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The Remote Sensing Applications Program of the National Agricultural Statistics Service: 1980-1987

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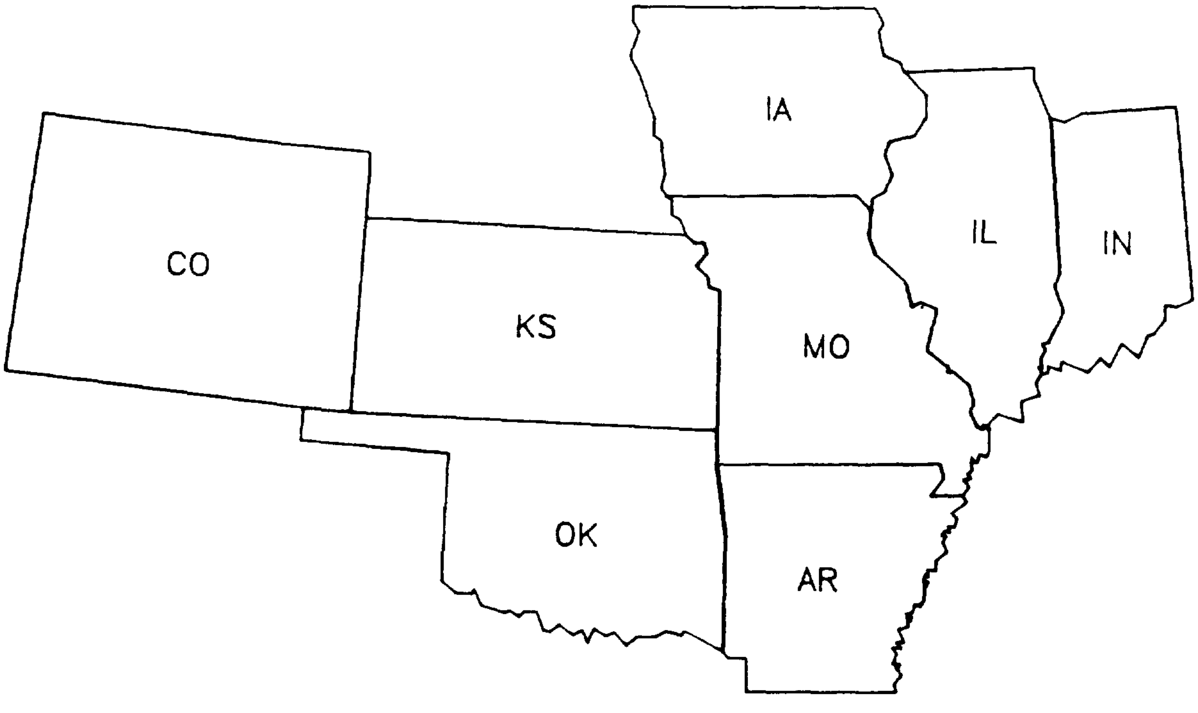
EIGHT STATE PROJECT AREA



THE REMOTE SENSING APPLICATIONS PROGRAM OF THE NATIONAL AGRICULTURAL STATISTICS SERVICE, 1980-1987 by J. Donald Allen and George A. Hanuschak, Research and Applications Division, National Agricultural Statistics Service, Washington, D.C. 20250, August 1988. NASS Staff Report No. SRB-88-08.

ABSTRACT

This report presents the results produced from the integration of Landsat satellite data into the crop area estimating program of the National Agricultural Statistics Service (NASS) and covers the years 1980-1987. The track record shows that the Landsat based crop area estimates for major producing regions of the U.S. were closer than the June Enumerative Survey (JES) direct expansion estimates to the Agricultural Statistics Board final estimates 21 out of 35 times. The basic methodology, data processing techniques and concepts, used in the Landsat estimating program, were developed through various research projects during the 1972-1979 time period and are presented briefly in this report.

The timing of this report is appropriate with 1987 being the final year of operational crop estimation using data from the Landsat Multispectral Scanner Sensor (MSS). In the future there will most likely be a return to the use of satellite data in the estimating program, but for now NASS will no longer be using this data to produce timely crop estimates. The primary reason for this discontinuation is the uncertain status of the current Landsat satellites which have already outlived their expected design lives. In addition new satellite technology in the United States, France, Japan, India and Russia has produced data far superior to that yielded by Landsat's MSS. However, in order for NASS to take advantage of the new U.S. and French data, more research is required to assess their feasibility so that when implemented, the anticipated improvement in the accuracy of the results will be cost effective.

KEY WORDS

Landsat, crop area estimates.

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SUMMARY

This report presents the results produced from the integration of Landsat satellite data into the crop area estimation program of the National Agricultural Statistics Service (NASS) and covers the years 1980-1987. The Landsat satellite data is combined with the conventional ground-gathered data, associated with the area sampling frame, in the form of a regression estimator. The basic methodology, data processing techniques and concepts, used in the Landsat estimating program, were developed through various research projects during the 1972-1979 time period and are presented briefly in this report. In order to process the very large volume of satellite data and properly calculate the regression estimator, NASS and several contractors have developed a complex and large (120,000 lines of code) software system called PEDITOR. During 1980-1987, PEDITOR was optimized for large scale applications. The project started with two states in 1980 and evolved into an eight state project for the years 1985-1987.

During the eight year Landsat-based crop area estimation project, there were three major findings. First, crop area estimates using Landsat data for large areas (up to eight states) could be done in a timely fashion with relatively small additional staffing. Secondly, the Landsat based estimate had considerably lower sampling errors than the conventional JES ground survey and the regional Landsat estimates were closer to the Agricultural Statistics Board final, 21 out of 35 times. Third, based on internal agency costs and benefits, the extra cost of processing the Landsat data was near but probably just short of the break even point for corn, soybeans, wheat and sorghum. This was the case even though major strides in cost efficient computer processing were made. Cloud cover, technical problems with the satellites or ground system, and the limits on the amount of information contained in Landsat's multi-spectral scanner were the major reasons for this. However, for cotton and rice, the Landsat estimator was clearly a cost effective improvement. There were also several other major benefits to the Agency from this eight year project. Some of the other major benefits were: the agency staff gained considerable and valuable experience in the use of supercomputers, video and vector digitization, multivariate analysis, vegetative indices, small area estimation, and land cover estimation and mapping. These and other benefits are presented in more detail in the conclusions section of this staff report.

The recent developments section of this staff report presents the current status of the Agency's remote sensing research program. Basically the eight state applications project has been discontinued in favor of a research program. Faced with limited resources and a need to prepare for the new and more advanced satellite sensors such as the Landsat Thematic Mapper and French SPOT systems, NASS management had to choose between an applications program, using an old sensor system, or a research program with the new sensors. Since the old satellite sensor, called the Multispectral Scanner Sensor (MSS) will not be flown on future earth resource satellites, management opted for the research program with an eye toward future applications. In order for NASS to take advantage of the more advanced sensors, research is required to assess their feasibility so that when implemented, the anticipated improvement in the accuracy of the results will be cost effective. The advanced sensor data from the commercial systems of the 1990's will contain improved spatial, spectral and temporal information in the data. To NASS, this will translate into more accurate acreage estimates and perhaps also crop condition or yield assessments if costs can be controlled through cost effective methodology.

INTRODUCTION AND BRIEF HISTORY

The National Agricultural Statistics Service (NASS), an agency within the United States Department of Agriculture (USDA), has the primary responsibility of providing statistics for domestic crop and livestock production. For the most part, the statistics are derived from data collected through a variety of sample surveys. For principal crops, the major surveys include a national area frame survey in June; a quarterly multiple frame survey (list and area) in June, September, December and March; and during the growing season, monthly objective yield surveys using actual field plots for yield forecasts. The area sampling frame used by the agency has been constructed and stratified based on land usage (primarily percent cultivated). NASS first began using remotely sensed data in the 1950's to aid in the construction of state area sampling frames; at that time, it was in the form of aerial photography. The use of earth resource satellite data from the U.S. Landsat was a natural extension in this process. In 1977, Hanuschak and Morrissey demonstrated the value of photo-interpreting Landsat imagery in area frame construction.

Landsat's value as a digital input in the development of a viable crop estimator also became recognized. In concert with the launch of Landsat I in 1972, NASS statisticians Donald Von Steen and William Wigton were selected by the National Aeronautics and Space Administration (NASA) to be principal investigators on the use of Landsat data for agricultural statistics. With a small research staff, they proceeded to conduct a pilot test of combining conventional ground-gathered data with Landsat digital data to form a crop area estimator. The pilot was considered worth pursuing further with several years of research. Full state tests in Illinois 1975 and Kansas 1976 are summarized in papers by Gleason et al. (1977) and by Craig et al. (1978). Finally, a timely (end of season) crop area estimate was calculated for Iowa in 1978. This is summarized in a paper entitled Obtaining Timely Crop Area Estimates Using Ground-Gathered and Landsat Data by Hanuschak et al. (1979). This experience plus NASS's participation and evaluation role in the interdepartmental (NASA, NOAA, USDA) Large Area Crop Inventory Experiment (LACIE) in the mid-70's led NASS to the point of large scale applications.

The progression of Landsat data usage in the crop estimating program of NASS was given additional impetus by the initiation of the AgRISTARS (Agriculture and Resource Inventory through Aerospace Remote Sensing) program which began on October 1, 1979. Initially, this was to be a six year project set to end September 30, 1985, but was later extended to October 1, 1986. It was an interagency program involving not only the USDA, but also the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, the U.S. Department of Interior, and the Agency for International Development. Its focus was to ascertain ways in which aerospace remotely sensed data could be utilized to answer agricultural resource questions as well as to meet identified information needs of the USDA. Moreover, it was to determine the usefulness, cost, and extent to which these data could be integrated into existing or future USDA systems so as to improve the objectivity, reliability, timeliness, and adequacy of information required to carry out USDA missions (NASA, 1981). The USDA AgRISTARS management team was lead by William Kibler (Administrator of NASS at the time) and Charles Caudill (Director of Statistical Research Division in NASS at the time and currently Administrator of NASS). One of the eight major AgRISTARS projects was to apply the above objectives toward estimating domestic crops and land covers (DCLC). It was in this area that the NASS research staff took the leadership role (NASA, 1981). Plans were to make crop estimates in two states in 1980 using the Landsat data, and each succeeding year two more states would be added with the goal of ten states being in the estimating program by 1984. The crops to be estimated were to be large area crops in homogeneous regions. In addition, research would continue in the area of determining land covers. The ultimate goal of the Landsat estimation program was to provide timely estimates of crop acreages which would have significantly smaller sampling errors than the estimates currently being used.

In summary, NASS employed a four prong approach in using the satellite data: 1) remote sensing was to be viewed as just another method of data collection, 2) remote sensing would supplement existing efforts, 3) integration into the estimation program would be founded through strong statistical procedures, and 4) resource effective techniques would have to be developed for the program to be successful. It was realized from the start that there would be both challenges and some constraints in using the then current satellite data. First, it was understood that it would be used as auxiliary data since statistical defensibility would require some source of ground data to be used to insure proper categorization of the satellite information. However, the satellite data would be available for large portions of the universe and not just the area frame sample which is a major advantage. Also, it was realized that cloud cover problems could prevent some of the data from even being available during the times when it might be needed. There would also be massive amounts of data to be processed which might limit the rate of the program's expansion. Completion of the crop acreage estimates would come at the end of the crop year because of the time needed to perform the analysis; this meant that the figures could not be used in early season forecasts. Finally, the resolution of the MSS data was such that some crops and some states with small field sizes could not be included in the estimation program.

THE LANDSAT SPACE PROGRAM

NASA's Landsat satellite series began with the launch of Landsat I in July 1972. This was followed by Landsat II in January 1975 and Landsat III in March 1978. The first two spacecraft were equipped with Return Beam Vidicon (RBV) cameras and Multispectral Scanners (MSS) while Landsat III provided data from a High Resolution Panchromatic (also referred to as RBV) camera as well as from a MSS. The decision was made to use the MSS data as opposed to the RBV data since MSS was in a form that was more adaptable for computer processing. It supplied four bands of data for analysis and a resolution of eighty meters (later sixty meters). A more detailed discussion of the satellite data used can be found in a report entitled <u>Obtaining Timely Crop Area Estimates Using Ground-Gathered and Landsat Data</u> by Hanuschak and others (1979). The point to point fly over period for these crafts was eighteen days. Landsat IV was launched in July 1982 with Landsat V being launched in March 1984. The point to point fly over period was sixteen days for these two satellites. They were equipped with the Multispectral Scanners as well as Thematic Mappers (TM). The TM data was considered superior since it provided seven bands of data as well as thirty meter resolution. However, all previous research by NASS had been directed at MSS data; in addition, the TM data was roughly five times more expensive to buy than MSS and even more expensive to process. These factors influenced the agency's decision to continue with MSS data until the benefits of the Thematic Mapper could be investigated further.

Due to vastly improving computer technology, the agency is currently in the process of researching the use of TM data. In addition, data from the French SPOT satellite which was launched in 1985 is also being examined. The French spacecraft provides three bands of MSS type data but with twenty meter resolution and a ten meter panchromatic band. The French SPOT satellite is also pointable which is a definite advantage for maximizing the probability of cloud-free coverage. There are possibilities for other data since Japan and India also has recently launched satellites with capabilities similar to the those of the Landsat series. In addition, there are plans at the present time to introduce Landsat VI in 1991. The intentions are that this Landsat will be equipped with a Thematic Mapper but not a Multispectral Scanner. As a result, data in the format currently used by NASS will no longer be available from sources in the United States once Landsat IV and V fail. At this time, both are deteriorating with only one satellite providing MSS data and the other providing only TM data.

