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MICHIGAN RESOURCE INVENTORIES: CHARACTERISTICS AND COSTS OF SELECTED PROJECTS USING HIGH ALTITUDE COLOR INFRARED IMAGERY*

William R. Enslin and Richard Hill-Rowley

Remote Sensing Project
Michigan State University
East Lansing, Michigan 48824

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ABSTRACT

The procedures and costs associated with mapping land cover/use and forest resources from high altitude color infrared (CIR) imagery are documented through an evaluation of several inventory efforts. CIR photos (1:36,000) were used to classify the forests of Mason County, Michigan into six species groups, three stocking levels, and three maturity classes at a cost of $4.58/sq. km. The forest data allow the "pinpointing" of marketable concentrations of selected timber types, and facilitate the establishment of new forest management cooperatives. Land cover/use maps and area tabulations were prepared from small-scale CIR photography at a cost of $4.28/sq. km. and $3.03/sq. km. to support regional planning programs of two Michigan agencies. Procedures were also developed to facilitate analysis of this data with other natural resource information. Eleven thematic maps were generated for Windsor Township, Michigan at a cost of $1,500 by integrating grid-geocoded land cover/use, soils, topographic, and well log data using an analytical computer program.

INTRODUCTION

Michigan State University, with support from the Office of University Affairs of the National Aeronautics and Space Administration (NASA), has been actively involved in the development of operational uses of high altitude color infrared (CIR) photography and other remotely-sensed data for improving management decisions and actions concerning natural resource problems. The camera systems aboard NASA RB-57 and U-2 aircraft have obtained high altitude CIR photography of over 60% of the land area of Michigan since September, 1969. This, or similar photography, has been applied to a broad spectrum of problems that concern state, regional, and local level agencies. These include: (1) highway corridor selection, (2) timber management and utilization, (3) farmland preservation, (4) removal of abandoned vehicles, (5) selecting optimum crop processing plant locations, (6) determining accessible rural water sites for recharging fire truck on-board supply, (7) land appraisal and tax equalization, and (8) regional land use planning. Table 1 lists the inventory characteristics of these applications which have been reported in a series of project publications.[1,2,3,4]

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TABLE I CHARACTERISTICS OF MICHIGAN APPLICATIONS

Application	Agency	Area	Inventory/Year	Imagery Used	Minimum Type/cell	Decision(s) or action(s) to date
Regional Land Use Planning	Soil Conservation Service, U.S.D.A.	Kalamazoo Watershed	22-category land use (1973-74)	1:31,680 to 1:120,000 CIR	4 ha (10 acres)	Recommendations for wildlife and wetlands management
	Southeast Michigan Council of Governments	7 county area in S.E. Mich.	8-category land use (1975)	1:60,000 & 1:120,000 CIR & 1:24,000 Pan	.4 ha (1 acre)	General planning
	Tri-County Regional Planning Commission	Tri-County Area	21-category land use (1976)	1:60,000 & 1:120,000 CIR	4 ha (10 acres)	Input to watershed non-point pollution models
Timber Management & Utilization	Mason Co. Soil Conservation District, West Mich. Reg. Plng. Comm., Packaging Corp. of America	Mason County	6 forest species groups, 3 stocking levels & 3 maturity classes (1974)	1:36,000 CIR	4 ha (10 acres)	Identification of merchantable timber and combining small private holdings into cooperative forest management units
Highway Corridor Selection & Co. Planning	Michigan Dept. of State Highways & Transp. and Traverse Bay Reg. Plng. Comm.	Grand Traverse County	24-category land use & 34-category special environments (1974)	1:36,000 CIR	4 ha (10 acres)	Highway corridor selection and determination of location for an industrial park
Farmland Preservation	Wayne County Plng. Comm.	Wayne County	8-category land use (1974)	1:120,000 CIR	2 ha (5 acres)	Five townships are preserving agricultural lands
Land Appraisal & Tax Equalization	Charlevoix Co. Equalization Department	Islands of Charlevoix County	6-category land cover (1975)	1:120,000 CIR	2 ha (5 acres)	Re-appraised property value and tax assessment
Agri-business Plant Location	Wickes Agriculture	Saginaw Bay Area	Agricultural lands (1973)	1:120,000 CIR, Skylab S190B	4 ha (10 acres)	Selection of crop processing plant location
County Wide Clean-Up of Abandoned Vehicles	Antrim Co. Plng. Dept.	Antrim County	All Abandoned vehicles (1975)	1:36,000 CIR	N/A	Removal of abandoned vehicles and enactment of junk vehicle ordinance
Identification of Rural Water Sites for Recharging Fire Truck Supply	Antrim Co. Plng. Dept. & Fire Dept.	Antrim County	4-waterbody & 5-accessibility parameters (1976)	1:36,000 CIR	.2 ha (½ acre)	Anticipated increase in fire fighting efficiency

