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MAPPING SOIL TYPES FROM MULTISPECTRAL SCANNER DATA *

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1. INTRODUCTION

Use of multispectral remote sensing and computer processing techniques in soil studies was recently reported by Kristof [5]. His results showed that this new technology can be used to "map" soil surface conditions over small areas with a reasonable degree of accuracy.

This type of automatic "mapping" is based primarily on soil spectral variations. The approach involves subjective selection of a set of reference or "training" samples from a gray-level display of spectral variations which was generated by a computer. Each resolution element [1] is then classified using a maximum likelihood ratio. Output is a computer printout on which the researcher assigns a different symbol to each class.

Success of this automatic classification was evaluated by considering the characteristics which make these soils different from one another. For example, one should not necessarily expect a computer classification based on surface spectral properties to discriminate soils which have a fragipan [9] from those which do not, since this feature occurs below the soil surface. In practice it is often instructive to compare the soil classes "mapped" on the computer printout with those mapped by conventional soil survey procedures [8].

2. STUDY AREAS

Four soil test areas were designated for this study. Two of the areas are located in the central part of Indiana in Morgan County near the West Fork of the White River. These were designated as Soil Test Areas 2 and 3 (STA 2 and STA 3). These two areas are located about 4 km apart. The soils were developed in late Wisconsin glacial material including glacial till, outwash, and aeolian sands. The soils belong to the Alfisol soil order (Gray-Brown Podzolic) and Mollisol soil order (Humic Gley and Alluvial) [9]. The topography of this area is nearly level to rolling.

The other two study areas are located in Tippecanoe County, Indiana, and were designated as Soil Test Areas 4 and 5 (STA 4 and STA 5). Soils in STA 4 are within the region of the Alfisols but include some wet Mollisols. These soils were developed in 45 to 90 cm of silt over glacial till. The topography is level to sloping. Soil Test Area 5 is also within the Alfisol region but includes some wet Mollisols. The topography is nearly level. The soils in the southern half of STA 5 were developed in glacial till with less than 40 cm of silt at the surface, whereas the soils of the northern half were developed in deeper silts.

3. PROCEDURES

Multispectral data from STA 2 and STA 3 were collected on April 28, 1967 by an airborne scanning spectrometer mounted in the University of Michigan aircraft. Data were taken from an altitude of 1200 m at approximately 1100 hours. Twelve wavelength bands were used in the computer analysis. These were: 0.40-0.44, 0.44-0.46, 0.46-0.48, 0.48-0.50, 0.50-0.52, 0.52-0.55, 0.55-0.58, 0.58-0.62, 0.62-0.66, 0.66-0.72, 0.72-0.80, and 0.80-1.00 μm.

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The multispectral data over STA 4 and STA 5 were collected on May 26, 1969, at approximately 1200 hours. The aircraft altitude was 1200 m above the terrain. Eleven wavelength bands were used in the analysis. These were: 0.40-0.44, 0.52-0.55, 0.55-0.58, 0.58-0.62, 0.62-0.66, 0.66-0.72, 0.72-0.80, 0.80-1.00, 1.00-1.40, 1.50-1.80, 2.00-2.60 μm.

Spectral data from the four test areas were classified using computer-implemented pattern recognition techniques. Reference or training samples were selected on the basis of a conventional soil survey map and were used to classify the remaining part of the soil test area. Additionally, STA 3 was classified using training samples from STA 2 and vice versa. Similar reciprocal classifications were conducted for STA 4 and STA 5 and an area adjacent to STA 4.

Samples were taken from each of the several soil series represented and the average relative spectral response in each wavelength band was computed. The average relative spectral response in various combinations of wavelength bands was also computed for representative areas within each mapped soil series. Additionally, a ratio (V/IR) was computed as the average relative spectral response in the visible wavelengths divided by the average relative spectral response in the reflective IR wavelengths. These ratios and averages were evaluated as to their usefulness in discriminating the various soil series (types) mapped. Relationships of these measurements to internal drainage characteristics, organic matter content, and color were investigated. Organic matter content and color were determined on surface soil samples collected only from STA 4 and STA 5. Computer "maps" produced by these various procedures were evaluated with respect to how well they agreed with conventional soil survey maps.

4. RESULTS

Soil Test Areas 2 and 3.

Figures 1 and 2 are a soil survey map and a computer classification of STA 3, respectively. The computer printout compares favorably with the soil survey map. Light colored soils such as Princeton fine sandy loam and Martinsville loam were assigned computer symbols ".", "-", and "=". The dark colored Rensselaer fine sandy loam was assigned the symbol "M", and the moderately dark Fox loam was assigned the symbol "H". Vegetation, water, roads, and other non-soil ground targets were left blank on the printouts.

