THE SOUTH DAKOTA COOPERATIVE LAND USE EFFORT: A STATE LEVEL REMOTE SENSING DEMONSTRATION PROJECT

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ABSTRACT

Remote sensing technology can satisfy or make significant contributions toward satisfying many of the information needs of governmental natural resource planners and policy makers. Recognizing this potential, the South Dakota State Planning Bureau and the EROS Data Center together formulated the framework for an ongoing Land Use and Natural Resource Inventory and Information System Program. Statewide land use/land cover information is currently being generated from LANDSAT digital data and high altitude photography. Many applications of the system are anticipated as it evolves and data is added from more conventional sources. This paper primarily deals with the conceptualization, design, and implementation of the program.

INTRODUCTION

All levels of government share the need for natural resource information. Intelligent planning, policy formulation, and decision making often require a great deal of qualitative and quantitative information. Without a solid information base, the planning process can be reduced to guesswork, a regrettable situation at best.

The cost of acquiring most types of resource data is relatively high, especially at finer levels of detail. Remote sensing technology, while not a panacea, can provide demonstrable reductions in the costs of data acquisition for some types of natural resource information.[1,2,3,4] It must, however, be used in an appropriate context with realistic expectations.

One of the principal areas where the potential application of remotely sensed data is being developed is in the generation of land use, or more precisely, land cover information.[5,6,7,8,9,10] Traditional data gathering methods, ranging from "windshield surveys" to low altitude photography, are generally too expensive and time consuming to perform more than once, if at all. The NASA Earth Resources Program, however, has significantly changed this situation. The synoptic, repetitive coverage of high resolution sensors on satellite platforms has made the collection, analysis, and dissemination of comprehensive regional land use data practical and cost-effective for the first time. Recognizing this potential, the South Dakota State Planning Bureau and the EROS Data Center undertook a cooperative land use demonstration project. Together they formulated the framework for the South Dakota Land Use and Natural Resource Inventory and Information System. Objectives were developed, and a three phase program designed.

Initially, three information sources are being tapped for this project. LANDSAT data, in digital and photographic formats, is being used to provide statewide land cover information at several levels of detail. High altitude photography will be used for more detailed large area analyses, and for verification of the results produced using smaller scale imagery. Conventional low altitude photography will be used for detailed small area analyses in selected urban and critical areas. Each sensor will be used at the most appropriate and cost effective scale, so that the intrinsic advantages of each may be fully exploited.

OBJECTIVES

During the formulation of the program, an attempt was made to develop a realistic set of goals and objectives. The result is shown in Figure 1. The emphasis of the objectives was to address natural resource information needs with what were felt to be practical applications of remotely sensed data. To date, this has been borne out.

The overall goal of the program has been to provide detailed, accurate land cover and natural resource information to improve and support governmental decision making, the comprehensive planning process, and state and local land use planning and policy formulation. Conventional data sources were inadequate to meet these needs. Where information existed at all, it was often dated, inaccurate, of insufficient detail, or a combination of the three. It was necessary, therefore, to develop new data sources. Remote sensing technology provided the only viable alternative in a sparsely settled state such as South Dakota.

PROGRAM

A three phase program was designed to operationalize the South Dakota Land Use and Natural Resource Inventory and Information System. Phase I has essentially been completed. Phases II and III are scheduled to run concurrently with fiscal years 1976 and 1977, respectively.

Phase I

Two major tasks were completed in Phase I. A statewide Level I inventory was visually interpreted from LANDSAT imagery. Level II and partial Level III information was digitally interpreted from LANDSAT computer compatible tapes for selected priority areas. The generalized information flows for this phase are depicted in Figure 2.

Visual interpretation.- Visual interpretation was done on color enhanced LANDSAT imagery at a scale of 1:250,000. A diazo process was used for the color enhancement, with MSS5 in positive red and MSS7 in negative blue being sandwiched to create a false color composite. These composites, produced from 1:1,000,000 positive transparencies, were then copied onto 35MM slides, one per quadrant, or four per scene. The actual interpretation was done using a rear projection technique. (see Figure 3) The slide image was then projected onto special composite chronaflex 1:250,000 USGS base maps, with the land use data interpreted in quarter section cells (160 acres) and drafted onto a mylar overlay. The overlays were then color coded, generalized, redrafted, and mosaicked at 1:500,000 using a cartographic projector. This was sent to the printer for final map reproduction at a scale of 1:1,000,000.

Digital interpretation.- Within the land use inventory program, the LANDSAT Imagery Analysis Package (LIMAP) was used for the analysis and display of LANDSAT CCTs. This system was developed by the principal author, with the exception of the clustering and discriminant function algorithms which were adapted from LARSYS. The generalized analysis procedure used is shown in Figure 4. Selected priority areas were categorized on a pixel by pixel basis, with display scales ranging from 1:24,000 (1.1 acre cells) to 1:500,000 (40 acre cells).

Analysis procedure: The first step in the analysis procedure consists of joining and reformatting the raw multispectral data. This is essentially a housekeeping function, making the data easier to store, access, and use. If coverage of the study area (usually a county or multicounty area) requires the use of consecutive images, the scenes are merged and the overlap discarded. Fortunately, all but one of South Dakota's counties are entirely within consecutive images. The problem of joining side-by-side images was safely avoided.

The next step consists of removing the spatial distortion present in the data. The distortion present can be attributed, for the most part, to three factors: the motion of the spacecraft, the rotation of the earth, and the angle of the satellite's orbit.[11] The algorithm performs a linear rectification on a nearest neighbor basis, with the output being properly north-south and east-west oriented. This reorientation would be a trivial matter, were it not for the large amount of information in each scene. Even though a simplified geometric correction procedure is used, the rectification of 3 million pixels takes well over an hour of computer time on a moderate sized computer with limited main storage. Once the data is rectified, greyscale line printer maps are generated for MSS5 and MSS7, usually at 1:24,000 (all pixels) and/or 1:48,000 (25% sample).

The next step is the most crucial of the entire process. This is where the statistical definitions of the land use categories are developed. Greyscale maps of the study area for MSS5 and MSS7 are examined spectrally and associated with ground truth information, often high altitude aerial photography. Small windows, called training fields, are located on the map and are submitted to a clustering algorithm. Through a man-machine interactive procedure, an optimal set of spectral classes is obtained which is representative of the ground cover types to be identified. Finally, the spectral characteristics (statistics) of the selected categories are used to classify all of the data points in the study area using a Gaussian maximum likelihood classifier.

Display options: Once the study area is categorized, two display options are available: grey tone line printer maps, or color coded land use plots. Individual categories, all categories, or selected categories can be displayed in either mode. These displays and supporting statistics can be generated for the entire area, or selected portions of it, either rectangular or polygonal. The scale of line printer maps can be varied from approximately 1:24,000 to 1:144,000. The scale of the color plots can be varied from 1:24,000 to 1:500,000. The resolution for both output media can be varied between 1.1 and 40 acres. An aggregation algorithm creates multipixel cells as required. This program allows user specification of decision rules, automatic creation of combination categories when ties occur, or a combination of the two approaches, as requested at the time of execution. Examples of several types of hard copy are presented in the Initial Results section.

Phase II

Figure 5 illustrates the information flows of Phase II. During this phase, land uses in the remainder of the state will be analysed digitally to Level II and partial Level III, except in large homogenous areas, such as arid grasslands, where computer processing is deemed superfluous. NASA high altitude imagery will be systematically utilized to verify digitally produced information. Where LANDSAT digital processing is found to be inadequate, one of two courses will be followed. Where the classification is satisfactory, with limited areas of confusion, high altitude imagery will be used to resolve any discrepancies present. Current budget and work program plans include the acquisition of hardware which will permit data refinement in an interactive mode. If the digital classification is unacceptable, high altitude imagery will be visually interpreted, classified, digitized and prepared for entry into the information system.

