LARS Print 110972

N73-16424

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The Laboratory for Applications of Remote Sensing

Purdue University
West Lafayette, Indiana

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ABSTRACT

Recent advances have been made in the technology of measuring radiance from the earth's surface using multiple-walength airborne scanning spectrometers. Concurrently, advances were being made in the application of computer-implemented pattern recognition techniques to these multispectral data.[2] Together these two tools have resulted in a capability for mapping various earth surface features with extreme rapidity and varying degrees of accuracy. This study compared computer-implemented mappings based on spectral properties of bare soil surfaces with mapping units of interest to soil surveyors. Some soil types could be differentiated by their spectral properties. In other cases, soils with similar surface colors and textures could not be distinguished spectrally. The spectral maps seemed useful for delineating boundaries between soils in many cases.

Bowers and Hanks (2) measured laboratory reflectance in the 400 to 2500 nm wavelength region of four Kansas soils. They concluded that surface moisture and organic matter strongly influence the reflectance and absorbance of solar radiant energy by soils. Cipra et al. (3) measured the reflectance of samples representing seven Indiana soil series under field conditions. They attributed percentage of visible incident energy reflected to soil color, texture, organic matter content, moisture content, and surface condition. The magnitude of the influence of each of these factors and their interactions were not discussed. Condit (4) examined spectral properties of 160 surface soil samples collected at various locations across the United States. Measuring laboratory conditions, he concluded that the general shapes of the spectral curves obtained for these soils could be classified into three types. These three types of curves could be represented by the chernozem-type soils, the pedalfer-type silts, and the laterite-type soils.

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[1]This work was sponsored under NASA Grant NGL 15-005-112 in cooperation with Purdue University and the Laboratory for Applications of Remote Sensing (LARS), West Lafayette, Indiana.

[2]Laboratory for Agricultural Remote Sensing. 1970. Remote Multispectral Sensing in Agriculture, Vol. 4 (Annual Report). Research Bulletin No. 873, Agricultural Experiment Station, Purdue University, Lafayette, Indiana.

Baumgardner et al. (1), using spectral measurements collected from aircraft, reported that soil organic matter appeared to be a dominant factor affecting reflectance when organic matter content was greater than 2%. Their study was conducted on a 25-ha test site in Indiana which included eight soil series, using spectral measurements in 12 wavelength bands ranging from 400 to 2600 nm.

Kristof (5) and Kristof and Zachary (6) conducted soils studies using multivariate pattern recognition techniques and computer processing of multispectral data collected by an airborne scanning spectrometer. Kristof and Zachary (6) concluded that "mapping" of soil types using these computerized procedures was partially successful.

In the present study we have attempted to determine how favorably the spectral maps produced by computer processing compared with conventional soil survey maps. Additionally, in cases where good agreement was not obtained, we have attempted to determine why the discrepancies occurred.

Materials and Methods

The three areas studied were designated as Soil Test Area 3 (STA 3), Soil Test Area 4 (STA 4), and Soil Test Area 5 (STA 5). Soil Test Area 3 is located along U.S. Highway 37 in Morgan County, in south central Indiana. The soils in STA 3 were developed in late Wisconsin glacial material, including till, outwash, and aeolian sands. They are Alfisols (Gray-Brown Podzolic) and Mollisols (Humic Gley and Alluvial soils). Topography is nearly level to rolling.

Soil Test Area 4 and 5 are located in Tippecanoe County, in west central Indiana. Soils in STA 4 are within the region of the Alfisols and include some wet Mollisols. These soils were developed in 45 to 90 cm of silt over glacial till. Soil Test Area 5 is also within the Alfisol region but the surface horizons are somewhat darker and contain slightly more organic matter than soils of STA 4. The area includes some wet Mollisols. The soils in the northern half of STA 5 were developed in moderately deep silts (1 to 1 1/2 m); whereas those in the southern half were developed in glacial till with less than 40 cm of silt at the surface. Table 1 gives the classifications of soil series occurring in STA 3, STA 4, and STA 5.

