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MACHINE PROCESSING ERTS-1 DATA IN ANALYZING LAND USE CONFLICTS IN THE INDIANAPOLIS METROPOLITAN AREA

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Abstract

This study focused on four areas of critical land use concern in Indianapolis, Indiana. They are land use changes in the environs of a water body, a large regional airport, several new subdivisions and an interstate beltline. Emphasis was placed on using ERTS-1 data to analyze impacts of the developments on the land uses in two study areas of Indianapolis. Both supervised and unsupervised procedures were used to analyze spectral data in the study areas and they were classified into seven land uses. The overall accuracy of the West Lakes study area was highly suitable for general planning and study area however, contained numerous complex associations of urban land uses that required spatial analysis, but the overall accuracy of the land use identification for state-wide planning was very encouraging.

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Introduction

Remote sensing techniques have been used to identify urban land uses and analyze urban land use changes for several decades.[1] The need for urban land use data has proliferated, as has the development of new instruments by which urban areas can be observed. The Earth Resources Technology Satellite (ERTS-1)[2] is one of the many advances in remote sensing technology that shows promise in monitoring and evaluating urban or metropolitan area land use features. The land uses in parts of several metropolitan areas have been analyzed successfully utilizing multispectral data obtained from ERTS-1.[3,4,5] It is evident from these studies that basic land use information can be obtained from satellite imagery and applied to problems currently confronting urban and regional planners. Foremost among these problems is developing procedures through which land use changes in metropolitan areas can be monitored and evaluated in order to facilitate intelligent development of the land in the future.

This study used machine processed ERTS-1 data in two areas of critical land use changes to test their application to state-wide land use mapping and planning programs. Environmentalists, planners, developers, academicians and decision-makers agree that optimum land use is a key physical issue facing the nation today with the myriad of long-term economic and social factors that are exerting increasing pressure on our land.[6] Consequently, most states are beginning to reassert responsibility in land use decisions either by having prepared, or by attempting to prepare, state land use plans.

A national land use policy would encourage state efforts by providing encouragement for state-wide land use plans. In whatever form the National Land Use Policy and Planning Assistance Act (S 268 and H.B. 10294) becomes law, as is nearly certain in 1974, it will strongly influence the applications of ERTS-1 data to state land use planning.[7] This is true of the 25 states that have statewide land use plans, the few states that are beginning to develop programs, and in the remaining states which have not yet acknowledged the need for land use planning.[8]

Predictions are that the President will sign a bill that contains sanctions to be levied against states that fail to qualify for land use planning assistance after three years by withholding transportation and recreation funds in the amounts of seven per cent the first year, 14 per cent the second year, and 21 per cent annually thereafter. On the other hand, the

Federal Land Use bill provides for five annual grants to states that include as much as 90 per cent of the cost of developing a state land use program. After five years a state must implement its land use program in order to receive further grants.

The national land use program includes, but is not limited to: (1) methods to identify and regulate land uses in areas of critical state concern; (2) methods to control land use impact by key facilities; (3) methods to control large-scale developments of more than local significance; and (4) methods to regulate the location of new subdivisions and control the surrounding land use.[9] In these four major areas of state concern, the state could fulfill its responsibilities either by doing its own planning and regulation or by reviewing local plans and controls.

The Study Areas

In an endeavor to test the feasibility of using ERTS-1 data to develop state land use plans, four major areas of state concern were selected for Indianapolis (Marion County), Indiana (Fig. 1) for which the state would be responsible if and when proposed federal legislation is enacted. The data for these analyses were obtained from four bands of spectral data (0.50μ-1.10μ) of the Earth Resources Technology Satellite (ERTS) pass over Indianapolis, Indiana on June 9, 1973 (Scene ID 1321-15593). These data were machine processed at Purdue University's Laboratory for Applications of Remote Sensing (LARS). The LARSYS software system is a package of computer programs, which have been designed to analyze and display remotely sensed multispectral data.[10]

Unsupervised and supervised procedures were used to analyze spectral data in the two study areas. The unsupervised approach was used to determine the spectral separability or uniformity between and among multispectral scanner data points that represent about 1.1 acres of ground area. In the unsupervised approach, the computer program defined the classes of spectral differences that were inherent in the data. In the supervised approach, the computer was "trained" to recognize the spectral characteristics of such selected earth surface features as trees, water and sparse vegetation. The spectral responses from training samples provided data for the computer program to classify automatically areas of unknown earth surface features. The study areas were ultimately classified into seven classes (Table 1) that are displayed

