Landsat Large-Area Estimates for Land Cover

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Abstract—A methodology for using ground-gathered and Landsat MSS data to obtain natural resources information over large areas was developed by the USDA, Statistical Reporting Service (SRS) and NASA/NSTL, Earth Resources Laboratory. The SRS's remote-sensing techniques for improving crop area estimates were expanded and modified to obtain land-cover data. These techniques employ statistical relationships between field-level ground data and corresponding Landsat pixels to determine classification accuracy and variances for acreage estimates. State-level and land-cover surveys were conducted in Kansas, Missouri, and Arkansas. During the Missouri project, all costs for person-hours, materials, and computer time were tracked for the various analysis steps. Classified Landsat data stored on computer tapes and area estimates with known precision are two products obtained from these surveys.

I. Introduction

THE U.S. Department of Agriculture's (USDA) Statistical Reporting Service (SRS) uses digital data from the Landsat satellite to improve 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 ([5], [7], [9], [11], [14]) discuss results from this procedure which has been applied to major crops in the midwest. Briefly, the SRS Landsat procedure for major crops consists of the following steps:

Ground truth collected during an operational survey, plus corresponding Landsat MSS digital data, are used to develop discriminant functions which in turn are used to classify Landsat pixels which represent specific ground covers.

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

All of the pixels contained in the Landsat scene(s) within the area of interest are classified.

Crop-area estimates are calculated by applying the regression relationship to the full scene classification results.

In 1979, the land-cover classification and measurement program within AgRISTARS gave the SRS a research charter to develop and evaluate techniques for obtaining land resources information. The overall objective was to determine if land-cover data obtained using the above methodology could be useful to other USDA agencies, or state and county level agencies, concerned with natural resources management. The National Areonautics Space Administration's Earth Resources Laboratory (ERL) at the National Space Technology Laboratory (NSTL) had prior experience in examining land cover and geographic information needs. Thus, NSTL and SRS personnel began joint remote-sensing research efforts to address land-cover information needs with major emphasis placed on SRS's methology for obtaining crop area estimates.

The following is a brief overview of land-cover research that was conducted during AgRISTARS:

1979 The SRS has a lead role along with NASA/ERL in land-cover research.

1980 Pilot study conducted in Kansas.

1981 Seventeen land covers classified and estimated at the state level in Kansas using unitemporal Landsat data.

1982 Results from 1981 analyzed and preparations made for 1983 test.

1983 Twenty-three land covers and five major crops classified and state-level estimates produced in Missouri using multitemporal Landsat data.

1984 The Soil Conservation Service (SCS), the Forest Service (FS), and the SRS jointly fund a state-level crop and land-cover survey in Arkansas using the SRS's June Enumerative Survey and multitemporal Landsat data.

This report will discuss, starting in Section III, each of the above studies in chronological order and will show how the results and experiences gained in one year helped to improve the survey for subsequent years. Section II presents the basic techniques and methodologies used to combine ground-gathered and Landsat MSS data to obtain crop classification and acreage estimates. Cited references which give additional details on these techniques are readily obtainable from the SRS. Modifications were made to these procedures to allow the classification and estimation of noncrop cover types. These changes are discussed within the appropriate land-cover study presentation.

II. Methodology

A. June Enumerative Survey

Every year during the last week in May and first week in June the SRS conducts a June Enumerative Survey (JES) in 48 conterminous states [3]. The JES is a probability survey based on a stratified area-frame sampling technique [6]. In this technique the area of a State is divided into homogeneous subdivisions called strata (Table I). Each stratum is further subdivided into smaller areas

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TABLE I
KANSAS AREA SAMPLING FRAME STRATA

Stratum	Description	Population Size	Sample Size	Average Segment Size (mi^2)
11	> 80% cultivated	25,028	170	1.00
12	50 to 80% cultivated	21,704	120	1.00
20	15 to 49% cultivated	21,286	100	1.00
31	Agri-urban	2,774	12	0.25
32	City	2,941	12	0.10
33	Resort area	247	2	0.25
40	Rangeland	3,147	15	4.00
50	Nonagricultural	294	2	1.00
61	Potential water	29	2	0.50
62	Water	231	0	1.00
	TOTAL	77,681	435	

called primary sampling units (PSU's). Out of each stratum a suitable number of PSU's are randomly chosen with probability of selection proportional to the area of the PSU. Each of the sampled PSU's is divided into sampling units called segments (a segment is a well-defined area of land that can be delineated on photographs and readily identified by data collection personnel in the field). In strata that are predominantly cultivated land, the average segment size is about 1 mi^2. After each sampled PSU is subdivided, one segment is randomly selected from each PSU.

The JES procedure requires that information be obtained for all the land within each of the sampled segments. To ensure that all the land is accounted for, aerial photographs are used as an enumeration aid. The boundaries for each segment are drawn on individual noncurrent photographic prints. These segment photographs and corresponding questionnaires are sent to field enumerators for data collection. As part of the data collection procedure, each enumerator is instructed to draw the boundaries of all fields, within each segment, on the segment photography (a field is defined as a continuous block of land containing the same crop or land cover). On the corresponding questionnaire the enumerator records the cover and size of each field, as well as livestock numbers and other agricultural information obtained from the operator.

The information collected during the JES is aggregated to the segment level and direct expansion estimates are then calculated to obtain state level estimates for crop acres [12]. The formulas for the direct-expansion estimator and its variance are as follows:

Let $\hat{Y}_c$ be the unbiased direct expansion estimate for the acres of crop c

$$\hat{Y}_c = \sum_{s=1}^{S} \frac{N_s}{n_s} \sum_{j=1}^{n_s} y_{jsc}$$

where

- y_{jsc} is the acres reported to crop c, in segment j, for stratum s,
- n_s is the number of segments sampled in stratum s,
- N_s is the total number of potential segments in stratum s, and
- S is the total number of strata.