The three study areas were field mapped at medium intensity using conventional soil survey procedures, giving considerable

attention to detail. Base photos were color for STA 3 and black and white for the other two areas. Aerial multispectral scanner data were collected by the University of Michigan's C-47 aircraft on April 28, 1967, at 1100 hours at an altitude of 1200 m above terrain (STA 3) and on May 26, 1969, at 1200 hours at an altitude of 1200 m above terrain (STA 4 and STA 5). Table 2 gives channel number disignations and wavelength bands for data collected.

The multispectral scanner data in analog form were digitized and then analyzed using LARSYS programs.[4] Soil Test Area 3 was analyzed using the unsupervised classifier NSCLAS (8), which uses a clustering algorithm to classify spectral data into the number of classes specified by the researcher. This classifier is unsupervised in the sense that "training" areas are not input by the researcher, that is, the researcher does not define the "training" classes from the ground observations. He specifies only the wavelength bands to be used, the rectangular area or areas to be classified, and the number of classes. The resulting classification then, is based entirely on the spectral data, and can be evaluated in terms of ground observations if desired.

The channels selected for the map shown in Fig. 1 were 2, 4, 6, 8, 12 and 12 (Table 2). After some experimentation it was decided to use 13 classes for the analysis of STA 3 and some surrounding area, which resulted in 8 classes being mapped within the boundaries of STA 3. This was done because programs allowed only rectangular boundaries to be entered into analysis procedures. Thirteen classes gave the best separation into two classes--green vegetation and nonvegetated soils.

Areas 4 and 5 were analyzed using a supervised classification approach (7). All eleven wavelength bands were used (Table 2). This classifier, $CLASSIFY, uses a maximum likelihood algorithm in the decision-making process. In this specific case, the analyst defines classes on the basis of field-observed soil types, and the computer uses spectral data from these "training" areas to characterize each soil type.

Results

Figure 1 is a computer printout of STA 3. The northeast area of Princeton fine sandy loam is represented predominantly by (.) with some (-) and (=) intermixed. In the middle of the printout Princeton fine sandy loam is a uniform area represented predominantly (.). The areas of Princeton fine sandy loam on the southwest side of the farm are represented predominantly by

[4]LARSYS is a software package developed by LARS for handling and analysis of multispectral data in digital form. A more complete description is given in the reference cited in footnote 3.

(-) and (=). Only one soil type of Princeton was mapped, however, reexamination in the field revealed the northeast area was predominantly loamy fine sand with some inclusions of fine sandy loam, while the southeast area was predominantly fine sandy loam with some inclusions of loamy fine sand. The two areas of Princeton differed in slope and organic matter content as well as texture.

Most of the area mapped Ockley loam on the soils map is represented by (=) on the printout. However, the east part of the Ockley is represented by (+). The large area mapped Fox loam is represented by (*) and (I) on the printout. Field examination revealed that the area with symbol (*) contained more sand in the surface than area represented by (I) but both areas fell within the range of characteristics of Fox loam.

The east side of the large area mapped Ross is represented largely by (*) and (+) with some (I) present. The area where (*) appears was later found to be an inclusion of Fox loam, which contained more sand in the surface horizon than the area mapped Ross.

The west side of the area mapped Ross is represented largely by (O). Field examination revealed no reason why the computer printout showed two different symbols (O and I) in the Ross area. The computer printout showed (O) and (H) for the area mapped Rensselear and the west part of the area mapped Ross. The soils of the glacial till area in the northeast part of the map (Miami and Crosby soils) were not well differentiated from the outwash and aeolian soils.

Upon further examination of the spectral data it was found that the measured values of spectral response were less relaible in the right hand one-third to the computer map. This was because of sun angle and/or look angle effects causing an apparent darkening of the data. This effect is most apparent to the right of a line from the legend symbols "Ro" to the legend symbol "F". It can be noted there is little agreement between soil boundaries and computer mapped boundaries beyond this point.

Figure 2 shows the soil map and the computer printout map for STA 4.

