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N78-14602

QUANTIFICATION OF SOIL MAPPING

BY DIGITAL ANALYSIS OF LANDSAT DATA*

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ABSTRACT

Soil survey mapping units are designed such that the dominant soil represents the major proportion of the unit. At times, soil mapping delineations do not adequately represent conditions as stated in the mapping unit descriptions. Digital analysis of Landsat multispectral scanner (MSS) data provides a means of accurately describing and quantifying soil mapping unit composition.

Digital analysis of Landsat MSS data collected on 9 June 1973 was used to prepare a spectral soil map for a 430-hectare area in Clinton County, Indiana. Fifteen spectral classes were defined, representing 12 soil and 3 vegetation classes. The 12 soil classes were grouped into 4 moisture regimes based upon their spectral responses; the 3 vegetation classes were grouped into one all-inclusive class.

Using these groupings, the spectral map was compared to a conventionally prepared soil map. Three mapping units were investigated in detail: a) Mahalasville silty clay loam, b) Reesville silt loam, 0 to 2 percent slopes, and c) Xenia silt loam, 2 to 6 percent slopes, eroded.

Results indicate that the percentage of soil mapping unit inclusions can be readily ascertained according to their soil moisture regimes and that soil complexes can be easily quantified. Thus, the composition of soil mapping units can be accurately determined.

INTRODUCTION

Soil maps depict soil conditions in a particular landscape scene with varying degrees of precision depending primarily upon the type of survey conducted and the ability of the mapper to analyze the landscape and identify the

*This work was accomplished under the National Aeronautics and Space Administration, Office of University Affairs, Grant No. NGL-15-005-186. Journal Paper No. 6690 Purdue University, Agricultural Experiment Station.

components of the mapping units delineated. Due to the subjective nature of soil surveys and the vast areas of land involved, it is often difficult to evaluate the accuracy of the soil surveys. Currently, field methods such as spot checking and line and point intercept transects are used to evaluate the composition of mapping units. (1) Various studies (2,3,4) to determine mapping unit composition suggest that many delineations do not adequately represent conditions as stated in the mapping unit descriptions. Also, many separations on a soil map often represent soil complexes rather than taxonomic units with minor inclusions as indicated. A study was undertaken to determine the feasibility of using digital analysis of Landsat multispectral scanner (MSS) data as a means of accurately describing and quantifying soil mapping unit composition. This paper examines three distinctly different soil mapping units, comparing their composition as described by conventional field mapping techniques and digital analysis of Landsat MSS data.

A 430-hectare tract located in Clinton County, Indiana was selected as the study area. Soils in this area developed from loess deposited over glacial till derived from the late Wisconsin glaciation and localized lacustrine deposits. The surface topography ranges from 0 to 6 percent slope but the slopes are commonly less than 2 percent.

Three soil mapping units were investigated in detail: a) Mahalasville silty clay loam, b) Reesville silt loam, 0 to 2 percent slopes and c) Xenia silt loam, 2 to 6 percent slopes, eroded. The Reesville and Xenia soils were developed in the loess over glacial till and the Mahalasville soil in the lacustrine deposits. The soils of this area had previously been mapped using conventional techniques by USDA/Soil Conservation Service (SCS) personnel as part of an on-going progressive survey.

DATA

Landsat-1 MSS data collected on 9 June 1973 were used as the main data source for this study. This scene was selected because the data were: a) of high quality, b) acquired when most cropland was in a bare soil state and c) free of interfering atmospheric and surface conditions (i.e., clouds, haze and standing water). However, Clinton County had received approximately 2.90 inches of precipitation in the week prior to the Landsat overpass.

The Landsat MSS data were geometrically corrected (i.e., rotated, deskewed and rescaled to a scale of 1:20,000) (5), and registered to ground control points selected from U.S. Geological Survey 7½ minute topographic quadrangle maps. These procedures produced a data set of an exact scale of 1:20,000 with points in the data registered to their exact ground position. The aerial photography and field sheets used by the USDA/SCS personnel are also at a scale of 1:20,000. These matching scales allowed for convenient comparisons between the conventionally developed soil map and the spectral soil map derived from computer-aided analysis of Landsat MSS data.

