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NASA CR- 142637
ERIM 193300-60-F

Final Report

ANALYSIS OF RECREATIONAL LAND AND OPEN SPACE USING ERTS-1 DATA

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APRIL 1975

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(E75-10262) ANALYSIS OF RECREATIONAL LAND AND OPEN SPACE USING ERTS-1 DATA Final Report, Jun. 1972 - Nov. 1974 (Environmental Research Inst. of Michigan) 42 p HC $3.75 CSCL 08B G3/43 N75-22873 Unclas 00262

Prepared for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Goddard Space Flight Center
Greenbelt, Maryland 20771
Contract NAS5-21783, Task V

1086A

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NOTICES

Sponsorship. The work reported herein was conducted by the Environmental Research Institute of Michigan for the National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland 20771, under Contract NAS5-21783, Task V. Dr. Ralph Sommers, NASA Lewis Research Center, is Scientific Monitor for NASA-GSFC. Contracts and grants to the Institute for the support of sponsored research are administered through the Office of Contracts Administration.

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College Park, Maryland 20740

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. NASA-CR- ERIM 193300-60-F	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle STUDY OF RECREATIONAL LAND AND OPEN SPACE USING ERTS-1 DATA		5. Report Date April 1975 6. Performing Organization Code
7. Author(s) I.J. Sattinger, R.D. Dillman, N.E.G. Roller		8. Performing Organization Report No. ERIM 193300-60-F
9. Performing Organization Name and Address Environmental Research Institute of Michigan Infrared and Optics Division P.O. Box 618 Ann Arbor, Michigan 48107		10. Work Unit No. Task V (MMC 086) 11. Contract or Grant No. NAS5-21783 13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Goddard Space Flight Center Greenbelt Road Greenbelt, Maryland 20771		Final Report June 1972 through November 1974 14. Sponsoring Agency Code

15. Supplementary Notes

Mr. Irvin J Sattinger (ERIM) was Principal Investigator for this project, and Mr. George Skrubb (Director, Oakland County Planning Commission) was Co-investigator

16. Abstract

The goal of this project was to develop and demonstrate the use of computer-processed ERTS-1 MSS data for the study of recreational land and open space. Wetland and wooded areas, other vegetation, water bodies, and residential areas were mapped for Southeast Michigan test sites. A 4-category map of an Oakland County site was prepared by edited level slicing of Bands 5 and 7, and a 13-category map of the site was prepared by maximum-likelihood ratio processing. Edited level slicing and multi-date analysis of March and June data were effective in mapping wetland and upland areas in Washtenaw and Livingston Counties. Analyses of results indicate mapping accuracies as high as 90 percent under certain conditions. Methods were developed for computing deer and waterfowl habitat quality ratings from ERTS recognition maps. Information is given on comparative costs of land use mapping with high-altitude aerial photography and with ERTS-1 data, for areas of 2,600 sq km and larger, showing lower costs for use of ERTS-1 data. This project demonstrated the utility of ERTS-1 data for such purposes as preliminary identification of suitable recreational sites, defining rural/urban boundaries, and mapping of wildlife habitat.

17. Key Words ERTS-1 Automatic data processing Recreational land Natural resources inventory	18. Distribution Statement Initial distribution is listed at the end of this document.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	46	

PREFACE

The goal of this sutdy was to develop methods of using ERTS data for the analysis of recreational land and open space. A substantial part of the project effort was devoted to the development and evaluation of computer-based methods of land use classification and analysis for this purpose. In addition, considerable attention was directed toward defining the potential applications of ERTS technology to recreational studies.

The investigation described herein was carried out under NASA Contract NAS5-21783, Task V. Mr. Irvin J. Sattinger, Research Engineer at the Environmental Research Institute of Michigan, was Principal Investigator for the project. Robert D. Dillman was responsible for the work on general land use mapping discussed in Section 2. Norman E.G. Roller was responsible for the work on habitat mapping discussed in Section 3.

The investigation was conducted in close cooperation with people and organizations who could view the work from the standpoint of the ultimate user of the data. The Co-investigator for this project was Mr. George Skrubb, Director of the Oakland County Planning Commission. The work was also reviewed by Mr. Larry Peterson, Outdoor Recreation Planner at the Lake Central Regional Office of the Bureau of Outdoor Recreation. As a result, full consideration was given to the applicability of the work to performing needed functions in recreational land use analysis. However, the conclusions and recommendations contained in this report do not necessarily reflect the views of the organizations mentioned above.

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STUDY OF RECREATIONAL LAND AND OPEN SPACE USING ERTS-1 DATA

1 INTRODUCTION AND SUMMARY

1.1 PROJECT OBJECTIVES

Increasing recognition is being given to the need for preserving and managing the nation's limited land resources to ensure their optimum use for both present and future generations. Two major goals of land use planning are the preservation of open space surrounding urban areas undergoing rapid development, and the acquisition, improvement, and management of land and water areas to meet recreational needs of the public. For these purposes, much detailed information on a variety of topics is required.

A number of studies have shown potential uses of remote sensing for recreational analysis and planning [1, 2]. The advent of the ERTS-1 satellite promises to provide much of this needed information in the form of synoptic and timely data on land use and natural resources over large areas. The objectives of this project were to investigate the technical and economic feasibility of using such data in the analysis of recreational land and open space, and to define potential areas of application.

The study was concerned with mapping and evaluation of land and water areas suitable for a wide variety of recreational uses. In particular, the use of land as wildlife habitat is of major significance in Michigan. A major portion of the study was therefore concentrated on the assessment of deer habitat and waterfowl habitat.

Although the study concentrated on sites in Southern Michigan of limited size, it is expected that the ultimate use of ERTS data will be directed toward studies of regional scope. With suitable modifications, the methods of inventory and analysis obtained over the experimental test sites can be adapted to many other areas of differing characteristics.

1.2 SUMMARY OF INVESTIGATION PROCEDURES AND RESULTS

The general problem of recreation site evaluation and selection was addressed in the first phase of the investigation. A frame of ERTS MSS data obtained on 28 September 1972 was used to perform land use mapping. The test site for this experiment was a 185 sq km area, located in Oakland County, which is characterized by the presence of a number of lakes, wetland and wooded areas, and residential areas. Both edited level-slicing and maximum likelihood ratio processing were used to classify land use and land cover. A description of the mapping procedures and results, including an accuracy check, are presented in Section 2.

Because of the importance of the consumptive and non-consumptive uses of wildlife in Michigan, the second phase of the investigation was concerned with the application of ERTS data for the assessment of wildlife habitat. The test site was a 6-township area in Washtenaw and Livingston Counties, consisting primarily of natural and agricultural areas. The site includes state-managed recreational and game areas and the E.S. George Reserve, an experimental game preserve belonging to The University of Michigan and used for research on the interaction between white-tailed deer population management and habitat response. Several methods were used to process ERTS data obtained at one or both of two dates, 27 March 1973 and 7 June 1973. An important result of this work was the development of methods for analyzing the processed data to obtain quantitative ratings of the quality of the terrain as deer habitat and as waterfowl habitat. These simple and effective modelling procedures have a number of potential uses for identifying suitable habitat and preparing specific plans for habitat improvement. Section 3 summarizes the work performed both in processing the ERTS data to inventory the natural resources of the area and in computing habitat quality ratings.

In Section 4, the results of the experimental work on the use of ERTS data are used to define the anticipated role of ERTS for recreational land analysis. Many potential applications are identified and ERTS processing costs are shown to compare favorably with costs of performing a similar function by the photointerpretation of high-altitude aerial photography.

In Section 5, conclusions based on the results of this project are presented and recommendations are made. The project demonstrated a high degree of technical and economic feasibility in using ERTS-1 data for conducting an inventory and mapping of types of land use and land cover significant for recreational studies. Also demonstrated was the capability for incorporating the resulting inventory data into a geographically-referenced computer data base where it can be combined with data from many other sources on land ownership, population distribution, and transportation networks. The availability of data in digital form makes possible many procedures for quantitative analysis and modelling which can be used for evaluation and management of recreational land. Certain of the methods demonstrated are recommended for early operational use. Additional research and development is outlined which can lead to further advances in bringing ERTS technology into extensive use by recreation planners and managers.

2
GENERAL LAND USE MAPPING

The objective of the first phase of the investigation was to determine the ability of various computer processing techniques to discriminate general types of land use and land cover, including residential areas, bodies of water, wooded areas, and other types of natural and cultivated vegetation. The test was confined to analyzing ERTS coverage for a single date.

2.1 DATA ACQUISITION

Usable ERTS-1 coverage of the Oakland County test site was obtained on 28 September 1972 (ERTS Frame 1067-15643). The usefulness of the data was limited to some extent by partial cloud cover, but at least some sections of Oakland County and adjacent areas in Southeast Michigan were cloud-free and usable. Since further coverage of the test site could not be obtained while foliage was visible till the following year, the data analysis began with usable sections of the available frame.

In support of this investigation, RB-57 Mission 205 was flown over Southeast Michigan (Site 279) in June 1972. Coverage of parts of Oakland County was obtained, but other parts could not be photographed due to developing cloud cover. However, coverage of other parts of Southeast Michigan was useful for a later phase of the investigation. In the absence of complete coverage of Oakland County, the 1972 RB-57 photography was supplemented where necessary by previous RB-57 coverage obtained in 1969.

