TM-85001

NASA

Technical Memorandum 85001

Monitoring Strip Mining and Reclamation with Landsat Data in Belmont County, Ohio

R. G. Witt, G. M. Schaal, and B. G. Bly

MARCH 1983

ACKNOWLEDGEMENT

TABLE OF CONTENTS

MONITORING STRIP MINING AND RECLAMATION WITH LANDSAT

DATA IN BELMONT COUNTY, OHIO

Executive Summary

The Belmont County, Ohio, Strip Mine Monitoring Project was one of three cooperative demonstration projects developed after a Landsat familiarization workshop in Columbus, Ohio on June 6, 1979. The project was done by the Ohio Department of Natural Resources (ODNR), Division of Water/Remote Sensing Unit, in close collaboration with the National Aeronautics and Space Administration's Eastern Regional Remote Sensing Applications Center (ERRSAC). The object of the project was to show the potential of operational Landsat technology for mapping and monitoring change in surface mines over a three-year period of time for Belmont County in eastern Ohio. After definition of project objectives, several members on ODNR's Remote Sensing Unit attended ERRSAC's one-week training course in December 1979 to learn about applications of satellite remote sensing and processing of Landsat digital data with the Office of Remote Sensing for Earth Resources (ORSER) software package.

Two Landsat multispectral scanner (MSS) data sets acquired in 1976 and 1979 were the prime data sources for the project. Most preprocessing functions, such as subsetting the County study area from both MSS scenes, registering the data sets to the Universal Transverse Mercator coordinate system, and digitizing the County boundary, were performed by ERRSAC using the Interactive Digital Image Manipulation System (IDIMS) software implemented on a Hewlett-Packard HP-3000 computer. A transfer tape containing each data set was prepared and sent to Pennsylvania State University for classification (processing) via remote terminal by ODNR personnel.

During processing, the ORSER software package was used to produce grayscale line-printer maps showing spectral uniformity and brightness within the data sets. These maps subsequently were used to select training sites representing all land cover categories of interest to the state analyst.

From training site statistics developed at ODNR, supervised classifications of the County were generated for both data sets on the IDIMS at ERRSAC. These classifications were refined by the ODNR analyst until they were satisfactory. The digitized Belmont County boundary was then overlaid on the classified images, final products were prepared, and acreage statistics were extracted for each category in both data sets.

Accuracy was assessed by use of thematic plotter maps of the classifications superimposed on several U.S. Geological Survey 7.5 minute topographic quadrangle maps. These were then compared with aerial photographs acquired the same years as the Landsat data set. The overall classification accuracy of both final

images (1976 and 1979) is about 86 percent. A color-keyed change detection image was also produced to graphically illustrate the extent of reclaimed strip mined areas and new surface mines.

The ODNR Remote Sensing Unit, in collaboration with the Ohio Division of Reclamation, has concluded that Landsat data are valuable and economical in terms of cost and time for delineating and monitoring strip mines and other land covers on a regional scale. The classified data provide both maps and statistical estimates of areal extent for all land use categories. Thus the ODNR recommends that Landsat technology be used to monitor strip mining and reclamation over the entire coal mining region of Ohio on a regular, operational basis.

I. Introduction

On June 6, 1979, a remote sensing workshop was held in Columbus, Ohio. Among the participants were the Eastern Regional Remote Sensing Applications Center (ERRSAC), the Ohio Department of Natural Resources (ODNR), and the Ohio Environmental Protection Agency. The purposes of the workshop were to demonstrate the applications of satellite data, to identify potential State users of Landsat data, and to initiate cooperative demonstration projects that would determine whether Landsat data could be used as a resource management tool in continuing State programs.

As a result of this workshop, three cooperative demonstration projects were developed. These were:

o   Surface-mine monitoring in Belmont County

o   Land-cover mapping and change detection in Clark County

o   Wildfowl habitat assessment in Pickaway County

This report addresses the first of the three projects.

Belmont County was chosen for the surface mine mapping project conducted by ERRSAC and the Remote Sensing Unit, Division of Water, ODNR. The Division of Reclamation collaborated by supplying technical information about strip mining practices and definition of State monitoring requirements.

II. Project Description

A. Background

Unreclaimed strip mined areas in Ohio are subject to excessive erosion that causes downstream sedimentation, landsliding and other mass movement. This results in loss of otherwise useful land as well as water quality problems. A major goal of Ohio's surface mine reclamation program, in addition to monitoring current strip mining and reclamation practices, is correction of the most severe mine-related problems in eastern Ohio's coal mining region. In this

process, the unaltered land covers in areas surrounding mine activities are surveyed to establish guidelines for planning appropriate restoration strategies.

