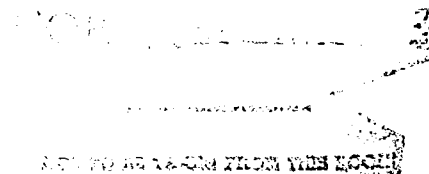


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Prime Agricultural Land Monitoring and Assessment Component
of the California Integrated Remote Sensing System

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Prime Agricultural Land Monitoring and Assessment Component
of the California Integrated Remote Sensing System

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Prepared for
Ames Research Center
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NASA

National Aeronautics and
Space Administration

Ames Research Center
Moffett Field, California 94035

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PRIME AGRICULTURAL LAND MONITORING AND ASSESSMENT COMPONENT OF THE CALIFORNIA INTEGRATED REMOTE SENSING SYSTEM

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Dr. John Estes

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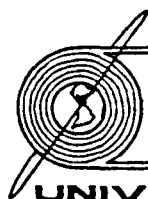
Mr. Tod Streich

**Geography Remote Sensing Unit
University of California, Santa Barbara**

September, 1981

Final Report

A report of research conducted for the
California Integrated Remote Sensing System (CIRSS),
Sponsored by the National Aeronautics and
Space Administration under Grant NAG 2-24



GEOGRAPHY REMOTE SENSING UNIT

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ABSTRACT

Research results are reported for a study investigating the use of digital Landsat techniques for monitoring agricultural land use conversions. Two study areas are investigated: one in Ventura County and the other in Fresno County (California). Ventura test site investigations include the use of three dates of Landsat data to improve classification performance beyond that previously obtained using single date techniques. The 9% improvement is considered highly significant. Also developed and demonstrated using Ventura County data is an automated cluster labeling procedure, considered a useful example of vertical data integration. Fresno County results for a single date Landsat classification paralleled those found in Ventura, demonstrating that the urban/rural fringe zone of most interest is a difficult environment to classify using Landsat data. A general raster-to-vector conversion program has been developed to allow Landsat classification products to be transferred to an operational county-level geographic information system in Fresno. Further work is required on this task to complete all project elements.

INTRODUCTION

California's land produces more food and fiber today than ever before, and as a state California continues to lead the nation in agricultural production. At the same time, additional space is needed for housing, transportation, wildlife and recreation, commercial enterprises, and all of the other activities that make up the fabric of modern American life. These naturally competing demands for land are becoming more and more a matter of public concern in California and other states. Increasingly, individual land use decisions affect the rights of others; many believe that we need to put these decisions in a perspective that will allow responsible consideration of as many legitimate interests as possible.

From an agricultural perspective, the basic demand for food and fiber products appears certain to increase, with factors such as open space and environmental quality tending to amplify, rather than offset, demands on prime land. It is obvious that the demand for retention of production lands is much more complex than a simple extension of the demand for food and fiber products. There is substantial doubt that the tremendous production increases realized in the past quarter-century can be duplicated through

additional intensification of production technology. Biological ceilings, increased energy costs, limited water availability, environmental constraints, and rising input costs in general are among the reasons most often cited. To the extent that increases in supply do not keep up with long-term increases in demand, our dependence on highly productive land will increase.

Many consider the present land market system inadequate for protection and rational utilization of our most productive land resources over the long run. Actions by local, state, and federal agencies may be necessary to assure a balanced approach to allocating land resources among conflicting users. Of concern to this project is that any actions, either governmental or private, should be based upon sound data regarding the true condition and dynamics of our land resources. This consideration leads to a requirement for efficient data collection and analysis capabilities; we believe that this requirement can most effectively be met by merging modern remote sensing and automated geographic information system techniques.

The California Integrated Remote Sensing System (CIRSS) program was initiated to demonstrate the concept of vertical data integration, which implies that data can be transferred between multiple levels

of organizations. The combination of remote sensing, geographic information systems, and vertical integration, in conjunction with better known potentials for horizontal integration (multiple use of data by organizations at a similar level), offers significant new opportunities for coordinated programs involving land resources.

