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ABSTRACT

ORSER-SSEL Technical Report 23-74

TECHNIQUES FOR DELINEATION AND PORTRAYAL OF LAND COVER TYPES USING
ERTS-1 DATA
G. W. Petersen and A. D. Wilson

Data from the Earth Resources Technology Satellite (ERTS-1) were

selected from test sites in Pennsylvania, Montana, and Texas for use

in land cover mapping. Each test site represented a uniquely different

agricultural setting. Photographic enlargement and enhancement,

classification of land use categories and generation of maps using

automatic data processing techniques, and an interactive color monitor

analysis system (General Electric IMAGE 100) were used to make land

cover delineations. Through the use of these techniques it was possible

to delineate, map, and determine the areal extent of bare soil, strip

mines, water, built-up areas, forest types and some agricultural crops.

Output products delineating these land use categories were in the form

of digital printouts, in black and white and in color, CalComp plotter

output, slides taken directly from the color monitor screen, and

various types of photographic products. The scales of these output

products ranged from 1:1,000,000 to approximately 1:24,000.

Interim Report

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TECHNIQUES FOR DELINEATION·AND PORTRAYAL OF LAND COVER TYPES USING
ERTS-1 DATA

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Date: December 1974

TECHNIQUES FOR DELINEATION AND PORTRAYAL OF LAND COVER TYPES

USING ERTS-1 DATA

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ABSTRACT

Data from the Earth Resources Technology Satellite (ERTS) were selected from test sites in Pennsylvania, Montana, and Texas for use in land cover mapping. Each test site represented a uniquely different agricultural setting. Photographic enlargement and enhancement, classification of land use categories and generation of maps using automatic data processing techniques, and an interactive color monitor analysis system (General Electric IMAGE 100) were used to make land cover delineations. Through the use of these techniques it was possible to delineate, map, and determine the areal extent of bare soil, strip mines, water, built-up areas, forest types, and some agricultural crops. Output products delineating these land use categories were in the form of digital print-outs in black and white and in color, CalComp plotter output, slides taken directly from the color monitor screen, and various types of photographic products. The scales of these output products ranged from 1:1,000,000 to approximately 1:24,000.

The mapping of land use or land cover is becoming of great concern on a regional as well as on a national level. The objectives of this project were to develop various techniques for delineating land cover types in areas that are predominately in agriculture, and to devise various methods for portraying these results.

TEST SITES

Test sites were selected in Texas, Montana, and Pennsylvania, encompassing the majority of agricultural activities in the United States.

Texas

The Texas study site lies north of the Rio Grande River in the southeastern part of the state. Much of the area is under canal irrigation, with well irrigation being used at higher elevations. Major crops include citrus, vegetables, sugar cane, cotton, and sorghum. Large areas of unirrigated, rough land have been left in native vegetation for pasture. Field size varies from less than 20 acres to over 160 acres. The climate is semi-humid with over 30 inches of rain per year, most of which occurs in the winter and spring months. Irrigation is generally required for many of the summer and fall crops. Soils are developed from aeolian deposits of sand and silt. In the flood plain valley, the soils are composed of alluvial silts and clays. The topography is generally flat, with occasional drainage features.

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Montana

The Montana study site is on the northern Great Plains in the midst
of the hard red winter wheat belt. The field size is generally quite large,
with 40-160 acres per field. The climate is semi-arid to arid with up to
15 inches of rainfall, occurring mostly in the winter or spring months.
Soils are developed on glacial till with a flat to gently rolling relief.
In regions of lesser rainfall, large areas have been left in native vege-
tation of short grass, used as rangeland for cattle.

Pennsylvania

The two Pennsylvania sites are located in large valleys between
forested ridges of the Appalachian Mountains. These agricultural areas
are characterized by small, irregular-shaped fields. The main crop types
are grasses, legumes, and corn with some oats, winter wheat, and barley.
The relief is rolling, and hence, strip cropping and contour farming are
common practices. In many portions of Pennsylvania, extensive areas are
also scarred due to coal mining activity.

PHOTOGRAPHIC ANALYSIS

The objective of the photographic analysis was to determine the
feasibility of delineating agricultural cover types from various types of
photographic enlargements. These enlargements were made from the 70 mm
ERTS negatives supplied by NASA. The density of these negatives made it
necessary to contact them onto a Kodak Fine Grain Release film. The re-
sulting positive transparency was then again contacted onto Kodak Fine
Grain Release film to obtain a negative transparency that was used in the
enlarging process. Various enlargements were made ranging in scale from
1:500,000 to 1:140,000, using negatives from the four different bands.
An enlargement of a band 7 Pennsylvania ERTS scene to a scale of approxi-
mately 1:140,000 is shown in Figure 1. In this enlargement it is possible
to delineate small streams, rivers, strip mines, forested ridges, and the
agricultural valleys. It was not possible to delineate individual agri-
cultural fields. However, with a similar enlargement from a portion of
an ERTS scene in Texas, it was possible to delineate individual agricul-
tural fields, as seen in Figure 2.

