ALTERNATE DATA SOURCES FOR SOIL SURVEYS ON RANGELAND

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FOR SOIL SURVEYS ON RANGELANDS

By Emil H. Horvath[1], Albert A. Klingebiel[2],

Donald G. Moore[3], and Eugene A. Fosnight[1]

ABSTRACT

Soil information is an essential theme in a digital information base for land management and resource monitoring, but public land management agencies seldom have detailed soil maps available for all of the area under their administration. Most of these agencies conduct soil surveys on a scheduled basis, but escalating costs and declining budgets are reducing the number of surveys that can be scheduled.

Digital elevation and satellite spectral data are available or are obtainable for all areas in the continental United States and may be used as an aid to produce soils data. A study was conducted in the Grass Creek Resource Area in north-central Wyoming to assess the utility of incorporating digital elevation and Landsat data into an information base for soil survey and to evaluate the usefulness of these data as an input to an order-three soil survey.

Slope-interval maps were produced from digital elevation data and topographic maps of three 7.5-minute quadrangle areas. These slope-interval maps were then overlaid on orthophotoquadrangles and used to produce photo-interpreted physiographic maps. These physiographic maps were digitized into a data base and used with Landsat multispectral scanner data to produce tabular summaries that describe each map polygon in terms of physiographic unit, slope, aspect, elevation, area, and spectral values. A good relationship was found between the physiographic units and soil mapping units

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defined during a conventional soil survey, and between the Landsat spectral categories and existing vegetation communities. Field evaluations confirmed the feasibility of using this approach for producing physiographic maps as an aid for mapping soils and range sites. The project is a cooperative investigation of the Earth Resources Observation Systems Data Center of the U.S. Geological Survey, the Soil Conservation Service, and the Bureau of Land Management.

INTRODUCTION

The need for information about soils when making land management decisions has long been recognized in the United States. Soil surveys are a part of land management plans and have been incorporated into data bases for this purpose since the 1800's. Public land management agencies, however, do not always have detailed soil maps for all the land that they administer. They conduct soil surveys on a scheduled basis; however, escalating costs and declining budgets limit the area that can be surveyed.

Various remote sensing techniques and different types of remotely sensed data have been used as tools for soil surveys, effectively reducing the field time required by increasing the efficiency of the survey procedures (2,4,10). Of the five soil-forming factors, none is as evident on western U.S. rangelands as topography or relief, thus soil scientists rely heavily on the relationships between soil patterns and physiography during the photo-interpretation process that accompanies a soil survey (5). Slope and aspect are closely associated with soil depth and available moisture, which in turn influence the kind and the amount of plants that will grow on a given site.

Recently, digital information systems that contain information about administrative and political boundaries, vegetation, geology, and soils have been established for much of our public land (6,7). These data are used in the decision-making process, and during this process the soils data frequently are indispensable (3). Geographic information systems have been used to derive land management information; however, the same approach may assist in deriving the basic resources data necessary as information layers by combining two or more layers of data. An example is the use of multispectral Landsat and digital elevation data to derive a map of ecologically significant vegetation communities (3).

Digital elevation (U.S. GeoData) information is available or obtainable for areas in the continental United States. At a scale of 1:24,000, with a vertical resolution of one meter (1,11) these data meet national map accuracy standards. The data are produced and marketed by the National Cartographic Information Center in Reston, Va. These elevation data may aid in reducing the field time necesary to achieve the goals of a soil survey without compromising the currently accepted standards of accuracy. The objective of this study was to assess the utility of incorporating digital elevation and Landsat spectral data into a digital information base for an order-three soil survey.

2

DESCRIPTION OF THE AREA

The Grass Creek Resource Area (GCRA) is located in the Bighorn basin in west-central Wyoming and extends from the Bighorn river on the east to the Wood River on the west. Owl Creek is the southern boundary and the Greybull River forms the northern boundary. Elevations range from about 1,300 m at Greybull to over 3,000 m in the Absaroka Mountains in the southwest corner of the resource area. Temperature extremes range from over 40° C. to record lows of -45° C. Mean annual precipitation ranges from 110 to 450 mm, with the most precipitation occurring at the higher elevations.

Three 7.5-minute quadrangles within the GCRA were selected for this project on the basis of differences in landscape, soils, and vegetation (Fig. 1).

Sucker Dam quadrangle is comprised of mostly level topography, with elevations from 1,300 to 1,600 m and annual precipitation from 112 to 200 mm. The dominant vegetation communities are associations of bluegramma and cactus, sagebrush, Gardner's saltbush, and mixed grasses. Dominant soils are associations of Torrifluvents, Torriorthents, Haplargids, and Natrargids (8).

