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Preliminary multispectral studies of soils

by Stevan J. Kristof

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ABSTRACT—Increasing need for more accurate and faster methods of mapping soils requires that new methods that will aid this important work be investigated. Preliminary multispectral studies with soils indicate the possibility of producing soil spectral maps using remote sensing techniques. The relationship of spectral measurements of soils and soil properties are discussed. In the future computer maps may aid the mapping and study of soil patterns on a large scale. For example, mapping and detailed study of soil associations appear to be entirely possible with the techniques described.

MAN has strived for years to classify the world about him in a logical manner. Soils have been a prime target of his classification schemes. Methods have been developed to arrange and sort soils into various meaningful categories, primarily on the basis of color, texture, climatic conditions, and parent materials (*6*).

Ground mapping of soils, though tedious and time consuming, has progressed to the point that over 50 million acres are mapped annually in the United States by the Soil Conservation Service (*1*). In the early 1900's plane tables were used to draw both a base map and a soil map (*7*). Later, the use of aerial photographic prints for base maps considerably improved the soil mapper's accuracy and proficiency.

Certain problems are inherent in the use of aerial photographs, however. Correlating the gray tones of black and white photographs with the brown, yellow, and red colors of soils is difficult. Color photography has reduced some of these tonal problems, but the photographic technique still depends largely on trained interpretors to make qualitative and not quantitative judgments. Variations in film, exposure, and development also may cause interpretative problems.

Land use planning and management have increased the need for soil maps and for determining new techniques that will help the soil mapper improve his output. Therefore, new methods to improve the accuracy and efficiency of soil mapping must be pursued.

Reported here are preliminary results obtained by computer mapping of soil surface conditions in small areas from multispectral data. Although these results are preliminary, they should help to map and understand soil patterns on a large scale.

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Research Location

The study area is located near U. S. Highway 37 in Morgan County, Indiana (Figure 1). The flight line of the airplane collecting both multispectral scanner and photographic data also is shown in this figure and is discussed in the procedure portion of this article.

The study area was covered by the early stage of the Wisconsin Glacier and is referred to as the Tipton Till Plain. The soils are Alfisols (gray-brown podzolic) developed primarily under dense forest. Surface colors vary but are generally light and low in organic matter. Topography is nearly level to rolling due to such geologic features as river bottoms, outwash terraces, and glacial-drift deposits. Farming in the area is diversified.

Procedure

In May 1967 the study area was photographed from a University of Michigan plane under contract to the aerial photo laboratory at Purdue University. The laboratory, in cooperation with the Bureau of Public Roads and the Indiana State Highway Commission, was studying the feasibility of adapting remote sensing techniques to engineering soil mapping. The Laboratory for Applications of Remote Sensing was asked to assist with the analysis of data and was given the opportunity to analyze the data for agricultural purposes.

The optical-mechanical scanner system in the aircraft collected reflected and radiated energy from 3,000 feet above the study area (*3*, *5*). The energy responses were measured in 18 different wavelength bands from 0.3 to 15 micrometers: one wavelength band in the ultraviolet spectrum, ten in the visible spectrum, and seven in the infrared spectrum, including two in the thermal infrared portion of the spectrum.

The energy response was obtained in a series of contiguous scan lines recorded on magnetic tapes. Scanner data were then converted from analog to digital form to allow computer examination of the data.[1]

Automatic Processing

Pattern recognition techniques were used in the classification procedure. The energy response values in digital form for each wavelength band were used to obtain a measured vector for

[1]Landgrebe, D. A., and T. L. Phillips. 1967. "A multichannel image data handling system for agricultural remote sensing." Presented at the Computerized Imaging Techniques Seminar in Washington, D. C.

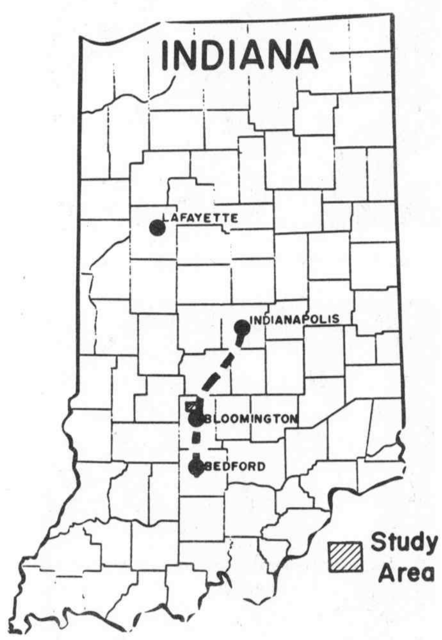

Figure 1. Location of scanner flights and study area.

