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LARGE AREA CROP INVENTORY EXPERIMENT (LACIE)

NASA NOAA USDA

LACIE PHASE III ACCURACY ASSESSMENT: FINAL REPORT

NASA
National Aeronautics and
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Lyndon B. Johnson Space Center
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LARGE AREA CROP INVENTORY EXPERIMENT (LACIE) PHASE III ACCURACY ASSESSMENT: FINAL REPORT

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
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PREFACE

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ACRONYMS AND ABBREVIATIONS

AA	Accuracy Assessment
ACC	adjustable crop calendar
BMTS	biometeorological time scale
CAMS	Classification and Mensuration Subsystem
CAR	CAS annual report
CAS	Crop Assessment Subsystem
CCEA	Center for Climatological and Environmental Assessment — an organization of the National Oceanic and Atmospheric Administration, Columbia, Missouri
CMR	CAS monthly report
CRD	crop reporting district
CUR	CAS unscheduled report
CV	coefficient of variation (standard deviation divided by the mean)
DO	an area of a segment "designated other" than agriculture, such as a mountain range
DU	an area of a segment "designated unidentifiable" because of clouds, cloud shadows, haze, and other obscurations
GSFC	Goddard Space Flight Center
I-100	Image-100 system
ITS	intensive test site
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 Earth at an altitude of approximately 915 kilometers; orbits Earth about 14 times a day and views the same scene at least every 18 days

LPP	LACIE performance predictor
MMT	million metric tons
MPAD	Mission Planning and Analysis Division
MSE	mean-square error
N	nonsignificant
NA	not available
NASA	National Aeronautics and Space Administration
n/M	the number of segments for which data were obtained (n) and the number of segments into which the entire state is divided (M)
NOAA	National Oceanic and Atmospheric Administration
PFC	production film converter
pixel	picture element
P1	Procedure 1
RD	relative difference = $\frac{\text{LACIE - STANDARD}}{\text{LACIE}}$
rev30	Revised, with a 30-day delay, LACIE estimate of U.S.S.R. wheat
RMSE	root mean-square error
S	significant
SD	standard deviation
USDA	U.S. Department of Agriculture
USDA/ASCS	USDA Agricultural Stabilization and Conservation Service
USDA/ESCS	Economics, Statistics, and Cooperative Service of the USDA; formerly the SRS
USDA/FAS	USDA Foreign Agricultural Service
USDA/SRS	USDA Statistical Reporting Service; merged with two other agencies to form the ESCS

USGP	U.S. Great Plains, an area encompassing the nine states of Colorado, Kansas, Minnesota, Montana, Nebraska, North and South Dakota, Oklahoma, and Texas and divided into the U.S. southern Great Plains and the U.S. northern Great Plains
USGP-7	Seven winter wheat states of the U.S. Great Plains (includes all the USGP states except North Dakota and Minnesota)
USNGP	U.S. northern Great Plains; a geographical division of the USGP, which includes the states of Minnesota, Montana, and North and South Dakota
USSGP	U.S. southern Great Plains; a geographical division of the USGP, which includes the states of Colorado, Kansas, Nebraska, Oklahoma, and Texas
YES	Yield Estimation Subsystem

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 benefit to be obtained by using remotely sensed data from the NASA land observatory satellite (Landsat) for agricultural application; 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 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 whether the procedures used are adequate to accomplish the objectives.

1.1 OBJECTIVES

The objectives of AA are as follows:

a. To determine whether the accuracy goal for the LACIE estimate of wheat production for a region or country is being met. The LACIE accuracy goal is a 90/90 at-harvest criterion for wheat production. This specifies that the at-harvest wheat production estimate for the region or country be within 10 percent of the true production with a probability of at least 0.9.

b. To determine the accuracy and reliability of early-season estimates and estimates made at regular intervals throughout a crop season prior to harvest. This includes a determination of the degree to which the 90/90 criterion is supported at these intervals during the crop season.

c. To investigate the various sources of error in the LACIE estimates of wheat production, area, and yield; to quantify and relate these error sources to causal elements in the estimation process; and to recommend procedures for reducing the error.

1.2 AA ACTIVITIES

To satisfy its objectives, AA personnel conduct several types of evaluations and present the results in monthly quick-look reports, a number of interim reports leading up to a final report, and certain special reports. The following paragraphs contain descriptions of the AA evaluations presented in the three types of reports.

1.2.1 ACTIVITIES REPORTED IN THE QUICK-LOOK REPORTS

The quick-look reports contain an AA evaluation of the LACIE estimates reported in the Crop Assessment Subsystem (CAS) monthly reports (CMR's) and the CAS unscheduled reports (CUR's). The quick-look reports are released 1 week following the release of a CMR or a CUR. The CMR's and CUR's contain the official LACIE estimates of wheat production, area, and yield and the corresponding statistics. The true wheat production, area, and yield for the particular region or country are, of course, unknown. Therefore, to ascertain the accuracy of the LACIE estimates, comparisons are made with a reference standard. In the United States, the reference standard consists of the most recent estimates (at the time of the comparison) released by the Statistical Reporting Service of the USDA (USDA/SRS).[1] In foreign countries, the reference standard consists of the most recent estimates released by the Foreign Agricultural Service of the USDA (USDA/FAS). The AA quick-look reports concompare the LACIE estimates of wheat production, area, and yield with the corresponding reference standard and significance tests of no difference at the region or country level. The relative difference (RD) calculated at the

[1] The USDA/SRS was merged with two other agencies to form the Economics, Statistics, and Cooperative Service of the USDA (USDA/ESCS) during the analysis period of this report. Data used in this report are credited to the USDA/SRS, even though some may have been from the USDA/ESCS.

zone level (or by states in the United States) is used to indicate problem areas; available blind site results are given, and an intensive test site (ITS) example is presented.

1.2.2 ACTIVITIES REPORTED IN THE INTERIM AND THE FINAL REPORTS

Interim reports are released at regular intervals throughout the crop season. They contain the results of the previous quick-look reports, a discussion of the 90/90 criterion as it applies to the region for which the LACIE estimates of wheat production are available, and the results of investigations of error sources (appendix A) in the LACIE wheat production estimate, including the blind site and ITS analyses. Any AA recommendations for improvement are also documented in the interim and final reports.

Each interim report is built upon the previous one by including data that became available during the interim period. Technical comments are solicited from various sources and are used to upgrade subsequent reports. Early-season and mid-season evaluations are presented in the first and second interim reports, late-season and at-harvest evaluations are presented in the third and fourth interim reports, and incidental investigations are given in occasional unscheduled interim reports. The fourth interim report also serves as a draft for the final report, which contains material similar to the interim reports but covering the entire year.

The above schedule was followed in Phases II and III. In Phase I, there were no interim reports, and the Phase I final report was incorporated into the Phase II final report.

1.2.3 ACTIVITIES REPORTED IN AA UNSCHEDULED REPORTS

From time to time, special investigations of interest to LACIE but not required on a regular basis are conducted and reported in AA unscheduled reports. The LACIE Phase III Unscheduled Interim AA Report was prepared to provide results while digitized ground-truth proportions for blind sites were being completed.

1.3 PROCEDURES USED IN OBTAINING LACIE PHASE III ESTIMATES

This report consists of evaluations of revised LACIE Phase III estimates of production, area, and yield for the U.S. Great Plains (USGP) region and for the U.S.S.R.; the original estimates were released in the CAS reports for LACIE Phase III. During Phase III, several changes were made in the aggregation procedures used by CAS. This final AA report presents an evaluation of the revised LACIE Phase III estimates released in the CAS annual reports (CAR's) for the USGP and the U.S.S.R. in December 1977. Estimates for each CMR of Phase III were recalculated using the methodology (see appendix A) that evolved during Phase III. The results in the CAR best represent the technology at the end of LACIE Phase III.

In LACIE Phase III, improved classification procedures were implemented. These procedures were designed to take advantage of the multitemporal differences in Landsat data and to be more automated and less labor-intensive than procedures used in LACIE Phase I or Phase II. As a result of LACIE experience through Phase II, the new procedures also identified and addressed a major problem — obtaining accurate area estimates in regions with small fields.

In the LACIE Phase III February aggregation, estimates were obtained using LACIE Phase II training field procedures, which involved using analyst-selected training fields to generate statistics for segment classification. In March, the Classification and Mensuration Subsystem (CAMS) implemented small-field procedures for processing segments. For the May and June aggregations, most of the estimates were obtained using a modified small-field procedure. This procedure involved analyst-selected, random, and 4-pixel fields which were used to start an interactive clustering algorithm and label at most 20 clusters that generate cluster statistics for segment classification. A bias correction was applied manually to the estimate to improve the estimate from machine classification and simultaneously reduce the amount of machine rework. In June 1977, the CAMS implemented a new classification procedure, Procedure 1 (P1), to eliminate the time-consuming delineation of training fields by the analyst and to increase the frequency of multitemporal classification. In the aggregations from July to December, P1 was used to obtain the new estimates. This procedure involved the use of randomly allocated dots on a systematic grid used to start an iterative clustering algorithm and label at most 60 clusters that generated cluster statistics for segment classification. A stratified areal estimate is automatically generated. Procedures using improved analyst aids (such as interpretation keys) and displays of quantitative spectral data (such as spectral aids and trajectory plots) were developed to improve the technology for identifying spring wheat directly from the Landsat data.

With the advent of the new approach, the blind site program was expanded to 212 blind sites (see appendix B) in Phase III for more detailed classification error analyses. Correct labeling at the pixel level was the key to the success of P1. Therefore, the blind site program was modified to allow a comparison of analyst pixel labels with ground-observed crop types. Ground truth was obtained from near-harvest inventories of crops on aerial photographs by the USDA Agricultural Stabilization and Conservation Service (USDA/ASCS). Subsequently, this ground-truth information was digitized and put on computer tape for comparison with Landsat imagery. During the year, many of the blind sites were deleted from the AA data base because of various problems that developed. The problems are noted in appendix B, page B-1.

The Phase III data for the blind sites are summarized in appendix C. The information related to each CAMS classification during the growing season is provided. In addition, 400-dot ground-truth proportions and a full image inventory of ground-truth proportions are listed.

The Phase II spring wheat blind site analyses indicated that a portion of the negative bias in the spring wheat proportion estimates was caused by the historical ratios of spring wheat to small grains used in reducing small-grain proportion estimates to spring wheat proportion estimates. Therefore, a task was initiated early in Phase III to develop econometric models[2] for forecasting these ratios with the intent of eliminating or reducing this bias.

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[2]The models were developed by Dwayne E. Umberger and Michael H. Proctor of the USDA LACIE Project in Columbia, Missouri.

An ITS program preceded and paralleled the blind site program. The ITS's are special nonoperational sites on which very detailed data are collected every 18 days. These ITS's are used to verify the CAMS procedure verification and are cited in the quick-look reports to illustrate particular situations encountered during the crop year. The Phase III ITS's in the United States and Canada are listed in appendix D.

The method of designating segments for spring and winter wheat production in the mixed wheat states of South Dakota and Montana is described in appendix E.

During Phase III, the suitability of proportion estimates for each LACIE sample segment was evaluated for its use in aggregation by CAS. Segments in counties where acreage estimates deviated significantly from the general trend measured in relation to the county historical acreages were rejected based on the screening procedure described in appendix F.

2. SUMMARY

LACIE Phase III results show significant improvement over Phase I and Phase II results because of better LACIE area estimation technology. Forecasts using econometric models for the ratio of wheat to small grains in spring wheat states proved to be better than forecasts using historical ratios. The new classification procedure, P1, provided results which showed that there was a major improvement over Phase II in the small-grain proportion estimates, particularly in the spring wheat area. Increased precision in classification and the achievement of the Phase III goal of a 2.3-percent sample error resulted for the first time in a total wheat area estimate for the United States for which the 90/90 hypothesis could not be rejected.

The expanded blind site program in the United States proved to be extremely useful for evaluating the area estimation technology in Phase III and is expected to be invaluable for future technology advancements. The ground data acquired and processed in Phase III were used to identify the major sources of labeling error (discussed in subsequent paragraphs). As a result, classification procedures have already been modified to acknowledge the primary sources of error and to minimize error effect.

The following sections summarize the evaluation of the LACIE Phase III estimates of wheat production, area, and yield for the U.S.S.R. and the USGP as reported in the respective CAR's.

2.1 U.S.S.R.

The results of the LACIE Phase III modified approach (defined in section 7, page 7-1) indicated that the 90/90 accuracy goal was achieved in the U.S.S.R., where the technology was able to identify the shortfall in the spring wheat crop 3 months prior to completion of harvest; similar accuracy goals were achieved in the winter wheat regions. The initial LACIE baseline total wheat production estimate of 93.1 million metric tons (MMT) in August 1977 was within 2 percent of the USDA/FAS January 28, 1978, figure of 92 MMT for the

U.S.S.R.; the LACIE final revised estimate released on January 23, 1978, of 91.4 MMT for total wheat production was within 1 percent.

Throughout 1977, several implementation problems and data processing backlogs were encountered. These problems resulted in some estimation error beyond that which would be encountered in a future, smoothly functioning operational system. Faulty data acquisition orders led to the loss of Landsat acquisitions over a portion of the U.S.S.R. winter wheat region. These problems were corrected in December 1977, and the LACIE estimates were recomputed using Landsat data assuming a 30-day processing delay operationally. The resulting estimates were released on January 23, 1978, 5 days before the final U.S.S.R. release. In a future operation, such results could be produced as early as August or September. These improved results were within 3 percent of the U.S.S.R. figures in August 1977, some 3 months before harvest.

A detailed examination of the conditions which led to the U.S.S.R. shortfall in spring wheat production and the response observed in the LACIE models provided conclusive indications that the LACIE forecast technology did indeed respond for good reason and in a timely fashion. Over most of the U.S.S.R. spring wheat regions, the growing season experienced warmer than average temperatures. These elevated temperatures led to moisture deficiencies through increased demand on available soil moisture. The potential evapotranspiration data indicated that the above-normal temperatures in the growing season seriously depleted the soil moisture supply throughout the southern portions of the U.S.S.R. spring wheat area. While the northern regions had normal to above-normal moisture in addition to these impacts, the April temperature was nearly 4° C above normal, which tended to deplete the preseason soil moisture supply.

2.2 USGP

As in Phases I and II, the final LACIE Phase III winter wheat production estimate for the USGP supports the LACIE accuracy goal. In fact, there was no significant difference between the LACIE and USDA/SRS winter wheat production estimates for the USGP for any month after May. The LACIE estimates of

USGP spring wheat production, however, were significantly different from the corresponding USDA/SRS estimates throughout Phase III; the LACIE 90/90 accuracy goal was not supported by the spring wheat production estimate because of a large underestimation. The underestimation of spring wheat production by LACIE in Phase III is attributed primarily to the underestimation of yield, although area, too, was significantly underestimated in every month except July. The 10-year test for total yield, when rerun to include the 1977 crop year, showed that the error due to yield fell outside the tolerance limits in 3 of the 10 years. This indicates that the yield estimates did not support the 90/90 accuracy goal.

When considering the total wheat production to include winter and spring wheat production values throughout the USGP, it has been determined that the 90/90 hypothesis cannot be rejected for the final LACIE total wheat USGP production estimate.

As in Phases I and II, the final LACIE winter wheat area estimate for the USGP was not significantly different at the 10-percent level from the corresponding USDA/SRS estimate. In fact, no significant difference was recorded after the August estimate. For the first time in LACIE, the resulting total wheat area estimates were not significantly different from those of the USDA/SRS. Moreover, this was true from the first estimate made in July to the end-of-the-season report. The final LACIE spring wheat area estimate for the USGP was significantly smaller than the corresponding USDA/SRS estimate, but there was great improvement in the RD of this estimate over the corresponding Phase I and Phase II estimates. This improvement of the spring wheat area estimation is attributed to the implementation of P1 and the use of econometric models to forecast the ratios of wheat to small grains.

The blind site investigations indicated better classification accuracy than in Phase II from July to the end of the crop year. The primary source of errors in classification was found to be due to mislabeling. A labeling error characterization study (ref. 1) identified and quantified the mislabeling of small grains as nonsmall grains as being due to the following.

a. Abnormal signature development caused by later planting, drought, grazing, crop rotation, plant variety, disease, and/or soil type.

b. Inability to resolve small fields using Landsat imagery.

c. A lack of Landsat acquisitions for both the postemergence and the tillering to heading stages.

In addition to providing a good understanding of the U.S. small-grain labeling accuracies, this intensive ground-truth analysis effort added confidence in the U.S.S.R. classification accuracy, since the small-grain fields in the U.S.S.R. are much larger and the small-grain signatures appear more homogeneous than in the USGP.

U.S. sampling error was calculated to be 1.9 percent for the USGP, well within the goal of 2.3 percent.

Unlike Phases I and II, the LACIE total wheat yield estimate was significantly different from the corresponding USDA/SRS estimate in every month during Phase III due to underestimates for both spring and winter wheat. The largest differences occurred in Oklahoma and Texas winter wheat yields and in Minnesota and Montana spring wheat yields. The spring wheat yield errors were apparently due to trend terms which failed to account for new varieties of wheat in Minnesota and for increased fertilizer being applied in Montana during the past 5 years. The winter wheat yield errors were due to trend terms which failed to account for more wheat acreage being fertilized in the last 3 years in Texas and Oklahoma.

The delta classifier (see section 6.10) was also evaluated by AA personnel in Phase III. It was concluded that the P1 estimator has a significantly smaller absolute error than does the delta classifier estimator and that the delta classifier estimator is unreliable as an estimator of winter small-grain proportions.

3. ASSESSMENT OF PRODUCTION ESTIMATES

An assessment of the 90/90 criterion and a comparison of LACIE and USDA/SRS production estimates for the USGP are presented in this section.

3.1 THE 90/90 CRITERION

Table 3-1 shows the production results of the 90/90 evaluation for the production estimates reviewed in this report. The method used in the 90/90 evaluation, described in appendix A, section A.3.3.4, is based on the estimated coefficient of variation (CV) and the RD for total wheat at the USGP level. [For the estimates discussed in this report for the seven winter wheat states of the USGP (USPG-7) or for the U.S. northern Great Plains (USNGP), the CV is "projected" to the USGP level (appendix A, section A.3.3.4.2); whereas the RD is assumed to be the same as at the USGP level.] These numbers are given in table 3-1, columns headed "CV" and "RD." Two RD's are reported for each estimate. One RD is as compared to the corresponding USDA/SRS monthly estimate. The second RD is as compared to the final USDA/SRS estimate. From the CV, the interval of tolerable relative bias, also given in table 3-1, is calculated. If the true relative bias is within this interval and the CV is accurate, then the estimator is a 90/90 estimator. Because the true relative bias is not known, the RD is taken as an estimate of the relative bias. If it falls within the tolerable limits for the relative bias, it is said that the estimate supports the 90/90 criterion. If the RD is outside the tolerable limits, a test is performed to determine whether it is significantly different from the nearest tolerable relative bias. The test is conducted by computing the probability of observing an RD equal to or greater than the absolute value of the observed RD, assuming that the true relative bias is the nearest tolerable relative bias and that the CV is as shown in table 3-1. This probability, called the "significance level," is also given in table 3-1. A probability of less than 10 percent indicates that the observed RD is significantly different at the 10-percent level from the nearest tolerable bias, and it is concluded that the estimate does not support the 90/90 accuracy goal. This is a relatively weak test in the

TABLE 3-1.— PRODUCTION RESULTS OF THE 90/90 EVALUATION[a]

Month, 1977	RD, % (a)	CV, %	Interval of tolerable relative bias, %	Significance level, %
February	-52.3	[b]7.6	(c)	(d)
	-62.3	[b]7.6	(c)	(d)
May	-14.0	[b]5.8	[-2.2, 1.5]	[d]2.12
	-13.8	[b]5.8	[-2.2, 1.5]	[d]2.27
June	-9.4	[b]5.3	[-3.4, 2.6]	[e]12.92
	-5.6	[b]5.3	[-3.4, 2.6]	[e]34.09
July	-9.0	5.0	[-3.9, 3.1]	[e]15.39
	-6.8	5.0	[-3.9, 3.1]	[e]28.10
August	-8.4	4.9	[-4.1, 3.3]	[e]18.94
	-6.9	4.9	[-4.1, 3.3]	[e]28.43
September	-11.6	4.8	[-4.2, 3.4]	[d]6.18
	-10.9	4.8	[-4.2, 3.4]	[d]8.08
October	-11.0	4.9	[-4.1, 3.3]	[d]7.93
	-10.4	4.9	[-4.1, 3.3]	[d]9.85
Final	-10.0	4.8	[-4.2, 3.4]	[e]11.31

[a]The first figure is the RD as compared to the corresponding USDA/SRS monthly estimate; the second is the RD as compared to the final USDA/SRS estimate.

[b]This figure is projected to the USGP level.

[c]A figure is not applicable; the CV is too large (>6.1) to support the 90/90 accuracy goal regardless of the size of the relative bias.

[d]The LACIE Phase III estimate does not support the 90/90 accuracy goal.

[e]The LACIE Phase III estimate supports the 90/90 accuracy goal.

second situation and means that there is not enough evidence to reject the hypothesis of a 90/90 estimator.

The final LACIE Phase III estimate does support the 90/90 accuracy goal. However, with a significance level of 11.31 percent, this support might be best viewed as "marginal."

For the months of February, May, September, and October, the LACIE Phase III estimate does not support the 90/90 accuracy goal, whether compared with the corresponding USDA/SRS monthly estimate or with the final USDA/SRS estimate. For the months of June, July, and August, the LACIE Phase III estimate does support the 90/90 accuracy goal in both comparative cases.

3.2 COMPARISON OF LACIE AND USDA/SRS PRODUCTION ESTIMATES

The relationship of LACIE production estimates and USDA/SRS estimates throughout the crop year is shown in table 3-2 and figure 3-1. Data were provided by the CAR corresponding to the February 8, May 9, June 7, July 11, August 10, September 9, and October 11 CMR's plus the final estimate of December 22, 1977. Winter wheat estimates for the USGP-7 are available for each of these report dates. These data are subtotaled for the five U.S. southern Great Plains (USSGP) states and for the mixed wheat states of Montana and South Dakota. Spring wheat estimates for the four USNGP states were generated only for the reports of July 11, August 10, September 9, October 11, and December 22, 1977; these data are also subtotaled for mixed wheat and pure spring wheat.

Table 3-3 compares the RD's and CV's during the year. All the RD's are computed on the basis of the final USDA/SRS production estimate as given in table 3-2. The CV's for 1977 and the 1977 final columns of RD and CV in tables 3-2 and 3-3 are identical.