An inventory of existing resource data will be undertaken during this phase. This is primarily in preparation for Phase III, when much of this data will be digitized and entered into the system. In addition, a land capability/suitability study will be done for a metropolitan area in the state. Appropriate natural resource data for the county will be selected and entered into the system. An overlay technique will be employed to reveal the intrinsic suitabilities and limitations for both urban and rural development. Alternative land development plans, and a package of appropriate policies to guide in the implementation of the selected alternatives will be presented to district, county, and municipal planning agencies.

The final major activity in this phase will be the visual interpretation of high altitude photography. Selected urban and critical areas will be categorized on the basis of quarter acre cells (approximately 30 x 30 meters). The basic interpretation technique will be the same as used on the LANDSAT imagery, with 1:24,000 quad maps replacing the 1:250,000 base maps. Upon completion of the interpretation, the land use and other resource data will be entered into the information system.

Phase III

During the final implementation phase, the breadth and depth of information available within the system will be greatly enhanced. The anticipated information flows are shown in Figure 6.

Level III land use information will be completed for the entire state. LANDSAT digital data interpreted in earlier phases will be adequate for most rural areas. Data for urban and critical areas will be interpreted from high altitude photography. Low altitude missions will be flown as required to meet special data needs. Once the land use data base is completed, a two to five year update cycle is projected. The actual frequency will depend on two factors: the amount of change since the last update, and the anticipated development pressure.

Several types of natural resource data will be added during this phase. These include, but are not limited to, soils data, topographic data, geologic data, hydrologic data, climatic data, surface and subsurface resource data, air and water quality data, and ownership type data. The presence of this data within the information system will allow a wide variety of detailed analyses to be performed as required for state and local planning and policy formulation.

The final major task performed in this phase will be the creation of linkages to the State Planning Bureau's Policy Information System. This system will contain comprehensive statewide social, economic, fiscal and demographic data. These linkages should greatly enhance the analytical capabilities of both systems, providing a basis for social, economic, and environmental impact assessment of alternative policy decisions.

INITIAL RESULTS

Central South Dakota

Analysis of a multi-county area in central South Dakota was recently completed. A single scene was selected for this analysis--May 15, 1973 (scene ID 1296-17014). All processing and display generation for this study area was performed by the LANDSAT Imagery Analysis Package.

Figures 7 and 8 show grey tone 25% sample line printer maps for Cow Creek Township in Sully County. The rectified data for MSS5 and MSS7 are displayed. The raw data was sliced on the basis of a visual examination of one dimensional histograms, and assigned to one of the five grey levels present.

Figure 9 is a single category map of bare soil in Cow Creek Township. For this display, the data has been aggregated into 4.4 acre cells (2 x 2 pixels). The scale of the original on this map, as in the previous two, is approximately 1:48,000. Figure 10 is an all category all pixel land use plot for the same township, (original scale = 1:62,500) and Figure 11 contains the legend for this plot.

Figure 12 consists of an all category plot of a major portion of Sully County at an original scale of 1:250,000, and Figure 13 contains the legend for this plot. Pixels have been aggregated into 10 acre cells (3 x 3 pixels) for this display. Cow Creek Township has been outlined for comparitive purposes.

Figure 14 is a listing of the land use categories which are being interpreted from LANDSAT CCTs with limited supplemental information. Higher resolution data sources would be required for the interpretation of more detailed information. This classification system is adapted from the Anderson system.[12]

Sioux Falls Analysis

As a comparison to the work being done at the State Planning Bureau, it was decided to run a comparison analysis using LARSYS 3.1 on the terminal at the EROS Data Center.

The area chosen for processing at EROS is located in the eastern portion of the state. Two LANDSAT-1 scenes were chosen for the analysis--August 15, 1972 (scene ID 1023-16433) and May 30, 1973 (scene ID 1311-16441).

Preprocessing.- The four bands of digital data from each scene were temporally overlayed, e.g., the data points were spatially registered to create a combined data set. The data were then geometrically corrected -- skew removed, oriented north-south, and scaled to 1:24,000 for line printer character maps.

Ground control/ground truth.- Important for the selection of training and test fields and overall assessment of classification accuracy was the assembly of a ground control aggregate and subsequent transfer of necessary ground truth information to the ground control. Nine U.S. Geological Survey 7.5 minute topographic guadrangles were trimmed and mosaicked to form a 1:24,000 scale ground control aggregate, the same scale as line printer character maps generated from the LANDSAT analysis. Ground truth available for the analysis included high altitude, color infrared aerial photography flown by NASA in 1970. Certain land use information, including location of industrial/commercial areas, newer housing, and older housing, were extracted from the aerial photography and indicated on the quadrangle-mosaic.

Training field selection.- Greyscale lineprinter character maps of the study area were generated for bands 5 and 7 for both August and May. Training fields were located for each of the land uses to be identified. Precise location of the training fields was possible by overlaying the greyscale maps with the ground control/ground truth aggregate on a light table. Training fields for commercial/industrial areas, newer housing, and older housing (divided into two distinct spectral classes because of differing tree canopy cover) were located on the band 5 greyscales, while the agriculture and forest samples were selected from band 7 maps. Because the May data included several small, cumulus clouds, training fields were located for two additional spectral classes, cloud and cloud shadow. Water bodies in the study area were not large enough to be spectrally identified.

A special problem arose in the selection of training fields to use for bi-temporal, agricultural land cover classification. The agricultural areas included a wide range of infrared reflectivity for both the August and May data sets. It was necessary, therefore, to create Gaussian subclasses of agricultural land cover types. Unfortunately, crop type information was not available to the analyst. Thus, the subclasses needed to be created solely on the basis of infrared reflectance. By careful and systematic scanning of both greyscale maps, agricultural field patterns were seen to be closely related to certain levels of reflectivity. The complete range of agricultural reflectivity in band 7 was ultimately divided into four levels for each date. The observation was made, moreover, that a given "level" (spectral class) of one date could be either of the other levels of the other date. For example, if crop type information had been available to the analyst, one of the sixteen possible combinations of agricultural bi-temporal land cover (16 combinations are possible, because of the 4 x 4 level matrix) might have been corn in August 1972, and dark bare soil in May 1973. One of the bi-temporal combinations, lowest reflectivity in August and highest in May, was not found to be a significant class for the analysis.

Location of training fields for the resultant fifteen agricultural classes completed the task of choosing representative areas to "train the computer" to identify the desired land uses--commercial/industrial, older housing (2 spectral classes), newer housing, forested, agriculture (15 spectral classes), cloud, and cloud shadow. The aggregate of training fields totaled 72, which included 1492 data points (1.0% of the 138,224 data points in the study area).

<u>Statistics/Feature Selection</u>.- Quantitative characterization of the land uses (spectral classes) was achieved by calculation of means for each class and covariance matrices for all pairs of classes. Using the spectral statistics, a feature selection processor was used to calculate separability coefficients for class pairs for 4-band combinations. The objective was to determine which 4-band set of pairs of spectral classes would be most separable (spectrally distinguishable). Selection of the "best 4" of the eight was largely arbitrary. Indeed, all eight channels might result in the most accurate maximum likelihood classification, but excessive computer time would have to be used. Previous studies have shown that four or five channels give acceptable classification results; use of more channels yields insignificant (small) gains in classification accuracy in consideration of the additional computer time used. Bands 5 and 7 from each date were chosen by the processor as the best four wavelengths. Divergence values (separability coefficients) for the 231 pairs of the 22 spectral classes were all satisfactory--213 pairs had values of 2000 (maximum separability; range is from 0 to 2000); 17 pairs had values from 1900 to 1999; and one pair (agricultural areas with very bright infrared reflectance in August and medium dark in May and medium-bright red in August and medium-dark red in May) had a value of 1750. The mean interclass divergence was 1997.

