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Use of ERTS Data for a Multidisciplinary Analysis of Michigan Resources

ERTS-1 Project 321
Proposal ORD-1158
Contract NAS5-21834
Type I Progress Report No. 4, June 28, 1973

Tasks I and II: Agriculture and Forestry.

First, it should be noted that most of the precision and precision composite imagery requested has now been received, making it possible to proceed with this phase of the analysis.

Analysis of the August 25th, 1972 frame (E-1033-15580) is continuing, and analysis is also underway forthe June 8th, 1973 ERTS pass (satellite data not yet received).

With respect to analysis of the August, 1972 data, approximately 70% of all fields and forest stands have been identified in a selected 6 x 25 mile test strip encompassing portions of Eaton, Clinton, and Ionia Counties. Ground truth information came from 3 sources: (1) field visitation; (2) U.S.D.A., A.S.C.S. field certification records; and (3) low level 70-mm, aircraft imagery. For purposes of more detailed acreage analysis, all fields and stands were identified in a 2 x 8 mile subsegment of the above test strip in Eaton Co. In addition, 4 sq. mi. were completely ground truthed in each of Ionia and Clinton Counties.

For the June 8th, 1972 pass, a 4 x 5 mile section of the Eaton Co. test strip was completely ground truthed by field visitation. In this ground truthing effort special attention was given to wheat since it is the most visible crop in early June. Also, 20 square miles in Eaton Co. were ground truthed for wheat only to allow assessment of wheat spindle streak mosaic disease. We are awaiting underflight imagery from the ERIM aircraft before continuing with the analysis of this disease.

It has become very clear during the computer analysis efforts by the subcontractors at ERIM that there is a substantial problem in associating ERTS pixels with specific fields and test plots in a scene and vice versa. Such a capability is important both in processor training and the assessment of recognition results, especially those for which area measurement accuracies are involved. The primary effort of the subcontractors at ERIM in support of Forestry and Agriculture tasks during this reporting period has been devoted to development of a computer-assisted procedure to assign ERTS pixels to specific fields or plots.@ Preliminary results were obtained, and refinement

@ Work also supported in part by ERIM ERTS Contract, NAS9-9784.

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of the procedure is in progress. An abstract for a descriptive paper, entitled "Correlation of ERTS MSS Data and Earth Coordinate Systems" by William A. Malila, Ross H. Hieber, and Arthur P. McCleer of ERIM, was prepared, submitted, and subsequently accepted for presentation at the Conference on Machine Processing of Remotely Sensed Data at Purdue University on October 16-18, 1973. A copy of the abstract is included as Appendix I.

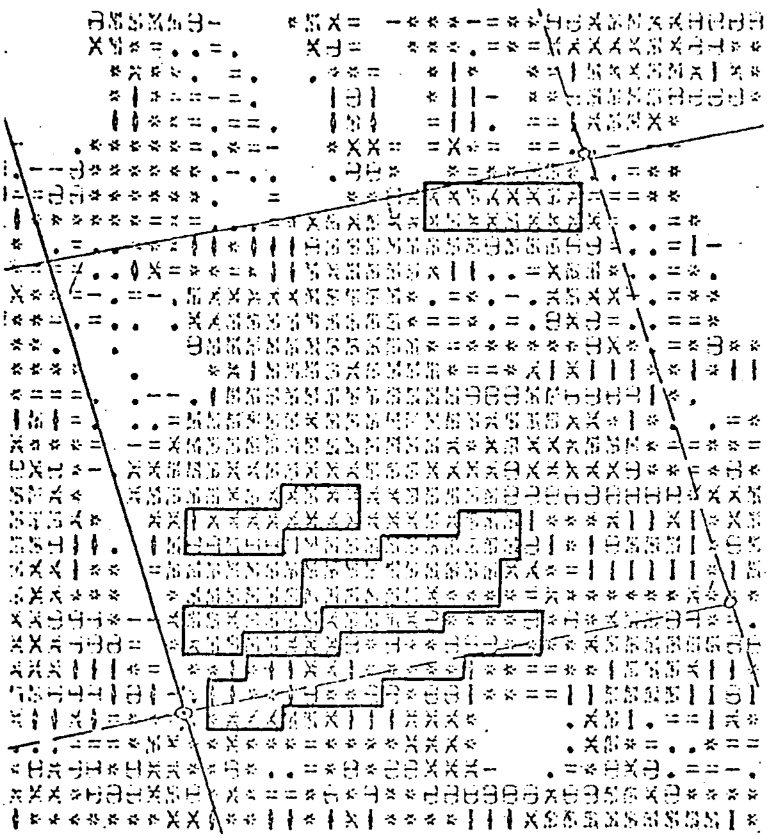
The essence and effectiveness of the new procedure can best be illustrated by the following example for four fields in Section 6, Benton Township, Eaton County, Michigan. The boundaries of these fields, as determined from a current aerial photograph, are shown in Fig. 1(d).

