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# THE USE OF ERTS-1 MSS DATA FOR MAPPING STRIP MINES AND ACID MINE DRAINAGE IN PENNSYLVANIA

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## ABSTRACT

Digital processing of ERTS-I MSS data for areas around the west branch of the Susquehanna River permits identification of stripped areas including ones that are not discernible from visual analysis of ERTS imagery. Underflight data and ground-based observations are used for ground-truth and as a basis for designing more refined operators to make sub-classifications of stripped areas, particularly with regard to manifestations of acid mine drainage; because of associated diagnostic effects on vegetation, seasonal changes in classification criteria are being documented as repeated, cloud-free ERTS-1 coverage of the same area becomes available. Preliminary results indicate that ERTS data can be used to moniter not only the total extent of strip in given areas but also the effectiveness of recla tion and pollution abatement procedures.


## 1. INTRODUCTION

Deposits of coal in the Eastern United States represent an important natural resource for meeting immediate and future critical energy needs. While widespread strip mining has already been carried out over large areas in Western Pennsylvania and in other areas of Appalachia, there remain extensive reserves at relatively shallow depths that can be and are being extracted by strip mining. However, the actual cost involved in providing energy from these deposits significantly exceeds that of simply extracting the coal, because not only must the areas stripped be reclaimed for other productive uses, but also because severe water pollution resulting from acid mine drainage from these areas must be monitered and controlled. Even without further mining activity, solving existing environmental problems of this nature resulting from past mining activities is proving to be difficult and expensive.

Therefore, it is important to have an effective capability for monitering the areal extent of stripping, detecting the areas adversely affected by acid mine drainage, and assessing the effectiveness of reclamation and pollution abatement procedures. Because of its repeated, complete areal coverage ERTS data provides a potential means of routinely monitering and evaluating the impact of strip mining on the environment in any region of interest.

The objective of the present study is to determine the usefulness of ERTS-I data (particularly the MSS data) for this application.

## 2. OBSERVATIONAL RESULTS

An area along the west branch of the Susquehanna River was chosen for the initial tests of the present study because it contains old stripped areas, new stripped areas, and numerous examples of acid mine drainage and related effects associated with the mining of bituminous coal in Pennsylvania. In addition detailed ground-based geological and geophysical observations are available for one particular part of the area near Kylertown. Aircraft underflight data from U-2 and C-130 flights are available for portions of the test area as well. These additional data provide very important ground truth for evaluating the results obtained from digital processing ERTS-I MSS tapes.

The MSS digital data tape (CCT 1045-15240) for the September 6, 1972 pass over Pennsylvania was used for the computer analysis. Even though only three of the MSS channels (4,5, 7) could be used on the tape for that particular day, remarkably good results were obtained by using these three good channels simultaneously to identify the characteristic features of strip-mined areas and acid mine drainage.

The data processing consisted first of subsetting the original data tape to obtain a working digital tape covering a test area approximately 20x20 miles square in size located on the west branch of the Susquehanna River in Clearfield County and extending south from Karthus to Philipsburg. Using a series of computer programs developed by Borden and others of the Office of Remote Sensing at the Pennsylvania State University (References 1-8) the test area tape was analyzed. First we located areas of both uniformity and high spatial contrast. These data alone defined the general boundaries of some stripped areas and showed distinctive features such as the river and Interstate 80 so that unambiguous correlations with conventional map features could be made. However, we found that applying the cluster analysis programs developed by Turner (Reference 8) provided the best definition of stripped areas as well as other features in the test area. Basically these programs group the data points into clusters each of which has a characteristic spectral response. No prior knowledge about the spectral response is required in this mode of operation, although we can use training areas as another program option. Not only was it possible to identify stripped areas unambiguously, but also sub-classifications of them were found that represent real differences in conditions, such as trenched areas, recent workings, and partly vegetated peripheral zones.

Several portions of the Susquehanna River itself were classified in the same category as strip mines; while surprising at first, this finding is now believed to represent refuse from nearby stripping that was dumped along the banks in which case the classification was proper. Other areas along the river were placed in the same category as areas of dying or dead vegetation caused by acid mine drainage elsewhere in the test area. The inference that the Susquehanna in this area is highly polluted by acid mine drainage is correct as is documented in Reference 9.

Especially detailed analysis was carried out for a small area around Kylertown. Sub-divisions of the stripped areas that were distinctly classified in this test area were: trenched areas, backfills, and new stripping or areas cleared for future stripping operations. Areas of dying or dead vegetation caused by acid mine drainage from these strip mines were distinctly classified by the cluster analysis and were correctly located, including a very small one that has been studied extensively with ground-based methods.

