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Digital Overlay of Cartographic Information on Landsat MSS Data for Soil Surveys

Cartographic data were digitized, spatially registered, and merged with processed Landsat data to produce image products useful for soil unit boundary delineation.

Introduction

Past research has demonstrated the capability of Landsat data to delineate features useful in locating and mapping soil resources. Podwysocki *et al.* (1977) used various image enhancement techniques to discriminate rock and soil types. Weismiller *et al.* (1979), Kristoff and Zachary (1974), Westin and Frazee (1976), Mathews *et al.* (1973), Lewis *et al.* (1975), and May and Petersen (1975), all have applied various procedures for using remotely sensed data to create image products for soils studies. Robinove (1979) used Landsat data to create a map showing terrain themes for land-use classification. He also overlaid soil boundaries on the data to create improved image products.

Abstract: *Cartographic soils data were digitized, spatially registered, and merged with processed Landsat image data. The Landsat Multispectral Scanner Subsystem (MSS) image data were used to generate a thematic map representing different soil surface characteristics and an enhanced image. The thematic map was generated using supervised and unsupervised classification procedures. The enhanced image was generated by performing a linear contrast stretch on data altered by a principal components transformation. Although both procedures yielded images useful for soil unit delineation, image enhancement was determined to be more suitable because it was more expedient and inexpensive. Enhanced images cost $0.06 per hectare, spectral classifications cost $0.08 per hectare. The overlay of cartographic data on Landsat data facilitates comparisons between the various processing methods used for soil unit boundary determination, delineation, and verification. This technique also provides for accurate and expedient spatial referencing for field observations and cartographic correlation.*

Occasionally, the limited spatial resolution of Landsat data (0.45 hectares or 1.11 acres) makes it difficult to delineate cultural features such as

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transportation networks and utility lines. These features are important navigational aids for a field scientist or planner, who must associate certain features on a Landsat MSS image with their exact locations on the ground or on other maps and photographs. The capability of an image product to provide accurate and expedient spatial referencing is an important consideration when making field observations or cartographic correlations. It would be a great advantage, therefore, if survey data, transportation networks, and an appropriate map projection graticule, could be accurately projected onto a Landsat MSS image product. Within the science of soil mapping, for example, such a composite image product would be a valuable aid in the delineation of soil unit boundaries.

The techniques explored in this project were designed to test the following hypotheses:

- Spectral thematic maps or enhanced images can be generated that portray image class patterns representing various terrain features, such as surface morphology (roughness), presence of rock fragments, and vegetative cover. These thematic maps can be used in the manual survey process to improve the speed and accuracy of soil unit boundary delineation.
- Overlay of soil unit boundary information on the processed satellite data can provide an image product ideal for assessing the ability of a particular data processing technique to delineate such boundaries and a means for evaluating soil unit variability which may be related to soil spectral variability.
- Geometric registration and overlay of other forms of cartographic data, such as transportation networks, a map projection graticule, or survey grids, can provide an image product which is greatly improved for soil survey use. Such a product facilitates the matching of image features and field data with their actual locations on the Earth's surface, and can contribute significantly toward the accuracy of a soil survey.

SURVEY AREA

The region selected for the study is a 112,500 hectare (277,000 acre) area of arid and semiarid rangeland near the town of Green River in east central Utah (Imhoff and Petersen, 1980). The Green River survey area is in the Colorado Plateau physiographic province, and is composed of relatively flat sedimentary rock which has been deeply dissected by fluvial erosion and faulting. The soils in this area are mostly Aridisols, Entisols, and Inceptisols. The natural vegetation of the area consists of desert shrubs and bunch grasses. A detailed description of the topography, climate, soils, and vegetation characteristic of this area can be found in the Soil Survey of the Carbon Emery Area, Utah (USDA, 1970).

Materials and Methods

The image processing techniques were implemented through a digital data processing system developed at the Office for Remote Sensing of Earth Resources (ORSER) at The Pennsylvania State University (Turner *et al.*, 1978). The ORSER digital processing system is a software package designed to analyze, manipulate, and display digital image data. This system was used to create the images for this study and to digitally merge the cartographic data. The ORSER Software Package can be purchased from The Pennsylvania State University.

