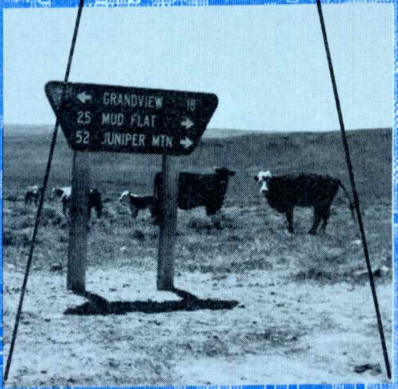
LARS Contract Report 082879

An Analysis of Landsat Data for Soils Investigations on Federal Lands in Southwestern Idaho

by William D. Di Paolo



Laboratory for Applications of Remote Sensing
Purdue University
W. Lafayette, Indiana 47906 USA
1979

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William D. DiPaolo

August 1979

ADDENDUM

William D. DiPaolo is employed by the United States Bureau of Land Management - Department of the Interior. His current mailing address is:

U.S. Bureau of Land Management
Branch of Remote Sensing (D-234)
Building 50, Denver Federal Center
Denver, Colorado 80225

Preface

This report represents part of a one-year visiting scientist program at Purdue University's Laboratory for Applications of Remote Sensing (LARS). The objectives of this program were basically twofold. First, become familiar with the technology including the LARS hardware and software; and second, demonstrate the applicability of this technology to the soils programs currently taking place on lands managed by the U.S. Bureau of Land Management in the western United States.

The actual time spent on the work contained in this report was approximately 7 months. This included two visits to the field for one week in November and 2 weeks in May. It should be noted that work in this area is still progressing and much still remains to be learned about the spectral nature of this environment and its applicability to the current soils effort. It was not the intent of this work to produce a third order soil survey map, but rather a map of separable spectral classes from which inferences could be made as to soil characteristics. This would then, hopefully, serve as a tool which would help the soil survey crews in their mapping effort to make a third order survey by increasing productivity, accuracy, and efficiency. These factors are becoming increasingly important due to the magnitude and scale of resource inventory programs scheduled in future years on BLM lands. With advances being made in analysis techniques, and the scheduled launch of Landsat-D in 1981 with its increased spectral capabilities and resolution, there is great potential for the use of this technology in future Bureau programs.

As one reads through each section of this report it will be seen that each step in the analysis procedure is important. Based on the experiences encountered during this project suggestions and recommendations are also made. Due to the short period of time available for the writing of this report, an adequate review or editing could not be made. Therefore, apologies are made here for any errors that may be found. It was the intent in this writing to document as many observations as possible both concerning laboratory and field investigations. It is hoped that future analyses in this region will be guided by this work, and also that the field observations and correlations made will help the soil scientist to better interpret the utility of this product.

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Abstract

An area located about 60 miles south of Boise, Idaho, encompassing over 250,000 acres, was analyzed using Landsat digital data. Assessing the applicability and potential contributions this technology could make toward the current third order soils survey effort in this region was the main purpose of this work. The study area selected is diverse in both cover type and topography. Elevations range from about 2300 feet in the lowlands around the Snake River to over 7000 feet in the mountain and plateau areas. The area consists of soils that have been derived from granitic and volcanic bedrock, fluvial and lacustrine sediments, loess, and alluvial fan deposits. Vegetation types vary in this area, and in many instances changes in natural vegetation in this area can generally be correlated to changes in soil type.

Many different analysis approaches and techniques were used, along with four different classification algorithms. These analysis techniques and different classifiers are discussed in this report.

Field work was performed to: 1) determine the cover types present in the study area and correlate these with the spectral classes generated at the lab; 2) to determine the factors contributing to the spectral response in this environment; and 3) to determine how these spectral classes and associated cover types would help in defining or delineating soil characteristics which would facilitate the field work involved in a third order soil survey. Each of these points is discussed in this report and a description of the spectral classes is given along with observations on the factors influencing the spectral response in this area.

Results of this study are given including some examples of classification output along with corresponding air and ground photos. Class acreages for each sample area and the entire study site are also given. Recommendations for future work and analysis procedures are presented along with an assessment of the potential contributions Landsat data can make to third order soil surveys on Federal lands in the western United States.

Acknowledgements

With special thanks and warm feelings to all those graduate students and staff at LARS who took time to assist me when I needed help and to answer my many questions. Thank you very much.

I would also like to thank the soil scientists from the U.S. Bureau of Land Management, Boise District Office, who assisted me in the field and showed a high degree of professionalism and patience during our long hours of field work. It is for these field personnel that this work is dedicated.

Finally, special thanks go to Glenda Bauer for the tedious typing of this report.

Introduction

The Bureau of Land Mangement, in the Department of the Interior, has the responsibility for the management of 474 million acres of public lands in 11 western states and Alaska. In addition, the Bureau has the responsibility for managing an estimated 500 million acres of the Outer Continental Shelf. The management of these lands entails decision making with respect to the multiple use of the land. Such uses would be in the fields of mining and minerals, oil and gas leasing, livestock grazing, timber production, fish and wildlife, outdoor recreation, watershed protection, wilderness preservation, environmental protection and enhancement, river basin planning, and general land use classification under the concept of multiple use.

In order to carry out the wide multitude of programs on the lands under its management, the Bureau has had to collect and handle large quantities of information. Within the Bureau over the past few years there have been many efforts toward the automation of an information system and the use of remote sensing to satisfy some of these information needs. An example would be of the work being carried out in the California Desert planning program using Landsat information to classify approximately 25 million acres.

In 1976 the Bureau entered into an agreement with NASA to begin a 3-phase ASVT effort (Application System Verification Test) to design and demonstrate a system capabile of satisfying as many of the BLM's information needs as possible using remote sensing as the primary data source. The main thrust of this study is in the identification and inventorying of wildland vegetation.

The first phase, which has been completed, was in Alaska, and the second phase is near completion in the northwest corner of Arizona. Phase 3 is just beginning in southwest Idaho, and encompasses an area of about 3 million acres.

This report concerns an analysis of a portion of this area to evaluate the feasibility of utilizing Landsat data for soils studies within this region. Soils investigations using this technology in this region have never been performed, so much still remains to be learned. It is hoped that future work in this area will benefit from the observations and results of this study.

The entire ASVT project site location is shown in Figure 1. The study area for the soils portion of this effort is located at the northern end of this area. It is located approximately 60 miles south of Boise, Idaho, south of the Snake River. It encompasses an area of about 254,655 acres. This general area was selected for this study by the soils staff at the Boise District BLM Office because of the diversity of soil types recognized within this area.

The terrain is diverse, and topographic elevations range from about 2500 ft near the Snake River to over 7000 ft in the mountainous areas. Precipitation ranges from about 6-14 inches in the lower elevations to over 20 inches in the mountains. Usually some isolated pockets of snow are found in the highlands well into May while temperatures in the lowlands are approaching 90° F. The summers are dry in this area with moisture occurring mainly during the winter and early spring.

Figure 1. Index map showing the location of the BLM ASVT Project area in the state of Idaho. The area encompasses over 3,000,000 acres.

An image of the study site is shown in Figure 2. This was generated from Landsat data (June 5, 1976) at a scale of 1:120,000. This shows band 7 (0.8-1.1μm), or the infrared region of the electromagnetic spectrum. Areas of green vegetation such as grasses, crops, or trees appear light on this image while water (the Snake River) is dark. The bright dissected lake sediments in the lowlands should not be confused with the light appearing vegetative areas in the highlands or the agricultural areas along the Snake River. The dimensions of this area are approximately 17½ miles wide and 22½ miles long.

Topographic elements within this area consist of dissected mountainous terrain and elevated plateaus to the south from which an older pediment surface has formed and alluvium has also been deposited toward the north. At the north end of the study area is the Snake River plain.

A geologic map of the study area is shown in Figure 3. The highlands are composed mainly of Cretaceous (~65my) granitic rocks exposed in the west and volcanic rocks dominating the mountain and plateau terrain to the south. The volcanics range in age from about 43my for the Challis Volcanics (rhyodacitic), to about 9-10my for the tuffaceous and rhyolitic rocks of the Little Jacks Formation, and 8-9my for the capping basalt flows. These higher areas are abruptly separated from the lowlands by normal faults which are downdropped to the north. Lacustrine and fluvial sediments of the Pliocene Chalk Hills Formation and the late Pleistocene or early Pliocene Glenns Ferry Formation underly the alluvium and loess deposited toward the Snake River from the highlands. These formations are exposed to the north where they have been dissected by drainages. Most of the soils within this area were generally formed in an arid environment. A generalized soils map of this area is shown in Figure 4.

Vegetative associations within the study site include the salt-desert shrub (hopsage-shadscale), big sagebrush-grassland, low sagebrush-grassland, grassland, juniper-sagebrush, and mountain brush. Where heavy domestic livestock grazing has occurred or where there have been fires, some native vegetative species have been replaced by invader species.

A June 5, 1976 Landsat-2 scene was selected for this study, and the data tape for this scene was used for this analysis. Aerial photography was flown over this area in mid-July 1976. The climatological data indicated that very little rain occurred during this period, so conditions were dry. Figure 5 is a color composite of the Landsat-2 scene used for this study. The study site can be seen located south of the Snake River. Analysis procedures were also started for a July 10, 1978 Landsat scene covering this area, but time did not permit the continuation of that analysis.

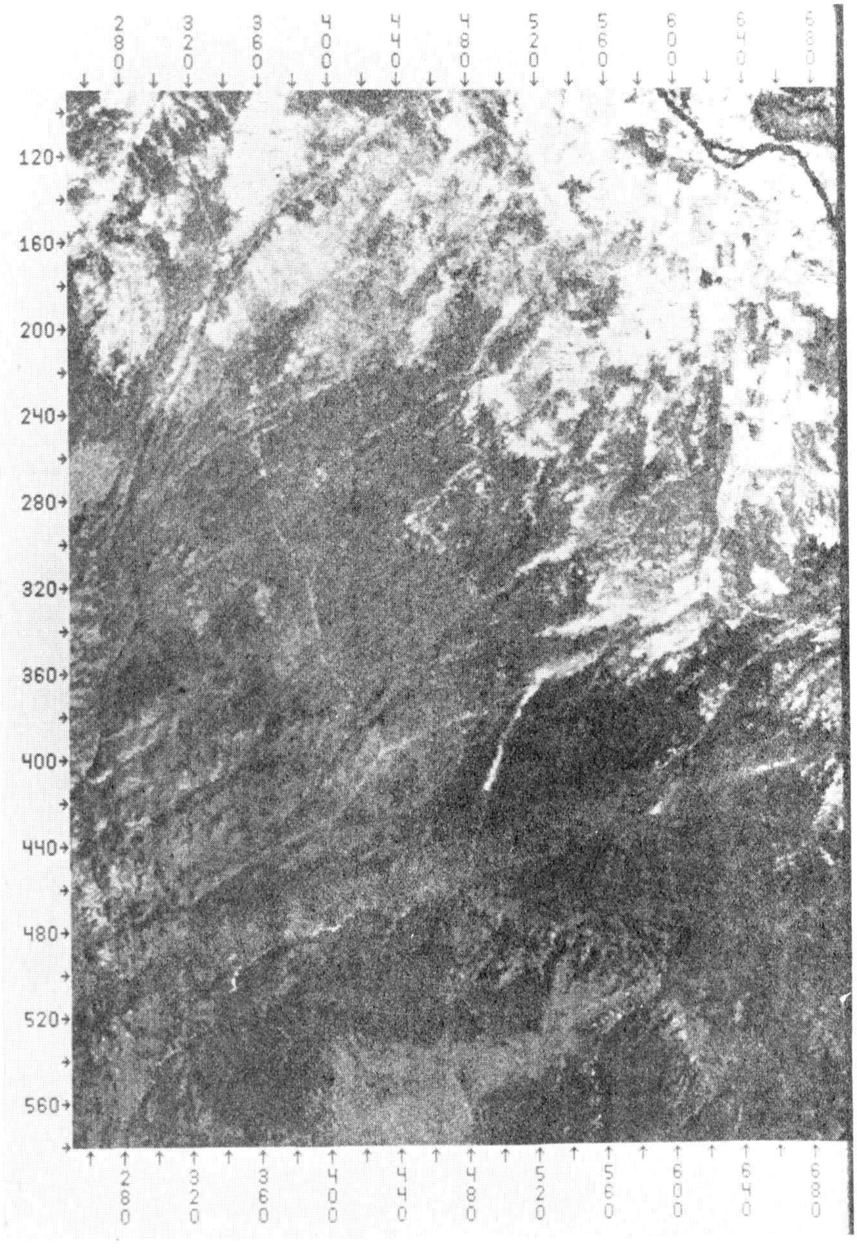


Figure 2. Band 7 of the study site encompassing an area of over 250,000 acres. This image was computer generated from a June 5, 1976 Landsat scene. Part of the Snake River can be seen in the upper right-hand corner.

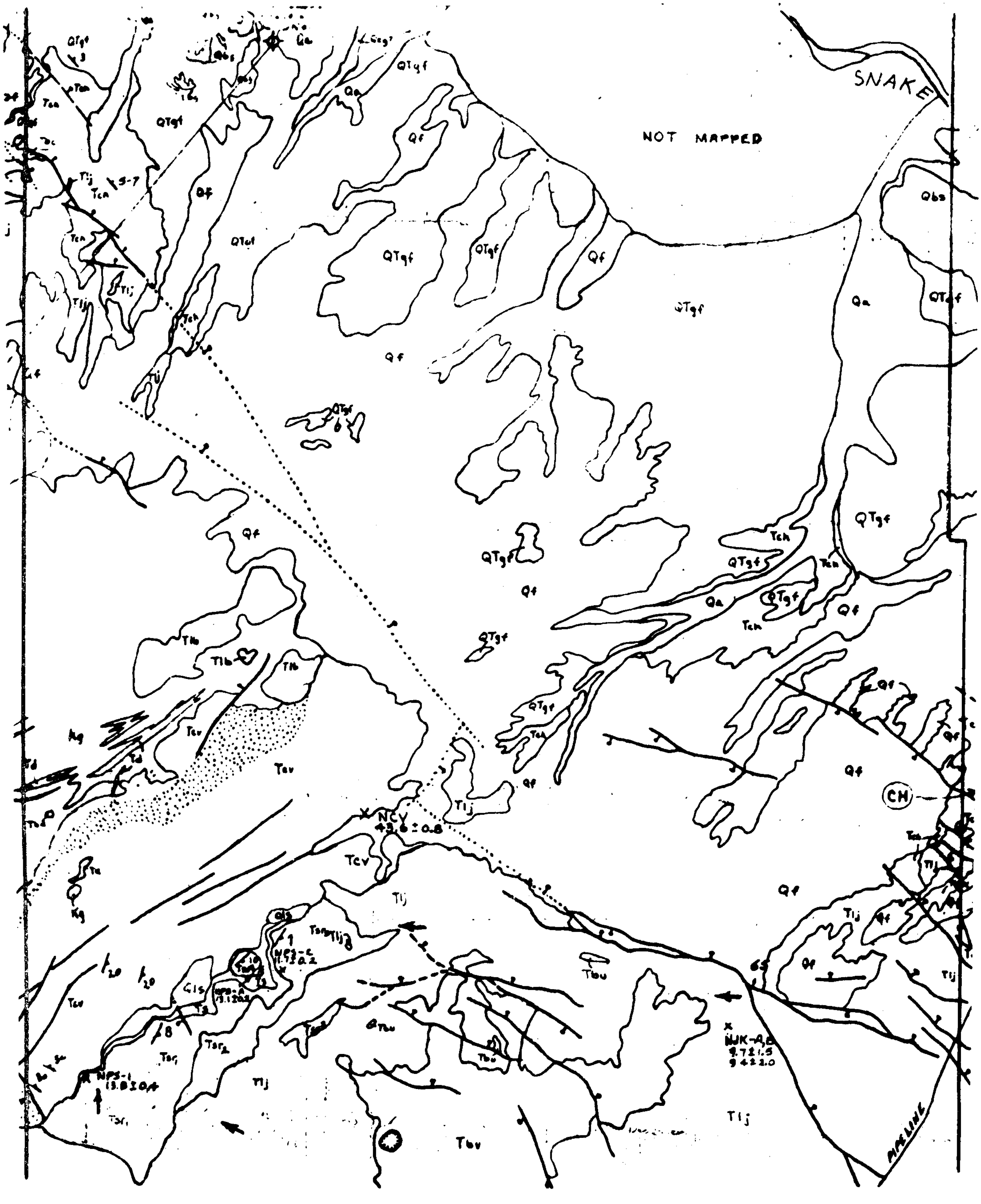


Figure 3. Geologic map of the study area.

