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PREFACE

This report is an effort to bring together the major projects undertaken during the last three years of our grant from University Applications of the National Aeronautics and Space Administration. It is not our intention to cover everything that was done to demonstrate the application of remote sensing technology or later to integrate this technology with other data sources. Rather it touches only those activities that proved to have practical application for us and our cooperators.

We would like to thank those organizations and agencies that worked with us and provided much data, specifically, the Eastern Remote Sensing Applications Center, Goddard Space Flight Center; Soil Conservation Service, USDA; Vermont Department of Forests, Parks and Recreation, Vermont Department of Water Resources (now Vermont Department of Environmental Conservation) and the Vermont Water Resources Research Center of the University of Vermont.

Many individuals played important roles in carrying out these demonstrations and studies. We particularly wish to recognize Jack McCarthy, Remote Sensing Technologist; D. Scott Denkers, Remote Sensing Technologist; Lee J. Kauppila, Research Computer Specialist; David A. Sousa, Computer Operator/Programmer and Eileen A. Powers, Natural Resource Data Specialist.

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INTRODUCTION

During the last two decades remote sensing technology has advanced at a rapid pace. Numerous demonstration projects have been completed and have shown that these technologies are useful to resource managers. The LANDSAT series of permanently orbiting satellites with multispectral sensors have provided resource managers with sources of data never before available. Remote sensing scientists working independently and in cooperation with private, local, state and federal agencies have repeatedly demonstrated specific applications.

Since its inception in 1978, the Remote Sensing Applications Program of the School of Natural Resources at the University of Vermont has undertaken some thirty-five demonstration projects where the data acquired by the Multi Spectral Scanner and more recently the Thematic Mapper aboard the LANDSAT series of satellites have been a major input. Success has been variable depending upon the specific objective of a project. In some instances other remote sensing devices were able to provide the data needed either more efficiently, at lower cost, or at a resolution that was necessary to accomplish the specific objective. A listing of the major projects carried out is included in Appendix A.

We know that there is still a shortfall in the acceptance of these technologies and their routine use. Part of this is due to insufficient knowledge on the part of potential users but also because of the realization that a single remote sensing data source does not provide all of the answers needed.

While remote sensing can involve a number or variety of sensing stimuli, the most common sensing device is the eye. When applied to image analysis, the human eye and brain apply the elements of image interpretation to solve and identify particular features or phenomenon. Until the launch of the first LANDSAT satellite in 1972, the aerial photograph was the principle source of remotely sensed information. To glean information from an aerial photograph requires intensive human interpretation of the imagery. Digital multispectral data has altered our aerial information gathering process. Computer processing of digital data can now be used reliably to map land cover type information to at least a level I classification and often times to level II, according to the USGS Land Cover/Use Classification scheme (Anderson et al). The LANDSAT sensor systems and those of other imaging satellites such as GOES, AVHRR and SEASAT have made global imaging on a repetitive basis a reality. If the flow of current information from imaging satellites remains uninterrupted and affordable, large area assessment projects directed at monitoring global change can move forward.

The speed with which a digital image can be processed into a usable product far exceeds that of manual interpretation techniques. It is this speed and the availability of regular repeat coverage that lures organizations to try using digitally processed image data. More accurate Level I and II classification results are being achieved with the finer spatial and spectral resolutions available on today's imaging satellites Unfortunately classification beyond Level II, that most regional and local officials are familiar with, is not possible with standard image processing techniques. Digital image processing within a computer makes extensive use of only one or two of the elements of image interpretation. In most cases only tone, represented by a range of digital values is analyzed in a classification algorithm. Some use of a derived texture value is also possible. Other elements are considered only superficially in the training site selection process (shape, size and association) and in the naming convention for the final product. Expansion beyond the Level I and II classification limit requires the use of information sources that are not available in the image data set. Information sources such as soils, topography and ownership are needed to extend classification systems beyond Level II and to shift the results from simply a land cover product to a more powerful land use output.

Successful integration of these multiple data sets must consider and accommodate differences in map scale, projection, resolution limit or minimum mapping unit and data format. To glean the greatest benefit from different data sources, it is necessary to use a total information system that is equally capable in accommodating both map and map feature attributes. Such capabilities exist in the form of geographic information systems. It is through the use of geographic information systems (GIS) that local, regional, national and global information needs can be met and managed. Within a GIS, remote sensing, either digital image processing or traditional manual photo interpretation, serves as an important data input source.

Successful implementation of such a total information system must first start at the local level where sufficiently accurate ground reference information is available to fully test methodologies. Soils, geologic, topographic and ownership information are just a few of the ancillary data sets needed for integration with the output of digital image processing to provide the desired detailed classifications. As procedures are developed and verified, projects can be scaled up to cover larger geographic regions. Coverage of larger geographic regions may require some data aggregation or generalization to be efficiently accommodated within current machine processing capabilities. The University of Vermont School of Natural Resources' Remote Sensing Applications Program has worked to enhance the merger of remote sensing with the manipulative powers of a geographic information system.

BACKGROUND AND OBJECTIVES

The Remote Sensing Applications Program (RSAP) was established at the University of Vermont in 1978 following our initial grant from NASA. All of our efforts over the next six years were directed toward the development and testing of applications of remotely sensed data and in particular, digital processed data from the LANDSAT series of satellites. During this period, we acquired a VAX 750 computer through outside funding sources. This computer and associated hardware and software were key factors in the success of the Remote Sensing Applications Program and the subsequent development of our Geographic Information System (GIS) laboratory. These resources have been dedicated almost exclusively to spatial mapping and the analysis of land resource variables.

This computer has served as host for the ARC/INFO state-of-the-art geographic information system and the ELAS image processing system. The ARC/INFO system is a product of the Environmental Systems Research Institute (ESRI) of Redlands, California. The ARC portion of the system handles the graphic or map portion of the GIS and INFO, an incorporated relational data base manager developed by HENCO Software, Inc. stores and analyzes all of the map feature attributes. This combination has made the ARC/INFO system one of the most powerful and versatile geographic information systems available. In addition to the polygon formatted ARC/INFO system, the School of Natural Resources maintains a grid cell based GIS called GRID that is also a product of ESRI.

Image processing was accomplished with the ELAS software package, displayed on an AED 767 color workstation. ELAS is a product of NASA's Earth Resources Laboratory located at the National Space Technology Laboratory in Slidell, Mississippi. Image processing output can be passed to the ARC/INFO via the GRID software and likewise ARC/INFO polygon files can be passed to the ELAS image processing system through a GRID interface.

The major thrust of efforts during the last three years has been to develop techniques for the merger of satellite data with other geographically related data sets to illustrate and define land conditions or capabilities. Many data layers such as soils and topography are very tedious and laborious to enter into the geographic information system. However, once they are within the computer's manipulative grasp, they require little if any maintenance. Land cover/use is a very dynamic layer which changes constantly because of and in spite of man. It is totally unrealistic to expect to manually interpret this information from photography for a large area and digitize results into a GIS on a regular basis. Such a task is ideally suited for digital processing of satellite data. Land cover information so derived can be converted to land use data by the merger of other data sets contained in the GIS.

Modelling studies that use enhanced data layers can depict such factors as erosion potential, forest growth, water run off potential, and crop yields. This type of information has widespread applications and affords the opportunity to approach situations from a planning phase rather than from a reactive phase to catastrophic events. By interfacing GIS technology with that of remote sensing, the manager may play out a series of scenarios and select the one that most closely depicts the desired objective. Policy makers certainly would benefit from review of these types of analyses before making many all important and sometimes irreversible decisions.

The material on the following pages describes a series of specific investigations undertaken to demonstrate the integration of remote sensing and GIS and development of usable techniques.