2.2 SITE DESCRIPTION

Intensive study was concentrated on an area of 185 sq km within Oakland County approximately nine miles northwest of Pontiac. It includes Big Lake, Pontiac Lake, the Pontiac Lake State Recreation Area, and the Huron Swamp, which is the site for a new 2000 acre park, the Oakland Metropolitan Park, recently announced by the Huron-Clinton Metropolitan Authority. The area studied is a natural area which includes the headwaters of several rivers. It supports a variety of vegetation, including mixed hardwoods, lowland hardwoods, oak-hickory stands, upland brush, grass and crops.

2.3 EDITED LEVEL SLICING

We began the study of the test area by preparing a four-category computer map, using edited level slicing techniques on Band 5 and Band 7 data. As a basis for preparing this map, we performed a preliminary analysis of training set signatures to determine the spectral bands in which the categories of forest, grass, urban, and water, could be separated exclusively on the basis of the digital value of scene radiance. In Band 5, certain areas, distinguished by their light tone (digital values above 26), include residential areas with little vegetation, and bare areas, such as sand and gravel pits or major highways. Based on this characteristic, the class of all such developed areas can be mapped from Band 5. If the quanta value of a scene element in Band 5 is 26 or less, the surface is then recognized by reference to Band 7. The signature analysis indicated that by using Band 7 alone, level slicing was able to separate the categories shown in Table 1.

TABLE 1. CATEGORIES OBTAINED BY EDITED LEVEL SLICING OF BAND 7

Digital Value	Class
0 to 11 (dark)	Water
12 to 18 (intermediate)	Grass & Other Vegetation
19 to 26 (light)	Forest
27 to 511	Blank

An evaluation of the resulting four-category map shown in Figure 1 indicates that water areas are consistently mapped. Residential areas with little tree cover are consistently mapped as Urban, but the older or lower-density residential areas with substantial tree and lawn cover tend to be mapped as Other Vegetation. This category also includes a wide variety of vegetative cover in non-urban areas, including some forested areas. This confusion can be reduced by increasing the lower limit of the range defined as forest, but cannot be completely eliminated, because some areas of forest and grass may have the same digital values, i.e., radiance, in a single band. The results obtained in this study of edited level slicing are discussed in Reference 3.

For studies which require a limited number of land use and land cover categories, this use of level slicing is a rapid and economical method for computer processing. Four-category mapping is adequate for certain preliminary studies of river valleys or scenic trail routes. It can also be compared with older photographs or land use maps to identify large areas of changing land use which require more detailed analysis. The breakdown can also be used for the selection of training sets for more sophisticated processing.

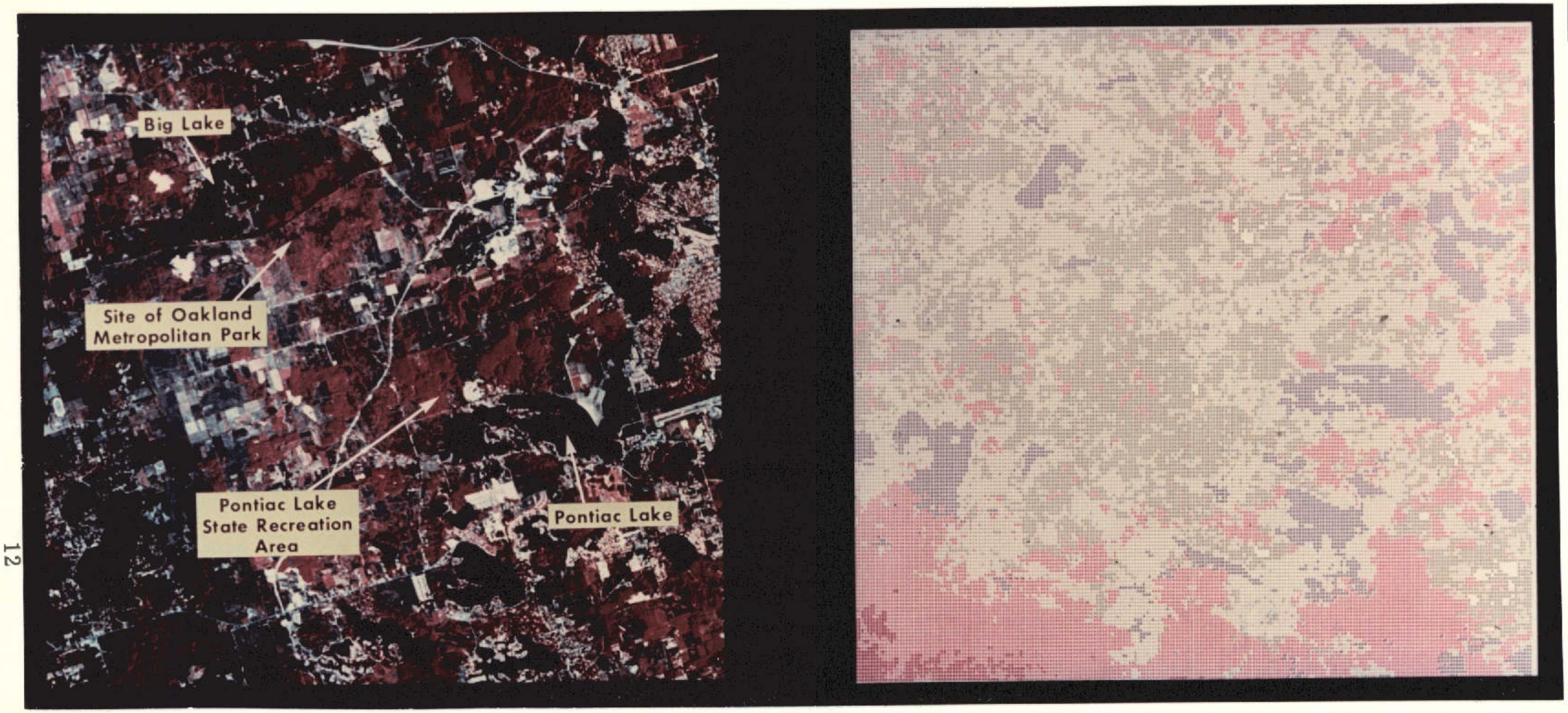
2.4 MAXIMUM LIKELIHOOD RATIO PROCESSING

In order to produce a more detailed map of land use and land cover for the Oakland County test site, the same digital data used for edited level slicing were subjected to maximum likelihood ratio processing.

2.4.1 SELECTION OF TRAINING SETS

The training areas on which to base maximum likelihood ratio processing included residential areas, sand and gravel pits, forest areas, other vegetative cover, and deep and shallow water (see Table 2). Since the coverage was obtained near the end of the growing season, very little bare soil is visible in the area. In selecting these training sets, we experienced several difficulties which somewhat limited the accuracy of our recognition mapping process. In some cases, training areas were inadvertently chosen which were later found to be covered by haze or clouds. We also encountered difficulty in selecting an area on the initial computer printout which coincided with a known area recognized on an RB-57 photograph. As a result, the surface covered by the training set was not a homogeneous type of ground cover in some cases. In spite of these initial problems in selecting suitable training sets, maximum likelihood ratio processing produced effective results.

In future processing, it will be possible to improve these results by working with a cloud-free frame and by adopting improved methods of selecting homogeneous training areas based on accurate geographic correlation of gray map and photograph.



RB-57 Photograph

ERTS-1 Digital Map

N

Blue = Water
Red = Urban
Dk. Green = Forest
Lt. Green = Other Vegetation

FIGURE 1. ERTS-1 DIGITAL MAP, OAKLAND COUNTY, MICHIGAN, 28 SEPTEMBER 1972

2.4.2 MAPPING RESULTS

The recognition map prepared by maximum-likelihood processing is shown in Figure 2. Symbols used are listed in Table 2.

A sizable area near the bottom of the test area is cloud covered, and small isolated clouds are distributed over other parts of the scene. The lower section of the picture was therefore mapped by symbols corresponding to urban or sand and gravel areas, which approach the clouds in brightness. Isolated clouds in other parts of the scene also appeared in the recognition map as soil or gravel and shadows caused by these clouds were mapped as water. These discrepancies are easily detected and accounted for in the overall checking of the area map.

2.4.3 WATER BODIES

The signature of water bodies is sufficiently different from other types of surface that they are reliably recognized and mapped. Large bodies of water, such as lakes, are mapped with very little error, except at the shoreline where mixtures of land and water occur in individual pixels. Even bodies of water as small as a hectare in size are usually detected, although their shape is distorted by the grid structure of the map, and their exact area is subject to considerable error. In one area (near the left edge of Figure 2) a series of small ponds or lakes occurs, but only one of these lakes was detected. Examination of the photography indicated that the other lakes or ponds contained substantial amounts of vegetation or algae, which would have interfered with the recognition process.