In table 3-2 and in tables following, the heading n/M indicates the number of segments for which data were obtained (n) and the total number of segments which were allotted to the state (M). For the mixed wheat states of Montana

TABLE 3-2.— MONTH-BY-MONTH COMPARISON OF LACIE AND USDA/SRS PRODUCTION ESTIMATES

[USDA/SRS predictions for February 1977 were released on December 22, 1976]

Region	n/M	USDA/SRS estimate, bu × 10^3	LACIE Estimate, bu × 10^3	LACIE CV, % 1977	LACIE CV, % 1976	RD, % 1977	RD, % 1976	Value of test statistic
Winter wheat — February								
Colorado	25/31	60 280	45 520	28.0	33	-32.4	37.0	
Kansas	82/121	356 400	199 123	18.4	17	-79.0	-26.9	
Nebraska	41/56	99 000	93 931	18.1	23	-5.4	39.2	
Oklahoma	35/46	132 600	69 688	16.7	29	-90.3	-41.1	
Texas	25/35	98 400	64 623	20.2	28	-52.3	-26.9	
USSGP	208/289	746 680	472 885	9.7	11	-57.9	-4.9	-5.97 S
Montana	30/58	79 300	56 803	30.4	NA	-39.6	NA	
S. Dakota	6/21	13 920	21 849	61.6	NA	36.3	NA	
Mixed wheat	36/79	93 220	78 652	27.9	NA	-18.5	NA	
USGP-7	244/368	839 900	551 536	9.3	NA	-52.3	NA	-5.62 S
Winter wheat — May								
Colorado	22/31	54 960	81 898	22.3	31	32.9	24.4	
Kansas	98/121	384 000	293 385	12.5	12	-30.9	-6.8	
Nebraska	38/56	103 700	102 497	15.4	19	-1.2	14.6	
Oklahoma	39/46	162 500	102 554	15.9	21	-58.5	-43.8	
Texas	30/35	101 200	81 789	16.5	17	-23.7	19.2	
USSGP	227/289	806 360	662 123	7.4	8	-21.8	-1.6	-2.95 S
Montana	28/58	75 600	96 173	23.1	NA	21.4	NA	
S. Dakota	3/21	15 000	28 809	46.2	NA	47.9	NA	
Mixed wheat	31/79	90 600	124 982	20.8	NA	27.5	NA	
USGP-7	258/368	896 960	787 105	7.1	NA	-14.0	NA	-1.97 S
Winter wheat — June								
Colorado	22/31	56 640	85 314	20.3	28	33.6	31.7	
Kansas	104/121	396 000	312 339	11.5	11	-26.8	14.4	
Nebraska	40/56	106 750	115 745	14.3	17	7.8	24.4	
Oklahoma	40/46	169 000	103 413	14.1	17	-63.4	-34.4	
Texas	30/35	110 000	90 667	14.7	17	-21.3	16.5	
USSGP	236/289	838 390	707 478	6.8	7	-18.5	11.4	-2.72 S
Montana	29/58	75 600	104 087	22.0	192	27.4	-569.8	
S. Dakota	7/21	13 600	36 457	30.8	46	62.7	34.1	
Mixed wheat	36/79	89 200	140 544	18.2	63	36.5	-147.1	
USGP-7	272/368	927 590	848 022	6.5	8	-9.4	1.7	-1.44 N

TABLE 3-2.— Continued.

Region	n/M	USDA/SRS estimate, bu × 10^3	LACIE Estimate, bu × 10^3	LACIE CV, % 1977	LACIE CV, % 1976	RD, % 1977	RD, % 1976	Value of test statistic
Winter wheat — July								
Colorado	21/31	54 280	73 383	19.8	30	26.0	6.0	
Kansas	96/121	381 300	372 688	10.7	11	-2.3	3.7	
Nebraska	29/56	106 750	122 819	15.0	16	13.1	27.3	
Oklahoma	35/46	169 000	114 725	12.7	18	-47.3	-64.3	
Texas	24/35	115 000	101 510	14.0	17	-13.3	-22.2	
USSGP	205/289	826 330	785 125	6.5	7	-5.2	-3.7	-0.80 N
Montana	27/58	75 600	69 502	15.5	53	-8.8	-211.2	
S. Dakota	9/21	16 320	51 718	43.9	27	68.4	63.1	
Mixed wheat	36/79	91 920	121 220	20.7	27	24.2	-46.7	
USGP-7	241/368	918 250	906 345	6.4	7	-1.3	-7.9	-0.20 N
Spring wheat — July								
Minnesota	22/47	115 190	78 481	16.1	NA	-46.8	NA	
N. Dakota	13/103	249 500	223 257	16.1	NA	-11.8	NA	
Spring wheat	35/150	364 690	301 738	13.4	NA	-20.9	NA	
Montana	5/48	52 235	34 939	40.0	NA	-49.5	NA	
S. Dakota	5/37	48 840	26 977	41.9	NA	-81.0	NA	
Mixed wheat	10/85	101 075	61 916	29.0	NA	-63.2	NA	
USNGP	45/235	465 765	363 654	12.1	NA	-28.1	NA	-2.32 S
Total wheat — July								
Montana	30/73	127 835	104 441	15.8	NA	-22.4	NA	
S. Dakota	13/45	65 160	78 695	17.3	NA	17.2	NA	
Mixed wheat	43/118	192 995	183 136	11.7	NA	-5.4	NA	
USNGP	78/268	557 685	484 874	9.3	NA	-15.0	NA	-1.61 N
USSGP	205/289	826 330	785 125	6.5	7	-5.2	-3.7	-0.80 N
USGP	283/557	1 384 015	1 269 999	5.0	NA	-9.0	NA	-1.66 S

TABLE 3-2.— Continued.

Region	n/M	USDA/SRS estimate, bu × 10^3	LACIE Estimate, bu × 10^3	LACIE CV, % 1977	LACIE CV, % 1976	RD, % 1977	RD, % 1976	Value of test statistic
Winter wheat — August								
Colorado	26/31	54 280	73 031	18.6	29	25.7	3.2	
Kansas	103/121	350 550	362 866	10.8	10	3.4	3.1	
Nebraska	31/56	106 750	114 134	13.9	16	6.5	26.5	
Oklahoma	37/46	175 500	119 208	12.3	18	-47.2	-54.0	
Texas	28/35	117 500	93 261	14.9	18	-26.0	-28.2	
USSGP	225/289	804 580	762 500	6.4	7	-5.5	-4.2	-0.86 N
Montana	39/58	75 600	88 789	14.4	36	14.9	-73.2	
S. Dakota	12/21	18 360	43 143	41.8	26	57.4	56.2	
Mixed wheat	51/79	93 960	131 932	16.8	23	28.8	-15.4	
USGP-7	276/368	898 540	894 432	6.1	7	-0.5	-5.6	-0.08 N
Spring wheat — August								
Minnesota	30/47	130 954	80 840	16.3	42	-62.0	-120.8	
N. Dakota	39/103	238 250	210 668	13.7	17	-13.1	-20.6	
Spring wheat	69/150	369 204	291 508	11.7	16	-26.7	-40.4	
Montana	23/48	50 050	34 939	22.7	29	-43.2	-116.2	
S. Dakota	24/37	58 168	48 075	17.7	18	-21.0	44.6	
Mixed wheat	47/85	108 218	83 014	14.0	17	-30.4	-26.6	
USNGP	116/235	477 422	374 522	9.6	13	-27.5	-37.8	-28.86 S
Total wheat — August								
Montana	52/73	125 650	123 728	13.8	20	-1.6	-88.0	
S. Dakota	30/45	76 528	91 218	16.0	14	16.1	51.0	
Mixed wheat	82/118	202 178	214 946	10.3	12	5.9	-19.8	
USNGP	151/268	571 382	506 454	8.7	11	-12.8	-32.7	
USSGP	225/289	804 580	762 500	6.4	7	-5.5	-4.2	-0.86 N
USGP	376/557	1 375 962	1 268 954	4.9	6	-8.4	-15.3	-1.71 S

TABLE 3-2.— Continued.

Region	n/M	USDA/SRS estimate, bu × 10^3	LACIE			RD, %		Value of test statistic
			Estimate, bu × 10^3	CV, %				
				1977	1976	1977	1976	
Winter wheat — September								
Colorado	25/31	54 280	68 675	17.9	29	21.0	8.5	
Kansas	107/121	350 550	359 652	10.7	10	2.5	3.7	
Nebraska	40/56	106 750	100 106	13.1	16	-6.6	13.5	
Oklahoma	38/46	175 500	121 845	12.4	18	-44.0	-56.7	
Texas	28/35	117 500	93 510	14.9	18	-25.7	-27.2	
USSGP	238/289	804 580	743 788	6.4	7	-8.2	-6.6	-1.28 N
Montana	39/58	78 400	96 021	13.9	30	18.4	-53.7	
S. Dakota	13/21	18 360	26 760	31.9	26	31.4	57.0	
Mixed wheat	52/79	96 760	122 781	12.9	21	21.2	-7.0	
USGP-7	290/368	901 340	866 570	5.8	7	-4.0	-6.6	-0.69 N
Spring wheat — September								
Minnesota	33/47	130 954	79 043	15.1	29	-65.7	-68.7	
N. Dakota	62/103	228 720	197 503	13.1	12	-15.8	-14.9	
Spring wheat	95/150	359 674	276 546	11.2	11	-30.1	-27.1	
Montana	30/48	48 070	39 357	18.6	25	-22.1	-86.5	
S. Dakota	26/37	55 968	40 759	17.5	19	-37.3	32.3	
Mixed wheat	56/85	104 038	80 116	12.7	15	-29.9	-26.4	
USNGP	151/235	463 712	356 662	9.1	10	-30.0	-27.0	-3.30 S
Total wheat — September								
Montana	53/73	126 470	135 379	13.7	15	6.6	-65.5	
S. Dakota	33/45	74 328	67 519	17.6	13	-10.1	46.1	
Mixed wheat	86/118	200 798	202 898	10.7	10	1.0	-14.7	
USNGP	181/268	560 472	479 443	8.6	10	-16.9	-22.8	
USSGP	238/289	804 580	743 788	6.4	7	-8.2	-6.6	-1.28 N
USGP	419/557	1 365 052	1 223 233	4.8	5	-11.6	-13.6	-2.42 S

TABLE 3-2.— Continued.

Region	n/M	USDA/SRS estimate, bu × 10^3	LACIE Estimate, bu × 10^3	LACIE CV, % 1977	LACIE CV, % 1976	RD, % 1977	RD, % 1976	Value of test statistic
Winter wheat — October								
Colorado	24/31	54 280	76 280	17.7	29	28.8	8.5	
Kansas	108/121	350 550	365 465	10.5	10	4.1	3.7	
Nebraska	39/56	106 750	107 830	13.4	16	1.0	13.5	
Oklahoma	41/46	175 500	113 064	12.9	18	-55.2	-56.7	
Texas	29/35	117 500	90 695	15.7	18	-29.6	-27.2	
USSGP	241/289	804 580	753 280	6.4	7	-6.8	-6.6	-1.06 N
Montana	43/58	78 400	87 712	14.4	29	10.6	-51.6	
S. Dakota	14/21	18 360	23 907	31.3	26	23.2	57.0	
Mixed wheat	57/79	96 760	111 619	13.1	20	13.3	-6.1	
USGP-7	298/368	901 340	864 900	5.9	7	-4.2	-6.5	-0.71 N
Spring wheat — October								
Minnesota	37/47	124 714	73 213	13.9	32	-70.3	-89.7	
N. Dakota	70/103	229 985	211 253	13.1	12	-8.9	-10.1	
Spring wheat	107/150	354 699	284 466	11.2	11	-24.7	-26.2	
Montana	33/48	50 665	38 683	17.4	25	-31.0	-65.7	
S. Dakota	32/37	55 968	39 748	16.4	18	-40.8	31.9	
Mixed wheat	65/85	106 633	78 431	11.9	16	-36.0	-19.8	
USNGP	172/235	461 332	362 896	9.1	10	-27.1	-24.9	-2.98 S
Total wheat — October								
Montana	58/73	129 065	126 395	13.5	13	-2.1	-56.9	
S. Dakota	38/45	74 328	63 655	17.1	13	-16.8	46.0	
Mixed wheat	96/118	203 393	190 050	10.6	9	-7.0	-11.7	
USNGP	203/268	558 092	474 515	8.8	8	-17.6	-20.9	
USSGP	241/289	804 580	753 280	6.4	7	-6.8	-6.6	-1.06 N
USGP	444/557	1 362 672	1 227 796	4.9	5	-11.0	-12.8	-2.24 S

TABLE 3-2.— Concluded.

Region	n/M	USDA/SRS estimate, bu × 10^3	LACIE Estimate, bu × 10^3	LACIE CV, % 1977	LACIE CV, % 1976	RD, % 1977	RD, % 1976	Value of test statistic
Winter wheat — Final								
Colorado	24/31	56 100	77 666	17.7	29	27.8	10.6	
Kansas	106/121	344 850	360 410	10.5	10	4.3	1.6	
Nebraska	39/56	103 250	109 823	13.1	16	6.0	14.9	
Oklahoma	42/46	175 500	113 387	12.9	18	-54.8	-56.7	
Texas	29/35	117 500	90 695	15.7	18	-29.6	-27.2	
USSGP	240/289	797 200	751 982	6.3	7	-6.0	-7.2	-0.95 N
Montana	43/58	81 200	89 224	14.4	30	9.0	-58.5	
S. Dakota	15/21	17 000	24 682	30.7	26	31.1	62.0	
Mixed wheat	58/79	98 200	113 906	13.1	20	13.6	-7.4	
USGP-7	298/368	895 400	865 888	5.8	7	-3.4	-7.2	-0.59 N
Spring wheat — Final								
Minnesota	38/47	128 429	74 955	13.6	32	-71.3	-89.6	
N. Dakota	73/103	227 515	211 990	13.0	12	-7.3	-6.6	
Spring wheat	111/150	355 944	286 945	11.1	11	-24.0	-23.2	
Montana	32/48	49 720	39 112	17.3	24	-27.1	-67.4	
S. Dakota	35/37	54 964	40 309	15.0	18	-36.4	38.2	
Mixed wheat	67/85	104 684	79 421	11.4	15	-31.8	-18.3	
USNGP	178/235	460 628	366 367	9.0	10	-25.7	-22.3	-2.86 S
Total wheat — Final								
Montana	57/73	130 920	128 336	13.5	13	-2.0	-62.1	
S. Dakota	41/45	71 964	64 991	16.6	13	-10.7	51.6	
Mixed wheat	96/118	202 384	193 327	10.5	9	-4.9	-11.9	
USNGP	209/268	558 828	480 273	8.7	8	-16.4	-19.2	-1.89 S
USSGP	240/289	797 200	751 983	6.3	7	-6.0	-7.2	-0.95 N
USGP	449/557	1 356 028	1 232 255	4.8	5	-10.0	-12.3	-2.08 S

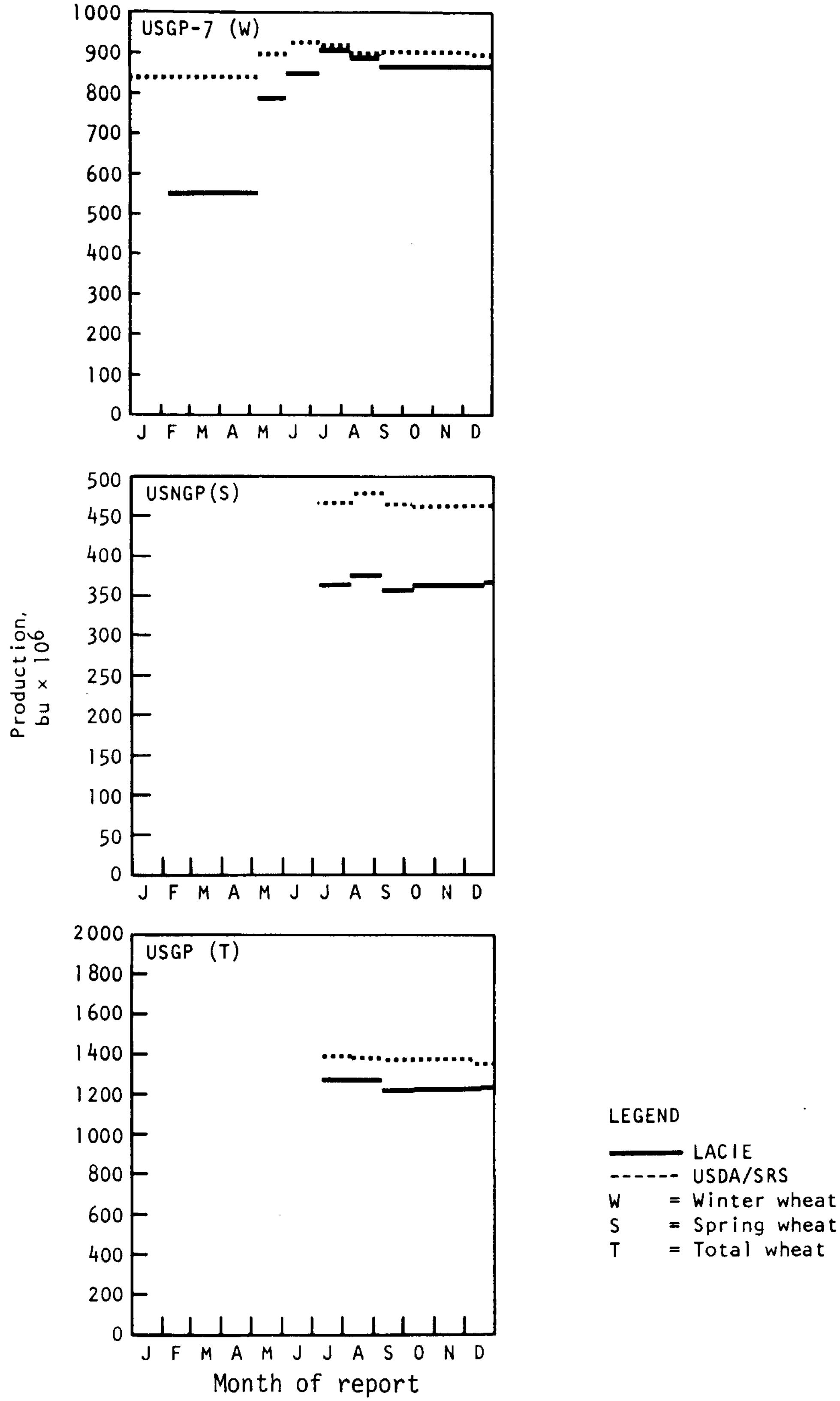

Figure 3-1.— LACIE and USDA/SRS production estimates. (USDA/SRS estimates for February 1977 were released on December 22, 1976.)

TABLE 3-3.— COMPARISON OF CV'S AND RD'S BASED ON THE USDA/SRS FINAL PRODUCTION ESTIMATE

Region	Final USDA/SRS, bu × 10^3	Feb. 1977		May 1977		June 1977		July 1977		Aug. 1977		Sept. 1977		Oct. 1977		Final 1977	
		RD	LACIE CV	RD	LACIE CV	RD	LACIE CV	RD	LACIE CV	RD	LACIE CV	RD	LACIE CV	RD	LACIE CV	RD	LACIE CV
Winter wheat																	
Colorado	56 100	-23.2	28.0	31.5	22.3	34.2	20.3	23.6	19.8	23.2	18.6	18.3	17.9	26.5	17.7	27.8	17.7
Kansas	344 850	-73.2	18.4	-17.5	12.5	-10.4	11.5	7.5	10.7	5.0	10.8	4.1	10.7	5.6	10.5	4.3	10.5
Nebraska	103 250	-9.9	18.1	-7.4	15.4	10.8	14.3	15.9	15.0	9.5	13.9	-3.1	13.1	3.3	13.4	6.0	13.1
Oklahoma	175 500	-152.0	16.7	-71.1	15.9	-69.7	14.1	-42.9	12.7	-47.2	12.3	-44.0	12.4	-55.2	12.9	-54.8	12.9
Texas	117 500	-81.8	20.2	-43.7	16.5	-29.6	14.7	-15.8	14.0	-26.0	14.9	-25.7	14.9	-29.6	15.7	-29.6	15.7
USSGP	797 200	-68.6	9.7	-20.4	7.4	-12.7	6.8	-1.6	6.5	-4.6	6.4	-7.2	6.4	-5.9	6.4	-6.0	6.3
Montana	81 200	-43.0	30.4	15.6	23.1	22.0	22.0	-16.8	15.5	8.6	14.4	15.4	13.9	7.4	14.4	9.0	14.4
S. Dakota	17 000	22.2	61.6	41.0	46.2	53.4	30.8	67.1	43.9	60.6	41.8	36.5	31.9	28.9	31.3	31.1	30.7
Mixed wheat	98 200	-24.9	27.9	21.4	20.8	30.1	18.2	19.0	20.7	25.6	16.8	20.0	12.9	12.0	13.1	13.8	13.1
USGP-7	895 400	-62.3	9.3	-13.8	7.1	-5.6	6.5	1.2	6.4	-0.1	6.1	-3.3	5.8	-3.5	5.9	-3.4	5.8
Spring wheat																	
Minnesota	128 429							-63.6	16.1	-58.9	16.3	-62.5	15.1	-75.4	13.9	-71.3	13.6
N. Dakota	227 515							-1.9	16.1	-8.0	13.7	-15.2	13.1	-7.7	13.1	-7.3	13.0
Spring wheat	355 944							-18.0	13.4	-22.1	11.7	-28.7	11.2	-25.1	11.2	-24.0	11.1
Montana	49 720							-42.3	40.0	-42.3	22.7	-26.3	18.6	-28.5	17.4	-27.1	17.3
S. Dakota	54 964							-103.7	41.9	-14.3	17.7	-34.9	17.5	-38.3	16.4	-36.4	15.0
Mixed wheat	104 684							-69.1	29.0	-26.1	14.0	-30.7	12.7	-33.5	11.9	-31.8	11.4
USNGP	460 628							-26.7	12.1	-23.0	9.6	-29.1	9.1	-26.9	9.1	-25.7	9.0
Total wheat																	
Montana	130 920							-25.4	15.8	-5.8	13.8	-3.5	13.7	-3.6	13.5	-2.0	13.5
S. Dakota	71 964							8.6	17.3	21.1	16.0	-6.6	17.6	-13.1	17.1	-10.7	16.6
Mixed wheat	202 884							-10.8	11.7	5.6	10.3	0.0	10.7	-6.8	10.6	-4.9	10.5
USNGP	558 828							-15.3	9.3	-10.3	8.7	-16.6	8.6	-17.8	8.8	-16.4	8.7
USSGP	797 200							-1.6	6.5	-4.6	6.4	-7.2	6.4	-5.9	6.4	-6.0	6.3
USGP	1 356 028							-6.8	5.0	-6.9	4.9	-10.9	4.8	-10.4	4.9	-10.0	4.8

and South Dakota, M indicates the segments of spring wheat or winter wheat, which may have segments in common, rather than a total for the state. Data that are not available are shown as NA. A test was performed for each major region to determine whether the LACIE estimate differed significantly (±1.64) from the corresponding USDA/SRS estimate. The results of this test are shown in the last column of table 3-2; significant differences are marked with an S and insignificant differences are marked with an N. The testing procedure is described in appendix A, section A.2.

The LACIE winter wheat production estimate for the USGP-7 remained below that of the USDA/SRS during the entire season. The original USGP-7 estimate had an RD of -52.3 percent; but increases in the LACIE estimate in May, June, and July reduced this RD to -1.3 percent in magnitude. The final RD between the LACIE and USDA/SRS figures was -3.4 percent. The difference between the LACIE and USDA/SRS winter wheat production estimates for the USGP-7 was significant in February and May but not in any month thereafter despite several large RD's in magnitude in the individual states, especially Oklahoma. The RD for the USGP-7 dropped each month through August when the difference between the two figures was only 4.1 million bushels (RD = -0.5 percent).