Gillies Draw quadrangle has level to rolling topography, with elevations that range from 1,600 to 2,000 meters and mean annual precipitation from 225 to 337 mm. The vegetation on this quadrangle is very similar to that of Sucker Dam, but larger areas are dominated by sagebrush communities. The soils are less affected by problems of salinity than those on the Sucker Dam quadrangle, and the dominant Great Groups in the area being primarily Torriorthents, Haplargids, and Camborthids.

Soapy Dale Peak quadrangle has rolling to steep topography in the north half of the quadrangle, and steep to very steep terrain in the south half. Precipitation averages 360 to 450 mm annually, and elevations range from 2,200 m to 3,000 m. Mixed grass communities occur on the non-forested hilltops and valleys, the latter frequently being heavily invaded by sagebrush. Forest communities vary from Juniper and Limber Pine associations to Limber Pine and Ponderosa Pine mixes.

THE DATA BASE

An existing digital data base for the Grass Creek Resource Area contained information on administrative boundaries, Landsat multispectral data for June 8, 1978, Landsat multispectral data for September 9, 1978, digitized order-three soil survey boundaries, precipitation zone boundaries, vegetation, and range capability classes derived by merging soil and vegetation data (3,8). All data had been geometrically corrected and geographically referenced to a Universal Transverse Mercator projection mapping base.

Digital elevation data (U.S. GeoData) for the three quadrangles were obtained from the National Cartographic Information Center in Reston, Virginia, (1,11). The 1:24,000 scale elevation data exist on a 30-meter grid in the Universal Transverse Mercator projection. These elevation data were used to generate slope maps, effectively adding new information to the data base. The algorithm used to compute slope for each pixel from this data (Fig. 2) used an average value of slope that was calculated as rise over 100 units of run for
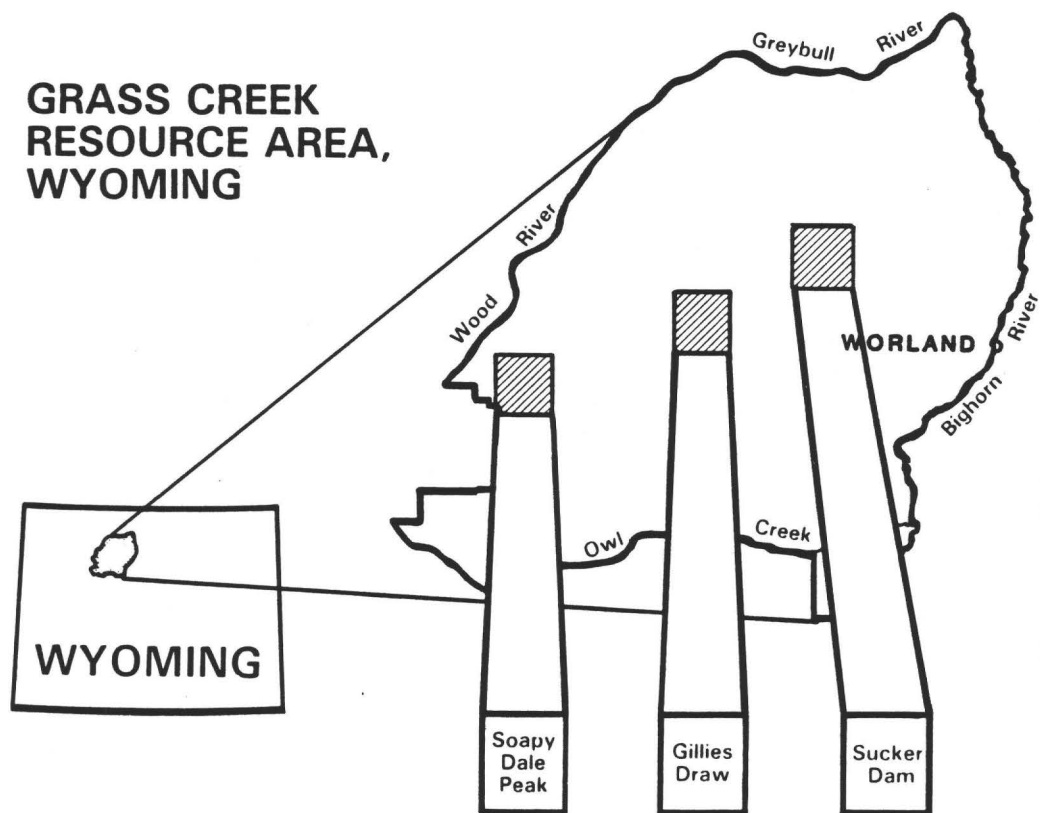
GRASS CREEK
RESOURCE AREA,
WYOMING

WYOMING

Greybull   River

Wood   River

WORLAND

Bighorn   River

Owl   Creek

Soapy
Dale
Peak

Gillies
Draw

Sucker
Dam

Figure 1.-- Location of the Grass Creek Resource Area and of the three
7.5-minute quadrangle areas that were selected for this study.