In 1979 researchers of the Geography Remote Sensing Unit, University of California at Santa Barbara, began a project under CIRSS to evaluate the use of digital Landsat analysis techniques for providing land use/land cover data concerning prime agricultural lands. The goals and objectives of the initial investigation were to:

- o Develop the conceptual design of a prime agricultural land component of CIRSS;
- o Explore vertical data integration issues applicable to prime agricultural land management; and,
- o Prepare a small area evaluation of a Landsat monitoring methodology.

To accomplish this the following tasks were undertaken:

- o An extensive literature review of prime agricultural land policy issues, remote sensing land cover classification and change detection techniques, and geographic information system processing was completed;
- o Major organizations concerned with prime agricultural land were identified and communications established;
- o A user information needs survey was conducted to evaluate information needs and the sources and characteristics of existing data sets;
- o Two dates of Landsat imagery (August 1973 and 1976) were geometrically rectified, registered, and classified by land use/land cover classes for a test site in Ventura County;
- o Two existing prime agricultural land maps (one prepared by the Department of Water Resources in conjunction with the Governor's Office of Planning and Research and the other by the Soil Conservation Service) were digitized and processed using a geographic information system to assess the Landsat products;

- o Vertical data integration issues most pertinent to prime agricultural land data were reviewed; and,

- o Recommendations for future work aimed at correcting deficiencies found in the preliminary demonstration were made and incorporated into a proposal for follow-on work.

The results of these tasks were reported in project progress and annual reports. The results of follow-on work are reported herein. Plans and progress of the project have been periodically reported to the CIRSS Task Force for their input and to assist their overall coordination of the CIRSS program. The Task Force is comprised of representatives from federal, state, regional, and local agencies within California, along with individuals from the private sector and the state's educational community.

Subsequent sections of this report provide a general review of research activities conducted from January 1980 through June 1981. Major attention during this period was directed towards the improvement of Landsat classification accuracies and the integration of Landsat products with county-level geographic information systems. Near the end of the project period the project focus

was significantly redirected, at the request of the CIRSS Task Force, towards state-level needs. These needs will receive additional attention during a subsequent project to be conducted in the June through December 1981 timeframe.

Study areas used for this project include a site in Ventura County, which is the same site previously used, and a site in Fresno County (see Figure 1), the nation's leading agricultural county.

Objectives

As part of the CIRSS program, the agricultural lands monitoring and assessment component is oriented towards vertical data integration and land use/land cover monitoring as applicable to prime agricultural land and related agricultural issues.

Specific objectives identified for the 1980/1981 project were:

- o Improvement of agricultural land use/land cover classification accuracies through the use of multirate Landsat data and the incorporation of local detailed land use information;
- o Demonstration of the methodology through incorporation

