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1983 Missouri Crop and Landcover Study

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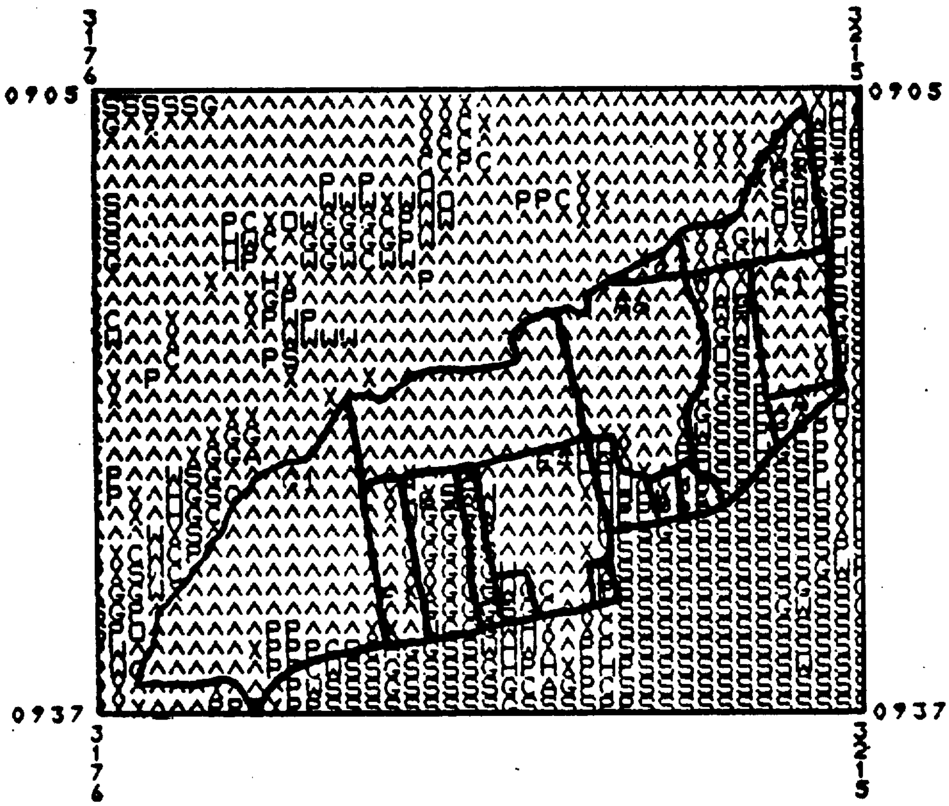

SEGMENT 8146 PART 1 OF 1

COVER: An outline of a JES segment with field boundaries, over the corresponding classified Landsat data. Classified data are as follows:

Symbol	Cover
C	Corn
Λ	Dense woodland
H	Other Hay
P	Permanent pasture
G	Sorghum
S	Soybeans
X	Waste
W	Winter Wheat
O	Oats

1983 MISSOURI CROP AND LAND COVER STUDY

BY

GEORGE MAY, MARTIN HOLKO, AND NED JONES

ABSTRACT

State-level classifications and estimates were made for five major crops and 23 land covers in Missouri during 1983. Crop Estimates were provided to the Crop Reporting Board of the Statistical Reporting Service in a timely manner. All the ground data were collected during the operational June Enumerative Survey (JES). JES direct expansion estimates are compared with the regression estimates created by combining the Landsat data and the JES data. Both unitemporal and multitemporal Landsat data were processed. Staff-hour requirements and computer costs for analyzing the crops and land covers were tracked through the entire project and are presented in different analysis scenarios.

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I. INTRODUCTION

USDA's Statistical Reporting Service (SRS) uses digital data from the Landsat satellite to improve precision of crop-area statistics based on ground-gathered survey data. This is accomplished by using Landsat digital data as an auxiliary variable in a regression estimator. Several reports (1, 2, 3) discuss results from this procedure applied to major crops in the Midwest. The SRS Landsat procedure for estimating major crops in the Midwest consists of the following steps:

1) Ground truth collected during an operational survey plus corresponding Landsat data are used to develop discriminant functions which in turn are used to classify Landsat pixels representing specific ground covers.

2) Areas sampled by the ground survey are classified and regression relationships developed between classified results and ground truth.

3) All of the pixels in the area of interest are classified.

4) Crop-area estimates are calculated by applying the regression relationships to the all-pixel classification results.

In 1981 SRS conducted a research project in Kansas to determine if it was feasible to extend the Landsat analysis procedure used for crop acreage estimation to estimate acreages for desired land-cover categories (4). In this study, the Landsat analysis for land cover was conducted independently of the crop analyses conducted by other SRS Remote Sensing Branch personnel. This research indicated the following: 1) deficiencies in the ground data for certain land covers, 2) a need to conduct a similar study in an area having more diverse land cover types, and 3) a need to use multitemporal Landsat data to improve land-cover classification. In 1982 Missouri was selected for continuing the land-cover research. Ground data were collected but no analyses were conducted due to insufficient Landsat data. Lack of cloud-free imagery throughout the growing season resulted in Landsat coverage for only 25 percent of the State.

In 1983 the land-cover research was continued in Missouri. The following changes in remote sensing procedures were made:

1) Areas of land previously defined as nonagricultural land were further categorized into specific land-cover types such as residential, idle, grassland, etc. (See Appendix A).

2) Additional ground data samples were selected in the nonagricultural strata to improve land-cover estimates.

3) Two dates of Landsat imagery were used.

II. OBJECTIVES

Objectives of the 1983 Missouri crop and land-cover study were:

1) Provide the SRS Crop Reporting Board (CRB) with estimates of crop area for winter wheat, rice, cotton, corn, and soybeans from a combined crop and land-cover Landsat analysis.

2) Provide area estimates for desired land covers from the combined analysis.

3) Provide a detailed classification of forest covers.

4) Produce classified data tapes of Missouri land covers.

5) Determine the additional cost of land cover analysis above the cost for crop analysis only.

6) Determine potential users of land cover analysis and their information needs.

III. GROUND DATA

During late May and early June each year, SRS conducts a nationwide survey called the June Enumerative Survey (JES). The JES uses an area-frame sampling technique (5) to sample areas of land called segments. The segments are selected through stratified sampling with the stratification based on percent cultivation. Table I lists the stratum definitions for the Missouri area frame and the number of segments in the population and the sample size.

Table I. Missouri, Area Frame and 1983 JES Sample Size used with the Domestic Crop and Land Covers

Stratum		Population size	Sample size no.
10	50+% cultivated	26,027	100
15	15-50% cultivated	969	4
20	50+% cultivated	13,372	75
25	15-50% cultivated	4,275	17
30	50+% cultivated	23,672	90
35	15-50% cultivated	4,556	17
40	50+% cultivated	14,253	50
45	15-50% cultivated	5,631	21
50	50+% cultivated	7,558	50
55	15-50% cultivated	670	2
91	Agri-urban	7,100	23
92	Agri-urban	4,629	12
I	Woodland	2,959	56
	Total	112,712	517

During the JES, each sample segment is visited by an enumerator who records all the field boundaries on an aerial photograph. The field acreage and cover type are recorded for each field in the segment. A field is an area of land with one continuous cultural practice under one ownership or management within the segment.

Because of late planting, some fields recorded at the time of the survey may contain crops that the farmer intends to plant. To insure the accuracy of the data for this project, these fields were revisited in August and any discrepancies with the data recorded in June were corrected.

The following modifications to the operational JES were necessary to aid the estimation of acreage of desired land covers.

A. Land Cover Definitions

Potential users of SRS-generated land-cover data were contacted to determine what land-cover types should be included in this study. Land-cover terms were defined in a manner that minimized additional training for SRS enumerators. The final list land covers and their definitions are listed in Appendix A.

B. Survey Forms

The addition of land cover required some modification to JES forms. Appendix B.1 shows a portion of the operational JES Part-ID form. The Part-ID is used for screening of segments for farm operations. Appendix B.2 shows the corresponding portion of the Part-ID used for this study. Column 13 was divided into four fields to allow entry of codes for different land covers contained within a tract. A tract is an area of land within a segment composed of one or more fields under the same ownership or management. In addition, the land covers were printed in the right-hand margin. Appendix C.1 shows the crops section of the operational JES questionnaire. Appendix C.2 shows the corresponding crops section used for this study. The changes were confined to questions 4 and 5. Question 4 was subdivided to allow the enumerator to separate nonagricultural land into a specific land cover or record it as waste (usually less than 3 acres) contained within a cropland field. Question 5 was subdivided to encourage the enumerator to identify native pasture separately from the standard permanent-pasture category. The land covers were also listed in the right-hand margin of the page.

C. Sample Size

Experience obtained in Kansas indicated that certain land covers were not adequately represented in the operational JES. This resulted in insufficient ground data for classifier training and acreage estimation. Forest is an important and extensive land cover in Missouri. In examining results from previous years, one could see that the sample allocation for the operational survey did not adequately sample forest land, especially coniferous forests, for land-cover work. For additional ground data, 67 segments from the nonagricultural and 15-50 percent cultivated strata were selected. Table 2 shows the allocation of these segments by strata.

NASA obtained low-altitude, infrared aerial photography over the additional segments during early spring of 1981 and 1982. Hard-copy prints at 8 inches to the mile were produced for each segment. These segments were photointerpreted for the forest, urban, and water land-cover categories. The reason for photointerpreting instead of adding the segments to the operational survey were: 1) adding these segments for ground enumeration would burden the enumerators and increase cost, 2) experience in Kansas indicated that enumerators have a difficult time correctly enumerating large non-agricultural segments due to inaccessibility, and 3) the goal was to improve the estimates for forest land which could easily be identified on infrared photography. Using 1- or 2-year old photography did not present a problem since forest, urban, and water land covers change slowly.

Table 2. Allocation of Additional Segments

Stratum	Land type	Sample size
		No.
1	(Woodland)	49
15	15 - 50% cultivated	1
25	15 - 50% cultivated	4
35	15 - 50% cultivated	3
45	15 - 50% cultivated	4
91	Agri-urban	3
92	Agri-urban	3

D. JES Edit

A detailed edit of the JES data was conducted at the Missouri State Statistical Office (SSO). As an aid for the edit, aerial photography of each JES segment was obtained from the Agricultural Stabilization and Conservation Service (ASCS) in Missouri. These photographs were used to verify field boundaries on older JES photographs. Since some enumerators had a tendency not to draw off the noncrop land fields in the 3- to 6-acre size range, the ASCS photography allowed the editor to break out these additional fields.