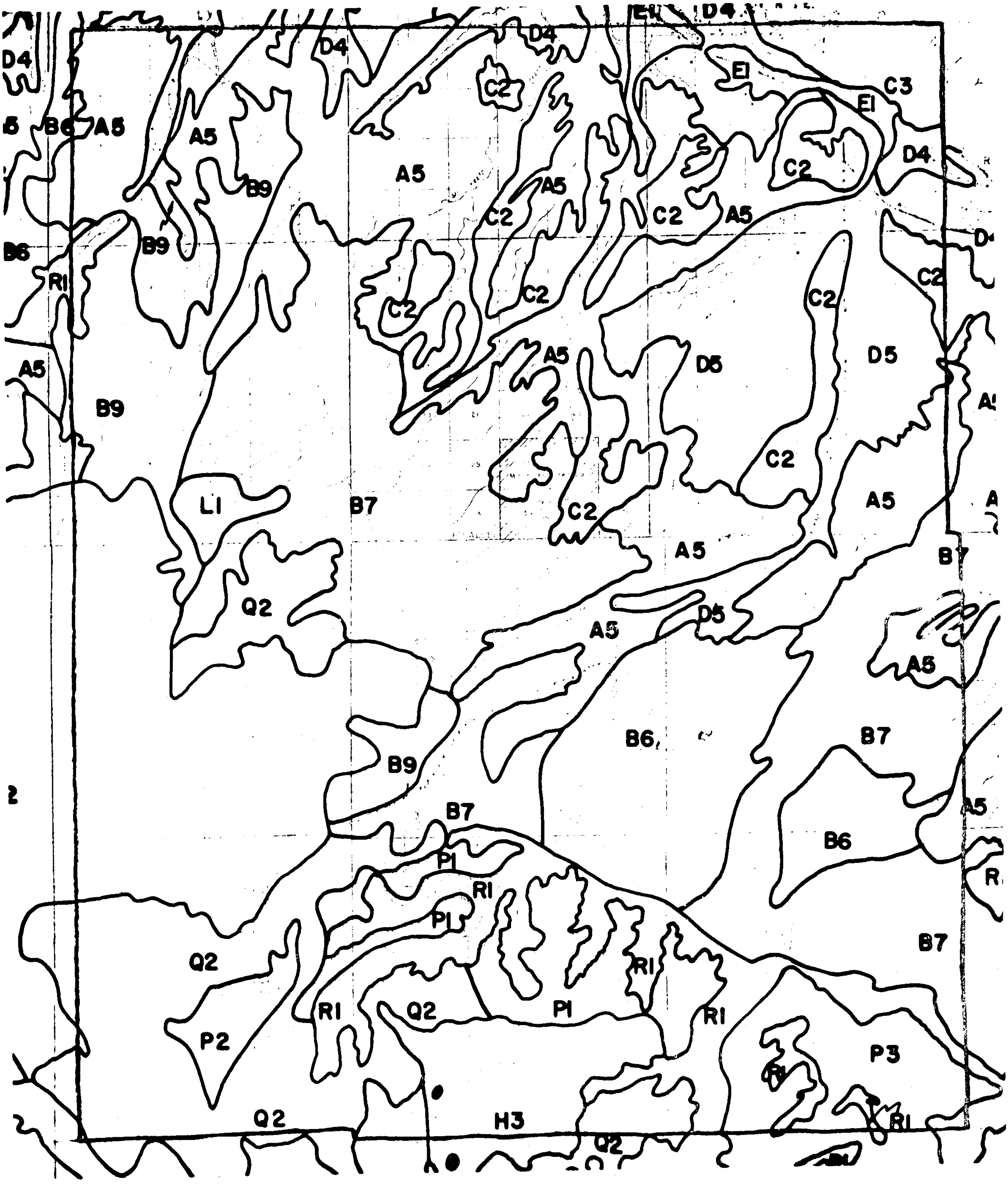


Figure 4. Generalized soils map of the study site.

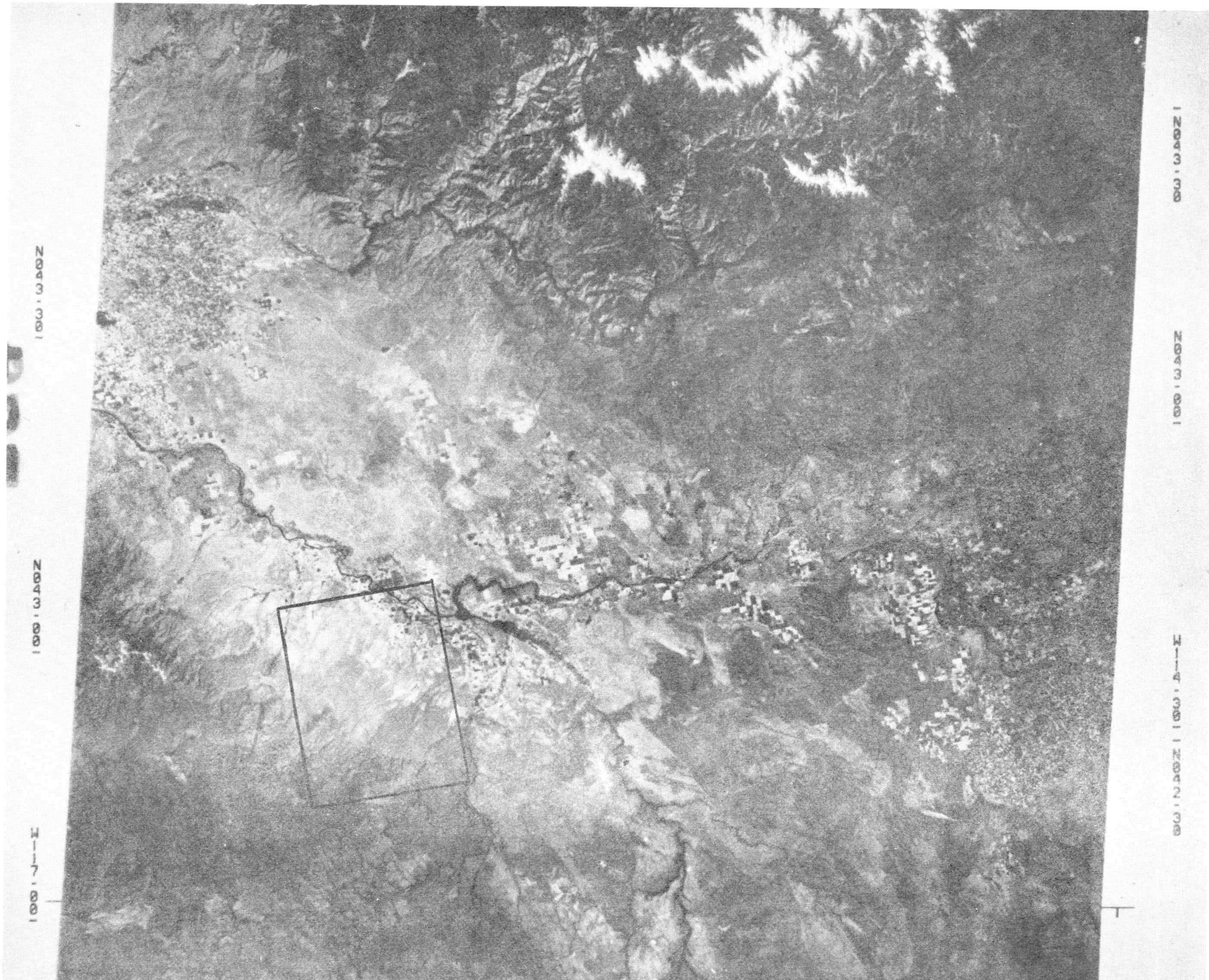


Figure 5. Color composite of the 6/5/76 Landsat-2 scene used for this study showing an outline of the study site.

Objectives

The major objective of this research was to see what information could be obtained from Landsat imagery and digitized data which would aid or could be incorporated in a third order soils survey for rangeland investigations. Therefore, it was not the intent of this project to produce a third order map, but rather to demonstrate the potential of this technology as a tool which might increase the efficiency, productivity, and accuracy of the soil survey crews, especially where large large acreages were involved.

Another objective was to determine the analysis techniques needed to produce a map containing representative and distinct spectral classes. Once these spectral classes were established, they were to be related to informational classes. Determining the spectral nature of these arid lands along with understanding the factors that contributed to the spectral response of the classes within this area was an additional objective.

These objectives would be met in a sequence in which each step would be important in obtaining a reliable result. First analysis procedures would be taken to produce spectrally distinct classes truly representing distinct cover types, being careful to have sampled all representative areas. Next, factors contributing to the spectral response of the cover types would be examined. Finally, with the requirements of the soil survey in mind, these classes and data from them would be arranged in such a way that the resource specialist would grain maximum benefit. Any limitations in using this technology or these methods would also be exposed.

Analysis Methods and Procedures

Table 1 is an abbreviated outline or list of most of the steps followed during the course of this analysis.

I. Study Site Selection

A. Meetings and discussions with field personnel

1) Discuss current field effort and information needs
2) State objectives of this project
3) Delineation of a general study site
4) Preliminary field reconnaissance
5) Obtain resource information and data for the study area

II. Acquisition of Ancillary Information and Landsat Imagery

A. Ancillary data

1) Color air photos (scale 1:31,680)
2) Topographic maps (scale 1:24,000 and 1:250,000)
3) Geologic maps and reports
4) County soils map and report
5) Ecological site descriptions and vegetation information
6) Correspondence with other researchers in this area

B. Landsat imagery

1) Obtain computer search of available Landsat imagery within this area from EDC
2) Select favorable scene dates based upon:

   a. percent cloud cover
   b. channel quality
   c. time period most favorable to resource enhancement
   d. climatological data

3) Select scene or scenes (if using multitemporal data)
4) Order CCT, images of the scene in each spectral band, and a color composite photo of the selected scene

III. State Analysis Objectives and Methods

Decide upon:
A. Supervised vs. unsupervised sampling approach
B. Stratification or boundary delineation within the study site
C. Multitemporal, digitized terrain data, or other resource overlays
D. Need for precision registration based on resource needs
E. Submit CCT for reformatting

IV. Selection of Detailed Study Site Boundaries

A. Find approximate line and column addresses for the study site
B. Submit this area for geometric correction, consisting of rotation, deskewing, and rescaling (No precision registration was required for this study)
C. Obtain lineprinter output of this area using PICTUREPRINT for channels 2 and 4

D. Identify topographic and man-made features on this output using air photos, topographic maps, and the Landsat image to delineate, by line and column addresses, the exact study site boundaries
E. Obtain output showing exact study site using GDATA

V. Examine Data

A. Obtain grayscale images of the study site in 4 spectral bands using GDATA

1) Look for bad data lines, clouds, shadows
2) Look for potential cluster sites

VI. Training - unsupervised multi-cluster block approach

A. Training areas or cluster blocks were selected based upon:

1) Diversity of cover type, i.e., representing a large number of different classes or cover types

a. Landsat, GDATA, and air photos were used to locate boundary areas or areas marking physiographic breaks
b. other ancillary data such as geologic and soils maps were used to locate sites with diversity in these areas

2) Landmarks (natural or manmade) which could easily be relocated on output, air photos, and the ground
3) Areas not containing bad data lines or clouds
4) Data well distributed throughout the entire study area and containing approximately 10-15% of the total points

B. Clustering - obtaining a spectral breakdown of classes within each individual training area

1) Using ancillary information (photos or maps), try to interpret or estimate the number of cover types or information classes in each area
2) This number is then increased 1½-2 times and used to specify the number of cluster classes requested in each area
3) A convergence factor of 98.5% is specified
4) Each class must contain a minimum of 40 points
5) Output products include:

a. a cluster map
b. a list of the number of points in each class, along with the means and variances for each spectral class
c. a table indicating possible class groupings
d. a statistics deck describing each spectral class

C. Identification of cluster classes

1) Use cluster maps and reference data in an attempt to assign informational names to spectral classes

a. use a Zoom Transfer scope when output products and air photos are at a different scale
b. have the air photo scale changed from 1:31,680 to 1:24,000 and then make a transparency of the computer output and overlay this directly on the air photo

2) Draw or generate calibrated spectral curves for each class showing the spectral nature of the class in all four channels
3) Using the RATIO processor, examine the ratios (VIS/IR) and magnitudes for each class

(Note: at this point in the analysis procedure field work would have aided in identification of the cluster classes)

VII. Merge Statistics from the Cluster Blocks into One Deck, Request a Cospectral Plot of Class Means, and Calculate Separability Value (D_T) for All Possible Class Pairs

A. Classes are pooled (statistically combined), separated, or deleted

1) Pooling decisions were based upon:

a. separability or transformed divergence value
b. class identification, both informational and spectral (spectral curves were referred to)
c. low variance for each class
d. low number of points per class

2) Classes were deleted when:

a. variances were very high
b. class identification was redundant or totally unknown
c. the number of class points was low

3) Classes were kept separate based upon:

a. the nature of their spectral curves
b. recommended computer groupings based upon a specified threshold value
c. high transformed divergence value (greater than 1500)

B. The steps in VII are repeated many times until all class pairs are separated by a transformed divergence value of 1500 or greater.

VIII. Classification

A. Each cluster area is classified using the MINIMUM DISTANCE to the means per point processor

1) Symbols are combined because:

a. speckled-appearing maps are difficult to interpret
b. 3rd order soil surveys require units having a minimum size of 10 acres
c. 16 symbols as a limitation on the Varian plotter

2) Then, the decision on which symbols to combine is based upon:

a. pairs with the lowest D_T value between them
b. those with the least amount of informational significance
c. those generally scattered among more homogeneous occurring classes

B. Cluster areas were reclassified using the ECHO classifier (Extraction and Classification of Homogeneous Objects) which is a spatial/spectral maximum likelihood classifier.

C. The entire study area was classified using CLASSIFYPOINTS which is a maximum likelihood per point classifier

D. Confusion in class identification prompted the creation of additional cluster blocks, and changing the number of classes specified within each area, and iteration of the previous steps

E. The study site was then divided into three main regions, or stratified, based on general physiography. These are the:

   1) Mountain and plateau
   2) Alluvial fan and dissected lake beds
   3) Agricultural area

F. Cluster blocks were rearranged within each area but were still set up to maintain the criteria listed under heading VI.