C.I.R.S.S. PRIME AGRICULTURAL LANDS PROJECT

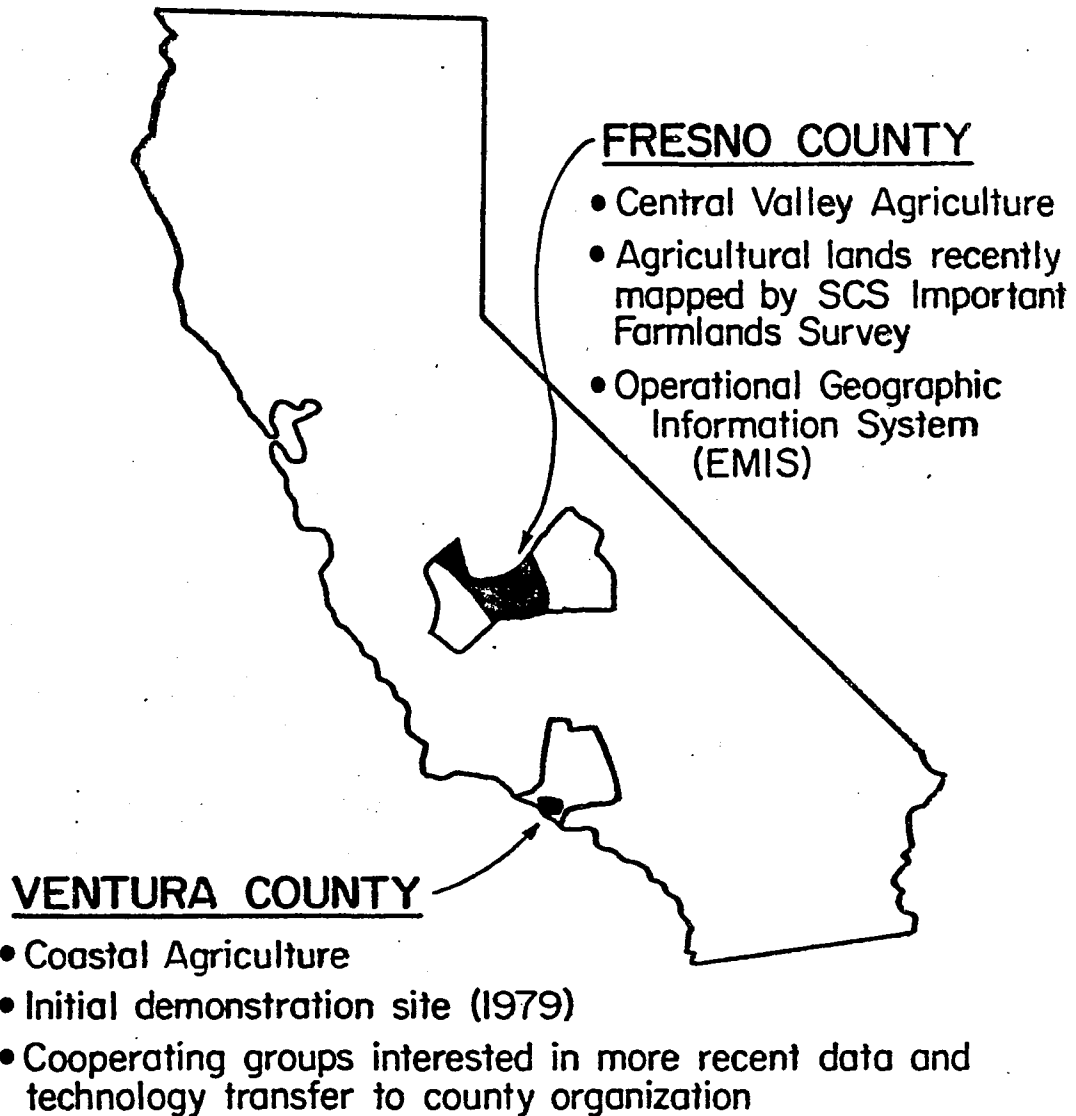


Figure 1. CIRSS Project Test Sites for Prime Agricultural Land Study.

of Landsat products into county-level geographic information systems;

- o To provide a large-scale demonstration of a Landsat technique that incorporates vertical data integration;
- o Application of existing Landsat change detection technology for monitoring changes important to prime agricultural land decision-making.

As noted earlier, the focus of the project was redirected from a county-level emphasis to a state-level emphasis near the end of the project period. The primary goal of this refocusing is to allow an evaluation of the potential of Landsat techniques for use by the California Department of Conservation's new Farmland Mapping and Monitoring program. A follow-on project has been proposed to more fully address operational alternatives for the Department of Conservation. The follow-on project will examine several alternatives not evaluated in the project discussed herein (including manual interpretation techniques and combined use of Landsat and aerial photography imagery).

VENTURA COUNTY STUDY

A study area located in Ventura County was the original test site of our initial investigations and continues to be used to evaluate advanced techniques. First year efforts developed a registered data set comprised of 1973 Landsat imagery (August 23), 1976 Landsat imagery (August 7), and two prime agricultural maps developed by 1) the Department of Water Resources in conjunction with the Governor's Office of Planning and Research and 2) the Soil Conservation Service's Important Farmland Mapping program.

During the project reporting period covered by this report this data set was substantially augmented by the incorporation of two additional dates of 1976 Landsat imagery (June 6 and October 28) and the preparation of 1973 and 1976 digital ground truth maps. The additional dates of 1976 Landsat data have provided an opportunity to test multirate classification techniques as one means to improve classification performance (a major need identified during first year efforts). The digital ground truth data provide for rapid technique evaluations and have allowed us to develop and demonstrate an automated cluster labeling procedure that we believe may have significant potential for

standardizing classification techniques. The methodology makes use of Landsat data and a detailed land use map to update both local and state level data sets, thus clearly demonstrating an applications example of vertical data integration.