The State of Oklahoma presented the most persistent winter wheat production estimation problem in Phase III. The RD for Oklahoma went from -90.3 percent in February to -54.8 percent for the final estimate, decreasing only to -44.0 percent in magnitude at its best in September. This underestimation is primarily due to yield underestimates in Oklahoma throughout Phase III.

The CV's for all LACIE state- and regional-level winter wheat production estimates, except those of South Dakota and Kansas, were less than or equal to those of the previous year for every reporting period in Phase III. The most marked reduction in the CV occurred in Colorado, although this state invariably had the highest production CV in the USSGP during Phase III. The production CV's for Montana winter wheat were also greatly reduced from those of Phase II in every reporting period. The Phase III production CV's for South Dakota were higher than those of Phase II in every month except June.

The LACIE USNGP spring wheat production estimates become available in July. As a result of underestimates by LACIE of both area and yield for the USNGP throughout Phase III, as compared with USDA/SRS estimates, the LACIE estimates of USNGP spring wheat production remained significantly below their USDA/SRS counterparts (at the 10-percent level); the RD was consistently between -25.7 percent and -30.0 percent, essentially unchanged from those of a year previous. Every state-level spring wheat production estimate published in the Phase III CAR was below its USDA/SRS counterpart, even though some reduction in the magnitude of the RD's for the individual states is evident when compared to those of Phase II.

The CV's for the LACIE USNGP spring wheat production estimates were generally less than or equal to those of a year previous. The largest CV's of the Phase II spring wheat production estimates (Minnesota and Montana) were reduced considerably during Phase III to levels more in line with CV's for the North and South Dakota estimates. The CV's of the USNGP regional production estimates were reduced slightly from those of the previous year.

All LACIE Phase III total wheat production estimates for the USGP were significantly different from the corresponding USDA/SRS estimates. Some reduction of magnitude in the RD was evident, whereas CV's of the production estimates at the USGP level were virtually unchanged from those of Phase II.

In table 3-3, the LACIE monthly estimates are compared to the corresponding final USDA/SRS at-harvest estimates. With these types of comparisons, the 90/90 hypothesis was not rejected by the LACIE estimates of June (projected), July, August, and final at the USGP level. This goal was not supported by the estimates of February and May, which were generated during the early season.

4. ASSESSMENT OF AREA ESTIMATES

The purpose of area estimate analyses is to quantify the error components in the LACIE estimation process and to determine their causes. The general approach in the USGP in LACIE Phase III was to compare the LACIE area estimates to various reference standards, including the ground-observed data for a random sample of the LACIE operational segments (blind site analysis), the historical SRS county-level area estimates, and the current SRS state-level area estimates.

Three major subjects are presented in this section: a comparison of LACIE and USDA/SRS wheat area estimates, a blind site investigation of proportion estimation error, and a discussion of classification and sampling errors.

4.1 COMPARISON OF LACIE AND USDA/SRS AREA ESTIMATES

Table 4-1 and figure 4-1 show how the LACIE and USDA/SRS area estimates are related as each were determined through the crop year. The RD's and the CV's are included in the table for all the estimates and tests of significant differences for regional estimates.

Table 4-2 compares RD's and CV's during the year; all of the RD computations are based on the final USDA/SRS area estimates in table 4-1. The CV's and the final RD's are identical in the two tables.

The initial LACIE winter wheat area estimate for the USGP-7 was significantly different at the 10-percent level from the corresponding USDA/SRS area estimate (RD = -74.4 percent), as shown in table 4-1. The second LACIE estimate, given in the May report, was not significantly different from the USDA/SRS estimate (RD = -3.1 percent) because the LACIE figure increased by more than 3.6 million hectares (9 million acres) and the USDA/SRS estimate decreased by 2.3 million hectares (5.6 million acres). The increase in the LACIE estimate was due to a detection of increased emergence and ground cover of the wheat, and the USDA/SRS decrease was due to the difference between

TABLE 4-1.— MONTH-BY-MONTH COMPARISON OF LACIE AND USDA/SRS AREA ESTIMATES

[USDA/SRS predictions for February 1977 were released on December 22, 1976]

Region	n/M	USDA/SRS estimate, ac × 10^3	LACIE			RD, %		Value of test statistic
			Estimate, ac × 10^3	CV, %				
				1977	1976	1977	1976	
Winter wheat — February								
Colorado	25/31	2 740	1 997	21.0	26	-37.2	20.0	
Kansas	82/121	13 200	6 888	13.9	12	-91.6	-63.5	
Nebraska	41/56	3 300	3 067	14.9	18	-7.6	24.4	
Oklahoma	35/46	7 800	3 206	9.6	24	-143.3	-90.0	
Texas	25/35	6 150	3 365	16.7	25	-82.8	-98.7	
USSGP	208/289	33 190	18 523	7.1	9	-79.2	-46.0	-11.15 S
Montana	30/58	3 050	2 127	21.1	NA	-43.4	NA	
S. Dakota	6/21	1 160	800	60.0	NA	-45.0	NA	
Mixed wheat	36/79	4 210	2 927	22.4	NA	-43.8	NA	
USGP-7	244/368	37 400	21 450	6.8	NA	-74.4	NA	-10.94 S
Winter wheat — May								
Colorado	22/31	2 290	3 600	14.2	24	36.4	32.3	
Kansas	98/121	12 000	10 439	6.2	6	-15.0	-15.0	
Nebraska	38/56	3 050	3 278	11.4	13	7.0	19.2	
Oklahoma	39/46	6 500	4 832	10.0	16	-34.5	-48.8	
Texas	30/35	4 400	4 196	14.2	14	-4.9	18.9	
USSGP	227/289	28 240	26 345	4.5	6	-7.2	-3.2	-1.06 N
Montana	28/58	2 800	3 369	18.8	NA	16.9	NA	
S. Dakota	3/21	750	1 107	43.1	NA	32.2	NA	
Mixed wheat	31/79	3 550	4 476	17.7	NA	20.7	NA	
USGP-7	258/368	31 790	30 821	4.6	NA	-3.1	NA	-0.68 N
Winter wheat — June								
Colorado	22/31	2 360	3 608	13.6	23	34.6	36.6	
Kansas	104/121	12 000	11 055	5.8	6	-8.5	-2.0	
Nebraska	40/56	3 050	3 839	9.5	12	20.6	28.1	
Oklahoma	40/46	6 500	5 228	9.0	14	-24.3	-39.8	
Texas	30/35	4 400	4 462	12.5	15	1.4	14.4	
USSGP	236/289	28 310	28 192	4.1	5	-0.4	3.9	-0.10 N
Montana	29/58	2 800	3 704	17.8	193	24.4	518.9	
S. Dakota	7/21	680	1 401	25.0	43	51.5	10.3	
Mixed wheat	36/79	3 480	5 105	14.6	65	31.8	-146.5	
USGP-7	272/368	31 790	33 297	4.1	6	4.5	-4.9	1.10 N

TABLE 4-1.— Continued.

Region	n/M	USDA/SRS estimate, ac × 10^3	LACIE Estimate, ac × 10^3	LACIE CV, % 1977	LACIE CV, % 1976	RD, % 1977	RD, % 1976	Value of test statistic
Winter wheat — July								
Colorado	21/31	2 360	3 268	13.4	25	27.8	23.3	
Kansas	96/121	12 300	12 919	4.5	6	4.8	-2.8	
Nebraska	29/56	3 050	3 844	11.6	11	20.7	27.4	
Oklahoma	35/46	6 500	5 755	7.1	15	-12.9	-56.5	
Texas	24/35	4 000	5 011	11.6	15	8.2	-8.9	
USSGP	205/289	28 810	30 797	3.6	5	6.5	-4.5	1.81 S
Montana	27/58	2 800	2 626	9.8	52	-6.6	-189.3	
S. Dakota	9/21	680	1 943	40.3	23	65.0	29.8	
Mixed wheat	36/79	3 480	4 569	18.1	25	23.8	-60.7	
USGP-7	241/368	32 290	35 366	3.9	5	8.7	-9.4	2.23 S
Spring wheat — July								
Minnesota	22/47	3 202	2 420	12.2	NA	-32.3	NA	
N. Dakota	13/103	9 500	9 071	10.7	NA	-4.7	NA	
Spring wheat	35/150	12 702	11 491	8.9	NA	-10.5	NA	
Montana	5/48	2 185	1 895	37.6	NA	-15.3	NA	
S. Dakota	5/37	2 332	1 269	40.4	NA	-83.8	NA	
Mixed wheat	10/85	4 517	3 164	27.7	NA	-42.8	NA	
USNGP	45/235	17 219	14 655	9.2	NA	-17.5	NA	-1.90 S
Total wheat — July								
Montana	30/73	4 985	4 521	9.9	NA	-10.3	NA	
S. Dakota	13/45	3 012	3 212	17.9	NA	6.2	NA	
Mixed wheat	43/118	7 997	7 733	23.3	NA	-3.4	NA	
USNGP	78/268	20 699	19 224	16.1	NA	-7.7	NA	
USSGP	205/289	28 810	30 797	3.6	5	6.5	-4.5	1.81 S
USGP	283/557	49 509	50 021	3.4	NA	1.0	NA	0.29 N

TABLE 4-1.— Continued.

Region	n/M	USDA/SRS estimate, ac × 10^3	LACIE Estimate, ac × 10^3	LACIE CV, % 1977	LACIE CV, % 1976	RD, % 1977	RD, % 1976	Value of test statistic
Winter wheat — August								
Colorado	26/31	2 360	3 253	11.3	24	27.5	22.3	
Kansas	103/121	12 300	12 579	4.8	5	2.2	-1.5	
Nebraska	31/56	3 050	3 556	10.2	11	14.3	26.6	
Oklahoma	37/46	6 500	5 963	6.7	15	-9.0	-46.3	
Texas	28/35	4 700	4 600	12.8	16	-2.2	-9.0	
USSGP	225/289	28 910	29 953	3.6	5	3.5	-3.2	0.97 N
Montana	39/58	2 800	3 355	7.9	35	16.5	-58.0	
S. Dakota	12/21	680	1 594	38.1	23	57.3	29.8	
Mixed wheat	51/79	3 480	4 949	13.4	22	29.7	-19.7	
USGP-7	276/368	32 390	34 902	3.6	5	7.2	-5.0	2.00 S
Spring wheat — August								
Minnesota	30/47	3 202	2 553	13.0	40	-25.4	-119.8	
N. Dakota	39/103	9 530	9 220	5.7	14	-3.4	-41.4	
Spring wheat	69/150	12 732	11 773	5.3	13	-8.1	-55.2	
Montana	23/48	2 185	1 942	18.0	28	-12.5	-105.4	
S. Dakota	24/37	2 332	2 309	13.4	12	-1.0	5.5	
Mixed wheat	47/85	4 517	4 251	11.0	12	-6.3	-32.4	
USNGP	116/235	17 249	16 024	4.8	10	-7.6	-49.5	-1.58 N
Total wheat — August								
Montana	52/73	4 985	5 296	6.4	19	5.9	-75.6	
S. Dakota	30/45	3 012	3 904	8.6	13	22.8	15.4	
Mixed wheat	82/118	7 997	9 200	12.8	11	13.1	-26.0	
USNGP	151/268	20 729	20 973	9.2	9	1.2	-43.4	
USSGP	225/289	28 910	29 953	3.6	5	3.5	-3.2	0.97 N
USGP	376/557	49 639	50 926	2.6	5	2.5	-18.7	0.96 N

TABLE 4-1.— Continued.

Region	n/M	USDA/SRS estimate, ac × 10^3	LACIE			RD, %		Value of test statistic
			Estimate, ac × 10^3	CV, %				
				1977	1976	1977	1976	
Winter wheat — September								
Colorado	25/31	2 360	3 059	10.3	24	22.9	18.6	
Kansas	107/121	12 300	12 468	4.5	5	1.3	-1.0	
Nebraska	40/56	3 050	3 130	9.2	11	2.6	11.7	
Oklahoma	38/46	6 500	6 083	7.2	14	-6.9	-47.9	
Texas	28/35	4 700	4 613	12.7	16	-1.9	-8.2	
USSGP	238/289	28 910	29 353	3.5	5	1.5	-6.2	0.43 N
Montana	39/58	2 800	3 628	6.9	29	22.8	-43.6	
S. Dakota	13/21	680	989	26.5	23	31.2	28.4	
Mixed wheat	52/79	3 480	4 617	7.8	20	24.6	-14.2	
USGP-7	290/368	32 390	33 969	3.2	5	4.6	-7.2	1.44 N
Spring wheat — September								
Minnesota	33/47	3 202	2 474	11.6	27	-29.4	-50.0	
N. Dakota	62/103	9 530	8 523	5.0	5	-11.8	-19.6	
Spring wheat	95/150	12 732	10 997	4.6	7	-15.8	-25.9	
Montana	30/48	2 185	2 187	12.2	23	0.1	-75.3	
S. Dakota	26/37	2 332	1 958	13.1	13	-19.1	2.1	
Mixed wheat	56/85	4 517	4 145	9.0	12	-9.0	-28.9	
USNGP	151/235	17 249	15 142	4.2	6	-13.9	-26.6	-3.31 S
Total wheat — September								
Montana	53/73	4 985	5 815	6.0	14	14.3	-57.2	
S. Dakota	33/45	3 012	2 947	11.0	12	-2.2	12.9	
Mixed wheat	86/118	7 997	8 762	13.4	9	8.7	-21.4	
USNGP	181/268	20 729	19 759	8.7	6	-4.9	-24.3	
USSGP	238/289	28 910	29 353	3.5	5	1.5	-6.2	0.43 N
USGP	419/557	49 639	49 111	2.5	4	-1.1	-13.9	-0.44 N

TABLE 4-1.— Continued.

Region	n/M	USDA/SRS estimate, ac × 10^3	LACIE Estimate, ac × 10^3	LACIE CV, % 1977	LACIE CV, % 1976	RD, % 1977	RD, % 1976	Value of test statistic
Winter wheat — October								
Colorado	24/31	2 360	3 395	9.9	24	30.5	18.6	
Kansas	108/121	12 300	12 669	4.2	5	2.9	-1.0	
Nebraska	39/56	3 050	3 375	9.6	11	9.6	11.7	
Oklahoma	41/46	6 500	5 658	7.7	14	-14.9	-47.9	
Texas	29/35	4 700	4 476	13.7	16	-5.0	-8.2	
USSGP	241/289	28 910	29 573	3.5	5	2.2	-6.2	0.63 N
Montana	43/58	2 800	3 314	7.8	28	15.5	-41.7	
S. Dakota	14/21	680	883	25.7	23	23.0	28.4	
Mixed wheat	57/79	3 480	4 197	8.2	19	17.1	-13.3	
USGP-7	298/368	32 390	33 771	3.2	5	4.1	-7.1	1.28 N
Spring wheat — October								
Minnesota	37/47	3 202	2 289	9.9	30	-39.9	-74.1	
N. Dakota	70/103	9 530	9 173	4.4	5	-3.9	-18.5	
Spring wheat	107/150	12 732	11 462	4.0	7	-11.1	-28.8	
Montana	33/48	2 185	2 150	10.3	24	-1.6	-55.7	
S. Dakota	32/37	2 332	1 909	11.6	13	-22.2	1.4	
Mixed wheat	65/85	4 517	4 059	7.7	12	-11.3	-22.4	
USNGP	172/235	17 249	15 522	3.6	6	-11.1	-27.3	-3.08 S
Total wheat — October								
Montana	58/73	4 985	5 464	5.5	12	8.8	-47.5	
S. Dakota	38/45	3 012	2 793	9.9	12	-7.8	12.5	
Mixed wheat	96/118	7 997	8 257	12.2	8	3.1	-17.8	
USNGP	203/268	20 729	19 719	7.7	5	-5.1	-24.7	
USSGP	241/289	28 910	29 573	3.5	5	2.2	-6.2	0.63 N
USGP	444/557	49 639	49 293	2.4	4	-0.7	-14.1	-0.29 N

TABLE 4-1.— Concluded.

Region	n/M	USDA/SRS estimate, ac × 10^3	LACIE Estimate, ac × 10^3	LACIE CV, % 1977	LACIE CV, % 1976	RD, % 1977	RD, % 1976	Value of test statistic
Winter wheat — Final								
Colorado	24/31	2 550	3 459	9.8	24	26.3	18.6	
Kansas	106/121	12 100	12 494	4.0	5	3.2	-1.6	
Nebraska	39/56	2 950	3 433	9.2	11	14.1	13.2	
Oklahoma	42/46	6 500	5 675	7.6	14	-14.5	-47.9	
Texas	29/35	4 700	4 476	13.7	16	-5.0	-8.2	
USSGP	240/289	28 800	29 537	3.4	5	2.5	-6.3	0.74 S
Montana	43/58	2 800	3 371	7.9	28	16.9	-48.1	
S. Dakota	15/21	680	912	25.0	23	25.4	33.2	
Mixed wheat	58/79	3 480	4 283	8.2	19	18.7	-14.7	
USGP-7	298/368	32 280	33 820	3.2	5	4.6	-7.3	1.44 N
Spring wheat — Final								
Minnesota	38/47	3 222	2 344	9.5	30	-37.5	-77.1	
N. Dakota	73/103	9 150	9 183	4.4	5	0.4	-16.9	
Spring wheat	111/150	12 372	11 527	4.0	7	-7.3	-27.9	
Montana	32/48	2 260	2 174	10.2	22	-4.0	-54.0	
S. Dakota	35/37	2 336	1 936	9.6	13	-20.7	2.8	
Mixed wheat	67/85	4 596	4 110	7.0	12	-11.8	-21.1	
USNGP	178/235	16 968	15 638	3.5	6	-8.5	-26.3	-2.43 S
Total wheat — Final								
Montana	57/73	5 060	5 545	5.4	12	8.7	-50.6	
S. Dakota	41/45	3 016	2 848	9.1	12	-5.9	15.3	
Mixed wheat	98/118	8 076	8 393	11.7	8	3.8	-17.9	
USNGP	209/268	20 448	19 921	7.6	5	-2.6	-24.2	
USSGP	240/289	28 800	29 537	3.4	5	2.5	-6.3	0.74 S
USGP	449/557	49 248	49 458	2.4	4	0.4	-13.9	0.17 N

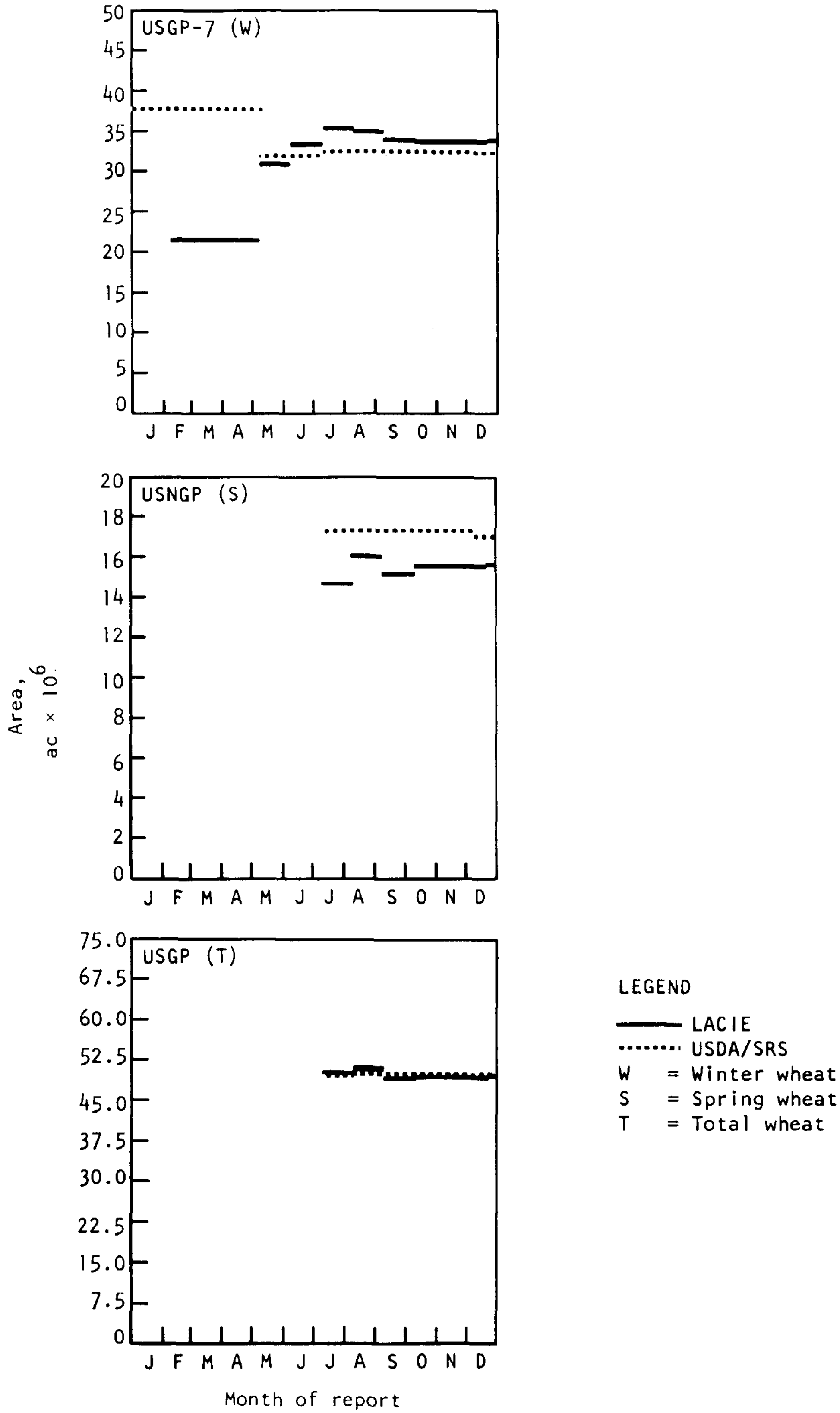

Figure 4-1.— LACIE and USDA/SRS area estimates. (USDA/SRS estimates of seeded acres for February 1977 were released on December 22, 1976.)

