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AN OVERVIEW OF REMOTE SENSING AS RELATED TO SOIL SURVEY RESEARCH

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ABSTRACT

An inventory of the advances made in the application of remote sensing technology to soil survey research and application is presented. Emphasis is placed upon the usefulness of computer-aided analysis of Landsat multispectral scanner (MSS) data as an aid to the soil survey effort.

In the 1930's aerial photography did much to improve the accuracy and speed of the soil survey effort in the United States. Since the mid 1940's laboratory and field research have provided significant information concerning the interrelationships of soil spectral reflectance characteristics and soil properties. Technological advances during this period contributed significantly to the ability to utilize computers to analyze multispectral scanner data. Research has shown that computer-aided remotely sensed data can be used to identify such soil parameters as organic matter content, texture, drainage characteristics, and depict soil boundaries.

The capability of the Landsat satellites to gather MSS data which provide a synoptic view of the earth's surface affords soil scientists enhanced capabilities with which to map soils. Utilizing computer processing of Landsat MSS data coupled with appropriate ancillary data and traditional aerial panchromatic black and white photography can allow the soil scientist to achieve more accurate and efficient soil mapping procedures. Future data acquisition systems possessing increased spectral definition and higher resolution will further add to the capability of the soil scientist to use satellite data as an aid in the soil survey.

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Remotely sensed data, in the form of black and white aerial photography, were first employed as a base map for the soil survey in Jennings County, Indiana in 1929 (3). Results were so improved over the previous use of plane tables to draw base and soil maps that by 1938 most U.S. surveys were being conducted with aerial black and white photographs as the base map (14). This advancement led to the present day soil survey capability which allows mapping of approximately 20 million hectares annually at a cost of $1 billion dollars (6).

As early as the 1930's the military initiated investigations into the use of color, color infrared, and false color photographic products for characterizing landscape scenes; however, civilian research in this area did not begin until after World War II. In the early 1960's soil researchers reported that boundaries between soil types could be more accurately differentiated from color photography than from black and white photography (5). Color and color infrared photography also proved to be useful in identifying soil drainage characteristics, slopes and organic matter contents (16). However, due to the high cost of color photography, black and white panchromatic photography has remained the major soil mapping aid.

Success at discerning objects with aerial photography prompted analysts to investigate more sophisticated remote sensing techniques involving digitized photography, optical-mechanical scanners, and multi-images. Due to the lack of computer analysis capabilities, early images collected with the optical-mechanical scanners were reduced to a photographic film format for analysis. Techniques such as a grey scale step wedge method were used to match and assigned tonal qualities within a given scene with individual earth surface features. Investigations of crop tonal responses revealed spectral response to be a combination of vegetative cover and soil background reflectance. In general, soils were characterized by a high spectral response in the thermal infrared, a rather low response in the reflective infrared, and a varied response in the visible portions of the spectrum (7).

Computer technology capabilities formulated in the 1960's made possible many advances in the field of remote sensing analysis such as overlaying optical-mechanical multiple aperture images. This provided investigators increased information about the scenes being studied and allowed a more accurate recognition of earth surface features. By 1965 the University of Michigan had improved upon the multiple aperture scanner by devising a single aperture 12 channel scanner (0.32 to 13.5 μm) with an internal calibration. Although capabilities devised for overlaying multiple aperture images were no longer necessary, these same methods could also be used to overlay and analyze multidate and multi-image date.

Researchers combined numerical statistical analysis techniques and data collected by the single aperture, 12 channel scanner to further study the application of remote sensing techniques to soil investigations. Early studies showed that Alfisols and Mollisols were spectrally separable despite the influence of cultural practices which contributed to shadowing and decreased reflectances of surface soils (4,15). Soil parameters such as texture, color, moisture relationships, organic matter content and soil type were reported as being distinguishable using numerical analysis of aircraft scanner data (1). However, some researchers noted that since soil series are differentiated by both surface and subsurface properties, identification of soil series was not feasible (9).

While investigations of multispectral scanner data acquired from aircraft platforms were being conducted, the interrelationships between the spectral responses of soils and their physical and chemical properties were being studied utilizing laboratory instrumentation. Laboratory data collected using an Exotech Model 20 spectroradiometer suggested that variation in moisture content of soils was one of the primary contributors to differences in the spectral response (2). Other research showed that soil properties such as cation exchange capacity and the contents of silt, clay, iron and organic matter were highly correlated with spectral response (11). Even though results from laboratory and field spectral data appear to support one another, spectra obtained in these two environments are not necessarily identical. This is evident when one considers the effects in the field of ozone, water vapor, O_2 and CO_2 absorption upon the incoming and reflected or emitted energy which are not present to nearly the same extent in the laboratory.

The launch of the Landsat (ERTS) satellite in July 1972 began a new era in the acquisition and availability of remotely sensed data. An array of detectors simultaneously senses radiation in four spectral bands ranging from 0.5 to 1.1μm over a 185 km wide swath. The continuous data gathering is processed in frames of data representative of 33,000 km. The resolution element of the MSS scanner is referred to as a pixel. This information element is rectangular in shape and is representative of a surface equal to 0.45 hectares. The system provides data in forms easily analyzed through image interpretation or digital analysis techniques.