The Russell soils of the computer printout, represented by (-), compared well with the Russell soils delineated on the soils map. The printout shows the delineations of the Russell

soils vary slightly from the soils map. In rechecking these areas it was observed that the printout for the Russell series was more accurate than the soils map.

Sandy areas in STA 4 were readily separated from silt loam and silty clay loam areas by the pattern recognition techniques. The area in the northeast corner represented by (/), the symbol for the Metea soils, correspond very well with the Metea delineation on the soils map. Some other areas not mapped as Metea sandy loam on the soil map were indicated as Metea on the printout. Reexamination of these areas showed there was more sand in the surface 10-20 cm than in soils of surrounding areas. However, these areas are not classified as Metea soils, but are inclusions of other soils of STA 4.

The area mapped Kokomo is rather uniform, except in some areas where some light-colored overburden has been mixed with the plow layer of the dark-colored Kokomo soil. In general, there was good agreement between the map and the printout for the Kokomo area.

In the south part of the farm the area mapped Toronto was also well separated on the printout. However, on the west side of the ditch the printout indicated Toronto soil where Del Rey and Kokomo were mapped. The Del Rey soil west of the ditch has a darker surface than that which is described as modal for the series. The Kokomo surface horizon is lighter colored than modal for the series because of some mixture of light-colored soils deposited from higher topographic positions. This area probably showed up as Toronto on the printout because the surface properties of the Kokomo and Del Rey soils in this area are similar to those of Toronto.

At the time this area was flown in May, part of the area west of the ditch was covered by oats approximately 20 cm tall. The computer was "trained" on separate samples in this area and was able to differentiate among series to some extent. It is not known at this time how much vegetative ground cover can be present without obscuring soil patterns.

The soils of the STA 5 (Fig. 3) are mainly Ragsdale silty clay loam (Typic Argiaquoll) and Reeseville (Acric Ochraqualf) in the northern part. In the southern part soils are mostly Brookston silty clay loam and silt loam (Typic Argiaquoll), Crosby silt loam (Aeric Ochraqualf), Celina silt loam (Aquic Hapludalf), and Reeseville silt loam.

There is excellent agreement among some of the areas on the soils map and the printout (for example, the Reeseville in the northern part). The Ragsdale soil was also well-delineated on the printout except for some inclusions on Brookston silt loam and silty clay loam. These inclusions were also observed in the field, but were too small and intermixed to delineate on the soil map. In the southwest part of the test area there was good identification of Brookston silty clay loam on the printout. The Brookston silty clay loam area showed a small percentage of Brookston silt loam and Ragsdale silty clay loam on the printout. Field check verified some inclusions of these two soils.

Reeseville soil in the southern part was accurately identified in the western part of the area, however, in the eastern part much of the Reeseville area was incorrectly identified by the computer as Crosby. Slightly sandier surface texture and darker color in the eastern part may have caused this problem. In this area the surface color of Crosby ranges from dark gray to grayish brown. Celina was delineated on the printout very well. Toronto was not well-delineated on the printout. In field mapping the areas of Toronto were small and hard to separate from Brookston and Ragsdale. Since Toronto is a transitional soil, it was difficult to distinguish from the darker-colored Mollisols by spectral properties and pattern recognition techniques.

For further evaluation of multispectral remote sensing technology in soil survey, training samples were taken from STA 5 and and an attempt was made to extend the same mapping units beyond STA 5 using the computer. This was done for an area south of STA 5. The training samples were adequate for about 3 km. Beyond this distance discrepancies were noted between ground observations and computer identification of soils.

Conclusions

This study revealed a definite relationship between multispectral imagery and soil types. Supervised classifications gave results which agreed more closely with the soil survey map than did unsupervised classifications. Sun-angle or look-angle effects, or both, were believed to limit the sensitivity of the method. This effect is ussally less pronounced in data collected near solar noon. In spite of these present limitations, it is believed that multispectral remote sensing and computerized pattern recognition techniques have potential in the area of soil mapping. Large areas of bare soil can be "mapped" rapidly by computer techniques and these maps may provide the soil scientist a useful supplement to aerial photography when making soil surveys.

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Table 1. Soils Occurring in the Study Areas.

