The Effect of Altitude on the Multispectral Mapping of Soil Organic Matter[1]

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Abstract

Spectral data obtained from three altitudes were studied and compared using an IBM 360/44 computer. Surface soil samples were collected from a selected test site and analyzed for organic matter content. Scanner data and pattern recognition techniques were used to prepare maps which depicted distribution over the landscape of surface soils with various levels of organic matter. The highest percent correct classification was obtained from the lowest flight altitude data, that is, 3,000 feet. Statistical correlations were obtained between organic matter content and reflectance data from all three altitudes. The 5,000-foot altitude data had the highest correlation for most channels and in the multiple-regression studies. Polynomial-regression studies indicated the possible existence of a non-linear relationship between organic matter and reflectance in some wavelengths.

Introduction

It is becoming increasingly important for man to obtain complete and accurate data concerning the land, vegetation, water, and mineral resources of the earth. If this information could be gathered rapidly and accurately, it could be useful in natural resource planning, crop yield prediction, and pollution detection (3, 4).

Studies are being conducted at the Laboratory for Applications of Remote Sensing (LARS) at Purdue University to establish the potential of remote sensing. Remote sensing may be defined as the identification and determination of characteristics of physical objects through the analysis of measurements obtained from a measuring device that does not come in physical contact with the objects. Airborne-optical-mechanical scanners are used to obtain relative measurements of energy radiated from single resolution elements on the ground. These measurements can be recorded in as many as 18 wavelength bands representing the electromagnetic spectrum from 0.40 to 14 μ m. They are recorded on magnetic tape in the analog form and later digitized for analysis by LARS data-processing systems.

The size of the resolution elements or remote sensing units (RSU's) increases with an increase in the altitude from which the scanner data are collected. The primary objective of this research was to determine the effects of altitude on multispectral "maps" based on organic matter content of soils. Baumgardner *et al.* (2) have established the feasibility of relating multispectral scanner data to

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organic matter content of soils. They used scanner data and pattern recognition techniques to prepare maps which depicted distribution over the landscape of surface soils with various levels of organic matter.

Methods and Materials

Scanner data were collected at 3,000-, 4,000-, and 5,000-foot altitudes over Flightline 24 (2) in Tippecanoe County, Indiana. A 100-acre farm, Soil Test Area 5 (STA5), was selected for intensive soil studies. This farm lies in a transitional zone between prairie and forest soils. The darker-colored-depressional soils have been formed under prairie vegetation; the lighter-colored soils ("high ground") under forest vegetation (Fig. 1). Small areas of transitional soils are also present. The parent material is primarily of glacial origin. In the northern section of the farm, deep silts are found, whereas the southern section is mainly till.

Ground truth data used for the classification of organic matter consisted of 193 surface-soil samples taken on a 150-foot interval grid pattern on STA5. Samples were taken to a maximum depth of 1 inch. The organic-matter content of each sample was determined by laboratory analysis (5). The samples were divided into five classes based on organic-matter content following Alexander (1).

Pictorial gray-scale computer printouts representing magnitude of reflectance from each RSU were obtained for each altitude. The printouts were gridded into 193 blocks corresponding to the 193 locations where soil samples had been collected. A set of reflectance data ("training sample") representative of each soil-sample location was selected and used to compute statistics (mean vectors and covariance matrices) for each of the organic matter classes (Table 1). Based on these statistics a maximum-likelihood classifier was used to classify the "training samples."

TABLE 1. *Five organic matter classes and number of "training samples" in each class (STA5).*

Percent Organic Matter	No. of Training Samples
3.5	83
2.5-3.5	45
2.0-2.5	24
1.5-2.0	30
0-1.5	11

The numbers of RSU's used for each "training sample" were 16 at 3,000 feet, 12 at 4,000 feet, and 9 at 5,000 feet.

The four channels found to be best for separating the classes were channels 8, 10, 11, and 12 (Table 2) for both the 4,000- and 5,000-foot flights. Channels 1, 7, 10, and 11 were the best for the 3,000-foot flight.

FIGURE 1. *Aerial photograph of Soil Test Area 5 (STA5).*

TABLE 2. *Combinations of channels which gave highest multiple correlation coefficients at various altitudes.*

3,000 feet		4,000 feet		5,000 feet	
Channel(s)[1]	MCC[2]	Channel(s)[1]	MCC[2]	Channel(s)[1]	MCC[2]
7	0.49	8	0.53	8	0.65
7,3	0.67	8,4	0.59	8,5	0.73
7,3,1	0.72	8,4,2	0.61	8,5,11	0.74
Twelve Channels	0.72	Twelve Channels	0.62	Twelve Channels	0.76

[1] Channel numbers and wavelengths are as follows: 1, 0.40-0.44; 2, 0.46-0.48; 3, 0.53-0.55; 4, 0.55-0.58; 5, 0.58-0.62; 6, 0.62-0.66; 7, 0.66-0.72; 8, 0.72-0.80; 9, 0.80-1.00; 10, 1.00-1.40; 11, 1.50-1.80; 12, 2.00-2.60.