The prior, manual, method required that the analyst locate each section corner "by eye" on a digital line-printer graymap of ERTS data. This location of corners is not always easy for all sections, and such was the case for this example. The lower section line was misplaced downward, partly because this particular section is shorter" than those above and below it along Cochran Road. As a result, Fields 21, 22, and 23 were mis-located by the analyst, as shown in Fig. 1(a) on a graymap of ERTS MSS channel 5.* (The section corners shown are much more accurately located than are the fields, having been determined subsequently with our new computer-aided procedure.) This error was not noticed until poor agreement was observed between recognition results and the assigned crop types. Additional analysis effort has expended on a check of the locations of these fields in the ERTS data, and the revised locations shown in Fig. 1(b) were determined. Note that the sizes of these pixel groups are smaller than the actual field areas because of our concern that they not contain any foreign elements (e.g., boundary elements).

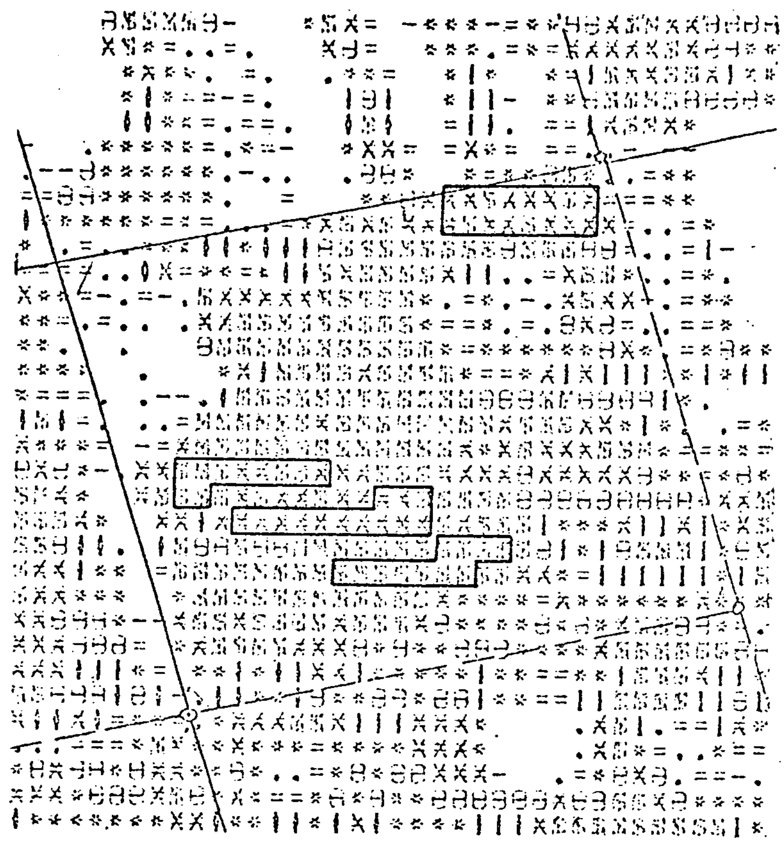
A computer-aided assignment of pixels is presented in Fig. 1(c); the dashed lines indicate the approximate locations of the field boundaries in the distorted ERTS-data display. Note the apparent good agreement between the field boundaries and the selected pixels. For example, the upper right-hand corner of Field 21 has a small notch missing as seen in Fig. 1(d). The two pixels omitted there in Fig. 1(c) are such that portions of their areas cross the boundary into the notch, while the upper right-most selected pixel lies entirely within the main field.

The computer aided procedure utilizes a numerically calculated map transformation from a standard Earth-coordinate system to the (scan line and point number) coordinate system of the ERTS data of interest. In this instance, a USGS topographical map served as the standard coordinate reference for several road intersections that were readily identified in the ERTS data. The derived transformation then was applied to the standard coordinates of the section corners (of Section 6) to locate them accurately within the ERTS data. Field vertices were determined relative to these section corners in an aerial photograph taken at the time of the ERTS pass. These relative locations of field vertices then were transformed to ERTS coordinates and pixels were selected.