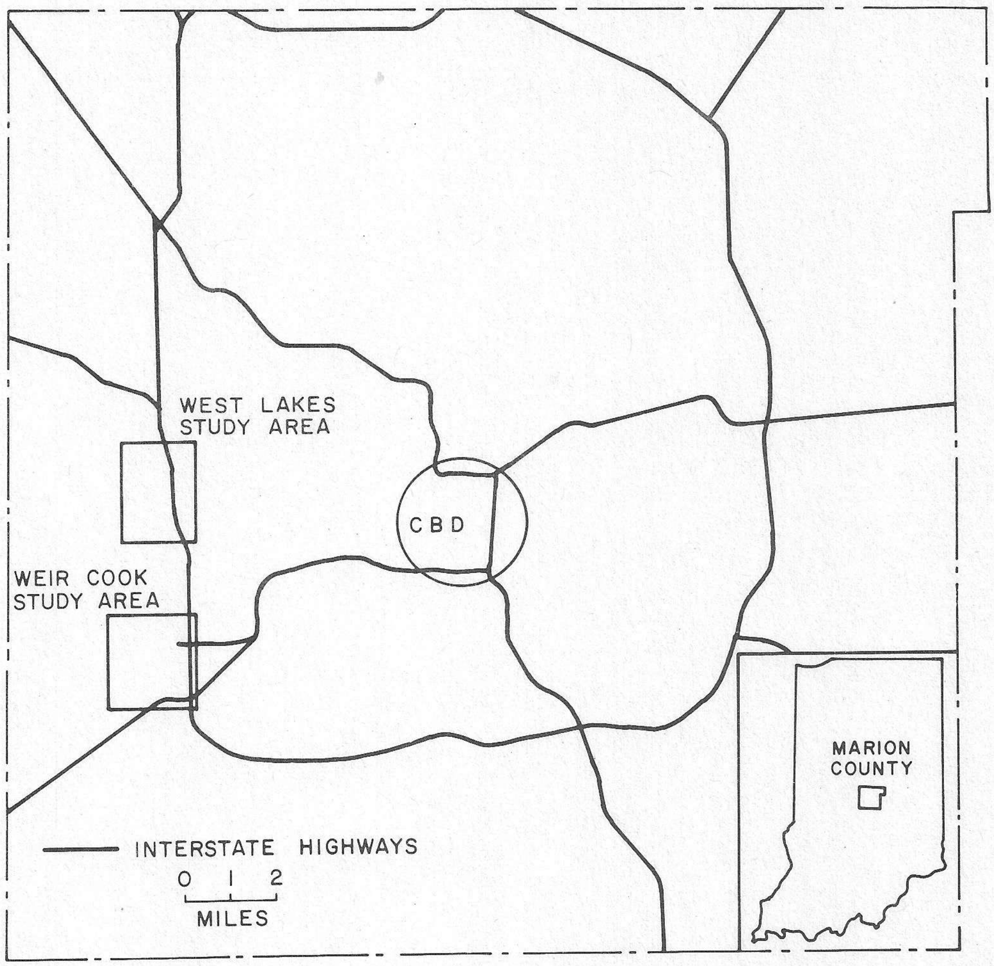


Fig. 1 Indianapolis/Marion County study area.

on alphanumeric printouts. Additional classes of earth surface features could have been obtained, but subclasses were not needed in this study. Geometrically corrected alphanumeric printouts and digital display photographic images were selected as modes of classification display. The alphanumeric printout form was used exclusively to display the results.

Since states will be required to establish criteria and methodologies for designating areas of critical state concern, another purpose of this study was to demonstrate the usefulness of ERTS-data not only in mapping land uses but also in analyzing basic land use changes. ERTS-1 data were applied to two rapidly-changing areas of the rural-urban fringe of Indianapolis. One area was rural countryside in 1941 (West Lakes) but changed rapidly to an urban area served by an inter-

Table 1 Classification of Indianapolis Land Uses

Alphanumeric Symbol*	Class Identification	Additional Characteristics
I	Trees	Canopied green vegetation that primarily is comprised of dense stands of deciduous forest.
-	Dense Vegetation	Primarily non-canopied, but continuous or nearly continuous green vegetation cover. Mature fields of crops, thick sod grass cover, and sparse stands of deciduous trees are common features.
=	Sparse Vegetation	Green vegetation that only partially covers the ground. Short scrubby grass or immature fields of crops with no trees are common features.
0	Water	Surface totally or nearly totally covered by water.
X	Suburban	Each resolution unit classified suburban has a combination of spectral responses from both large amounts of green vegetation and man-made materials (e.g. roads, rooftops). Single family suburban and low-density multiresidential dwellings dominate, but four lane roads, isolated commercial establishments, parts of airport runways and highway interchanges are some of the other features that are classified as suburban.
M	Inner City/ Disturbed Land	Generally dominated by materials of relatively high spectral response in all ERTS bands. A typical feature near a city core is highdensity housing. In suburban areas the symbol identifies almost bare disturbed land (primarily soil or regolith with some vegetation present).
Y	Commerce/ Industry	Generally comprised of material of high spectral response in all ERTS bands. Earth surface feature that lack green vegetation or water. Rooftops, roads, sidewalks, metal, asphalt, and crushed rock material are common components of commercial, industrial, and very high-density residential structures.

