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1981 AgRISTARS DCLC FOUR STATE PROJECT

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I. ABSTRACT

This paper summarizes the work performed under the major crop area estimation element of the 1981 AgRISTARS (Agriculture and Resource Inventory Surveys Through Aerospace Remote Sensing), DCLC (Domestic Crops and Land Cover) Project.

The DCLC objective of providing timely, more precise year-end state and sub-state crop area estimates for SRS was accomplished. Corn and soybeans planted area estimates were provided for Missouri and Iowa. Harvested winter wheat estimates were provided for Kansas and Oklahoma.

II. BACKGROUND AND OBJECTIVES

AgRISTARS is a cooperative effort of the U.S. Department of Agriculture (USDA), the National Aeronautics and Space Administration (NASA), the U.S. Department of Commerce (USDC), the U.S. Department of the Interior (USDI), and the Agency for International Development (AID). DCLC is one of eight projects under the AgRISTARS program. During 1981, the Applications Section of the Remote Sensing Branch (RSB) of SRS and the Kansas, Missouri, Oklahoma and Iowa State Statistical Offices (SSO's) of SRS implemented the second phase of the DCLC project.

LANDSAT data were combined with ground-gathered survey data to provide timely, more precise year-end major crop area estimates in selected States. A regression estimator as described in Cochran (Section 17.1-7, third edition)[1] was used. The regression estimator as used by the RSB has been described by Hanuschak and others.[2] The DCLC project initially started with two States in 1980. Kansas and Iowa were chosen as the first two states. Missouri and Oklahoma were added in 1981.

The SRS objective of providing timely, year-end state and sub-state crop area estimates with reduced sampling errors, using ground gathered data in combination with LANDSAT data, was accomplished. Winter wheat harvested area estimates for Kansas and Oklahoma were provided to the SRS Crops Branch and the SSO's on October 30, 1981. Corn and soybeans planted area estimates were provided to the Crops Branch and SSO's on December 16, 1981, for Iowa and Missouri. For Missouri, rice and sorghum planted area estimates were also provided to the SSO and the Crops Branch. The data were reviewed by the Crops Branch and SSO's in their final end of season Annual Crops Summary.

A Land Cover Study was also completed in Kansas during 1981. The Land Cover Study results will be summarized in an upcoming report.

III. STATE STATISTICAL OFFICE CONTRIBUTION

The SSO's played an integral part in the outcome of the DCLC project. Part of their role was to be the primary ground data collectors. In this role the SSO's provided field boundary, acreage, crop and land cover type data for the randomly selected SRS area segments. These data were collected during the June Enumerative Survey (JES) and special follow-up surveys in Iowa and Missouri. The data were used to establish training fields for computer classification of LANDSAT digital data and again for estimation. After collecting the ground data, an intensive field level edit was made by each state followed by digitization and plotting of the segment data.

Prior to FY80 these functions were performed by the Remote Sensing Branch (RSB) Staff. In view of an expanding program, it was apparent due to efficiency considerations that some tasks would have to be performed in a decentralized fashion. Thus, the field level edit, digitization and plotting functions were successfully transferred to each of the four SSO's.

The field level edit is a labor intensive effort. It was performed during a two week period following the JES. Recorded information on photographs, questionnaires and computer records were verified.

Segment digitization is the process of converting segments from fields drawn on aerial photographs or topographic maps to a computer file of coordinates in a geographic coordinate system. This task was performed using a tablet digitizer, in conjunction with an interactive software sub-system (EDITOR). After the segments were digitized, they were plotted and checked for accuracy. In 1981, a greater amount of time was required for digitization than in previous years. This was due to problems with a sudden change in the Bolt, Beranek and Newman (BBN) data processing facility operating system requested by the General Accounting Office (GAO) and equipment breakdowns in the SSO's and Remote Sensing Branch.

The other major role of the SSO's was interpretation of the final state and sub-state level estimates which were generated at the end of the project.

IV. LANDSAT DATA ACQUISITION

In 1981, the following LANDSAT products were used: 1:1,000,000 scale positive black and white transparencies (bands 5 and 7), 1:250,000 scale paper products (bands 5 and 7) and computer compatible tapes (CCTs). Delivery of these products involved two phases. The data were first transmitted from satellite to NASA Goddard where it was processed and sent via DOMSAT to the EROS Data Center (EDC). EDC in turn processed the data, filled the data order, and shipped the products to SRS. While data delivery was improved, the 10-14 day requirement for delivery after acquisition was not met. Delivery times ranged from about 1 week to 20 weeks with an average time of 3 to 4 weeks. As a result of not obtaining some data in a timely manner, a considerable amount of overtime work had to be performed to meet timeliness deadlines. This turnaround time must be improved for the continued expansion of the DCLC program.