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The decisions and actions taken illustrate some of the benefits that have accrued through the application of small-scale CIR aerial photography. Costs associated with providing these benefits are not easily quantified since most of these inventories were accomplished under the NASA grant and detailed cost records on individual projects were not maintained. Limited cost information is, however, available for the forest mapping project, and more complete cost data were recorded for the Kalamazoo and Tri-County land use inventories carried out on a contract basis. Another contract not listed in the table developed a Resource Map Portfolio for Windsor Township using land cover/use information from the Tri-County inventory along with other information gathered mainly from soil surveys. This project provided cost information for grid geocoding of resource information and its subsequent storage and manipulation in a computerized regional information system for analysis and map production. The following discussion describes these applications and documents associated procedures and costs.

APPLICATIONS

Timber Management & Utilization

Over half the forest resources in the eastern United States are in small, privately-owned woodlands. Few of these forest resources are managed or reach the market because of their small size and varied ownership. The mixture of state and federal forest lands with privately-owned woodlands further complicates management and utilization efforts.

The economy of Mason County, Michigan, is heavily dependent on its forest resources. Wood harvesting, processing, and sales make timber-based industries and employment the second most important source of income for the County. Minimum economic operation of a typical mill requires the processing of timber from about 10,121 hectares (25,000 acres) of forested lands each year. The scattered, fragmented nature of the forest holdings in Mason County has made it increasingly difficult for companies and their contractors to locate and gain access to these supplies of harvestable timber in the County. Sixty-seven percent of the woodland acreage is in private ownership for which no data existed on forest type, location, or condition.

Continued adequate procurement of timber was, therefore, crucially dependent on securing reliable information on the location and characteristics of privately-owned forest resources.

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The MSU-NASA Remote Sensing Project was asked to help a group composed of the Mason-Lake Soil Conservation District, the Packaging Corporation of America, and the West Michigan Regional Planning Commission in developing a method for obtaining this essential information. The forest resources of the entire County were inventoried using 1:36,000 CIR aerial photography and the classification system shown in Table 2. Four maps were produced at a scale of 1:25,000 showing forest stands by their location, species composition, stocking, and maturity.

The West Michigan Regional Planning Commission has gridded these photo-derived maps using a four hectare (10 acre) cell matrix, and has encoded the forest data for inclusion in its computer information system.[5] The system facilitates the "pinpointing" of marketable concentrations of selected timber types. For example, tables were recently produced which listed, by township, the location and acreage of merchantable northern hardwoods.

Industrial foresters are now using the maps and computer printouts on a daily basis to direct much of their fieldwork. For example, the Parish Yard of Duz Kirk Enterprises had an immediate demand for oak veneer. Through inspection of the maps and a requested computer printout, company personnel were able to quickly locate a large tract of saw-log size oak. One landowner in this area sold a portion of the stumpage on 24 hectares (60 acres) of his land. This tract was selectively cut producing for the landowner a return of $4,349. Additionally, the forest data is being used in the long-term scheduling of timber procurement as well as for programming the acquisition of new land. According to industrial foresters, the maps have allowed them to accomplish more work, make better use of field forester's time, and has allowed them to reach more private landowners.