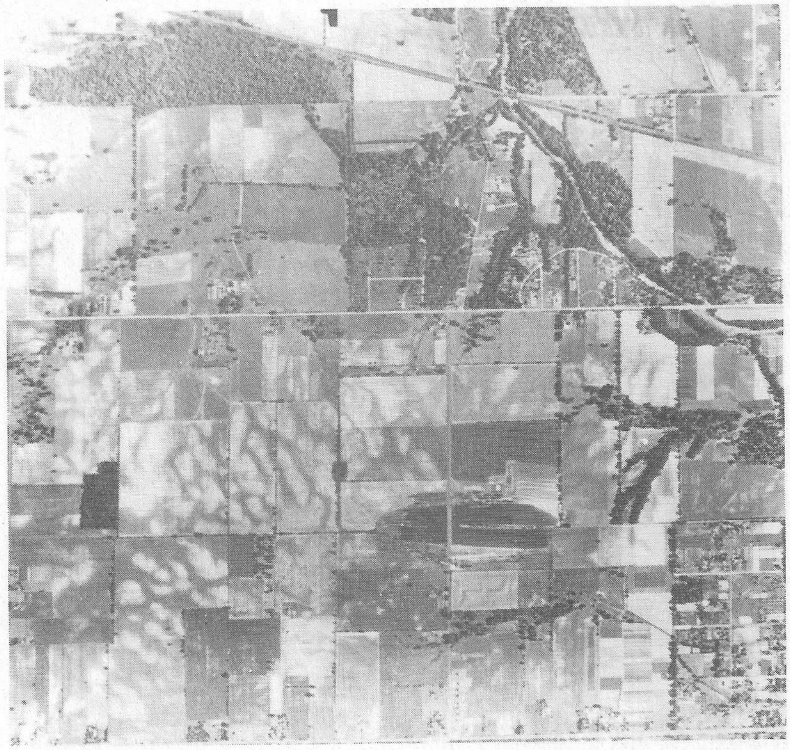
*The legend for alphanumeric symbols found in Figures 6 and 7 are presented in this table.

state highway and a highway interchange (Figs. 2 and 3). A wide variety of urban land uses were photographed that range from forest areas to commercial sites. This urban-rural contact zone had complex land use patterns of spectral responses because of an admixture of materials such as green vegetation, soil, concrete, asphalt, crushed rock and water. But, other land uses in this urban-rural contact zone had relatively uncomplicated patterns of spectral responses because they were comprised of phenomena having narrow ranges. For example, the dense forest and the body of water were earth surface features that had direct spectral response characteristics because these features were comprised of a rather homogeneous material and they occurred in a regular pattern. In contrast, the interstate highway was identified by a linear series of "suburban" because this land use feature is a spectral combination of concrete and green vegetation. Other examples can be given concerning the identification of spectrally complex land uses through analysis of the spatial arrangement of earth surface features in the rural-urban fringe.

The second study area selected was the Weir Cook (Indianapolis) Municipal Airport Area (Figs. 4 and 5). The large regional airport has one 10,000-foot runway, seven other runways, a control tower, an instrument landing system with high intensity lights, a radar advisory and sequencing service, a radio beacon, a VOR navigation station and extensive terminal and maintenance facilities. These specialized land uses were difficult to classify spectrally as distinct entities because functionally they are a combination of two or more different earth surface features. The runway areas of the Weir Cook Municipal Airport are an unassorted mixture of spectrally diverse phenomena. The wider portions of the concrete runways were similar spectrally to the commercial/industrial areas. Between concrete runway areas are large patches of short grass that were identified spectrally as sparse vegetation. But, shorter and narrower concrete runways were similar spectrally to suburban areas because a single ERTS-1 resolution unit is a combination of spectral responses from concrete and adjacent areas of sparse vegetation.

The Classification System

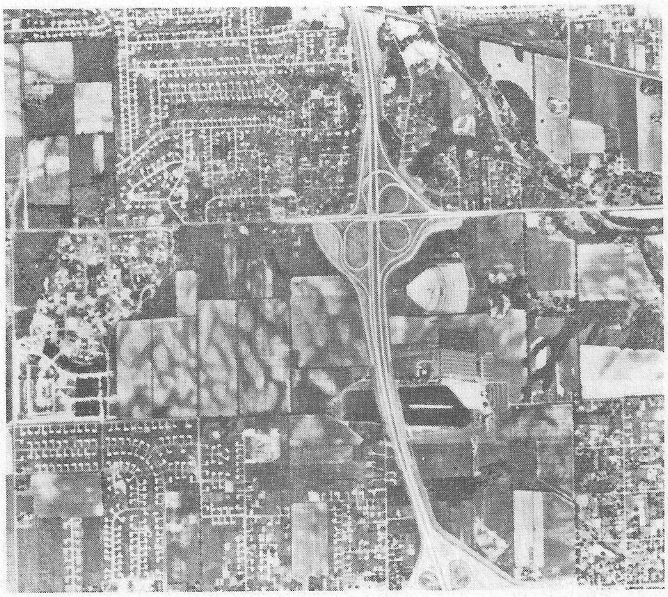
The general land uses, as determined from aerial photographs, topographic maps, and ground truth studies, were delimited on the classification printouts of the West Lakes (Fig. 6) and Weir Cook (Fig. 7) study areas. The land use areas, as identified by their number on these figures, were



