MACHINE-ASSISTED ANALYSIS OF LANDSAT DATA IN THE STUDY OF CROP-SOILS RELATIONSHIPS

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ABSTRACT

To date, relatively few studies have dealt with crop-soil interactions as they affect the appearance of agricultural areas on Landsat imagery, and hence crop and soil classification or the analysis of agricultural land use.

The Image 100,[1/] a computer-based data analysis system which allows an interpreter to interact directly and rapidly with Landsat computer compatible tape data, provided a tool to assist in the evaluation of the extent and significance of these interactions. Used with timely and accurate ground data, the system made possible a determination of the variability in crop spectral appearance, from soil type to soil type, as recorded on Landsat data. Information was provided in the form of spectral distribution histrograms for each crop-soil class on each Landsat band. Several crop categories in a test area in Brookings County, South Dakota, were classified using training fields that were selected to be representative of each major crop-soil class. Accuracies in each case, on a total acreage basis, were greater than 90 percent.

1/ The use of the brand name in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

TABLE

INTRODUCTION

Although numerous studies have been conducted dealing with either crop identification or soil classification using computer processed Landsat data, few if any have dealt with the crop/soil interaction, either as it affects classification results or agricultural land use. This application example describes the use of the Image 100 Data Analysis System as a tool (1) in the classification of agricultural crops and (2) in defining the effects of the underlying soils on the appearance of crops as recorded on Landsat data.

The methods and results discussed here have been presented primarily as an <u>example</u> of some of the ways in which a highly interactive digital analysis system can be used in the analysis of soil/crop relationships. The results are not intended to portray the ultimate in accuracy, or even in the capabilities of the system. The emphasis is on the technique as a tool rather than on the results of this particular example. Readers may envision numerous ways in which the kind of data described could be used in different ways for specific purposes, or alternative ways in which the analysis might have been carried out to support the application described here. If so, this application example will have served its purpose.

The work described here was prepared in cooperation with Dr. Fred C. Westin and Mr. Gary D. Lemme of the Department of Plant Science, South Dakota State University (SDSU), who are engaged in an extensive soil normalization study in conjunction with the Remote Sensing Institute, SDSU. The test area is a strip 25 miles (40 km) long and 2 miles (3.2 km) wide in Brookings County, South Dakota.

Soils in the area are derived from loess, glacial till, glacial outwash, and alluvium. The principal crops are corn, small grains (primarily wheat and oats), alfalfa, and grass (including pasturelands and haylands). Field-by-field ground data for the entire test area was acquired coincidently with the Landsat overpass (June 30, 1974) by SDSU personnel, and detailed soils maps are available.

THE INFORMATIONAL REQUIREMENT

Information on soil/crop interactions is important for several reasons. In land use planning, analysis of land productivity, and planning of cropland management practices, information regarding the existing distribution of crops within soil associations is critical. A knowledge of the effect of soil type on crop appearance can lead to a more judicious selection of training sets and a better understanding of the performance of the classifier. It is possible that this could provide a basis for the normalization of the soil influence on crop appearance through the development of factors for each soil association which could be used to improve crop classification accuracy. Thus, this example may well be of interest to a fairly wide range of readers, both those interested in crop/soil relationships _per se_ and those involved in the development of advanced remote sensing analysis techniques.

APPROACH TO ANALYSIS

The initial step in the analysis was the acquisition of a CCT (computer compatible tape) of the June 30, 1974 Landsat scene covering the Brookings test site. A June 30 image was chosen based on the phenology of the crops of interest in the test area. During late

June, both small grains (primarily oats in eastern South Dakota) and corn are green, growing vigorously, and provide significant crop cover. At an earlier date, corn is generally quite young and hence provides sparse cover, while later many of the small grain fields have dried or have been harvested. The tape data were entered into the EROS Data Center Image 100 System (Figure 1) and a Landsat scene overview on the color television monitor was used to determine the coordinates of the test strip in terms of pixel (picture element) lines and columns. That portion of the scene containing only the test strip was enlarged and displayed at a scale such that each pixel on the color monitor screen represented one Landsat pixel. Thus, the full screen display contained 511 pixels in a horizontal direction and 369 pixels in a vertical direction, equivalent to an area approximately 18 statute miles (29 km) on a side. All analysis and classification work was done at this scale (Figure 2).

Next, all of the region outside the test strip was deleted (Figure 3), so that classification work and acreage determination could be performed only on the test strip data.

Once the test strip had been isolated, the analysis system was used for two purposes: (1) determination of the radiometric values of crops in different soil types; and (2) classification of crops in the test strip.

In order to ascertain the influence of soil type on the radiometric value of crops, a number of sample fields within each of the soil-crop classes were delineated through the use of an adjustable cursor. A histogram program was used to obtain a printout of the