<u>Maximum likelihood classification</u>.- Because the classes were spectrally separable, as indicated by the feature selection processor, a Gaussian maximum likelihood classifier was used to categorize (classify) each of the data points in the study area into one of the twenty-two spectral classes. Class means and covariance matrices were used to create the decision boundaries. A common form of output of the classification results is a lineprinter alphanumeric character map, which displays the different land uses with different letters/symbols (Figure 15). A medium altitude aerial photograph of approximately the same area is included as Figure 16. Other possible output formats include lineprinter character maps with overprinting, color or black-and-white computer-driven plotter maps, color-coded photos from cathode ray tube (CRT) devices, and color-coded maps (film or print) from film recorders.

<u>Classification Verification</u>.- Quantitative assessment of classification accuracy was achieved by selection of rectangular areas, termed "test fields," for each of the land use classes. Two townships, Sioux Falls, and Mapleton, were chosen for the verification. The former is primarily urban while the latter is mostly rural. The townships contain 40,386 LANDSAT pixels, which represented 29 percent of the study area originally classified. Within the townships, 136 test fields were selected, containing 20,391 pixels or 51 percent of the two-township area.

Four generalized land use classes--commercial/industrial, forested, residential (3 spectral classes), and agricultural (15 spectral classes)--were tested for classification accuracy. Of the commercial/industrial pixels, 80 percent were correctly classified; 81 percent of the residential pixels were correct; forested was 69 percent; and agriculture 85 percent. The overall classification accuracy of test fields was 84 percent.

<u>Classification results: Discussion</u>.- Although a classification accuracy of 85 percent is satisfactory for regional resource inventories, it is appropriate to discuss sources of classification error. One problem is largely a

matter of definition of land uses versus spectral reflectance. New industrial parks, for example, typically have extensive landscaping, resulting in large expanses of green vegetation. In such areas, the buildings and parking lots will be accurately classified, but the surrounding lawns and shrubbery are usually classified as parks or agriculture. Another problem of definition arises in agricultural areas. A number of earth surface features--country road right-of-ways, narrow shelterbelts, homesteads, stock ponds, weedy areas in fields, and small alluvial depressions--are usually too small to be spectrally identifiable at LANDSAT resolution, yet are large enough to influence the reflectance values of LANDSAT pixels and will often result in classification error.

Another problem in LANDSAT classification is border pixels. Data points which are collected on boundaries between two land uses often have reflectance values characteristic of neither land use. Erroneous classifications sometimes result.

Within residential areas, a particular classification problem arises in transitional areas between distinct regions of older housing, characterized by mature tree canopy, and distinct areas of newer housing, characterized by large lawns and brightly reflecting rooftops and streets. Between these two land uses there is often an area with "medium" sized trees. Such areas are often misclassified as agricultural land cover.

Additional classification iterations.- Attempts were made to refine the classification results, by redefinition of the statistical characterization of the land use (spectral) classes. This was accomplished by altering the set of training fields for certain classes.

Initially, the training fields for three of the fifteen agricultural classes were changed. Overall classification accuracy was increased one percent to 85 percent, but class accuracy for two land uses--commercial/industrial and residential--decreased, from 80 to 65 percent and from 81 to 80 percent, respectively. Agricultural areas were more accurately identified increasing from 85 to 86 percent, while forested accuracy remained stable at 69 percent.

Training fields were altered for industrial/commercial areas for the third iteration, resulting in no change in overall classification accuracy. Industrial/commercial identification was increased to 69 percent accuracy, while percentages for the other three land uses were unchanged.

The results of this comparative analysis will be included in the Phase I report generated by the Bureau.

CONCLUSION

The Land Use and Natural Resource Inventory and Information System will substantially increase the amount and extent of resource information readily available to all levels of government in South Dakota. The natural resource management process will proceed on a stronger informational base. The speed with which information can be generated and the depth to which it can be analysed will be greatly improved.

Such an information system has many potential applications. Some of those projected for this demonstration include:

--All the county land use inventories completed so far are to be included as integral parts of the land use component of the respective counties' comprehensive plans.

--During Phase II of the program, LANDSAT data from 1972 and 1975 is going to be used to determine how much rangeland has been broken in an arid country, mainly due to the skyrocketing price of small grains. If current drought conditions persist, a report detailing recently plowed areas with excessive slopes will be prepared and submitted to the Soil Conservation Service for further action.

--During the latter part of Phase II of the program, when a wider range of data is available within the system, a land suitability study will be undertaken for a large, predominantly urban county.

--During Phase III, formal linkages will be developed between the Land Use and Natural Resource Information System, and the state's Policy Information System. The latter system is composed primarily of social, economic, fiscal, and demographic data. These linkages should greatly enhance the analytical capabilities of both systems.

Other applications which may be worthy of investigation include:

--The Commission of School and Public Lands, responsible for the management of over one million acres of grassland, has expressed interest in rangeland condition evaluations.

--A Planning District Director has suggested using drainage basin data in conjunction with delineations of bare soil areas from early spring imagery to detect soil erosion areas in order to enhance lake preservation efforts.

A generalized summary of projected applications appears in Figure 17.

It is the authors' hope that this effort, and others like it, will lead to an increased recognition of the role of remotely sensed data, as well as other types of quantitative resource information, in federal, state, and local governmental planning and policy formulation. If governmental natural resources planning is to proceed on a firm informational foundation, "planners intuition" must be replaced by more quantitative data sources. The overriding concern of this demonstration project is to make a significant contribution to that end.