Test Site Characteristics

Ventura County encompasses a region of abundant natural vegetation and associated wildlife, well developed agricultural areas, and rapidly expanding urban developments. Ventura's population increased from approximately 200,000 to 430,000 between 1960 and 1975, and most of this increase was accommodated by converting prime agricultural land to non-agricultural uses.

A very large and nearly contiguous block of prime soils exists in coastal Ventura County on the Oxnard Plain and the low terraces north of the Santa Clara River. These lands are among the most valuable in the State, producing strawberries, tomatoes, and orchard crops, as well as an extremely wide variety of vegetables. The Oxnard Plain is particularly valuable in terms of gross yields for certain crops and intensive specialty agriculture exists in most areas that have not been converted to urban uses.

The climate of the region is typically Mediterranean. This climate type occurs only in the midlatitudes, usually along the west coast of continental land masses, most notably in California, Southern Chile, Western Australia, and, of course, the Mediterranean. It is characterized by relatively long dry summers, short wet winters, and relatively little seasonal variation in temperature due to oceanic influences. This uniquely mild climate is largely responsible for the significance of specialty crops in these regions, for several crops are often present that cannot be successfully grown elsewhere.

A test site encompassing two 7 1/2 minute USGS topographic quadrangles (the Oxnard and Camarillo Quads) were selected in 1979 to demonstrate a Landsat methodology for monitoring prime agricultural land. These two quadrangles are adjacent to one another, sharing the same latitudinal coordinates, and include a major portion of the fertile Oxnard Plain. Representative areas of natural vegetation, agriculture, and urban concentrations are present in the test site, providing an excellent opportunity to evaluate Landsat techniques.

Landsat Multidate Classification

An analysis of errors associated with the single date classifications previously undertaken in Ventura County strongly suggested that major problems associated with bare soil conditions in agriculture could be reduced or eliminated through use of multirate imagery. Using the three dates of Landsat imagery prepared for 1976, as discussed earlier, a supervised classification was undertaken using the same training and test sites used in the single date classification. Table 1 presents a comparison of single date versus multiple date classification performances, with overall accuracy being improved from 82% to 91%. This improvement, which requires very accurate registration of the digital imagery, is considered extremely significant and begins to put Landsat classification performance into the realm of a useable product for monitoring agricultural land use change.

Land cover accuracy was determined from a systematic random sampling of "ground truth" data, mapped from high altitude aerial photography with appropriate field verifications. Sampling positions were chosen randomly, but were subjected to spatial stratification criteria in order to insure an adequate spatial distribution. The number of samples to be used (320) was derived from a sampling procedure outlined by Kilpatrick (1978). The sample of 320 points is slated to be adequate to obtain results of

LANDSAT CLASSIFICATION ACCURACY						
LANDSAT CATEGORY	GROUND TRUTH / PHOTO VERIFICATION					
	AGRI CULTURE	URBAN	NATIVE VEG	BARREN	WATER	TOTAL
AGRICULTURE	148	2		1	2	153
URBAN	10	55		7		72
NATIVE	25	4	29			58
BARREN	2	4	1	8		15
- WATER					22	22
TOTAL	185	65	30	16	24	320

correct classification =82%

Table 1. Single Date Landsat Classification for Ventura Test Site.

LANDSAT CLASSIFICATION ACCURACY						
LANDSAT CATEGORY	GROUND TRUTH / PHOTO VERIFICATION					
	AGRI CULTURE	URBAN	NATIVE VEG	BARREN	WATER	TOTAL
AGRICULTURE	176	2				178
URBAN	3	60		5		68
NATIVE VEGETATION	6	1	29			36
BARREN		2	1	11		14
WATER					24	24
TOTAL	185	65	30	16	24	320

correct classification = 91%

Table 2. Multiple Date Landsat Classification for Ventura Test Site.

85 percent accuracy at a 95 percent confidence level.

Positional location and determination of category from "ground truth" map observation is based on a methodology used by Stow (1979). The position of sample points is determined by measuring along the axis of the map projection used in the geometric rectification of the LANDSAT data (Lambert Conformal Polyconic, in our case). Locations of sample points represent the theoretical position of the LANDSAT grid center point that is represented by the sample.