PRIMARY DATA SOURCES

To accurately test and evaluate data merging techniques, it was necessary to have a large data base available from which to draw information and to test results. The Vermont geographically referenced data sets provide such a data base. During the course of this study information on almost one million acres was entered in the GIS, providing an ideal test site. Creation of this data base during this period was a cooperative agreement between the University and the U.S. Soil Conservation Service. Since the termination of these studies, authorization for a complete statewide data base was enacted by the Vermont Legislature. The various data layers contain detailed map and text data on soils, topography, transportation networks, stream and river courses, political and watershed boundaries.

Classified land cover information was obtained from a variety of remotely sensed data sources including color infrared photography which was manually interpreted to polygon maps and LANDSAT Multispectral Scanner and Thematic Mapper data. A major source of land cover data for much of this area was acquired from Thematic Mapper scene E-40162-15062 acquired over northwestern Vermont on October 26, 1982.

Selection of Thematic Mapper data to provide most of the land cover information for this data base is the result of a series of conscience decisions and compromises. While all other data layers in the data base were in a visually pleasing and spatially accurate polygon format, the inclusion of gridded data in a fixed grid format at first seemed to be a step down in quality. It was necessary to recognize that land cover is constantly changing and maintenance of this dynamic information layer by traditional photo interpretation and subsequent digitizing is both costly and very time consuming. Digital processed satellite data provided the only reasonable alternative available to regularly map land cover over large areas. The decision was made to use these data sets to test the utility of merging satellite data with other data sets within a GIS to both improve land cover classification results and to model change events.

Initial processing of this scene was performed at the Goddard Space Flight Center on the IDIMS system with the assistance of NASA personnel. For data reduction purposes, all 7 Thematic Mapper bands were entered into a canonical analysis program. From the data transformation prescribed by the canonical analysis, three new axes of information were found to describe 99% of the variability in the scene. Initial classification of the area was accomplished with the IDIMS' unsupervised classifier ISOCLAS. To supplement the ISOCLAS results, supervised classification techniques were also used. A total of 63 separate signatures were developed to identify 11 separate land cover classes. These classes were identified as water, hardwood forest, softwood forest, bare soil, urban, hay/alfalfa, wetlands/brush and grass/abandoned fields. At the completion of the classification process, the data set was geometrically corrected to UTM coordinates with pixel size set at one-quarter acre.

ST. ALBANS AREA LAND COVER TO LAND USE TRANSFORMATION

BACKGROUND

Output from classified digital data acquired by satellite scanners depicts land cover information as opposed to land use information. Limitations in spatial resolution and spectral similarities between features contribute to this shortcoming. Transportation networks are an excellent example of a land use category that is generally not resolvable from satellite data. One method for developing the detail of a transportation network is to digitize a data overlay of this information which works fairly well for orientation purposes. While this may be adequate for some purposes, it does not produce an enhanced layer of information that can be used to develop specific land use information. Many features such as soils, topography and transportation networks are very stable and change little over time.

Land cover is a dynamic information layer that changes at varying rates depending on the cover and the location. Maintenance of this data layer by traditional photo interpretation and transfer and subsequent digitizing is time consuming and difficult. The use of digital image processing techniques can expedite this task.

METHODS

An area near St. Albans in northwestern Vermont was selected for study. It is twenty-five miles north of Burlington and a major transportation hub on the route to Montreal. The area is agricultural with the exception of St. Albans city. For many years the shoreline of St. Albans Bay has been lined with camps and cottages, and in recent years some suburban development has occurred, especially in areas convenient to Interstate 89.

Examination of the land cover classification for this area prepared from Thematic Mapper data revealed two major shortcomings. First, the classification was unable to resolve the road network in the area, and secondly, it exhibited the usual confusion associated with the mapping of a heterogeneous urban area. For the most part the classification of the agricultural and forest lands was quite acceptable and a good indicator of land use.

The first step in overcoming these shortcomings was to convert the gridded or raster data format of the classified image to polygon format within the ARC/INFO geographic information system. Following this, the road network was digitized and a new data layer created. At the same time the areas of confusion in the urban portions of St. Albans were corrected through manual photo interpretation of 1982 1:24,000 black-and-white panchromatic aerial photography. This was then merged with the digitized road network to create a correcting mask and merged with the polygon format classified image data to create the land use classification shown in Figure 1.

RESULTS

The primary purpose for carrying out the procedures described here was to determine the feasibility of improving the utility of remotely sensed data, in this case TM data, through the addition of other information by harnessing the capabilities of a GIS. The interfacing of remote sensing and GIS technologies allowed us to achieve results that neither could have done alone. In effect, some of the misclassification in the classified TM data can be corrected through the use of a GIS.

Figure 1. Classified Thematic Mapper data image of St. Albans, Vermont region that has been enhanced by the incorporation of a digitized composite transportation and urban land cover layer to create a land use data layer.

MODELING OF LAND COVER AND SOIL ATTRIBUTES

BACKGROUND

Existing land cover/use plays a significant role in soil erosion and runoff and can have a great impact on the water quality of an area. Nonpoint pollution has been identified as a major water quality problem and many nonpoint problems are related to soil erosion. Any comprehensive analysis of water quality problems must integrate the land cover/use and the changes that occur with the more permanent or non-changing attributes of the soils. When this is done, it is then possible to model erosion and or runoff potential by merging remotely sensed data with soils and other data layers within the capability of a GIS.

METHODS

The Stevens Brook watershed, an 11,037 acre subwatershed of the St. Albans Bay watershed was selected as a study area. The area is located in northwestern Vermont twenty-five miles north of Burlington. The entire watershed is being monitored as part of a long-term cooperative study of the Vermont Water Resources Research Center and the Soil Conservation Service of the U.S. Department of Agriculture. The area is primarily agricultural but since the City of St. Albans drains into Stevens Brook, urban land represents a third of the watershed (Table 1).

Land cover was determined from classified data acquired from Thematic Mapper scene E-40162-15062 over northwestern Vermont. Only agricultural land cover consisting of lands in hay/alfalfa, bare soil and corn were considered in the analysis.

Erosion factors are used to predict the erodibility of a soil and its tolerance to erosion in relation to specific kinds of land use and treatment.

Table 1. Land Use in the Stevens Brook Subwatershed.

Land Use	Acres	Percent
Urban	3,686	33.4
Agriculture	6,854	62.1
Forest	232	2.1
Wetland	265	2.4
Total	11,037	100.0

The soil erodibility factor (K) is a measure of the susceptibility of the soil to erosion by water. Soils having the highest K values are the most erodible. K values range from .01 to 0.64 for the soils in the area. To estimate erosion potential (PE) the erosion factor is modified by a slope length factor (LS).

The attributes needed to develop soil erodibility factors existed in the data base associated with the soils map data layer. Slope length factors were derived from the topographic data layer and when combined with the erodibility factor, produced the erosion potential for each of the three major agricultural land use types. The results of the data layer integration are shown in Table 2.

Another example of where the merger of remotely sensed data with other data layers can produce valuable map and statistical information is in the creation of Runoff Curve Numbers. This calculation incorporates land use, soil hydrologic characteristics and the slope of the land. Hydrologic soil groups are used to estimate runoff from precipitation. Soils are placed in one of four groups on the basis of the intake of water after the soils have been wetted and have received precipitation from long-duration storms. Group A soils have a high infiltration (low runoff potential) when thoroughly wet and have a high rate of water transmission. Group B soils have a moderate infiltration rate when thoroughly wet and a moderate rate of water transmission. Group C soils have a slow infiltration rate when thoroughly wet and a slow rate of water transmission. Group D soils have a very slow infiltration rate (high runoff potential when thoroughly wet and a very slow rate of water transmission.

Data on the hydrologic grouping was available in the data base associated with the soils data layer for this area. A calculation matrix for the

Table 2. Erosion potential of agricultural lands in the Stevens Brook Watershed.