ACKNOWLEDGEMENTS

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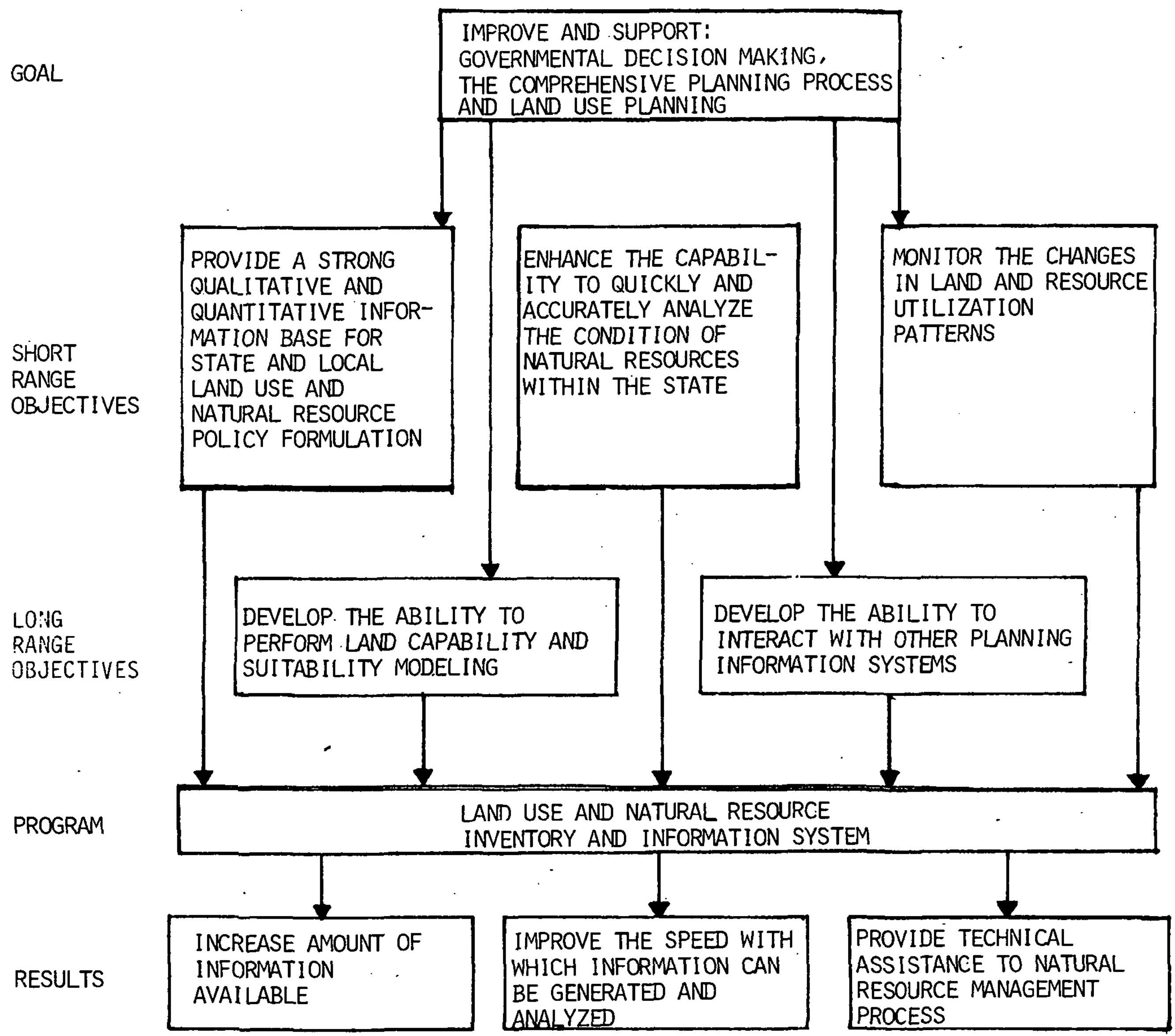

FIGURE 1.-GOAL AND OBJECTIVES OF THE SOUTH DAKOTA LAND USE AND NATURAL RESOURCE INVENTORY AND INFORMATION SYSTEM

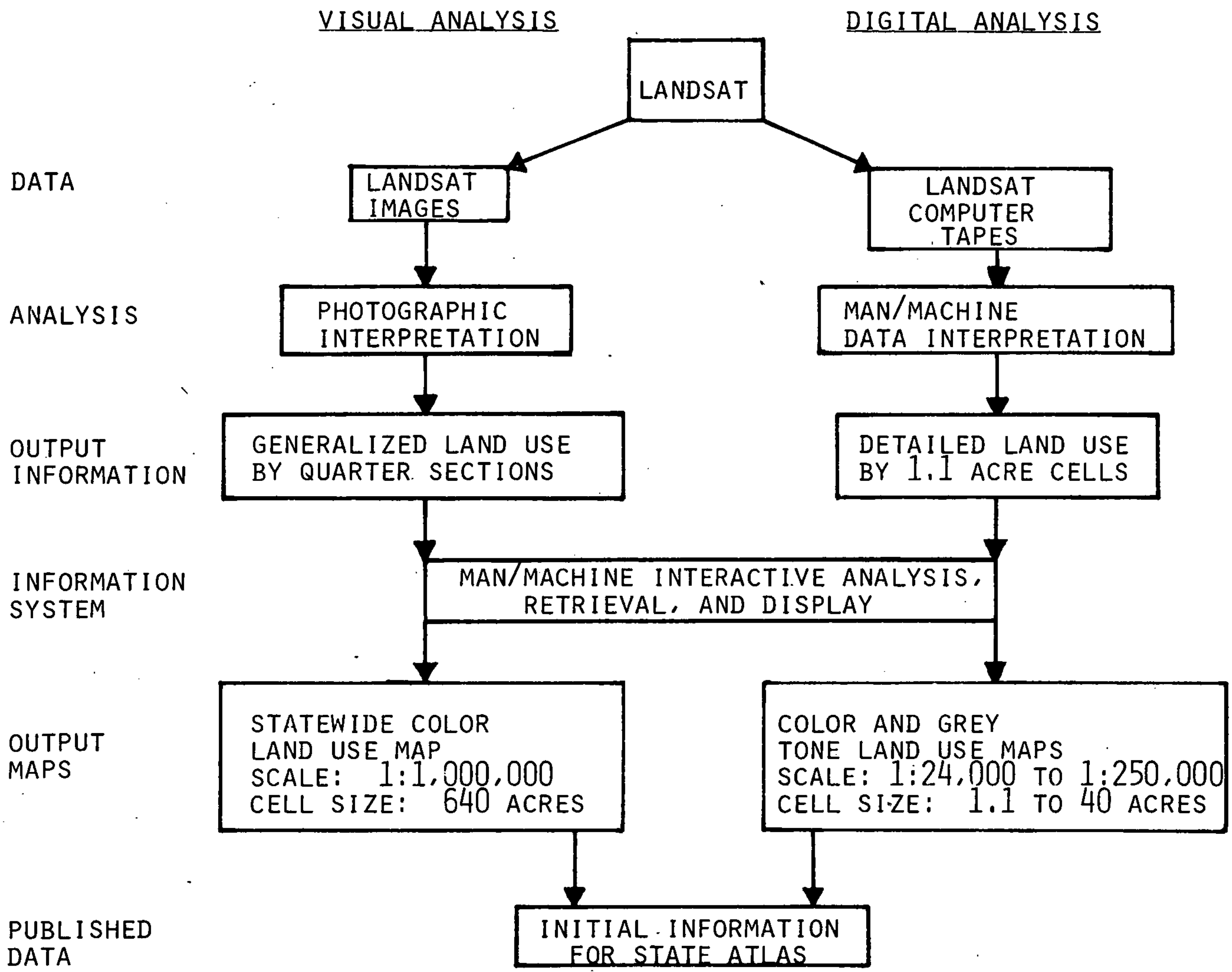

FIGURE 2.-INFORMATION FLOWS: PHASE I (FY 1975)

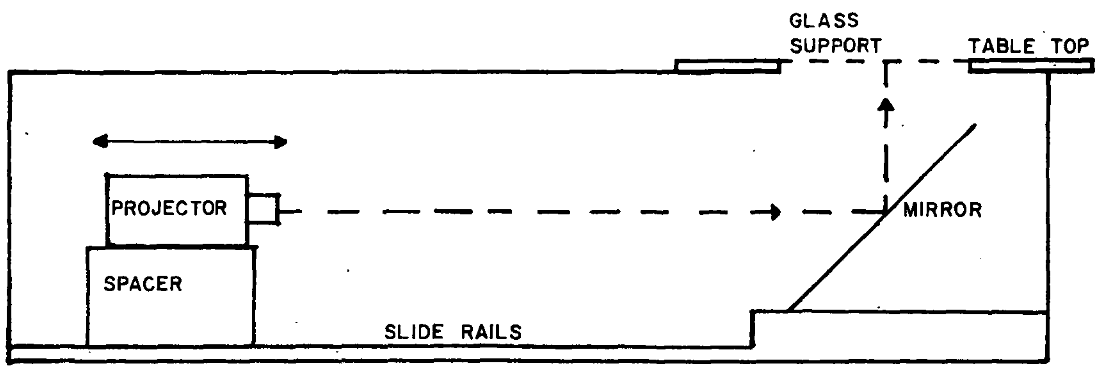

FIGURE 3.-REAR PROJECTION SYSTEM

DATA ACQUISITION

TAPE COPYING AND REFORMATTING

RECTIFICATION
(Elimination of data distortion)