The equipment used in the process consists of an IBM systems 370/3033 processor (a smaller computer could also be used); a Tektronix Model 4954 Graphics Tablet (digitizer); a Computer Automatic ALPHA LSI minicomputer; a Ramtek color display system; and a Conrac color CRT. The graphics tablet and color display system interface with the minicomputer which communicates with the IBM 370/3033 over a telephone line.

In order to produce images suitable for mapping soils, statistical classification techniques and image enhancement techniques were used to create image products that portrayed spectral patterns representing a variety of soil surface features and cover types. The images were created from 13 June, 1977 Landsat data (scene 2873-16592). The cartographic data, as of yet unpublished, was provided by the Soil Conservation Service (SCS), and consisted of a soils map drawn on a black-and-white aerial orthophoto quad scaled to 1:24,000. This map represents the Tidwell 1 NW 7 1/2-minute topographic quadrangle and contains information such as soil units (series, type, and phase) boundary lines, a latitude and longitude coordinate grid, an SCS survey graticule, and transportation networks.

As a first step in processing the imagery, the ORSER SUBGM program was used to geometrically correct the Landsat data. Transformations were completed to correct Earth rotational skew, orient the data to true north, eliminate pixel overlap, and create square (79 m by 79 m) pixels. Two Landsat MSS image products were then generated. The first was a spectral thematic map where both supervised and unsupervised procedures were used to obtain the classification categories. The second product was an enhanced image created by the application of a contrast stretch and an equal area density slicing technique. The two procedures are sometimes collectively referred to as a uniform contrast stretch.

Because the spectral response from the irrigated areas contrasted so greatly with the nonirrigated region, the spectral thematic map was created using a dual approach. The nonirrigated region, which constitutes most of the survey area, was classified using an unsupervised procedure. The parameters for the clustering algorithm were chosen to yield meaningful patterns only in the nonirrigated region. The irrigated areas were classified using a supervised procedure. The spectral themes generated from both procedures were checked against field observations.

To generate the enhanced image, a principal components transformation was first performed on the data. This transformation serves to reduce data dimensionality and to concentrate the system variance on fewer axes. The data defined by the first principal component accounted for 87 percent of the total system gray-level variance and was subjected to a linear stretch extending the contrast range from 127 to 256 gray levels. Finally, a uniform density slicing technique was applied. This technique yields equal-area or equal-population density slices of the contrast stretched data along the axis. Color assignments were made to the various density slices to visually enhance the separations of gray-level.

In order to geometrically register the Landsat image data to a cartographic data base, ground control points were located that were easily definable on both the Landsat imagery and the SCS soil map. In this case the soils map was drawn on a photograph (orthophoto) cartographically registered to the corresponding U.S. Geological Survey (USGS) topographic quadangle. The soils map was provided by the Utah Soil Conservation Service and no assessment was made in this study to evaluate the geodetic accuracy of the map. Most important, however, was the cartographic registration between the Landsat imagery and the soils map. Any geodetic registration error that may have been associated with the soil maps was not detectable by the mapping teams in the field and was therefore considered unimportant.

Easily defined points, such as sharp bends in the river, irregularities in the edges of shale escarpments, highway intersections, and railroad trestles, were selected as ground control points. Eighteen widely scattered points were defined throughout an area encompassing about 11,000 hectares. A corner point was selected to serve as a common origin for both the Landsat data and the cartographic data. On the line printer character map, the control points were defined by their scanline and element numbers. Their counterparts on the photograph were digitized as single points, using the graphics tablet, and stored on the minicomputer disk.

At this stage, two factors were taken into account:

- The Landsat data set has a pixel coordinate system with its origin in the upper left corner; therefore, the element and scanline numbers (x,y) increase eastward and southward, respectively. The coordinate system on the graphics tablet has its origin in the lower left corner and the x and y coordinates increase eastward and northward, respectively.
- The Conrac color CRT used with the Ramtek system has a maximum raster image field of 512 by 512, and neither the Landsat image nor the digitized data conform to these specifications. The Landsat image size also does not conform to the field size of the digitized data.