B. Objectives

The objectives of this project were:

o   To produce Level I (Anderson et al., 1976) land cover maps for 1976 and 1979 Landsat images over Belmont County. In addition, the barren land category was to be subdivided into the level IV categories of Schaal, 1977. Specific level IV categories to be identified were (1) active or inactive unreclaimed strip mines, (2) inactive graded mines, and (3) inactive partially reclaimed (vegetated) areas.

o   To produce a "differenced-image" map showing spatial distribution of land cover changes occurring over the three-year time period with respect to strip mining and reclamation.

o   To produce statistical data with acreage counts of all categories for both years.

C. Study Area

Belmont County has long been Ohio's leading producer of high-grade bituminous coal (see USGS, 1963). Figure 1 shows that its total production is nearly equal to that of the second- and third-ranking Ohio counties combined. The County's strategic location on the Ohio River in the industrial heart of the Appalachian Basin (Figures 2 and 3) has helped make this part of Ohio very important to both State and regional economies.

The vegetation in Belmont County at the time of the earliest surveys was a mixed forest of oak, sugar, maple, and beech. Much of this original ground cover has been removed by agriculture and mining. Agriculture is currently the primary activity in the County in terms of persons employed, but revenues from mining and manufacturing exceed those from agriculture.

Much strip mining in Belmont County was done prior to 1977 when reclamation laws were less stringent than those put in force in that year. A large part of the area affected by early stripping has become revegetated through natural processes, but a significant part is still essentially unreclaimed by modern standards.

3

FIGURE 1. Coal Production in Ohio by County

Production (millions of tons)

