j|s)$ = the CV of the acreage estimate resulting from sampling error.

Since the acreage estimate $\hat{A}$ for zone is

$$\hat{A} = \sum_{i=1}^{N} \hat{A}_j \tag{7}$$

under the assumption in equation (5), the variance of $\hat{A}$ is given by

$$V(\hat{A}) = \sum_{i=1}^{N} V(\hat{A}_j)$$

$$= \sigma_c^2 + \sigma_s^2 \tag{8}$$

where $\sigma_c^2 = \sum_{j=1}^{N} \sigma_{c_j}^2$ and $\sigma_s^2 = \sum_{j=1}^{N} \sigma_{s_j}^2$.

Thus,

$$CV^2(\hat{A}) = \frac{\sigma_c^2}{A^2} + \frac{\sigma_s^2}{A^2}$$

$$= CV^2(\hat{A}|c) + CV^2(\hat{A}|s) \tag{9}$$

2.2 YIELD

The LACIE Phase II operational yield model was formulated on a regional basis. The Phase II operational procedure implements this model at the district and zone levels to generate the yield estimates and variances of yield estimates for the district and zone, respectively.

The following statistical yield model is formulated according to the LACIE Phase II procedure. It reflects only the relationship between the estimate and the true value and the necessary assumptions in the model. Let $\hat{Y}_j$ be the yield estimate for the true yield Y_j of the *jth* CRD. The model may be written as

$$\hat{Y}_j = Y_j + \varepsilon_{Y_j} \tag{10}$$

where ε_{Y_j} is a yield error predominantly from equational error. The assumptions for the model are given as follows.

1. ε_j is a random variable with mean zero and unknown variance $\sigma^2_{Y_j}$; that is,

$$E\left(\varepsilon_{Y_j}\right) = 0 \tag{11}$$

   and

$$V\left(\varepsilon_{Y_j}\right) = \sigma^2_{Y_j} \tag{12}$$

2. ε_{Y_i} and ε_{Y_j} are uncorrelated, $i \neq j$, so that

$$COV\left(\varepsilon_{Y_i},\varepsilon_{Y_j}\right) = 0 \tag{13}$$

   Thus,

$$E(\hat{Y}_j) = Y_j \tag{14}$$

$$V(\hat{Y}_j) = \sigma^2_{Y_j} \tag{15}$$

   and $\hat{Y}_i$ and $\hat{Y}_j$, $i \neq j$, are uncorrelated.

2.3 PRODUCTION

Let $\hat{W}_j$ be the estimate of the true production W_j for the *jth* CRD. The statistical model for the production estimate is formulated as $\hat{W}_j = W_j + \varepsilon_{W_j}$ for $i = 1,2,\cdots,N$. The production estimation error ε_{W_j} may be shown as a function of sampling, classification, and yield errors. In particular, by derivation,

$$\hat{W}_j = \hat{A}_j \hat{Y}_j$$

$$= \left(A_j + \varepsilon_{c_j} + \varepsilon_{s_j}\right)\left(Y_j + \varepsilon_{Y_j}\right)$$

$$= A_j Y_j + \varepsilon_{c_j} Y_j + \varepsilon_{s_j} Y_j + A_j \varepsilon_{Y_j} + \varepsilon_{c_j} \varepsilon_{Y_j} + \varepsilon_{s_j} \varepsilon_{Y_j} \quad (16)$$

It follows that

$$\varepsilon_{W_j} = \varepsilon_{c_j} Y_j + \varepsilon_{s_j} Y_j + A_j \varepsilon_{Y_j} + \left(\varepsilon_{c_j} + \varepsilon_{s_j}\right) \varepsilon_{Y_j} \quad (17)$$

The assumption which is made for deriving the variance of production in LACIE Phase II is that

$$E\left[\left(\varepsilon_{c_j} + \varepsilon_{s_j}\right)\varepsilon_{Y_j}\right] = E\left(\varepsilon_{c_j} + \varepsilon_{s_j}\right) E\left(\varepsilon_{Y_j}\right)$$

which implies that $\quad COV(\hat{A}_j, \hat{Y}_j) = 0 \quad (18)$

A further assumption, which is not immediately necessary and will be recalled and discussed when used, is that the production error ε_{W_j} is normally distributed with mean zero and unknown variance $\sigma^2_{W_j}$; that is,

$$\varepsilon_{W_j} \sim N\left(0, \sigma^2_{W_j}\right) \quad (19)$$

Under assumptions in equations (2), (3), (11), and (18), the following results are obtained from equation (17).

