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USE OF LANDSAT DIGITAL DATA TO ASSIST IN MAPPING SOILS ON ARIZONA RANGELANDS

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I. ABSTRACT

The outline and results of more than three years of field and laboratory studies are presented. The work was done in cooperation with the Soil Conservation Service, the Bureau of Land Management, and the Forest Service. Spectral maps generated from Landsat satellite data were used to aid in soil and vegetation surveys of five sites in southeastern Arizona. The sites are rangeland with varied physiography and relief, but generally sparse vegetation. It was found that spectral maps show a very positive correlation with grey tones or color patterns on photographs, and can be an excellent auxiliary tool for locating boundaries of mapping units. They can also aid in the location of representative sites for pedon descriptions, and could be used as an aid to quality control and map correlation studies in the field. The type and/or color of the geologic parent material was the dominant factor affecting the response recorded by the satellite.

II. INTRODUCTION

The studies outlined in this paper are the result of a cooperative exchange of knowledge and experience that began in 1976 among soil scientists from The University of Arizona, Laboratory for Applications of Remote Sensing at Purdue University, Bureau of Land Management (BLM), Forest Service (FS), and Soil Conservation Service (SCS). The objective of this research was to evaluate Landsat digital data as a complementary tool to assist soil scientists with their field mapping. The budgetary and time constraints under which field soil scientists operate are well known, and these aspects were especially considered.

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Although soil mapping applications were stressed, applications to vegetation and other natural resources inventories were also considered.

The study areas were rangelands, and are located in southeastern and central Arizona. Rangelands are defined as land that for physical reasons is not suited for cultivation, but is a source of forage for native or domestic animals, as well as a source of wood products, water, and wildlife[16]. Table 1 lists the areas identifying them by their local name, the size of the study area, and the geographic coordinates. The physical description of the areas are presented in the discussion for each study area; however, the following general comments can be made about all areas. Elevations varied from 700 to 2300 meters with a complex variety of soils, geologic, topographic, and climatic conditions. The ground cover was generally sparse, rarely exceeding 25 percent, and averaged about 10 to 15 percent. The methodology and nomenclature employed with reference to soil taxonomy and mapping are described in The Soil Survey Manual[14] and in Soil Taxonomy[15].

The Landsat data were processed by the LARSYS system and all data were geometrically corrected[12]. The single picture element resolution is approximately 0.45 hectare.

III. FIELD STUDIES

A. SAN SIMON VALLEY STUDY

The initial research began during 1975 and 1976 when single band spectral maps were produced in Bands 4 and 5 for this 370,000 hectare area. The area was chosen because of its very sparse vegetation and because SCS soil scientists had recently completed a soil map of the area for the Bureau of Land Management. The

BLM was in the process of developing an environmental impact statement of the area to support their management recommendation plans and they were interested in the application of this technology to managing these lands.

The physiography of this area ranges from broad alluvial plains to steep slopes with elevations ranging from 700 to 1200 meters. The geologic parent material for the soils is composed primarily of coarse-grained alluvium, Precambrian and Tertiary granitic and volcanic rocks embracing a wide lithologic range from rhyolitic to basaltic in nature. The vegetation is mostly composed of desert shrubs and grasses, and is sparse (generally less than 15% ground cover). The soils of the area are mainly Typic and Vertic Torrifluvents, Typic Haplargids, Typic Paleargids, Typic Calciorthids, Typic Gypsiorthids and some Lithic Haplargids or Lithic Torriorthents.

The single band spectral units and the soil mapping unit delineations were markedly similar. Several mapping unit boundaries were more clearly defined on the spectral map than on the aerial photos used as a base map by the soil scientists. Two 4500 hectare areas were selected for further intensive study and the four Landsat spectral bands were combined into twelve spectral categories for each of these sites. This combination of spectral bands improved the single band data and the resultant spectral maps were more closely related to the existing soil maps. Several discrepancies were noted, resulting in the identification of various mapping unit inclusions[1, 4].

B. WINKELMAN AREA STUDY

During 1977 a joint study with the Bureau of Land Management was undertaken, and June 1976 Landsat data were purchased. The objective of this study was to use Landsat spectral maps to assist the BLM in the preparation of a semi-detailed soil survey of a 350,000 hectare area. The output was produced prior to the field mapping and was to be used as an integral part of their in-field mapping operation.

