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Preliminary Multispectral Studies of Soils[1/]

by

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Introduction

Man has strived for many years to classify the world about him in a logical manner. Soil, being a necessary part of man's existence on this planet, has been of prime importance in classification schemes. Methods have been developed to arrange and sort soil into various meaningful categories, primarily utilizing soil color, texture, climatic conditions and parent materials (7).

Ground mapping of soils, even though a tedious and time consuming task, has progressed so that annually over 50 million acres in the United States are mapped by the Soil Conservation Service (1). Beginning in the early 1900's, plane tables were used to draw both a base map and a soil map (8). A great advancement which considerably improved the soil mapper's accuracy and proficiency was the use of aerial photography for a base map.

Photography, however, is not an all inclusive tool; there are many problems inherent in the use of photographic techniques. Originally, it was difficult for the soil mappers to correlate the gray tones of black and white aerial photographs to the brown, yellow, and red colors of soils. Since the introduction of color aerial photography, some of these tonal problems have been lessened. The photographic technique, however, still depends largely on trained interpretors to make qualitative and not

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quantitative judgments. Variations between different batches of the same film type, exposures, and development processes may also cause interpretative problems to the soil mapper and photo interpretors.

The need for soil maps is continually rising because of the increased importance being placed on proper land use planning and management. With this increasing demand, the need for determining new techniques to assist the soil mapper in improving his output becomes greater. Therefore, new methods to increase the accuracy and the efficiency of the soil mapping must be pursued. It is the purpose of this paper to report preliminary results obtained by computer mapping of soil surface conditions in small areas from multispectral data. Even though these results are preliminary, it is visualized that they should be a great aid in helping to map and understand soil patterns on a large scale.

Description of Research Location

The areas studied in this research are found near U.S. Highway 37 in Morgan County, in South Central Indiana (Figure 1). The total length of the flightline flown by the airplane collecting both multispectral scanner and photographic data are shown in this figure and will be discussed in the data collection portion of the paper.

The study area was covered by the early stage of Wisconsin Glaciation and is referred to as the Tipton Till Plain. The soils are gray-brown podzolic soils developed mostly under a dense forest cover. The surface colors are quite varied and are generally light in color and low in organic matter. The topography is nearly level to very rolling due to geologic features such as river bottoms, outwash terraces, and glacial drift deposits. Farming in this area is diversified with grain crops and livestock enterprises.

Procedure

In May, 1967, the study area was flown by a University of Michigan plane under contract to the aerial photo lab at Purdue University. The air photo lab in cooperation with the Bureau of Public Roads and the Indiana State Highway Commission was interested in studying the feasibility of adapting remote sensing techniques to engineering soil mapping. The Laboratory for Applications of Remote Sensing (LARS), then the Laboratory for Agricultural Remote Sensing, was asked for assistance in the analysis of the data and given the opportunity to analyze the data for agricultural purposes.

Data Collection

The optical-mechanical scanner system in the University of Michigan aircraft collected reflected and radiated energy from 3000 feet above the study area (3,5). The optical-mechanical scanner was used to measure the energy responses in wavelengths from approximately 0.3-15 micrometers. These energy responses were measured in 18 different wavelength bands within this wavelength region. One wavelength band was obtained in the ultraviolet portion of the spectrum (0.32-0.38 micrometers). In the visible spectrum, ten wavelength bands were recorded which 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 and 0.66-0.72 micrometers. There were seven wavelength bands collected in the infrared portion which were 0.72-0.80, 0.80-1.0, 1.5-1.8, 2.0-2.6, 3.0-4.1, 4.5-5.5, and 8-14 micrometers. The last two wavelength bands are measured responses in the thermal infrared portion of the spectrum.

The energy response in these wavelength bands was obtained in a series of contiguous scan lines recorded on magnetic tapes. The scanner data was then converted from analog to digital form to allow examination of the data (6). Thus, the reflected and radiated energy from the study area was converted to the digital form so it could be processed by computer techniques.

Automatic Processing

Pattern recognition techniques were used in the classification procedure. The measured response values in the digitized form for each of the wavelength bands were utilized to obtain a measured vector for each cover type, soil area, or other material of interest.