E. Multiple-Date Ground Data

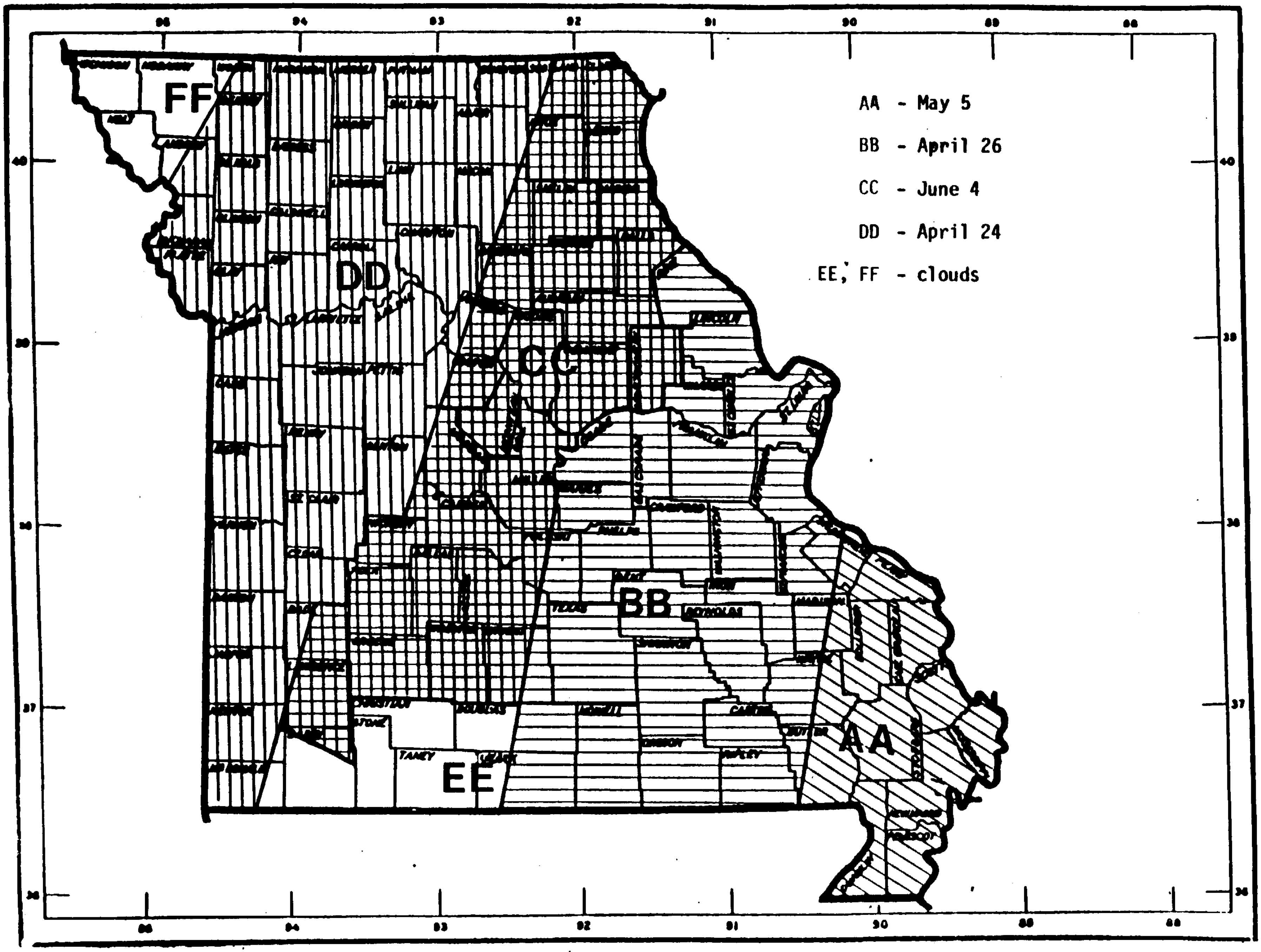
Since two dates of Landsat data were being used for this study, it was necessary to maintain a ground data set with two observations for each field within a segment. Cover 1 corresponded to the ground cover that would appear first during the crop year. Cover 2 corresponded to the cover that would exist second if different from cover 1.

IV. LANDSAT DATA

Two dates of Landsat data were used to 1) enable the estimation of crop acreages for both a spring harvested crop (winter wheat) and fall harvested crops (corn, soybeans, rice, cotton), and 2) improve land-cover classification results. Only spring imagery was used to produce Landsat regression estimates of winter wheat acreage. Figure 1 shows the analysis districts and Landsat dates which comprise the winter wheat study area. An analysis district is an area of land covered by Landsat imagery from the same overpass date or combination of dates.

For the summer-planted crops and the land-cover categories, two dates of imagery were combined to make up the Landsat data set wherever possible. This multitemporal data set was created by overlaying the fall imagery onto the spring imagery (6). The multitemporal data set contained eight channels of Landsat data for each pixel. The first four channels were the reflectance values from the spring date; the second four channels were the values from the fall date. Figure 2 shows the analysis districts used for all covers other than winter wheat. Notice that in figure 2, areas A, C, E, and G were covered with multitemporal data. Area I had only fall data, areas B and H had only spring data, and areas D and F had no Landsat coverage. This meant that direct expansion

Figure 1. Spring 1983 Landsat Coverage, For Missouri Winter Wheat Estimates



estimates produced from ground data were used for areas B, D, F, and H for acreage estimates of corn, soybeans, and rice because no satellite coverage was available. Direct expansion estimates were used for areas D and F for all land covers.

V. LANDSAT ANALYSIS

SRS Landsat analysis procedures consists of three primary steps: classifier development, classification-estimation, and accumulation.

A. Classifier Development

After the Landsat data and the ground data are put in computer-readable forrn and registered to each other, the segment field boundaries are located in the Landsat digital data. This results in a set of pixels for each cover type. When a field is doubled cropped (e.g., winter wheat followed by corn) the double cropping is considered to be a separate cover type. The pixels for each cover are then clustered using the Classy clustering algorithm (7). This produces several spectral signatures (categories) for each cover.

Each spectral signature consists of the mean vector and the covariance matrix of the reflectance values for each category. The statistics for all categories and cover types are then reviewed and combined to form the discriminant functions for a Gaussian Maximum Likelihood classifier for each analysis district (8).

B. Classification Estimation

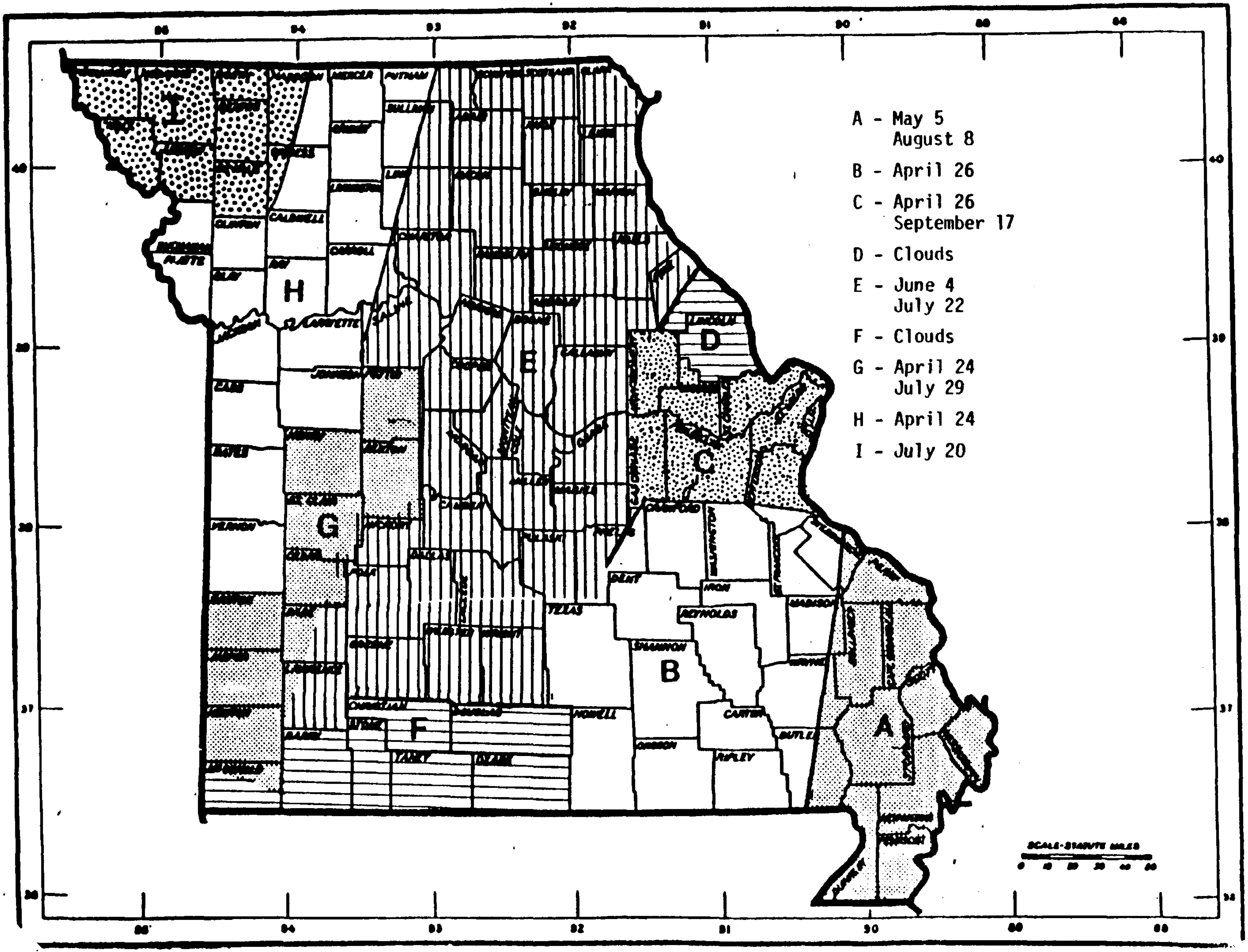
To reduce processing cost, the classification-estimation is done in two stages for each analysis district: small-scale and full-frame. In small-scale processing, each pixel associated with a segment is classified to a category. The number of pixels classified to each category is summed to segment totals by cover type. These totals are used as the independent (auxiliary) variable in a regression estimator. Corresponding to the segment total pixels classified to each cover, the reported acreages for each cover type are summed to segment totals and used as the dependent variable. The segment totals are used to calculate least squares estimates of the parameters for the single-variable regression estimator. A separate regression estimator for reported acreage is developed for each crop or land cover in each stratum.

