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CROP IDENTIFICATION AND ACREAGE MEASUREMENT UTILIZING LANDSAT IMAGERY

Statistical Reporting Service
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16. Abstract

This paper summarizes work completed by the Statistical Reporting Service, USDA, using ground observations obtained from our area frame. This frame is the key to making good estimates of crop acreages and yield as well as income and livestock. It turns out to be essential for making good use of satellite imagery as well. One critical step in using multi-spectral scanner CCT's is to identify and estimate the amount of energy for each crop that is reflected in each band. Area frame data can provide unbiased estimates of crops reflectances in the whole image, since the data were selected scientifically from the whole image.

Another equally critical step in making immediate use of satellite imagery is needed after the image has been classified. By observing how known probability data are classified or more accurately misclassified, we can adjust total image classifications so that pixels can be converted to acres in a statistically sound way.

The work presently being done by SRS directly evolved from this study. The project's intent is to reduce sampling error of the crop acreage estimates.

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"And the Lord said, 'Behold, they are one people, and they have all one language; and this is only the beginning of what they will do; and nothing that they propose to do will now be impossible for them. Come, let us go down, and there confuse their language, that they may not understand one another's speech'... Therefore, its name was called Babel, because there the Lord confused the language of all the earth..."

Genesis 11:6-9

"And we have been misleading each other ever since."

Dr. Thomas Szasz,
The Second Sin,
1974

But this is an effort to dispel some of this confusion with respect to remote sensing.

The Authors

ACKNOWLEDGEMENTS

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In addition, we tender our appreciation to our scientific monitor, Mr. Frederic Gordon for his patience during the final draft of this document.

Preface

This report provides step by step details of nearly two and one half years of work at the Statistical Reporting Service (SRS) under NASA contract AG328. The contract specified that we perform crop classification of LANDSAT data (formerly ERTS) in four states. All the classification was performed at Purdue using LARSYS. Other systems were tried, but LARSYS was flexible enough to suit our needs.

The basic objective was to evaluate LANDSAT data and to find ways to use this data to improve the present acreage estimates. This is no easy task since the current estimates are cost effective and sufficient in most areas - the exception being local estimates.

The procedures that were developed were to improve state or strata within state estimates. This project is being followed through with 1975-76 program, which is to perform wall to wall classification of LANDSAT data in Illinois, Kansas, and 44 counties in Texas.

Specifically, the objectives as presented in the original proposal are:

1. Develop methods of crop species identification from space imagery by photo interpretation and discrimination technique within the context of: (1) multiple frame sampling, and (2) an alternative approach using the techniques of double sampling. The study would compare the accuracy of results using LANDSAT imagery compared with the additional improvement using aircraft imagery when both are combined with ground data.

2. Develop methods for estimating crop acreages by extracting information from space imagery in the context of the agencies operating constraints.

The scope of this ambitious study was somewhat reduced since much of the imagery came very late in the growing season.

Less than optimum imagery was available, so less than optimum results were obtained. Nevertheless, the conclusions were that if satellite imagery were available and if software were available, LANDSAT type data could be useful and provide substantial gains in state estimates. SRS has moved ahead to build software, so that when the imagery is available, SRS will be ready to use it. However, it is vital that the data be ready for processing within 48 hours after it has been taken. Otherwise, it is of little value.

Table of Contents

TABLE OF FIGURES

Table of Figures cont.

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I. Introduction

The Statistical Reporting Service (SRS), U.S. Department of Agriculture, prepares estimates of crops, livestock, poultry, dairy, prices, and related agricultural topics.

Crop reports provide estimates of acreages farmers intend to plant in the coming season, the acres planted and harvested, production, disposition of the crop, and remaining stocks. Forecasts of yield and production are issued monthly during the growing season based on information voluntarily provided by farmers and from counts, measurements, and observations made in sample fields by SRS enumerators.

Livestock and poultry reports include estimates of animals on farms and ranches or in feedlots. Estimates are made of breeding and production intentions; yearend estimates cover production and disposition of major livestock and poultry species. SRS also reports slaughter numbers and meat production.

Dairy reports indicate milk cows, monthly and annual milk production, and use of milk. Production of major manufactured dairy products is reported weekly and monthly.

Price reports show prices received by farmers for nearly 200 products and prices paid for about 500 items needed for production or family living. Reports cover indexes of prices received and paid, parity prices, and season average prices of crops, livestock, and livestock products.

Other reports deal with labor and wages, fertilizer, seeds, bees and honey, mink, naval stores, stocks of major commodities, cold storage holdings, exports and other agricultural elements.

The scope of agricultural estimates has increased with the demands for information by producers, processors, manufacturers, and Government program planners, but the original goal has remained steady - to help farmers market farm products more effectively.

The launching of ERTS-1 (now LANDSAT) on July 24, 1972 opened a new potential source of agricultural data. This investigation has provided SRS with an opportunity to evaluate a different source of data relative to crop acreage estimates. In addition, there was presented the opportunity to determine whether the theory of sampling is flexible enough to utilize efficiently satellite data in conjunction with other survey procedures. If it were possible to blend these sources, a substantial increase in survey accuracy would ensue.

1/ Preparing Crop and Livestock Estimates, Statistical Reporting Service, March, 1974.

The objectives of this investigation were as follows:

1. Develop methods to identify crop species utilizing satellite and aircraft imagery.

2. Develop methods of estimating crop acreages utilizing satellite imagery.

3. Within the context of multi-stage and multiple frame sampling, develop methods of utilizing all three sources of data (ground, aircraft, and satellite) to make crop acreage estimates. Combining all three sources in a statistical model should result in a marked improvement over any one source for making crop acreage estimates.

The study areas were selected Crop Reporting Districts in Missouri, Kansas, South Dakota, and Idaho. The major crops of concern were wheat, corn, cotton, soybeans, sugar beets, potatoes, alfalfa, and grain sorghum. Some of the crops are grown in only one area while others are common to two or three. This provided the opportunity to observe crops grown under different conditions.

II. Data Acquisition

2.1 Ground Observations

In order to evaluate the new methodology, one needs independently collected (control) data. For this study, ground truth collected in the same manner as is now being used by the Statistical Reporting Service, (SRS) was used as the control data for evaluating results from both the satellite and aircraft imagery.

The thrust of the ground truth portion of the LANDSAT project is to identify the crops visible from the air on previously designated areas of land. Our ground truth identifies the crop species present and the exact location of the fields for the survey.

Throughout the growing season, the species, acreage, and condition of crops in these fields are observed periodically. This provides progressive reports about crop maturity development and a record of any changes in acreage or species. This data provides survey acreage for crops which could be compared against other sources of data and corresponding estimates.

The condition of the crop in each field is noted as supplementary information. During the processing of aerial photography and satellite imagery the condition code would, in some cases, provide some basis why a corn field was classified incorrectly.

The first enumerative survey was conducted in late May and early June of 1972 by SRS. This data was used as a source of original data and was then updated by special enumerators. 1/ However, the estimates of crop acreages generated by the JES survey included both crops already planted and crops to be planted. At the time of the enumerative survey, the wheat in Missouri might still be in the field and was recorded as such on the questionnaire. In addition, the farmer's intention to plant soybeans was recorded for that same field. The LANDSAT ground truth was only concerned with crops and ground vegetation present on the day the enumerator visited the segments. For this reason, the June Enumerative Survey (JES) acreage estimates could be different from the LANDSAT acreage estimates; however, provisions were made through the updating of JES so such differences could be measured.

The LANDSAT ground truth was also used as a training device to classify aerial photography and satellite imagery. Since the exact location of each field and the crop species present in the field was known, we could identify the field on the aerial photography or satellite imagery and train the computer to recognize and identify all similar fields. After identification, a separate estimate of acreage can be generated from these other sources of data and compared against the ground truth acreage estimates.

2.1.2 Source of Ground Data

The test areas used in this study were SRS Crop Reporting Districts (CRD) A CRD is a contiguous group of counties within a state which have similar farming activities. Generally, each state is composed of about nine such districts.

Within each of these CRD's are randomly selected areas of land (segments) that range in size from about one-half square mile to three square miles. Since the CRD's are independent strata, estimates can be made for each individual strata by multiplying the segment totals by the reciprocal of their probability of selection and summing over the CRD. For the JES and the LANDSAT study, these segments are the test sites for the classification of the aircraft and satellite imagery. The information obtained from these segments on crops present constituted our ground observations.

1/ See Appendix B for a list of terms and definitions used for the June Enumerative Survey (JES) and LANDSAT fieldwork.

Ground data was collected for segments in CRD six in South Dakota, seven in Kansas, and nine in Missouri. In Idaho, the study area was not a CRD, but a land use stratum which included the intensive agriculture areas of Jerome, Minidoka, Twin Falls, and Cassia Counties. The study areas within each state were selected since they represented an area with a manageable volume of data and a comparable number of segments.

Table 1--States and numbers of segments in study area.

State	Number of Segments
South Dakota	50
Kansas	48
Missouri	42
Idaho	44
TOTAL	184

The four different test sites (see Figures 1, 2, 3, and 4) were selected to fulfill operational objectives. First, we wanted to monitor the progressive stages of growth and maturity of the major crop species. The original satellite launching data would have allowed monitoring crop growth from April through November of 1972. Mature wheat in Kansas could be compared to pre-headed and headed wheat in South Dakota with similar comparisons being made for other crops. Secondly, we wanted the scattered areas to help insure at least some good imagery. Imagery of cloud cover over selected areas is useless. Presumably, the distant areas would not all be engulfed with inclement weather as the aerial photography and satellite imagery were obtained. Thirdly, we wanted to answer whether or not corn in Missouri was spectrally different from corn in South Dakota, etc. Fourthly, we wanted to look at several different crops and their responses to different locational environments of soil, topography, and climate. The four State analysis gives indication of within and between State variations necessary prior to operational surveys of this type. The major crops included in the study are shown in Table 2.

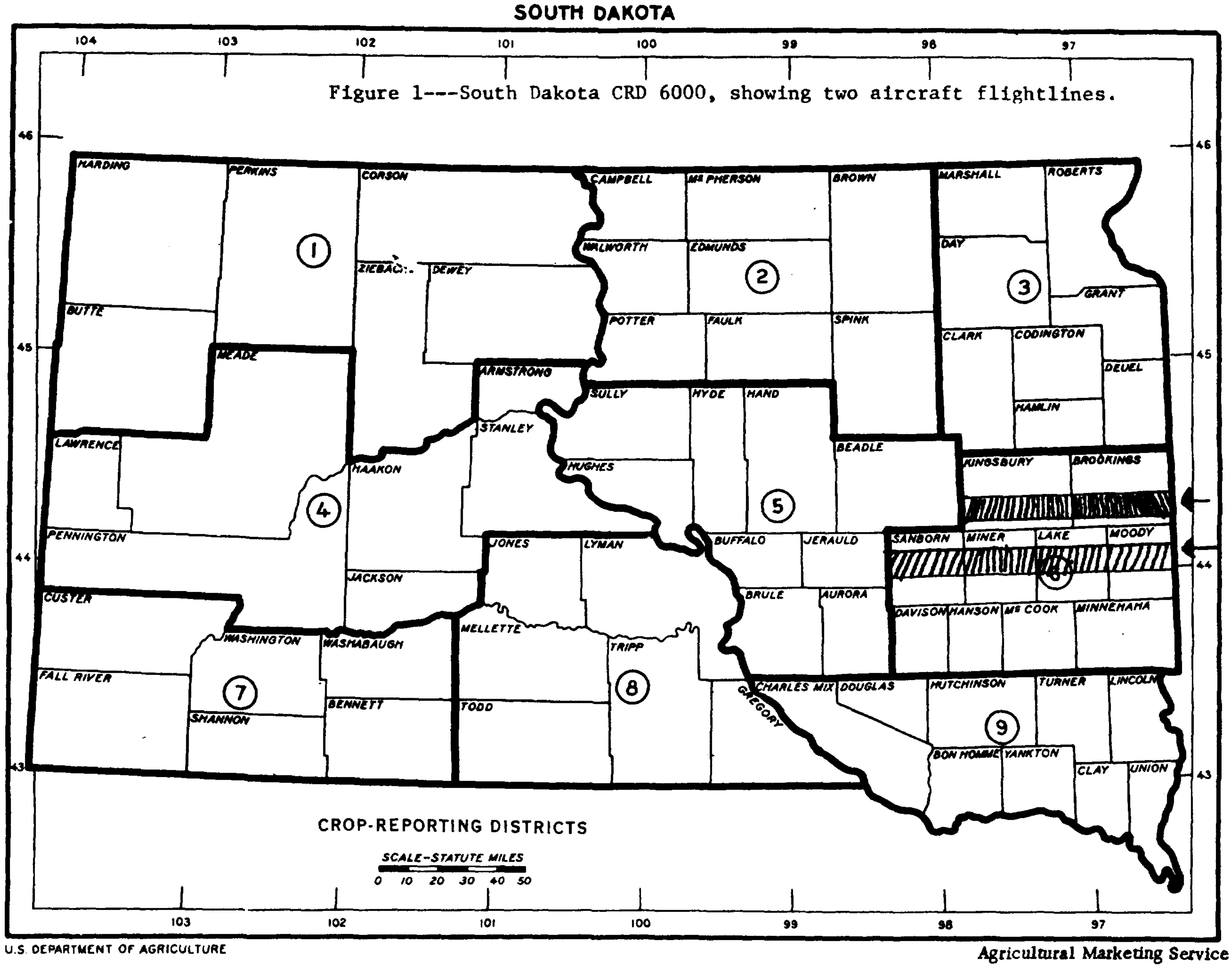

Figure 1---South Dakota CRD 6000, showing two aircraft flightlines.

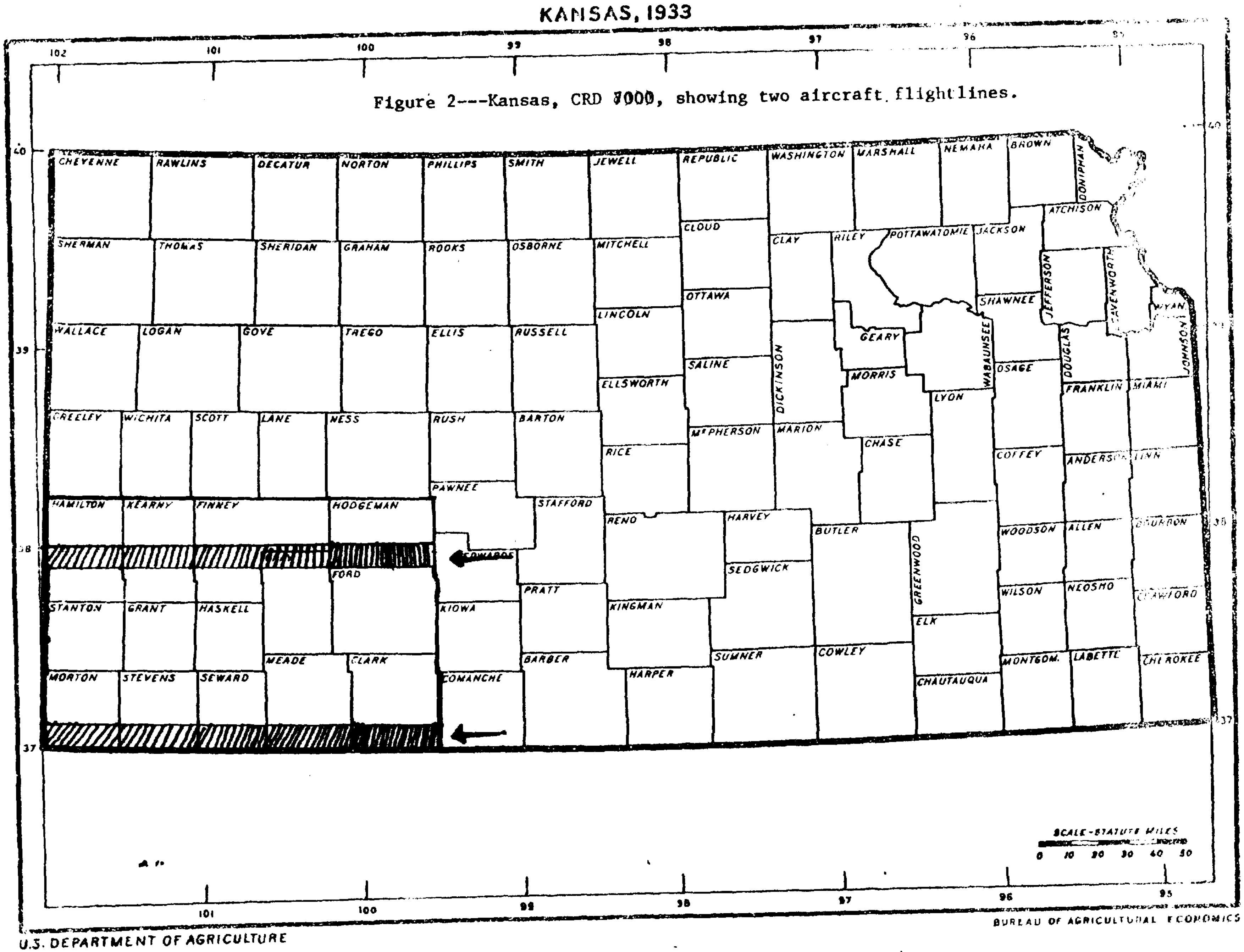

Figure 2---Kansas, CRD 7000, showing two aircraft flightlines.

MISSOURI

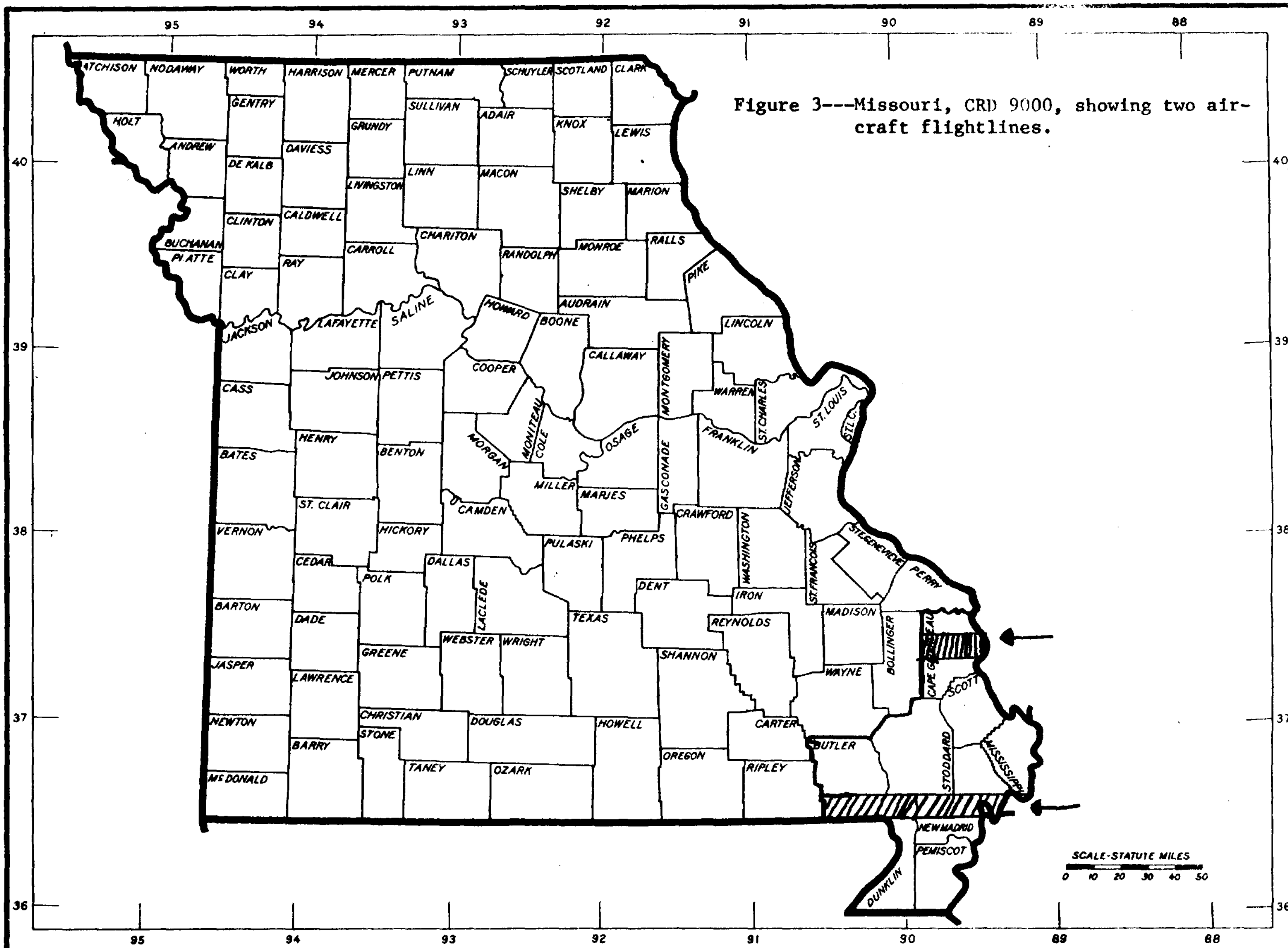

Figure 3---Missouri, CRD 9000, showing two aircraft flightlines.