TABLE 4-2.— COMPARISON OF CV'S AND RD'S BASED ON THE USDA/SRS FINAL AREA ESTIMATES

Region	Final USDA/SRS, ac × 10^3	Feb. 1977		May 1977		June 1977		July 1977		Aug. 1977		Sept. 1977		Oct, 1977		Final 1977	
		RD	LACIE CV	RD	LACIE CV	RD	LACIE CV	RD	LACIE CV	RD	LACIE CV	RD	LACIE CV	RD	LACIE CV	RD	LACIE CV
Winter wheat																	
Colorado	2 550	-27.7	21.0	29.2	14.2	29.3	13.6	22.0	13.4	21.6	11.3	16.6	10.3	24.9	9.9	26.3	9.8
Kansas	12 100	-75.7	13.9	-15.9	6.2	-9.5	5.8	6.3	4.5	3.8	4.8	3.0	4.5	4.5	4.2	3.2	4.0
Nebraska	2 950	3.8	14.9	10.0	11.4	23.2	9.5	23.3	11.6	17.1	10.2	5.8	9.2	12.6	9.6	14.1	9.2
Oklahoma	6 500	-102.7	9.6	-34.5	10.0	-24.3	9.0	-12.9	7.1	-9.0	6.7	-6.9	7.2	-14.9	7.7	-14.5	7.6
Texas	4 700	-39.7	16.7	-12.0	14.2	-5.3	12.5	6.2	11.6	-2.2	12.8	-1.9	12.7	-5.0	13.7	-5.0	13.7
USSGP	28 800	-55.5	7.1	-9.3	4.5	-2.2	4.1	6.5	3.6	3.8	3.6	2.6	3.5	2.6	3.5	2.5	3.4
Montana	2 800	-31.6	21.1	16.9	18.8	2.4	17.8	-6.6	9.8	16.5	7.9	22.8	6.9	15.5	7.8	16.9	7.9
S. Dakota	680	15.0	60.0	38.6	43.1	51.5	25.0	65.0	40.3	57.3	38.1	31.2	26.5	23.0	25.7	25.4	25.0
Mixed wheat	3 480	-18.9	22.4	22.3	17.7	31.8	14.6	23.8	18.1	29.7	13.4	24.6	7.8	17.1	8.2	18.7	8.2
USGP-7	32 280	-5.0	6.8	-4.7	4.6	3.1	4.1	8.7	3.9	7.5	3.6	5.0	3.2	4.4	3.2	4.6	3.2
Spring wheat																	
Minnesota	3 222							-33.1	12.2	-26.2	13.0	-30.2	11.6	-40.8	9.9	-37.5	9.5
N. Dakota	9 150							-0.9	10.7	0.8	5.7	-7.4	5.0	0.3	4.4	0.4	4.4
Spring wheat	12 372							-7.7	8.9	-5.1	5.3	-12.5	4.6	-7.9	4.0	-7.3	4.0
Montana	2 260							-19.3	37.6	-16.4	18.0	-3.3	12.2	-5.1	10.3	-4.0	10.2
S. Dakota	2 336							-84.1	40.4	-1.2	13.4	-19.3	13.1	-22.4	11.6	-20.7	9.6
Mixed wheat	4 596							-45.3	27.7	-8.1	11.0	-10.9	9.0	-13.2	7.7	-11.8	7.0
USNGP	16 968							-15.8	9.2	-5.6	4.8	-12.1	4-2	-9.3	3.6	-8.5	3.5
Total wheat																	
Montana	5 060							-11.9	9.9	4.5	6.4	13.0	6.0	7.4	5.5	8.7	5.4
S. Dakota	3 016							6.1	17.9	22.7	8.6	-2.3	11.0	-8.0	9.9	-5.9	9.1
Mixed wheat	8 076							-4.4	23.3	12.2	12.8	7.8	13.4	2.2	12.2	3.8	11.7
USNGP	20 448							-6.4	16.1	2.5	9.2	-3.5	8.7	-3.7	7.7	-2.6	7.6
USSGP	28 800							6.5	3.6	3.8	3.6	2.6	3.5	2.6	3.5	2.5	3.4
USGP	49 248							1.5	3.4	3.3	2.6	0.1	2.5	0.1	2.4	0.4	2.4

planted area and area for harvest. During the remainder of Phase III, the USDA/SRS winter wheat area estimate for the USGP-7 region remained essentially unchanged. The LACIE estimate increased to be significantly larger than the USDA/SRS figure in July (RD = 8.7 percent) and August (RD = 7.2 percent). The September, October, and December LACIE USGP-7 area estimates were not significantly different from the corresponding USDA/SRS estimates.

At the state level, the primary area estimation problems occurred in Colorado (final RD = 26.3 percent) and South Dakota (final RD = 25.4 percent); Colorado was the only state in which the RD was consistently larger than the RD in Phase II. Initial large underestimates in Oklahoma improved as the season progressed.

The CV's of the final winter wheat estimates for all states in the USGP-7 except South Dakota were smaller than those of Phase II, indicating the overall higher degree of reliability of the LACIE Phase III area estimates.

The LACIE spring wheat estimates became available in July. There was a significant difference at the 10-percent level between the LACIE and the USDA/SRS spring wheat area estimates for the USNGP region in every month except August. Furthermore, at the state level, in only two instances (the September estimate for Montana and the final estimate for North Dakota) did the LACIE estimate equal or exceed that of the USDA/SRS, although RD's were generally much improved from those of a year ago. The exception was the RD for South Dakota, which was much larger in magnitude than that reported for each Phase II report.

Although much less severe than in Phase II, the underestimation problem in Minnesota was the outstanding accuracy problem for spring wheat area in the USNGP during Phase III. This problem is evident in the RD, except in September as shown in tables 4-1 and 4-2, as well as in the absolute difference between LACIE and USDA/SRS estimates.

The CV's of the LACIE spring wheat area estimates for Phase III were generally smaller than those of Phase II. The CV's of the Minnesota estimates showed the greatest reduction from Phase II levels, although they were among the largest for the USNGP states in all Phase III reports. For the USNGP, the Phase III CV was about 40 percent smaller than that of Phase II, on the average.

The revised LACIE total wheat area estimates for the USGP region (available from July onward) were not significantly different from the corresponding USDA/SRS estimates in any reporting period of Phase III. In fact, the RD between the two estimates stayed between -1.1 percent and 2.5 percent over the entire season.

As in the cases of winter and spring wheat, the CV of the USGP total wheat area estimate was invariably smaller in Phase III than in Phase II, ranging from 2.4 to 3.4 percent during the current season.

4.2 BLIND SITE INVESTIGATION OF PROPORTION ESTIMATION ERROR

This section contains an analysis of proportion estimation error, both weighted and unweighted, using the blind site estimates and the corresponding ground-truth proportion estimates for harvested wheat and/or small grains. The LACIE estimates are actually estimates of small grains for which forecast ratios of wheat to small grains have been applied.

4.2.1 WHEAT PROPORTION ESTIMATION ERROR (WEIGHTED ANALYSIS)

A weighted analysis of aggregated acreage estimates was made to determine the bias due to classification. Near-harvest ground observations were obtained and analyzed for 92 winter wheat segments and 53 spring wheat segments in Phase III. The LACIE aggregation process weights were used to obtain a weighted average of the differences between the at-harvest wheat proportion estimates and the ground-observed wheat proportions (table 4-3). The results indicated a negative bias in the LACIE at-harvest area estimation process because of winter and spring wheat proportion estimation errors at the segment level.

TABLE 4-3.– ESTIMATES OF LACIE WHEAT ACREAGE ESTIMATION BIAS DUE TO CLASSIFICATION

Region	Blind sites/ acquired segments	LACIE wheat area estimate, ac × 10^3	Bias	Standard deviation of bias	Relative bias, %	CV, %	Value of test statistic
Winter wheat							
Colorado	11/24	3 459	-567	340	-16.4	9.8	
Kansas	24/106	12 494	-1161	476	-9.3	3.8	
Nebraska	16/39	3 433	-218	227	-6.4	6.6	
Oklahoma	15/42	5 675	-831	442	-14.6	7.8	
Texas	9/29	4 476	-141	708	-3.2	15.8	
USSGP	75/240	29 537	-3049	1104	-10.3	3.7	-2.8 S
Montana	14/43	3 371	157	222	+4.7	6.6	
S. Dakota	3/15	912	-451	491	-49.5	53.8	
USGP-7	92/298	33 820	-3213	1181	-9.5	3.5	-2.7 S
Spring wheat							
Minnesota	11/38	2 344	-770	356	-32.8	15.2	
Montana	9/32	2 174	-780	425	-35.9	19.5	
N. Dakota	21/73	9 183	-1442	535	-15.7	5.8	
S. Dakota	12/35	1 936	-672	499	-34.7	25.8	
USNGP	53/178	15 638	-3653	916	-23.4	5.9	-4.0 S
Total wheat							
USGP	145/449	49 458	-6440	1441	-13.0	2.9	-4.5 S

4.2.2 WINTER SMALL GRAINS' PROPORTION ESTIMATION ERROR (UNWEIGHTED ANALYSIS)

Results from the investigation of winter small grains' proportion estimation errors are shown in figure 4-2 and table 4-4. The small-grains' proportion estimates used in this study are from the Phase III CAR released on December 22, 1977. Estimates are compared with the digitized ground-truth proportion for all but 12 blind sites in the USSGP region; the dot-count ground-truth proportions were used for those 12 sites because digitized ground truth was not available. Digitized ground-truth proportion is more reliable because it was determined by evaluating every picture element (pixel) in the segment, whereas the dot-count ground-truth proportion was obtained by evaluating a sample of pixels. However, an AA study (section 6.5) showed that the average differences between these two types of ground-truth proportion were not significant for any state in the USSGP region.

Figure 4-2 shows plots of the proportion estimation errors ($\hat{X}$ - X) versus the ground-truth harvest proportion (X) for the February, July, and final CAS reports, where $\hat{X}$ is the CAMS small-grain proportion. Points lying above the horizontal line $\hat{X} - X = 0$ correspond to overestimates of small grains' proportions, and points below the line correspond to underestimates.

The plot for February shows that as the ground-truth small grains' proportions for the segments increased, the proportion estimation errors tended to show larger negative biases in magnitude. Most of the large underestimates of 20 percent or more in the February plot were improved by July; as a result, the regression coefficients decreased in magnitude from -0.64 for the February data to -0.46 for both the July and the final data. In many cases, large underestimates in February resulted from late planting and retarded the development of small grains because of dry soil conditions and abnormally cold weather early in the season. The small grains in many of the fields had not sufficiently emerged and were not detectable in the early season acquisitions; but as more of the small grains in the fields became visible in later acquisitions, the LACIE proportion estimates tended to compare better with the ground truth.

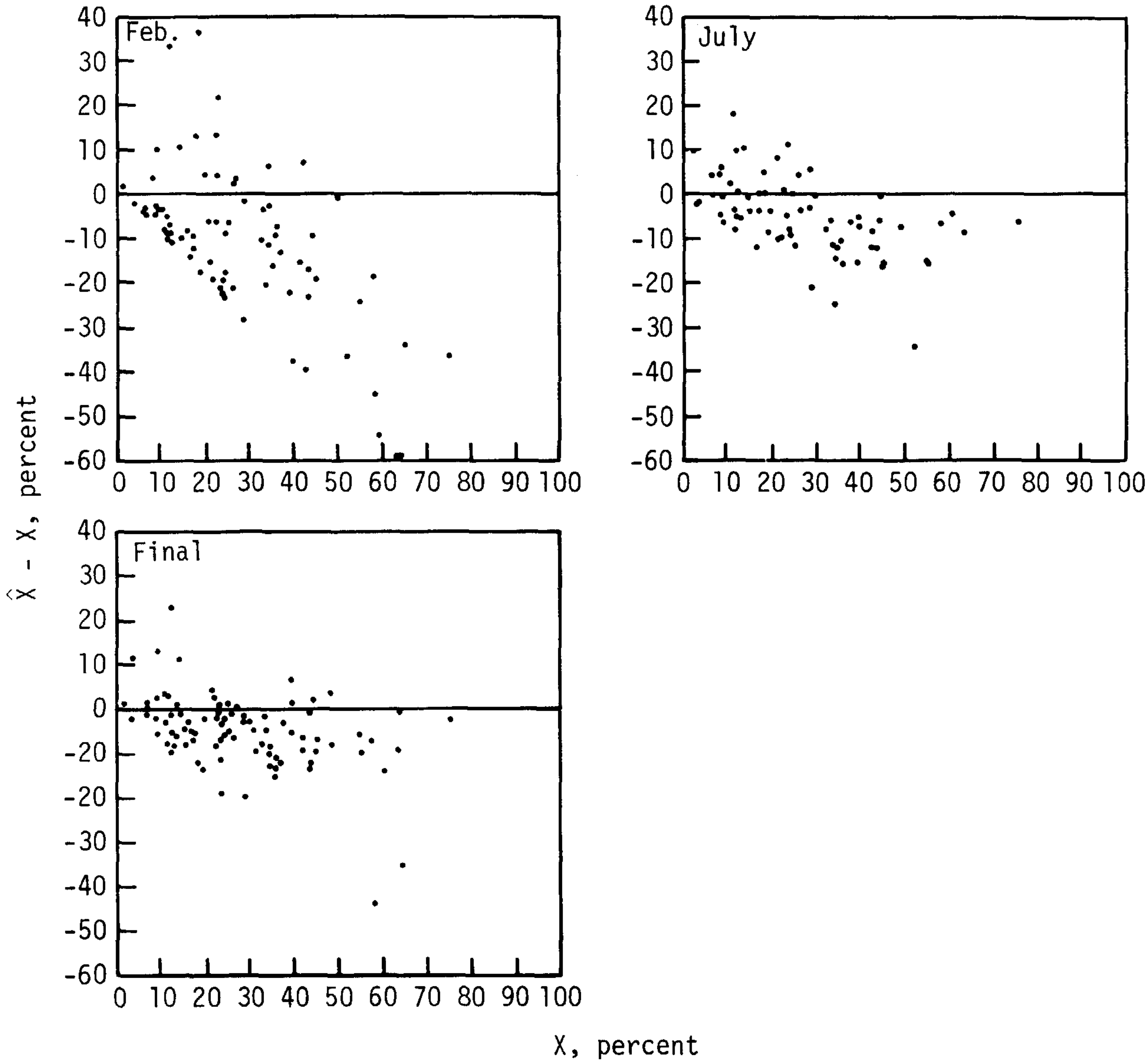

Figure 4-2.— Plot of proportion estimation error ($\hat{X}$ - X) versus ground-truth harvest proportion (X) for winter small grains for blind sites.

TABLE 4-4.— WINTER SMALL-GRAIN BLIND SITE RESULTS[a]

Region	Blind sites/ sample segments	$\bar{\hat{X}}$	$\bar{X}$	$\bar{D}$	$S_{\bar{D}}$	90% confidence limits for population D	
February							
Colorado	10/31	12.8	20.9	-8.1	1.2	(-10.1, -6.1)	S
Kansas	21/121	14.3	30.1	-15.8	3.7	(-21.9, -9.7)	S
Nebraska	16/56	21.2	20.1	1.1	3.0	(-3.8, 6.0)	N
Oklahoma	14/46	17.3	37.6	-20.3	4.5	(-27.7, -12.9)	S
Texas	10/35	16.5	24.0	-7.5	3.1	(-12.6, -2.4)	S
Montana	7/58	8.8	27.4	-18.6	3.7	(-24.7, -12.5)	S
S. Dakota	1/21	NA	NA	NA	NA	NA	
USGP-7	79/368	15.6	26.8	-11.2	1.8	(-14.2, -8.2)	S
May							
Colorado	10/31	15.5	20.9	-5.4	1.7	(-8.2, -2.6)	S
Kansas	23/121	22.2	32.5	-10.3	2.6	(-14.6, -6.0)	S
Nebraska	16/56	14.2	19.5	-5.3	2.1	(-8.8, -1.8)	S
Oklahoma	15/46	25.8	35.3	-9.5	3.6	(-15.4, -3.6)	S
Texas	11/35	20.6	22.4	-1.8	2.7	(-6.2, 2.6)	N
Montana	5/58	12.6	28.1	-15.5	5.3	(-24.2, -6.8)	S
S. Dakota	1/21	NA	NA	NA	NA	NA	
USGP-7	81/368	19.4	27.0	-7.6	1.2	(-9.6, -5.6)	S

[a]Symbol definitions:

$\bar{\hat{X}}$ = average of harvested small grains' proportion estimates.

$\bar{X}$ = average of ground-truth small grains' proportion estimates for harvested small grains.

$\bar{D} = \bar{\hat{X}} - \bar{X}$.

$S_{\bar{D}}$ = standard error of $\bar{D}$.

S = hypothesis of no bias was rejected.
N = hypothesis of no bias was not rejected.

TABLE 4-4.— Continued.

Region	Blind sites/ sample segments	$\bar{\hat{X}}$	$\bar{X}$	$\bar{D}$	$S_{\bar{D}}$	90% confidence limits for population $\bar{D}$	
			June				
Colorado	10/31	16.2	20.9	-4.7	1.8	(-7.7, -1.7)	S
Kansas	26/121	21.8	30.1	-8.3	2.3	(-12.1, -4.5)	S
Nebraska	17/56	18.4	19.1	-0.7	1.9	(-3.8, 2.4)	N
Oklahoma	15/46	26.6	35.3	-8.7	3.3	(-14.1, -3.3)	S
Texas	11/35	21.1	22.4	-1.3	2.5	(-5.4, 2.8)	N
Montana	5/58	14.5	28.0	-13.5	3.6	(-19.4, -7.6)	S
S. Dakota	2/21	NA	NA	NA	NA	NA	
USGP-7	86/368	20.3	26.1	-5.8	1.1	(-7.6, -4.0)	S
			July				
Colorado	7/31	18.4	19.8	-1.4	1.3	(-3.5, 0.7)	N
Kansas	22/121	25.9	30.3	-4.5	1.5	(-7.0, -2.0)	S
Nebraska	14/56	16.6	19.7	-3.1	2.4	(-7.3, 1.1)	N
Oklahoma	13/46	31.8	35.6	-3.8	1.6	(-6.4, -1.2)	S
Texas	8/35	23.1	25.8	-2.7	2.8	(-7.3, 1.9)	N
Montana	7/58	12.0	27.0	-15.0	3.3	(-20.4, -9.6)	S
S. Dakota	2/21	NA	NA	NA	NA	NA	
USGP-7	73/368	22.4	26.9	-4.5	0.9	(-6.0, -3.0)	S
			August				
Colorado	10/31	19.9	21.4	-1.5	1.1	(-1.5, 0.5)	N
Kansas	23/121	27.2	31.5	-4.3	1.4	(-6.7, -1.9)	S
Nebraska	14/56	15.7	17.8	-2.1	1.3	(-4.4, 0.2)	N
Oklahoma	13/46	35.8	38.0	-2.2	1.3	(-4.5, 0.1)	N
Texas	9/35	24.1	25.5	-1.4	2.7	(-6.4, 3.6)	N
Montana	11/58	12.7	27.5	-14.8	2.8	(-19.4, -10.2)	S
S. Dakota	2/21	NA	NA	NA	NA	NA	
USGP-7	82/368	23.0	27.3	-4.3	0.6	(-5.3, -3.3)	S

TABLE 4-4.— Concluded.

Region	Blind sites/ sample segments	$\bar{\hat{X}}$	$\bar{X}$	$\bar{D}$	$S_{\bar{D}}$	90% confidence limits for population D	
September							
Colorado	11/31	17.3	20.6	-3.3	1.3	(-5.7, -0.9)	S
Kansas	24/121	27.3	31.5	-4.2	1.2	(-6.3, -2.1)	S
Nebraska	17/56	14.0	18.3	-4.3	1.1	(-6.2, -2.4)	S
Oklahoma	13/46	36.9	38.0	-1.1	1.4	(-3.6, 1.4)	N
Texas	9/35	24.3	25.5	-1.2	2.7	(-6.2, 3.8)	N
Montana	10/58	13.8	27.1	-13.4	2.9	(-18.7, -8.1)	S
S. Dakota	2/21	NA	NA	NA	NA	NA	
USGP-7	86/368	22.5	26.9	-4.4	0.7	(-5.6, -3.2)	S
October							
Colorado	11/31	17.8	20.6	-2.8	1.4	(-5.3, -0.3)	S
Kansas	25/121	26.3	30.7	-4.4	1.2	(-6.5, -2.3)	S
Nebraska	16/56	16.0	20.2	-4.2	1.4	(-6.7, -1.8)	S
Oklahoma	14/46	35.3	39.3	-4.0	2.8	(-9.0, 1.0)	N
Texas	9/35	24.4	25.5	-1.1	2.4	(-5.6, 3.4)	N
Montana	10/58	15.7	27.4	-11.7	3.0	(-17.2, -6.2)	S
S. Dakota	2/21	NA	NA	NA	NA	NA	
USGP-7	87/368	22.9	27.5	-4.6	0.8	(-5.9, -3.3)	S
Final							
Colorado	11/31	17.8	20.6	-2.8	1.4	(-5.3, -0.3)	S
Kansas	25/121	25.8	30.4	-4.6	1.1	(-6.5, -2.7)	S
Nebraska	16/56	16.8	20.2	-3.4	1.3	(-5.7, -1.1)	S
Oklahoma	15/46	34.9	40.9	-6.0	3.0	(-11.2, -0.7)	S
Texas	9/35	24.4	25.5	-1.1	2.7	(-6.1, 3.9)	N
Montana	12/35	15.8	25.7	-9.9	2.5	(-14.4, -5.4)	S
S. Dakota	2/21	NA	NA	NA	NA	NA	
USGP-7	90/368	22.9	27.7	-4.8	0.8	(-6.1, -3.5)	S

Table 4-4 contains the results of the state and regional statistical analyses of the blind site data on winter small grains. The following factors are listed.

a. The average small grains' proportion estimate, $\bar{\hat{X}}$.

b. The average ground-truth small grains' proportion, $\bar{X}$.

c. The average difference, $\bar{D} = \bar{\hat{X}} - \bar{X}$.

d. The standard error of the average difference, $S_{\bar{D}}$.

e. The 90-percent confidence limits for the population average difference.

The formulas for calculating these factors are given in appendix A.

To determine whether the population average difference for a particular state or region is significantly different from 0, one may simply check whether the corresponding confidence interval contains 0. If it does, the population average difference is not significantly different from 0; that is, there is insufficient evidence to conclude that a bias exists because of proportion estimation error. If the confidence interval does not contain 0, the hypothesis of no bias is rejected and is denoted as S. A hypothesis which is not rejected is denoted as N. The test was performed at the 10-percent level of significance.

In table 4-4, the average proportion estimation errors for the USGP-7 region were negative and significantly different from 0 at the 10-percent level each month during the season. The average proportion estimation error for the USGP-7 region decreased in magnitude each month from -11.2 percent in February to -5.8 percent in June. From the July through final reports, the average proportion estimation errors for the USGP-7 region were all close to -4.5 percent, indicating that the average proportion of small grains in the segments was underestimated each month in that period.

4.2.3 SPRING SMALL GRAINS' PROPORTION ESTIMATION ERROR (UNWEIGHTED ANALYSIS)

Figure 4-3 and table 4-5 contain spring small grains' proportion estimation error results that are analogous to the winter small grains' results contained in section 4.2.2.

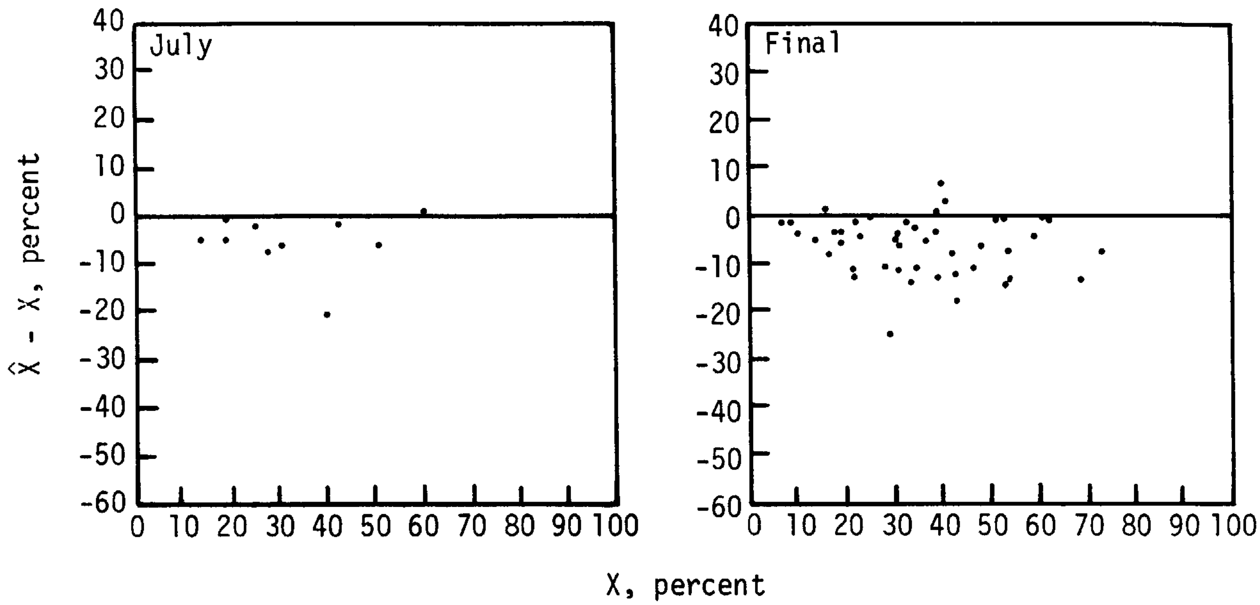

Figure 4-3.— Plot of proportion estimation errors versus digitized ground-truth proportions for spring small grains for blind sites.