The estimated variance is:

$$V(\hat{Y}) = \sum_{s=1}^{S} \frac{(N_s - n_s)N_s}{n_s(n_s - 1)} \sum_{j=1}^{n_s} (y_{jsc} - \bar{y}_{.sc})^2$$

where

$$\bar{y}_{.sc} = \sum_{j=1}^{n_s} \frac{y_{jsc}}{n_s}.$$

In 1972, SRS personnel started to investigate the potential of using *digital* Landsat data to improve the precision of the estimates obtained from the JES. The procedure developed consists of the following steps:

1) Analysis District Selection: Landsat data are selected and boundaries of Landsat analysis districts defined.

2) Signature Development: Data collected during the JES and corresponding Landsat data are used to develop a maximum likelihood classifier for each analysis district.

3) Small-Scale Processing: The Landsat pixels representing the area within each segment contained in an analysis district are classified. A regression relationship is developed between the number of pixels classified to a crop and the acres recorded for that crop on the JES.

4) Full-Frame Processing: All of the Landsat pixels within the analysis district are classified. Estimates are calculated at the analysis district level by applying each crop regression relationship to the all-pixel classification results.

5) State-Level Accumulation: The estimates for all analysis districts are combined to create a state level estimate for each crop of interest.

B. Analysis District Selection

An analysis district is an area of land covered by Landsat imagery of the same overpass date. Depending on the location and availability of Landsat data, each state is divided into a number of districts with each being analyzed separately. The Landsat analysis district location is treated as a geographical post-stratification imposed on the original strata. As a result of this post-stratification, SRS personnel must determine the number of PSU's and the sampled segments which fall into each post-stratum. This results in two strata categories:

1) The first stratum category corresponds to the area of the state for which there is no Landsat coverage. This area may be noncontiguous. The portion of each land-use stratum within these geographical areas makes up the post-strata. We let M_s be the total number of segments in the nonLandsat area in land use stratum s, and m_s be the number of sampled segments in the non-Landsat area in land use stratum s.

2) The second stratum category corresponds to the areas of the state where the analysis districts are defined. In these areas each stratum consists of the area of intersection between the land use strata and a Landsat analysis district. Here, we let $M_{\dot{a}s}$ be the number of PSU's in analysis district a, land use stratum s, and $m_{\dot{a}s}$ be the number of sampled segments in analysis district a, land use stratum s.

C. Signature Development

Signature development is done independently for each analysis district and consists of four phases. The first phase is segment calibration and digitization. Segment calibration is a first-order linear transformation that maps points on the segment photograph to a USGS map base. Segment digitization is the process by which field boundaries drawn on the segment photograph are recorded in computer-compatible form. The combined process of calibration and digitization gives us the capability of digitally locating every JES field relative to a map base.

The next phase in signature development is the registration of each Landsat scene. The SRS's Landsat registration process is a third-order linear transformation that maps each Landsat pixel within a scene to a map base [4]. Corresponding points selected on a 2° map and a 1:250 000 Landsat image are used to generate this mathematical transformation. The combination of segment calibration, digitization, and Landsat registration provides the capability to locate each JES segment in its corresponding Landsat scene (to within about 5 pixels of the correct location). Since this registration is not accurate enough for selecting training data, line plots of segment field boundaries and corresponding greyscale prints are overlaid and each segment is manually located to within $\frac{1}{2}$ pixel of the correct location. This procedure allows accurate identification of all the pixels associated with any JES field. The result of this is a set of pixels labeled by land cover.

The third phase of signature development is supervised clustering. In supervised clustering all of the pixels for each cover are processed through one of two available clustering algorithms: classy or ordinary clustering. Classy is a maximum likelihood clustering algorithm developed at Johnson Space Center in Houston, TX [8]. Ordinary clustering is an algorithm derived from the ISODATA algorithm of Ball and Hall [2]. Each clustering algorithm generates several spectral signatures (categories) for each cover. Each spectral signature consists of a mean vector and the covariance matrix for the reflectance values for that category.

In the fourth phase, the statistics for all categories from all covers are reviewed and combined to form the discriminant functions of the maximum likelihood classifier.

D. Small-Scale Processing

In small-scale processing, each pixel associated with a JES segment is classified to a category. The category totals corresponding to crops of interest are summed to segment crop totals. These crop totals are used as the independent variable in a regression estimator. Correspondingly, the acres reported on the JES for each crop are summed to segment totals and used as the dependent variable. The segment totals are used to calculate least squares estimates for the parameters of a linear regression.

The linear regression equations for analysis district a, stratum s, and crop c are of the form

$$y_{jasc} = b_{0asc} + b_{1asc}x_{jasc}$$

where

y_{jasc} is the reported acres of crop c, from segment j, analysis disctrict a, land use stratum s;

x_{jasc} is the crop total classification for segment j, analysis district a, land use stratum s, and

b_{0asc}, b_{1asc} are the least squared estimates of the regression intercept and slope parameters for crop c, analysis district a, land use stratum s.

E. Full-Frame Processing

The classifier used in small-scale processing is used to classify every pixel in the analysis district. The classified results are tabulated by category and land-use stratum. For each crop of interest, the category totals are summed to stratum crop totals. From these totals the population averages per segment are calculated. Using the population average, a stratum-level regression estimate is made for that analysis district for each crop.