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Figure 4---Idaho, CRD 2000, showing two aircraft flight-lines.

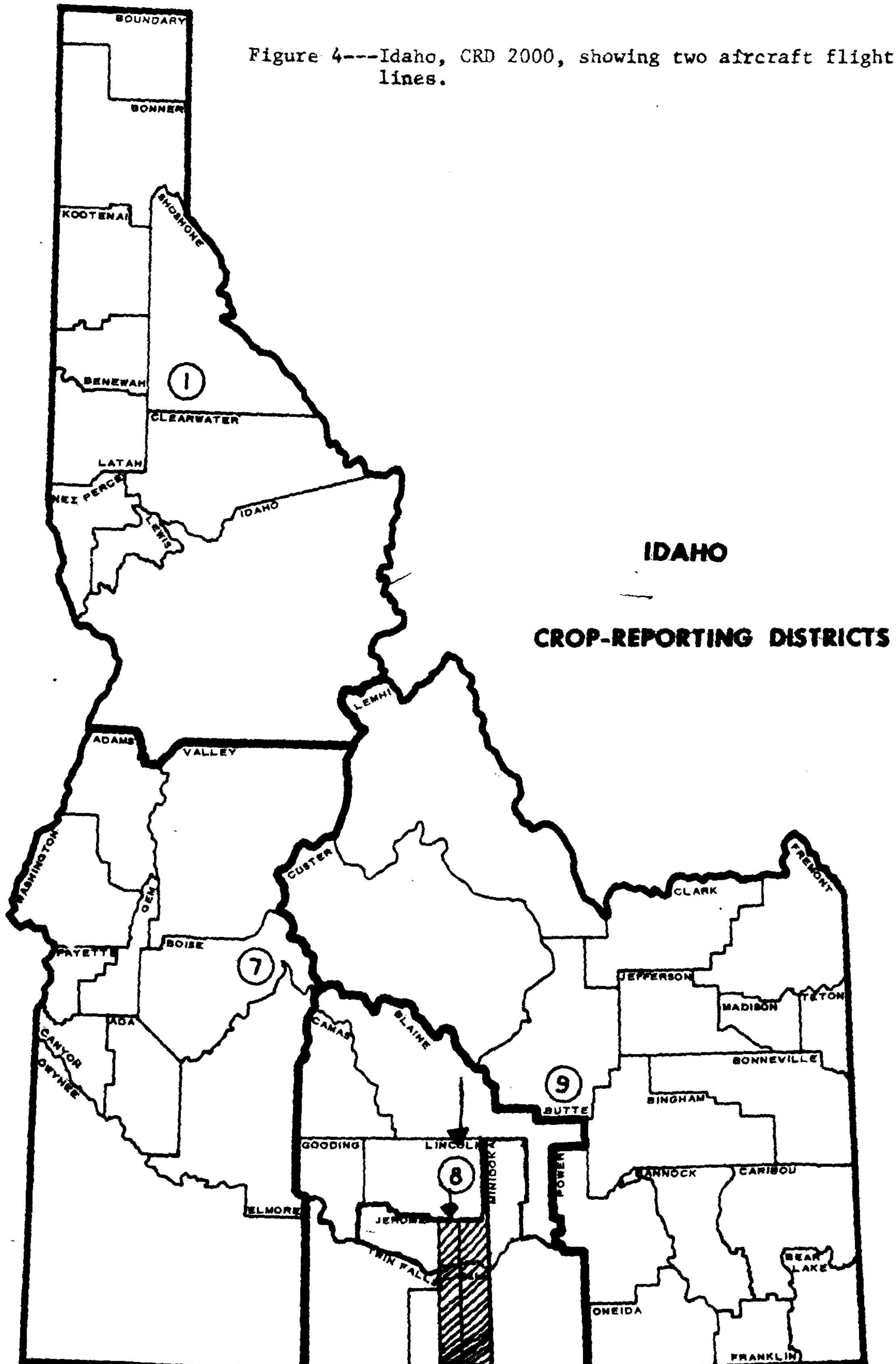

Table 2--Major crops included in LANDSAT investigation.

CROP / STATE	Alfalfa	Corn	Cotton	Field Beans	Grain Sorghum	Mixed Grain	Potatoes	Sugar Beets	Soybeans	Wheat
South Dakota		X							X	X
Kansas	X	X			X			X		X
Missouri		X	X						X	X
Idaho				X		X	X	X		

2.1.3 Collection of Ground Data

During the JES, large scale (1/7920) aerial photos were used to record exact field locations. Each tract was coded with a letter A, B, C, ... and each field within a tract was given a number 1, 2, 3, ... A tract corresponds to that part of a farm operation which lies within the segment. Figure 5 is an example of a segment and how the tracts and fields were delineated. The segment was delineated in red, the tracts in blue, and the fields within tracts were in red. As part of the JES and prior to collection of LANDSAT survey ground observations, similar aerial maps were obtained for all segments included in the LANDSAT study. Tract and field boundaries were transferred from the JES photos to the LANDSAT maps and all acres in the segments were accounted for prior to any LANDSAT fieldwork. Therefore, the enumerators were only required to verify the accuracy of the previous fieldwork and note new situations during any current survey period.

Ground observations collected for the LANDSAT study were recorded on a computer generated recording form. This form provided unique identification of each field within each segment for recording the crop present, the condition of the crop, and the number of acres in that field. Computer generation allowed automatic entry of all previous data on the form. Figure 6 is an example of the recording form used by the enumerators to update survey work and record new observations for each field.

FIGURE 5

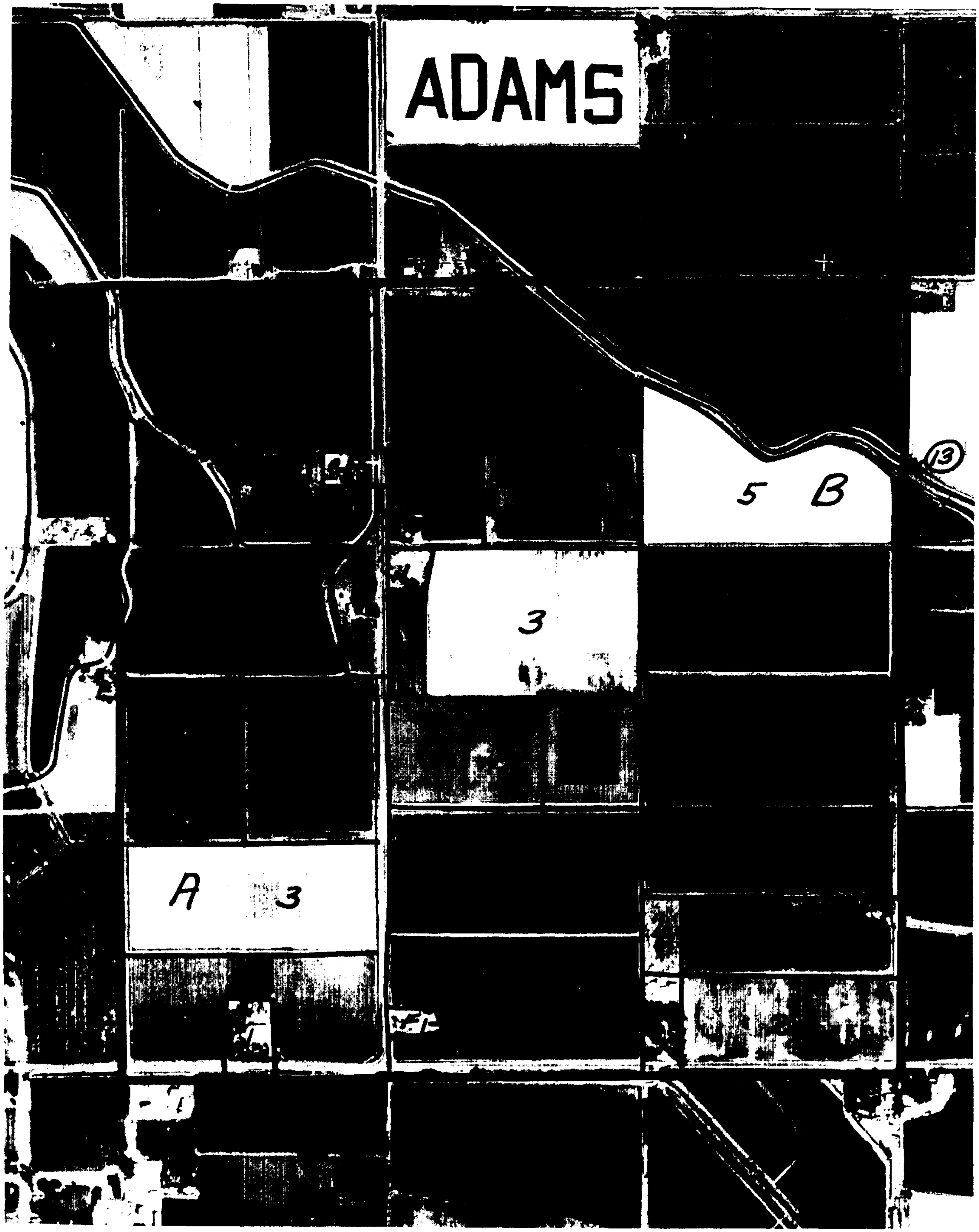

Figure 6---Ground truth record form, Kansas segment 3086, tract 3, third visit.

OMB NUMBER 40-572045
APPROVAL EXPIRES 6-30-73

ERTS GROUND TRUTH (76) KANSAS (47) SEGMENT (3086) TRACT (03) PAGE 01 OF 01

FIELD NO.	FIRST VISIT (JES)		SECOND VISIT JULIAN DATE (221)			THIRD VISIT JULIAN DATE (___)			FOURTH VISIT JULIAN DATE (___)			FINAL VISIT JULIAN DATE (___)		
	ACRES	CROP	ACRES	CROP	CONDITN	ACRES	CROP	CONDITN	ACRES	CROP	CONDITN	ACRES	CROP	CONDITN
01	8	0000	8	OTHR	____	0	____	____	0	____	____	0	____	____
02	44	CORN	44	CORN	TASS	0	____	____	0	____	____	0	____	____
03	1	WNWH	1	FLOW	CLEA	0	____	____	0	____	____	0	____	____
04	9	PSTR	9	PSTR	GREE	0	____	____	0	____	____	0	____	____
05	136	PSTR	136	PSTR	GREE	0	____	____	0	____	____	0	____	____
06	119	FLOW	39	FLOW	CLEA	0	____	____	0	____	____	0	____	____
07	28	WNWH	28	GSOR	GREE	0	____	____	0	____	____	0	____	____
03	150	FLOW	125	FLOW	CLEA	0	____	____	0	____	____	0	____	____
09	135	WNWH	135	WNWH	HARV	0	____	____	0	____	____	0	____	____
10	0	____	25	GSOR	GREE	0	____	____	0	____	____	0	____	____
11	0	____	80	GSOR	GREE	0	____	____	0	____	____	0	____	____
TOT	630		630			0			0			0		

PERMISSION UNASKED SEGMENT (3086) TRACT (03) PAGE 01 OF 01

Visit one (base) data was obtained directly from the JES questionnaire, which was completed in late May 1972 and/or early June 1972. 1/ The JES data was identified and keypunched for all "fields" in the segments. The identification of each field was required in order to delete crops which might have been reported as fields to be planted at a later date. For example, a 20 acre field could be recorded both as wheat, and also as soybeans to be planted after the wheat was harvested. Since aerial photography and satellite imagery would record only crops present, the ground observation could only correspond to what was in the field at the time of visit, and only the wheat would be punched. If the wheat field was now soybeans, this change was made during the update.

After completion of all the ground observations, the four State Statistical Offices involved in the LANDSAT study were sent an evaluation form to evaluate the computer printout recording form. From the answers to the evaluation, the following can be said:

1. The Form Printout is a workable method of collecting ground observations. There might have been a small problem orienting the enumerators to a different form than the accustomed one. However, with training, the transition was short. The enumerators were able to record acres and crop species without difficulty.

2. The crop condition codes were generally adequate, but several suggestions were made. The suggestions were a) call this "State of Growth" rather than "Condition," b) change the grain codes from "prefruit" to "blade" and "fruit" to "heading," c) remove pasture from the hays and code the pastures as lush, grazed, and range, and finally d) add the code weedy to fallow.

3. The new printout format did not create unusual editing or keypunching situations.

2.1.4 Average Field Size

Classification results from LANDSAT imagery indicate that field size may have a significant affect on how well the classification might be. Also, early reported results by other investigators suggested that relatively poor classification was obtained from fields less than 20 acres. Several inquiries to the Statistical Reporting Service for information on size of field prompted the preparation of a detailed tabulation of fields by size

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1/ See Appendix B for a copy of a JES questionnaire and the keypunching instructions for the LANDSAT survey.

and by crop (See Tables 3, 4, 5, and 6). The data for this tabulation is from the 1972 SRS JES in the four test sites. It should be pointed out that this information only represents the four test areas.

In the Missouri test site, 28.7 percent of the fields are 20 acres or greater and account for 68 percent of the land area. Thirty-eight percent of the cotton fields are greater than 20 acres, but account for 73 percent of the reported cotton acreage. Forty-one percent of the soybean fields were 20 acres plus and represents 77.5 percent of the soybean acreage. The average size of all fields in Missouri was 17.11 acres.

South Dakota reported that 92 percent of the corn acreage and 89 percent of the oats were in fields larger than 20 acres. Overall, 52 percent of the reported fields were greater than 20 acres with an average field size of 28.74 acres. The average field size needs to be viewed with some caution in that it can be heavily influenced by large or small acreages for relatively unimportant land uses such as pasture, farmstead, etc.

Kansas showed 98.5 percent, 99.1 percent, 98.5 percent, 95.6 percent of the corn, wheat, sorghum, and alfalfa acreage respectively, were grown in fields larger than 20 acres. Field size should not be a limiting factor in identifying these crops in Kansas. Average size of all fields in Kansas was 108.31 acres.

The test area in Idaho contained some large areas of waste and pasture which influenced the average field size and the distribution. About 50 percent of the corn was planted in fields larger than 20 acres. Eighty-five percent of the barley was in 20 acre plus fields. Ninety-four percent of the potatoes were contained in fields larger than 20 acres. About 65 percent of the sugar beets were grown in 20 acres plus fields.

If field size is a factor in one's ability to do crop classification, the results in Kansas should be substantially better than in the other three states. Field shape may be a greater limiting factor than size, particularly in areas which contain irregular fields.

2.1.5 Timing and Workload of Fieldwork

Because of the delay in the launch of LANDSAT-1, the update surveys did not begin until August 1972. Prior to the first visits, a training school was conducted in each State involved. The training was to 1) instruct State Statistical Offices (SSO) personnel regarding enumeration, editing, keypunching, and mailing procedures, and 2) instruct enumerators regarding the collection of ground observations. 1/

1/ See Appendix A for Enumerator Instructions, for Ground Observation Editing Instructions, and B for Ground Observation SSO Keypunching Instructions.

Table 3 --Distribution of fields by size and crop for the four county test areas in South Central IDAHO, based in June Survey Data.

Crop	0-4.9 Acres				5-9.9 Acres				10-14.9 Acres				15-19.9 Acres				20-29.9 Acres				30 + Acres			
	Fields		Acres		Fields		Acres		Fields		Acres		Fields		Acres		Fields		Acres		Fields		Acres	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Farmstead, etc.	138	55.9	303.9	1.2	46	18.6	288.1	1.1	18	7.3	213.1	0.8	5	2.0	81.0	0.3	14	5.7	333.3	1.3	26	10.5	24,708.8	95.3
Corn	6	10.9	15.1	1.7	13	23.6	95.1	10.9	11	20.0	134.7	15.4	11	20.0	180.0	20.6	9	16.4	214.8	24.5	5	9.1	235.6	26.9
Oats	1	25.0	2.2	4.2	-	-	-	-	-	-	-	-	3	75.0	50.5	95.8	-	-	-	-	-	-	-	-
Barley	6	7.6	13.8	0.5	9	11.4	70.3	2.3	10	12.7	116.9	3.7	15	19.0	253.7	8.1	11	13.9	257.1	8.2	28	35.4	2,414.1	77.2
Winter Wheat	-	-	-	-	11	29.7	78.7	5.0	8	21.6	91.5	5.9	1	2.7	17.0	1.1	4	10.8	88.7	5.7	13	35.2	1,284.3	82.3
Mixed Grain	10	21.3	32.3	5.2	16	34.0	115.3	18.6	9	19.2	113.7	18.3	3	6.4	50.5	8.1	4	8.5	93.0	15.0	5	10.6	216.2	34.8
Spring Wheat	5	17.2	19.3	4.4	8	27.6	51.7	11.8	8	27.6	91.9	21.1	3	10.3	53.5	12.3	1	3.5	22.0	5.0	4	13.8	198.0	45.4
Potatoes	-	-	-	-	1	5.3	8.0	0.8	2	10.5	27.6	2.8	1	5.2	18.0	1.8	1	5.3	25.0	2.6	14	73.7	905.0	92.0
Sweet Corn	2	13.3	6.5	1.3	2	13.4	12.0	2.5	3	20.0	35.1	7.3	1	6.7	16.3	3.4	2	13.3	41.7	8.7	5	33.3	369.6	76.8
Vegetables	1	100.0	1.0	100.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dry Beans	10	7.6	31.1	1.4	30	22.7	223.7	10.3	37	28.0	434.2	19.9	20	15.1	320.1	14.7	20	15.2	467.5	21.5	15	11.4	701.3	32.2
Dry Field Peas	3	20.0	9.9	4.1	-	-	-	-	4	26.7	49.0	20.4	4	26.6	70.5	29.3	3	20.0	77.0	32.0	1	6.7	34.0	14.2
Wild Hay	1	100.0	4.0	100.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alfalfa	40	15.3	132.2	2.6	68	26.0	472.0	9.4	52	19.8	621.5	12.4	34	13.0	565.5	11.3	30	11.4	729.3	14.6	38	14.5	2,486.2	49.7
Other Hay	-	-	-	-	3	60.0	21.9	31.1	-	-	-	-	1	20.0	15.6	22.1	-	-	-	-	1	20.0	33.0	46.8
Clover	-	-	-	-	2	100.0	14.8	100.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sugar Beets	8	11.1	25.6	1.7	13	18.0	95.8	6.5	17	23.6	193.5	13.1	12	16.7	204.9	13.8	11	15.3	274.8	18.6	11	15.3	684.5	46.3
Apples	-	-	-	-	1	100.0	7.0	100.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pasture	70	30.8	170.4	0.1	47	20.7	299.7	0.1	19	8.4	228.1	0.1	14	6.2	223.4	0.1	17	7.5	397.7	0.1	60	26.4	455,091.6	99.5
Cropland Pasture	5	20.0	12.1	3.3	10	40.0	72.3	19.5	5	20.0	56.5	15.2	1	4.0	19.0	5.1	-	-	-	-	4	16.0	211.0	56.9
Summer Fallow	5	12.8	16.7	0.9	8	20.5	53.4	2.9	2	5.1	28.3	1.6	2	5.1	31.0	1.7	7	18.0	177.5	9.8	15	38.5	1,509.6	83.1
Other Crops	-	-	-	-	-	-	-	-	-	-	-	-	1	100.0	17.0	100.0	-	-	-	-	-	-	-	-
Soil Improvement Crops	3	33.3	8.0	10.1	4	44.5	28.9	36.4	1	11.1	11.0	13.9	-	-	-	-	-	-	-	-	1	11.1	31.4	39.6
Idle Cropland	21	51.2	61.0	13.9	14	34.2	93.7	21.4	2	4.9	26.5	6.1	1	2.4	15.0	3.4	-	-	-	-	3	7.3	241.6	55.2
TOTALS:																								
Number of fields	335				306				208				133				133				248			
Acres	865.1				2,102.4				2,473.1				2,202.5				3,199.4				491,355.8			
Number of fields % of total	24.5				22.4				15.2				9.7				9.7				118.2			
Acres % of total	0.2				0.4				0.5				0.5				0.6				97.8			
Average size of field-acres	2.6				6.9				11.9				16.6				24.1				1,973.3			
Average Size of all fields = 367.91 acres																								