TABLE 4-5.— SPRING SMALL-GRAIN BLIND SITE RESULTS[a]

Region	Blind sites/ sample segments	$\bar{\hat{X}}$	$\bar{X}$	$\bar{D}$	$S_{\bar{D}}$	90% confidence limits for population $\bar{D}$	
July							
Minnesota	6/47	17.8	25.7	-7.9	2.4	(-12.7, -3.1)	S
Montana	0/48	NA	NA	NA	NA	NA	
N. Dakota	2/103	52.0	54.8	NA	NA	NA	
S. Dakota	2/37	29.0	30.5	NA	NA	NA	
USNGP	10/235	26.9	32.5	-5.6	1.8	(-8.9, -2.3)	S
August							
Minnesota	10/47	31.9	36.8	-4.9	1.1	(-6.9, -2.9)	S
Montana	2/48	6.8	11.2	NA	NA	NA	
N. Dakota	8/103	36.6	42.4	-5.8	2.1	(-8.8, -2.8)	S
S. Dakota	5/37	23.6	27.1	-3.5	1.6	(-6.9, -0.1)	S
USNGP	25/235	29.7	34.6	-4.9	0.9	(-6.4, -3.4)	S
September							
Minnesota	11/47	34.8	39.0	-4.2	1.3	(-6.6, -1.8)	S
Montana	3/48	18.2	20.2	-2.0	1.6	(-6.7, 2.7)	N
N. Dakota	17/103	31.6	39.2	-7.6	1.5	(-10.2, -5.0)	S
S. Dakota	6/37	18.8	28.3	-9.5	2.8	(-14.8, -3.9)	S
USNGP	37/235	29.4	35.8	-6.4	1.0	(-8.1, -4.7)	S

[a]Symbol definitions:

$\bar{\hat{X}}$ = average of harvested small grains' proportion estimates.

$\bar{X}$ = average of digitized ground-truth small grains' proportion estimates for harvested small grains.

$\bar{D}$ = averaged difference, $\bar{\hat{X}} - \bar{X}$.

$S_{\bar{D}}$ = standard error of $\bar{D}$.

S = hypothesis of no bias was rejected.

N = hypothesis of no bias was not rejected.

TABLE 4-5.— Concluded.

Region	Blind sites/ sample segments	$\bar{\hat{X}}$	$\bar{X}$	$\bar{D}$	$S_{\bar{D}}$	90% confidence limits for population D	
October							
Minnesota	12/47	34.1	38.5	-4.4	1.1	(-6.4, -2.4)	S
Montana	5/48	22.3	25.8	-3.5	2.2	(-8.2, 1.2)	N
N. Dakota	20/103	32.2	38.1	-5.9	1.1	(-7.8, -4.0)	S
S. Dakota	6/37	19.4	28.3	-8.9	3.0	(-14.9, -2.9)	S
USNGP	43/235	29.8	35.4	-5.6	0.8	(-6.9, -4.3)	S
Final							
Minnesota	12/47	33.9	38.5	-4.6	1.1	(-6.6, -2.6)	S
Montana	5/48	22.3	25.8	-3.5	2.2	(-8.2, 1.2)	N
N. Dakota	20/103	32.4	38.0	-5.6	1.1	(-7.5, -3.7)	S
S. Dakota	8/37	16.5	27.4	-10.9	2.2	(-15.1, -6.7)	S
USNGP	45/235	28.8	34.9	-6.1	0.8	(-7.4, -4.8)	S

The plots in figure 4-3 show a tendency to underestimate the proportion of spring small grains in the segments, but the downward trend observed in the plots of winter small grains was not seen in the plots for spring small grains. Those conclusions were based on two facts: 8 of the 10 proportion estimation errors in the July plot were randomly distributed between 0.0 and -10.0 percent, and the regression coefficient for the final data on spring small grains was only 0.1. In parts of Montana and North Dakota, the small grains suffered from moisture stress, but the crops were reported in fair to good condition in most areas. There were no reports of adverse crop conditions affecting the proportion estimates in Montana and North Dakota, implying a negative bias in the proportion estimation error under near-normal conditions.

Like the average proportion estimation errors in the USGP-7 region, the errors for the USNGP as shown in table 4-5 were negative each month during the growing season and were significantly different from 0 at the 10-percent level each month.

4.2.4 WINTER WHEAT PROPORTION ESTIMATION ERROR (UNWEIGHTED ANALYSIS)

This section presents the results of segment-level wheat proportion estimation error investigations based on comparisons of LACIE wheat proportion estimates with corresponding ground-observed wheat proportions. The term "unweighted" is used to indicate that the analyses do not involve the expansion factors, or weights, from the aggregation logic.

Blind site results for the investigation of winter wheat proportion estimation errors for the USGP-7 region are shown in figure 4-4 and table 4-6. The LACIE proportion estimates used are from the Phase III CAS annual report, December 22, 1977. Figure 4-4 shows plots of the proportion estimation error ($\hat{X}$ - X) versus $\hat{X}$ for the February, July, and final CAS reports, where $\hat{X}$ is the LACIE harvested wheat proportion estimate and X is the ground-observed harvested wheat proportion. Points lying above the horizontal line $\hat{X} - X = 0$ correspond to overestimates, and points lying below the line correspond to underestimates of wheat proportions.

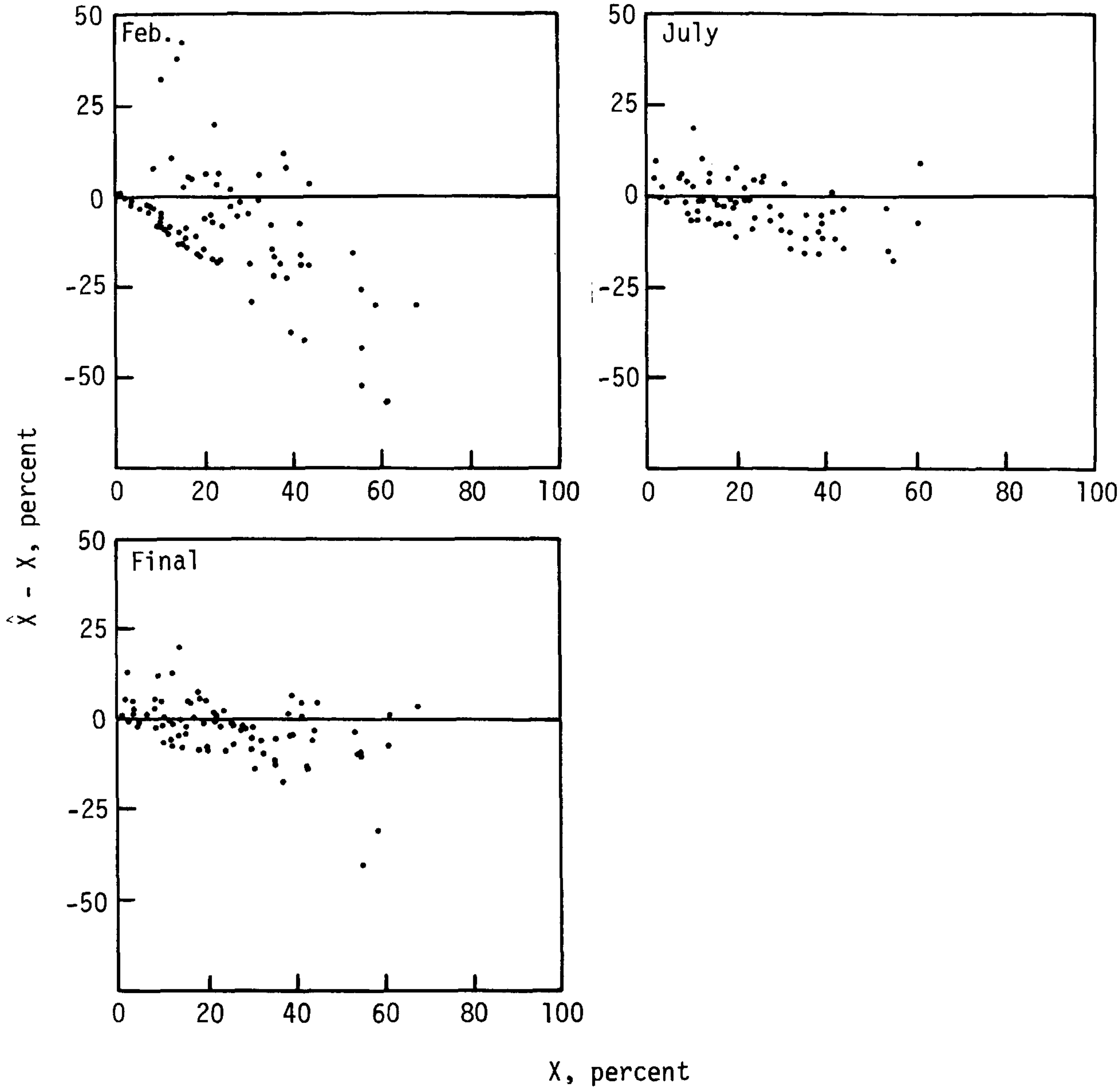

Figure 4-4.— Plots of proportion estimation errors versus ground-observed proportions for winter wheat blind sites.

TABLE 4-6.– WINTER WHEAT BLIND SITE RESULTS[a]

Region	Blind sites/ sample segments	$\hat{\bar{X}}$	$\bar{X}$	$\bar{D}$	$S_{\bar{D}}$	90% confidence limits for population D	
February							
Colorado	10/31	12.9	22.3	-9.5	1.8	(-12.7, -6.3)	S
Kansas	19/121	14.9	30.2	-15.3	3.9	(-22.0, -8.6)	S
Nebraska	16/56	20.8	17.7	3.1	3.0	(-2.2, 8.3)	N
Oklahoma	14/46	17.0	36.8	-19.9	4.2	(-27.3, -12.5)	S
Texas	9/35	15/3	25.6	-10.3	3.4	(-16.6, -4.0)	S
Montana	7/58	8.8	14.7	-6.0	1.9	(-9.7, -2.2)	S
S. Dakota	2/21	7.9	11.3	-3.4	2.6	(-19.9, 13.2)	N
USGP-7	77/368	15.6	25.3	-9.8	1.7	(-12.6, -7.1)	S
May							
Colorado	10/31	15.4	22.3	-6.8	2.2	(-10.9, -2.7)	S
Kansas	23/121	22.1	30.6	-8.5	2.6	(-12.9, -4.1)	S
Nebraska	16/56	13.9	17.1	-3.2	1.8	(-6.4, -0.1)	S
Oklahoma	15/46	25.3	34.3	-9.0	3.4	(-15.0, -3.1)	S
Texas	10/35	19.4	23.4	-4.0	2.5	(-8.6, 0.6)	N
Montana	5/58	12.6	17.2	-4.6	2.9	(-10.7, 1.6)	N
S. Dakota	2/21	6.2	11.3	-5.1	4.3	(-32.1, 21.9)	N
USGP-7	81/368	18.9	25.4	-6.5	1.1	(-8.4, -4.6)	S

[a]Symbol definitions:

$\hat{\bar{X}}$ = Average of harvested wheat proportion estimates.

$\bar{X}$ = Average of dot-count ground-truth wheat proportion estimates for harvested wheat.

$\bar{D}$ = Averaged difference, $\hat{\bar{X}} - \bar{X}$.

$S_{\bar{D}}$ = Standard error of $\bar{D}$.

S = Significantly different from 0 at the 10-percent level.

N = Not significantly different from 0 at the 10-percent level.

TABLE 4-6.— Continued.

Region	Blind sites/ sample segments	$\bar{\hat{X}}$	$\bar{X}$	$\bar{D}$	$S_{\bar{D}}$	90% confidence limits for population $\bar{D}$	
June							
Colorado	10/31	16.2	22.3	-6.1	2.4	(-10.4, -1.8)	S
Kansas	25/121	22.3	29.0	-6.7	2.4	(-10.8, -2.6)	S
Nebraska	17/56	18.0	16.7	1.3	1.6	(-1.5, 4.1)	N
Oklahoma	15/46	26.1	34.3	-8.2	3.2	(-13.9, -2.6)	S
Texas	10/35	20.2	23.4	-3.2	2.5	(-7.8, 1.4)	N
Montana	5/58	14.5	17.2	-2.6	2.8	(-8.6, 3.4)	N
S. Dakota	3/21	5.7	7.8	-2.1	3.7	(-12.8, 8.6)	N
USGP-7	85/368	20.1	24.6	-4.5	1.1	(-6.3, -2.6)	S
July							
Colorado	7/31	18.4	19.3	-0.9	1.4	(-3.6, 1.8)	N
Kansas	21/121	26.5	29.1	-2.7	1.4	(-5.2, -0.2)	S
Nebraska	14/56	16.4	17.0	-0.6	1.9	(-4.0, 2.8)	N
Oklahoma	13/46	31.4	35.2	-3.8	1.7	(-6.8, -0.8)	S
Texas	8/35	21.4	25.5	-4.1	2.5	(-8.8, 0.5)	N
Montana	8/58	11.3	15.3	-4.0	1.6	(-7.1, -0.9)	S
S. Dakota	3/21	7.2	7.6	-0.4	1.0	(-3.3, 2.6)	N
USGP-7	74/368	21.7	24.2	-2.5	0.7	(-3.7, -1.3)	S
August							
Colorado	10/31	19.9	21.3	-1.4	1.8	(-4.7, 1.8)	N
Kansas	22/121	28.0	30.6	-2.6	1.3	(-4.8, -0.4)	S
Nebraska	14/56	15.5	16.2	-0.8	1.3	(-3.0, 1.5)	N
Oklahoma	13/46	35.3	36.9	-1.6	1.6	(-4.4, 1.2)	N
Texas	9/35	22.4	25.2	-2.8	2.8	(-8.1, 2.5)	N
Montana	12/58	11.8	14.0	-2.2	1.2	(-4.5, 0.0)	N
S. Dakota	3/21	7.0	7.6	-0.6	0.8	(-3.1, 1.9)	N
USGP-7	83/368	22.4	24.2	-1.8	0.6	(-2.8, -0.8)	S

TABLE 4-6.— Concluded.

Region	Blind sites/ sample segments	$\hat{\bar{X}}$	$\bar{X}$	$\bar{D}$	$S_{\bar{D}}$	90% condfidence limits for population $\bar{D}$	
September							
Colorado	11/31	17.3	20.2	-2.9	1.6	(-5.8, -0.1)	S
Kansas	23/121	28.0	30.5	-2.5	1.1	(-4.4, -0.5)	S
Nebraska	17/56	13.7	16.0	-2.3	1.1	(-4.2, -0.4)	S
Oklahoma	13/46	36.3	36.9	-0.5	1.6	(-3.4, 2.4)	N
Texas	9/35	22.6	25.2	-2.6	2.9	(-8.0, 2.8)	N
Montana	12/58	12.8	13.6	-0.7	1.0	(-2.6, 1.1)	N
S. Dakota	3/21	5.0	7.6	-2.6	2.6	(-10.1, 4.9)	N
USGP-7	88/368	21.7	23.7	-1.9	0.6	(-2.9, -0.9)	S
October							
Colorado	11/31	17.8	20.2	-2.4	1.7	(-5.4, 0.7)	N
Kansas	24/121	27.0	29.4	-2.4	1.1	(-4.3, -0.6)	S
Nebraska	16/56	15.7	18.0	-2.2	1.3	(-4.5, 0.1)	N
Oklahoma	14/46	34.8	38.2	-3.4	2.8	(-8.3, 1.6)	N
Texas	9/35	22.7	25.2	-2.5	2.9	(-7.9, 2.9)	N
Montana	14/58	13.6	13.4	0.1	1.0	(-1.7, 1.9)	N
S. Dakota	3/21	5.0	7.6	-2.6	2.6	(-10.1, 4.9)	N
USGP-7	91/368	21.9	24.0	-2.1	0.7	(-3.3, -1.0)	S
Final							
Colorado	11/31	17.8	20.2	-2.4	1.4	(-5.0, 0.2)	N
Kansas	24/121	26.5	30.2	-3.7	1.1	(-5.6, -1.8)	S
Nebraska	16/56	16.5	19.5	-3.0	1.3	(-5.3, -0.7)	S
Oklahoma	15/46	34.4	40.5	-6.1	3.1	(-11.5, -0.7)	S
Texas	9/35	22.7	24.9	-2.2	2.8	(-7.4, 3.0)	N
Montana	13/58	14.2	14.9	-0.7	1.2	(-2.8, 1.4)	N
S. Dakota	3/21	5.0	5.6	-0.6	1.6	(-3.9, 5.1)	N
USGP-7	91/368	22.0	25.1	-3.1	0.7	(-4.3, -1.9)	S

Table 4-6 contains the results of the statistical analysis of the winter wheat blind site data. The following factors are listed:

- The average wheat proportion estimate, $\bar{\hat{X}}$.
- The average ground-observed wheat proportion, $\bar{X}$.
- The average difference, $\bar{D} = \bar{\hat{X}} - \bar{X}$.
- The standard error of the average difference, $S_{\bar{D}}$.
- The 90-percent confidence limits for the population average difference, $\bar{D}$.

To infer whether the population average difference for a particular state or region is significantly different from zero, one may simply check whether the corresponding 90-percent confidence interval contains zero. It it does, the population average difference is not significantly different from zero; that is, there is insufficient evidence to conclude that there is a bias due to proportion estimation error. If the confidence interval does not contain zero, the hypothesis of no bias is rejected. The test is performed at the 10-percent level of significance.

The plot for February winter wheat shows that early in the 1977 season there was a tendency for the proportion of wheat in the segments to be underestimated by a greater margin for segments with larger proportions of wheat. This trend became less pronounced as the season progressed, and it appeared to be insignificant in the July and final plots for winter wheat.

The results in table 4-6 indicate the presence of a negative bias in LACIE winter proportion estimates for the USGP-7 region for each month shown. This indicates that for these blind sites the proportion of winter wheat for the USGP-7 region was underestimated in each reporting period. However, the wheat proportion estimation error decreased in magnitude each month, starting with May and ending in August. From August through the final reporting month, there was a slight increase each month in the magnitude of the wheat proportion estimation error for the USGP-7 region. Inspection of figure 4-4 for the final estimates indicates that two outliers were the main causes of the increase.

Although the average winter wheat proportion estimation errors for the individual states in the USGP-7 tended to be negative, they decreased in magnitude as the season progressed. The number of states with a population average difference that was not significantly different from zero at the 10-percent level increased from two in February to six in October. In the February and the final report, the average proportion estimation error for Oklahoma was nearly twice as large as the average for the other states in the USGP-7. The proportion estimation error for Oklahoma in May through October does not appear to be significantly different from the estimates of other states because the two outliers previously mentioned were in Oklahoma. One was acquired for the October analysis (note the increase in $\overline{D}$ and $S_{\overline{D}}$ from September to October for Oklahoma in table 4-6), and the second was acquired for the final analysis (note the further increase in $\overline{D}$ and $S_{\overline{D}}$ from October to final for Oklahoma).

Figure 4-5 displays plots of proportion estimation error versus ground-observed proportion for each state in the USGP-7 winter wheat region, using the final LACIE proportion estimates. The two outliers are again apparent in the plot for Oklahoma. Investigation of these two blind sites indicated that there was no Landsat acquisition during the tillering-to-heading stages of wheat. As a result, the analyst mislabeled most of the wheat pixels as nonsmall grains. Excluding these two outliers yields an average proportion estimation error of -0.8 with a standard error of 1.4 for the remaining 13 blind sites, and the negative bias is no longer indicated.

Two other states with seemingly large standard errors of the average differences for the final estimates are Texas and South Dakota. The large standard error is expected for South Dakota because only three blind sites are available. However, there are nine blind sites in Texas, and inspection of the plot for Texas reveals one outlier that is an extreme overestimate. Omitting this outlier yields an average difference of -4.5 with a standard error of 1.6, indicating a negative bias in the Texas winter wheat proportion estimates. Investigation of this site indicates an acquisition pattern similar to that

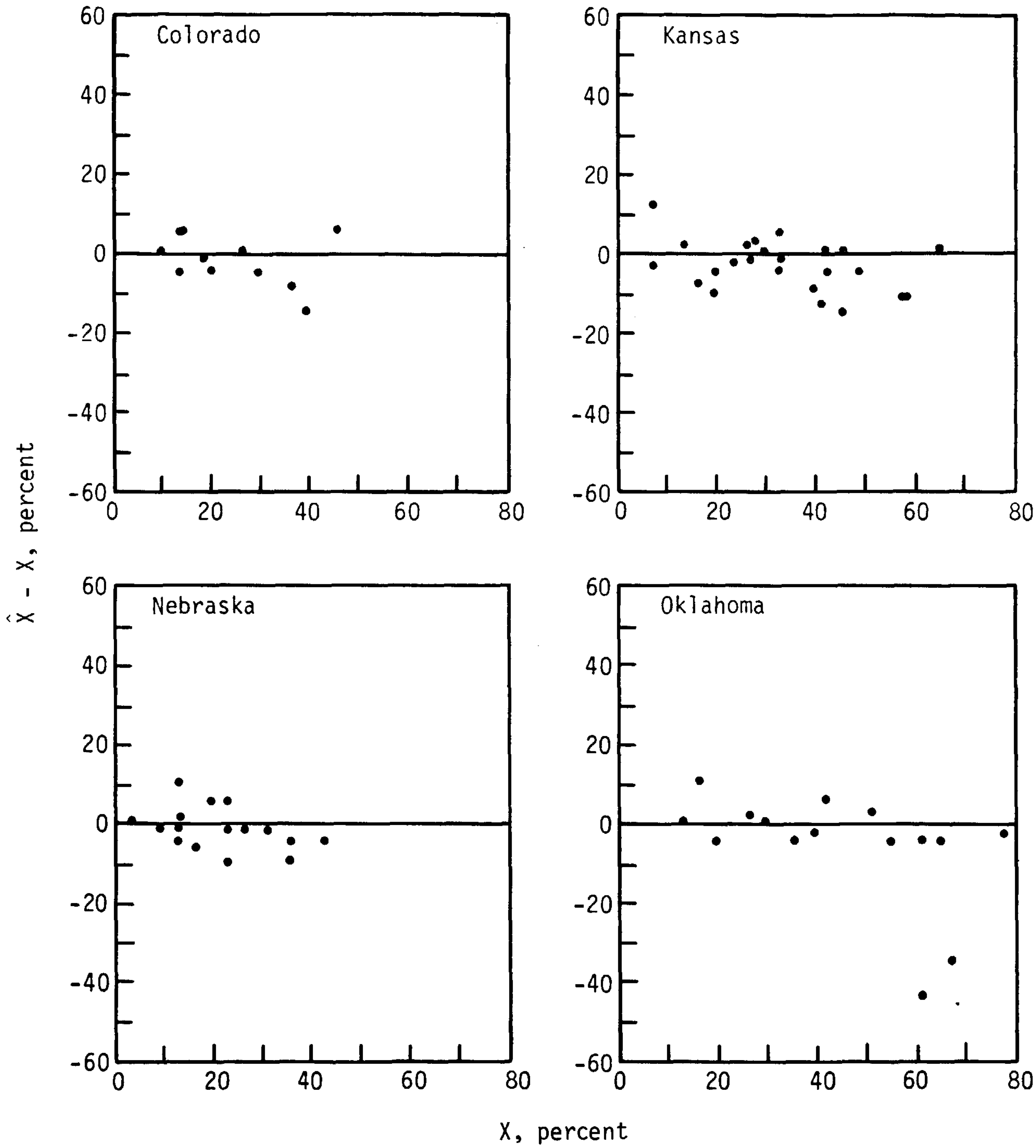

Figure 4-5.— Plots of at-harvest proportion estimation errors versus ground-observed proportions for winter wheat blind sites by state.

