Interpreting Land Use Change Through Satellite Imagery

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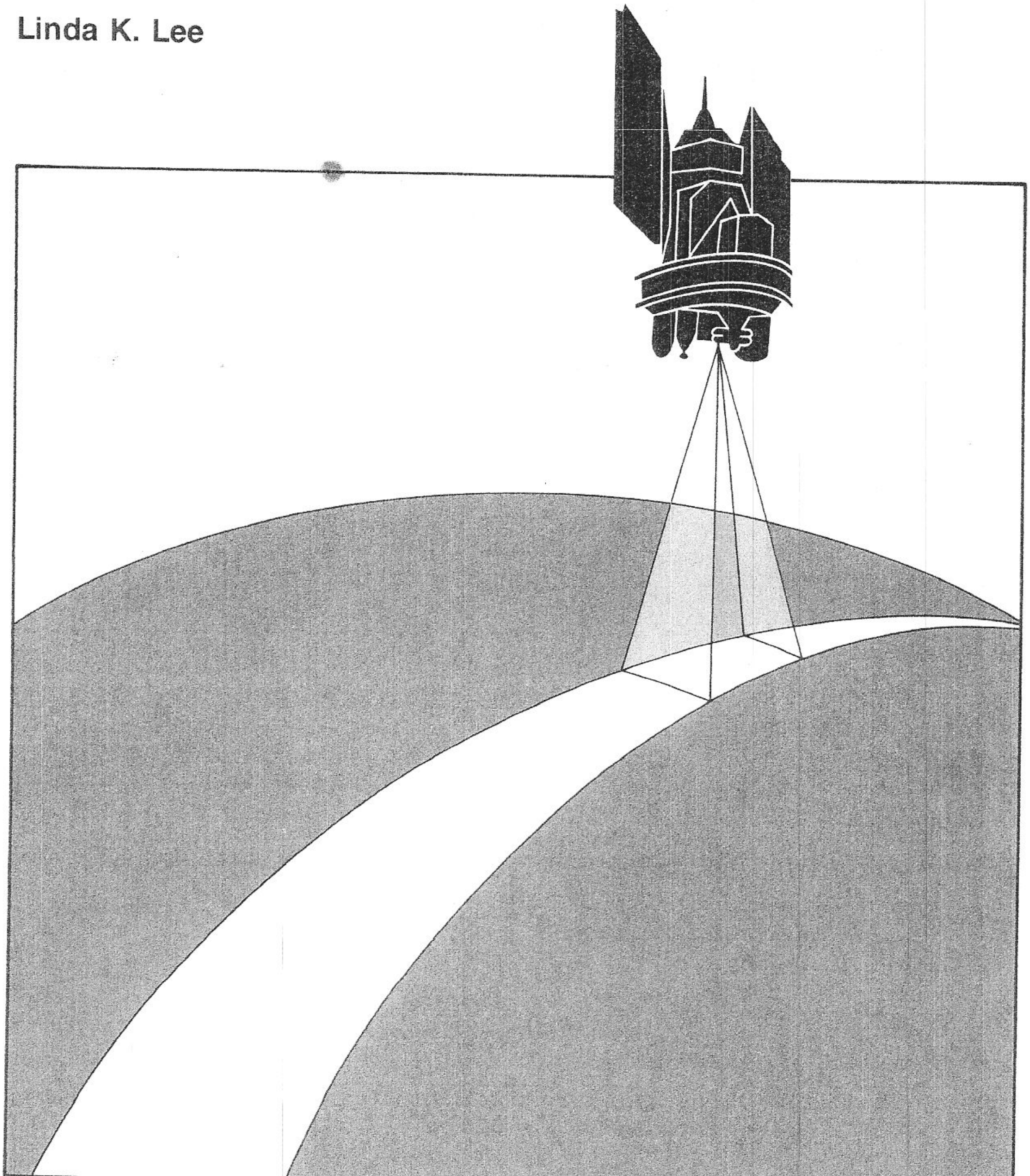

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ABSTRACT

Employing a multiperiod approach to monitor land use change may compound the problems associated with interpretation of satellite imagery. In this feasibility study, data from satellite imagery were used to inventory new cropland development in the Great Plains and Southeast between 1972 and 1976. Cloud cover problems, intensified by the two-period approach used, made data more difficult to interpret. Field checks were also more difficult because of the scattered and irregularly shaped land use change sites.

Keywords: Cropland development, land use change, satellite imagery.

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SUMMARY

This feasibility study used data from satellite imagery to analyze new cropland development in the Great Plains and Southeast. It differed from other land use studies using satellite imagery as it analyzed land use change between two time periods rather than inventorying land use at a single time period.