1941

1956

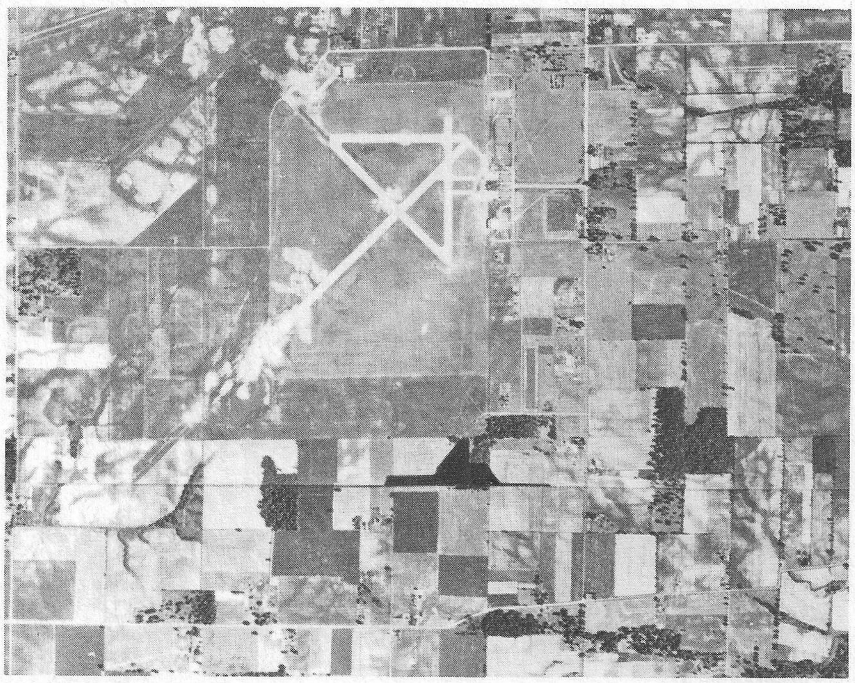
Fig. 2 West Lakes Area aerial photographs.



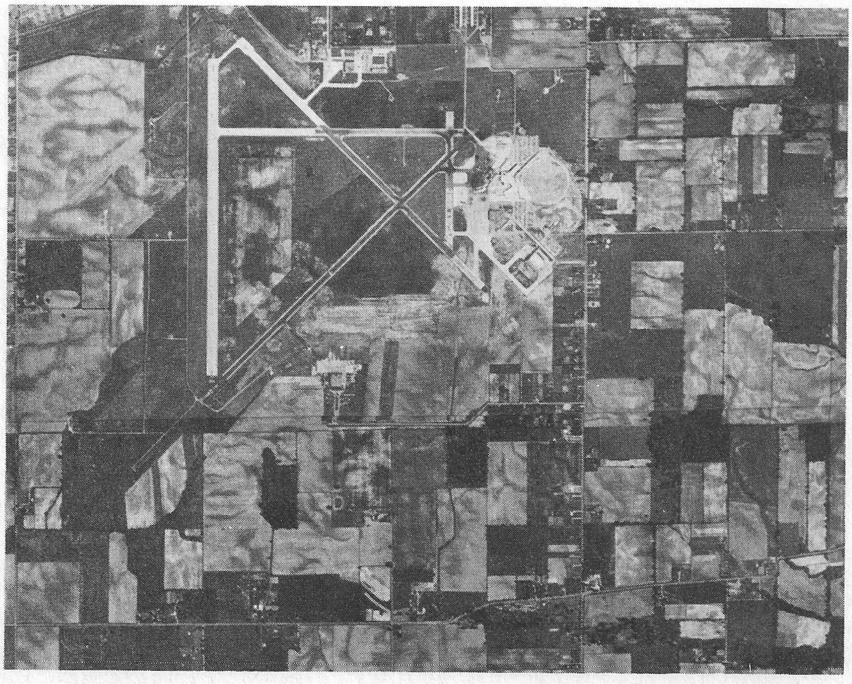
1962

1970

Fig. 3 West Lakes Area aerial photographs.