There are normally only three different Landsat products used by NASS' statisticians in their analysis process. The first of these are 1:1,000,000 scale transparencies. These are used to evaluate cloud coverage and, in turn, to decide what combinations of imagery dates can be used to provide the best data. Secondly, there are 1:250,000 scale black and white paper products which are actually photographic interpretations of the scenes. These are used in the registration process. Lastly, there are the data tapes themselves. The costs of these products remained relatively stable up to 1983 when a large price increase occurred. Expenditures in this area have ranged annually from ten to fifteen percent of the total project costs since 1983.

METHODOLOGY

The methodology used by NASS in its crop estimating programs is best described in Scope and Methods (1983). Currently, major surveys use multiple sampling frames. More precisely, a list frame is used from which samples are drawn with an area frame used to account for the incompleteness which is inherent in the list. However, it should be noted that the area frame can stand alone as a complete frame covering the entire population and, as a result, is used to provide indications for crop acreages as well as being a complementary part of a multiple frame indication. The area frame estimator works well for major crops and livestock inventories, but not so well with minor or rare items such as specialized crops. Area frame procedures are most recently described by Nealon and Cotter in a paper entitled Area Frame Design for Agricultural Surveys.

A major source of crop data for NASS is the June Enumerative Survey (JES) which is conducted nationwide each year. This particular survey relies on the area frame which is itself a stratified population. From the frame, a sample of approximately 16,000 land segments is randomly selected with the segment size ranging from 40 to 2400 acres and averaging 450 acres. The segment data is expanded to state, regional, and national totals using methods as outlined by Cochran in Sampling Techniques (1977). At the national level, sampling errors are normally less than two percent for major crops such as corn, soybeans, and winter wheat. Survey training programs, efforts at standardization, and edits and analysis are used to reduce and control the nonsampling errors. Crop acreage estimates based on the JES are published around July 10 each year. Final year end estimates are published around January 15 of the following year.

In crop acreage estimation, the Landsat data is used in conjunction with the JES data in the form of a regression estimator. A discussion of these procedures can again be found in Cochran. The exact nature of this estimator as used by NASS was initially described by Von Steen and Wigton's paper entitled Crop Acreage Identification and Measurement Utilizing Landsat Data (1976). The estimator is described in numerous NASS research reports and most recently it was described in detail in Holko and Sigman's paper entitled The Role of Landsat Data in Improving U.S. Crop Statistics (1984). Some current additional information can be found in The Future of Remote Sensing in U.S. Crop Estimating Programs by Hale and Yost (1987). Therefore, a detailed description of the JES direct expansion and the Landsat/JES combined regression estimator will not be reiterated in this staff report. Studies by Chhikara and the NASS research staff have cited two technical problems with the regression estimator. They are: 1) a bias in the regression estimator associated with small sample sizes, and 2) using the same area frame segments to estimate both the parameters of the discriminant functions and the regression. Current and future research projects will address these problems. A short verbal description of the process used to calculate the regression estimator follows in the next paragraph.

Briefly, the process begins with the calibration of the JES land segments to a map base; that is, the exact location of a segment is translated into a set of latitudinal and longitudinal coordinates. Then, the ground data is collected through the JES, edited, and put into machine language. The field boundaries that were indicated during the JES are then digitized along with the segment boundaries. Each frame or scene of Landsat data, each covering an area of 200 kilometers by 185 kilometers, must also be registered or assigned latitudes and longitudes. Details of the evolution of the registration procedures can be found in Cook's Landsat Registration Methodology Used by U.S. Department of Agriculture's Statistical Reporting Service (1982). The next step requires that the segments and fields be mapped onto the Landsat scenes using the coordinate system that was derived during calibration and registration. Each pixel (a square area covering .8 acres of a scene) that overlaps a JES segment is assigned a crop or cover type based on the corresponding JES ground data. In addition, each pixel also has a signature or set of MSS measurements. In the ensuing phase, relationships are developed between the signatures and the ground data. Then, all the segment data is classified into crop types based on these relationships. Next a regression relationship is developed between the real ground data and the classified pixels. The entire Landsat scene is then classified based on the relationships developed from the JES segments. In the succeeding step, the regression relationship is applied to the full scenes. All the data is finally aggregated across scenes for the Landsat estimate. The final estimate will also include JES expansions for areas not covered by Landsat scenes. A cloud covered area domain estimator from Cochran is used in these situations as described by Hanuschak in 1975.

Normally, it takes approximately three to four months to obtain and analyze fully the Landsat data for a state. Also, it is desirable that the data being used pertain to the optimum growing period for the crop being estimated. For winter wheat in the central part of the United States, this means that Landsat data would normally be at its best if it related to the time period between mid April and the end of May. The optimum for the spring crops being estimated would ideally relate to the period between mid July and the end of August. Because of this timing, the Landsat indications are used only in setting end of the season acreage estimates.

In order to determine the success associated with the estimator, its relative efficiency (RE) is calculated (Hanuschak, Wigton, and Allen et al., 1982). The RE in essence is a measurement of the gain in precision of the regression estimator as compared to the JES direct expansion:

$$\text{RE} = \frac{\text{Variance (JES direct area expansion)}}{\text{Variance (Landsat/JES combined regression estimator)}}$$

Additionally, this value can be thought of as the factor by which the JES sample size would have to be increased in order to yield a direct expansion with a variance equal to that obtained using the Landsat data. In the same paper, an approximate break even RE in terms of cost effectiveness was calculated to be approximately in the 2.5 - 3.5 range using 1981 cost data. That is, an RE above that range would indicate that it is cheaper, for the same estimate precision, to use the Landsat plus JES approach as compared to expanding the JES sample size. The cost/benefit ratio is certainly not an exact measure and is subject to many various assumptions and questions such as:

1.) would or would not the agency continue a general purpose JES?

2.) what is the financial benefit to the agricultural sector of the economy if NASS cuts the corn acreage variance estimate by a factor of two to three?

3.) what would be the cost of a ground survey for only crop and land use information for remote sensing analysis and not a general purpose JES?

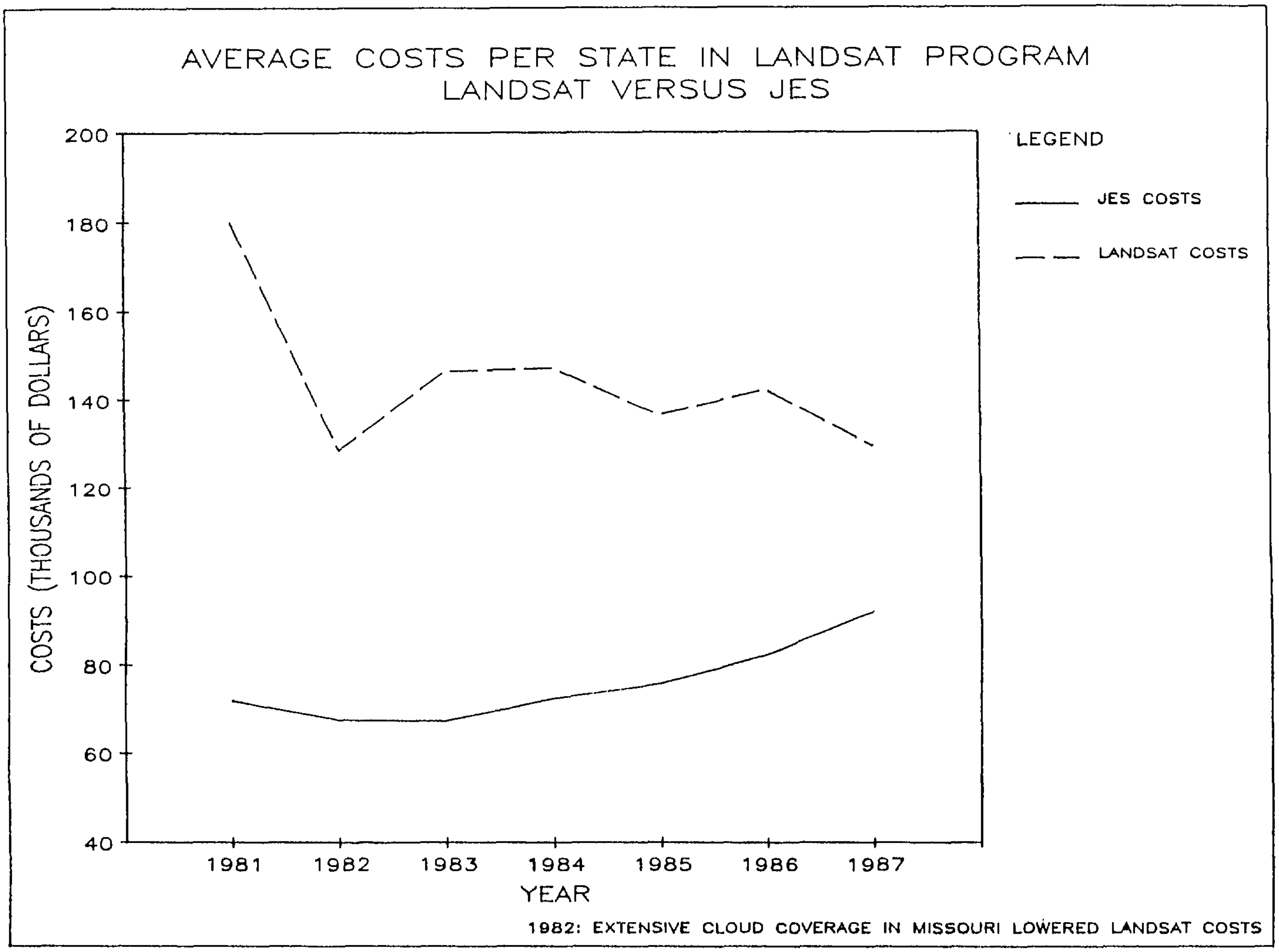
4.) what is value of county level remote sensing estimates that the JES doesn't provide?

5.) what would be the magnitude of the gains in estimating other items if the sample size of the JES were to be doubled or tripled?

6.) could the general purpose JES be doubled or tripled in terms of overall response burden and implementation (enumerator and state office workload, potential nonsampling errors, etc.)?

Over time, the costs of the JES have increased with the remote sensing costs decreasing. As a result, the break even point for cost effectiveness has declined considerably. In 1987, by the same criterion, relative efficiencies exceeding the 1.5-2.5 range would be considered an indication of cost effectiveness. A graphical representation of the total Landsat costs and the JES costs follows in Figure 1. The Landsat costs are all costs associated with the Landsat estimate above and beyond the operational JES costs.

FIGURE 1


AVERAGE COSTS PER STATE IN LANDSAT PROGRAM
LANDSAT VERSUS JES
LEGEND
JES COSTS
LANDSAT COSTS
COSTS (THOUSANDS OF DOLLARS)
200
180
160
140
120
100
80
60
40
1981
1982
1983
1984
1985
1986
1987
YEAR
1982: EXTENSIVE CLOUD COVERAGE IN MISSOURI LOWERED LANDSAT COSTS

SOFTWARE AND HARDWARE CONFIGURATION

In order to process the very large volume of satellite data and properly calculate the regression estimator, NASS and several contractors have developed a complex and large software (120,000 lines of code) system called PEDITOR (originally EDITOR). Ozga et. al. 1977 described the original development of the EDITOR system jointly by NASS, U.S. Geological Survey, and the coders at the University of Illinois' Center for Advanced Computation starting in 1974. The base software system was an interactive version on Purdue University's LARSYS system. The system was then revised by NASS, USGS and CAC to use NASS ground gathered area frame data and then process them in the correct form for a regression estimator. Over the years, as the NASS remote sensing projects became more operational, it became apparent that the EDITOR system should be portable and not tied to only a few hardware configurations. Thus in 1985, NASS and NASA-Ames programming staffs began a conversion of the EDITOR system into a portable system called PEDITOR. During the DCLC project years, EDITOR and PEDITOR were optimized for "large-scale applications" and an operational eight state program. If the space program of the U.S. government or private sector were committed to two or three operational MSS type satellites, then NASS was prepared to expand to ten to twenty states. Since this is not the case, PEDITOR will become a research system for the next several years and the analysts will search for the most cost effective and accurate methodology for TM and SPOT.

One Landsat MSS scene contains approximately 50 million data values on a CCT (roughly equivalent to one national June survey). At the peak of the DCLC project (1984-87), approximately 50-75 Landsat MSS scenes were being processed per crop season. Just for future comparison, one Landsat TM or French SPOT scene will contain approximately 350 million data values. This will undoubtedly pose a data processing challenge, but the cost and capacity breakthroughs in CPU and storage show great promise in handling this new higher resolution data.

The authors choose to not list all the historical hardware associated with the DCLC project because of the cumbersome length. However, there have been two obvious communalities, to all the hardware configurations for DCLC over the years, 1.) a high speed and reliable telecommunications network and 2.) access to a supercomputer. A list of the major components of the hardware configuration in the last year (1987) of the DCLC project and in current 1988 research activities is the following:

<u>CPU Hardware</u>

PC-AT's
PC-386's
PDP 11-44
SUN 3
IBM 3084
IBM 3090 with Vector Processor
CRAY - XMP Supercomputer
MIDAS System
Raster Tech Display
MicroVAX 3500

Peripherals	Telecommunications Network(s)
Plotters	MMDS
Printers	Boeing
Video Digitization Grinnell Image Processor	
Video Camera	
Point Mode ALTEK Digitizers	
2 - State Statistical Offices	
2 - Remote Sensing Section	

Without PEDITOR and cost effective hardware configurations, the NASS staff could not have accepted the challenge of processing earth resource satellite data.

