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EVALUATION OF TRANSITION YEAR CANADIAN TEST SITES

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16. Abstract

The following evaluation results obtained from the Transition Year Canadian test sites are presented: The segment proportion estimates are compared to the ground-truth proportion estimates, and detailed labeling error characterizations are given. The spring small-grain proportion accuracy in the Canadian test sites was found to be comparable to that of the Large Area Crop Inventory Experiment Phase III and Transition Year results in the U.S. spring wheat states. The spring small-grain labeling accuracy was 94 percent, and the direct wheat labeling accuracy was 89 percent, despite the low barley separation accuracy of 30 percent.

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TECHNICAL REPORT

EVALUATION OF TRANSITION YEAR CANADIAN TEST SITES

Job Order 74-402

This report describes Accuracy Assessment activities of the Foreign Commodity Production Forecasting project of the AgRISTARS program.

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For

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Space and Life Sciences Directorate

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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PREFACE

The work which is the subject of this document was performed in support of the Earth Observations Division, Space and Life Sciences Directorate at the Lyndon B. Johnson Space Center, National Aeronautics and Space Administration. Under Contract NAS 9-15800, personnel of Lockheed Engineering and Management Services Company, Inc., performed the tasks which contributed to the completion of this research.

The following scientists and other personnel assisted in compiling this report: N. J. Clinton assembled the small-grain confusion matrices; W. R. Johnson assisted in computing the statistics used in the proportion estimation evaluation; E. J. Cooper, J. I. Delgado, J. M. Jones, B. B. Schroder, and B. A. Tolbert compiled the 209-dot ground-truth data for the Canadian test sites used in the labeling error characterization studies; and G. D. Spikes and W. L. West III participated in the operational processing of the test sites and provided insight into the Transition Year Canadian technical problems and issues.

A. G. Houston of the National Aeronautics and Space Administration provided technical assistance during the evaluations and reviewed the final report.

CONTENTS

TABLES

FIGURES

1. INTRODUCTION

Fifteen Saskatchewan, Canada, test sites were processed by analysts in an operational mode during 1979. Landsat acquisitions of the sample segments were acquired in 1978 during the Large Area Crop Inventory Experiment (LACIE) Transition Year (TY). (Figure 1-1 shows the segment locations.) The segments were analyzed for "direct wheat" (i.e., spring wheat, oats, and flax) and barley. Direct wheat proportion estimates were produced on only 4 of the 15 segments since the analysts determined that barley separation acquisitions were unavailable for the remaining 11 segments.

The results and conclusions of two evaluations, a proportion estimation evaluation using ground-truth data and the labeling error characterization studies, are presented in sections 2 and 3, respectively.

1.1 OBJECTIVES

The objectives of this report are to present the evaluation of the segment proportion estimates as compared to the ground-truth proportion estimates and to provide detailed labeling error characterizations for a subset of the 15 segments.

1.2 SCOPE

The proportion estimates for all 15 test sites were evaluated, but only 7 of the 15 segments were selected for detailed labeling error analysis and characterizations. Resource and time constraints did not permit a complete analysis of all segments.

The four segments with direct wheat estimates and three additional segments with relatively large proportion estimation errors were selected for labeling error characterizations.

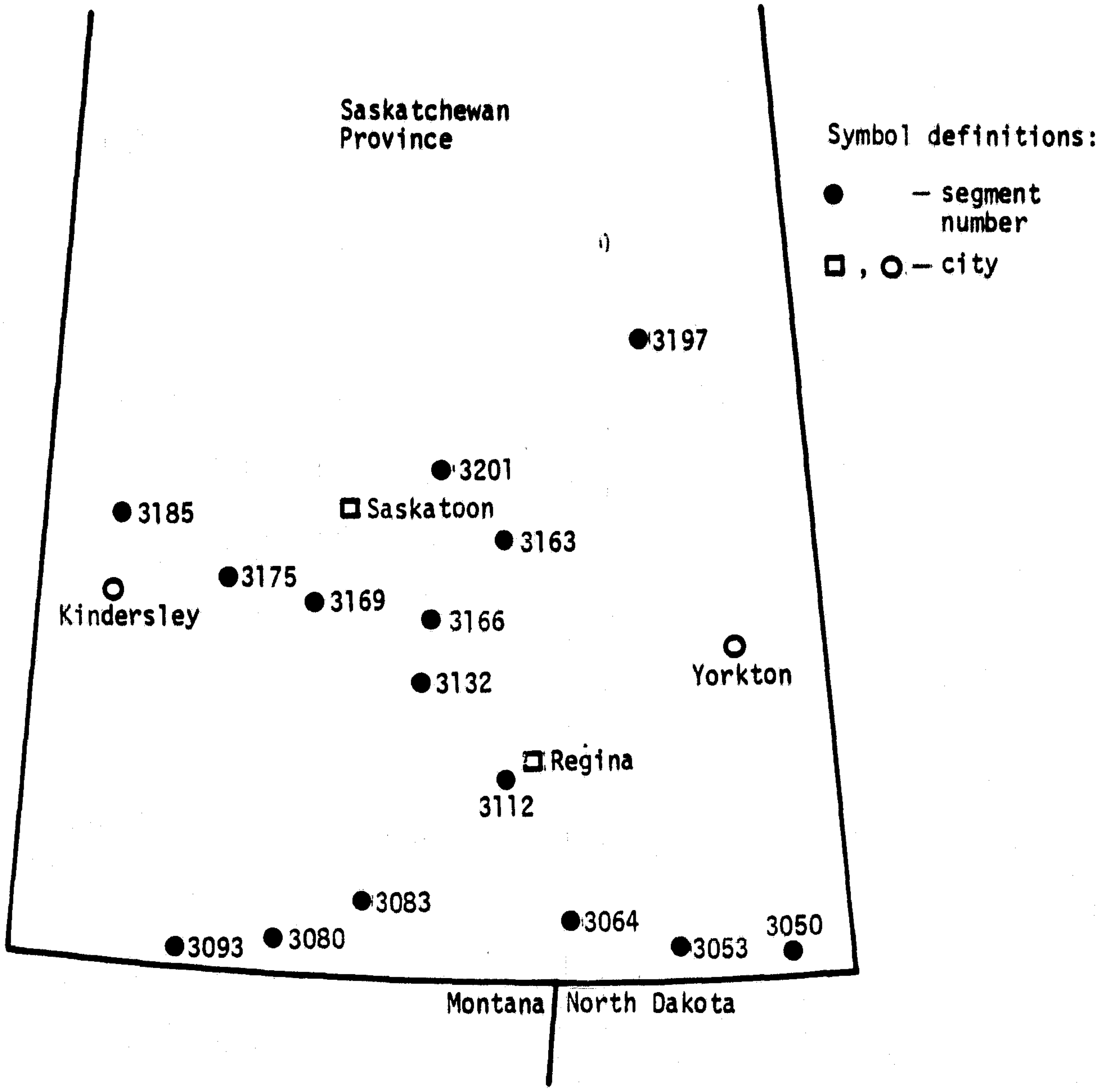

Figure 1-1.- 1978 TY Canadian test site locations.