Figures 3 and 4 are a soil survey map and a computer classification, respectively, of the soils of STA 2. Figure 4 was made using training samples of STA 3. Using this procedure some of the soil areas were thresholded, that is, were left blank on the printout. The reason for the blank areas can be explained in that the multispectral response of the soil in the thresholded area was not like the response of any soil in the STA 3 training samples. Some of the Martinsville loam in STA 2 was erroneously classified as Princeton fine sandy loam. Much of the Princeton soil in STA 2 was thresholded. However, this failure to classify is not illogical since the classification was based on spectral similarity to the reference samples, and the Princeton soil on STA 2 has a much higher average relative response than any of the reference samples in STA 3 (Table I).

Table I also shows that soils of the same series did not have the same average relative spectral response in the two test areas. This measurement for Martinsville loam, however, was similar in both areas (87.84 and 90.37).

Soil Test Areas 4 and 5.

Figures 5 and 6 are a soil survey map and a computer classification of STA 4 and an area adjacent to STA 4. There was reasonably good agreement between the soil survey map and the computer "map".

Figures 7 and 8 are a soil survey map and a computer classification of STA 5, respectively. Here again, reasonably good agreement was obtained, except that much of the Brookston soil was "mapped" as Ragsdale by the computer.

Table II lists some descriptive information for the soils of STA 4 and STA 5. Table III gives average relative spectral response information for the soils of STA 4 and STA 5. Only the Toronto and Brookston soil series were common to the two test areas.

Figure 9 is a computer printout of STA 4 and the adjacent area produced by using training samples from STA 5. In general, the Brookston soil in the area adjacent to STA 4 was correctly classified by this method. The Toronto soil of STA 4 was incorrectly classified as Brookston. The other soils of STA 4 were all classified incorrectly with respect to soil series. This was inevitable since samples of the Fincastle, Russell, Xenia, Metea, Del Rey, and Kokomo series were not used in the training samples. Most of the resultant classifications are, however, related to the color and organic matter content of the soils as given in Table II.

Figure 10 shows a classification of STA 5 using training samples from STA 4. The light and dark soils were distinguished from one another, however, much of the Brookston soil was "mapped" by the computer as Kokomo rather than Brookston. The Toronto soil was also "mapped" mostly as Kokomo rather than Toronto. Most of the Reesville area was "mapped" as Fincastle. This result is quite logical since the Reesville and Fincastle series are similar in most respects, including surface color and texture.

5. CONCLUSIONS

"Mapping" of soil types using multispectral scanner data and computer-implemented pattern recognition techniques was partially successful. Soil series are conventionally differentiated by surface and subsurface properties, so that they cannot be expected to have observable surface differences in all cases. Some difficulty was encountered when attempting to "map" a soil series (or soil type) in one soil test area using training samples from another soil test area located at a distance of several km from the first. These difficulties could have been due to differences in illumination at the two soil test areas, differences in surface roughness, surface texture, or surface color, adjustments in instrumentation during data collection, or other factors. Since any given soil series has, by definition, an allowable range of surface conditions, it is inevitable that some spectral variations will occur within a soil series. The best identification and discrimination of soil series seemed to result when these variations within soil series were much smaller than variations between soil series. In some instances, the spectral variations within series were greater than between series.

A computed value defined as average relative spectral response was useful in predicting how well the "mapping" of soil series could be accomplished. A ratio of visible to infrared response appeared to have additional utility in characterizing the spectral properties of soils.

REFERENCES

1. Baumgardner, M. F., S. Kristof, C. J. Johannsen, and A. Zachary. 1970. Effects of organic matter on the multispectral properties of soils. Proceedings of the Indiana Academy of Science for 1969. Volume 79. p. 413-422.

2. Holmes, R. and R. B. MacDonald. The physical basis of system design for remote sensing in agriculture. Proceeding of the IEEE. Volume 57. No. 4. April 1969.

3. Johannsen, C. J. 1969. The detection of available soil moisture by remote sensing techniques. Ph.D. Thesis. Purdue University.

4. Lent, J. D. 1969. Automatic interpretation in wildland management. The use of remote sensing in conservation, development, and management of the natural resources of the State of Alaska. Department of Economic Development, State of Alaska. p. 117-126.

5. Kristof, S. J. 1971. Preliminary multispectral studies of soils. Soil and water conservation. Volume 26, Number 1. p. 15-18.

6. Remote multispectral sensing in agriculture. Agricultural Experiment Station, Purdue University, Lafayette, Indiana. Research Bulletin 873, December 1970. 112 p.

7. Simakova, M. S. 1959. Soil mapping by color aerial photography. Academy of Sciences of U.S.S.R., Dokuchaev Soil Institute Moskva.

8. Soil Survey Staff. 1951. Soil Survey Manual. USDA Handbook 18. 503 p.

9. Soil Survey Staff. 1960. Soil Classification, a comprehensive system: 7th approximation. Washington, D.C.: U.S. Government Printing Office. 265 p.