$$E\left(\varepsilon_{W_j}\right) = 0$$

That is, $\quad E(\hat{W}_j) = W_j \quad (20)$

By taking the variances of both sides of equation (16), one obtains: $V(\hat{W}_j) = Y_j^2 V(\hat{A}_j) + A_j^2 V(\hat{Y}_j) + V(\hat{A}_j)V(\hat{Y}_j)$. It is noteworthy that the unbiased estimator for $V(\hat{W}_j)$, $\hat{V}(\hat{W}_j)$, is given by

$$\hat{V}(\hat{W}_j) = \hat{Y}_j^2 \hat{V}(\hat{A}_j) + \hat{A}_j^2 \hat{V}(\hat{Y}_j) - \hat{V}(\hat{A}_j)\hat{V}(\hat{Y}_j) \qquad (21)$$

where $\hat{Y}_j$, $\hat{A}_j$, $\hat{V}(\hat{Y}_j)$, and $\hat{V}(\hat{A}_j)$ are the estimates of Y_j, A_j, $V(\hat{Y}_j)$, and $V(\hat{A}_j)$, respectively; and since yield variance is underestimated at the district level, the production variance obtained from equation (21) is underestimated also in the LACIE Phase II system.

The CV of production at the nine-state level is given by

$$CV(\hat{W}) = \frac{\left[\sum_{j=1}^{N} \hat{V}(\hat{W}_j)\right]^{1/2}}{\hat{W}}$$

$$\hat{W} = \sum_{j=1}^{N} \hat{W}_j \qquad (22)$$

3. ERROR BUDGET

This section describes the method of determining the upper bound on the CV of production allowed by the 90-90 criterion. The 90-90 criterion can be expressed by the following probability statement.

$$\Pr[|\hat{W} - W| \le 0.1W] \ge 0.90$$

$$\Rightarrow \Pr[-0.1W \le \hat{W} - W \le 0.1W] \ge 0.90$$

$$\Rightarrow \Pr[-0.1W - B \le \hat{W} - (W + B) \le 0.1W - B] \ge 0.90$$

$$\Rightarrow \Pr\left[\frac{-0.1W - B}{\sigma_{\hat{W}}} \le \frac{\hat{W} - (W + B)}{\sigma_{\hat{W}}} \le \frac{0.1W - B}{\sigma_{\hat{W}}}\right] \ge 0.90 \qquad (23)$$

Where the bias $B = E(\hat{W}) - W$ and $\sigma_{\hat{W}} = [V(\hat{W})]^{1/2}$. Under the assumption stated in equation (19), equation (23) becomes

$$\Pr\left[\frac{\frac{-0.1W - B}{W + B}}{CV(\hat{W})} \le Z \le \frac{\frac{0.1W - B}{W + B}}{CV(\hat{W})}\right] \ge 0.90 \qquad (24)$$

$$\Rightarrow \Pr\left[\frac{-0.1 - \frac{0.9B}{B + W}}{CV(\hat{W})} \le Z \le \frac{0.1 - \frac{1.1B}{B + W}}{CV(\hat{W})}\right] \ge 0.90 \qquad (25)$$

where $CV(\hat{W}) = \frac{\sigma_{\hat{W}}}{E(\hat{W})}$ and $Z = \frac{\hat{W} - (W + B)}{\sigma_{\hat{W}}}$ is the relative error of the proportion estimate (relative to $\sigma_{\hat{W}}$) having standard normal distribution; that is, $Z \sim N(0,1)$.

NOTE: Since a large number of samples are utilized for the LACIE estimates, the distribution of the relative error approximates standard normal distribution. Thus, the assumption of normality for ε_{W_j} may be eliminated in the LACIE study. The assumption of equation (19) is made for developing equation (25) without the consideration of sample sizes.

If $\hat{W}$ is an unbiased estimator of W, then B = 0 and equation (25) reduces to

$$\Pr\left[\frac{-0.1}{CV(\hat{W})} \le Z \le \frac{0.1}{CV(\hat{W})}\right] \ge 0.90$$

or

$$\Pr\left[|Z| \le \frac{0.1}{CV(\hat{W})}\right] \ge 0.90 \qquad (26)$$

Thus, it follows that $\frac{0.1}{CV(\hat{W})} = 1.645$, which implies that $CV(\hat{W}) = 0.06$ is the maximum CV of the production estimate that can be tolerated for the production estimate if the 90-90 criterion is to be satisfied.