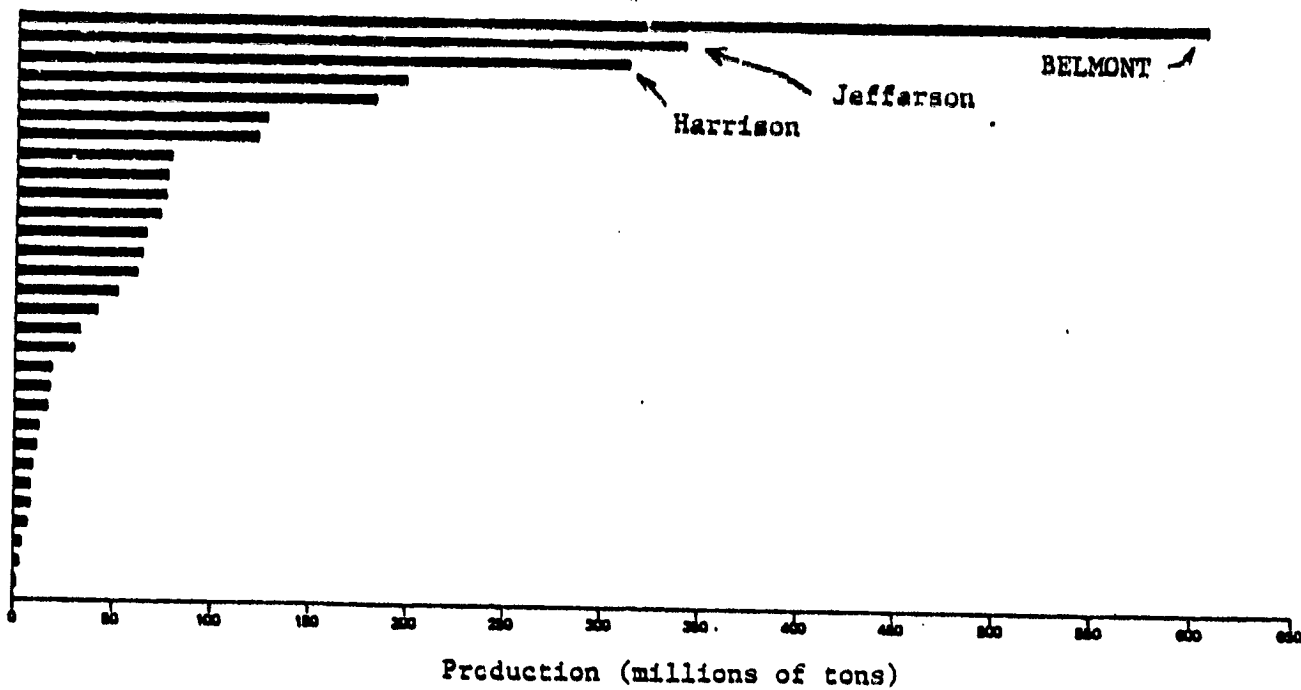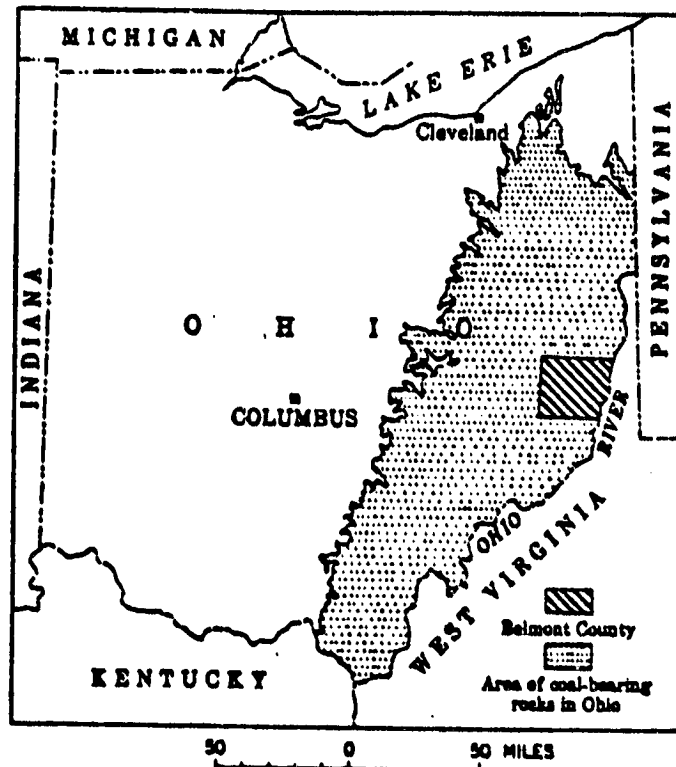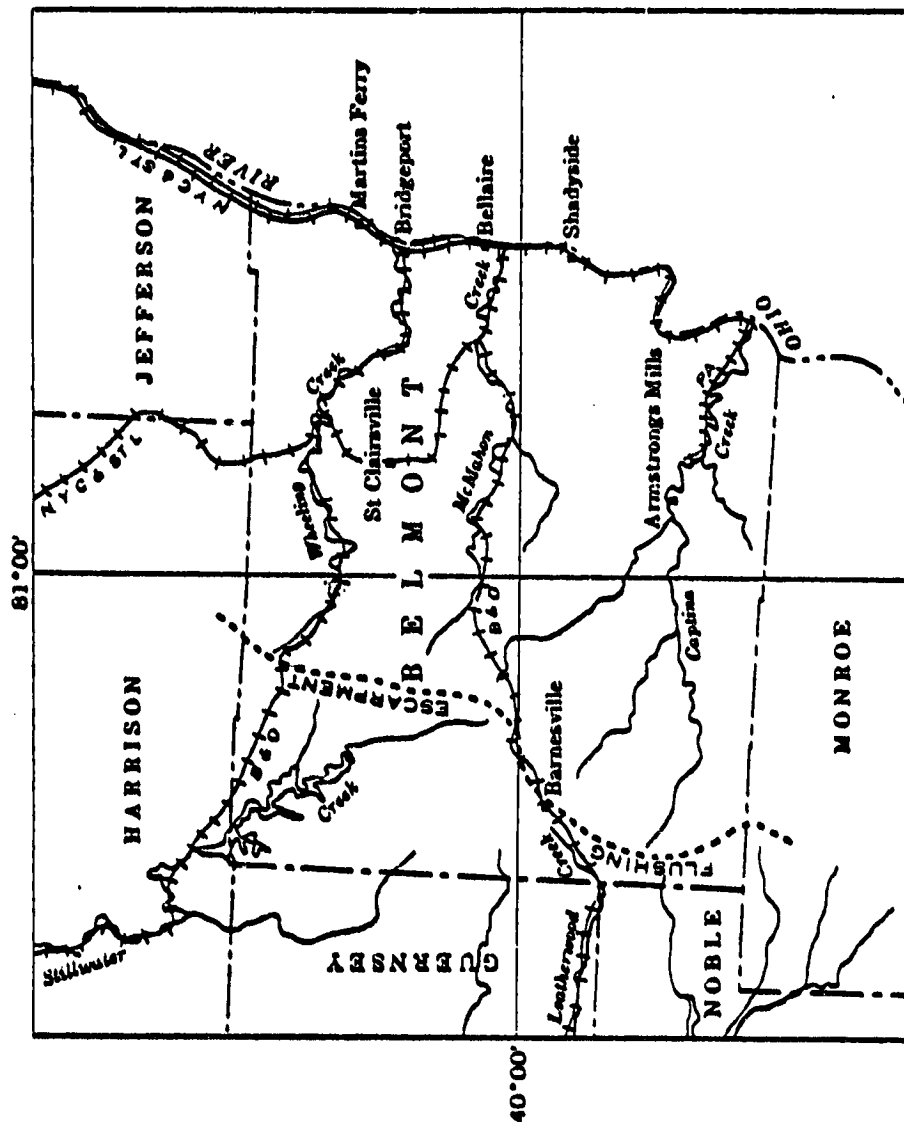FIGURE 2. Location Map for Belmont County