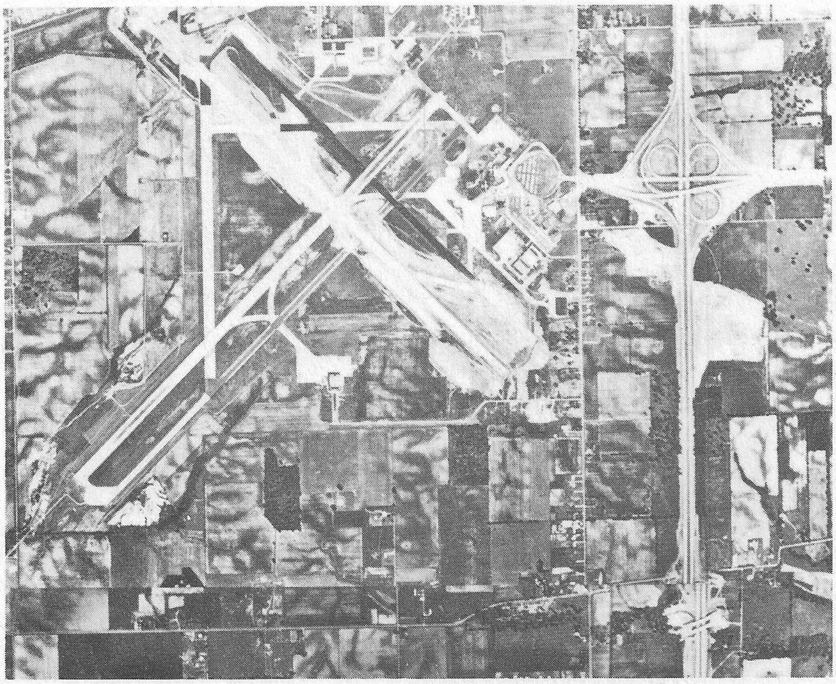


1941

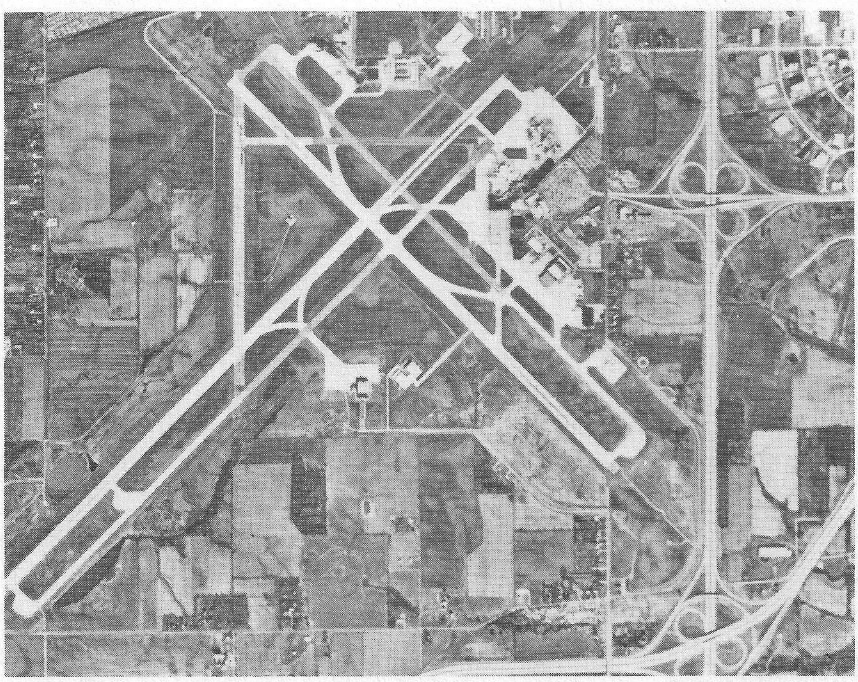


1956

Fig. 4 Weir Cook Airport aerial photographs.



1962



1970

Fig. 5 Weir Cook Airport Area aerial photographs.