Since only one observation for $\hat{W}$ occurs at the nine-state level in LACIE Phase II, the bias B cannot be accurately estimated. However, a confidence interval might be computed to determine the upper and lower limits for B. If it is assumed that the USDA/SRS value for wheat production, W_0, is the true value, then

$$Z = \frac{\hat{W} - (W_0 + B)}{\sigma_{\hat{W}}} \sim N(0,1)$$

and

$$\Pr\left[-C_\alpha \le \frac{\hat{W} - (W_0 + B)}{\sigma_{\hat{W}}} \le C_\alpha\right] = 1 - \alpha \qquad (27)$$

where α is the known significance level, and C_α is the percentage point of the standard normal distribution at the α-level.

For the given α, $\hat{W}$, W_0, and $\sigma_{\hat{W}}$, the confidence limits for the bias can be obtained directly from equation (27).

4. ERROR COMPONENT ESTIMATION

The formulas for estimating the various error components for the LACIE Phase II AA are presented in this section.

4.1 ACREAGE ESTIMATION ERROR COMPONENTS

In the acreage model, equation (1), the two major error components are derived from classification and sampling. If $\{b_i\}_{i=1}^{n}$ represents the blind-site wheat proportions from ground truth, and $\{X_i\}_{i=1}^{n}$ represents the county wheat proportions from the 1969 Agricultural Census, then the classification error σ_c^2 is estimated by

$$\hat{\sigma}_c^2 = \frac{1}{n} \sum_{i=1}^{n} (Y_i' - b_i)^2 \qquad (28)$$

where Y_i' is the LACIE wheat proportion estimate from the *ith* blind site and n is the number of samples. The sampling error σ_s^2 is estimated by regressing b_i on X_i to obtain

$$\hat{\sigma}_s^2 = \frac{\sum_{i=1}^{n} (\hat{b}_i - b_i)^2}{n - 2} \qquad (29)$$

where $\hat{b}_i$ is the predicted value of b_i from the regression.

4.2 PRODUCTION ESTIMATION ERROR COMPONENTS

Since production is the product of acreage and yield, the acreage and the yield errors comprise the production error. The formulas for estimating these error components are given at the zone or higher level in this section.

4.2.1 ACREAGE

The acreage error (variance) for the zone or higher level was shown in equation (8), and assumptions were made and discussed in section 2.1.

4.2.2 YIELD

The yield error is more complicated and must be expressed in terms of variances for acreage and production estimates. The yield variance estimate for the zone or higher level, as given in the CAS software requirements document (ref. 3), is as follows.

$$\hat{V}(\hat{Y}) = \frac{\hat{Y}^2}{S}\left(\frac{\sum_{i=1}^{S} \hat{V}(\hat{W}_i)}{\left(\sum_{i=1}^{S} \hat{W}_i\right)^2} + \frac{\sum_{i=1}^{S} \hat{V}(\hat{A}_i)}{\left(\sum_{i=1}^{S} \hat{A}_i\right)^2} - 2\left\{\frac{\sum_{i=1}^{S}\left[\hat{Y}_i\hat{V}(\hat{A}_i)\right]}{\left(\sum_{i=1}^{S} \hat{A}_i\right)\left(\sum_{i=1}^{S} \hat{W}_i\right)}\right\}\right)$$

where

$\hat{Y}$ = yield estimate for the area.

$\hat{W}_i$ = production estimate for the *ith* CRD.

$\hat{V}(\hat{W}_i)$ = estimated variance of $\hat{W}_i$.

$\hat{A}_i$ = acreage estimate for the *ith* CRD.

$\hat{V}(\hat{A}_i)$ = estimated variance of $\hat{A}_i$.

$\hat{Y}_i$ = yield estimate for the *ith* CRD.

S = number of CRD's within the area.

An approximate formula for $\hat{V}(\hat{Y})$ can be derived in the following manner.

Let the statistical model for yield estimation at the zone or higher level be

$$\hat{Y} = Y + \varepsilon_Y \qquad \text{with} \qquad E(\varepsilon_Y) = 0 \tag{30}$$

where $\hat{Y}$ is the estimate of the true yield Y at this level, then

$$V(\hat{Y}) = V(\varepsilon_Y) = E\left(\varepsilon_Y^2\right)$$

$$= E[(\hat{Y} - Y)^2]$$

$$= E\left[\frac{\hat{A}\hat{Y} - \hat{A}Y}{\hat{A}}\right]^2 \tag{31}$$

If the sample size is large, $\hat{A}$ should not differ greatly from A. The approximation consists of replacing $\hat{A}$ by A in the demoninator of equation (32). This gives

$$V(\hat{Y}) \cong \frac{1}{A^2}E[\hat{W} - \hat{A}Y]^2 \qquad (32)$$

Since it was assumed $E(\hat{W}) = W$, $E(\hat{A}) = A$, and $COV(\hat{A},\hat{Y}) = 0$, equation (32) can be written as follows.