In order to obtain conformable data sets, an algorithm was designed to rescale the digitized data, including the ground control points. This algorithm restructured the data, placing the origin in the upper left corner to conform with the Landsat system, recomputed the maximum length of the image, and rescaled the data to fit within the range of 0 to 500 in the x and y directions.

The rescaled ground control point coordinates and their unaltered counterparts from the Landsat image were input to the ORSER RUBRFUN program. The RUBRFUN program runs a stepwise linear regression with the two sets of ground control points and produces a set of equations used to resample and "stretch" the Landsat image to conform to the rescaled digitized ground control points. Registration was achieved to within 1.0 pixels. The equations generated by this program were input to a rubber sheet stretching program (ORSER DISPGM). This program produced a new resampled and stretched image, geometrically conforming to both the digitized soils data and the image field specifications of the Conrac color display.

The first step in overlaying the digitized ancillary data onto the Landsat digital data was to read the digitized lines and points, with their associated symbols, into the computer memory. Scan lines, obtained from the Landsat image file stored in compressed character map format, were compared one-by-one with the digitized data file. Intersections between a given digitized line or point and each Landsat scan line were calculated. When any portion of a scan line intersected or came within a pixel of an ancillary data point or line, changes were made as follows: In the case of an ancillary data point, the nearest pixel was changed from the Landsat data value to the symbol associated with the digitized mapping element. If a digitized line was perpendicular to the Landsat scan line, the value of the Landsat pixel nearest the intersection of the lines was changed to the value of the digitized mapping element. When the digitized line intersected the Landsat scan line at less than 90 degrees, all Landsat pixels less than one pixle width from the digitized line were changed. If the digitized line was parallel to a Landsat scan line and within one pixel width of it, the scan line pixels between the end points of the digitized line were changed (Figure 1). After these modifications were made to the Landsat data set, each scan line was written into a new output file.

The modified image was then processed through an ORSER display program, and a color was assigned to each symbol representing the spectral class categories of the Landsat data and the cartographic overlay. The use of pseudo-color assignments improved the visual separability between the various gray levels and the cartographic data.

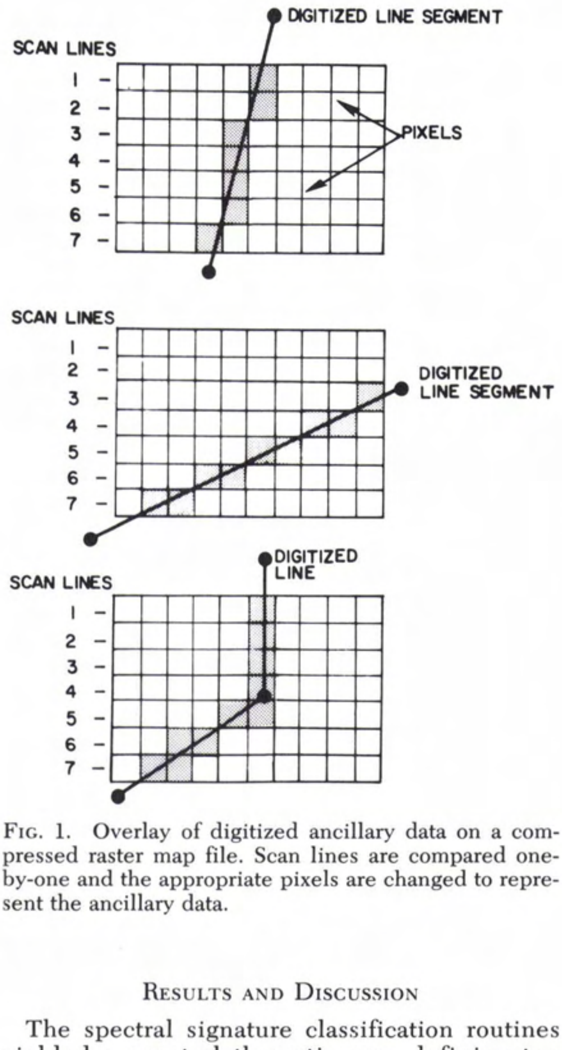

FIG. 1. Overlay of digitized ancillary data on a compressed raster map file. Scan lines are compared one-by-one and the appropriate pixels are changed to represent the ancillary data.