TABLE I. AVERAGE RELATIVE SPECTRAL RESPONSE AND COMPUTED RATIO (V/IR) FOR REPRESENTATIVE SAMPLES OF EACH SOIL TYPE IN VISIBLE AND REFLECTIVE INFRARED WAVELENGTH BANDS.

Soil Types	Visible Wavelengths (0.40-0.72 μm)	Infrared Wavelengths (0.72-1.00 μm)	Ratio (V/IR)*
STA 2			
Princeton fine sandy loam	131.32	89.47	1.47
Martinsville loam	90.37	73.76	1.23
Fox loam	83.05	68.57	1.21
STA 3			
Princeton fine sandy loam	94.98	76.57	1.24
Martinsville loam	87.84	72.22	1.22
Fox loam	76.07	62.95	1.21
Ockley loam	85.57	71.52	1.20
Miami loam	79.74	67.86	1.18
Ross silt loam	73.06	62.25	1.17
Crosby loam	83.87	72.85	1.15
Rensselaer fine sandy loam	66.53	56.91	1.17

* The ratio (V/IR) is defined as the average relative spectral response of an object in the visible portion of electromagnetic spectrum divided by the average relative response in the reflective infrared portion of the spectrum.

TABLE II. DESCRIPTIVE INFORMATION FOR SOIL SERIES OF STA 4 AND STA 5.

Soil Type	Present Classification of Soil Series	Soil Test Area	Internal Drainage Class of Soil Series	Average Percent Organic Matter of Soil Samples	Typical Color of Moist Soil Samples
Kokomo silty clay loam	Typic Argiaquoll	4	Very poorly drained	4.25	10YR 2/1
Brookston silty clay loam	Typic Argiaquoll	4	Very poorly drained	4.00	10YR 2/1
Toronto silt loam	Udollic Ochraqualf	4	Somewhat poorly drained	2.19	10YR 3/1
Metea silt loam	Arenic Hapludalf	4	Well drained	2.35	10YR 4/2
Del Rey silt loam	Aeric Ochraqualf	4	Somewhat poorly drained	1.70	10YR 4/2
Fincastle silt loam	Aeric Ochraqualf	4	Somewhat poorly drained	1.62	10YR 4/2
Xenia silt loam	Aquic Hapludalf	4	Well drained	1.36	10YR 4/2
Russell silt loam	Typic Hapludalf	4	Well drained	1.65	10YR 4/3
Ragsdale silty clay loam	Typic Argiaquoll	5	Very poorly drained	4.20	10YR 2/2
Brookston silt loam	Typic Argiaquoll	5	Very poorly drained	3.38	10YR 2.5/1.5
Brookston silty clay loam	Typic Argiaquoll	5	Very poorly drained	4.07	10YR 2.5/1
Toronto silt loam	Udollic Ochraqualf	5	Somewhat poorly drained	2.80	10YR 3/1
Crosby silt loam	Aeric Ochraqualf	5	Somewhat poorly drained	1.80	10YR 4/2
Celina silt loam	Aquic Hapludalf	5	Moderately well drained	1.60	10YR 4/2
Reesville silt loam	Aeric Ochraqualf	5	Somewhat poorly drained	1.96	10YR 4/2