DCLC PROGRAM COVERAGE AND RESULTS

From 1980 to 1987, the DCLC program expanded from two states (Iowa and Kansas) and three crops of interest (corn, soybeans, and wheat) to eight states (Arkansas, Colorado, Illinois, Indiana, Iowa, Kansas, Missouri, and Oklahoma) and three additional crops of interest (cotton, rice, and sorghum). This alone was a significant accomplishment with nearly the same personnel resources. Figures 2 and 3 show the percent of the total U.S. planted acreage across states, by crop, that the Landsat estimates represented. The crops and relative efficiencies of the regional estimates (sum of state estimates for each crop) are shown in Appendix C for each year of the project.

Tables 1 through 6 show a comparison of the track record of the June Enumerative Survey estimates and Landsat based estimates as compared to the Agricultural Statistics Board (ASB) final official estimate for each crop. The ASB final is the official statistic released in the most recently available USDA/NASS Crop Report. These official statistics are based upon the interpretation of an expert panel who evaluate the JES, Landsat, administrative or check data, yield indications, and national balance sheet data and, starting in 1987, multiple frame Agricultural Survey indications.

Across all crops and all years there were 35 regional estimates calculated. They are shown in detail in Appendix A. Out of these 35 estimates, the Landsat based estimator was closer to the ASB final 21 times or 60 percent of the time. While this is not a statistically significant difference (1.18 standard errors away from a proportion of 50 percent), it is still intriguing to see such a new and complex technology outperform the June Enumerative Survey, in terms of estimated accuracy, 60 percent of the time. The estimated accuracy measure used in this paper assumes the Board final to be the best approximation to "true values".

Also, 9 of those 35 regional estimates accounted for less than 15% of U.S. total, those for cotton and sorghum and 1980 soybeans. For the remaining 25 regional estimates for corn, soybeans, wheat and rice, which were the major crops of interest and the larger regions in the study, the Landsat estimates were closer than the JES to the ASB final 17 times or 68 percent of the time (1.80 standard errors away from a proportion of 50 percent). Appendix B gives a rather detailed written description of the DCLC project on a year by year basis.

Probably the most impressive thing about the Landsat estimator is that such a new complex technology did not seem to suffer from any major nonsampling errors which seems to be the case, at least initially, with many major survey methodology changes.

FIGURE 2

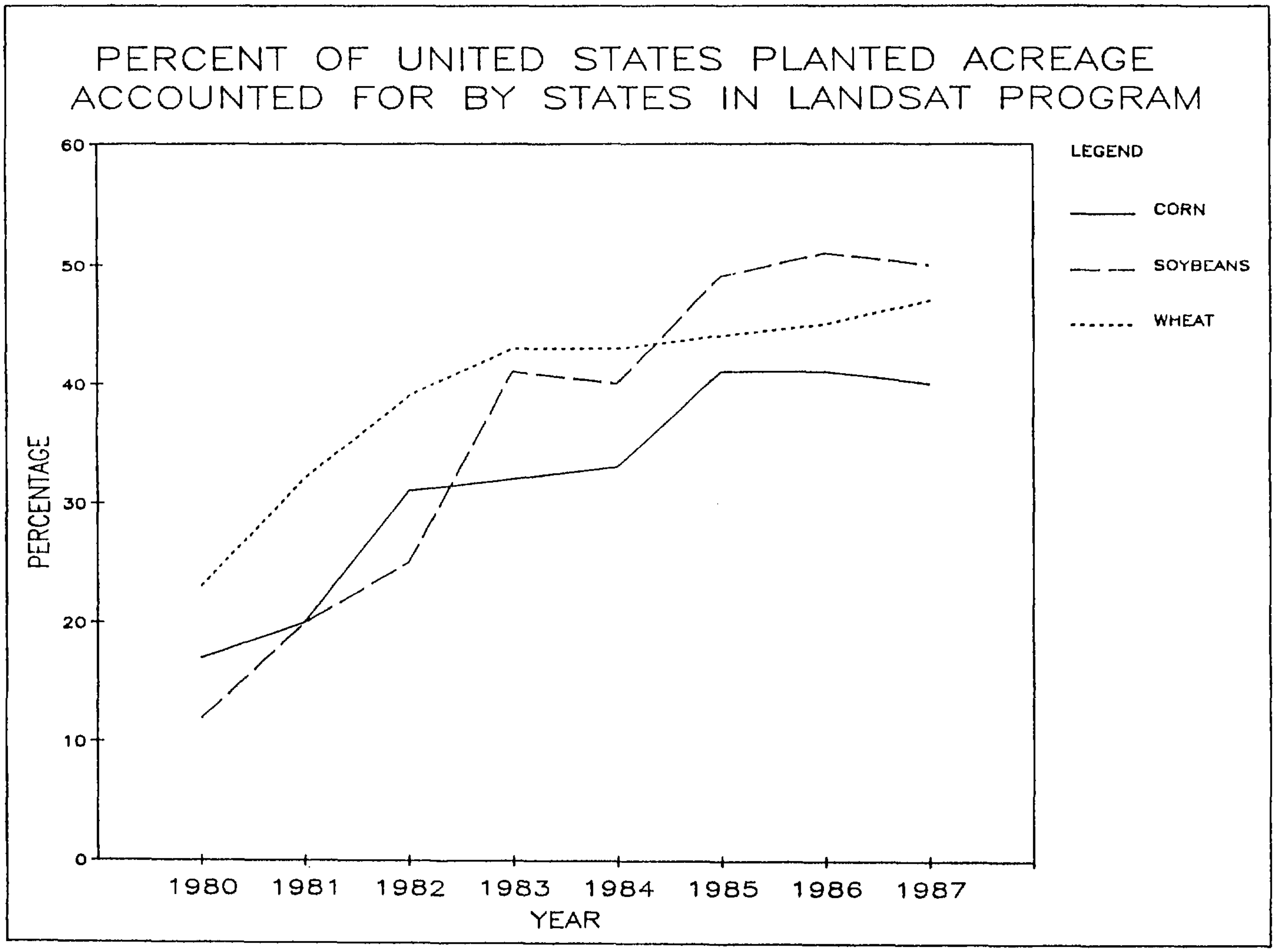

PERCENT OF UNITED STATES PLANTED ACREAGE
ACCOUNTED FOR BY STATES IN LANDSAT PROGRAM
LEGEND
CORN
SOYBEANS
WHEAT
PERCENTAGE
0
10
20
30
40
50
60
1980
1981
1982
1983
1984
1985
1986
1987
YEAR

FIGURE 3

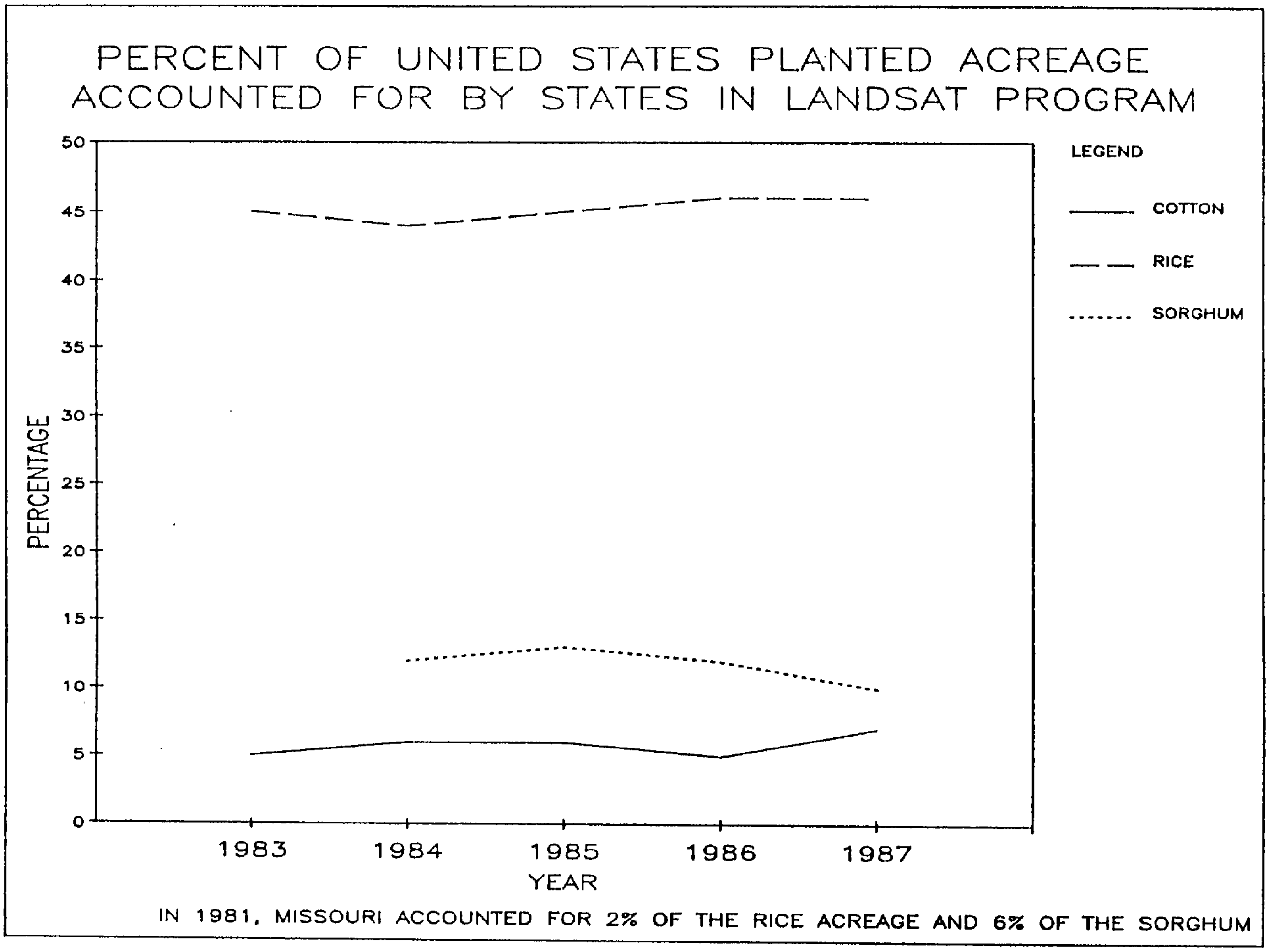

PERCENT OF UNITED STATES PLANTED ACREAGE ACCOUNTED FOR BY STATES IN LANDSAT PROGRAM
PERCENTAGE
50
45
40
35
30
25
20
15
10
5
0
1983
1984
1985
1986
1987
YEAR
LEGEND
COTTON
RICE
SORGHUM
IN 1981, MISSOURI ACCOUNTED FOR 2% OF THE RICE ACREAGE AND 6% OF THE SORGHUM

TABLE 1

CORN PLANTED ACRES

Year	June Enumerative Survey as % of ASB Final	Landsat Estimate as % of ASB Final
1980	98.4	99.5*
1981	100.3*	98.8
1982	101.1	99.5*
1983	103.4	99.8*
1984	99.8*	97.1
1985	100.1*	99.4
1986	98.6	99.1*
1987	100.0*	97.6
Overall	100.2*	98.9

TABLE 2

SOYBEAN PLANTED ACRES

Year	June Enumerative Survey as % of ASB Final	Landsat Estimate as % of ASB Final
1980	100.8*	98.0
1981	104.0	97.9*
1982	103.3	100.4*
1983	100.7*	97.9
1984	103.4	99.3*
1985	100.9*	98.5
1986	103.7	101.3*
1987	102.6	101.2*
Overall	102.4	99.3*

* Most accurate survey result for a given year (or overall) as compared to the ASB final.

TABLE 3

WHEAT HARVESTED ACRES

Year	June Enumerative Survey as % of ASB Final	Landsat Estimate as % of ASB Final
1980	107.4	104.0*
1981	107.7	103.9*
1982	106.4	101.4*
1983	104.0	100.9*
1984	101.0*	98.1
1985	103.0	100.0*
1986	102.4*	95.7
1987	100.6*	96.0
Overall	104.1	100.0*

TABLE 4

COTTON PLANTED ACRES

Year	June Enumerative Survey as % of ASB Final	Landsat Estimate as % of ASB Final
1983	98.4*	76.9
1984	89.0	104.4*
1985	93.0*	109.4
1986	133.9	120.1*
1987	122.1	108.1*
Overall	107.3	103.8*

* Most accurate survey result for a given year (or overall) as compared to the ASB final.

TABLE 5

RICE PLANTED ACRES

Year	June Enumerative Survey as % of ASB Final	Landsat Estimate as % of ASB Final
1981	150.6	100.0*
1982	--	--
1983	117.4	109.2*
1984	97.0*	96.7
1985	102.7*	109.7
1986	91.2	94.3*
1987	90.3*	88.1
Overall	108.2	99.7*

TABLE 6

SORGHUM PLANTED ACRES

Year	June Enumerative Survey as % of ASB Final	Landsat Estimate as % of ASB Final
1984	105.8	95.0*
1985	102.4*	89.9
1986	96.3*	86.3
1987	99.4*	93.1
Overall	101.0*	91.2

* Most accurate survey result for a given year (or overall) as compared to the ASB final.

PROJECT COST

Project cost data were maintained during the eight year DCLC project. Reviewing the cost history prior to DCLC project contributes to one's perspective on the DCLC project costs. When the first full state project (Illinois - 1975 data) was done, over a period of two years and included a lot of original analysis software (EDITOR) development, the total cost was $750,000. The first real time full state application (Iowa - 1978 data) project, by comparison, cost $300,000. The first year DCLC (1980) costs were $200,000 per state and this was reduced to an average of approximately $140,000 per state for the 1982-1986 and ended with $129,000 per state in 1987. None of the cost data have been adjusted for inflation which would show even more dramatic cost reductions over time. The two major reasons for the sharp drop in costs are: 1.) efficient use of computer resources with a range of computing involving supercomputers, mainframe, mini, and micro computers, and 2.) doing more states with basically the same amount of personnel resources. The proper mix of hardware and optimized software tended to maximize the gains in cost efficiency. The two graphs that follow (Figures 4 and 5) show the total average cost per state in 1978 and 1980-1987 and a more detailed cost breakout for 1981-1987.