Determination of the "ground truth" land cover category is made when an entire 80 x 80 meter area around the sample point on the map lies entirely within a single category. Samples lying on or sharing two separate categorical polygons are not counted. This may introduce some bias to the analysis, but insures that no interpretative decision between categories is necessary.

Categories were compared at a level of generalization similar to that of the USGS Level I (Anderson, 1976). It was necessary to aggregate several of the LANDSAT derived classification categories to this more general level, in order to be more comparable with the "ground truth" classification.

Automated Cluster Labeling Procedure

As part of this project, both supervised and unsupervised classification methodologies have been investigated for monitoring land use changes. Multidate spectral differencing has been used both as a distinct method of change detection and as a preprocessing step prior to land use classification. This section provides a comparison between a "conventional" unsupervised approach to classification, using analyst assigned labels, and an automated digital approach to cluster labeling, using a detailed land use map and spectral masking techniques. The later approach is fundamentally based upon the integration of remote sensing and geographic information system techniques.

The conventional cluster labeling procedure was accomplished as follows for each date of imagery. First, each set of four MSS bands of LANDSAT data were clustered and the statistical values thus obtained used as a basis for classifying the test site into 100 unlabeled classes (clusters). An interactive video display system was used to display a color infrared rendition (MSS 4, 5, and 7) of the LANDSAT imagery. Upon this background, each cluster was individually displayed using the graphic overlay capability

of the video system: this overlay could be rapidly removed or recalled to assist the analyst in selecting a cluster label. This mode of operation allows both the spectral characteristics of each cluster (as represented by its color) and spatial distribution to be used in assigning labels.

When all clusters had been assigned to one of five classes (urban, native vegetation, agriculture, water, and barren), the raw cluster numbers were converted to form a five class image. Change detection was accomplished by subtracting the 1973 classification from 1976 classification; this allowed both the location and type of change to be shown on a change detection image. The 1976 digital ground truth image allowed classification and change detection performance to be rapidly assessed by simple overlay and cross-tabulation functions available in IBIS.

The automated approach to cluster labeling was accomplished using digital ground truth imagery in a more direct manner. Binary spectral change and stable masks were first created by subtracting 1973 MSS 5 from 1976 MSS 5 and selecting cutoff points that divided the image into about 30% change and 70% stable. Spatial smoothing was applied to the binary mask to remove any isolated pixels due to possible sensor mis-registration and edge effects.

A 3-by-3 moving window was passed over the binary mask and only the changed pixels were checked for replacement. For each neighborhood, if the pixel at the center was labeled as changed and 5 or more neighborhood pixels were labeled as stable, then the center pixel was relabeled as stable. The four MSS bands of 1976 LANDSAT imagery were then clustered and the resulting classification image (100 clusters) was cross-tabulated with the spectrally stable portions of the 1973 digital ground truth image. Using a simple plurality decision rule, cluster labels were assigned based upon the most predominant land use present. At this stage a tabular listing of each cluster number with descriptive information about the total number of pixels, percentage of change pixels, percentage of training pixels, and name of the label allowed the analyst to intervene into the labeling process. A cluster with too few training pixels could then be displayed and manually assigned a label. These labels were then used to classify areas of spectral change. Finally, statistics in the form of truth tables were automatically generated describing the accuracy of the labeling process for stable areas. Figure 2 summarizes the processing flow.

Accuracy assessments of both the manual and automated cluster labeling procedures have proven very similar, with overall classification performance of the automated procedure slightly higher

than that obtained manually (84% versus 80%). Major advantages of the automated procedures include its complete repeatability and statistical basis, whereby confidence statements can be made regarding classification performance.