   1) An additional cluster block was added where a geological formation was not previously found to be represented

G. These cluster blocks were classified using MINIMUM DISTANCE

   1) Symbols were again combined, and new Varian symbols were created

H. Each of the three major regions was blocked out as close as possible to its boundaries, and then classified using MINIMUM DISTANCE

   1) Output was obtained in the form of:

      a. alphanumeric symbols from the lineprinter with each class represented by an individual symbol, and also a map generated with symbols combined
      b. Varian plotter symbols with certain classes combined under the same symbol

I. This output was taken to the field and checked. Certain symbol groupings were changed.

J. The boundaries of the major areas were then digitized.

K. The LAYERED CLASSIFIER was used next so that the digitized boundaries could be incorporated as extra channels.

L. Final maps were created after this area was classified by using PRINTRESULTS to obtain alphanumeric output and GRESULTS to obtain Varian symbol output. Acreages were also calculated.

From Table 1 it can be seen that meetings with field personnel, statement of objectives, site selection, and gathering of ancillary data were the first steps in this analysis process. Next, the quality of the data was examined, and this data was coordinated with the reference data so that a familiarity with the area and cover types could be gained. Two LARSYS processors were used to exhibit the data. These were PICTUREPRINT and GDATA. IDPRINT was also run. The exact boundaries of the study site were then delineated. The CCT had been reformatted and geometrically corrected but not precision registered.

In using GDATA, it was found that in the Tonal Pattern, manmade features such as roads were observed more easily as were subtle tone changes. The Texture Pattern revealed topographic patterns better. Both patterns were found to be very useful in identifying cluster areas when used together in all 4 channels.

Several analysis techniques or approaches were used during the course of this study in trying to convert the Landsat data into distinct spectral classes. Due to the heterogeneous nature of this environment within the study area, an unsupervised multicluster block approach was used to obtain training statistics. The size of the cluster blocks ranged from about 40 x 40 pixels to about 80 x 80 pixels. Ancillary data consisted of color air photos at a scale of 1:31,680, a geologic map, complete topographic map coverage at a scale of 1:24,000 and a county soils report.

The main objectives in selecting cluster blocks, from which training statistics would be derived, were to

1) select areas representing many different cover types or classes,
2) omit areas with bad data lines or clouds, and
3) select areas with distinctive features which could be correlated to air photos or maps such as road intersections or canyons.

At first, 6 cluster blocks each containing 16 classes were picked, but trying to identify patterns for registration proved very difficult. Next, 12 classes were specified for all 6 areas except in the agricultural area where 14 were picked. This facilitated registration with the air photos and enabled a more accurate identification of the spectral classes. Preliminary classification of the study area using the MINIMUM DISTANCE to the means classifier and ECHO revealed that possibly not all of the classes within the study area were adequately represented or sampled, and that more cluster blocks would be needed. Three additional blocks were added, and their location was based upon geologic and soils units not previously represented. Here, the ancillary data helped in assuring that all major cover types were included in the sampling. Again, 12 classes were requested and a convergence of 98.5% was specified. The total number of classes for these nine cluster areas was 110.

Subsequent classification attempts exhibited a certain amount of class confusion. This appearedgenerally where granitic rocks were being confused with exposed lake sediments. Therefore, the study site was divided along physiographic boundaries into three major areas. These were the mountain, fan and agricultural areas. It was hoped that this would reduce some of the confusion resulting between classes located in the highlands and those in the lowlands. An additional cluster block was added within the mountain area bringing the total number within the entire study site to 10 representing about 16% of the study area being clustered. Figure 6 shows the approximate location of the cluster blocks. These blocks were again placed in areas within each major division where most classes or cover types were represented, and where distinctive features could be found to help relocate these sites easily on the air photos and maps, and on the ground.

During the clustering process, it is felt that selecting the proper number of classes, and having total representation are most important. Therefore, the positioning of the cluster blocks on boundary or margin areas is important in trying to make certain that all cover types are adequately represented; but, correlation between output and maps or air photos is also important if proper class identification is to be achieved. Therefore, natural features or manmade features such as roads should also be included to facilitate registration. If ground truthing is performed,

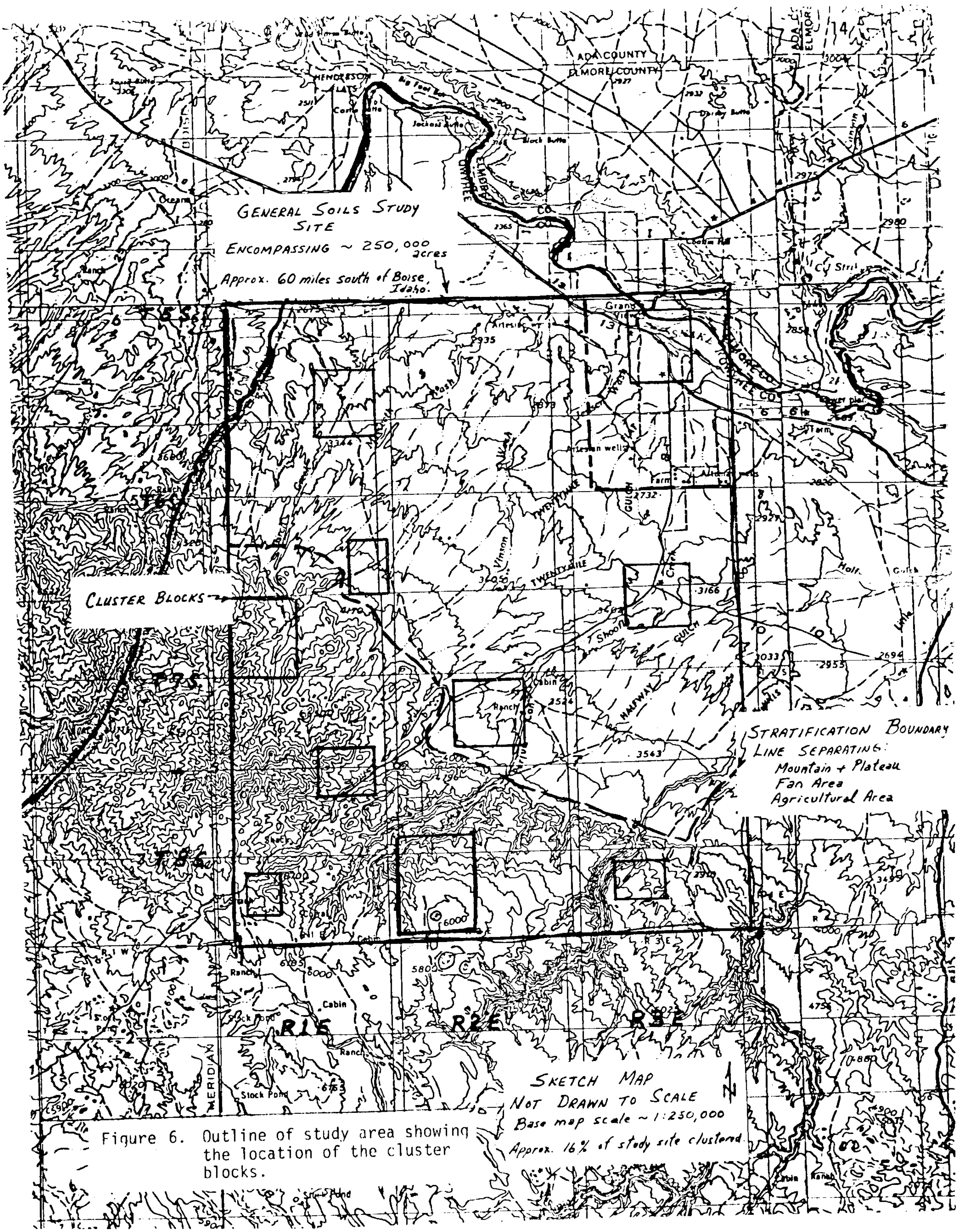


Figure 6. Outline of study area showing the location of the cluster blocks.

road intersections, drainages, distinct canyons, or hills will aid in field checking cluster sites. At this point it should be mentioned that field reconnaissance during and after the clustering process is highly recommended if possible. These observations will enable the analyst to make more intelligent pooling decisions during the next step in the analytical procedure.

Specifying the proper number of classes is also very important in the clustering process, and a rule of thumb has been to select 1½-2 times the number of classes observed within the cluster block. It is better to select more classes than needed because their statistics can always be pooled or combined later. If too few classes are selected, several spectral signatures may be represented by one information class which will cause subsequent misclassification. It was found that just specifying a high number of classes could also cause some confusion, and hamper registration attempts. Therefore, the analyst should try to be as accurate as possible in determining class numbers, but avoid selecting too few classes. The number of classes specified in the CLUSTER processor was found to considerably affect the amount of CPU time used. The clustering process, other than the final classification, was found to be the most expensive procedure. One 50 pixel x 50 pixel cluster block cost 1367 seconds of CPU time when 16 classes were requested, and when 14 classes were requested it cost 128 seconds to run. The following table compares 6 cluster areas, each being the same in size, and having the same convergence factor of 98.5%.

Table 2.

Area	Size (pixels)	CPU time in sec. (16 classes)	CPU time in sec. (12 classes)
1	3600	353	272
2	5600	516	343
3	4800	356	190
4	5600	728	704
*5	2500	1367	128
6	6400	701	417

*Area 5 represents 14 classes rather than 12.

The RATIO processor was run after each cluster routine, and this was found to be useful when determining class relationships. RATIO exhibits cluster classes in order of magnitude, and ordered by the ratio of the response of the visible bands divided by the IR bands. Class variances within each channel are also printed.

Calibrated spectral curves were generated for each class within the cluster blocks. These enabled one to get a visual idea of the spectral signature of each class. The spectral nature of this environment will be discussed in the next section of this report. Examples of these spectral curves from 3 cluster areas are shown in Figures 7,8,9. Cluster statistics were used to create these curves.

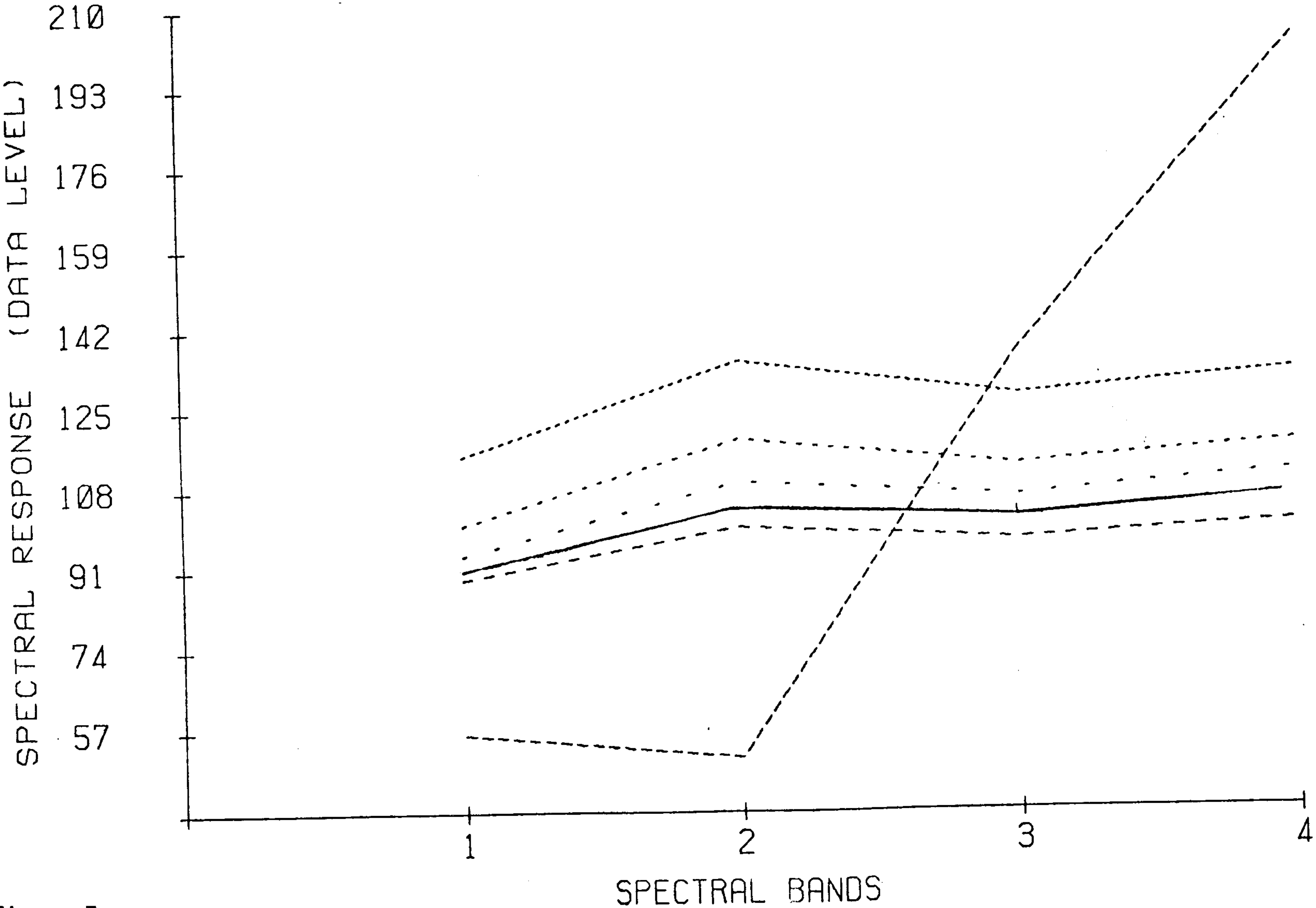


Figure 7.