RESULTS AND DISCUSSION

The spectral signature classification routines yielded a spectral thematic map defining ten spectral categories based on a variety of soil surface characteristics such as terrain roughness, percent of area of rock outcrop, parent material type, presence of rock fragments, and vegetation type and canopy densities. The inclusion of cartographic data produced composite images of improved interpretability (Plate 1). The image enhancement procedure provided an image product with 15 spectral classes on the basis of variation in gray level over all four spectral channels (Plate 2). Although both processing methods produced image products that appeared viable, a few factors concerning their suitability for soils mapping became evident.

Supervised spectral signature classification is a relatively subjective processing method, iterative in nature and dependent upon ground truth information for class definition. As a result, this form of spectral signature classification is a relatively expensive processing technique requiring particular care in its planning and implementation. Unsupervised spectral signature classification with a minimum of detailed analyst-defined class definitions may be more suitable for soils mapping. Image enhancement, on the other hand, is a fairly objective processing method, applicable over large areas. It does not require ground truth information in order to generate a viable image product. Also, the nature of image enhancement is such that the definitions of the spectral classes are open to interpretation, allowing a soil scientist to use his own experience and training in making final interpretations. In the field, SCS personnel found that the patterns portrayed by the enhanced imagery did indeed help in locating soil unit boundaries. These factors make image enhancement an economically attractive as well as logistically attractive processing technique for soil surveys. Lyon and George (1979) reached a similar conclusion when comparing band ratioing techniques to supervised classification procedures for vegetation mapping in Alaska.

The inclusion of soil bondaries presented an excellent opportunity to compare the spectral signature classification themes and the patterns on the enhanced images with ground truth information (Plates 1 and 2). As a result, it was possible to make comparisons between processing methods for their respective abilities to predict soil unit boundaries as they are mapped in the field.

The composite images demonstrated that the spatial orientation and geometric relationships between spectral patterns portrayed on the Landsat images and the field mapped soil boundaries were approximately the same. Thus, both processing methods produced images which could be valuable as tools for delineating soil unit boundaries. The overlay of the cartographic data demonstrated that the patterns in the enhanced image (Plate 2) appeared to be more similar to the field data than its thematic counterpart (Plate 1). This provided further evidence that image enhancement was the more viable processing method.

Another fact made visually evident as a result of the inclusion of the cartographic data was that the spectral patterns portrayed on both the spectral thematic map and the enhanced image were more spatially detailed than the mapped soil boundary lines. Frequently, the Landsat data were capable of resolving the presence of mapping inclusions, such as areas of extreme stoniness or sandiness within a more homogeneous mapping unit. Although these inclusions are mentioned in the soil unit descriptions, they are seldom delineated on a soils map because of their small areal extent. The ability of Landsat data to delineate these areas provides good evidence that the 0.45 ha spatial resolution of the data is more than adequate for surveys of arid and semiarid regions.