The multiperiod approach of this study appeared to compound the usual problems associated with satellite imagery interpretation. In particular, it intensified cloud cover and field checking problems.

To obtain cloud-free imagery on two comparable dates, we used alternate counties for 13 percent of the original sample in the Great Plains and 19 percent in the Southeast, thereby introducing some sample bias. In addition, field checks were more difficult because of the scattered and irregularly shaped land use change sites.

Combining satellite data with other measurement techniques may prove the most promising use of satellite imagery in inventorying land use change. Careful field checks should also be an integral part of the interpretation process.

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INTERPRETING LAND USE CHANGE THROUGH SATELLITE IMAGERY

By Linda K. Lee*

INTRODUCTION

Monitoring changes in the use of natural resources through periodic inventories can provide information leading to better management of our nonrenewable natural resources. The amount of land available for crop production, in particular, has become a vital public issue. In recent years, declines in the cropland base have occurred due to urbanization and to construction of highways and reservoirs. But an even larger cropland base may now be required because of possible declines in agricultural productivity resulting from soil erosion and from constraints on the use of pesticides, fertilizers, energy, and water. In the past, cropland losses have been partially offset by new cropland development, primarily from pasture and rangeland. However, the amount of new cropland development depends on economic price-cost relationships which vary over time.

Our objective in this study was to assess the feasibility of using satellite imagery to inventory new cropland development. We selected the period between 1972 and 1976, a period of high agricultural prices, which could help us measure more effectively cropland owners' response to favorable price-cost relationships. We used imagery from LANDSAT satellites, a family of earth resources observation satellites.1/

In this report we present and analyze the results of the study. We discuss the limitations of LANDSAT imagery for similar projects and propose guidelines for future LANDSAT land use change inventory projects. Findings of our research should be useful to groups involved in natural resource inventories, particularly those who monitor natural resource change.

LANDSAT Technology

Since the launching of LANDSAT I in 1972, numerous projects have used satellite imagery to monitor the agricultural sector. The following brief explanation of the remote sensing process should help the reader better understand the technical aspects of remote sensing projects.

Each satellite circles the earth 14 times a day at a height of 570 miles. A given point on the earth's surface is covered once every 18 days by the same LANDSAT

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1/ Participating in the planning stages of the project were Robert C. Otte, NRED, ESCS, and Ernest H. Hardy, Cornell University.

satellite, and once every 9 days by either one of two satellites. The basic element of LANDSAT data is the set of measurements (or signature) by the satellite's multispectral scanner (MSS) of a 0.4-hectare area of the earth's surface. The MSS measures the amount of electromagnetic energy reflected and/or emitted by objects receiving, then retaining energy from the sun. Different objects retain different kinds and amounts of energy and thus the spectral response, or signature, of various objects will differ. It is the differences between such signatures that allow the classification of land uses.

The scanners on LANDSAT I (no longer in operation) and LANDSAT II measure energy in four spectral bands--two in the visible wavelengths, two in the infrared. LANDSAT III has an additional thermal infrared band. Each band can be analyzed separately or in combination with other bands to classify land uses. Two forms of data are available for analysis--MSS imagery or MSS digital data on tapes. Manual photointerpretation techniques or computer-assisted techniques may be used to interpret the former, whereas computer-assisted techniques are necessary to analyze the digital data. The studies described in the following sections use both methods of analysis.

LACIE Project

The LACIE project, the Large Area Crop Inventory Experiment, was a cooperative project of the U.S. Department of Agriculture (USDA), the National Aeronautics and Space Administration (NASA), and the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce. LACIE, a three-phase project, began November 1974 and ended October 1978. It developed, tested, and evaluated a system for predicting area, yield, and production estimates for major wheat-producing areas of the world through the combined use of satellite, weather, climate, and historical agricultural data (9). 2/ The LACIE objective was to estimate wheat production by individual country. Aerial extent of wheat was derived from a computer-assisted analysis of LANDSAT data, whereas yield was estimated from statistical models relating crop yield to local meteorological conditions, notably precipitation and temperature.

Evaluations of LACIE through USDA's Economics, Statistics, and Cooperatives Service's (ESCS) ground survey estimates indicate the project achieved greater success in the winter wheat regions of the world. In areas where spring wheat was grown, there were problems in differentiating between that crop and other spring-sown small grains. In addition, the regression yield models were not adequately responsive to episodic events. They will require improvement to achieve accurate estimates in years of large deviations from normal yields.

Other Studies

The ESCS Statistics group has used LANDSAT data as an auxiliary variable for its agricultural surveys (8). Analysts estimate crop acreages by a regression estimator; enumerator data are from the June Enumerative Survey as the primary survey variable and LANDSAT digital data are used as the auxiliary variable. ESCS statisticians have conducted major demonstrations in Illinois, Kansas, and Iowa with this technique (1, 2, 3). Their studies have been research oriented, and, except for the Iowa study, none of these projects has produced timely crop acreage estimates.