$$V(\hat{Y}) \cong \frac{1}{A^2}E(\hat{W}^2 + \hat{A}^2Y^2 - 2\hat{W}\hat{A}Y)$$

$$= \frac{1}{A^2}\{V(\hat{W}) + Y^2V(\hat{A}) - 2Y[COV(\hat{W}\hat{A})]\} \qquad (33)$$

Since

$$COV(\hat{W}\hat{A}) = E(\hat{W}\hat{A}) - E(\hat{W})E(\hat{A})$$

$$= E(\hat{A}^2)Y - A^2Y$$

$$= [V(\hat{A}) + E^2(\hat{A})]Y - A^2Y$$

$$= YV(\hat{A}) \qquad (34)$$

equation (33) can be written as

$$V(\hat{Y}) \cong \frac{1}{A^2}[V(\hat{W}) - Y^2V(\hat{A})]$$

$$= \left[\frac{Y^2V(\hat{W})}{A^2Y^2} - \frac{V(\hat{A})Y^2}{A^2}\right]$$

$$= Y^2\left[\frac{V(\hat{W})}{W^2} - \frac{V(\hat{A})}{A^2}\right] \qquad (35)$$

Consequently, this gives $CV^2(\hat{Y}) \cong CV^2(\hat{W}) - CV^2(\hat{A})$ or $CV^2(\hat{W}) \cong CV^2(\hat{Y}) + CV^2(\hat{A})$.

The estimated variance for the yield estimate, $\hat{V}(\hat{Y})$, may be obtained by replacing Y, W, A, $V(\hat{W})$, and $V(\hat{A})$ in equation (35) with the estimators $\hat{Y}$, $\hat{W}$, $\hat{A}$, $\hat{V}(\hat{W})$, and $\hat{V}(\hat{A})$, respectively. This gives

$$\hat{V}(\hat{Y}) \cong \hat{Y}^2 \left[\frac{\hat{V}(\hat{W})}{\hat{W}^2} - \frac{\hat{V}(\hat{A})}{\hat{A}^2} \right] \tag{36}$$

Values for $\hat{V}(\hat{W})$, $\hat{W}$, $\hat{V}(\hat{A})$, and $\hat{A}$ at the zonal (state) level are given in the CMR's.

5. EFFECT OF ERRORS IN ACREAGE AND YIELD ON THE VARIANCE OF THE PRODUCTION ESTIMATE

Although the production error components are the acreage and yield errors, the production error at the zone or higher level will not be computed directly from these component errors at the same level. The effect of these errors on the production error will be determined by omitting the corresponding terms in the formulas for the variance of the production estimate given in section 2.3.

1. Production variance without acreage error: The variance is estimated as in equation (21), except that the first term is omitted; that is,

$$\hat{V}'(\hat{W}) = \sum_j \left[\hat{A}_j^2 \hat{V}(\hat{Y}_j) - \hat{V}(\hat{A}_j)\hat{V}(\hat{Y}_j) \right] \tag{37}$$

2. Production variance without yield error: It is estimated as in equation (21), except that the second term is omitted; that is,

$$\hat{V}''(\hat{W}) = \sum_j \left[\hat{Y}_j^2 \hat{V}(\hat{A}_j) - \hat{V}(\hat{A}_j)\hat{V}(\hat{Y}_j) \right] \tag{38}$$

3. Production variance without sampling error: Equation (21) is used to estimate this variance, except that

$\hat{V}(\hat{A}_j)$ is replaced by $\frac{\hat{\sigma}_c^2}{\hat{\sigma}_c^2 + \hat{\sigma}_s^2}\hat{V}(\hat{A}_j)$; that is,

$$\hat{V}_1(\hat{W}) = \sum_j \left[\frac{\hat{\sigma}_c^2}{\hat{\sigma}_c^2 + \hat{\sigma}_s^2}\hat{Y}_j^2\hat{V}(\hat{A}_j) + \hat{A}_j^2\hat{V}(\hat{Y}_j) - \frac{\hat{\sigma}_c^2}{\hat{\sigma}_c^2 + \hat{\sigma}_s^2}\hat{V}(\hat{A}_j)\hat{V}(\hat{Y}_j) \right] \tag{40}$$