SAMPLE DATA TO DEVELOP CATEGORIES

CATEGORIZE ENTIRE IMAGE, PRINT GREY TONE MAPS AND STATISTICS FOR RELEVANT PORTIONS OF IMAGE

PRODUCTION OF COLOR PLOTS FOR SELECTED AREAS (Township base)

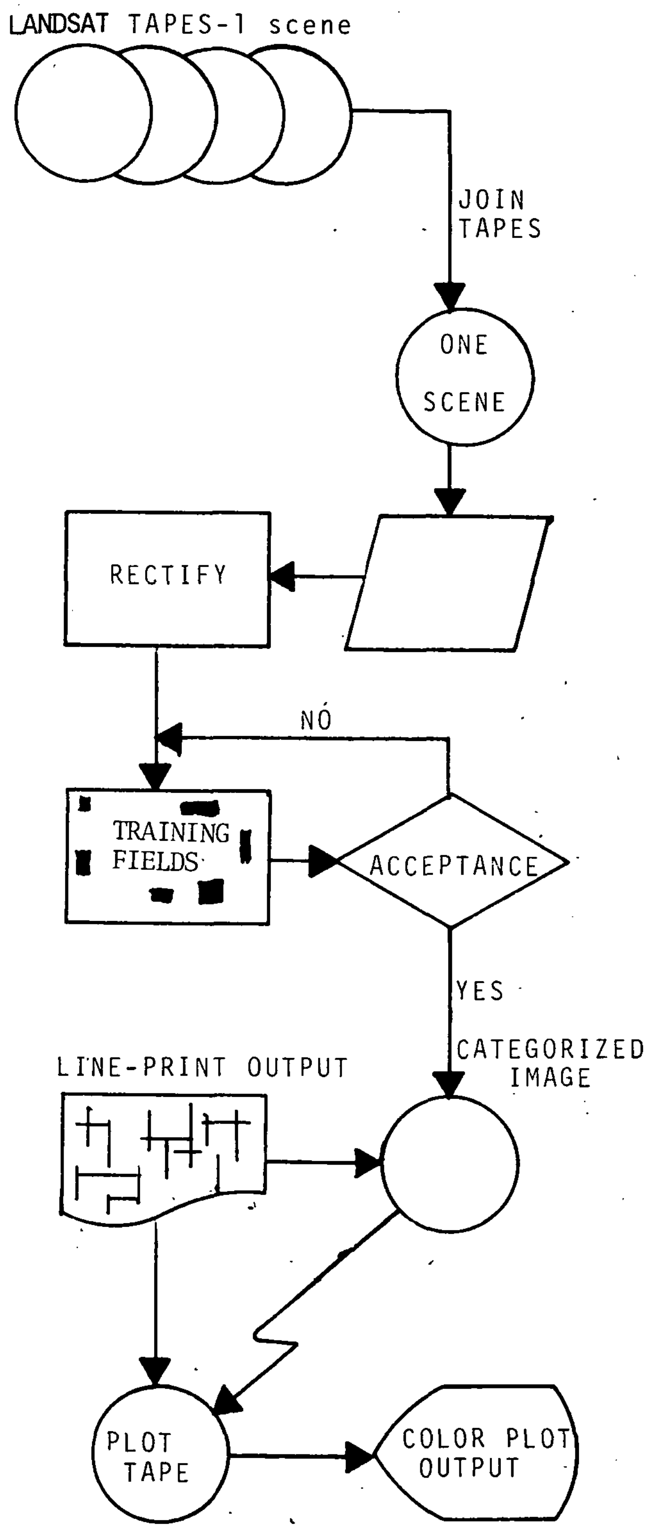

FIGURE 4.-LAND USE INVENTORY ANALYSIS PROCEDURE

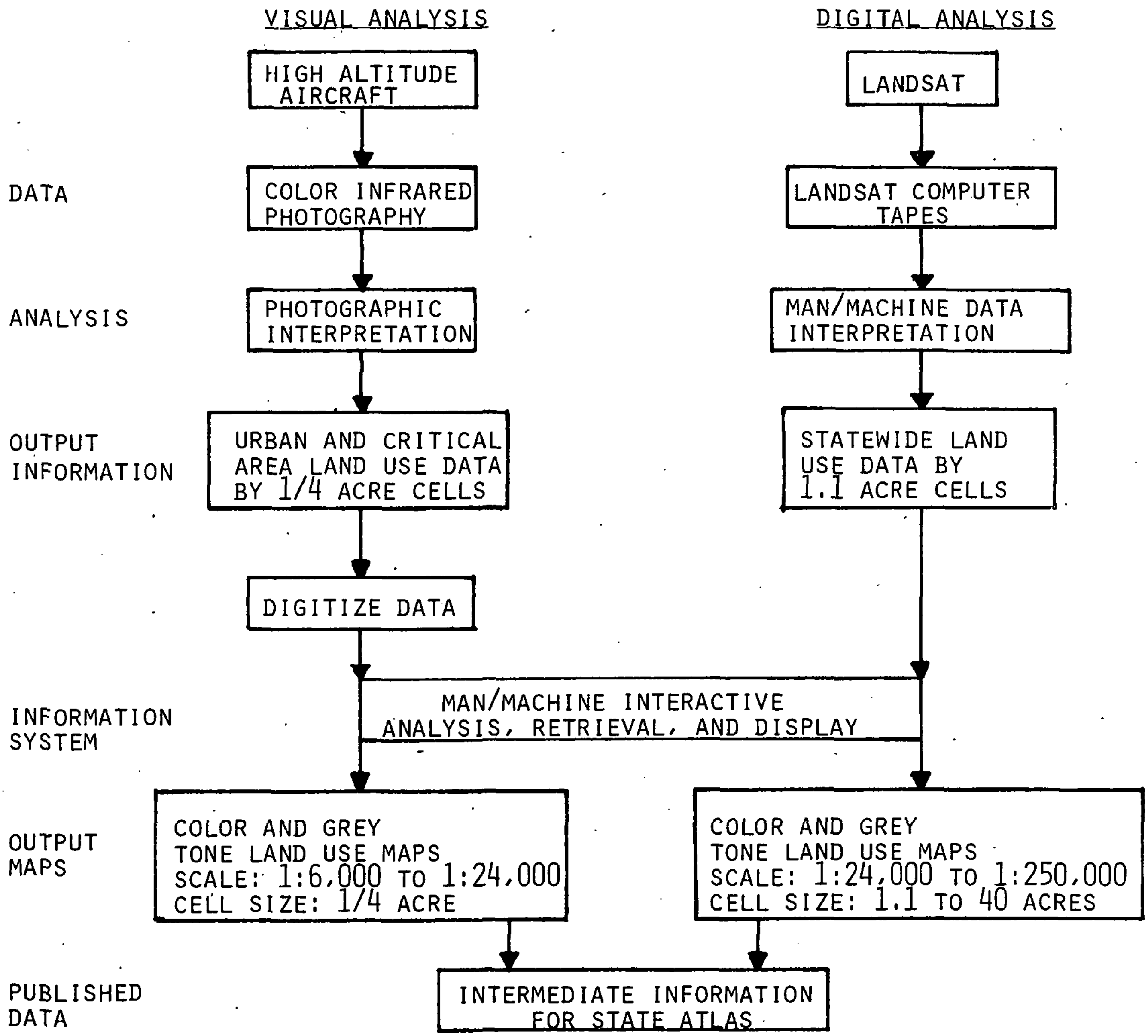

FIGURE 5.-INFORMATION FLOWS: PHASE II (FY 1976)