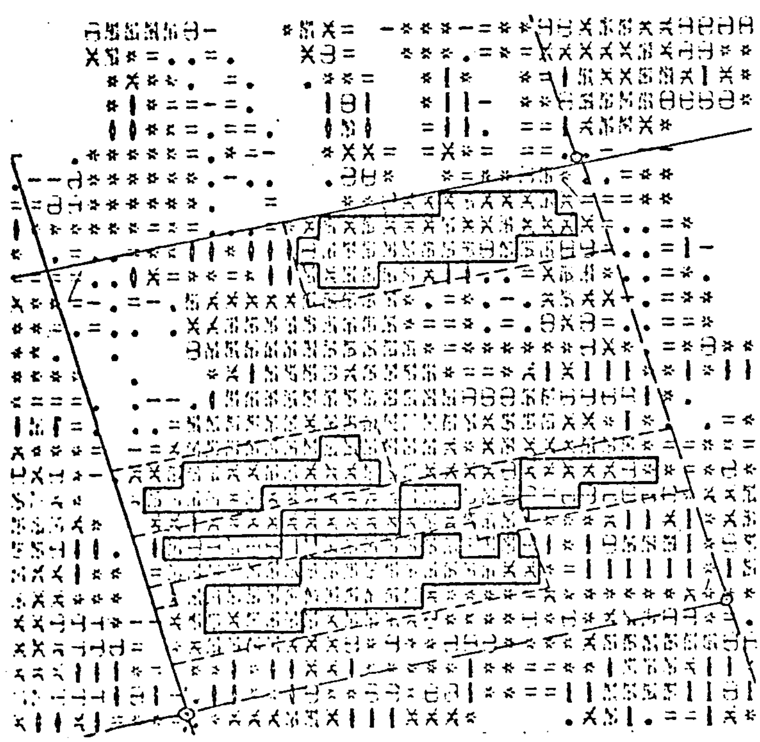
* The geometric distortion in the digital display is caused both by the rotation of the Earth Between scans (an effect not compensated for in bulk ERTS digital data) and by a difference between line and point sampling characteristics of ERTS data and the line-printer character spacings.



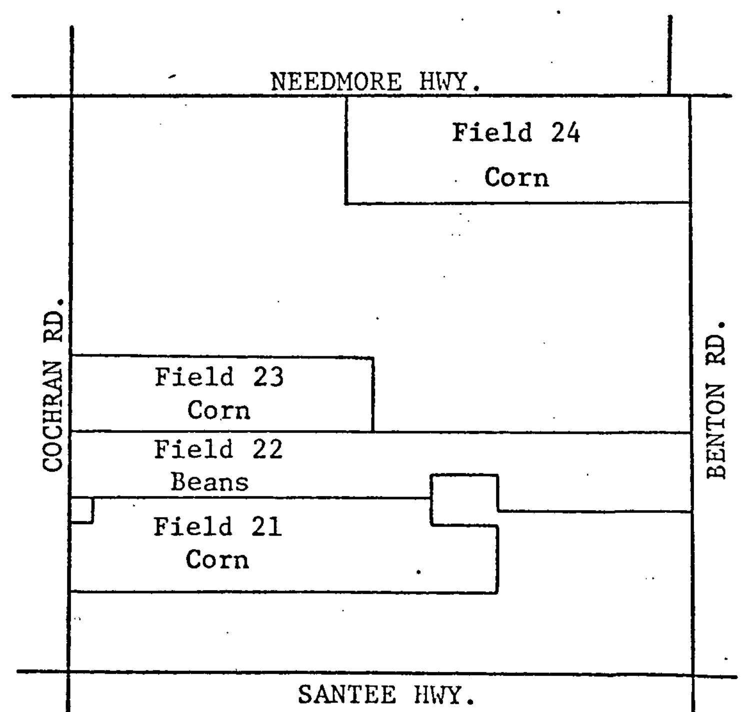
ORIGINAL MANUAL ASSIGNMENT
(a)



REFINED MANUAL ASSIGNMENT
(b)



COMPUTER-AIDED ASSIGNMENT
(c)



ACTUAL FIELD BOUNDARIES
(d)

FIGURE 1. FIELD LOCATION EXAMPLE, SEC. 6 OF BENTON TWP.

The procedure gives indications that it will improve the speed, accuracy, and consistancy of ERTS pixel assignments over those attainable by current, solely manual methods. However, the method must be more fully tested to evaluate its accuracy and applicability to varied ERTS analysis problems.

The agriculture/forestry ground truth information has been assembled into a photo overlay format to facilitate use of the new point transfer technique in subsequent processing to be done during the next period.

The spatial resolution of the ERTS multispectral scanner (MSS) is such that a single resolution element will frequently contain a mixture of two or more scene materials. The results of this phenomenon will be errors in the classification of surface materials and inaccuracies in subsequent estimates of crop acreages. Under subcontract No. 2, personnel of the Environmental Research Institute of Michigan have developed techniques for estimating the proportions of unresolved materials in individual resolution elements by use of multispectral scanner data. The main objective of work under this subcontract is to apply these techniques to ERTS-1 MSS data and to determine the extent to which the accuracy of crop acreage estimates can be improved.