PROCEDURES

Landsat MSS data covering the study area was input into a clustering algorithm program. This algorithm divided the MSS data into groups of sample points of similar spectral characteristics. A statistics processor was utilized to calculate the mean relative reflectance values and covariance matrices for each of these individual cluster groupings. Cluster groupings were either deleted retained or combined based upon their statistical separability characteristics. This procedure indicated that there were 15 spectrally separable classes within the study area. The statistics developed on each of these 15 classes were used by computer-implemented pattern recognition techniques as implemented by LARSYS (6) and a maximum likelihood Gaussian classifier to assign each of the data points to one of the 15 spectrally separable classes.

A ratio $(A = \frac{V}{IR})^*$ and the summed response (total magnitude of the relative intensity values of all four Landsat bands) calculated for each spectral class were used to identify 12 soil and 3 vegetation classes within the 15 spectral classes.

After classification, these classes were grouped into four major soil classes and one all-inclusive vegetation class. Each major soil class was assigned to one of four soil moisture regimes based upon the magnitudes of their respective summed responses (Table I). The class with the highest total reflectance represented moderately well drained soils; the class with the lowest reflectance represented poorly drained soils. These groupings were verified by detailed field checking.

An alphanumeric spectral map delineating the 12 soil and 3 vegetation classes was produced at a scale of 1:20,000. Field checks were conducted to evaluate the agreement between the conventionally developed soil map and the spectral soil map. Field observations included a) precise location of the three mapping units on both types of soil maps, b) notation of the various soil types and their respective moisture regimes included in the three mapping units and c) notation of the boundaries (agreements and disagreements) of the three mapping units and of their individual soil components.

RESULTS

The conventionally prepared soil map of the study area and the enhanced boundaries of the 1) poorly drained Mahalassville, 2) moderately well drained Xenia and 3) somewhat poorly drained Reesville mapping units are shown in Figure 1. For comparative purposes the three mapping units as delineated on the conventional soil map were superimposed upon the spectral soil map (Figure 2). Distinct boundary differences existed between the two maps. Also, significant inclusions not delineated on the conventionally prepared soil map were noted on the spectral soil map. In all cases, the spectral map identified inclusions within each mapping unit that had different drainage characteristics than were identified by the named mapping unit. For example, significant portions of the moderately well drained Xenia mapping unit were shown to be poorly and somewhat poorly drained according to the computer classification. Field checks of a major portion of the questionable areas revealed the spectral classification to be correct.

Statistics derived from the spectral classification of the study site (Table II) indicate that 51 percent of the Mahalassville mapping unit is appropriately classified as poorly drained. The majority of the other 49 percent of the mapping unit was classified as very poorly and somewhat poorly drained. Similarly, the spectral classification indicates that 46 percent of the Reesville and 30 percent of the Xenia mapping units were appropriately classified as the named mapping unit. Exclusive of vegetation the remainder of the Reesville mapping unit was classified as poorly and moderately well drained. Similarly, the remainder of the Xenia mapping unit was classified as poorly and somewhat poorly drained. In both the Reesville and Xenia mapping units contrasting inclusions constituted a large enough percentage of the named unit to justify additional separations or the mapping of a soil complex.

CONCLUSIONS

Digital analysis of Landsat multispectral scanner data can provide detail and definition of soil features not readily discernible through visual interpretation of Landsat imagery. It is apparent from this study that digital

*where V is the relative intensity of the mean spectral responses of the visible wavelengths $\{(0.5 \text{ to } 0.6\mu\text{m}) + (0.6 \text{ to } 0.7\mu\text{m})\}$ and IR is the relative intensity of the mean spectral response of the reflective infrared wavelengths $\{(0.7 \text{ to } 0.8\mu\text{m}) + (0.8 \text{ to } 1.1\mu\text{m})\}$

analysis of Landsat MSS data can provide quantification of soil mapping. The percentage of soil mapping unit inclusions can readily be ascertained according to their soil moisture regimes, and soil complexes can be easily quantified. Thus, the composition of mapping units can be accurately determined.

The use of digital analysis of Landsat data as a mapping tool to quantify soil mapping unit compositions should greatly increase the accuracy of soil surveys. By utilizing this quantification procedure, other aspects of the soil survey, such as soil interpretations for urban uses, may be also greatly enhanced.

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TABLE I. RELATIVE SPECTRAL RESPONSES OF GROUPED CLASSES.