TABLE I

Spectral Response from Cluster Analysis of the Kylertown Area

| Categories | Symbol | | Channels 4 | 5 | 7 | Percent Area |
|---|---|---|---|---|---|---|
| Forests | 1 | - | 23.43 | 14.29 | 24.42 | 68 |
| Open fields | 2 | X | 27.20 | 21.37 | 21.27 | 17 |
| Trenches (strip mine) | 3 | + | 30.50 | 25.72 | 11.00 | 4 |
| Backfills (strip mine) | 4 | * | 32.89 | 30.67 | 14.56 | 5 |
| Acid mine drainage | 5 | 0 | 24.67 | 15.67 | 14.33 | 4 |
| New stripping | 6 | = | 38.00 | 41.00 | 19.00 | 1 |
| New or future stripping | 7 | Z | 46.00 | 52.33 | 23.67 | 1 |

TABLE II

Distances of Separation for Categories

| | | 1 - | 2 X | 3 + | 4 * | 5 0 | 6 = | 7 Z |
|---|---|---|---|---|---|---|---|---|
| 1 | - | 0.0 | 8.62 | 19.00 | 21.33 | 10.25 | 30.91 | 44.24 |
| 2 | X | 8.62 | 0.0 | 11.63 | 12.80 | 9.33 | 22.52 | 36.30 |
| 3 | + | 19.00 | 11.63 | 0.0 | 6.54 | 12.09 | 18.81 | 33.30 |
| 4 | * | 21.33 | 12.80 | 6.54 | 0.0 | 17.11 | 12.36 | 26.91 |
| 5 | 0 | 10.25 | 9.33 | 12.09 | 17.11 | 0.0 | 29.01 | 43.44 |
| 6 | = | 30.91 | 22.52 | 18.81 | 12.36 | 29.01 | 0.0 | 14.64 |
| 7 | Z | 44.24 | 36.30 | 33.30 | 26.91 | 43.44 | 14.64 | 0.0 |

Table I summarizes the cluster analysis results for the Kylertown test area. From examining the array of ground-based data mentioned earlier we were able to identify the categories of features found by the cluster analysis. These are listed in the first column of Table I. The degree to which these categories are separated is indicated in Table II where the distances of separation among the clusters are given. The smaller the distance between two categories the more similar they are. For example the sub-classifications 3 and 4 that differentiate trenched portions of stripped areas from backfills have a relatively small distance separation and are generally similar in spectral response as can be seen from Table I values.

The digital processing used has the further advantage that not only are features correctly classified but the total area affected by stripping can be routinely calculated from the estimates of the total area represented by each category output by the cluster analysis program. For example, we found that strip mines cover approximately 20 per cent of the test area around the Susquehanna and about 11 per cent of the area around Kylertown. The last column of Table I gives the percentage area represented by each category for Kylertown.

The spectral response was found to be quite similar for stripped areas at different locations within the test area suggesting that these characteristic signatures can be used to obtain an accurate map of existing strip mines for larger areas or perhaps the entire state or region. Also repeated application of this type of analysis will provide up to date estimates of the location and extent of new strip mining and provide current information on reclamation and acid mine drainage.

While visual examination of the ERTS-I imagery reveals the location of the larger strip mines it is not possible to distinguish the sub-classifications and details found by the digital analysis described above. The areas affected by acid mine drainage cannot be discerned and identified by visual analysis of the ERTS imagery. Therefore, digital processing is required to extract adequate information on the details of strip mining and acid mine drainage.

## 3. SUMMARY AND CONCLUSIONS

1. ERTS-I MSS data can be used in appropriate digital processing programs to map the extent and type of stripping that exists at the present time, including sub-classifications of each stripped area.

2. Based on the preliminary findings of this report it appears feasible to use ERTS data to moniter periodically the extent and location of current strip mining activity for large regions and to evaluate the effectiveness of reclamation and pollution abatement procedures.

3. Surface areas affected by acid mine drainage from strip mines can be located and mapped effectively through careful digital processing of the ERTS-I MSS data. They cannot be located from visual analysis of ERTS imagery.

4. Temporal coverage of stripped areas spanning different seasons supplied by repeated ERTS passes promises to provide even more powerful classification criteria because of the profound effects that strip mines and acid mine drainage have on vegetation.

## 4. REFERENCES


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