	Potential Erosion Ranges			
Land Cover Type	Slight PE<.1	Moderate PE.1-.26	Severe PE>.26	Total
	Percent	Percent	Percent	
Hay/alfalfa	13	7	2	22
Bare soil and cornfields	17	12	7	36
Grassland	20	14	8	42
Total	50	33	17	100

derivation of Runoff Curve Numbers is shown in Table 3. A summary of the Runoff Curve Number calculations for the Stevens Brook Watershed is shown in Table 4.

RESULTS

The purpose of this study is not to indicate how accurately the mergers developed can predict erosion potential and runoff. We have developed models which produce estimates based on remotely sensed data and a soils data base both of which are subject to error. However, a merger of the type presented, though subject to error, does enable us to model these factors by simulating changes in land use. For example, we can simulate the conversion of an existing pasture to a cultivated crop and predict the change in erosion potential and runoff. A model of the form presented here has other desirable characteristics. It requires only limited ground truth or remotely sensed data to periodically update the land use on a regional basis in order to keep the model functional.

Table 3. Calculation matrix for the derivation of Runoff Curve Numbers for the Stevens Brook Watershed.

Cover Description	Soil Hydrologic Group A	B	C	D
Cultivated & Bare Soil	67	76	83	86
Pasture or Range	52	69	79	84
Meadow (Hay, Alfalfa)	30	58	72	78
Forest	25	55	70	77
Urban	74	84	90	92

Table 4. Area by calculated Runoff Curve Number for the Stevens Brook Watershed.

Runoff Curve Number	Acres
25	342
55	2,943
70	4,105
74	41
77	1,739
84	509
90	952
92	406
TOTAL	11,037

The average Runoff Curve Number for the Stevens Brook Watershed is 68.9.

MAPPING FOREST PRODUCTIVITY BY INTEGRATING REMOTELY SENSED DATA WITH SOILS DATA IN A GIS

BACKGROUND

Worldwide, the land base devoted to the production of renewable natural resources continues to shrink. As this trend continues, land productivity becomes an increasingly important issue. In recent years agriculturists have devoted considerable effort to the determination of those agricultural lands having the highest productivity. Many studies have been conducted to determine the extent of land use change on prime and good agricultural soils both here in the United States and throughout the world. Ascertaining and mapping the productivity of forest lands is equally important.

The most widely accepted measure of forest productivity is site index. This measure which uses the average height of dominant and codominant trees of a given species at a specified age has long been considered as a useful measure of forest land productivity. Because site index is costly to measure over large areas, numerous investigators have attempted to develop methods whereby it can be measured indirectly through association with other variables. Some of the variables used include topographic features, vegetation and soils. Post and Curtis (1970) developed a set of site index equations based upon elevation, latitude and soil series group for northern hardwood stands growing on glacial acid till soils in the Green Mountains of Vermont.

METHODS

A 1600-hectare area (Vermont orthophoto map sheet #112260) encompassing part of the town of Fairfield in northwestern Vermont was selected for forest land productivity mapping in this study. The land cover is a mixture of forest and agricultural areas almost totally in private ownership. The topography is gently rolling and ranges from Fairfield Pond at an elevation of 550 feet to hills in the northwest that rise to just under 1,000 feet. Most of the forested area is comprised of even aged stands that were established on abandoned agricultural lands.

Land cover for the study area was derived from a Landsat 4 thematic mapper scene (E-40162-15062) acquired on October 26, 1982. All seven thematic mapper bands were processed by canonical analysis and three new axes of information were found to describe ninety-nine percent of the variability in the scene. Sixty-three separate signatures were developed to identify eleven land cover classes. These include water, hardwoods, softwoods, bare soil, urban, hay/alfalfa, wetlands/brush, and grass/abandoned fields (Table 5). The classified data set was geometrically corrected to UTM coordinates using a pixel size of one-quarter acre and subsequently converted from raster (grid) to polygon format. Thematic mapper data alone were unable to resolve the road network and were upgraded by merging it with a correcting mask composed of a digitized road right-of-way data layer.

Soils data for the study area were derived from the Franklin County Soil Survey as published by the Soil Conservation Service (Table 6). Soil series polygons had been previously digitized and labeled. Text data for the various labels were contained in the S01-5 data base. The soils polygon map for the study area was subset from the larger geographically registered Franklin County soils data base which had been checked and edited by SCS soil scientists.

A topographic data layer was created by digitizing one hundred foot contour intervals from the 1:62500 USGS quad sheet covering the study area. An overlay of land cover and soils was created showing hardwood forest areas by soil series. This in turn was overlaid with the topography layer. The

Table 5. Satellite derived land cover classification for the Fairfield Pond area of northwestern Vermont. 1982.

Category	Acres	Hectares	Percent
Transportation and Urban	145	59	4
Hay and Alfalfa	500	202	12
Bare soils, Cornfields	161	65	4
Grasslands, Abandoned fields	226	92	6
Brushlands, Wetlands	205	83	5
Hardwoods	1565	633	40
Softwoods	685	277	17
Water	467	189	12
Total	3954	1600	100

Table 6. Area of general soils class in the Fairfield Pond study area.

General soils class	Area		
	Acres	Hectares	Percent
Limerick-Rumney	81	33	2
Georgia-St. Albans	13	5	*
Au Gres-Wareham	113	46	3
Munson-Buxton-Belgrade	207	46	5
Scantic-Raynham-Binghamville	317	129	8
Windsor-Missisquoi	230	93	6
Carlisle-Terric Medisaprists	25	10	1
Woodstock-Tunbridge	1251	506	32
Peru-Stowe	923	373	23
Cabot Westbury	327	132	8
Water	467	189	12
Total	3954	1600	100

*less tha 0.5 percent

data values associated with each layer were processed using the equations developed by Post and Curtis. The resulting values were assigned to the corresponding hardwoods-soil series-elevation polygon.

RESULTS

The final output site index classification map provides a visual representation of the geographic distribution of each site index class (Figure 2). Most site index equations in the northeast are expressed in predicted height at age fifty as opposed to age seventy-five of the Post and Curtis equations. In conformance with common practice, the data were converted to the age fifty base. The study area is fifty-seven percent forested and two-thirds of this is northern hardwoods. Twenty percent of the hardwood forest area is site index seventy or higher (Table 7). The remaining eighty percent of the hardwood stands are of site index sixty-nine or lower.

No attempt was made to assess the accuracy of the site index classification. To do so would not have been a test of the technique or methodology employed, but a test of the site index equations developed by Post and Curtis which was not the purpose of this study. The techniques developed and used in this study were designed to provide an efficient and economical method for mapping forest land productivity as expressed by site index.

In instances where site index can be estimated by soil attributes, elevation, aspect, latitude or any other parameter that can be geographically referenced and input to a data base, then this tool will work. When combined with land cover, i.e. cover type or species derived from remotely sensed data, the geographic information system is capable of providing locational and statistical data on site productivity for the use of the forest land manager.