V. DATA PROCESSING

Prior to processing the LANDSAT data, analysis districts were determined. Analysis districts consisted of counties partially or completely contained in one or more scenes of the same LANDSAT pass. Areas overlapping two scenes were assigned to a specific scene by looking at cloud cover, data quality, imagery dates, and each scene's containment relative to the other.

Several data processing centers were used in processing the JES and LANDSAT data to calculate regression estimates. The Martin Marrietta Data System (MMDS), Bolt Beranek and Newman (BBN), Washington Computer Center (WCC), and the CDC 7600 computer at NASA Ames were used. The major software package used was EDITOR. EDITOR is an interactive and comprehensive data analysis system for processing LANDSAT and JES data.[3] EDITOR was used for calibration, digitization, registration and other analysis of the JES and LANDSAT data. EDITOR runs on a modified DEC System-10 computer and is available at BBN in Cambridge, Massachusetts. Some EDITOR programs are also available on CDC 7600 and CRAY-1S computers at NASA Ames.

A data set containing ground data from the JES was created and edited using a set of SAS programs on the MMDS. The final edited data set was then transferred to BBN. Boundary information for each field of crop data was digitized on BBN and converted to a geographic coordinate system by calibrating the segment photo to U.S. Geological Survey (USGS) maps. The calibration process consisted of locating corresponding points on both the aerial photograph and the USGS map on which the segment could be located. A regression routine then converted the digitizer coordinates to map coordinates by using coefficients calculated from the corresponding points data.

LANDSAT computer compatible data tapes were reformated at WCC and copies of the tapes containing the reformated data were mailed to BBN and to NASA Ames for processing.

Each selected scene was registered to USGS maps in Washington, DC. This process called registration relates LANDSAT row-column coordinates with USGS map latitude-longitude coordinates by means of third order bivariate polynomial equations.

A second step of registration followed the initial scene registration. This step consisted of using grey-scale print-outs and segment plots to shift each segment to a more accurate location based on interpretation of lightness-darkness regions within the print-out.

An EDITOR operation termed "masking" was next used to establish the location of the LANDSAT pixels for each field. The locations were stored in "segment mask" files which were then used to extract LANDSAT pixels corresponding to specific crop types or land uses. Criteria that could also be used in selecting pixels were field boundary information (that is, to include or exclude field boundary pixels), crop conditions, field codes and field size. This extracting process is known as packing and the files are termed "packed" files.

Packed files containing no field boundary pixels were clustered by crop type and land cover using an algorithm called CLASSY.[4] Files containing more than 5,000 pixels were sampled before clustering to save computer costs and reduce turnaround time. The statistics describing the clusters generated by CLASSY were saved in "statistics" files which were combined to form a "combined statistics" file representing all sampled crop and land covers for the segments in the sample.

The combined statistics file was used to classify pixels into a cover type. Counts of the classified pixels were made by cover types within a segment. The classified pixel counts along with the corresponding JES data were used in making sample level estimates. Full frame classification, aggregation of pixels by stratum and large scale estimation were performed for each analysis district. Full frame classifications were performed on a CDC 7600 computer at the NASA Ames Research Center. After the data for each analysis district for each State were processed, a state level estimate for each crop of interest was obtained using an accumulation program. The accumulation program aggregates estimates to a state total. Area estimates for which LANDSAT data are or aren't available are included in the state total.

Table 1.--1981 AgRISTARS DCLC Winter Wheat Acreage Estimates for Kansas

Analysis District	Imagery	JES Direct Expansion			LANDSAT Regression			Relative Efficiency
	Date	Estimate (Acres)	Standard Error	CV(%)	Estimate (Acres)	Standard Error	CV(%)	
AD29GHI	4/25	899,620	153,008	17.0	998,397	65,370	6.5	5.5
AD30GHI	4/17	2,093,325	133,804	6.4	1,975,892	79,484	4.0	2.8
AD31GHI	4/9	4,669,771	219,604	4.7	4,292,326	135,262	3.2	2.6
AD32HI	3/5	2,025,819	128,089	6.3	2,047,128	92,587	4.5	1.9
AD33HI	3/6	1,587,294	130,168	8.2	1,607,691	88,161	5.5	2.2
ADDE	---	2,169,714	144,195	6.6	2,169,715	144,195	6.7	1.0
STATE		13,473,494 1/	389,061 1/	2.88 1/	13,091,149	256,951	1.96	2.3