In this area elevations ranged from 700 to 1500 meters with varying physiography. The lithology ranged from Precambrian to Holocene in age, consisting largely of Pinal Schist and Ruin Granite intrusive rocks, Miocene Big Dome Formation, and Quaternary alluvium[5]. The vegetation is desert shrubs, desert grasses, and chaparral. The soils are Ustollic, Lithic, and Typic Haplargids, Typic Calciorthids, Lithic Torriorthents or Lithic Haplargids, and Typic Torrifluvents[4].

Five training sites, each 4500 hectares in size, were selected within the area on the basis of varying parent material, topography, and differences in vegetation type and density. All four Landsat spectral bands were used in the classification and each site was classified into 12 spectral categories. These classes were then pooled based on the spectral statistics, resulting in a total of 60 categories for the entire area. Through further refinement a final spectral map of the area was prepared having 23 spectral classes. This spectral map was used in conjunction with orthophotomaps and aerial photos of the area during the mapping process [3, 4].

Table 1. Location of Study Sites

Field Study ID	Hectares	Latitude	Longitude
San Simon Valley	370,000	N 32° 48'	W 109° 22'
		N 32° 30'	W 109° 10'
Winkelman Area	350,000	N 33° 10'	W 110° 50'
		N 32° 30'	W 110° 25'
Flying UW Ranch	4,500	N 32° 57'	W 110° 57'
		N 32° 55'	W 110° 45'
Tonto National Forest	200,000	N 33° 55'	W 110° 50'
		N 33° 25'	W 110° 30'
Coronado National Forest	800,000	N 32° 07'	W 109° 30'
		N 31° 22'	W 108° 52'

C. FLYING UW RANCH STUDY

A detailed study was done in 1978 on a 4500 hectare segment of the Flying UW Ranch, and again the four bands were combined to produce a 12 class spectral map of the study area. This area is quite similar to the Winkelman study area and was chosen because of the availability of extensive natural resource information, which could be used to better evaluate spectral data as a complementary soil mapping tool. The same Landsat data and processing described for the Winkelman area was also used in this study.

Four soil scientists from BLM, SCS, and the FS were provided with spectral data information and asked to evaluate its use in mapping the soils of the area. These data were complementary information to be used in addition to aerial photographs, topography maps, geologic maps, and orthophoto maps of the area. These soil scientists independently mapped the soils of the area, making diverse use of the different types of imagery. Later, several conferences were held to discuss results and compare the soil maps with the spectral data from a qualitative point of view[2, 3, 5, 10, 13].

D. TONTO NATIONAL FOREST STUDY

In 1978 a cooperative study began with the soil survey team of the Tonto National Forest in central Arizona, again using the June 1976 Landsat data. The characteristics of this rangeland were different from the previously described areas, particularly with respect to amounts of vegetative cover, topography and elevation.

The physiography of the area was extremely varied, from alluvial bottoms and dissected terraces to steep mountain lands. Elevations ranged from 700 to 2300 meters. The vegetation changed from desert shrub types and open grassland on the lower elevations to chaparral and Pinyon-Juniper woodland to Ponderosa Pine forest on the highest elevations. The geology is composed mainly of Quaternary alluvium, granite, schist, basalt, rhyolite and diabase. The soils of the area consist largely of Typic, Udic, and Aridic Haplustalfs, Typic Eutroboralfs, Typic Ustorthents, Typic Torriorthents, and Typic Haplargids[7, 9].

The initial plot study was conducted on two sites, each approximately 4500 hectares in size, and data from the four Landsat spectral bands were used to classify the area into ten spectral categories. The field soil scientists extensively studied and evaluated the data from these two areas and successfully incorporated it as an integral part of their on-going field survey program. The training site data were expanded into the surrounding area of about 200,000 hectares and used to help complete the soil survey of that area. Based on this work the Tonto Forest decided to use spectral maps of the area during the survey of approximately one million hectares within that forest to be completed in 1985[7].

E. CORONADO NATIONAL FOREST STUDY AREA

During the summer of 1979 soil scientists from the Coronado National Forest worked with University of Arizona scientists to study the feasibility of using spectral maps for the survey of the Chiricahua and Peloncillo mountain ranges and surrounding areas. Much of this area has difficult accessibility, and extrapolating information from accessible areas was important. They were also interested in using and evaluating this technology for its overall application to the soil mapping program.