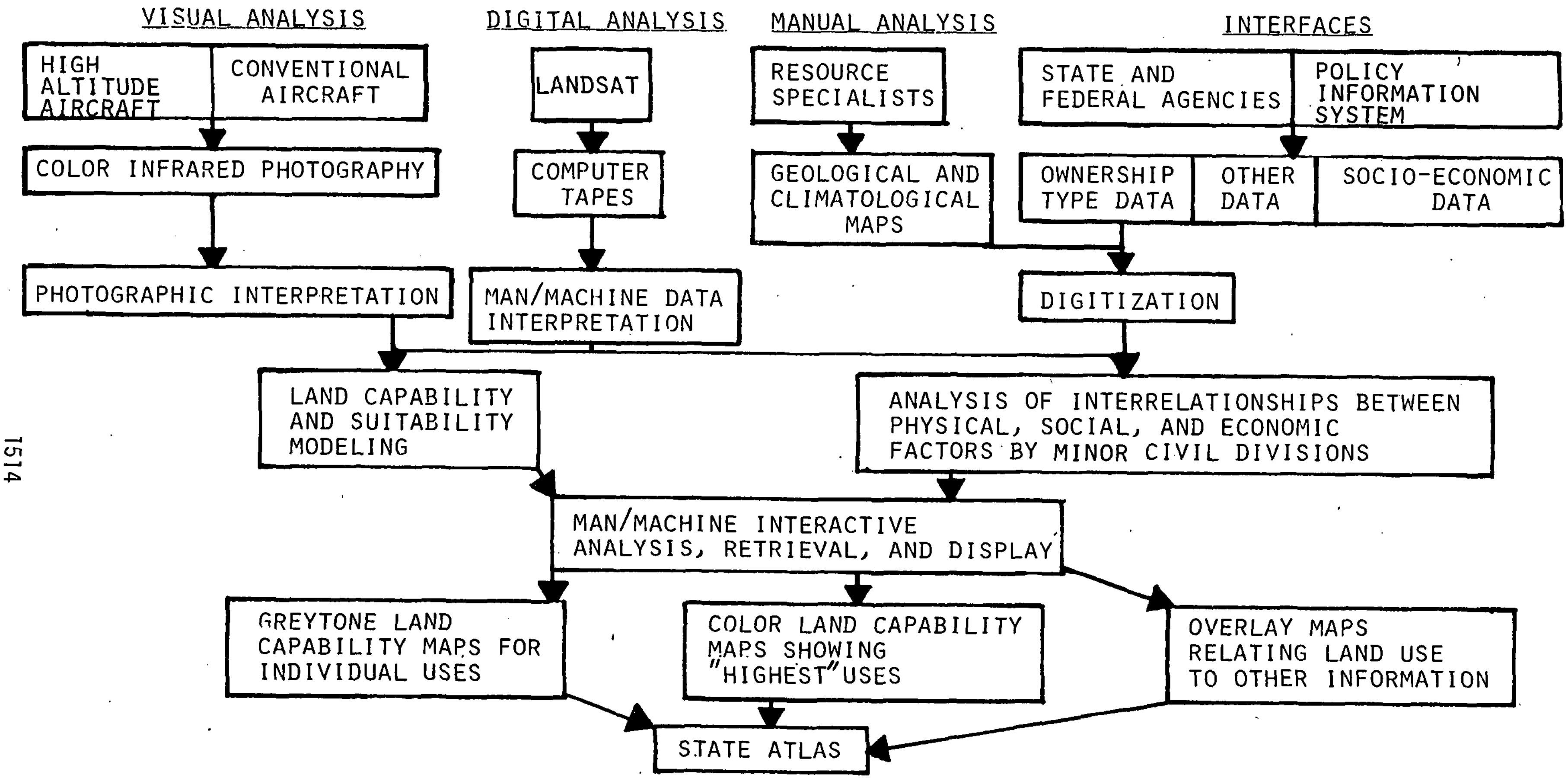

FIGURE 6.-INFORMATION FLOWS: PHASE III (FY 1977)

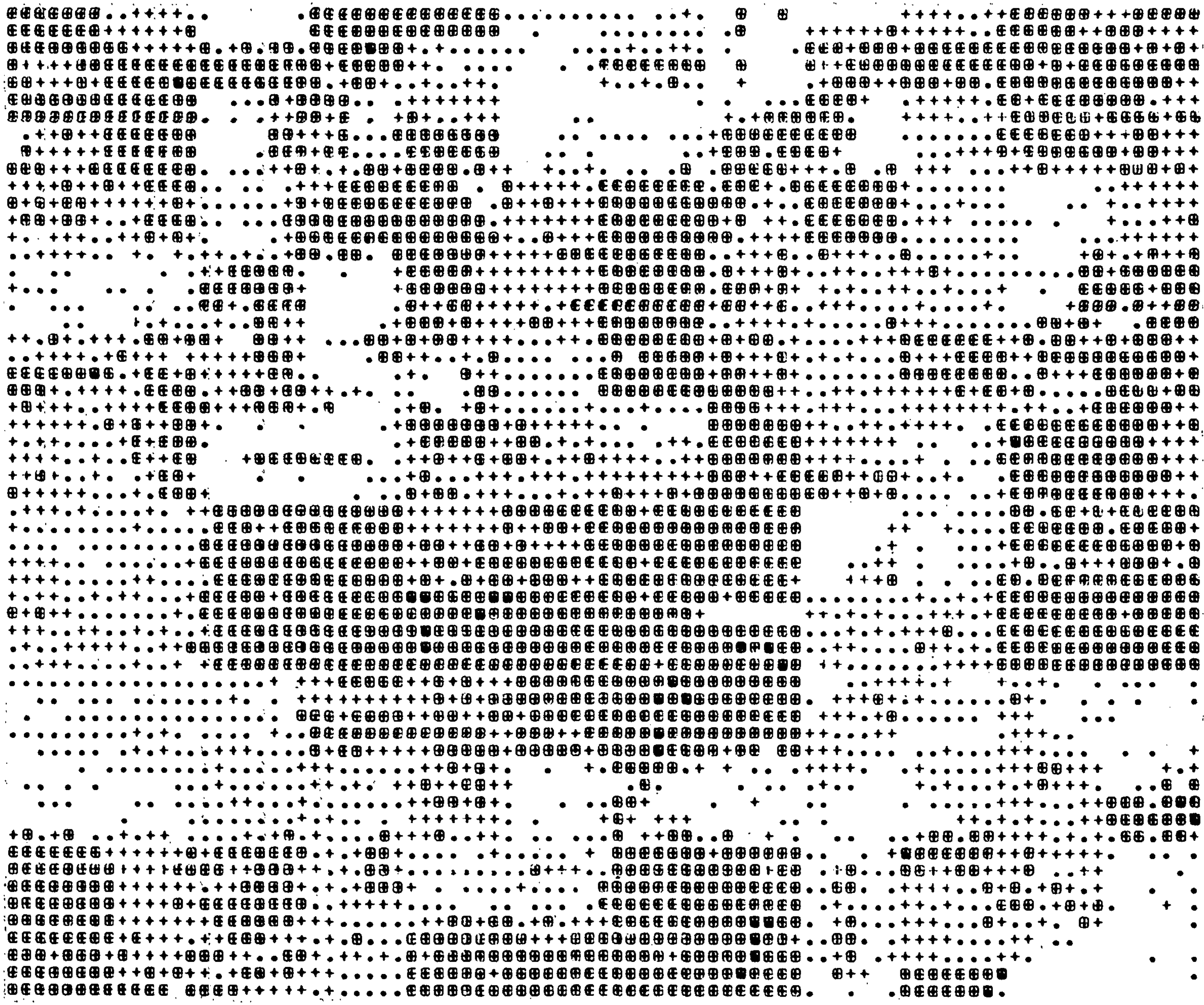

FIGURE 7.-25% SAMPLE GREY TONE LINE PRINTER MAP OF MSS5 FOR COW CREEK TOWNSHIP (ORIGINAL SCALE APPROXIMATELY 1:48,000)