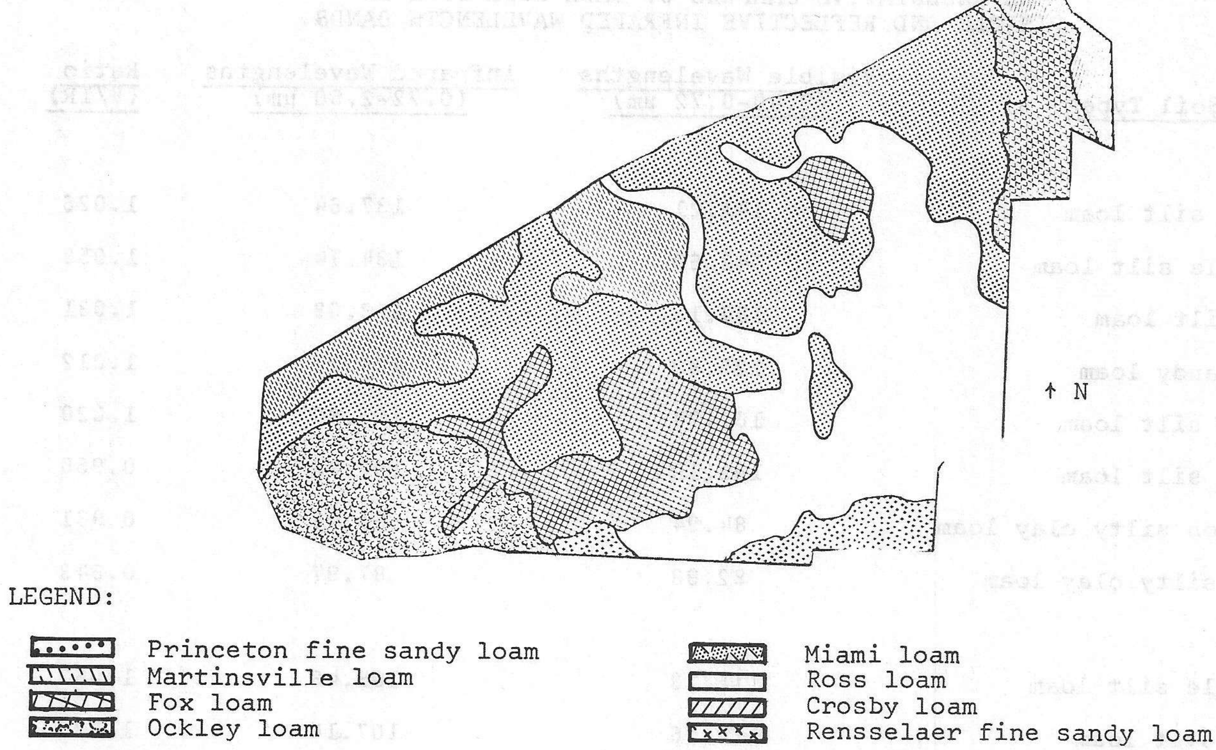


FIGURE 1. SOIL SURVEY MAP OF STA 3.

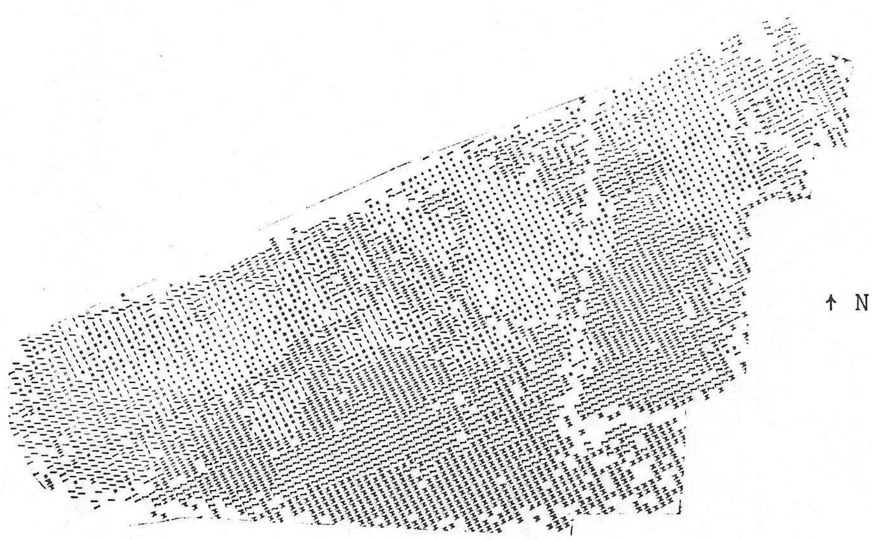


FIGURE 2. COMPUTER CLASSIFICATION OF STA 3.

TABLE III. AVERAGE RELATIVE SPECTRAL RESPONSE AND COMPUTED RATIO (V/IR) FOR REPRESENTATIVE SAMPLES OF EACH SOIL TYPE IN VISIBLE AND REFLECTIVE INFRARED WAVELENGTH BANDS.

Soil Types	Visible Wavelengths (0.40-0.72 μm)	Infrared Wavelengths (0.72-2.60 μm)	Ratio (V/IR)
STA 4			
Russell silt loam	141.21	137.64	1.026
Fincastle silt loam	142.60	134.74	1.058
Xenia silt loam	137.15	133.08	1.031
Metea sandy loam	125.80	124.27	1.012
Del Rey silt loam	107.94	105.80	1.020
Toronto silt loam	102.10	107.48	0.950
Brookston silty clay loam	84.94	91.28	0.931
Kokomo silty clay loam	82.93	87.97	0.943
STA 5			
Reesville silt loam	115.73	108.48	1.067
Crosby silt loam	110.76	107.14	1.033
Celina silt loam	105.25	103.46	1.017
Toronto silt loam	103.53	107.16	0.966
Brookston silt loam	93.25	98.72	0.944
Brookston silty clay loam	82.10	87.04	0.943
Ragsdale silty clay loam	78.76	85.10	0.925