Soil Type	Classification
Crosby loam	Aeric Ochraqualf
Miami loam	Typic Hapludalf
Ockley loam	Typic Hapludalf
Princeton fine sandy loam	Typic Hapludalf
Martinsville loam	Typic Hapludalf
Fox loam	Typic Hapuldalf
Ross silt loam	Cumulic Hapludoll
Rensselear fine sandy loam	Cumulic Hapludoll
Kokomo silty clay loam	Typic Argiaquoll
Brookston silty clay loam	Typic Argiaquoll
Toronto silt loam	Udollic Ochraqualf
Metea silt loam	Arenic Hapludalf
Del Rey silt loam	Aeric Ochraqualf
Fincastle silt loam	Aeric Ochraqualf
Xenia silt loam	Aquic Hapludalf
Russell silt loam	Typic Hapludalf
Ragsdale silty clay loam	Typic Argiaquoll
Brookston silt loam	Typic Argiaquoll
Crosby silt loam	Aeric Ochraquoll
Celina silt loam	Aquic Hapludalf
Reeseville silt loam	Aeric Ochraqualf

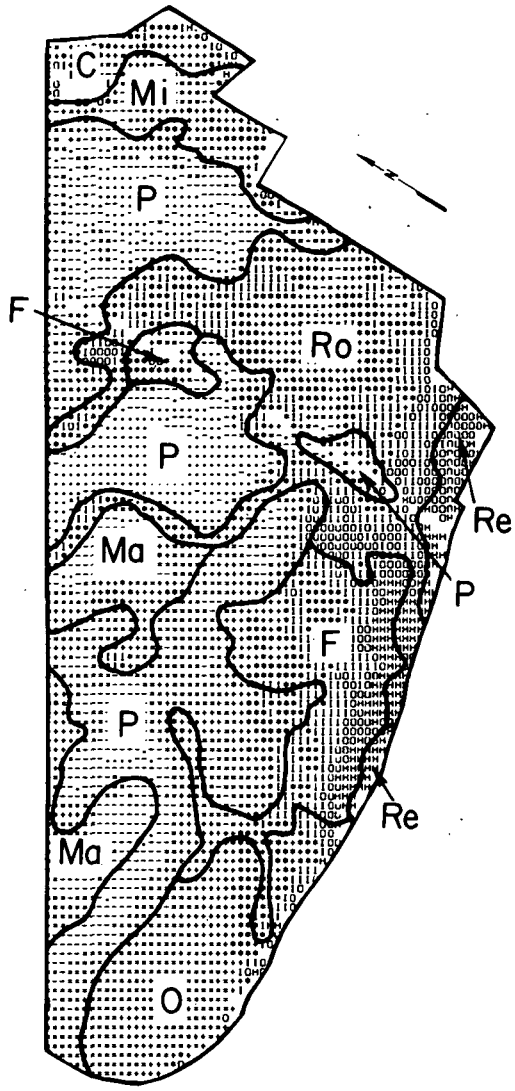
Table 2. Wavelength bands used in this study.

STA 3

Channel no.	wavelength band (nm)
2	440-460
4	480-500
6	520-550
8	580-620
10	660-720
12	800-1000