On the basis of these values, the pattern recognition categorizer was programmed to determine differences among the various materials. Figure 2 shows the mean response of green vegetation, bare soil, and water in the 12 different wavelength bands used in this study. The wide variation in the responses of these different materials in the different wavelength bands can be seen.

Next, the categorizer was trained on the basis of the spectral pattern of each category of interest. In this case, different soil spectral patterns or soil tones were located, and the categorizer was trained on the basis of the wavelength responses for each soil category that was selected. These soil categories were based on spectral response of the soil surface at the time of flight. The digitized data collected from unknown target materials were then examined and classified by comparison with the spectral pattern of the known target materials. The spectral pattern or signature of soils varies in a similar manner (Figure 3). The differences in the three soil categories shown in Figure 3 are not as great as the spectral responses shown in Figure 2.

In this study, color aerial photographs were taken within several days of the scanner data and were used to help establish the ground truth and the location of the specific target materials. Sample areas containing trees, grass, wheat, water, and bare soil were selected from the computer printouts showing the responses in specific wavelength bands. Computer symbols were assigned for each target material, and the computer was instructed to print that symbol when it recognized each material. To delineate different soil categories, training samples were selected in a similar manner for each soil category.

Results and Discussion

After the computer had been trained to recognize trees, grass, wheat, bare soil, and water a classification of green vegetation, soil, and water, was attempted. The results of this attempt are shown in Figure 4. The likeness of the computer printout to the aerial photograph is very striking. Note that the computer data is presented in a line by line format which represents individual scan lines from the optical-mechanical scanner of the airplane. The computer was instructed to identify each individual sample point within each scan line. Each sample point represents an area of approximately 9 feet by 9 feet. When the radiance spectral response from a sample point was different from that of the three categories given to the categorizer, the computer was instructed not to print a symbol but to leave the area blank. Therefore, areas such as the roads, farmsteads, and fencerows around the fields are blank.

The results in Figure 4 could be improved by (1) taking more care in the selection of the training samples for the categories which one wants to identify, (2) sampling more points along each individual scan line and (3) possibly adding more scan lines for analysis purposes (5). Also the results may sometimes be improved by the selection of a different combination of wavelength bands for performing the classification. In this study, four wavelength bands were selected. These included wavelengths in the green, (0.52-0.55 micrometer) red (0.58-0.62 micrometer), and near infrared (0.72-0.80 micrometer and 0.80 and 1.00 micrometer) wavelength region.

On the aerial photograph in Figure 4 dark and light patterns of the soils can be seen. The computer categorizer was trained with samples of dark and light colored areas from the fields shown on the photograph. Green vegetation and water categories were given to the categorizer but no symbol was assigned. Therefore these categories were left blank and the areas of soil were printed by the computer as shown in Figure 5. The computer was instructed to print an "I" when it recognized dark soil and a "-" when it recognized light colored soil in this illustration. A comparison of the computer printout with the aerial photograph shows that the dark and light soil patterns are rather accurately displayed.

In a closer examination of the aerial photograph, the variations of the dark soils may be seen. Also, an intermediate tone between the dark and light colored areas can be noted. Samples from selected vector points were obtained for the darkest areas, the intermediate tone areas, and the light areas. Spectral plots of these categories were shown previously in Figure 3. Using similar techniques as described for the two categories of soil, the computer was instructed to printout three categories. These are shown in comparison with an aerial photograph in Figure 6, and appear quite accurate.

The researcher noted there appeared to be a large standard deviation of the mean responses for these categories of soil. This indicated there was a possibility of distinguishing more distinct categories based on the spectral properties. It was found that by selecting individual training points and comparing the spectral response with other points, many more soil categories could be defined. Figure 7 shows an attempt at mapping 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 they are shown. Tone variations were not evident in every case. This led the researcher to suspect that variations in surface structure such as roughness or crusting factors may play an important role in spectral responses of soils. The effects of moisture content have been shown to vary spectral responses of soil, also (2).