RECENT DEVELOPMENTS

At the end of 1987, the decision was made to rechannel some of the resources of the remote sensing applications group back into a research program. There were several reasons for this. Foremost was the concern over the anticipated failure of the current Landsat satellites. At the present time, Landsat IV and V are still functioning. However, because of hardware problems, only one of the satellites is providing MSS data, and it may fail soon. This has produced two obstacles for NASS. First, past studies have shown that two MSS satellites are needed in order to provide coverage adequate enough to overcome cloud coverage (Winings, 1982), and second, all of the present methodology is geared toward the use of the MSS data so the use of other types of data is not possible at this time. This is further compounded by the fact that future Landsat satellites will not carry multispectral scanners. In addition, there is a need to study the new high resolution sensors on the pointable French Spot satellite as well as Landsat's Thematic Mapper to evaluate their suitability for use in an operational program. The program change also allows for more resources to be applied to the research on computer assisted area frame construction. In connection with this, NASS has recently received a grant from NASA headquarters to aid and speed up this effort. This all translates into the need for more very well targeted research. Another factor influencing the decision to defer the applications program was the reduction in available funding. Federal budget cuts have demanded that some projects be curtailed, and remote sensing applications with expenditures exceeding one million dollars per year was remote sensing management's choice when coupled with the above considerations. On a positive note, the cessation of the remote sensing applications program is being viewed as only a transition period that will lead to even better course of action in the usage of advanced higher resolution satellite data. The advanced sensor data from the commercial systems of the 1990's will contain improved spatial, spectral and temporal information in the data. To NASS, this will translate into more accurate acreage estimates and perhaps also crop condition or yield assessments if costs can be controlled through cost effective methodology.

FIGURE 4

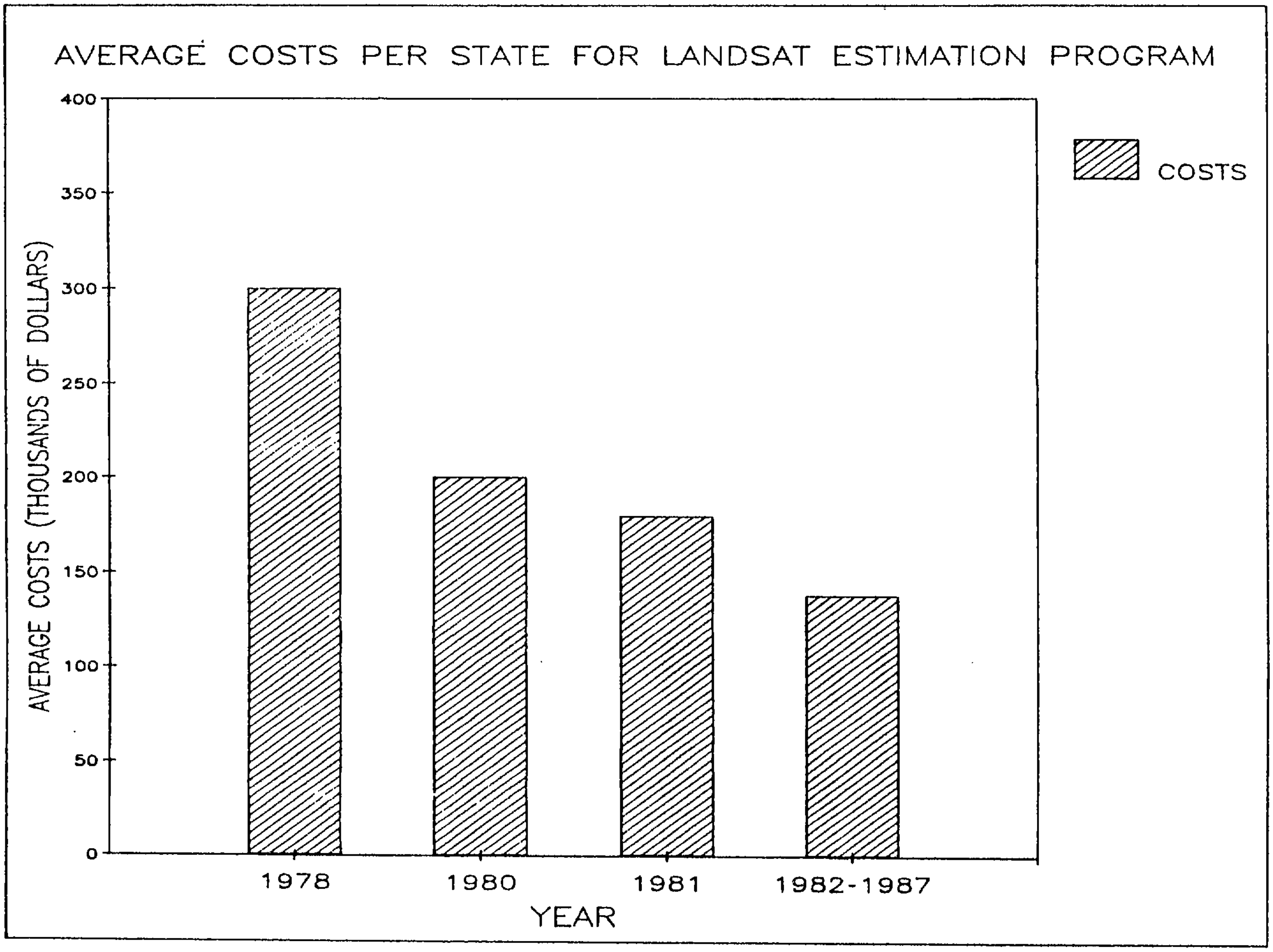
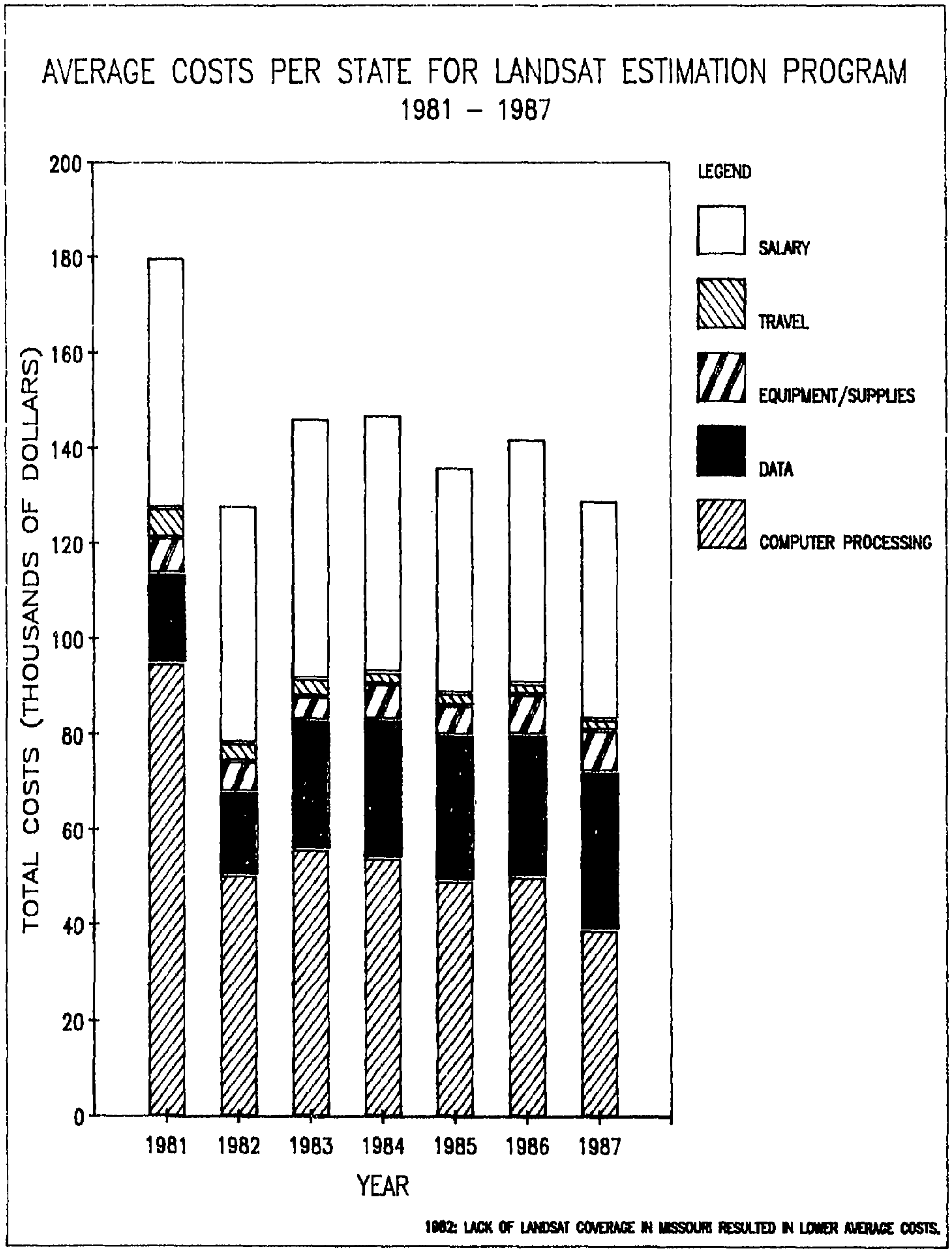

AVERAGE COSTS PER STATE FOR LANDSAT ESTIMATION PROGRAM
AVERAGE COSTS (THOUSANDS OF DOLLARS)
400
350
300
250
200
150
100
50
0
1978
1980
1981
1982-1987
YEAR
COSTS

FIGURE 5



1982: LACK OF LANDSAT COVERAGE IN MISSOURI RESULTED IN LOWER AVERAGE COSTS.

CONCLUSIONS AND OBSERVATIONS

In the eight year DCLC crop area inventory project, there were three major findings. First, that crop area estimates using Landsat data for large areas (up to eight states) could be done in a timely fashion with relatively small additional staffing. Secondly, the Landsat based estimate had considerably lower sampling errors than the conventional JES ground survey and the regional Landsat estimates were closer to the Agricultural Statistics Board final, 21 out of 35 times. Third, based on internal agency costs and benefits, the extra cost of processing the Landsat data was near but probably just short of the break even point for corn, soybeans, wheat and sorghum. This was the case even though major strides in cost efficient computer processing were made. Cloud cover, technical problems with the satellites or ground system, and the limits on the amount of information contained in Landsat's multi-spectral scanner were the major reasons for this. However, for cotton and rice, the Landsat estimator was clearly a cost effective improvement. There are many other considerations, findings and benefits from this eight year DCLC project. It is not feasible to recall or list each and every one of them. Some other considerations and observations of potentially major significance are the following:

1) The agency research staff gained considerable experience in the use of supercomputers.

2) The agency research staff gained considerable experience in the use of specialized hardware for digitization, both vector and video. The vector digitization and visual land use interpretation from Landsat imagery experience was passed on to the area sampling frame construction staff and has paid big dividends in efficiency and built-in quality control for area frames.

3) The agency has a small highly trained staff to evaluate the more advanced satellite sensors of today and the future.

4) The agency staff gained an international reputation for its Landsat methodology and large scale inventory capabilities and efficient use of supercomputers.

5) Several agency managers, William Kibler and Charles Caudill, led the management team of the major interdepartmental research program AgRISTARS, mostly as a result of the research progress in the 1970's and the DCLC project plans.

6) Statistical formulas were developed (by Huddleston, Fuller, Sigman, Cardenas, Walker, Chhikara) for small area (county level) crop acreage estimates.

7) The research staff of NASS, along with the USDA's Soil Conservation Service and several other federal and state government agencies, demonstrated that land cover inventories in addition to crop acreage inventories could be successfully conducted using the Landsat regression estimator.

8) The use of Landsat MSS data for yield forecasting and estimation was examined but it was determined that any increase in information on crop yields was not cost effective compared to NASS's conventional yield surveys.

9) To the authors knowledge, economic benefit studies to determine the "value to the agricultural economy" of more accurate crop area estimates have not been conducted during the study period by professional economists. Therefore, thorough results from a cost/benefit analysis (internal and external costs and benefits) are not available.

REFERENCES

Allen, Richard D. "Domestic Crops and Land Cover Implementation Plan." Report No. DC-U1-CO648; JSC-17799. U.S. Dept. of Agr., Stat. Rep. Serv.; NASA, Johnson Space Center. November 1981.

Angelici, Gary and others. "PEDITOR: A Portable Image Processing System." Paper presented at the 1986 International Geoscience and Remote Sensing Symposium, Zurich, Switzerland, September 8-11, 1986.

Chhikara, Raj S. "A Simulation Study for an Evaluation of USDA Landsat Derived Crop Acreage Estimation." University of Houston, February 1987.

Chhikara, Raj S. and J. J. McKeon. "Estimation of County Crop Acreages Using Landsat Data as Auxiliary Information." University of Houston, June 1987.

Chhikara, Raj S., A. G. Houston, and J. C. Lundgren. "Crop Acreage Estimation Using a Landsat Based Estimator as an Auxiliary Variable," IEEE Transactions on Geoscience and Remote Sensing, Vol. GE-24, No. 1 (Jan. 1986), pp. 157-168.

Cochran, William G. Sampling Techniques. New York, New York: John Wiley and Sons, Inc., 1977.

Cook, Paul W. "Landsat Registration Methodology Used by U.S. Department of Agriculture's Statistical Reporting Service - 1972-1982." Paper presented at the 1982 American Statistical Association's meeting, Cincinnati, Ohio, August 1982.