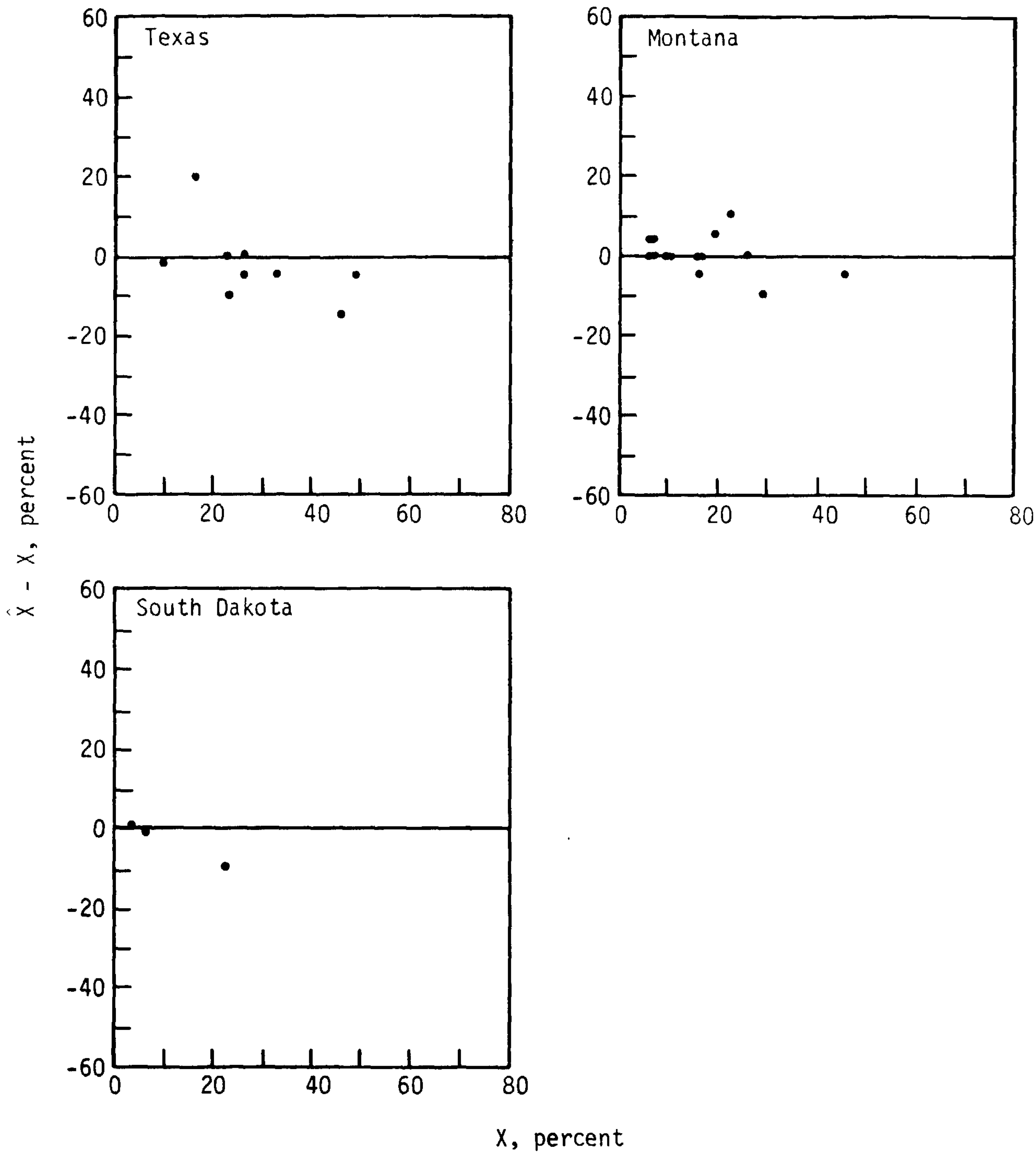

Figure 4-5.— Concluded.

of the two Oklahoma outliers. In this case, however, missing a key acquisition leads to overestimation rather than underestimation. This indicates that when a key acquisition is missing, a proportion estimate should not be made because positive identification of pixel labels is very difficult.

4.2.5 SPRING WHEAT PROPORTION ESTIMATION ERROR (UNWEIGHTED ANALYSIS)

Figure 4-6 and table 4-7 contain spring wheat proportion estimation error results that are analogous to the winter wheat results presented in the preceding section.

The downward trend that was evident in the February plot of winter wheat proportion estimation error versus the ground-observed proportion of winter wheat is also seen in the July spring wheat plot, demonstrating that the problem of underestimating the proportion of wheat early in the season in segments with larger proportions of wheat exists for spring wheat and for winter wheat. There was a gradual improvement in the LACIE estimates of the proportion of spring wheat (in the segments with large proportions of spring wheat) as the season progressed, but the trend is still present in the final spring wheat plot.

The average wheat proportion error for spring wheat had a tendency to be negative. The average spring wheat proportion estimation error for the USNGP region was negative for each month; and except for July, the population average differences were significantly different from zero at the 10-percent level (see table 4-7). This sequence of negative average wheat proportion estimation errors for the USNGP region increased in magnitude from the July through the September reports and decreased slightly in the October and final reports. From August through the final report, the average proportion estimation error for Montana was not significantly different from zero at the 10-percent level. In July, South Dakota had an average wheat proportion estimation error that was significantly different from zero at the 10-percent level. There were no data for Montana in July.

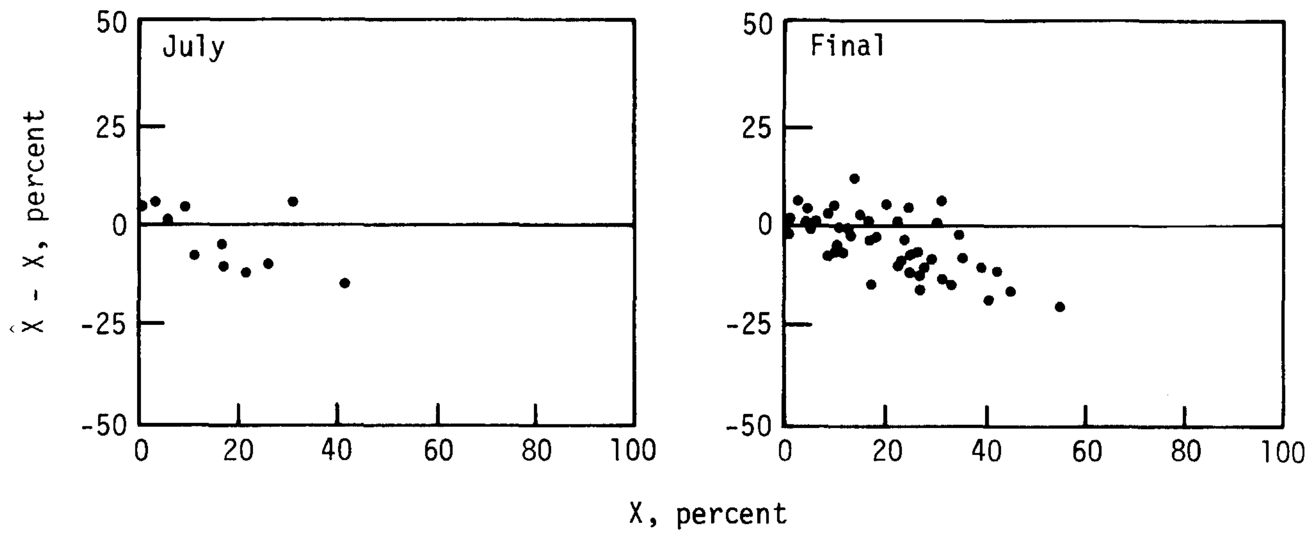

Figure 4-6.— Plots of proportion estimation errors versus ground-observed proportions for spring wheat blind sites.

TABLE 4-7.– SPRING WHEAT BLIND SITE RESULTS[a]

Region	Blind sites/ sample segments	$\bar{\hat{X}}$	$\bar{X}$	$\bar{D}$	$S_{\bar{D}}$	90% confidence limits for population $\bar{D}$	
			July				
Minnesota	6/47	9.1	11.1	-2.0	2.5	(-7.1, 3.0)	N
Montana	0/48	-	-	-	-	-	
N. Dakota	2/103	32.6	36.8	-4.2	10.3	(-69.2, 60.8)	N
S. Dakota	3/37	11.2	15.8	-4.6	4.9	(-18.9, 9.8)	N
USNGP	11/235	13.9	17.1	-3.1	2.3	(-7.3, 1.0)	N
			August				
Minnesota	10/47	17.3	22.6	-5.2	2.4	(-9.6, -0.9)	S
Montana	4/48	4.2	11.7	-7.5	5.9	(-21.3, 6.3)	N
N. Dakota	8/103	24.4	27.3	-2.8	3.4	(-9.4, 3.7)	N
S. Dakota	9/37	9.8	11.3	-1.6	2.0	(-5.3, 2.1)	N
USNGP	31/235	15.3	19.1	-3.8	1.5	(-6.3, -1.3)	S
			September				
Minnesota	11/47	19.0	23.7	-4.7	2.3	(-8.8, -0.6)	S
Montana	7/48	9.9	12.1	-2.2	2.4	(-6.8, 2.4)	N
N. Dakota	17/103	20.9	25.7	-4.8	1.7	(-7.8, -1.8)	S
S. Dakota	9/37	8.4	11.3	-2.9	2.5	(-7.6, 1.8)	N
USNGP	44/235	16.1	20.1	-4.0	1.1	(-5.8, -2.2)	S
			October				
Minnesota	12/47	18.6	22.9	-4.3	2.2	(-8.2, -0.4)	S
Montana	9/48	11.9	15.7	-3.8	2.3	(-8.1, 0.5)	N
N. Dakota	20/103	21.0	25.1	-4.0	1.5	(-6.6, -1.5)	S
S. Dakota	9/37	7.9	9.4	-1.5	2.3	(-5.8, 2.8)	N
USNGP	50/235	16.4	20.1	-3.6	1.0	(-5.2, -2.0)	S
			Final				
Minnesota	12/47	18.5	21.1	-2.6	1.9	(-6.0, 0.8)	N
Montana	9/48	12.0	14.6	-2.7	2.0	(-6.3, 0.9)	N
N. Dakota	21/103	21.3	25.2	-3.9	1.4	(-6.4, -1.5)	S
S. Dakota	11/37	7.1	10.1	-2.9	1.6	(-5.7, -0.1)	S
Total	53/235	16.1	19.3	-3.2	0.8	(-1.9, 0.8)	N

[a]Symbol definitions:

$\bar{\hat{X}}$ = Average of harvested wheat proportion estimates.

$\bar{X}$ = Average of dot-count ground-truth wheat proportion estimates for harvested wheat.

$\bar{D}$ = Averaged difference, $\bar{\hat{X}} - \bar{X}$.

$S_{\bar{D}}$ = Standard error of $\bar{D}$.

S = Significantly different from 0 at the 10-percent level.

N = Not significantly different from 0 at the 10-percent level.

Figure 4-7 displays the plots of proportion estimation error versus ground-observed proportion for each state in the USNGP spring wheat region. There are no obvious outliers for any of the states, but the tendency to underestimate the larger proportions is apparent in each state.

4.3 SAMPLING AND CLASSIFICATION ERRORS

The following study was performed to measure the contributions of classification and sampling errors to within-stratum area variance and to estimate the classification and sampling error contributions to the CV's of the area estimates. Since the proportion estimates used in this section were obtained by ratioing small-grain estimates (winter or spring), the classification error referred to herein is actually compounded with the ratio error. Section 6.2 discusses the breakdown of this error into classification and ratio error components.

To estimate the within-stratum area variances resulting from classification and sampling errors, one first constructs the following three basic regression models:

a. True segment proportion versus historical stratum proportion.

b. LACIE segment proportion versus ground-truth segment proportion.

c. LACIE segment proportion versus historical stratum proportion.

These regression models are used to obtain, respectively, the estimates for the variance contribution resulting from sampling (often called sampling variance), the variance contribution resulting from classification (often called classification variance), and the total variance, which includes any correlation between classification and sampling. The maximum likelihood estimation technique, assuming normality, is then used to obtain the optimal estimates for sampling and classification variances. A detailed description of this method is presented in appendix A (section A.3.1.5.1).

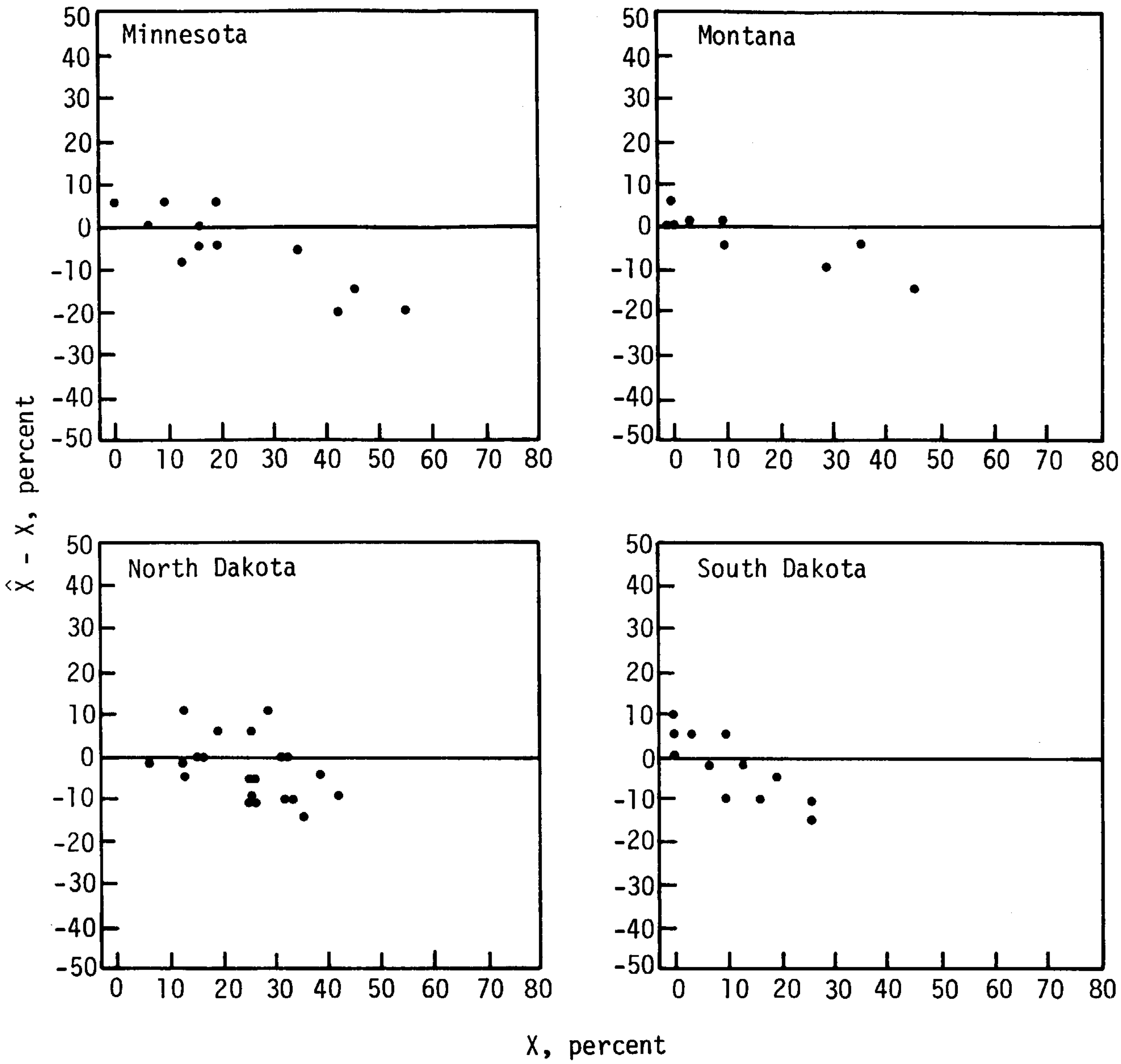

Figure 4-7.— Plots of at-harvest proportion estimation errors versus ground-observed proportions for spring wheat blind sites by state.

When the previously mentioned variance estimates are obtained, the ratio ρ of the within-stratum sampling variance estimate to the total within-stratum area variance estimate can be calculated easily. Assuming that this ratio applies to each zone and each higher region, the variances of the large area estimate resulting from classification and sampling are given by

$$\hat{\eta}^2 = (1 - \rho)\hat{V}^2$$

and

$$\hat{\nu}^2 = \rho\hat{V}^2$$

where

$\hat{\eta}^2$ = classification variance

$\hat{\nu}^2$ = sampling variance

$\hat{V}^2$ = area variance

Consequently, the estimated CV of a large area estimate $\hat{A}$ resulting from classification is given by

$$\hat{CV}(\hat{A}/C) = \frac{\hat{\eta}}{\hat{A}}$$

and the estimated CV of a large area estimate resulting from sampling is given by

$$\hat{CV}(\hat{A}/S) = \frac{\hat{\nu}}{\hat{A}}$$

where $\hat{CV}(\hat{A}/C)$ and $\hat{CV}(\hat{A}/S)$ are often casually referred to as the classification CV and the sampling CV, respectively.

Estimates of these variances and CV's for the LACIE Phase III final estimates are tabulated below.

Crop	Within-stratum area variance	Variance component		Percentage error		Classification CV, %	Sampling CV, %
		Due to classification	Due to sampling	Due to classification	Due to sampling		
Winter wheat USGP-7	104.1	41.6	62.5	40	60	2.0	2.5
Spring wheat USNGP	65.6	26.2	39.4	40	60	2.3	2.8
Total wheat USGP	100.4	39.6	60.8	40	60	1.5	1.9

These results show that the sampling CV is larger than the classification CV for winter, spring, and total wheat estimates. The indication is that sampling contributes slightly more to the area variance than does classification. Moreover, winter wheat has smaller CV's for both classification and sampling than does spring wheat. The sampling CV for the total wheat area estimate is 1.9 percent, well within the sampling accuracy goal of 2.3 percent.

4.4 ACREAGE ESTIMATION BIAS DUE TO NONSAMPLED AND NONRESPONSIVE AREAS

To investigate bias caused by the ratio estimation used to estimate the wheat area in nonsampled and nonresponsive areas in the United States, analysts performed aggregations in which the LACIE proportion estimate for each segment was replaced by the corresponding 1976 USDA/SRS county wheat proportion. Table 4-8 shows the results of this mock aggregation for all allocated segments and the comparisons with 1976 USDA/SRS estimates. The RD at the USGP level is -2.5 percent, indicating a possible small negative bias caused by the group II and group III ratio estimation procedure used for those counties not allocated segments. This is larger than the observed RD of 0.8 percent obtained in a similar study of the Phase II sample segment allocation to the USGP, which was based on wheat production for an epoch year; the Phase III allocation was based on small-grain production for an epoch year.

TABLE 4-8.— ACREAGE ESTIMATION BIAS DUE TO NONSAMPLED AREAS

Region	Allocated segments	1976 USDA/SRS, ac × 10^3	Mock aggregation, ac × 10^3	RD, %
Winter USGP-7	368	31 500	30 478	-3.4
Spring USNGP	235	19 768	19 527	-1.2
Total USGP	[a]557	51 268	50 005	-2.5

[a]Total after allocation redesignated.

While investigating to determine the allocation that would have resulted from using the epoch-year wheat production rather than the epoch-year small-grain production, the analyst found that 32 counties currently designated group III should have been group I or group II and that 16 counties designated group I and 43 designated group II should have been group III counties. The decision was made to redesignate the 16 group I and 43 group II counties as group III counties, causing the original allocation to the United States of 601 segments to be reduced to 557 segments (table 4-8). It was infeasible at the time to allocate more sample segments to the 32 incorrectly designated counties; the use of the group III estimator to estimate their wheat area accounts for at least part of the observed difference.

TABLE 4-9.— ACREAGE ESTIMATION BIAS DUE TO NONSAMPLED AND NONRESPONSIVE AREAS

Crop/ region	Acquired segments/ allocated segments	1976 USDA/SRS, ac × 10^3	Mock aggregation, ac × 10^3	RD, %
February				
Winter USGP-7	244/368	31 500	30 408	-3.6
May				
Winter USGP-7	256/368	31 500	30 737	-2.5
June				
Winter USGP-7	272/368	31 500	30 556	-3.1
July				
Winter USGP-7	241/368	31 500	30 978	-1.7
August				
Winter USGP-7	276/368	31 500	30 678	-2.7
Spring USNGP	116/234	19 768	19 934	0.8
Total USGP	376/557	51 268	50 612	-1.3
September				
Winter USGP-7	290/368	31 500	30 641	-2.8
Spring USNGP	151/234	19 768	19 523	-1.3
Total USGP	419/557	51 268	50 164	-2.2
October				
Winter USGP-7	298/368	31 500	30 475	-3.4
Spring USNGP	172/234	19 768	19 548	-1.1
Total USGP	444/557	51 268	50 023	-2.5

Table 4-9 contains the results of aggregating the 1976 USDA/SRS county wheat proportions for each segment acquired and processed for each Phase III monthly estimate made except the final, which is expected to be similar to that for the October estimate. The difference between the mock aggregation and the USDA/SRS estimate in this study is due to errors in the group II and group III ratio estimation procedure used for both those counties not allocated segments and those counties whose allocated segments were lost to nonresponse.

The results show that the error due to the ratio estimation of the nonsampled and nonresponsive areas for each month during Phase III is approximately the same as the error due to nonsampled areas alone, indicating that the error due to group II and group III ratio estimation of areas lost to nonresponse is negligible. A small negative bias in the ratio estimation technique applied to nonsampled areas is suggested, particularly in the winter wheat region special studies.