Timber could contribute much more to the Mason County economy if management and marketing of both public and private forests were better coordinated. The Mason-Lake Soil Conservation District has launched a pioneer program in cooperative forest management called "Operation Woodchuck" to facilitate this sort of development.[6] Under the program, many small parcels are pooled into cooperative units for the management and marketing of their forest resources; parcels, which if considered separately, would be uneconomical for timber procurement. Two pilot forest management cooperatives, or "Woodchucks", were formulated and established in 1972 and 1973 by a

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MICHIGAN RESOURCE INVENTORIES

TABLE 2 FOREST CATEGORY DEFINITIONS

Species Types

Pine - Forest stands in which eastern white pine, red pine, jack pine, or introduced pines, singly or in combination, comprise 40% or more of the stocking. Includes both plantations and natural stands, which are not to be differentiated from each other.

Oak - Forest stands in which upland oaks comprise 40% or more of the stocking.

Northern hardwoods - Forest stands in which mixtures of sugar maple, beech, basswood, cherry, and other upland hardwoods, singly or in combination, comprise 40% or more of the stocking.

Aspen-birch - Forest stands in which aspen (quaking aspen, bigtooth aspen, and balsam poplar) and/or white birch comprise 40% or more of the stocking.

Lowland hardwoods - Forest stands in which mixtures of ash, elm, maple, and other lowland hardwoods, singly or in combination comprise 40% or more of the stocking.

Swamp conifers - Forest stands in which mixtures of northern white cedar, tamarack, and eastern hemlock, singly or in combination comprise 40% or more of the stocking.

Non-forest - Any area which has 25% or less stocking.

Stand Size Classes

Saplings - Forest stands with an average height of 10 meters or less.

Pole timber - Forest stands with an average height of between 10 and 20 meters.

Saw timber - Forest stands with an average height exceeding 20 meters.

Stocking Levels

Low - Forest stands with between 25 and 50% crown cover. Those stands with less than 25% crown cover are classified as non-forest.

Medium - Forest stands with between 50 and 75% crown cover.

High - Forest stands with between 75 and 100% crown cover.

process involving identification of potential sites from A.S.C.S. black and white aerial photography followed by site visits for direct, on-land evaluation of wood production potential. After a candidate area had been chosen, extensive field observations and measurements were taken to determine forest conditions and to prepare a forest cover type map.

This process of formulating "Woodchucks" proved to be complex and time-consuming. Expansion of the program into all parts of Mason County was difficult because of the lack of information on the location and condition of privately-owned forest tracts. Without forest type maps, tracts could not be coherently and reliably identified as potential program sites. With the development of the photo-derived forest type maps, however, the District Conservationist has now been able to quickly identify candidate sites for inclusion in the program. This strengthened procedure consists of obtaining a computer listing of areas of merchantable material, for example, concentrations of mature aspen. The tabulations identify those sections within townships which contain the largest concentration of the requested timber type. A comparison of these areas with the maps and aerial photos permit the rapid selection of new Woodchuck sites.

Using this procedure, "Woodchuck Three" was established in May, 1975, in Sherman Township, Mason County. The area covers 367 hectares (907 acres) and is composed of 13 ownerships, including state, township, corporate, and private lands. Aided by the maps and aerial photography, a multiple-use management and timber marketing plan has been written for this unit and has been approved by all the owners. Woodland harvesting, scheduled for 470 acres, will produce over 2,500 cords of timber which will provide between $5,000 and $7,500 of new income to be distributed among the 13 landowners, and an estimated $70,000 to the economy of Mason County. Under the multiple-use management plan which has been established for "Woodchuck Three", additional projects have been completed or are scheduled. These include construction of new access roads and farm ponds, the planting of erosion-controlling vegetation, and the identification of specific areas for wildlife, upland game, and pasture management.

Because of these photo-derived maps, an unparalleled opportunity for cooperative forest management and procurement now exists in Mason County. They have proved to be invaluable to industrial foresters and they provide the missing link in the establishment of large-scale cooperative management programs for

small private woodland holdings. By facilitating wood procurement operations and cooperative forest management, the forest resource maps help ensure that wood-using industries will continue to provide much-needed forest products, employment, and income for Mason County. Over 2,025 hectares (5,000 acres) of woodlands have been brought under cooperative management to date, and the Mason-Lake Soil Conservation District will attempt to establish one cooperative each year.