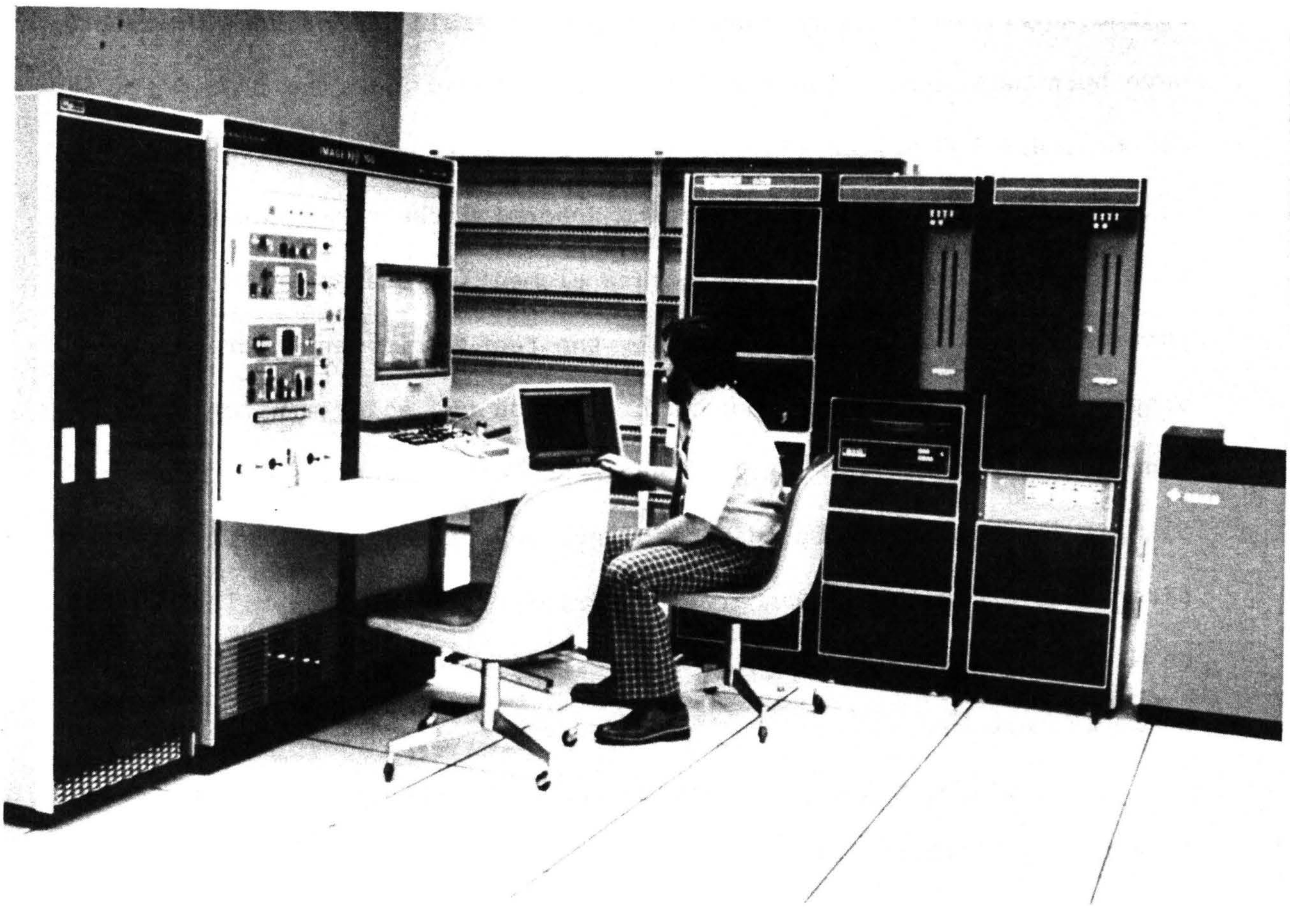

Figure 1.--Image 100 Data Analysis System at the EROS Data Center.