AREA 1 (Classes 1-6)
Alluvial Fan

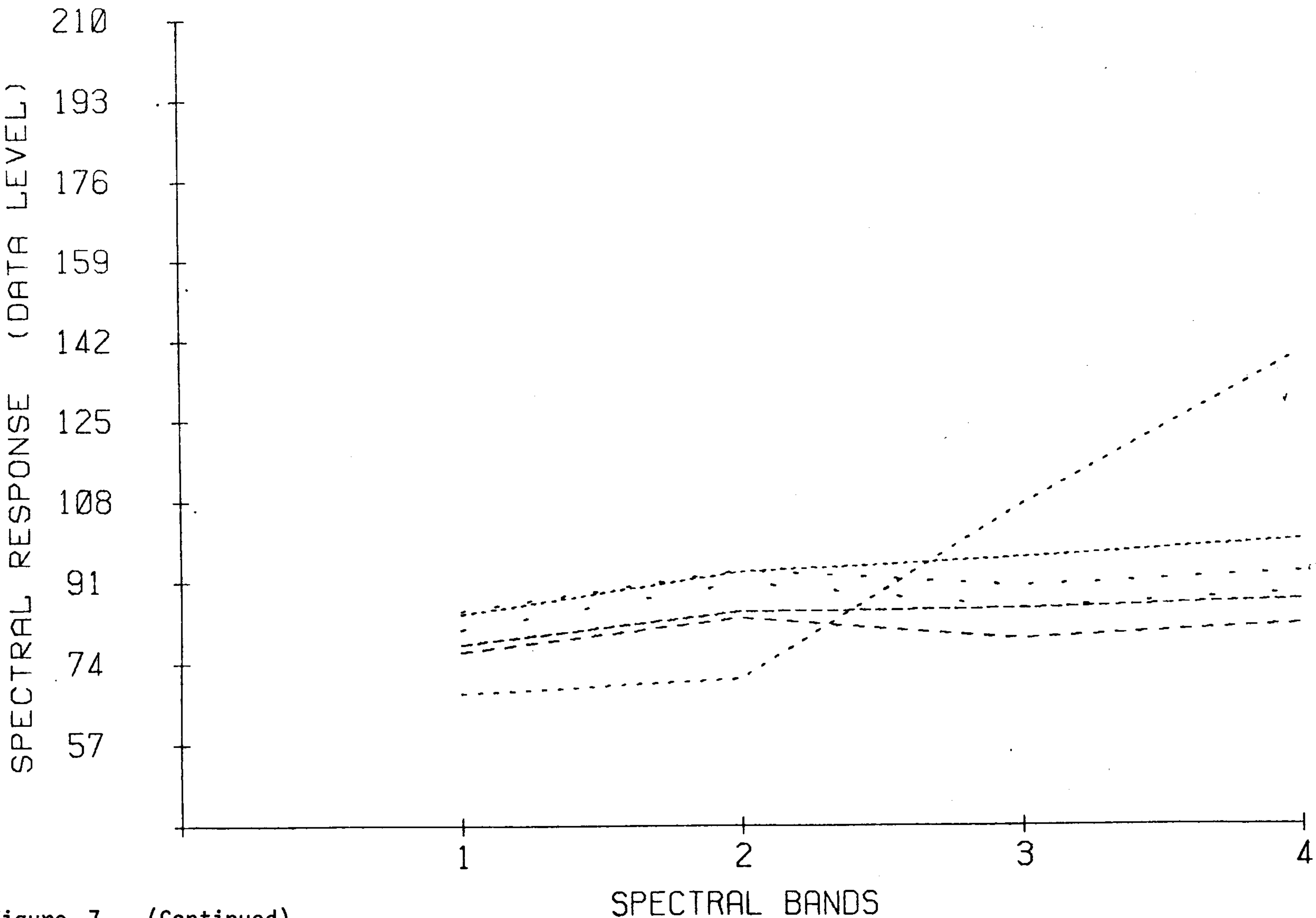


Figure 7. (Continued).

AREA 1 (Classes 7-12)
Alluvial Fan

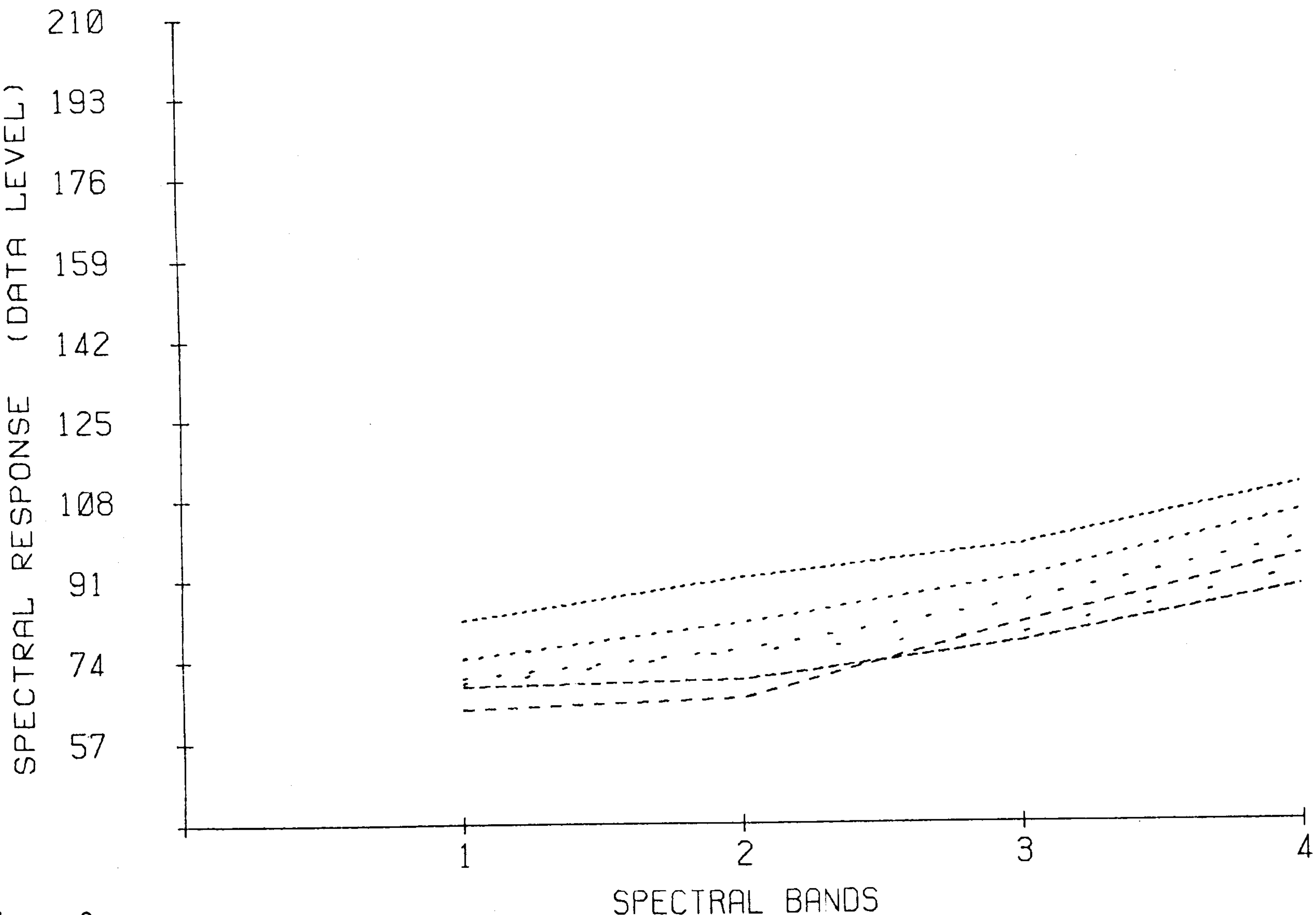


Figure 8.

AREA 2 (Classes 1-6)
Mountain and Plateau

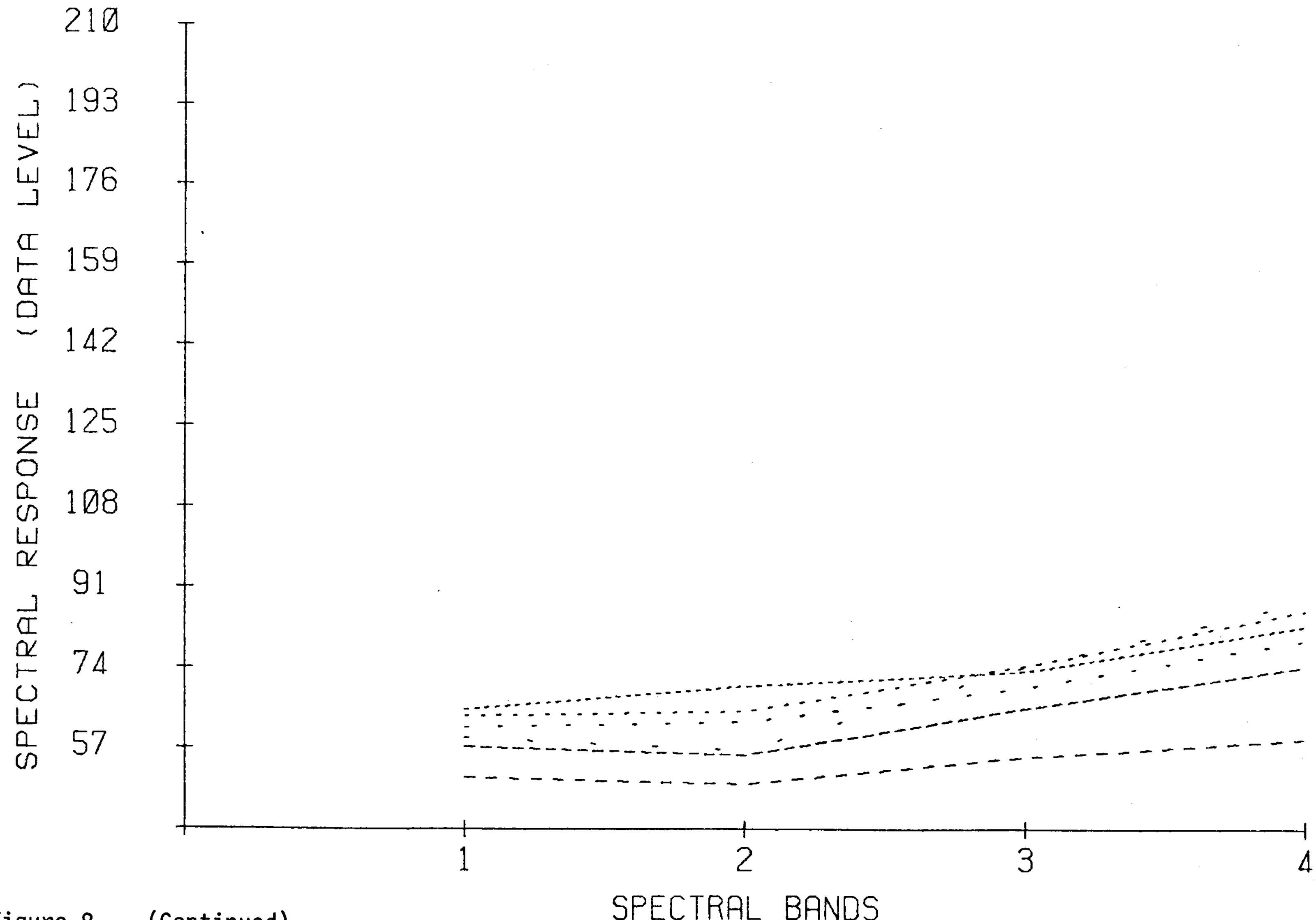


Figure 8. (Continued).

AREA 2 (Classes 7-12)
Mountain and Plateau

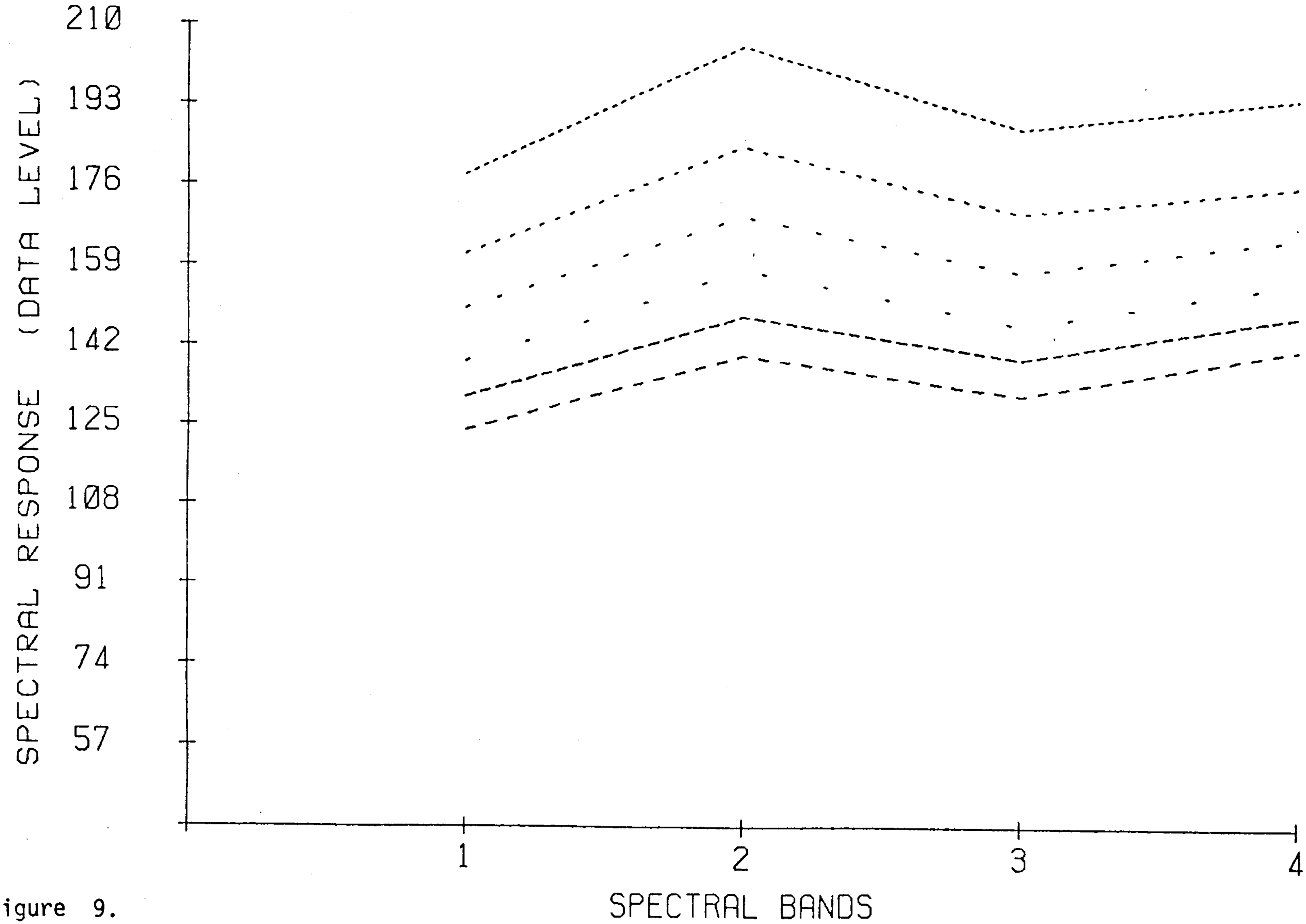


Figure 9.