In an effort to obtain additional information, a positive-negative
approach was used. In this technique, the negative of band 5 was placed
in direct contact, and in registration with, the positive transparencies
of bands 4, 6, or 7. This should result in features common to both bands
being printed darker or lighter than features not common to the two bands.*
The most useful combination appeared to be the 5-6 combination, as shown
in Figure 3. Slightly more detail is seen in this combination than in

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*There was an immediate problem, however, in obtaining registration,
as film is subject to contraction and expansion with changes in temperature
and humidity. It was not possible to obtain perfect registration of band 4
with band 5, as band 4 was slightly larger than band 5. Bands 4 and 5 also
respond very similarly to the same features and hence, the resulting image
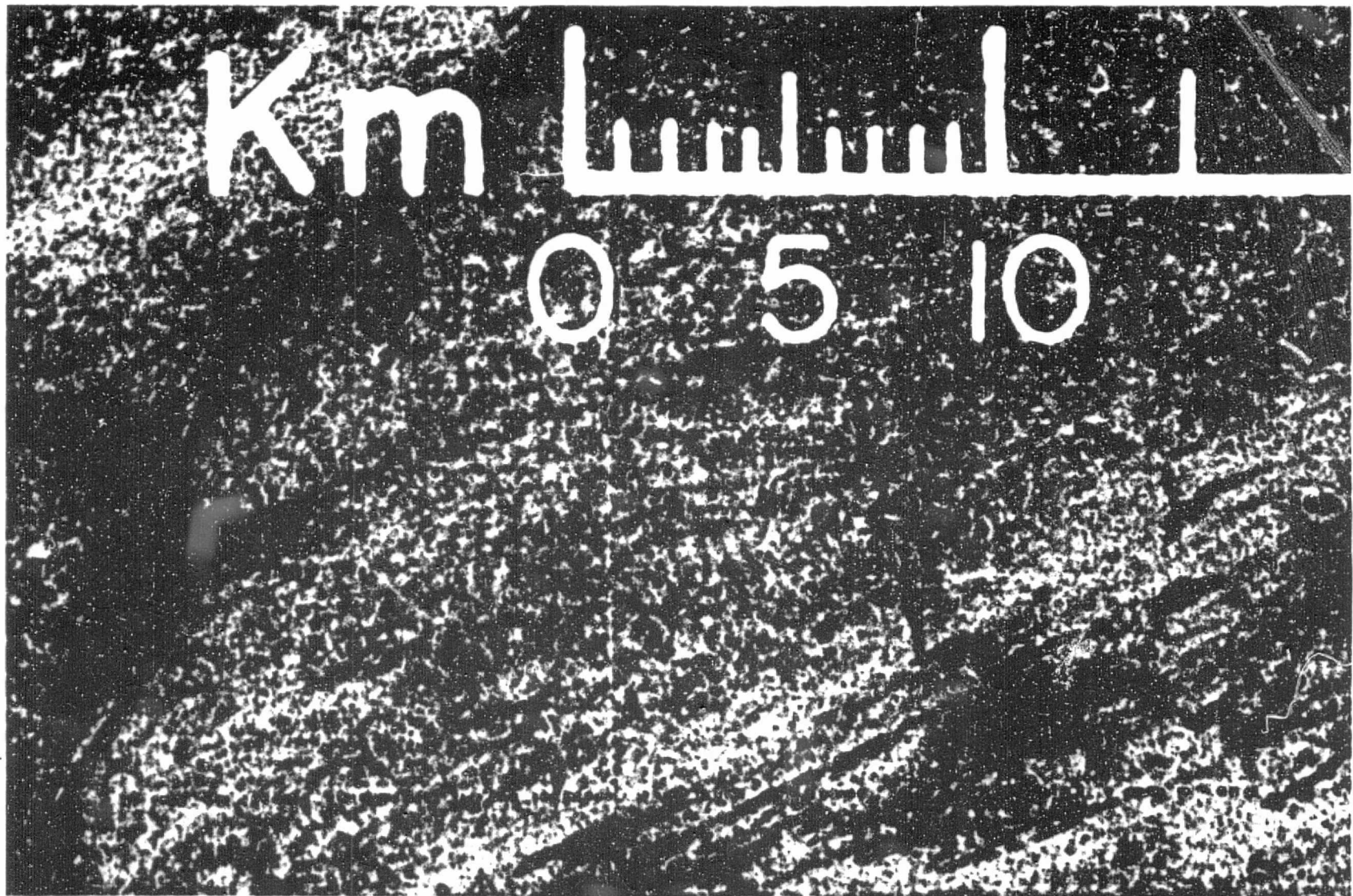had very low contrast with very little detail.