2/ Underscored numbers in parentheses refer to references at the end of this report.

LANDSAT digital data have been utilized in North Dakota in the Regional Environment Assessment Program (REAP) to produce a land cover inventory for the State (6). Multicolor maps for 10 land cover categories were one of several products of this program. Several land cover categories proved particularly difficult to map. The spectral response of pastureland was difficult to distinguish from cropland and/or rangeland, for example. Selected updating of the maps is planned.

LANDSAT has been useful particularly in less developed countries where census data on agricultural output are usually not available. Manual interpretation techniques were used in Laos to provide relatively inexpensive data that did not require the availability of highly specialized computer processing capabilities (5). The quality of data provided by LANDSAT in developing countries is usually superior to existing data sources.

These and similar projects have used LANDSAT imagery to estimate crop acreage in an inventory effort or in combination with other information to estimate crop production. LANDSAT was used as a primary data source in most studies, although the ESCS Statistics' projects used it as an auxiliary variable. Integrating LANDSAT data with other ground information may be the most effective use of satellite imagery; however, LANDSAT can be invaluable to many projects because it can provide data not available through traditional sources.

DESCRIPTION OF STUDY

This study uses LANDSAT as primary data. The time period studied and the data sought did not correspond to existing periodic inventories. Furthermore, both the purpose and methodology differ from those of previous studies. The purpose is to determine specific land use changes rather than to inventory current land use. Therefore, two time periods rather than one are employed. LANDSAT imagery for 1972 and 1976 was utilized so that cropland development during 4 years of favorable price-cost relationships for farm products could be estimated.

One advantage of the land use change approach is that one can focus on a smaller area for imagery interpretation. Interpreting a smaller area also makes the use of less expensive manual interpretation techniques more feasible. These two factors mean land use change inventories are less expensive than comprehensive land use inventories.

Study Design

Two regions were chosen for analysis: the Central Great Plains Winter Wheat and Range Region (Great Plains region) and the Southeastern Alluvium Coast and Tidewater Region (Southeastern region) (see figure). These regions were chosen based on evidence of cropland development--irrigation development in the Great Plains and clearing of forestland for crops in the Southeast. A systematic sample of 20 percent of the counties in each region was selected (tables 1 and 2). In the Great Plains 45 counties were used, and in the Southeast, 85 counties were selected.

Cloud cover of the land, a problem inherent in LANDSAT imagery, introduced some bias into the selection process. Cloud cover prevented inclusion in the sample of some first-choice counties. Alternate counties were chosen for 13 percent of the counties in the Great Plains and 19 percent of the counties in the Southeast.

Five categories of land use change in the two regions were selected for identification. In the Southeast the categories were conversions of: (1) forest to cropland

Cropland Development Study Regions

and (2) pasture to cropland. In the Great Plains the categories were conversions of: (1) nonirrigated cropland to irrigated cropland, (2) rangeland to irrigated cropland, and (3) rangeland to nonirrigated cropland.

Procedures

The interpretation of the LANDSAT imagery was contracted to the Resource Information Laboratory (RIL) at Cornell University. Manual techniques developed by RIL in earlier research projects were adapted to this project (4).

LANDSAT imagery was obtained for the study counties from the EROS Data Center in Sioux Falls, S. Dak. The dates of the images were determined by the season of the year in which the changes were expected to be most obvious. In the Southeast, spring imagery was selected to show the best contrast between forest and cleared land. It was assumed that in the spring, cropland would appear as bare ground on the imagery, due to recent plowing or planting, whereas pasture would show slight vegetation. In practice, it was impossible to distinguish cropland from pasture, so this distinction had to be abandoned.

In the Great Plains, late summer and early autumn dates were used. It was thought irrigated crops would be taller and greener than nonirrigated crops or range during the dry season. Distinctions between range and nonirrigated cropland would be determined by field patterns and differences in amount of vegetation.

Because LANDSAT I was launched in the summer of 1972, spring imagery for the Southeast was available only for 1973. Because several 1973 spring scenes in the Southeast did not have acceptable images due to cloud cover, images from the fall of 1972 or 1973 were occasionally substituted or an alternate county was used. This substitution was necessary despite the frequency of LANDSAT coverage of a given area.

Images were ordered from EROS in a 55.8 mm black and white film positive form (called a chip). Generally, for each scene, bands 5 and 7 were ordered for the early year, and band 5 was ordered for the later year. This combination was determined through experimentation at the beginning of the project on three counties--Beaver County, Okla.; Ford County, Kans.; and Catahoula Parish, La. The combination of bands 5 and 7, once enlarged and color enhanced, provided a greater color volume as a base to contrast against the image of the latter year. 3/ In the Southeast, changes could be identified from band 5 alone for both years.