STA 4 and STA 5

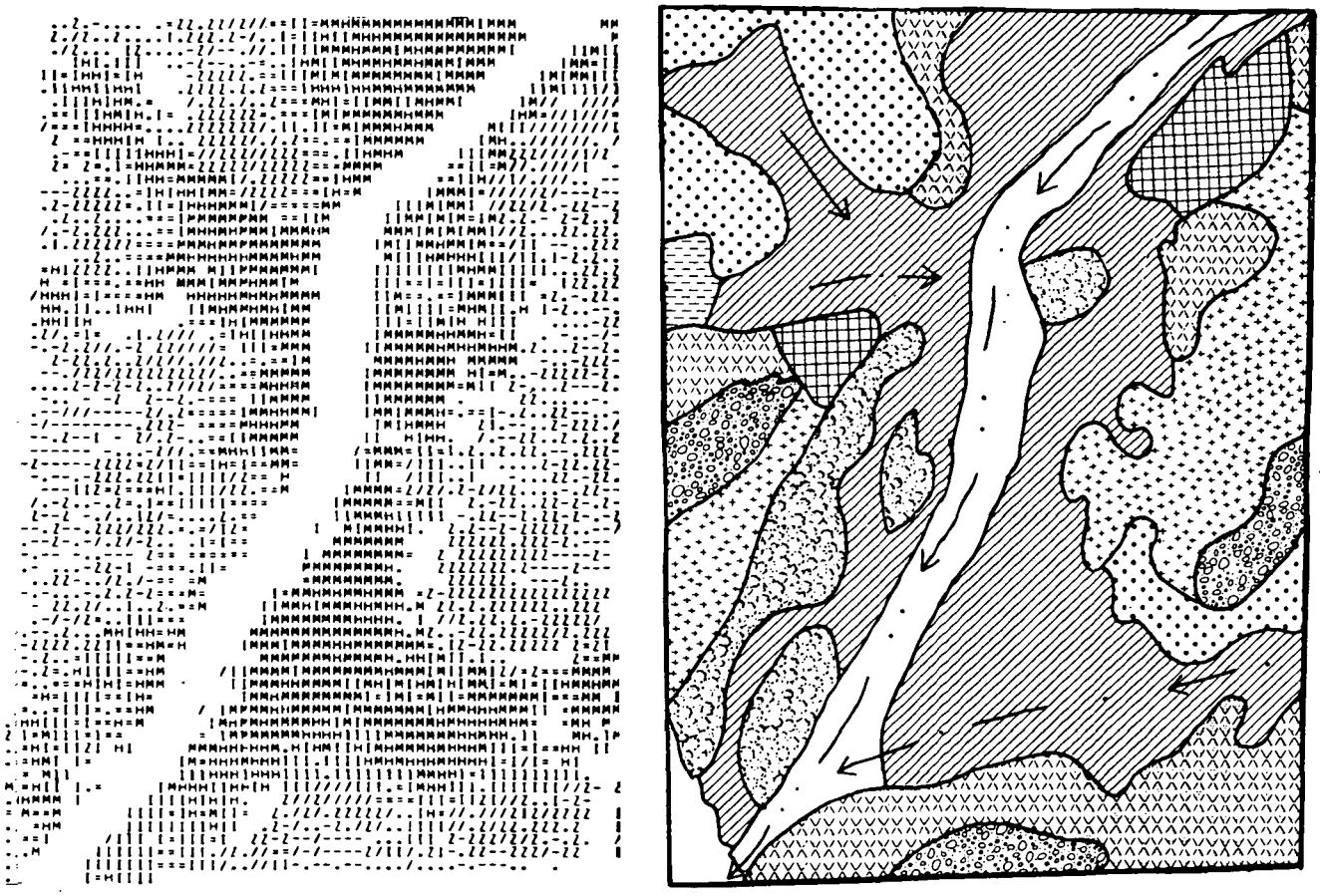
Channel no.	wavelength band (nm)
1	400-440
3	520-550
4	550-580
5	580-620
6	620-660
7	660-720
8	720-800
9	800-1000
10	1000-1400
11	1500-1800
12	2000-2600



SOIL MAPPING UNITS

C	Crosby l	Ma	Martinsville l
Mi	Miami l	F	Fox l
O	Ockley l	Ro	Ross sil
P	Princeton fsl	Re	Rensselear fsl

Figure 1. Nonsupervised computer classification for STA 2 with soil survey map overlaid. Blank areas are primarily vegetation and other non-soil materials.



TRAINING CLASS SYMBOLS

Z	Fincastle sil
·	Xenia sil
–	Russell sil
I	Toronto sil
H	Brookston sil
H	Brookston sicl
M	Kokomo sicl
/	Metea sl
=	Del Ray sil

SOIL MAPPING UNITS

- Fincastle sil
- Xenia sil
- Russell sil
- Toronto sil
- Brookston si cl
- Kokomo si cl
- Metea sl
- Del Ray sil

Figure 2. Computer classification and soil survey map of STA 4. Blank areas on the classification indicate "threshold" points; no classification decision made.