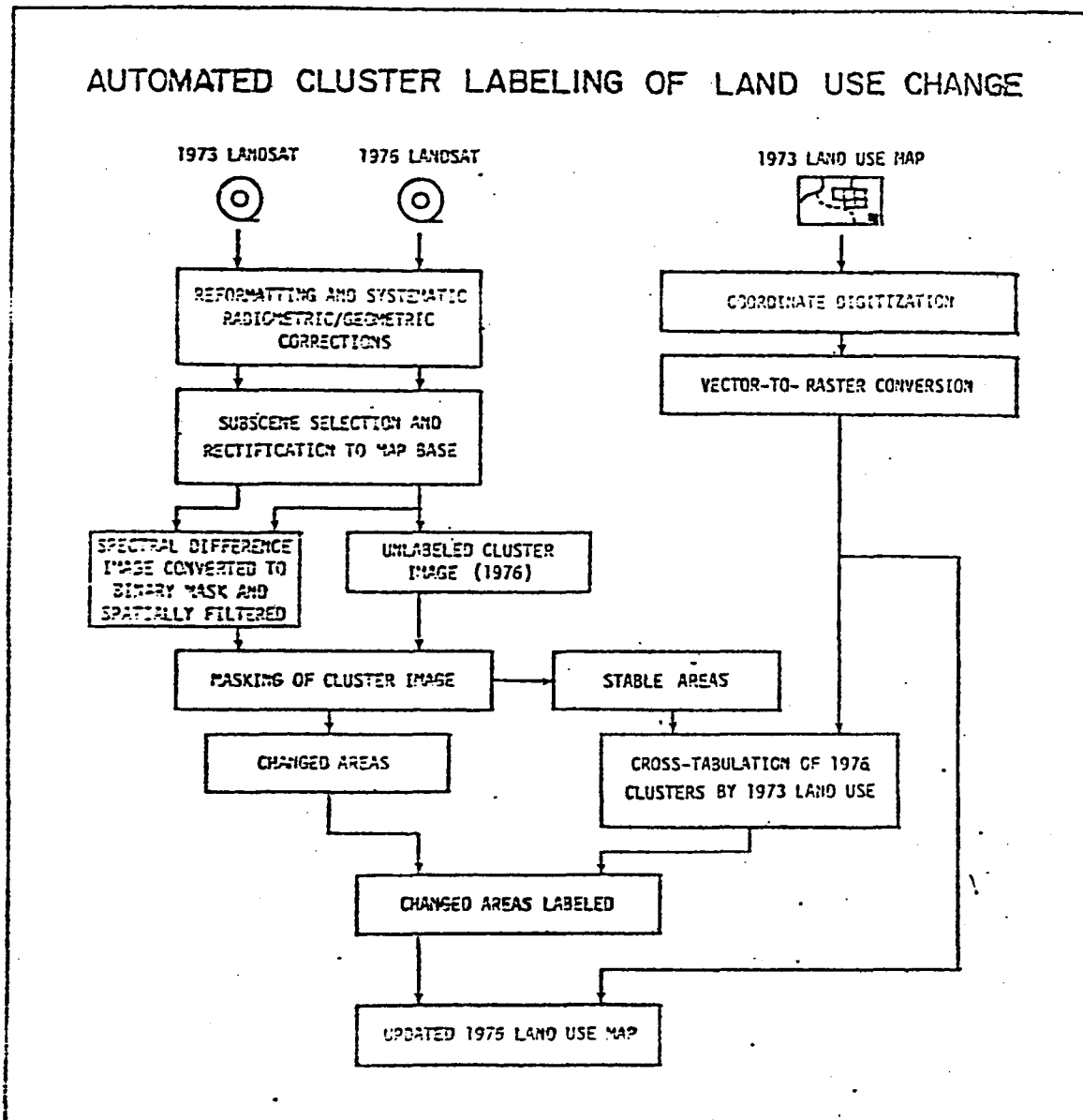


Figure 2. The basic flow of an automated cluster labeling procedure is shown above. The concept of extensive digital ground truth, incorporated here through overlay and cross-tabulation of clusters by stable land use areas, could be extended to a supervised training procedure. Not shown here is the possibility of an iterative reclustering option for those clusters found to be a mixture of informational classes. Generation of a spectral difference image that maximizes the amount of real land use change detected and minimizes the amount of irrelevant spectral change is critical to the updated land use map accuracy. Additional research is underway to optimize the spectral difference procedure.