The Mason County forest resource information has proved to be of such value to a variety of users that a decision has been made by the West Michigan Regional Planning Commission to inventory the forest resources of four other counties in its nine-county region. Using the methodology developed for Mason County, a recently established survey firm has prepared forest inventories for two other counties.[7]

Regional Land Cover/Use Inventories

The first extensive land cover/use inventory in Michigan, derived from high altitude CIR photography, was prepared for the eastern one-third of the Kalamazoo-Black-Macatawa- Paw Paw River Basin in 1973 (2,590 sq. km.; 1,000 sq. mi.).[8] The inventory was prepared for the Soil Conservation Service as a demonstration effort under the NASA grant to MSU. Eighteen land cover/use types were mapped from 1:60,000 and 1:120,000 NASA CIR photography with a minimum mapping unit of 4 hectares (10 acres), and tabulated area statistics were prepared by county, sub-basin, and township.

Its success prompted the SCS to secure similar land cover/use data for the western 5,310 sq. km. of the Kalamazoo Basin, using commercially acquired CIR photography. A $25,000 contract was awarded to MSU for preparation of the inventory. Twenty-two categories of land cover/use were mapped from 1:31,680 CIR photography to a 4 hectare (10 acre) type size (Table 3). The delineations were transferred onto 1:63,360 mylar copies of USGS topographic quadrangles. Category area statistics were calculated by county, sub-basin, and soil association.

The SCS watershed project will lead to a series of policies and action programs for the preservation of essential agricultural land, forests, and wetlands. For example, the land cover/use maps were used in analyzing wildlife habitat[9] and wetlands[10] from which specific management priorities and county recommendations were identified.

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TABLE 3

LAND COVER/USE CLASSIFICATION SCHEMES

	Kalamazoo		Tri-County
1	Residential	1	Residential
2	Comm. & Institutional	2	Comm. & Institutional
3	Industrial	3	Industrial
4	Trans. & Utilities	4	Trans. & Utilities
5	Extractive	5	Extractive
6	Other Urban	6	Other Urban
7	Cultivated Cropland	7	Cultivated Cropland
8	Tree Fruits	8	Tree Fruits
9	Bush Fruits	9	Bush Fruits
10	Confined Feeding	10	Confined Feeding
11	Permanent Pasture	11	Permanent Pasture
12	Brushlands	12	Brushlands
13	Broadleaved Forest	13	Broadleaved Forest
14	Coniferous Forest	14	Coniferous Forest
15	Mixed Forest	15	Mixed Forest
16	Open Water	16	Open Water
17	Forested Wetlands	17	Forested Wetlands
18	Shrub Swamp	18	Shrub Swamp
19	Marsh	19	Marsh
20	Open Water Vegetated	20	Solid Waste Disposal
21	Ornamental Horticulture	21	Sewage Treatment
22	Barren Land (principally sand dunes)		

MICHIGAN RESOURCE INVENTORIES

A land cover/use inventory was also prepared for the Tri-County Regional Planning Commission as a part of the Commission's area-wide water quality program. Funds for the program are provided by the Environmental Protection Agency under Section 208 of the Federal Water Pollution Control Act Amendments of 1972. A 21-category land cover/use inventory was prepared for each county (Clinton, Eaton, and Ingham) from 1972 NASA CIR photography at scales of 1:60,000 and 1:120,000 (Table 3). The information was transferred onto county base maps at a scale of 1:48,000 which were supplied by the Planning Commission, and are consistent with other maps being prepared for its regional water quality study. In addition, the total area of each land cover/use category was calculated and tabulated for each township, county, and major river basin. The total cost of the contract for the 4,416 sq. km. (1,705 sq. mi.) area was $16,500. The maps reflect the complex geographic pattern of urban development, farmlands, and natural areas, and provide a bench mark data base from which regional land/resource-use programs will develop.

COSTS AND PROCEDURES

The costs associated with these three inventories are itemized in Table 4. The projects carried out for the Kalamazoo Basin and the Tri-County area were contract arrangements in which a detailed record of cost was kept. The Mason County project was a demonstration effort under the NASA grant. Time-record information was collected for tasks accomplished and this has been translated into cost information by using wage levels that were current at the time.

