N 73-28513

Paper L 20

A COMPARISON OF LAND-USE DETERMINATIONS USING DATA FROM ERTS-1 AND HIGH ALTITUDE AIRCRAFT

M. Ann Lundelius,* C. Mark Chesnutwood, Joe G. Garcia and R. Bryan Erb†
Earth Observations Division, NASA Johnson Space Center, Houston, Texas

ABSTRACT

A manual interpretation of ERTS-1 MSS system corrected imagery has been performed on a study area within the Houston Area Test Site to classify land-use using the Level I categories proposed by the Department of the Interior. The two types of imagery used included: (1) black and white transparencies of each band enlarged to a scale of approximately 1:250,000 and (2) color transparencies composited from the computer compatible tapes using the film recorder on a multispectral data analysis station. The results of this interpretation have been compared with the 1970 land-use inventory of HATS which was compiled using color ektachrome imagery from high altitude aircraft (scale 1:120,000). Urban data from the same scene was also analyzed using a computer-aided (clustering) technique. The resulting clusters, representing areas of similar content, were compared with existing land-use patterns in Houston. A technique was developed to correlate the spectral clusters to specific urban features on aircraft imagery by the location of specific, high contrast objects in particular resolution elements. The surface feature composition within each picture element (pixel) could then be determined from the aircraft imagery. It was concluded that ERTS-1 data could be used to develop Level I and many Level II land-use categories for regional inventories and perhaps to some degree on a local level.

1. INTRODUCTION

The purpose of this paper is to report on the ERTS-1 investigation at the Johnson Space Center (JSC) and in particular on the use of ERTS-1 data as a source of information for compiling land-use inventories. The work of the Earth Observations Division Investigation teams and the Land-Use/Urban Analysis team in particular is acknowledged. The objectives of the overall ERTS-1 investigation at NASA/Houston are threefold: (1) To determine the categories of land-use in the Houston Area Test Site (HATS) which can be derived from ERTS-1 data and to map these for a portion of the test site; (2) To assess the utility of ERTS-1 data to detect, identify, delineate and measure features of applications interest in forest, range, coastal, agricultural and urban areas; and (3) To evaluate, with the U.S. Department of Agriculture, the utility of ERTS-1 data to detect and identify specific crop species, determine categories of land use in agricultural areas, locate field boundaries and measure crop and land-use acreages.

The investigation teams are utilizing both conventional and computer-aided interpretation techniques in working with the data. Aircraft imagery is being used as a basis for comparison with ERTS-1 data along with a land-use map of HATS derived from manual interpretation of high altitude aircraft imagery.

2. CLASSIFICATION SCHEME

The classification scheme chosen for this investigation is that described in the U.S. Department of the Interior Geological Survey Circular #671. This scheme has been proposed for possible adoption on a national basis (see Appendix I). A subsidiary objective of the investigation was to see how well this scheme fitted the Houston region and what, if any, modifications might be required to produce a meaningful classification.

*Lockheed Electronics Company, Inc., Houston, Texas.

†S. H. Tunnell, W. P. Bennett, V. L. Cook and D. P. McGuigan of LEC are acknowledged as contributors to this paper.

3. DATA USED

ERTS-1 data from two passes over HATS were utilized for general land-use determinations. These passes, on August 29 and October 4, 1972,[1] occurred in generally clear conditions and the satellite data appears to be excellent. On the August pass, high altitude underflights were flown over a portion of the test site. Both imagery and digital data were acquired from the NASA Data Processing Facility. The imagery was utilized in the form of black and white prints of each band enlarged from the 70 mm positive transparencies to a scale of approximately 1:250,000. The digital data was used in two ways: It was used for computer-aided classification by spectral pattern recognition, and was also used to provide color composites of 2 and 3 bands using the film recorder on a multispectral data analysis station giving essentially a first generation film product at a scale of approximately 1:250,000.

4. MANUAL IMAGE INTERPRETATION

A manual interpretation of enlarged black and white imagery, primarily bands 5 and 7, was carried out and the Level I categories were delineated for approximately one quarter of an ERTS-1 scene. The following categories were detected and identified: urban and built-up, agricultural land, rangeland, forest land, water and non-forested wetland. Of the remaining Level I categories, two do not apply to the Houston region, these being tundra and permanent snow and ice fields. In the particular area studied there was no barren land.