2.4.4 RESIDENTIAL AREAS

As indicated in the discussion of training sets, residential areas with little vegetative cover tend to be mapped as homogeneous areas similar to sand or bare soil. This situation would be approached for a trailer park. In areas containing substantial amounts of trees and lawn, the mapping consists of a mixture of light tones and various types of vegetation. Because of the mottled character of such residential areas, it would be difficult to select a single signature which would be consistently mapped in such areas. Residential areas with substantial vegetation cover have to be recognized not from single pixels but from textural analysis of a group of such pixels. The heterogeneous character of residential areas may provide a basis for distinguishing such areas from trailer parks, bare fields, sand and gravel pits, commercial and industrial areas, and for delineating the rural/urban boundary. Although residential areas are generally distinguishable from other types of land use, some confusion might occur for residential areas whose composition closely approximates either completely paved areas or completely vegetated areas.

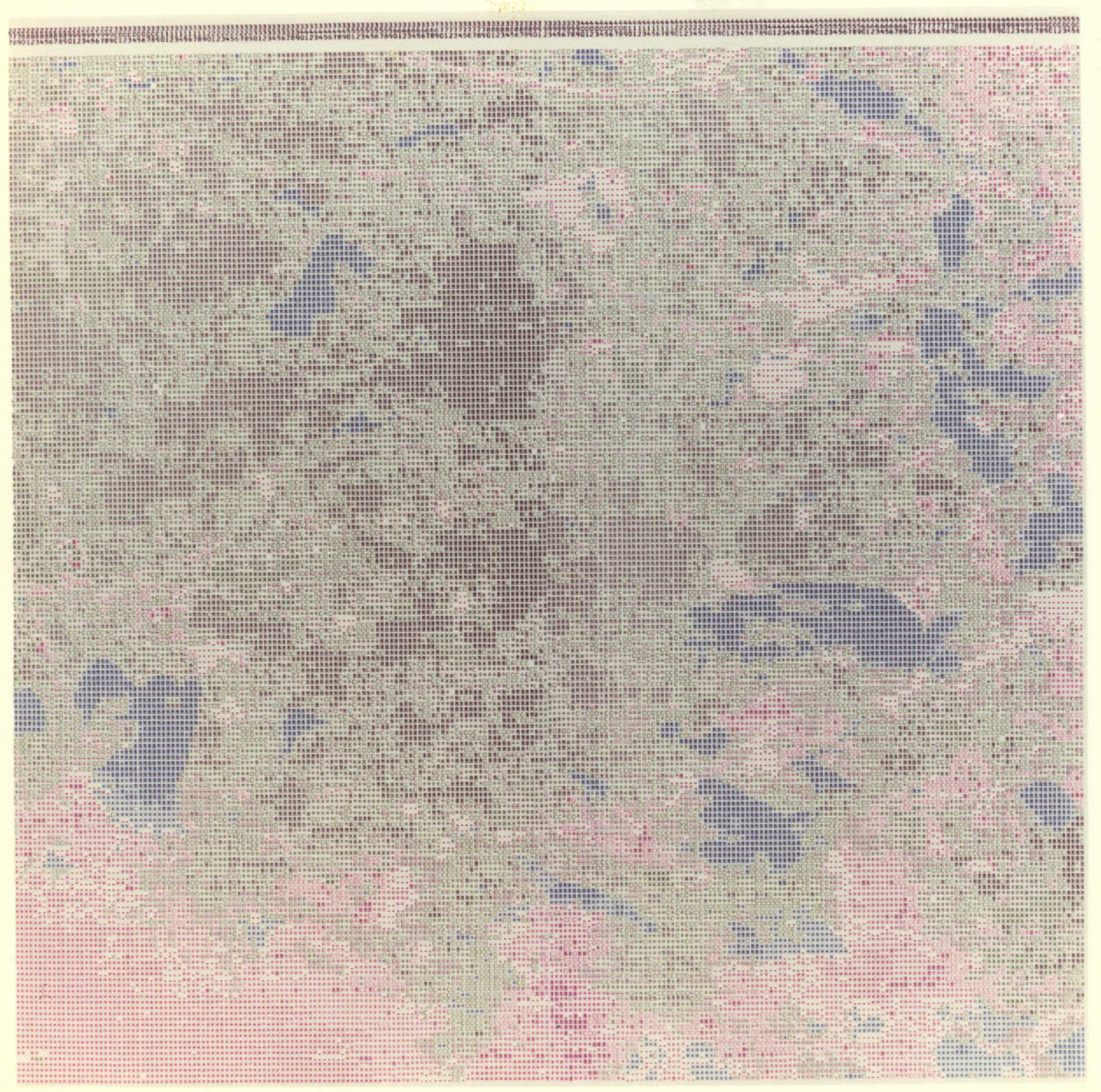


FIGURE 2. DIGITAL RECOGNITION MAP OF OAKLAND COUNTY TEST AREA

TABLE 2. TRAINING SETS

Training Set	Symbol	Elements	Hectares
Water, shallow or haze-covered	Blue *	1121	500
Water, deep	Blue M$	2318	1020
Soil, gravel	Red .	1899	839
Medium density residential	θ	3924	1730
Medium density residential (haze)	Red *	2714	1200
Medium density residential (haze)	Red X-	1780	785
Medium density residential (50% vegetation)	Red O	1512	668
Trailer park	Red M$	435	192
Mixed hardwood forest	M$	7821	3450
Transition (forest/grass)	*	3858	1700
Grass, upland brush	Green O	6478	2860
Grass, active cultivation	Green *	5902	2605
Golf course	Green X=	1835	810
Unclassified		35	15
Total		41632	18374

2.4.5 HIGHWAYS

The only highway which is clearly shown on the recognition map is a short section of I-75 at the extreme top of the map, which is represented by a linear distribution of various red symbols.

2.4.6 FORESTED AREAS

In the test area, the trees are predominantly deciduous, with the majority of the forest-covered areas consisting of mixed and lowland hardwoods. Two separate training sets were used to identify forests. The resulting training sets were consistently recognized as forest in the recognition map, confirming the estimate that these training sets were selected in areas of homogeneous forest cover. Visual comparison of the recognition map with aerial photography indicates a reasonably good correlation of location, size, and shape of wooded areas as small as 5 or 10 hectares. There may, however, be a tendency to map as forest some areas which have been designated in the vegetation map of Oakland County as upland brush.

No attempt was made in this recognition mapping process to distinguish among various communities or species of trees. There is little coniferous tree cover in the area studied, and suitable training sets for differentiation of major types were not easily available. For many studies of recreational land, such differentiation of tree types would be significant.

2.4.7 OTHER VEGETATION

A check on the accuracy of recognition mapping of vegetation categories other than forest is difficult to accomplish in the area under study. The rural areas are characterized by great variability of surface cover and there are few homogeneous areas of sufficient size to be isolated for comparison with aerial photography.

A study of the signatures of training sets of other vegetation indicates that some of these signatures are reasonably distinguishable from each other. However, the selection of training sets did not provide a separation of vegetation into sufficiently clear-cut categories. Thus, the general mapping of other vegetation as a single group appeared to be quite effective, but the distinction among individual categories was inconclusive. In Section 3, covering the second phase of the project, additional experience in mapping specialized types of vegetation is reported on.

2.4.8 ACCURACY CHECK

One suitable approach to the task of checking the computer map accuracy is to compare the map with the photograph with respect to shape and extent of sizable features. General conclusions reached from this method of comparison have been discussed above. In addition, an accuracy check was performed on an East-West transect taken through the northern part of White Lake and a large trailer park several miles east which was used as the training set for one of the urban classes (Red M$). This transect contains 227 pixels. The accuracy of the digital map prepared by maximum likelihood ratio processing was checked by comparing it to an RB-57 color IR photograph of the area. A similar accuracy check was performed on a map obtained by conventional photointerpretation of the ERTS image of the same area.

Table 3 shows the comparison of pixel classification from the two sources. The matching data were aggregated into the four major classes of water, urban, forest, and other vegetation. The number of matching pixels amounted to 208 out of 227, for an accuracy of 92%. These results may be compared with the match of RB-57 photography against the same transect of a land use map prepared by photointerpretation of ERTS imagery. For the same four classes, the number of matching pixels yielded a total of 169 out of 227 for an accuracy of 74%.

In comparing this latter result with the accuracy cited for digital mapping, it should be kept in mind that this result was probably not the best possible performance that can be expected from ERTS photointerpretation. The imagery used for the purpose included the black and white transparencies for Bands 5 and 7, and the color transparency of the same scene. If improved imagery can be used for the photointerpretation, such as color imagery with better resolution, it should be possible to improve the accuracy rating above that noted. However, a significant advantage of digital mapping over ERTS photointerpretation probably accounts for some of the difference. Every pixel in the complete scene is analyzed by the digital processing, whereas with photointerpretation, realistic limitations on photointerpretation effort require the placing of boundaries around what appear to be homogeneous areas of land cover. For the complex scene characteristic of the area we are investigating, this grouping process of photointerpretation reduces the amount of detail which can be incorporated into the final product.