The cost estimates presented in Table 4 are based on the wages paid to the staff who performed the specified functions. In some cases different wages were paid for the same work task, as student employment regulations dictate different wage levels on the basis of experience and academic standing. Also included in this table, however, is an indication of the number of hours necessary to complete a given task so that a total cost with a different or standardized wage structure can be estimated. The following discussion presents the technical procedures used in the projects along with the costs incurred in carrying them out, and attempts to clarify cost differences between the inventories.

The inventories were prepared by student employees with varying degrees of skill and speed in photo interpretation.

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TABLE 4 INVENTORY COSTS

EXPENSE CATEGORY	KALAMAZOO (5,800 Km^2)	TRI-COUNTY (4,416 Km^2)	MASON (1,308 Km^2)
WAGES			
CATEGORIZATION			
Interpretation	$4,570 1,112 hrs	$3,965 853 hrs	$2,020 505 hrs
Field Checking	$670 163 hrs	$150 33 hrs	$160 40 hrs
CARTOGRAPHY	$1,726 420 hrs	$986 249 hrs	$404 101 hrs
AREA CALCULATIONS	$1,110 270 hrs	$789 167 hrs	
SUB TOTAL	$8,076 ($1.39/Km^2) 1,965 hrs (3.0 Km^2/hr)	$5,890 ($1.33/Km^2) 1,302 hrs (3.4 Km^2/hr)	$2,584 ($1.98/Km^2) 646 hrs (2.0 Km^2/hr)
SUPPORTIVE			
Photo Acquis.	$10,500	$984	$1,000
Travel	$312	$65	$150
Supplies & Mat.	$172	$674	$300
Administration	$423	$1,275	$200
Overhead	$5,355	$4,514	$1,754
TOTAL	$24,838 ($4.28/Km^2)	$13,402 ($3.03/Km^2)	$5,988 ($4.58/Km^2)

Errors that might occur as a result of these differences were minimized by providing all of the interpreters with a short training period in identification of the various categories to be mapped. When an interpreter encountered a problem in identification, it was resolved by a more experienced interpreter, who also performed a quality control function by randomly checking portions of each interpreted frame. The quality control procedure was repeated several times throughout the interpretive phase of each project.

The categories were delineated on acetate sheets which were taped over every other photo in a flight line. Roads and water features were delineated to form a rough grid pattern on the acetate overlays, enabling interpreters to systematically identify and delineate the land cover/use or forest types within each area. The delineations were drawn with a double-zero technical fountain pen: red ink being used for roads, blue ink for water features, and black ink for land cover/use boundaries.

Most land cover/use categories were easily identified with the aid of a 10-power hand lens; however, when interpretation problems occurred, the photography was viewed stereoscopically for a more precise interpretation. Mapping the forest categories required stereoscopic viewing of the transparencies and this was accomplished using a Bausch & Lomb Zoom 240 stereoscope mounted on a Richards light table. Average stand height was measured with a parallax bar and stocking level was determined by ocular estimation of crown closure. When 1:120,000 scale photography was used, it was necessary to increase its scale approximately twice with a projector-enlarger in order to accomplish mapability at the minimum type size of 4 hectares. The enlarged image was projected onto tracing paper and the categories were delineated with red, blue, and black lead pencils (colors correspond with those of the ink colors used on the acetate sheets). Areas that could not be classified through photo interpretation were noted and subsequently field checked.

The interpretation phase of both land cover/use inventories was accomplished at a rate of 5.2 sq. km./hr. (2.0 mi./hr.). This is to be expected as the classification scheme and aerial photographic sources are comparable and the interpreters were of approximately equal skill and experience. Interpretation of the forest in Mason County took twice as long, or a rate of 2.6 sq. km./hr. because stereoscopic viewing and height measurements were necessary.

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Field checking costs varied predominantly in relation to the distance from the interpretation site to the study areas rather than the number or type of field checks to be investigated. Overnight stays were required while field checking in Mason County and the Kalamazoo Basin, whereas, the Remote Sensing Project office is located within the Tri-County area.

When the photo interpretation was completed, the information from the delineated acetate and tracing paper sheets were transferred onto base maps at the user specified scale. The transferring was done using a Kargl Reflecting Projector, a device with which a cartographer can match the delineation scale to that of the base map, and also correct for some planimetric distortions inherent in aerial photography. The final maps for the three inventories were prepared at an average rate of 15 sq. km./hr. (5.8 sq. mi./hr.); however, map construction costs did vary slightly due to different base map specifications (type, scale, and legend).