Figure 1: Enlargement of band 7 of ERTS scene 1350-15190, 8 July 1973. Note the small fields in this Pennsylvania scene.
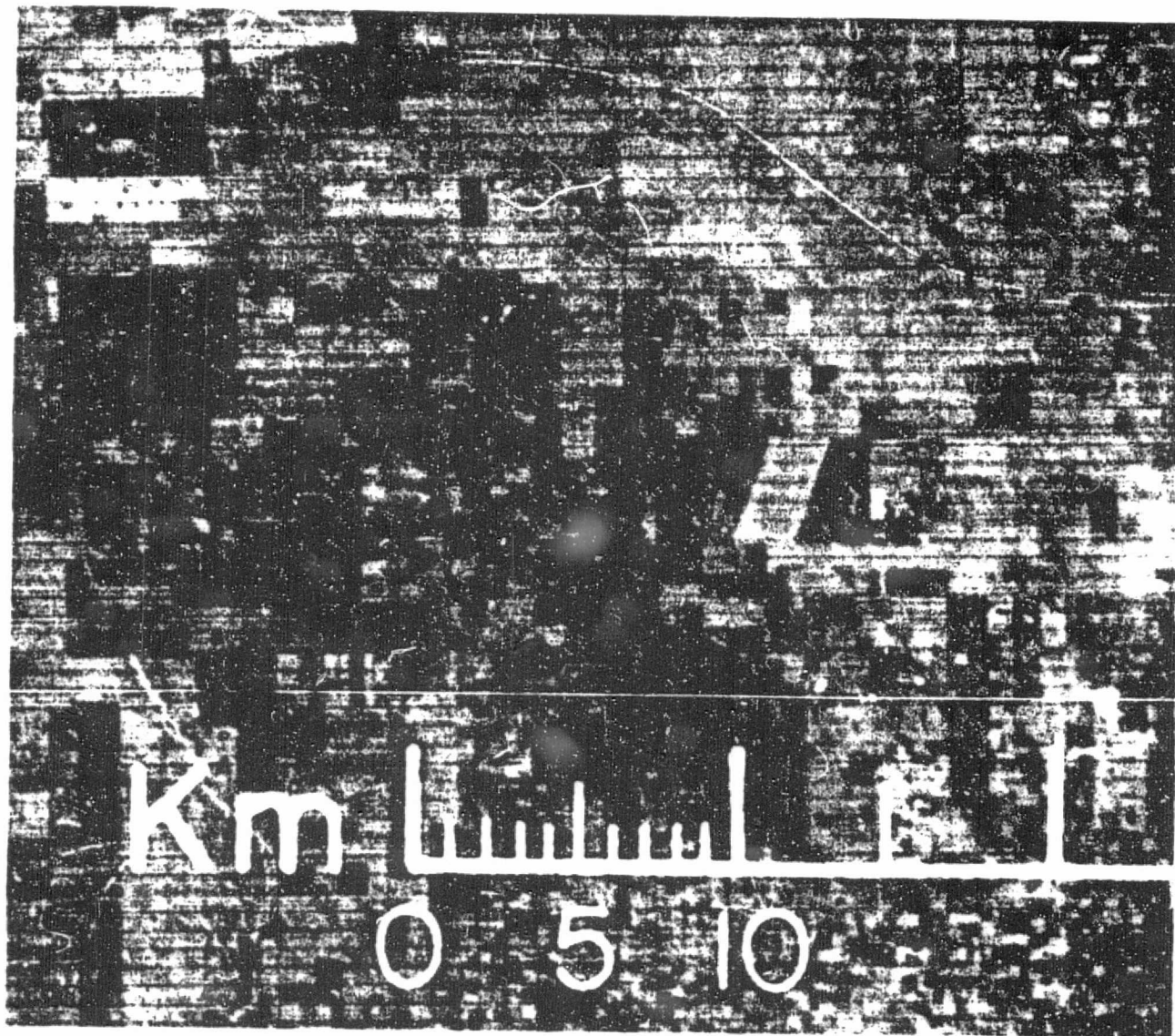
Figure 2: Enlargement of the band 4-5-7 color composite of ERTS scene 1146-16323, 16 December 1972. Note the large fields in this Texas scene.

Figure 3: Enlargement of the negative of band 5 combined with the positive of band 6.
(Pennsylvania ERTS scene 1350-15190, 8 July 1973.)

the 5-7 result, although the 5-7 combination has higher contrast. The 5-6 combination has areas of grey that are lacking in the 5-7 combination and in the individual bands 5, 6 or 7. The combinations were enlarged to 1:140,000. This technique was use for enhancing certain features, such as strip mines, urban areas, and water, but was not useful for making delineations within agricultural areas.

The products obtained through photographic analysis appear to be useful in areas with large agricultural fields, such as Texas. However, in areas with small fields, such as in Pennsylvania where the fields are often less than 10 acres in size, photographic analysis appears inadequate for delineation of agricultural cover types.

DIGITAL ANALYSIS

The limited success of photographic analysis for land cover mapping led to the use of the ERTS-1 digital data tapes. The programs used in the analysis and classification of these digital tapes were those of the Office for Remote Sensing of Earth Resources (ORSER) at The Pennsylvania State University. These programs are documented in the ORSER-SSEL Technical Report 16-74, "ERTS and Aircraft Multispectral Scanner Digital Data Users Manual."

The first test site investigated was in north central Montana, using ERTS scene 1052-17452 from 13 September 1972. An area within this scene encompassing approximately 800 square miles was analyzed. Signatures were developed for summer fallow, stubble, winter wheat, native vegetation, and water. Often it was necessary to use more than one signature to map a specific category. For example, four signatures were required to encompass the full range of varying amounts of weed growth and differences in the density of wheat stubble. Several summer fallow signatures were also required. Considerable difficulty was encountered in trying to classify the native vegetation around the Fresno reservoir area. In contrast, some features were very easily classified, such as small bodies of water which were only a few acres in size.