Cook, P. W., G. A. Hanuschak, and S. B. Winings. "AgRISTARS DCLC Applications Project - 1982 Corn and Soybeans Area Estimates for Iowa and Illinois." Paper presented at the Seventeenth International Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, May 9-13, 1983.

Cook, P. A., R. A. Kestle, and G. May. "A Continuing Development of an Application for Landsat Data: 1983 DCLC Winter Wheat Acreage Estimates For Four States." Paper presented at the Eighteenth International Symposium on Remote Sensing of Environment, Paris, France, October 1-5, 1984.

Cotter, Jim and Jack Nealon. "Area Frame Design for Agricultural Surveys." U.S. Dept. of Agr., Nat. Agr. Sat. Serv., 1987.

Craig, Michael E., M. Cardenas, and R. S. Sigman. "Area Estimates by Landsat: Kansas 1976 Winter Wheat." U.S. Dept. of Agr., Econ. Stat. Serv., August 1978.

Gleason, C. P., G. A. Hanuschak, R. R. Starbuck, and R. S. Sigman. "Stratified Acreage Estimates in the Illinois Crop-Acreage Experiment." U.S. Dept. of Agr., Stat. Rep. Serv., March 1977.

Hale, Robert C. and Mickey B. Yost. "The Future of Remote Sensing in U.S. Crop Estimating Program." U.S. Dept. of Agr., Nat. Agr. Stat. Serv., April 1987.

Hanuschak, George. "Landsat Estimation with Cloud Cover." Proceedings of the 1976 Symposium on Machine Processing of Remotely Sensed Data, West Lafayette, Indiana, 1977.

Hanuschak, G.A. and K.M. Morrissey. "Pilot Study of the Potential Contributions of Landsat Data in the Construction of Area Sampling Frames." U.S. Dept. of Agr., Stat. Rep. Serv., October 1977.

Hanuschak, George A. and others. "Obtaining Timely Crop Area Estimates Using Ground-Gathered and Landsat Data." Technical Bulletin No. 1609. U.S. Dept. of Agr., Econ., Stat., and Coop. Serv. August 1979.

Hanuschak, G.A., R.D. Allen and W. H. Wigton. "Integration of Landsat Data into the Crop Estimation Program of USDA's Statistical Reporting Service 1972-1982." Paper presented at the 1982 Machine Processing of Remote Sensed Data Symposium, West Lafayette, Indiana, July 8, 1982.

Holko, Martin L. and Richard S. Sigman. "The Role of Landsat Data in Improving U.S. Crop Statistics." Paper presented at the Eighteenth International Symposium on Remote Sensing of Environment, Paris, France, October 1-5, 1984.

Holko, Martin L. "The Results of Integration of the Northstar Microcomputers into the Remote Sensing Branch's Data Processing System." SRS Staff Report No. AGES 840609, June 1984.

Holko, Marty. "A Remote Sensing Application Methodology and Results." Unpublished working paper. U.S. Dept. of Agr., Stat. Rep. Serv., 1984.

Jones, E. M. Jr. "Classifier Study." Unpublished paper, U.S. Dept. of Agr., Nat. Agr. Stat. Serv., 1987.

Jones, Ned and George May, "Automatic Segment Shifter Study." U.S. Dept. of Agr., Stat. Rep. Serv., 1984.

Kalaic, M.T. "Automatic Segment Shifting Algorithm Theory, Test, and Evaluation." Report No. DC-Y2-04325, NSTL/ERL 209, NASA, June 1982.

Kleweno, David D. and Charles E. Miller. "1980 AgRISTARS DC/LC Project Summary-Crop Area Estimates for Kansas and Iowa." ESS Staff Report No. AGESS-810414. U.S. Dept. of Agr., Econ. Stat. Serv., March 1981.

Lennington, R. K., and M. E. Rassbach. "Mathematical Description and Program Documentation for CLASSY - An Adaptive Maximum Likelihood Clustering Method." Report No. LEC-12177 (JSC-14621). Lockheed Electronics Company, Inc. April 1979.

Lundgren, James C. "A Study of Bias and Variance in Landsat Data Based Regression Estimates for Crop Surveys Using Simulated Data." Report No. LEMSCO-20239. Lockheed Engineering and Management Services Company, Inc. December 1984.

May, G.A., and M.C. Craig. "Analysis of Man-Induced and Natural Resources of an Arid Region in California," International Symposium on Remote Sensing of Environment, First Thematic Conference: Remote Sensing of Arid and Semi-Arid Lands, Cairo, Egypt, January 1982.

May, G.A., M.L. Holko and N. Jones Jr.. "Landsat Large-Area Estimates for Land Cover," IEEE Transactions on Geoscience and Remote Sensing, Vol. GE-24, No. 1 (Jan. 1986), pp. 175-184.

Mergerson, James W., and others. "1981 AgRISTARS DCLC Four State Project." Paper Presented at the Eighth International Symposium on Machine Processing of Remotely Sensed Data, July 7, 1982.

Mergerson, J.W., P.W. Cook and G.A. Hanuschak. "Applications of Satellite Remote Sensing for U.S. Crop Acreage Estimation, 1980-81 Results." Paper presented at the Sixteenth International Symposium on Remote Sensing of Environment, Buenos Aires, Argentina, 1982.

Mergerson, J.W., V.B. Johnson and R.A. Kestle. "AgRISTARS DCLC Applications Project: 1982 Winter Wheat Area Estimates for Colorado, Kansas and Oklahoma." Paper presented at the Ninth International Machine Processing of Remotely Sensed Data Symposium, West Lafayette, Indiana, June 21-23, 1983.

NASA, AgRISTARS: Annual Report - Fiscal Year 1981. AP-J2-04225. January 1982.

NASA, AgRISTARS: Annual Report - Fiscal Year 1982. AP-J2-0393. January 1983.

NASA, AgRISTARS: Annual Report - Fiscal Year 1980. AP-JO-04111. June 1981.

Ozga, Martin. "Experience with the Use of Supercomputers to Process Landsat Data." Paper presented at the 1984 International Symposium on Machine Processing of Remotely Sensed Data, West Lafayette, Indiana, June 1984.

Ozga, Martin. "USDA/SRS Software for Landsat MSS-Based Crop Acreage Estimation." Paper presented at the International Geoscience and Remote Sensing Symposium, Amherst, Massachusetts, October 7-9, 1985.

Ozga, M., W. Donovan and C. Gleason. "An Interactive System For Agricultural Acreage Estimates Using Landsat Data." Proceedings of the 1977 Symposium on Machine Processing of Remotely Sensed Data, West Lafayette, Indiana, 1977, pp. 113-123.

Pratt, Bill. "The Future of Remote Sensing." Paper presented at the Statistical Reporting Service's National Conference, May 1984.

Sigman, Richard and Gail Walker. "Use of Landsat for County Estimates of Crop Areas: Evaluation of the Huddleston-Ray and Battese-Fuller Estimators." SRS Staff Report No. AGES 820909. U.S. Dept. of Agr., Stat. Rep. Serv., September 1982.

Sigman, Richard. "Aerospace Remote Sensing: Research Results." Paper presented at the Statistical Reporting Service's National Conference, May 1984.

Sigman, R.M., M. Ozga, and P. Zuttermeister. "Large Scale Test of a Video Digitizing Procedure for Ground Data Labeling of Landsat Pixels." Unpublished paper, U.S. Dept. of Agr., Stat. Rep. Serv., 1984.

U.S. Department of Agriculture, Statistical Reporting Service, Statistical Research Division. "Research Goals and Activities." March 1986, pp. 2-10.

U.S. Department of Agriculture, Statistical Reporting Service, Scope and Methods of the Statistical Reporting Service. Miscellaneous Publication No. 1308, September 1983.

Vogel, Frederic A. "Applications of Remote Sensing." U.S. Dept. of Agr., Nat. Agr. Stat. Serv., September 1986.

Von Steen, Don and W. Wigton. "Crop Identification and Acreage Measurement Utilizing Landsat Imagery." U.S. Dept. of Agr., Stat. Rep. Serv., 1976.

Winings, Sherman B. "Landsat Image Availability for Crop Area Estimation." Paper presented at the Eighth International Machine Processing of Remotely Sensed Data Symposium for Applications of Remote Sensing, West Lafayette, Indiana, July 1982.

Winings, Sherm. "Multitemporal vs. Unitemporal Analysis of MSS Landsat Data on a Full State Basis." U.S. Dept. of Agr., Stat. Rep. Serv., 1985.

DISCUSSION OF APPENDICES

Appendix A: These tables present the yearly estimates for the states involved in the remote sensing project. The JES estimate is the direct expansion from the June survey and does not include any data collected in the follow up survey or any updates that may have been made during the processing for the regression estimate. The relative efficiencies are based on the standard errors that appear in the tables. The NASS final estimate is the most recently adopted figure of the Agricultural Statistics Board of NASS.

Appendix B: This appendix gives a rather detailed written description of the DCLC project on a year by year basis.

Appendix C: The crops involved and the relative efficiencies of the regional estimates (sum of state estimates for each crop) are presented in this appendix.

APPENDIX A

TABLE A.1 AREA ESTIMATES FOR CORN

State/Year		JES Direct Expansion Estimate (Thous.Acres)	JES Direct Expansion Standard Error (Thous.Acres)	Landsat Regression Estimate (Thous. Acres)	Landsat Regression Standard Error (Thous. Acres)	Relative Efficiency	Final NASS Estimate (Thous. Acres)
Arkansas	1986	56	20	74	11	3.3	90
	1987	63	24	*			70
Illinois	1982	11884	289	11558	260	1.2	11700
	1983	8604	275	8353	253	1.2	8200
	1984	11024	273	10565	200	1.9	11200
	1985	11664	283	11262	276	1.1	11600
	1986	10403	260	10661	216	1.4	10600
	1987	9301	252	9017	213	1.4	9250
Indiana	1985	6152	190	6072	151	1.6	6300
	1986	5786	186	5567	150	1.5	5850
	1987	4753	170	4477	123	1.9	4800
Iowa	1980	14172	288	14334	229	1.6	14400
	1981	14400	317	14382	254	1.6	14400
	1982	13841	294	13759	278	1.1	13750
	1983	9163	278	9059	201	1.9	9100
	1984	13481	301	13331	197	2.3	13400
	1985	13838	304	14353	209	2.1	13900
	1986	12133	275	12361	195	2.0	12300
	1987	10175	289	10338	185	2.4	10300
Missouri	1981	2149	184	1914	125	2.2	2100
	1982	2298	194	*			2130
	1983	1873	148	1555	110	1.8	1700
	1984	2147	187	2019	110	2.9	2100
	1985	2771	194	2507	108	3.2	2600
	1986	2584	173	2431	113	2.3	2550
	1987	2364	159	2133	82	3.8	2250

* No regression estimate made.

TABLE A.2 AREA ESTIMATES FOR SOYBEANS

State/Year		JES Direct Expansion		Landsat Regression			Final
		Estimate	Standard Error	Estimate	Standard Error	Relative Efficiency	NASS Estimate
		(Thous.Acres)		(Thous. Acres)			(Thous. Acres)
Arkansas	1983	4105	195	3867	172	1.3	3900
	1984	4115	204	3989	136	2.3	4050
	1985	3774	200	3546	170	1.4	3750
	1986	3687	193	3237	131	2.2	3400
	1987	3396	177	3303	127	1.9	3200
Illinois	1982	9553	292	9309	268	1.2	9250
	1983	9133	263	9065	244	1.2	9100
	1984	9284	274	8950	205	1.8	9200
	1985	8983	260	9104	240	1.2	9100
	1986	9099	259	9187	216	1.4	9050
	1987	8598	258	8716	218	1.4	8600
Indiana	1985	4511	182	4313	131	1.9	4500
	1986	4022	166	4229	144	1.3	4300
	1987	4264	161	4397	123	1.7	4300
Iowa	1980	8369	276	8130	236	1.4	8300
	1981	8056	257	8093	202	1.6	8100
	1982	8746	265	8482	244	1.2	8470
	1983	7795	244	7907	218	1.3	8000
	1984	8713	268	8432	145	3.4	8500
	1985	7982	260	8107	163	2.5	8200
	1986	8937	276	8907	187	2.2	8500
	1987	7931	257	7759	154	2.8	7950
Missouri	1981	5699	307	4852	213	2.1	5120
	1982	6525	307				5800
	1983	5622	315	4961	239	1.7	5300
	1984	5997	309	5655	165	3.5	5500
	1985	5876	300	5180	158	3.6	5300
	1986	6106	295	5528	174	2.9	5450
	1987	5516	311	5117	148	4.4	4900

TABLE A.3 AREA ESTIMATES FOR RICE

State/Year		JES Direct Expansion Estimate (Thous.Acres)	JES Direct Expansion Standard Error (Thous.Acres)	Landsat Regression Estimate (Thous. Acres)	Landsat Regression Standard Error (Thous. Acres)	Relative Efficiency	Final NASS Estimate (Thous. Acres)
Arkansas	1983	1035	119	930	80	2.2	925
	1984	1060	113	1133	69	2.7	1160
	1985	1062	112	1146	78	2.1	1060
	1986	907	96	951	44	4.8	1030
	1987	909	103	899	51	4.1	1020
Missouri	1981	116	49	77	24	4.2	77
	1982	121	50	*			80
	1983	125	53	149	27	3.9	63
	1984	140	64	63	24	7.1	77
	1985	101	45	96	33	1.9	72
	1986	94	44	84	11	16.0	68
	1987	73	38	59	17	5.0	67

TABLE A.4 AREA ESTIMATES FOR COTTON

State/Year		JES Direct Expansion Estimate (Thous.Acres)	JES Direct Expansion Standard Error (Thous.Acres)	Landsat Regression Estimate (Thous. Acres)	Landsat Regression Standard Error (Thous. Acres)	Relative Efficiency	Final NASS Estimate (Thous. Acres)
Arkansas	1983	357	82	254	48	2.9	320
	1984	442	94	458	61	2.4	470
	1985	480	94	518	40	5.5	465
	1986	499	83	475	47	3.1	324
	1987	708	103	654	41	6.3	575
Missouri	1983	64	37	75	11	11.3	108
	1984	122	45	204	28	2.6	164
	1985	94	36	157	18	4.0	152
	1986	173	50	128	21	5.7	178
	1987	226	66	173	14	22.2	190

* No regression estimate made.