Table 4--Distribution of number of fields by size and crop for Crop Reporting District 7, based on June Survey Data - KANSAS

Crop	0-4.9 Acres				5-9.9 Acres				10-14.9 Acres				15-19.9 Acres				20-29.9 Acres				30 + Acres			
	Fields		Acres		Fields		Acres		Fields		Acres		Fields		Acres		Fields		Acres		Fields		Acres	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Farmstead, etc.	41	56.9	82.5	20.0	19	26.4	106.8	25.8	5	6.9	50.0	12.1	2	2.8	34.0	8.2	3	4.2	68.0	16.5	2	2.8	72.1	17.4
Corn	2	4.2	7.5	0.2	2	4.2	14.0	0.4	2	4.2	20.0	0.5	1	2.1	18.0	0.4	2	4.1	45.0	1.1	39	81.2	3,880.4	97.4
Oats	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	100.0	40	100.0	-	-	-	-
Barely	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	100.0	152.0	100.0
Winter Wheat	5	2.5	11.8	0.1	4	2.0	27.2	0.2	1	0.5	12.0	0.1	5	2.6	83.7	0.5	23	11.6	560.8	3.4	160	80.8	15,747.8	95.7
Rye	-	-	-	-	-	-	-	-	1	100.0	10.0	100.0	-	-	-	-	-	-	-	-	-	-	-	-
Vegetables	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	100.0	40.0	100.0
Sorghum	1	1.5	2.0	0.1	1	1.5	9.0	0.1	1	1.5	14.0	0.2	5	7.4	81.0	1.1	3	4.5	73.0	1.0	56	83.6	7,138.1	97.5
Alfalfa	1	4.3	4.0	0.2	1	4.4	7.5	0.5	2	8.7	22.0	1.4	2	8.7	34.0	2.3	2	8.7	55.0	3.5	15	65.2	1,435.7	92.1
Other Hay	2	20.0	6.0	4.3	4	40.0	26.0	18.4	-	-	-	-	-	-	-	-	2	20.0	44.0	31.2	2	20.0	65.0	46.1
Sugar Beets	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	100.0	129.0	100.0
Pasture	-	-	-	-	3	2.6	24.0	0.1	8	6.9	91.9	0.3	3	2.6	49.4	0.2	5	4.3	129.5	0.4	97	83.6	31,190.6	99.0
Cropland Pasture	1	6.2	3.9	0.4	2	12.5	13.8	1.4	2	12.6	22.6	2.3	1	6.2	17.0	1.8	-	-	-	-	10	62.5	918.0	94.1
Summer Fallow	5	2.7	15.3	0.1	3	1.6	20.7	0.1	6	3.2	64.0	0.4	10	5.3	167.2	0.9	10	5.4	241.8	1.3	153	81.8	17,798.8	97.2
Other Crops	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	100.0	60.0	100.0
Soil Improvement Crops	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	100.0	515.0	100.0
Idle	-	-	-	-	1	25.0	6.0	6.5	-	-	-	-	1	25.0	18.0	19.6	-	-	-	-	2	50.0	68.0	73.9
TOTALS:																								
Number of fields	58				40				28				30				52				546			
Acres	133.0				255.0				306.5				502.3				1,257.1				79,210.6			
Number of fields % of total	7.7				5.3				3.7				4.0				6.9				72.4			
Acres % of total	0.2				0.3				0.4				0.6				1.5				97.0			
Average size of field-acres	2.3				6.4				10.9				16.7				24.2				145.1			
Average Size of all fields = 108.31 acres																								

Table 5--Distribution of number of fields by size and crop for Crop Reporting District 9, based on June Survey Data - MISSOURI

Crop	0-4.9 Acres				5-9.9 Acres				10-14.9 Acres				15-19.9 Acres				20-29.9 Acres				30 + Acres			
	Fields		Acres		Fields		Acres		Fields		Acres		Fields		Acres		Fields		Acres		Fields		Acres	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Farmstead, etc.	71	57.7	134.1	13.1	17	13.8	107.8	10.5	16	13.0	184.5	18.0	6	4.9	97.0	9.5	8	6.5	186.0	18.2	5	4.1	315.0	30.7
Cotton	18	14.1	59.7	2.0	21	16.4	139.0	4.8	18	14.0	211.0	7.2	22	17.2	368.5	12.8	16	12.5	384.0	13.2	33	25.8	1744.5	60.0
Corn	6	20.0	16.0	4.3	8	26.7	52.9	14.3	9	30.0	106.0	28.6	1	3.3	15.0	4.1	4	13.3	960	26.0	2	6.7	84.0	22.7
Oats	1	100	4.0	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Barley	2	100	7.0	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Winter Wheat	4	4.6	9.7	0.6	15	17.2	106.0	6.0	25	28.7	278.7	15.8	13	15.0	212.2	12.1	16	18.4	362.5	20.6	14	16.1	759.6	44.9
Rye	3	42.9	7.5	13.8	3	42.8	22.0	40.3	-	-	-	-	-	-	-	-	1	14.3	25.0	45.9	-	-	-	-
Watermelons	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	100	35.0	100
Soybeans	30	16.3	71.2	1.7	30	16.3	204.5	4.9	28	15.2	328.3	7.9	20	10.9	334.4	8.0	32	17.4	757.9	18.2	44	23.9	2476.0	59.3
Sorghum	2	28.5	7.0	7.7	2	28.6	12.0	13.2	1	14.3	10.0	11.0	-	-	-	-	1	14.3	25.0	27.5	1	14.3	37.0	40.6
Wild Hay	-	-	-	-	1	100	8.0	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alfalfa	2	66.7	7.0	31.8	-	-	-	-	-	-	-	-	1	33.3	15.0	68.2	-	-	-	-	-	-	-	-
Other Hay	3	23.1	9.0	3.1	4	30.8	27.0	9.3	-	-	-	-	-	-	-	-	1	7.7	24.0	8.3	5	38.4	229.0	79.3
Clover	1	20.0	4.0	5.2	2	40.0	12.7	16.6	-	-	-	-	-	-	-	-	1	20.0	20.0	26.1	1	20.0	40.0	52.1
Pasture	18	28.6	56.5	4.4	11	17.5	73.2	5.8	5	7.9	58.5	4.6	7	11.1	113.3	8.9	11	17.4	248.4	19.5	11	17.5	722.6	56.8
Cropland Pasture	3	42.8	11.0	12.4	1	14.3	6.0	6.7	1	14.3	10.0	11.2	-	-	-	-	-	-	-	-	2	28.6	62.0	69.7
Other Crops	-	-	-	-	1	50.0	8.0	24.2	-	-	-	-	-	-	-	-	1	500	25.0	75.8	-	-	-	-
Soil Improvement Crops	20	47.6	41.5	14.1	13	30.9	91.4	31.1	5	11.9	55.5	18.9	1	2.4	18.8	6.4	2	4.8	47.0	15.9	1	2.4	40.0	13.6
Idle	17	25.8	50.6	7.2	19	28.8	120.2	17.1	17	25.7	196.7	28.0	5	7.6	87.8	12.5	5	7.6	102.0	14.5	3	4.5	146.0	20.7
TOTALS:																								
Number of fields	201				148				125				76				99				123			
Acres	495.8				990.7				1439.1				1262.0				2302.8				6720.7			
Number of fields % of total	26.0				19.2				16.2				9.9				12.8				15.9			
Acres % of total	3.8				9.5				10.9				9.6				17.4				50.9			
Average Size of field-acres	2.47				6.69				11.51				16.61				23.26				54.64			
Average Size of all fields = 17.11 acres																								

Table 6--Distribution of number of fields by size and crop for Crop Reporting District 6, based on June Survey Data - SOUTH DAKOTA

Crop	0-4.9 Acres				5-9.9 Acres				10-14.9 Acres				15-19.9 Acres				20-29.9 Acres				30 + Acres			
	Fields		Acres		Fields		Acres		Fields		Acres		Fields		Acres		Fields		Acres		Fields		Acres	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Farmstead, etc.	33	30.5	89.8	10.5	49	45.5	337.6	39.4	14	13.0	157.0	18.4	6	5.6	93.0	10.9	3	2.7	62.0	7.3	3	2.7	115.0	13.5
Corn	5	2.9	13.9	0.2	12	6.9	92.3	1.4	15	8.6	179.0	2.7	16	9.2	270.8	4.1	42	24.1	1016.3	15.5	84	48.3	5003.6	76.1
Oats	7	5.9	22.0	0.6	10	8.4	73.1	2.0	10	8.4	113.0	3.1	12	10.1	205.1	5.5	30	25.2	679.1	18.3	50	42.0	2611.8	70.5
Barley	-	-	-	-	5	26.3	39.3	7.0	1	5.3	14.0	2.5	6	31.6	95.0	17.0	-	-	-	-	7	36.8	411.0	73.5
Winter Wheat	1	33.3	2.5	6.7	-	-	-	-	1	33.3	11.0	29.3	-	-	-	-	1	33.3	24.0	64.0	-	-	-	-
Soybeans	-	-	-	-	1	8.3	8.5	3.7	2	16.7	20.0	8.6	3	25.0	53.2	22.9	5	41.7	113.0	48.5	1	8.3	38.0	16.3
Sorghum	2	25.0	8.0	3.9	-	-	-	-	-	-	-	-	1	12.5	15.0	7.3	3	37.5	63.0	30.7	2	25.0	119.0	58.1
Wild Hay	2	8.7	4.4	0.9	7	30.5	46.5	9.1	2	8.7	26.0	5.1	1	4.3	15.5	3.0	4	17.4	89.0	17.3	7	30.4	332.0	64.6
Alfalfa	6	6.5	19.2	0.9	9	9.9	61.2	2.8	20	22.0	233.2	10.7	13	14.3	211.0	9.6	23	25.3	519.0	23.7	20	22.0	1144.0	52.3
Other Hay	10	55.5	20.0	4.0	1	5.6	5.0	1.0	2	11.1	20.0	4.1	1	5.6	16.0	3.2	-	-	-	-	4	22.2	433.0	87.7
Flax	1	5.6	2.5	0.7	1	5.5	7.0	1.9	3	16.7	35.0	9.5	2	11.1	34.0	9.3	8	44.4	192.0	52.4	3	16.7	96.0	26.2
Pasture	6	6.8	14.5	0.3	4	4.6	25.5	0.5	12	13.6	128.0	2.8	3	3.4	46.0	1.0	9	10.2	220.0	4.8	54	61.4	4186.0	90.6
Cropland Pasture	5	10.4	15.5	1.1	6	12.5	41.7	3.0	9	18.8	109.4	7.8	4	8.3	69.0	4.9	10	20.8	227.5	16.3	14	29.2	935.3	66.9
Summer Fallow	8	12.7	22.5	1.3	4	6.4	27.0	1.6	7	11.1	75.0	4.4	10	15.9	171.9	10.0	13	20.6	303.5	17.7	21	33.3	1113.8	65.0
Other Crops	7	53.7	21.7	16.2	3	23.1	21.5	16.0	2	15.4	23.0	17.1	-	-	-	-	-	-	-	-	1	7.8	68.0	50.7
Soil Improvement Crops	-	-	-	-	1	8.3	8.0	2.8	1	8.3	13.0	4.5	3	25.0	49.0	16.8	5	41.7	122.0	41.9	2	16.7	98.8	34.0
Idle	6	23.1	16.2	3.5	2	7.7	16.8	3.6	3	11.5	33.0	7.1	4	15.4	65.0	14.1	6	23.1	135.2	29.3	5	19.2	196.0	42.4
Rye	-	-	-	-	1	11.1	5.0	2.6	1	11.1	11.0	5.6	2	22.2	31.0	15.9	4	33.4	77.0	39.5	2	22.2	71.0	36.4
Spring Wheat	1	16.7	1.3	0.9	1	16.6	8.0	5.7	1	16.7	10.0	7.1	-	-	-	-	-	-	-	-	3	50.0	122.0	86.3
Durum Wheat	-	-	-	-	1	50.0	6.0	22.2	-	-	-	-	-	-	-	-	1	50.0	21.0	77.8	-	-	-	-
TOTALS:																								
Number of fields	100				118				106				87				166				283			
Acres	274.0				830.0				1210.6				1440.5				3863.6				17094.3			
Number of fields % of total	11.7				13.7				12.3				10.1				19.3				32.9			
Acres % of total	1.1				3.4				4.9				5.8				15.6				69.2			
Average Size of Field-acres	2.74				7.03				11.42				15.56				23.27				60.40			
Average Size of all fields = 28.74 acres																								

The timetable for the collection of the ground observations was:

August 3	Enumerator training schools
August 7-11	Survey fieldwork
August 11	Enumerators mail update survey forms to SSO's
August 14-17	SSO's edit forms and keypunch data
August 17	SSO's mail forms and data cards to Washington, D.C.
August 24	Form printout run for next survey fieldwork
August 25	Printout sent to SSO's
September 9	Enumerators receive printout
September 11-15	Survey fieldwork
September 15	Enumerators mail forms to SSO's
September 18-21	SSO's edit and keypunch updates
September 21	SSO's mail forms and data cards to Washington, D.C.
September 27	Printout run for next survey fieldwork
September 28	Printout sent to SSO's
October 7	Enumerator receive printout
October 13	Enumerators mail forms to SSO's
October 16-19	SSO's edit and keypunch updates
October 19	SSO's mail forms and data cards to Washington, D.C.
October 27	Final printout run

Although the data was not summarized monthly, it would have been possible to do so after the summarization program had been implemented. After implementation of the summary program, it would have been possible to have summarized the data within 14 days from completion of fieldwork.

For each survey period, enumerators observed about 3,800 fields and recorded the data on about 1,100 forms. Because of this volume, the computer generated survey form was a necessity. The numbers of segments, tracts, and fields observed on each update survey are shown in Table 7.

Table 7--Number of segments, tracts, and fields by test site.

State	Number of Segments	Number of tracts	Number of Fields
South Dakota	50	217	860
Kansas	48	274	854
Missouri	52	284	772
Idaho	44	311	1358
TOTAL	194	1086	3844

2.1.6 Summarization of Ground Observations

Since these segments were selected at random within a CRD, an expansion is possible to estimate totals for the CRD. The following estimator could be used.

$$\hat{Y}_j = F \sum_{i=1}^{n} \hat{y}_{ij}$$

Where $F = \frac{N}{n}$ (the inverse of the probability of selection) and N = total number of sampling units in the test site, and n = the number of sampling units in the sample, and Y_{ij} is the acreage of the jth crop in the ith sampling unit.

The standard error of Y_j is $[Se(y_j)]$

$$\text{where:} \quad Se(y_j) = \sqrt{\frac{n \sum_{i=1}^{n} (Fy_{ij})^2 - \frac{(\sum_{i=1}^{n} Fy_{ij})^2}{n}}{n-1}}$$

$$\text{The coefficient of variation (C.V.)} = \frac{Se(\hat{y}_j) \times 100}{\hat{Y}_j}$$

The update observations were summarized in the same manner as the JES. Estimates of the acreages, standard errors, and coefficients of variation by crop and date are included in Tables 8, 9, 10, and 11. The Coefficients of Variation, which are measures of the relative precision of the estimates, ranged from about 10 percent to 100 percent, depending upon the particular crop or land use being estimated. For most major crops the C.V.'s were around 16 to 30 percent. On the other hand, crops which are not very important to that area and which were found in only one field in the selected JES segments had C.V.'s of around 100 percent.

2.1.7 Flightline Ground Observations

Flightline Selection: Each of the four study areas was divided into flightlines such that all flightlines in a single study area were of the same width. The width of the flightlines was limited to the swath width of the RB-57 and U-2 aircraft photo coverage and varied from 8 to 12 miles, depending on the area. Two flightlines in each study area were then selected at random, without replacement. The approximate locations of the selected flightlines are shown in Figures 1, 2, 3, and 4.

Table 8--Estimated acres, standard errors, and coefficients of variation by crop and date, IDAHO, 1972.

Crop \ Date	June Enumerative Survey			August 7-11			September 11-15			October 10-13		
	Estimated Acres	Standard Error	Coefficient of variation	Estimated Acres	Standard Error	Coefficient of variation	Estimated Acres	Standard Error	Coefficient of variation	Estiamted Acres	Standard Error	Coefficient of variation
CORN	63,983	15,495	24.2	63,929	15,362	24.0	32,607	9,110	27.9	12,123	5,307	43.8
OATS	2,430	1,685	69.3	1,617	939	58.0	-	-	-	-	-	-
BARLEY	136,629	29,281	21.4	73,616	18,540	25.2	3,842	2,956	75.0	-	-	-
WINTER WHEAT	59,270	24,190	40.8	39,592	19,868	50.2	510	504	98.9	8,873	4,037	45.5
MIXED GRAIN	27,293	7,109	26.1	45,461	22,032	48.5	348	241	69.3	440	308	70.0
SPRING WHEAT	20,211	6,221	30.8	19,244	5,762	30.0	2,600	1,369	52.7	1,274	922	72.4
POTATOES	49,288	17,490	35.5	48,477	17,488	36.1	48,338	17,479	36.2	7,327	4,055	55.3
FRUIT	324	321	98.9	324	321	98.9	324	321	98.9	324	321	98.9
FIELD BEANS	101,069	20,836	20.6	102,904	21,384	20.8	45,767	12,856	28.1	7,683	3,474	45.2
PEAS.	11,118	4,960	44.6	-	-	-	-	-	-	-	-	-
ALFALFA	230,118	29,518	12.8	220,659	27,882	12.6	227,323	28,244	12.4	227,657	28,084	12.3
OTHER HAY	3,517	1,762	30.1	4,094	1,855	45.3	8,752	3,891	44.5	8,752	3,891	44.5
CLOVER	686	679	98.9	686	679	98.9	686	679	98.9	686	679	98.9
SUGAR BEETS	68,695	16,346	23.8	68,191	16,278	23.8	69,415	16,409	23.6	67,806	16,070	23.7
FARMSTEAD, ETC.	124,706	15,998	12.8	88,622	12,165	13.7	91,217	12,332	13.5	98,390	13,007	13.2
PASTURE	233,103	40,691	17.5	261,380	45,343	17.3	263,102	45,498	17.3	253,334	45,421	17.2
FALLOW	87,434	33,947	38.8	88,729	35,632	40.2	84,689	34,752	41.0	80,790	34,770	43.0
IDLE	20,393	8,087	39.7	114,637	18,621	16.2	362,953	42,650	11.8	456,749	43,517	9.5
TOTAL	1,242,544			1,242,142			1,242,473			1,242,408		

Table 9--Estimated acres, standard errors, and coefficient of variation by crop and date, KANSAS, 1972.