[2] MCC=Multiple Correlation Coefficient.

Results and Discussion

Figures 2 and 3 are computer "maps" based on organic matter content. Results of classifying the RSU's in the "training samples" revealed over-all correct classifications of 40 to 50%, being greatest using 3,000-foot data. These low-classification percentages were probably due to the problem of locating the "training samples" on the printout. At the 3000-foot altitude each RSU represented approximately 81 ft^2, at 4,000 feet approximately 144 ft^2, and at 5,000 feet approximately 225 ft^2. The soil samples were taken in the field from an area of approximately 25 ft^2. Therefore each "training sample" on the printout represented a larger area than that which was actually sampled in the field.

To evaluate the classification based on organic matter, another test site 10 miles away on the same flightline was mapped using STA5 training samples. This particular site (Soil Area D of Baumgardner *et al.*) (2) was chosen because the organic matter content and the location of 73 surface soil samples had been established. The locations of these samples were found on the printout and used as "test samples." Classification results for these "test samples" were 72.7% correct using data from the 3,000-foot altitude.

To determine the strength of the relationship between spectral reflectance and organic matter content, stepwise multiple-regression procedures were used. Correlation coefficients (r values) were obtained for each altitude (Fig. 4). Stepwise multiple-regression results are presented in Table 2.

As shown in Figure 4, the correlation coefficients generally increased as the flight altitude increased. Table 2 presents the combinations of channels selected to achieve the highest correlation coefficient at each step.

In stepwise multiple-regression, the existence of a linear correlation between the spectral data and organic matter was assumed. To investigate the possibility of a non-linear relationship, polynomial-re-

CLASSES

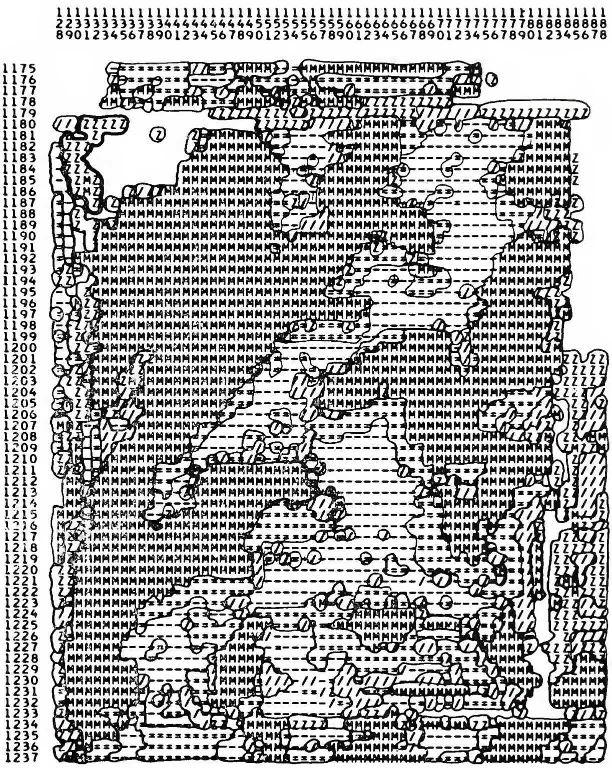
SYMBOL	CLASS	THRES PCT	SYMBOL	CLASS	THRES PCT
-	0-1.49	0.5	Z	2.5-3.49	0.5
=	1.5-1.99	0.5	M	3.5-6.0	0.5
/	2.0-2.49	0.5			

NUMBER OF POINTS DISPLAYED ARE 13356

FIGURE 2. *Computer classification of organic matter content of STA5 (3,000-foot altitude).*

CLASSES

SYMBOL	CLASS	THRES PCT	SYMBOL	CLASS	THRES PCT
-	0-1.49	0.5	Z	2.50-3.4	0.5
=	1.50-1.9	0.5	M	3.50-6.0	0.5
/	2.00-2.4	0.5			



NUMBER OF POINTS DISPLAYED ARE 3843

FIGURE 3. *Computer classification of organic matter content of STA5 (5,000-foot altitude).*

gression studies were conducted. Figure 5 shows the curve obtained from 3,000-foot data for Channel 7, which was similar to the curves for most of the other channels. The polynomial regression curves for the other two flight altitudes were similar. The quadratic effects were not statistically significant at the $\alpha=0.05$ level for any of the three sets of data shown.