Let $\hat{Y}_{\dot{a}sc}$ be the analysis district level regression estimator for crop c and stratum s. Then

$$\hat{Y}_{\dot{a}sc} = M_{\dot{a}s}[\bar{y}_{.asc} + b_{1asc}(\bar{X}_{.asc} - \bar{x}_{.asc})]$$

where

$$\bar{y}_{.asc} = \sum_{j=1}^{m_{\dot{a}s}} \frac{y_{jasc}}{m_{\dot{a}s}}$$

$$\bar{x}_{.asc} = \sum_{j=1}^{m_{\dot{a}s}} \frac{x_{jasc}}{m_{\dot{a}s}}.$$

$M_{\dot{a}s}$, $m_{\dot{a}s}$, x_{jasc}, and y_{jasc} are as defined above, and $\bar{X}_{.asc}$ is the population average number of pixels per segment classified to crop c, analysis district a, and land use stratum s.

The estimated variance is

$$V(\hat{Y}_{\dot{a}sc}) = \frac{(m_{\dot{a}s} - 1)}{(m_{\dot{a}s} - 2)}(1 - r_{asc}^2)\frac{(M_{\dot{a}s} - m_{\dot{a}s})M_{\dot{a}s}}{m_{\dot{a}s}(m_{\dot{a}s} - 1)} \cdot \sum_{j=1}^{m_{\dot{a}s}} (y_{jasc} - \bar{y}_{.asc})^2$$

where r_{asc} is the sample correlation between y_{jasc} and x_{jasc}.

F. State-Level Accumulation

The final step of Landsat analysis is the combining of all of the estimates (one for each post stratum) into a state-level estimate of the area of the desired crop.

Let $\hat{Y}_{\hat{c}}$ be the final state level estimate for the acres of crop c.

Then

$$\hat{Y}_{\hat{c}} = \sum_{a=1}^{A} \sum_{s=1}^{S_{\dot{a}}} \hat{Y}_{\dot{a}sc} + \sum_{f=1}^{L} M_f \bar{y}_{.fc}$$

where

$$\bar{y}_{.fc} = \sum_{j=1}^{m_f} \frac{y_{jfc}}{m_f}.$$

M_f, m_f are as previously defined with subscript f used to distinguish from strata with Landsat coverage,
$\hat{Y}_{\dot{a}sc}$ is as defined earlier,
y_{jfc} is the acres reported to crop c for segment j in the non-Landsat post stratum f,
$S_{\dot{a}}$ is the number of land use strata in analysis district a,
A is the number of analysis districts, and
L is the number of land use strata in the area where there is no Landsat coverage.

The estimated variance is

$$V(\hat{Y}_{\dot{c}}) = \sum_{a=1}^{A} \sum_{s=1}^{S_{\dot{a}}} V(\hat{Y}_{\dot{a}sc}) + \sum_{f=1}^{L} \frac{(M_f - m_f)M_f}{m_f(m_f - 1)} \cdot \sum_{j=1}^{m_f} (y_{jfc} - \bar{y}_{.fc})^2.$$

G. Evaluation of the Landsat Estimate

Landsat data are used as supplemental information to improve the precision of the area estimates obtained from the JES. Unlike area frame construction, the effectiveness of this use of Landsat data can be measured. The measure used is the efficiency of the Landsat estimator relative to the JES direct expansion estimator. This relative efficiency (*RE*) is defined as the ratio of the variance of the direct expansion to the variance of the Landsat estimate. Equivalently, this is the factor by which the sample size would have to be increased to produce a direct expansion estimate with the same precision as the Landsat estimate.

$$RE = \frac{V(\hat{Y}_c)}{V(\hat{Y}_{\dot{c}})}.$$

Recent studies have suggested possible bias in the Landsat regression estimates. During 1985 SRS is conducting research in two mid-western states to examine this problem.

III. 1980 Kansas Pilot Study

A. Objectives

The first step in implementing and expanding the above procedures for land-cover research was to determine if land-cover information could be obtained using JES techniques and methodology. A pilot study was conducted in Kansas using 86 SRS segments from nonagricultural strata. The objectives were 1) test the feasibility of having regular enumerators use land cover definitions to classify parcels of land, and 2) obtain preliminary variance information for direct expansions of cover types in the non-agriculture strata.

B. Selection of Land Cover Definitions

The short-time period between the initiation of the AgRISTARS program and this study required that land-cover definitions be used that were readily available and accepted by other land classification systems. Because of these restrictions, the land-cover classification system set forth in USGS Professional Paper 964 [1] was used as a basis for defining the land-cover codes. This resulted in a scheme which combines the Level I and Level II classification system in the above paper.

Using these definitions, the enumerators went to each of the 86 segments during August and observed the land covers present. Everything inside a segment was placed into one of the defined land covers. The minimum mapping size was 1 acre.

C. Results

Enumerators did an excellent job in conducting the survey and in many instances extracted more information than necessary. Analysis of the land-cover data indicated that some land-cover terms were too broadly defined. This indicated a need for increasing the number of land-cover types for enumeration and a better definition of these terms. Direct expansion estimates were obtained using the 86 segments and the variances examined. Specific conclusions were difficult to make due to the small sample sizes. The results did indicate that the JES may have the potential for providing state-level acreage estimates for several noncrop cover types.

IV. 1981 Kansas Study

A. Objectives

The objectives for the 1981 study were to 1) produce land cover classifications and acreage estimates for the entire state using ground-gathered and Landsat MSS data; 2) incorporate the land-cover survey into the SRS's regular June Enumerative Survey; 3) produce statistically based regional land-cover estimates and maps, and 4) determine if land-cover information obtained from this study could be useful to federal and state agencies.

B. Land Cover Definitions

The approach taken in developing terms and definitions for the 1981 survey was to solicit inputs from federal and state agencies that gather, analyze, and/or disseminate land-cover information within Kansas. Definitions used for surveys conducted by the Soil Conservation Service and Forest Service were added to this study. Seventeen land covers pertinent to the landscape of Kansas were defined and are presented in the left-hand column of Table II.