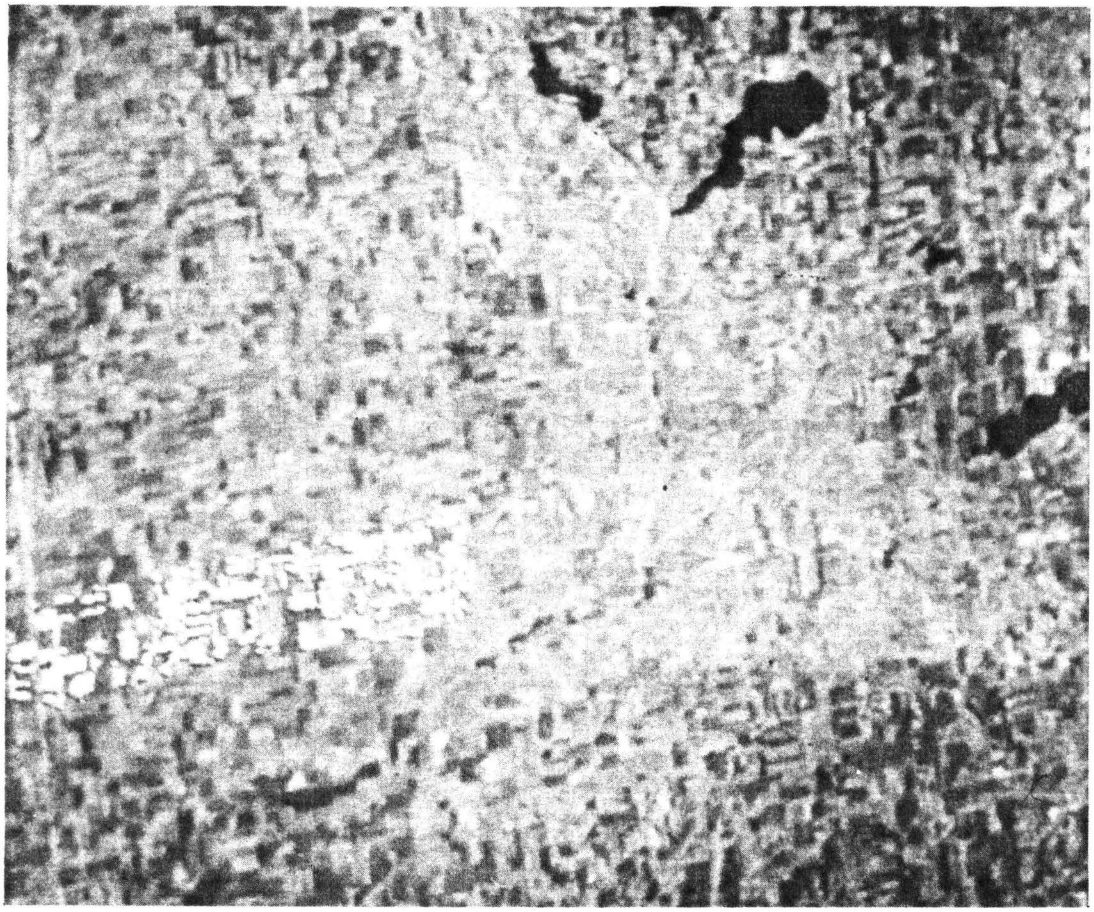

Figure 2.--Image 100 video display of a Landsat image of the northeast 1/4 of Brookings County, South Dakota. The total area shown is approximately 18 miles (29 km) across (east-west), and covers approximately 250 square miles (640 square km). The 9 by 2 mile (14.4 by 3.2 km) test strip appears at the lower left.

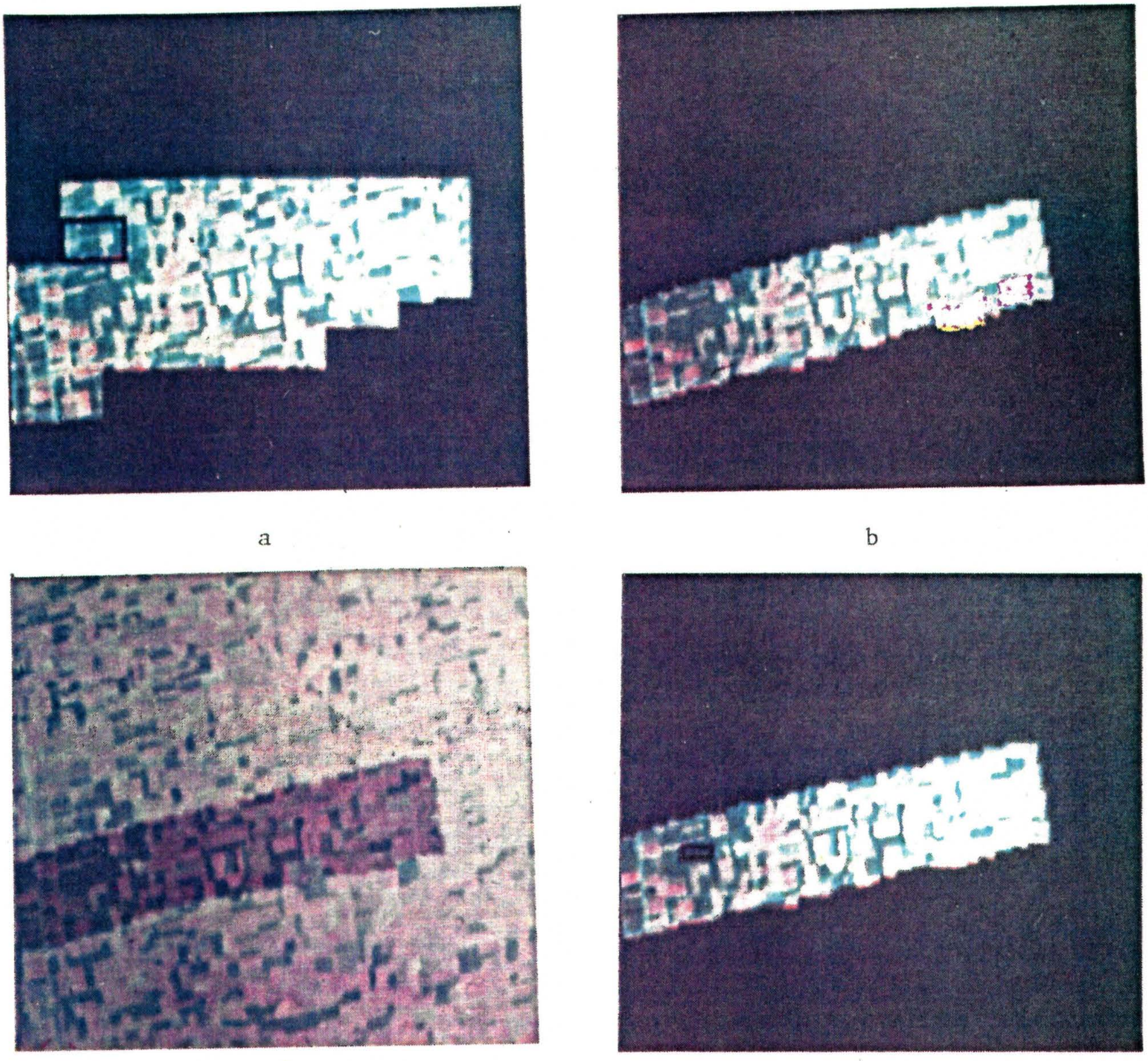

Figure 3.--All four images show a 2 by 9 mile (3.2 by 14.4 km) portion of the test strip as displayed on the color monitor. (a) Those portions of the image not in the test strip are in the process of being deleted. (b) The test strip as finally defined. (c) The test strip superimposed on the entire image. (d) The test strip with the cursor (small black rectangle) outlining a training field.

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2 2/3

3 1/4

frequency distribution of pixel counts versus radiometric values for all delineated areas within a class, (i.e., a crop-soil class) as well as printout of maximum, minimum, and mean radiometric values (Figure 4).

The crop classification was accomplished by first delineating a number of training fields representative of each crop type. An attempt was made to select training fields in various soil types for each crop type in a proportion approximately equal to the actual proportion of each crop on each soil type. Approximately 5 or 6 training fields were selected for each crop type. Using a "one-dimensional"[2/] classification procedure, the area within the test strip was classified. Each crop type was assigned a specific color track (theme) such that all pixels in that type could be displayed as that color on a television monitor (Figure 5).