FIGURE 8.-25% SAMPLE GREY TONE LINE PRINTER MAP OF MSS7 FOR COW CREEK TOWNSHIP
(ORIGINAL SCALE APPROXIMATELY 1:48,000)

FIGURE 9.-SINGLE CATEGORY LINE PRINTER MAP OF BARE SOIL FOR COW CREEK TOWNSHIP-4.4 ACRE CELLS
(ORIGINAL SCALE APPROXIMATELY 1:48,000)

CØW CREEK TØWNSHIP
15MAY73 1296-1701400
ALL PIXEL DISPLAY

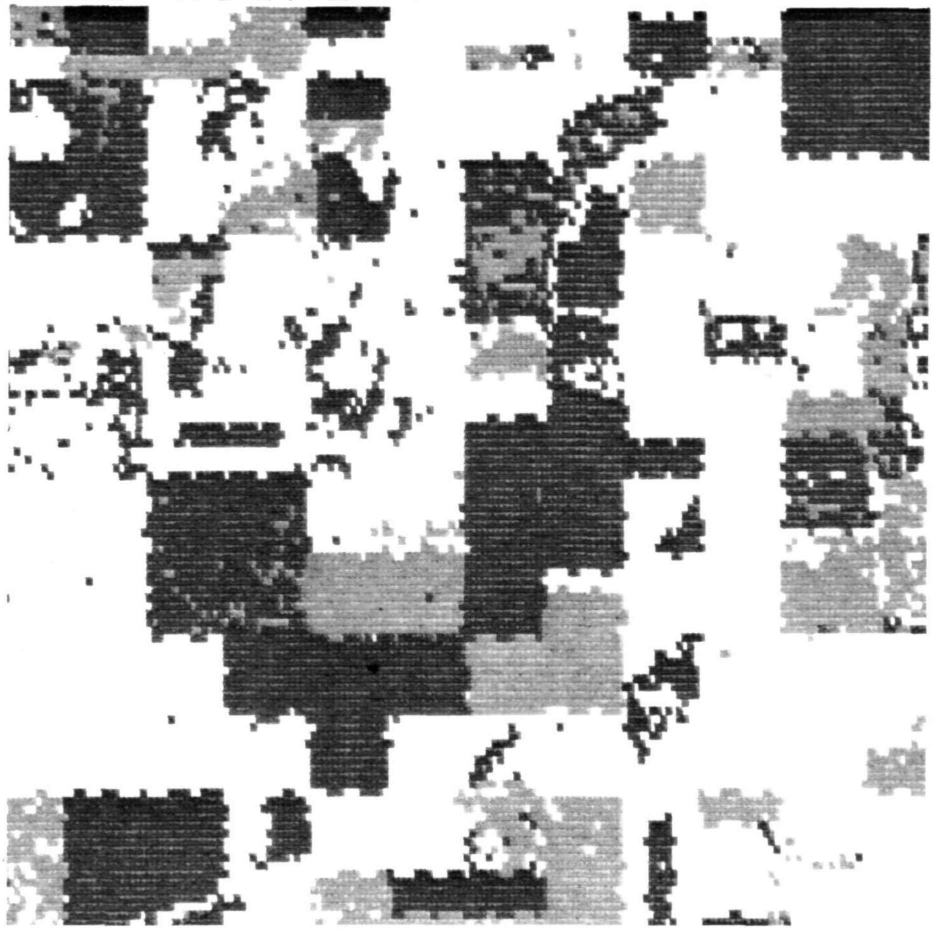

FIGURE 10.- CODED ALL CATEGORY ALL PIXEL LAND USE PLOT FOR COW CREEK TOWNSHIP (ORIGINAL SCALE = 1:62,500)

CATEGØRY	FREQ	PCT
500 WATER	8.	0.04
211 CR BARE SØIL	5643.	28.12
300 RANGELAND	11157.	55.60
213 CR SMALL GRAINS	3260.	16.24

FIGURE 11.- LEGEND FOR COW CREEK TOWNSHIP PLOT

SULLY CØUNTY S.D.

15MAY73 1296-1701400

1C ACRE AGGREGATIØN (3X3 PIXELS)

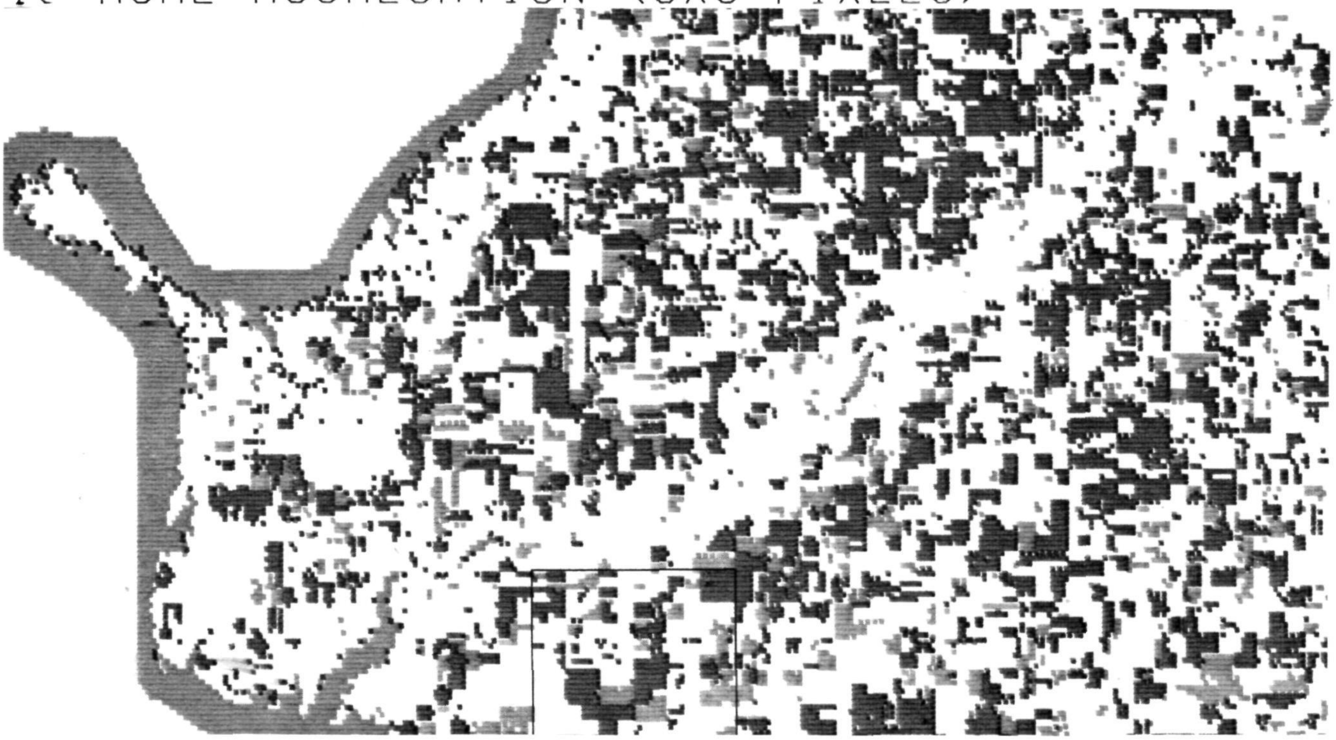

FIGURE 12.- CODED ALL CATEGORY LAND USE PLOT FOR SULLY COUNTY. COW CREEK TOWNSHIP IS OUTLINED. CELL SIXE IS 10 ACRES. (ORIGINAL SCALE = 1:250,000)