An area containing several large fields of bare soil and located a short distance from the first study area was utilized 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 of the area in Figure 8. Again, the results are quite striking. There are some variations within one of the bare soil fields which show that perhaps tillage practices may have an effect on mapping soil categories by this technique. These variations and other factors are being studied further.

Soil patterns within vegetation are sometimes quite evident. Attempts are now being made to determine if soil categories can be mapped using the spectral variations of the vegetation for training purposes. Preliminary results show this to be quite promising and indicate that it may not be necssary to have a bare soil area in order to make a spectral map of that 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, the surface color variations caused by temporal and spectral variations due to soil moisture, and the spectral variations due to differences in cultural practices. Attempts are now being made to determine how accurate these soil spectral categories compare with soil surveys made by soil mappers in the field. Cultural practices and moisture variations certainly affect the 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 use of multispectral sensing techniques and automatic data recognition techniques developed at the Laboratory for Applications of Remote Sensing at Purdue University appear to have potential in the area of soil mapping.

The possibility of flying over an area and obtaining a map of different soil surface patterns within hours after the data were collected seems to be of great value to ultimate users--city planners, soil conservation personnel and others. This study illustrates that 6 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 in the interpretation of this data. This indicates how important it is to have accurate information about the study area at the time the scanner data are obtained.

Maps showing the surface radiance of large areas can be made rapidly. Statistical comparisons of the spectral measurements of the soil surfaces can be obtained with ease. It is conceivable that uniform units within one 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 the surface soil measurements truly represent the soil beneath the surface. Soil association surveys appear to be a promising output by this technique.

Additionally, areas that have special problems such as drainage, run-off and erosion could be mapped in detail. The amount of eroded areas could be distinguished because of its high contrast with the soil surrounding it. Surveys made with remote sensing techniques after a heavy rain could provide damage estimates in a rapid and timely manner.

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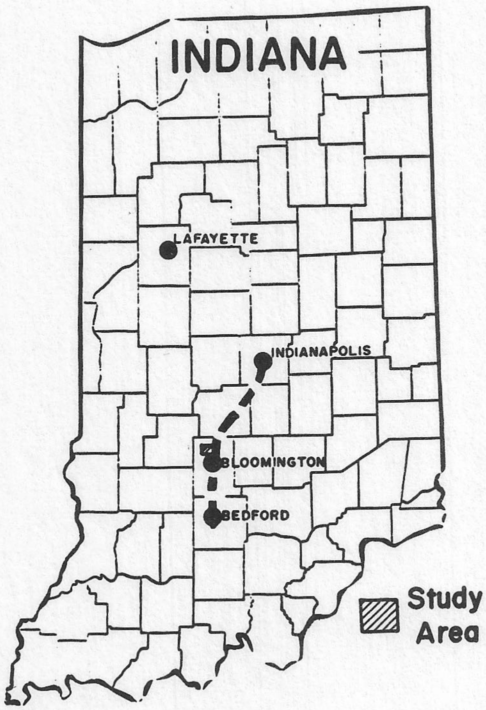

Figure I. Location of Scanner flights and Study area.

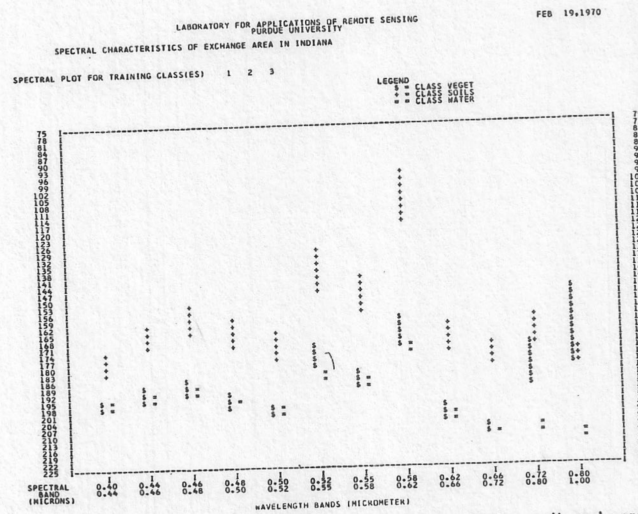

Figure 2. Relative Spectral Response of green vegetation, soil and water for 12 different wavelength bands.