In full-frame processing, every pixel in the Landsat scene is classified with the classifier selected from small-scale processing. The classified results are then tabulated by category and stratum. For each cover used in small-scale processing, the category totals are summed to stratum totals. From these tabulations, population averages of the number of pixels per segment by stratum are calculated. A regression estimate for the acreage of each crop or land cover is made for each stratum through use of population averages. The stratum estimates are then summed to an analysis district estimate.

C. Accumulation

In the accumulation step, a direct-expansion estimate is computed from the ground data for all areas for which a regression estimate does not exist. This direct-expansion estimate is then summed with the analysis district regression estimates to obtain a State-level acreage estimate (11).

Figure 2. Multi-Temporal Landsat Data Coverage For Missouri Summer Crop Estimates and Landcover Estimates



D. Overall Approach

Two Landsat analyses were completed for the study (fig. 3). First, a complete analysis was conducted using spring Landsat data to estimate winter wheat acreages. Second, the summer crop analysis was conducted using the multitemporal Landsat data; however, in some areas only fall data was available, so only unitemporal Landsat data were used. Fall crop analysis was conducted so that classifier development and classification included all land-cover categories, thus reducing processing. Analysis district A (fig. 2) was the first area analyzed since it contains nearly all of Missouri's rice and cotton. After this analysis was completed, State-level estimates for corn and soybeans were produced. After the analysis of the areas used for crop acreage-estimates were completed and estimates delivered to the CRB, analysis districts B and H were analyzed for land covers only. Land-cover estimates were then calculated for all analysis districts shown in figure 2 and State-level estimates produced.

VI. RESULTS

The CRB was provided timely direct expansion and regression estimates in December 1985 for winter wheat, cotton, rice, corn, and soybeans. The ratio of the variance of the direct expansion (which uses JES data only) to the variance of the Landsat regression estimate defines the relative efficiency (R.E.) of the regression estimator. It is the factor by which the ground data sample would have to be increased to produce direct expansion estimates with the same precision as the regression estimates.

A. Winter Wheat

Landsat regression estimates for Missouri winter wheat were made for the first time in 1983. Regression estimates for planted and harvested acreage are shown in Table 3 . The relative efficiencies of 1.8 and 1.9 are not as high as desired. Part of the reason for the poor results may be the USDA Payment in Kind (PIK) program implemented in early 1983. PIK enabled farmers to enroll acreage normally planted to winter wheat in a program guaranteeing the farmer a specified number of bushels of winter wheat from government reserves for not planting the acreage; however, the program was implemented after the winter wheat was planted, so acreage enrolled in the program had to be destroyed before mid-June. This situation caused some confusion in the Landsat data for both the planted and harvested acreage estimates. For the planted acreage estimate, there was some acreage called "winter wheat planted" that had been destroyed under the PIK program prior to Landsat overpass date. The classifier did not classify these fields as winter wheat, reducing the correlation between reported winter wheat planted and classification results. Similarly, there were fields of winter wheat under the PIK program which had not been destroyed by the time of the Landsat overpass. These fields were classified to winter wheat; however, they were not recorded as winter wheat harvested acreage, which resulted in poor correlation between reported harvested acreage and the classification results.

B. Cotton

Landsat regression estimates for cotton acreage were produced for the first time in 1983. In Missouri, cotton is isolated to a very small area, known as the "Boot Heel" (analysis district A, fig. 2). This isolation has two effects on the results of our Landsat analysis. First, the JES is not designed to efficiently estimate isolated crops like cotton in Missouri as shown by the high CV of the direct expansion estimate in Table 3. Second, the processing necessary to produce the Landsat regression estimate is reduced because Landsat analysis is needed only for the area where the crop is grown.

Figure 3. Landsat Data Processing and Estimation Steps

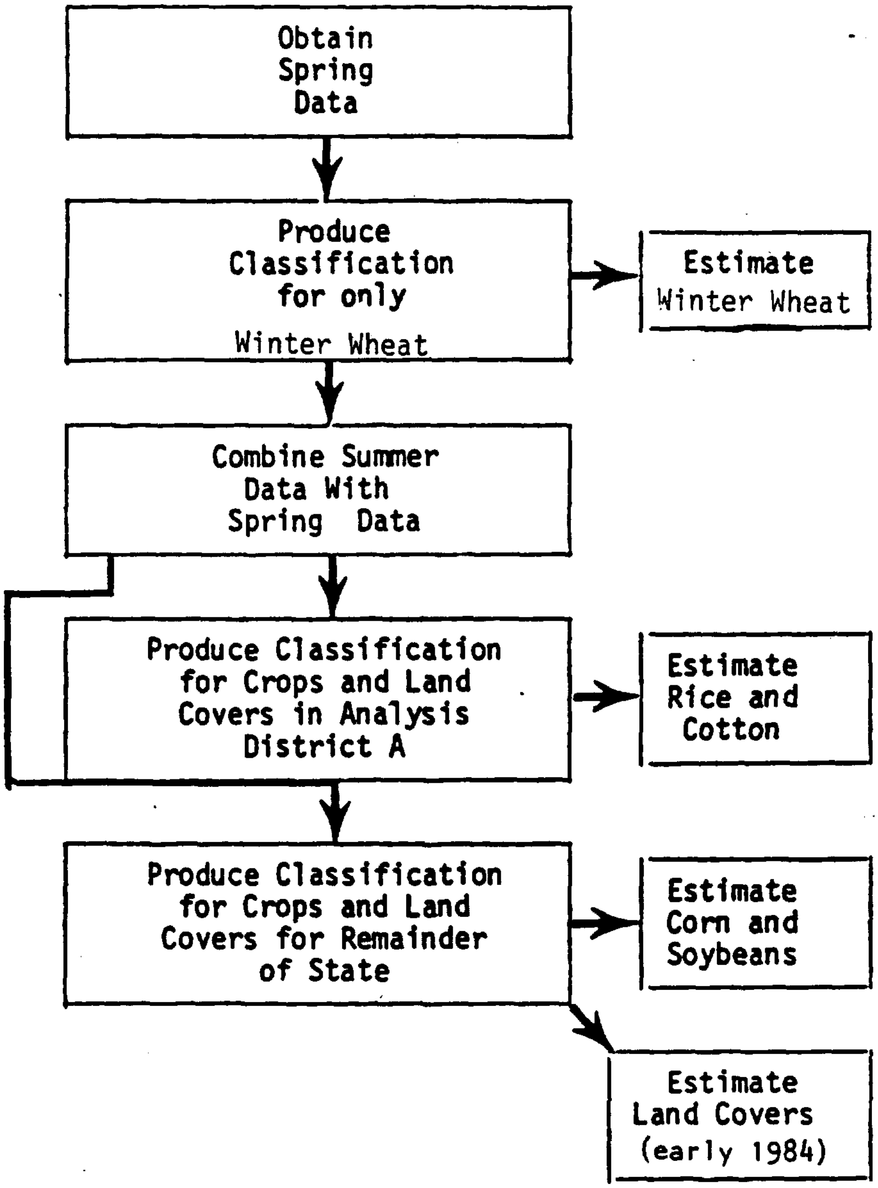


TABLE 3. **JES Direct Expansion Estimates and Landsat Regression Estimates, Missouri, 1983**

Crop	Direct Expansion Estimate	Direct Expansion Standard Error	Direct Expansion CV	Regression Estimate	Regression Standard Error	Regression CV	R. E.
	(1,000 Acres)		Pct.	(1,000 Acres)		Pct.	Unit
Winter Wheat (Planted)	2,229	174	7.8	2,314	131	5.7	1.8
Winter Wheat (Harvested)	2,041	162	8.0	2,140	120	5.7	1.9
Cotton (Planted)	62	35	56.6	75	11	14.7	11.1
Rice (Planted)	128	54	42.2	113	24	12.8	5.1
Corn (Planted)	1,762	140	7.9	1,555	110	7.0	1.6
Soybeans (Planted)	5,556	303	5.4	4,961	239	4.8	1.6

1/ Analysis district direct expansions estimates, standard errors, and coefficients of variation (CV) are SRS Remote Sensing Branch direct expansions.

2/ R. E. is the relative efficiency of the estimate. It is the proportional increase in the ground data sample size required to produce estimates of the same precision as those obtained from ground data and Landsat data combined.

Despite the potential and reported gain (R.E. greater than 1), further investigation is necessary to determine the validity of Landsat regression estimates for crops like cotton. In the case of Missouri, the CRB estimated 108,000 acres of cotton based on other survey indications. Although the regression estimate of 75,000 acres is closer to the board than the JES direct expansion, it is statistically different from 108,000 at the 0.05 level of significance. This statistical difference may be due to an underestimate of the Landsat regression estimators variances (9).

C. Rice

Like cotton, rice is also isolated to "Boot-Heel" area of Missouri. In addition to the advantages mentioned for cotton, rice exhibits a spectral reflectance pattern that makes it easier to classify than other crops and, therefore, should provide a good regression estimate. The rice Landsat regression estimate (Table 3) was statistically different at the 0.05 level of significance from the CRB's estimate of 63,000 acres planted. The JES direct expansion was also larger than the CRB estimate, but not significantly different. Again, the Landsat regression estimators variance may be underestimated. Note that this is a reworked Landsat regression estimate.

The initial regression estimate (Table 4) was larger. Two concerns prompted a re-examination of the estimate. First, like cotton, the Landsat regression estimate was greater than the JES direct expansion; however, unlike cotton, the CRB estimate was less than the JES estimate. Second, a Landsat regression estimate for Missouri rice was produced in 1981. The JES direct expansion was 116,000 acres that year, the Landsat regression was 76,000 acres, and the CRB final estimate was 77,000 acres.