The combined categories of agricultural and rangeland were easily identified, but delineating the boundary between these categories was difficult. Field size and shape considerations were helpful, but the delineation is considered the least reliable of the Level I determinations. Further, the definitions were modified to the extent that pasture was grouped with rangeland. There is also a definitional issue regarding the Level I classification of oil and gas extractive areas. The land surrounding producing wells is normally grazed and thus qualifies as rangeland. However, for this effort it was designated as extractive in the urban and built-up category, holding with the original scheme. In this part of Texas it is difficult to select objectively between the rangeland and non-forested wetland categories.

The results of this classification were compared with a land-use map of HATS previously developed from small scale imagery acquired by high altitude aircraft. This map was derived from a manual interpretation of color ektachrome imagery at a scale of 1:120,000. For this previous study, carried out in 1971, a 20 category classification scheme was used.[2] To make possible a comparison with the Level I ERTS interpretation, this 20 category classification was aggregated to conform to the scheme adopted for the investigation. The agreement is generally good as can be seen by referring to Figures 1 and 2.

To make a quantitative comparison, however, a different technique was adopted. The composite color images produced at JSC from the digital data were used for a manual interpretation striving to extend beyond the Level I in the Urban and Water categories.

The conventional color composites, simulating color infrared photographs by combining bands 4, 5 and 7 were generally best for large cultural features, forest areas and extractive areas such as oil fields, but poor for small urban places and for the agricultural versus range differentiation. Using composites of bands 5, 6 and 7 the agricultural areas were more readily distinguished from rangeland. Small urban places and roads through forests were also more readily delineated on this composite. A composite of bands 5 and 7 was also studied and found most useful for cultural features.

The results of this study of color composited images from the digital data were that several Level II categories could be delineated from the ERTS-1 data. In the urban and built-up classification only three Level II categories or aggregates of categories could be identified: (1) an aggregate of commercial

---

[1]Scene ID 1036-16244 and 1073-16244

[2]Bryan Erb, "Applications Experiments in the Houston Area," Fourth Annual Resources Review, JSC 05937, vol. I (Jan 1971), p. 21-9, fig. 4.

and services, industrial and transportation, communication and utilities; (2) strip and clustered settlements and, (3) extractive areas. By deduction, the balance of the urban classifications are an aggregate of the residential and/or open and other categories. No success was expected or found with the institutional category. Thus four Level II groupings could be delineated within the urban and built-up classification. In comparison, somewhat greater detail can be derived from the high altitude aircraft data. A delineation of open land is readily obtained and the commercial-industrial-transportation grouping can be further broken down but with limited reliability. Again, the institutional category cannot be delineated with confidence.

In the water category all of the Level II categories could be delineated to include water bodies of a few acres in size. This classification compares well with that possible from the high altitude aircraft data. Another part of the investigation (carried out by the Coastal team and reported on separately in this symposium) also addressed the delineation and areal measurement of Level II features, specifically wetlands by computer-aided techniques. Good success in identification was achieved. Areal measurements were made of features a few hundred acres in size and determined accurate on the order of 90 percent based on measurements of rectified photographs from synchronous aircraft underflights.

In parallel with this investigation at JSC, a land-use determination was contracted at the Stephen F. Austin University. This effort used color infrared imagery acquired in April, 1972, by a high altitude aircraft. This determination was used as a basis for a preliminary quantitative comparison with the delineations arrived at by interpretation of the ERTS-1 data. A grid was superimposed on both interpretations and a success count made.

5. COMPUTER – AIDED CLASSIFICATION

Another major portion of this investigation has been the application of computer-aided spectral pattern recognition techniques. Both supervised and unsupervised methods have been used, however, in the land-use work only the latter method has been employed to date. The specific technique used is a clustering of the MSS data in all four channels into groups of resolution elements with like spectral content. It is then necessary, of course, to apply intelligence to the features thus clustered by correlating them to known surface characteristics derived from aircraft data or from surface observations.

ERTS-1 digital data over a portion of the Houston area was processed by the clustering method and there resulted six groups with spectrally similar features. A very preliminary comparison with the 1970 land-use maps indicates that the breakdown approximates very roughly the Level II features in the urban and built-up Level I category. It should be noted that the clusters do not correspond uniformly to actual urban patterns. One reason, of course, is that any resolution element at the ERTS-1 scale may comprise a complex conglomeration of features. It is also apparent in the data from August 29 that atmospheric haze over part of Houston perturbs the clustering results seriously. An effort being pursued as part of this investigation (by the Signature Expansion team and reported on separately in this symposium) is the correction of data for such local atmospheric effects.

The spectral content of the ERTS-1 data appears to be sufficiently high that considerable success can be obtained in computer-aided classifications at Level II. Other efforts which are part of this investigation (being carried on by the Forest team, the Range team and the Agriculture team, and also reported on separately) have shown considerable success in applying these techniques to classifications in their special areas which are at the Level II or more detailed levels.

