Paper A 4

THE UTILITY OF ERTS-1 DATA FOR APPLICATIONS IN AGRICULTURE AND FORESTRY

R. Bryan Erb, *NASA, Johnson Space Center, Houston, Texas*

ABSTRACT

A comprehensive study has been undertaken at the NASA Johnson Space Center to determine the extent to which ERTS-1 data could be used to detect, identify (classify), locate and measure features of applications interest in the disciplines of Agriculture and Forestry. The study areas included: six counties in five states in which were located examples of the most important crops and practices of American agriculture; and a portion of the Sam Houston National Forest, a typical Gulf coastal plain pine forest.

The investigation utilized conventional image interpretation and computer-aided (spectral pattern recognition) analysis using both image products and computer compatible tapes. The emphasis was generally upon the computer-aided techniques.

It was concluded that ERTS-1 data can be used to detect, identify, locate and measure a wide array of features of interest in agriculture and forestry.

INTRODUCTION

This study was part of a comprehensive investigation carried out at the Johnson Space Center (JSC) to support the goals of the Center in exploring applications of space remote sensing. In general, this effort attempted to determine the role of ERTS, aircraft and ground data in the definition and development of the technology for an Earth Resources Survey program.

More specifically, the objectives of the portion of the investigation reported in this paper were:

(1) To assess the utility of ERTS data to detect, identify, locate and measure features of applications interest in agricultural and forest areas.

(2) To conduct a cooperative program with the U.S. Department of Agriculture (USDA) - Agricultural Stabilization and Conservation Service (ASCS) to evaluate the utility of ERTS-1 data for their crop inventory needs.

This investigation was supported by both NASA and the USDA. The involvement of ASCS field personnel was essential to obtaining ground truth and ASCS also supported the analyses with staff located at Houston. The U.S. Forest Service (USFS) also has staff members located at Houston, and they supported the investigation in both analysis and field work.

TEST SITES

The agricultural test sites, one each in Montana, Nebraska, Iowa and Georgia and two in California, were chosen by ASCS to cover examples of the most important crops and practices in American agriculture. The six sites chosen comprise a subset of 18 sites in which ASCS is conducting, at the county level, an image interpretation investigation of ERTS data. The ASCS County executive personnel acquired complete descriptions of all crops in a 3 by 10 km (2 x 6 miles) test area once each year and then provided updates of the descriptions for 50 fields in each area synchonous with each ERTS pass. No aircraft flights were made over these test sites, however, ASCS photography was available.

The forest test area was the Raven District of the Sam Houston National Forest (SHNF). This is a typical pine forest of the Gulf coastal plain, located about 90 miles north of the city of Houston. The USFS Team at JSC has been carrying out remote sensing investigations in the SHNF for over two years and had acquired detailed ground data and several aircraft flights which were utilized by the ERTS investigation team.

APPROACH

The investigation utilized a number of analytical techniques and made some attempt at comparisons among them in terms of the ability to extract information from the ERTS data. The investigation teams were organized to include specialists in the appropriate scientific disciplines, persons skilled in image interpretation and others skilled in digital techniques. This mix of skills worked well and provided excellent cross-training of all personnel.

Image interpretation was carried out on several types of materials as follows:

a. GSFC Material: Enlarged 70 mm B&W
9 1/2 inch B&W
Color Composites

b. JSC first generation images created from digital tapes.

Some efforts were expended on image enhancement and additive color projection techniques. Equipment used included:

a. I^2S Model 2000 multichannel film viewer

b. I^2S Mini Addcol

c. Itek Additive Color Viewer/Printer

The main thrust of the investigation was focused on computer-aided processing of the digital data by spectral pattern recognition techniques. Both nonsupervised and supervised techniques were employed.

For each area of investigation an attempt was made to quantify how well applications features could be:

a. detected - i.e., established that something unique was there

b. identified - i.e., assigned to some classification

c. located - i.e., position established with respect to a geographic grid or readily identified control points

d. measured - i.e., the areal extent determined.

The term "applications features" means regions on the ground which can be precisely located and described and which are directly related to some resource which is manageable and to which remote sensing could be applied. For example, a stand of pine timber or a field of corn would be an applications feature.