FIGURE 3.   Index Map of Belmont County, Ohio, showing the location of main towns, streams, and railroads, and the main drainage divide, the Flushing escarpment (USGS, 1963).

D. Data Sources

The following data sources were used:

o Landsat multispectral scanner (MSS) data from April 1976 and September 1979.

o Black-and-white 1:30,000-scale aerial photographs from April and October 1976.

o Black-and-white 1:12,000-scale aerial photographs from May 1979.

o Color-infrared 1:120,000-scale aerial photograph of the northwest portion of the County from 1979.

o Land use/land cover maps at 1:120,000 scale from 1979 (ODNR Remote Sensing Unit).

o 7.5 minute U.S. Geological Survey topographic quadrangle maps for all of Belmont County.

III. Methodology

The scenes were chosen on the basis of two criteria. First, they had to be at least three years apart to detect significant changes in land use, particularly where strip mining and reclamation were concerned. Second, there had to be aerial photographs available as close to the dates of the scenes as possible. This was particularly important since areas of stripping and reclamation may change over only a few months.

A. IDIMS Preprocessing

The boundary of Belmont County was located within the Landsat scene and all MSS data within the scene were extracted by use of ERRSAC's Interactive Digital Image Manipulation System (IDIMS). This extracted data set was geometrically corrected with a series of automated preprocessing programs. To transform the data set, these programs computed correction formulas for known Landsat distortions on the basis of information on image size, center point latitude, and pixel shape. In the correction process, the data were deskewed and rotated to true north, and output pixels were squared at 50 meters. The geocorrected data were map-registered, copied to tape in ORSER-compatible format by procedures documented by Sekhon (1980), and shipped to the Pennsylvania State University computer facility. In October 1980 processing was switched to COMNET, a commercial time-sharing computer firm, and subsequently to UNI-COLL, another commercial facility. Digital analysis of the 1976 subscene was performed with the ORSER software package on the IBM 370/108 computer at the Pennsylvania State University via a remote access terminal at ODNR in Columbus, Ohio. Analysis of the 1979 subscene accessed data implemented on commercial systems.

B.   ORSER Processing

The data were classified with a minimum-distance classifier in which each category is described by its spectral mean and distribution of samples. The probability that an observation (pixel) belongs to a given category decreases with the Euclidean distance (ED) from the mean.

The first step in processing was to generate a brightness map of Belmont County. The map was generated to assist ODNR in geographically locating intensive study areas (ISAs) to be analyzed in detail within the County. Specific areas were identified by visually correlating blocks of Landsat data, grouped according to brightness, with features identified on the aerial photographs. The ISAs were then extracted from the ORSER file containing the County data and saved as separate image files. This process eliminated the need to refer frequently to the entire original data set. The area surrounding Piedmont Lake, the largest and most complex ISA, was particularly suited for obtaining strip mine signatures because it contained mines in all phases of development and reclamation. Uniformity maps of the ISAs were generated to highlight the spatial patterns of spectral homogeneity and contrast. From the homogeneity maps, training sites were selected for each land cover category.

The training sites for the supervised classification were selected without difficulty for the water, forest, and agricultural categories; each site selected covered more than 40 acres. Rangeland was more difficult to identify because it occurred in areas of 20 acres or less. Standard deviations for these categories were generally less than two sigmas.

The remaining category classified was barren land. This category was subdivided into the three strip mine categories mentioned under Objectives. It was the selection of training sites for these categories that required the bulk of the analyst's time. The easiest selection method found was to first classify and map all categories but barren categories, and then to look for uniform unclassified areas. These areas averaged only five to 15 acres. Obtaining the larger areas necessary for developing valid signatures required that many of the small training sites which had similar signatures be combined and analyzed to determine whether they were statistically similar. Even in "building" training sites in this manner, several combined sites had standard deviations between two and three sigmas.