2. PROPORTION ESTIMATION EVALUATION

2.1 APPROACH AND METHODOLOGY

The TY Canadian ground observation inventories are incomplete because of improper alinement of the ground-truth areas relative to the Landsat image of the sample segment. Consequently, segment proportion estimates were computed for ground observation areas common to both the original inventory and the Landsat image of the sample segment. The analyst estimates were calculated by using a random sample approach. This approach allowed analysts to label and evaluate all available grid dots in the ground-truthed area of a segment. Of the 209 available dots per segment, an average of 181 were studied by the analysts. This resulted in proportion estimates which could be evaluated against their corresponding ground observation estimates. The results of this evaluation are provided in table 2-1.

The ground-observed proportion estimates were computed using approximately 600 systematically selected ground-truth labels. Estimates of direct wheat, barley, and total spring small grains (which includes direct wheat and barley) were computed based on these selected dots. Two independent estimates were computed for each segment using the procedure described above, and the final proportion estimates were calculated using the average of the two. The results of the averaging are provided in table 2-2.

The results in tables 2-1 and 2-2 were used in a study which compared the segment proportion estimates with the ground-truth estimates. All 15 segments were evaluated for total spring small-grain accuracy. The four direct wheat segments were analyzed for barley separability, as well as for total spring small-grain accuracy. The results of these analyses are provided in table 2-3.

TABLE 2-1.- PROPORTION ESTIMATES DERIVED FROM ANALYST LABELING OF ALL DOTS FOR TY CANADIAN TEST SITES

Segment number	Direct wheat, percent	Barley, percent	Spring small grains, percent
3050	39.5	8.8	48.3
3053	51.2	4.3	55.6
3064			48.2
3080			14.7
3083			45.5
3093			22.2
3112	59.0	3.5	62.5
3132			42.3
3163			29.2
3166			23.9
3169			45.9
3175			48.4
3185	39.8	5.2	45.0
3197			21.3
3201			41.4
Average			39.6

TABLE 2-2.- PROPORTION ESTIMATES DERIVED FROM 600-DOT GROUND TRUTH OF TY CANADIAN TEST SITES

Segment number	Direct wheat, percent	Barley, percent	Spring small grains, percent
3050	48.1	1.3	49.4
3053	52.2	2.5	54.7
3064	48.3	3.4	51.7
3080	14.3	0	14.3
3083	41.4	0	41.4
3093	25.0	0	25.0
3112	63.4	.8	64.1
3132	42.4	1.8	44.2
3163	32.9	5.1	37.9
3166	29.1	1.5	30.5
3169	37.2	4.8	42.0
3175	44.8	9.8	54.6
3185	38.7	11.6	50.2
3197	20.2	8.9	29.1
3201	43.6	5.1	48.6
Average			42.5

TABLE 2-3.- PROPORTION ESTIMATION ERROR OF TY CANADIAN TEST SITES

[Analyst proportion estimate minus ground-truth proportion*]

Segment number	Direct wheat, percent	Barley, percent	Spring small grains, percent
3050	-8.6	7.6	-1.1
3053	-1.0	1.8	.9
3064			-3.5
3080			.4
3083			4.1
3093			-2.8
3112	-4.4	2.8	-1.7
3132			-1.9
3163			-8.7
3166			-6.7
3169			3.9
3175			-6.2
3185	1.1	-6.4	-5.2
3197			-7.8
3201			-7.3
Results:			
Mean error	-3.2	1.5	-2.9*
Standard deviation	4.3	5.8	4.1
Mean squared error	24.0	27.2	24.1
Number of segments	4	4	15

*The value of the t-test statistic = -2.7, which indicates that the average difference between analyst spring small-grain proportion estimates and ground-truth proportion estimates is significantly different from zero at the 10-percent level.

2.2 RESULTS

2.2.1 LACIE PHASE III/TY COMPARISON

2.2.1.1 Spring Small-Grain Proportion Estimation Comparison

The TY Canadian processing resulted in a mean error of -2.9, a standard error of 1.9, and a relative difference (RD) of -6.8 percent for spring small-grain proportion estimation accuracy. These results compare favorably with the U.S. northern Great Plains (USNGP) results for the TY, where the mean error was -0.8, the standard error was 1.0, and the RD equaled -3.9 percent. The TY Canada results were significantly better than the LACIE Phase III results for the USNGP (which were -6.1, 0.8, and -17.5 percent for the mean error, standard error, and RD, respectively).

The LACIE Phase III and TY results for the USNGP were computed using the 400-dot ground-truth proportion estimation technique. See table 2-4 for a comparison of the data described above.

2.2.1.2 Direct Wheat/Barley Proportion Estimation Comparison

The Canadian TY direct wheat and barley proportion estimation was computed from a very small sample (four sample segments). Because of this small number of estimates, definite conclusions regarding these results are not possible. The mean error for the TY direct wheat and barley estimates of -3.2 and 1.5 are comparable to the TY USNGP results of -0.7 and -0.1 for direct wheat and barley, respectively. The TY Canadian result is also comparable to the USNGP LACIE Phase III direct wheat result, which has a mean error of 0.5. Direct barley was not computed during Phase III; therefore, a comparison cannot be made. Table 2-5 contains comparative results for the USNGP Phase III, USNGP TY, and Canadian TY proportion estimation accuracies.

TABLE 2-4.- COMPARISON OF SPRING SMALL-GRAIN PROPORTION ESTIMATION ACCURACIES

Statistic	LACIE Phase III USNGP	TY USNGP	TY Canada
n	45	45	15
$\overline{P}_{SG}$	34.9	20.5	42.5
$\overline{D}$	-6.1	-.8	-2.9
$\sigma_{\overline{D}}$	.8	1.0	1.9
RD	-17.5%	-3.9%	-6.8%

TABLE 2-5.- COMPARISON OF DIRECT WHEAT/BARLEY PROPORTION ESTIMATION ACCURACIES

Statistic	LACIE Phase III USNGP (North Dakota only)		TY USNGP		TY Canada	
	Direct wheat	Barley	Direct wheat	Barley	Direct wheat	Barley
n	20	-	45	45	4	4
$\overline{P}_{SG}$	25.1	-	17.6	2.9	50.6	4.0
$\overline{D}$	.5	-	-.7	-.1	-3.2	1.5
$\sigma_{\overline{D}}$	1.8	-	1.1	1.5	2.2	2.9
RD	2.0%	-	-4.0%	-3.5%	-6.3%	37.5%

Symbol definitions:

n = number of sample segments

$\overline{P}_{SG}$ = ground-truth proportion (400-dot)

$\overline{D}$ = mean error

$\sigma_{\overline{D}}$ = standard error

2.2.2 CORRELATION STUDY OF SPRING SMALL-GRAIN ESTIMATES

Plots of the spring small-grain test site data in tables 2-1 and 2-2 are shown in figure 2-1. The data points show that there is approximately a 3-percent negative bias of analyst dots, with 11 of the 15 points below the perfect correlation line (45° diagonal). The correlation coefficient for these data is $r = 0.956$. The value of the t-test statistic is -2.7 (RD = -6.4 percent), which indicates that the average difference between analyst spring small-grain proportion estimates and ground-truth proportion estimates is significantly different from zero at the 10-percent level. This result is comparable to the TY proportion estimation performance in the USNGP.