Table 2.--1981 AgRISTARS DCLC Winter Wheat Acreage Estimates for Oklahoma

Analysis District	Imagery	JES Direct Expansion			LANDSAT Regression			Relative Efficiency
	Date	Estimate (Acres)	Standard Error	CV(%)	Estimate (Acres)	Standard Error	CV(%)	
AD30IJK	4/8	2,833,681	160,561	5.67	2,780,929	80,187	2.88	4.01
AD31IJK	4/27	1,424,402	138,581	9.73	1,278,307	99,563	7.79	1.94
AD32IJ	3/5	265,562	30,909	11.64	175,641	27,625	15.73	1.25
					265,562 2/	30,909 2/	11.64 2/	1.00 2/
AD33IJ	3/6	318,573	61,453	19.29	291,530	46,860	16.07	1.72
ADDE	---	1,609,642	174,149	10.82	1,609,642	174,149	10.82	1.00
STATE	---	6,455,074 1/	289,242 1/	4.48 1/	6,136,049	249,020	4.06	1.35
					6,225,970 2/	249,585 2/	4.01 2/	1.34 2/

1/ State estimate, standard error and CV are from the JES Direct Expansion ignoring analysis districts.
2/ Because of unusual regression parameters and the small number of segments, the estimate was also calculated using direct expansion for analysis district AD32IJ and another state total shown.

Table 3.--1981 AgRISTARS DCLC Soybean Planted Acreage Estimates for Missouri

Analysis District	Imagery	JES Direct Expansion			LANDSAT Regression			Relative Efficiency
	Date	Estimate (Acres)	Standard Error	CV(%)	Estimate (Acres)	Standard Error	CV(%)	
AD24IJ	7/19	451,838	52,273	11.6	437,229	25,216	5.8	4.30
AD25IJ	7/20	715,364	86,272	12.1	630,979	66,547	10.6	1.68
AD26GHI	7/21	321,113	62,902	19.6	324,218	54,333	16.8	1.34
AD27G	8/9	544,588	77,426	14.2	430,687	50,175	11.6	2.38
AD27HI	8/9	213,638	64,942	30.4	219,940	32,940	15.0	3.89
AD28GH	9/15	1,030,180	138,164	13.4	976,629	95,895	9.8	2.08
AD29G	8/11	683,841	99,570	14.6	612,794	44,831	7.3	4.93
ADDE	---	1,219,885	139,431	11.4	1,219,885	139,431	11.4	1.00
STATE		5,158,408 1/	285,477 1/	5.5 1/	4,852,351	213,249	4.4	2.08

Table 4.--1981 AgRISTARS DCLC Soybean Planted Acreage Estimates for Iowa

Analysis District	Imagery	JES Direct Expansion			LANDSAT Regression			Relative Efficiency
	Date	Estimate (Acres)	Standard Error	CV(%)	Estimate (Acres)	Standard Error	CV(%)	
AD27EF	7/31	547,604	68,979	12.6	652,133	31,009	4.8	4.95
AD27FG	8/9	465,258	83,418	17.9	479,082	20,977	4.4	15.81
AD28FG	9/15	584,140	74,507	12.8	535,862	43,673	8.1	2.91
AD29EFG	8/11	1,264,631	106,728	8.4	1,289,599	57,284	4.4	3.47
AD30EF	8/12	2,132,882	129,259	6.1	2,124,002	65,855	3.1	3.85
ADDE	---	3,012,216	167,053	5.5	3,012,216	167,053	5.5	1.00
STATE		7,998,021 1/	277,070 1/	3.5 1/	8,092,894	201,603	2.5	1.63

1/ State estimate, standard error and CV are from the direct expansion (after field level edit and planting intentions follow-up survey). State level direct expansion estimate is not the sum of the analysis district direct expansions. State level direct expansion uses original area frame land use stratification.