It was found that a classification hierarchy was almost indispensible in conducting an investigation such as this. The classification scheme served as a guide to increasingly refined discriminations and as a meterstick against which to compare performance of various information extraction techniques. The classification hierarchy used for the most general descriptions is close to that given in USDI Circular 671, but modified at the Level II to accommodate computer-aided spectral analysis rather than human interpretation of the spatial cues contained in the data. The classifications at the more detailed levels were generated by the investigators for the purposes of the present effort and are shown in Figures 1 and 2.

RESULTS

The results reported herein represent only the highlights of the investigation. Much more detailed accounts will be given in documents to be published by JSC.

Detection

Agricultural vs. nonagricultural and cropland vs. noncropland could be distinquished quite well by image interpretation using essentially spatial cues. The same discrimination using nonsupervised computer-aided techniques was only fair. Image interpretation techniques were used to detect individual fields. In areas of strip/fallow farming for green winter wheat, fields aligned north-south could be detected as small as

45-60 meters in width. Fields aligned east-west, however, could not be detected unless 90-135 meters wide. Rectangular fields with good contrast could be detected in parcels down to 4-16 hectares in size. The boundary between fields of like appearance could be detected when the gap was 12 meters and of high contrast to the fields. Pine timber stands could be detected by image interpretation down to plots 4 hectares in size. Water bodies were detectable under the best conditions down to 1 or 2 hectares in size. Rural settlements, being more complex features, could not be detected with confidence unless 40 hectares in size. Forest right-of-ways, such as for roads, power or pipelines, could be detected when as narrow as 28 meters.

A test of detectability limits for various image media was carried out on 30 forest features which included: timber stands of 2-75 hectares, right-of-ways and streams 14+M width and lakes of 2 or more hectares in areal extent. Using six different image media various numbers of the features could be detected as follows:

° JSC color composites from CCT	21 of 30 features
° Band 5, 9 1/2" transparency	20
° Band 6	16
° GSFC color composite	15
° Band 7	11
° Band 4	4

Identification

A major portion of the investigation effort was focused on the identification or classification of specific features on the ground. The test areas were classified by the various techniques discussed above and the results were displayed in the form of classification maps. The classifications resulting from image interpretation were depicted by conventional cartographic techniques. The results of image enhancement efforts were recorded photographically. Results of digital classifications were recorded on film using the same tape-to-film screening and recording device (data analysis station) with which first generation color composites were made from ERTS digital data. Typical examples of the classification results from the digital analysis are shown in Figures 3 through 5 for Hill County, Montana, Holt County, Nebraska and the SHNF in Texas.

The details of the classification performance for these and other sites is given in Figures 6 and 7 for agriculture and forest features respectively.

The results shown in Figure 6 pertain to data acquired during the 1972 growing season. In the case of Hill County, Montana, data was obtained late in the year (August) and much of the wheat had been harvested. Recent work for a series of three data sets spanning the 1973 growing season shows improved performance in classification of wheat if registered data sets from two or three ERTS passes are used. Wheat classification accuracies in the range of 90-95% were obtained with 5-10% of the confusion crops (barley) identified as wheat when such temporal data sets were analyzed.

Location

Some effort was devoted to assessing the accuracy with which specific features could be located on the earth's surface. One technique used involved the construction of a custom Universal Transverse Mercator (UTM) grid from control points taken off 1:24,000 topographic maps. Distinct features in the ERTS data such as field corners in Hill County, Montana, could then be located to an accuracy of approximately 200 meters. A similar approach was used to superimpose a UTM grid on a portion of an ERTS scene by correcting the location of each pixel digitally again using control from maps. An example of this is described in a companion paper.* It should be noted that the 200 meter figure is considered to hold only close to the region for which control was established.

Measurement

The areal extent of the various features was determined by several techniques both manual and semi-automatic. The results of typical determinations are given in Figure 8.

SCIENTIFIC AND TECHNICAL FINDINGS

The main scientific and technical findings were:

- Agricultural and cropland can be separated from other classes of land use and this is best done by conventional image interpretation using spatial cues.

- Crop types can be classified best by spectral pattern recognition techniques. Accuracies in the range of 70-90% can be achieved with single data sets. It should be noted that this is as good performance as has been historically achieved with aircraft data.

- Use of a registered data set (two or more passes) can improve classification performance to the 95% range.