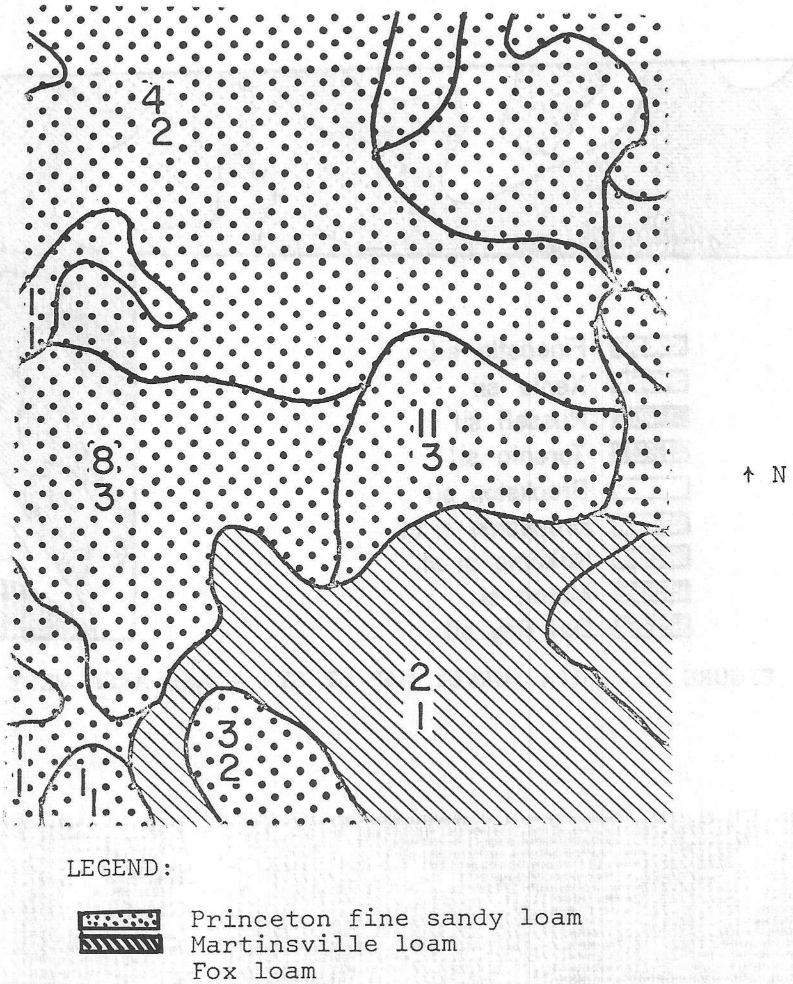


FIGURE 3. SOIL SURVEY MAP OF STA 2.

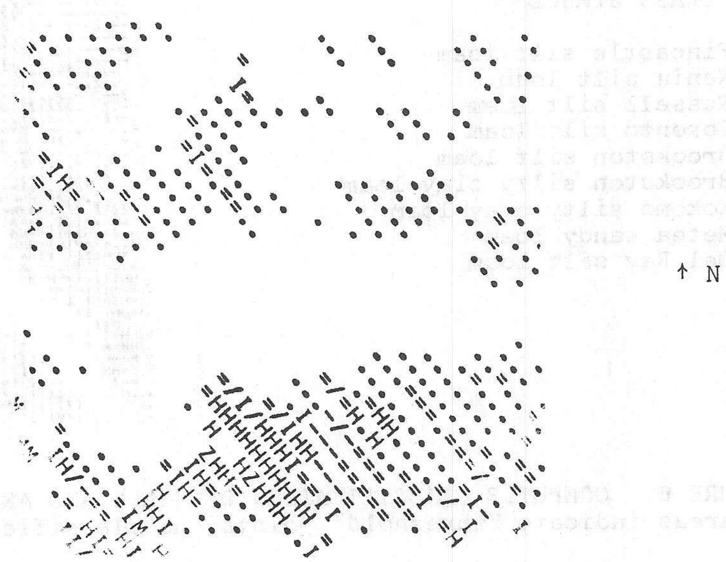


FIGURE 4. COMPUTER CLASSIFICATION OF STA 2.