The images were enlarged in two stages to an 8 x 10 film positive. This was a scale change of 1:3,300,000 on the chip to 1:370,000 on the film positive. Highway maps of each county were ordered and enlarged to a standard scale of 1:63,360 (1 inch per mile) to use as a base map for each county.

Diazo transparencies of the 8 x 10 film positive were prepared with diazo color film in magenta, cyan, and yellow. Interpretation keys were prepared based on work done on the three pilot counties: Ford, Beaver, and Catahoula Parish (see app. 2 and 3). Areas of change between the 2 years were identified, coded, and mapped on the base map with a projector. Land use change acreages were tabulated using a prepared grid (1/8-inch square = 10 acres).

3/ For further description of this process, see (7).

ANALYSIS OF RESULTS

The data collected from the LANDSAT analysis appear in tables 1 and 2. No imagery could be obtained for less than 1 percent of the total study area due to cloud cover. It is difficult to discuss the reliability of the data in tables 1 and 2 as location problems in field checking prevented definitive conclusions. Consequently, no expansions to a regional level are attempted. However, using the field check data and available secondary data, one can draw tentative conclusions.

Informal field checks were conducted throughout the project by RIL and USDA personnel. County Soil Conservation Service (SCS) personnel were also consulted informally through telephone interviews during the interpretation phase of the project. We attempted a formal field check, using SCS personnel, after completing the interpretation phase of the project. A 10-percent sample of land use change areas in a random 10-percent sample of counties was selected for ground checks. RIL staff members prepared identification maps with numbered sample sites for ground checks. The SCS conservationists were asked to determine the land use for each sample site in 1972 and again in 1976 using their knowledge of the area and office records, such as airphotos or farm plans. A sample of areas with no change was included as a check on omissions in interpretation. An example of a field check form is included in appendix 3.

For the six pilot counties field-checked in this manner, the results were disappointing. 4/ In Dare County, N.C., where logging was underway, clear cutting as a part of a timber operation was indistinguishable from land cleared for crops. The results from the remaining five counties indicated that SCS field observations and the satellite interpretations agreed in 39 of 131 sample sites, for a 30-percent accuracy rate. When the sample sites were divided into "change" and "no change" sites, satellite interpretation and field checks agreed in 21 out of 32 "no change" sites (65 percent) and 18 of 99 "change" sites (18 percent).

Two explanations are possible for the apparent differences in accuracy. Mapping location problems may have prevented field checkers from locating the exact site. As the "no change" sites were generally larger than the sample "change" sites, this would account for the more accurate identification of "no change" sites. The field check design may have contributed to this problem. Also, much of the land use change detected by satellite imagery may have been caused by cloud conditions, water, or crop conditions changing the reflectance properties (signature) of a particular land use category.

It is possible that LANDSAT imagery was not aligned with county maps, thus preventing field checkers from locating sample sites. This may have resulted from the manual techniques of transferring land use change sites to county maps for field checking. In addition, the land use change sites in this project were particularly difficult to identify on the ground as they were scattered and irregularly shaped.

However, the formal and informal checks indicated many deviations from the signatures established by the interpretation keys. Vegetation response for each land use category not only differed within regions, but within counties, and between scenes and within the same scene. Some of the interpretation problems encountered are described below:

a. Pasture and cropland in the Southeast were indistinguishable.

4/ The six counties field-checked in this manner were Dare, N.C.; Cateret, N.C.; Queen Anne, Md.; Sheridan, Kans.; Clinch, Ga.; and Union, Miss. The results did not merit continuing field checks in the remaining sample counties.

Table 1--LANDSAT data for Southeastern region (85 counties), 1972-76

State and county	Total land 1/	Forestland cleared	Total land not interpreted 2/
		Acres	
Alabama:			
Barbour 3/	570,240	2,438	16,840
Choctaw 3/	83,040	3,682	--
Dale 3/	357,440	2,115	--
Henry	354,560	8,036	--
Mobile	793,536	7,521	8,160
Tuscaloosa	853,120	5,103	--
Wilcox 3/	575,168	6,147	--
Arkansas:			
Desha	470,912	1,320	--
Cleveland 3/	384,640	541	27,840
Lee	388,992	1,697	--
Little River 3/	311,040	150	--
Phillips	450,565	1,839	--
Prairie	422,848	4,411	--
Florida:			
Baker	374,144	1,341	--
Calhoun	358,912	3,407	--
Dixie	443,136	3,564	--
Jefferson	387,328	4,028	--
Liberty	536,704	1,510	--
Nassau	416,000	8,661	--
Washington	374,592	1,862	--
Georgia:			
Brantley	286,080	6,402	--
Brooks	313,920	7,796	--
Clay	128,000	3,598	--
Clinch	509,760	7,577	--
Dodge	318,976	3,588	--
Evans	118,848	1,051	--
Houston	243,200	2,660	--
Jeff Davis	211,520	2,956	--
Macon	257,664	4,474	--
Pierce	218,880	2,357	--
Pulaski	162,112	2,359	--
Seminole	157,184	458	--
Terrell	210,560	3,789	--
Turner	187,328	2,766	--
Kentucky:			
Calloway	245,824	609	--
Louisiana:			
Beauregard 3/	757,568	3,988	--
Calcasieu 3/	707,200	3,071	6,360