Crop \ Date	June Enumerative Survey			August 7-11			September 11-15			October 10-13		
	Estimated Acres	Standard Error	Coefficient of variation	Estimated Acres	Standard Error	Coefficient of variation	Estimated Acres	Standard Error	Coefficient of variation	Estimated Acres	Standard Error	Coefficient of variation
CORN	347,849	114,470	32.9	420,127	135,917	32.4	407,164	132,121	32.4	273,442	94,154	34.4
OATS	3,492	2,432	69.6	-	-	-	-	-	-	-	-	-
BARLEY	13,268	13,210	99.6	-	-	-	-	-	-	-	-	-
WINTER WHEAT	1,435,362	229,965	16.0	12,221	12,221	100.0	284,485	194,752	68.5	2,104,732	454,589	21.6
RYE	873	869	99.6	-	-	-	-	-	-	-	-	-
VEGETABLES	3,492	3,476	99.6	3,492	3,476	99.6	3,492	3,476	99.6	-	-	-
GRAIN SORGHUM	643,962	169,342	26.3	755,179	177,470	23.5	736,193	169,471	23.0	696,388	163,769	23.5
ALFALFA	136,018	55,375	40.7	115,330	44,472	38.6	114,632	43,994	38.4	111,751	43,192	38.7
OTHER HAY	12,308	5,546	45.1	19,553	11,064	56.6	18,768	11,064	59.0	20,950	8,396	40.1
SUGAR BEETS	11,261	11,211	99.6	11,261	11,211	99.6	11,261	11,211	99.6	11,261	11,211	99.6
FARMSTEAD, ETC.	36,087	8,771	24.3	40,407	8,974	22.2	40,835	9,303	22.8	43,070	9,362	21.7
PASTURE	2,833,548	677,704	23.9	2,855,906	676,409	23.7	2,852,414	676,603	23.7	2,821,531	677,660	24.0
FALLOW	1,643,081	274,249	16.7	2,097,958	420,635	20.1	1,824,046	248,501	13.6	321,400	89,726	27.9
IDLE	8,031	4,389	54.7	817,062	114,382	14.0	869,428	124,413	14.3	758,288	106,675	14.1
TOTAL	7,128,632			7,148,496			7,162,718			7,162,813		

Table 10--Estimated acres, standard errors, and coefficient of variation by crop and date, MISSOURI 1972.

Crop \ Date	June Enumerative Survey			August 7-11			September 11-15			October 10-13		
	Estimated Acres	Standard Error	Coefficient of variation	Estimated Acres	Standard Error	Coefficient of variation	Estimated Acres	Standard Error	Coefficient of variation	Estimated Acres	Standard Error	Coefficient of variation
COTTON	528,908	78,357	14.8	486,784	73,218	15.0	486,784	73,218	15.0	360,011	62,474	17.4
CORN	67,308	16,849	25.0	65,306	18,051	27.6	63,123	18,068	28.6	36,738	11,797	32.1
OATS	728	726	99.7	-	-	-	-	-	-	-	-	-
BARLEY	1,274	899	70.6	-	-	-	-	-	-	-	-	-
WINTER WHEAT	319,997	56,649	17.7	-	-	-	-	-	-	45,672	20,547	45.0
RYE	9,917	5,669	57.2	-	-	-	-	-	-	4,549	4,537	99.7
FRUIT	6,369	6,351	99.7	6,369	6,351	99.7	6,369	6,369	99.7	6,369	6,351	99.7
SOYBEANS	759,198	144,117	19.0	1,052,448	165,294	15.7	1,046,807	165,754	15.8	1,020,987	165,473	16.2
GRAIN SORGHUM	16,559	8,308	50.2	17,286	8,432	48.8	17,286	8,432	48.8	11,646	7,217	62.0
ALFALFA	4,003	2,852	71.2	4,003	2,852	71.2	4,185	2,905	69.4	4,185	2,905	69.4
OTHER HAY	54,043	29,708	55.0	56,263	27,400	48.7	56,627	25,684	45.4	50,440	25,419	50.4
CLOVER	13,956	9.751	70.0	11,773	6,245	53.0	15,412	7,107	46.1	15,412	7,107	46.1
FARMSTEAD, ETC.	186,402	50,733	27.2	215,423	51,195	23.8	215,423	51,181	23.8	215,605	51,227	23.8
PASTURE	249,197	60,376	24.2	248,741	59,177	23.8	245,648	58,312	23.7	250,015	59,119	23.6
FALLOW	53,533	18,786	35.1	68,509	23,694	34.6	85,613	29,849	34.9	66,871	19,929	29.8
IDLE	132,523	25,566	19.3	155,668	27,506	17.7	150,937	26,852	17.8	306,060	57,034	18.6
TOTAL	2,403,915			2,388,573			2,394,214			2,394,560		

Table 11--Estimated acres, standard errors, and coefficient of variation by crop and date, SOUTH DAKOTA, 1972.

Crop \ Date	June Enumerative Survey			August 7-11			September 11-15			October 10-13		
	Estimated Acres	Standard Error	Coefficient of variation	Estimated Acres	Standard Error	Coefficient of variation	Estimated Acres	Standard Error	Coefficient of variation	Estimated Acres	Standard Error	Coefficient of variation
CORN	957,449	98,744	10.3	947,272	101,201	10.7	942,467	100,559	10.7	858,267	92,184	10.7
OATS	539,315	86,785	12.4	111,660	37,787	33.8	3,203	3,195	99.7	41,176	17,773	43.2
BARLEY	81,434	28,820	35.4	15,696	12,757	81.3	-	-	-	3,640	3,630	99.7
WINTER WHEAT	5,460	3,811	69.8	3,858	3,497	90.6	-	-	-	-	-	-
RYE	28,392	12,817	45.1	9,755	7,215	74.0	5,824	5,809	99.7	23,150	9,444	40.8
SPRING WHEAT	30,474	16,216	53.2	30,765	15,664	50.9	7,426	6,099	82.1	-	-	-
DURUM WHEAT	3,931	3,921	99.7	3,931	3,921	99.7	3,931	3,921	99.7	-	-	-
FRUIT	-	-	-	1,893	1,888	99.7	1,893	1,888	99.7	1,893	1,888	99.7
SOYBEANS	33,881	17,118	50.5	33,444	15,167	45.3	33,444	15,167	45.3	26,310	13.065	50.0
GRAIN SORGHUM	28,848	13,158	44.1	33,051	13,772	41.7	11,502	5,923	51.5	11,066	5,923	53.5
ALFALFA	318,515	57,431	18.0	301,051	51,701	17.2	302,279	51,709	17.1	311,699	57,239	18.4
OTHER HAY	146,371	45,984	31.4	255,864	59,386	23.2	281,720	60,601	21.5	255,862	60,802	23.8
FLAX	53,362	19,391	36.3	60,788	21,716	35.7	15,870	11,101	70.0	7,280	5,158	70.9
FARMSTEAD, ETC.	132,147	16,318	12.3	122,405	13,698	11.2	128,885	18,553	14.4	128,594	18,634	14.9
PASTURE	879,189	122,810	14.0	854,961	120,382	14.1	845,352	119,635	14.2	845,352	119,635	14.2
FALLOW	291,854	50,598	17.3	192,963	37,458	19.4	190,924	36,820	19.3	185,683	36,365	20.0
IDLE	69,189	20,321	29.4	621,783	72,420	11.6	823,949	83,360	10.1	899,136	88,844	9.9
TOTAL	3,600,811			3,601,140			3,598,669			3,599,108		

Each flightline contained a number of sampling units (JES segments). Even though the segments already existed before the flightlines were constructed, their appearance in the sample was still random. The number of segments within each flightline varied by flightline and state - Table 12. Once it was determined which segments fell within the flightline, a count of all other possible segments in the flightline was made, thus the probability of a segment being selected is $\frac{m_i}{M_i}$ within the ith flightline.

This is a multistage sample design where the selection of flightlines is the first stage and the second stage of selection is the segments. Whereas in this particular case, maps were used as the frame to select the sample, it might have been possible to select a similar sample using ERTS imagery or aerial photography.

Table 12--Number of segments within flightline by flightline and by state.

State	Flightline	Number of segments	
		JES	Added for classifier training
Missouri	1	2	5
	2	8	6
Kansas	1	5	2
	2	9	3
South Dakota	1	4	6
	2	5	4
Idaho	1	6	6
	2	9	10

Flightline estimates for the study areas are explained below.

The estimates of totals for a two-stage sample design are as follows:

$$Y_k = \frac{N}{n} \sum_{i=1}^{n} \frac{M_i}{m_i} \sum_{j}^{m_i} y_{ijk}$$

where: Y_k is the estimate of the total acreage of the kth crop or characteristic within a study area,

N is the total number of flightlines,

n is the number of flightlines in the sample,

M_i is the total number of segments within the selected flightlines,

m_i is the number of selected segments within the selected flightlines.

The variance of $\hat{Y}_k$ is:

$$\mathrm{var}(\hat{Y}_k) = N^2\left(\frac{N-n}{N}\right)\frac{S_{k1}^2}{n} + \frac{N}{n}\sum_{i=1}^{n}\frac{M_i(M_i-m_i)}{M_i m_i}\, s_{k2i}^2$$

where: $$S_{k1}^2 = \sum_{i=1}^{n}\frac{(Y_i-\overline{Y})^2}{n-1}$$

$$S_{k2i}^2 = \sum_{j=1}^{m_i}\frac{(Y_{ij}-Y_i)^2}{m_i-1}$$

and $$\mathrm{C.V.} = \sqrt{\frac{\mathrm{Var}(\hat{Y})(100)}{\hat{Y}}}$$

2.1.8 Results of Flightline Ground Observations

As would be expected from a sample of size 2 from the heterogeneous study areas, the flightline estimates in all four States were not very reliable. Coefficients of variation, the measures of precision of the estimates ranged from 20 to 100 percent. For most crop, the between flightline component of variance was the largest contributor to the total estimated variance. Therefore, if the computed variance components are any indication, the easiest way to reduce the variance would be to add more flightlines.

In several cases, the CRD estimates from the flightline ground observations compare favorably with those from the JES, but the size of the standard error would indicate that this is due to chance. Flightline estimates of total acres by crop, the estimated between and within flightline components of variance, and standard errors, and coefficients of variations of the estimated totals are shown by study areas in Tables 13-18. Generally, these computations were made only for the crops which were classified from the LANDSAT and aircraft imagery. However, some of the crops shown were not included in the LANDSAT or aircraft classification.

For Missouri, all three of the update ground surveys were tabulated for the selected flightlines. This was to correspond with the occurrence of useable LANDSAT imagery from each of the months, August, September, and October. The only significant changes in estimated totals occurred between the September 11-15 and October 10-13 ground surveys. These changes occurred as cotton and soybeans were harvested, causing the use to change from those crops to idle (stubble) land or fallow (plowed). The only flightline totals shown for the other three study areas are for the update survey periods August 7-10 (Idaho and South Dakota) and September 11-15 (Kansas).

Except for Kansas, the between flightline variance component was based on all flightlines in the study area in order to get a reasonable estimate of this variance.

The main conclusion to be drawn from the flightline ground observation analysis is that in order to get reliable estimates from this multi-stage sampling approach, more flightlines are needed but is is not necessary that they cover such a wide swath. Also, in constructing flightlines, the total size (length times width) of the flightlines should be kept as equal as possible. For example, flightline 2 in Missouri is much smaller than flightline 8. This variation in size can contribute significantly to the overall precision of the estimates.

2.2 Data Acquisition - LANDSAT Imagery

2.2.1 Objectives

Satellite imagery required for this project included both the computer compatible MSS digital data tapes and various types of photographic images.

The photographic images were required to:

1. determine if a particular LANDSAT frame was usable, and

2. to assist in locating individual test sites (segments) in the frame.

Table 13--Estimated totals, between and within flightline components of variance, standard errors, and coefficients of variation of the estimated totals by crops, Missouri Study Area, August 7-10, 1972.

Crop	Estimated Acres for CRD	Between Flightline Variance	Within Flightline Variance	Standard Error	Coefficient of Variation
Cotton	309,096	79,585,100,901	1,760,246,861	285,211	92.3
Corn	82,602	2,676,330,320	253,508,210	54,127	65.5
Fruit	33,390	929,039,587	185,838,406	33,390	100.0
Soybeans	1,533,204	1,174,865,916,260	52,150,144,244	1,107,707	72.2
Grain Sorghum	20,790	51,070,314	22,424,259	8,573	41.2
Other Hay	199,800	33,265,369,332	1,339,221,600	186,023	93.1
Clover	30,240	762,017,518	152,409,600	30,240	100.0
Farmstead, etc.	517,716	80,235,265,331	6,671,987,712	294,800	56.9
Pasture	276,606	29,869,978,560	2,352,207,811	179,581	64.9 *
Fallow	46,746	1,820,917,590	83,905,414	43,644	93.4
Idle	249,030	33,103,771,942	1,234,579,858	185,306	74.4

* The between flightline variance is based on all flightlines.

Table 14--Estimated totals, between and within flightline components of variance, standard errors, and coefficients of variation of the estimated totals by crops, Missouri Study Area, September 11-15, 1972.

Crop	Estimated Acres for CRD	Between Flightline Variance	Within Flightline Variance	Standard Error	Coefficient of Variation
Cotton	309,096	79,585,100,901	1,760,246,861	285,211	92.3
Corn	82,602	2,676,303,320	253,508,210	54,127	65.5
Fruit	33,390	929,039,587	185,838,406	33,390	100.0
Soybean	1,533,204	1,174,865,916,260	42,150,144,224	1,107.707	72.2
Grain Sorghum	20,790	51,070,314	22,424,259	8,573	41.2
Other Hay	178,200	26,452,114,920	1,471,219,200	167,103	93.8
Clover	30,240	762,017,518	152,409,600	30,240	100.0
Farmstead, etc.	517,716	80,235,265,331	6,671,987,712	294,800	56.9
Pasture	276,606	29,896,978,560	2,352,207,811	179,581	64.9 *
Fallow	68,346	526,723,656	87,015,814	24,774	36.2
Idle	249,030	33,103,771,942	1,234,579,858	185,306	74.4

* The between flightline variance is based on all flightlines.

Table 15--Estimated totals, between and within flightline components of variance, standard errors, and coefficients of variation of the estimated totals by crops, Missouri Study Area, October 10-13, 1972.

Crop	Estimated Acres for CRD	Between Flightline Variance	Within Flightline Variance	Standard Error	Coefficient of Variation
Cotton	212,742	37,700,879,084	1,196,149,683	197,223	92.7
Corn	82,602	2,676,303,320	253,508,210	54,127	65.5
Fruit	33,390	929,039,587	185,838,406	33,390	100.0
Soybeans	1,467,378	1,048,235,439,110	53,444,905,920	1,049,610	71.5
Grain Sorghum	15,066	3,694,552	19,308,022	4,796	31.8
Other Hay	178,200	26,452,114,920	1,471,219,200	167,103	93.8
Clover	30,240	762,017,518	152,409,600	30,240	100.0
Farmstead, etc.	517,716	80,235,265,331	6,671,987,712	294,800	56.9
Pasture	276,606	29,896,978,560	2,352,207,811	179,581	64.9 *
Fallow	68,346	526,723,656	87,015,814	24,774	36.2
Idle	392,130	97,687,578,082	2,542,832,141	316,592	80.7
Winter Wheat	24,804	512,493,601	102,622,253	24,804	100.0

* The between flightline variance is based on all flightlines.

Table 16--Estimated totals, between and within flightline components of variance, standard errors, and coefficients of variation of the estimated totals by crops, Kansas Study Area, September 11-15, 1972.

Crop	Estimated Acres for CRD	Between Flightline Variance	Within Flightline Variance	Standard Error	Coefficient of Variation
Alfalfa	152,390	18,578,718,288	2,437,398,690	144,969	95.1
Pasture	3,208,195	88,735,891,538	223,622,366,804	1,054,031	34.9
Corn	1,146,690	15,166,828,880	3,634,212,685	137,117	99.6
Grain Sorghum	1,146,070	129,998,137,680	182,470,351,826	558,989	48.8
Winter Wheat	29,045	674,889,620	168,722,676	29,045	100.0
Fallow	1,086,780	215,995,641,680	30,751,534,531	495,938	45.7
Sugar Beets	46,255	1,711,620,020	85,585,359	42,393	91.7

Table 17--Estimated totals, between and within flightline components of variance, standard errors, and coefficients of variation of the estimated totals by crops, Idaho Study Area, August 7-10, 1972.

Crop	Estimated four co. acres	Between Flightline Variance	Within Flightline Variance	Standard Error	Coefficient of Variation
Corn	106,909	359,570,842	489,692,090	29,142	27.3
Barley	77,572	4,533,887,611	276,569,320	69,501	89.6
Winter Wheat	39,754	1,165,824,646	109,949,320	35,718	89.9
Mixed Grain	31,713	407,075,135	65,268,794	21,733	68.5
Spring Wheat	30,090	488,902,450	83,624,281	23,928	79.5
Potatoes	109,054	1,499,274,753	465,840,844	44,326	40.6 *
Field Beans	57,071	2,023,502,496	334,116,679	48,555	85.1
Alfalfa	203,120	5,369,614,922	4,002,751,528	96,811	47.7
Sugar Beets	91,019	403,669,920	511,370,942	30,249	33.2
Farmstead, etc.	139,227	1,789,834,480	284,669,027	45.547	32.7 *
Pasture	827,398	368,272,987,764	15,481,398,570	619,479	74.9
Fallow	192,285	13,256,360,708	618,122,640	117,790	61.3 *
Idle	133,502	3,211,847,210	652,799,570	62.166	46.6

* The between flightline variance is based on all flightlines.

Table 18--Estimated totals, between and within flightline components of variance, standard errors, and coefficients of variation of the estimated totals by crops, South Dakota Study Area, August 7-10, 1972.

Crop	Estimated Acres for CRD	Between Flightline Variance	Within Flightline Variance	Standard Error	Coefficient of Variation
Corn	908,350	51,266,009,138	3,367,476,285	233,738	25.7 *
Flax	35,335	1,056,185,780	264,116,571	36,335	100.0
Fallow	111,055	1,568,220,500	616,904,097	46,745	42.1
Pasture	759,550	48,067,051,520	5,193,126,612	230,782	30.4
Sudex	61,510	1,971,303,680	310,693,399	47,770	77.7
Alfalfa	272,720	4,805,000,000	919,799,185	75,662	27.7
Idle	788,525	25,315,726,472	2,401,924,450	169,463	21.5 *

* The between flightline variance is based on all flightlines.

The computer compatible data tapes were used:

1. to generate the grey-scale computer printouts needed in locating the individual segments (and fields) within the LANDSAT frame, and

2. as data input into the computer crop classification routines.