Task III: Evaluation of Soils, Soil Conditions, and Landforms

Researchers at the Environmental Research Institute of Michigan (ERIM) have been working with Michigan State University (MSU) personnel to develop and test the use of automatic processing techniques for the purpose of obtaining soil and terrain information. This report documents the progress to date of this task and suggest directions for future research. The data used thusfar in this research are ERTS MSS digital tapes of portions of Eaton, Ingham, and Clinton Counties (E-1033-15580, August 25, 1972) and M-7 multispectral scanner data collected with the ERIM C-47 aircraft. The aircraft data were collected in 12 synchronous bands from an altitude of 5000 ft over a detailed soil test area north of East Lansing, Michigan (October 19, 1972). Both data sets are considered suboptimum for this research due to the small percentage of the scene having bare fields at the times of data collection. However, processing of these data has allowed the testing of techniques which should prove useful when more desirable data become available.

1.1 BACKGROUND. Spatial soil information is important in the planning and management of a wide variety of human enterprises -- agriculture, forestry, urban development, near-surface mining, road and highway construction, and watershed maintenance, to name a few. Yet our current knowledge of the nature and distribution of soils for such planning and management purposes is inadequate in many areas and woefully lacking in some others. For example, only 13 of the 81 counties in Michigan have modern published detailed soil survey information and at least a dozen counties have no more than reconnaissance land-type survey information obtained prior to 1935. For this reason we are intrigued by the possibility of ERTS providing useful soil information for extensive areas and the capability of modern (computer) processing to objecttively extract this information from ERTS and other multispectral data. Our ultimate objective is to provide synoptic terrain information which will speed up the arduous process of field mapping while increasing the accuracy of the soil maps produced.

Two questions must be answered if we are to obtain the objectives:

1. What kind of useful soil information might we logically expect to obtain from ERTS and other, higher resolution, multispectral systems, and

2. What are the best, cost-effective methods of obtaining this soil information from these data?

A general answer is provided to the first question below (Sec. 1.2), while the second question forms the basis for the current on-going research (Sec. 2).

1.2. USEFUL SOIL INFORMATION. Three categories of soil information are considered useful for most planning and management purposes -- slope, texture, and natural drainage. If ERTS can be shown to provide consistently accurate spatial information for any one of these categories, we will have accomplished our objective. At the present time slope information is not considered to be obtainable from ERTS data. However, both surface texture and natural drainage do affect the surface appearance of soils -- the latter somewhat more consistently than the former. Natural drainage differences are evidenced by variations in natural and cultivated vegetation and soil organic matter accumulation. Where soils are free of a vegetative cover, marked albedo differences frequently indicate the locations of organic soils, and poorly-drained, somewhat poorly-drained, and well-drained mineral soils. For the same drainage conditions, coarse-textured soils are generally lighter than finer textured soils. As a result of these differences in soil appearance, aerial photographs have been routinely used as a soil survey mapping base for almost two decades and provide a basis for the use of multispectral scanner data.

1.3. SPATIAL RESOLUTION. In attempting to utilize ERTS multispectral scanner data for soil mapping purposes, we are aware of the spatial limitations imposed by ERTS resolution and the blurring of boundaries between ground features. Resolution is defined as the smallest distance between which two objects are perceived as distinct -- about 300 ft in the case of ERTS. Consequently, unless a spectrally distinct soil unit is at least roughly 600 ft by 600 ft ($\sim$ 8 acres) in areal extent, one cannot be assured that even a single ERTS resolution element will contain data from it and it alone. Unfortunately, textural and natural soil drainage variations of soils derived from glacial materials frequently occur on a finer scale than this. Thus, ERTS data might be useful only for a "first cut" mapping or for generalized "soil association" mapping. The primary value of ERTS obtains from the large area over which it collects quantitative data. We believe that parallel analyses of higher-resolution aircraft data are important to a determination of the accuracy and precision of classification results with ERTS data, particularly in areas where modern soils maps do not exist.

2.0. PROCESSING

Processing to date has consisted of three distinct exploratory processing efforts -- two using ERTS data and one using C-47 aircraft data. The ERTS efforts are briefly described below.

2.1. DIGITAL ANALYSIS OF SOIL SIGNATURES. Average signal levels were obtained for 18 bare soil sample areas in each of the four ERTS bands. These signal levels were presented in the previous Type I report dated April 10. Analysis of these spectral signatures is based on the first eight sample areas of known soil drainage and texture characteristics. Soils of the remaining 10 sample areas were outside of the detailed soil test site and their types were not specifically known.