TABLE A.5 AREA ESTIMATES FOR SORGHUM

State/Year		JES Direct Expansion Estimate (Thous. Acres)	JES Direct Expansion Standard Error (Thous. Acres)	Landsat Regression Estimate (Thous. Acres)	Landsat Regression Standard Error (Thous. Acres)	Relative Efficiency	Final NASS Estimate (Thous. Acres)
Arkansas	1984	635	82	559	60	1.9	620
	1985	970	114	857	84	1.8	940
	1986	624	79	603	76	1.1	675
	1987	398	44	429	41	1.2	420
Missouri	1981	1148	140	992	125	1.3	980
	1982	1019	130	*			880
	1983	696	104	*			740
	1984	1500	183	1361	108	2.9	1400
	1985	1478	149	1292	126	1.4	1450
	1986	1182	129	1016	96	1.8	1200
	1987	735	101	632	63	2.6	720

* No regression estimate made.

TABLE A.6 AREA ESTIMATES FOR WINTER WHEAT PLANTED

State/Year		JES Direct Expansion		Landsat Regression			Final
		Estimate (Thous.Acres)	Standard Error (Thous.Acres)	Estimate (Thous. Acres)	Standard Error (Thous. Acres)	Relative Efficiency	NASS Estimate (Thous. Acres)
Arkansas	1986	838	102	734	52	3.8	885
	1987	825	90	849	49	3.4	930
Colorado	1982	3422	241	3023	137	3.1	3300
	1983	4050	424	3767	293	2.1	3800
	1984	3408	216	3409	147	2.2	3800
	1985	3635	231	3833	147	2.5	3700
	1986	3314	231	3164	164	2.0	3300
	1987	2677	183	2550	114	2.6	3100
Kansas	1982	14344	418	14187	298	2.0	14100
	1983	13528	400	13200	354	1.3	13200
	1984	12686	376	12528	258	2.1	13300
	1985	12672	379	11908	251	2.3	12400
	1986	11399	395	10943	322	1.5	11500
	1987	10743	342	10133	220	2.4	10700
Missouri	1983	2239	174	2314	131	1.8	2200
	1984	2403	172	2137	129	1.8	2350
	1985	1504	145	1263	98	2.2	1500
	1986	998	109	872	91	1.4	1050
	1987	823	92	679	66	1.9	900
Oklahoma	1982	8156	316	7507	246	1.7	8000
	1983	7939	299	7832	260	1.3	7800
	1984	7813	295	7493	236	1.6	7700
	1985	7769	325	7841	213	2.3	7800
	1986	7505	294	7196	173	2.9	7400
	1987	7172	286	7123	165	3.0	7200

TABLE A.7 AREA ESTIMATES FOR WINTER WHEAT HARVESTED

State/Year		JES Direct Expansion		Landsat Regression		Relative Efficiency	Final NASS Estimate (Thous. Acres)
		Estimate (Thous.Acres)	Standard Error	Estimate (Thous. Acres)	Standard Error		
Arkansas	1986	875	102	726	52	3.8	815
	1987	772	86	768	47	3.3	840
Colorado	1982	3154	224	2798	121	3.4	2910
	1983	2948	285	2748	199	2.1	3000
	1984	3214	216	3200	136	2.5	3200
	1985	3474	231	3683	142	2.6	3450
	1986	2940	215	2767	131	2.7	2900
	1987	2486	178	2353	119	2.2	2500
Kansas	1980	12883	400	12480	336	1.4	12000
	1981	13473	389	13091	257	2.3	12100
	1982	14028	413	13864	297	1.9	13100
	1983	11496	379	11063	306	1.5	10800
	1984	11220	354	11129	249	2.0	11200
	1985	11800	365	11127	251	2.1	11400
	1986	10468	359	9932	282	1.6	10200
	1987	10072	325	9526	210	2.4	9900
Missouri	1983	2051	163	2140	120	1.8	1850
	1984	2246	165	2045	126	1.7	2050
	1985	1405	139	1215	96	2.1	1280
	1986	661	88	532	71	1.5	570
	1987	789	89	645	62	2.1	770
Oklahoma	1981	6455	289	6136	250	1.3	6400
	1982	7201	295	6572	222	1.8	6900
	1983	4262	209	4172	183	1.3	4300
	1984	5287	248	4962	196	1.6	5300
	1985	5603	268	5609	169	2.5	5500
	1986	5215	231	4889	162	2.0	5200
	1987	4808	232	4775	155	2.2	4800

APPENDIX B

DETAILED PROJECT DESCRIPTION BY YEAR, 1980-1987

Results from 1980:

The first two states to enter the estimation program were Iowa and Kansas. Prior research projects in both of these states indicated that the use of Landsat data was feasible for the purpose of producing state crop acreage estimates. In addition, since Iowa was the nation's largest corn and soybean producer, it was only natural to select it for the program with those two crops targeted for estimation. The reasoning was similar for deciding to estimate the harvested winter wheat acreage in Kansas. For the program, the state offices were given the responsibility of collecting and editing the JES data as usual, but in the case of Iowa, an additional follow up survey was conducted to obtain data for fields that were still to be planted at the time of the JES. The states were also given the added task of digitizing the JES fields and segments. Digitization not only involved creating boundary tracings but also converting these tracings into a computer file of geographic coordinates; this work was performed using a DEC System-10 computer at the Bolt, Beranek, and Newman (BBN) processing center. The JES data was processed at the Martin Marietta Data System on a IBM 3081. Most of the processing of Landsat data was performed on an ILLIAC IV computer at NASA with clustering done using the LARSYS algorithm. Additional details on the methodology surrounding this algorithm can be found in LARSYS - Pattern Recognition: A Basis for Remote Sensing Data Analysis by P.H. Swain (1972). The data analysis itself was done at BBN using EDITOR which at the time was an extensive interactive analysis package designed to analyze ground data along with satellite data. The components are outlined in An Interactive System For Agricultural Acreage Estimates Using Landsat by Ozga, et al. (1977). Reformatting of Landsat data tapes was performed at the Washington Computer Center.

In Kansas, the optimum time frame or window for satellite coverage was April and May for the winter wheat crop. Unfortunately, Landsat II which was launched in January of 1975 was beginning to deteriorate and was nonoperational during those months. In addition, the data that was available from Landsat III during the frame was of unacceptable quality in approximately half the scenes that were examined. Much of this was due to data handling and processing problems at NASA Goddard as opposed to problems with the spacecraft. Overall, forty scenes from April and May (Landsat III) were studied with an additional four scenes from June (Landsat II). In the end, there were twelve scenes used in the final analysis with nearly forty five percent of the wheat area in Kansas being excluded from the regression analysis due to poor data quality and to cloud coverage. Methodology for a domain estimator was developed by Hanuschak (1976) which called for using the JES direct expansion for the areas excluded due to cloud cover. In Iowa, the optimum time frame for Landsat coverage was from mid July to the first week of September. Consequently, imagery was available from both satellites. As with Kansas though, there were problems with some of the Landsat III data. Potentially there were seventy eight scenes for study. However, by mid February only twenty one had been received and deemed to be usable. In the final analysis, two Landsat III scenes that were outside the optimum window were used along with eight Landsat II scenes. In addition, the quality of the data eventually used was much less than desired. Almost one fourth of the state's area was excluded from the regression analysis due to data problems and cloud coverage. With both states data acquisition was not as timely as anticipated with much of the delay being the result of the reprocessing of Landsat III data by NASA. A detailed study in Kansas showed that approximately twenty percent of the Landsat products were available for ordering within twenty days of the satellite fly over date while thirty percent were not available until after one hundred and twenty days; the average was about seventy five days. Once the paper products were ordered, there was on the average twenty seven days before they were received. The average delivery time for the Kansas data tapes was about eighteen days (Kleweno and Miller, 1981). One of the goals of the 1980 Landsat project was to provide estimates for Kansas by December 1 and those for Iowa by December 23. Unfortunately, the delays experienced during the data acquisition process prevented this goal from being met. In Kansas, estimates were ready on December 4, but in Iowa, the estimates were not completed until early March of the following year. This combined with the data problems and the lower than expected RE's made the 1980 experience somewhat disappointing. The relative efficiency of the Kansas estimate was only 1.4 while in Iowa the corn estimate had an RE of 1.6 while that for soybeans was 1.4.

However, on the positive side was the fact that the first efforts since Iowa in 1978 of actually integrating the Landsat data into the estimating program had been completed and had demonstrated the feasibility of an operational program. Also, the Kansas and Iowa state offices had successfully completed the additional duties which the project had required of them, thus illustrating that the decentralization of some activities could work. The costs for 1980 totaled approximately $400,000 or $200,000 per state. The following graphs (figures B.1 and B.2) show the Landsat coverage for Iowa and Kansas in 1980.

FIGURE B.1

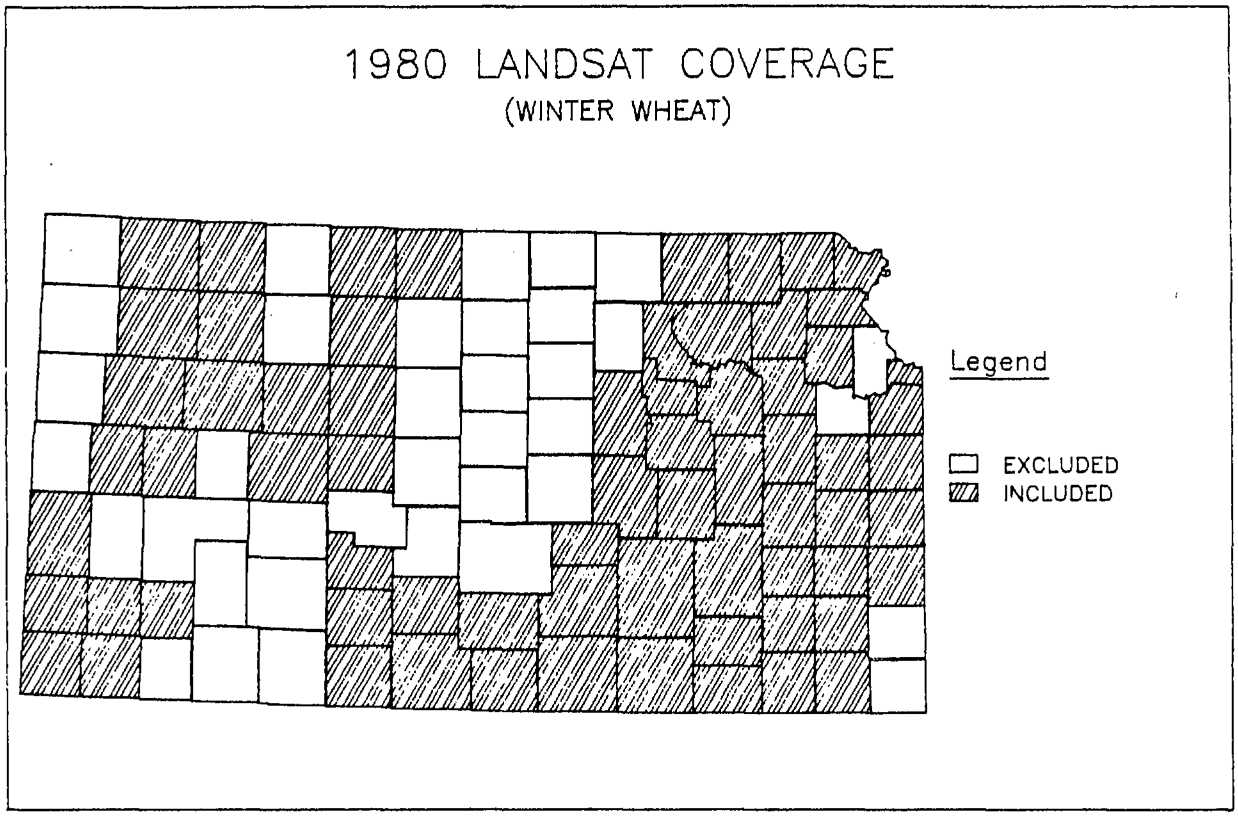
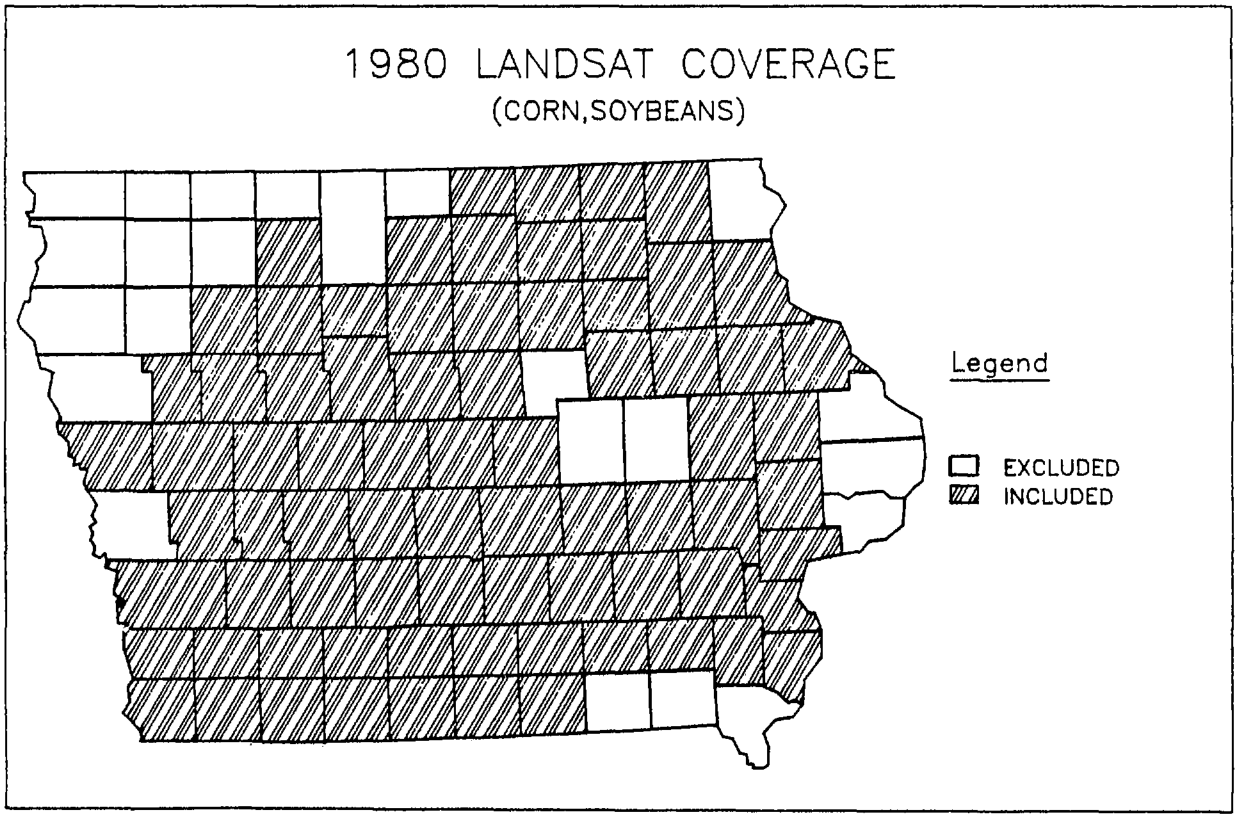