Once the land cover in this area had been classified, the result was output on a line printer with each alphanumeric symbol representing a specific category. Mapped categories may be a single signature, but are often a grouping of signatures that better represent the selected features. Although these character maps are quick and easy to obtain, they have a disadvantage in their inherent distortion. The standard computer line printer has 10 characters to the inch across a line and either 6 or 8 lines to the inch. Thus, character maps have two scales: for a square pixel, the difference in scale between the lines and the elements will be either 25 percent (8 lines/inch) or 66 percent (6 lines/inch). Because of the rectangular shape of the ERTS pixel, the 6 lines/inch map is elongated in the line direction 21 percent compared to the element scale. The use of 8 lines/inch compresses the lines 10 percent relative to the elements. Thus, 8 lines/inch is the best choice to use for minimal distortion in the final output.*

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*Since the time of this work, ORSER has developed geometric and scale correction programs.

After the maps were output in the 8 lines/inch format their size still rendered them relatively cumbersome. To make them more manageable, the digital printouts were mosaicked and photographed using a high contrast film. This mosaic was reduced to a 4 x 5 inch print, resulting in a scale of approximately 1:362,000, or a linear reduction of 30X. At this reduction it was still possible to read the individual characters with a hand lens (see ORSER-SSEL Technical Report 3-74). Such a map, further reduced by 25 percent, is shown in Figure 4. This photographic map format, along with a table listing the areal percentages in each land cover type (also determined by the programs), became a convenient means of representing the results of the land cover type analyses in this study. This technique was then applied to an agricultural area in southeastern Pennsylvania. A 450-square-mile area, from ERTS scene 1080-15185 (11 October 1972) was selected where it was possible to make the following delineations:

(1) woodlands
(2) bare soils
(3) grassland
(4) stubble
(5) water and wetlands
(6) urban
(7) disturbed lands, such as quarries

The photographically reduced land cover output map of this area is shown in Figure 5. A comparison of Figures 4 and 5 gives a striking example of the differences in field sizes between Montana and Pennsylvania -- the easily discernible fields in Montana contrasted to the indistinguishable fields in Pennsylvania.

A predominantly forested area in north central Pennsylvania was also selected for analysis (ERTS scene 1244-15305, from 24 March 1973) and an area approximately 450 square miles in size was subset. It was possible to delineate several different forest densities, water, and Interstate Highway 80; and, as can be seen in Figure 6, the drainage network is well depicted. It can also be seen from this figure that reproduction of maps of this type as negative, rather than positive, prints would serve to emphasize other features of possible interest.

Another technique that was used to emphasize features was to output the digital data in four colors, using colored computer ribbons. This resulted in a product where each land cover type was a different color. The number of colors could be increased, using a series of overprintings; however, it takes considerable time to change the ribbon and allow for repetitive printing of the lines.

The various output products from the line printer all have an inherent distortion due to the fixed character spacing of the printer and the orbital path of ERTS. To eliminate these distortions, an LMAP program has been developed in which the resulting output is corrected and plotted on a CalComp plotter to a predetermined scale.*

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*This technique is no longer necessary, due to the recent development of geometric and scale correction programs at ORSER.
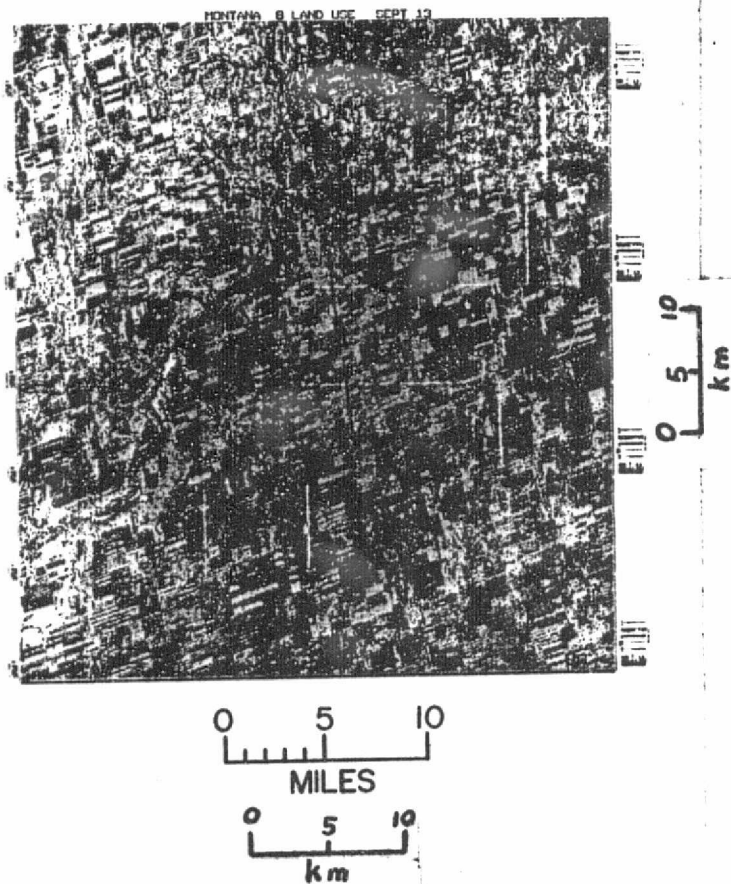
Figure 4: Land cover map of an area in north central Montana produced by photographically reducing mosiacked alphanumeric computer printouts. (ERTS scene 1052-17452, 13 Sep 72.)
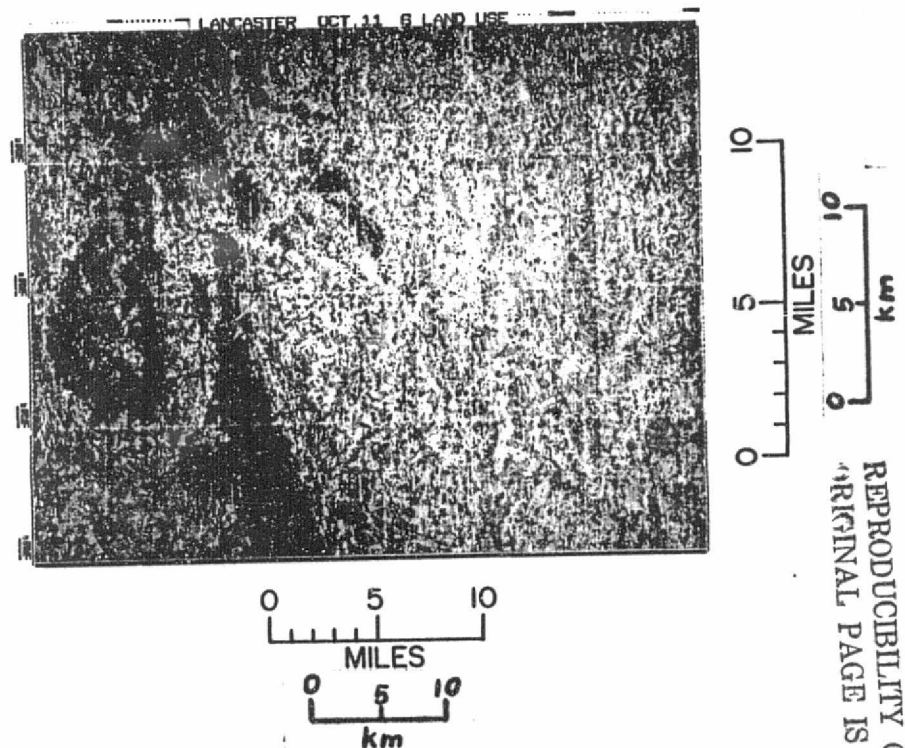