5. ASSESSMENT OF YIELD ESTIMATES

The LACIE Phase III and USDA/SRS yield estimates as each set was determined through the year are given in table 5-1 and figure 5-1.

Table 5-2 shows a comparison of the RD's and CV's during the year; all the RD's in the table are computed on the basis of the final USDA/SRS yield estimate. The RD's in table 5-2 were computed from the yield data listed in table 5-1. The CV's and the 1977 final columns of RD and CV in both tables are identical.

5.1 COMPARISON OF LACIE AND USDA/SRS YIELD ESTIMATES

Table 5-1 shows that the LACIE estimate of winter wheat yield for the USGP-7 region remained relatively constant throughout Phase III, varying by only 0.2 bushel per acre, whereas the corresponding USDA/SRS estimates ranged over 1.5 bushels per acre, excluding the estimate derived by AA personnel. All LACIE USGP-7 regional yield estimates were below the corresponding official USDA/SRS estimates during Phase III; the underestimate was significant at the 10-percent level for all estimates except those of the August and the final reports.

The LACIE underestimates were particularly apparent for Oklahoma and Texas. The trend term and the May precipitation variable in the Center for Climatic and Environmental Assessment (CCEA) yield models may have contributed, either together or individually, to the large underestimation of yield. Specifically, the trend term, which depends on a multitude of factors including irrigation and fertilization, has been assumed to be constant since 1960 for the Oklahoma and Texas/Oklahoma Panhandle models. However, increases in both wheat acreage under irrigation and fertilizer application rates in these areas since 1960 indicate that the question of extending the trend term beyond 1960 should be further investigated. At any given time, the yield may vary around the trend curve according to the weather. The three Texas models showed that the yields were above the CCEA trend for 1977, indicating that

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

Region	USDA/SRS estimate, bu/ac	LACIE			RD, %		Value of test statistic
		Estimate, bu/ac	CV, %				
			1977	1976	1977	1976	
Winter wheat — February							
Colorado	*	22.8	18.9	21	NA	21.3	
Kansas	*	28.9	12.1	12	NA	22.4	
Nebraska	*	30.6	10.5	14	NA	19.6	
Oklahoma	*	21.7	13.8	17	NA	34.5	
Texas	*	19.2	16.5	19	NA	36.2	
USSGP	*	25.5	6.7	7	NA	28.3	
Montana	*	26.7	22.4	NA	NA	NA	
S. Dakota	*	27.3	17.5	NA	NA	NA	
Mixed wheat	*	26.9	16.3	NA	NA	NA	
USGP-7	*	25.7	6.3	NA	NA	NA	
Winter wheat — May							
Colorado	24.0	22.8	17.4	20	-5.3	-11.7	
Kansas	32.0	28.1	10.8	10	-13.9	7.0	
Nebraska	34.0	31.3	10.8	14	-8.6	-6.0	
Oklahoma	25.0	21.2	12.5	14	-17.9	3.2	
Texas	23.0	19.5	11.6	13	-17.9	0.6	
USSGP	28.6	25.1	6.1	6	-13.9	1.6	-2.28 S
Montana	27.0	28.5	13.7	NA	5.3	NA	
S. Dakota	20.0	26.0	18.6	NA	23.1	NA	
Mixed wheat	25.5	27.9	11.1	NA	8.6	NA	
USGP-7	28.2	25.5	5.5	NA	-10.6	NA	-1.93 S
Winter wheat — June							
Colorado	24.0	23.6	15.2	17	-1.7	-7.8	
Kansas	33.0	28.3	10.0	9	-16.6	16.1	
Nebraska	35.0	30.2	10.7	13	-15.9	-5.1	
Oklahoma	26.0	19.8	11.0	10	-31.3	3.9	
Texas	25.0	20.3	10.6	12	-23.2	2.7	
USSGP	29.6	25.1	5.6	5	-17.9	7.6	-3.20 S
Montana	27.0	28.1	13.2	12	3.9	-8.3	
S. Dakota	20.0	26.0	18.6	15	23.1	26.5	
Mixed wheat	25.6	27.5	10.7	9	6.9	0	
USGP-7	29.2	25.5	5.1	5	-14.5	6.4	-2.85 S

*A yield estimate was not generated by the USDA/SRS in February 1977.

TABLE 5-1.— Continued.

Region	USDA/SRS estimate, bu/ac	LACIE Estimate, bu/ac	LACIE CV, % 1977	LACIE CV, % 1976	RD, % 1977	RD, % 1976	Value of test statistic
Winter wheat — July							
Colorado	23.0	22.5	14.8	17	-2.2	-22.2	
Kansas	31.0	28.8	9.7	9	-7.6	6.1	
Nebraska	35.0	31.9	9.7	12	-9.7	0	
Oklahoma	26.0	19.9	10.7	10	-30.7	-4.8	
Texas	25.0	20.3	10.8	12	-23.2	-12.3	
USSGP	28.7	25.5	5.6	5	-12.5	0.8	-2.23 S
Montana	27.0	26.5	12.1	9	-1.9	-7.6	
S. Dakota	24.0	26.6	18.9	15	9.8	47.4	
Mixed wheat	26.4	26.5	10.1	9	0.4	8.7	
USGP-7	28.4	25.6	5.1	5	-10.9	1.1	-2.14 S
Spring wheat — July							
Minnesota	36.0	32.4	12.8	NA	-11.1	NA	
N. Dakota	26.3	24.6	15.1	NA	-6.9	NA	
Spring wheat	28.7	26.3	12.6	NA	-9.1	NA	
Montana	23.9	18.4	14.9	NA	-29.9	NA	
S. Dakota	20.9	21.3	12.1	NA	1.9	NA	
Mixed wheat	22.4	19.6	9.3	NA	-14.3	NA	
USNGP	27.0	24.8	10.5	NA	-8.9	NA	-0.85 N
Total wheat — July							
Montana	25.6	23.1	NA	NA	-10.8	NA	
S. Dakota	21.6	24.5	NA	NA	11.8	NA	
Mixed wheat	24.1	23.7	14.6	NA	-1.7	NA	
USNGP	26.9	25.2	15.4	NA	-6.7	NA	
USGP	28.0	25.4	3.9	NA	-10.2	NA	-2.62 S

TABLE 5-1.— Continued.

Region	USDA/SRS estimate, bu/ac	LACIE Estimate, bu/ac	LACIE CV, % 1977	LACIE CV, % 1976	RD, % 1977	RD, % 1976	Value of test statistic
Winter wheat — August							
Colorado	23.0	22.5	14.8	17	-2.2	-24.3	
Kansas	28.5	28.8	9.7	9	1.0	4.5	
Nebraska	35.0	32.1	9.5	12	-9.0	0	
Oklahoma	27.0	20.0	10.3	10	-35.0	-5.3	
Texas	25.0	20.3	11.3	20	-23.2	-17.6	
USSGP	27.8	25.5	5.6	5	-9.0	-0.8	-1.61 N
Montana	27.0	26.5	12.1	9	-1.9	-9.6	
S. Dakota	27.0	27.1	18.5	14	0.4	37.5	
Mixed wheat	27.0	26.7	9.9	8	-1.1	3.4	
USGP-7	27.7	25.6	5.1	5	-8.2	-0.7	-1.61 N
Spring wheat — August							
Minnesota	40.9	31.7	11.6	11	-29.0	-0.3	
N. Dakota	25.0	22.8	12.8	11	-9.6	14.8	
Spring wheat	29.0	24.8	10.7	9	-16.9	9.5	
Montana	22.9	18.0	14.0	9	-27.2	-5.4	
S. Dakota	24.9	20.8	11.6	14	-19.7	41.4	
Mixed wheat	24.0	19.5	8.9	9	-23.1	4.5	
USNGP	27.7	23.4	8.6	7	-18.4	7.6	-2.14 S
Total wheat — August							
Montana	25.2	23.4	NA	4	-7.7	-6.8	
S. Dakota	25.4	23.4	NA	5	-8.5	42.0	
Mixed wheat	25.3	23.4	10.4	4	-8.1	4.8	
USNGP	27.6	24.1	10.7	6	-14.5	7.4	
USGP	27.7	24.9	3.9	4	-11.2	2.6	-2.87 S

TABLE 5-1.— Continued.

Region	USDA/SRS estimate, bu/ac	LACIE Estimate, bu/ac	LACIE CV, % 1977	LACIE CV, % 1976	RD, % 1977	RD, % 1976	Value of test statistic
Winter wheat — September							
Colorado	23.0	22.5	14.8	17	-2.20	-12.2	
Kansas	28.5	28.8	9.7	9	1.0	4.5	
Nebraska	35.0	32.0	9.3	12	-9.4	2.1	
Oklahoma	27.0	20.0	10.2	10	-35.0	-6.2	
Texas	25.0	20.3	11.3	5	-23.2	-17.6	
USSGP	27.8	25.3	5.6	5	-9.9	-0.4	-1.77 S
Montana	28.0	26.5	12.1	9	-5.7	-7.0	
S. Dakota	27.0	27.1	18.5	14	0.4	39.9	
Mixed wheat	27.8	26.6	10.2	8	-4.5	6.2	
USGP-7	27.8	25.5	5.1	5	-9.0	0.4	-1.76 S
Spring wheat — September							
Minnesota	40.9	31.9	11.2	11	-28.2	-12.5	
N. Dakota	24.0	23.2	12.3	11	-3.4	4.1	
Spring wheat	28.2	25.1	10.3	9	-12.4	-1.1	
Montana	22.0	18.0	14.0	9	-22.2	-4.0	
S. Dakota	24.0	20.8	11.6	13	-15.4	30.4	
Mixed wheat	23.0	19.3	9.0	8	-19.2	1.9	
USNGP	26.9	23.6	8.3	7	-14.0	-0.4	-1.69 S
Total wheat — September							
Montana	25.4	23.3	12.1	5	-9.0	-5.2	
S. Dakota	24.7	22.9	9.2	5	-7.9	38.1	
Mixed wheat	25.1	23.2	15.0	4	-8.2	5.4	
USNGP	27.0	24.3	11.5	7	-11.1	1.5	
USGP	27.5	24.9	4.2	4	-10.4	0.4	-2.48 S

TABLE 5-1.— Continued.

Region	USDA/SRS estimate, bu/ac	LACIE Estimate, bu/ac	LACIE CV, % 1977	LACIE CV, % 1976	RD, % 1977	RD, % 1976	Value of test statistic
Winter wheat — October							
Colorado	23.0	22.5	14.8	17	-2.2	-12.2	
Kansas	28.5	28.8	9.7	9	1.0	4.5	
Nebraska	35.0	32.0	9.3	12	-9.4	2.1	
Oklahoma	27.0	20.0	10.4	10	-35.0	-9.3	
Texas	25.0	20.3	11.7	5	-23.2	-17.6	
USSGP	27.8	25.5	5.6	5	-9.0	-0.4	-1.61 N
Montana	28.0	26.5	12.1	9	-5.7	-7.0	
S. Dakota	27.0	27.1	18.5	14	-0.4	39.9	
Mixed wheat	28.7	26.6	10.2	8	-4.5	6.2	
USGP-7	27.8	25.6	5.1	5	-8.6	0.4	-1.69 S
Spring wheat — October							
Minnesota	38.9	32.0	10.8	11	-21.6	-8.9	
N. Dakota	24.1	23.0	12.4	11	-4.8	7.0	
Spring wheat	27.9	24.8	10.5	9	-12.5	2.2	
Montana	23.2	18.0	14.0	9	-28.9	-6.3	
S. Dakota	24.0	20.8	11.6	13	-15.4	30.8	
Mixed wheat	23.6	19.3	9.1	8	-22.3	2.3	
USNGP	26.7	23.4	8.5	7	-14.1	1.9	-1.66 S
Total wheat — October							
Montana	25.9	23.1	11.7	5	-12.1	-6.6	
S. Dakota	24.7	22.8	10.0	5	-8.3	38.1	
Mixed wheat	25.4	23.0	14.0	4	-10.4	5.4	
USNGP	26.9	24.1	10.8	6	-11.6	3.0	
USGP	27.5	24.9	4.3	4	-10.4	1.1	-2.42 S

TABLE 5-1.— Concluded.

Region	USDA/SRS estimate, bu/ac	LACIE Estimate, bu/ac	LACIE CV, % 1977	LACIE CV, % 1976	RD, % 1977	RD, % 1976	Value of test statistic
Winter wheat — Final							
Colorado	22.0	22.5	14.8	17	2.2	-9.7	
Kansas	28.5	28.8	9.7	9	1.0	3.2	
Nebraska	35.0	32.0	9.3	12	-9.4	2.1	
Oklahoma	27.0	20.0	10.4	10	-35.0	-6.2	
Texas	25.0	20.3	11.7	5	-23.2	-17.6	
USSGP	27.5	25.5	5.6	5	-7.8	-0.8	-1.39 N
Montana	29.0	26.5	12.1	9	-9.4	-7.0	
S. Dakota	25.0	27.1	18.5	14	7.7	43.0	
Mixed wheat	28.2	26.6	10.2	8	-6.0	6.5	
USGP-7	27.7	25.6	5.1	5	-8.2	0.0	-1.61 N
Spring wheat — Final							
Minnesota	39.9	32.0	10.7	11	-24.7	-6.9	
N. Dakota	24.9	23.1	12.4	11	-7.8	8.5	
Spring wheat	28.8	24.9	10.4	9	-15.7	3.6	
Montana	22.0	18.0	14.0	9	-22.2	-8.5	
S. Dakota	23.5	20.8	11.6	13	-13.0	36.6	
Mixed wheat	22.8	19.3	9.1	8	-18.1	2.3	
USNGP	27.1	23.4	8.4	7	-15.8	3.4	-1.88 S
Total wheat — Final							
Montana	25.9	23.1	11.6	5	-12.1	-7.7	
S. Dakota	23.9	22.8	10.9	5	-4.8	42.9	
Mixed wheat	25.1	23.0	13.6	4	-9.1	5.0	
USNGP	27.3	24.1	10.6	6	-13.3	4.1	
USGP	27.5	24.9	4.3	4	-10.4	1.1	-2.42 S

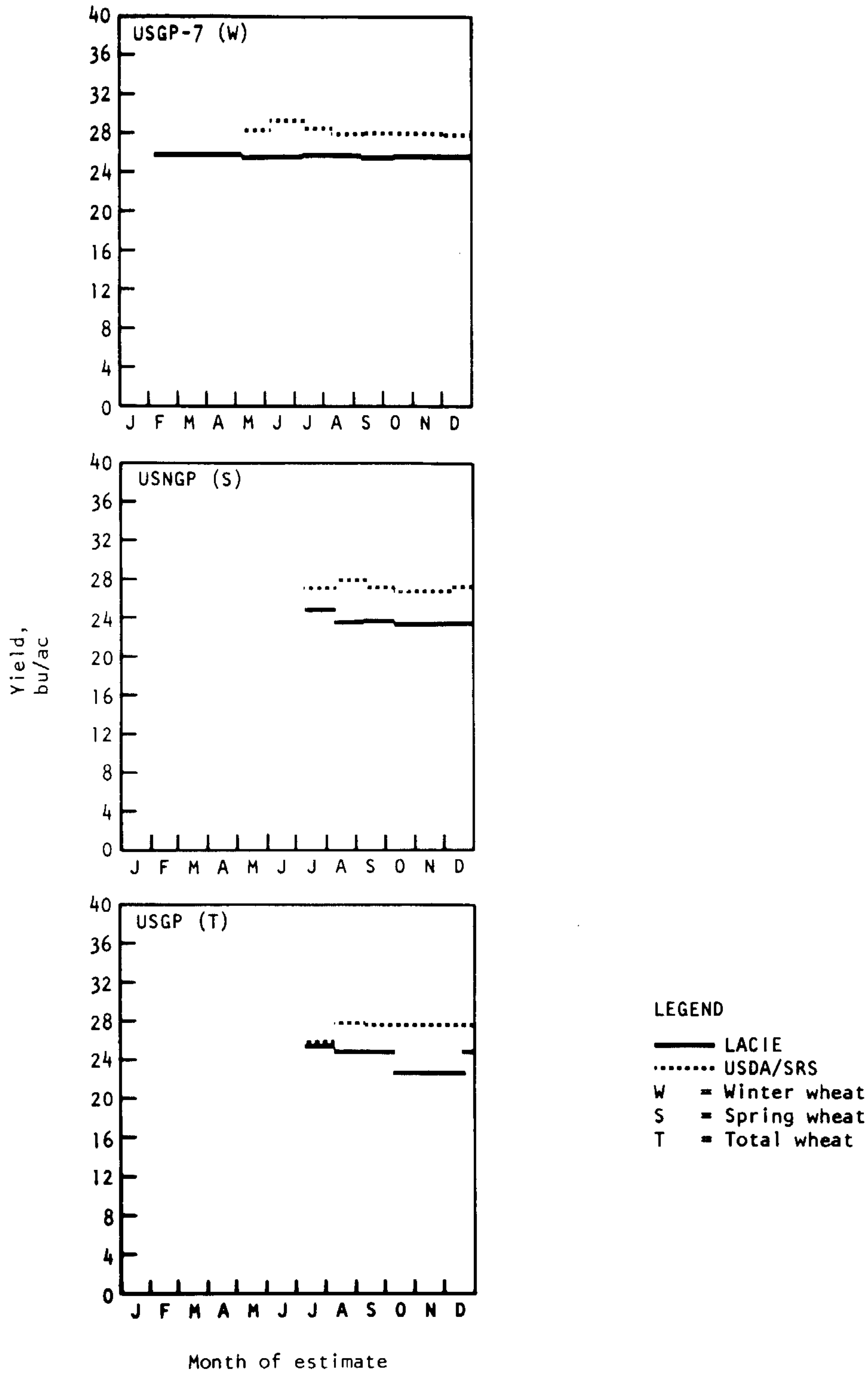

Figure 5-1.— LACIE and USDA/SRS yield estimates. (USDA/SRS yield estimates for February 1977 derived from predicted production and seeded acres estimates released on December 22, 1976.)

TABLE 5-2.— COMPARISON OF CV'S AND RD'S BASED ON THE USDA/SRS FINAL YIELD ESTIMATES

Region	Final USDA/SRS, bu/ac	Feb. 1977		May 1977		June 1977		July 1977		Aug. 1977		Sept. 1977		Oct. 1977		Final 1977	
		RD	LACIE CV	RD	LACIE CV	RD	LACIE CV	RD	LACIE CV	RD	LACIE CV	RD	LACIE CV	RD	LACIE CV	RD	LACIE CV
Winter wheat																	
Colorado	22.0	3.5	18.9	3.5	17.4	6.8	15.2	2.2	14.8	2.2	14.8	2.2	14.8	2.2	14.8	2.2	14.8
Kansas	28.5	1.4	12.1	-1.4	10.8	-0.7	10.0	1.0	9.7	1.0	9.7	1.0	9.7	1.0	9.7	1.0	9.7
Nebraska	35.0	-14.4	10.5	-11.8	10.8	-15.9	10.7	-9.7	9.7	-9.0	9.5	-9.4	9.3	-9.4	9.3	-9.4	9.3
Oklahoma	27.0	-24.4	13.8	-27.4	12.5	-36.4	11.0	-35.7	10.7	-35.0	10.3	-35.0	10.2	-35.0	10.4	-35.0	10.4
Texas	25.0	-30.2	16.5	-28.2	11.6	-23.2	10.6	-23.2	10.8	-23.2	11.3	-23.2	11.3	-23.2	11.7	-23.2	11.7
USSGP	27.5	-7.8	6.7	-9.6	6.1	-9.6	5.6	-7.8	5.6	-7.8	5.6	-8.7	5.6	-7.8	5.6	-7.8	5.6
Montana	29.0	-8.6	22.4	-1.8	13.7	-3.2	13.2	-9.4	12.1	-9.4	12.1	-9.4	12.1	-9.4	12.1	-9.4	5.6
S. Dakota	25.0	8.4	17.5	3.9	18.7	3.9	18.6	6.0	18.9	7.7	18.5	7.7	18.5	7.7	18.5	7.7	18.5
Mixed wheat	28.2	-4.8	16.3	-1.1	11.1	-2.6	10.7	-6.4	10.1	-5.6	9.9	-6.0	12.2	-6.0	10.2	-6.0	10.2
USGP-7	27.7	-7.8	6.3	-8.6	5.5	-8.6	5.1	-8.2	5.1	-8.2	5.1	-8.6	5.1	-8.2	5.1	-8.2	5.1
Spring wheat																	
Minnesota	39.9							-23.2	12.8	-25.9	11.6	-25.1	11.2	-24.7	10.8	-24.7	10.7
N. Dakota	24.9							-1.2	15.1	-9.2	12.8	-7.3	12.3	-8.3	12.4	-7.8	12.4
Spring wheat	28.8							-9.5	12.6	-16.1	10.7	-14.7	10.3	-16.3	10.5	-15.7	10.4
Montana	22.0							-19.6	14.9	-22.2	14.0	-22.2	14.0	-22.2	14.0	-22.2	14.0
S. Dakota	23.5							-10.3	12.1	-13.0	11.6	-13.0	11.6	-13.0	11.6	-13.0	11.6
Mixed wheat	22.8							-16.3	9.3	-16.9	8.9	-18.1	9.0	-18.1	9.1	-18.1	9.1
USNGP	27.1							-9.3	10.5	-15.8	8.6	-14.8	8.3	-15.8	8.5	15.8	8.4
Total wheat																	
Montana	25.9							-12.1	NA	-10.7	NA	-11.2	12.1	-12.1	11.7	-12.1	11.6
S. Dakota	23.9							2.5	NA	-2.1	NA	-4.4	9.2	-4.8	10.0	-4.8	10.9
Mixed wheat	25.1							-5.9	14.6	-7.3	10.4	-8.2	15.0	-9.1	14.0	-9.1	13.6
USNGP	27.3							-8.3	15.4	-13.3	10.7	-12.3	11.5	-13.3	10.8	-13.3	10.6
USGP	27.5							-8.3	3.9	-10.4	3.9	-10.4	4.2	-10.4	4.3	-10.4	4.3

the weather was good; yet the LACIE estimate was still approximately 20 percent below the USDA/SRS estimate.

The RD's between the LACIE Phase III and the USDA/SRS yield estimates for the USGP-7 were considerably larger in magnitude than those of Phase II; the CV's were virtually unchanged.

In the USNGP, the LACIE estimate of spring wheat yield was significantly lower than that of the USDA/SRS in every month except July, the first month in which spring wheat estimates were made available. After July, the RD's for all states and regions of the USNGP were negative. Accuracy generally did not improve during Phase III, either on a state or regional basis, as evidenced by the RD's.

While all four state-level LACIE spring wheat yield estimates were below their USDA/SRS counterparts, the underestimate in Minnesota was the largest. The Minnesota yield model trend extends from 1955 through 1975, yet in the last few years there has been a sharp increase in spring wheat yields not reflected in the yield trend term. The higher wheat yields in Minnesota may be explained in part by the introduction in 1970 of a new variety of spring wheat called Era, which yields well, even under adverse climatic conditions, and responds well to fertilizer. By 1977, Era had become the dominant spring wheat variety in the state, occupying approximately 70 to 75 percent of the spring wheat acreage. In recent years, there has been a strong positive trend in the application of nitrogen fertilizer to wheat, and Era has consistently outyielded other varieties of spring wheat by 10 to 20 percent.