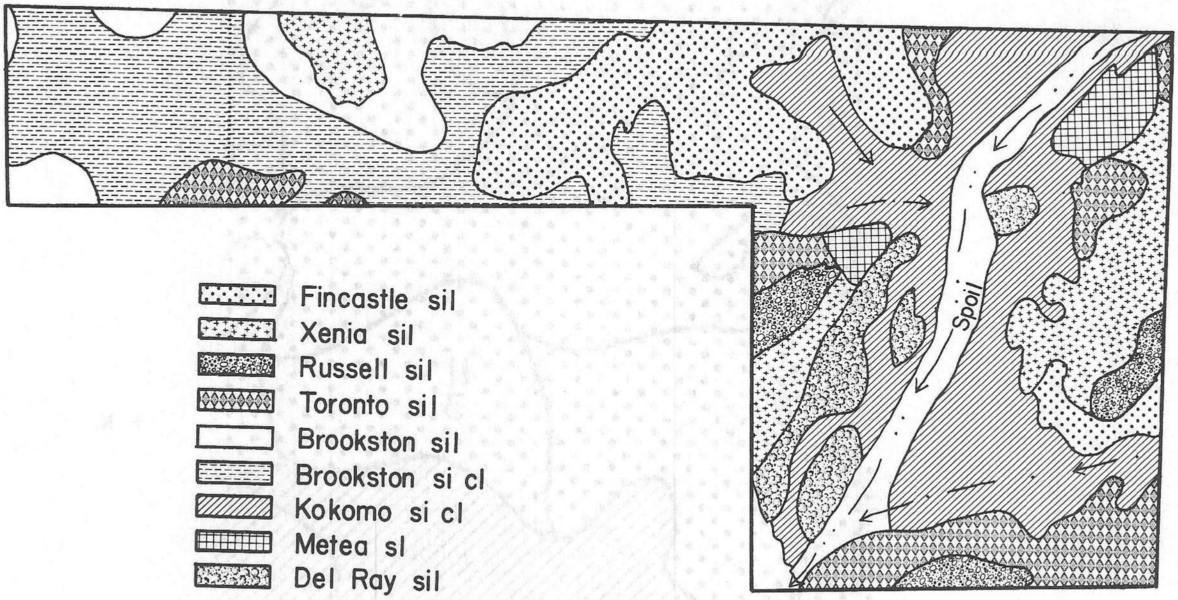
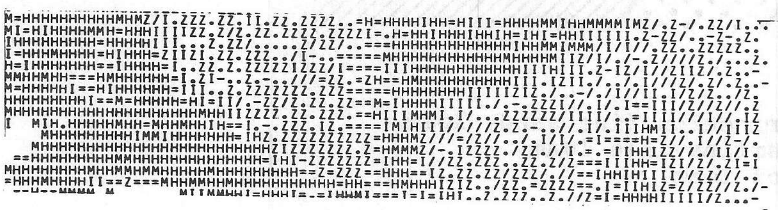


FIGURE 5. SOIL SURVEY MAP OF STA 4 AND AREA WEST OF STA 4.



TRAINING CLASS SYMBOLS

Z	Fincastle silt loam
·	Xenia silt loam
-	Russell silt loam
I	Toronto silt loam
H	Brookston silt loam
H	Brookston silty clay loam
M	Kokomo silty clay loam
/	Metea sandy loam
=	Del Ray silt loam

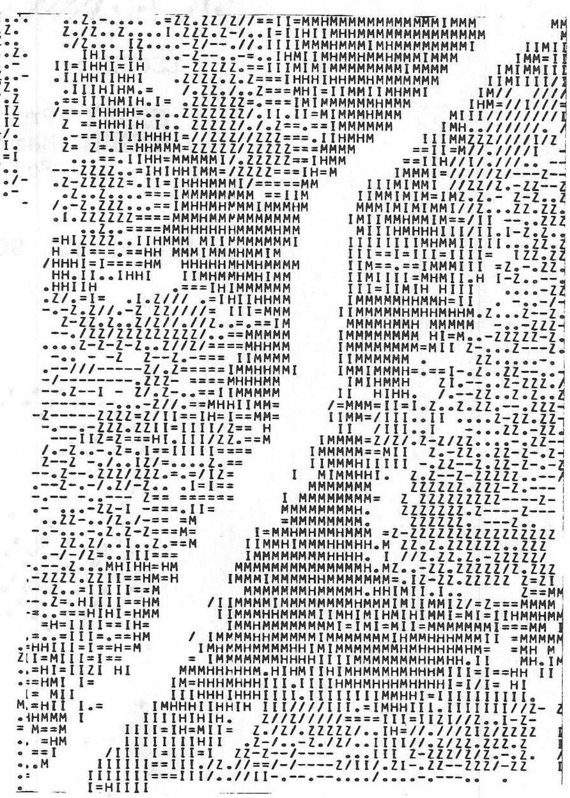
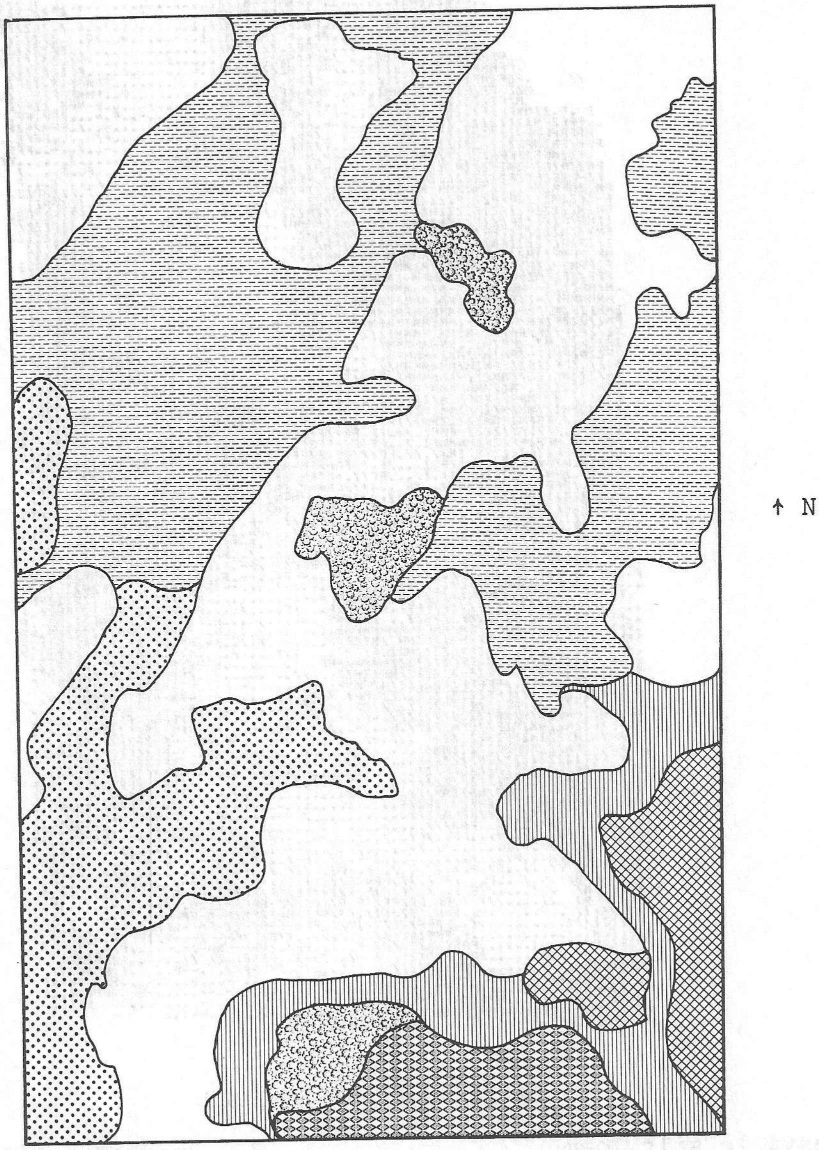