4

A	B	C
D	E	F
G	H	I

The Slope of E $= 100 \times \sqrt{\sum_{i=1}^{4} v^2}$

where:

$$v_1 = \frac{A-E}{\overline{AE}} - \frac{I-E}{\overline{IE}}$$

$$v_2 = \frac{B-E}{\overline{BE}} - \frac{H-E}{\overline{HE}}$$

$$v_3 = \frac{C-E}{\overline{CE}} - \frac{G-E}{\overline{GE}}$$

$$v_4 = \frac{F-E}{\overline{FE}} - \frac{D-E}{\overline{DE}}$$

Figure 2.—Computation of slope from digital elevation data, where slope is calculated as percent in units of rise per hundred units of run in eight directions and then averaged for each element.

5

eight directions from each 30-meter grid cell. Using slope breaks that were desirable for soil mapping slope interval maps were produced for each of the three 7.5-minute quadrangles, with consideration for the differences in physiography between the three quadrangles. For example, narrow slope classes were selected for the more gentle terrain in the Sucker Dam quadrangle, and broader categories were chosen for the steeper areas, such as those found in the Soapy Dale Peak quadrangle. Care was taken to avoid using slope classes that would dissect similar types of physiography. Thus, the slope classes selected for Sucker Dam were 0-2, 3-7, 8-15, 16-30, and greater than 31%; the slope classes selected for the Gillies Draw quadrangle were 0-3, 4-12, 13-25, 26-40, and greater than 40%; and the slope classes for Soapy Dale Peak were 0-5, 6-15, 16-40, and greater than 40%.

To avoid incorporating some unwanted detail in the slope-class maps, a smoothing algorithm to eliminate areas smaller than 10 acres was applied to the images before printing the slope-class maps (9). Figure 3 is an example of a slope-class map for a portion of the Soapy Dale Peak quadrangle.

LANDSAT DATA

Using the June 8, 1978, Landsat multispectral scanner data for the three quadrangles, a clustering algorithm was used to separate fourteen spectral categories. A maximum-likelihood algorithm was then used on the four-band spectral data to generate spectral maps, wherein areas are depicted that are relatively uniform in terms of the multispectral data (9). The spectral maps were color-coded to identify fourteen spectral classes and printed at a scale of 1:24,000. These types of maps have been used successfully to determine the placement of pedon description sites and to help delineate soil-vegetation interactions (3,4). To aid in the interpretation of these spectral maps, a transformation was employed to calculate the relative brightness and greenness of the individual spectral classes. These transformations were of the form:

$$\text{Brightness} = (MSS4 + MSS5 + MSS6) / 3, \text{ and}$$
$$\text{Greenness} = (MSS6 + MSS7 - MSS5) / 2$$

where MSS4, MSS5, MSS6, and MSS7 are the radiance values for the four Landsat multispectral scanner bands. The brightness and greenness values were calculated for the unclassified spectral data and later used in the tabular summaries.