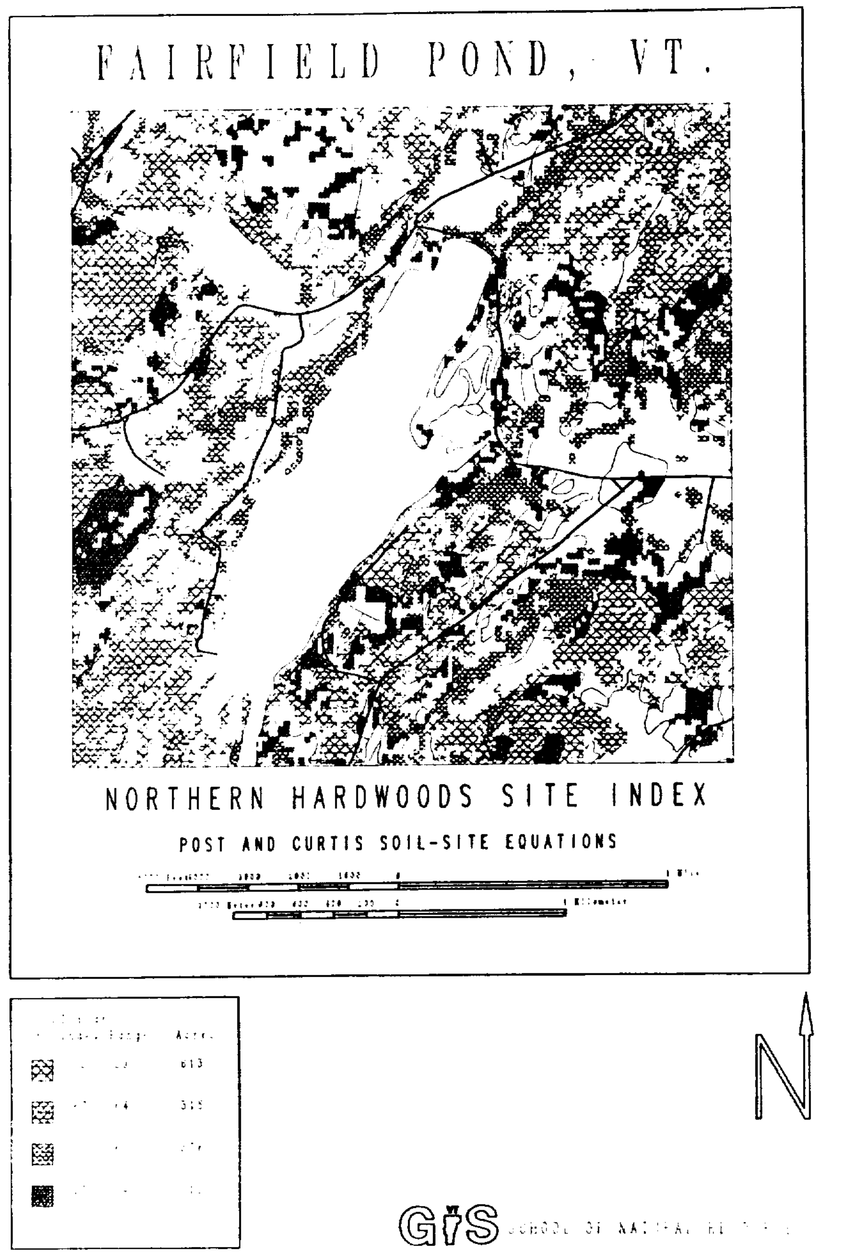

Figure 2. Site index of northern hardwood stands in the Fairfield Pond Region of Vermont. The transportation network has been overlaid on this map.

Table 7. Area of northern hardwood stands in the Fairfield Pond study site by site index class.

Site Index Class (Ht. at age 50)	Area		
	Acres	Hectares	Percent
55-59	613	248	40
60-64	315	128	20
65-69	306	124	20
70-74	312	126	20
Total	1546	626	100

ENHANCEMENT OF LAND COVER/USE CLASSIFICATION

BACKGROUND

Knowledge of the capabilities of the earth's soils and the effective application of this knowledge is important to projects analyzing global change. By combining interpreted soils information with satellite data, additional information can be developed that is not possible through the use of either data set alone. In Vermont and other areas where detailed soils mapping has been completed, soils can be grouped into categories of high potential, good potential and low potential for agricultural production. This information can be applied to a classified satellite data set to further refine land cover categories that were not separable by spectral response alone. This is particularly true for grass cover crops and areas in perpetual grass cover that are not reliably distinguishable through normal classification procedures. For example, in dairy farming regions like Vermont, it is difficult to accurately distinguish hay crops like alfalfa and timothy which are considered cultivated crops by the Soil Conservation Service from those fields used as pasture. Farmers usually use fields with better soils to grow cultivated crops and use those with poorer soils for pasture.

METHODS

The testing of classification accuracies and evaluation of the effects of merging other data sets with the satellite land cover data to improve mapping results requires considerable ground reference information. We were fortunate to have available a large watershed of approximately 33,000 acres for which very accurate land use information is maintained. This watershed is monitored by the Vermont Water Resources Research Center, which is a part of the School of Natural Resources. All of this information is maintained within our GIS.

The St. Albans Bay Watershed is located in northwestern Vermont, twenty-five miles north of Burlington, the state's largest urban area. This watershed drains 52.1 square miles (33,344 acres) of farm, forest, and urban land into St. Albans Bay on Lake Champlain (Table 8).

Agriculture is the most common use of land in the St. Albans Bay Watershed. About 60% of the watershed or 20,000 acres is in cropland, hayland, or pasture. Hay and corn are the principal crops. Trends in agricultural land use include converting the better quality pastures to crop or hayland and the poorer quality pastures to woodland, recreational, or urban use. Residential development of former farmland is ongoing, especially on the higher land overlooking Lake Champlain.

Woodland covers about 25% of the watershed or 10,000 acres. Since the average farmer maintains 10-20% of his land as forest, probably 5000 acres or more of this woodland is associated with farms. More than 80% of the forested land is hardwood, mainly beech, birch, and maple. The balance is softwood, primarily red and white pine.

Urban and industrial uses, including 3000 acres for Interstate 89, account for about 12% of the watershed, or 4,000 acres. These uses are concentrated around St. Albans City, but occur also around Georgia Center, in suburban developments off the interstate, and around the perimeter of the Bay, in the form of camps and cottages.

A detailed land use map of the St. Albans Bay Watershed that was used for ground reference information is shown in Figure 3. It was prepared through manual photo interpretation and on the ground surveys. The opportunity to draw upon existing resources provided us with much of the data required for this work. If we had been faced with the extensive data entry and data base building tasks, most of this work would not have been possible.

Table 8. Land Use in the St. Albans Bay Watershed.

Land Use	Acres	Hectares	Percent
Urban	4,001	1,619	12.0
Agriculture	19,673	7,961	59.0
Forest	8,669	3,508	26.0
Wetland	1,001	405	3.0
Total	33,344	13,493	100.0