See footnotes at end of table.

Continued--

Table 1--LANDSAT data for Southeastern region (85 counties), 1972-76--Continued

State and county	Total land 1/	Forestland cleared	Total land not interpreted 2/
		Acres	
Louisiana: (continued)			
Caldwell 3/	352,448	1,451	--
Cameron 3/	922,368	513	99,230
Catahoula	474,944	4,973	--
Morehouse	514,560	9,949	--
Natchitoches	828,800	11,554	--
St. John the Baptist	145,024	201	--
St. Tammany	567,360	521	--
West Baton Rouge	129,856	539	--
Winn	608,256	9,561	--
Maryland:			
Queen Anne	240,192	11,417	27,820
Missouri:			
Pemiscott	315,456	3,841	--
Mississippi:			
Chickasaw	323,776	1,689	--
George	307,520	4,596	1,118
Jackson	470,848	5,685	2,534
Lamar	320,000	1,082	--
Leflore	379,008	2,379	9,900
Marshall	454,208	4,722	--
Pearl River	529,920	624	--
Simpson	375,686	1,648	8,640
Tunica	293,056	2,656	--
Union	269,952	434	--
North Carolina:			
Beaufort	528,704	1,963	--
Cateret	432,912	1,085	--
Dare	*	1,883	--
Harnett	385,664	1,689	--
New Hanover	118,656	230	--
North Hampton	343,040	1,672	--
Perquimans	157,696	902	--
Wilson	239,744	700	--
South Carolina:			
Clarendon	383,552	15,567	--
Marion	311,936	1,878	--
Berkeley	710,144	12,340	--
Hampton	359,424	2,212	--
Tennessee:			
Carroll	381,312	265	--
Henry	363,008	742	--

See footnotes at end of table.

Continued--

Table 1--LANDSAT data for Southeastern region (85 counties), 1972-76--Continued

State and county	Total land 1/	Forestland cleared	Total land not interpreted 2/
		Acres	
Texas:			
Camp	123,008	285	--
Chambers 3/	394,304	259	--
Hardin	574,080	1,812	--
Jasper 3/	580,480	6,078	--
Liberty	755,200	1,038	24,960
Nacogdoches 3/	577,280	2,897	--
Rusk	600,768	711	--
San Patricio	438,592	2,183	--
Tyler	588,096	4,240	7,800
Virginia:			
Nansemond (Suffolk)	*	1,989	--
Northampton 3/	140,864	446	--
Prince George	182,400	1,500	--
Surry	177,408	1,899	--

-- = not applicable
*data not available
1/ Data from 1974 U.S. Census of Agriculture.
2/ Cloud cover prevented interpretation.
3/ Counties used as alternates for 1972 survey counties are as follows:

Alabama--
- Barbour alternate for Bullock.
- Choctaw alternate for Coffee.
- Dale alternate for Elmore.
- Wilcox alternate for Clark.

Arkansas--
- Cleveland alternate for Hempstead.
- Little River alternate for Nevada.

Georgia, Houston alternate for Jenkin.

Louisiana--
- Beauregard alternate for Bossier.
- Calcasieu alternate for Vermillion.
- Caldwell alternate for Evangeline.
- Cameron alternate for Lafourche.

Texas--
- Chambers alternate for Fort Bend.
- Jasper alternate for Montgomery.
- Nacogdoches alternate for Polk.
- Rusk alternate for San Jacinto.

Virginia, Northampton alternate for Chesapeake.