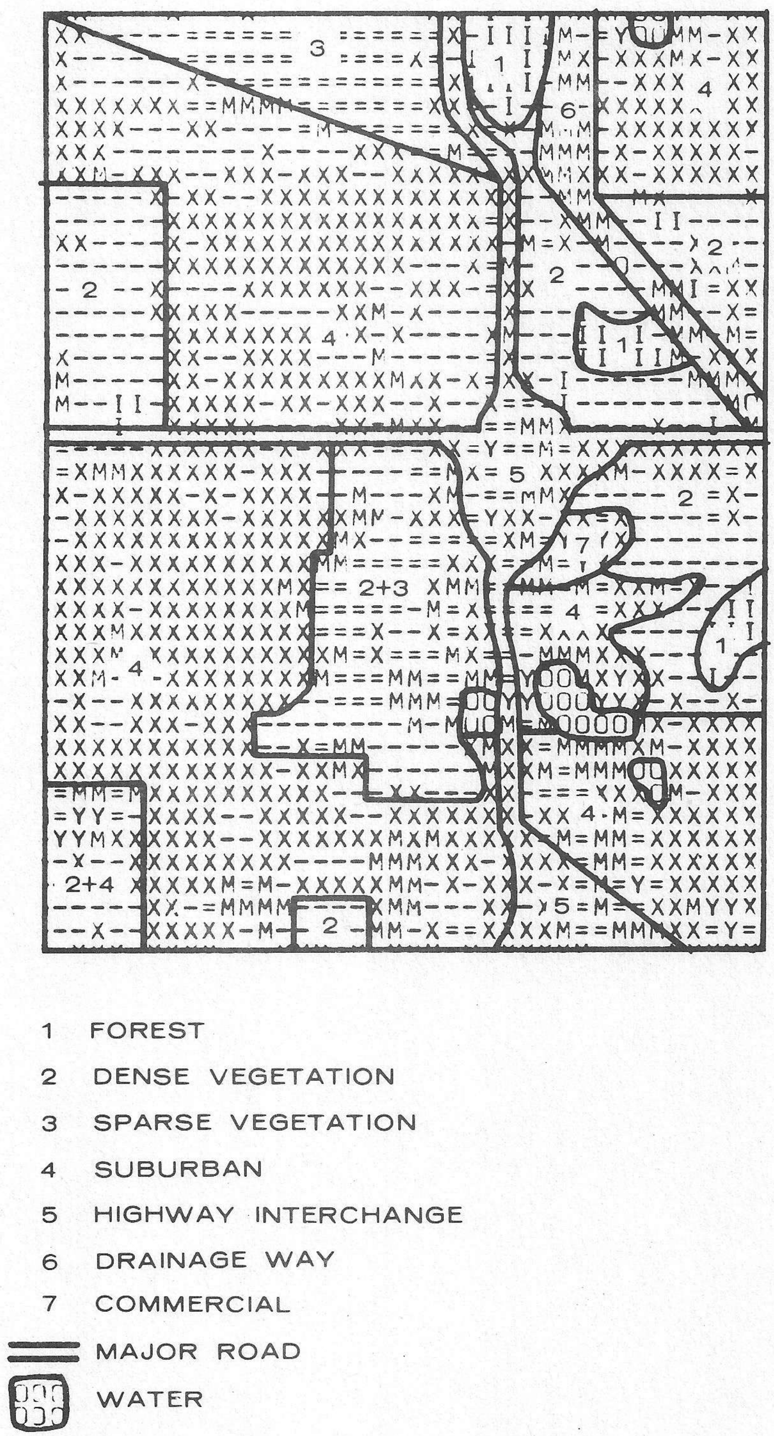
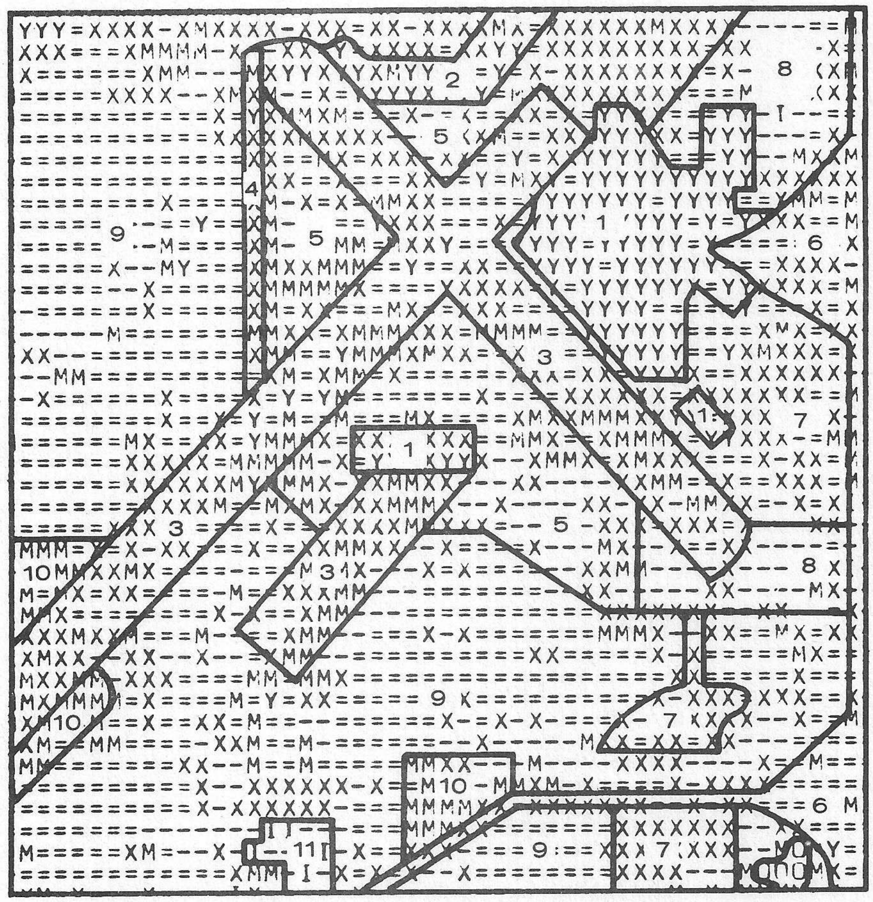


Fig. 6 Classification of West Lakes Area land uses obtained from machine processing of ERTS-1 data.