3
WILDLIFE HABITAT ASSESSMENT

The presence of wildlife in an area substantially increases its value as a base for outdoor recreation. Important wildlife species in Southern Michigan providing high consumptive and non-consumptive value include the white-tailed deer and several species of waterfowl, primarily ducks. In the case of deer, 600,000 hunters in Michigan annually bag between 65,000 and 75,000 animals, roughly 10 percent of the state's entire herd. From the standpoint of the Michigan Department of Natural Resources, an inventory of the present distribution and quality of the habitat of these game species and knowledge of the rate at which their habitat is being altered or eliminated are essential if effective steps are to be taken to protect and upgrade the quality of the recreational experience derived from this resource. Thus, the ability to conduct an

TABLE 3. ACCURACY COMPARISON

Class	Percent of Pixels in Class Correctly Identified	
	ERTS Photointerpretation	ERTS Digital Mapping
Water	89	89
Urban	44	74
Vegetation	92	97
Forest	52	92
Overall	74	92

inventory of habitat quality, extent and distribution and to provide rapid and quantitative analysis of the results at reasonable cost has major value for both the management of individual wildlife species and the development of further recreational opportunities.

Recently developed remote sensing methods promise to aid wildlife managers in the habitat assessment process by providing them with current, synoptic looks at the environment. Multispectral scanner systems in general, and ERTS in particular, provide data in the form of records stored on magnetic tape suitable for computer analysis. As a result, computer processing can make quantitative results available at a cost and in a time frame needed for practical management decision-making on a regional basis. To illustrate potential uses of computer-compatible remote sensing data in the field of wildlife management, an experiment was conducted to investigate the feasibility of using this emerging technology in the management of white-tailed deer and migratory waterfowl.

Three separate tasks were performed:

(1) Recognition maps were prepared by maximum likelihood ratio computer processing of a combination of ERTS data obtained in two different seasons. By using data from two seasons it is possible to take advantage of significant phenological variations in the appearance of important cover types, thus improving the multispectral capability for identifying key components of the habitat.

(2) A method was devised and demonstrated for using this information on terrain feature abundance and arrangement quantitatively in rating local habitat quality for both white-tailed deer and waterfowl.

(3) An evaluation was made of the performance and cost of four different methods of computer processing of ERTS data for use in regional wetland inventory and evaluation programs.

3.1 MULTI-DATE PROCESSING

3.1.1 EXPERIMENTAL PROCEDURES

The study site for the experiment is a 6-township area (560 sq km) located at the western edge of the boundary between Livingston and Washtenaw Counties in Southeast Michigan (Figure 3). The center of the area consists of an interlobate glacial moraine zone with vegetation cover characteristic of the Central Hardwood Forest. The northeast part of the site contains a large, level outwash plain, which consists essentially of agricultural land, while to the southeast, there is a low rolling till plain, containing agriculture mixed with pasture and scattered wood lots.

A preliminary study indicated that of the ERTS data available at the time of the analysis, maximum contrasts in appearance of features of interest, and therefore optimum discrimination,

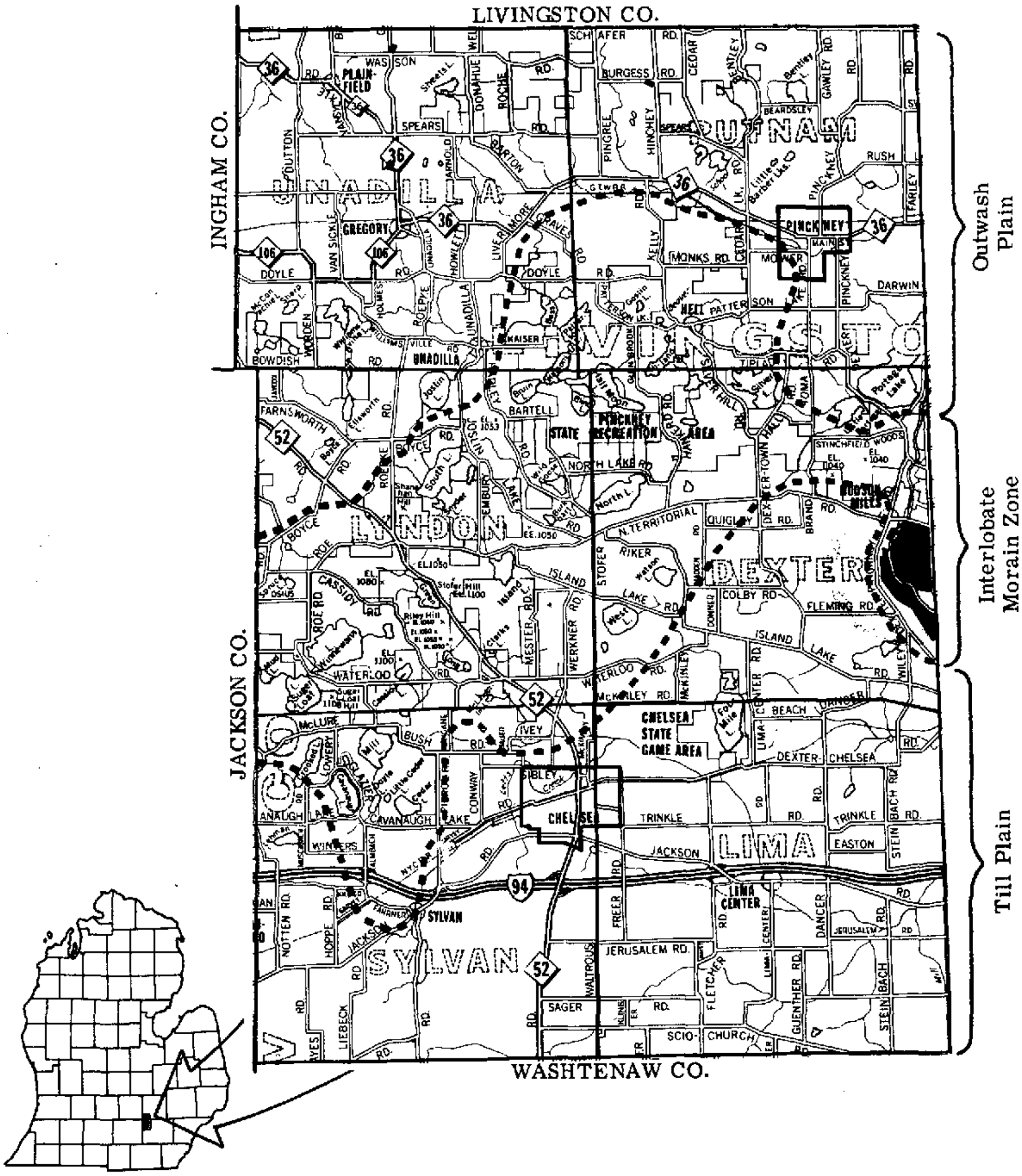


FIGURE 3. LOCATION AND GENERAL PHYSIOGRAPHIC CONDITIONS OF THE WILDLIFE HABITAT TEST SITE

could be obtained by analyzing ERTS data for early spring (Frame 1247-15481, 27 March 1973), and late spring (Frame 1319-15474, 7 June 1973).

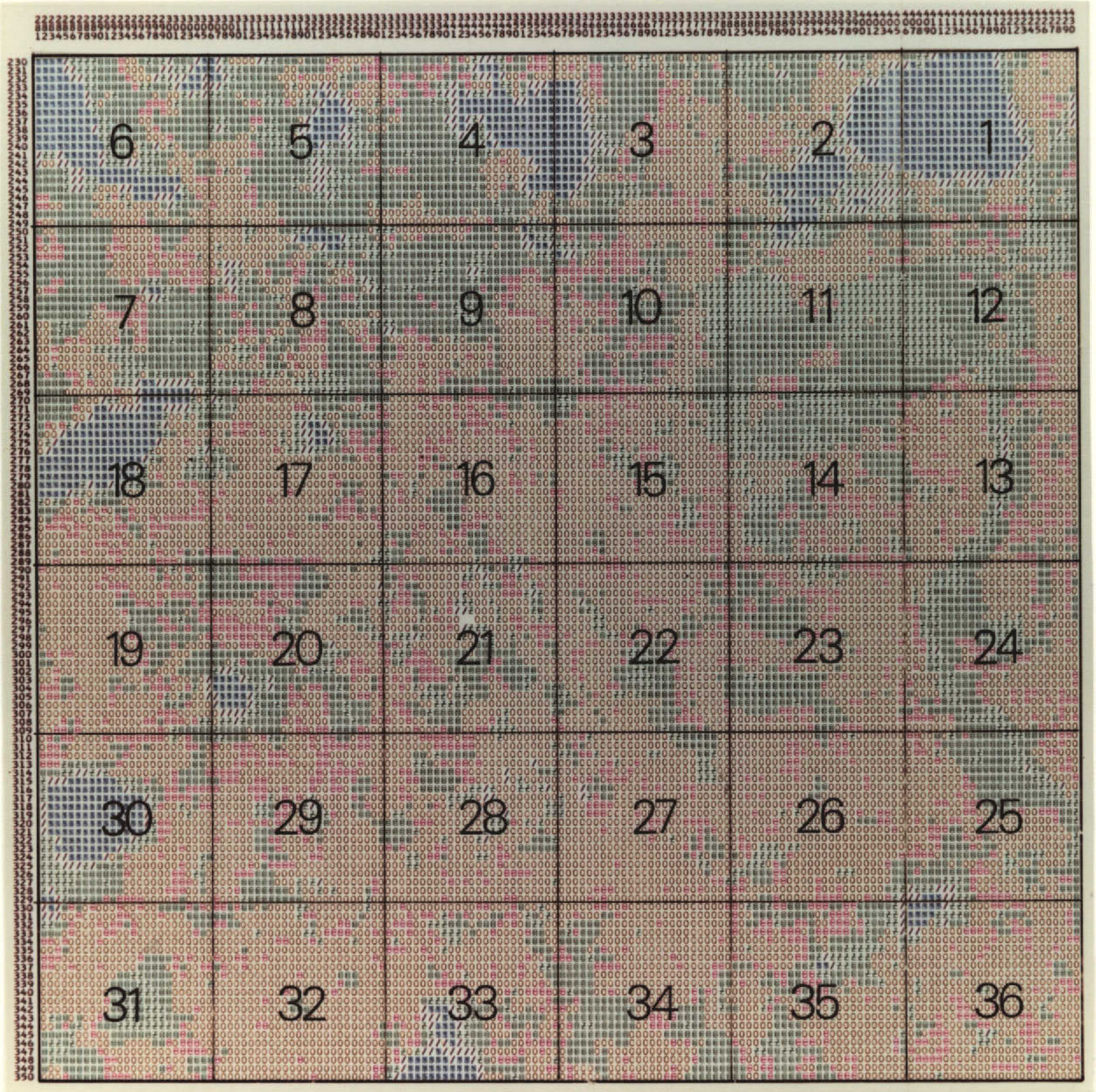
To perform recognition mapping using ERTS data from these two data sets,the digital data for each individual date were rotated, scaled, and transformed so that both data sets had the same line and point numbers designating an identical spot on the ground (within the limits of 1/2 pixel), and the individual digital elements comprising the scene were oriented parallel to a north-south axis. The two data sets were then merged by matching line and point numbers and digitally overlaying them on a new output tape, which now had eight channels of spectral data, four from each of the original dates [4].