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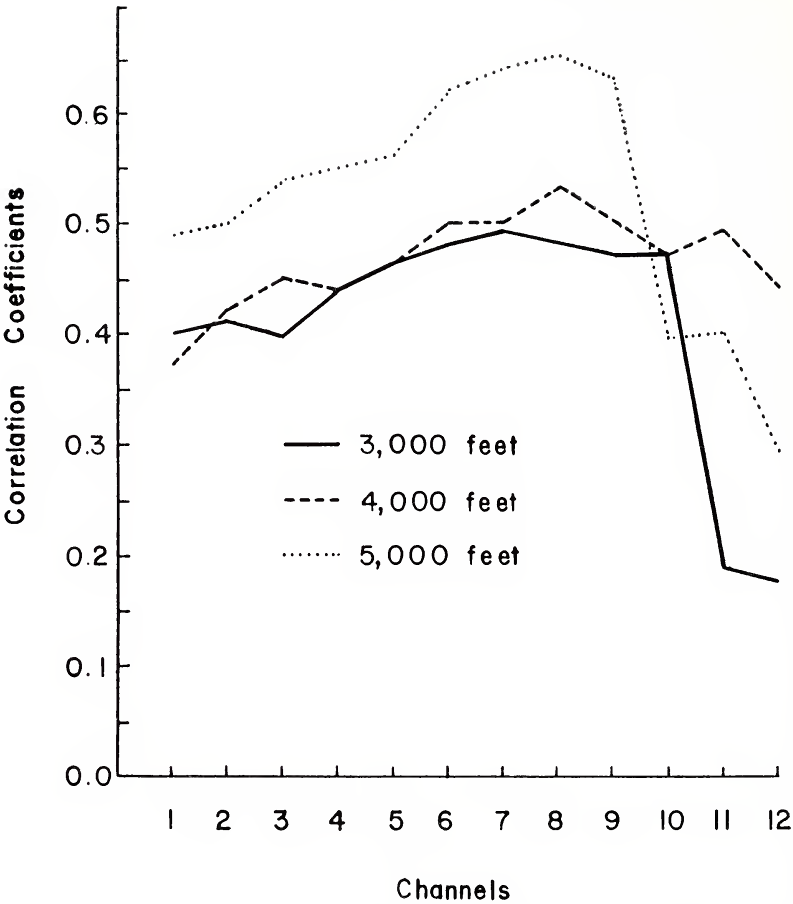

FIGURE 4. *Correlation coefficients between average radiance in each wavelength band and organic matter content for each of three altitudes.*

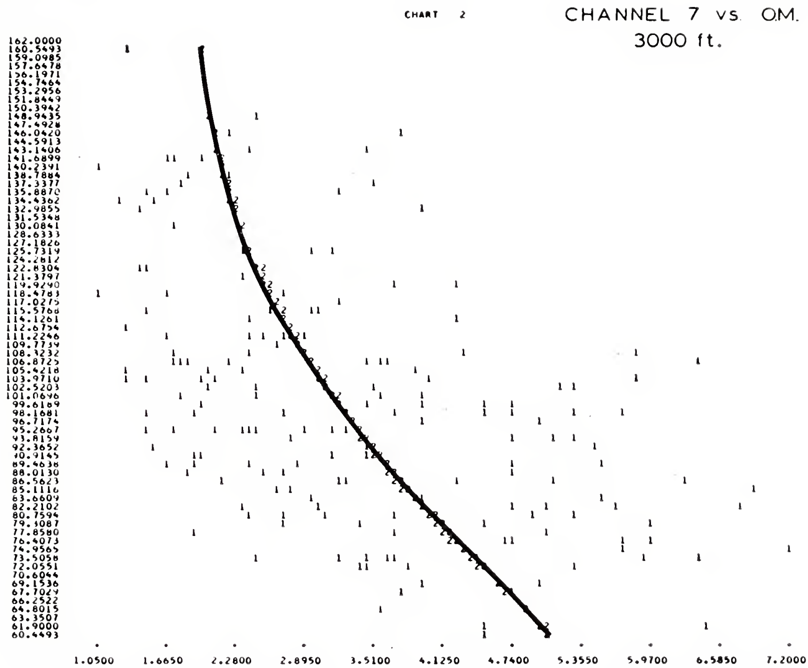

FIGURE 5. *Polynomial regression of organic matter on average radiance in Channel 7 (3,000-foot altitude).*

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