2.2.3 TREND ANALYSIS

Plots of the proportion estimation error versus the ground-truth proportions for the spring small grains in the Canadian test sites are shown in figure 2-2. It does not appear that the trend for the error is related to the proportion estimate value as in the U.S. Great Plains wheat segments, where larger negative errors were associated with larger proportion estimates. (See figure 4-6 in reference 1, page 4-32.)

2.2.4 DISTRIBUTION OF SPRING SMALL-GRAIN PROPORTION ESTIMATION ERRORS

The plot in figure 2-3 indicates that a bimodal distribution of spring small-grain errors exists. The dashed line in the figure approximates the division between the two distributions. The six segments with the larger proportion estimation errors (3163, 3166, 3175, 3185, 3197, and 3201) and segment 3169 are the northernmost segments processed. The RD for these seven northernmost segments is -11.2 percent, whereas the southernmost segments have a much smaller RD of -1.6 percent. Except for segment 3169, the northernmost segments had poor accuracies, due partially to differences in agricultural cropping practices that exist between the area containing these segments and those in the southernmost area. The southernmost segments, where spring wheat and barley are the primary crops, generally have less complex cropping practices. In the northernmost segments, rapeseed, corn, and potatoes are grown along with small grains. It is believed that the more complex cropping system increased the number of analyst decisions, which in turn increased the opportunity for labeling errors to occur.

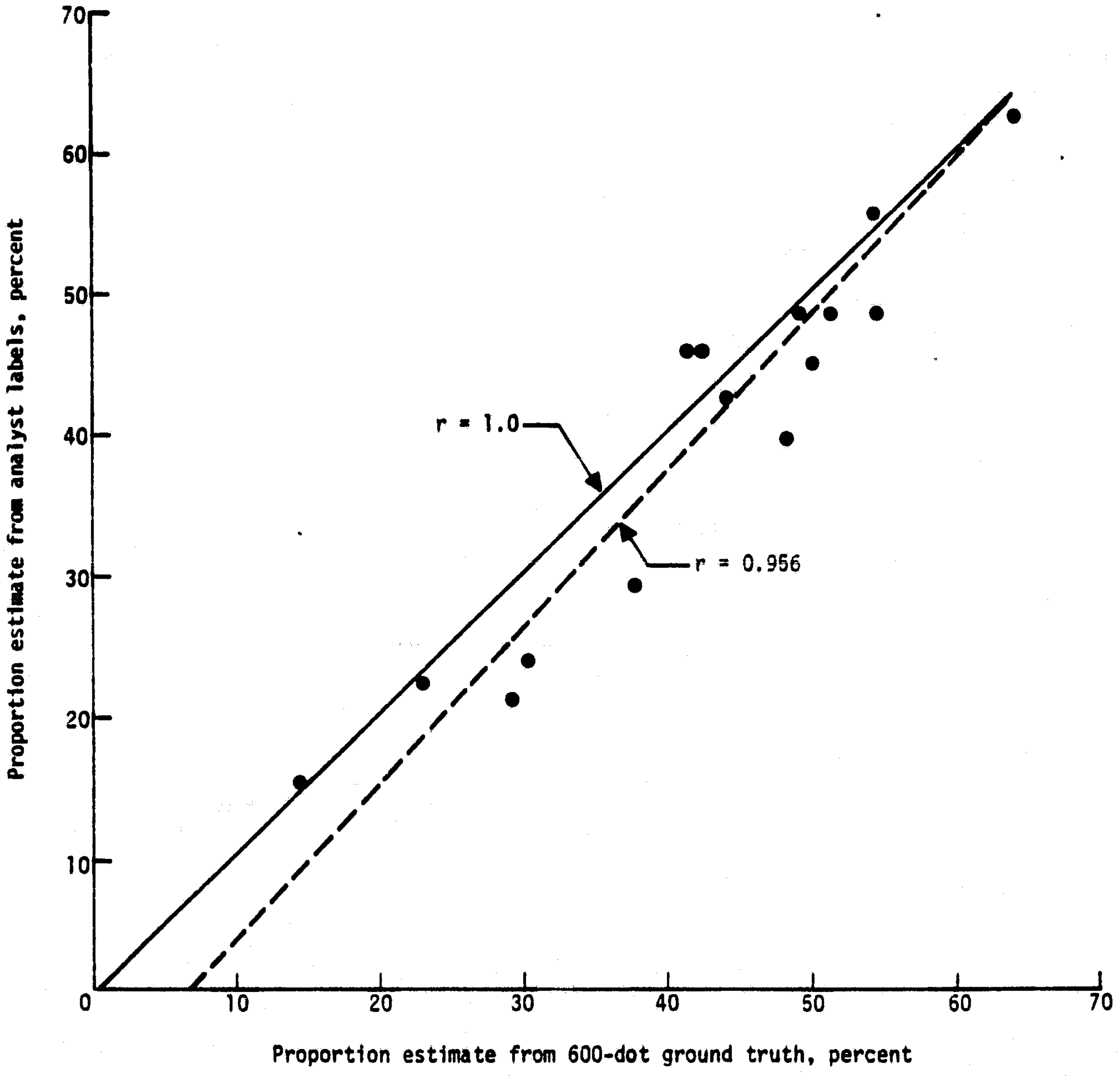

Figure 2-1.- Plot of spring small-grain proportion estimates derived from analyst labels versus proportion estimates derived from ground truth.