Since urban categories are generally difficult to identify and were of little interest in this project, a decision was made to digitize and remove the major urban areas during classification. These generalized urban areas were then overlaid onto the final classifications.

During the classification process, ODNR routinely compared the results of statistical modification with previous classification maps and aerial photographs. Signature development from individual land cover categories was ended when further modifications did not noticeably improve the category accuracy or when the analyst felt that the classification results accurately represented the supporting information.

A statistical evaluation was consistently done to review the signature means, standard deviations, and frequency histograms of each training site. The histograms were helpful in assessing the validity of the statistical samples. From the histogram analysis it sometimes became evident that a category should be divided into two categories or eliminated because of excessive spectral variation. Another statistical tool used to determine spectral similarity was the distance of separation (DOS) measure. DOS tables measure the Euclidean distance (ED) between categories and were used to eliminate redundant signatures. After a basic classification had been achieved, the EDs associated with many of the signatures were adjusted in an effort to optimize discrimination among categories.

After the ED fine-tuning, the revised signature catalog containing 30 spectral classes developed for eight categories was sent to ERRSAC and entered into an IDIMS statistical file. Final category signatures for both dates are listed in Appendix B.

Final refinement of the classifications and differencing of the two classifications were conducted with the IDIMS. The classification was fine-tuned on IDIMS because the interactive color display allowed quick and easy variation of class assignments. Color classification maps of the Lake district, an area of heavy strip mine activity, were generated and sent to ODNR. After receiving approval, ERRSAC generated geometrically corrected 1:24,000-scale thematic plotter maps of the area for use in the accuracy assessment.

C. Accuracy Assessment

A simple random-sampling technique was used to determine the accuracy of the classifications (see Mason, 1978, pp. 262-267). A decision was made by the participants that they wanted to be 95% certain that the accuracy figure arrived at was correct, within an error margin of ± 5%.

A mylar grid was constructed with each cell representing 100 pixels (10 x 10) at a scale of 1:24,000 to superimpose over thematic plotter maps of several quadrangles in Belmont County. A formula (Appendix A) was used to determine the number of cells to be randomly selected.

The mylar grid was numbered on the x and y axes, and values for x and y were chosen from a table of random numbers. The grid was superimposed upon the thematic plotter maps, and the land covers were recorded for each of the selected cells. Approximate proportions of land cover in a cell (e.g., 50%, 20%, 20%, and 10% for four different land uses in one cell) might be recorded as ++, +, +, -.

After the land covers were identified and recorded, the grid was overlaid onto existing 1979 ODNR land use/land cover maps of the same scale. The same cells were checked and the land use(s) recorded. The photointerpreted 1979 land use data were then compared with the Landsat data. If the majority of land covers within the Landsat cells agreed with the majority of land covers in the photointerpreted cells, the Landsat data classification was considered correct. The 1976 Landsat land cover data were compared with 1976 aerial photographs.

The number of pixels correctly classified out of the total sample was 150/174 for the 1976 classification and 141/163 for the 1979 classification. Thus both classifications are about 86% correct.

IV. Results

A. Discussion

This project provided the first experience for the ODNR with hands-on analysis of Landsat digital data. In learning the procedures and gaining experience, the only major handicap encountered was using a small-format line printer for the output. Training sites were selected with few problems, but when it was necessary to get an overall look at a classification map, the black-and-white alphanumeric paper printouts taped together were not easily used. If ODNR decides to analyze Land t data on an operational basis, it is highly recommended that a cathode ray tube (CRT) with color display be acquired.

Another area that bears emphasis is the need to have ground truth data corresponding as closely as possible in time to the Landsat data. As mentioned earlier, this is particularly important when dealing with strip mining and reclamation activities, which have a tendency to change the landscape relatively quickly. It is neither realistic nor prudent to pick a training site to use for classifying an entire scene when the training site is not 100% identifiable. The closest attention must be paid to correctly identifying the training sites. In most cases, this means planning for the acquisition of future scenes, or searching for appropriate photographic coverage when existing scenes are involved.

An alternative to aerial coverage was considered in classi-
fying the later scene in Belmont County. That alternative
was to pick several sites throughout a project area (each
of differing land use or cover) and monitor them through
time with information supplied by landowners, or obtained
visually during overflights. Once the tapes are preprocessed
and ready for training site selection, the monitored areas
would be located and selected as training sites. Tnough
this process was not actually tried, the same results were
obtained by simply using the old training sites from the
earlier scene. It soon became apparent that the old sites
were no longer statistically valid or interchangable with
the second Landsat data set.