4. Production variance without classification error: The variance is estimated as in equation (21), except that $\hat{V}(\hat{A}_j)$ is replaced by $\frac{\hat{\sigma}_s^2}{\hat{\sigma}_c^2 + \hat{\sigma}_s^2}\hat{V}(\hat{A}_j)$; that is,

$$\hat{V}_2(\hat{W}) = \sum_j \left[\frac{\hat{\sigma}_s^2}{\hat{\sigma}_c^2 + \hat{\sigma}_s^2}\hat{Y}^2\hat{V}(\hat{A}_j) + \hat{A}_j^2\hat{V}(\hat{Y}_j) - \frac{\hat{\sigma}_s^2}{\hat{\sigma}_c^2 + \hat{\sigma}_s^2}\hat{V}(\hat{A}_j)\hat{V}(\hat{Y}_j) \right] \tag{41}$$

The CV's corresponding to the variances in equations (37) through (41) are given by

$$CV_L(\hat{W}) = \frac{\left[\hat{V}_L(\hat{W})\right]^{1/2}}{\hat{W}} \quad \text{for} \quad L = 1,2,3,4 \tag{42}$$

If the reduction in the production CV obtained by omitting the acreage error is greater than that obtained by omitting the yield error [that is, if $CV_1(\hat{W}) < CV_2(\hat{W})$], this implies that the acreage estimate contributes more error to $CV(\hat{W})$ than the yield estimate. A similar comparison can be made in assessing the contributions of the classification and sampling errors to $CV(\hat{W})$.

APPENDIX D

CROP GROWTH STAGE INVENTORY FORM

Check one:

☐ Spring Wheat

☐ Winter Wheat

Crop Year______

GROWTH STAGE DATES FOR 10% DEVELOPMENT

MONTH AND DAY OF MONTH

ITS SEG. NO.	CRD #	PLANTING DATE[1]	EMERGENCE DATE[1]	JOINTING DATE[2]	HEADING DATE[2]	SOFT DOUGH DATE[3]	RIPE DATE[4]	HARVEST DATE[5]

[1] Date at which 10% of fields in CRD were planted or emerged, respectively.

[2] Date at which 10% of fields in CRD had begun to joint or head, respectively.

[3] Date at which 10% of fields in CRD had begun to enter soft dough stage (turning color to greenish-yellow to yellow).

[4] Date at which 10% of fields in CRD are ripe (hard dough) stage or when they were swathed. (Indicated swathed if applicable).

[5] Date at which 10% of fields in CRD have been harvested either as standing grain or out of swath.

Check one:

☐ Spring Wheat

☐ Winter Wheat

Crop Year______

GROWTH STAGE DATES FOR 50% DEVELOPMENT

MONTH AND DAY OF MONTH

ITS SEG. NO.	CRD #	PLANTING DATE[1]	EMERGENCE DATE[1]	JOINTING DATE[2]	HEADING DATE[2]	SOFT DOUGH DATE[3]	RIPE DATE[4]	HARVEST DATE[5]

[1] Date at which 50% of fields in CRD were planted or emerged, respectively.

[2] Date at which 50% of fields in CRD had begun to joint or head, respectively.

[3] Date at which 50% of fields in CRD had begun to enter soft dough stage (turning color to greenish-yellow to yellow).

[4] Date at which 50% of fields in CRD are ripe (hard dough) stage or when they were swathed. (Indicated swathed if applicable).

[5] Date at which 50% of fields in CRD have been harvested either as standing grain or out of swath.

Check one:

☐ Spring Wheat

☐ Winter Wheat

Crop Year______

GROWTH STAGE DATES FOR 90% DEVELOPMENT

MONTH AND DAY OF MONTH

ITS SEG. NO.	CRD #	PLANTING DATE[1]	EMERGENCE DATE[1]	JOINTING DATE[2]	HEADING DATE[2]	SOFT DOUGH DATE[3]	RIPE DATE[4]	HARVEST DATE[5]

1 Date at which 90% of fields in CRD were planted or emerged, respectively.

2 Date at which 90% of fields in CRD had begun to joint or head, respectively.

3 Date at which 90% of fields in CRD had begun to enter soft dough stage (turning color to greenish-yellow to yellow).

4 Date at which 90% of fields in CRD are ripe (hard dough) stage or when they were swathed. (Indicated swathed if applicable).

5 Date at which 90% of fields in CRD have been harvested either as standing grain or out of swath.