Table 5.--1981 AgRISTARS DCLC Corn Planted Acreage Estimates for Iowa

Analysis District	Imagery	JES Direct Expansion			LANDSAT Regression			Relative Efficiency
	Date	Estimate (Acres)	Standard Error	CV(%)	Estimate (Acres)	Standard Error	CV(%)	
AD27EF	7/31	1,919,493	151,874	7.9	1,931,249	73,335	3.8	4.29
AD27FG	8/9	771,366	79,143	10.3	809,085	35,193	4.4	5.06
AD28FG	9/15	1,046,414	78,714	7.5	1,071,253	71,049	6.6	1.23
AD29EFG	8/11	1,717,529	90,986	5.3	1,737,908	65,437	3.8	1.93
AD30EF	8/12	3,560,716	143,057	4.0	3,398,413	89,876	2.6	2.53
ADDE	---	5,433,875	193,293	3.6	5,433,876	193,293	3.6	1.00
STATE		14,449,408 1/	331,169 1/	2.3 1/	14,381,784	253,848	1.8	1.56

Table 6.--1981 AgRISTARS DCLC Corn Planted Acreage Estimates for Missouri

Analysis District	Imagery	JES Direct Expansion			LANDSAT Regression			Relative Efficiency
	Date	Estimate (Acres)	Standard Error	CV(%)	Estimate (Acres)	Standard Error	CV(%)	
AD24IJ	7/19	127,657	56,294	44.1	45,483	23,453	51.6	5.76
AD25IJ	7/20	67,827	22,476	33.1	70,118	12,405	17.7	3.28
AD26GHI	7/21	278,899	51,554	18.5	259,047	34,050	13.3	2.29
AD27G	8/9	260,823	48,597	18.6	252,062	35,319	14.0	1.89
AD27HI	8/9	65,948	19,486	29.5	59,911	14,005	23.4	1.94
AD28GH	9/15	393,348	78,928	20.1	346,230	43,216	12.5	3.34
AD29G	8/11	347,300	82,108	23.6	338,883	38,202	11.3	4.62
ADDE	---	542,351	89,798	16.6	542,351	89,798	16.6	1.00
STATE		2,064,351 1/	177,395 1/	8.6 1/	1,914,085	125,208	6.5	2.16

1/ State estimate, standard error and CV are from the direct expansion (after field level edit and planting intentions follow-up survey). State level direct expansion estimate is not the sum of the analysis district expansions. State level direct expansion uses original area frame land use stratification.

VI. ESTIMATION RESULTS

Estimation results for 1981 are in Tables 1-6. Relative efficiency measures the degree of improved precision obtained from using the LANDSAT data in addition to the randomly selected JES segment data. The figure obtained indicates the factor by which the sample size would have to be increased to equal the precision obtained using LANDSAT data in conjunction with the ground data. The state level relative efficiencies for the four States ranged from 1.3 to 2.3. Relative efficiencies at the LANDSAT analysis district levels ranged from 1.2 to 15.8. These results were negatively impacted due to missing LANDSAT data in some areas due to clouds, and failure to achieve 10 to 14 day delivery of LANDSAT data to SRS from time of acquisition.

VII. PROGRAM COSTS AND CONTRIBUTIONS

Since the AgRISTARS DCLC program has now expanded to six States, there is a renewed interest in the relationship between program costs and contributions. Some historical perspective provides insight into the cost trend associated with SRS's use of LANDSAT data in conjunction with the ground data from the JES.

The first entire State project was conducted from 1975 to 1977 using 1975 data. The study area was Illinois. The cost associated with this project included all research and development efforts including a comprehensive software system (EDITOR). The total project cost was approximately $750,000. The first timely project for an entire State was conducted in 1978 using 1978 data from Iowa. Since most of the methodology and software had already been implemented, the cost decreased to about $300,000. In 1980, the AgRISTARS DCLC project costs for Iowa and Kansas were approximately $200,000 per State. In 1981, the project costs for Iowa, Kansas, Oklahoma, and Missouri were approximately $180,000 per State. There is an obvious downward trend in the LANDSAT project costs that is expected to continue as the move from research and development to applications continues.

The cost of the JES for the 1981 four State project was approximately $64,000 per State. The estimated overall cost per State associated with estimates from the JES ground data only, and the JES plus LANDSAT regression estimates is shown in Table 7. The costs can be ratioed for various relative efficiencies to determine if the improvement in statistical precision is cost effective relative to the alternative of increasing the JES sample size.

The use of LANDSAT data in conjunction with JES data is cost effective for all relative efficiencies with a corresponding cost ratio less than or equal to one. Using this criterion a relative efficiency of about 2.5 would be the break even point. In future years it is expected that the break even point will be lower. The reason for this expectation is that JES costs per unit probably will rise and JES plus LANDSAT costs per unit will probably decrease. The JES costs per unit will probably increase due to increases in travel and interview costs. More efficient computer data processing and proration of labor costs over larger geographic areas should result in lower JES plus LANDSAT costs per State.