In addition, a theme area program was used to print out pixel counts and equivalent number of acres and hectares in each crop type within the test strip. It should be noted that while selecting training fields, the histogram program was used to adjust the upper and lower bounds of radiometric values for each crop so that the

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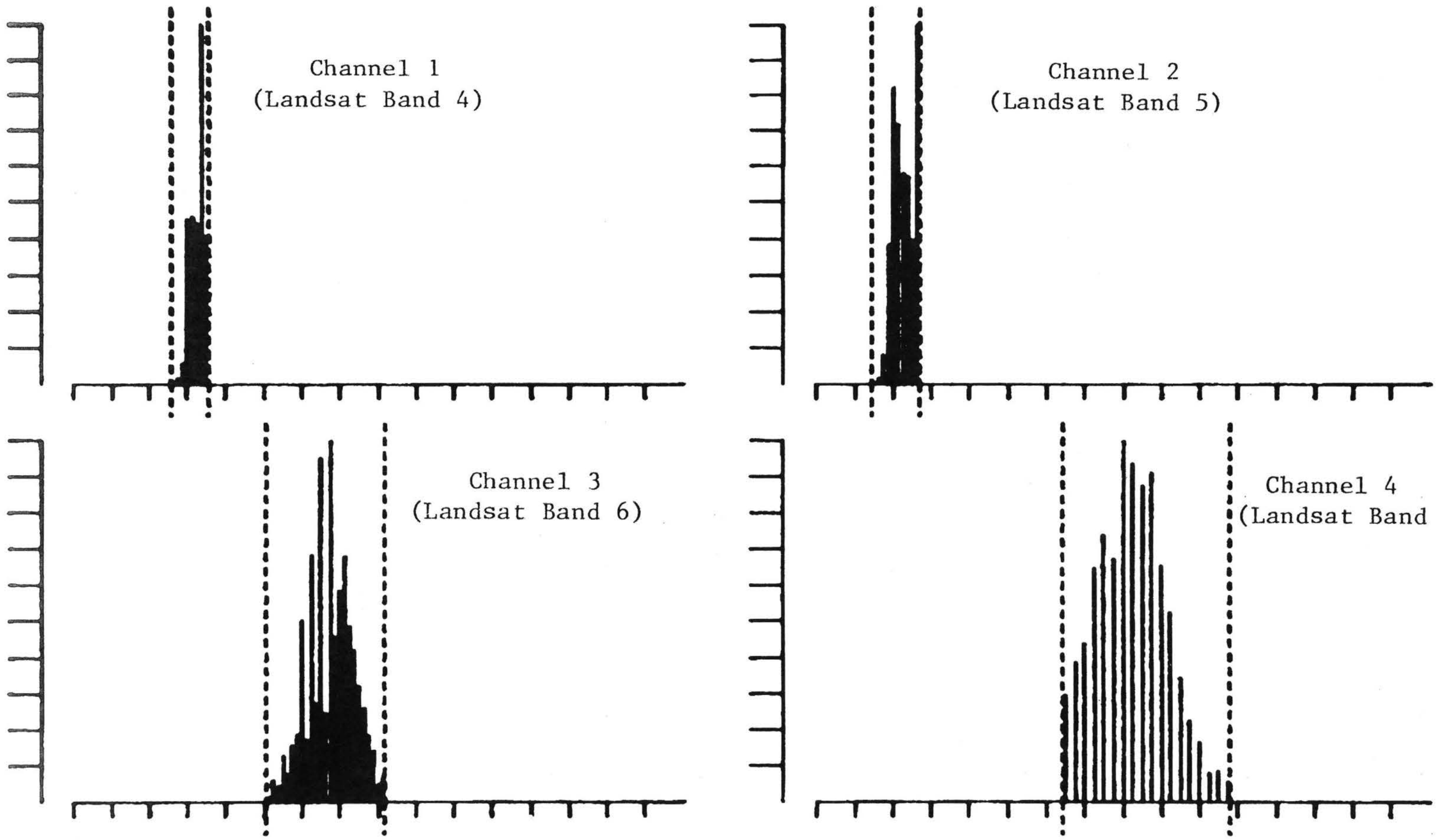
2/ As performed by the Image 100, the "one-dimensional" classification identifies, as in the class of interest, all pixels whose radiance values fall within the range of radiance values occurring in the training set, in each of the spectral bands used for the classification. Therefore, no statistical decision-making algorithms are involved other than defining the maximum and minimum radiance values for each band in the training area(s).