Prior to the launch of Landsat, it was hypothesized that the multispectral scanner data could provide the capability to map soils at the family level of the taxonomic classification. Simulated spacecraft imagery suggested that accurate delineation of soil associations could be accomplished in grassland areas and areas of slight tree cover (12).

Landsat data provides information in the visible and near infrared portion of the spectrum with a synoptic view over a much more extended area than capable with aerial photography. Early Landsat research proved successful in identifying gross variations in soil features. The synoptic view enabled the observation and delineation of repeating soil patterns, land use, slope effects and drainage patterns (19). Soil association maps of single counties have been produced by image interpretation of simulated infrared and individual single band black and white imagery (10,13). Image interpretation of Landsat data has been used to produce a soil association map of the entire state of South Dakota, an endeavor requiring approximately five weeks at a cost of $0.02/ha (20).

During the mid-1970's research has been conducted at Purdue University/ Laboratory for Applications of Remote Sensing (LARS) specifically using computer-aided analysis of Landsat MSS data to aid the national soil survey. Identification of a narrow strip of mollisols (prairie) running east and west for approximately 64 km in a predominantly Alfisol area (timber) across north central Indiana prompted specific investigations related to the soil survey and soil identification. This strip of Mollisols formed in moderately heavy textured, poorly drained, loess covered glacial drift which filled a pre-glacial tributary of the Teays River system (16). Spectral analysis of the Mollisols and adjacent areas indicated that there could be successful separation of predominantly mollic areas and mollic inclusions within the Alfisol area. Other studies in a nearby area correlated soil moisture characteristics with spectral soil classes and showed that soil boundaries were readily identified and soil maps units easily quantified (8).

Spectral soil maps produced from Landsat data have shown discrepencies when compared to traditional soil survey maps. These discrepencies may be due to different map size units and techniques used in producing the maps. Landsat resolution is .45 ha per spectral point at 1:24,000 while a detailed soil survey generally depicts areas 1.0 hectare or larger. When field data were gathered at a scale corresponding to the Landsat resolution, high correlations were observed.

A spectral soil map produced for Chariton County, Missouri provided results that stimulated new data analysis techniques. Since Landsat MSS data portray only surface reflectance properties, widely varying soils with respect to horizonation and parent materials may exhibit the same spectral properties. Ancillary data in the form of physiographic boundaries provided added information and allowed for correlation of soil series and spectral soil classes (18).

Analysis procedures developed in conjunction with the soil survey in Indiana and Missouri were extended to Jasper County in northwestern Indiana. Previous success at preparing soil association maps and methods of utilizing ancillary data boundaries prompted the initial preparation of a parent material map that would be coupled with Landsat MSS data to produce a spectral soil map with designated soil series.

Investigations suggest that results generated by computer-aided analysis of satellite MSS data will be of great aid to the soil scientists. Specifically, they can aid in the following:

1) Preparation of soils association maps

2) Delineation of parent material boundaries

3) Refinement of soil map unit boundaries

4) Quantification of soil map units

5) Determination of percent inclusions within soil map units

6) Preparation of single feature maps, i.e., drainage, organic matter content.

It must be stressed that computer-aided analysis of MSS data alone cannot produce a soil survey. These techniques in association with ancillary data may prove to be a concise method for aiding in the preparation of all orders of soil surveys. Just as the aerial photograph greatly enhanced the accuracy and speed of soil survey in the early 20th century, the use of satellite multispectral scanner data will also become a valuable tool to the soil scientist. Its usefulness will be further enhanced with the ability to collect data in the middle and thermal infrared portions of the spectrum and with the increasing resolution of future satellite systems.

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CORRECTION

The Soil Conservation Service has called attention to an error in the article "Application of Remote Sensing Technology to Soil Survey Research" by Weismiller and Kaminsky in the November-December 1978 issue (vol. 33, no. 6). The article's first paragraph on page 287 states, "The advancement enables soil surveyors today to map about 20 million hectares (49.4 million acres) a year at a cost of $1 billion (6)."

The reference cited (Agr. Inf. Bul. 328) states only that SCS maps soils on about 50 million acres of land a year. No mention is made of mapping costs. SCS's main concern, however, is the reference to a cost of $1 billion for a survey of 50 million acres. This represents an expenditure of $20/acre, more than 10 times the actual cost.

In 1978, SCS mapped 50 million acres on a budget of $45 million. The average cost/acre was 90 cents. Costs ranged from 24 cents/acre in the West, where reconnaissance surveys predominate, to $1.83/acre in eastern states, where detailed mapping and other factors limit the production per man.

Dr. Weismiller has acknowledged the error. Part of a sentence was accidently omitted from an early draft of the article.

In addition on page 288, line 7 should read "33,000 square kilometers (12,700 square miles)."