The reasons for this are variation in such actors as
atmospheric conditions, vegetation growth conditions, etc,
etc. These variables change with time so that what was a
good training site in the past is not necessarily good in
the future. However it is accomplished, the need for proper
selection of training sites is crucial for accurate
classification, and availability of supporting ground truth
should be considered when selecting a Landsat scene for
analysis.

The statistical accuracy of the results is comparable to
that in similar projects using different data sets. When
examined thoroughly, the results are even more useful than
the percentage figures might suggest. For example, the
greatest discrepancies were in rangeland and agricultural
land (which includes pasture). If these categories were
considered together as open fields, then the accuracy would
be significantly higher. In fact, for the Ohio Division of
Reclamation, identifying open fields vs. stripped land or
forest land is quite sufficient, particularly with regard to
changes in mined areas over time. It is not important that
what was a stripped area in 1976 is now (1979) rangeland or
agriculture, or that what was a pasture in 1976 is a strip-
ped area in 1979. The important fact is that a stripped
area has been adequately reclaimed or that a formerly non-
stripped area is now being affected by mining. It is this
general trend that is important, and in this project such
trends were correctly identified. It may of course be
important in other, future projects to separate range from
agricultural land. Recognizing this, more emphasis would be
placed on making that type of distinction.

B. Statistical Data

There are a few discrepancies in the 1976 and 1979 classifi-
cations (see Table I). These discrepancies are due
primarily to three factors. First, the 1976 scene was the
initial attempt at classifying Landsat data, and some parts
of the classification may be less than optimal. Second,
the two scenes were from different seasons (spring and
summer). There was less vegetation in the spring than in

10

the summer scene, particularly for the forest category in which there was more reflectance from ground cover in the spring with the leaves off. Third, there were actual changes in land use from 1976 to 1979, particularly in the mine classes.

TABLE I

Landsat Acreage Statistics

Landsat Classifications

Category	1976 Acres	Percent	1979 Acres	Percent
Mines; active/ disturbed	18,287	5.3	3,206	0.9
Mines; barren/ graded	5,456	1.6	4,782	1.4
Mines; partially reclaimed	9,123	2.7	16,017	4.7
Rangeland	70,609	20.5	95,804	27.9
Agriculture	94,669	27.5	58,067	16.9
Forest	131,718	38.3	150,603	43.8
Water	1,954	0.6	3,949	1.1
Urban	7,499	2.2	7,362	2.1
Unclassified	4,610	1.3	4,159	1.2
Total	343,925	100	343,949	100

Discrepancies notwithstanding, the statistics when grouped into stripped vs. non-stripped areas give an excellent overview of stripping activities over the observation period. The area affected by stripping was reduced from 9.6% of the County to 7.0% from 1976 to 1979 (Table II). Rangeland and agricultural land combined were reduced from 48% (1976) to 44.8% (1979). The forest category increased from 38.3% in 1976 to 43% in 1979. At least part of this increase was due to refinement in forest identification in the 1979 summer scene. Grouping the categories in this manner gives a better indication of land cover changes over the observation period.

TABLE II

Aggregated Landsat Acreage Statistics

| | 1976 | | | 1979 | |
	Acres	Percent		Acres	Percent
Stripping	32,866	9.6		24.005	7.0
Open Land	165,278	48.0		153,871	44.8
Forest	131,718	38.3		150,603	43.8
Water	1,954	0.6		3,949	1.1
Urban	7,499	2.2		7,362	2.1
Unclassified	4,610	1.3		4,159	1.2
Total	343,925	100.0		343,949	100.0

C. Products

The project produced eight color-coded classification maps for Belmont County: land cover maps of the entire County for 1976 and 1979 (Figures 4 and 5); larger scale land cover maps of the Piedmont Lake area for 1976 and 1979; a land cover change detection map of the entire County and the Piedmont Lake portion, showing changes in land use from 1976 to 1979; and a change detection map of the entire County and the heavily stripped area, showing only changes in stripping and reclamation from 1976 to 1979 (Figure 6). Also produced were two sets of 1:24,000-scale thematic mylar plotter maps showing land use in 1976 and 1979 for the Piedmont Lake area.

V. Conclusions

A. Successes and Limitations

The project fulfilled all the objectives required by the Division of Reclamation in II(B); i.e., it produced level I landcover maps of Belmont County for both dates (as well as identifying level IV surface mine areas), showed areas of change with an image-differencing map, and generated statistical data (acreage counts) of all classification categories for both dates. The final classification accuracies were relatively high, especially considering the level of discrimination within the barren land category. Most important is the fact that the user agency involved, ODNR's Remote Sensing Unit, is very satisfied with the results of the project and recommends (see part B) that Ohio continue to use Landsat data on an operational basis. At the scale considered here (county or regional), Landsat is the best available tool for mapping and monitoring change in surface mined areas.