Figure 5: Land cover map of an area in southeastern Pennsylvania produced by photographically reducing mosaicked alphanumaric computer printouts. (ERTS scene 1080-15185, 11 Oct 72.)
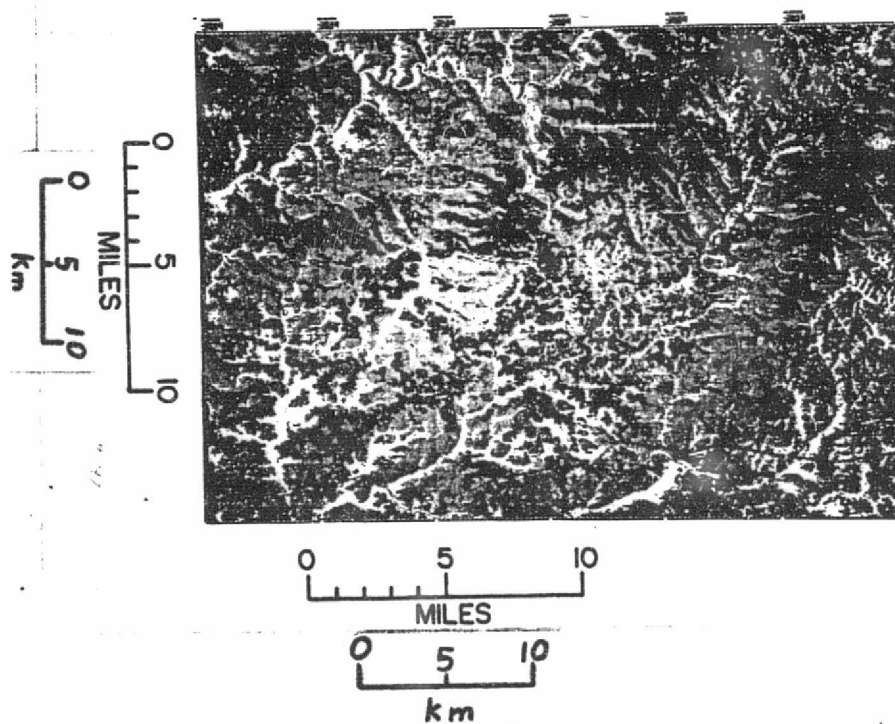
Figure 6: Land cover map of an area in north central Pennsylvania produced by photographically reducing mosaicked alphanumeric computer printouts. (ERTS scene 1244-15305, 24 Mar 73.)

A test site in Texas was selected to evaluate the usefulness of the CalComp plotter output. A portion of the 16 December 1972 ERTS scene (1146-16323) was plotted at a scale of 1:90,000 (Figure 7). This figure illustrates some of the problems inherent in CalComp output. For example, the intricate patterns of these categories at this scale greatly reduce the legibility of the output. If areas of large areal extent are to be output at scales larger than 1:168,000, it would be most desirable to output single category maps. Therefore, the optimum use of the CalComp plotter would be to map small areas or to map large areas in single categories.

INTERACTIVE ANALYSIS

The General Electric Company has developed an interactive, on line, user controlled, multispectral signature extractor and analysis system, designated the IMAGE 100. The system is designed around a color cathode ray tube (CRT) display with the image continually updated from a memory disk. Facilities are provided for radiometric correction of the data and for three forms of channel comparisons. Training areas are selected via a joy stick controlled cursor. Signatures of the training area are obtained and the classification applied to the scene in a matter of seconds.