The land cover/use maps were used to estimate the total area of each category within specified analysis zones (e.g. township, river basin, county). Land cover/use acreage was determined using the following procedure:

1) A dot grid was prepared with 1 dot representing a unit area at the base map scale.
2) The analysis boundaries were traced on clear mylar sheets.
3) The dot grid was placed over the maps and registered in a consistent manner.
4) The land cover/use on which each dot fell was recorded as the predominant category for that cell. If a dot fell on a delineation line, it was assigned to the land cover/use type immediately to the southeast (down and to the right).
5) The number of dots counted for each analysis zone was converted to an area measurement by the appropriate conversion factor and then corrected for sampling error.

Area calculations were performed only for the Kalamazoo Basin and Tri-County inventories. The rates were similar--Kalamazoo 21.5 sq. km./hr. (8.3 sq. mi./hr.) and Tri-County 26.4 sq. km./hr. (10.2 sq. mi./hr.)--the difference being that in the Kalamazoo Basin tabulations for soil associations were required by the contracting agency.

The items discussed above are the primary costs involved in the technical part of the projects. A number of other supportive costs are also incurred. Photo acquisition is potentially the largest supportive cost. CIR aerial photography was specifically flown for the Kalamazoo Basin project, whereas existing photography was used in the Tri-County and Mason County inventories. The costs recorded in Table 4 represent the purchase price of the imagery.

Costs of supplies and materials basically cover acetate sheets, drafting supplies, mylar copies of base maps, and reproduction of the final maps. The expenditures for Tri-County were higher than the others as a more elaborate report and demonstration materials were required by the contracting agency.

Administration charges are difficult to estimate. The administrator of each project was either involved with other phases of a particular project, or even other projects, and this made hourly estimation and these costs liable to error. The actual expenditures in Table 4, therefore, broadly reflect the wages paid for administrative functions. Administration of the Kalamazoo Basin and Mason County projects was accomplished by a graduate student under faculty supervision, and this supervision is not represented in the expenditures. Tri-County was solely administered by a staff member which makes this cost seem relatively high. The University applied a 63% overhead on all wages and salaries which constitutes a major supportive, and indirectly, administrative cost.

The Kalamazoo Basin, Tri-County, and Mason County inventories were prepared at a total cost of $4.28, $3.03, and $4.58 per square kilometer, respectively. These costs are broadly in line with those reported for similar inventories conducted in Washtenaw County, Michigan ($3.22/sq. km.)[11] and the Eastern Kalamazoo Basin ($2.88/sq. km.).[12] Costs associated with deriving similar land cover/use data using alternative sources were also estimated in the Eastern Kalamazoo Study. Interpretation of 1:20,000 black and white photography would have cost $3.41 a sq. km., and a "windshield" type survey using aerial photographs would be $15.93 a sq. km. The inventory efforts reported here then, are competitive in terms of cost and suggest that high altitude CIR photography is a good data source for the provision of land cover/use information even if the imagery has to be generated for that specific purpose.

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INFORMATION SYSTEM

Generation of a land cover/use inventory is only the first step in the planning process. Planning agencies routinely require the synthesis of large quantities of different types of data over an extensive area and this, combined with a more technical approach to planning issues, has led to a rapid expansion for the role of computer technology in the everyday activities of planning agencies. Computers are well suited for the task of assisting the regional planning process because they can store thousands of pieces of information from a wide variety of data sources. Data can be geocoded (assigned to a specific piece of land) so that the characteristics of any particular land parcel can be retrieved, combined with other data similarly geocoded, then mapped. Present computer systems can perform these tasks very quickly, inexpensively, and with a technical accuracy not achievable with traditional manual methods.

The Resource Analysis Program (RAP), developed at the MSU Remote Sensing Project, is a computer software system designed to assist in the integration of a variety of geographic data.[13] The system features a simple user-language in conversational format for accessing a wide array of analytical and mapping functions. The analytical phases provide the process (methods of analyses) for grid-based geocoded resource data. The mapping phases permit the graphic display of the data analyses using either a high-speed line printer or a plotter as the mapping device.