The first step in the re-examination of the rice estimate was to confirm the JES data used. This examination revealed a 42.5 acre field recorded as rice on the JES. In the followup survey, this field was changed to idle cropland. This change, however, was not made in the data used for calculating the rice estimate. Correcting this error resulted in over a 6,000 acre reduction in the estimate.

Secondly, the classifier used in the original Landsat analysis was re-examined. In the original analysis, the classifier was made up of all categories identified by the Classy clustering algorithm for all crops. This resulted in some categories being generated from a small number of pixels (i.e. less than 75). Based on previous studies (9), it was hypothesized that these categories were affecting the classification results. To verify this, most categories created by fewer than 75 pixels were discarded. Table 5 shows the number of categories eliminated. Some categories for land covers were kept with fewer than 75 pixels because of the limited amount of training data available.

Table 4. Initial and Reworked Rice Landsat Regression Estimates Compared with Crop Reporting Board (CRB) Estimates, Missouri, 1983

Estimate	LANDSAT Regression		State Total	
	Estimate	Standard error	Estimate	Standard error
		Acres		
Initial	131,577	20,277	149,399	26,972
Reworked	91,993	11,797	113,004	24,068
CRB	-	-	63,000	-

Results of the revised Landsat analysis are shown in Table 4. The new analysis resulted in an additional reduction of over 33,000 acres; however, redefining of analysis boundaries increased the non-Landsat analysis area by more than 3,000 acres. The revised regression estimate was reduced to 113,000 acres. This is still statistically different from the CRB estimate at the 0.05-level of significance. As with cotton, this statistical difference could be due to an underestimate of the regression estimator's variance.

Table 5. Categories Containing Fewer Than 75 Pixels in the Rice Analysis

Category Name	Categories Number	Pixels per category
Winter wheat	2	62, 56
Sorghum	4	74, 66, 39, 74
Other hay	1	60
Corn	2	35, 56
Soybeans	8	68, 46, 76, 95, 54, 84, 44, 54
Rice	5	30, 20, 46, 21, 65
Cropland pasture	1	38
Cotton	1	38
Total	25	

D. Corn and Soybeans

Corn and soybean regression estimates were produced for areas A, C, E, G, and I in figure 2. Table 3 shows the acreages estimates for corn and soybeans.

Despite the use of multitemporal data, the R. E. of 1.6 for corn and soybeans was poorer than the 2.1 and 2.2 obtained in 1981 when analysis was done for crop acreage only. Part of the loss in efficiency was due to the lack of Landsat coverage in analysis district H (Fig. 2). Landsat data were available for the corresponding area in the 1981 study.

E. Land Cover

The direct expansion and regression estimates for land covers are listed in Table 6. Two land covers have large acreage differences between their respective types of estimates. The regression estimate for row crops is 798,000 acres less than the direct expansion estimate. This trend is also indicated in Tables 18 and 19 for corn and soybeans. A major portion of the decrease in row crops came from stratum 10 which had 380,000 fewer acres in the regression estimate. No explanation for these difference could be found. The two estimates cannot be compared using a t-test because they are not independent. Also, the regression estimate variance may be underestimated.

The hardwood regression estimate increased by 640,000 acres. Table 7 compares the hardwood direct-expansion and regression estimates by analysis area. The major difference between the two estimates is found in analysis district B (fig. 2). A breakdown by strata for the area indicates that most of the increase is in stratum 45 which has a direct-expansion estimate of 542,000 and a regression estimate of 1,135,000. The r-square for the regression is 0.80 and the stratum contains six segments of which five are heavily forested.

TABLE 6. **JES Direct Expansion Estimates and Landsat Accumulation Estimates, Missouri, 1983**

Land Cover	DIRECT EXPANSION			ACCUMULATION			
	Estimate	Standard Error	CV	Estimate	Standard Error	CV	Relative Efficiency
	--1,000 acres--		Pct.	--1,000 acres--		Pct.	R. E.
Row crops	8,540	362	4.2	7,742	246	3.2	2.2
Sown crops	2,391	175	7.3	2,548	127	5.0	1.9
Idle/cropland	2,100	164	7.8	2,016	139	6.9	1.4
Hay	3,110	197	6.4	2,981	171	5.7	1.3
Cropland/pasture	1,435	234	16.3	1,246	150	12.0	2.4
Other pasture	7,699	424	5.5	7,624	380	5.0	1.2
Farmsteads	385	23	6.1	387	24	6.0	1.0
Hardwood	10,500	529	5.0	11,140	443	4.0	1.4
Conifer	182	43	23.9	188	22	11.6	4.0
Conifer-Hardwood	1,150	248	21.6	1,148	245	21.4	1.0
Grazed Forest	2,885	298	10.3	2,706	300	11.1	1.1
Brushland	1,286	143	11.1	1,319	139	10.5	1.1
Idle grassland	1,403	140	10.0	1,331	133	10.0	1.1
Residential	963	105	10.9	823	96	11.6	1.2
Commercial	328	82	24.9	306	41	13.6	3.9
Other urban	140	39	27.9	123	30	24.7	1.7
Transportation	297	53	18.0	289	53	18.5	1.0
Lakes	308	119	38.7	265	109	40.9	1.2
Ponds	84	18	20.8	84	13	15.6	1.8
Rivers	130	44	33.8	104	23	22.5	3.5
Disturbed land	44	18	40.1	42	16	37.7	1.2
Transitional	183	138	75.0	-	-	-	-
Wetlands	107	87	81.8	-	-	-	-

TABLE 7. Comparison of Direct Expansion and Regression Estimates for Hardwoods by Analysis District, Missouri, 1983 Land Cover

	DIRECT EXPANSION		REGRESSION	
Analysis	Acres	CV	Acres	CV
	1,000 Acres	Pct.	1,000 Acres	Pct.
A	699	18.4	659	19.2
B	3,605	8.0	4,219	4.0
C	1,064	18.7	744	6.3
D/F	1,064	20.2	1,064	20.2
E	2,918	9.1	2,872	6.9
G	575	17.7	667	11.2
H	816	13.2	753	10.7
I	208	21.2	165	19.0
STATE TOTAL	10,500	5.0	11,140	4.0

TABLE 8. Comparison of 1983 Forestland Estimates from SRS Landsat Study with 1972 Forest Service Estimates, Missouri

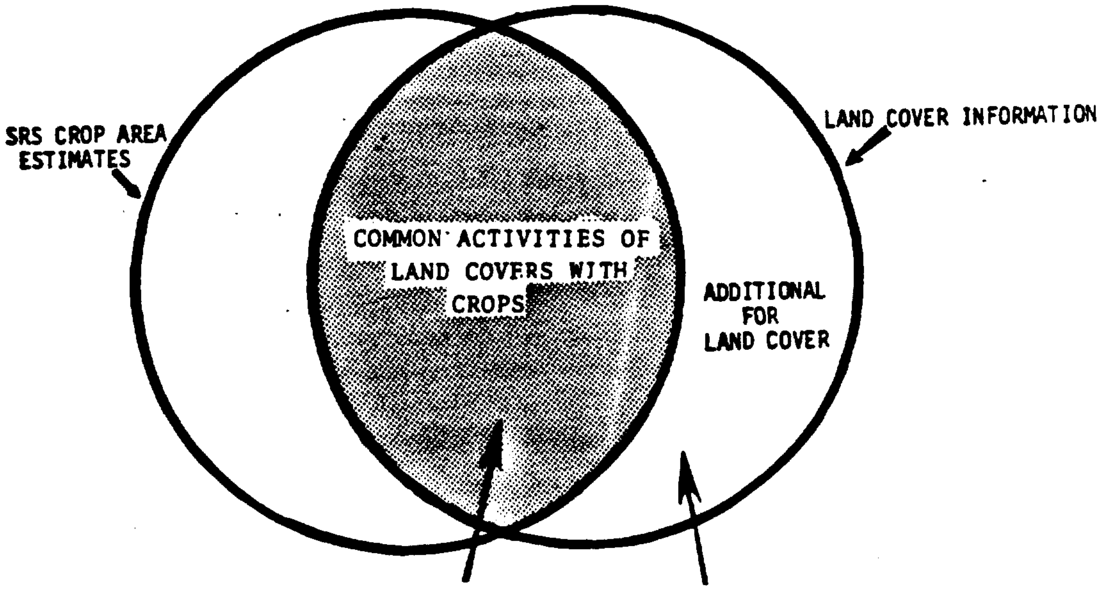
Category	SRS	FS
	---1,000 acres---	
Hardwood	11,140	11,620
Conifer	188	204
Conifer-Hardwood	1,148	541
(unproductive)	-	298
(reserved)	-	256
TOTAL	12,476	12,919
Grazed	2,706	2,803

Potential users of the land-cover data who participated in defining terms for this project were very interested in the outcome of the forestland estimates. The latest State survey conducted by the Forest Service (FS) was in 1972 (10). Table 8 compares SRS and FS estimates for these various categories. The "unproductive" and "reserved" categories are special breakdowns by the FS for hardwoods and conifers. This study was not able to provide estimates for these specialty categories, but the acreages associated with these categories are contained in the estimates from this study for hardwood, conifer, or conifer-hardwood. Since the 1972 FS survey, there has been forest-to-cropland conversion in Missouri, especially north of the Missouri River. Comparison of the Landsat study total forestland estimate to the FS estimate supports this decline.

VII. COSTS

An overall objective of the 1980-83 land-cover studies was to determine if the cost for obtaining SRS crop-area estimates from remote sensing could be reduced by providing land-cover information on a reimbursable basis to other users. As shown in figure 4, there are several activities and costs that are common to both crop and land-cover analyses.

Figure 4. COST EFFECTIVENESS FOR CROP AND LAND COVER ANALYSES.



- GROUND DATA COLLECTION
- LANDSAT DATA COSTS
- LANDSAT/SEGMENT REGISTRATION
- SEGMENT DIGITIZATION

- INCREASED TIME FOR:
  - Enumeration
  - Data Editing
  - Classification
  - Estimation

A specific objective of the 1983 study was to determine costs for obtaining the various crop and land-cover estimates. The following is a breakdown of these costs.