- A phenomena of the MSS data known as blooming is apparent at boundaries of fields of high contrast, thus obscuring the true boundary and making accurate area measurement difficult.

- Surface features can be located to within about 200 meters of their true position on the earth (over small geographic areas).

---

* "The Utility of ERTS-1 Data for Applications in Land Use Classification," J. E. Dornbach and G. E. McKain, Third ERTS Symposium, Washington, D.C., December 10-12, 1973.

° Area measurements of selected fields can be made from ERTS data to accuracies on the order of 90%.

° Classification hierarchy is useful for focusing an investigation and ERTS data can be used to discriminate between some classes to Level IV, (e.g., alfalfa vs. cotton) and in one case to a Level V (corn vs. popcorn).

° Training field data derived in Imperial County was used to classify in Butte County (700 Km distance) with some success. For some features no recognition was obtained but for alfalfa and bare soil test field results were 70 and 80% respectively.

° ERTS data can be used to detect, classify and measure some Level III and IV features typical of Texas forests.

° Accuracy of classification is in the range of 75 to 90%.

° Classification accuracy at Levels III and IV is better by ADP techniques than by image interpretation.

° Area measurement of large timber stands from ERTS data agrees with data from aircraft imagery to a typical accuracy of 89%.

° Effects of a light ground fire (set to clear brush) over a 40 hectare stand were clearly visible on ERTS data.

° A two hectare portion of a pine stand which was infested by pine-bark beetle was detected indirectly in exploring the cause for misclassification in a supervised ADP analysis.

APPLICATIONS

Two applications activities with user agencies are underway utilizing in part the understanding and techniques derived in this investigation.

One application is a crop acreage inventory activity with the USDA. A plan is currently being developed for a large area survey of wheat.

The other is a project with the Southern and Pacific Northwest Regions of the U.S. Forest Service. This activity is a continuation of a project to explore the application of aircraft data which started in 1971 with the SHNF test site. Two Forest Service employees resident at JSC are undertaking analysis of ERTS data over the Sabine National Forest to compare ERTS results with those derived from aircraft and from the Skylab Earth Resources Experiment Package (EREP).

CONCLUSIONS

The general conclusions which can be stated at this time are the following:

° ERTS-1 data can be used to detect, identify, locate and measure a wide array of features of interest in agriculture and forestry.

° The utility of the information extracted from ERTS-1 data is likely to be greatest for large area applications.

° The computer-aided analysis techniques perform as well or better than conventional image interpretation, especially for the more detailed classifications, but both techniques will be useful for most Earth Resource Surveys.

° Classification performance with ERTS data is as good as has been historically achieved with aircraft data.

° The feasibility of large area crop and forest resource classification has been demonstrated and elements of appropriate agencies are working with NASA to pursue specific applications.

NASA-S-73-1521

AGRICULTURE CLASSIFICATION HIERARCHY

LEVEL I / LEVEL II / LEVEL III / LEVEL IV

- AGRICULTURE
  - CROPLAND
    - BROADLEAFED CROPS
      - PEAS, TOBACCO, COTTON, PEANUTS, ALFALFA, SOYBEANS, SUGAR BEETS
    - COARSE GRAINS
      - CORN
      - SORGHUM
    - SMALL GRAINS
      - RYE, OATS, RICE, WHEAT, BARLEY
    - FALLOW
      - WET BARE SOIL
      - DRY BARE SOIL
  - NONCROPLAND (SOD, PASTURE, ORCHARDS, VINEYARDS, FEEDING OPERATIONS)
- NONAGRICULTURE

Figure 1

NASA-S-73-1516

FOREST CLASSIFICATION HIERARCHY

LEVEL I / LEVEL II / LEVEL III / LEVEL IV

- FOREST
  - STANDING TIMBER
    - PINE, ESTABLISHED
    - HARDWOOD, ESTABLISHED
  - CUTOVER TIMBER
    - PINE, CUTOVER
    - PINE, SITE PREPARED
      - PINE, SITE PREPARED
      - PINE, SITE PREPARED/ VEGETATION
    - PINE, REGENERATED
    - HARDWOOD, CUTOVER
- WATER
  - STREAMS AND LAKES
  - IMPOUNDMENTS
- OTHER
  - BRUSH
    - WEEDS
    - BRUSH
  - CULTIVATED
  - GRASS
  - RIGHTS-OF-WAY
    - RIGHTS-OF-WAY, DIRT ROADS AND UTILITY LINES
    - RIGHTS-OF-WAY, PAVED ROADS
    - CUT AND BULLDOZED
    - BARE SOIL
  - RURAL SETTLEMENT