AREA 4 (Classes 1-6)
Lake Sediments

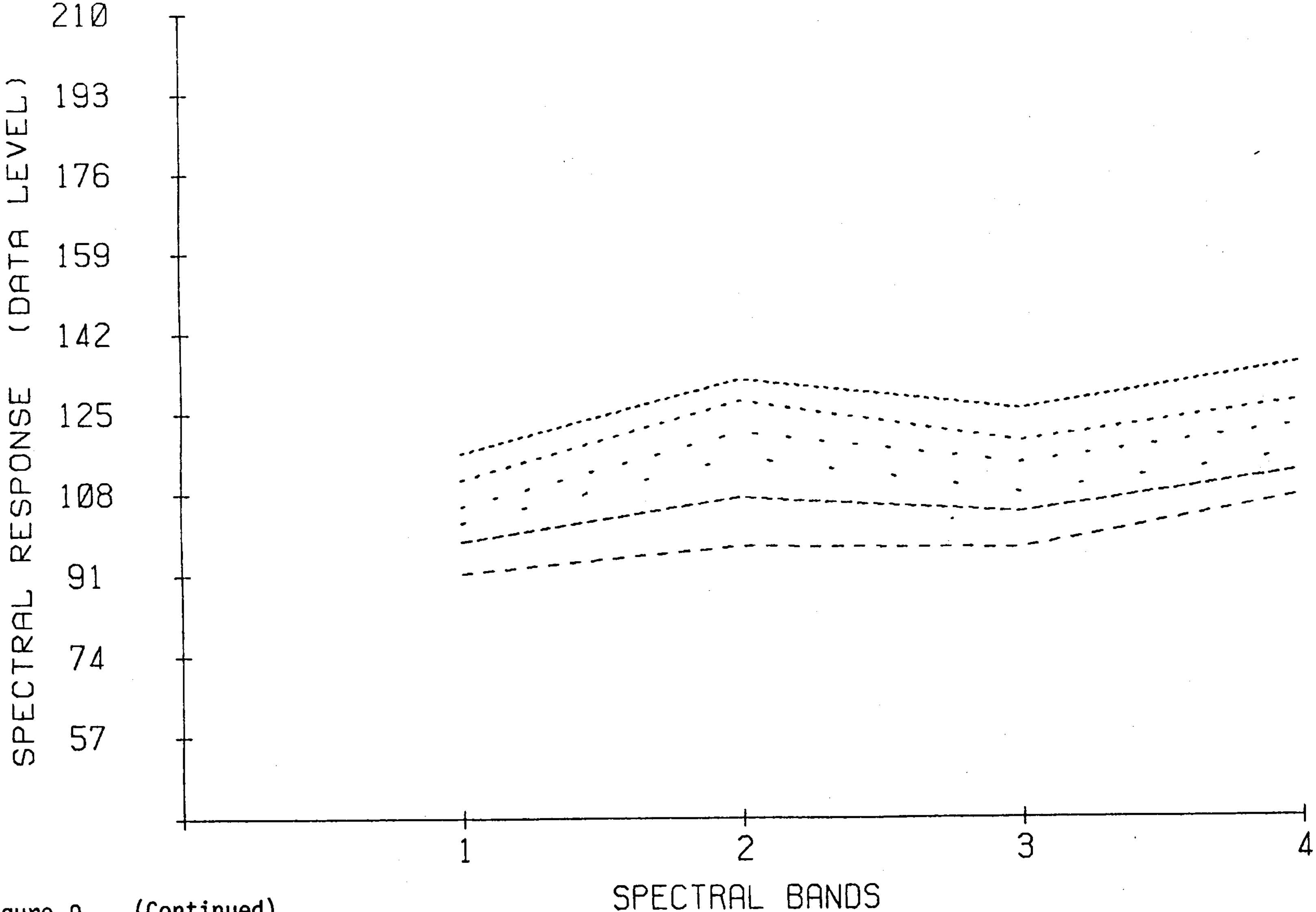


Figure 9. (Continued).

AREA 4 (Classes 7-12)
Lake Sediments

A pooling process was used to combine classes with similar spectral responses and statistics from the different cluster blocks within each stratified area. Classes with low separability or transformed divergence were pooled while those with high variance, uncertain identification, or redundancy with others were eliminated. This process was repeated several times until classes were found to be as separable, or spectrally distinct, as possible while still maintaining the level of detail needed by the resource specialist. A transformed divergence of about 1550 was found to be significant to separate non-vegetative classes in this area while a D_T of about 1480 was found significant for the dominantly vegetative classes. Statistics were produced from this process for each of the areas stratified. These statistics were then incorporated into a Minimum Distance to the means classifier. This proved to be a very quick algorithm, taking only about 1/3 CPU hour to classify the entire 250,000 acres.

Table 1 section VII lists the criteria upon which classes were pooled, deleted, or kept separate. Each analyst generally has his own idea on achieving maximum separability while still maintaining class accuracy. It was generally found that the total pooling or the total deletion of classes caused inaccurate results. Using the LARSYSXP processor MERGESTATISTICS, a bispectral plot was generated which enabled one to visually keep track of class combinations or deletions. The LARSYSDV processor SEPARABILITY with the attached computer grouping table provided a guide for class groupings under a specified threshhold value. This guide was found useful, although in certain cases it was not strictly followed. From this process, the Mountain area emerged with 21 classes; the Fan area had 20 classes; and the Agricultural area contained 9 highly separable classes.

The next step in the analysis procedure involved classification. Each cluster block was classified as a test before the entire area was classified. Four classifiers were used in this study. These were MINIMUM DISTANCE, ECHO, CLASSIFYPOINTS, and LAYER.

MINIMUM DISTANCE is a linear classification rule which assigns each pixel to the class whose mean is closest in Euclidean distance. This was found to be the least expensive of all the classifiers used, which is a reflection of the complexity of implementation. Results appeared very comparable to the other more complex and expensive classifiers. While studies at this time were not performed to determine accuracy, workers at LARS have found the accuracy of MINIMUM DISTANCE to be comparable to the more expensive classification algorithms.

ECHO, which means Extraction and Classification of Homogeneous Objects, utilizes both spectral and local spatial information. It is a sample classifier rather than a "per point" classifier. That is, picture elements which have similar spectral characteristics can be classified as a group. Statistical tests are used to group data into homogeneous regions, and then each region is classified using a maximum likelihood sample classification algorithm. ECHO was found to be an extremely useful tool to smooth out the data. Large homogeneous areas could be seen quite clearly. Where pixel detail is a necessity, or inclusions of pixels within larger units would aid in resource identification, ECHO may not be beneficial. It may tend to "smooth out" too much detail, and give a blocky artificial appearance to the map. Examples of two areas classified using ECHO and MINIMUM DISTANCE are shown in Figures 10,11,12,13. ECHO was found to be twice as expensive as MINIMUM DISTANCE. It should be noted that factors such as cell size and homogeneity are determined by the analyst, and further experimentation might have resulted in a more acceptable product for this study.

CLASSIFYPOINTS performs a maximum likelihood classification on a point-by-point basis. The decision rule assumes that each training class can be characterized by a weighted multivariate normal distribution which is described in terms of the class means and a covariance matrix. The algorithm uses this information for each data point to calculate the probability that the point belongs to a certain training class. This classifier was the most expensive, costing about three times as much computer time as MINIMUM DISTANCE.

Since the study site had been classified according to physiography, the boundaries separating these areas could only be approximated, and obtaining accurate acreages for each area would not be possible. In addition, each area would emerge as a separate map rather than as one map showing the entire area. Therefore, it was decided that these boundaries should be digitized to more accurately reflect their location. Figures 14 & 15 show the study site with the digitized boundaries superimposed. It can be seen that the site was divided into four areas, but the area in the upper right corner above the Snake River was classified using the statistics from the mountain and plateau area.

The LAYERED classifier was used so that the digitized boundary data could be incorporated into the classification. The data representing the digitized boundaries were inserted as extra channels. The LAYERED classifier utilizes decision tree logic with an optimum subset of features at each tree node to classify each pixel. Therefore, the classifier, which is actually the same as CLASSIFYPOINTS, is made more efficient because of the minimization of computational requirements brought about by the multistage decision procedure. The design of the decision tree was a lengthy process involving many steps. First, the processor DISTANCE was run to calculate distances similar to separability for each class. Statistics for each area were inserted separately, so each processor had to be run three separate times. Next, the DESIGN processor incorporated the information from DISTANCE to calculate the optimum decision tree for each area, and then punched out decks describing each decision tree. All six decks were then edited, combined, and ordered. This ordered deck along with other sets of statistics was then inserted into the LAYERED CLASSIFIER control cards. Since the decision tree is constructed to use the best features for discriminating spectral classes, the time to run LAYERED was found to be about ½ that of CLASSIFYPOINTS. It is hoped that implementation of this processor will become less complex in the future. Naturally, complexity will vary depending upon the number of channels, classes, and so forth. In this study there were 10 channels and 54 classes.

In the classification of this study site, which consisted of 491 lines and 451 columns, the following amounts of computer time were used for each classifier:

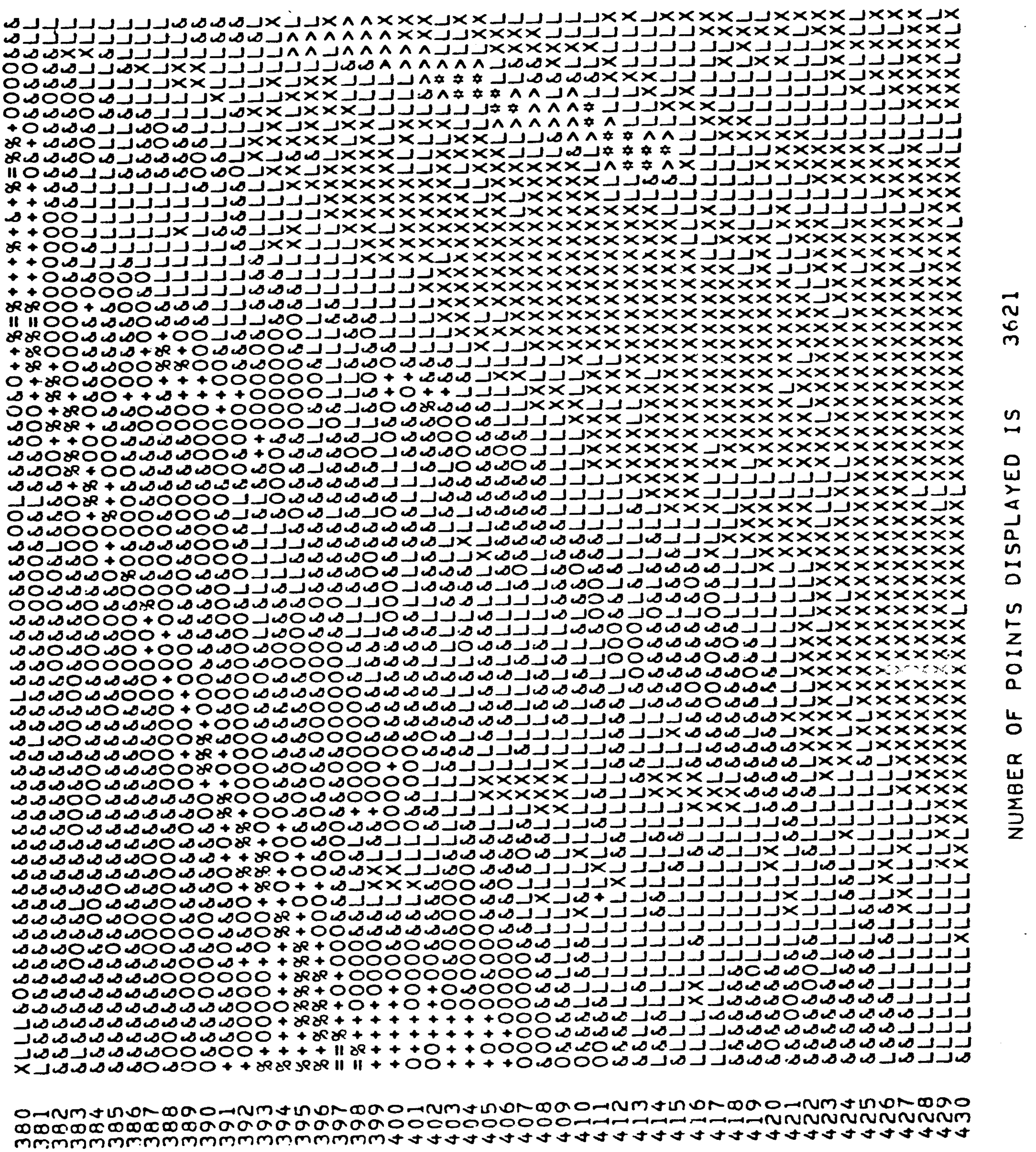


Figure 10. MINIMUM DISTANCE classification of Area 1.

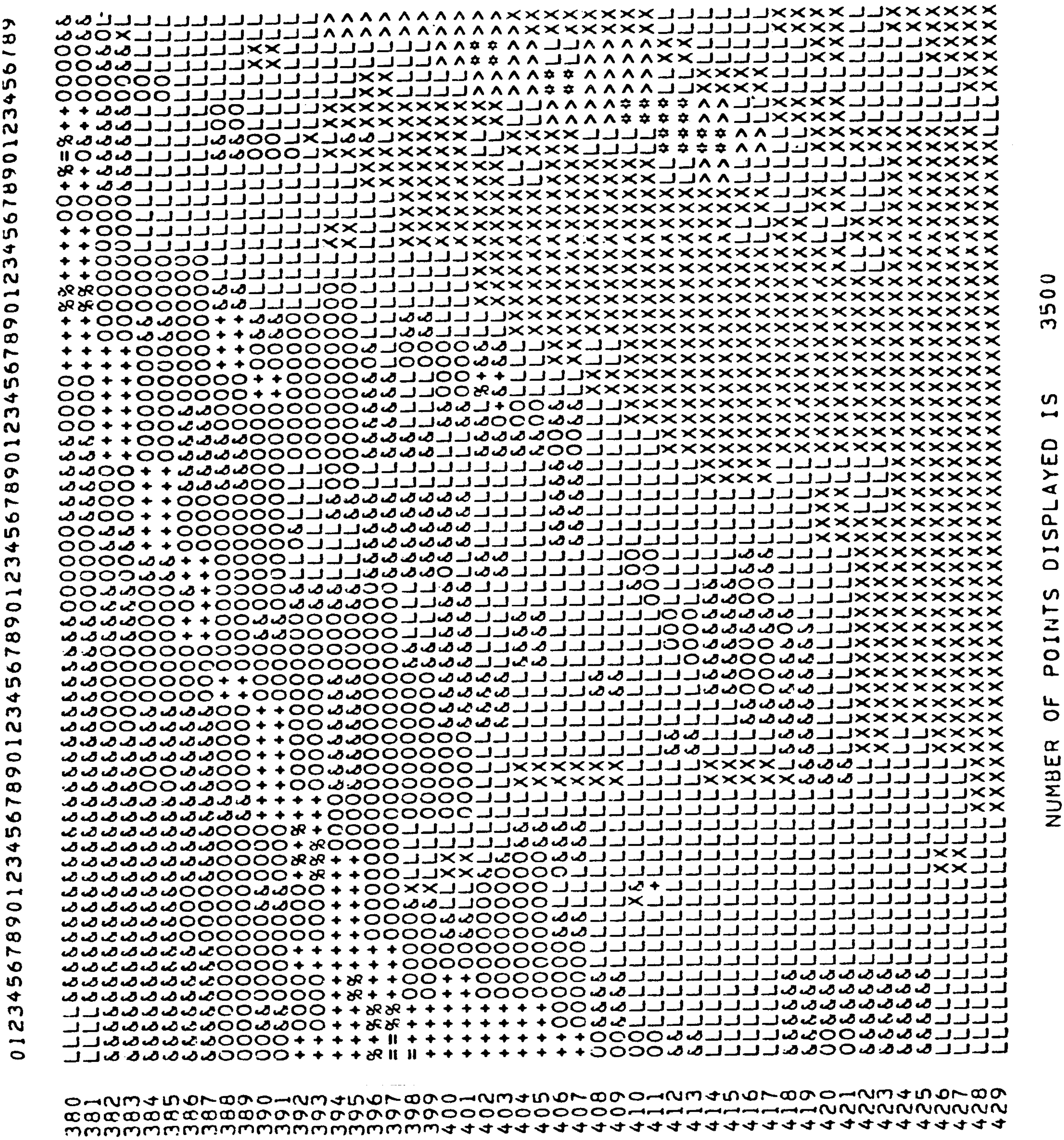


Figure 11. ECHO classification of Area 1.