ERTS Band 4 (0.5-0.6 μm) showed three distinct signal levels associated with soil drainage: (i) well drained, (ii) somewhat poorly and poorly drained, and (iii) organic soils (poorly drained). In each class, the $\pm$ one standard deviation range of each sample overlapped the $\pm$ one standard deviation range of the other samples but did not overlap the other two classes. Well drained soils, regardless of texture, showed the highest signal values. The single samples of somewhat poorly and poorly drained soils were almost identical in their mean values and signal ranges. Organic soils showed the lowest mean signal values and variance.

ERTS Band 5 (0.6-0.7 μm) generally showed the same relative signal differences as Band 4. The well-drained soils were separate from the somewhat-poorly and poorly drained soils, and the organic soils. The well-drained soils either increased in signal values or remained about the same, while both of the other soil groups decreased in signal levels from Band 4.

ERTS Band 6 (0.7-0.8 μm) showed less difference between the mineral soils, although the organic soils were still clearly distinct from the mineral soils in signal values. While the poorly drained soil had signal variations overlapping two of the well drained soils, the somewhat poorly drained soil had a very large variance which overlapped the mean recorded values for all mineral soils. All soil signal values were greater than those recorded in Band 5.

ERTS Band 7 (0.8-1.1 μm) showed the lowest signal values for all of the soil samples and the least difference between soils. Again, organic soils were distinct from mineral soils, but there was no significant difference between the mineral soils in this band on the basis of either drainage or texture.

The conclusions of this limited analysis are that 1) Bands 4 and 5 are similar in providing the best separation of signal values on the basis of natural drainage of mineral soils, 2) all bands separated mineral from organic soils, and 3) no specific separation of well drained soils on the basis of texture was possible. The ten unknown soils had signal values comparable to those of mineral, predominantly well drained soils.

One question which occurred during this analysis was whether these soils could be better separated on the basis of ratio values of two ERTS bands. Two ratios are of interest as a result of previous aircraft data studies* which indicate that a red/green ratio indicates differences in soil color (Munsell hue) and a Near IR/red ratio indicates vegetative and moisture differences. Specifically, the corresponding ERTS ratios are: Band 5/Band 4 and Band 7/Band 5. Values representative of additive path radiance values for the signals were subtracted from the mean signals and relative ratioed signal values were computed, as presented in Table 1.

2.2 PROCESSING OF ERTS DATA. Two types of digital processing were explored on ERTS data -- three-band recognition and two-band ratio processing.

2.2.1. Recognition Processing. Using ERTS Bands 4, 5, and 7, four composite soil signatures were constructed from the training areas described in Table I. These included organic soils, somewhat poorly and poorly drained soils, well drained-medium textured soils, and well drained-coarse textured soils. These signatures were used alone, without any other signatures, to classify a portion of the ERTS frame containing the detailed soil study site. Because of the sparcity of areas of bare soil in August and the absence of signatures for competing materials, a tight threshold limit was found to be necessary to avoid high levels of false-recognition in non-bare-soil areas. A portion of the recognition map produced with maximum likelihood decision rule, is shown in Fig. 2. Most of the recognized areas are bare soil except as noted below. The results indicate the following:

i) Areas of organic soils are correctly differentiated from areas of mineral soils.

ii) A number of surface water areas are incorrectly identified as organic soil (however, as already mentioned, no background signatures were used for water).

iii) Mineral soil areas were generally correctly differentiated from both the organic and non-soil areas. However, it is not clear that mineral soils were further correctly classified

*Wagner, T. W., R. Dillman, and F. Thomson, "Remote Identification of Soil Conditions with Ratioed Multispectral Data", to be published in proceedings of the second conference on Remote Sensing of Earth Resources, Tennessee Space Institute, Tullahoma, Tennessee, March 1973.