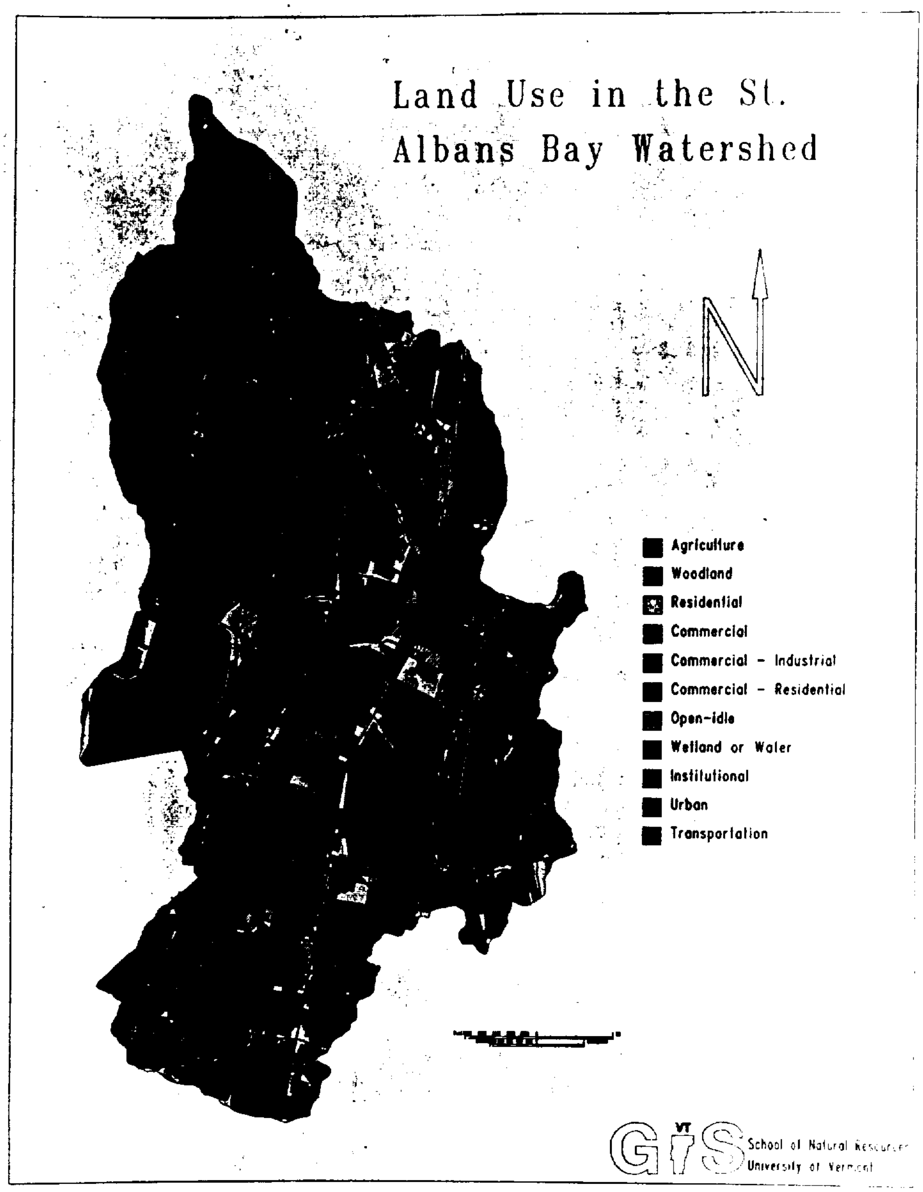

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Figure 3. Land use map of the St. Albans Bay Watershed produced through manual photo interpretation and on the ground verification.

Our experience has shown that the polygon format is more desirable when raster or grid satellite data is being merged with other data sets that are in a polygon format. This allows the addition or merger of data sets with finer resolution (ie. road networks) than that of the grid satellite image. Resultant maps plotted at relatively large scales (eg. 1:24,000) are also superior in appearance to traditional grid cell maps. This greatly improves their acceptance by the user community. However, there are many instances where the only product desired is a set of statistics and a map is not required or desired. This is frequently true for analyses of large areas.

In order to retain the benefits of the polygon system's ability to accommodate data sets of varying resolution, the Remote Sensing Applications Program developed a method to efficiently merge large areas of satellite data with other data sets. This was accomplished through the conversion of the satellite's grid cell data to a point coverage data set within the ARC/INFO geographic information system. Since the ARC/INFO system treats point coverages as polygon coverages in a degraded form, they can readily be merged with other data sets within the GIS. This conversion to point data uses the coordinates of the cell's center to define the point. The resultant points no longer are restricted to a simple XYZ address and description. They now have a polygon attribute table attached that will maintain the results of any action taken on a point.

Specific benefits of this approach include: 1) reduced processing time over normal grid cell to polygon conversion, 2) retained ability to merge data sets of varying resolutions, and 3) greater attribute or data base management capabilities.

The classified TM data set was converted to point format and then overlaid on the previously prepared polygon format land use map. A comparison of the classified TM data and the manually photo interpreted data is shown in Table 9. At this point no attempts had been made to improve the TM data classification by adding masks or integrating other data sources. Errors in classification are apparent and are greatest in the urban areas and in the agricultural areas between those areas that are tilled and those that are untilled.

The next step in classification improvement was to create a new data layer by digitizing the road network within the watershed. Next the areas of confusion in the urban portions of the watershed were corrected through manual photo interpretation. This was also digitized and merged with digitized road network to create a correcting mask. The correcting mask was merged with the point (polygon) classified TM data.

Next all of the soils occurring on agricultural lands were grouped according to productivity potential. Higher productivity soils are devoted to alfalfa production while those of lower productivity are used for hay. From the analysis shown in Table 9 there is confusion and lack of clear separability when based on spectral attributes alone. The results of modifying the classification with soil productivity data and the urban-highway mask are shown in Table 10.

RESULTS

Improvement in the classification results can be seen by comparing the various classes in Table 9 with those in Table 10. This study shows the potential for integrating satellite data with other data layers to improve the accuracy of the classification. Data layers such as soils and road networks change little over time and require little effort in updating. Limited ground

Table 9. Comparison of TM classifications and photo interpreted classification <u>before</u> data layer interpretation.

P.I. Class.	Bare Soil Corn	Brush Wetlands	Grassland	Hardwoods	Hayland	Softwoods	Urban	Water	Total
Ag. Land	136	11	49	543	191	1	26		957
Barn	253	17	47	79	175	3	49		623
Commercial	244		24	49	55	4	146		522
Comm/Indus	267	8	30	87	91		169		483
Comm/Res	509	3	217	319	277	48	951		2,324
Corn	7,258	282	741	1,415	3,658	75	352	31	13,812
Farmstead	36		7	12	14	5	12	1	87
Hay	4,737	307	2,059	2,432	18,495	216	412	2	28,660
Hay/Pasture	1,601	286	1,468	2,147	7,806	134	279	1	13,722
Institution	128	9	16	25	140		43		361
Open-Idle	393	55	205	655	406	60	214		1,998
Open-Rec.	40	7	47	74	258	4	37		467
Pasture	1,953	562	2,022	3,790	7,291	483	413	14	16,528
Residential	1,421	137	571	1,317	1,623	186	722	60	6,037
Roads	324	19	88	262	232	29	150	4	1,108
Sew. Treat.	8	4	1	13			6		32
Urban	291	25	104		86	262	1,008		1,776
Water	50	34	5	128	3	34	152	5,987	6,393
Wetland	138	297	46	592	38	61	78	13	1,263
Woodland	1,679	2,174	1,962	13,909	2,206	4,020	1,451	46	27,447
Woodland/Past.	468	449	1,152	4,223	1,948	1,219	398	7	9,415
TOTAL	21,934	4,686	10,861	32,081	44,993	6,844	7,068	6,166	134,633

Table 10. Comparison of TM classifications and photo interpreted classification <u>after</u> data layer interpretation.

P.I. Class.	Bare Soil Corn	Brush Wetlands	Grassland	Hardwoods	Hayland	Softwoods	Urban	Water	Total
Ag. Land	136	11	57	69	183	1	26		483
Barn							623		623
Commercial							522		522
Comm/Indus							652		652
Comm/Res							2,324		2,324
Corn	7,258	282	1,044	1,415	3,355	75	352	31	13,812
Farmstead							87		87
Hay	4,737	307	4,432	2,432	16,122	216	412	2	28,660
Hay/Pasture	1,601	286	1,929	2,147	7,345	134	279	1	13,722
Institution							361		361
Open-Idle	393	55	124	665	487	60	214		1,998
Open-Rec.	40	7	78	74	227	4	37		467
Pasture	1,953	562	3,576	3,790	5,737	483	413	14	16,528
Residential							6,037		6,037
Roads							1,158		1,158
Sew. Treat.							32		32
Urban							2,250		2,250
Water	50	34	4	128	4	34	152	5,987	6,393
Wetland	138	297	57	592	27	61	78	13	1,202
Woodland	1,679	2,174	2,838	13,909	1,330	4,020	1,451	46	27,447
Woodland/Past.	468	449	1,795	4,223	1,305	1,219	398	7	9,864
TOTAL	18,450	4,457	15,934	29,444	36,122	6,307	17,858	6,101	134,683

truthing on an as needed basis would keep these data layers current. Agricultural land cover includes those crops such as pasture which changes little with time while crops such as hay, alfalfa and corn are rotated on a regular basis. The dynamic portion of this cover must be regularly updated through on-the-ground examination or small format aerial photography. Regardless of the method it would only have to be used on the areas of highest productivity. Since the areas of lower productivity are more constant in their cover, less field or other updating would be necessary. The integration of digital multispectral data with soils and other prepared data layers within the database and mapping capabilities of a GIS proved to be a successful method of improving the land cover/use classification.