1 AIRPORT TERMINAL
2 TECHNICAL SCHOOL
3 WIDE RUNWAY COMPLEX
4 NARROW RUNWAY
5 INTER - RUNWAY / NAVAGATION EQUIPMENT COMPLEX
6 HIGHWAY INTERCHANGE
7 SUBURBAN / SMALL BUILDING COMPLEX
8 DENSE VEGETATION
9 SPARSE VEGETATION
10 BARE SOIL / DISTURBED LAND
11 FOREST
MAJOR ROAD
WATER

Fig. 7 Classification of Weir Cook Airport Area land uses obtained from machine processing of ERTS-1 data.

generalized for the purpose of cartographic clarity. In selected areas, two dominant land uses were mixed, thus both uses were indicated for these regions. Frequently, within each identified land use region there were different land uses too small to be identified at the scale of reproduction used in this study. However, the estimation of the land use identification accuracy using ERTS-1 data included all points classified on the alphanumeric printout. A majority of the land uses in both study areas were identified directly from the seven-class ERTS-1 classification. However, analysis of spatial arrangements of the spectrally distinct seven classes (Table 1) added greater precision to the land use interpretation in both selected areas. The specific name assigned to each symbol generally corresponds to the type of area used as training sets for the computer classification program. The name given to an alphanumeric symbol on the printout is incomplete because a variety of earth surface features, other than those indicated on the legend, can have similar spectral responses. A list of earth surface features and land uses that are associated with each symbol of the classification in the study areas is also indicated (Table 1).

The West Lakes Area

West Lakes is a suburban area affected by the recent construction of several single-family residential suburban developments, two multifamily residential suburban developments, highway interchanges, interstate highways, water bodies, and a water drainage way. Some patches of forest, cropland, and open fields still remain.

The classification of the West Lakes Area by ERTS-1 data was highly accurate (Fig. 6). Even such major land use details as the wider spacing of housing in the newer suburban areas could be detected. Individual farmsteads in the rural portion of the study area were identified, and the general degree of crop maturity and plant density also was determined.

The features in the West Lakes Area that presented minor identification problems were highway interchanges, interstate highways, and a drainageway that contained a small amount of water. However, analysis of the spatial arrangements of classes combined with some prior general knowledge of the area permitted a relatively easy delimitation of these land use features.

The overall accuracy of the printout of the West Lakes Area was 93 per cent by using the classification developed for this study. The other seven per cent was identified by ground truth and with the use of the series of photographs that covers the years 1941, 1956, 1962 and 1970 (Figs. 4 and 5). Especially noteworthy from the four photographs is the dynamic effects of the interstate highway and the interchange located near the center of the 1962 and 1970 photographs. During the 29 years of photographic records, the open space had been largely converted to suburban uses, as shown by #4 on the legend of the printout. Residential and commercial uses have dominated the recent built-up areas. The problems of leapfrogging over the dense and sparse vegetation zones located adjacent to, and southwest of, the interchange is typical of developments that are located on cheaper lands farther from the most accessible transportation.

In particular, the interstate highway and the highway interchange required a ground truth examination of the combinations of earth surface features in order to determine the precise nature of the functional land use. But, from a state planners viewpoint virtually 100 per cent of the West Lakes Study Area land uses were identified accurately at a scale suitable to use for general planning and evaluation purposes at a state level of land use planning.

The Weir Cook Municipal Airport Area

The classification of land uses in the Weir Cook Municipal Airport Study Area (Fig. 7) was much more difficult than in the West Lakes Study Area because approximately 35 per cent of the area's land uses were complex combinations of spectral responses. Suburban, forest, cropland, soil, water, and the airport features associated with the air terminal complex were easily and accurately identified directly from the classification printout. Airport runways and service areas, highway interchanges, and interstate highways often require spatial analysis of the classification data in order to ascertain the correct land use identification, but approximately 65 per cent of the Area's land uses were accurately identified directly from the classification printout. Analysis of the spatial arrangement of the classification was used on the remaining 35 per cent of the study area. For example, a linear feature that was several resolution units (each unit on the alphanumeric printout represents an area approximately 60 meter by 80 meters) wide and contained a complex mixture of "commerce-industry," "suburban," "soil," and "sparse vegetation" was identified as a runway complex. This type of analysis resulted in an additional 25 per cent correct identification of the Area's land uses. Only 10 per cent of the general land uses in the Weir Cook Municipal Airport Study Area were not identified with certainty until additional ground truth information was provided. A 90 per cent accuracy of land use identification for general planning purposes was very encouraging. It confirmed impressions that frequent analysis of general land use changes in metropolitan environments can be rapid, easy, and accurate using machine-processing of ERTS-1 multispectral data even for such a complex area as a large regional airport.