The spring wheat yield estimate for Montana was well below the corresponding USDA/SRS value. The LACIE underestimate was apparently due to a trend term which failed to account for increased fertilizer usage in the last several years. The Montana spring wheat yield model trend terms extend from 1932 to 1955 and from 1955 to 1972. A plot of the amount of fertilizer applied since 1964, however, indicates that fertilizer usage had not stabilized through

1977 (fig. 5-2). The general increase in application rates since 1972 was not reflected in the second trend term of the model.

The CV's for the LACIE USNGP spring wheat yield estimates were slightly larger than those of Phase II. On the state level, the CV's were essentially unchanged with the exception of Montana, which showed a moderate increase of 14 percent in Phase III compared to 9 percent throughout Phase II.

The LACIE total wheat yield estimate for the USGP region remained below the USDA/SRS estimate during Phase III as a result of underestimates for both USGP-7 winter wheat and USNGP spring wheat. The RD remained at approximately -10 to -15 percent. In general, the yield comparisons reflect a tendency to underestimate, which is primarily responsible for the underestimation of USGP wheat production.

The results of the historical tests over a 10-year period (1967 to 1976) are shown in table 5-3. The large model error in 1974 resulted from the cold wet spring, which caused a delay in spring planting and hindered the winter wheat from coming out of dormancy.

Table 5-4 shows that for the 10-year test, all of the individual models supported the 90/90 criterion. The spring wheat models as a group tended to overestimate yield, with particular problems occurring in the North Dakota and the Red River (of the North) models. The winter wheat models performed well as a group. The models for the Bad Lands, Colorado, and Kansas showed the largest error rates.

The contingency table (table 5-5) shows that for the spring wheat models, the modeled trend appeared to be an overestimate of the actual trend, that there was a significant (at the 1-percent level) overestimation of below-normal yields and an underestimation of above-normal yields, and that the tendency toward a positive bias for the aggregated spring wheat region is due in part to trend errors.

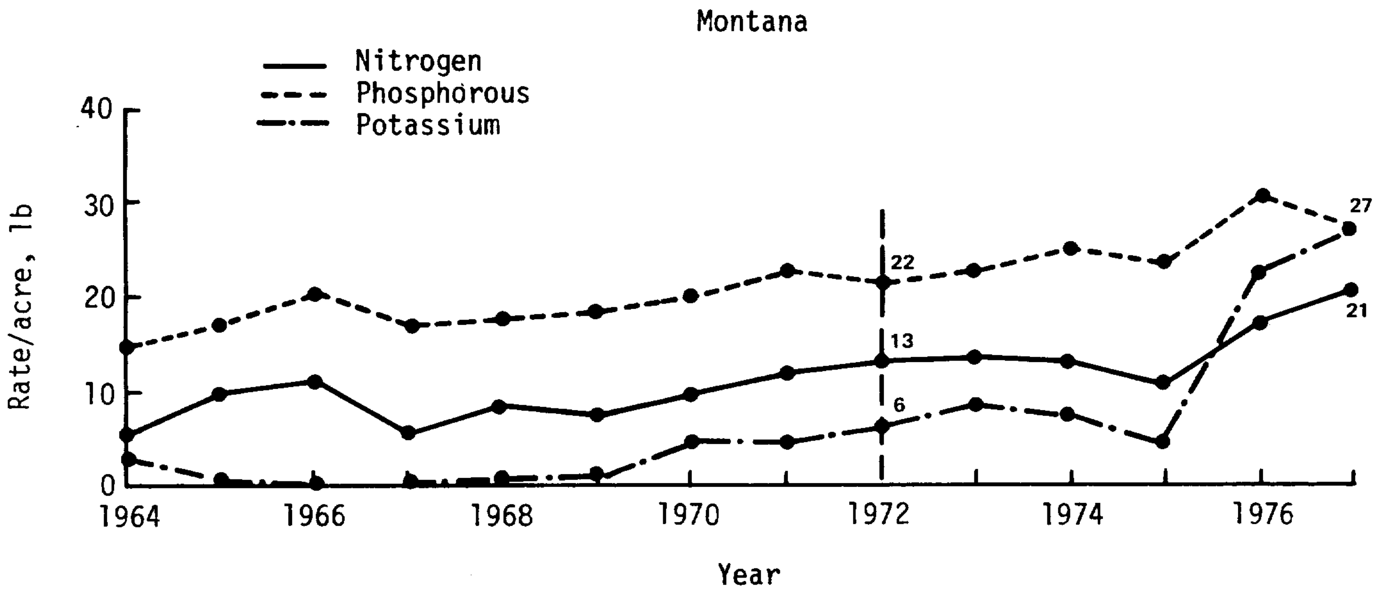

Figure 5-2.— Plot of fertilizer application rates for wheat in Montana.

TABLE 5-3.— THE 10-YEAR BOOTSTRAP TEST FOR U.S. PHASE III YIELD MODELS WITH CONTINUED TREND

Year	Total wheat		Spring wheat		Winter wheat	
	USDA/SRS, bu/acre	Model error	USDA/SRS, bu/acre	Model error	USDA/SRS, bu/acre	Model error
1967	21.6	0.9	22.9	0.3	21.0	1.1
1968	26.0	-1.4	26.1	-1.9	25.9	-1.2
1969	28.4	1.0	28.4	2.2	28.4	.5
1970	28.2	-1.6	23.5	-1.0	30.4	-1.9
1971	30.8	-2.9	30.6	-1.7	30.9	-3.7
1972	29.3	-.2	28.5	2.2	29.7	-1.5
1973	30.8	-.2	27.7	.2	32.4	-.3
1974	23.8	4.6	20.8	6.6	25.5	3.4
1975	26.8	.5	25.7	.8	27.4	.3
1976	26.4	.7	25.3	2.0	27.1	-.1
Mean error	+0.1 bu/acre		+1.0 bu/acre		-0.4 bu/acre	
RMSE	1.90 bu/acre		2.56 bu/acre		1.84 bu/acre	

TABLE 5-4.— THE 10-YEAR BOOTSTRAP TEST FOR U.S. PHASE III YIELD MODELS UTILIZING CONTINUED TREND WITH THE 90/90 CRITERION TEST

Model	Crop	Mean error, bu/acre	RMSE, bu/acre	Supports 90/90 criterion
Montana	Spring wheat	-0.6	2.18	Yes
North Dakota	Spring wheat	1.2	2.94	Yes
Red River of the North	Spring wheat	1.4	3.95	Yes
Minnesota	Spring wheat	0.6	3.81	Yes
South Dakota	Spring wheat	0.8	3.00	Yes
Montana	Winter wheat	-0.3	2.69	Yes
Bad Lands	Winter wheat	-0.1	4.61	Yes
Nebraska	Winter wheat	0.2	2.92	Yes
Colorado	Winter wheat	-0.8	3.42	Yes
Kansas	Winter wheat	-0.3	3.39	Yes
Oklahoma	Winter wheat	0.1	2.21	Yes
Panhandle	Winter wheat	-0.5	2.69	Yes
Texas Low Plains	Winter wheat	-0.6	2.74	Yes
Texas Edwards Plateau	Winter wheat	-0.8	2.88	Yes
Texas, south central	Winter wheat	0.8	2.69	Yes
Total	Spring wheat	1.0	2.56	
Total	Winter wheat	-0.4	1.84	
Total	Wheat	0.1	1.90	

TABLE 5-5.– CONTINGENCY TABLE OF MODEL ERROR AND DEVIATION OF ACTUAL YIELD FROM TREND FOR ALL SPRING WHEAT MODELS

USDA/SRS DEVIATION FROM TREND, PERCENT

MODEL ERROR, PERCENT	< – 20	– 20 TO – 10	+ 10 TO + 10	+ 10 TO + 20	> + 20	
< – 20						MODEL UNDERESTIMATED
– 20 TO – 10	1		2		2	
– 10 TO + 10	2	8	18	3	1	
+ 10 TO + 20	4	2	2			
> + 20	4	1				MODEL OVERESTIMATED

YIELD BELOW TREND

YIELD ABOVE TREND

$\chi^2 = 33.79$

d.f. = 16

5.2 CROP CALENDAR MODEL ACCURACY

Crop growth stage estimation based on current year weather conditions serves two vital components of LACIE: CAMS and the Yield Estimation Subsystem (YES). Initially, CAMS relies on the crop growth information early in the year to determine whether the small grains, and in particular the wheat, are sufficiently emerged to be detectable. Once the Robertson model predicts the crop to have emerged (Robertson biostage 2.0), analysis of the segment for wheat percentage is initiated. The winter wheat crop is also monitored to ascertain whether it has emerged from dormancy. In some northern regions of the winter wheat producing states of the USGP, crop estimates are not attempted prior to and during dormancy because of limiting conditions, among them being too sparse a canopy and snow cover. The next major growth period of interest to CAMS is the period after dormancy to heading, when the analyst relies on the Robertson crop stage to ascertain the approximate expected intensity of the wheat vegetation signature in comparison to other spring-planted crops. Heading to senescence or maturity is another key stage in the separation of wheat from other vegetation. During this stage, the appearance of wheat is significantly different from other vegetation types. Senescence to harvest and postharvest stages are very important to the analyst because the Landsat acquisitions during this period of maturation and harvest of wheat, other small grains, and grasses permit verification of the early-season identification of small grains.

This very general description of the crop calendar function in CAMS aids in qualitatively understanding the effect of growth stage prediction errors. For example, if the Robertson model predicts full emergence at a date earlier than the date at which crops are fully emerged (growth model is ahead of actual progress), CAMS will analyze the segment in a period when some amount of the wheat is incompletely emerged, depending on the magnitude of the growth model prediction error. Since incompletely emerged wheat fields will go undetected by the analyst, the growth model prediction error can result in a negative bias in the segment proportion estimate. In all cases, if the model predictions run too far ahead of the actual growth stage, the analyst will anticipate an onset of changing signatures within the segment which will not occur at the predicted rate. Thus, if the growth model predicts 90-percent senescence within the segment and the analyst bases his labeling decision on this fact, certain fields could be discarded as being nonwheat because a senescent signature was expected and the analyst did not observe a change.

Inasmuch as the interactions between the growth model prediction errors and CAMS errors are not fully understood and their relationships to each other remain unquantified, substantial prediction errors in the model could result in substantial errors in analyst labeling.

The currently implemented operational yield models in LACIE do not depend on the crop growth model. However, the response of wheat yield to meteorological conditions is known to depend quite strongly on the growth stage at which these conditions are present. For example, high temperatures during heading and after wheat maturity do not affect yields in the same way. The second-generation yield models being evaluated for LACIE in Phase III depend on the crop growth models; the effects of certain meteorologically related variables are weighted differently, depending on the estimated growth stage of the plant. Errors in the growth model can thus strongly influence the yield estimation error; for example, if high temperatures are experienced the last 2 weeks in May in an area where heading is occurring and the growth model (running fast) is predicting that the crop is ripe, the second-generation yield models will fail to predict the actual reduction in yield.

The AA effort within LACIE has designed an evaluation of the crop growth models using ground-acquired information from ITS's in the yardstick region. In Phase III, this evaluation was conducted over 22 ITS's in the United States (fig. 5-3) and 11 ITS's in Canada (fig. 5-4).

The average ground-observed growth stage for the wheat crop within each ITS is calculated from periodic field-by-field observations obtained by the USDA/ASCS personnel, who record detailed information about each field on the ground-truth periodic observation form (fig. 5-5). The observer identifies the growth stage of each field as one of the 10 stages listed on the form. All sites are

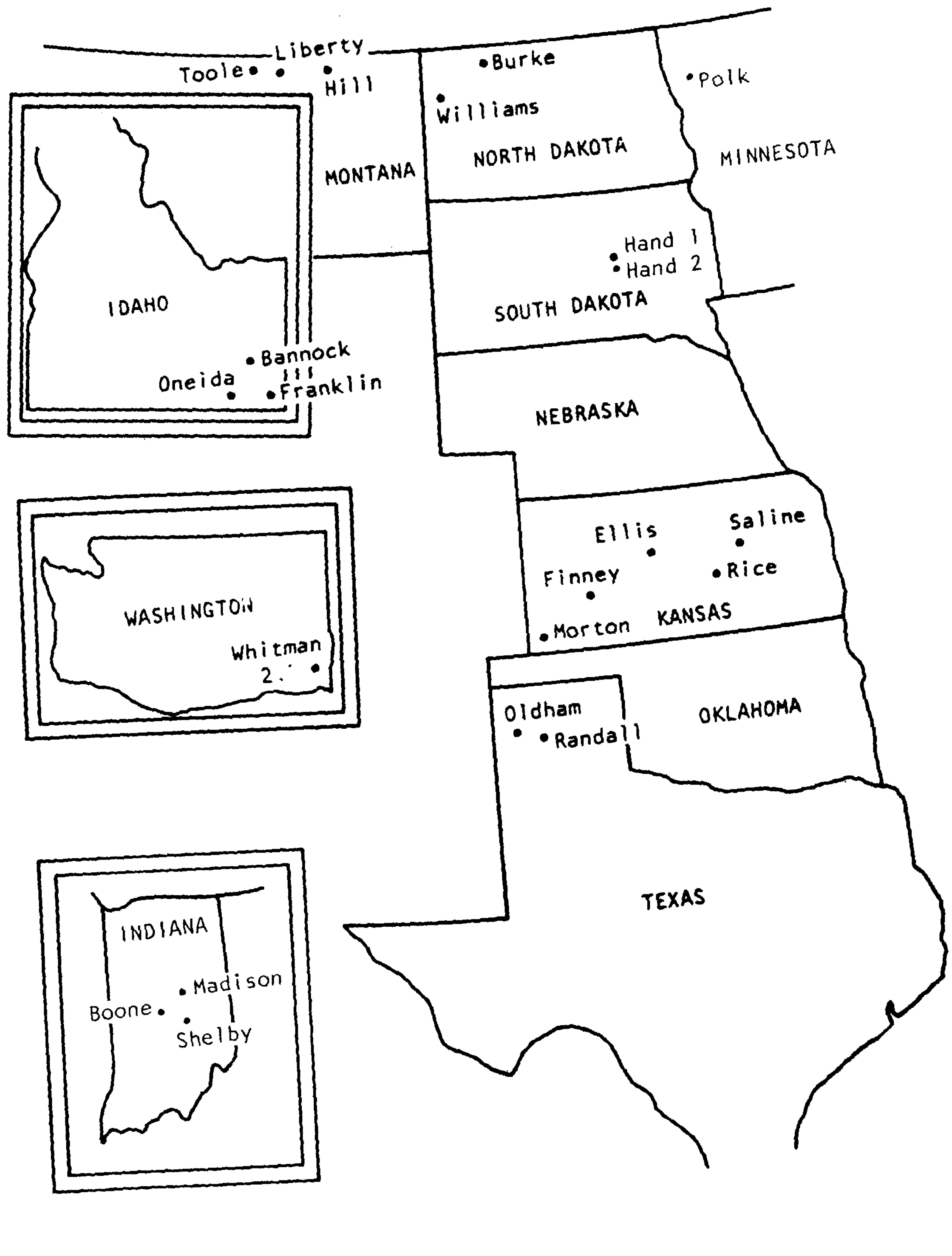

Figure 5-3.— Map of ITS's in U.S. wheat-producing areas.

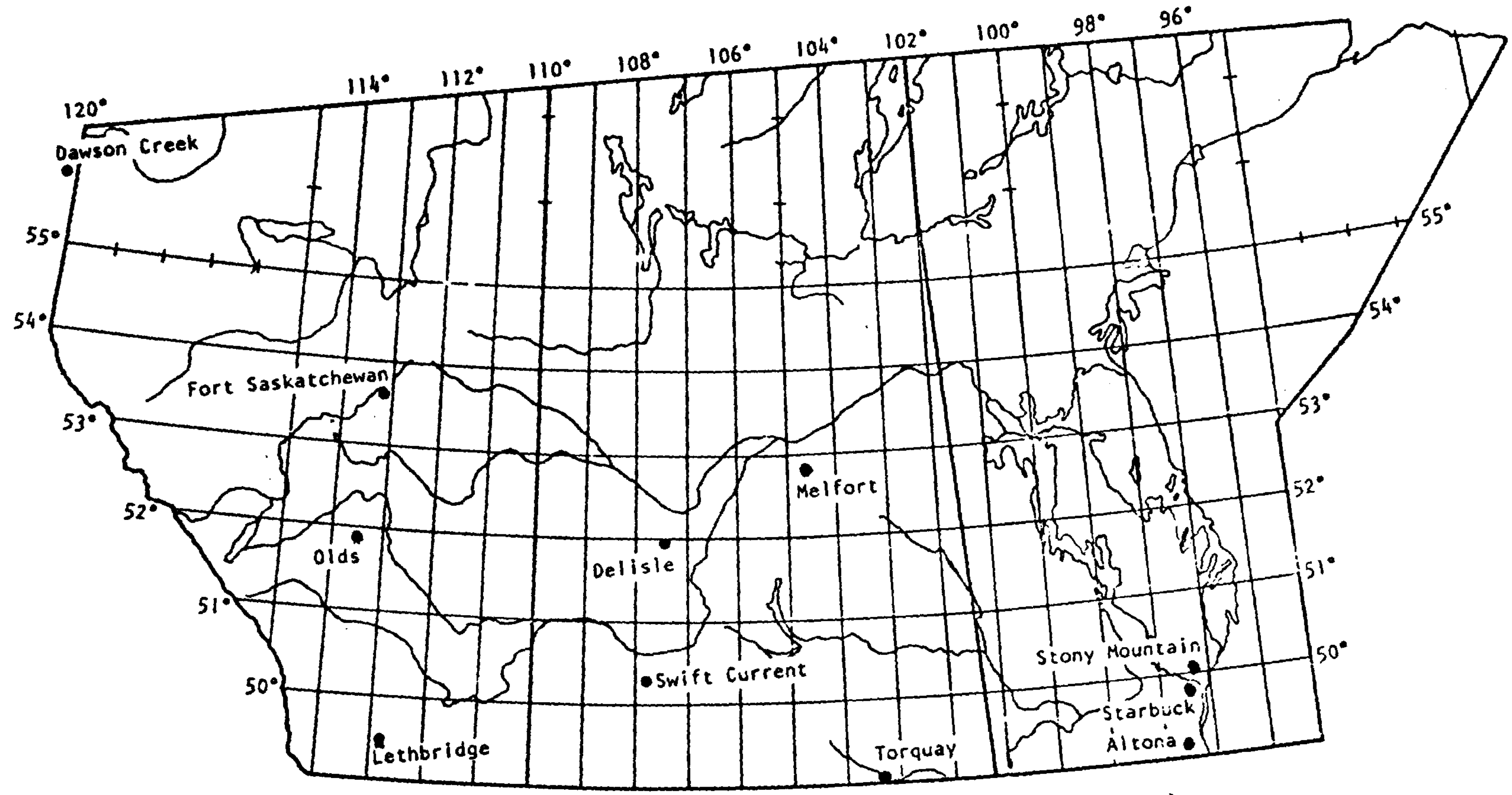

Figure 5-4.— Map of ITS's in Canada.

GROUND TRUTH PERIODIC OBSERVATION FORM

TEST SITE # 40 (WHITMAN (2), WASHINGTON)
OBSERVATION 09

	MONTH	DAY	
LANDSAT PASS DATE	8	24	/77
OBSERVATION DATE	8	[illegible]	/77

RAINFALL SINCE LAST OBSERVATION ____ IN.

LAND USE CODES
100-SPRING WHEAT
200-BARLEY
300-OATS
400-WINTER WHEAT
500-GRASSES/PASTURE
600-OTHER CROPS
601-RAPESEED
602-RYE
604-FLAX
607-CORN
617-SOYBEANS
618-COTTON
700-SUMMER FALLOW
900-UNKNOWN CROPS

GROWTH STAGES
01-NOT PLANTED
02-PLANTED NO EMERGENCE
03-EMERGENCE
04-TILLERING, PREBOOT, PREBUD
05-BOOTED OR BUDDED
06-BEGINNING TO HEAD OR FLOWER
07-FULLY HEADED OR FLOWERED
08-BEGINNING TO RIPEN
09-RIPE MATURE
10-HARVESTED
11-DOES NOT APPLY

GROUND COVER (%)
1- 0- 19
2-20- 39
3-40- 59
4-60- 79
5-80-100

SURFACE MOISTURE CONDITIONS
1-DRY
2-DAMP
3-WET
4-STANDING WATER

WEED GROWTH
1-NEGLIGIBLE
2-SLIGHT
3-MODERATE
4-HEAVY

FIELD OPERATIONS
01-BARE GROUND
02-BARE DISKED/CULTIVATED
03-BARE PLOWED
04-BARESEEDED
05-STANDING STUBBLE
06-STUBBLE DISKED/CULTIVATED
07-STUBBLE PLOWED
08-STUBBLE SEEDED
09-BURNED
10-GRAZED
11-WINDROWED OR SWATHED
12-MOWED OR COMBINED
13-STACKED OR BALED
14-OTHER

GROWTH/YIELD DETRACTANTS
01-SALINITY
02-INSECTS
03-DISEASE
04-DROUGHT
05-MOISTURE
06-WIND
07-HAIL
08-FROST
09-BIRDS
10-POT HOLES
11-UNEVEN STAND
12-WEEDS
13-WINTERKILL
14-LODGING
15-OTHER

STAND QUALITY
1-POOR
2-BELOW AVERAGE
3-AVERAGE
4-ABOVE AVERAGE
5-EXCELLENT
6-DOES NOT APPLY

FIELD NO.	ACREAGE	LAND USE CODE	GROWTH STAGE (CIRCLE ONE)	GROUND COVER (CIRCLE ONE)	PLANT HEIGHT (INCHES)	SURFACE MOISTURE (CIRCLE ONE)	WEED GROWTH (CIRCLE ONE)	FIELD OPERATIONS (CIRCLE ONE)	GROWTH/YIELD DETRACTANTS (CIRCLE ONE)	STAND QUALITY RATING (CIRCLE ONE)	COMMENTS
43	233.7	414	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	10	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12 13 14 15	1 2 3 4 5 6	Y N
20	511.6	700	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	-	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12 13 14 15	1 2 3 4 5 6	Y N
31	455.0	414	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	10	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12 13 14 15	1 2 3 4 5 6	Y N
30	306.6	700	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	-	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12 13 14 15	1 2 3 4 5 6	Y N
29	401.0	414	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	10	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12 13 14 15	1 2 3 4 5 6	Y N
27	89.1	700	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	-	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12 13 14 15	1 2 3 4 5 6	Y N
25	377.1	414	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	10	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12 13 14 15	1 2 3 4 5 6	Y N
8	304.8	414	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	10	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12 13 14 15	1 2 3 4 5 6	Y N
49	265.0	700	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	-	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12 13 14 15	1 2 3 4 5 6	Y N
50	160.0	614	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	-	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12 13 14 15	1 2 3 4 5 6	Y N
2	126.0	400	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	10	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12 13 14 15	1 2 3 4 5 6	Y N
6	108.9	400	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	10	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12 13 14 15	1 2 3 4 5 6	Y N
5	61.5	700	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	-	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12 13 14 15	1 2 3 4 5 6	Y N

Figure 5-5.— USDA/ASCS ground truth periodic observation form.