Table 2--LANDSAT data for Great Plains region (45 counties), 1972-76

State and county	Total land 1/	Rangeland converted to-- Non-irrigated cropland	Rangeland converted to-- Irrigated cropland	Cropland converted to irrigated cropland	Total land not interpreted 2/
	Acres				
Kansas:					
Chautauqua	414,080	982	--	--	--
Cloud	455,040	--	--	980	--
Ford	698,176	1,768	4,418	17,220	15,824
Graham	570,176	1,007	1,764	5,981	--
Hamilton	634,880	10,544	6,832	9,814	--
Harper	512,640	1,025	--	924	14,400
Kingman 3/	552,960	403	585	1,924	--
Kiowa	460,800	2,752	4,810	13,753	--
Logan	686,720	1,136	40	4,979	--
Lyon	538,240	242	--	5,015	--
McPherson	573,312	77	--	5,134	4,340
Phillips	574,208	749	2,374	6,029	--
Saline	460,800	355	332	313	--
Sheridan	571,456	460	3,379	20,082	--
Trego	576,650	1,367	588	1,767	--
Wabaunsee	507,136	732	610	3,384	--
Wichita	420,484	--	1,781	21,706	--
Nebraska:					
Butler	372,480	--	--	7,415	--
Hall	343,360	--	973	8,919	--
Harlan	355,904	--	--	9,655	--
Kearney	327,680	--	7,222	10,254	--
Keith	660,672	81	5,355	8,617	--
Seward	365,632	--	--	9,662	13,440
New Mexico:					
Curry	897,792	4,549	2,432	28,846	--
Oklahoma:					
Beaver	1,153,730	4,075	484	6,339	12,000
Caddo	814,080	--	949	1,624	13,900
Cotton 3/	416,320	439	--	305	--
Harmon 3/	348,800	483	--	773	34,030
Jefferson 3/	499,200	5,571	--	328	2,400
Tillman 3/	576,832	379	2,894	--	576,832
Texas:					
Callahan	548,047	901	75	300	--
Carson	576,000	--	213	24,891	--
Cottle	576,064	1,068	--	--	--
Dawson	577,280	472	44	5,215	--
Garza	584,896	529	--	88	--
Hale	626,560	--	1,381	22,696	--
Hemphill	578,304	601	173	1,513	--

See footnotes at the end of table.

Continued--

Table 2--LANDSAT data for Great Plains region (45 counties), 1972-76--Continued

State and county	Total land 1/	Rangeland converted to--		Cropland converted to irrigated cropland	Total land not interpreted 2/
		Non-irrigated cropland	Irrigated cropland		
			Acres		
Texas (cont.):					
Hutchinson	559,936	527	1,207	16,100	--
Jack	604,928	--	--	--	--
Lipscomb	597,760	5,180	6,199	4,603	--
Midland	600,768	751	52	749	--
Potter	574,768	--	--	1,350	--
Scurry	578,304	374	--	46	--
Stonewall 3/	592,768	839	--	283	--
Yoakum	531,200	1,903	1,903	9,763	--

-- = not applicable

1/ Data from 1974 U.S. Census of Agriculture.

2/ Cloud cover prevented interpretation.

3/ Counties used as alternates for 1972 survey counties are as follows:
Kansas, Kingman alternate for Canadian.
Oklahoma--
Cotton alternate for Ellis.
Harmon alternate for Kiowa.
Jefferson alternate for McClain.
Tillman alternate for Woodward.
Texas, Stonewall alternate for Tom Green.

b. Fields of soybeans may appear as forested areas on images made in the late spring. The crop at that time may be dense enough to be misinterpreted as brush or forest.

c. Flood conditions in several counties in the Southeast caused misinterpretations of land uses.

d. Deciduous forests in the Southeast may show up on October imagery as cleared areas, if the images were made after the autumn leaf fall.

e. In the Great Plains, natural vegetation may have been misclassified as newly irrigated land. Wetter soil conditions in the later imagery (1972) due to recent rainstorms or a wet year could cause natural vegetation to have a spectral response similar to that for irrigated crops.

f. Conversions of range to nonirrigated cropland were extremely difficult to distinguish from the imagery. In some instances field boundary changes were the only means of identifying the change.

g. The use of different fall dates may have caused some misinterpretations of irrigated cropland. If the image of the early year is taken after the harvest of the irrigated crop, the land may appear as nonirrigated. If the image of the later year is taken earlier in the season, before harvest, the same area will appear as irrigated and will be interpreted as a land use change.

Ground data might help evaluate the project results. However, no county data are available on clearing in the Southeast for the 1972-76 time period. Some published data are available on irrigation in the Great Plains States that correspond generally to the 1972-76 time period (table 3). These data were collected mostly from county extension agents and represent informed estimates of irrigation activity, not field surveys. In addition, these data represent net irrigation change, whereas the LANDSAT data in this study encompass only additions to irrigated land. In some areas, substantial acreages were removed from irrigation during the 1969-74 time period. Even in areas with no recorded irrigation declines, conversions to irrigation may have been offset by withdrawal of irrigation systems on other cropland.