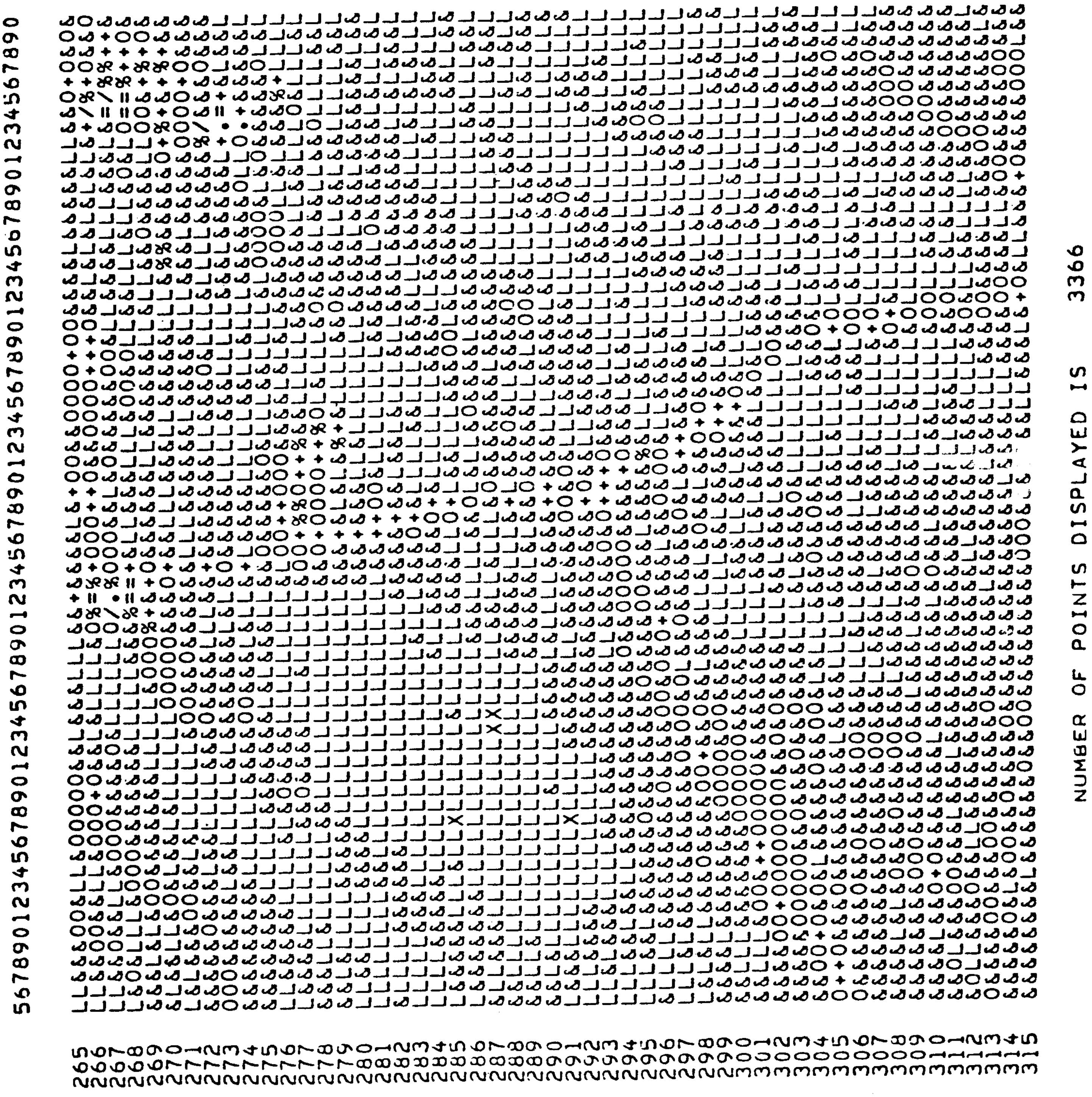


Figure 12. MINIMUM DISTANCE classification of Area 3.

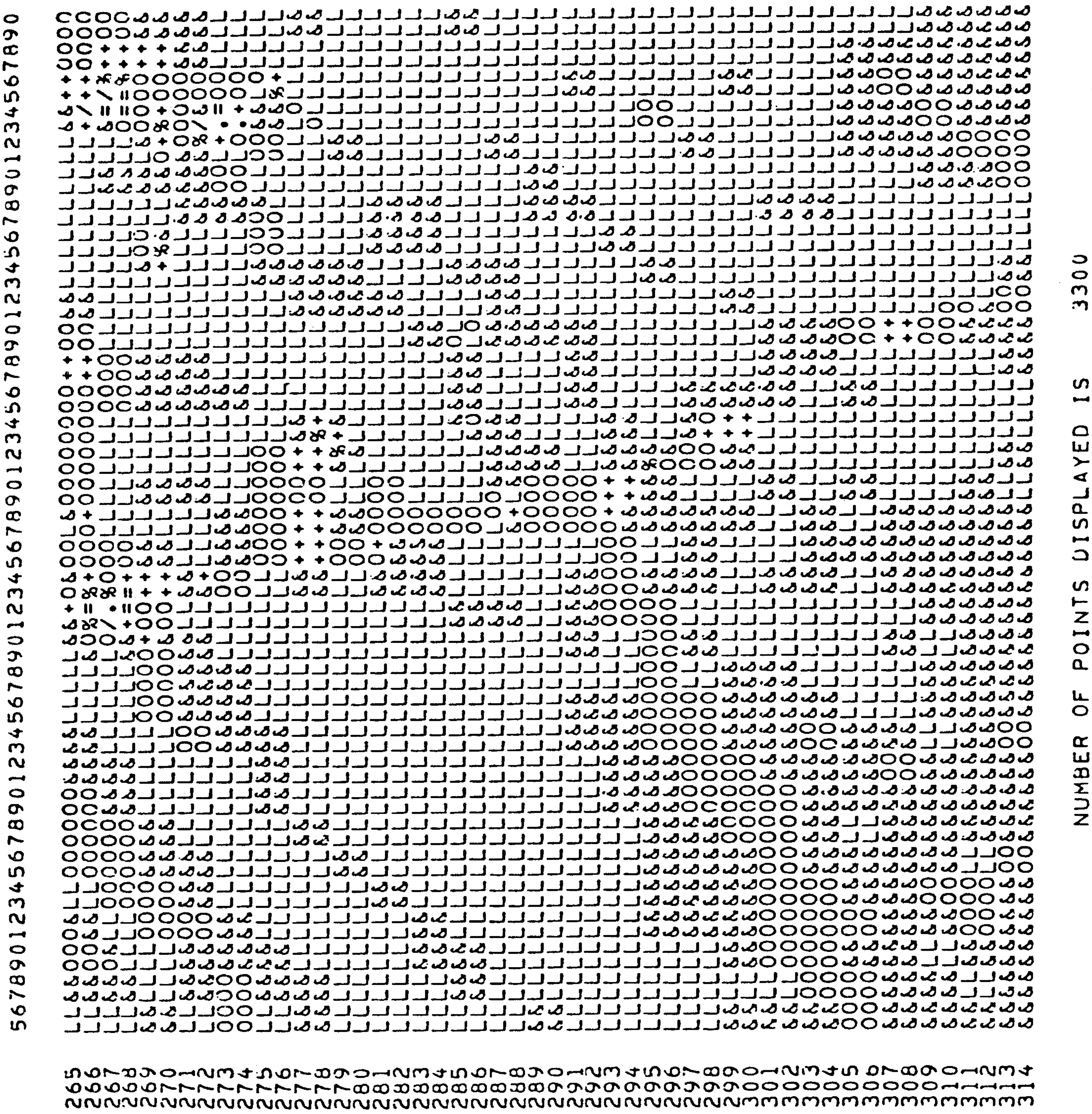


Figure 13. ECHO classification of Area 3.

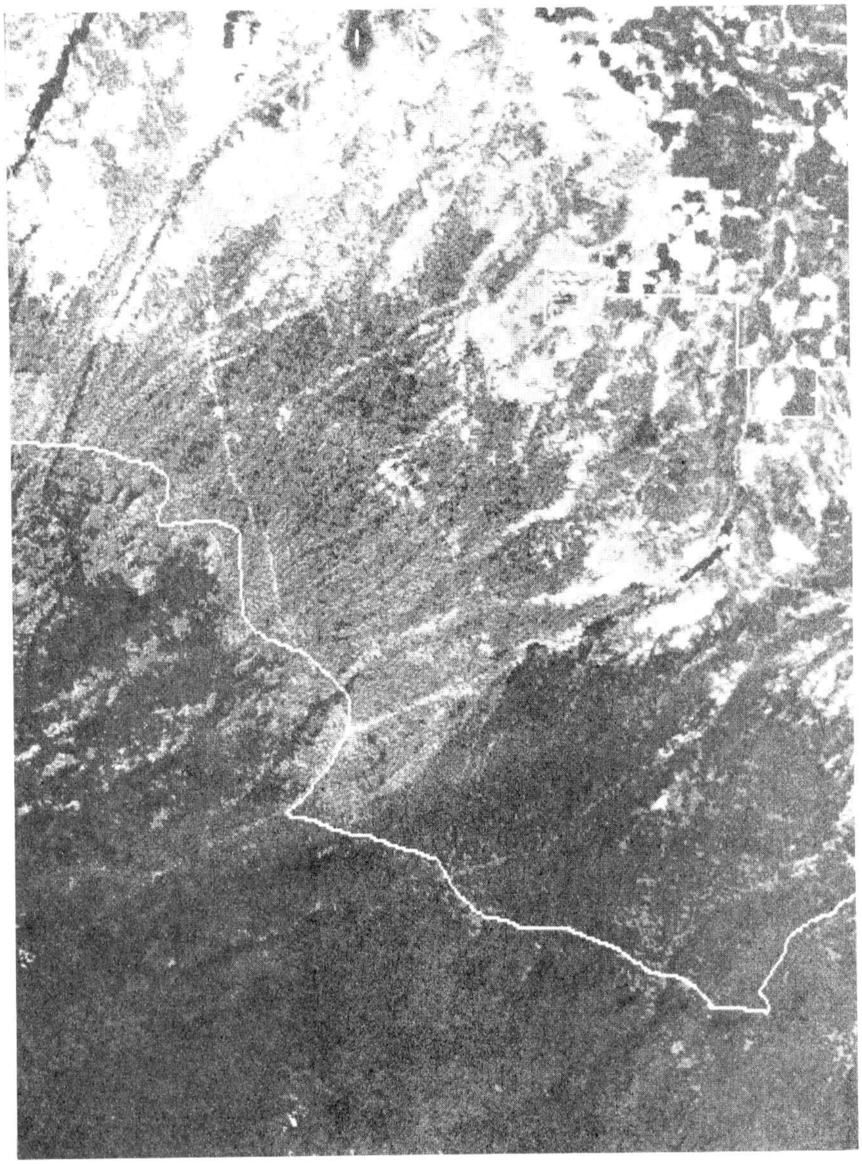


Figure 14. This shows the digitized boundaries separating the classification areas. Separate statistics were generated for each area; then these statistics and digitized boundary data were incorporated into the Layered Classifier to obtain one map of the study site along with tabulated acreages for each spectral class.

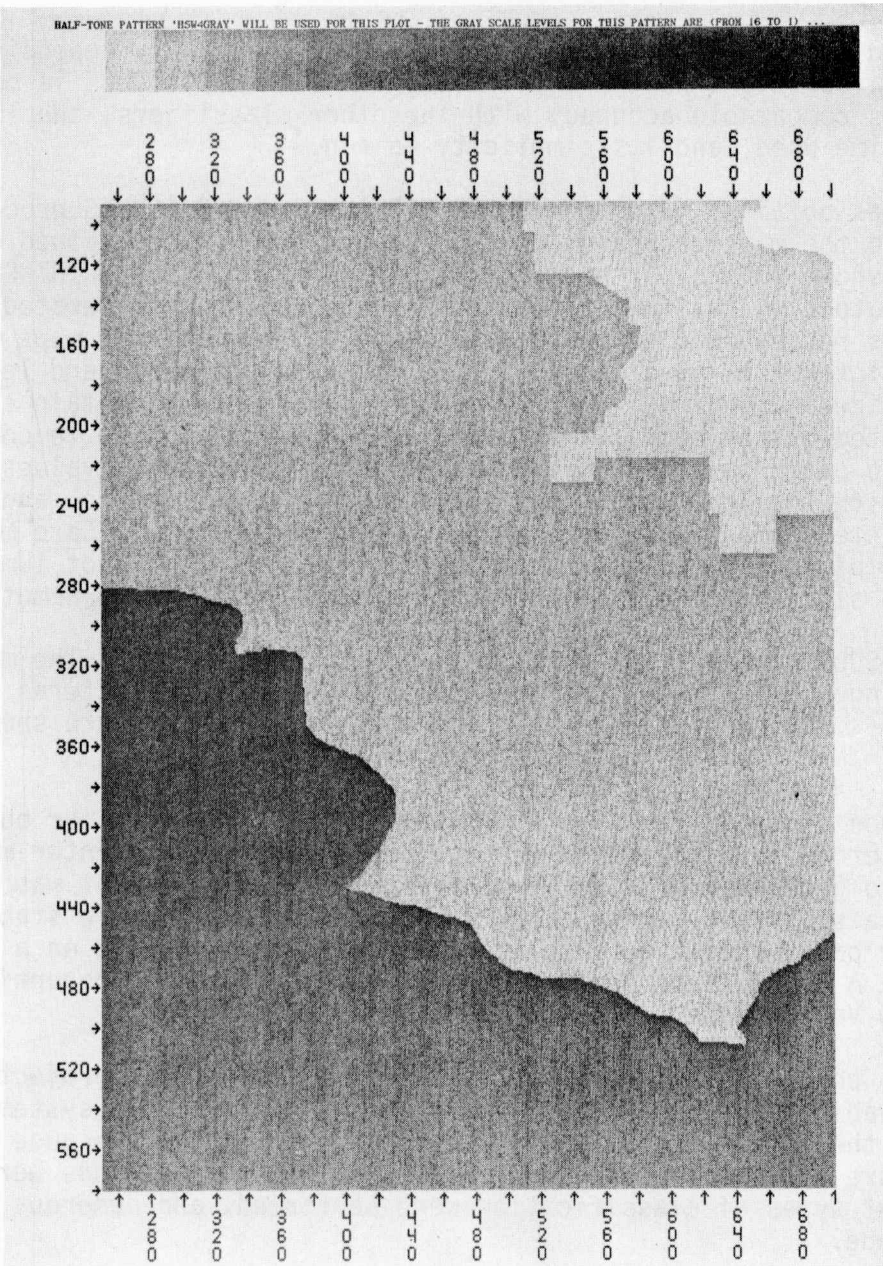


Figure 15. Map showing the areas contained within the digitized boundary.

CLASSIFYPOINTS	63 min.
ECHO	44 min.
LAYER	36 min.
MINIMUM DISTANCE	22 min.

It should be pointed out that these CPU times will vary depending upon the time of day or night run. It is felt that MINIMUM DISTANCE is most useful because of its comparable accuracy with the other classifiers, the low amount of computer time used, and its simplicity to run.