Figure 2

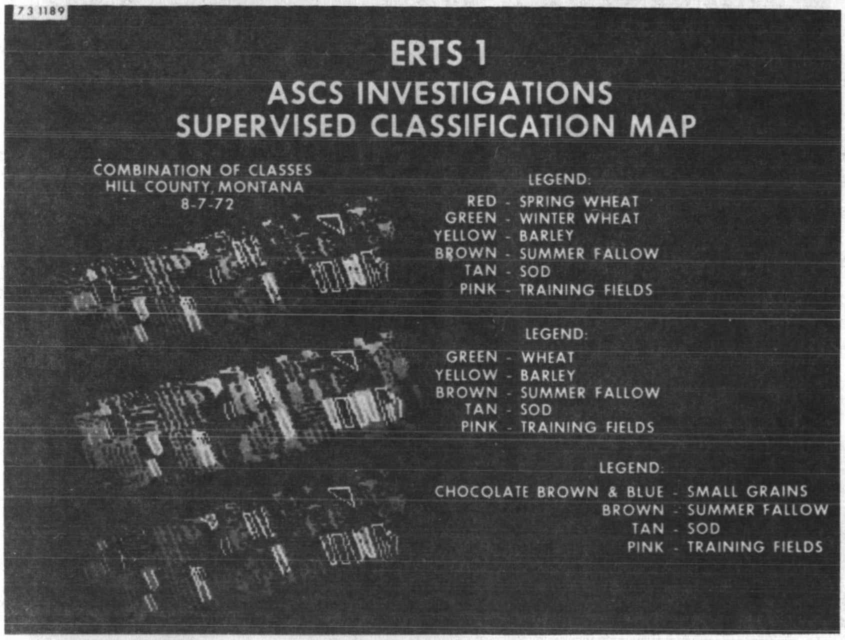

Figure 3

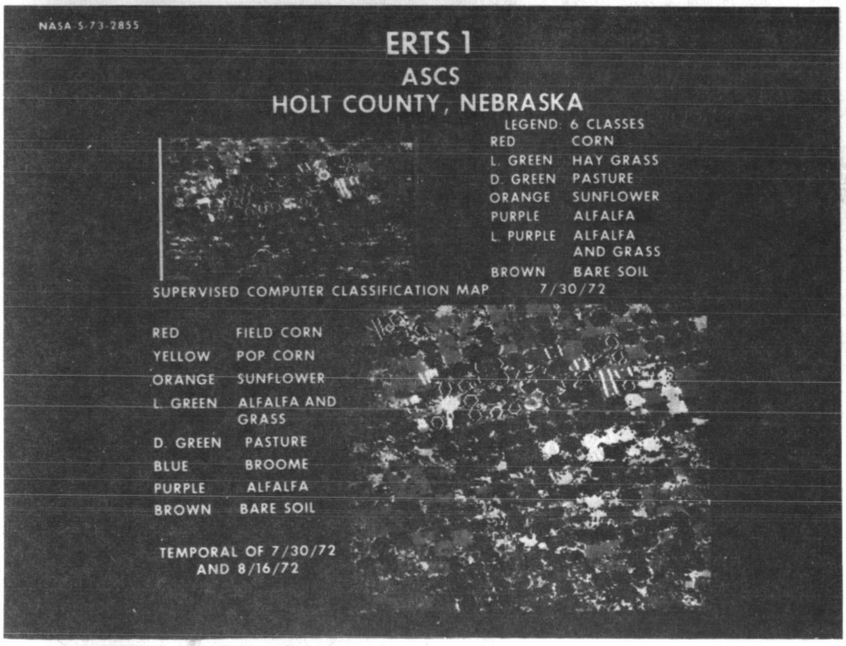

Figure 4

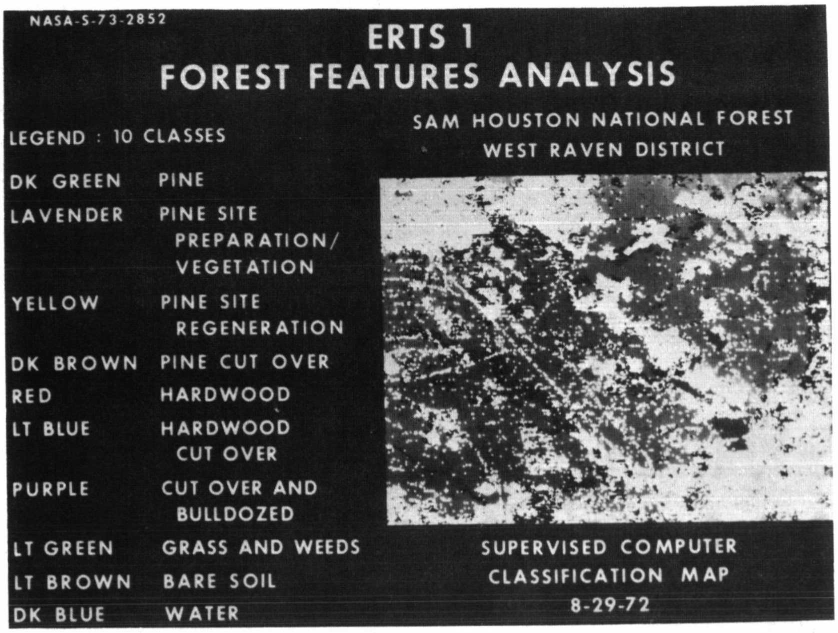

Figure 5

NASA-S-73-3274

AGRICULTURE-RESULTS
IDENTIFICATION (CLASSIFICATION)

FEATURE	METHOD	PERFORMANCE %
● SMALL GRAINS, GRAIN STUBBLE	IMAGE INTERPRETATION (SINGLE DATA SET)	33-59
● SOD		91
● SUMMER FALLOW		88
● SMALL GRAINS	SUPERVISED ADP (SINGLE DATA SET)	96
● SOD		90
● SUMMER FALLOW		87
● WHEAT, BARLEY		65-88
● TRUCK FARMING CROPS		78
● CORN FIELDS	SUPERVISED ADP (SINGLE DATA SET)	73 OF 76 FIELDS
● CORN, POPCORN, SUNFLOWERS	SUPERVISED ADP (REGISTERED SET OF TWO PASSES)	95-99

Figure 6

NASA-S-73-1514

FOREST - RESULTS

IDENTIFICATION (CLASSIFICATION)

FEATURE	METHOD	PERFORMANCE	
• TIMBER CLASSES AT LEVEL III PINE, SITE PREPARED, REGENERATED	SUPERVISED ADP	85 - 100%, TEST BY PIXEL	