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ALARM RESOLUTION   128  128  128  128  +
#  LB  UB  DEL     PEAK  MEAN   VAR    +
1  21  28    3     928.  26.1   2.0    +
2  12  21   10     575.  18.1   4.5    +
3  41  65   25     322.  54.0  22.3    +
4  52  86   35     290.  65.8  53.6    +
TRAINING AREA=256962. PIXELS           +
ALARMED AREA= 63463.PIXELS( 24.2%)     +
TYPE CHANNEL (1-4), OR E(X)IT
```

Figure 4.--A histogram display of the spectral signature of oats in the test area. The vertical axis of each graph is relative frequency of pixel occurrence and the horizontal axis is radiometric value. At the left is a statistical summary showing the lower bound (LB), upper bound (UB) and range (DEL) of radiometric values for each channel, as well as peak frequency, mean radiometric value and variance of radiometric values. "Alarm Resolution" refers to the number of steps from minimum to maximum in each channel, and "Training Area" specifies the number of pixels used in deriving the data.

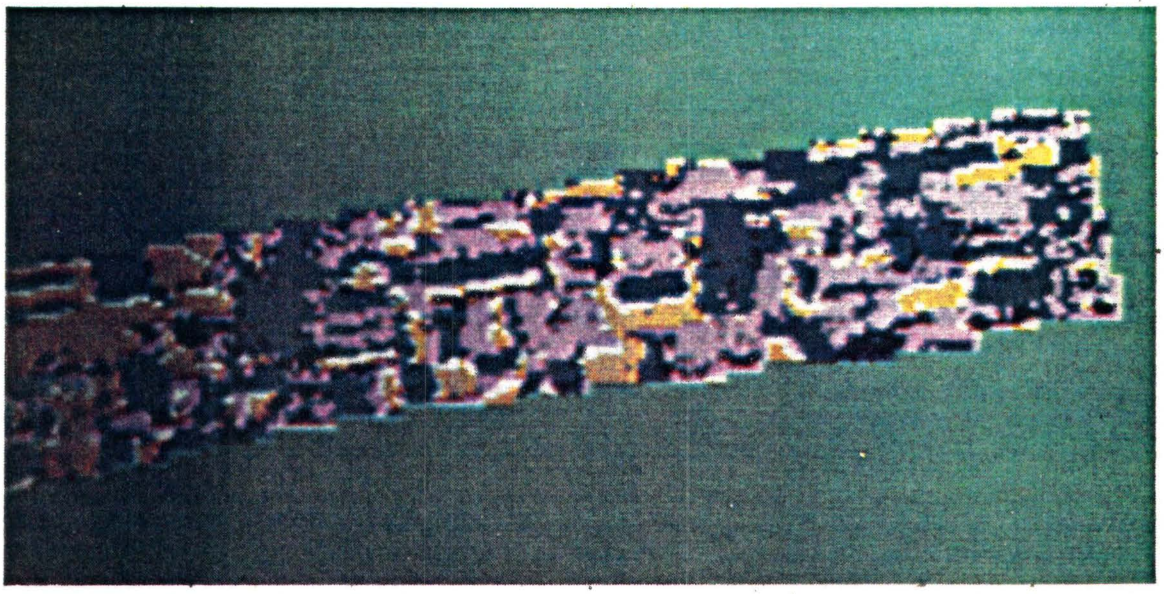

Figure 5.--The final classification of crop types within the test strip as photographed from the color monitor. Corn is color-coded as yellow, oats as blue, and grass as pink. Black areas are those not classified as one of the three crop types. Map printouts of the same area are shown in Figures 9 and 10.

possibility of assigning a pixel to more than one crop class was minimized.[3/]

END PRODUCTS

The end products of the analysis consisted of both graphic and tabular data illustrating the effect of soil type on crop appearance (actually, on the radiometric values of each crop as sensed by the Landsat multispectral scanner and recorded on a computer tape), and map and tabular summaries of the actual crop-type classifications.