Output was obtained by using the PRINTRESULTS and GRESULTS processors. In addition to the maps, acreages for each class were also obtained. These acreages are shown in another section in this report. Using PRINTRESULTS, lineprinter output in the form of alphanumeric symbols was generated, and each class was represented by a separate symbol. Then, if the maps were difficult to interpret, or classes were found to be scattered and less than 10 acres in size as required in a third order soil survey, certain classes were represented by one symbol. The decision on which symbols to combine was based upon pairs having the lowest transformed divergence values between them, those with the least amount of informational significance, and those generally scatterd among more homogeneous occurring classes. Care must be taken when combining symbols so that significant classes are not lumped together, and also that the needs of the resource specialist are met.

From GRESULTS, output was generated on a Varian plotter. The main limitation in using GRESULTS was that the number of symbols or patterns was limited to 16. Patterns were created for each area and they are shown in Figure 16.

Based upon comments from field personnel, the Varian plotter output was much easier to interpret than was the alphanumeric lineprinter map. Both maps were generated at a scale of 1:24,000. Varian output was also generated on a semi-transparent paper which appeared to be more stable than other plotter paper used, and also it could easily be overlaid on a 7½' topographic map. A light table permitted easy viewing of the topographic map under the new Varian paper.

Finally, concerning costs or computer times during this project, there is great variability depending upon the type and speed of the system, the time of day, the complexity of the processor and so forth. Because of the research nature of this project, many different analysis methods were used, many different types of classification were performed, and numerous iterations were made.

Table 3 gives a very general estimate of the cost of an analysis of this size without including field trips and expenses, analyst's salary, or the purchasing of air photos, Landsat images or other ancillary data.

NUMBER OF POINTS DISPLAYED IS

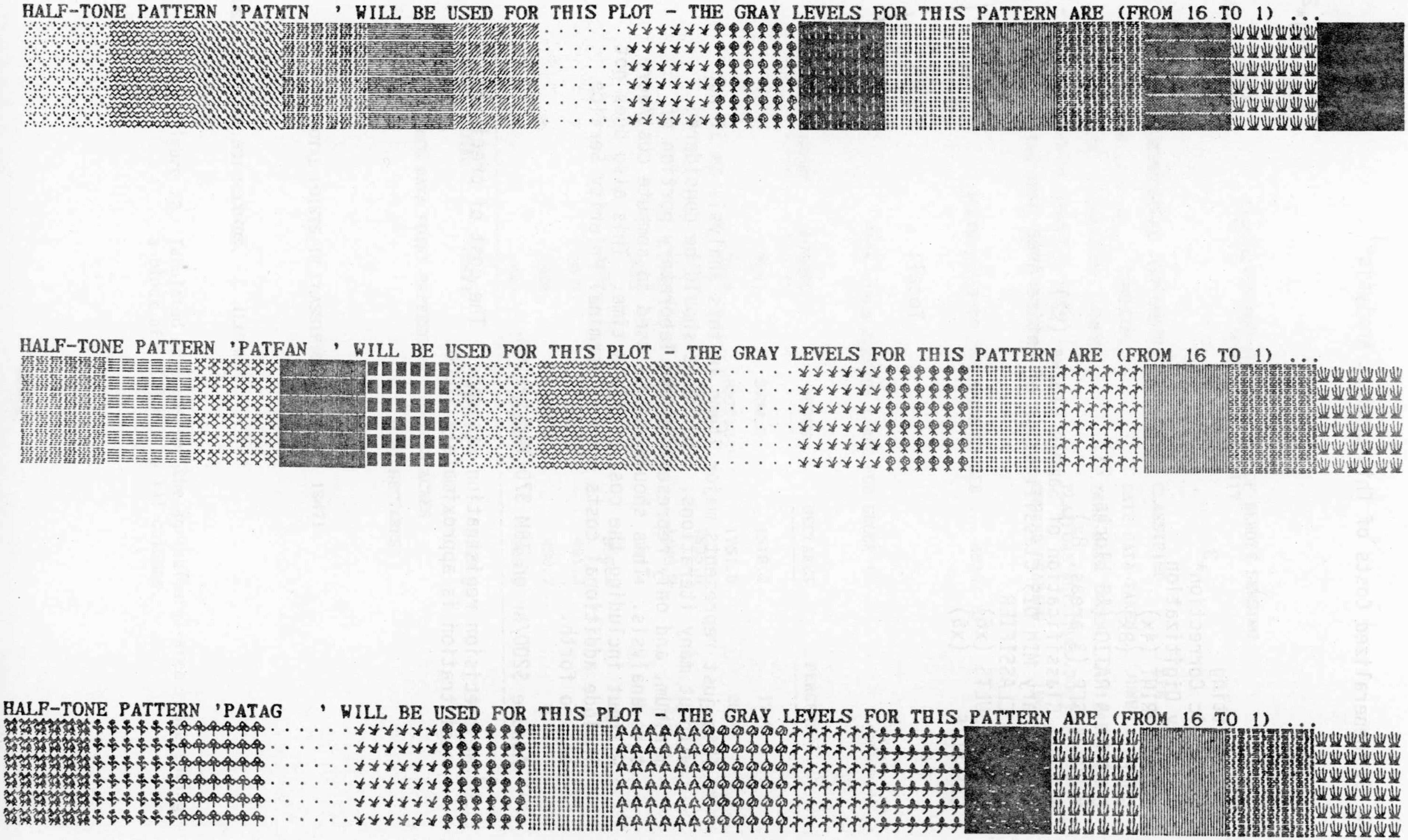


Figure 16. Varian plotter symbols created for the Mountain, Fan, and Agricultural areas.

Table 3. Generalized Costs of This Landsat Analysis*[1]

Item	Cost ($)*[2]
CCT	200
Reformatting	135
Geometric Correction*[3]	332
Boundary Digitization	1010
PICTUREPRINT (4x)	30
GDATA (8x)	55
CLUSTER & RATIO (10 blocks, 2x)	366
MERGE & SEP (3 areas, 8x)	31
MIN DIS Classification of Sample Blocks (x2)	85
Preliminary MIN DIS Classification of Entire Area	83
LAYERED CLASSIFIER	123
PRINTRESULTS (x6)	33
GRESULTS (x5)	78
Total:	$2,561

*[1] This just represents major items in this analysis as if run without many iterations. This cost should be considered minimum, and only representing the laboratory portion of this analysis. This should not be used to compute cost/acre without including the cost of field time. This also does not include additional costs such as Terminal Priority Service and so forth.

*[2] Assume $200/hr on IBM 370/148 system.

*[3] No precision registration was done. The cost of precision registration is approximately $2000.

Field Observations and Procedures

Field examination of the preliminary classification maps generated at LARS occurred during the last two weeks in May, 1979. Good weather during this period permitted field investigations each day with no delays. Helicopter time was also available for one day, and this was used in the mountain areas.

Ideally, field examinations should also be made during the sampling or clustering process, but this was not possible for this project. One week was also spent on a general reconnaissance of this area in November 1978. It is felt that more field time was needed to adequately examine all class types in areas outside of the cluster blocks. Figure 17 shows a gray tone map of the study site with the cluster blocks superimposed. This map represents band 6 of the June 5, 1976 Landsat-2 scene used in this analysis. Field investigations should also be made around the date of the image being studied. In this way the vegetative resources would be in a similar state of growth on the ground as they are in the Landsat data. For example, green grasses are present in this area during the spring, but by mid-summer they are burned off. Therefore, the evidence for a certain vegetative spectral response found in the data may not be noticed on the ground if field checking is done later in the summer. It should also be mentioned that ancillary air photo coverage should be flown as close as possible to the date (month/day) of the Landsat scene being analyzed. This would greatly facilitate the identification of information classes during the analysis process.

The field procedure during the examination in May consisted of using the 1:31,680 resource photos which are color, and also blow-ups of these which were enlarged to 1:24,000 scale to be compatible with the computer output scale. A mylar sheet was placed on the enlarged photos and features such as roads, agricultural fields, canyons and so forth were drawn on the mylar. These are the types of features which could generally be seen on the computer output and so the mylar could be laid over the printout and fairly accurate registration could be achieved. Any points plotted on the air photo mylar could then be correlated with pixel types by overlaying this mylar on the output. Soil samples were taken and their location was also plotted, as were photo points. These points were also cross-referenced to the field notes where detailed descriptions of the ground cover were written. Figures 18 and 19 show some examples of the field procedure.

The objectives of the field work at this time were: (1) to relate spectral classes with cover types on the ground; (2) to determine the factors that contributed to the spectral response in this environment; and most important (3) to determine how these spectral classes and associated cover types would aid in defining soil characteristics which would facilitate the field work and increase the accuracy of the soil scientist in his preparation of a third order soils survey for large acreages of western federal lands.

Concerning objective (1), generally different spectral classes or symbols on the maps brought to the field were found to reflect actual changes in cover types. Although a statistical study could not be performed at this time on the reliability, or confidence, that a particular spectral class would always indicate a particular cover type, it was found that in most cases, with a few exceptions, in the areas visited the relationship between a spectral class and cover type was consistent within classification strata. In most

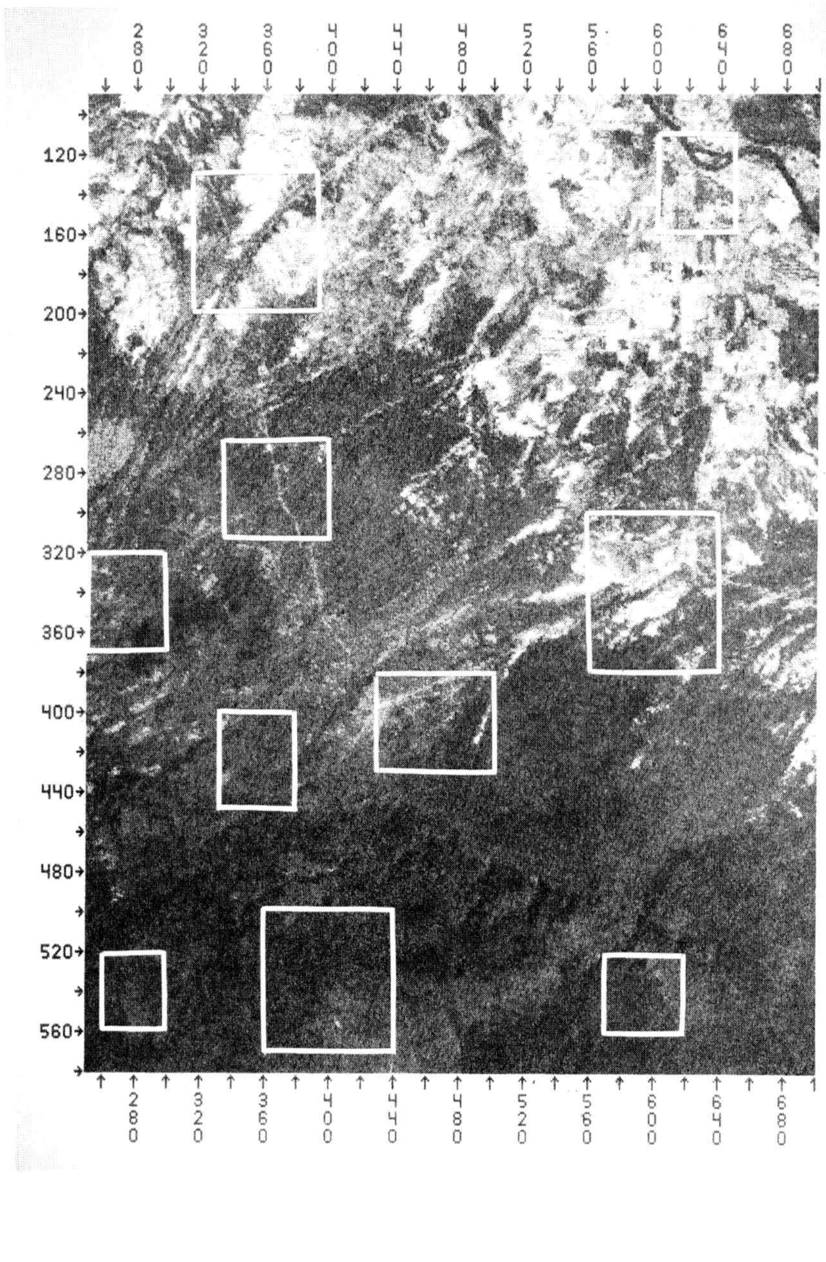


Figure 17. Grayscale map generated from Landsat data showing the study site in spectral band 6 with the location of the cluster blocks.

Figure 18. Correlation of air photos and spectral maps with ground cover types (above). Using a hand auger for soil sampling (below).

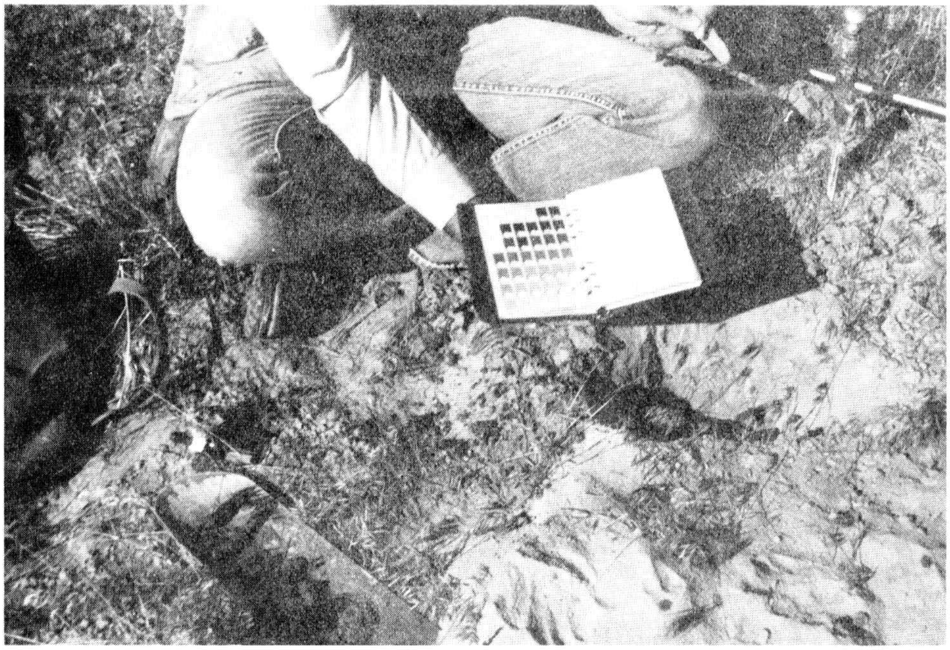


Figure 19. Examination of soil characteristics such as texture and color is an important part of the ground-truth process.

Figure 20. Alfalfa field in the agricultural area within the Snake River plain.

cases, no pure classes of any one cover type were found to contribute to a spectral response. Instead, mixtures determined the spectral signature such as different vegetation types, shrub-undercover ratios, non-vegetative ground cover types (alluvium, silt, rock, etc.) and slope. These factors will be discussed later in this report. While the multispectral scanners on the Landsat satellite generally have a resolution of about 1.1 acre, it was found that their sensitivity was great enough to delineate data at a scale more detailed than that required in a third order survey. Because of this detail, one of the problems in both the field and the lab was to determine which classes or symbols needed to be combined in order to avoid confusion and aid in user interpretation. Yet, care was taken to try not to combine classes which alone would indicate a distinct soil characteristic. Criteria for the combination of symbols was mentioned in the previous section on Analysis Procedures.