6. CORRELATION OF ERTS DATA TO URBAN FEATURES

As mentioned in the previous section, a closer look at the results of the unsupervised classification indicated that the clusters do not correspond uniformily to actual urban patterns. Consequently an effort was made to merge this technique with conventional image interpretation to determine why distinctly different urban features were being classified as clusters of similar spectral characteristics.

The inherent spatial and spectral heterogeniety of urban features, made it desirable to examine the actual spectral composition of urban features represented by individual picture elements (pixels) in somewhat more detail than is normally necessary in analyzing homogeneous spectral responses of agricultural and forestry features. One pixel from an urban scene may comprise a very complex conglomeration of features (roofs, pavements, trees, grass, and shadows) each with its own range of spectral reflectivities integrated into an average spectral response. In order to locate and identify a specific pixel and determine its feature composition a simple technique was developed utilizing a computer printout map and aerial photographs of several scales over which transparent grids as a means of identifying points common to both media.

The clustering program was used to produce the printout in which each pixel was identified by a scan line number and an element number. In the clustering program each pixel was classified into categories of similar spectral reflectivities. Small objects of very high reflectivity (white or aluminum roofs) were often classified as individual pixels which could be readily identified on the aerial photographs. By specifically identifying and locating three or more individual pixels which lay on or near two of the printout grid lines, it became possible to construct a corresponding photo grid. A transparent grid was initially constructed to fit a 1/60,000 scale photo in which each grid cell represented 25 pixels. Successful use of this grid encouraged the construction of another transparent grid which could be used on a 1/1980 scale photo enlargement. With this large scale photo and grid it became possible to estimate the percentages of objects with different reflectivities in each pixel which made up the integrated spectral signature for that specific pixel. For the particular urban scene used in this study the clustering program classified each pixel into one of six clusters. The fraction of each pixel with certain levels of brightness found within the pixels in the six clusters are listed in the following table:

BRIGHTNESS COMPOSITION OF PIXELS IN AN URBAN SCENE

(PERCENTAGE OF AREA WITHIN A PIXEL)

PANCHROMATIC BRIGHTNESS	CLUSTER					
	1	2	3	4	5	6
High	80	20	36	4	80	56
Medium	20	80	64	8	4	
Low				88	16	44

Once specific pixels have been located the urban features comprising the pixels which constitute each cluster can be determined. For the test area (downtown Houston) shown in Figure 3, the feature composition is as follows:

Cluster 1 – Large buildings or building complexes with high-reflective roofs
Cluster 2 – Open grass-covered fields with few trees
Cluster 3 – Predominantly grass-covered areas but with a greater proportion of moderately bright objects (pavements, roads)
Cluster 4 – Predominantly tree-covered areas with small areas of roofs and streets intermixed
Cluster 5 – Predominantly paved- and roof-covered areas with many short shadows, but no trees
Cluster 6 – Complex mixture of roofs and trees or pavements and long shadows

Although the descriptions of the six clusters were purposely made quite general in order to relate as closely as possible to typical urban land-use terminology, numerous inconsistencies occurred not only within the study scene but also when these same clusters were examined in other parts of the metropolitan area. This was particularly true in the more highly built-up areas where the intermixture of very bright objects and low brightness objects was a conglomeration of bright roofs and shadows rather than bright roofs and trees as represented by cluster number six.

It is concluded from the sample detailed study of the urban area that our preliminary clustering techniques did not permit a consistent automatic classification of multispectral scanner data into categories according to usual urban land-use terminology. Although the geographical distribution of some of the clusters did coincide very well with some of the known land-use categories there was a sufficient number of classification anomalies to seriously affect the accuracies of delineations to be expected in analyzing an unfamiliar urban area. The capability of determining the spectral composition of individual pixels should be a valuable means of adjusting the clustering program parameters to provide cluster classifications more accurately. This capability should also be useful in selecting training fields for supervised data manipulations in future work.

7. CONCLUSIONS

An investigation in progress at the Johnson Space Center is exploring the utility of ERTS-1 data for land-use inventories in the Houston area. Sufficient work has been done to reach the following tentative conclusions:

(1) All applicable Level I and many Level II land-use categories can be delineated by manual interpretation of ERTS-1 images. Much better results are obtained with composites constructed directly from the digital data than with enlargements of the separate black and white material from the NDPF.

(2) Computer-aided classification can provide good results on many Level II classifications. Level I classifications may be best arrived at by aggregating more detailed determinations.

(3) The results of classifications derived by manual interpretation of ERTS-1 data compare well with those derived from high altitude aircraft data. However, aircraft data permit determination of a few more Level II categories.