The results of an analysis of the histograms are summarized in Figures 6, 7, and 8. Figure 6 illustrates the fact that although there may be considerable overlap in radiometric value between two crops in one Landsat band, another band may provide sufficient separation and lack of overlap to permit adequate separation.

Figures 7 and 8 show the effects of underlying soil type on crop appearance. It should be noted that for both corn and grass there is a definite difference in radiometric value of the crop depending on the soil. Corn on Kranzburg soil has higher radiometric values in all four Landsat bands than corn on Lamoure soils. This is probably due to the effect of the light-toned Kranzburg soil showing through the corn, which provides less than 100 percent crown closure at the early date (June 30) on which the data were acquired. On the other hand,

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3/ Those interested in a detailed discussion of the details and operation of the Analysis System used in this example are referred to the Image 100 User Manual, distributed by the Ground Systems Department, Space Division, General Electric Company, Daytona Beach, Florida.

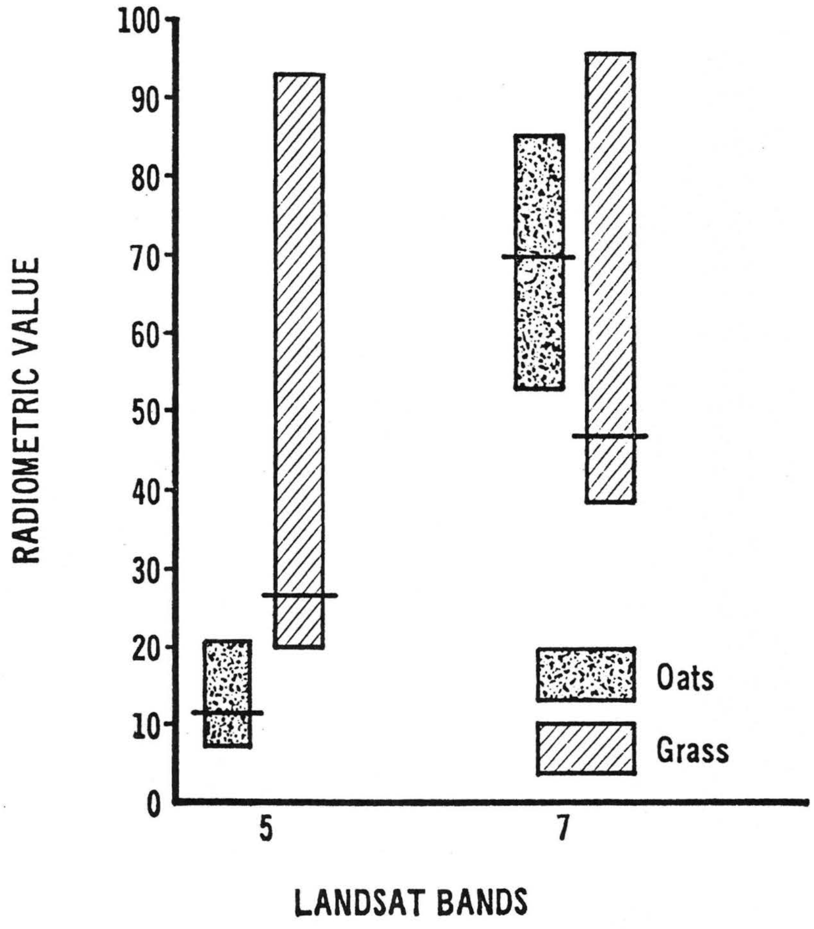

Figure 6.--The radiometric values of oats and grass within the training areas in the test strip. The vertical bars contain the entire range of values, while the horizontal lines indicate mean values. Note the considerable overlap in band 7, even though the means are well separated, whereas in band 5 the two classes do not overlap despite fairly close mean values.

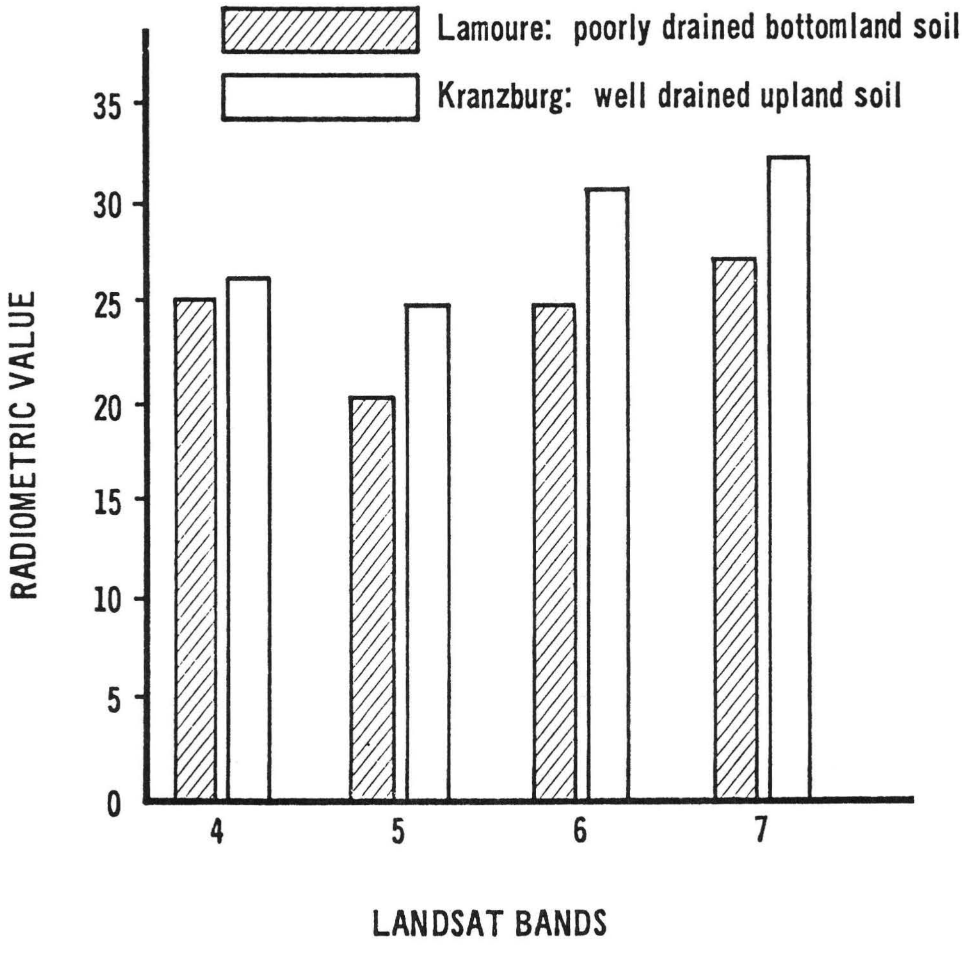