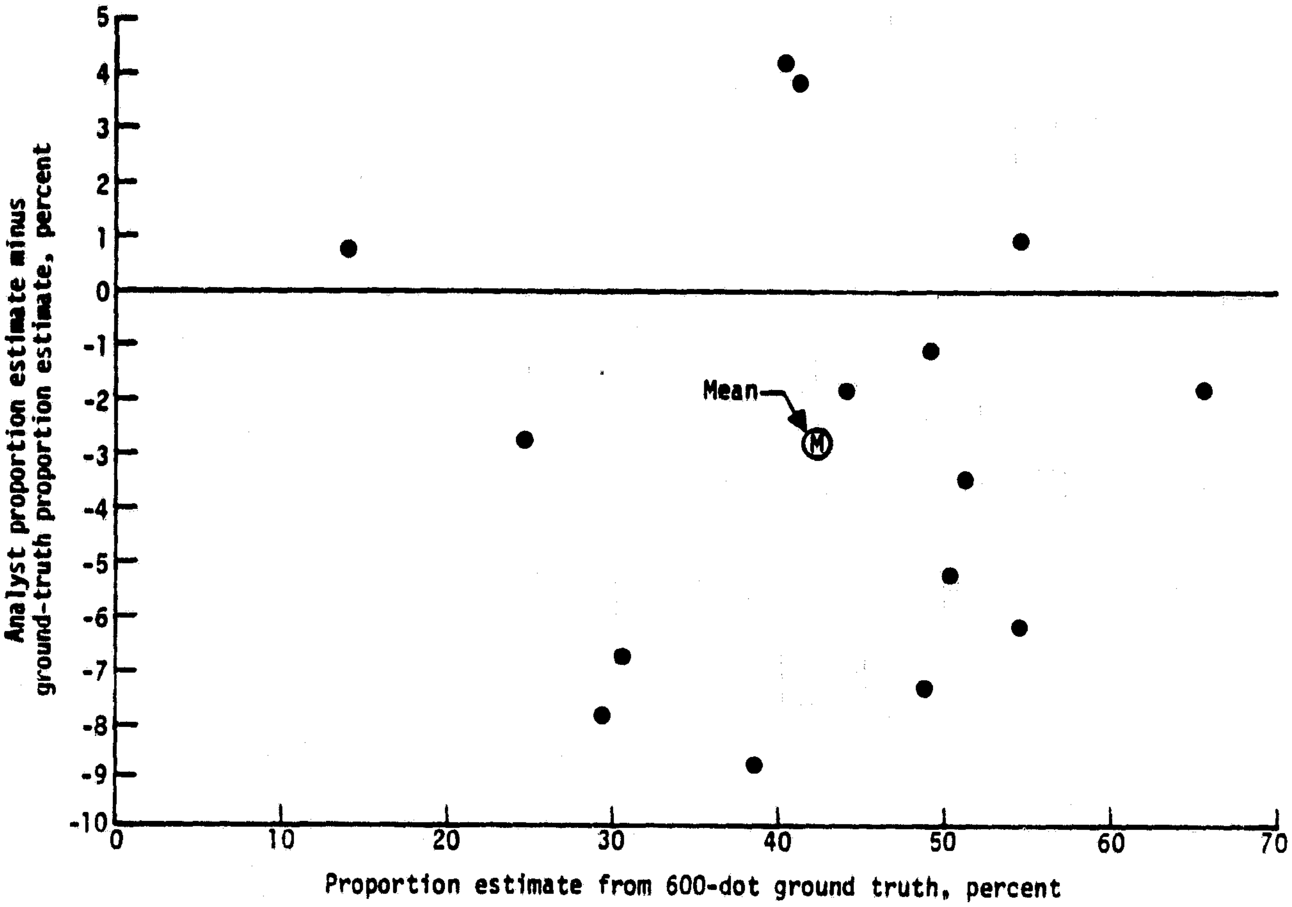

Figure 2-2.- Plot of proportion estimation error versus ground-truth proportions for spring small grains.

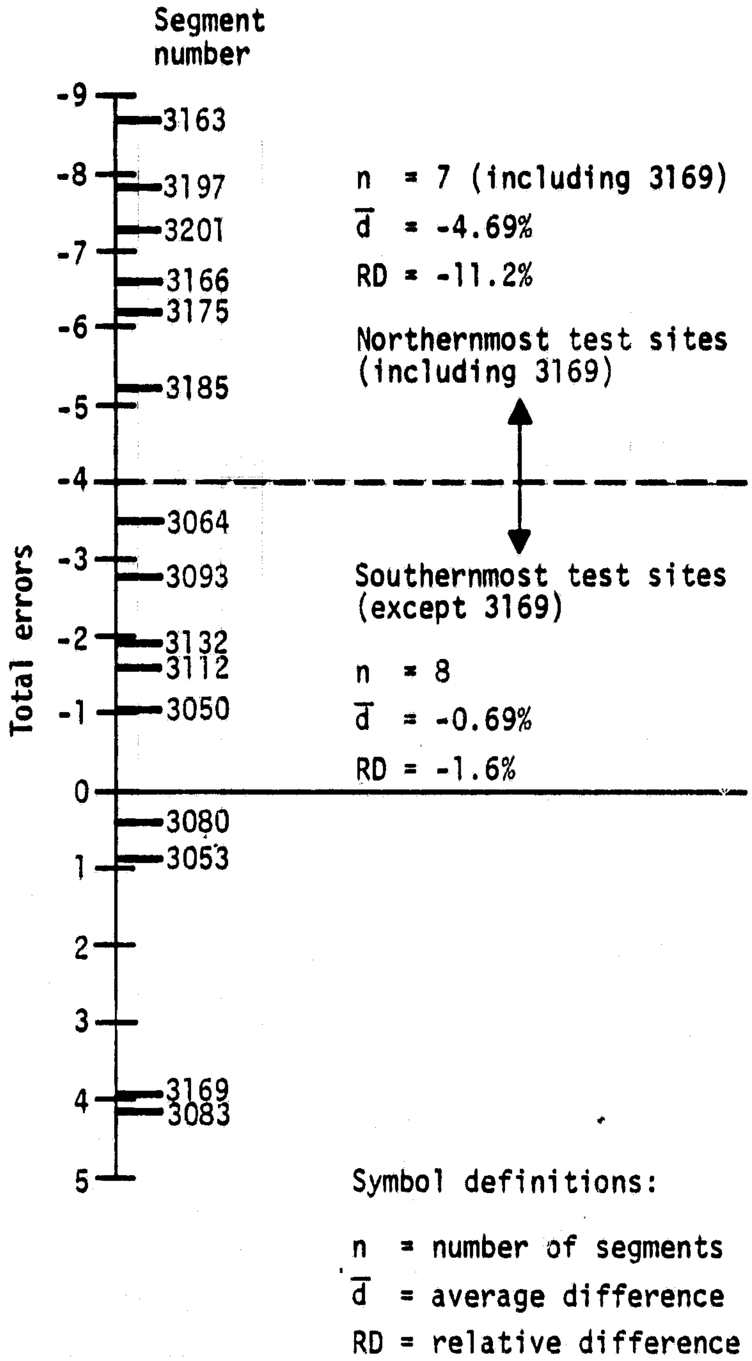

Figure 2-3.- Plot of spring small-grain proportion estimation error for the northernmost versus the southernmost segments. A distinctive break in accuracy (dashed line) is evident between the two groups of segments.

The differences in these two areas, northernmost and southernmost segments, are evident from the results of the detailed labeling accuracy study from which this conclusion was derived. These results are discussed in section 3.2.1.