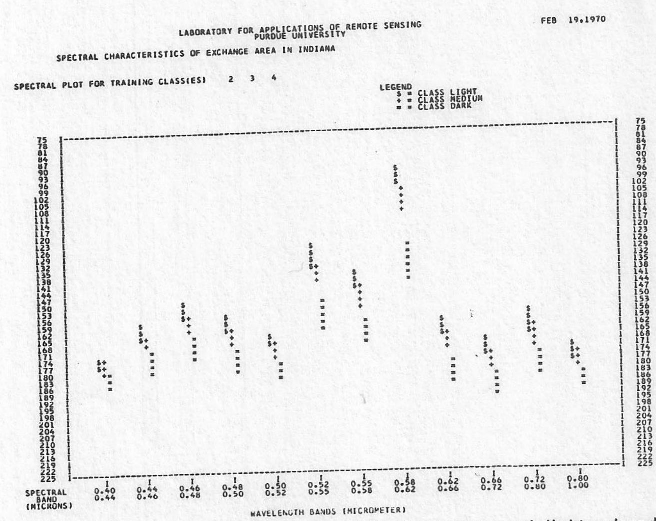

Figure 3. Relative Spectral Response of dark, medium and light colored soils for 12 different wavelength bands.

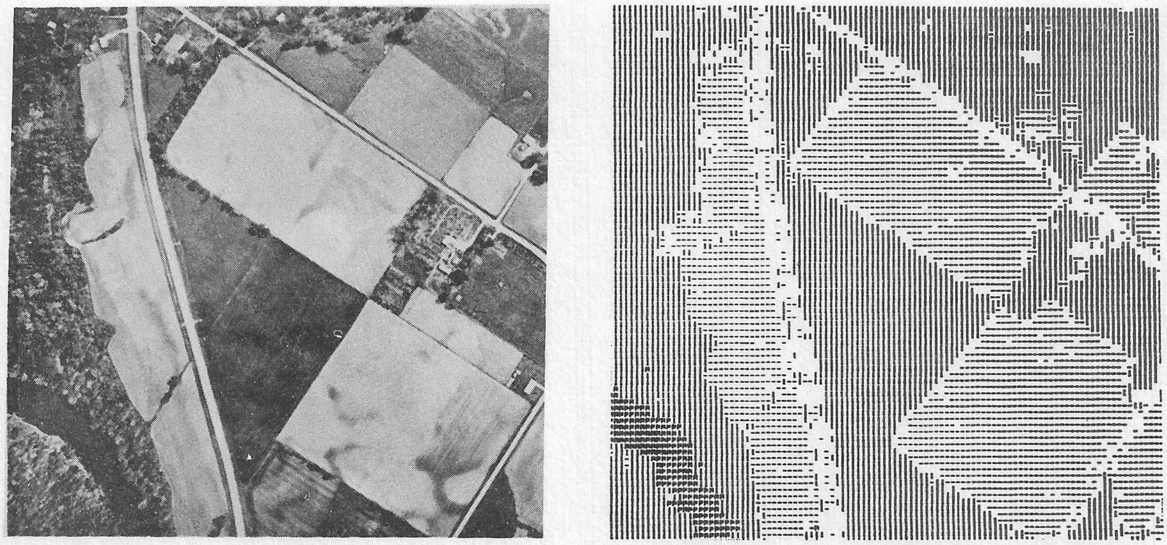

Figure 4. Aerial photograph and computer printout of Green Vegetation (I), Soil (–) and Water (M).

Figure 5. Aerial photograph and computer printout of dark and light colored soils.

Figure 6. Aerial photograph and computer printout of dark, medium and light colored soils.

Figure 7. Aerial photograph and computer printout of six soil categories.

Figure 8. Aerial Photograph and Computer Printout of Six Soil Categories from an Area a Short Distance from Area in Figures 4, 5, 6, and 7