(4) The USDI proposed national land-use classification scheme can be generally followed at Level I for the Houston area but a few of the definitions require some modification. Some Level II (urban) categories are difficult to determine even with aircraft data.

(5) A cooperative use of conventional manual and computer-aided techniques can be useful to correlate ERTS-1 data to specific urban features and to establish the feature composition of specific resolution elements.

A conclusion of the total investigation is that ERTS-1 appears capable of providing data with which it is possible to detect, identify, and delineate surface features of applications interest. Furthermore, it appears possible, on the basis of limited tests, to measure the areal extent of such features with good accuracy.

The overall conclusion is that ERTS-1 data can be used to study a significant array of features in several disciplinary areas and thus contribute to land-use inventory work on a regional and to some degree, on a local level.

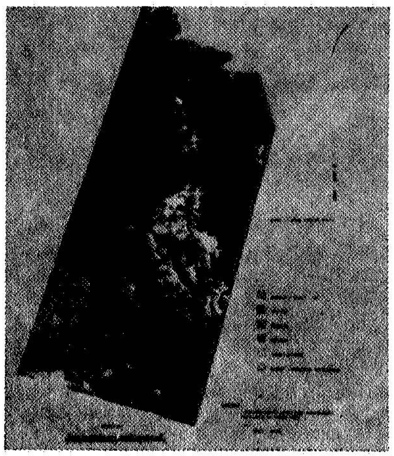

Figure 1 - Level 1 land use in HATS from high altitude aircraft data

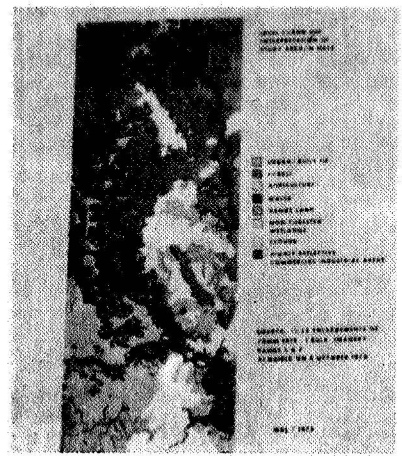

Figure 2 - Level 1 land use in HATS from ERTS-1 data

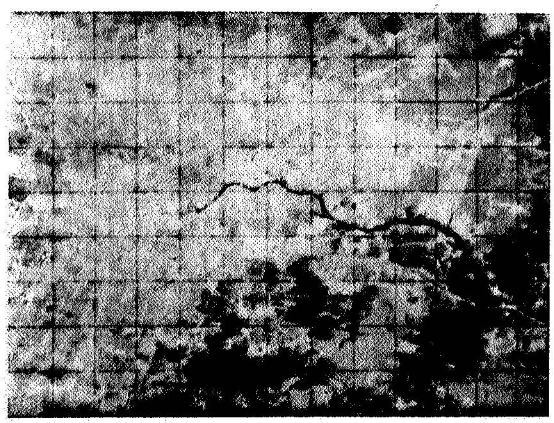

Figure 3 - Photo of downtown Houston with superimposed grid of ERTS resolution elements

APPENDIX I

LAND USE CLASSIFICATION SYSTEM FOR USE WITH REMOTE SENSOR DATA

LEVEL I	LEVEL II
URBAN AND BUILT-UP LAND	RESIDENTIAL COMMERCIAL AND SERVICES INDUSTRIAL EXTRACTIVE TRANSPORTATION, COMMUNICATIONS, AND UTILITIES INSTITUTIONAL STRIP AND CLUSTERED SETTLEMENT MIXED OPEN AND OTHER
AGRICULTURAL LAND	CROPLAND AND PASTURE ORCHARDS, GROVES, BUSH FRUITS, VINEYARDS AND HORTICULTURAL AREA FEEDING OPERATIONS OTHERS
RANGELAND	GRASS SAVANNAS (PALMETTO PRARIES) CHAPARRAL DESERT SHRUB
FOREST LAND	DECIDUOUS EVERGREEN (CONIFEROUS AND OTHER) MIXED
WATER	STREAMS AND WATERWAYS LAKES RESERVOIRS BAYS AND ESTUARIES OTHER
NON-FORESTED WETLAND	VEGETATED BARE
BARREN LAND	SALT FLATS BEACHES LAND OTHER THAN BEACHES BARE EXPOSED ROCK OTHER
TUNDRA	TUNDRA
PERMANENT SNOW AND ICEFIELDS	PERMANENT SNOW AND ICEFIELDS

Appendix 1 - Land use classification scheme