Terrain feature classification was then performed using the four of these eight bands which were found to be most effective for the purpose. These four bands were MSS Bands 5 and 7 for each of the two dates. Data from these bands were used as input to an unsupervised clustering operation which provides an unbiased set of spectrally separable training sets. This operation resulted in the identification of 25 such spectrally distinctive signatures. Using these 25 signatures to train the classifier, terrain feature recognition processing was then performed for the entire study site using a modified maximum-likelihood ratio classification algorithm. The actual vegetation cover type or other terrain feature associated with each of the cluster signatures was identified by comparing the resulting recognition map with high-altitude aerial photography. Table 4 summarizes the cover types identified by this means. In some cases, more than one vegetation cover type or other terrain feature was associated with a given cluster signature. On the other hand, many of the other clusters which were recognized actually represent various conditions of the same basic vegetation cover type or land use class (see Figure 4a).

3.1.2 ACCURACY EVALUATION

In the accuracy evaluation seven areas were analyzed representing a 4 percent sample of the study site. The analysis was performed by comparing the recognition map with high-altitude photography. Table 5 summarizes the results of this analysis in percentage form and Table 6 presents an overall mapping accuracy estimate.

An examination of the results of this error analysis indicates the following causes for some of the deficiencies in the recognition mapping performance. Only half the urban land use area was correctly identified by the computer, much of the error resulting from classifying urban as agriculture. The omission represents the largest error of this type associated with any of the categories for which mapping was attempted. The primary reason for this marginal performance was that the definition of the urban class is based largely on function rather than terrain cover.



a) Digital Cover Type Map, Showing Numbers of Sections of Township

SYMBOL	COVER TYPE/LAND USE
0 (Brown)	Agriculture
θ (Red)	Brush
Ө (Green)	Upland Hardwood Forest
Ƶ (Green)	Conifer Forest/Shrub Swamp
/ (Black)	Other Wetlands
¤ (Blue)	Water

FIGURE 4. DEER HABITAT DIGITAL COVER TYPE MAP AND LOCAL HABITAT QUALITY ASSESSMENT, DEXTER TOWNSHIP

b) High Altitude Photograph (11 August 1973)

Outwash Plain

Interlobate Moraine Zone

Till Plain

38	41	33	69	65	24
72	78	45	45	3	22
52	49	72	68	87	93
78	75	98	71	86	72
31	83	57	31	31	83
64	3	92	90	67	48

c) Habitat Quality Ratings

FIGURE 4. DEER HABITAT DIGITAL COVER TYPE MAP AND LOCAL HABITAT QUALITY ASSESSMENT, DEXTER TOWNSHIP .(Concluded)

TABLE 4. COVER TYPE DESCRIPTIONS OF SPECTRALLY SEPARABLE CLUSTERS OF SCENE ELEMENTS

CLUSTER NUMBER	COVER TYPE(S)
14	Urban-residential/<60% herbaceous ground in pasture or old fields
1	Bare soil/urban/gravel or concrete roads
7	Bare sandy soil
4, 5, 6, 18	Agricultural fields; characterized by various combinations of different soil types and crop stubble
2, 21	Flooded or low areas in agricultural fields
9, 17	Idle and old fields/pasture
11	Woody brush or 10-45% crown closure of old field reforestation
22	Upland coniferous forest, >40% crown closure
3	Upland hardwood forest, >80% crown closure
25	Upland hardwood forest, 45-80% crown closure
24	Wooded swamp/shrub swamp
8, 10, 12, 13, 15	Shrub swamp; characterized by various combinations of shrub density and different degrees of spring flooding
16, 23	Shallow marsh; 2 basic classes of vegetation density
20	Deep marsh
19	Water

TABLE 5. ACCURACY ANALYSIS (%) OF TEMPORAL-SPECTRAL RECOGNITION PERFORMANCE FOR LAND USE AND WILDLIFE COVER TYPE MAPPING IN SOUTHERN MICHIGAN

GROUND TRUTH

CLASSIFICATION RESULTS		Urban	Agri-culture	Brush	Forest		Wetlands			Water	Percent Commission Errors	
LEVEL I LAND USE / WILDLAND COVER TYPES					Upland Hardwoods	Upland Conifers	Shrub Swamp	Shallow Marsh	Deep Marsh		Level I	Wildland
Cover Type	Cluster											
Urban/ Residential	14	51	3	2	1		1				27	
Active Agriculture (including Pasture & Old Fields)	1, 2, 4, 5, 6, 7, 9, 17, 18, 21	38	84	13	1		<1	7			18	
Brush	11	4	5	73	1						19	
Upland Hardwood Forest	3, 25	6	3	5	93	7	1				7	10
Upland Conifer Forest	22				<1	92	1					3
Shrub Swamp	8, 10, 12 13, 15, 24	1	5	7	4	1	96	27	5		19	26
Shallow Marsh	16, 23						1	66				8
Deep Marsh	20								95			0
Water	19									100	0	
Percent Omission Errors (Incorrect Identifications) — Level I		49	16	27	6		4			0		
Percent Omission Errors (Incorrect Identifications) — Wildland					7	8	4	34	5			

SUMMARY OF CORRECT IDENTIFICATIONS

	Urban	Agri-culture	Brush	Upland Hardwoods	Upland Conifers	Shrub Swamp	Shallow Marsh	Deep Marsh	Water
Level I Land Use: % Correct Identification Totals	51	84	73	94		96			100
Wildland Cover Type: % Correct Identification Totals	51	84	73	93	92	96	66	95	100

TABLE 6. OVERALL CORRECT SCENE IDENTIFICATION OF MULTIDATE RECOGNITION MAPPING IN SOUTHERN MICHIGAN

Land Use Categories	Including Urban Category	Excluding Urban Category
Average of class correct identification performance	83	89
Percent scene correctly recognized	86	90
Wildland Cover Types		
Average of class correct identification performance	83	87
Percent scene correctly recognized	85	88

A simple and practical method of improving the urban classification is to enter the urban class into the computer manually rather than automatically.

In the agricultural land use class, the omission errors were fairly minor. In the recognition of brush, there is very little commission error, but omission errors are quite sizable, since very sparse and very heavy brush tend to be classified as old field or forest, respectively. Nonetheless, recognition results obtained for this category should have adequate statistical accuracy to recognize those areas of most value as deer habitat and should thus be adequate for assessing the importance of this cover type's contribution to the quality of wildlife habitat. Finally, there is a substantial omission error associated with shallow marsh; more than 1/4 of this cover type is misclassified as shrub swamp. Presumably, because of the early dates of coverage used here, the shallow marsh vegetation had not developed sufficiently to permit its separation from shrub foliage of the swamps.

To summarize different vegetative cover types may be confused with each other because the combination of plant reflectance, percent ground cover, and plant structure may result in similar spectral signatures at the two dates chosen. Thus, although it is possible to optimize the recognition of certain cover types or land use classes through the judicious selection of scene dates, the availability of only two scene dates precludes optimum classification results for many classes normally of interest for this application. Therefore, a decision must be made to select dates which favor the discrimination of those classes considered of greatest significance for habitat assessment.

3.2 DEER HABITAT ASSESSMENT

To demonstrate habitat assessment techniques based on the use of ERTS data, 69 one-square-mile sections in two townships (Unadilla and Dexter), which covered three different physiographic areas, were selected for detailed analysis.

The carrying capacity of a given unit area of habitat depends on having the right proportion and arrangement of essential food and cover requirements within the daily activity radius of the wildlife species under study. As a result, generally-accepted techniques for habitat assessment are based on the measurement and evaluation of three characteristics of the environment.