C. Ground Data Collection

The land-cover ground data were collected during the JES and were considered a part of the regular crop survey. Ground data for crop and noncrop cover types were collected in 435 sample segments. The addition of land covers required some modification to JES forms. A training school was held prior to the survey to familiarize enumerators with the land-cover terms and to discuss enumeration techniques. After collection, the ground data went

TABLE II
DIRECT EXPANSION AND REGRESSION ESTIMATES FOR LAND COVERS WITHIN KANSAS

Land Cover Categories	DIRECT EXPANSION Estimate (Acres)	DIRECT EXPANSION Standard Error	REGRESSION Estimate (Acres)	REGRESSION Standard Error	Relative Efficiency
Cropland	28,349,166	487,446	28,008,390	363,571	1.8
Permanent Pasture	3,145,220	525,561	2,970,378	486,070	1.2
Rangeland	16,452,963	752,294	15,828,804	466,533	2.6
Farmstead	404,467	22,710	416,270	19,521	1.4
Forest (Not Grazed)	935,398	151,104	1,009,638	70,832	4.6
Forest (Grazed)	693,086	194,579	744,089	98,132	4.0
Wooded Strips	481,442	52,665	480,958	48,840	1.2
Residential	461,235	69,559	450,713	33,838	4.2
Commercial/Industrial	116,629	28,391	89,438	18,139	2.4
Transp. Commun., & Util.	503,095	132,872	506,319	123,320	1.2
Other Urban	143,434	29,072	145,683	27,288	1.1
Stripmines, Quarries, G. Pits	137,775	56,683	109,434	29,026	3.8
Sand Dunes	4,818	1,833	-	-	-
Ponds (<40 AC)	199,557	28,074	182,520	18,715	2.3
Lakes (>40 AC)	183,447	17,983	-	-	-
Rivers	138,298	72,672	131,717	65,913	1.2
Transitional	78,742	41,249	-	-	-

through a quality-control process and were digitized into computer readable format.

D. Landsat Data

The 1981 Landsat data obtained for this study are shown in Fig. 1. The earliest date was April 25 and the latest August 31. These data were registered and classified according to the procedures described in Section II.

E. Results

The direct expansion (ground data only) and regression (ground and Landsat data) acreage estimates, for the seventeen land covers within Kansas are given in Table II. The relative efficiency of the regression estimates are also listed.

The direct expansion standard error is high for several noncrop cover types. One reason for this is because the JES sample is designed for an agricultural survey. As indicated in Table I, most of the 435 sample segments fall in agricultural strata 11, 12, and 20, while very few fall in the remaining nonagricultural strata. One method for lowering the standard error of noncrop covers is to select more segments from nonagricultural strata. For example, precision of the estimates for commercial/industrial and other urban categories can be improved by selecting additional samples in strata 31, 32, and 33 and enumerating these segments during the JES. This can be accomplished with minimal effort because, as shown in Table I, the population for each stratum has been defined.

The standard errors for the regression estimates were lower than the direct expansion for all cover types. For example, the regression standard error for grazed forest, not grazed forest, and residential was less than one-half the direct expansion standard errors. The regression standard errors were lowered for commercial/industrial and other urban, but additional improvement in these estimates will have to come from increasing the sample size or from the use of multitemporal Landsat data.

A state-level land-cover classification must be produced in order to derive these regression estimates. Therefore, this classification can be used to obtain land cover map-type products and associated acreage counts for any land area within the state whose boundaries are recorded in a computer-readable format. Map-type products of several counties were obtained from an electrostatic plotter and a cathode ray tube display using NASA/NSTL's software [10].

In summary, the feasibility of using USDA SRS crop area estimation methodology to obtain land-cover classification products and area estimates was demonstrated in Kansas. The 1981 Kansas study indicated that some noncrop cover types were poorly estimated using the current JES sample allocation. Incorporating the collection of land-cover ground data with the JES eliminates the need for two separate ground data activities.

V. 1982 STUDY

Based on analysis of the Kansas results, another state-level land-cover study needed to be conducted in a more diversified geographic location. Missouri was selected for the next study, and changes were made to the JES sample allocation and enumeration procedures. Ground data were collected, but the study was cancelled due to inadequate Landsat data. Only 25 percent of the state had adequate Landsat coverage due to cloud problems throughout the summer and fall months.

VI. 1983 MISSOURI STUDY

A. Objectives

During 1983 the SRS wanted to estimate several crops within Missouri using JES and Landsat data. Other federal and state agencies expressed interest in classifying and estimating several noncrop covers, especially forest categories. To meet these various requirements, the following objectives were established.

1) Provide SRS with area estimates for winter wheat, rice, cotton, corn, and soybeans from a combined crop and land-cover Landsat analysis.

2) Provide classified data tapes and area estimates of defined Missouri land covers.

3) Determine the additional cost of doing land cover analysis with crop analysis.

B. Land-Cover Definitions

Potential users of SRS-generated land-cover data were contacted and asked to determine what land-cover types should be included in this study. The final list of land covers are presented in the left-hand column of Table IV (given later).