A. June Enumerative Survey

Adding 23 land covers to the survey in 1982 and 1983 resulted in a 2.2-percent increase in the JES cost when compared with the average cost of 1980 and 1981 when only crops were enumerated. A major reason for this small increase is that enumeration of land covers can be done by visual inspection with little time spent asking questions of tract operators. Many land covers are delineated while driving through a segment or from reviewing a current photograph of the segment. Some acreage determinations are made by planimetering or gridding land-cover fields. In many cases, this is more accurate than asking the tract operator because the operator may not know the acreage of a pond or a tract of wasteland that the enumerator has subdivided into several separate land-cover fields.

The JES enumeration costs for 1980-84 are shown in Table 9. The adjusted salary costs are reflected in 1980 dollars after adjusting for pay increases.

TABLE 9. Enumeration Costs for the JES Missouri, 1980-84

Year	Salary Cost	Pay Adjustment	Adjusted Salary Cost	Mileage Cost	Total Adjusted Cost
			Dollars		
1980	25,674	1.000	25,674	12,145	37,819
1981	28,291	.917	25,931	12,569	38,500
1982	31,623	.875	27,667	11,720	39,387
1983	32,574	.841	27,396	11,214	38,610

B. Ground Data Edit

The following are the staff-hours required to complete the ground data edit conducted by the Remote Sensing Branch with assistance from the SSO's:

1981: 121 staff-hours (crops only)

1983: 172 staff-hours (crops and land cover)

The addition of land covers increased the edit time by 42 percent. The editor examined all land-cover fields for proper enumeration and corrected any errors found.

C. Digitizing

To determine the amount of additional time needed to digitize land covers, a 5 percent subsample of segments was randomly selected from each stratum. Digitization is the process by which the segment field boundaries located on aerial photographs are recorded in computer-readable form. For each segment in the subsample, a record was kept on the time required to digitize the crop and land-cover fields for the 1983 project. A piece of acetate was then placed over the segment and a second field-level edit was conducted in the office. This second field-level edit was done according to survey procedures required to obtain only crop information. The segments were redigitized and the amount of time recorded. Total digitizing time for segments in the subsample edited only for crops was 472 minutes. Total time for segments edited for crops and land cover was 504 minutes, resulting in a 6.8 percent increase due to the land-cover fields. One reason for this small increase is that during the regular JES enumeration crops, wasteland and forests larger than 5 acres are delineated and digitized anyway.

D. Landsat Data

The following are the costs for Landsat materials:

Item	Dollars
Computer compatible tapes	15,330
1:250,000-scale prints	2,520
1:1,000,000-scale transparencies	1,470
Creation of multitemporal tapes	1,920
TOTAL	21,240

E. Landsat Analysis

Staff hours, CPU (min.), and computer costs were recorded for various steps required to process the Landsat data and to generate regression estimates. These steps and associated costs were tracked separately for winter wheat, summer crops, and land covers as shown in Tables 10, 11, and 12. The Bolt Beranek and Newman (BBN) DEC-10 and NASA/Ames, Cray 1-S computer billing figures used to convert minutes of CPU to computer costs are given in appendix D. It can be seen from this appendix that in order to determine computer cost for a single processing step, the CPU had to be recorded by computer type, and in the case of BBN, the shift in which the CPU time was incurred.

Several limitations of direct cost comparisons between winter wheat, summer crops, and land cover are caused by:

1) Winter wheat was estimated using spring Landsat data (unitemporal) while most of the corn, soybeans, rice, cotton, and land covers were estimated using spring and fall data (multitemporal).

2) A larger area of the State was estimated for winter wheat compared with the area for summer crops (compare fig. 1, areas AA, BB, CC, DD, with fig. 2, areas A, C, E, G, and I).

3) Most of the segments were manually shifted (precision registration) for winter wheat; therefore, very little cost was incurred for segment shifting in summer crops and land-cover estimates (Compare processing step 3 in all tables).

4) Areas B and H in figure 2 were analyzed only for land-cover estimates and the associate resource requirements represent a large percentage of the total costs given in Table 12. If these two areas had been processed for land covers during winter wheat analysis, the total resource costs for land cover would have been reduced. Comparing Landsat dates for areas B and H in figure 2 with the same areas in figure 1 indicates that the same Landsat data was processed twice. If the fall Landsat data anticipated for areas B and H had been available, these areas would have been analyzed for summer crops and land-cover estimates.

Some statements can be made by comparing the cost tables. There is a large increase in computer cost when classifying eight channels of data versus four channels. Comparisons of processing step 9 in Tables 10 and 11 indicate the magnitude of this increase. For the land-cover estimates, 52 percent of the total cost was incurred during small-scale estimation and proration/accumulation (steps 7 and 11). In their current configuration, the programs used in these steps are expensive to run. The programs use only one crop or land cover at a time; therefore, completing the land-cover work required 23 runs for each program. Current plans to rewrite the software for these steps should drastically reduce the computer time needed to estimate numerous land covers.

In order to compare resource requirements between different estimates, a common test area for Landsat estimation must be established. Such an effort was made using analysis districts A, C, E, G, and I in figure 2. Table 11 represents the cost of doing corn, soybeans, rice, and cotton for this area, except for manual segment shifting. Requirements for shifting the segments found in this area would be 39 staff-hours, 232 minutes of CPU, and $1,211 in computer costs. Inserting these values into step 3 results in a total cost of producing regression estimates for only summer crops (Table 13).

Table 10. Costs of Landsat Regression Estimates for Winter Wheat, Missouri, 1983

	Processing step	Staff-time	CPU time	Computer cost
		Hours	Minutes	Dollars
1.	Ground data edit	22	52	$ 271
2.	Determine analysis districts, segment coordinates, and pull segment windows	38	43	224
3.	Manual segment shifting and plotting	56	332	1,730
4.	Create segment masks, pack files, and scattergrams	36	296	1,184
5.	Clustering and statistics file editing	24	48	192
6.	Small-scale classification	28	*	270
7.	Small-scale estimation	35	61	281
8.	County mask generation and frame unit update	33	186	969
9.	Large-scale classification	27	*	1,387
10.	Large-scale aggregation/ estimation	17	51	266
11.	Proration and accumulation	18	74	386
12.	File management	29	38	198
13.	Connect time		(296 hrs.)	676
TOTAL		363	1,181	8,034

*Only computer-run costs tracked.

Table 11. Costs of Landsat Regression Estimates for Corn, Soybeans, Rice, and Cotton (summer crops), Missouri, 1983

	Processing step	Staff-time	CPU time	Computer cost
		Hours	Minutes	Dollars
1.	Ground data edit (terminal)	20	21	109
2.	Determine analysis districts, segment coordinates, and pull segment windows	34	84	406
3.	Manual segment shifting and plotting	5	23	119
4.	Create segment masks, pack files and scattergrams	28	339	1,625
5.	Clustering and statistics file editing	44	74	333
6.	Small-scale classification	14	*	457
7.	Small-scale estimation	45	122	634
8.	County mask generation and frame unit update	105	168	756
9.	Large-scale classification	57	-	2,622
10.	Large-scale aggregation/ estimation	22	86	387
11.	Proration and accumulation	26	118	615
12.	File management	33	50	260
13.	Connect time		(524 Hrs.)	1,299
14.	Create Multitemporal Tapes	*	*	1,920
TOTAL		433	1,085	11,542

*Only computer-run costs tracked

**Not available

Table 12. **Costs of Landsat Regression Estimates for Land Covers, Missouri, 1983**

	Processing step	Staff-time	CPU time	Computer cost
		Hours	Minutes	Dollars
1.	Ground data edit (terminal)	20	17	88
2.	Determine analysis districts, segment coordinates, and pull segment windows	15	20	92
3.	Manual segment shifting and plotting	10	52	270
4.	Create segment masks, Pack files and scattergrams	37	254	1,016
5.	Clustering and statistics file editing	48	45	180
6.	Small-scale classification	15	*	220
7.	Small-scale estimation	86	224	1,167
8.	County mask generation and frame unit update	38	42	193
9.	Large-scale classification	20		2,218
10.	Large-scale aggregation/ estimation	40	87	453
11.	Proration and accumulation	30	915	4,758
12.	File management	23	31	161
13.	Connect time		(300 hrs.)	690
TOTAL		382	1,687	11,506

*Only computer run costs tracked

What would be the cost if winter wheat estimates were obtained from the above analysis? In doing summer crops, the winter wheat data was also processed. The double-cropped winter wheat/soybeans were analyzed as a separate category and the single crop winter wheat was processed so that it could be combined with other sown crops in generating land-cover estimates. To obtain regression estimates for winter wheat from the summer crop analysis would require only increased resources for processing steps 1, 7, 10, and 11 which are ground data editing, small-large-scale estimation, and proration/accumulation, respectively. These steps are independent of the number of Landsat channels used; therefore, requirements incurred for these items in processing the spring data for winter wheat (Table 10) were added to summer crop requirements for the test area. Table 17 gives total requirements for simultaneously obtaining winter wheat and summer crop estimates. Some additional resource requirements would be needed for file management (step 12) and terminal connect time (step 13), but this increase would be very small compared with total costs.

Given the cost data generated from this project, it is impossible to obtain "winter wheat only" analyses costs for the test area. It is also very difficult to obtain accurate total cost figures for analyzing "land covers only." For example, processing steps 4 and 8 require creation of segment and county masks. Because summer crops and land covers were analyzed together, it is impossible to split these costs between the two groups. The cost was assigned to summer crops. The cost of estimating "summer crops and land covers" for the test area can be estimated as follows. Resource requirements for B and H were 142 staff-hours, 601 minutes of CPU, and a computer cost of $3,659. Subtracting these values from Table 12 and adding the remainder to summer crop analysis results in total costs shown in Table 13. Also given in Table 13 are the costs for simultaneously doing summer crops, winter wheat, and land cover.

Several assessments can be made from the data presented in Table 13. Analyzing and estimating winter wheat with summer crops required 16 percent more staff-hours and a 7.5 percent increase in computer costs. This is drastically cheaper than doing two separate analyses to estimate winter and summer crops. Although exact figures for doing only winter wheat in the test area are not available, an appreciation of the magnitude of these costs can be obtained by examining the totals at the bottom of Table 10. As mentioned earlier, these costs are for a larger percentage of the State than the Table 13 test area, but they are for unitemporal analysis; however, all cost figures in Table 13 are for multitemporal analyses.