2.3 CONCLUSIONS

The analysis of the analyst-derived proportion estimates compared with the 600-dot ground-truth estimates shows a small underestimation (RD = -7.0 percent) of spring small grains. This underestimation is statistically significant (the value of t-test = -2.7), but the results are better than those for LACIE Phase III in the U.S. spring wheat states and are comparable to the TY results in the same area.

The direct wheat results indicate an underestimation of direct wheat (RD = -6.4 percent) but an overestimation of barley (RD = 36.1 percent). It should be pointed out that these results are for only four segments, which is too few a number to arrive at any definite conclusions.

Proportion estimation accuracy was better for the southernmost Saskatchewan segments (RD = -1.6 percent). The poorer proportion estimation accuracy for the northernmost segments (RD = -11.2 percent) is believed to result from the cropping system in this region, which is generally more complex than in the southernmost area of Saskatchewan. It has been concluded that the more complex cropping system resulted in more decision points for the analyst, which in turn increased the potential for labeling errors.

3. LABELING ERROR CHARACTERIZATION STUDIES

3.1 APPROACH AND METHODOLOGY

Seven segments, which include the four barley separation segments and three additional segments with relatively large spring small-grain proportion estimation errors, were evaluated for spring small-grain and direct wheat accuracies. The evaluation studies compared the analyst labels against ground truth. This resulted in a numerical tabulation of the errors, both omission and commission, and a characterization of these errors.

For the four direct wheat segments, in the analysis, three classes of labels were measured against ground truth; i.e., barley, direct wheat, and all other crops as a single group labeled as nonspring small grains. These four segments also were analyzed along with the three additional segments as a single group for two-class accuracy; i.e., spring small grains and nonspring small grains. In addition, the two groups of segments (four direct wheat and three additional) were analyzed separately for their two-class accuracies.

All analyst labels, for both type 1 and 2 dots, were grouped and evaluated together, rather than separately as in previous accuracy assessment evaluations.

3.2 TWO-CLASS ANALYSIS OF SEVEN SEGMENTS

The results of tabulating the number of spring small-grain errors for each of the seven segments are shown as confusion matrices in table 3-1. The matrices are arranged such that the four segments processed for direct wheat are on the left [tables 3-1(a) through (d)] and the three additional segments are on the right [tables 3-1(e) through (g)].

The percentage of correctly labeled picture elements (pixels) was quite high and relatively close for all segments except one. The percentage of correctly labeled spring small grains varied for all segments, from approximately 91 percent to 98 percent, except for segment 3197 which had a relatively low

TABLE 3-1.- TWO-CLASS SPRING SMALL-GRAIN ACCURACIES FOR ALL SEVEN SEGMENTS

Analyst-derived direct wheat estimates

(a) Segment 3050

$$\begin{array}{c|cc} & AI_{SSG} & AI_0 \\ \hline GT_{SSG} & \frac{79}{82} = 0.963 & \frac{3}{82} = 0.037 \\ GT_0 & \frac{2}{87} = 0.023 & \frac{85}{87} = 0.977 \end{array}$$

(b) Segment 3053

$$\begin{array}{c|cc} & AI_{SSG} & AI_0 \\ \hline GT_{SSG} & \frac{99}{101} = 0.980 & \frac{2}{101} = 0.020 \\ GT_0 & \frac{2}{77} = 0.026 & \frac{75}{77} = 0.974 \end{array}$$

(c) Segment 3112

$$\begin{array}{c|cc} & AI_{SSG} & AI_0 \\ \hline GT_{SSG} & \frac{99}{101} = 0.980 & \frac{2}{101} = 0.020 \\ GT_0 & \frac{3}{65} = 0.046 & \frac{62}{65} = 0.954 \end{array}$$

(d) Segment 3185

$$\begin{array}{c|cc} & AI_{SSG} & AI_0 \\ \hline GT_{SSG} & \frac{77}{85} = 0.906 & \frac{8}{85} = 0.094 \\ GT_0 & \frac{2}{96} = 0.021 & \frac{94}{96} = 0.979 \end{array}$$

Additional segments selected for error characterizations

(e) Segment 3163

$$\begin{array}{c|cc} & AI_{SSG} & AI_0 \\ \hline GT_{SSG} & \frac{51}{52} = 0.981 & \frac{1}{52} = 0.019 \\ GT_0 & \frac{0}{119} = 0 & \frac{119}{119} = 1.00 \end{array}$$

(f) Segment 3169

$$\begin{array}{c|cc} & AI_{SSG} & AI_0 \\ \hline GT_{SSG} & \frac{75}{79} = 0.949 & \frac{4}{79} = 0.051 \\ GT_0 & \frac{9}{102} = 0.088 & \frac{93}{102} = 0.912 \end{array}$$

(g) Segment 3197

$$\begin{array}{c|cc} & AI_{SSG} & AI_0 \\ \hline GT_{SSG} & \frac{31}{46} = 0.674 & \frac{15}{46} = 0.326 \\ GT_0 & \frac{1}{121} = 0.008 & \frac{120}{121} = 0.992 \end{array}$$

Symbol definitions:

AI_{SSG} = analyst-interpreter proportion estimate of spring small grains

AI_0 = analyst-interpreter proportion estimate of nonspring small grains

GT_{SSG} = ground-truth proportion estimate of spring small grains

GT_0 = ground-truth proportion estimate of nonspring small grains accuracy of 67 percent. The low labeling accuracy for segment 3197 can be attributed to the analysts being overly concerned with separating rapeseed from spring small grains and inadvertently mislabeling 12 spring small-grain dots. In this report, these errors are referred to as "oversights," which accounted for 80 percent of the omission errors in this segment and 34 percent of all omission errors in the seven segments evaluated.

The confusion matrix for omission and commission errors for the seven segments treated as a group is given in table 3-2. The percentage of correctly labeled spring small-grain dots is approximately 94 percent, which can be considered as excellent performance. This result exceeds the TY U.S. spring wheat states accuracy of approximately 70 percent by a considerable amount; however, a number of factors unique to Canada may account for this difference.

The excellent spring small-grain labeling accuracy may be attributed primarily to three major factors: the data set, the uniqueness of Saskatchewan agricultural practices, and the segment processing approach. The data set was thoroughly screened to eliminate segments with inadequate and marginal acquisition histories. The intent was to select segments which had acquisitions in all four major biowindows, and this is believed to have contributed to the improved labeling accuracy.

The uniqueness of agricultural practices in Saskatchewan was recognized during the segment processing when ancillary data inputs indicated that almost exclusively spring crops, including spring small grains, are grown in this province. The ancillary statistics indicated the presence of very few summer crops; i.e., beans and potatoes. For all of Saskatchewan, beans and potatoes combined amounted to 0.02 percent of all crops sown in 1971. This implies that limited confusion could be expected from these crops. The ancillary data and previous years' intensive test site data showed that rapeseed was the only other major spring crop.