This area is about 800,000 hectares and the climate, geology, and vegetation vary widely. Elevations range from less than 1000 meters to over 3000 meters. Landforms range from gently sloping alluvial plains to steep mountainous land. The vegetation generally ranges from desert shrubs and grassland to Pinyon-Juniper woodland and Ponderosa Pine forest, being quite dense at the higher elevations. The geology in this area consists largely of Quaternary alluvium derived from rhyolite and andesite; alluvium derived from limestone and sandstone; alluvium derived from basalt; mixed alluvium, and residual limestone, sandstone, rhyolite, andesite, and basalt materials. The soils are primarily Typic and Lithic Ustorthents, Typic Ustifluvents, Typic, Aridic, Fluventic, Udic, and Lithic Ustochrepts, Typic Dystrochrepts, Aridic and Lithic Haplustolls, Aridic and Udic Haplustalfs, and Ustalfic Haplargids.

The area was subdivided into four regions, which were to be mapped independently. Each of these regions was classified into 12 spectral categories, using spectral bands 5 and 6. A subsample of the entire area was designated as training, using every tenth data line and column. These spectral maps are currently being used and evaluated during the mapping of soils and vegetation in these areas[6].

IV. EVALUATION OF ARIZONA RANGELAND SURFACE FEATURES WHICH AFFECT LANDSAT SPECTRAL DATA

In evaluating Landsat spectral data it is important that the relationships among the earth's surface features and Landsat spectral measurements be quantitatively defined. Statistical studies are in progress to determine the empirical relationships among rangeland surface features and the four spectral bands of the Landsat system. If this can be established, the predictive capability of spectral satellite data with regard to site characteristics may be determined. Preliminary results are presented in the next section of this paper. This problem has been previously approached with very encouraging results[8, 11, 17].

V. RESULTS AND DISCUSSION

The interpretation and application of the spectral information varied greatly among the field soil scientists, but the field studies conducted generally lead to similar results. The following points were commonly agreed upon:

An overall view of an allotment or mapping area showing the location and uniformity of spectral classes prior to any field studies greatly aids in the planning and development of a soil survey.

If properly used as an additional source of information about the area, the spectral maps will result in significant time savings to the field scientists making natural resource inventories.

The spectral categories are well correlated to specific site characteristics such as density of vegetation, slope, surface rock cover, texture, color, and nature of the parent material. This indicates a predictive capability for the satellite data for mapping rangeland soils.

Identification of subtle differences between mapping units is often possible with spectral data.

Under the rangeland conditions where these studies were conducted, the type and/or color of the geologic parent material was the dominant factor affecting Landsat spectral data. This is restricted to vegetative cover less than about 25% and elevations from 700 to 1800 meters.

VI. CONCLUSIONS

As a result of more than three years of field and laboratory studies, in cooperation with the previously mentioned soil scientists, agencies, and institutions, the following conclusions can be drawn:

The biggest obstacle to this technology being accepted and used is the lack of training of field soil scientists to understand this information. The data and the form it is presented in tends to be confusing, and a field scientist must have an open mind, be knowledgeable in extracting information from spectral maps, and have a keen interest in using the information.

Spectral maps show a very positive correlation with grey tones or color patterns on photographs, and are an excellent auxiliary tool to locate boundaries of mapping units for natural resource inventory mapping.

The spectral maps can aid in the location of representative sites for pedon descriptions. This is largely due to a consistent relationship between such sites and the relatively uniform spectral categories.

Spectral data can be used for quality control and map correlation studies in the field. This should be particularly useful to state and regional staff as they monitor the on-going soil mapping activities.

Remotely sensed computer processed information is only a supplement to all the materials that are presently employed in making a survey. It will not replace any of these. The information can provide additional information to the soil scientist and assist him to do his job better.

In addition, studies conducted so far indicate that Landsat spectral data have important predictive capability. The approximation of earth surface feature values prior to on-site investigations will greatly aid the field soil scientists in their work. These data may help in selecting sites for mapping unit descriptions, determining the quantitative values of mapping unit components and inclusions, and contribute to speedier and more efficient quality control during and after the mapping process.

The question of projected costs is frequently raised. This research did not consider this aspect, mainly because of its experimental nature. Future studies must address this question, but it needs to be evaluated with respect to the conclusions stated above, and related to an operative soil survey program rather than as experimental research.

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