The first variable which measures habitat suitability is the relative abundance of certain essential habitat components, primarily vegetative cover types, and is collectively termed <u>food and cover</u> (FC). For deer habitat, an optimum mix of cover types per unit of land in Southern Michigan consists of 15 percent agriculture (including old fields), 35 percent brush, 35 percent upland hardwood forest, and 15 percent conifers, lowland forest or shrubby wetlands. A scoring system was used to determine the degree to which the relative abundance of these important cover types in each one-square-mile section of the two townships approached this optimum mix.

The second variable of major importance is the degree of interspersion of the habitat's food and cover components in relation to the species' mobility characteristics. To measure interspersion (INT), the total amount of edge tabulated for each of the key cover types was divided by the area for that type, and the ratios for all of the cover types were added together to form a single value for each section.

The third variable is the degree of juxtaposition of "desirable edge" present. Good juxtaposition provides animals with access to essential cover types across short distances. To quantify juxtaposition (JUX), the amount of edge associated with each of the 6 possible combinations of the 4 key cover types was multiplied by a "desirability factor" and the resulting score for each edge combination added up to form a summary statistic for this habitat characteristic.

The computed values of the three variables for each section were then combined in an equation to represent the relative deer habitat quality rating of the section. This equation was of the form:

$$\text{Deer Habitat Quality Rating} = k_1 FC(k_2 \text{ INT} + k_3 \text{ JUX})$$

where k_1, k_2, k_3, are constants which tend to eliminate redundancy in the information derived from the ERTS data for each of the variables, FC, INT, and JUX.

The computed values of habitat quality were then adjusted from their absolute form, so that the ratings now vary from 0 to 100 in the 69-section study area. The relative nature of the ratings can thus be interpreted more easily. Figure 4(b) shows deer habitat quality ratings for Dexter Township.

The mean value and standard deviation of the ratings is shown in Table 7 for each of the three physiographic divisions in this township. The generally poorer ratings on the outwash plain are a reflection of the preponderance of agriculture in this area. The improved ratings typically found in the moraine zone are a result of the greater abundance of upland hardwood forest and a better mixing of desirable cover types. It should be pointed out, however, that the standard deviation of the ratings for this physiographic area is also greater, reflecting the greater degree of local variation of habitat quality in the region. Overall, the ratings of the till plain are the highest, presumably because of an optimal mix of natural groupings of favorable wildland cover types which are in turn well interspersed with a substantial amount of agriculture. Again, a fairly large standard deviation indicates quite a bit of local variation.

Analysis of the ratings of individual sections indicates that the arbitrary placement of the sampling grid to coincide with individual township sections may introduce a bias into the ratings of individual sections. The rating of the individual section may then be out of line with those of

TABLE 7. SUMMARY OF DEER HABITAT QUALITY RATING STATISTICS FOR THE MAJOR PHYSIOGRAPHIC DIVISIONS OF THE STUDY AREA

Physiographic Division	Mean ($\bar{x}$)	Standard Deviation (σ)
Outwash Plain (30 sections)	53	17
Interlobate Moraine Zone (26 sections)	57	24
Till Plain (13 sections)	64	28

adjacent sections, even though the resources of the sections are similar. This bias is not unique to ERTS data, but is typical of any method which uses a sampling grid. Refinements of the rating determination should be considered to eliminate this bias. One possibility would be a method which averages a weighted combination of the ratings for a block of sampling units and assigns the resulting average value to the central unit.

3.3 WATERFOWL HABITAT ASSESSMENT

The wetlands classification system devised by Golet and Larson [5] for use in mapping freshwater wetlands in the glaciated northeastern U.S. uses a system of classes and subclasses. The primary stratification of wetlands at the class level is similar to the freshwater types outlined by Martin et al. [6] and used in the last national wetlands survey in 1955 [7]. To characterize wetlands at the class level, it employs five basic structural life forms (trees, shrubs, emergents, surface vegetation, and submergents) and the depth of and degree of fluctuation of surface water during the growing season. The subform distinctions are primarily useful for characterizing special differences in ecology and stand density within a life form.

ERTS has an important role to play in large area waterfowl habitat assessment because it has been shown in this investigation to be capable of mapping all of those wetlands which appear to have moderate to high value in Michigan. Waterfowl, like deer, require a daily and seasonal mix of different structural types of vegetation, and so are sensitive to the presence and length of certain types of edge in their habitat. Therefore, the same conceptual approach used to assess the habitat of deer was used, with suitable modifications, for assessment of waterfowl habitat.

The study site selected for this phase of the investigation was composed of part of Unadilla Township and all of Lyndon Township, just to the south. Lyndon Township contains at least one sizable area of managed waterfowl habitat. The categories of the remote sensing experiment recognition results were combined to produce the six basic components of the landscape that are relevant to an analysis of waterfowl habitat in this region: open water, deep marsh, shallow marsh, shrub swamp, agriculture, and other (including forest).

To determine the value of FC, the food and cover requirements variable for waterfowl, a system was developed which applied a weighting factor to each type of cover component in accordance with the estimated relative value of each of these habitat components. The interspersion variable, INT, and the juxtaposition variable, JUX, were calculated in the same fashion as for deer habitat. In this case, weighting scales were modified to reflect the importance of those different combinations of cover type boundaries appropriate to waterfowl requirements. The four habitat components for which these variables were calculated are the four wetland classes: open water, deep marsh, shallow marsh, and shrub swamp.

Using the individual values of these variables for each section, the waterfowl habitat quality rating was developed in the same manner as for deer habitat, and ratings were again normalized to range from 0 to 100. Table 8 summarizes the ratings for the three physiographic divisions of the study area. Habitat ratings for the entire outwash plain, derived by the methods previously discussed, are generally low, because the right variety and relative abundances of desirable cover types occur only in a few sections. In the interlobate moraine zone, wetlands are generally more abundant, leading to a higher mean rating, but the larger standard deviation indicates that they are by no means evenly distributed.

The demonstrated method of habitat rating through computer analysis also provides a simple and straightforward means of evaluating the status of local wetland habitat condition. The same procedures used for habitat rating can also be applied by the resource manager for the purpose of determining how to go about upgrading the recreational opportunities on these facilities through a program of additional habitat acquisition and existing habitat improvement. This could be done by examining the values of FC, INT, and JUX for the individual sections in the area under consideration. These values will suggest the appropriate remedial action to be taken, such as increasing the amount of a certain type of edge, or the total amount of wetland edge. As an aid in performing this type of very local analysis, an ERIM software package already exists which permits the determination of the number, location, and size class distribution of classified recognition results [8, 9].

3.4 COMPARISON OF WETLAND INVENTORY TECHNIQUE

In order to provide the manager or land-use planner with an objective means of determining which approach to wetlands inventory using ERTS data would best fulfill his information requirements, several alternative MSS digital data processing techniques were investigated. The four approaches were:

(1) Level slicing of Band 7 for the single best available date for wetland mapping (27 March 1973);

(2) Level slicing of an edited red channel (Band 5) for the single best available date for wetlands mapping (27 March 1973);

(3) Maximum likelihood ratio (MLR) processing for the single best available date (27 March 1973); and

(4) Maximum likelihood ratio (MLR) recognition processing of a combination of the two best available dates (27 March 1973 and 7 June 1973).

The results of using these techniques to inventory Lyndon Township are shown in Table 9.

TABLE 8. SUMMARY OF WATERFOWL HABITAT QUALITY RATINGS FOR THE MAJOR PHYSIOGRAPHIC DIVISIONS OF THE STUDY AREA

Physiographic Division	Mean ($\bar{x}$)	Standard Deviation (σ)
Outwash Plain (37 sections)	12	14
Interlobate Moraine Zone (32 sections)	29	23
Interface Between These Two Areas (16 sections)	15	18

TABLE 9. PERFORMANCE AND SURVEY COSTS OF 4 MSS WETLAND INVENTORY TECHNIQUES APPLIED TO ERTS DATA

Mapping Technique \ Performance	Error in estimating percent relative abundance of wetlands in scene.*	Percent water correctly identified	Percent marsh correctly identified	Percent swamp correctly identified	Percent overall correct recognition: Average of 3 classes	Percent overall correct recognition: Total Scene	Survey Cost $/sq km	Survey Cost $/sq mi	Comments
Single Band Level Slicing of Near IR Data	+40%	83	37	70	63	72	0.70	1.81	Much marsh missed, some called water; some swamp called marsh; much lowland forest called swamp.
Level Slicing of a Red Band Edited Using a Near IR Channel	+9%	91	60	71	74	78	0.90	2.34	Some water called marsh. Considerable marsh missed, much lowland forest called swamp.
Single Date MLR Processing	+5%	91	68	82	80	84	1.60	4.15	Some water called marsh, considerable marsh missed. Some lowlands forest called swamp.
MLR Processing of Temporal Data	-4%	100	75	96	91	96	2.60	6.73	Moderate amount of marsh missed.

*Positive error indicates overestimates of relative abundance.

Table 9 also includes estimates of the cost of processing ERTS data by each of the four methods. The costs include representative allowances for overhead expenses, but data acquisition costs are limited to the purchase of ERTS magnetic tapes. The estimates are based on our experience with processing techniques and procedures presently in use and are thus believed to be on the conservative side. Substantial reductions in cost should be possible in the future, as fully operational performance is achieved through additional experience and advanced technology. Additional details on processing and mapping costs are presented in Section 4.7.