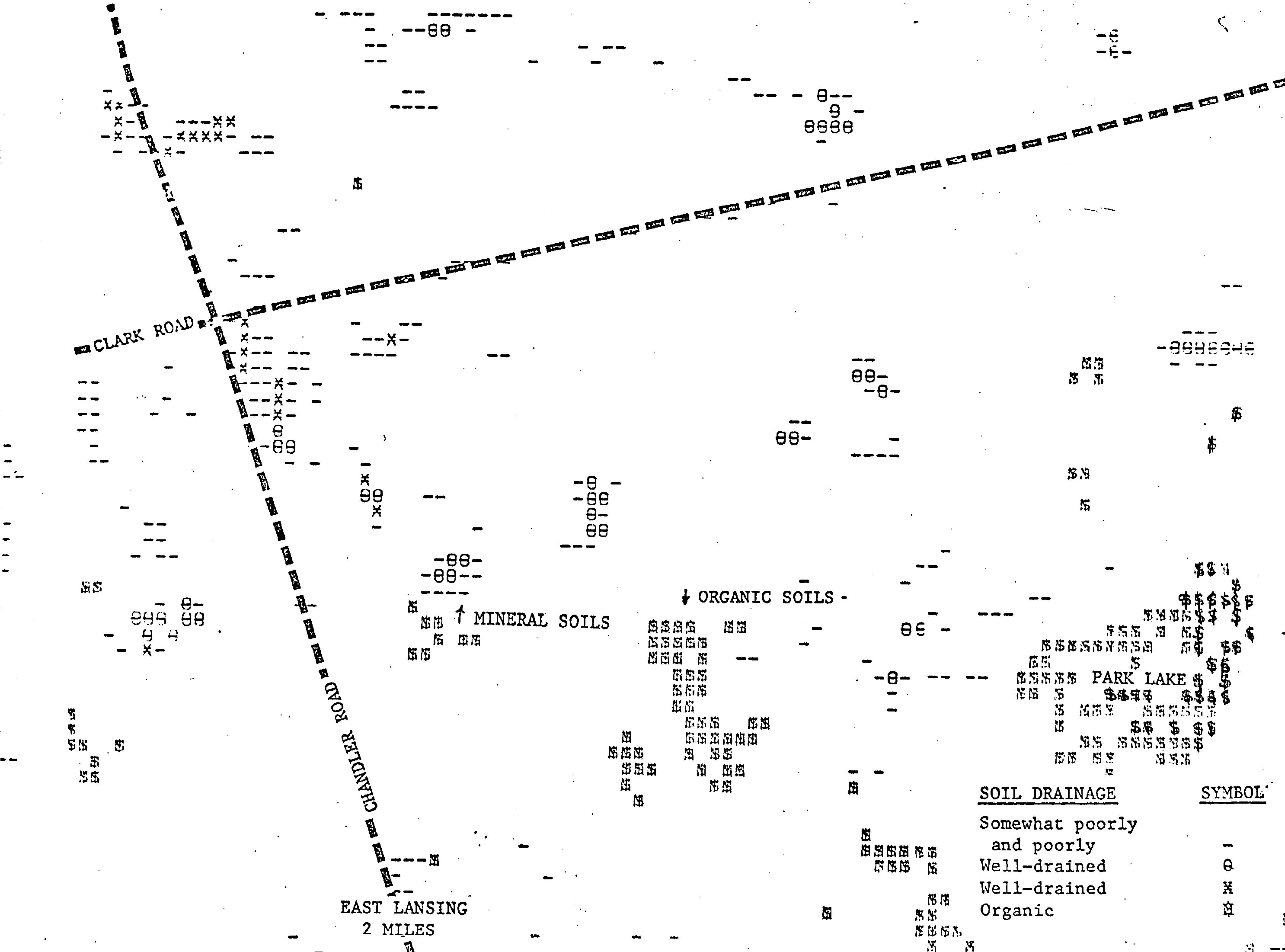


FIGURE 2. MAXIMUM LIKELIHOOD RECOGNITION MAP FOR SOILS SIGNATURES ONLY

into subclasses using the remaining three soil signatures. It appears that a larger portion of the area was mapped as poorly or somewhat poorly drained than is thought to be the case, according to soils maps of the area. This uncertainty is due partly to the edge effect imposed by the 300-ft resolution of the ERTS system. Clear misclassifications occurred around the edges of many of the bare fields, probably due to the inclusion of non-soil materials within the ERTS resolution elements. Another reason for uncertainty results from the fact that mineral soils of different drainage classes frequently occur within the same field. Larger bare soil areas are required in order to determine whether these mineral soils can be correctly differentiated on the basis of drainage. Textural differences of the well drained soils do not appear to significantly affect soil spectral signatures.

2.2.2. Ratio Processing. Ratio processing is a simple image enhancement technique that can be coupled with a choice of ratio values to classify scene materials. While, in general, several different ratios can be utilized in the computer decision operation, the exploratory ratio processing described here employed only a single ratio transformation -- Band 7/Band 5.

The procedure was to initially subtract a path radiance term from each ERTS band, approximated by a value for the darkest object in the scene in each band, and then to print a computer graymap in which ranges of ratio values were indicated by discrete digital symbols. The value ranges were automatically selected on the basis of a random sampling of values for the entire scene. This procedure produced a digital display of the entire scene, of which bare soil areas represented a small portion -- both in areal extent and in digital range symbols. A second digital display (Fig. 3) was also produced in which eight digital range values encompassed only that limited range of values thought to represent soil areas on the first digital display. The values selected for this second display were obtained through examination of a histogram of the ratio values for the entire scene. Bare soil areas were expected to have low ratio values in comparison to most non-bare (vegetated) areas. Thus the higher ratio values were assigned a "blank" symbol and were excluded from the second digital display.