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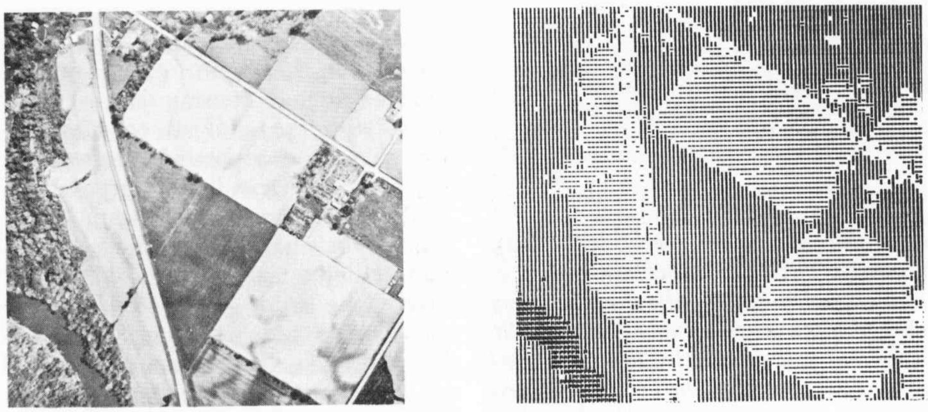

Figure 2. Aerial photograph and computer printout of green vegetation (I), soil (-), and water (M).

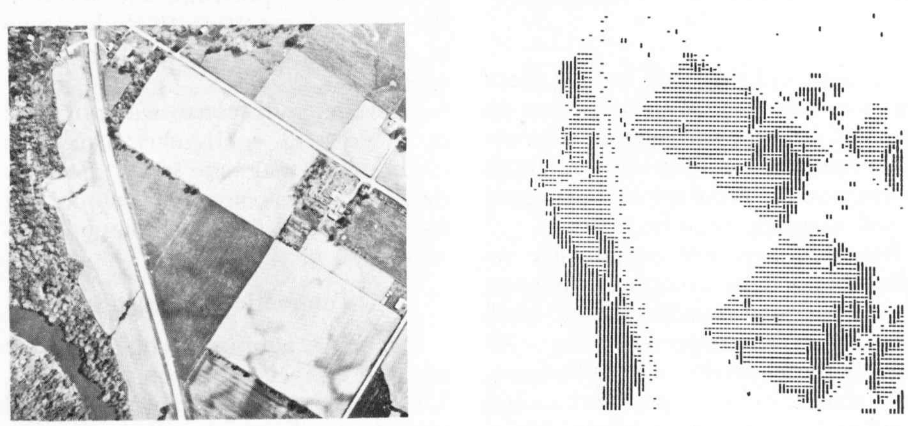

Figure 3. Aerial photograph and computer printout of dark and light colored soils.

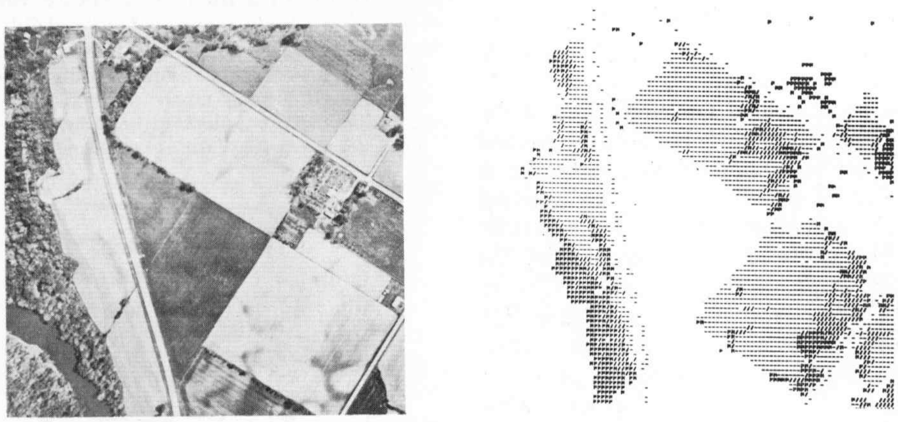

Figure 4. Aerial photograph and computer printout of dark, medium, and light colored soils.

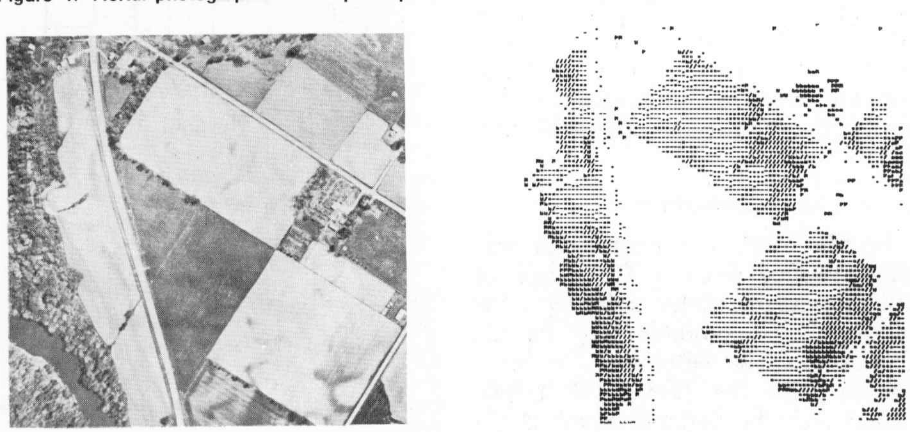

Figure 5. Aerial photograph and computer printout of six soil categories.

each cover type, soil area, or other material of interest. Based on these values, the pattern recognition categorizer was programmed to determine differences among the various materials.