In contrast to ORSER classification programs, which use a statistical base, the IMAGE 100 uses techniques developed from photointerpretation. In the statistically oriented programs, a signature is a single reflectance value in each channel (the mean value of the training area). In the Image 100, a signature is the low and high limits in each channel of the training area.

A study site was selected in the vicinity of Shamokin, in east central Pennsylvania, for analysis on the IMAGE 100. This study site, shown on ERTS scene 1350-15190, of 8 July 1973, encompassed an area of approximately 676 square miles (24 miles x 24 miles) and represented a wide variety of land uses.

To allow comparisons between the IMAGE 100 system and the Penn State processing systems, it was first necessary to analyse this area digitally. Through the use of an unsupervised classification procedure, the following categories were delineated: (1) forest land with a northern aspect, (2) forest land with a southern aspect, (3) valley trees, (4) wheat, (5) corn, (6) alfalfa-grass-pasture, (7) disturbed land, (8) built-up areas, (9) strip mines, and (10) water. These ten land cover categories were delineated by alphanumeric output at a scale of approximately 1:20,000. In general, the classification was accurate. However, some misclassification resulted where several types of land use occurred within a given pixel. There were also some instances where signatures were derived but it was impossible to determine a category for them. The alphanumeric output of this area is shown in Figure 8. This output product illustrates some of the problems encountered in the handling of large sheets of computer output. In this example the individual computer sheets were not uniformly flat, resulting in the six vertical lines (one for each sheet of output) in the figure. Another problem is the lack of definitive features, due to inadequate exposure when the computer output was photographed. Nevertheless, it was possible to use this output to make comparisons with the IMAGE 100 output.
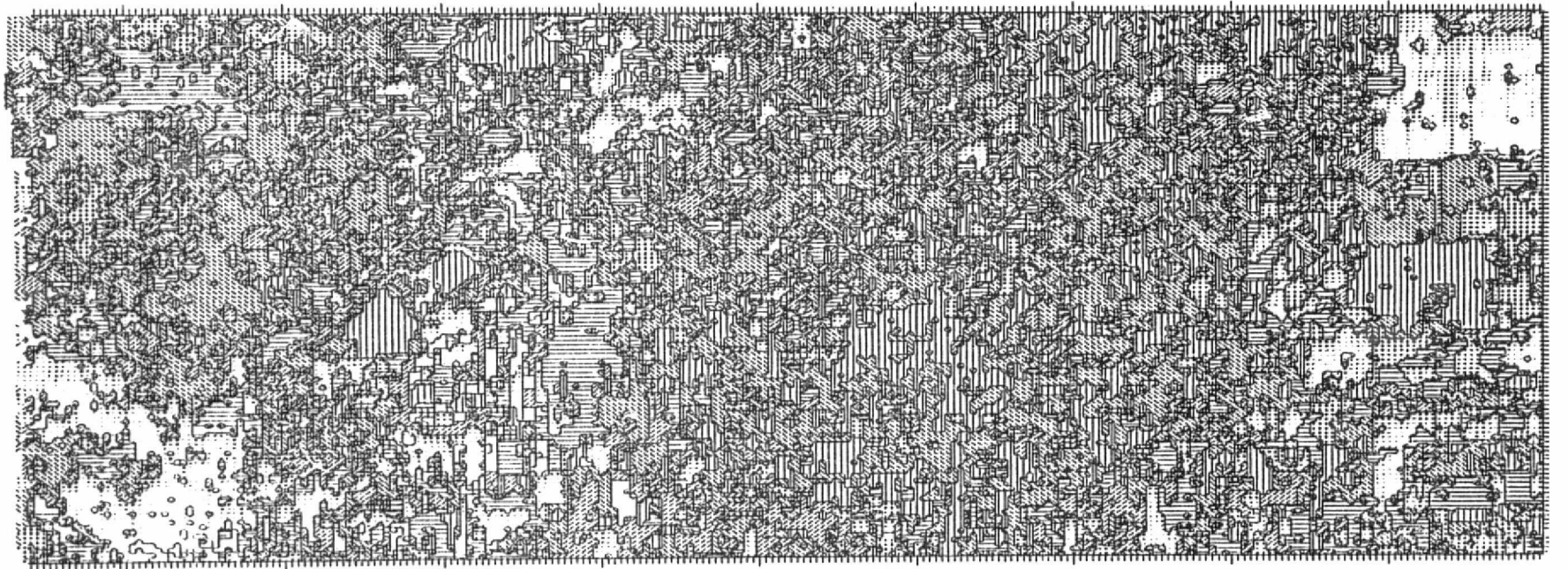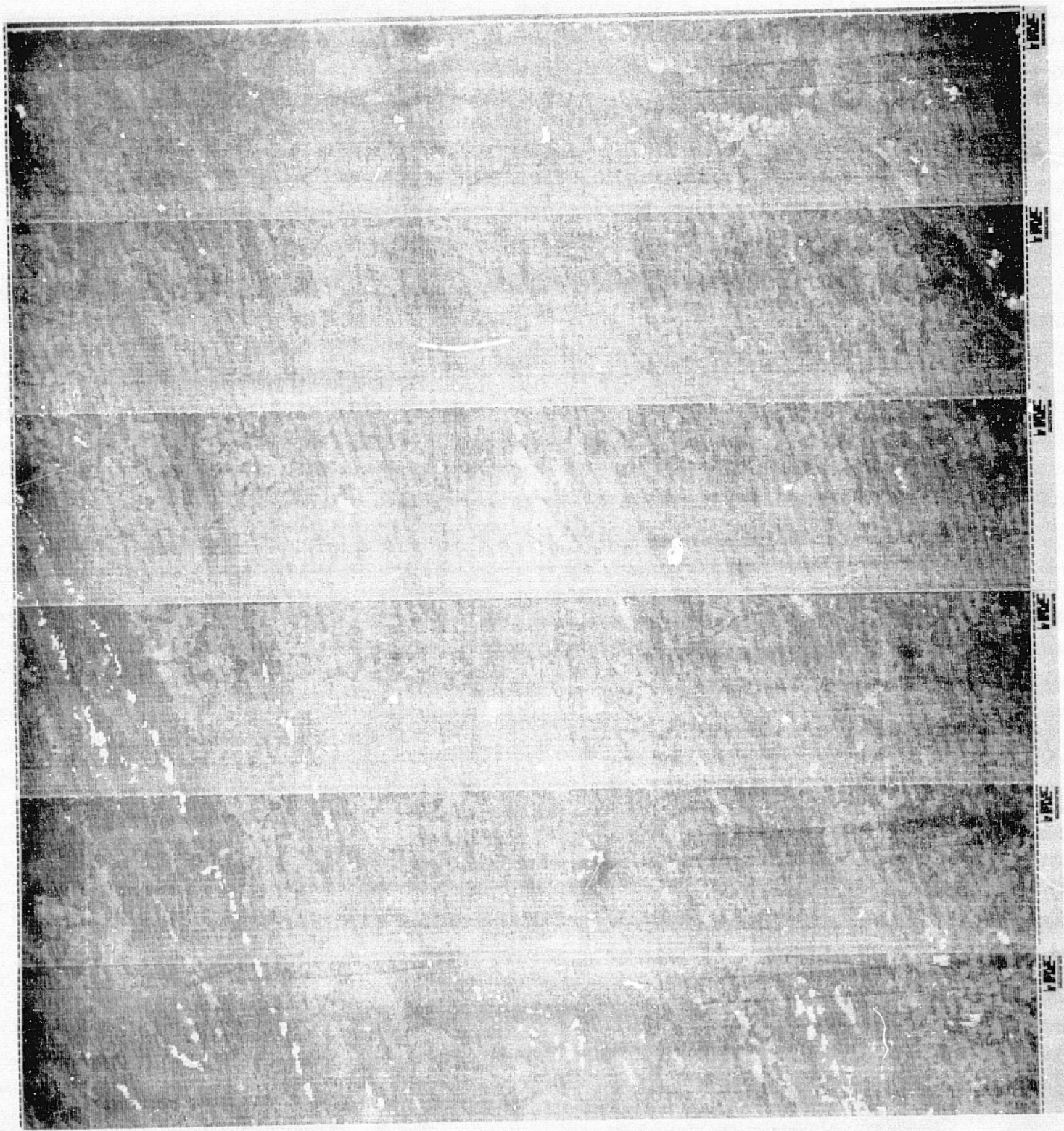
Figure 7: Land cover map of an area in southeastern Texas produced using
a Calcomp plotter. (ERTS scene 1146-16323, 16 December 1972.)