Figure 7.--Influence of soils on radiometric values of corn in selected plots in the Brookings test strip (June 30, 1974 data). Values plotted are mean radiometric values for each crop-soil combination.

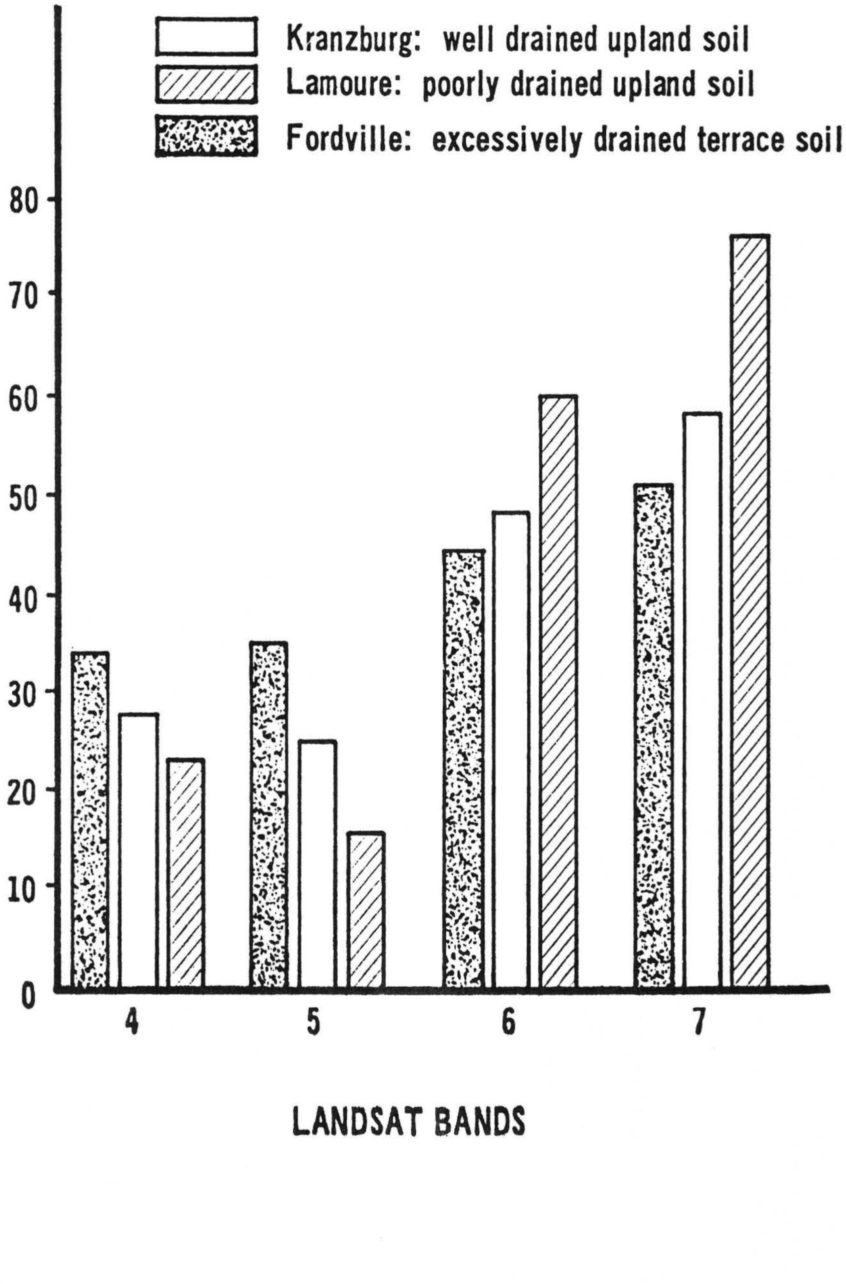

Figure 8.--Influence of soils on radiometric values of grass in selected plots in the Brookings test strip (June 30, 1974 data). Values plotted are mean radiometric values for each crop-soil combination.

grass on Kranzburg soil is ligher (higher radiometric values) in bands 4 and 5 than it is on Lamoure soil, but darker on bands 6 and 7. In this case the effect is probably due to plant color rather than soil color, as grass fields in the test area generally have 100 percent cover by June 30. Grass on the Lamoure soils is generally more lush, thus appearing darker on bands 4 and 5 and lighter in bands 6 and 7. The poorest stands of grass on Fordville soils are lighest of all in bands 4 and 5 and darkest of all in bands 6 and 7.

Figure 5 illustrates the results of the crop classification as displayed on the color monitor. The same information can be given in map-printout form (Figures 9 and 10). Although there is distortion from a true planimetric representation on these thematic maps, it is possible to rectify the printouts to fit a planimetric base map.

Finally, Table 1 presents the results of the crop classification in tabular form, compared with the ground data. These data were obtained using the theme area program of the Image 100, in which the number of pixels in each theme (and hence in each crop type as classified) are counted and tabulated, and the equivalent acreage calculated.

SUMMARY