It was hoped that the symbol ranges which were automatically selected would separate soils of differing drainage classes. In retrospect, a more logical approach would have been to determine a priori the ratio values for soil samples of different drainage classes and to assign symbols for each prior to printing them out. This latter procedure will be utilized in future ratio processing for soils identification.

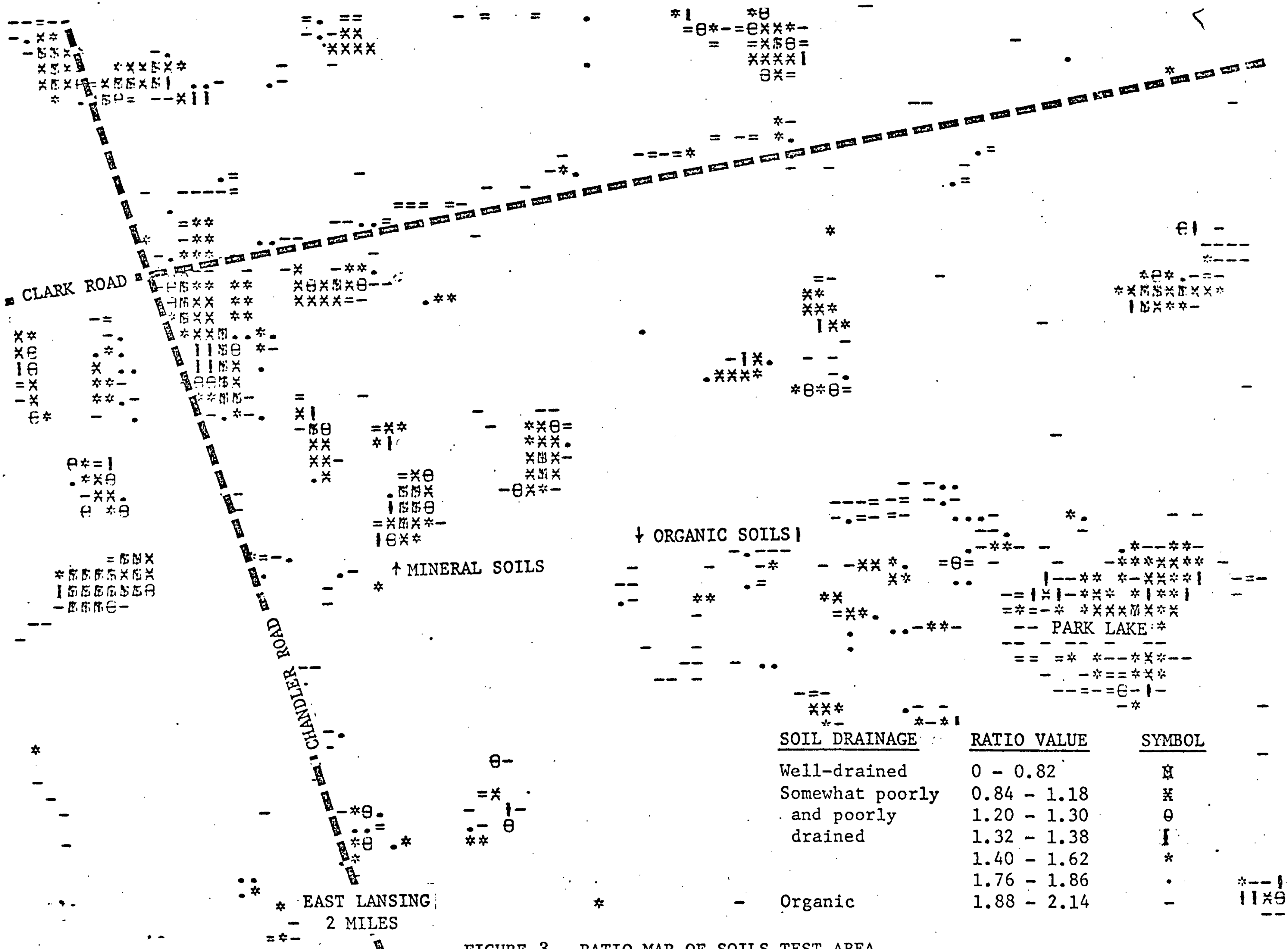


FIGURE 3. RATIO MAP OF SOILS TEST AREA, $\left(\frac{\text{Band 7}}{\text{Adjusted Band 5}}\right)$