The 1941, 1956, 1962 and 1970 photographs (Figs. 4 and 5) depict striking land use changes that occurred in the Weir Cook Municipal Airport Area. Since 1970, another 3700-foot runway was constructed to the east of the longest 10,000-foot runway and parallel to it. This new runway, labeled as 22L and 4R. was easily identified and correctly delimited from the printout. In contrast to the 1970 photograph the ERTS-1 printout also revealed a more extensive airport terminal area, a larger area of parking and more auxillary areas to the northeast of the study area. The June 1973 pass also revealed another large area of radio navigation equipment and approach and landing lights located to the north of the longest runway 22R. In general, the 90 per cent accuracy was remarkable when one analyzes the complex association of specialized urban land uses that occur in the Weir Cook Municipal Airport Study Area.

Conclusions

Land uses that are comprised of complex mixtures of earth surface features were difficult to identify with exact precision. Since the land uses of this study were often mixtures of two or more of the following: 1) green vegetation; 2) soil or regolith; 3) water; 4) higher spectral response man-made materials; 5) lower spectral response man-made materials; and 6) other natural non-chlorophyll materials. Land uses were described best by the relative proportion and spatial arrangement of one or more of these six broad earth surface feature categories.

Some land uses associated with suburban areas required a ground truth study of patterns and combinations of earth surface features. This was necessary in order to determine the precise nature of land uses that were difficult,if not impossible, to identify directly through machine processed spectral data.

It is conceivable that a computer program can be written that will assist in identifying complex land uses through the analysis of patterns of less complex land uses or earth surface features of which the more complex land uses are comprised. Direct spectral identification of some of these complex land uses is also possible with additional research or further advances in remote sensing technology.

The use of ERTS-1 permits frequent and regular temporal steps for keeping land use data files up to date. Under ideal conditions, an area could be spectrally analyzed and classified into land uses every 18 days. The possibility of viewing land use changes on an 18-day interval provides for a dynamic series of current land use data that are of enormous value in monitoring changes, anticipating future growth and analyzing spatial interrelationships.

After proper classification and coding, ERTS-1 data can be plotted on an accurate square grid system and matched with social and economic data and geographically displayed in new and more meaningful ways. By assigning codes to the ERTS-1 grid, local social and economic records can then be aggregated for mapping by linking these local data with ERTS-1 data.

The gathering of ERTS-1 data does not negate the utility of many other data sources. To be most effective for state land use planning, other data should be compatible with ERTS-1 information. Therefore, states should consider constructing information storage and retrieval systems so that inputs from ERTS-1 imagery can be used most meaningfully for land use planning and management programs.

References

[1] Stone, K., "Developing Geographical Remote Sensing," Remote Sensing: Techniques for Environmental Analysis, (Estes, J. E. and Senger, L.W. editors), 1974, pp. 1-14, Hamilton Publishing Company, Santa Barbara, California.

[2] Earth Resources Technology Satellite Data Users Handbook, National Aeronautics and Space Administration, 1972, Goddard Space Flight Center, Greenbelt, Maryland.

[3] Todd, J. W., Mausel, P. W., and Wenner, K., "Preparation of Urban Land Use Inventories by Machine Processing of ERTS MSS Data," Symposium on Significant Results Obtained from the ERTS-1, NASA/Goddard, New Carrollton, Maryland, Vol. 1, Sec. B, 1973, pp. 1031-1039.

[4]Lindgren, D. T., "Urban Applications in Remote Sensing," Remote Sensing: Techniques for Environmental Analysis, op. cit., pp. 225-242.

[5]Ellefsen, R., Swain, P.H., and Wray, J.R., "Urban Land Use Mapping by Machine Processing of ERTS-1 Multispectral Data: A San Francisco Bay Area Example, "LARS Information Note (032973), The Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, Indiana, 1973, pp. 1-15.

[6]Environmental Quality, The Fourth Annual Report of the Council on Environmental Quality, 1973, pp. 214-219.

[7]Heyman, I.M., "Federal Impacts on Land-Use Regulation," Land Use Controls Annal 1972, 1973, pp. 7-14.

[8]Suloway, S., Editor, "A Summary of State Land Use Controls," Land Use Planning Reports, 1973, pp. 1-34.

[9]Bosselman, F. and Callies, D., The Quiet Revolution in Land Use Control, Council on Environmental Quality, 1971, pp. 314-327.

[10]Cipra, J.E., Henderson, J.A., and Gardner, J.V., "An Interpretation of a Geologic Map of Fannin County, Texas Prepared by ADP Techniques from ERTS MSS Data, "Remote Sensing of Earth Resources, Vol. 2, 1973, p. 915.