The decision of whether to choose single or multi-date data processing must be based on a consideration of the ultimate usage of the recognition results and the accuracies required to fulfill that usage. This need for accuracy must also be balanced against the extra cost in manpower and processing time required for multi-date analysis. Examination of Table 9 indicates that MLR single date processing of the best available single date probably represents the best all-around approach to the task of conducting cost-effective large area wetland inventory surveys. However, if class accuracy identification is of paramount importance, MLR processing of temporal data is clearly the best choice of the available techniques.

4
APPLICATIONS FOR RECREATION LAND ANALYSIS

The results obtained in this investigation as well as those of other ERTS investigators indicate that ERTS data can be used for a number of functions related to the analysis of recreational land and open space. Specific applications discussed below may either use ERTS data directly in special studies or take advantage of a multi-purpose computer-based data bank which incorporates ERTS data and data from other sources.

4.1 REGIONAL SURVEYS

During the early phases of regional surveys of recreation potential, major emphasis is placed on obtaining gross data on recreational land supply for comparison with present and projected recreation demand. This requires the identification of those sites which have desirable physical characteristics for development, with special emphasis on soils, topography, vegetation, and water resources. Many of these physical factors can be observed by remote sensing methods. To identify the supply of sites for such purposes as parks, camping, picnicking, boating, and swimming, rather general criteria can be applied (see Table 10). Some field work should be conducted to confirm or improve the preliminary evaluation made from remote sensing coverage.

TABLE 10. SOUTHEAST MICHIGAN RECREATION LAND SURVEY SITE EVALUATION CRITERIA [10]

	Max. Score**
* Land Area	25
* Lake Surface Area	25
* River and Stream Size	15
* Waterfront Length Along Lake	25
* Miles of River or Stream	25
Relief	15
* Vegetative Cover	20
Accessibility	10
* Threat of Adverse Land-Use Changes	20
Environmental Intrusions	10
Unique Features	15
Aesthetics	10

*Observable from ERTS data.

**See Ref. 10 for definition of scores.

ERTS data would have adequate resolution for this purpose and would have the added potential for automatic rating of suitable sites. It has the additional advantage of providing more up-to-date information than is likely to be available from photography, and thus ensures better accuracy and facilitates frequent updating of survey results.

Recreational site evaluation requires consideration of a number of factors not directly observable by ERTS. For final site selection, the mapping of potential recreational areas from ERTS data should be combined with information on soils, topography, population distribution and income levels, transportation networks, land ownership, and use of adjacent land. This additional information, provided from sources other than remote sensing, could be prepared in the form of map overlays or, for automatic analysis, could be incorporated into the computer data base on the same geographic grid as the ERTS-derived data.

4.2 DELINEATION OF OPEN SPACE

A significant application of ERTS data is to delineate open space in a rapidly urbanizing area as an important indicator of environmental quality. Continuous monitoring of ERTS data can be used to determine the rate and direction of urbanization as it affects the availability of open space. This information expressed in quantitative form should serve to stimulate action to preserve areas needed to maintain environmental quality or to provide recreational opportunities.

This application requires methods of defining the rural/urban boundary in a metropolitan area and relating open space to signatures of vegetation and other surface types. Techniques for defining the boundary can be based on the classification of urban areas discussed in Section

2.4.4. The identification of open space exclusively from ERTS may be subject to some error, particularly in distinguishing urban areas with substantial vegetative cover from space without residential development. However, once an inventory of potential recreation sites and delineation of open space has been completed, it can be updated frequently through the analysis of ERTS imagery collected sequentially in time.

4.3 SITE DEVELOPMENT

In some cases, ERTS data may be useful in the early stages of recreation site planning. For geographically extensive sites, such as scenic trails, abandoned railroad right-of-way, wild or scenic rivers, long shorelines, and large park areas, preliminary layouts of route structures roads, services, impoundments, etc., might be made. Any detailed planning of such facilities, however, would require the acquisition and study of aerial photography.

4.4 MONITORING ENVIRONMENTAL CONDITIONS

ERTS data may be used for a number of purposes in continued monitoring of environmental conditions for large recreational sites. Such purposes include the monitoring of water pollution, sedimentation and eutrophication of sizable bodies of water, urban encroachment, detection of damage to forests through disease, insects, drought, or fire, and observation of sucessional changes of vegetation.

4.5 WILDLIFE HABITAT ASSESSMENT AND MANAGEMENT

ERTS data lends itself to the identification, assessment, and improvement of suitable deer habitat through the mapping of the relative abundance and arrangement of significant food and cover types. Management of deer habitat could be assisted through continuous monitoring to note changes in urban, agricultural, or forest land use, plant successional changes, and burning or cutting of forests. Similarly, waterfowl habitat preservation and management requires data on wetland types, size, and distribution, adjacent land use, and availability of surface water. Practical procedures have now been developed for analyzing ERTS data to arrive at quantitative measures of habitat quality (see Section 3 and Reference 9).

4.6 OTHER APPLICATIONS

The techniques developed under this project will also find many applications beyond those of recreational land analysis.

The development of public policies for land management is placing increasing emphasis on measures which assure the assignment of land to its best use. The use of ERTS data, in combination with information from other sources, for recreational land analysis is one of the tools which can contribute to this major goal. The methods discussed in this report are also applicable, with appropriate modification, for evaluating the suitability of land for many other uses, as well.

Land use and natural resource inventories provide the data base needed for many other specific purposes, such as highway or power line corridor selection, forest mapping, and hydrologic studies.

4.7 COST COMPARISON

As one measure of the potential advantage of ERTS data, we can compare the costs of providing land use and land cover maps from ERTS data with the costs of accomplishing the same function from high-altitude or low-altitude aircraft.

It would be desirable to compare the cost of two alternatives for providing identical products. However, this is not a practical procedure, since the most effective use of each alternative will produce substantially different products. Photointerpretation of aerial photography will produce a result with substantially higher resolution than can be obtained with ERTS data. ERTS data, on the other hand, provides time-synchronous coverage of large areas in a single frame. The coverage is repeated at frequent intervals, so that up-to-date information is always available and dynamic changes can be observed. We will therefore confine this discussion to a comparison of the two methods in producing somewhat different products and leave it to the user to take account of the differences in the products.

The specific comparison given here is between the following two products:

- Photointerpretation of aerial photography and preparation of a land use and land cover map in 4-hectare cells.

- Computer-processing of ERTS data to produce a computer-printed land use and land cover map in units of 0.5 hectare.

Cost data on the first alternative, based on a mapping project for the Upper Kalamazoo Watershed, is summarized in Table 11 [11].

In this project an area of about 2600 sq km (1000 sq mi) was mapped using a classification system with 18 categories of land use and land cover and a minimum type size of 4 hectares. The data source for this map was color-infrared photography at scales of 1:60,000 and 1:120,000 obtained by the NASA RB-57 aircraft.

The Kalamazoo project resulted in a total interpretation and mapping cost of $2.13 per sq km ($5.54 per sq mi). Of this total cost, $1.68 per sq km represents supervision, photointerpretation, ground truth collection, mapping, and clerical work. The remainder includes the cost of photographic products, equipment use, and materials and supplies. The total manpower cited for the work consists of 0.015 hr per sq km for supervision and

TABLE 11. COST DATA FOR UPPER KALAMAZOO WATERSHED STUDY*

Item	Man-hours	Cost	Cost/sq km
Project Planning	40	$ 345	$ .13
Photo Products		802	.31
Photointerpretation Equipment Use		708	.27
Photointerpretation	620	2,325	.90
Field Survey	35	114	.04
Field Survey Equipment Use		15	.01
Mapping Equipment Use and Supplies		332	.13
Mapping	100	898	.34
TOTAL	795	$5,539	$2.13**

*Data acquisition and overhead costs not included.

**$5.54 per square mile.

coordination, and 0.290 hr per sq km for technical work. It should be noted that costs for photointerpretation, ground truth collection, and mapping personnel are based on graduate student wage rates. These rates are substantially below the going market rate for full-time professional personnel. The full rates would probably double these cost items. Data acquisition and overhead charges have been excluded from the costs in Table 11. Collection of color IR aerial photography would add at least $1.00 per sq km ($2.59 per sq mi) to these costs.

These figures can be compared with the cost of producing a computer-processed ERTS map. The processing would consist of combined edited level slicing and ratio processing of data for a single date resulting in a map showing 12 categories [12]. The complexity of this type of processing is assumed to be comparable with the level slicing of a red band edited by the use of a near-infrared channel, which was discussed in Section 3.4 as one type of processing. The costs in Table 12 are therefore consistent with those of Table 9 ($0.90 per sq km), except that overhead costs have been excluded in Table 12, since they are not relevant to the present analysis. The estimates thus cover only costs for personnel, materials and supplies, and equipment use. Data acquisition costs include only the purchase of the magnetic tape ($50 per tape). The estimates cover the preparation of computer printouts, photographic reproductions, summary statistics and an accompanying report. Special modelling or computer analysis is not included, and would involve additional cost.