Not doing a separate winter wheat estimate would free-up several hundred staff-hours during the spring and summer months. Since state estimates for winter wheat, cotton, and rice are required by December 7 and corn and soybean estimates are due December 14, a multitemporal analysis is preferable.

Analyzing and estimating the 23 land covers with summer crops required 51 percent more staff-hours and a 62 percent increase in computer costs. A majority of the land-cover costs was incurred during the estimation processes. Improving the efficiency of these programs will lower land-cover costs.

VIII. SUMMARY/RECOMMENDATIONS

Landsat-based acreage estimates for winter wheat, corn, soybeans, rice, and cotton were presented to CRB in a timely manner. Four channels of Landsat data (unitemporal) were used to produce the winter wheat estimates. The R. E.'s were not high as expected.

Table 13. Total Resource Requirements for Different Analysis Procedures Using a Common Test Area, Missouri 1983

Category	Staff Time	CPU Time	Computer cost
	Hours	Minutes	Dollars
Summer Crops	467	1,294	$ 12,634
Summer Crops and Winter Wheat	542	1,481	13,572
Summer Crops and Land Cover	707	2,380	20,481
Summer Crops, Winter Wheat, and Land Cover	782	2,567	21,419

Problems associated with the PIK program had a negative effect on the remote sensing analyses. Eight channels of Landsat data (multitemporal) were used to estimate acreages for the summer crops and land covers; however, the R. E.'s for corn and soybeans were lower than those obtained in 1981 using unitemporal data. A partial explanation of the lower R. E. was the lack of Landsat data in a large corn and soybean producing area. High R. E.'s were obtained for rice and cotton but the validity of the Landsat regression estimates for these specialized crops needs further investigation.

Area estimates for 23 land covers were produced after obtaining the crop estimates. In addition to the estimates, the classified Landsat data were saved on tape. The utility of the classified tapes will be assessed by potential users of the land-cover data.

Staff-hours and CPU time requirements to conduct the crop and land-cover study were tracked through the entire project. Combining winter wheat analyses with summer crops, thus, eliminating a separate unitemporal analysis for winter wheat, would provide considerable savings of resources. A considerable amount of CPU time was required to estimate the land covers; however, reconfiguration of the estimation programs and the ability to run these programs in batch mode would drastically reduce the cost of the land-cover analysis. The addition of land cover had minimal impact on data collection for the JES and digitizing costs.

The following recommendations are made based on this study.

1) SRS should pursue a cooperative agreement with other agencies to make land-cover estimates in the Domestic Crop and Land Cover DCLC States. This would allow us to share the DCLC technology and reduce the cost of producing DCLC crop estimates.

2) Further research is needed to improve classifier accuracy, and study the effect various factors such as drought have on spectral separability.

3) The estimation program in EDITOR should be changed so that the entire set of ground truth files do not have to be read each time a different cover is estimated in an analysis district.

4) In States such as Missouri where winter wheat and summer crops are estimated a single multitemporal data set should be used for both winter wheat and summer crops DCLC estimates.

5) Additional research is required to determine if the addition of land covers affected the classification results of summer crops.

Using the same statistical files to estimate crops as those used to estimate land cover may have an adverse affect on the crops estimates. The problem with the rice estimate may have indicated such a difficulty. A study making parallel crops estimates using a "normal" crop estimating statistical file and using land-cover statistical files may shed more light on this potential problem.

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APPENDIX A: LAND COVER TERMS AND DEFINITIONS

NATIVE PASTURE

Land on which the natural vegetation (presettlement) is predominantly grasses, grasslike plants, or forbs suitable for grazing and browsing use. If any of the natural vegetation is cut for hay, then these acres only should be included in cropland as "native hay."

CROPLAND PASTURE

Cropland in rotation pasture and all other cropland used or to be used for pasture or grazing during current year, excluding cropland grazed after harvest.

OTHER PASTURE

Pasture which does not properly fit the native or cropland pasture definitions. This category includes grasses, legumes, and other forage crops solely planted or interplanted with natural covers for grazing. Intensive management may include such things as reseeding, renovation, mowing, and fertilizing.

Exclude:
- -- Pasture acreage cut for dry hay (include as "other hay" in cropland)
- -- Pasture acreages in crop rotation
- -- Small grains pastured
- -- Woodland with more than 17 percent trees or canopy cover that is being grazed or pastured
- -- Native pasture

NATIVE HAY

Land on which natural vegetation is predominantly grasses, grasslike plants, or forbs cut for hay.

FOREST

Land cover by 17 percent trees or canopy cover.

CONIFER-- Forest that consist of 67 percent or more of any cone bearing such as pine, cedar, or any combination. These are trees that keep their needles or leaves year round.

HARDWOOD-- Forest that consist of 67 percent or more of any hardwoods such as oak, hickory, walnut, cottonwood, sycamore, elm, or any combination. These are deciduous trees; that is, they lose their leaves each fall.

MIXED-- Forest comprised of both conifer and hardwood with neither category dominating.

GRAZED FOREST

Land that meets the forest category, except the area is grazed by livestock.

RESIDENTIAL

Land used for single and multidwelling family residences. Residential land ranges from high density, as found in urban cores, to low density, where houses are located on lots of more than 1 acre. Many residential areas, such as housing subdivisions, display uniform spacing of buildings, lawns, and driveways. Housing situations existing on military bases, colleges, or living quarters for laborers near a work base should be placed within the Industrial, Commercial, and Services classification.

INDUSTRIAL, COMMERCIAL, AND SERVICES

Areas used predominantly for the production and sale of goods and services such as central business districts, shopping centers, commercial strip development, manufacturing plants, junkyards, and lumber mills. Institutions such as schools, churches, and military bases are also included.

TRANSPORTATION, COMMUNICATION, AND UTILITIES

These categories are often an integral part of a more dominant land use. Unless they can be readily mapped separately, they should remain a part of the larger land use. Railroads, airports, and major surfaced roads are typical examples of transportation. The communication and utility category should include substations, sewage treatment plants, gas and oil pumping stations, etc. Only paved roads with four lanes or more should be delineated.

OTHER URBAN

This category should be used for such things as zoos, golf courses, parks, cemeteries, waste dumps, etc. Lots and open grassland areas not considered a part of a residential dwelling should be included in other urban.

MIXED

Where two or more of the above categories (Residential, Commercial, Industrial, Transportation, and Other Urban) occur together and when the area for the smallest category exceeds 1/3 of the total area being delineated then it should be classified as mixed. If the smaller category is less than 1/3 the area delineated, then the category appropriate to the dominant land use is applied.

WATER (3 TO 10 Acres)

Ponds or lakes that contain water and are greater than 3 acres but do not exceed 10 acres.

WATER (10 TO 40) Acres

Lakes or irrigation reservoirs larger than 10 acres but less than 40 acres.

WATER (40 ACRES)

Lakes and reservoirs that contain water and are larger than 40 acres.

PERENNIAL STREAMS (66 TO 660 FEET)

Streams that contain flowing water and are wider than 66 feet but less than 660 feet wide from bank to bank.

RIVERS (660 FEET)

Rivers that contain flowing water and wider than 660 feet from bank to bank.

DRY STREAMBEDS

Streams that do not contain flowing water and are wider than 66 feet. If narrower than 66 feet, than place it in the surrounding landcover.

WETLANDS

Land with standing water having some vegetative growth such as swamps and marshes.

IDLE GRASSLAND

Grasses, legumes, and other forage crops not planted for grazing or harvesting, and do not qualify for the hayland or pasture categories. This would include such things as abandoned grassfields or a grass waterway used as a conservation practice.

BRUSH

Young woody vegetation not being used for pasture. Examples of this category are buckbrush, multifloral rose, and old unmanaged fields containing woody vegetation. If pastured, include in one of the pasture categories. Exclude areas being reestablished as forest.

STRIP MINES, QUARRIES, GRAVEL PITS

Include all extractive mining activities that have significant surface expression. Unused pits or quarries that have been flooded should be placed in the appropriate water category.

TRANSITIONAL

This category is used for areas which are in transition from one land use activity to another. The enumerator should avoid interpreting the past or future use. Examples of transitional areas are forestlands being cleared for agriculture, bare ground in development of a residential subdivision, and land being altered by sanitary landfills.

FARMSTEADS

That part of a farm or ranch that is occupied by the dwellings, buildings, corrals, gardens, and family orchards. Dwellings do not have to be occupied to be categorized as a farmstead.

APPENDIX B.1: OPERATIONAL PART-ID SURVEY FORM

11	12	13	14	15	16	19	20
OFFICE USE	How many acres are inside these blue lines?	LAND USE	Is at least 80% of tract in woods?	Does tract have potential for wheat or livestock before Jan. 1, 1985?	Will any crops be stored on this tract before Jan. 1, 1985?	Does tract operator live inside or outside segment?	Do any other persons living in this house operate a farm or ranch?
— —	846 .		832 ☐ YES = 1 ☐ NO →	818 ☐ YES = 1 ☐ DK = 2 ☐ NO = 3	807 ☐ YES = 1 ☐ DK = 2 ☐ NO = 3	☐ Inside → ☐ Outside Stop	☐ YES New line ☐ NO -Stop
— —	846 .		832 ☐ YES = 1 ☐ NO →	818 ☐ YES = 1 ☐ DK = 2 ☐ NO = 3	807 ☐ YES = 1 ☐ DK = 2 ☐ NO = 3	☐ Inside → ☐ Outside Stop	☐ YES New line ☐ NO -Stop
— —	846 .		832 ☐ YES = 1 ☐ NO →	818 ☐ YES = 1 ☐ DK = 2 ☐ NO = 3	807 ☐ YES = 1 ☐ DK = 2 ☐ NO = 3	☐ Inside → ☐ Outside Stop	☐ YES New line ☐ NO -Stop
— —	846 .		832 ☐ YES = 1 ☐ NO →	818 ☐ YES = 1 ☐ DK = 2 ☐ NO = 3	807 ☐ YES = 1 ☐ DK = 2 ☐ NO = 3	☐ Inside → ☐ Outside Stop	☐ YES New line ☐ NO -Stop
— —	846 .		832 ☐ YES = 1 ☐ NO →	818 ☐ YES = 1 ☐ DK = 2 ☐ NO = 3	807 ☐ YES = 1 ☐ DK = 2 ☐ NO = 3	☐ Inside → ☐ Outside Stop	☐ YES New line ☐ NO -Stop
— —	846 .		832 ☐ YES = 1 ☐ NO →	818 ☐ YES = 1 ☐ DK = 2 ☐ NO = 3	807 ☐ YES = 1 ☐ DK = 2 ☐ NO = 3	☐ Inside → ☐ Outside Stop	☐ YES New line ☐ NO -Stop
— —	846 .		832 ☐ YES = 1 ☐ NO →	818 ☐ YES = 1 ☐ DK = 2 ☐ NO = 3	807 ☐ YES = 1 ☐ DK = 2 ☐ NO = 3	☐ Inside → ☐ Outside Stop	☐ YES New line ☐ NO -Stop

A — 01
B — 02
C — 03
D — 04
E — 05
F — 06
G — 07
H — 08
I — 09
J — 10
K — 11
L — 12
M — 13
N — 14
O — 15
P — 16
Q — 17
R — 18
S — 19
T — 20
U — 21
V — 22
W — 23
X — 24
Y — 25
Z — 26
AA — 27
BB — 28
CC — 29
DD — 30
EE — 31
ETC.