Including all full State projects since the first full State project in Illinois in 1975, the majority of relative efficiencies at the sub-state level have easily passed the cost ratio criterion but results have been considerably more mixed at the State level. State level relative efficiencies vary according to the number of satellites available, the amount of cloud cover during the optimum window, and the timeliness and quality of LANDSAT data delivered to SRS.

However, there are several problems associated with the 1981 cost ratio criterion. One problem is that it does not reflect the benefits associated with keeping a staff trained in the technical knowledge of new and vastly improving satellite sensors. Another problem is that it doesn't reflect the benefits to SRS of the improved precision of major items (other than crop area) on the JES questionnaires that would occur if the JES sample size were increased. This second problem is somewhat diminished in that there exists some serious questions about whether or not it would be feasible to increase the JES sample size by a factor of 2-1/2 or more. With current budget restrictions and limitations on both full and part-time staff, and the additional recruitment and training of JES enumerators required to increase the JES sample size, use of LANDSAT data becomes perhaps the only feasible alternative for future expansion of data collection for domestic crop area estimation.

VIII. SUMMARY

More precise and timely crop area estimates were provided using LANDSAT data in conjunction with ground gathered data for four States. Winter wheat harvested area estimates for Kansas and Oklahoma were provided to the SRS Crops Branch and the state offices on October 30, 1981. Corn and soybeans planted area estimates were provided to the Crops Branch and the State offices on December 16, 1981, for Iowa and Missouri.

The SSO's played a key role in the project by performing field level edits, digitization, plotting, and state and sub-state evaluation of regression estimates.

The project was hampered due to failure to obtain data within 10 to 14 days after acquisition and problems with the BBN computer system.

IX. ACKNOWLEDGEMENTS

The authors wish to acknowledge the outstanding support provided by SRS's Remote Sensing Branch Support Staff (Sandra Stutson, Tjuana Fisher, George Harrell, Eric Hendry, Lillian Schwartz, Archie Nesbitt, Pearl Jackson) and Ed Camara. Thanks also go to Robert Slye and Ethel Bauer of the NASA-Ames Research Center. The support of the four state offices (Kansas, Oklahoma, Iowa, and Missouri) and the Research

TABLE 7. Cost of JES and JES + LANDSAT Comparisons 1/ (Dollars)

Relative Efficiency	1. Cost of JES 2/	2. Cost of JES Plus LANDSAT 3/	Cost Ratio (2 ÷ 1)
1.0	64,000	180,000	2.81
2.0	146,000	180,000	1.23
2.5	187,000	180,000	0.96
3.0	228,000	180,000	0.79
4.0	320,000	180,000	0.58
5.0	392,000	180,000	0.46

TABLE 8. Major Item Costs JES and JES + LANDSAT 1/ (Dollars)

JES Cost/State		JES + LANDSAT Cost (4 States) 3/	
SSO	55,000	SSO	50,000
DC Staff	7,000	DC Staff	210,000
MMDS	2,000	BBN	355,000
Total	64,000	EROS	25,000
		NASA (Ames)	25,000
		Travel	25,000
		Equipment	10,000
		Materials	20,000
		Total	780,000
		Cost/State	180,000

1/ Cost of initial area frame development and current sample size JES drawing is not included. This cost is approximately $80,000/state (1983 Nebraska cost projection).
2/ The cost of additional sampling and materials for relative efficiencies greater than 1.0 is included.
3/ Cost figures represent additional costs.

Section of the Remote Sensing Branch in implementing this project is sincerely appreciated. Members of the following SRS work units also contributed to this effort: Sampling Frame Development Section, Methods Staff, Enumerative Survey Section, Crops Branch, and Systems Branch. JES cost data were provided by Larry Sivers, Ron Radenz, Jim Ramey and Wayne Gardner of SRS. The authors wish to thank Mary Ann Higgs for a fine word processing effort.