FRESNO COUNTY STUDY

Fresno County is the nation's leading county in terms of agricultural production. Located in California's Central Valley, the agricultural portion of Fresno County is simultaneously both expanding and being encroached upon, as natural vegetation is converted to agriculture and urban areas expand into surrounding agricultural lands. Primarily due to the existence of an operational geographic information system developed and maintained by the Fresno County Planning and Data Processing Departments, Fresno County was proposed as a study area for a large scale demonstration of techniques developed in Ventura County.

Original project plans called for a large test site on the order of twenty (20) USGS 7 1/2 minute quadrangles, and the use of two years of Landsat data (a single date anniversary data set such as that originally used in Ventura County) to monitor land use changes. In addition, it was proposed to adapt or develop a means to convert Landsat products from their inherent raster or grid format into the vector or polygonal format used by Fresno County in their Environmental Management Information System (EMIS).

As the plans were reviewed and data sets prepared it became necessary to reduce the scope of the project somewhat; instead of a comprehensive large area study, Fresno County personnel recommended a two stage approach involving one intensive test site (one USGS quadrangle) that would evaluate the raster-to-vector conversion task and a larger test site (the originally proposed 20 quadrangle test site) that would be classified but not further processed pending the results of the single quadrangle test.

In addition, the two year approach had to be abandoned due to image quality (cloud cover) and problems associated with the test site falling in the overlap region of four different Landsat frames. A single date data set for 1979 has been prepared and classified. As with the Ventura County study, single date classification performance is considered only marginally adequate; two additional dates of 1979 Landsat data have been acquired in conjunction with another project and it is being proposed that follow-on work consider their incorporation into the analyses to improve classification performance.

Test Site Characteristics

The intensive test site selected for analysis in Fresno County comprises the Sanger USGS 7 1/2 minute quadrangle. Located in the valley floor portion of Fresno County just southeast of Fresno City, the region is composed of intensive agriculture with limited amounts of natural vegetation and expanding urban centers. Cropping patterns include a great deal of vegetable crops and small fields around urban areas; these patterns are very similar to those found in Ventura County in terms of their difficulty to correctly interpret using just one date of Landsat imagery.

Whereas we feel that our Ventura and Fresno County test sites represent two rather difficult sites to monitor (because of the variety of cropping practices) it must be noted that this is typical of those areas of most concern; namely, agricultural regions falling within expanding urban fringes. It was noted earlier in Ventura County that high land rents in these regions led to a large amount of multiple cropping (several crops per season), which leads to the need for multiple dates of Landsat type imagery and/or higher resolution data sets.

Data Set Preparation

It was noted earlier that the test site selected for intensive analysis in Fresno County generally falls in the overlap region of four different Landsat frames. Problems associated with this and cloud cover on 1975 Landsat tapes acquired for the project led to the eventual selection of a single 1979 date of Landsat imagery (August 20) for analyses. In addition to this date, two additional dates of the area are presently available through another project (May 4 and July 6).

Prior to classification the August 1979 data was geometrically rectified using VICAR image processing programs and control points located on both the imagery and the USGS quadrangle map of the area.

A ground truth map of the area was created using NASA high altitude aerial photography and a Department of Water Resources land use survey map. This map was subsequently coordinate digitized and converted into a registered image format using IBIS programs.

Landsat Classification

Classification of the Landsat imagery was accomplished using manual cluster labeling procedures as discussed in the Ventura analysis section. Accuracy assessment was also accomplished in a similar manner, with Table 3 showing the classification performance for a random sample of points. In general, the performance is similar to that found in Ventura County single date classification tests. The nature of these and Ventura County results suggests that multirate imagery and/or manual intervention will be necessary to improve performance to satisfactory levels for operational programs.

Raster-to-Vector Conversion Program

As a major theme of the overall CIRSS program, operational vertical data integration as related to prime agricultural land is receiving special attention in this study. The incorporation of detailed local land use data for the purpose of improving Landsat classification accuracies demonstrates "upward" integration; the distribution of prime agricultural change detection maps in a scale independent machine readable format demonstrates "downward" integration. Two separate approaches were taken in incorporating detailed land use data into the Landsat processing sequence:

LANDSAT CLASSIFICATION ACCURACY						
LANDSAT CATEGORY	GROUND TRUTH / PHOTO VERIFICATION					
	AGRI CULTURE	URBAN	NATIVE VEG	BARREN	WATER	TOTAL
AGRICULTURE	225	2	5			232
URBAN	13	24		5		42
NATIVE VEGETATION	18	2	16			36
BARREN		5		5		10
WATER						
TOTAL	256	33	21	10		320

correct classification = 84%

Table 3. Single Date Landsat Classification for Fresno Test Site.