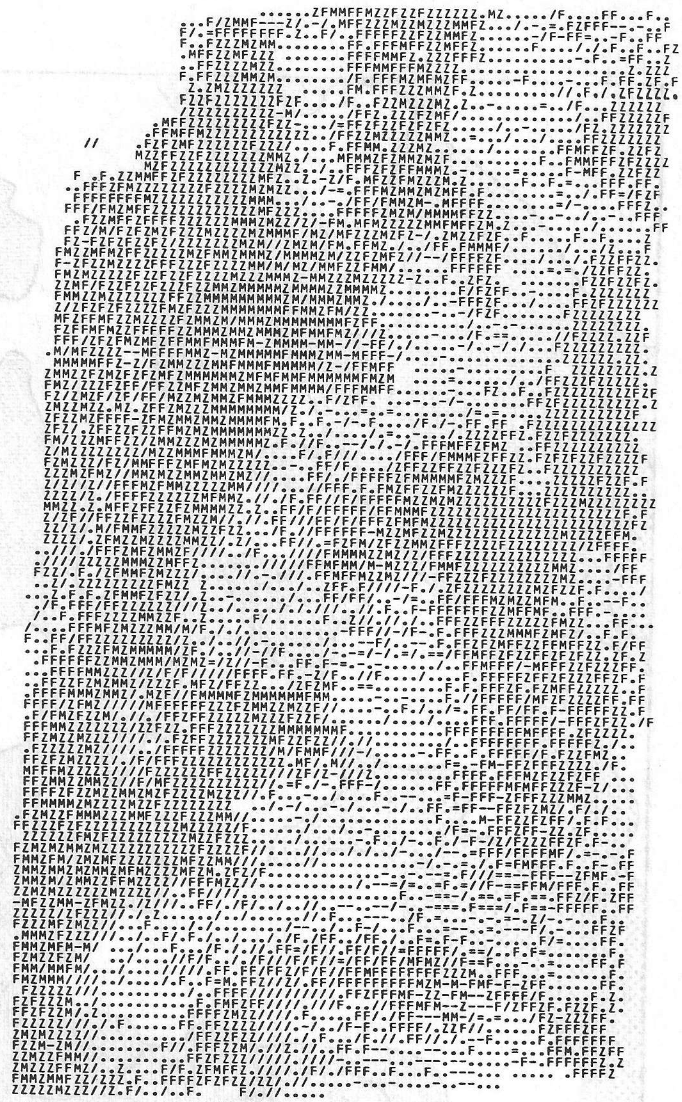
FIGURE 6. COMPUTER CLASSIFICATION OF STA 4 AND AREA WEST OF STA 4.
Blank areas indicate "threshold" points, no classification decision made.