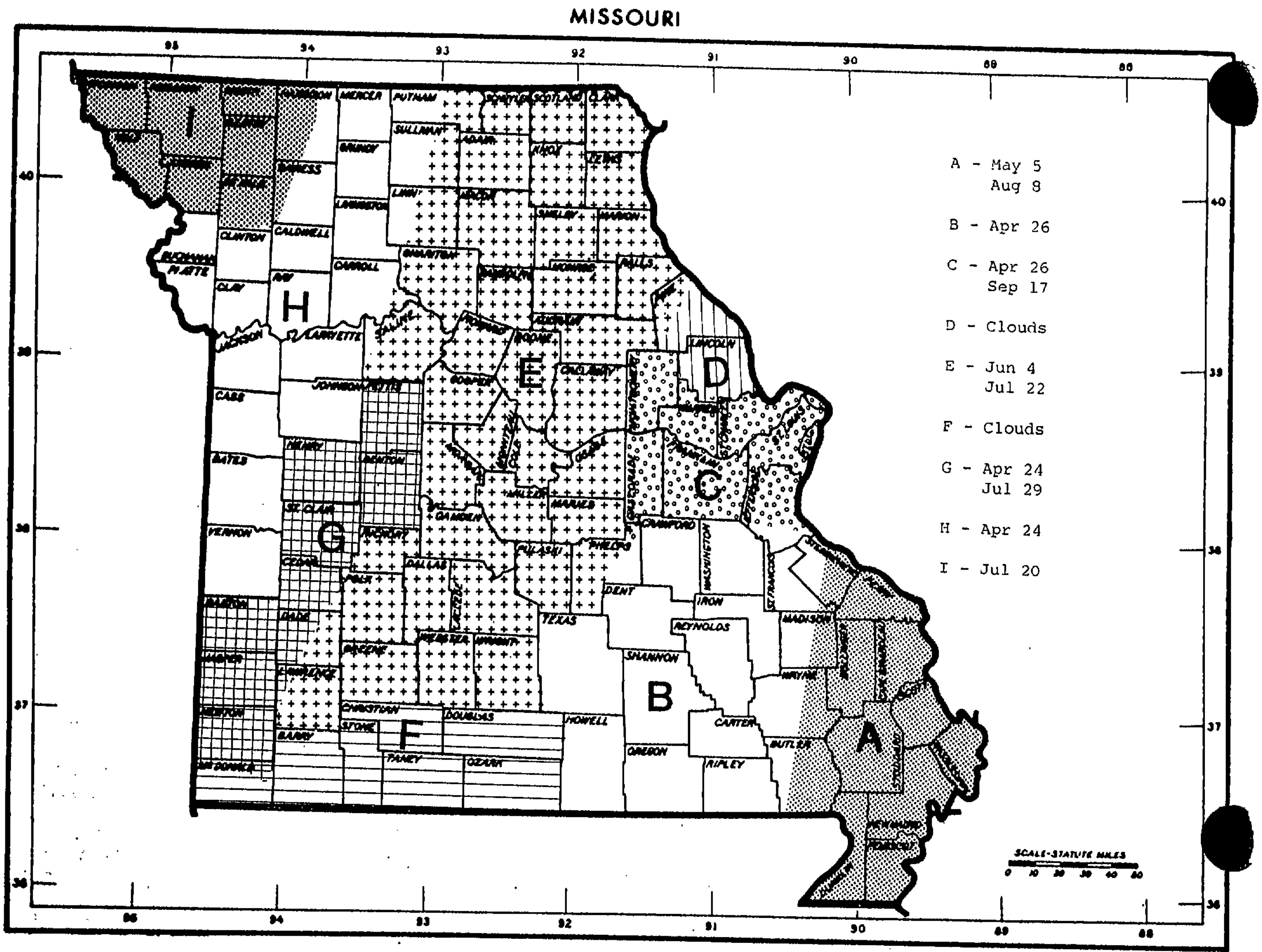


Fig. 1. 1981 dates of Landsat MSS digital dates analyzed for the Kansas land cover study.

C. JES Sample Size

Forest is an important and extensive land cover in Missouri and several agencies expressed interest in this cover. The results from previous years indicated that the sample allocation of 450 operational JES segments did not adequately sample forest land, especially coniferous forests. To provide better ground data, 67 segments from the nonagriculture strata were added.

D. Landsat Data

Two dates of Landsat data were used to enable the estimation of crop acreages for a spring crop (winter wheat) and fall crops (corn, soybeans, rice, cotton) and improve land cover classification results. Fig. 2 shows the analysis districts and Landsat dates which comprised the multitemporal data set. These data sets were created by overlaying the fall imagery onto the spring imagery. Only spring data were used to produce regression estimates for winter wheat.

E. Crop Acreage Results

During the first two weeks in December, the SRS's Crop Reporting Board was provided direct expansion and regression estimates for all five crops. These estimates were timely input data for the SRS's year-end crop acreage reports. Table III lists these estimates and associated statistics.

Several points should be made concerning these regression estimates. The relative efficiencies for the estimates of winter wheat, corn, and soybeans was less than anticipated. In 1983, USDA implemented the "Payment in Kind" (PIK) program, which enabled farmers to enroll acreage normally planted in wheat in a program that would guarantee the farmer a specified price for wheat for not planting the acreage. This program was implemented after the winter wheat was planted, which caused some confusion between the ground and Landsat data.