APPENDIX B.2: MODIFIED PART-ID SURVEY FORM

12	13					15	16	18	19
How many acres are inside these blue lines?	For the acres in Col. 12, identify the land cover(s) and their associated acres which best describe the tract.					Does tract have potential for wheat or livestock before Jan. 1, 1984?	Will any crops be stored on this tract before Jan. 1, 1984? (Missouri only)	Does tract operator live inside or outside segment?	Do any other persons living in this house operate a farm or ranch?
846	Fld. No.	1	2	3	4	818	807		
	Cover					☐ YES = 1 ☐ DK = 2 ☐ NO = 3	☐ YES = 1 ☐ DK = 2 ☐ NO = 3	☐ Inside ▶ ☐ Outside Stop	☐ YES New line ☐ NO -Stop
	Code								
•	Acres	•	•	•	•				
846	Fld. No.	1	2	3	4	818	807		
	Cover					☐ YES = 1 ☐ DK = 2 ☐ NO = 3	☐ YES = 1 ☐ DK = 2 ☐ NO = 3	☐ Inside ▶ ☐ Outside Stop	☐ YES New line ☐ NO -Stop
	Code								
•	Acres	•	•	•	•				
846	Fld. No.	1	2	3	4	818	807		
	Cover					☐ YES = 1 ☐ DK = 2 ☐ NO = 3	☐ YES = 1 ☐ DK = 2 ☐ NO = 3	☐ Inside ▶ ☐ Outside Stop	☐ YES New line ☐ NO -Stop
	Code								
•	Acres	•	•	•	•				
846	Fld. No.	1	2	3	4	818	807		
	Cover					☐ YES = 1 ☐ DK = 2 ☐ NO = 3	☐ YES = 1 ☐ DK = 2 ☐ NO = 3	☐ Inside ▶ ☐ Outside Stop	☐ YES New line ☐ NO -Stop
	Code								
•	Acres	•	•	•	•				
846	Fld. No.	1	2	3	4	818	807		
	Cover					☐ YES = 1 ☐ DK = 2 ☐ NO = 3	☐ YES = 1 ☐ DK = 2 ☐ NO = 3	☐ Inside ▶ ☐ Outside Stop	☐ YES New line ☐ NO -Stop
	Code								
•	Acres	•	•	•	•				
846	Fld. No.	1	2	3	4	818	807		
	Cover					☐ YES = 1 ☐ DK = 2 ☐ NO = 3	☐ YES = 1 ☐ DK = 2 ☐ NO = 3	☐ Inside ▶ ☐ Outside Stop	☐ YES New line ☐ NO -Stop
	Code								
•	Acres	•	•	•	•				
846	Fld. No.	1	2	3	4	818	807		
	Cover					☐ YES = 1 ☐ DK = 2 ☐ NO = 3	☐ YES = 1 ☐ DK = 2 ☐ NO = 3	☐ Inside ▶ ☐ Outside Stop	☐ YES New line ☐ NO -Stop
	Code								
•	Acres	•	•	•	•				

A —	01	Q —	1
B —	02	R —	1
C —	03	S —	1
D —	04	T —	2
E —	05	U —	2
F —	06	V —	2
G —	07	W —	2
H —	08	X —	2
I —	09	Y —	2
J —	10	Z —	2
K —	11	AA —	2
L —	12	BB —	[illegible]
M —	13	CC —	[illegible]
N —	14	DD —	[illegible]
O —	15	EE —	[illegible]
P —	16	ETC.	

Land Cover Codes

873 Cn.F.
Forest-Conifer
874 H.F.
Forest-Hardwood
875 M.F.
Forest-Mixed
876 B.
Brush
877 I.G.
Idle Grassland
878 Wetl.
Wetlands
879 W3—10
Water 3 to 10 acres
880 W10—40
Water 10 to 40 acres
881 W > 40
Water > 40 acres
882 P.S. 66—660
Perennial streams
66—660 feet
883 R. 660 +
Rivers > 660 feet
884 SM, Q, GP
Strip mine, Quarries and Gravel Pit
885 Ind.
Industrial, Commercial and Servic
886 T.C.U.
Transportation, Communication, Utiliti
887 Res.
Residential
888 Mxd.
Mixed (Res., Trans., Ind., Com'l)
889 O. Urb.
Other Urban
890 Transit.
Transitional
891 U.F.S.
Farmsteads(Unoccup.
893 D.S.B.
Dry Stream Beds

APPENDIX C.1: OPERATIONAL SECTION-A SURVEY FORM

SECTION A — ACREAGES OF FIELDS AND CROPS INSIDE BLUE TRACT BOUNDARY

How many acres are inside this blue tract boundary drawn on the photo *(or map)*? .... Acres [•]

Now I would like to ask about each field inside this blue tract boundary and its use in 1984.

FIELD NUMBER	827 1	827 2	827 3	827 4	827 5
1a. Total Acres in Field	828 •	828 •	828 •	828 •	828 •
2. Crop or Land Use *(Specify)*					
3. Occupied Farmstead or Dwelling	843 •				
4a. Continuous Waste, Roads Ditches, etc. (5.0 acres or more)	831 •	831 •	831 •	831 •	831 •
4b. Continuous Woods (Include Grazed Woodland) (5.0 acres or more)	830 •	830 •	830 •	830 •	830 •
4c. Woods, Waste, Roads, Ditches, etc. (Non-continuous parcels)	829 •	829 •	829 •	829 •	829 •
5. Pasture — Permanent — Not in crop rotation	842 •	842 •	842 •	842 •	842 •
5. Pasture — Cropland — Used only for pasture	856 •	856 •	856 •	856 •	856 •
6. Two Crops Planted in this Field for harvest this year or two uses of the same crop?	☐ YES ☐ NO 844 •	☐ YES ☐ NO 844 •	☐ YES ☐ NO 844 •	☐ YES ☐ NO 844 •	☐ YES ☐ NO 844 •
7. Acres Left to be Planted?	61_ •	61_ •	61_ •	61_ •	61_ •
8. Acres Irrigated and to be Irrigated?	6_ _ •	6_ _ •	6_ _ •	6_ _ •	6_ _ •
11. Winter Wheat — Planted	540 •	540 •	540 •	540 •	540 •
12. Winter Wheat — For Grain	541 •	541 •	541 •	541 •	541 •
13. Rye — Planted and to be planted	547 •	547 •	547 •	547 •	547 •
14. Rye — For Grain	548 •	548 •	548 •	548 •	548 •
15. Oats — Planted and to be planted	533 •	533 •	533 •	533 •	533 •
16. Oats — For Grain	534 •	534 •	534 •	534 •	534 •
17. Barley — Planted and to be planted	535 •	535 •	535 •	535 •	535 •
18. Barley — For Grain	536 •	536 •	536 •	536 •	536 •
19. Corn — Planted and to be planted	530 •	530 •	530 •	530 •	530 •
20. Corn — For Grain	531 •	531 •	531 •	531 •	531 •
21. Sorghum *(Excl. crosses)* — Planted and to be planted	570 •	570 •	570 •	570 •	570 •
22. Sorghum *(Excl. crosses)* — For Grain	571 •	571 •	571 •	571 •	571 •
23. Other Uses of Grains Planted — Use					
Acres abandoned, silage, etc. — Acres	•	•	•	•	•
24. HAY — Alfalfa and Alfalfa Mixtures (Cut and to be cut for hay)	653 •	653 •	653 •	653 •	653 •
25. HAY — Grain (Cut and to be cut for hay)	666 •	666 •	666 •	666 •	666 •
26. HAY — Other Hay (Cut and to be cut)	654 •	654 •	654 •	654 •	654 •
27. Soybeans — Planted and to be planted	600 •	600 •	600 •	600 •	600 •
30. Rice — Planted and to be planted — Check Kind	☐ S ☐ M ☐ L	☐ S ☐ M ☐ L	☐ S ☐ M ☐ L	☐ S ☐ M ☐ L	☐ S ☐ M ☐ L
Acres	60_ •	60_ •	60_ •	60_ •	60_ •
31. Cotton Upland *(Exclude Am. Pima)* — Planted and to be planted	524 •	524 •	524 •	524 •	524 •
37. Other Crops — Acres planted or in use	— — — •	— — — •	— — — •	— — — •	— — — •
38. Land in Summer Fallow	847 •	847 •	847 •	847 •	847 •
39. Idle Cropland — Idle all during 1984	857 •	857 •	857 •	857 •	857 •

APPENDIX C.2: MODIFIED SECTION-A SURVEY FORM

SECTION A — ACREAGES OF FIELDS AND CROPS INSIDE BLUE TRACT BOUNDARY (Cont'd)

Enumerator Entered Tract Acres [.]