Considerable variation exists between the LANDSAT data and the irrigation survey data. These variations are difficult to evaluate, however, due to the different techniques used and the difference between net and gross data. However, interpretation of both field checks and published data appears to indicate that these represent interpretation problems in the LANDSAT data. The field check data indicate that if map location problems were the reason land use change areas could not be verified in the field, LANDSAT accurately identified the correct land use for both years 65 percent of the time.

CONCLUSIONS

During this study we discovered several limiting factors that should be considered in any future work. Although some are inherent in the LANDSAT technology, others may be unique to this study.

The first limitation was the problem of cloud cover. It was a problem in both regions studied, although it was more serious in the Southeast. Alternate counties had to be selected, which meant a departure from the original sample and the introduction of some bias if the data were expanded to a regional level.

Table 3--Irrigation changes in selected counties recorded by irrigation survey and LANDSAT data

State and county	Change in irrigation	
	Irrigation survey 1972-75	LANDSAT 1972-76
	Acres	
Kansas:		
Chautauqua	-500	--
Cloud	1,000	980
Ford	26,500	21,638
Graham	9,300	7,745
Hamilton	4,520	16,196
Harper	415	924
Kingman	4,926	2,509
Kiowa	2,356	18,563
Logan	2,700	5,019
Lyon	-160	5,015
McPherson	14,720	5,134
Phillips	788	8,403
Saline	2,896	645
Sheridan	42,968	23,461
Trego	470	2,355
Wabaunsee	-170	3,994
Wichita	-35,040	23,487
Total	77,689	146,068
Oklahoma:		
Beaver	9,000	6,823
Caddo	52,500	2,573
Cotton	-1,697	305
Harmon	560	773
Jefferson	100	328
Tillman	8,800	3,273
Total	69,263	14,075
Texas:		
Carson	5,875	25,104
Dawson	-38,500	5,259
Garza	-815	88
Hale	34,220	24,077
Hemphill	6,500	1,686
Hutchinson	22,000	17,307
Lipscomb	13,200	10,802
Potter	1,700	1,350
Scurry	1,000	46
Yoakum	28,000	11,666
Total	73,180	97,385

-- = data not available.

The multiperiod approach of the project compounded the problem. Comparable dates were often not cloud free for both 1972 and 1976. This required substitutions, to the extent of spring for fall imagery in some cases, and it prevented complete comparability in the time periods used, thus increasing problems of interpretation. Even with the use of alternate counties, a small percentage of the land area could not be interpreted because of cloud cover.

Cloud conditions are an inherent factor in any use of LANDSAT imagery. However, any multiperiod approach to a problem that uses LANDSAT will be seriously limited if cloud cover prevents analysis of comparable time periods. Furthermore, the results of this study and the use of alternate counties would seem to indicate that selecting an unbiased random sample may be difficult with LANDSAT.

Using one interpretation key for all the counties in a region was also a limiting factor in this study. In actuality, field checking showed many deviations from the signatures established by this key. These variations in interpretation can be reduced by careful field checking at various stages in the project. The selection of imagery should be checked first to make sure no unusual weather conditions, such as flood or drought, are present that might result in misinterpretation.

Second, interpretation keys should be based on a knowledge of known sample sites, a variety of which should be located throughout the study region. Midproject field checks in other selected sites should be conducted to correct any unforeseen interpretation problems. The telephone interviews conducted with SCS personnel in this study were not sufficient. However, it is doubtful that all interpretation problems can be eliminated; therefore, a final field check should be conducted to assess the accuracy of interpretations.

The failure of the field checks in this study to assess the project adequately stemmed largely from the uncertain alignment of LANDSAT imagery with county maps. Registering LANDSAT data to a map base is difficult in any project. Procedures for registering scenes to a map base have been developed by ESCS for use in their digital programs. New LANDSAT technology will provide data precisely registered to ground control points in either tape or digital form, thus making registration to a map base simpler.

However, the land use change sites in this project were particularly difficult to field check because they were scattered, irregularly shaped, and not always visible from a road. In addition, determination of the prior land use was sometimes difficult as a result of the focus on land use change rather than on a comprehensive inventory. The ESCS project uses known sample plots from their June Enumerative Survey as field sites to establish a ground-truth data base. LANDSAT data is thereby tied to key plots where ground data are clearly defined. This type of approach would appear necessary, especially where the sites to be checked are scattered and irregular.

Field checking procedures are an important component of any LANDSAT project. The difficulties encountered in this study can probably be reduced in future projects, although field checking land use change sites appears to be more difficult than a single-time period inventory field check.

The field checking process employed in this study does not permit a definitive statement about the accuracy of the data. However, some conclusions can be drawn. We encountered problems in interpreting satellite imagery that are common to other satellite imagery studies--for example, unusual weather conditions, difficulty in generalizing interpretations over large areas, and confusion between spectral responses. Cloud cover is also a problem with any use of satellite imagery. In this study, 13 percent of the counties in the Great Plains and 19 percent in the Southeast were alternates, which introduced some sample bias.