MAPPING SEWAGE DISPOSAL CAPABILITY

BACKGROUND

One of the greatest obstacles to comprehensive monitoring of global change is the assembly of all necessary information. Such a task requires the knowledge of many professions and the subsequent integration of this information into a plan or model. Within current computer capabilities there exists the capability to capture and utilize the information from many experts, without the individuals being present. These computer based systems are known as "Expert Systems."

We have worked to establish such a system for soils information. The heart of the system is the SOI-5 soil interpretation records developed by the Soil Conservation Service of the U.S. Department of Agriculture. These interpretation records are available for every mapped soil identified by the Soil Conservation Service. Information within the data base are divided into 8 separate categories which include: 1) Identification, 2) Estimated soil properties, 3) Use interpretations, 4) Capability and predicted yields, 5) Woodland suitability, 6) Wind breaks, 7) Wildlife habitat suitability, and 8) Potential native plant suitability. All of these data were derived from soil surveys.

The soil survey is a detailed inventory and evaluation of the most basic resource of an area -- the soil. It is useful in adjusting land use, including urbanization, to the limitations and potentials of natural resources and the environment. It also can help avoid soil-related failures in uses of land.

During the conduct of a soil survey extensive notes are made about the nature and unique aspects of behavior of the soils. These notes include data on erosion, yield estimates, flooding, the functioning of septic tank disposal systems and other factors affecting the soils under various uses and management. This field experience and the measured data are used as a basis for predicting soil behavior.

This information is useful in the planning and management of soils for crops and pasture, building sites, transportation systems and sanitary facilities. From these data, the potential of a particular soil for a specified land use can be determined. Soil limitations to these land uses can be identified and failures caused by unfavorable soil properties can be avoided. A site where soil properties are favorable can be selected, or practices that will overcome the soil limitation can be initiated.

Planners and others using the soil survey can evaluate the impact of specific land uses on the overall productivity of an area and on the environment. Productivity and the environment are closely related to the nature of the soil. Planning should maintain or create a land-use pattern in harmony with the natural soil. Health officials, engineers and other specialists can find information that is useful in locating septic fields, sources of sand and gravel and sites that cause difficulty in excavation. The safe disposal of wastes, for example, is related to the properties of the soil.

METHODS

By incorporating the SOI-5 records into the INFO relational data base manager of the ARC/INFO GIS it is possible to perform many mapping assignments which in the past required the direct involvement of a trained soil scientist. During the last year of our grant, we acquired the latest edition of the soil interpretation records for all counties currently in our data base and restructured the data base to facilitate queries. The resultant interpreted soil maps, when used as either a stand alone product or in conjunction with remotely sensed land use information can be a powerful planning tool.

In order to demonstrate the type of analyses that are possible using this data base, a study depicting the capability of the soil to support on-site sewage disposal was developed.

The town of Colchester, Vermont just north of Burlington was chosen as a study site. Colchester was formerly a farming community but is rapidly becoming a bedroom community for Burlington. Few farms remain and development, both residential and commercial, is proceeding at a rapid rate.

The first step was to group the Soil Potential Index (SPI) values developed by the Soil Conservation Service. The SPI is the numerical rating of the soil's relative potential for septic tank absorption fields. It is used to rank soils from very high to very low potential and is derived from indices of soil performance, cost of corrective measures, and costs established for continuing limitations, if any. The SPI equation is:

$$SPI = P - CM - CL$$, where:

P = performance index (P is set at 100 as a locally established standard)

CM = index of costs of corrective measures needed to overcome or minimize the effects of soil limitations.

CL = index of costs resulting from continuing limitations. CL is included in the costs of Corrective Measures (CM).

Thus for this study, $SPI = P - CM$

The resulting values between) and 100 for the soils are broken into groups for specific septic disposal application or method. Three groups were used for this study.

RESULTS

The output of the calculations is shown in Figure 4. This map shows the capability of soils in Colchester for on-site sewage disposal. More than one-

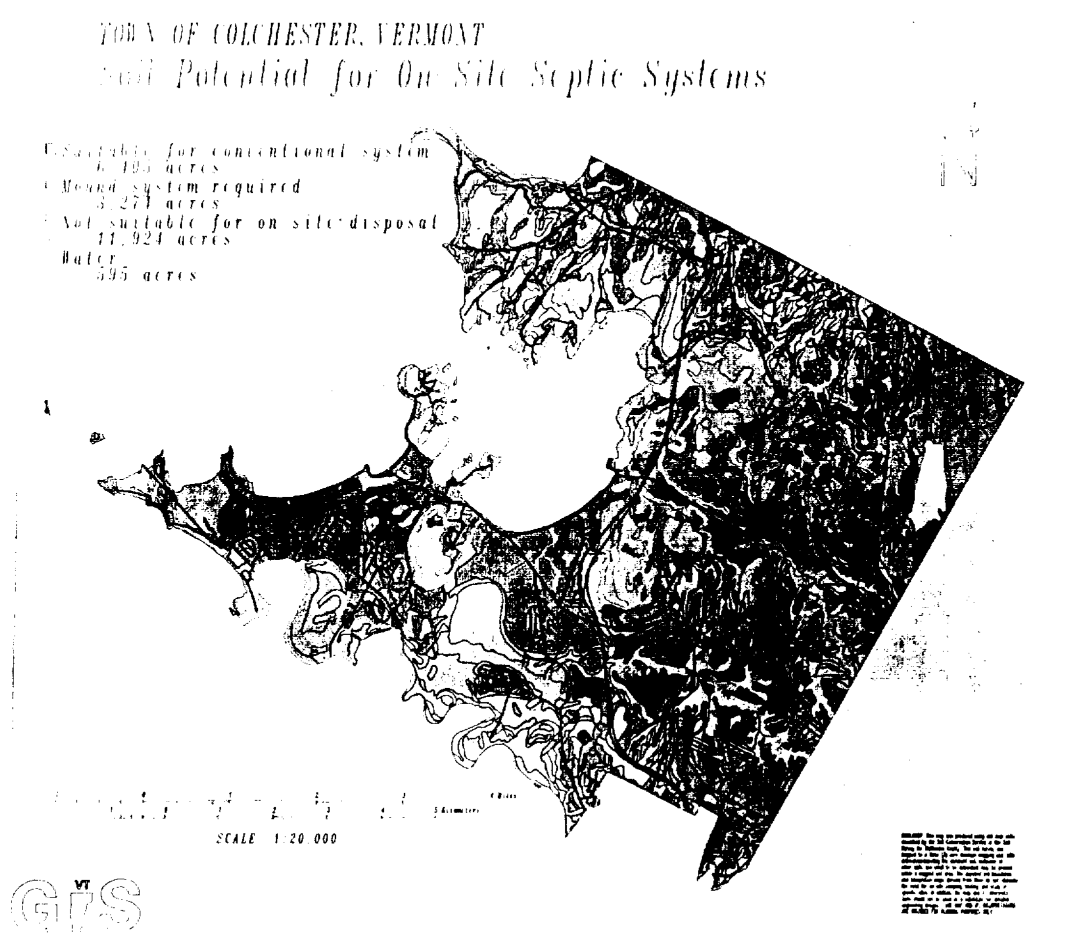

Figure 4. On-site sewage disposal capability for the Town of Colchester, Vermont. This illustrates one type of soil interpretation that can be accomplished using the SOI-5 soils data base.

half of the area of the town is not suitable for on-site disposal. Before development can proceed in these areas, a comprehensive sewage system and treatment facility would have to be constructed. The method is efficient and revealing because it shows problem and non-problem areas. These products can be used to help the Town of Colchester better plan and manage its future.