2.2.2 Approach

Photographic imagery obtained from NASA included 70mm positive and negative transparencies and system corrected 9.5" positive B&W transparencies for all LANDSAT frames which include (1) any part of one of the four sites, and (2) any part which had less than 50 percent cloud cover. Precision 9.5 color composite photographs were also ordered, but not analyzed. Enlargements (1/250,000) of the composite photographs for selected frames were obtained from the ASCS photo lab in Salt Lake City.

System corrected MSS digital tapes were also obtained for all frames having less than 50 percent cloud cover.

2.2.3 Evaluation

We received LANDSAT 70mm transparencies and the system corrected ditigal data tapes as a standing order. The first digital data tapes were received November 1, 1972. Tapes received between November 1 and November 16 included scenes taken as early as August 15. After November 16, tapes generally were received about four weeks after the scene was taken. The initial delay in receiving data tapes was serious only in that various computer programs could not be tested operational,until at least one set of tapes has been received.

In retrospect, a more desirable procedure would have been to place a standing order for either 9.5 inch or 70mm transparencies of all LANDSAT frames which covered any part of a target area. Then, a selection of data tapes to be ordered could have been made from these transparencies. This would have effected a substantial reduction in the number of data tapes received and stored, but essentially unused because of incomplete clould-free coverage over a given site during a particular cycle.

The 1/250,000 scale color enlargements to selected LANDSAT frames were used to visually locate specific training sites in the LANDSAT frame.

2.3 Data Acquisition - Aerial Photography

2.3.1 Objectives

High altitude photogrpahy was acquired from NASA and the South Dakota Remote Sensing Institute (SDRSI) to meet the following objectives.

1. Develop methods of crop species identification from aerial photography by computer classification techniques, and compare the results with the ground data and with the results obtained using LANDSAT imagery.

2. Estimate crop acreages by expansion of classification results to the flightline level and crop reporting district level.

3. To assist in the location of segments on the LANDSAT frame or printouts.

2.3.2 Approach

Flightline Selection

Adjacent, non-overlapping flightlines were drawn on aeronautical charts to provide complete coverage of the land area within each of the four LANDSAT test site areas for this project. The flightlines constructed were 8-10 miles wide and sufficiently long to traverse the full length of the test site. Within each LANDSAT test site, two flightlines were randomly selected for aerial photography overflights. NASA provided high altitude, color positive, infrared aerial photography (9 inch format) for both selected flightlines for each LANDSAT test site. Attempts were made to coordinate overflight dates for the aerial photography with the LANDSAT imagery. NASA provided aerial photography on two separate dates for the Kansas, South Dakota, and Missouri test sites, and three dates for the Idaho test site. The South Dakota Remote Sensing Institute also provided photographic coverage (70mm color positive, infrared) for the selected flightlines in the Kansas, South Dakota, and Missouri test sites for one overflight date. Photographic check-in procedures were as follows:

1. Locate, delineate, and identify all JES segments and training segments on the aerial photography from County Highway maps.

2. Record the frame number or numbers each segment is located on.

Tables 19-22 summarizes the photographic coverage for each segment.

2.3.3 Scanning Procedures

The JES segments were scanned on a microdensitometer with an effective aperture size of 240 microns square. Reduction of the volume of data was one of the primary considerations which lead to the choice of such an aperture. Using this aperture, one data point covers a land area approximately 95 feet square on the NASA photography. Each segment was scanned with a clear, red, green, and blue color filter and in two scanning modes. Thus, multivariate observations are obtained for each data point. Prior to actual scanning of the photography, it was necessary to record coordinates of corner points of fields and field boundaries to identify training data for the classifier. A sketch of each segment was made from large aerial maps (scale: 8" - 1 mile) showing each field (small land area devoted to one crop species or agricultural practice). Field boundary coordinate information was recorded on these sketches. Figure 7 is a simplified sketch of a JES segment with field boundary coordinates recorded. Appendix D contains detailed instructions for the scanning procedures.

Data Conversion and Preparation for Classification

Output data from the microdensitometer is stored on magnetic tapes. Each file on the magnetic tape corresponds to one segment scanned with one color filter and recorded in one scanning mode. In order to obtain multivariate observations for each data point, a software program, PDSCMS (Appendix E), was developed to merge the data from several microdensitometer output files, each file corresponding to a scanning mode filter combination into one file which was compatible with the Statistical Analysis System (SAS).

In order to perform crop classification using discriminant analysis, it is necessary to "train the classifier." To facilitate automated assignment of training data for each crop class, a software program was developed. The program generated SAS program statements to assign tract and field identifiers to data points on the basis of the coordinates of each pixel. The program assigns these labels only to data points contained within user defined rectangles whose sides are parallel to the scanning axes. The tract and field identifiers were then used to merge the microdensitometer data with the ground information collected during the 1972 growing season.

The ground information that was collected monthly included the crop species and crop condition for each tract and field within the segment. The crop condition and crop species was used to form the group for classification with discriminant analysis. Thus, an observation vector in the merged data set contains the following information.

1. The value of relative light intensity for each of two scanning modes and four filter combinations,

Figure 7--Sketch of Segment Showing Field Boundaries and Crop Classes.

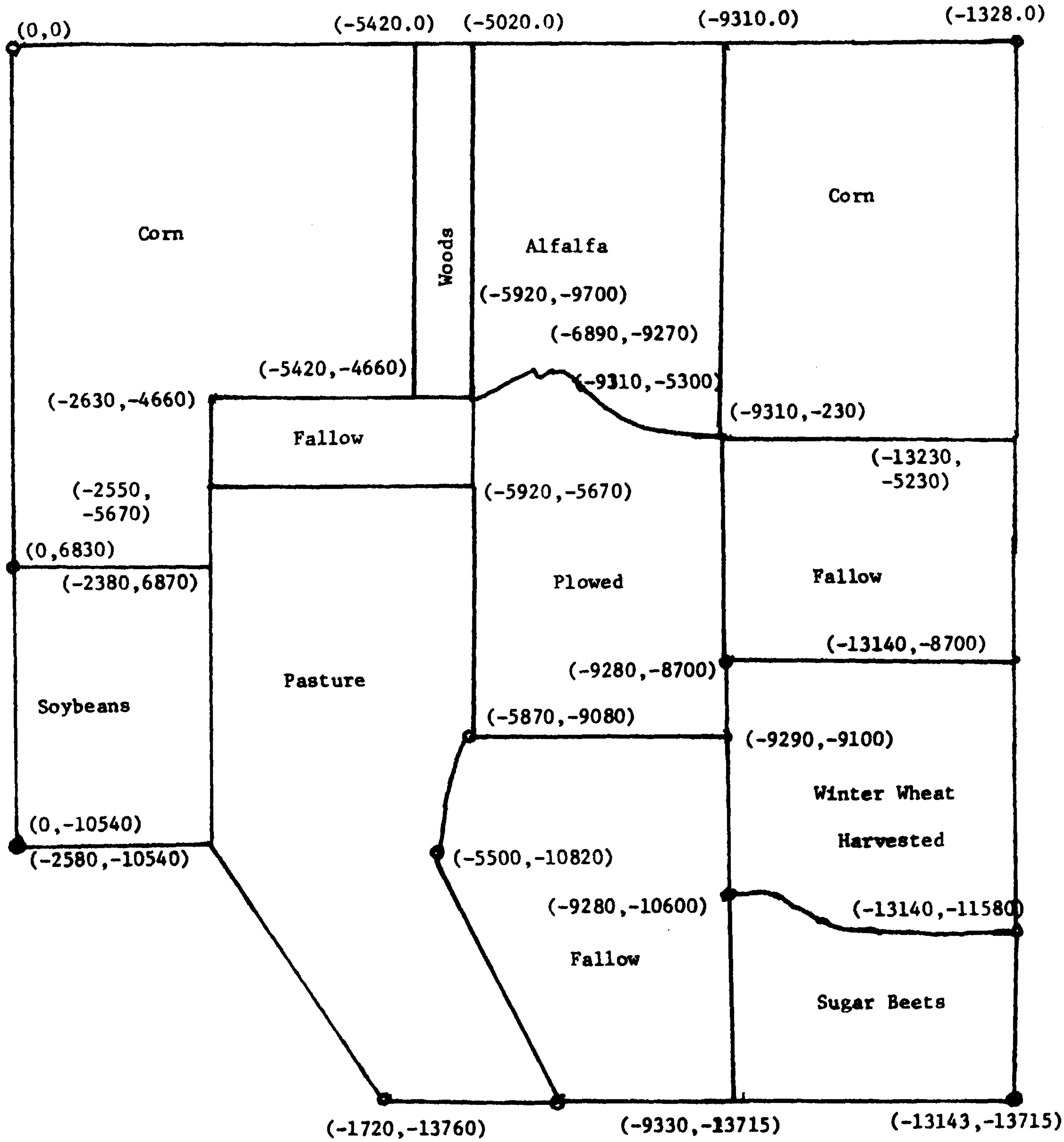


TABLE 19

MISSOURI AERIAL PHOTOGRAPHY

Mission; Date:	208; 8/28/72		211; 9/19/72		S.D.R.S.I.; 9/19-20/72
Camera, Roll	RC-8; 33	ZEISS: 34	RC-8; 42	ZEISS; 44	4 filters
Segments	Frame No.	Frame No.	Frame No.	Frame No.	Frame No.
F.L. 2					
4418	29	--	99	--	38 & 39
4420	31	55	98	25	42
F.L. 8					
4411	05	7	127		3
3412	07	--	124		28 & 29
1413	07	12	124	78	19 - 25
4414	04	6	128	84	6 & 7
1435	13	22	120	69	9
3436	10	17	122	73	2
4458	11	--	121		
4460	08	16	123	76	32 & 33
Extra					
3416	28	--	--		
4417	30	53	98		
4419	29	--	99		
3432	15	--	118		
4434	12	--	120		
4437	10	--	123		
Training					
2A1	31	55	97	23	44 & 45
2A2	30	55	98	24	47 - 53
2B	29	--	100		29 & 30
2C	29	--	99		33
2D	28	49	100		25 & 26
8A	05	6	128	85	11 & 12
8B	07	12	125	79	14 & 15
8C	11	18	121	72	37 & 38
8D	11	19	121	72	5 & 6
8E	12	--	120		41 & 43 20 & 21
8F	15	26	118	64	15 & 16

TABLE 20

KANSAS AERIAL PHOTOGRAPHY

Mission; Date:	208; 8/18/72		: 211; 9/17/72		:S.D.R.S.I.; 8/12-14/72
Camera; Roll	:RC-8; 1	:ZEISS; 3	:RC-8; 33	:ZEISS; 35	:4° Filters of 4 rolls Each
Segments	:Frame No.	:Frame No.	:Frame No.	:Frame No.	: Frame No.
F.L. 3					
4087	41	--	19	--	B26 - 31
1089	43	85	17	29 & 271	-
4101	48	95	13	20 & 280	A27 - 30
3106	37	72	23	259	B 1 - 5
4107 Noc	34	66	27	--	C40
1113	53	107	07	08 & 291	A53 - 56
4114	50	100	10	16 & 285	A34 - 38
1115	40	79	21	265	B12 - 15
3116	41	81	19	268	B22
F.L. 10					
4120	14	26	--	--	D12 - 16
3122	24	48	--	--	C23 - 26
4124	18	35	--	--	C 1 - 8
1125 Noc	Noc	--	--	--	-
4130	22	43	--	--	C17 - 19
Extra					
4088	44	--	17	--	-
Training					
3-A	50	101	10	14 & 286	A42
3-B	36	70	25	45	C36
3-C	37	72	24	260	-
3-D	40	81	20	266	B 7 & 8
3-E	40	81	20	267	B18
3-F	42	83	19	32 & 269	B39 - 51
3-G	42	83	19	32 & 269	B57 - 64
3-H	43	--	17	--	B36
3-I	43	85	17	30 & 272	A 3
3-J	43	87	17	28 & 273	A 8
3-L	46	--	14	--	A15
3-M	47	--	13	--	A18
3-P	54	109	06	07 & 293	A49 & 50
10-A	24	--	--	--	C32
10-E	9	17	--	--	D 2 - 5

Note: RC-8 and ZEISS coverage of segments 1113, 4114, and 3A are also available from Mission 217 dated 10/24/72.

TABLE 21

SOUTH DAKOTA AERIAL PHOTOGRAPHY

Mission; Date:	211; 9/22/72		211; 9/14/72		S.D.R.S.I.; 8/27/72
Camera, Roll	RC-8; 54	ZEISS; 56	RC-8; 17	ZEISS; 19	4 filters and 4 folls
Segments	Frame No.	Frame No.	Frame No.	Frame No.	Frame No.
F.L. 3				None	
3196	2934	70			46
4197	2932	66			54
1199	2934	71			50
4210	2930	62			5 & 6
F.L. 5				None	
1213	2908	18	188		26
1223	2912	27	184		14
3236	2906	14	191		35
4237	2906	--	191		32
4240	2915	--	181		8
Extra				None	
1195	2934	--			
4198	2933	69			
4208	2928	--			
4211	2928	--			
3212	2909	--	187		
4214	2908	20	188		
3222	2913	--	--		22 & 23
4224	2912	27	184		
1235	2906	--	190		
1239	2918	--	179		
4241	2918	39	179		
Training				None	
3-A3	2930	62			1
3-B-9	2933	68			53
3-C-3	2935	--			44
3-C-5	2935	72			48
3-C-6	2935	--			41
3-D-8	2935	74			38
5-C-2	2913	27	184		12
5-C-3	2913	29	184		20
5-C-4	2913	29	--		16
5-E-2	2908	17	189		29

TABLE 22

IDAHO AERIAL PHOTOGRAPHY

Mission; Date	72-138; 8/11/72	9/7/72	10/25/72
Camera Segments	RC-8 Frame No.	RC-8 Frame No.	RC-8 Frame No.
F.L. 5			
8101	4702, 4812-13	3885-86, 3900-01	5565-66, 5652-53, 5820
8103	-	3881	5647
8111	4699-4700, 4814-15	3884-85, 3902-03	5650-51
3423	4816	3904-05	--
1554	4699,4814-15	3883-84	5650-51
1559	4699,4815-16	3883-84, 3903-04	5650, 5667
F.L. 6			
8094	4812	3900-01	5664, 5822
8098	4811-12	3899-3900	5817, 5663-64
8109	4813	3886, 3901-02	5665
9110	4700,4814	3884-85, 3901-02	5661, 5665-66
8113	4814-15	3902-03	5666-67
8265	4816	3904-05	5668
2332	4811-12	3899-3900	5663, 5817
8339	4816	3904-05	5668
3422	4812-13	3900-01	5664, 5821-22
Extra			
8096	4703		
8099	4701		
8102	4701		
8112	4814	3902-03	5666-67
8115	4701		
1549	4702		
1550	4702		
Training			
5-A-2	4702-03, 4810-11	3887-88, 3899	5654, 5817-18-19
5-B-2	4702,4812-13	3886-87, 3900-01	5653, 5820
5-C-2	4814-15	3884-85, 3902-03	5665-66
5-D-2	4699-4700, 4814-15	3884-85	5650-51
5-K-5	4815	3903-04	5667
5-K-6	4815	3903-04	5667
6-C-2	4812-13	3900-01	5664-65, 5821-22
6-D-1	4812-13	3900-01-02	5664-65, 5812-22
6-F-3	4813-14	3901-02	5665-66, 5821
6-F-4	4813-14	3901-02	5665-66, 5821
6-H-1	4814	3901-02	5665-66
6-H-2	4814	3901-02	5665-66
6-I-1	4814	3902-03	5666-67
6-I-2	4814	3902-03	5666-67
6-J-4	4814 -15	3902-03-04	5666-67
6-L-4	-	3902	5665-66, 5822-23, 9095

2. The x,y - coordinates,

3. The tract, field number,

4. Crop and crop condition on four month visits.

There are eight spectral variables, two spatial variables, and four label variables making up each pixel.

III. Software and Data Processing

3.1 Segment and Field Location

3.1.1 Objectives

A primary objective of this phase of the project was to develop procedures which would enable the user to locate small areas in LANDSAT images that are identified on maps. These areas must be identified with great accuracy if they are to be used either as training sites or discriminant analysis or as test sites on the estimation procedures.

3.1.2 Approach

The method used to find segments and field boundaries was mostly a manual operation. The procedure is outlined below.

1. The exact location of the individual JES segments was drawn on county highway maps.
2. The approximate locations of the JES segments on 1/250,000 scale color enlargements of the LANDSAT frame were determined by a visual comparison of the enlargement with the county highway maps.
3. Grey scale maps of large areas around the location of each segment were generated from computer compatible MSS tapes. Generally, these maps were from response band 5.
4. Visual correlation of features distinguishable on the county highway maps, on the color enlargements of the LANDSAT imagery and on the grey scale computer printouts was used to find the location of individual segments in the LANDSAT frame.

Field boundaries had been drawn on 1"/660' scale aerial photographs of the JES segments. These photographs were then used as a basis for sketching the field boundaries on the computer grey scale printouts. Next, an area definition card was punched for every scan line that crossed each field. A more detailed description of this procedures is included in Appendix C.

Two different computer programs were used to produce grey level maps. The first was called NMAP and is from the Penn State Classification System. This system had several good points.

1. It could map any combination of channels to a maximum of 16 channels.

2. It can produce grey-level maps with variable proportion of points in an interval.

3. It can use either LANDSAT or LARSYS III format tapes as input.

Some of NMAPS disadvantages are:

1. It requires a format conversion run,

2. It must do a map to obtain initial grey level response histogram.

To speed up the mapping process, a second mapping program RAD MAP was developed. It has the following advantages over NMAP.

1. It maps at a faster rate.

2. It can sample to determine the response histogram and set the grey levels accordingly.

The major disadvantages are:

1. It will only map one band at a time.

2. It is limited to LANDSAT computer compatible tapes.

3.1.3 Evaluation

The segment location procedure described here was reasonably effective in southwestern Kansas and in the Snake River Valley of Idaho. These areas were characterized by a regular 'checkerboard' road pattern, moderately large regular fields, and by a number of crops which had distinctly different reflectance patterns. We had more difficulty in east central South Dakota and in southeastern Missouri. The principal problem in South Dakota was that, at the time the LANDSAT imagery was taken crops seemed to look much the same. Also, there were not many of the distinctive field patterns as were found in Kansas. Missouri was characterized by irregular road and field patterns and by heavy woodlands which helped to hide the roads.

A more fully automated procedure is needed for any further work in this area. Among the possibilities for inclusion in such a procedure could be the following.

1. A program which could compute the approximate location of test sites in a given LANDSAT frame.

2. The use of affine transformation to locate points in small areas of the LANDSAT frame (CITARS, F.G. Hall, M.E. Bauer, W.A. MALILA).

3. A grid digitizer to convert map boundaries to a series of data points which could be converted to LANDSAT frame coordinates.

3.2 Software Implementation for Crop Classification

3.2.1. Objectives

The main objective was to find and install in the USDA Washington Computer Center a series of computer programs to perform discriminant analysis (pattern recognition). In addition, the following related objectives should be satisfied.

A) The software should be relatively easy to install and maintain.

B) The system should use a uniform control card setup for both the system and in-house developed programs.

C) The program package should be highly modular to permit experimentation.

D) The program should provide support software for data handling.

E) Programs should be easy to use and not require a lot of cumbersome vendor JCL statements.

F) The software system must be reasonably efficient. This may be in terms of fast computational algorithms and/or data reduction schemes to reduce volume.

3.2.2 Approach

There were three systems available to us that could perform the require discriminant analysis.

The first package considered was SAS [1/], (Statistical Analysis System). This system is written to run only an IBM 360/370 computer, and is distributed in both load module and source form. Installation is as simple as creating a program library or adding numbers to an existing program library. Maintenance is minimal because the authors provide all necessary program support and send updated library tapes.