The cost comparison for 2600 sq km indicates that land use and land cover maps prepared from high-altitude aerial photography would cost $2.13 per sq km ($5.54 per sq mi) while the computer maps prepared for the same area from ERTS data would cost $1.63 per sq km ($4.25 per sq mi). The cost advantage in favor of ERTS substantially increases for larger areas. If a map were made of the area covered by one quarter of an ERTS frame (8258 sq km or 3190 sq mi), the resulting map would cost about $0.51 per sq km ($1.33 sq mi). If the processing were extended to a full ERTS frame, these units costs would be reduced further by nearly 50 percent.

Maximum likelihood ratio processing is at present a more complex procedure than level slicing or ratio processing. Use of this procedure may increase mapping costs per sq km by 75 percent over the simpler processing methods, but is able to produce more detailed land inventories. The cost of maximum-likelihood ratio processing can be reduced if special-purpose processing equipment is used. A system utilizing such equipment is presently under development at the Environmental Research Institute of Michigan [13]. The system greatly reduces the time and cost of ERTS data analysis by achieving very high data rates and facilitating the interaction between operator and machine needed for rapid and efficient operation. Accurate estimates of processing costs are not available at the present time, but it is believed that the cost of maximum likelihood processing would become approximately equal to level slicing or ratio processing.

TABLE 12. ESTIMATED COST DATA FOR ERTS-1 PROCESSING

ITEM	COSTS: 1/4 ERTS Frame (8258 sq km, 3190 sq mi)	COSTS: Complete ERTS Frame (33030 sq km, 12758 sq mi)
Project planning	$ 200	$ 400
Interpretation and analysis	800	1,600
Computer personnel	700	1,900
Computer use charge	500	1,400
Field survey	700	950
Travel	350	450
Clerical	200	325
Photo products	150	600
Materials and supplies	150	550
Report preparation	500	700
TOTAL	$4,250	$8,875
Cost of processing total area	$0.51 per sq km ($1.33 per sq mi)	$0.27 per sq km ($0.70 per sq mi)
Cost of processing 2600 sq km area (1000 sq mi)	$1.63 per sq km ($4.25 per sq mi)	

NOTES: 1. Data acquisition and overhead costs not included in above figures.

2. These costs are for processing based on edited level slicing or ratio processing methods.

This cost comparison data should be used only for rough comparison purposes, since available data do not permit precise evaluation of cost components. However, the data indicate that even at the present limited state of development, ERTS processing would be less expensive for comparable results than methods of manual photointerpretation. Moreover the cost advantage in favor of ERTS is even greater for mapping large areas. Anticipated improvements resulting from additional experience and further techniques and equipment development will increase this advantage further.

5
CONCLUSIONS AND RECOMMENDATIONS

This investigation has shown that a number of applications of ERTS technology to problems in recreation land analysis are both technically and economically feasible. The advantages of economy, timeliness, and accuracy of data analysis are enhanced by the use of automatic classification methods.

5.1 ADVANTAGES OF AUTOMATIC CLASSIFICATION

As compared with photointerpretation of ERTS imagery, automatic classification exhibits capabilities which make it useful for analysis of recreational land and open space.

1. Because of their quantitative nature, the data can be processed to distinguish a large number of separable classes. This processing provides the maximum available information on the type of surface cover.

2. Automatic processing allows the analysis of individual pixels, so that the identification process can be applied at the highest available resolution.

3. Information presented in digital map form can be more easily interpreted than raw photography.

4. Alternatively, if data on geographic cells of greater extent are to be recorded, the aggregated data on each cell will provide more information than a gross identification of the character of the cell.

5. The data are in computer-compatible form, so that they can be merged with other computer-based data for a variety of analyses. Specifically, the computer-based data bank permits the use of automatic methods of site identification and evaluation, based on size and juxtaposition of types of surface cover, location with respect to transportation and urban centers, etc.

5.2 EDITED LEVEL SLICING

For studies which require a limited number of land use and land cover categories, the use of edited level slicing is a rapid and economical method for computer processing of ERTS data. It is believed that maps prepared by this method would be adequate for certain preliminary studies of such geographically extensive sites as river valleys or scenic trail routes, and for wildlife habitat assessment.

5.3 MAXIMUM LIKELIHOOD RATIO PROCESSING

Maximum likelihood ratio processing is at present a more complex procedure than level slicing or ratio processing. It may increase mapping costs per sq km by 75 percent over the simpler processing methods, but is able to produce more detailed land inventories. Equipment presently being developed under another program [13] promises to substantially reduce the time and cost of maximum likelihood processing, making it more competitive with the simpler method. Processing of combined data for two or more dates substantially increases the ability to discriminate various cover types and land use categories, but requires further development of rapid and efficient methods of registering digital data from more than one ERTS frame accurately.

5.4 GENERAL LAND USE MAPPING

Generalized land use maps were prepared for a 185 sq km area in Oakland County using a single ERTS frame acquired in September, 1972. A four-category map was prepared using edited level slicing and a 13 category map was prepared using maximum likelihood ratio processing. An accuracy check indicated that four major categories of land use (water, urban, forest, and other vegetation) were mapped with 92 percent of the pixels correctly identified.

Experience under other studies [12, 14] indicates that some methods of processing ERTS data not tried in this project (e.g., ratio processing) may have advantages under certain conditions or for certain types of terrain surface. Decisions on the most appropriate method of ERTS data processing for a particular situation should take these other options into consideration.

5.5 MAPPING COST COMPARISON

Estimates of the cost of computer-processing of ERTS data under various conditions have been prepared. Excluding all ERTS data acquisition costs except purchase of magnetic tapes, and including typical overhead charges, the cost of mapping 1/4 ERTS frame (8258 sq km or 3190 sq mi) would range from $0.70 per sq km ($1.81 per sq mi) for level slicing of a single near-infrared band to $2.60 per sq km ($6.73 per sq mi) for maximum likelihood ratio processing of temporal data.

A comparison of costs (excluding data acquisition and overhead) was made between using high-altitude color infrared photography obtained by the NASA RB-57 aircraft to produce an 18-category map and ratio processing of ERTS data to produce a 12-category map. Costs of mapping a 2600 sq km area would amount to \$2.13 per sq km (\$5.54 per sq mi) for aerial photography and \$1.63 per sq km (\$4.25 per sq mi) using edited level slicing and ratio processing of ERTS data for a single date. If the mapped area increases to that of a full ERTS frame, the cost of aerial photography per unit area would remain approximately constant while that of ERTS data would fall to \$0.27 per sq km (\$0.70 per sq mi).

5.6 WILDLIFE HABITAT ASSESSMENT

Procedures were demonstrated which used ERTS processing results for modelling both deer habitat and waterfowl habitat to derive habitat quality ratings. These procedures used quantified measures of three important variables for habitat assessment: (1) relative abundance of key cover types, (2) interspersion of these cover types and (3) juxtaposition of favorable combinations of cover types. These variables were used to compute a relative rating value for habitat quality of individual one-square-mile sections of a 69 sq mi (180 sq km) test area in Washtenaw and Livingston Counties. The demonstrated procedures are merely illustrative of an effective approach to habitat modelling. Continuing research is needed to achieve an improved correlation between remote sensing data and variables which represent the quality of wildlife habitat.

Habitat modelling procedures can be used for such purposes as monitoring trends in total wildlife habitat available, identifying suitable sites for public acquisition or preservation and developing plans for improving the quality of existing habitat.

5.7 WETLAND INVENTORY

The necessary data base for waterfowl habitat assessment can be provided through large-scale wetland inventory projects covering individual states or multi-state regions. To determine suitable methods of performing wetland inventory, four different mapping techniques were used to map surface water, marsh, and swamp. The best performance was obtained by using maximum likelihood ratio processing of ERTS data for two dates (27 March 1973 and 7 June 1973). The resulting accuracies were 100 percent for water, 75 percent for marsh, and 96 percent for swamp. The proper choice of method depends on the objectives of the inventory. A good compromise between accuracy and cost may be obtained by the use of MLR processing for the best single date. The detail and accuracy of information obtained by wildlife habitat mapping could be further increased through the use of multi-stage mapping methods combining ERTS data for an entire area with higher resolution photography or airborne multispectral scanner data for sample areas selected from the examination of ERTS data.

5.8 APPLICATIONS

Certain processing and analysis methods of ERTS data are considered ready for operational use in recreational land analysis. Specifically, several methods of processing single-date ERTS data are well-developed and provide acceptable accuracies for many purposes. Government agencies with responsibilities in these areas should consider incorporating such operational uses in their current activities.

Specific applications to the analysis of recreational land and open space listed below may either use ERTS data directly in special studies or take advantage of a multi-purpose computer-based data bank which combines ERTS data and data from other sources:

Regional surveys of sites with recreational potential
Delineation of rural/urban boundaries and open space
Preliminary steps in site planning
Monitoring environmental conditions (e.g., water quality, forest damage, and successional changes in vegetation)
Wildlife habitat assessment, improvement, and management

This report has necessarily been limited to presenting the basic approach to these applications. In order to realize the full potential of ERTS imagery, however, each application will require further definition of information requirements and special adaptation of computer processing methods. With sufficient training and experience, recreation planning and management personnel should be able to assign an important role to ERTS technology in the development and management of the nation's recreational resources.

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