Figure 8: Land cover map of an area in east-central Pennsylvania, produced by photographically reducing mosaicked alphanumeric computer output.

When using the IMAGE 100, only a portion of an ERTS scene can be displayed at one time, as the CRT is limited to 512 lines and 512 elements. The system has an OVERVIEW program which displays about one sixth of the data points in an ERTS scene and locates the line and element coordinates of the desired study site. Due to the small size of the CRT pixel, less than a millimeter, it is desirable to have each ERTS pixel displayed more than once on the CRT. For this study a magnification factor of 2 was used, resulting in each ERTS pixel occupying four CRT pixels. This is a relative low rate of magnification; for detailed analysis of an area, a magnification factor of at least three is recommended. The amount of magnification, of course, reduces the number of ERTS pixels that can be displayed on the CRT.

Using the Shamokin data, an area of 256 elements and 185 lines, representing a square on the ground, was displayed on the CRT. Through the use of horizontal and vertical adjustments, the image was adjusted to as nearly as possible represent a square on the CRT. This adjustment results in an image that is nearly distortion free.

Before the data is read onto the memory disk, the user has the option of radiometric adjustment. The usual operating procedure is to scale the data values to a range of 0 to 255, corresponding to the intensity range accepted by the CRT. This "radiometric" correction was applied to the ERTS data by multiplying ERTS channels 4, 5, and 6 by 2, and channel 7 by 4.