PHYSIOGRAPHIC MAPS

Orthophotoquads served as the base on which the lines resulting from the subsequent interpretations were drawn. The slope-class maps were plotted on acetate, overlaid on topographic maps and traced, correcting for displacement of polygons that may have occurred during the smoothing. At the same time landforms that may have been related to the different slopes are considered. A portion of this re-traced slope-clas map is shown in figure 4 overlaying a topographic map. This new slope-class overlay was placed on the orthophoto to further interpret the slope-class delineations with respect to surface grey-tones and physiography. The resulting slope-class maps depict polygons within given slope intervals that also delineate certain types of landforms. An example of a finished slope-class map, extracted for an area within the Soapy Dale Peak quadrangle, is illustrated in Figure 5.
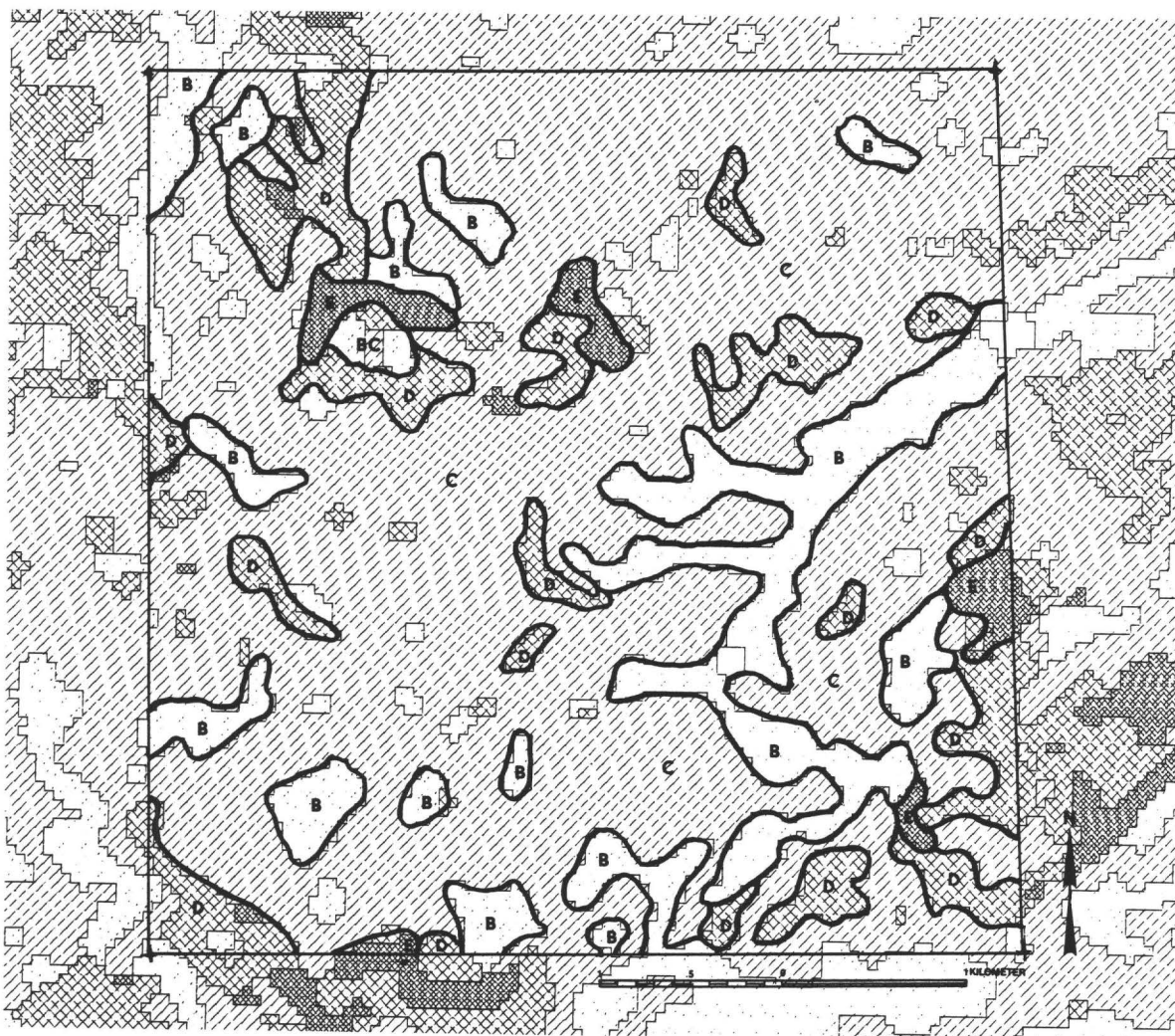
Figure 3.—Example of a plot of a smoothed digital slope-class map of a
portion of the Soapy Dale Peak quadrangle where larger polygons have been
traced to aid in the interpretation.