The system allows the user to create his own procedures by modifying existing procedures or writing them from scratch. The SAS supervision provides software support such that all usual control card and data management features are available to the user. A user procedure is treated exactly like a normal SAS procedure.

In general, SAS is easy to use, and the SAS language permits almost unlimited manipulation of data. However, the conversion of LANDSAT data tapes into SAS observations requires considerable programming because the SAS language has no simple provision to break up a line of data into a series of SAS observations.

The original procedure DISCRIM, prints a line for every data point classified. Clearly, this is too much output for an LANDSAT file. In addition, the procedure reads the entire data set twice, once to find the calibration data, and once to classify. The procedure does not have the calibration data, nor create a SAS file of classification results.

Procedure DISCRIM was modified to create an in-house procedure that did not print the results for each point calibrated, but rather created a SAS compatible file that could be read in using the input processor.

Drs. Barr and Goodnight extended the features of the discriminant procedure in the following ways:

1. Limit the printing of point by point classification results to desired levels and always print a summary.
2. Accepted calibration and unknown data from separate files.
3. Save and reuse the calibration results.
4. Output the classified data as a SAS file for later analysis.

1/ Developed at the Pennsylvania State University, Department of Forestry, by A. J. Barr and J. H. Goodnight.

The second software package was the Penn State Classification System.[1/] This system was written in FORTRAN, and should have been easy to install. Some special input/output software has to be provided by the Penn State Computer Center. This special software was obtained from Penn State. One routine worked and one did not, but a substitute was found. The Penn State System does work now at the WCC. The point is that the Penn State System may not be completely transportable to other computing centers.

The core programs use a common set of control cards which facilitates learning to use the programs. There are some related programs that were developed by other users that do not strictly adhere to the control card setup used by the main line programs. The maximum likelihood classification software is an example.

In spite of the fact that the program is broken down into subroutines, it cannot be considered modular. There are many different subroutines called GETLIN that are used to retrieve lines of data from the file. Other critical subroutines share the same problem.

In addition, these subroutines do not provide for complete file control. Therefore, any user defined program must partially process the input file in conjunction with some version of GETLIN.

This non-modularity makes it difficult to modify or change the program.

The package does not utilize a system monitor program to manipulate data files. One must use the standard vendor JCL to create and pass files between programs and runs.

This system does use a data reduction scheme to speed up processing. Normally, an investigator is interested in only a portion of a LANDSAT image. The programs permit the user to subset the image and retain only the areas of interest. A table of contents record, preceedings, the file, permits the user access to any particular area as though he had the entire image. Unnecessary data is not processed, thus it is more efficient.

The Penn State Classification System is really a collection of main level programs that can process a common file. The major programs are SUBERTS, SUBAIR, TPINFO, MERGE, NMAP, UMAP, STATS, ACLASS, ACLUS, DCLASS, and DCLUS.

1/ Developed at the Pennsylvania State University, Department of Forestry, by Dr. F. Y. Borden and Associates.

SUBERTS and SUBAIR are used to reformat and subdivide LANDSAT and aircraft tapes into the Penn State format.

MERGE is used to combine data from different passes into temporal overlays.

TPINFO prints the heading and table of contents records from a standard file.

NMAP assigns mapping symbols to all points of specified grey levels. It is used to prepare line printer maps.

UMAP assigns mapping symbols based on contrast differences. It is also used to outline boundaries.

STATS computes calibration statistics to be used by the classification programs.

ACLASS performs a discriminant analysis of spectral signatures that have been normalized by reducing all data to a unit sphere. It is used to compensate for sun angle, and was developed for airborn scanners.

ACLUS is an unsupervised cluster analysis program which uses the angular classification algorithm.

DCLASS performs a Euclidian distance discriminant analysis of multispectral data.

DCLUS is an unsupervised cluster analysis which uses the Euclidian distance algorithm.

In addition to the above core programs, a maximum likelihood quadratic classification package was supplied as a related program. This program is not control card compatible with the core programs, but it uses the standard file.

The third software package considered was LARSYS III.[1/] The initial consideration was to install it in-house. The support group at LARS and our scientific monitors convinced us that this was beyond our means.

[1/] Developed at Purdue University, Laboratory of Applications of Remote Sensing.

LARSYS is written for a different operating system than what we have at the USDA Washington Computer Center. Conversions would be expected to take several man years, and would require some systems level programmers.

The staff at LARS has been very generous in providing both computer time and computer system personnel at various times for a period of two years.

IV. Data Analysis - Objectives and Concepts

In this section, the objectives and concepts relating to the LANDSAT investigation, both LANDSAT imagery and aircraft, are formulated. The results are presented by states, LANDSAT imagery first then aircraft photography. At the conclusion, ways to use the classification results to make acreage estimates and a method to combine data from aircraft and satellite is presented.

4.1 Crop Classification

4.1.1 Objectives

1. Investigate the use of parametric discriminate functions.

2. Estimate the rate of misclassification for each type of crop.

3. Investigate the value of temporal overlays in reducing errors of misclassification.

4. Determine differences in classification rates between states.

5. Determine differences in classification rates between months within states.

6. Evaluate the use of training data parameters from (a) one LANDSAT frame to another, and (b) in aerial photography from one flightline to another.

7. Estimate the difference in classification results between dependent and independent data used in testing.

4.1.2 Concepts

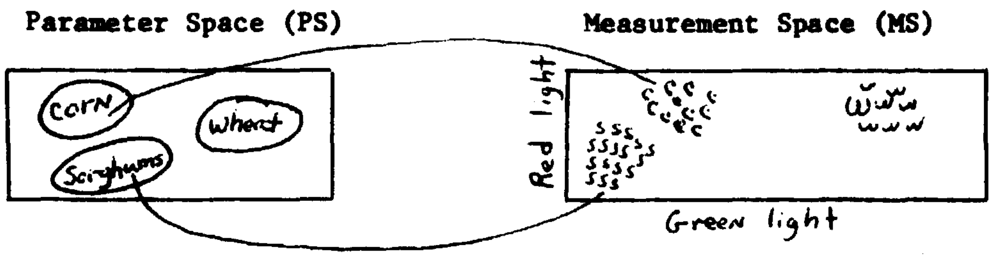
Discriminant Analysis

This background is intended to be general and enable the reader to understand the detailed computations and results that follow. Kendall and Stuart formulate Discriminant Analysis and Classification by stating...

"We shall be concerned with problems of differentiating between two or more populations on the basis of multivariate measurements... We are given the existence of two or more populations and a sample of individuals from each. The problem is to set up a rule, based on measurements from these individuals, which will enable us to allot some new individual to the correct population when we do not know from which it emanates." 1/

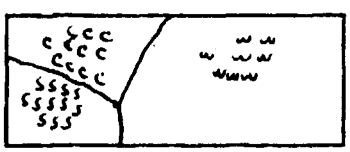
For example, the land population of interest was the Southwest Crop Reporting District (CRD) in Kansas. Wheat, sorghums, corn, oats, rye, and pasture are the major populations of interest. From every acre in the CRD, we have light intensity readings for green light, red light, and two infrared wavelengths. These light intensities are multivariate measurements that will be used to allot or classify each data point into a crop type such as corn, wheat, or sorghums. A graphical representation of the above formulation would be as follows:

Figure 8--Conceptualized mapping from agricultural fields into measurement space.



A sample of fields from each crop type is selected and their respective light intensities obtained. These sample points are plotted on a two-dimensional graph showing relative positions of each crop type in the Measurement Space (MS). The problem is to partition the measurement space in some optimal fashion so that points are allotted as nearly correct as possible. Figure 9 shows the measurement space as it might be partitioned.

Figure 9--Partitioned measurement space.



1/ M.G. Kendall and A. Stuart, The Advanced Theory of Statistics, 2nd Ed., Vol. 3, page 314.

Any point, no matter where it is in MS will be classified as one of the three crops. An unknown point where the number 1 is located in Figure 9 will be classified as wheat because wheat is probably the group to which it belongs. Likewise, a point in position 2 would be classified as sorghum and a point in position 3 would be classified as corn. A point in position 4 would also be classified as wheat, but the probability that it is actually wheat is not as great as that of a point in position 1.

There are many ways to partition a measurement space. We have done a simple non-statistical partition above, simply draw lines. Visually partitioning the measurement space may work when it is one or two dimensional, but for more than two dimensional measurement spaces, a visual partition is not possible. For most LANDSAT and aerial photography classification studies a four dimensional measurement space has been used.

The method used in this report was that of constructing contour "surfaces" in the MS. These dividing surfaces were constructed so that points falling on the dividing surface have equal probabilities of being in either group on each side. Those points not on the dividing surface always have a greater probability of being classified into the crop for which the point is interior to the contour surface. If prior knowledge of the population density function indicates that the density is multivariate normal, then a multivariate normal density distribution will be estimated for each crop. It is hoped that the data is approximately multivariate normal since only the mean vector and covariance matrix is required to estimate a discriminant function. Usually small departures from normality will not invalidate the procedure, but certain types of departures (for example, bimodal data) may be very detrimental to the statistical technique. However, the error rate and estimator properties are dependent on the assumptions of the distributions and prior information.

For example, in this study a multivariate normal density was assumed so it becomes quite simple to estimate the density functions and the discriminant scores which in turn determine boundaries.

The discriminant score for ith population is:

$$P_i \, (2\pi)^{-\frac{q}{2}} \, |\Sigma_i|^{-\frac{1}{2}} \, e^{-\frac{1}{2}(\chi-\mu_i)' \Sigma_i (\chi-\mu_i)}$$

where P_i is the prior probability for the ith crop

Σ_i is the covariance matrix (qxq) for the ith crop

μ_i is the mean vector (q length) for the ith crop

X_{ij} is a set of measurements of an individual from the ith population. $j \neq i$ or $j = i$

or its equivalent discriminant score the $\log_{(e)}$ of S_i =

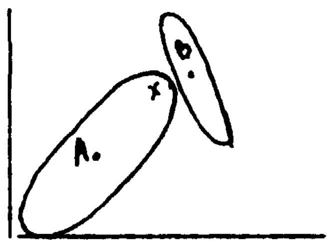
$$\log_e (P_i) - 1/2 \log_e |\Sigma_i| - 1/2 (\chi-\mu_i) \Sigma_i^{-1} (\chi-\mu_i)$$

The boundary between two populations is quadratic (curved) and the point χ that fall in the boundary have an equal probability of being in either population.

When an unknown land point is classified, its measurement vector is compared to the mean vector for each crop represented. The point is assigned to the crop whose mean point is "nearest" from a statistical point.

The procedure used for finding the "nearest" mean uses the Mahalanobis measure of distance, not the Euclidean. This is illustrated in Figure 10.

Figure 10--Measurement Space showing two crop density functions and an unknown point (χ).



The point χ is actually closest (Euclidean distance) to the mean vector (center point) of B. However, when one takes into account the variance and covariances, χ is found to be closest to Group A based on a probability concept and an outlier of Group B. Therefore, the point would be classified into Group A, because the probability that the point (χ) is a member of Group A is much greater than for Group B.

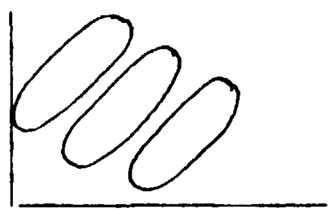
So the partitioning of the MS is done by computing the means for each crop type and using the Mahalanobis distances from this mean. This distance depends on the covariance matrix and is a measure of probability. The discriminant functions without prior probabilities are:

1) $(X - \overline{X}_i)' S^{-1}(X - \overline{X}_i)$, which is a sample estimate of $(X - \mu_i)'\Sigma^{-1} (\chi-\mu_i)$ if linear discriminant functions are used, and

2) $-1/2 \log_e |\Sigma_i| -1/2 (X - \bar{X}_i)' S_i^{-1} (X - X_i)$ if quadratic discriminant functions are used. These functions are the exponents of the density formula of the multivariate normal distribution C_{exp} - $1/2 (X - \mu_i) \Sigma_i^{-1} (X - \mu_i)$ depending on the i'th crop. If $\Sigma_i = \Sigma_j$ for all $i \neq j$ linear discriminant functions are used.

It is worth pointing out that if linear discriminant functions are used, one assumes (1) that $\Sigma_i = \Sigma_j$ and (2) that for all crops in the MS the major and minor axes are equal, and (3) the sample data of each crop has the same slope. Such an event in two-space is shown in Figure 11.

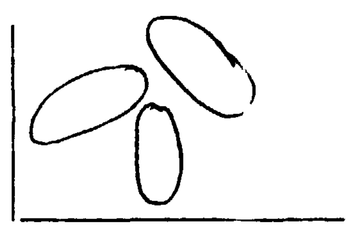
Figure 11--Measurement Space where crop types have same covariance matrix.



This space can be partitioned effectively with straight lines thus we can use linear discriminant functions.

Figure 12 shows a MS where covariance matrices are not equal, and therefore, linear discriminant functions are not appropriate. In either case, the Mahalanobis distance is used.

Figure 12--Measurement Space when crops have different covariance matrices.



In Figure 11, even though a common center point is not present, a common covariance (ellipse) matrix would be computed. In Figure 12 a different covariance matrix will be needed for each crop type. When the off-diagonal elements in the covariance matrix are unequal, the slopes of the data are different and linear discriminant functions are not appropriate.

The above techniques follow from our first assumption that the data is normally distributed in the MS. In practice, however, one does not decide what the distribution of the population density is in MS and program the correct procedure. One uses the available procedures for analyzing data. Most available programs assume multivariate normal data because the program and the calculations are greatly simplified. Thus, it becomes necessary to justify the use of these simplified programs.

In order to explain better how a parametric procedure can reduce the work load, consider that the first step in the discriminant analysis (DA) is to estimate the population density function in the MS, with a sample of points from each crop. Once these population density functions have been estimated, then partitioning the space is extremely simple.

To estimate a multivariate population density in MS for corn where we have no prior information except sample data on corn is extremely difficult. If a sample of 1000 points was available, each of these 1000 data points would need to be stored in the computer. On the other hand, if we are working with a multi-dimensional normal distribution, theory tells us that the sufficient statistics are computed (mean vector variance matrix) and stored in the computer.

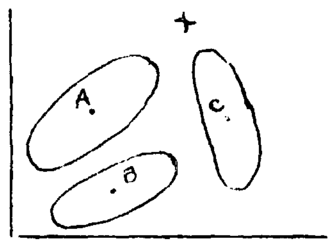
The individual data points could be discarded because no additional information about the population distribution in the MS is available in these points. (There would be information about how well the data fits the normal distribution in these 1000 data points).

Another consideration is that all the techniques we have described require independent random samples from each crop in order to estimate the population density in the MS (training data). This point is mentioned because most remote sensing analysts do not work with randomly selected points. In this study we have tried to work with randomly selected fields. However, the points within these fields are not a random sample of all possible points in a given crop, but the data are nested within fields. Consequently, the random selection is restricted to the selection of fields within the randomly selected segments.

One type of prior information that can be used in the classification procedure is the relative frequency of occurrence (prior probabilities) for each of the K populations in the total land population. For example, if 1/3 of all land is wheat, and 1/3 is pasture as it might be in parts of Kansas, this information would be used and it would effect the partitioning of the measurement space accordingly. If a crop has a high chance of selection, then the area in the MS would be increased. Conversely, if a certain crop has a very low chance of occurrence, then the area in MS would be adjusted downwards.

One last point to be covered on procedures used would be to define what is meant by thresholding. Suppose some unknown crop for which there is no sample in the original data set is to be classified. With the present system, the point will be classified as Crop A, B, or C, depending on its probability of being in either A, B, or C. For example, in Figure 13, if the probability P(AIX) that the point χ was Crop A is .01 and P(BIX) = .001, and P(CIX) = .02 the point χ would be classified as belonging to Crop C, even though the probability is only .02. It would be an outlier in MS for Crop C, and therefore, we may want to let it remain unclassified.

Figure 13--Measurement Space showing an outlier and three crop areas with 95% confidence limits.



4.1.3 Description of LANDSAT Data

The satellite data used in this report is LANDSAT Multi-Spectral Scanner (MSS) data and is described in Section 3 of Data User's Handbook. 1/

The MSS is a passive electro-optical system that can record radiant energy from the scene being sensed. All energy coming to earth from the sun is either reflected, scattered, or absorbed and, subsequently, emitted by objects on earth. 2/ The total radiance from an object is composed of two components, reflected radiance and emitted radiance. In general, the reflected radiance forms a dominant portion of the total radiance from an object at shorter wavelengths of the electromagnetic spectrum, while the emissive radiance becomes greater at the longer wavelengths. The combination of these two sources of energy would represent the total spectral response of the object. This, then, is the "spectral signature" of an object and it is the differences between such signatures which allows the classification of objects using the statistical techniques just discussed. The particular product is system corrected images refers to

1/ Published by Goddard Space Flight Center.

2/ Baker, J.R. and E.M. Mikhail, Geometric Analysis and Restitution of Digital Multispectral Scanner Data Arrays. LARS information note 052875.

products that contain the radiometric and initial spatial corrections introduced during the film conversion. Every picture element (pixel) is recorded with 4 variables - each variable corresponds to one of the 4 MSS bands. Table 23 shows the relationship between the MSS bands and light wavelengths.

Table 23--Sensor spectral band relationships.

Sensor	Spectral Band Number	Wavelenghts (micrometers)	Color	Band Code
MSS	1	.5 - .6	Green	4
MSS	2	.6 - .7	Red	5
MSS	3	.7 - .8	Near Infrared	6
MSS	4	.8 - 1.1	Infrared	7

The numbers are similar to transmission values - zero radiances at Step 15 which is black on positives and maximum radiance at Step 1 which is white on positives. The radiance varies linearly with gray scale step transmission between these values with the difference between each step corresponding to 1/14th of the maximum radiance. The recording format in the CCT is 8 bits, the sensor range is 7 bits, and the actual dynamic range of usable data is between 5 and 6 bits.

The analysis was started by first locating the test and training data (ground observations with either the Penn State University program (NMAP) or an in-house program (RADMAP) that produces gray scale maps. 1/ After the ground enumeration information was located on LANDSAT CCT's, rectangular areas within fields were located and punched using the LARS field description card format. Once these cards were obtained and checked, the statistics function in LARSYS was employed to extract univariate graphs to detect bimodal classes.

In most cases, analysis proceeded from the statistics program to the Program for classify points, but with the introduction of a feature to use prior probabilities. These classifications were stored on tape by file number so the print results function could be run more than once.

4.1.4 Results

The results will be presented by state since there was a slightly different situation in each state. All LANDSAT analysis is presented first then the aircraft follows.

1/ See Section - Segment Location

Missouri LANDSAT:

The Crop Reporting District (CRD) that was the test site was in the southeast corner of the state. This area is outlined in black on the map of Missouri, Figure 3.

Summary of Results

The Missouri test site covers 4,660 square miles. There are 50 segments, each about a mile square. These segments constitute a random sample from all land areas. The ground enumeration was taken from these segments. This information was used for both training and testing.

Analysis of Missouri data was done using a tape that was assembled at LARS. The data for three dates, August 26, September 13, and October 21, 1972, were geometrically corrected then overlayed to create a tape with temporal data. Therefore, data used for analysis from three different times in the growing season was available and covered an area that contained 29 of the JES segments in this CRD. The principle results are summarized below:

1. A test was run on the covariance matrices between crops to see if they were equal. The results of this test were that they very likely were not equal. Thus, linear discriminant functions seemed inappropriate.

2. Best overall correct classification rate was 70%. This included using temporal overlays and using unequal prior probabilities.

3. Unequal prior probabilities for crops improved classification results by 10% over using the assumption of equal probabilities for crops.

4. The temporal data improved the classification by 10% even though the dates were not optimum.

5. One classification was run on data to estimate the effect of independent data. The difference was 9%, and was an over-estimate.