FIGURE B.2



Results from 1981:

Missouri and Oklahoma were added to the Landsat estimating program in 1981. Winter wheat estimates were made for Oklahoma which normally ranks second or third among the states in acreage. In Missouri estimates were generated for corn, soybeans, winter wheat, rice, and sorghum. Missouri normally ranks among the top five states in sorghum, soybean, and rice acreage and among the top ten states in winter wheat and corn. Crop estimation in Iowa and Kansas was also continued. State responsibilities were similar to those of the previous year. A follow up survey was instituted in Missouri as well as continued in Iowa. Plans to shift some of the registration responsibilities to Kansas failed because of equipment problems. On the positive side, efforts to shift many preanalysis functions from statisticians to support personnel were highly successful. During 1981, an unexpectedly greater amount of time was required by the states in the digitization process due to changes in the operating system at BBN as well as the before mentioned equipment breakdowns at the state offices. The same data processing centers that were used in 1980 were again utilized in 1981. However, the Landsat data being handled at NASA was processed using a CDC 7600 as opposed to the ILLIAC-IV. Also, the LARSYS clustering algorithm was replaced by the CLASSY algorithm. Details on this clustering method can be found in CLASSY - An Adaptive Maximum Likelihood Clustering Algorithm by Lennington and Rassbach (1979). Although CLASSY out performed the LARSYS algorithm, it proved to be much more costly (NASA, 1982). The problems experienced in 1980 with NASA's initial handling of the satellite data were corrected and nonexistent in 1981.

The relative efficiencies of the 1981 estimates were impacted somewhat by the cloud cover and the slow delivery process for Landsat data. Some of the cloud cover problems were the result of having to rely on only the Landsat III satellite since Landsat II had ceased functioning. In the end, nearly eighty five percent of Kansas was covered, but nearly thirty percent of the data was from early March which was outside the optimum window. In Iowa, approximately sixty percent of the soybean crop was covered with imagery from the optimum time frame while sixty five percent of the corn crop was covered. It was also necessary to use early dates for Oklahoma, while in Missouri cloud cover problems were considered to be severe requiring the use of September imagery. As for the slow delivery of Landsat products, one of the goals for 1981 was to have delivery within ten to fourteen days from the point of being ordered. In reality, delivery times ranged from one to twenty weeks with an average of three to four weeks. Winter wheat estimates were completed by October 30 with the corn and soybean estimates ready by December 16. Thus, the goals of providing the wheat estimates by December 1 and the other estimates by December 22 were successfully met. In addition, rice and sorghum estimates were also provided to Missouri on December 16. For the wheat estimates the RE's were 1.3 in Oklahoma and 2.3 in Kansas. The values for the corn estimates were 1.6 in Iowa and 2.2 in Missouri while the soybean estimates had RE's of 1.6 in Iowa and 2.1 in Missouri. However, the relative efficiency of the rice estimate was excellent at 4.2. The overall costs of the project were about $720,000 or approximately $180,000 per state.

Results from 1982:

In 1982 Colorado was added to the wheat program, and Illinois was added to the corn and soybeans program. Illinois normally ranks second in corn acreage and first in soybeans while Colorado is usually fourth in winter wheat acreage. This meant that there were now six states in the program, but unfortunately cloud coverage in Missouri was so severe in 1982 that no Landsat regression estimates were made for the state. This was dually damaging since it was also intended to make multitemporal estimates in Missouri; that is, imagery from spring and summer were going to be used in combination to produce the regression estimates. Nevertheless, when combined, Illinois and Iowa accounted for about thirty percent of the nation's soybean production in 1982 and about thirty seven percent of the national corn crop. Likewise, thirty seven percent of the nation's wheat production was harvested in the three wheat states that were in the program. The decision was made to estimate both planted and harvested acreages for the wheat crop for 1982. One of the greatest advancements in the Landsat project was the introduction of video digitization which was used for Colorado and Illinois; the other states continued to use manual digitization. However, in Iowa and Missouri, the processing was no longer done at BBN with microcomputers being used instead for this function; this change produced significant savings in computer costs as well as reduced staff time. The year also saw the implementation of ASMA as a tool to alleviate the time consuming process of manual shifting segments; the concepts that led to this computer program are outlined in Automatic Segment Shifting Algorithm Theory, Test and Evaluation by M.T. Kalcic (1982). Unfortunately, the value of ASMA was questionable; the feeling was that it generated too many incorrect shifts in addition to being too expensive to execute (Jones and May, 1984). For the most part, analysts felt that the segment shifts had to be checked manually after the automated shift, and as a result found its benefit to be greatly diminished. Another advancement was the use of computer generated questionnaires which diminished the some of the manual tasks associated with the follow up surveys in the corn and soybean states. The same data processing centers were again used; however, at NASA a CRAY-1S was utilized instead of the CDC 7600 which in effect reduced data processing costs. The program was again hampered by the slow delivery of Landsat products which necessitated overtime hours by the work force. However, these costs were offset by a reduction in computer costs.

With the launch of Landsat IV in July of 1982, it was hoped that with two satellites providing imagery that some of the problems with cloud cover experienced the previous year would be alleviated. Unfortunately, there were some start up complications with the satellite, and quality data was not available until mid September.In addition, there were technical problems with Landsat III. As a result, cloud cover again hindered the effectiveness of the Landsat program. In Colorado, only the eastern part of the state along with several western counties was to be covered by Landsat since together they accounted for ninety seven percent of the acreage. In the end, over fifteen percent of the area was excluded from regression because of clouds while over a fourth of the area was covered by July imagery which was well outside of the March - April window. Cloud coverage in Kansas caused about a fifth of its acreage to be excluded from regression with a somewhat greater proportion being excluded in Oklahoma. In Iowa and Illinois cloud coverage was even a greater hindrance with about a third of the soybean acreage in both states being excluded from regression. In addition, over forty percent of the Illinois' corn acreage was not covered with a about thirty percent of Iowa's excluded. Much of the data used for both states were outside the optimum window, coming from early July and around the first of September. As alluded to earlier, imagery for Missouri was so limited that no estimates were attempted there. Obviously, the relative efficiencies of the Landsat estimates in the other states were impacted by the lack of optimum imagery. The RE's for the corn and soybeans estimates were from 1.1 to 1.2. For wheat the RE's ranged from 1.7 to 2.0 in Kansas and in Oklahoma. In Colorado the estimates were much better yielding RE's in excess of 3.0. One objective was to have the winter wheat results to the states by November 15; this was met with Kansas and Oklahoma receiving theirs on October 27 and Colorado receiving its on November 8. Other estimates were to be completed by December 15 with actual completion on December 16. In order to meet these goals, it was necessary to work overtime hours which was largely necessitated by the slow delivery of the Landsat products. For the winter wheat states, delivery of ordered products was four weeks from the date of fly over. Delivery times after May were much worse in comparison. The elapsed time between the satellite overpass and the delivery of data tapes ranged from forty eight to one hundred and fifteen days with a median delivery time of eighty six days. Overall costs in 1982 for the Landsat project were less than anticipated at $700,000 excluding the JES.

Results from 1983:

For 1983 only Arkansas was added to the Landsat program; the fact that previous research had been conducted there made its addition natural. Also, it allowed for the extension of the Landsat program into the estimation of cotton while greatly expanding the rice coverage. Soybean estimates were also to be made for the state. Arkansas normally accounts for forty percent of the nation's rice production and usually ranks sixth in cotton production. Since the cropland in the state is concentrated in the east, only part of the state was to be covered by the Landsat data. Arkansas was also included in the group of states that conducted follow up surveys; the follow up survey itself was expanded to include not only a recheck of fields not yet planted at the time of the JES but also a recheck of all tracts which were originally enumerated through observation as opposed to interview. The states making winter wheat estimates were also extended to include Missouri; at the same time, the decision was made to include only eastern Colorado in the Landsat analysis since the western counties incorporated the year before did little to justify the additional expense of their inclusion. In addition, no sorghum estimate was made in Missouri because the data was not adequate enough to provide reliable correlations. Video digitization was expanded with Arkansas joining Colorado and Illinois. Oklahoma, Kansas, Missouri, and Iowa were provided with Northstar microcomputers to perform their digitization. The final analysis of these two approaches supported the expansion of the video digitization procedure which was undertaken in 1984 (Ozga, Sigman, and Zuttermeister, 1984). One of the major accomplishments of 1983 was the implementation of a multitemporal approach for estimation of late crops in Missouri. During the year, work was also begun on the conversion of the EDITOR software into a more portable program language. Processing centers were the same as before except a CRAY X-MP was used at NASA. There were also beginning to be growing concerns from the fact that almost nine out of ten times the regression estimate was less than the JES direct expansion; this spearheaded a renewed search for explanations. Research in this area which actually began as early as 1975 has been addressed in many papers but most notably in various reports by Chhikara (1986,1987) and Lundgren (1984). This research pointed to a slight theoretical downward bias in the regression estimator.

One of the highlights of 1983 was the significant improvement in the delivery of Landsat products. Much of this improvement was attributed to the fact that the National Oceanic and Atmospheric Administration (NOAA) had assumed full responsibility for handling acquisitions. For the most part, the data that was available was from the optimal window for the winter wheat states. The exception was Colorado where some late June data was used. However, since only imagery from Landsat IV was available, cloud cover greatly impacted the regression estimates. For Kansas, there was no coverage at all for the central part of the state while in Oklahoma only about sixty percent of the final estimate was from regression. Coverage in the late crop states was better with approximately twenty to twenty five percent of the acreage in Iowa and Illinois being excluded from the regression estimate. The situation in Missouri was similar despite the fact that a multitemporal approach was used. In addition most of the Illinois imagery was outside of the optimum window. Another factor that influenced the 1983 estimates was the government Payment-in-Kind (PIK) program which was designed to encourage farmers to reduce production. As a result of the program, many of the winter wheat fields that were growing at the time of the imagery were cut, abandoned, and/or diverted to other uses. This, in turn, caused difficulties in correlating the ground data with the satellite data. The end result was lower relative efficiencies for the wheat estimates. The RE's for wheat planted ranged from a high of 2.1 in Colorado to a low of 1.3 in both Kansas and Oklahoma. The combined RE for the four wheat states was 1.6. The relative efficiencies of the other estimates were impacted by cloud coverage. The RE for the three corn states combined was 1.5 while the joint RE for the four states estimating soybeans was 1.4. The RE's for the cotton and rice estimates in Missouri and Arkansas combined were much better at 3.3 and 2.4 respectively. The goal had been to have the estimates for the wheat states ready by November 15, all Arkansas estimates ready by November 18, and the remaining estimates completed by December 15. Wheat estimates were actually complete on November 14 with Arkansas estimates ready on November 21. The other estimates were completed by December 22. The costs of the Landsat estimation program were $1,025,000 or about $146,400 per state. Improvements since the research efforts in 1978 had reduced registration time for a scene from two weeks to an average of four hours. The costs of classifying a scene had been reduced from an average of over $1000 in 1981 to a range of $35 to $150.