CATEGØRY		FREQ	PCT
500	WATER	3531.	6.91
211	CR BARE SØIL	12709.	24.86
300	RANGELAND	30492.	59.64
213	CR SMALL GRAINS	4398.	8.60

FIGURE 13.- LEGEND FOR SULLY COUNTY PLOT

LEVEL I	LEVEL II	LEVEL III
000 Uncategorized		
100 Urban and Built Up		
	110 UB Residential-Old	
	115 UB Residential-New	
	120 UB Commercial	
	130 UB Industrial	
	140 UB Transportation	
	160 UB Mixed	
	170 UB Other	
200 Agriculture		
	210 AG Cropland	
		211 CR Bare Soil
		212 CR Fallow
		213 CR Spring Grains
		214 CR Winter Grains
		215 CR Corn
	240 AG Other	
300 Rangeland		
400 Forest Land		
	410 FL Deciduous	
	420 FL Evergreen	
	430 FL Mixed	
500 Water		
600 Wetland		
	630 WT Riverbottom	
700 Barren Land		

Figure 14.-Land use categories, as adapted from Anderson system[12]

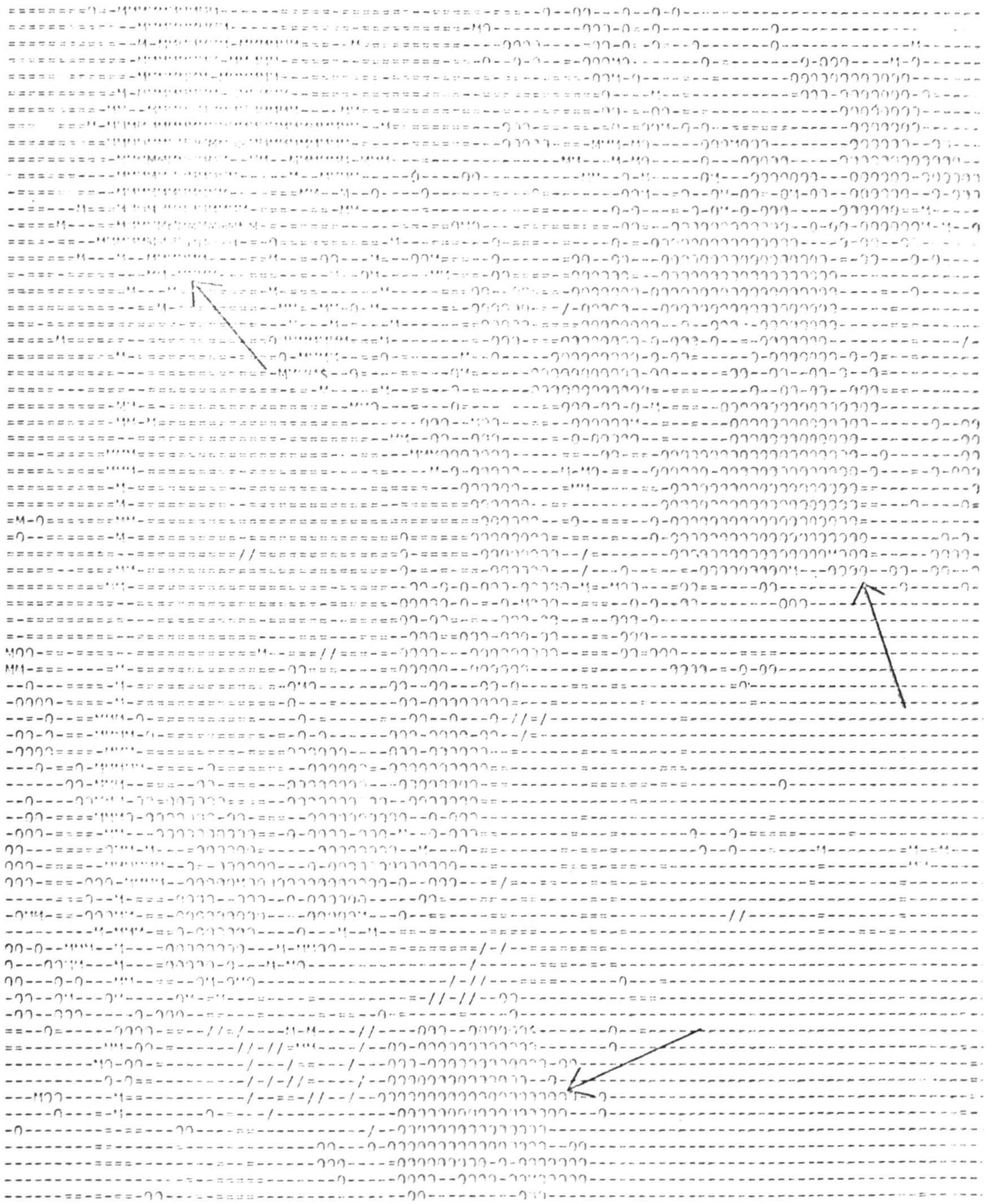

FIGURE 15.-COMPUTER-AIDED CLASSIFICATION OF BITEMPORAL (AUGUST, 1972 AND MAY, 1973) LANDSAT DATA COLLECTED OVER SIOUX FALLS.
SYMBOLS: M-COMMERCIAL/INDUSTRIAL;
O-NEW RESIDENTIAL;
=-OLD RESIDENTIAL;
/-FORESTED;
--AGRICULTURE/GRASSY.
ARROWS INDICATE LOCATION OF FEATURES SHOWN IN FIGURE 16

FIGURE 16.-1971 U.S.G.S. AERIAL PHOTOGRAPH OF A PORTION OF SIOUX FALLS, SOUTH DAKOTA. ARROWS INDICATE LOCATION OF SOME FEATURES SHOWN IN FIGURE 15.

State Policy

- Resource development policy
- Land use policy
- Critical area identification and evaluation
- Natural resource management

Local Planning

- Comprehensive land use and resource planning
- Land use change analysis
- Local technical assistance
- Flood plain delineation
- Land use suitability studies

Environmental Monitoring

- Critical area identification and evaluation
- Water resources planning
- Water quality monitoring
- Wildlife habitat evaluation

Agriculture

- Land capability analysis
- Crop inventories and yield forecasting
- Rangeland condition evaluation
- Pest infestation and crop disease monitoring
- Conservation practice monitoring

Economic Development

- Transportation and Transmission corridor studies
- Land capability and suitability modeling
- State development policy
- Future alternatives projection

Figure 17.-Potential uses of information produced by South Dakota Land Use and Natural Resource Inventory and Information System.