The improvement in the precision for corn and soybeans are poor considering the use of multitemporal data. Part of the loss in efficiency was due to the lack of fall Landsat data in a large corn and soybean producing area (area *H*

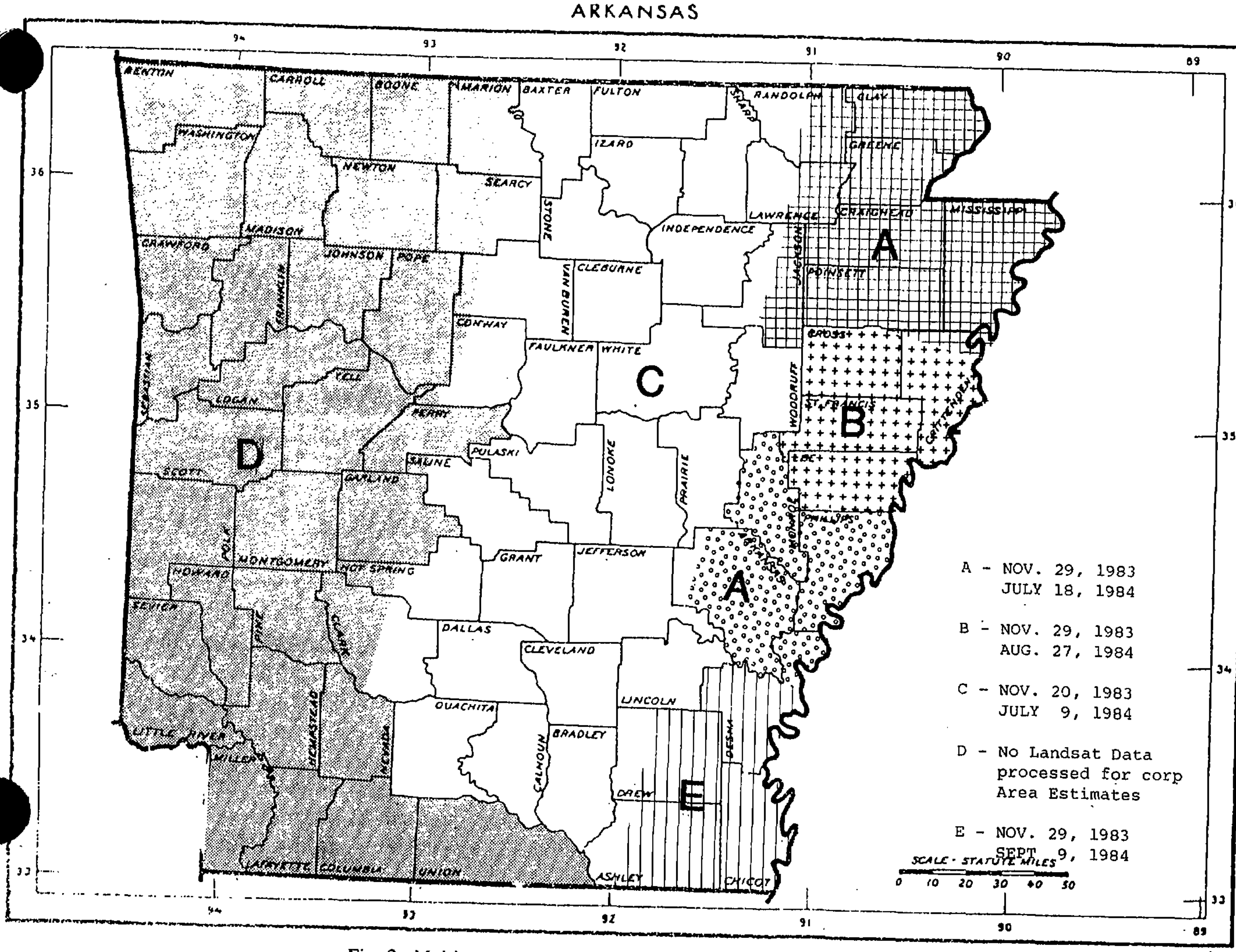


Fig. 2. Multitemporal Landsat digital data analyzed in Missouri.

TABLE III
PLANTED ACREAGE ESTIMATES FOR MAJOR CROPS IN MISSOURI

	DIRECT EXPANSION		LANDSAT REGRESSION		
Crops	Estimate	Standard Error	Estimate	Standard Error	Relative Efficiency
Winter Wheat	2,229,000	174,000	2,314,000	131,000	1.8
Cotton	62,000	35,000	75,000	11,000	10.1
Rice	128,000	54,000	149,000	27,000	3.9
Corn	1,762,000	140,000	1,555,000	110,000	1.6
Soybeans	5,656,000	303,000	4,961,000	239,000	1.6

in Fig. 2). The regression precisions for cotton and rice estimates improved dramatically. These are specialized crops grown only in the Missouri "Boot Heel" region. The JES is not designed to estimate crops concentrated in a small area of a state and this is shown by the high standard error of the direct expansion estimates for these two crops.

F. Land-Cover Results

The direct expansion and regression estimates for land covers are listed in Table IV. Potential users of the land-cover data who participated in defining terms for this project were interested in the outcome of the forestland estimates. The latest state survey conducted by the Forest Service was in 1972 [13]. Table V is a comparison of 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 for hardwood, conifer, or conifer-hardwood.

G. Project Costs

A specific objective of the 1983 study was to determine costs for the various crop and land-cover estimates. The 1983 cost for conducting the JES in the 450 operational segments for crops and land covers was $43 788. This was an 11.5-percent increase when compared to the average JES costs of 1980 and 1981 when no additional land covers were enumerated. Some of this increase is due to an increase in salaries. Total cost for Landsat tapes, prints, and transparencies was $21 240.