The inclusion of transportation network lines

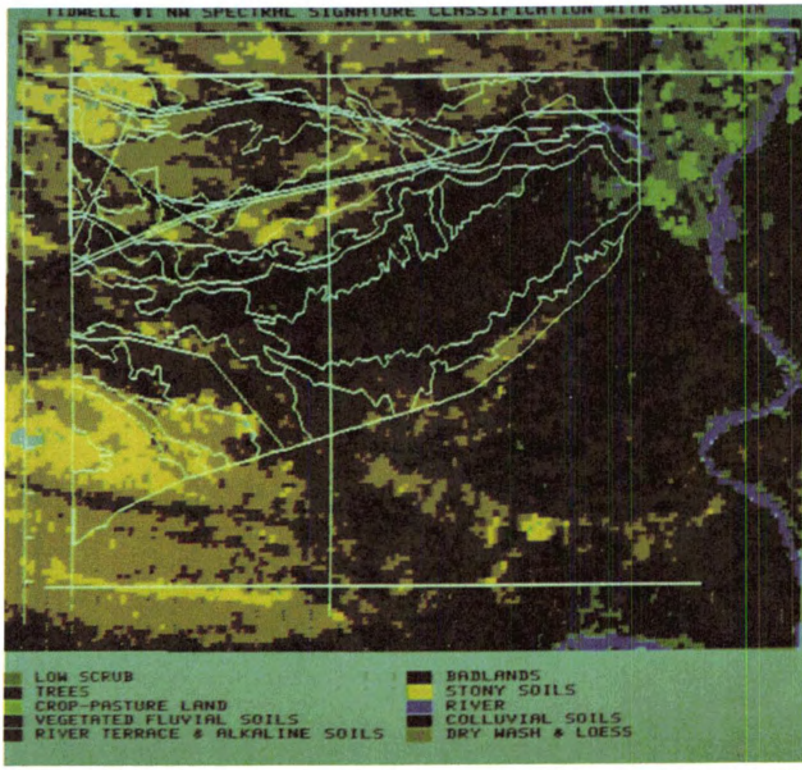

PLATE 1. Spectral signature classification map of a portion of the Tidwell-1 NW area with overlay of the ancillary data (1:111,000).

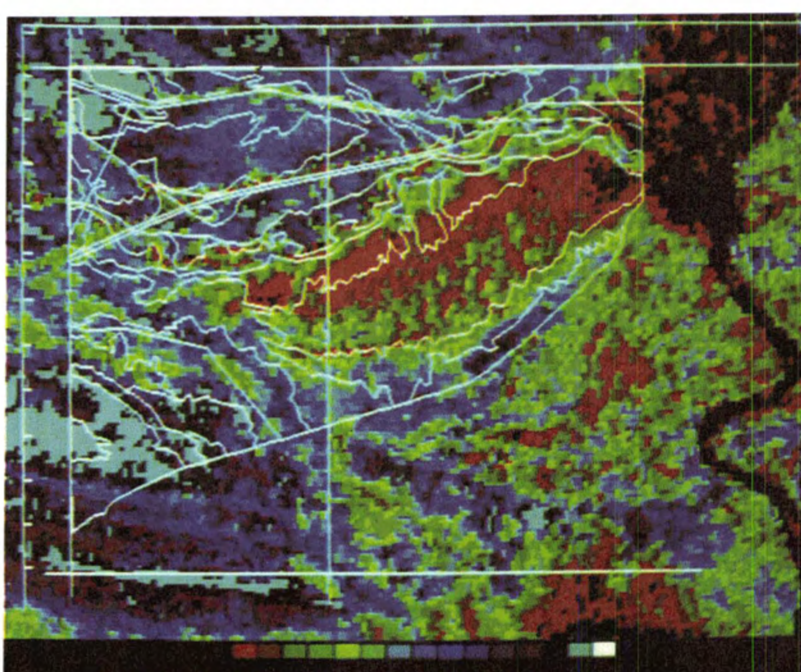

PLATE 2. Contrast-stretched principal components axis 1 data representing the Tidwell-1 NW area with overlay of the ancillary data (1:111,000).

and map projection coordinate grids in the overlays made it much easier to compare the image products with other ancillary information. The use of grids and transportation data also minimized confusion about the correct spatial orientations and placement of the classified units on the images in relation to other types of mapped data.

Comparison of previously mapped soil units with the spectral classification products and the enhanced images created a context whereby assessment could be made not only of the ability of the Landsat data to delineate soil unit boundaries, but also of the accuracy of the current survey data. Landsat data, in the form of spectral thematic maps and/or enhanced images, combined with various types of ancillary data may decrease the time needed to survey a particular area, but may also increase the accuracy of that survey.

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