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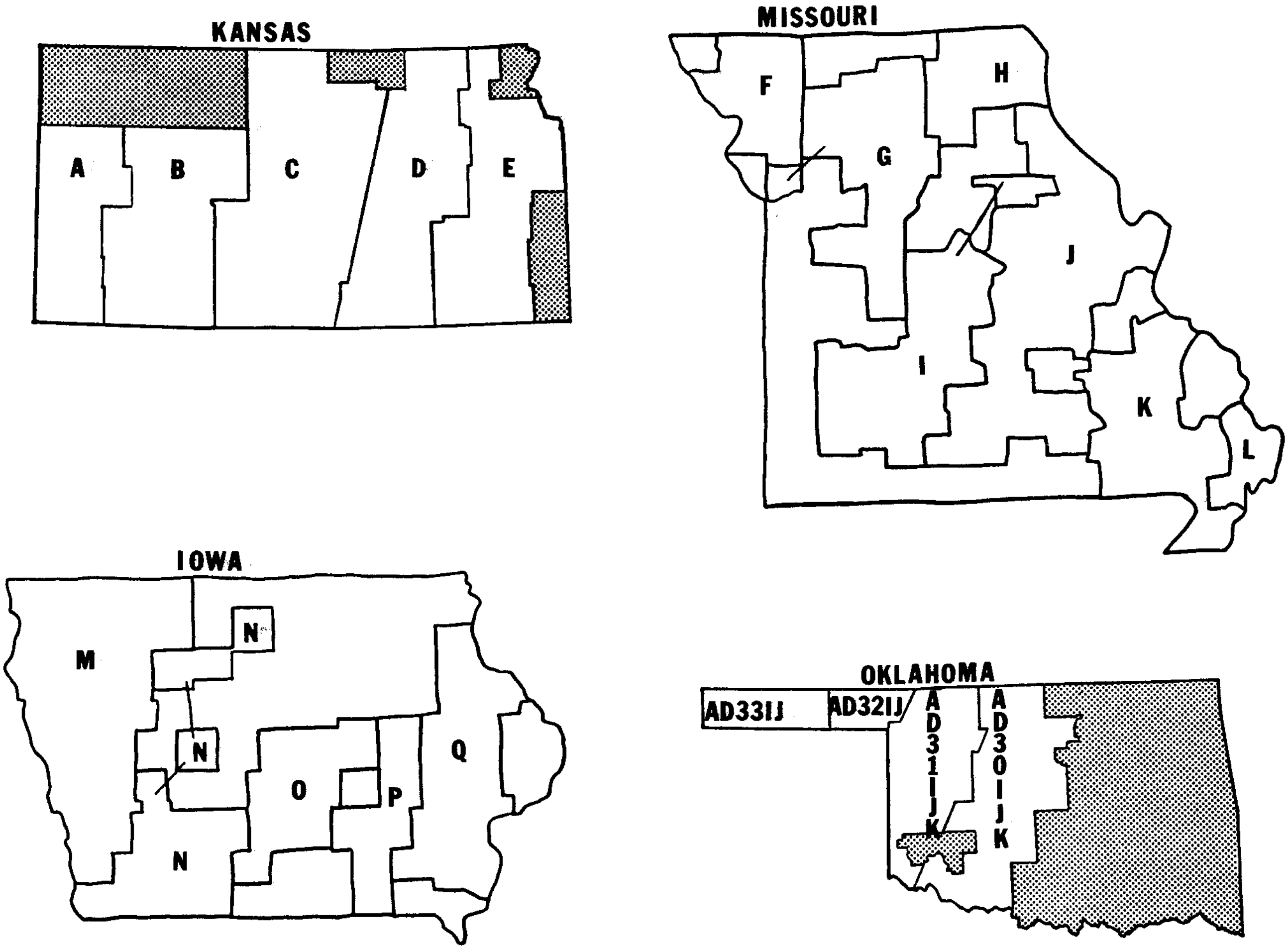
TABLE 9. JES and JES + LANDSAT Benefits

JES Costs	JES + LANDSAT Costs
$64,000/State and Increasing	$180,000 Additional/State and Decreasing
Benefits	Benefits
Objective Method	Objective Method
National and State Estimates (Multiple items)	Improved National, State and Sub-state Estimates (Major crops only)
Potential to do Land Cover area estimates (State Level)	No Additional Respondent Burden
	Research and Development and Utilization of an Improving Technology (Next Generation of Satellites)
	Public Relations Benefit
	Potential to do Land Cover Estimates (State and Sub-State)
	Procedure Uses ALL Crop Area Information in the JES

1981 DCLC FOUR STATE PROJECT
ANALYSIS DISTRICTS



A - AD33HI
B - AD32HI
C - AD31GHI
D - AD30GHI
E - AD29GHI

F - AD29G
G - AD28GH
H - AD27G
I - AD27HI
J - AD26HI
K - AD25IJ
L - AD24IJ

M - AD30EF
N - AD29EFG
O - AD28FG
P - AD27FG
Q - AD27EF

Unlabelled areas were assigned to analysis district ADDE.
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