TABLE I. RATIOS OF MEAN SIGNAL VALUES* FOR EIGHT SOIL SIGNATURES

Soil Drainage	Soil Texture	Ratio $\frac{\text{Band 5}}{\text{Band 4}}$	Ratio $\frac{\text{Band 7}}{\text{Band 5}}$	Extreme** Ratios for $\left(\frac{\text{Band 7}}{\text{Band 5}}\right)$ Min.	Max.
Well	Coarse	1.61	0.66	0.52	0.86
Well	Coarse	1.51	0.71	0.64	0.80
Well	Medium	1.49	0.76	0.59	0.98
Well	Medium	1.50	0.79	0.70	0.88
Somewhat Poorly		1.49	1.08	0.68	1.62
Poorly		1.48	0.97	0.74	1.24
Organic		1.07	2.75	1.42	5.17
Organic		1.17	2.93	1.50	5.40

*Path radiance (darkest object) contributions of 18 and 10 digital counts were subtracted from Band 4 and Band 5 values, respectively, before ratios were computed. The original values were presented in the previous bimonthly progress report.

**The extreme ratios were computed by using (mean $\mp$ one std. dev.) in numerator and (adjusted mean $\pm$ one std. dev.) in denominator.

Evaluation of the ratio image of bare soil areas indicates results similar to those obtained from the maximum likelihood processing except that organic soils are inadequately recognized. Based on the computed ratio values of the six soil training sets mentioned in Section 2.2.1, well drained soils were represented by a single symbol M$, and somewhat poorly and poorly drained soils were represented by six digital symbols. Only one symbol, -, probably fell within the range of organic soil values. Thus, organic soil areas were under-represented due to the fact that their higher values were excluded in the digital range selection.

Associated with the low ratio ranges for mineral soils were clear misclassifications of other non-vegetated terrain. In particular, heavily commercial (E. Lansing) and surface water areas (Park Lake) had ratio values identical with those printed out for mineral soils. It is unlikely that processing using the Band 7/Band 5 ratio alone will be able to eliminate these misclassifications.

As in the case of the maximum likelihood processing, overlapping of ERTS resolution elements to non-bare areas along the edges of fields probably caused greater portions of these fields to be recognized as somewhat poorly and poorly drained than is the actual case.

These soil recognition maps of a few, small areas produced from ERTS-1 data appear quite promising. The processing techniques which produced these recognition maps will be applied to May 21st and June 8th ERTS-1 data over Test Site IV and to June 9th ERTS-1 data over Test Site III.

Ground truth information such as location of bare soils, soil conditions, and location of vegetation which might be recognized as bare soil was obtained on the day of the ERTS-1 pass over the respective test site. Each test site is about 4 by 20 miles in size. A C-47 underflight was made on June 8 over both Test Sites III and IV. The ground truth information will be used in processing both the computer compatible tapes of the ERTS-1 data and the analog tapes of MSS data of the M-7 scanner.

Additional ground truth information will be obtained to determine the accuracy of existing soil and landform maps. Discrepancies between the recognition maps and the soil and landform maps will be checked in the field. Field studies will also be made in areas which are recognized incorrectly to determine the reasons for these errors.

APPENDIX I

CORRELATION OF ERTS MSS DATA AND EARTH COORDINATE SYSTEMS*

William A. Malila
Ross H. Hieber
Arthur P. McCleer

ERIM, Environmental Research Institute of Michigan
P. O. Box 618
Ann Arbor, Michigan 48107

ABSTRACT

Experience has revealed a severe problem in the analysis and interpretation of ERTS multispectral scanner (MSS) data. The problem is one of accurately correlating ERTS MSS pixels with various Earth coordinate systems. The problem is caused primarily by the relatively large ($\sim$ 80 m square) ground resolution element of ERTS. Analysis areas are usually specified on aerial photographs or topographic maps. It is difficult for an interpreter, examining a digital image display, to accurately identify which ERTS pixels (picture elements) belong to specific areas and test plots, especially when they are small. Therefore, we have developed a computerized procedure to correlate coordinates from topographic maps and/or aerial photographs with ERTS data coordinates. Application to data from other multispectral scanners is anticipated.

In the procedure, a map transformation from Earth coordinates (e.g., latitude and longitude, UTM grid, or relative grid on a photograph) to ERTS point and line numbers is calculated using selected ground control points and the method of least squares. The map transformation is then applied to the Earth coordinates of selected areas to obtain the corresponding

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ERTS point and line numbers. An optional provision allows moving the boundaries of the plots inwards by variable distances (typically half a resolution element) so the selected pixels will not overlap adjacent features.

Examples are presented to show improved accuracy, consistency, and efficiency over conventional procedures.