7
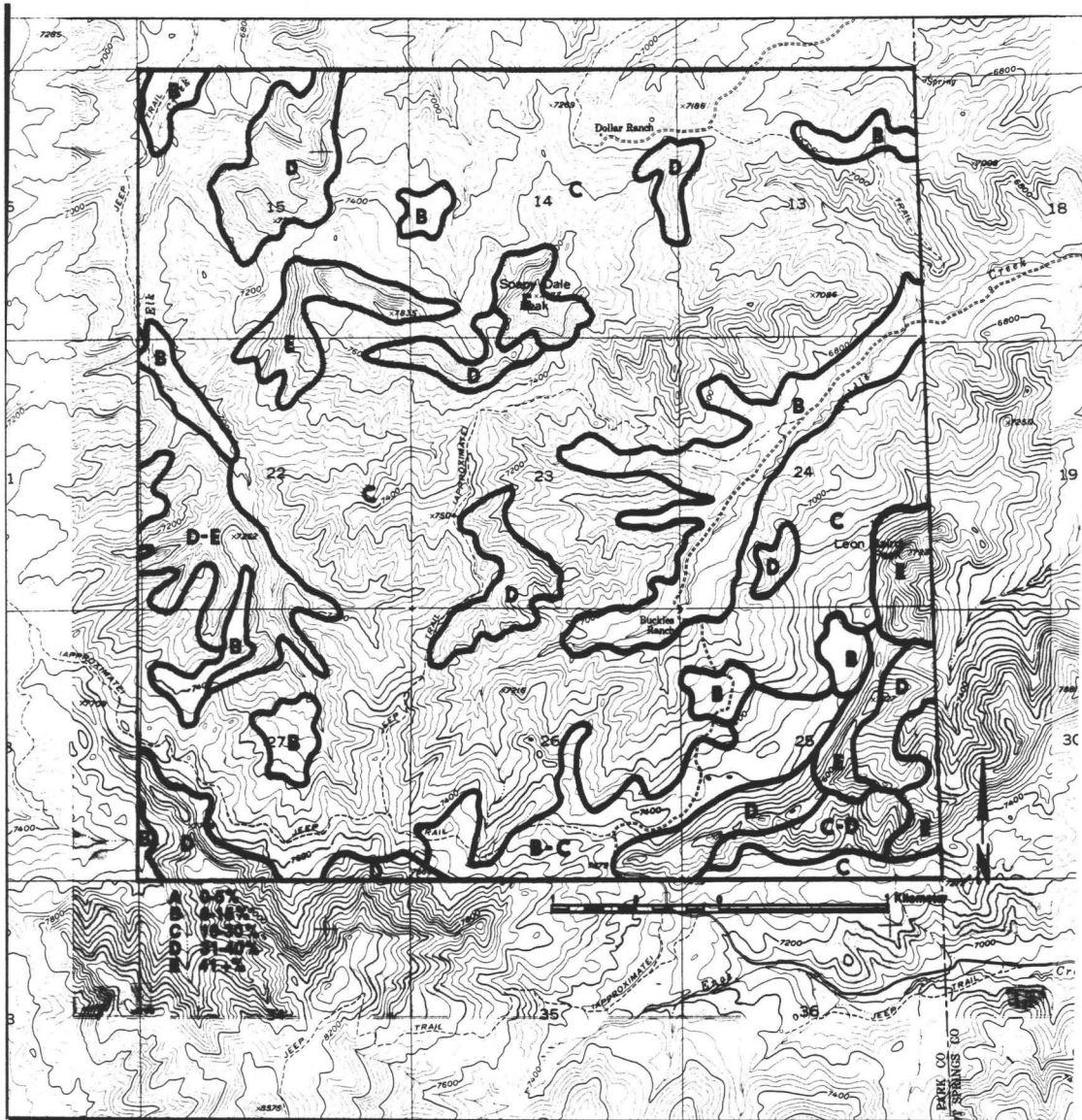
Figure 4.—Example of a slope-class map overlaying a portion of the Soapy Dale
Peak topographic map, where the lines of the digital slope class product
were adjusted to correct for displacement of polygons that may occur
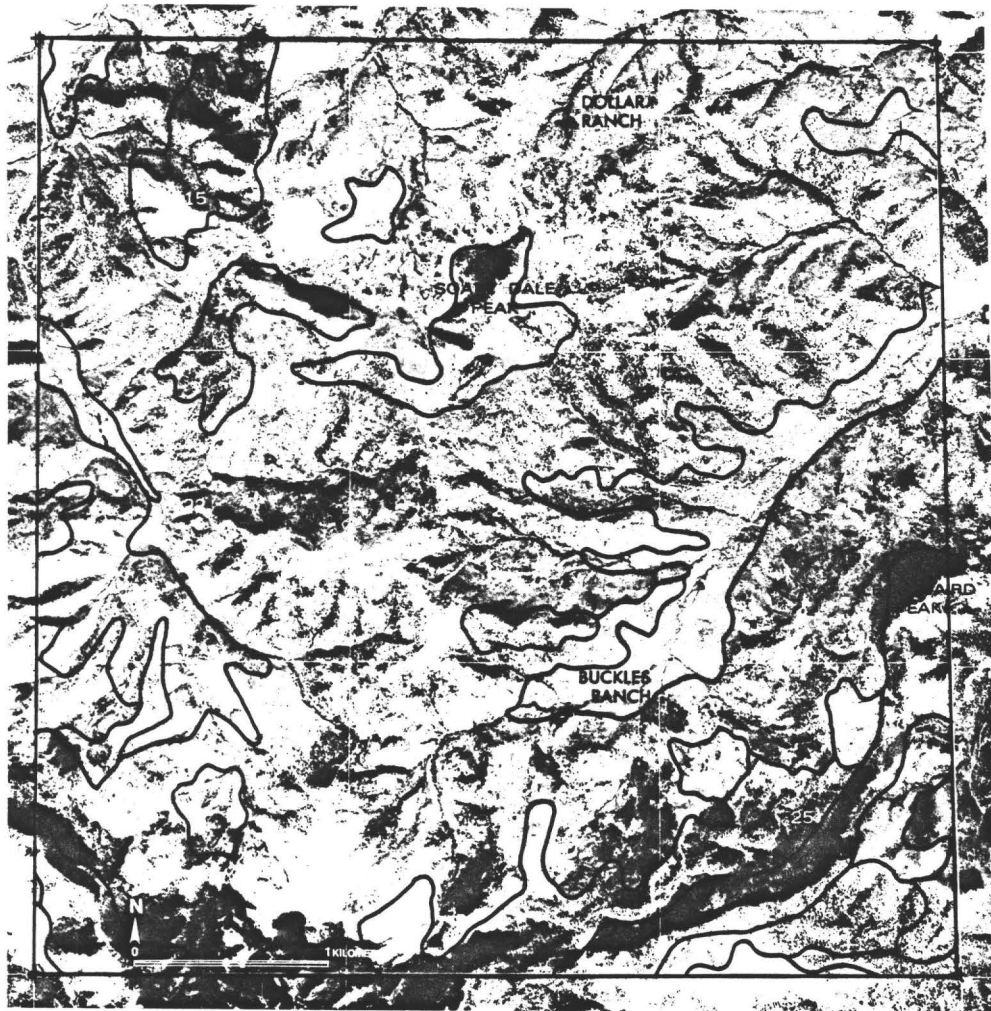during area filtering.