An application in Windsor Township, Eaton County, Michigan, will serve as a medium for discussing the RAP system. The objective of this study was to develop a series of resource maps that focus upon land characteristics relevant to non-point water pollution.

Windsor Township is typical of the planning region, and indeed of much of the country, in that only basic resource data exist: a recent soil survey, a land cover/use map (from the Tri-County Inventory), and the standard USGS topographic survey. In addition, the State Geological Survey maintains a file of driller-submitted water well records of basic lithology data on the near surface environment. The water well data were used to obtain maps of depth to bedrock and generalized permeability of the glacial drift. These five resource maps were geocoded using a 4-hectare (10-acre) dot grid matrix, providing the basic data for the study program and the analyses using the RAP system.

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The data were comparatively analyzed by employing various algorithms of RAP, such as a standard overlay technique and site index scaling. The test in Windsor Township resulted in a Resource Management Portfolio which contains 11 maps: 1) surface topography and natural features; 2) land cover/use; 3) potential ground water recharge management areas; 4) soil phosphorus availability; 5) potential on-site erosion; 6) potential phosphorus loading source areas; 7) limitations for septic tanks; 8) limitations for sanitary landfills; 9) limitations for spray irrigation waste disposal; 10) soil stability; 11) limitations for general agriculture.

The costs of implementing RAP in Windsor Township (93 sq. km.; 36 sq. mi.) are presented in Table 5. The process involves two components: creating the master file and producing a map. The master file costs, of course, are a one-time investment since the data base can be used for a variety of regional studies. Creating the master file involves manual labor to code the data, verify its accuracy, prepare machine-readable records, and operate the various computer programs that are used in the process. Map production costs involve primarily computer and computer-related charges using the MSU CDC 6500 computer system. These costs are quite sensitive to the type of analysis being conducted and the type of map product to be produced. On the average, computer and plotter time costs about $35 per map. The maps can also be plotted on a mylar base for an additional $5 to facilitate reproduction. The costs reported in this document do not include the development costs of RAP which are substantial in both man-hour input and computer time. A detailed breakdown of this cost is not currently available.

SUMMARY

This paper has described the characteristics of several applications of color infrared photography in Michigan by combining a review of the procedures and results from this inventory and information system work with related time/cost data. Within each project, a host of variable circumstances made cost determinations very difficult to systematically record and analyze, however, a fairly clear statement of inventory costs does emerge.

The success of the Mason County project has not only led to expansion of forest inventory efforts in the West Michigan Regional Planning area, but has also prompted the Michigan Department of Natural Resources to organize agencies and private

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TABLE 5 WINDSOR TOWNSHIP INFORMATION SYSTEM:

TIME/COST PARAMETERS

TIME (in hours)	
Grid-Geocoding:	
Land Use	4.0
Soils	13.5
Elevation	12.5
Distance to Water	10.5
Well Log Data	37.0
Computer Operation	33.0
Portfolio Preparation	62.0
Administration	40.0
TOTAL	212.5
COST	
Labor	$637.50
Overhead (66% of wages)	$420.75
Computer Charges	
Execution	$181.29
Plot	$150.20
Mylar Charges	$110.00
TOTAL	$1,499.74

firms in a cooperative venture to obtain color infrared photography of the entire state. A complex set of arrangements for cost participation have been proposed and are currently under discussion so that several sets of imagery will be available to the project participants.

Some regional planning agencies in Michigan, besides Tri-County, are also securing land cover/use information through manual interpretation of aerial photography, whereas others are relying on computer-assisted categorization of LANDSAT data. The costs of data capture through photo interpretation of high altitude CIR have been documented in this paper. Both data sources, however, have advantages and limitations with respect to providing land cover/use information in an accurate, cost-effective manner. A research area currently being investigated is the development of a procedure that combines the best elements of aerial photography and satellite data sources to provide accurate, cost-effective land cover/use information.[14]

The Windsor Township project has shown the potential and costs of integrating land cover/use with other natural resource data to provide information for a variety of planning decisions. While the development of this technology is still an active area of research, the present system has established a framework for future implementation and utilization of a computer information system by planning agencies in the state.

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