<u>Spectral Map Symbol</u>	<u>Drainage Class</u>	<u>Range of Summed Response</u>	<u>Range of Ratio A</u>
/	Moderately Well	184.47-218.13	1.03-1.33
+	Somewhat Poorly	162.47-176.20	1.32-1.35
X	Poorly	136.31-151.05	1.16-1.35
M	Very Poorly	118.78	1.40
Blank	(Vegetation)	140.93-150.49	0.59-0.74

TABLE II. COMPOSITION OF SOIL MAPPING UNITS.

Characteristics of Named Mapping Unit

<u>Mapping Unit</u>	<u>Spectral Class</u>	<u>Internal Drainage Class</u>	<u>Size of Mapping Unit (Hectares)</u>	<u>% and Area (Hectares) of Unit Represented by Named Series</u>
Mahalasville Silty clay loam	X	Poorly	47.65	51.40% 24.49
Reesville silt loam, 0 to 2 percent slopes	+	Somewhat Poorly	51.21	46.08% 23.60
Xenia silt loam, 2 to 6 percent slopes, eroded	/	Moderately Well	13.36	30.00% 4.01

Percent and Area (Hectares) of Inclusions within the Above Mapping Units Identified by Drainage Classes

<u>Spectral Symbol</u>	<u>Very Poorly Drained</u>	<u>Poorly Drained</u>	<u>Somewhat Poorly Drained</u>	<u>Moderately Well Drained</u>	<u>(Vegetation)</u>
X	21.49% 10.24	--- ---	17.75% 8.46	9.34% 4.45	.02% ---
+	.88% 0.45	20.00% 10.24	--- ---	18.26% 9.35	14.78% 7.57
/	--- ---	16.67% 2.23	40.00% 5.34	--- ---	13.33% 1.78

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FIGURE 1. CONVENTIONAL SOIL MAP INDICATING THE
(1) MAHALAVILLE, (2) XENIA, AND
(3) REESVILLE MAPPING UNITS.

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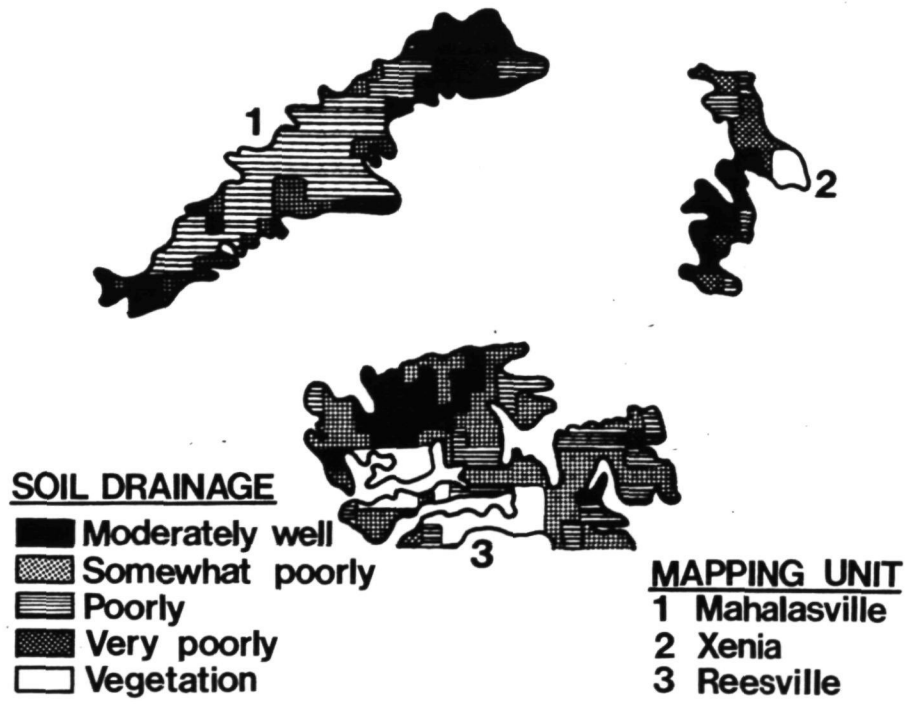


FIGURE 2. CONVENTIONALLY DELINEATED MAPPING UNITS SUPERIMPOSED UPON THE SPECTRAL SOIL MAP.