Next, different soil spectral patterns or soil tones were identified, and the categorizer was programmed according to the wavelength responses for each soil category selected. These soil categories were based on the soil surface spectral response at the time of flight. Digital data collected from unknown target materials were then examined and classified by comparing them with the spectral pattern of known target materials.

Color aerial photographs, taken within days after the scanner data were collected, helped establish the ground truth and location of specific target materials. Sample areas containing trees, grass, wheat, water, and bare soil were selected from computer printouts showing the energy responses in specific wavelength bands. Each target material was assigned a computer symbol, and the computer was programmed to print that symbol when it recognized the material. To delineate different soil categories, training samples were selected similarly for each soil category.

Results and Discussion

Once the computer had been programmed to recognize trees, grass, wheat, bare soil, and water, an attempt was made to classify green vegetation, soil, and water (Figure 2). The likeness of the computer printout and the aerial photograph is striking. The computer data are presented in a line-by-line format which represents individual scan lines from the optical-mechanical scanner. The computer identifies each individual sample point on a scan line. Each sample point represents an area about 9 feet square. When the radiance spectral response from a sample point was different from that of the three categories programmed into the categorizer, the computer left the area blank (roads, farmsteads, fencerows, etc.).

Figure 2 could be improved by (1) more carefully selecting the training samples for the categories to be identified, (2) sampling more points along each scan line, and (3) possibly adding more scan lines (5). The results might sometimes be improved also by selecting different combinations of wavelength bands.

Dark and light patterns in the soils are visible on the aerial photograph in figure 2. The computer categorizer was programmed with samples of these patterns. Green vegetation and water categories were fed into the categorizer, but no symbol was assigned. Therefore, these categories were left blank when the soil areas were printed (Figure 3). The computer was programmed to print an "I" when it recognized dark soil and a "-" when it recognized a light soil.

Closer examination of the aerial photograph revealed variations in the dark soils, also, an intermediate tone between the dark and light soils. Samples from selected vector points were obtained for the darkest areas, the intermediate areas, and the light areas. Using techniques similar to those described for the two soils categories, the computer was programmed to print out three categories (Figure 4). The comparison with the aerial photograph appears quite accurate.

A large standard deviation of mean responses for these categories of soil indicated the possibility of identifying more distinct categories based on the spectral properties. By selecting individual training points and comparing the spectral response with other points, many more soil categories could be defined. Figure 5 shows an attempt to map six distinct soil spectral categories.

Examination of these categories in the field showed that the overall tone of the soil may not have been entirely responsible for the categories as shown. Tonal variations not being evident in every case suggested that variations in surface structure, such as roughness or crusting factors, may play an important role in spectral responses of soils. Moisture content also has been shown to effect spectral responses of soil (*2, 4*).

An area containing several large fields of bare soil and located a short distance from the first study area was used to see if the classification technique could be repeated. An attempt was made to classify six soil spectral categories from the bare soil area. These are compared to an aerial photograph in figure 6. Again, the results are striking. Variations within one field show that tillage practices may affect mapping categories.

Figure 6. Aerial photograph and computer printout of six soil categories from an area near that in figures 2, 3, 4, and 5.

Soil patterns within vegetation are sometimes evident. Attempts now are being made to determine if soil categories can be mapped using spectral variations of vegetation. Preliminary results indicate that bare soil may not be needed to make a spectral map of a region.

Soil can be classified into many different categories using this technique. The limits seem to be determined by the amount of detail desired by the soil mapper and the ultimate user of the survey map, surface color variations caused by temporal and spectral variations due to soil moisture, and spectral variations due to differences in cultural practices. Attempts now are being made to determine how accurately these soil spectral categories compare with soil surveys made by soil mappers in the field. Cultural practices and moisture variations certainly affect overall computer mapping accuracy, but it is believed that the computer printout with the mapped soil categories would be a great aid to professional personnel in soil mapping.

Conclusions

The possibility of flying over an area and obtaining a map of different soil surface patterns within hours after the data are collected seems to be of great value to ultimate users—soil conservation personnel and others. This study illustrated that six different categories of soil surface conditions can be mapped with reasonable accuracy by computer techniques. Observations of actual surface moisture, erosion, organic matter content, and surface roughness factors would have greatly aided the interpretation of data. This indicates how important it is to have accurate information about a study area at the time scanner data are obtained.

Maps showing the surface radiance of large areas can be made rapidly. Statistical comparisons of the spectral measurements of soil surfaces can be obtained with ease. Conceivably, uniform units within a soil series could be more easily recognized with the remote sensing technique. Complex associations of two soils could be studied and separated in more detail if surface soil measurements truly represent the soil beneath the surface. Soil association surveys appear to be possible using this technique.

Additionally, areas with special drainage, runoff, or erosion problems could be mapped in detail. Remote sensing surveys after heavy rain also could provide rapid, timely estimates of flood damage.

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