Data Analysis - LANDSAT

In the analysis, the equality of the covariance matrices was checked first because this is essential for the linear discriminant analysis assumptions to be valid. A test presented in Morrison's Multivariate Statistical Methods, page 152, was used to test the within crop covariance of LANDSAT data. This test is not robust with respect to certain departures from normality.

For the following example, August 26, 1972 imagery bands 4, 5, and 7 were used. The covariance matrices for cotton, soybeans, and grass were tested. The test was conducted as follows. The null hypothesis states that the covariance matrices are equal.

$$H_0: \Sigma_1 = \Sigma_2 = \Sigma_3$$

The alternative hypothesis is:

$$H_1: \Sigma_i \neq \Sigma_j \quad \text{for some } i \neq j$$

S_i is an estimate of Σ_i based on m_i degrees of freedom where i is a crop.

$$S \text{ cotton} = \begin{bmatrix} 6.76 & 7.01298 & .4914 \\ 7.01298 & 11.0889 & -5.6643 \\ .4914 & -5.6643 & 39.69 \end{bmatrix}$$

$$S \text{ soybeans} = \begin{bmatrix} 6.6049 & 8.3623 & .8265 \\ 8.3623 & 13.9876 & -6.3146 \\ .8265 & -6.3398 & 64.6416 \end{bmatrix}$$

$$S \text{ grass} = \begin{bmatrix} 5.6169 & 5.8416 & .7525 \\ 5.8416 & 9.7344 & -6.3398 \\ .7525 & -6.3398 & 40.3225 \end{bmatrix}$$

Now we form the pooled estimate of Σ.

$$S = \sum_{i=1}^{k} \frac{m_i s_i}{m} \quad \begin{bmatrix} 6.5567 & 7.4436 & .6638 \\ 7.4436 & 12.1519 & -6.0189 \\ .6638 & -6.0189 & 50.2976 \end{bmatrix}$$

The statistic for the modified likelihood - ratio test is:

$$M = m \ln |S| - \sum_{i=1}^{k} m_i \ln |S_i|$$

$= 149.25$

Next, we form the scale factor:

$$C^{-1} = 1 - \frac{2P^2 + 3P - 1}{6(p+1)(k-1)} \sum_{i=1}^{k} \frac{1}{m_i} \frac{1}{\Sigma m_i} = .00678$$

and MC^{-1} is distributed approximately chi-squared with degrees of freedom 1/2 $(K-1)p(p+1)$ as m_i tends to infinity if H_0 is true.

$$MC^{-1} = .48.77 \quad d.f. = 12 \quad \alpha = .05 \quad \chi^2(12 \; \alpha = .05) = 22.36$$

Thus, we must reject the null hypothesis i.e. the data does not support the assumption that the covariance matrices are equal.

Therefore, the necessary assumptions for valid linear discriminant analysis are not met and better results might be attained by using quadratic discriminant functions. Generally, we used the quadratic approach on our analysis. However, it should be pointed out that upon close examination, the covariance matrices are very similar in many respects. Corresponding elements in the three covariance matrices are of at least the same order of magnitude and have the same sign. Under such conditions, it is possible to get acceptable results from a linear approach.

Conclusions of similar tests for the September 14, 1972 data were the same, the covariance matrices were unequal.

Results of the discriminant analysis (DA) are presented in a classification matrix (CM). Table 24 is an example of a CM using quadratic discriminant functions with unequal prior probabilities. The prior probabilities came from the June Survey early in the season. That is, it was not assumed that corn, cotton, soybeans, grass, and other all have the same probability of occurrence. The classification parameters were obtained from the same data that was used in the testing phase.

Although 12 bands were available, since three dates were involved, only nine were used in this study because three were of poor quality. There were two consecutive LANDSAT images that contained 29 segments. All data was used both to partition the measurement space (MS) and test the partition. The CM will be biased upward because data was used for both purposes, however, this bias should be small if ample data are available.

Table 24--Classification matrix of quadratic discriminant functions with unequal prior probabilities using data from three overflights1/, Missouri Study Area.

Group	No. of sample points	Percent Correct	Number of samples classified into: Cotton	Corn	Soybean	Grass	Miscellaneous
Cotton....	927	79.7	739	2	137	26	23
Corn......	58	44.8	9	26	7	14	1
Soybean...	852	71.8	99	12	612	96	23
Grass.....	240	53.3	42	1	66	128	4
Misc......	140	89.3	17	2	44	13	64
Totals....	2217		906	43	866	277	125

Overall performance 70.8 percent

1/
August 26, 1972, MSS bands 4, 5, 7
September 14, 1972, MSS bands 5, 7
October 2, 1972, MSS bands 4, 5, 6, 7

The leftmost column in Table 24 identifies the crop - cotton, corn, soybeans, grass, and miscellaneous. The next column gives the number of sample values in each of the crop classes. For example, there are 927 pixels to be classified. The next column tells the percent of these that were classified correctly as cotton (79.7%). The rest of the columns give the number of these pixels that were classified into each crop class, i.e. 739 were classified correctly as cotton, while the remainder were misclassified as follows: 2 of the 927 as corn, 137 as soybeans, 26 as grass, and 23 as miscellaneous. The overall performance in this table was 70.8 percent. To compute this figure, the correctly classified pixels were divided (the diagonal elements - 1569) by the total pixels 2217.

The prior probabilities used in this study were based on a statistical sampling of the entire land area. Data that is collected in this way enables the user to estimate the prior probability and take advantage of this procedure. Historic data could be used, but they are more difficult to justify when important changes between years are occurring.

The next table is the same as the last, except that equal prior probabilities were used.

Table 25--Classification matrix of quadratic discriminant functions with equal prior probabilities using data from three overflights 1/, Missouri Study Area.

Group	No. of sample points	Percent Correct	Number of samples classified into: Cotton	Corn	Soybean	Grass	Miscellaneous
Cotton....	927	74.3	689	21	83	36	98
Corn......	58	58.6	4	34	3	10	7
Soybean...	852	39.7	101	49	338	137	227
Grass.....	240	57.1	34	22	22	138	25
Misc......	140	75.0	14	5	7	9	105
Total.....	2217		842	131	453	329	462

Overall performance 58.8 percent

1/
August 26, 1972, MSS bands 4, 5, 7
September 14, 1972, MSS bands 5, 7
October 2, 1972, MSS bands 4, 5, 6, 7

Most classifications done so far by other remote sensing analysts have used this assumption that the crop classes are all equally likely to occur. Most people feel this assumption is not detrimental, however, this example illustrates that it can make a difference. Especially, if acreage for the crop classes does vary vastly or when crops are hard to distinguish. Two properties are worth noting, classification results, and the statistical properties are much better in Table 24 than in Table 25. For example, in Table 24 the total number of pixels classified as cotton is 906, compared to the actual number of 927. In Table 25, the number of cotton pixels is 842.

A similar comparison is even more drastic with soybeans. In Table 24, 866 pixels were classified as soybeans while 842 actual points were soybeans. In Table 25, there were 453 points classified as soybeans. Further, the statistical properties of the estimates are better since if the data is normal, and the prior probabilities are correct, we obtain unbiased estimates of crop categories and we can estimate the Bayes error rates (minimum error rates) using the classification.

A chi-square test for discriminatory power was run on the CM of Table 24 and 25. 1/ The null hypothesis is that the classification was done strickly at random. If the null hypothesis is correct, then the spectral information was useless as far as giving information that would help assign the data to a crop class. If the above hypothesis is correct, then the statistic $\frac{(n-e)^2}{e} + \frac{(\bar{n}-\bar{e})^2}{\bar{e}}$ has a chi-square distribution with 1 degree of freedom. Where n and $\bar{n}$ are the number of correctly classified and misclassified points respectively and e and $\bar{e}$ are the expected number of correctly classified and misclassified points under the null hypothesis.

The chi-square for Table 24 is 4626 and for Table 25 is 2782. These chi-square values with one degree of freedom are highly significant, and therefore, we conclude that the classification was not done at random. Another chi-square test based on the difference between the marginal sums and the correct number of data points in each class for Table 25 is as follows:

$$X^2_{(5)} = \frac{(906-927)^2}{927}+\frac{(43-58)^2}{58}+\frac{(866-852)^2}{852}+\frac{(277-240)^2}{240}+\frac{(140-125)^2}{125} =$$

$$.47 + 3.87 + .23 + 5.70 + 1.61 = 11.89$$

This chi-square statistic is similar to the one before, except that there are 4 degrees of freedom. $\sum_{i=1}^{k} \frac{(n-e)^2}{e_i}$ where n and e have the same meaning as before.

This chi-square value of 11.89 is significant, and therefore, the hypothesis that the marginal totals in Table 24 are estimating the actual row totals is rejected. Note that the components for grass and corn are the major contributors to the significant chi-square.

The authors know of no statistical test that compare one C.M. with another C.M., but there are two criteria that can be used to help evaluate a certain C.M. The first criterion simply assigns each misclassified point a loss of 1 and each correctly classified point as loss of 0. Under this criterion, Table 24 has a loss value of 648 and Table 25 has a loss value of 914. This criterion is crude, but it seems reasonable for our purposes to give a misclassified corn pixel the same weight as the misclassified cotton pixel.

1/ S. James Press, Applied Multivariate Analysis, pages 381-383.

The next criterion is a bit more subtle. It uses the marginal totals in the C.M. For example, in Table 24 the column sum for cotton is 906. This means that 906 pixels were classified as cotton. Actually, there were 927 cotton pixels. In Table 25, there were 842 pixels classified into the cotton group. This is not close to the correct number of 927. The marginal estimate (906) from Table 24 is within 2 percent of the actual. In Table 25, the marginal estimate of 842 or within 9 percent. Table 26 presents these estimates along with the percentages of the true value.

Table 26--Marginal estimate and difference from actual values.

Group	Actual	Unequal Prior Probabilities			Equal Prior Probabilities		
		Estimate	Difference	Percent	Estimate	Difference	Percent
Cotton..	927	906	21	2.2	842	85	9.2
Corn....	58	43	15	25.9	131	73	125.9
Soybean.	852	866	14	1.6	453	399	46.8
Grass...	240	277	37	15.4	329	89	37.1
Winter Wheat...	85	27	27	68.2	346	261	307.1
Odd.....	55	98	43	78.2	116	61	110.9

In every case, unequal prior probabilities were superior to the equal prior probabilities model and in some cases, substantially so. For example, the number of corn pixels for Table 25 was 131 or 125.9 percent of the difference from the actual 58. The number of corn pixels for Table 24 is 43 or 25.9 percent of the difference from the actual 58 pixels. Soybeans, a very important item, also shows a significant improvement over the equal probability model. Actually, the soybean estimate for the equal prior probability model was 46.8 percent which the estimate for the unequal prior probability model was 1.6 percent.

Next, the point classification systems were compared to the per-field classification scheme. Table 27 presents the C.M. for the per-field classifier system. With a point classification system, each point in a field can be assigned to any of the crop categories. With the sample classifier, all points in the field are assigned to the same crop class. One drawback to the procedure is that there were a large number of fields that were not assigned to a crop because the data set was not large enough. The technique requires the covariance matrix to be inverted and therefore, p+1 data points are required (where p is the number of variables). However, if enough points are present, classification performance has generally been found to be excellent.

In the work done in Missouri using the sample classifier, about 40 percent of the fields were not classified because the required number of points for the classifier (10 is this particular case) exceeded the number of points present within the defined fields. Of the total number of fields, 32.9 percent were correctly identified. Considering only those fields which were classified, 54 percent were classified correctly.

Table 27--Per-field classification matrix based on data from 3 overflights.1/

Group	No. of fields	Percent fields correct	No. of samples	COTTON	CORN	SOY-BEANS	GRASS	MISC.	NOT CLASSIFIED
Cotton	38	63.2	927	24	0	2	0	1	11
Corn..	7	14.3	58	0	1	0	1	1	4
Soy-beans.	58	25.9	852	9	3	15	3	8	20
Grass.	31	9.7	240	3	1	1	3	2	21
Misc..	9	44.4	140	1	0	1	1	4	2
Totals	143	32.9	2217	37	5	19	8	16	58

1/
August 26, 1972, MSS bands 4, 5, 7
September 14, 1972, MSS bands 5, 7
October 2, 1972, MSS bands 4, 5, 6, 7

Temporal Overlay

The next analysis investigated the value of a temporal overlay of the three LANDSAT passes. This particular data set was a temporal overlay of three LANDSAT passes. Each pass could also be compared with the three passes. However, there were 3 bad bands in the total of 12. Two poor quality bands were in the September 14 imagery and one poor quality band was in the August 26 imagery. This makes it difficult to compare the three dates since the number of bands were confounded with dates. Nevertheless, the C.M.'s for each date are presented in Tables 28, 29, and 30. These tables can be compared to the 9 band-overlay of Table 24 since they are all unequal prior probability models.

Table 28--Classification matrix using August 26, 1972, MSS bands 4, 5, and 7 with unequal prior probabilities.

Group	No. of sample points	Percent Correct	Number of samples classified into				
			Cotton	Corn	Soybean	Grass	Miscellaneous
Cotton...	927	60.6	562	1	311	22	31
Corn.....	58	10.3	12	6	30	2	8
Soybean..	852	86.0	70	2	733	29	18
Grass....	240	8.3	42	7	167	20	3
Misc.....	140	31.4	9	3	76	8	44
Totals...	2217		696	19	1317	81	104

Overall performance 61.5 percent

Table 29--Classification matrix using September 13, 1972, MSS bands 5 and 7 with unequal prior probabilities.

Group	No. of sample points	Percent Correct	Number of samples classified into				
			Cotton	Corn	Soybean	Grass	Miscellaneous
Cotton...	927	69.7	646	0	246	14	21
Corn.....	58	0.0	12	0	16	20	10
Soybean..	852	67.6	175	1	576	74	26
Grass....	240	42.1	40	0	97	101	2
Misc.....	140	22.8	14	2	82	10	32
Totals...	2217		887	3	1017	219	91

Overall performance 61.0 percent

Table 30--Classification matrix using October 2, 1972, MSS bands 4, 5, 6, and 7 with unequal prior probabilities.

Group	No. of sample points	Percent Correct	Number of samples classified into				
			Cotton	Corn	Soybean	Grass	Miscellaneous
Cotton...	927	73.2	679	6	161	59	22
Corn.....	58	12.1	30	7	14	1	6
Soybean..	852	62.4	200	7	532	76	37
Grass....	240	27.9	83	0	89	67	1
Misc.....	140	17.9	30	1	73	11	25
Totals...	2217		1022	21	869	214	91

Overall performance 59.1 percent

Table 31 summarizes these three classification matrices in 1 table.

Table 31--Comparison of multitemporal classification performance to classification of single dates. 1/ Missouri Study Area.

Group	Multitemporal	Aug. 26	Sept. 14	Oct. 2
Cotton	29.7	60.6	69.7	73.2
Corn	44.8	10.3	0.0	12.1
Soybeans	71.8	86.0	67.6	62.4
Grass	53.3	8.3	42.1	27.9
Misc.	89.3	31.4	22.8	17.9
Overall	70.8	61.6	61.1	59.2

1/ Unequal prior probabilities were used for all classification.

The same classifications were run for all dates individually except that equal prior probabilities were used.

Table 32--Classification matrix for August 26, 1972, based on MSS bands 4, 5, and 7 using equal prior probabilities.

Group	No. of sample points	Percent Correct	Number of samples classifed into				
			Cotton	Corn	Soybean	Grass	Miscellaneous
Cotton...	927	60.7	563	92	108	63	101
Corn.....	58	56.9	2	33	0	7	16
Soybean..	852	15.3	57	72	130	245	348
Grass....	240	45.4	32	41	26	109	32
Misc.....	140	62.9	11	10	13	18	88
Totals...	2217		665	248	277	442	585

Overall performance 41.6 percent

Table 33--Classification matrix for September 13, 1972 based on MSS bands 5 and 7 using equal prior probabilities.

Group	No. of sample points	Percent Correct	Number of samples classified into				
			Cotton	Corn	Soybean	Grass	Miscellaneous
Cotton...	927	60.7	563	92	108	63	101
Corn.....	58	56.9	2	33	0	7	16
Soybean..	952	15.3	57	72	130	245	348
Grass....	240	45.4	32	41	26	109	32
Misc.....	140	62.9	11	10	13	18	88
Totals...	2217		665	248	277	422	585

Overall pefformance 50.8 percent

Table 34--Classification matrix for October 2, 1972 based on MSS bands 4, 5, 6, and 7 using equal prior probabilities.

Group	No. of sample points	Percent Correct	Number of samples classified into				
			Cotton	Corn	Soybean	Grass	Miscellaneous
Cotton...	927	66.7	618	35	30	149	95
Corn.....	58	37.9	21	22	4	4	7
Soybean..	952	20.8	142	46	177	141	346
Grass....	240	42.5	58	9	23	102	48
Misc.....	140	60.7	20	8	8	18	85
Totals...	2217		860	120	242	414	581

Overall performance 45.3 percent

Table 35 summarizes these tables.

Table 35--Comparison of multitemporal classification performance to classifications of single dates using equal prior probabilities. 1/ Missouri Study Area.

Group	Multitemporal	Aug. 26	Sept. 13	Oct. 2
Cotton	74.3	60.7	71.4	66.2
Corn	58.6	56.9	34.5	37.9
Soybeans	39.7	15.3	28.9	20.8
Grass	57.1	45.4	44.6	42.5
Misc.	75.0	62.9	65.7	60.7
Overall	58.8	41.6	50.8	45.3

The temporal overlay classification of Table 25 shows an overall performance of 58.8 percent as compared to 41.6 percent, 50.8 percent, and 45.3 percent, respectively, for Tables 32, 33, 34. Based on these comparisons, the temporal overlay does improve the classification, However, the evaluation can become more difficult to interpret in the temporal overlay tapes because of changes in land use from one date to the next. Thus, the time of year becomes very important in areas where double-cropping is common or preparation of land follows each crop. It should be pointed out that these dates were not optimal. Other dates would have given different results.

Independent Test Data

The last exercise was completed to estimate the C.M. in Missouri on independent data. Since the number of fields and points within are small and the area covered is large, we need more training data to represent the total area. It did not seem possible to divide the set into halves and still have enough training data. It was decided to use a jacknife procedure. This procedure has the advantage of giving unbiased estimates that are simple to calculate. The data were divided into three equal subgroups, two groups were used to train with and the third group was used as a test group. This was repeated three times, each time with a different group used as test data. These three tables are presented separately, then the three are combined and presented to give an unbiased estimate of the classification matrix where independent test data is used. By using independent data, it is hoped that the bias caused by using the same data for both training and testing would be eliminated, but the variance of each item in the latter tables may be somewhat higher than those in the previous tables since a smaller data set was used.

One cotton field of 27 points was not included in any of the three groups. So the total in Table 39 is 27 pixels smaller than the total of earlier tables. Table 39 is the matrix sum of Tables 36, 37, and 38.

Table 36--Classification matrix using August 26, 1972, MSS bands 4, 5, and 7 with subgroups 2 and 3 as training data and subgroup 1 as test data.

Group	No. of sample points	Percent Correct	Number of samples classified into				
			Cotton	Corn	Soybean	Grass	Miscellaneous
Cotton	479	56.2	269	11	129	36	34
Soybean..	138	45.7	35	6	63	17	17
Grass	66	34.8	15	7	15	23	6
Misc.	68	16.2	1	4	39	13	11
Totals	751		320	28	246	89	68
Overall performance 48.7 percent							

Table 37--Classification matrix using August 26, 1972 MSS bands 4, 5, and 7 with subgroups 1 and 3 as training data and subgroup 2 as test data.