Results from 1984:

No new states were added for 1984 due to personnel ceilings and limitations in processing capabilities. This allowed for progress in other areas and a consolidation of procedures. During the year, advancement was made in the conversion of the Editor software into a more portable language. In addition, a batch environment was created for many of the analysis programs in an effort to trim computer costs. ASMA was also effectively abandoned as too expensive and not reliable enough (Jones and May, 1984). Moreover, Iowa and Oklahoma were shifted to video digitization, leaving only Kansas and Missouri using the Northstar systems. Efficiencies in the video system were also further enhanced during the year. Some analysis activities were performed in house on MIDAS (microcomputer image display and analysis system) which was a group of components from various manufacturers that were put together by NASA for the sole purpose of analyzing Landsat data. Other processing was performed at the same centers as the previous year.In 1984, county estimates were made for the first time; initially, they were done only for Oklahoma, Kansas, and Illinois. A detailed explanation of that methodology can be found in The Use of Landsat for County Estimates of Crop Areas by Walker and Sigman (1982). Landsat V was also launched in March; unfortunately, Landsat IV had begun to fade, and as a result, there were surcharges made on data acquisition requests for its imagery. Multitemporal estimates were continued in Missouri (spring and summer scenes) for late crops and initiated in Arkansas (winter and summer scenes). In addition, the eastern portion of Iowa was analyzed using the multitemporal approach because of data problems. The decision was also made to exclude permanently south central Missouri from the Landsat analysis since only a small portion of the target crops were grown in that area.

Difficulties with cloud cover in 1984 were alleviated somewhat by the fact that there were two satellites to provide data. Landsat coverage in Colorado was the best to date for the state and the relative efficiencies of the winter wheat estimates were 2.2 for planted acres and 2.5 for harvested acres. Kansas also had complete coverage with optimum dates. The RE's there were 2.1 for planted acres and 2.0 for harvested acres. In Missouri, a large portion in the southern part of the state was cloud covered causing the RE's to be 1.8 and 1.7. Oklahoma had almost ninety percent coverage with optimum dates for the most part, but the RE of both estimates was 1.6. For the soybeans states, the RE's ranged from 1.8 in Illinois to 3.5 in Missouri; the states combined had an overall RE of 2.6. Ninety two percent of the area was covered by the regression estimate. For corn, there was ninety percent coverage with the overall RE at 2.2. Rice, cotton, and sorghum were estimated in Arkansas and Missouri. The respective overall RE's for those crops were 3.2, 2.4, and 2.6. The goal was to complete wheat, cotton, and rice estimates by December 7 with other estimates ready by December 14. In actuality, the wheat estimates were completed by November 23, but the other estimates were not finished until December 21. County estimates were available to the states on February 4. The costs of the Landsat estimation program in 1984 was just under $1,030,000 or about $147,000 per state.

Results from 1985:

In 1985, Indiana was added to the group of states estimating corn and soybeans. Now, in a normal year, almost half of the nation's soybean acreage would be covered by the Landsat estimation program. Similarly, about forty percent of the corn acreage would be covered. Indiana also joined the groups of states making a follow up survey and using video digitization. In Oklahoma, ten additional counties were added to those to be covered by Landsat. County estimates were also done for all the states in 1985. Conversion of EDITOR programs continued with most jobs now being executed on the IBM 3081 or NASA's CRAY X-MP. The refinements made the software much more suitable for an operational environment. The DEC20 at BBN was also used as well as the in house PDP-11/44 and Northstars. The ordering system for Landsat products was also enhanced with the use of a IBM PC-XT. This marked the final year of any processing at the Washington Computer Center. During the year, it was recognized that there were areas in which subjectivity was being introduced by the analysts and that an effort would have to be made to limit it. An outgrowth of this was the recognition of the need for documentation in the form of training modules for new statisticians. For all practical purposes, 1985 can be viewed as the year in which the remote sensing project was finally considered to be completely operational.

The responsibility for Landsat was shifted from NOAA to the private sector in 1985 with the transition being a smooth one. Landsat IV was still fading, and as a result, a surcharge of $1,395 (including the costs of products that were automatically generated) was again imposed for its use. Cloud cover was a problem in all the states except Colorado. There, optimal data was used with the resulting relative efficiency of the estimate for wheat planted being 2.5. In Kansas, sections of the eastern part of the state were excluded from regression while in Missouri some areas in the central part of the state were lost despite using a multitemporal approach. In Oklahoma, multitemporal data (fall and spring) was used for the first time. These three wheat states individually had RE's ranging from 2.2 to 2.3. The four state region had a combined RE of 2.3 for planted as well as harvested acres. The RE for the five soybean states combined was 1.9, ranging from 1.2 in Illinois to 3.6 in Missouri. The RE for the four corn states combined was 1.6, ranging from 1.1 in Illinois to 3.2 in Missouri. A large section in western Illinois was excluded from the corn and soybean analysis as were scattered areas of western Indiana. A section in central Iowa was also omitted. In Arkansas, some counties normally included for soybeans were not covered even though a multitemporal approach was used. In addition, it was not possible to use optimum windows in all the areas where coverage was available. The RE's for cotton, rice, and sorghum in Arkansas and Missouri combined were 5.3, 2.0, and 1.5 respectively. The goal for 1985 was to have the winter wheat, cotton, and rice estimates completed by December 6 with the remaining estimates ready by December 27. These goals were met with the early estimates finished by December 4 and the others by December 24. The costs totaled almost $1,100,000 or just over $136,000 per state.

Results from 1986:

There were no new states added for 1986. However, winter wheat and corn were added to the crops being estimated in Arkansas. One of the major advancements during the year was the completion of the conversion of EDITOR to a portable language. All data processing and analysis were done using a CRAY X-MP, a IBM 3090 (SIERRA) with a vector processor, a IBM 3081, the Northstars, and the PDP-11/44. This marked the final year of any processing at BBN and, in addition, marked the switch from NASA's CRAY system to Boeing's CRAY. This switch was necessitated by telecommunications problems with NASA plus added restrictions which they were placing on the use of their computer. Also, IBM PC-AT's were purchased to help in some of the analysis since several of the PEDITOR (portable EDITOR) programs could be accommodated by personal computers. Many questions were raised during the year. The digitizing equipment in Kansas, Iowa, and Washington, D.C. was aging as were various printers and plotters. Should they be replaced or repaired? Also, was there a way to limit the cost of CLASSY (hopefully the use of the Boeing CRAY)? Since Landsat IV continued to deteriorate, there would soon only be one satellite to obtain imagery from. How was this problem to be addressed?

Delivery of Landsat products had reached the point where receipt was usually within fourteen days of the order date. As a result, there were no problems in completing the estimates in a timely fashion. The wheat estimates (excluding the multitemporal calculations in Missouri and Arkansas) were ready by October 6 with the remaining estimates ready by December 22. There were cloud cover problems again despite the use of two satellites; however, there was significant improvement from 1985. In Iowa, eighty to ninety percent of the land area was covered, but almost a third of the imagery was outside the optimum window. In Arkansas, multitemporal data was used for nearly all the counties which were in the Landsat program; dates in only one area were not optimum. A multitemporal approach was again used in Oklahoma and Missouri. The coverage in Oklahoma was excellent with near optimum dates for the imagery. In Missouri, large areas were omitted from the regression analysis due to cloud cover. The situation in Indiana was similar with almost twenty percent of the soybean estimate and thirty percent of the corn estimate coming from the JES direct expansion. In addition, the dates of the imagery were earlier than hoped for. There was vast improvement in the coverage for Illinois with about ninety five percent of the state cloud free as opposed to seventy five percent the year before. Coverage was even better in Colorado with optimum imagery being obtained for the entire area of interest. In Kansas, there were classification problems in the eastern part of the state which resulted in its omission from the regression estimate; dates for the imagery used ranged from March 28 to May 13. There were improvements in the overall relative efficiencies of the corn, soybeans, and rice estimates while the RE's of the other estimates were below those for the previous year. The RE's of the corn estimates ranged from 1.4 in Illinois to 3.2 in Arkansas. The overall RE for corn was 1.7. For soybeans, the RE's ranged from 1.3 in Indiana to 2.9 in Missouri with a combined regional RE of 2.0. The RE of the winter wheat planted estimate was 2.2 for the five program states combined, ranging from 1.4 in Missouri to 3.8 in Arkansas. The overall RE of the cotton, rice, and sorghum estimates were 3.5, 5.4, and 1.5 respectively. The costs of the Landsat project in 1986 averaged just over $142,000 per state.

Results from 1987:

The same eight states as in 1985 and 1986 were again included in the Landsat estimation program. The major advancement for 1987 was the implementation of improved editing and data collection procedures for the JES ground data; this resulted in less work on the part of the analysts since the data files were in a more usable form when first accessed. There were also continued improvements in PEDITOR as well as software modifications for the county estimates program. Most of the documentation and training material for PEDITOR was also completed. Data processing was conducted on the same systems as the previous year; however, the IBM PC-AT's continued to play an expanded role in the analysis process with more PEDITOR programs shifted to them. Registration activities which were previously done on the MIDAS were switched to IBM PC-XT's during the summer.

Landsat IV continued to function and delivery for most products was made within two weeks, with the transparencies normally arriving in one week. The estimates were all completed in a timely manner with wheat estimates ready by September 23 (excluding multitemporal estimates in Arkansas and Missouri) and the remaining estimates completed by December 14. The relative efficiencies of the estimates were improved over the previous year for the most part. Nearly complete imagery was obtained for all the states making wheat estimates except Missouri. In Colorado, a multitemporal (spring and summer) approach was used in one area because the data quality of the spring scene alone was inadequate. In Oklahoma, there was one area where a unitemporal estimate was made because no cloud free imagery was available from the fall. On the other side, some areas in east central Missouri were completely lost due to clouds. Nevertheless, the RE's for the Missouri's estimates all improved except for rice which still had a respectable RE of 5.0. Coverage was mixed for the states not estimating wheat. Imagery for Iowa was optimum and complete except for a few counties. Also, there was good coverage for Illinois although the dates of most of the imagery were later than desired. Conversely, there were major problems in Indiana. Some areas were not covered at all with most other areas covered by imagery outside the optimum window. Nevertheless, the RE's for the Indiana estimates were improved from the previous year. The RE's for the corn estimates ranged from 1.4 in Illinois to 3.8 in Missouri. For soybeans, the range was from 1.4 in Illinois to 4.4 in Missouri while the range for planted wheat was from 1.9 in Missouri to 3.4 in Arkansas. The costs of the Landsat project for 1987 averaged just over $129,000 per state, which was a substantial improvement over 1986.

APPENDIX C

TABLE C.1

1987 LANDSAT COVERAGE AND RELATIVE EFFICIENCY OF REGIONAL ESTIMATE

State	Crop					
	Corn	Cotton	Rice	Sorghum	Soybeans	Winter Wheat
Arkansas		x	x	x	x	x
Colorado						x
Illinois	x				x	
Indiana	x				x	
Iowa	x				x	
Kansas						x
Missouri	x	x	x	x	x	x
Oklahoma						x
RE	2.0	8.0	4.2	2.1	2.3	2.6

TABLE C.2

1986 LANDSAT COVERAGE AND RELATIVE EFFICIENCY OF REGIONAL ESTIMATE

State	Crop					
	Corn	Cotton	Rice	Sorghum	Soybeans	Winter Wheat
Arkansas	x	x	x	x	x	x
Colorado						x
Illinois	x				x	
Indiana	x				x	
Iowa	x				x	
Kansas						x
Missouri	x	x	x	x	x	x
Oklahoma						x
RE	1.7	3.5	5.4	1.5	2.0	2.2

TABLE C.3

1985 LANDSAT COVERAGE AND RELATIVE EFFICIENCY OF REGIONAL ESTIMATE

State	Crop					
	Corn	Cotton	Rice	Sorghum	Soybeans	Winter Wheat
Arkansas		x	x	x	x	
Colorado						x
Illinois	x				x	
Indiana	x				x	
Iowa	x				x	
Kansas						x
Missouri	x	x	x	x	x	x
Oklahoma						x
RE	1.6	5.3	2.0	1.5	1.9	2.3

TABLE C.4

1984 LANDSAT COVERAGE AND RELATIVE EFFICIENCY OF REGIONAL ESTIMATE

State	Crop					
	Corn	Cotton	Rice	Sorghum	Soybeans	Winter Wheat
Arkansas		x	x	x	x	
Colorado						x
Illinois	x				x	
Iowa	x				x	
Kansas						x
Missouri	x	x	x	x	x	x
Oklahoma						x
RE	2.2	2.4	3.2	2.6	2.6	1.9

TABLE C.5

1983 LANDSAT COVERAGE AND RELATIVE EFFICIENCY OF REGIONAL ESTIMATE

State	Crop					
	Corn	Cotton	Rice	Sorghum	Soybeans	Winter Wheat
Arkansas		x	x		x	
Colorado						x
Illinois	x				x	
Iowa	x				x	
Kansas						x
Missouri	x	x	x		x	x
Oklahoma						x
RE	1.5	3.3	2.4		1.4	1.6

TABLE C.6

1982 LANDSAT COVERAGE AND RELATIVE EFFICIENCY OF REGIONAL ESTIMATE

State	Crop					
	Corn	Cotton	Rice	Sorghum	Soybeans	Winter Wheat
Colorado						x
Illinois	x				x	
Iowa	x				x	
Kansas						x
Missouri						
Oklahoma						x
RE	1.2				1.2	2.0

TABLE C.7

1981 LANDSAT COVERAGE AND RELATIVE EFFICIENCY OF REGIONAL ESTIMATE

State	Crop					
	Corn	Cotton	Rice	Sorghum	Soybeans	Winter Wheat
Iowa	x				x	
Kansas						x
Missouri	x		x	x	x	x
Oklahoma						x
RE	1.7		4.2	1.3	1.9	1.8

TABLE C.8

1980 LANDSAT COVERAGE AND RELATIVE EFFICIENCY OF REGIONAL ESTIMATE

State	Crop					
	Corn	Cotton	Rice	Sorghum	Soybeans	Winter Wheat
Iowa	x				x	
Kansas						x
RE	1.6				1.4	1.4

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