IMPACT ON AGRICULTURE OF A PROPOSED HIGHWAY

BACKGROUND

As with many other locations in the world, the metropolitan area of Burlington, Vermont is growing quite rapidly. With this growth has come conflict between existing land use activities and pressures for expansion of new facilities to meet population needs. Within the next few years, the communities of Williston, Essex and Colchester will probably be bisected by a circumferential highway that will pass to the northwest of Burlington. The initial environmental impact study, or EIS was found to be deficient in its analysis of the effect this highway would have on the remaining farms in the three town area. The Vermont Agency of Transportation retained a private consulting firm to evaluate this issue. The School of Natural Resources was retained by this consultant to perform the mapping and photo interpretation work for this project.

The objective of this study was to evaluate the proposed highway corridor location, in relation to existing agricultural land and activities. From this evaluation, recommendations could be made that might help mitigate negative impacts from the location of the route.

METHODS

Our activities consisted of two separate but related tasks. The first involved the use of the School's GIS to display and analyze existing and proposed activities in the three towns that were related to the impact of the highway on agriculture. The second task involved the evaluation of other highways that had been built in the state and the associated impacts on the agricultural activities in the surrounding areas. This evaluation involved the interpretation of aerial photography acquired before and after construction.

I. GIS Mapping and Evaluation

The GIS analysis involved both the use of existing digital data and the generation and incorporation of new information into the computer system. All information was compiled on and incorporated into the GIS using overlays of the Vermont orthophoto base maps. The proposed highway location was transferred from very large scale aerial photography on to the orthophotos using a Map-O-Graph and Stereo Zoom Transfer Scope. Data layers used in this analysis included: 1) soils, 2) existing transportation network, 3) surface waters, 4) farm boundaries, 5) zoning boundaries, 6) sewer service areas, and 7) town boundaries.

Using the data base management capabilities for attribute handling, numerous maps of individual "layers" and composite overlays were generated. The interpretations included agricultural soil potential and a ranking of the various farms in the three towns by both viability and suitability. Farm ranking was provided by a panel of agricultural experts from Chittenden County. Farms that were ranked as "suitable" had the physical resources (eg. good soil and facilities) to be a successful farm. The "viability" ranking considered other factors and included the owner's desire to remain in agriculture and monetary resources. All of these factors had to be considered to provide an unbiased analysis.

Besides the agricultural resources, each of the town's zoning plans and areas that had been enhanced by the availability of a sewer system were included in the analysis. If a town had not acted to protect its agricultural interests, and had in fact acted to enhance an area for commercial/residential development, then citing the negative impact of the proposed highway may seem inappropriate.

In all, a series of approximately a dozen maps were created and used at the public meetings held in each town. Particular attention was paid to the points where this proposed highway crossed existing roads. In some locations an intersection was proposed and in other cases, an overpass was planned. Clearly an intersection would create greater development pressure than would an overpass.

II. Photo Interpretation of Similar Sites.

Three separate sites within Vermont were identified for temporal evaluation. Sites were selected in Brattleboro, White River and St. Johnsbury, Vermont. All of these locations had a limited access highway built within the twenty years. In all three cases, it was clear that the road had adversely affected agriculture in the area, either through the loss of acreage from the road itself, or by limiting the accessibility of portions of a farm to the owner. It was clear that the strength of the individual's desire to remain in agriculture was one of the principal determining factors in either the demise or continuation of a farm, following the road's construction.

RESULTS

This project clearly demonstrated the effectiveness of remote sensing and GIS technologies to evaluate impacts such as new highway construction. From this analysis, it was clear that agriculture in the area would be adversely impacted, largely through expanded development pressures. With only one exception, this study found that the proposed road location would not consume large quantities of existing farm land. A recommendation was made to move one section of the proposed road location in Colchester to reduce the loss of agricultural land in an intensive "truck farm" area. In addition, two proposed intersections, one in Williston and the other in Colchester were recommended for conversion to overpasses to reduce development pressures on neighboring farm land.

LANDFILL SITING ANALYSIS

While efforts to recycle more of our waste products are intensified, a need still exists to identify suitable sites for safe disposal of that which cannot be recycled. Through funding from the Chittenden Regional Planning Commission, we were able to use the geographic information system to conduct an initial landfill site screening analysis. Physical limitations to the site were used to reduce the area of consideration. These exclusion factors included high elevation regions, very permeable soils, and areas with high water tables. The resultant reduced area of potential sites was output in map form.

Areas for potential sites were photo interpreted to determine current land use. Areas under development and prime agricultural lands were eliminated from the analysis at this point. This further reduced the areas of interest and facilitated the identification of sites that would be ground checked and subjected to more intensive engineering studies.

SUMMARY AND CONCLUSIONS

Land managers increasingly are becoming dependent upon remote sensing and automated analysis techniques for information gathering and synthesis. There is good reason for this. Remote sensing and geographic information system (GIS) techniques provide quick and economical information gathering for large areas.

Remote sensing has grown dramatically during the late 1970s and the 1980s. New satellites, carrying new sensors with increased spatial and spectral resolution, have become operational and continue to provide users with timely synoptic data. Remote sensing, however, cannot be considered in a vacuum. The outputs of remote sensing classification and analysis are most effective when combined with a total natural resources data base within the capabilities of a computerized GIS. The utility of remote sensing products increases when they can be compared and merged with data from other sources such as transportation networks, soils surveys, meteorological data, geologic maps and census data. There is an increase in the flexibility of these procedures when the computer and a geographic information system are used in combination as a spatial analysis tool. This combination of various data sources frequently produces synergistic results that are of greater use than any or all of the individual sources taken separately. We see GIS and remote sensing as one entity concerned with capturing, storing, processing, analyzing and outputting geographic data.

We have presented some examples of the successes, as well as the problems, in integrating remote sensing and geographic information systems. Most have been attempts to demonstrate and solve the problems of cooperators in the wide user community. At this point, three years after the termination of the project, many of these techniques have become routine operations for municipal and state government planners and managers in Vermont and our neighboring states.

The need to exploit remotely sensed data and the potential that geographic information systems offer for managing and analyzing such data continues to grow. As the potential for increased use has grown, so has the capability to utilize this potential. Since the termination of this project, new and greatly improved computer hardware and software have become available. New microcomputers with vastly enlarged memory, multi-fold increases in operating speed and storage capacity that was previously available only on mainframe computers are a reality. Improved raster GIS software systems have been developed for these high performance microcomputers. Vector GIS systems previously reserved for mini and mainframe systems are available to operate on these enhanced microcomputers. Image processing that were developed on mini computer systems have been revised to run on this new generation of microcomputers. At the same time vendors of software that ran on the previous generation of microcomputers, have been able to expand and upgrade their offerings. Although this trend toward more powerful microcomputer systems will not eliminate the need for GIS systems configured for larger computers, true GIS capability is now available, at reasonable cost, to many users who cannot afford the larger systems.

One of the more exciting areas that is beginning to emerge is the integration of both raster and vector formats on a single computer screen. This technology will allow satellite imagery or digital aerial photography to be presented as a background to a vector display. Through direct on-line photo interpretation it will be possible to interactively update land cover maps, assess agricultural areas by soil characteristics and many other tasks.