LEGEND:

- Ragsdale silty clay loam
- Brookston silty clay loam
- Brookston silt loam
- Toronto silt loam
- Crosby silt loam
- Celina silt loam
- Reesville silt loam

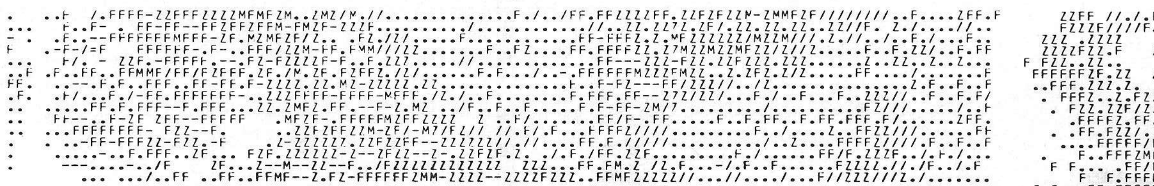
FIGURE 7. SOIL SURVEY MAP OF STA 5.

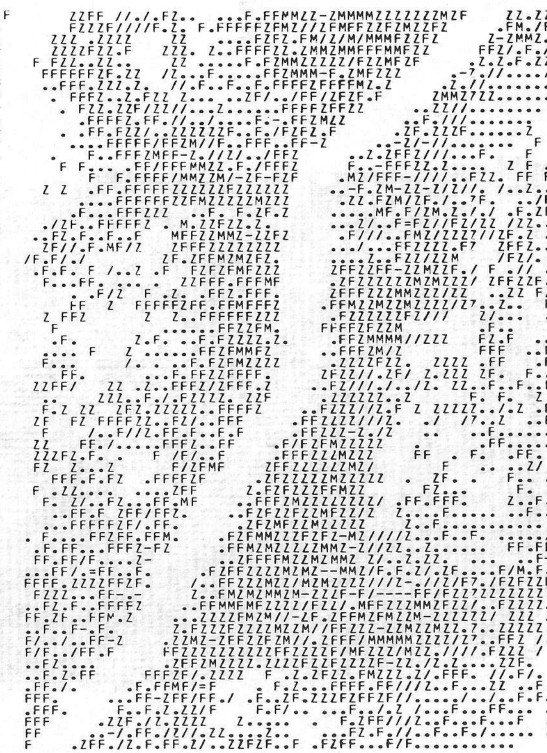


TRAINING CLASS SYMBOLS

·	Reesville silt loam
-	Crosby silt loam
=	Celina silt loam
/	Toronto silt loam
F	Brookston silt loam
Z	Brookston silty clay loam
M	Ragsdale silty clay loam

FIGURE 8. COMPUTER CLASSIFICATION OF STA 5.

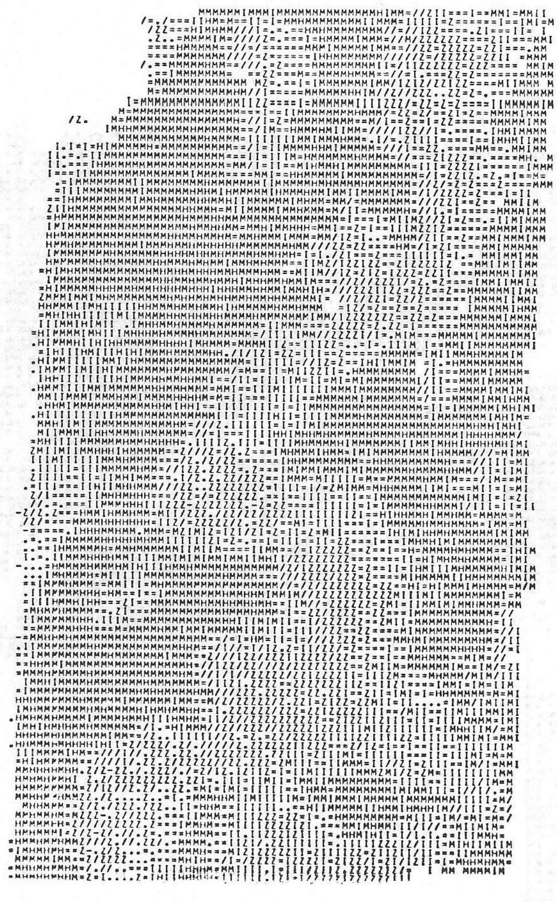




TRAINING CLASS SYMBOLS

·	Reesville silt loam
-	Crosby silt loam
=	Celina silt loam
/	Toronto silt loam
F	Brookston silt loam
Z	Brookston silty clay loam
M	Ragsdale silty clay loam

FIGURE 9. COMPUTER CLASSIFICATION OF STA 4 USING TRAINING SAMPLES OF STA 5.



TRAINING CLASS SYMBOLS

·	Xenia	I	Toronto
-	Russell	Z	Fincastle
=	Del Ray	H	Brookston
/	Metea	M	Kokomo

FIGURE 10. COMPUTER CLASSIFICATION OF STA 5 USING TRAINING SAMPLES OF STA 4.