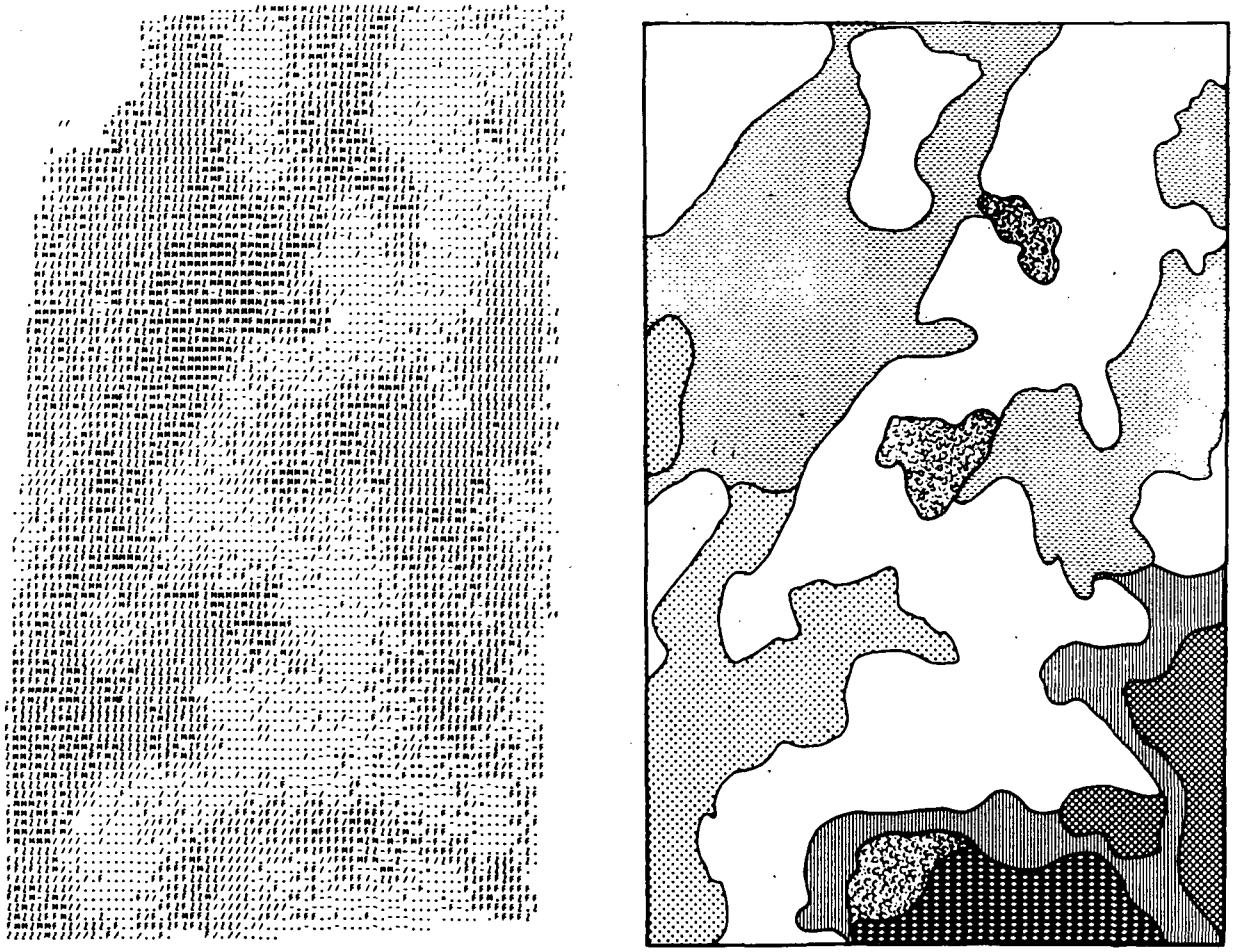


Figure 3. Computer classification and soil survey map of STA 5.