The implication of the above factors is that the only major potential confusion crop is rapeseed; therefore, if a crop seems to emerge in the spring,

TABLE 3-2.- TWO-CLASS SPRING SMALL-GRAIN ACCURACIES FOR ALL SEVEN SEGMENTS COMBINED

$$
\begin{array}{c c c}
 & AI_{SSG} & AI_{0} \\
GT_{SSG} & \frac{511}{546} = 0.936 & \frac{35}{546} = 0.064 \\
GT_{0} & \frac{19}{667} = 0.028 & \frac{648}{667} = 0.972
\end{array}
$$

from May through June, it is probably either a spring small grain or rapeseed. The qualifier to this is that the spring-emerged crops must, after emergence, progress through a multitemporal signature which includes at least turning and harvest or postharvest signatures. This identification technique is consistent with the TY detailed analysis procedures (see ref. 2, appendix C, section C.1).

The rapeseed was readily separated from the spring small grains because of its distinctive bright pink/purple signature. It was concluded that, once the rapeseed was separated, the remaining spring crops were most likely to be spring small grains. The labeling results show that this decision process was satisfactory.

The steps described above were enhanced by the Canadian processing technique which emphasized the team approach, whereby labeling decisions to be made were discussed thoroughly by a team. Since only 15 segments were involved in the processing, it was possible to utilize this approach to advantage.

The team attempted to maximize the use of ancillary data (e.g., crop calendars, Saskatchewan census subdivision statistics, and meteorological data) and intensive test site data from LACIE Phase III. In addition, since only 15 segments were being processed, the analyst timeline was increased to 2.5 man-days per segment to ensure adherence to proper analysis procedures. This compares to the LACIE Phase III timeline of approximately 1.5 man-days per segment for analyst processing, quality assurance, and operations verification. The latter should not be confused with the analyst processing timeline (a subset of the 1.5 man-days) which was 3 to 4 hours during Phase III.

3.2.1 DETAILED ERROR CHARACTERIZATIONS FOR SPRING SMALL GRAINS

The labeling error characterizations are summarized by segment in table 3-3. The total numbers of errors of omission and commission for the seven segments are 35 and 19, respectively. Oversights or mislabeling without any observable reason accounted for the majority of the errors, 22 errors (20 omission and 2 commission). The next largest error was caused by border/edge dot confusion,

TABLE 3-3.- DETAILED SPRING SMALL-GRAIN ERROR CHARACTERIZATION

Segment number	Total errors		Error cause										
			Misidentification							Border/edge co[illegible]sion		Oversights	
			Omission errors		Commission errors								
	Omission	Commission	Grass/ pasture	Rapeseed	Beans/ potatoes	Grass/ pasture	Rapeseed	Fallow/ residue	Winter rye	Omission	Commission	Omission	Commission
3050	3	2	2				1		1			1	
3053	2	2						1		2	1		
3112	2	3				1			1			2	1
3163	1	0								1			
3169	4	9		1	4	1	1			1	2	2	1
3185	8	2	4	1							2	3	
3197	15	1	1	1*						1	1	12	
Total	35	19	7	3	4	2	2	1	2	5	6	20	2

*Barley pink-up confused as rapeseed signature.

11 errors (5 omission and 6 commission). The third largest error was caused by omission errors resulting from grass/pasture confusion, seven errors. Summer crop confusion of beans and potatoes resulted in four commission errors, all four of which were in segment 3169. Although the bean and potato fields emerged later than the majority of the spring small grains, their lateness was not considered to be outside the range for small grains predicted by the normal crop calendars. An evaluation of these fields indicates that possibly they may be separated from the spring crops because of the later green-up or emergence and bright red signatures; but, this will probably result in omission of some flax and spring wheat which exhibit similar signatures.

The remainder of the omission and commission errors resulted from confusion of rapeseed, winter rye, and idle fallow with residue. It has been concluded that only the oversights (22 errors) could have been labeled correctly and that the labeling errors resulting from border/edge confusion (11 errors) and misidentification (21 errors) were justifiable. The implication of this analysis is that if the oversight errors had not occurred there would have been 15 omission errors (2.2 percent) and 17 commission errors (3.1 percent), resulting in an unbiased spring small-grain proportion estimate for these seven segments.

3.2.2 DISTRIBUTION OF SPRING SMALL-GRAIN LABELING ERRORS

The proportion estimation evaluation (section 3.2) indicated that the northernmost Saskatchewan segments generally have higher estimation errors than the southernmost segments. This is supported by the detailed error characterization, which shows a total of 40 labeling errors of omission and commission for the four northernmost segments evaluated and only 14 errors for the three southernmost segments. The distribution of labeling errors by segment is shown in figure 3-1.

As stated previously, the reason for the high estimation errors for the northernmost segments is that the more complex cropping practices in this region