Group	No. of sample points	Percent Correct	Number of samples classified into				
			Cotton	Corn	Soybean	Grass	Miscellaneous
Cotton...	290	57.6	167	36	11	19	57
Corn.....	29	13.8	1	4	0	8	16
Soybean..	308	13.0	48	53	40	20	147
Grass....	42	28.6	1	11	4	12	14
Misc.....	57	78.9	0	2	8	2	45
Totals...	726		217	106	64	63	279

Overall performance 36.9 percent

Table 38--Classification matrix using August 26, 1972 MSS bands 4, 5, and 7 with subgroups 1 and 2 as training data and subgroup 3 as test data.

Group	No. of sample points	Percent Correct	Number of samples classified into				
			Cotton	Corn	Soybean	Grass	Miscellaneous
Cotton...	131	47.3	62	22	1	22	24
Corn.....	29	41.4	3	12	2	5	7
Soybean..	406	200	6	29	8	137	226
Grass....	132	43.2	20	27	0	57	28
Misc.....	15	0.0	5	2	0	8	0
Totals...	713		96	92	11	229	285

Overall performance 19.5 percent

Table 39--Classification matrix combining Tables 36, 37, and 38.

Group	No. of sample points	Percent Correct	Number of samples classified into				
			Cotton	Corn	Soybean	Grass	Miscellaneous
Cotton...	900	55.3	498	69	141	77	115
Corn.....	58	27.6	4	16	2	13	23
Soybean..	852	13.0	89	88	111	174	390
Grass....	240	28.3	36	45	19	92	48
Misc.....	140	40.0	6	8	47	23	56
Totals...	2190		633	226	320	379	632

Overall performance 34.6 percent

The comparable classification where non-independent data was used is shown in Table 40.

Table 40--Classification matrix using August 26, 1972, MSS bands 4, 5, and 7.

Group	No. of sample points	Percent Correct	Number of samples classified into				
			Cotton	Corn	Soybean	Grass	Miscellaneous
Cotton...	927	60.7	563	92	108	63	101
Corn.....	58	56.9	2	33	0	7	16
Soybean..	852	15.3	57	72	130	245	348
Grass....	240	45.4	32	41	26	109	32
Misc.....	140	93.6	11	10	13	18	131
Totals...	2217		665	248	277	442	585

Overall performance 43.6 percent

Anytime the results differ this much between data sets, we know the data set is either too small or the bias is large. Obviously, we have not reached the point where we have covergence of parameters based on independent and non-independent data sets. The sample sizes necessary depends on the variation in the data set and the variation in the data set is generally a function of how dispersed the data really is. One thing is certain with a small data set, either procedure may lead to erroneous conclusions.

Kansas:

The LANDSAT analysis was done on the CRD in the southwest corner of the State. Figure 2 shows the State of Kansas with the study area outlined.

Analysis of Kansas LANDSAT Data

The objective of the analysis of Kansas LANDSAT data were the following:

1. Test the covariance matrices of the most important crops to see if they were equal.

2. Compute the classification rates for the Kansas test site.

3. Compute the correlation coefficients between ground observation acreage and classified pixels.

4. Study the effect of classification in one LANDSAT frame using training parameters from an adjoining pass taken one day apart.

5. Study the classification of a Kansas county.

Approach:

1. LANDSAT imagery for the study area was too cloudy to be useful, prior to September 21, 1972. The study was based on September 21 and 22 imagery. The area of interest in Kansas was divided by two LANDSAT passes, thus the training data was also divided. Twenty-two segments were in the September 21 imagery. Seven of these segments were hidden by clouds. Therefore, 15 segments were used as training and test data.

   Since the time of year was not conducive to optimal results, a visual inspection of the grey-scale printout of MSS band 5 and ground truth was used to select particular fields to use as training fields; i.e. those fields which were partially harvested and those with a confusion of symbols were discarded. Another reason for selecting fields was to compare parameters from one pass with those from another as described in this report.

As a first step, the covariance matrices of the most important crops were compared and tested within frames and between frames. Tables 41 and 42 show the pertinent data.

The test criterion was computed and indicates that the within-crop covariances are statistically different. Also, the covariances between frames for the same crops were tested and are significantly different.

This would indicate that quadratic discriminant analysis could produce better results. In addition, a method of signature extension would be complicated if one wished to go from one frame to another.

2. The next step was to employ the quadratic classifier for the training data. The classification based on these select fields is presented in Table 43.

   The overall performance was 91.2%. The classification used the standard pointwise quadratic discriminant functions found in LARSYS with the added feature of allowing unequal prior probabilities for the different crops. The unequal prior probabilities use information that is available about the likelihood of certain crops. If, for example, corn is more likely to be encountered than grain sorghum, corn is given a higher chance of occurrence. In most classifications using unequal prior probabilities done in Kansas, the prior probabilities were:

   1) Alfalfa - .03
   2) Pasture - .72
   3) Corn - .09
   4) Grain Sorghum - .16

Prior probabilities in this report were computed from a probability survey conducted by the Statistical Reporting Service in June 1972, (June Enumerative Survey).

In Table 43, the number of pixels to be classified are not proportional to the prior probabilities. The prior probabilities are based on acreage of all segments in the Crop Reporting District, and not the segments in frame 1060-16512. Development of proper prior probabilities for areas divided by LANDSAT passes presents additional problems. A better correspondence would have resulted in higher overall classification; however, 91.2% is very good.

Table 41--Covariance matrices and mean vectors for frame 1060-16512. (September 21, 1972).

		Mean	Covariance			
Alfalfa	n = 43					
		26.63	3.430			
		19.58	4.531	8.535		
		50.81	-2.357	-8.199	27.346	
		30.28	-2.751	-7.357	16.363	12.301
Pasture	n = 6378					
		29.70	10.926			
		26.36	12.975	21.821		
		56.88	10.351	12.698	22.487	
		20.07	4.405	4.332	11.388	7.339
Corn	n = 332					
		31.63	46.883			
		29.71	77.701	133.003		
		43.03	26.525	42.905	33.798	
		24.84	2.728	-6.399	11.275	10.978
Grain Sorghum	n = 508					
		32.21	115.096			
		27.32	130.402	154.965		
		43.78	78.251	85.757	76.431	
		25.65	18.089	16.152	29.548	18.198

Table 42--Covariance matrices and mean vectors for frame 1061-16570. (September 22, 1972).

		Mean	Covariance			
Alfalfa	n = 78					
		24.23	8.180			
		15.96	12.793	24.701		
		55.61	-18.345	036.494	71.234	
		34.51	-15.063	-29.604	50.802	39.313
Pasture	n = 320					
		28.62	5.290			
		25.53	6.109	11.002		
		35.98	3.534	3.061	19.272	
		19.81	1.056	0	11.213	8.237
Corn	n = 337					
		24.52	1.877			
		19.91	2.183	9.120		
		36.88	0.339	-5.114	17.056	
		22.82	-0.081	-5.291	11.039	8.820
Grain Sorghum	n = 177					
		27.16	32.718			
		22.76	49.217	77.088		
		43.69	2.100	2.865	16.646	
		27.09	-15.639	-24.393	10.975	19.448

Table 43--Classification matrix for September 21, 1972 MSS bands 4, 5, and 7, using quadratic discriminant functions with unequal prior probabilities in Kansas test site for select fields.

Class	No. of sample points	Percent Correct	Number of samples classified into				
			Alfalfa	Pasture	Corn	Sorghum	Threshold
Alfalfa..	43	100.0	43	0	0	0	0
Pasture..	172	98.3	0	169	2	1	0
Corn.....	51	90.2	0	1	46	4	0
Grain Sorghum..	78	69.2	0	10	14	54	0
Totals...	344		43	180	62	59	0

Overall performance 91.2%

A classification was then done using all identifiable fields in the 15 segments. The results of this classification are presented in Table 44. The overall performance was 90.2%.

There was a small decrease in overall performance between Table 43 and Table 44. However, a random sample of ground truth yields a better representation of all land and allows statistical inferences about the pixels.

The second pass required to cover the Kansas test site was analyzed in the same way as described above. The second scene contained 23 segments, but one of these segments fell in a non-agricultural area. In addition, to the random segments, two additional segments were selected which contained sugar beets.

Table 45 presents the classification of select fields for the second pass. The fields were selected from the grey-scale printout as described above. The overall performance was 75.5%.

Table 44--Classification matrix for September 21, 1972 imagery (MSS bands 4, 5, 6, and 7), using quadratic discriminant functions with unequal prior probabilities in Kansas test site.

Class	No. of sample points	Percent Correct	Number of samples classified into				
			Alfalfa	Pasture	Corn	Grain Sorghum	Threshold
Alfalfa..	43	93.0	40	2	0	1	0
Pasture..	6378	95.0	23	6061	123	142	29
Corn.....	332	37.7	38	110	125	59	00
Grain Sorghum..	508	64.8	38	77	60	329	44
Totals...	7261		139	6250	308	531	33

Overall performance 90.2%

Table 45--Classification matrix for September 22, 1972 imagery (MSS bands 4, 5, 6, and 7), using quadratic discriminant functions with unequal prior probabilities in Kansas test site for select fields.

Class	No. of sample points	Percent Correct	Number of samples classified into				
			Alfalfa	Pasture	Corn	Grain Sorghum	Threshold
Alfalfa..	78	84.6	66	12	0	0	0
Pasture..	230	93.0	0	214	11	5	0
Corn.....	337	65.0	0	93	219	25	0
Grain Sorghum..	177	63.9	3	34	18	122	0
Totals...	822		69	353	248	152	0

Overall performance 75.5%

Table 46 represents a classification of the second scene, using all identifiable fields. The overall performance was 65.8%. This decrease in performance could be attributed to several things. The number of crops being classified was increased from four to seven. Increasing the number of crops will reduce the performance. Secondly, there was a confusion between most crops and pasture. This could have resulted from using late September imagery; all crops are spectrally similar. Thirdly, the frequency of the data pixels presented for classification differed drastically from the prior probabilities used.

Table 47 is a classification study using the same select training fields that were used in Table 45. However, in Table 47 equal prior probabilities were applied. In Table 47, the overall performance at 79.2% is actually better than the 75.5% in Table 45. Applying prior probabilities based on all fields to a non-random selection of fields in a particular area is the cause for the lower classification in Table 45.

Table 48 presents a classification of all identifiable fields in scene 1061-16570, using equal prior probabilities. This table is comparable with the weighted classification presented in Table 46. The overall performance was increased 4.4% by using prior probabilities. When all fields are used in the classification, the total acres per crop more closely estimate the true prior probabilities of the model.

The increase caused by using unequal prior probabilities in Kansas was not as great as it had been in other areas. The smaller gain from prior probabilities is perhaps caused by the fact that the LANDSAT data contained more information; i.e., the classes were more separable. Thus, the expected gain from prior probabilities is greater in areas where classification is poorer.

3. The correlations between acres and pixels were calculated. Coordinates of ground truth segments were carefully defined. The training data from each scene were used to classify the segments in that scene. The classified pixels in the two scenes were then combined (i.e., Tables 44 and 46 were combined) and correlations with known ground truth acreage were computed.

   Correlations between acreage and pixels were calculated as follows:

Total Acreage vs Total Pixel	$r^2 = .88$	$r = .94$
Pasture Acreage vs Pasture Pixel	$r^2 = .84$	$r = .92$
Corn Acreage vs Corn Pixel	$r^2 = .62$	$r = .79$
Grain Sorghum vs Grain Sorghum Pixel	$r^2 = .58$	$r = .76$

Table 46--Classification matrix for September 22, 1972 imagery (MSS bands 4, 5, 6, and 7), using unequal prior probabilities, Kansas, all fields.

Class	No. of sample points	Percent Correct	Number of samples classified into						
			Alfalfa	Pasture	Corn	Grain Sorghum	Winter Wheat	Sugar Beets	Threshold
Alfalfa	287	56.4	162	57	12	23	16	6	0
Pasture	4975	90.6	19	4508	45	44	156	0	23
Corn	1698	40.8	1	684	693	174	99	0	0
Grain Sorghum	2869	55.3	89	300	357	1586	265	0	4
Winter Wheat	863	13.3	14	431	16	41	115	0	4
Fallow	1508	64.6	10	285	44	56	134	2	3
Sugar Beets	25	0.0	16	2	1	1	5	0	0
Totals	12225		311	6267	1168	1925	790	8	34

Overall performance 65.8 percent

Table 47--Classification matrix for September 22, 1972 imagery, MSS bands 4, 5, 6, and 7, using quadratic discriminant functions with equal prior probabilities in Kansas test site for select fields.

Class	No. of sample points	Percent Correct	Number of samples classified into: Alfalfa	Pasture	Corn	Grain Sorghum	Threshold
Alfalfa..	78	84.6	66	11	0	1	0
Pasture..	230	75.2	3	173	38	16	0
Corn.....	337	87.5	0	29	295	13	0
Grain Sorghum..	177	66.1	14	16	30	117	0
Totals...	822		83	299	363	147	0

Overall performance 79.2%

When pixels and acreage are this highly correlated, remotely sensed data is beneficial.

4. In this study, the statistics compiled on one LANDSAT frame were used to classify points in the adjacent frame. As described earlier, two adjacent passes were used to obtain necessary coverage of Kansas. The select fields from both scenes (as described in Section A), had four classes (alfalfa, pasture, corn, grain sorghum. These four classes were also the classes for the "all fields" in frame 1060-16512. One requirement is that the same classes be used for training as those classified. The classification used the quadratic discriminant function with unequal prior probabilities.

   Table 49 presents the results of classifying the select fields in frame 1060-16512, using training statistics generated from select fields in frames 1061-16570. The overall performance was 54.4%; however, the average performance by classes 1/ was 33.3% correct classification. The 100% correct classification of the pasture class greatly influenced the overall classification.

1/ The average performance by classes is computed by averaging the percent identified for each class.

Table 48--Classification matrix for September 22, 1972 imagery, 4 bands using equal prior probabilities Kansas.

Class	No. of sample points	Percent Correct	Number of samples classified into							
			Alfalfa	Pasture	Corn	Grain Sorghum	Winter Wheat	Fallow	Sugar Beets	Threshold
Alfalfa........	287	50.5	145	18	30	9	24	4	57	0
Pasture........	4975	80.1	61	3986	371	66	340	106	22	23
Corn,..........	1698	70.3	80	267	1193	69	39	32	18	0
Grain Sorghum..	2869	42.1	496	115	620	1209	149	103	174	3
Winter Wheat...	863	23.4	20	350	50	44	202	149	44	4
Fallow.........	1508	50.5	18	208	79	120	256	762	62	3
Sugar Beets....	25	56.0	6	2	2	0	1	0	14	0
Totals.........	12225		826	4946	2345	1517	1011	1156	391	33

Overall performance 61.4%

Table 49--Classification matrix of select fields in frame 1060-16512 classification, using statistics from select fields in frame 1061-16570.

Class	No. of sample points	Percent Correct	Number of samples classified into: Alfalfa	Pasture	Corn	Grain Sorghum	Threshold
Alfalfa..	43	0.0	0	41	0	1	1
Pasture..	172	100.0	0	172	0	0	0
Corn.....	51	0.0	3	7	0	41	0
Grain Sorghum..	78	33.3	7	28	15	26	2
Totals...	344		10	248	15	68	3

Overall performance 54.4%

Table 50 is a classification of all identifiable fields in the segments in frame 1060-16512, using the statistics generated from the select fields in frame 1061-16570. The classifications with an overall performance of 65.5% and an average class performance of 48.5% are very good. Here again, it was the correctly classified pasture points which kept the averages high. In Table 50, more fields were classified and the influence of prior probabilities was more beneficial than in the cases where select fields were classified.

Table 51 shows a classification of select fields in frame 1061-16570, using statistics generated from all fields in frame 1060-16512. In this study the overall performance slipped to 49.0% but the average class performance was 59.1%. Classification was very good in all classes except corn, which was confused with pasture and grain sorghum. The time of year may have caused this confusion.

5. The border of Stevens County, Kansas was drawn on a grey-scale map of MSS band 5. The area was then defined on punch cards and classified. Training data for the classification were obtained from segments in the Crop Reporting District which contains Stevens County. Three of these segments were actually in Stevens County. A total of 410,505 pixels were classified which correspond to a calculated 466,560 acres in the county.

Table 50--Classification matrix of all fields in frame 1060-16512 classification, using statistics generated from "select fields" in frame 1061-16570.

Class	No. of sample points	Percent Correct	Number of samples classified into				
			Alfalfa	Pasture	Corn	Grain Sorghum	Threshold
Alfalfa..	43	65.1	28	3	0	12	0
Pasture..	6378	93.2	7	5943	11	277	140
Corn.....	332	7.5	8	79	25	204	16
Grain Sorghum..	508	28.3	16	105	75	144	168
Totals...	7261		59	6130	111	637	324

Overall performance 85.5%

Table 51--Classification matrix of select fields in frame 1061-16570 classification, using statistics generated from "all fields" in frame 1060-16512.

Class	No. of sample points	Percent Correct	Number of samples classified into				
			Alfalfa	Pasture	Corn	Grain Sorghum	Threshold
Alfalfa..	78	80.8	63	12	0	0	3
Pasture..	230	94.3	0	217	4	8	1
Corn.....	337	9.2	5	140	31	161	0
Grain Sorghum..	177	52.0	12	30	43	92	0
Totals...	822		80	399	78	261	4

Overall performance 49.0%

Alfalfa, pasture, corn, and grain sorghum were the crops classified. The following classification was obtained:

Number of Pixels	Alfalfa	Pasture	Corn	Grain Sorghum	Threshold
410,505	5,362	172,021	30,448	165,107	37,567
	1.3%	41.9%	7.4%	40.2%	9.2%

The prior probabilities as a percentage which were applied were the following:

Alfalfa	3%
Pasture	72%
Corn	9%
Grain Sorghum	16%

There is confusion between pasture and grain sorghum. Ways to use this data to produce a final estimate will be discussed in the section on estimation.

South Dakota

The test site in South Dakota is in the eastern part of the State. Figure 1 shows this Crop Reporting District.

Analysis of LANDSAT Data in South Dakota

Objectives:

The objective of this section was to determine the classification accuracy in the South Dakota test site.

Approach:

Imagery for three dates was available. However, the August and early September imagery was too cloudy to be useful. Thus, later September imagery was used. All 34 segments were contained in one LANDSAT frame (1060-16491). The segments and fields within segments were located and defined on punch cards. These segments were used for both training and classifying.

The LARS classifier with unequal prior probabilities was used. The classifier is a standard discriminant analysis.

Tabld 52 presents a classification of pixels in all segments in South Dakota. The overall performance was 30%, but the average class performance was 15%. Almost all classes in Table 52 were classified as either pasture or oats.

There were two reasons for this. First, prior probabilities used were large for pasture and oats, and second, the spectral data is quite similar at this period of time for all crops.

An attempt to improve the classification results was made by selecting fields that looked homogeneous.

These selected fields were used as training data and then classified. The results of this classification are presented in Table 53. The overall performance was 26% and the average class performance was 44%. There appears to be very little information in the data which would aid in the separation of crops. The influence of the prior probabilities again was the reason pasture and oats had high correct classification rates.

There must be reasons for the very poor classification rates. As an attempt to determine the reasons for the poor results, we have studied the means and covariances. They are in Table 54. It appears to be impossible to separate these classes with this data. Simply looking at the data does not necessarily show the true multivariate situation in four dimensional - but it does give an indication.

<u>Summary</u>

In South Dakota, late September imagery was used because of cloud cover in earlier imagery. Classification results were poor. Examination of Table 54 showed very little information in the data for the separation of the classes of interest. This late in the season, crops were classified as either pasture or oats.

The use of homogeneous fields selected from gray scale printouts and ground truth did not improve classification, and actually reduced the overall performance rates.