1. Standard coordinate digitizing of map products and the subsequent use of the IBIS rasterization process were completed for the Ventura test site.

2. A FORTRAN program was developed for converting a plot extract file from the Fresno County EMIS system directly to an IBIS interface file.

The first approach is tedious and time consuming, but has the inherent flexibility that will be required for an operational state-wide monitoring program. The second approach is typically more accurate but can only be used in those jurisdictions that maintain geo-based information systems with up-to-date land use data base components.

Incorporating Landsat derived prime agricultural land change detection maps into the Fresno County EMIS system is a major project objective. A literature search was conducted at the start of the project to determine the state-of-the-art of operational image to vector conversion programs. None of the programs available in the public domain provided adequate processing capabilities. Consequently, a general raster-to-vector process was developed enabling a VICAR image to be converted to an EMIS

input file. The system has been tested on the Ventura data sets with satisfactory results. Subsequently, however, a "bug" has been detected when certain data set characteristics are present. The final delivery of a Landsat based land use/land cover map to Fresno County awaits the correction of this problem, which appears minor.

SUMMARY

Results reported herein demonstrate the need for multitemporal Landsat imagery to achieve classification accuracies in the range considered suitable for monitoring agricultural land use conversion (ie. >90%). This appears largely due to the complexity of agricultural and urban activities in the urban/rural fringe zone of most interest. Alternative methods for improving accuracy include the incorporation of more sophisticated algorithms and techniques considered inappropriate for any presently contemplated, the use of higher resolution imagery (eg. high altitude aerial photography), and combined manual/ digital processing modes.

The development and demonstration of an automated cluster labeling procedure is documented and presents an excellent example of vertical data integration that may allow some standardization of Landsat classification procedures.

A general raster-to-vector conversion program has been developed that significantly increases the flexibility of incorporating Landsat products into operational geographic information systems. A small amount of work remains prior to inclusion of this program

into the VICAR/IBIS processing system; the nature of the program design should also allow its easy transfer to other systems.

Follow-on work has been proposed that will more fully evaluate state level options for an operational farmland mapping and monitoring procedure. The work accomplished to date will provide a substantial basis for such an evaluation, although the scope of operational alternatives will need to be substantially broadened from the purely digital Landsat approaches investigated to date.

APPENDIX I

Publications based exclusively or largely upon the work presented herein include:

"Deriving Land Use/Land Cover Change Statistics from Landsat: A Study of Prime Agricultural Land", in Proceedings of the Fourteenth International Symposium on Remote Sensing of the Environment, May 1980.

"Monitoring Land Use Changes", by J.E. Estes, D.A. Stow, and J.R. Jensen, in Proceedings of Conference on Remote Sensing for Resource Management, Kansas City, Missouri, October 1980.

"Flexible Processing of Remote Sensing Data Through Integration of Image Processing and Geobased Information Systems", by W. H. Hallada, F.C. Mertz, L.R. Tinney, M.J. Cosentino, and J.E. Estes, in Proceedings of the Fifteenth International Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, May 1981.

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16. Abstract Research results are reported for a study investigating the use of digital Landsat techniques for monitoring agricultural land use conversions. Two study areas are investigated: one in Ventura County and the other in Fresno County (California). Ventura test site investigations include the use of three dates of Landsat data to improve classification performance beyond that previously obtained using single date techniques. The 9% improvement is considered highly significant. Also developed and demonstrated using Ventura County data is an automated cluster labeling procedure, considered a useful example of vertical data integration. Fresno County results for a single date Landsat classification paralleled those found in Ventura, demonstrating that the urban/rural fringe zone of most interest is a difficult environment to classify using Landsat data. A general raster-to-vector conversion program has been developed to allow Landsat classification products to be transferred to an operational county-level geographic information system in Fresno. Further work is required on this task to complete all project elements.					
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