Some shortcomings in the results should be mentioned. First, the classifications show large increases in the extent of the forest and range categories and a large decrease in the agricultural category from 1976 to 1979. These data probably do not indicate real trends within the study area, but more likely reflect classification statistics that placed greater emphasis on delineating strip mined and reclaimed land than on the other categories. Second, the spatial resolution of the MSS is such that this sensor is more useful for mapping the general pattern and extent of surface mines over large areas than for delineating individual mined sites. Detecting and accurately mapping small impoundments was a particular problem. Nevertheless, the classifications provide very good estimates of surface mined areas. The problems mentioned here could and will be alleviated by: a) more careful selection and precise location of training sites for agricultural, range, and forest categories; and b) use of higher resolution (30 meter) data from the Landsat Thematic Mapper, which can be expected to increase classification accuracy for small surface mined areas (see Irons, 1981).

B. User Evaluation

The Landsat color-coded classification maps clearly illustrate a number of complex site characteristics relating to stripmine reclamation which would otherwise be difficult to compare between sites. The land cover changes indicated by the analysis clearly show the problem spots and reclamation trends in the area.

Landsat analysis will be of immediate use to the Ohio Division of Reclamation in several ways:

1. Estimating coal reserves and future mining trends through comparison of mined and unaffected areas.

2. Evaluating the effectiveness of past and current reclamation techniques.

3. Statistically summing acreage affected by mining in specific drainage basins.

4. Monitoring the location and extent of current mining permits at a scale commensurate with Landsat data.

5. Conducting surveys and inventories of abandoned mined land for areas greater than 100 acres.

6. Providing land cover information for areas around mining sites for environmental planning and restoration.

Experience has shown that, on the regional scale, all of

13

these tasks could be completed much more quickly and inexpensively with Landsat data than with aerial photography or ground-based techniques.

C. Recommendations for Future Activities

The application of Landsat data is recommended for monitoring strip mining and reclamation over the entire coal mining region of Ohio. With the experience gained through this project, an operational system could readily be used to provide the data required by the Division of Reclamation for analyzing present and future effects of strip mining in Ohio. It is recommended that ODNR decide soon about the operational status of Landsat data processing so that a smooth and timely transition can be made from demonstration status to operational status.

It is nearly certain that, once an operational system is in place and projects are underway, there will be spinoff benefits in land cover data generated as by-products of the main thrust to other divisions in ODNR. For example, the Division of Forestry could benefit from the forest statistics. With additional training, the forest statistics could be subdivided into more useful data (e.g., associations such as coniferous/deciduous/mixed forest types).

Landsat and other similar satellites with electromagnetic recording sensors are increasingly valuable in resource monitoring as the process becomes a more automated one. With the advent of an operational Landsat program in 1983, and the availability of improved spectral and spatial performance, it is evident that refined classification will be possible. Now is the time to establish an operational system for use by persons responsible for managing Ohio's land and its resources.

14

REFERENCES

1. Anderson, J. R., Hardy, E. E., Roach, J. T., and R. E. Witmer. 1976. A land cover classification system for use with remote sensing data. U. S. Geological Survey Professional Paper 964, Washington, D.C., 33 p.

2. Irons, J. R., Lachowski, H. M., and Chris Peterson. 1981. Potential utility of the thematic mapper for surface mine monitoring in Second Eastern Regional Remote Sensing Applications Conference, Danvers, Massachusetts, March 9-11,1981, Proceedings: pp. 129-138.

3. Mason, R. D. 1978. Statistical Techniques in Business and Mathematics. Richard D. Irwin, Inc. Homewood, Illinois. 596 p.

4. Schaal, G. M. 1981. Land use land cover classification system (second revised edition). Ohio Department of Natural Resources, Columbus, Ohio, 15 p.

5. Sekhon, R. S. 1981. Application of Seasat-1 synthetic aperture radar (SAR) data to enhance and detect geological lineaments and to assist Landsat land cover classification mapping. Computer Sciences Corporation TM-81-6238 under contract NAS 5-24350, Silver Spring, MD.

6. U. S. Geological Survey Professional Paper 380. 1963. Geological and Coal Resources of Belmont County, Ohio USGS, Reston, VA., 113 p.

Accuracy Statistics

$$Sp = \sqrt{\frac{P(1-P)}{n}}$$

where Sp = standard error of the proportion (the figure we are looking for).

P = sample proportion from past experience.
n = sample size (how many samples do we look at).