8

Figure 5.--Example of a finished slope-class map for a portion of the Soapy
Dale Peak quadrangle, generated by overlaying a plot of the digital
slope-class map on the orthophoto and tracing all units considered
important for mapping physiography.

The revised slope-interval maps were then overlaid on the orthophotos
during a photo interpretation process that resulted in physiographic maps.
Each mapping unit was labeled according to soil subgroup, parent material,
landform, and slope category. The soil subgroup and parent material
information was derived from existing maps of the area, and the slope category
information was derived from the digital slope-class maps. The soil
association and geology maps were consulted during the interpretation.
Table 1 give an example of the tabular result of this interpretation, and an
excerpt from a finished physiographic map is presented in Figure 6.

TABULAR SUMMARIES

The physiographic maps were digitized and entered into the data base,
after which information from other data layers was listed by physiographic
unit (Table 2).

On these tabular summaries, several layers of information within the data
base are examined with respect to specific delineations. The mapping unit
number of the polygon is listed so that it may be cross-referenced to the
tabular information resulting from the interpretation (Table 1). Area, mean
percent slope, dominant aspect, and mean elevation are listed for each
polygon, as are the Landsat data in terms of brightness and greenness
transformations and occurrence of various spectral classes. By studying the
number of different classes and the number of spectral-class polygons of
various dimensions that occur within physiographic unit polygons, clues may be
obtained about the relative complexity of the surface patterns within a
polygon.

FIELDWORK

The physiographic maps were used as overlays on the orthophotos and on the
fourteen-class spectral maps during the field checking. Twenty sites were
selected for each 7.5-minute quadrangle, with the intention of sampling as
many different types of physiography and soils as possible. Each site and the
surrounding area were located on the physiographic and spectral maps and, once
located in the field, evaluated with respect to soils, physiography,
vegetation types, and range sites. A helicopter was used as a field vehicle
to reach areas that were not readily accessible by car.

RESULTS

During the fieldwork a good relationship between the physiographic units
and soils was found. The spectral maps frequently gave clues to patterns of
vegetation types and to soil mapping unit inclusions within physiographic
units. The slope categories, derived from the digital elevation data as
represented on the physiographic map, were found to be consistently accurate
on all three quadrangles with the exception of the nearly level (0-2%) areas
on the Sucker Dam quadrangle. When level areas had been identified on the
digital slope map, they were found to be correct; however, many inclusions of
level areas occurred within the 3-7% slope category. On all three quadrangles
the spectral classes that occurred within the physiographic units helped
identify range sites. This was true where the spectral classes related to
soil/vegetation interactions that identified different range sites. Figure 7
is a portion of the Soapy Dale Peak quadrangle where the physiographic map was

10

Table 1.--Example of tabular results from image and map interpretation, using slope-class overlays on an orthophoto, for a portion of the Soapy Dale Peak quadrangle.