However, the multiperiod approach used here seemed to intensify the usual problems associated with satellite imagery. Cloud-free imagery was necessary for two time periods rather than one. Sampling was consequently more difficult.

In addition, the use of two time periods made field checking more difficult. Determination of a prior land use, not just the current land use, was necessary to check land use change. The irregular land use change sites were also more difficult to locate in the field. The use of less expensive manual map registration techniques, rather than computer-assisted methods, may have contributed to the field checking problems encountered in this study.

Determining land use change through LANDSAT data may be more difficult than other types of inventory efforts, but LANDSAT data can offer unique information for the agricultural sector. Combining LANDSAT data with other measurement techniques, as does the ESCS studies, may be the most promising use of satellite imagery because the impact of such problems as cloud cover are minimized. Where no other information is available, satellite imagery alone could be invaluable--if its limitations are recognized. In both cases, careful field checks should be an integral part of the interpretation process. We hope our experiences will enable researchers in future projects to make maximum use of the information potential of satellite imagery.

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Appendix table 1--Interpretation key for Southeastern counties, by land use

Interpretation	Forest	Cropland
Physical characteristics	Dark areas, no regular boundaries, large, may follow stream/river patterns, color may show some mottling	Rectilinear areas, regular boundaries may be small areas
Color signatures: Early year (1972) Cyan-band 5	Dark blue, fairly solid color, but may show some mottling	Clear to light blue
Late year (1976) Magenta-band 5	Dark magenta, fairly solid color, but may show some mottling	Clear to light pink
Composite	Forest both years--dark purple	Cleared both years--clear to light purple

Notes:

Conversions: Areas forested in early year (1972), cleared in late year (1976) visible as dark blue (early-year forested response) areas showing through a clear or pale magenta area (nonforested response).

Colors: In some instances, the early year Band 5 is in magenta (instead of cyan) and the late year Band 5 is in cyan (not magenta). In such cases, they appear as magenta areas.

Band 7 was ordered for all areas, but the yellow diazo of this band showing moisture responses often conceals detail and makes interpretation more difficult. For this reason, Band 7 (in yellow) was used only where it does not interfere with interpretation.

Flooding: Several areas in the study may have flood conditions evident on the image (obvious from river boundaries and widths). This may reduce the accuracy of the interpretation as wet conditions can conceal detail.

Clearcutting is a common forestry management practice in pine stands in this region. Clearcut areas which have not been replanted would be interpreted as areas cleared for cultivation. Soil Conservation Service contact people would be able to verify if clearcutting is done, but they may not be able to identify locations.

Land which has been cleared for housing developments would likely be interpreted as areas cleared for cultivation. As with clearcut forest lands, we would not be able to identify the intended use of a given cleared area.

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Appendix table 2--Interpretation key for Western counties

Interpretation	Irrigated cropland		Nonirrigated cropland	Rangeland
	Pivot systems	Other		
Physical characteristics	Dark, solid color distinct circles; size: 1/2" in diam. at 1:63,360	Dark, solid color sharply defined boundaries--square or rectangular size: 1/2" square or smaller (unless neighboring sections are irrigated)	Rectilinear patterns regular boundaries	Generally irregular boundaries, but may occur in patches in cropped areas, generally large areas, mottled appearance drainage channels may be visible, but faint
Color signatures Early year (1972) Cyan-5 Yellow-7	Dark blue	Dark blue	Tone range from pale yellow to yellow-green to light green	Dark green--maybe slightly mottled
Late year (1976) Magenta-5	Dark magenta	Dark magenta	Tone range from pale pink to medium pink	Medium dark magenta, maybe slightly mottled
Composite	New irrigation: dark magenta; old irrigation: dark purple; discontinued irrigation: dark cyan		Old: light yellow brown to light green brown; new: see note below	Old: dark green-brown, maybe slightly mottled

Notes:

Conversions: Locate new irrigation/cropland given above guidelines and identify prior use based on diazos of early year.

Rangeland to nonirrigated cropland: Shows a very subtle visual change--distinctions may appear primarily as a boundary shift evident on late year diazo as compared to early year. Would occur primarily along the interface between rangeland and cropland (evident in diazo of early year). The area will be lighter on the late year diazo; thus the dark green of the early year will be visible.

Irrigation equipment can be moved--so may see a system which has gone out of use (cyan) near a new one (magenta). This happens occasionally. We will make no adjustments in the tabulation for this.

Imagery: In some cases, Band 5 was ordered for early year and Bands 5 and 7 for late year. Interpretation is then reversed--new irrigation is cyan, not magenta, and so on.