Also, Z = Q/Sp (Q is 5%, as in ±5%)

Since we are seeking a 95% confidence level, we determine the value of Z (a table is contained in most statistics books) to be 1.96; therefore 1.96 = 0.05/Sp or Sp = 0.05/1.96 = 0.0255. Substituting 0.0255 into the original formula, we have

$$0.0255 = \sqrt{\frac{P(1-P)}{n}}$$

Solving for n:

$$0.0255^2 = P(1-P)/n$$
$$n = P(1-P)/0.00065$$

To arrive at a value for P (sample proportion from past experience), initial samplings of 73 and 106 cells were used for the 1979 and 1976 data, respectively.

It was found that 64 of the 73 and 92 of the 106 were correct, for sample proportions (P) of 88% and 87%. Finally, solving for n:

$$n = \frac{0.88 \ (1-0.88)}{0.00065} = 162 \ (1979)$$

$$n = \frac{0.87 \ (1-0.87)}{0.00065} = 174 \ (1976)$$

Since for 1979, 73 samples were previously chosen, 90 samples remained. Similarly, for 1976, 106 were previously sampled, leaving 68 to be sampled.

The results were:

    1979 - 77 of the 90 correct
    1976 - 58 of the 68 correct

The totals then were:

    1979 141 (64+77) correct from 163 samples = 85.9%
    1976 150 (92+58) correct from 174 samples = 86.2%

16

Thus it can be said that we are 95% confident that the 1979 data are 80.9% to 90.9% accurate (85.9% ± 5%). Similarly, it is 95% certain that the 1976 data are 81.2% to 91.2% accurate (86.2% ± 5%)

APPENDIX B.

Signatures

1976 Landsat Data Set

Channel

	Name	1	2	3	4
1.	WATER1	18.5	15.1	11.6	5.7
2.	WATER2	25.9	22.9	15.5	6.7
3.	FOREST1	22.8	24.3	41.5	41.1
4.	FOREST2	20.1	18.9	38.5	37.1
5.	RANGE1	25.5	27.3	50.9	51.0
6.	STRIP2	30.9	35.7	52.6	48.5
7.	STRIP3	32.3	39.3	57.9	54.0
8.	STRIP5	32.3	42.0	47.0	35.0
9.	STRIP6	34.0	40.1	40.4	30.1
10.	STRIP8	30.5	34.8	37.1	27.3
11.	AGRIC1	26.4	26.4	56.9	56.2
12.	AGRIC3	25.5	23.7	60.2	63.6
13.	AGRIC4	25.8	30.5	35.8	28.5
14.	AGRIC7	22.7	20.2	66.3	72.8
15.	AGRIC8	25.7	24.3	66.3	70.1
16.	AGRIC9	25.7	24.5	64.1	67.9
17.	WATER3	29.5	30.6	19.7	8.0
18.	RANGE3	26.4	29.3	47.9	46.1
19.	STRIP7	36.0	51.0	62.0	47.0
20.	FOREST3	22.7	22.1	44.7	44.9
21.	STRIP4	32.7	37.2	38.9	27.6
22.	STRIP1	27.7	32.6	46.4	43.6

1979 Landsat Data Set

Channel

	Name	1	2	3	4
1.	FOREST1	14.2	11.9	50.1	59.4
2.	FOREST2	14.2	11.9	40.4	46.1
3.	AGRIC1	19.4	18.1	58.8	62.9
4.	AGRIC2	19.9	20.7	54.4	56.8
5.	STRIP1	31.1	37.8	38.9	29.5
6.	STRIP2	21.4	26.4	39.9	35.9
7.	STRIP3	30.9	38.9	42.3	33.7
8.	STRIP4	19.7	20.8	37.8	36.1
9.	AGRIC4	20.8	23.4	50.3	52.8
10.	WATER1	13.8	10.4	7.3	2.3
11.	RANGE1	15.5	14.6	47.9	52.2
12.	WATER2	20.0	18.0	10.8	4.1
13.	STRIP7	25.8	31.2	48.9	43.3
14.	STRIP6	24.3	29.7	33.3	26.1
15.	AGRIC3	18.4	15.9	64.5	70.7
16.	FOREST3	14.8	13.5	45.9	53.0
17.	FOREST4	13.7	11.4	35.1	38.6
18.	RANGE2	17.1	14.6	53.3	58.3
19.	RANGE3	16.6	14.6	51.4	56.5

(Strip mine signatures #7 and #14 are for active areas; #5 and #13 are for barren/graded areas; #6 and #8 are for partially reclaimed areas).