Person hours, CPU (in minutes), and computer costs

TABLE IV
LAND COVER DIRECT EXPANSION AND REGRESSION ESTIMATES FOR MISSOURI

	DIRECT EXPANSION		REGRESSION		
Cover	Estimate	Standard Error	Estimate	Standard Error	Relative Efficiency
Hardwood	10,499,754	529,061	11,139,532	443,461	1.4
Conifer	181,568	43,325	187,650	21,782	4.0
Conifer-Hardwood	1,149,738	247,934	1,148,447	245,461	1.0
Grazed Forest	2,884,732	297,743	2,705,512	299,958	1.0
Brushland	1,286,435	143,382	1,318,875	138,723	1.1
Row Crops	8,539,851	361,734	7,742,383	246,344	2.2
Sown Crops	2,391,119	175,337	2,547,815	127,349	1.9
Idle/cropland	2,100,277	163,574	2,015,582	139,389	1.4
Hay	3,110,286	197,393	2,980,606	171,303	1.3
Cropland/Pasture	1,434,850	234,325	1,245,797	149,895	2.4
Other Pasture	7,698,684	423,699	7,624,049	380,381	1.2
Idle Grassland	1,403,300	140,411	1,331,205	133,127	1.1
Farmsteads	385,091	23,474	387,434	23,515	1.0
Residential	962,910	105,045	823,018	95,629	1.2
Commercial	328,253	81,590	305,556	41,463	3.9
Other Urban	140,229	39,114	122,873	30,365	1.7
Transportation	296,577	63,422	288,724	53,398	1.0
Lakes	307,755	118,936	265,246	108,556	1.2
Ponds	84,270	17,563	84,438	13,130	1.8
Rivers	129,922	43,887	103,729	23,368	3.5
Disturbed Land	44,223	17,741	42,455	16,020	1.2
Transitional	183,379	137,668	-	-	-
Wetlands	106,830	87,386	-	-	-

*Fields that are double cropped are included in the estimates for each crop.

TABLE V
COMPARISON OF 1983 FORESTLAND ESTIMATES FROM SRS LANDSAT STUDY WITH 1972 FOREST SERVICE ESTIMATES

Category	SRS	FS
Hardwood	11,139,532	11,619,900
Conifer	187,650	204,300
Conifer-Hardwood	1,148,447	540,500
(Unproductive)	(included above)	298,300
(Reserved)	(included above)	256,100
TOTAL	12,475,629	12,919,100
Grazed Forest	2,705,512	2,803,100

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.

In this study, winter wheat was analyzed using unitemporal spring Landsat data. A second analysis using multitemporal spring and fall data was done for summer crops and land covers. Table VI presents the total resource requirements for Landsat analysis. Analyzing and estimating the 23 land covers with summer crops required 51 percent more person hours and a 62-percent increase in computer cost. A majority of these costs were incurred during the acreage estimation processes. Since this study these estimation programs have been rewritten which should reduce future costs of producing land-cover estimates.

In summary, 23 land covers and five major crops were classified and estimated. The classifications were saved on

TABLE VI
TOTAL RESOURCE REQUIREMENTS FOR DIFFERENT LANDSAT ANALYSES USING A COMMON TEST AREA

Category	Person-hours	CPU (min.)	Computer Cost
Unitemporal Winter Wheat	237	773	$ 5,262
Multitemporal Summer Crops	467	1,294	12,634
Multitemporal Summer Crops and Land Covers	707	2,380	20,481

TABLE VII
COST FOR 1984 ARKANSAS CROP AND LAND COVER PROJECT

MATERIALS
Landsat Data - $17,000 ($730x20 scenes + B/W Prints)
Blank Tapes - $ 2,000 ($25 x 80)

DATA PROCESSING
Martin Marietta - $2,000 (ground data)
ARPANET - $4,000 (Electronic data transmissions)
IBM 33-30 - $2,000 (tape reformat & data editing)
DEC-10 - $36,000 (multitemporal overlay, digitizing, registration, signature development)
CRAY-1S - $8,000 (full scene classification)

PERSONNEL
Data Analyst - $25,000 (1/2 MYE at GS13)
Support Staff - $10,000

TOTAL $106,000

tape and the utility of the classified data are being assessed by potential users of the land-cover data. Increasing the sample allocation of the regular JES provided improved estimates of forest categories due to more samples in the forest strata. Cost figures were kept for all analysis steps and the additional cost of doing land cover was determined. The increase in precision of crop and land-cover estimates, when using multitemporal Landsat data, was not as high as originally anticipated. Research is needed to determine if the addition of land covers had an adverse affect on the classification results of summer crops.