• TIMBER CLASSES AT LEVEL IV SITE PREPARED VS SITE PREPARED/VEGETATED		88 - 100%, TEST BY PIXEL	
• 14 FOREST CLASSES ACCURACY OF CLASSIFICATION COMPARED TO GROUND TRUTH MAPS	IMAGE INTERPRETATION		
	SINGLE BAND	7 CLASSES	56%
	MULTIPLE BANDS	10	66
	JSC COMPOSITE	10	69
	I^2S ENHANCEMENT	7	59
	UNSUPERVISED ADP	14	87
	SUPERVISED ADP	12	78

Figure 7

NASA-S-73-1539

AGRICULTURE AND FOREST - RESULTS

MEASUREMENT

FEATURE		METHOD	PERFORMANCE (% ERROR) REFERENCE TO GROUND TRUTH
• ESTABLISHED PINE 3000+ HECTARES		SUPERVISED ADP PLANIMETERING OF RECTIFIED CLASSIFICATION MAP	- 11%
		UNSUPERVISED ADP PIXEL COUNT	± 3 TO 15%
• LONG NARROW FIELDS 12 - 70 HECTARES	HILL CO., MONTANA	PLANIMETERING OF SCALED COLOR ENHANCEMENTS	± 2 - 17%
• SQUARE TO RECTANGULAR FIELDS, 30 OR LARGER HECTARES	IMPERIAL CO., CALIF.		± 1 - 3%
• RICE, 65 HECTARES	SAN JOAQUIN, CALIF.	COUNT OF ADP PIXELS	± 5 - 10%

Figure 8