In addition to greatly improved microcomputers and software, the development of peripheral hardware has accelerated at a parallel pace. Digitizers and plotters of greatly improved capability are available at reasonable cost. A most useful and exciting technological upgrading has been the development of low cost partial- and full-page scanners. Just a few years ago, polygon maps such as soils maps had to be digitized or sent out to be scanned on very expensive equipment. This was also true for aerial photographs. Both options were time consuming and expensive. Now for less than two thousand dollars, a full-page high resolution scanner can create raster or vector files from line drawings or continuous tone black-and-white or color images. None of these technological developments was available for use during the period of our investigations. Now we have them and their use by planning and managerial practitioners has become routine.

As a result of this technology, we have the capability to query the data bases that we create for both spatial and non-spatial information. This was a key factor in the conduct of these studies. Equally important is the capability to join both types of information through relationships developed within the structure of the GIS. Functions of the GIS software such as overlay, merge, union, map join, intersect and dissolve enabled us to integrate data from multiple sources into a single data layer. We can create data that did not previously exist.

Once data sets have been entered, the flexibility of the GIS allows additional data sets to be added for the same or other geographic locations. These may include data sets from past and future points in time thus creating a data base that permits study of change.

The landscape of the earth will continue to change as demands for resources accelerate. We must continue to develop methods that will enable us to analyze and predict the changes that will result from these demands. The merging of remote sensing and GIS technologies provides a method for monitoring and analyzing these changes.

REFERENCES

Anderson, J.R., Hardy, E.E. and Roach, J.T. 1972. A land use classification system for use with remote sensor data. Washington, D.C. U.S. Geological Survey Circular 671. 16 pp.

Post, B.W. and R.O. Curtis. 1970. Estimation of Northern Hardwood Site Index from Soils and Topography in the Green Mountains of Vermont. Bulletin 664 Agricultural Experiment Station, University of Vermont, Burlington, Vermont.

UVM/SCHOOL OF NATURAL RESOURCES
REMOTE SENSING APPLICATIONS PROJECTS

YEAR	TITLE/DESCRIPTION	COOPERATING AGENCIES
1978-1987	General Education and Technology Transfer	NASA/ERRSAC VT DEPT. OF FORESTS AND PARKS VT DEPT. OF FISH AND WILDLIFE STATE OFFICE/SCS UVM/COLLEGE OF AGRICULTURE VT STATE PLANNING OFFICE NH STATE PLANNING OFFICE NH FISH AND GAME DEPT. NH WATER RESOURCES DEPT. CENTRAL VERMONT PUBLIC SERVICE CORP.
1978-CONT.	Systems Development for Data Handling and Analysis	UVM/COMPUTING CENTER PENN STATE UNIVERSITY UVM SCHOOL OF NATURAL RESOURCES VT AGENCY OF ENVIRONMENTAL CONSERVATION
1978-1981	Vermont Land Cover Classification	ERRSAC VT DEPT. FORESTS AND PARKS VT DEPT. WATER RESOURCES VT FISH AND WILDLIFE DEPT. ADIRONDACK PARK COMMISSION
1978-1980	Land Use Change Demonstration	CHARLOTTE PLANNING COMMISSION CHITTENDEN COUNTY REGIONAL PLANNING COMMISSION
1979	Land Cover/Use Classification for Planning	CENTRAL VERMONT REGIONAL PLANNING COMMISSION TOWN MANAGERS OF FAYSTON, WAITSFIELD, AND WARREN VT TAX DEPARTMENT
1979-1981	Vermont Remote Sensing Data Inventory	UVM/DEPT. OF GEOGRAPHY U.S. FOREST SERVICE VT HIGHWAY DEPT.
1979-1980	Land Cover/Use Change for Watershed Monitoring	UVM/WATER RESOURCES RESEARCH CENTER SOIL CONSERVATION SERVICE CHITTENDEN COUNTY SCS CRREL-CORPS OF ENGINEERS
1979-1986	Forest Insect Defoliation Detection	VT DEPT. FORESTS AND PARKS U.S. FOREST SERVICE

1979-1980	Lake and Pond Watershed Cover Classification	VT DEPT. WATER RESOURCES
1980	River Watershed Cover Inventory	STATE OFFICE/SCS
1980	Coniferous Species Differentiation	UVM/FORESTRY DEPT. VT DEPT. OF FORESTS AND PARKS
1980-1982	Water Quality Monitoring	VT DEPT. WATER RESOURCES ERRSAC ENVIRONMENTAL PROTECTION AGENCY
1980	Water Use Conflict Study	UVM/RECREATION MANAGEMENT PROGRAM
1980	Water Body Inventory	UVM/WILDLIFE BIOLOGY PROGRAM VT FISH AND WILDLIFE DEPT. SOIL CONSERVATION SERVICE
1981-1982	Brighton Land Cover/Use Mapping for Planning	BRIGHTON PLANNING COMMISSION ST. REGIS PAPER COMPANY
1981-1983	Morristown Farmland Inventory and Agricultural Land Study	CENTRAL VERMONT REGIONAL PLANNING COMMISSION MORRISTOWN PLANNING COMMISSION VERMONT EXTENSION SERVICE LAMOILLE COUNTY DEVELOPMENT COUNCIL
1981	Site Analysis for Planning	CITY OF WINOOSKI
1981-1982	New Hampshire LANDSAT Demonstration	NEW HAMPSHIRE STATE AGENCIES INCLUDING STATE PLANNING, FISH AND GAME, FORESTRY COMMISSION ERRSAC UNIVERSITY OF NEW HAMPSHIRE
1981-CONT.	Small Format Aerial Photography	VT DEPT. FORESTS AND PARKS UVM SCHOOL OF NATURAL RESOURCES CENTRAL VERMONT PUBLIC SERVICE CORP. UVM COLLEGE OF AGRICULTURE
1981-1982	LANDSAT Demonstration to Essex County Soil	ESSEX COUNTY SOIL CONSERVATION
1981	Forest Insect Defoliation Mapping	VT DEPT. FORESTS AND PARKS
1981-1982	Northeast Kingdom LANDSAT Land/Cover Classification	ST. REGIS PAPER COMPANY

1982	Tinmouth Channel Cover Type Mapping	CENTRAL VERMONT PUBLIC SERVICE CORP. VT DEPT. OF FISH AND WILDLIFE
1982	New Hampshire Deer Yard Mapping	NEW HAMPSHIRE FISH AND GAME DEPT.
1981-1982	Southern Lake Champlain Water Study	VT DEPT. OF WATER RESOURCES ENVIRONMENTAL PROTECTION AGENCY
1982-1983	Spring Phosphorous Concentrations of VT's Lakes & Ponds	VT DEPT. OF WATER RESOURCES
1982-1983	Aquatic Vegetation Mapping	VT DEPT. OF WATER RESOURCES
1982	Power Line Right of Way	VERMONT ELECTRIC POWER CO., INC.
1982-1983	Spruce Budworm Stand Condition Rating	INTERNATIONAL PAPER CO.
1982	Watershed Cover Type Mapping	CENTRAL VERMONT PUBLIC SERVICE CORP.
1982-1983	Vermont Cover Type and Soils Boundary Digitizing, Integration and Map Production	VERMONT DEPT. OF AGRICULTURE
1983-1985	Thematic Mapper Classification	NASA, GODDARD SOIL CONSERVATION SERVICE U.S. FOREST SERVICE VT AGENCY OF ENVIRONMENTAL CONSERVATION
1983-1987	Creation of the Vermont State Data Base	SOIL CONSERVATION SERVICE VT AGENCY OF ENVIRONMENTAL CONSERVATION VT STATE PLANNING VT DEPT. OF TRANSPORTATION VT. DEPT. OF AGRICULTURE
1983-1984	TMIS/GIS Demonstration	GREEN MOUNTAIN NATIONAL FOREST