VII. 1984 ARKANSAS STUDY

A. Objectives

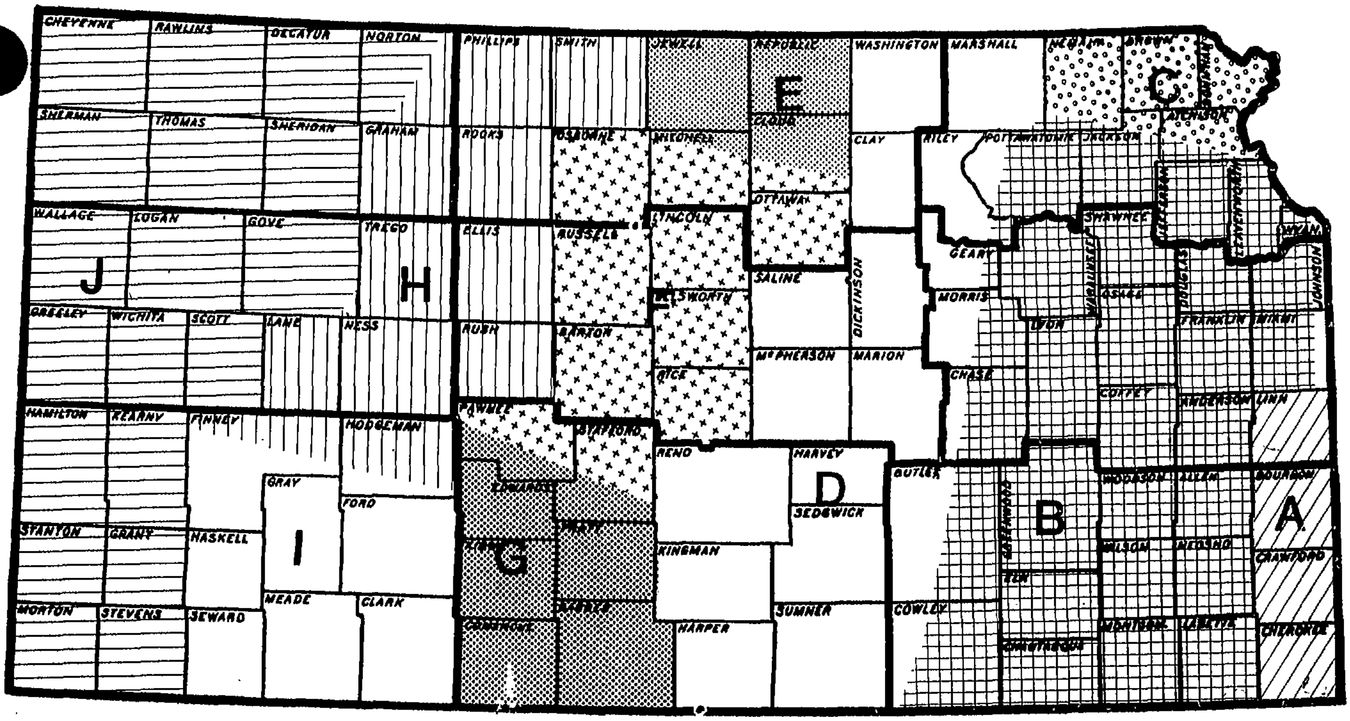
Land-cover results obtained from the Kansas and Missouri studies generated interest within the Soil Conservation Service and Forest Service. These two agencies along with the SRS jointly defined and funded a crop and land-cover study in Arkansas. The overall objectives of this study were to 1) utilize SRS's ground data collection and Landsat analysis techniques to produce a crop and land-cover classification for the entire state and 2) provide this classification on tapes so that each agency could independently utilize the land-cover data in their respective programs.

The SRS used the classified data to obtain 1984 planted acreage estimates for cotton, rice, soybeans, and sorghum. SCS will use the classified data in their next national resources inventory and FS will utilize the data in their forest land inventory.

B. Project Costs

The additional costs over normal JES costs for conducting this project are given in Table VII. These costs were evenly divided between the three agencies.

KANSAS



A - June 17	D - May 14	G - August 31	J - July 10
B - April 25	E - May 24	H - July 9	
C - August 11	F - April 27	I - June 21	

Fig. 3.

TABLE VIII
DIRECT EXPANSION AND REGRESSION ESTIMATES FOR MAJOR CROPS IN ARKANSAS

Cover	DIRECT EXPANSION Estimate	Standard Error	LANDSAT REGRESSION Estimate	Standard Error	Relative Efficiency
Cotton	442,000	94,000	458,000	61,000	2.4
Rice	1,161,000	118,000	1,133,000	69,000	2.9
Soybeans	4,124,000	204,000	3,989,000	136,000	2.3
Sorghum	671,000	85,000	659,000	60,000	2.0

C. Land Cover Definitions

Representatives from the three agencies met and established the terms and definitions for the survey. A listing of the land cover classification categories are shown below:

Hardwood Forest	Native Pasture
Mixed Forest	Improved Pasture
Conifer Forest	Row Crops
Clearcut Forest	Sown Crops
Barren Land	Hay
Urban	Other Land Use
Water	

D. Landsat Data

Multitemporal Landsat data were obtained for most of the state. Conifers are an important land cover; therefore, late fall 1983 and winter 1984 were obtained for the first date of the multitemporal data set. The second date of Landsat data were obtained from summer and fall 1984. Most of the crop land is located in the eastern half of Arkansas. To meet the SRS due dates for crop estimates, eastern Arkansas was analyzed first. Fig. 3 delineates the analysis districts and Landsat dates.

E. Results

The direct expansion and regression estimates for the crops generated for the SRS are given in Table VIII. These estimates were produced and delivered on December 1 in time for the year-end crop acreage report. The land-cover estimates and classified tapes for the SCS and FS will be generated during the first quarter of 1985. Therefore, these results were not available for inclusion in this paper.

VIII. CONCLUSIONS

Five years of research were conducted in developing and evaluating techniques for obtaining large-area land-cover classifications and area estimates. The remote-sensing techniques developed by the USDA's SRS for improving crop area estimates formed the basis for this research. The overall objective of applying this technology for the purpose of obtaining land-cover information was met. The following are specific conclusions from the land-cover research.

1) SRS's JES provides a vehicle, on an annual basis, for

obtaining ground truth data for land cover surveys that utilize Landsat data.

2) For classification and estimation purposes the operational JES segment allocation does not adequately sample many noncrop cover types. This can be corrected by increasing the sample size in strata for which the land cover(s) are located.

3) The SRS's deadline for timely crop area estimates can still be met when noncrop covers are included in the survey and Landsat analyses.

4) Two products can be obtained from the techniques discussed in this report: a) acreage estimates with measures of precision and b) classified Landsat data contained on tapes.

5) The utility of classified Landsat data for land-cover studies by other federal and state agencies is still being assessed.

6) Large increases in computer time and person hours were incurred when analyzing noncrop covers with crops. This can be offset by multiple agencies sharing the cost of a crop and land-cover survey.

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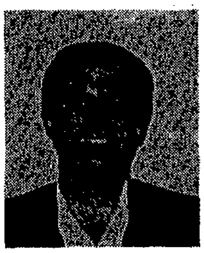

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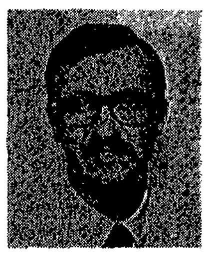

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