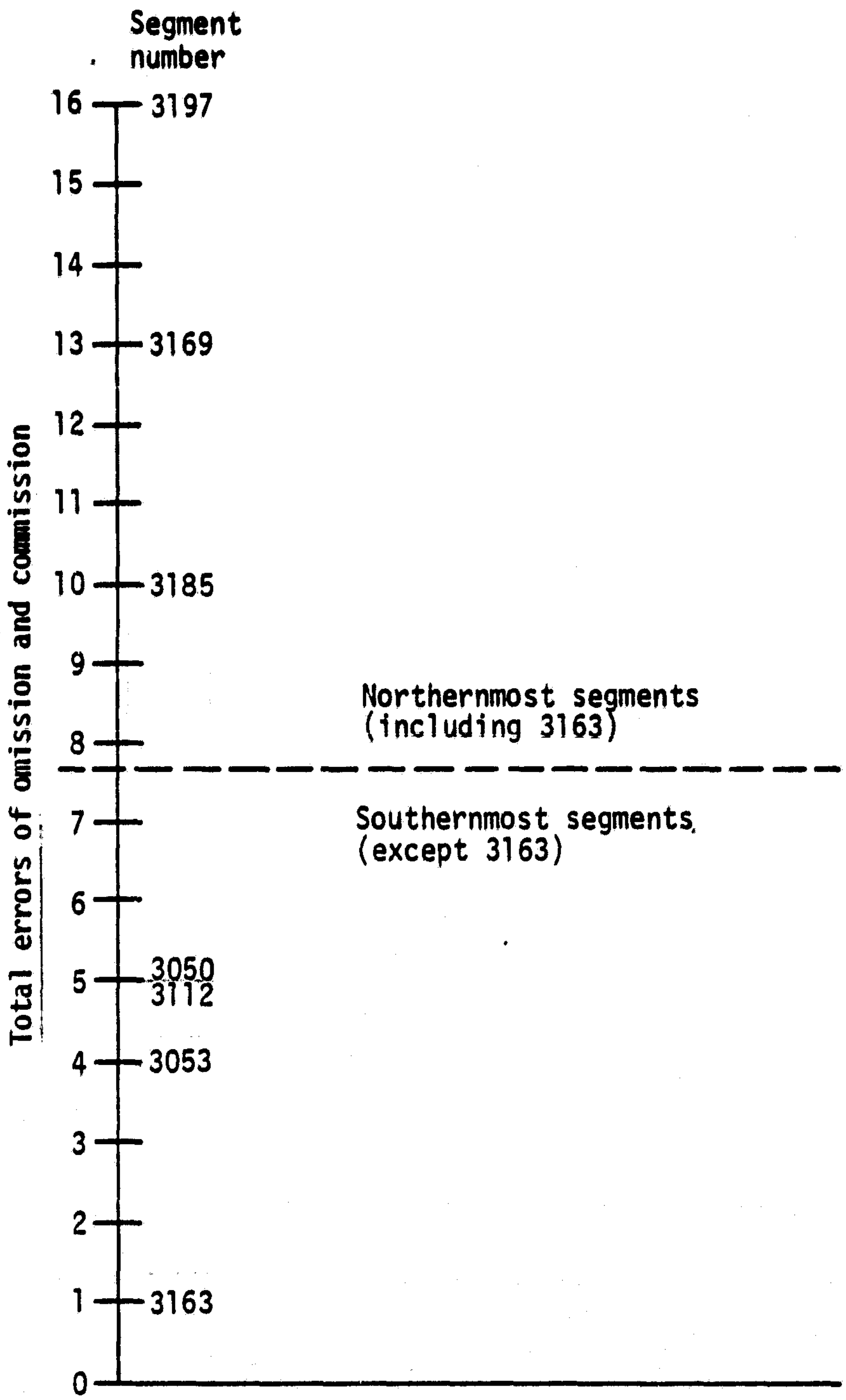

Figure 3-1.- Distribution of labeling errors in the seven segments.

increased the number of analyst decisions, which in turn increased the opportunity for the occurrence of labeling errors.

3.3 TWO-CLASS ANALYSIS OF FOUR DIRECT WHEAT AND THREE ADDITIONAL SEGMENTS AS SEPARATE GROUPS

The 96-percent correctly labeled spring small grains for the four direct wheat segments [table 3-4(a)] is significantly better than the 89-percent accuracy for the three additional segments [table 3-4(b)]. The difference in the two results is the relatively low labeling accuracy of segment 3197, which is included in the three-additional-segments grouping.

3.4 THREE-CLASS ANALYSIS OF THE FOUR DIRECT WHEAT SEGMENTS

The results of tabulating the number of errors for each of the four direct wheat segments (3050, 3053, 3112, and 3185) are shown as confusion matrices in tables 3-5(a) through (d). Table 3-6 contains the confusion matrix for the four segments combined.

The percentages of correctly labeled direct wheat and barley are approximately 89 and 31 percent, respectively (table 3-6). The results clearly indicate that barley could not be separated consistently from the other spring small grains in Saskatchewan using the barley separation procedure (ref. 2, appendix C, section C.1.2.2). Barley was primarily confused with spring wheat; a minor amount was confused with rapeseed and grass/pasture. The result for labeling direct wheat is rather good, approximately 89 percent correctly labeled, compared to the TY labeling accuracy of approximately 70 percent for the U.S. spring wheat states.

Barley incorrectly labeled as spring wheat accounted for 14 errors, while barley labeled as nonspring small grains amounted to 4 errors (table 3-6). In addition, 26 spring wheat ground-truth pixels were incorrectly labeled as barley.

The confusion occurred when barley was incorrectly labeled as direct wheat on the predicted barley separation acquisition. The barley was turning and being

TABLE 3-4.- TWO-CLASS SPRING SMALL-GRAIN ANALYSIS

(a) Four direct wheat segments

$$\begin{array}{c} \\ GT_{SSG} \\ GT_0 \end{array} \begin{array}{cc} AI_{SSG} & AI_0 \\ \left[\begin{array}{cc} \frac{354}{369} = 0.959 & \frac{15}{369} = 0.041 \\ \frac{9}{325} = 0.028 & \frac{316}{325} = 0.972 \end{array}\right] \end{array}$$

(b) Three additional segments

$$\begin{array}{c} \\ GT_{SSG} \\ GT_0 \end{array} \begin{array}{cc} AI_{SSG} & AI_0 \\ \left[\begin{array}{cc} \frac{157}{177} = 0.887 & \frac{20}{177} = 0.113 \\ \frac{10}{342} = 0.029 & \frac{332}{342} = 0.971 \end{array}\right] \end{array}$$

TABLE 3-5.- THREE-CLASS ANALYSIS OF THE FOUR DIRECT WHEAT SEGMENTS

[Spring wheat/barley separation]

(a) Segment 3050

	AI_S	AI_B	AI_0
GT_S	$\frac{64}{79} = 0.823$	$\frac{12}{79} = 0.159$	$\frac{3}{79} = 0.038$
GT_B	$\frac{2}{3} = 0.667$	$\frac{1}{3} = 0.333$	$\frac{0}{3} = 0$
GT_0	$\frac{3}{87} = 0.034$	$\frac{0}{87} = 0$	$\frac{84}{87} = 0.966$

(b) Segment 3053

	AI_S	AI_B	AI_0
GT_S	$\frac{87}{97} = 0.897$	$\frac{7}{97} = 0.072$	$\frac{3}{97} = 0.031$
GT_B	$\frac{4}{4} = 1.0$	$\frac{0}{4} = 0$	$\frac{0}{4} = 0$
GT_0	$\frac{2}{77} = 0.026$	$\frac{0}{77} = 0$	$\frac{75}{77} = 0.974$

(c) Segment 3112

	AI_S	AI_B	AI_0
GT_S	$\frac{94}{101} = 0.931$	$\frac{5}{101} = 0.050$	$\frac{2}{101} = 0.020$
GT_B	$\frac{0}{0} = 0$	$\frac{0}{0} = 0$	$\frac{0}{0} = 0$
GT_0	$\frac{3}{65} = 0.046$	$\frac{0}{65} = 0$	$\frac{62}{65} = 0.954$

(d) Segment 3185

	AI_S	AI_B	AI_0
GT_S	$\frac{61}{66} = 0.924$	$\frac{2}{66} = 0.030$	$\frac{3}{66} = 0.045$
GT_B	$\frac{8}{19} = 0.421$	$\frac{7}{19} = 0.369$	$\frac{4}{19} = 0.211$
GT_0	$\frac{2}{96} = 0.021$	$\frac{1}{96} = 0.010$	$\frac{93}{96} = 0.969$

Symbol definitions:

AI_B = analyst-interpreter proportion estimate of barley

AI_S = analyst-interpreter proportion estimate of spring wheat

GT_B = ground-truth proportion estimate of barley

GT_S = ground-truth proportion estimate of spring wheat

TABLE 3-6.- THREE-CLASS ANALYSIS OF THE FOUR DIRECT WHEAT SEGMENTS COMBINED

[Spring wheat/barley separation]

	AI_S	AI_B	AI_O
GT_S	$\frac{306}{343} = 0.892$	$\frac{26}{343} = 0.075$	$\frac{11}{343} = 0.032$
GT_B	$\frac{14}{26} = 0.538$	$\frac{8}{26} = 0.308$	$\frac{4}{26} = 0.154$
GT_O	$\frac{10}{325} = 0.031$	$\frac{1}{325} = 0.003$	$\frac{314}{325} = 0.966$

harvested along with the majority of the direct wheat. These fields were labeled correctly according to the direct wheat procedure (ref. 2, appendix C, section C.1.2.2); however, since the barley did not ripen before spring wheat as expected, it was omitted and labeled as direct wheat. The normal crop calendar used for the analysis of segment 3050, which had considerable barley/spring wheat confusion, is shown in figure 3-2. The crop calendar indicates that barley should normally ripen before spring wheat, but potential confusion is evident since the flax and oats crop calendars for the ripe-to-harvest period are similar to that for barley.

The incorrect labeling of spring wheat as barley occurred because of the early ripening signature for spring wheat on the barley separation acquisition. Procedurally, these fields were also labeled correctly. The problem apparently is because varieties of spring wheat and barley behave differently than those used in the development of the direct wheat procedure.

Of the four barley fields labeled as nonspring small grains, two were narrow fields in segment 3185. These fields were near the edge of a lake and therefore were interpreted as grass/pasture. Also in segment 3185, two barley fields were interpreted to be rapeseed because of the distinctive bright purple/pink signature on the August acquisition. Rapeseed correctly labeled as nonspring small grains in segment 3185 exhibited somewhat similar signatures on the same August acquisition; therefore, the confusion between barley and rapeseed is understandable. It is possible that a different or more complete data set may have provided information to avoid this confusion.

3.5 CONCLUSIONS

Approximately 94 percent of the spring small grains for the seven Saskatchewan segments were labeled correctly, which can be considered as excellent performance. This result exceeds the TY U.S. spring wheat states labeling accuracy of 70 percent.

The direct wheat labeling accuracy was good, approximately 89 percent, despite the low barley separation accuracy of 30 percent. This compares to the TY

PERCENT OF AREA IN DEVELOPMENT STAGE BY SPECIFIED DATE

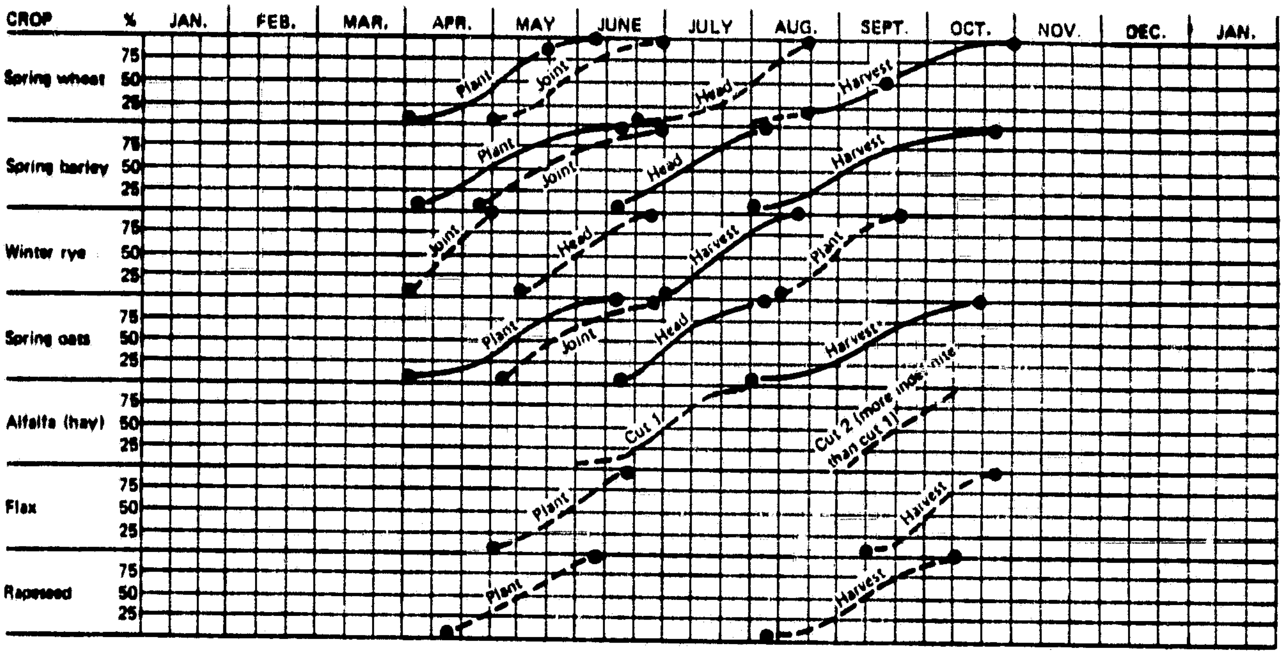

Figure 3-2.-- Southern Saskatchewan crop calendar used in the analysis of segment 3050. A dashed line indicates an estimate.

U.S. spring wheat states labeling accuracies of 70 and 65 percent, respectively.

The high spring small-grain labeling accuracy of 94 percent may be attributed to three major factors: a good data set with adequate acquisition histories, few confusion crops in Saskatchewan, and a processing technique which emphasized the team approach in all aspects of the analysis procedures.

The detailed characterization of the spring small-grain errors shows that the largest sources of errors are analyst oversights, border/edge dot confusion, and grass/pasture confusion. From the analysis, it can be concluded that the spring small-grain labeling accuracy could have been higher if the oversight omission and commission errors had not occurred.

Labeling errors, both omission and commission, were higher in the northernmost segments than in the southernmost segments. It has been concluded that this is because of the more complex cropping system in the region occupied by these segments. It is believed that the more complex cropping practices resulted in more analyst decisions, which increased the opportunity for the occurrence of labeling errors. Many of these errors were those designated as "oversight errors."

The results show that barley separation was largely unsuccessful in the Canadian test sites. A better understanding of the development of barley and spring wheat in Saskatchewan is required in order to develop a procedure to separate barley from the other spring small grains in this region. Research into these problems should continue.

4. REFERENCES

1. LACIE Phase III Final Accuracy Assessment Report. LACIE-00478 (JSC-13766), Aug. 1979.

2. Detailed Analysis Procedures for Transition Project (FY79). LACIE-00724 (JSC-13756), May 1979.