Total Acres

FIELD NUMBER.	827 6	827 7	827 8	827 9	Office Use
1a. Total Acres in Field	828 .	828 .	828 .	828 .	840 .
2. Crop or Land Use *(Specify)*					
3. Occupied Farmstead or Dwelling					
4d. Non-Crop Land Cover (Fld. generally 3 + ac.) (Line 4d must = Line 1)	— — — .	— — — .	— — — .	— — — .	
4e. Cropland Waste (Generally <3 ac.) (Record water on Line 4d)	829 .	829 .	829 .	829 .	
5a. Pasture — Native — Not in crop rotation	871 .	871 .	871 .	871 .	
5a. Pasture — Cropland — Used only for pasture	856 .	856 .	856 .	856 .	
5a. Pasture — Other — Not native or cropland pasture	892 .	892 .	892 .	892 .	
6. Two Crops Planted in this Field for harvest this year or two uses of the same crop?	☐ YES ☐ NO / 844 .	☐ YES ☐ NO / 844 .	☐ YES ☐ NO / 844 .	☐ YES ☐ NO / 844 .	
7. Acres Left to be Planted?	61_ .	61_ .	61_ .	61_ .	
8. Acres Irrigated and to be Irrigated?	6__ .	6__ .	6__ .	6__ .	
11. Winter Wheat — Planted	540 .	540 .	540 .	540 .	
12. Winter Wheat — For Grain	541 .	541 .	541 .	541 .	
15. Oats — Planted and to be planted	533 .	533 .	533 .	533 .	
16. Oats — For Grain	534 .	534 .	534 .	534 .	
19. Corn — Planted and to be planted	530 .	530 .	530 .	530 .	
20. Corn — For Grain	531 .	531 .	531 .	531 .	
21. Sorghum *(Excl. crosses)* — Planted and to be planted	570 .	570 .	570 .	570 .	
22. Sorghum *(Excl. crosses)* — For Grain	571 .	571 .	571 .	571 .	
23. Other Uses of Grains Planted — Use					
Acres abandoned, cut for hay, silage, etc. — Acres	.	.	.	.	
24. Alfalfa and Alfalfa Mixtures (Cut and to be cut for hay)	653 .	653 .	653 .	653 .	
25. Other Hay (Cut and to be cut)	654 .	654 .	654 .	654 .	Office Use
26. Soybeans — Planted and to be planted	600 .	600 .	600 .	600 .	602 .
29. Rice — Planted and to be planted — Check Kind	☐ S ☐ M ☐ L	☐ S ☐ M ☐ L	☐ S ☐ M ☐ L	☐ S ☐ M ☐ L	
29. Rice — Acres	60_ .	60_ .	60_ .	60_ .	
30. Cotton Upland *(Exclude Am. Pima)* — Planted and to be planted	524 .	524 .	524 .	524 .	
38. Other Crops — Acres planted or in use	— — — .	— — — .	— — — .	— — — .	
39a. Idle Cropland — Idle all during 1983	857 .	857 .	857 .	857 .	

Land Cover Codes
872 [illegible] Forest Grazed
873 [illegible] Forest Conifer
874 [illegible] Forest Hardwood
875 [illegible] Forest Mixed
876 [illegible] Brush
877 [illegible] Idle grassland
878 [illegible] Wetlands
879 [illegible] Water 3 to 10 acres
880 [illegible] Water 10 to 40 acres
881 W > 40 Water > 40 acres
882 [illegible] Perennial streams [illegible]
883 [illegible] Rivers > [illegible] feet
884 SM Q GP Strip mine, Quarries and Gravel Pit
885 Ind Industrial, Commercial and Service
886 [illegible] Transportation, Communication, Utilities
887 Res Residential
888 Mxd Mixed (Res., Trans., Ind., Com.)
889 O Urb Other urban
890 Trans Transitional
891 [illegible] Farmstead (Unoccupied)
892 [illegible] Dry Stream Beds

Soybeans Following Another Crop

APPENDIX D: COST FIGURES USED

BBN/DEC-10

1st shift	$5.21/CPU min.
2nd shift	$2.61/CPU min.
3rd shift	$1.30/CPU min.
1st shift	$2.65/hour connect time
2nd shift	$1.33/hour connect time.
3rd shift	$0.66/hour connect time.

CRAY 1-S

$3.70/category for 8-channel classification
$1.50/aggregation
$0.50/CPU sec.

APPENDIX E: BREAKDOWN OF STATE ESTIMATES BY ANALYSIS DISTRICT ESTIMATES

APPENDIX E: TABLE 14. Acreage Estimates for Winter Wheat Planted, Missouri, 1983

	Direct expansion 1/				LANDSAT Regression			
Analysis district	Imagery date	Estimate	Standard error	CV	Estimate	Standard error	CV	R. E.4/
	Mo./day	--1,000 Acres--		Pct.	--1,000 Acres--		Pct.	Unit
AA	5/5	747	96	12.8	678	79	11.7	1.5
BB	4/26	218	50	23.1	150	37	24.9	1.8
CC	6/4	425	57	13.4	337	36	10.7	2.5
DD	4/24	823	110	13.4	1,131	80	7.1	1.9
EE & FF	----	18	7	42.4	8	7	42.4	1.0
STATE (AFTER FLE)		2,229 2/	174 2/	7.8 2/	2,314	131	5.7	
STATE (BEFORE FLE) 3/		2,239	174	7.8				1.8

SEE PAGE 34 FOR FOOTNOTES

TABLE 15. Acreage Estimates for Winter Wheat Harvested, Missouri, 1983

Analysis district	Imagery date	Direct expansion[1/] Estimate	Standard error	CV	LANDSAT regression Estimate	Standard Error	CV	R. E.[4/]
	Mo./day	--1,000 Acres--		Pct.	--1,000 Acres--		Pct.	Unit
AA	5/5	680	88	13.0	616	72	11.7	1.5
BB	4/26	200	48	23.9	137	37	27.0	1.7
CC	6/4	394	54	13.8	310	34	11.1	2.5
DD	4/24	757	103	13.6	1,063	71	6.7	2.1
EE & FF	----	13	6	46.8	13	6	46.8	1.0
STATE (AFTER FLE)		2,041[2/]	162[2/]	8.0[2/]	2,140	120	5.7	
STATE (BEFORE FLE)[3/]		2,051	163	7.9				1.9

TABLE 16. Acreage Estimates, for Cotton Planted Missouri, 1983

Analysis District	Imagery Date	Direct expansion[1/] Estimate	Standard Error	CV	LANDSAT Regression Estimate	Standard Error	CV	R. E.[4/]
	Mo./day	--1,000 Acres--		Pct.	--1,000 Acres--		Pct.	Unit
A	5/5, 8/25	61	35	56.6	75	11	14.7	10.1
B,C,D, E,F,G, H,I,	-----	0	0	--	0	0	--	1.0
STATE (AFTER FLE)		62[2/]	35[2/]	56.6[2/]	75	11	14.7	
STATE (BEFORE FLE)		[3/]	64	37	57.2			11.1

SEE PAGE 34 FOR FOOTNOTES

TABLE 17. Acreage Estimates, for Rice Planted Missouri, 1983

Analysis District	Imagery Date	Direct expansion[1/] Estimate	Standard Error	CV	LANDSAT Regression Estimate	Standard Error	CV	R. E.[4/]
	Mo./day	--1,000 Acres--		Pct.	--1,000 Acres--		Pct.	Unit
AD23IJ	5/5, 8/25	108	50	46.3	92	12	13.0	17.4
ADDE	----	18	18	99.8	21	21	99.8	1.0
STATE (AFTER FLE)		128[2/]	54[2/]	42.2[2/]	113	24	12.8	
STATE (BEFORE FLE)[3/]		125	53	42.7				5.1

TABLE 18. Acreage Estimates, for Corn Planted* Missouri, 1983

Analysis District	Imagery Date	Direct expansion[1/] Estimate	Standard Error	CV	LANDSAT Regression Estimate	Standard Error	CV	R. E.[4/]
	Mo./day	--1,000 Acres--		Pct.	--1,000 Acres--		Pct.	Unit
A	5/5, 8/25	191	45	23.5	140	25	17.9	3.2
C	4/26, 9/17	83	21	25.3	78	16	20.1	1.7
E	6/4, 7/22	671	77	11.5	624	56	8.9	1.9
G	4/24, 7/29	61	29	48.0	28	22	78.0	1.7
I	7/20	325	70	21.5	253	46	18.2	2.3
B,D,F,H	--	432	72	16.6	432	72	16.6	1.0
STATE (AFTER FLE)		1,762[2/]	140[2/]	7.9[2/]	1,555	110	7.0	
STATE (BEFORE FLE)[3/]		1,769	138	7.8				1.6

SEE PAGE 34 FOR FOOTNOTES.

TABLE 19. **Acreage Estimates, for Soybeans Planted* Missouri, 1983**

Analysis District	Imagery Date	DIRECT EXPANSION 1/ Estimate	Standard Error	CV	LANDSAT REGRESSION Estimate	Standard Error	CV	R. E. 4/
	Mo./day	--1,000 Acres--		Pct.	--1,000 Acres--		Pct.	Unit
A	5/5, 8/25	1,090	140	12.8	978	105	10.7	1.8
C	4/26, 9/17	260	64	24.6	214	22	10.3	8.5
E	6/4, 7/22	1,540	141	9.2	1,280	78	6.1	3.2
G	4/24, 7/29	305	70	23.1	246	43	17.5	2.7
I	7/20	823	102	12.5	683	66	9.7	2.4
B,D,F,H	--	1,560	165	10.6	1,560	165	10.6	1.0
STATE (AFTER FLE)		5,556	303	5.5	4,961	239	4.8	
STATE (BEFORE FLE) 3/		5,559	306	5.5				1.6

*Acres recorded as planted as of August 1 Follow-up Survey. Does not include acres planted and abandoned prior to this survey.

1/ Analysis district direct expansions estimates, standard errors and coefficients of variation (CV) are SRS Remote Sensing Branch direct expansions.

2/ State-level direct expansion estimate, standard error and CV are from JES data After Field Level Edit (FLE).

3/ State-level direct expansion is not equal to the sum of the analysis district direct expansions. The estimate, standard error and CV are from the JES State-level direct expansion, Before the Field Level Edit (FLE).

4/ R. E. is the relative efficiency of the estimate. It is the proportional increase in the ground data sample size required to produce estimates of the same precision as those obtained from ground data and Landsat data combined.