The next procedure is to extract signatures from selected features and to use these signatures for classification. This procedure can be illustrated by giving the steps necessary for extracting the signature of a strip mined area. The initial image of the area displayed on the CRT is similar to an ERTS color composite. The strip mined area appears as a dark spot in the midst of the reddish forest. Through the use of appropriate commands entered at the Tektronix control panel, a window area is reserved in a portion of the scene which is of little interest. This window is available to further enlarge a selected portion of the scene. To enlarge an area into this window the cursor, of predefined size, is positioned around the selected feature. Appropriate commands are entered at the console, and the machine displays the enlargement in the window. It takes approximately two minutes for the enlargement to appear in the window. Using the window mode, enlargements of 4, 6, or 8 times are possible, in addition to any enlargement that was specified when the data was first read into the memory area. It is possible to change both the size and the shape of the cursor. The basic shape is a rectangle, but it is possible to position the rectangle either vertically or at a 45 degree angle. When the cursor has been positioned around the training area, a command is entered and in a matter of seconds the signature is extracted and the image on the CRT is classified. If there is too much of the scene classified into strip mine, for example, the cursor can be reduced in size to obtain a signature more representative of the desired category.

Frequently it may be desirable to examine the signatures. This is accomplished by entering a commond for histograms of the signatures, which are then displayed on the face of the Tektronix scope. The signatures of the IMAGE 100 are typically unimodal histograms. If any of

the histograms have a range that is not sharply pointed, these "stray" points can be easily removed. The histogram of the individual channel is displayed and the cursor on the Tektronix scope can then be used to remove the offending data values. The classification resulting from the modification of the signature is immediately seen on the CRT. This signature extraction and classification is continued for each desired feature, resulting in a thematic display on the CRT. At the time of this analysis, the only facility available for recording the output was to photograph the CRT. A print made from one of these photographs is shown in Figure 9.

The thematic maps produced on the IMAGE 100 generally agreed with the categories delineated on the line printer output from the digital analysis. However, the IMAGE 100 tended to misclassify some categories. For example, in Figure 9 too much of the area is classified into grasses and alfalfa. This is probably a result of the signature extraction technique, where the categories are determined by looking at a small number of representative pixels rather than a large number, as is done with the digital computer. Hence, the statistical validity of the signature may be in question.

The IMAGE 100 appears to have some weaknesses in the statistical handling of the data. However, it is a very fast system that outputs a good quality, relatively distortion-free, image. It would appear that the most optimum system would be a combination of a color monitor with a powerful computing system such as the one at The Pennsylvania State University. This would result in a good statistical analysis of the data with the capability of displaying the output results on a color monitor equipped with a hard copying device.

CONCLUSIONS

ERTS data can be used to map land cover in agricultural areas, although in some parts of Pennsylvania, with small irregular fields, many of the pixels overlap field boundaries and cause difficulties in classification.

Various techniques and devices were used to display the results of these land cover analyses. The most promising approach would be a user-interactive color monitor interfaced with a large computer so that classification results could be displayed on the CRT and these results output by a hard copier.

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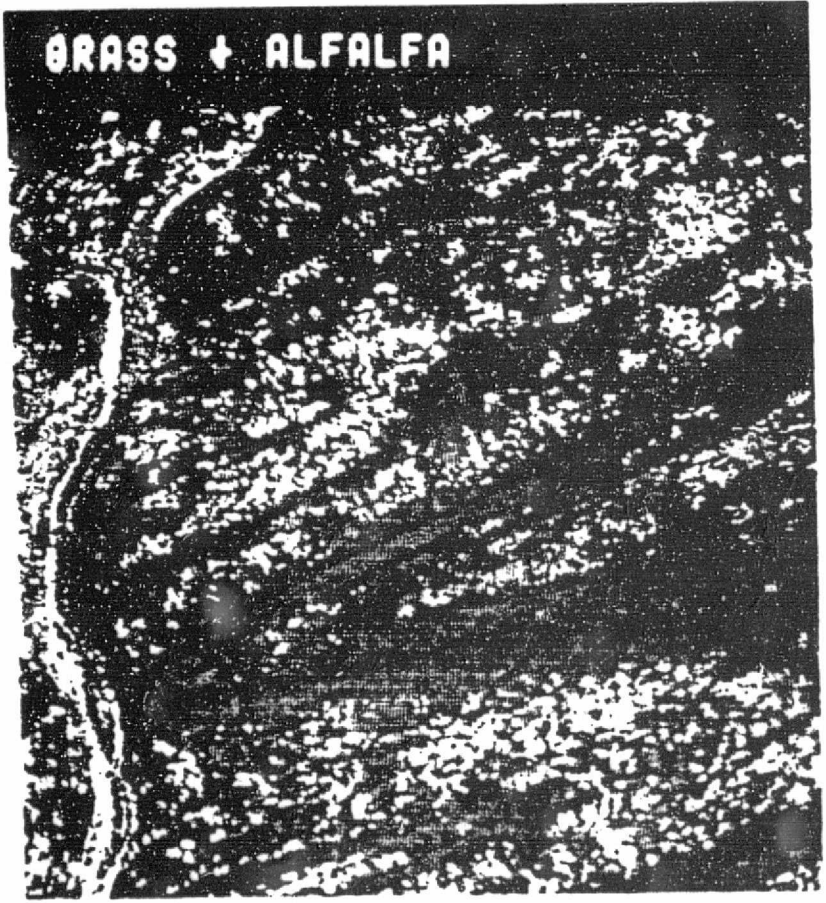Figure 9:   Thematic map of an area in east central
            Pennsylvania produced on the General
            Electric Image 100.   (ERTS scene 1350-
            15190, 8 July 1973.)