The Image 100 image analysis system was used to demonstrate the potential of such equipment as a tool for providing information on the spectral distribution of Landsat pixels representative of a variety of crop-soil combinations, and for classifying crop types using training fields selected on the basis of crop-soil types. Information derived in this way can provide greater insight into the effect of soils on

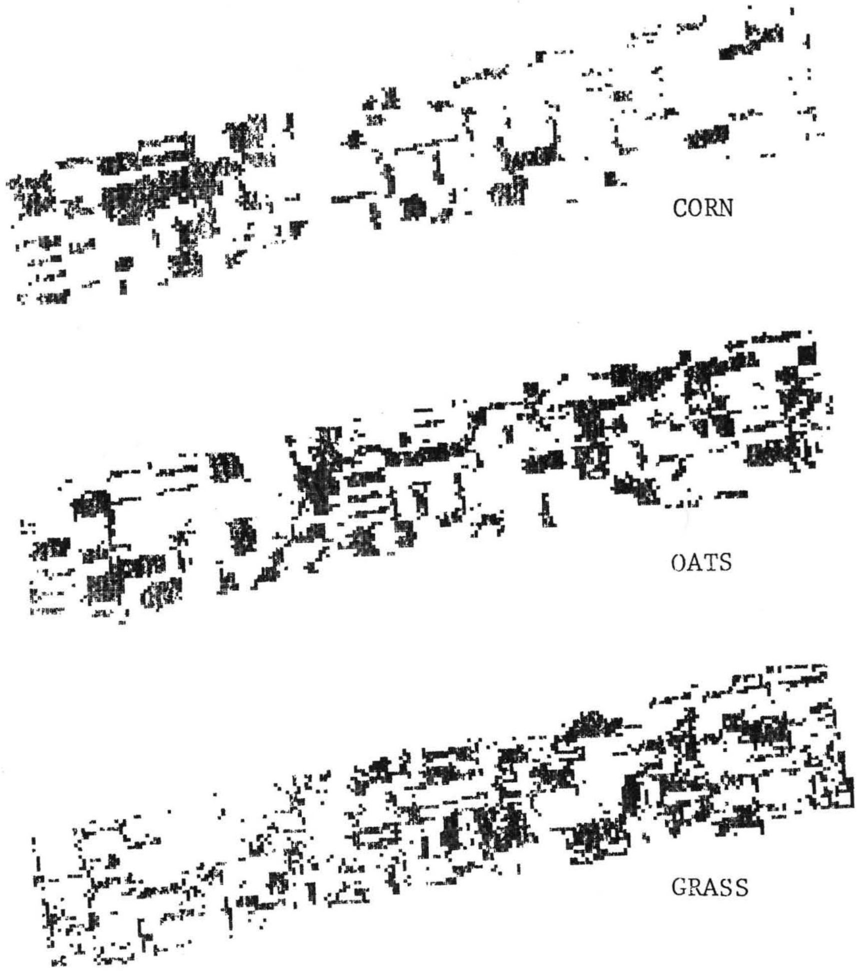

Figure 9.--Computer printout showing the results of the classification of the test strip for corn, oats, and grass. Each dot represents one Landsat picture element (approximately 1.1 acres or .45 hectares).

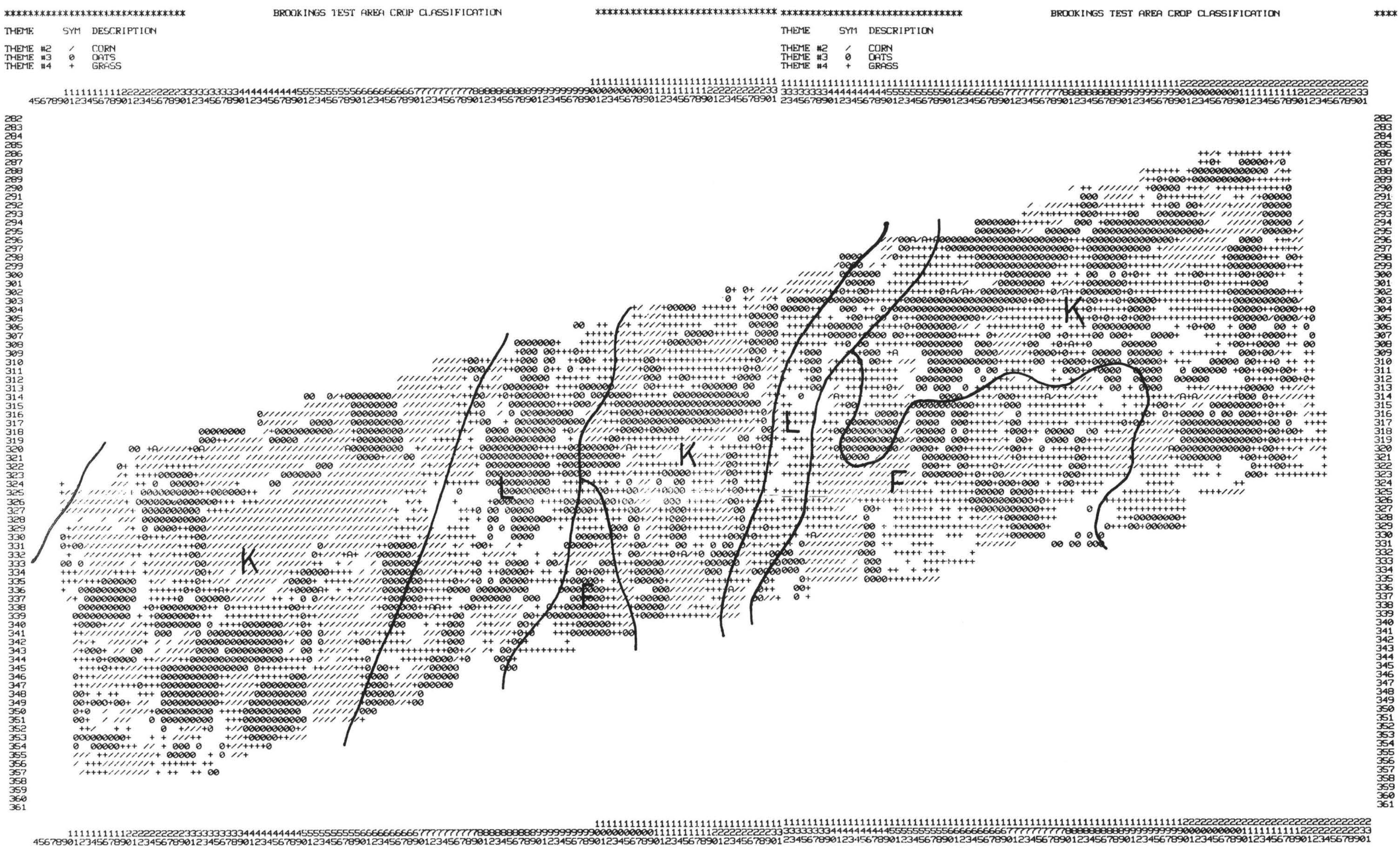

Figure 10.--A composite printout of the classification results. Each symbol represents one Landsat picture element. The broad soil associations in the test strip are delineated. Level, poorly drained soils (Lamoure) are annotated as "L", excessively drained terrace soils (Fordville) are annotated as "F", and well drained upland soils (such as Kranzburg) are annotated as "K".

TABLE 1

Classification Accuracy Brookings Test Strip: 30 June 1974

[Results of the classification of the three major crop classes in the test strip. The error in percentage was calculated on a total acreage basis rather than pixel-by-pixel or field-by-field.]

CLASS	IMAGE 100 CLASSIFICATION		GROUND TRUTH		% ERROR
	HECTARES	ACRES	HECTARES	ACRES	
CORN	4,233	10,459	4,119	10,178	2.76
SMALL GRAIN	3,769	9,314	4,154	10,265	9.26
GRASS	3,518	8,693	3,247	8,024	8.34

OVERALL ACCURACY = 93.2%

crop appearance, and can be used to investigate the possible improvement of crop classification caused by taking soil effects into account in the selection of training fields.