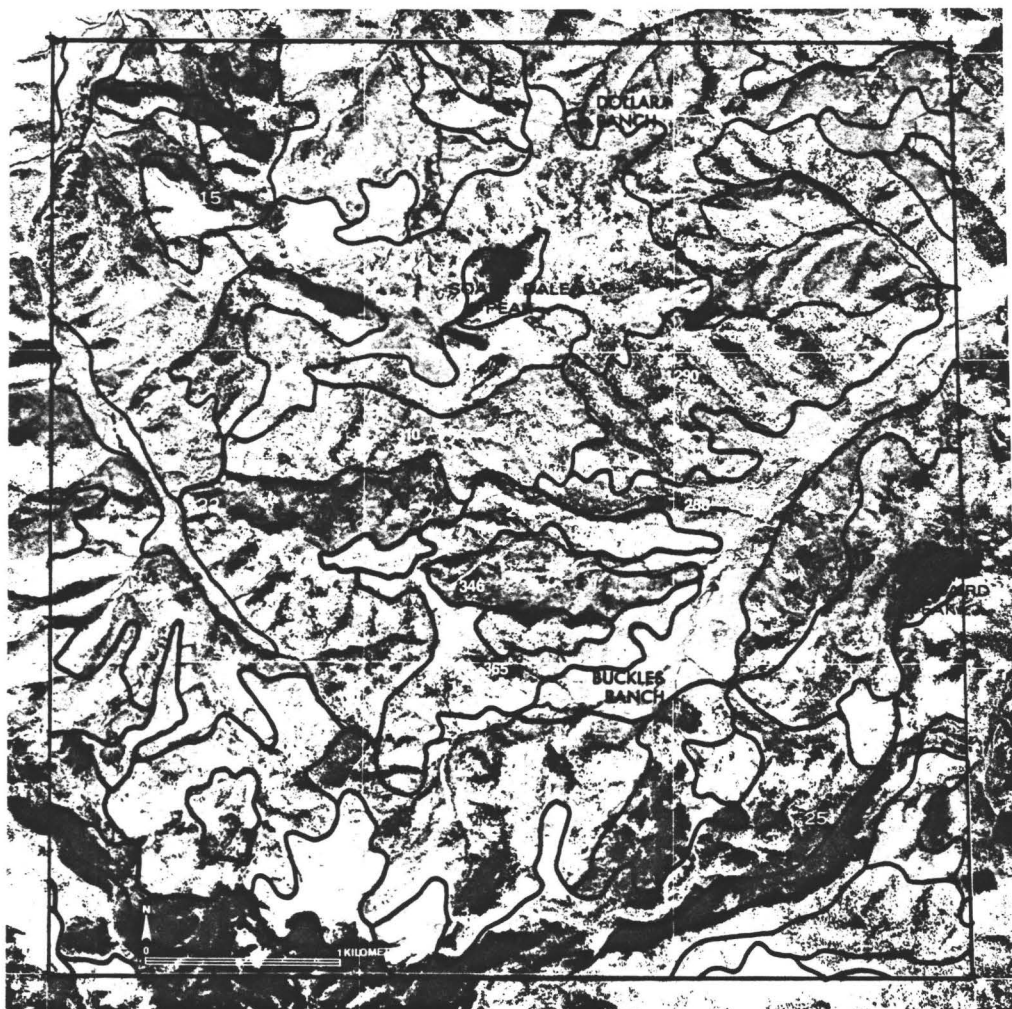| Physio- graphic Unit	Soil Subgroup	Slope Category (percent)	Parent Material	Landform
209 C	Ustic Torriorthents	16-40	Residuum from shale and silt- stone	Moderately steep to steep
211 B	Borollic Haplargids	6-15	Alluvium from sedimentary sandstone and shale	Sloping alluvial fans and bottoms
222 C	Argic Pachic and Argic Lithic Cryoborolls	16-40	Fine-grained igneous rocks	Moderately steep to steep mountain slopes
225 C	Argic Pachic Cryoborolls	16-40	Alluvium from clay shale	Moderately steep to steep mountain slopes

11

Figure 6.—Portion of a finished physiographic map for the Soapy Dale Peak quadrangle overlaying an orthophoto. The five polygons that have been labeled are described in Table 2.

12

Table 2.--Portion of a tabular summary generated for the Soapy Dale peak quadrangle, listing information from the digital data base for the five polygons numbered on the physiographic map in Figure 6.

(SD indicates standard deviation)

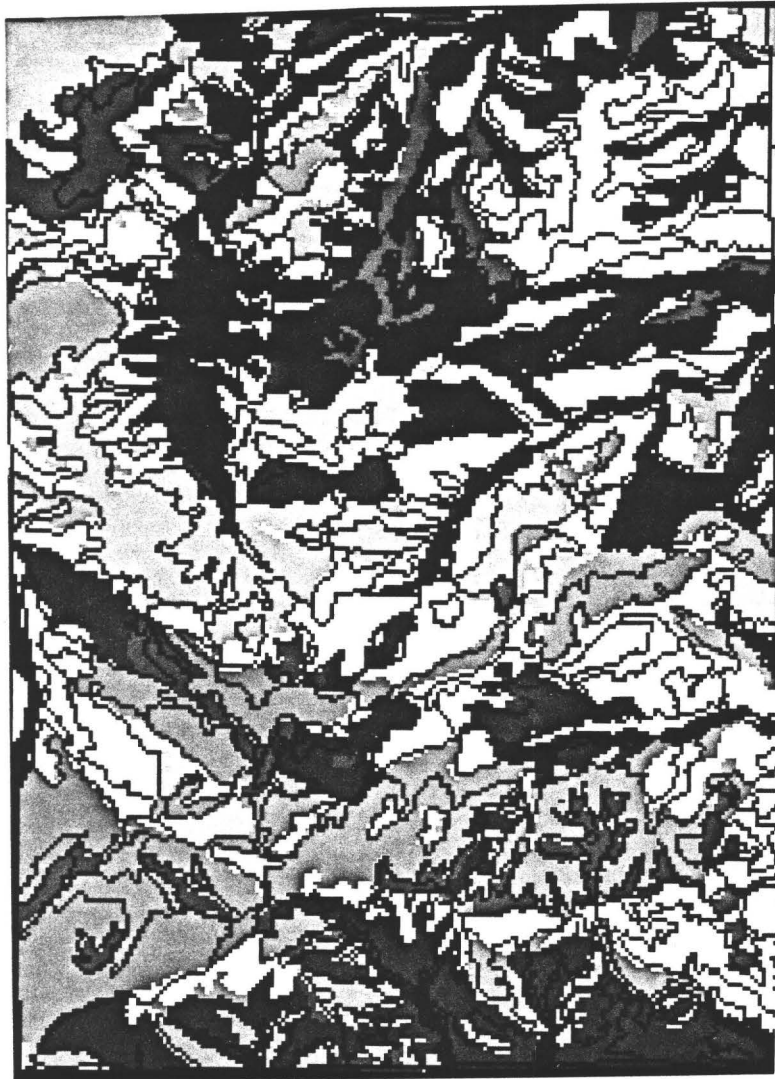| POLYGON DESCRIPTORS				TERRAIN DATA			SPECTRAL DATA				SPECTRAL CLASSES							
							Brightness		Greenness		Dominant		Secondary		No. Polygons			
Polygon No.	Physio- graphic Unit*	Total Area (acres)	Precipi- tation Zone (inches)	Mean Slope %	Dom. Aspect	Mean Elev. (feet)	Mean	SD	Mean	SD	Class	Area %	Class	Area %	1 Acre	2-30 Acres	31-60 Acres	>60 Acres
258	211 B	379	16-20	12	East	6812	25	4	23	3	5	40	3	26	0	4	2	2
290	209 C	247	16-20	25	South	7025	27	3	25	2	5	46	3	25	0	1	1	2
310	225 C	185	16-20	23	South	7307	25	4	23	3	5	55	3	21	1	3	1	1
346	222 C	96	16-20	23	North	7118	26	4	24	3	3	50	5	22	0	5	1	0
365	209 C	122	16-20	25	East	7191	26	4	25	2	5	46	3	23	2	4	1	0

*See Table 1.

13

Figure 7.--Physiographic map (black lines) for the Soapy Dale Peak quadrangle placed over an order-three soil survey (colors), where different colors represent different soil mapping units and the black lines delineate different physiographic units.

14

overlaid onto an existing order-three soil survey map, that had been generated by conventional soil survey methods. This overlay provides a qualitative comparison between the two maps. It was noticed that there are more lines on the physiographic map than on the soil survey map. In many instances lines that were present on the physiographic map but not on the soil survey map were due to slope differences that were evident in the terrain information.

CONCLUSIONS

Physiographic and spectral maps produced from digital terrain and Landsat multispectral scanner data identify slope interval categories and delineate units that relate to soils and range sites. When the two products were used in the field with the associated tabular summaries, they were found to be useful when delineating and labeling soil taxonomic units.

It is important to keep in mind the interpretation steps that the resource scientist has to take at the various levels of building the data base and during the mapping process. These steps are essential in the production of physiographic maps, where all the factors of soil formation as well as the genesis of the soils should be taken into consideration.

Preliminary field evaluations suggest that the use of physiographic maps and related data as discussed in this report could improve the quality and reduce the costs of making order-three soil surveys commonly used in rangeland management.

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16