The study site was stratified into three general areas to avoid some confusion of classes which was encountered in previous analysis attempts. These three areas consist of 1) the mountain and plateau regions, 2) alluvial fan, pediment, and dissected lacustrine sediment areas, and 3) the agricultural lands in the Snake River floodplains. Separate statistics and spectral classes were generated for each area.

For the agricultural area, nine spectral classes were obtained representing water (the Snake River), bare soil, silts, lake sediments, three distinct crop types, and mixtures of vegetation and soil or new crops. Much more detail with more classes could have been obtained for this area, but since interest in crop identification was of minor concern for this study, only nine highly separable classes were selected. Crop types observed in this area were alfalfa, winter wheat, pasture, corn, and possibly potatoes or sugar beets. Acreages of these areas can automatically be tabulated if desired. An example of one of the alfalfa fields is shown in Figure 20. Figure 21 shows the MINIMUM DISTANCE classification map for this area. Figure 22 represents the output showing tabulated acreages for this area, while Table 4 describes each class.

In the classification for the fan and lake sediments areas, twenty spectral classes resulted. Statistics for these classes were retained but in certain areas it was found that when twenty symbols were used, the resulting map appeared difficult to interpret due to the large number of different pixels. Also, this was much more detailed than was required by the soil scientist. Mapping units were to be larger than 10 acres and generally more on the scale of 40 acres or larger. Therefore, symbols were made similar for spectral classes which were thought to represent similar cover types, and also for classes which had the lowest transformed divergence values separating them. This resulted in ten different symbols which could be considered different cover types. At this point it should be mentioned that in an arid and locally saline environment such as this, a critical balance exists between different soils types and native vegetation present. Only certain native species dominate because of this restrictive environment. As the age of the soils increases and where they are less likely to be disturbed by nature or man, this soil-plant relationship becomes most significant. Areas that have been recently dissected or heavily eroded, or have been overgrazed or burned tend to have less of a soil-plant relationship.

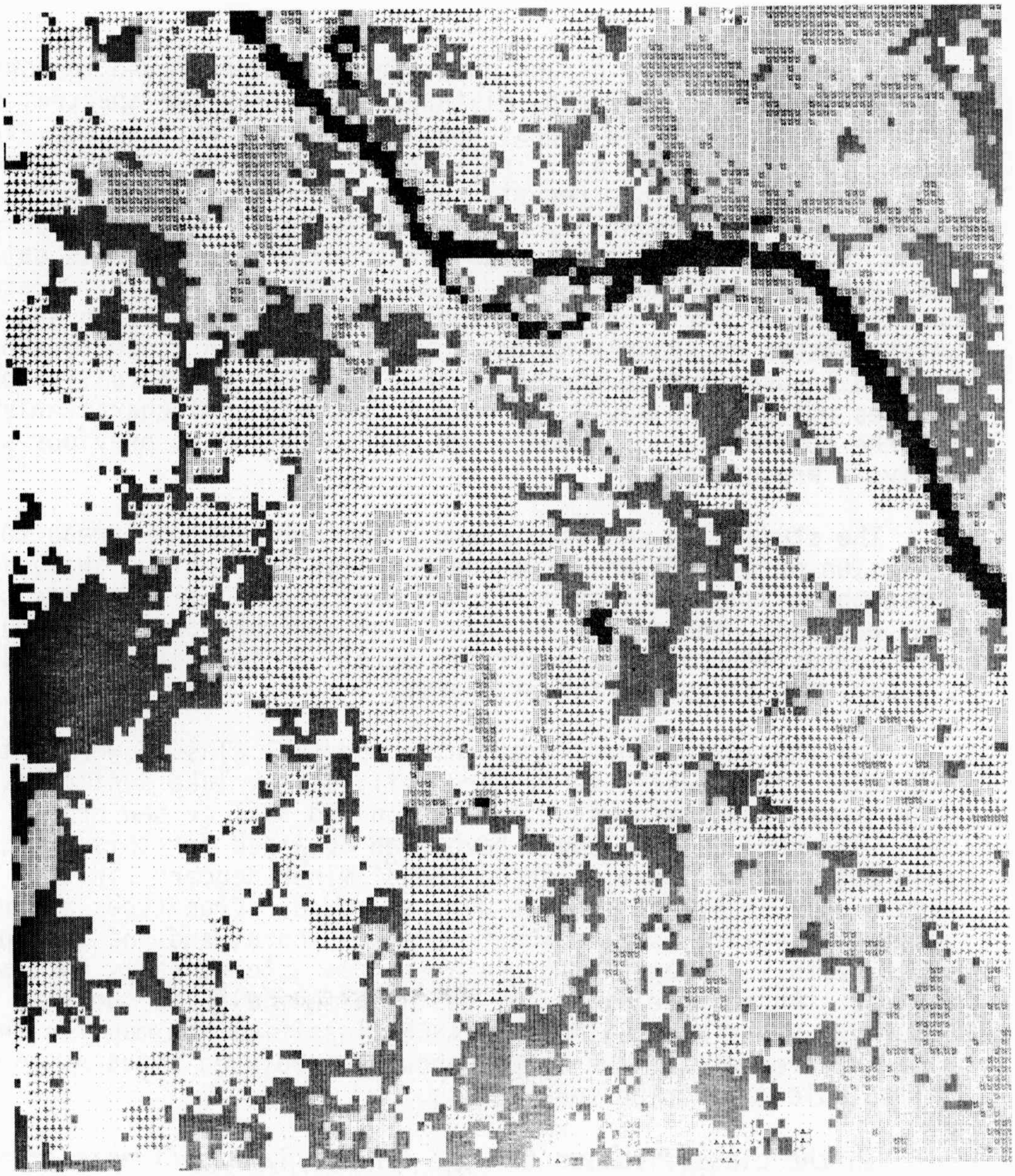
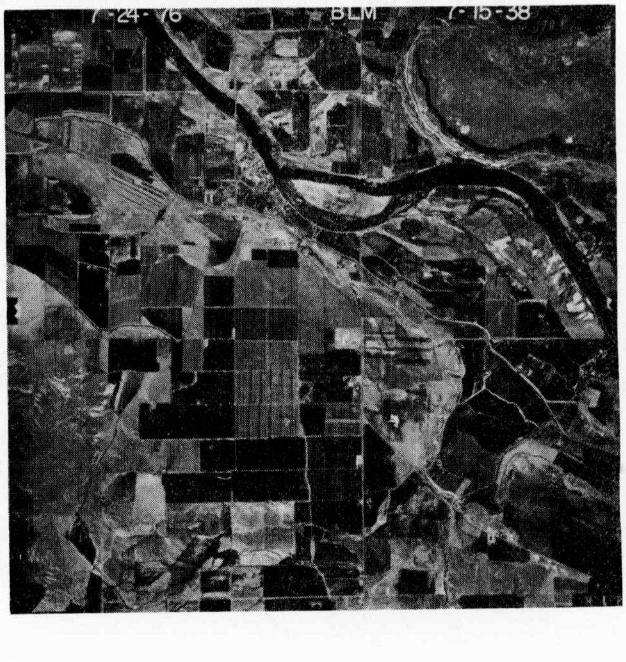


Figure 21. Classification map of the agricultural area using the MINIMUM DISTANCE classifier. An air photo of this area is also shown.



DIPAOLO

LABORATORY FOR APPLICATIONS OF REMOTE SENSING
PURDUE UNIVERSITY

JULY 18,1979
05 27 26 PM
LARSYS VERSION 3

CLASSIFICATION STUDY 912068873
RUN NUMBER............ 76021701
FLIGHT LINE... 250017411 IDAHO
DATA TAPE/FILE NUMBER.. 4538/ 1
REFORMATTING DATE. JAN 13,1979

CLASSIFIED APR 30,1979
DATE DATA TAKEN... JUNE 5,1976
TIME DATA TAKEN..... 1141 HOURS
PLATFORM ALTITUDE..3062000 FEET
GROUND HEADING..... 180 DEGREES

CLASSIFICATION TAPE/FILE NUMBER ... 4829/ 13

TEST FIELD ACREAGE TABLE FOR GROUP 1

GROUP	POINTS	ACRES	HECTARES	PERCENT
1	3261	3750.0	1518.2	17.7
2	3763	4327.3	1751.9	20.4
3	3297	3791.4	1535.0	17.8
4	2463	2832.4	1146.7	13.3
5	2022	2325.2	941.4	10.9
6	1195	1374.2	556.4	6.5
7	1055	1213.2	491.2	5.7
8	968	1113.2	450.7	5.2
9	447	514.0	208.1	2.4
TOTAL	18471	21241.0	8599.6	100.0

EACH DATA POINT REPRESENTS 1.15 ACRES
0.47 HECTARES

TOTAL POINTS IN CLASSIFICATION = 18471

TIME USED WAS 25.531 SECONDS. (LARSMN)

Figure 22. Tabulated acreages for the agricultural area representing a block of 131 lines by 141 columns.

Agricultural Area Legend

Bright soil, silts and lake sediments

Soil

Soil, some vegetation

Soil, some vegetation (a little more vegetation than the previous class)

Mix; vegetation and soil, or new crops

Crops 1

Crops 2

Crops 3

Water

Table 4. This is a description of the 9 spectral classes within the agricultural area, along with their symbols displayed on the map. The classes are numbered 1-9 from top to bottom.

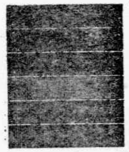
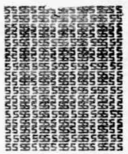
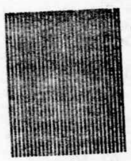
Although, in some cases there may still be a few scattered plants which were the dominant species at one time, and they may give a clue to the characteristics of the underlying soil. In areas where disturbance has occurred, invader plants such as Rabbitbrush, Russian Thistle, Horsebrush, Cheat Grass, and so forth, take over. Depending on the density of this vegetation, a different spectral response may occur. While in some cases this may cause confusion or misclassification of certain areas, a positive factor could be that a fairly accurate tabulation of the acreage of rangeland which is in poor condition can be made. In the study site for the project it was generally found that mixtures of native and invader vegetation existed and these mixture areas could be discerned spectrally. In one sample area where some native vegetation had been burned or grazed off at one time, field observations indicated two different plant types and therefore most likely a change in soil type. The computer output for this site showed a dominance of one symbol type indicating the same soil type over this area. Sample holes were then dug which confirmed that the soil was indeed the same type and thus the spectral data was correct. It appears then that at this particular locality the soil type was the dominant factor contributing to that spectral signature or class.

Generally, the soil-plant relationship was found to be correct throughout most of this study area, and the higher or old alluvial fans, pediment surfaces, mountain and plateau areas exhibited the best vegetation to soil type relationship. In these areas, where they are not disturbed by fire or over-grazing, the landforms are older with more stable soil development, and thus a better established natural vegetative community. The relationship between vegetative communities and soil type, or characteristic, identification will be discussed shortly. A description of the classes recognized spectrally and described in the field within the fan classification area is given in Table 5.

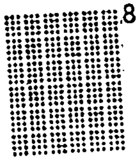
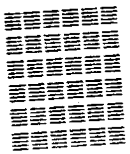
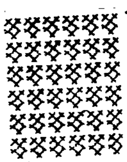
Many other plants were observed and noted during this field work, but it is felt that their contribution to the site description and spectral response was of minor importance. Many of the species were still in flower during this period of field work which aided in their identification.

Field investigations in the mountain and plateau areas revealed more distinct correlations between native vegetation and soil characteristics. Factors such as elevation, slope, and aspect also contributed to soil and vegetative varieties. The correlation between soil type and vegetation is expected to be best in the mountainous regions because of the greater age of the landforms, lack of recent soil modification, and greater stability of native plant species. Certain species are found to be good indicators of soil depth. As in the lower fan areas, there were isolated areas of disturbance caused by fire and over-grazing which could contribute to some misclassification where the spectral signatures reflected vegetation. In these higher areas, the green underbrush and the density of vegetation appeared to be the dominant spectral factors. Green forbs or grasses underlying sage caused more of a vegetative response than just the sage would have by itself. Where the vegetation was less dense, usually the outcropping bedrock or soil dominated the response. Shadows, very bright granites or silicic volcanics all proved to contribute to some classification problems. It was for this reason that the fan area was classified separately from the mountainous region. Confusion such as granites being classified as limestones or lake sediments was avoided.

Table 5.

Class	Soil Type or Description (if known)	Major and Minor Plant Types Found	Ecological Site Name	Additional Remarks
 1	Typic durargid - silty clay upper layer with a gravelly loam. May also be described as fine, montmorillonitic, mesic with a lime silica hardpan at 15+ inches.	Shadscale and bud sagebrush, with some bottlebrush squirreltail, horsebrush, and rabbitbrush. Estimated plant cover at one locality was about 15%.	Calcareous restrictive 7-10" ppt	Occurs on nearly level to gently sloping fan or pediment surfaces. Desert pavement, consisting of volcanic rocks, covers most of the surface giving it a smooth, dark appearance.
 2	Possibly a Calciorthid or Duric camborthid	Russian thistle and cheat grass with some shadscale. There are generally few shrubs.	Calcareous restrictive 7-10" ppt	Generally associated with lake sediments where the surface has been disturbed, eroded, or is sloping and dissected. Also found along roads, in drainages, and heavily grazed areas. A thin layer of alluvium or silt may also cover the surface.
 3	Possibly a Calciorthid or Torriorthent - the soil is usually high in calcium and carbonate, and may have a duripan. It is generally calcareous at the surface. Locally, the surface color was found to be 10YR7/2, light gray with pebbles on the surface. Locally this may represent a Duric camborthid.	Dominantly shadscale with some bud sagebrush, horsebrush, hop sage, wild rye, and cheat grass.	Calcareous restrictive 7-10" ppt	Generally found on higher mounds or ridges associated with a gravel layer. Drainage may be poor and conditions are dry and saline. Locally, pebbles may be found at the surface. Where associated with convex microrelief, there is less leaching away of salts. This class is also seen locally on southerly facing hillsides.
 4	Haplargids - Typic haplargid - non-calcareous at the surface. Locally carbonates are present at 10". Locally, the surface color is 10YR5/2, grayish brown.	Shadscale mix with Wyomingensis, horsebrush, rabbitbrush. Locally may represent greasewood (?) in larger drainages.	Sandy loam 7-10" approaching Calcareous restrictive 7-10". May also possibly mark a transition between the loamy and shallow sites.	May represent areas of heavy grazing, or possibly fire disturbance because of the invader species. Found locally in micro depressions and generally on gravelly ridges. Also generally associated with alluvial fan parent material.

Class	Soil Type or Description (if known)	Major and Minor Plant Types Found	Ecological Site Name	Additional Remarks
5	This class represents an area covered by crops, generally alfalfa, and usually found as long narrow fields along drainages and in canyons within the study site. It also represents less dense crops or a mixture of soil and crops. Some greasewood or dense riparian vegetation that may be present along the boundaries of these agricultural fields may have also been included under this classification, although this percentage should be negligible.			
6	Coarse sandy loams to loams, moderately deep to deep. Some stones and gravel may occur on the surface and in the profile. Generally less salts in this soil. Its location in depressions and drainages may indicate greater moisture. The pH is generally less than 8.6 and the root depth greater than 16".	Wyoming big sage, spiny hop sage, some horsebrush, and rabbitbrush. Shrub cover approximately 15-20%.	Loamy 7-10" ppt	Found in broad depressions in alluvial fans or in drainages cut in the pediment surface. Also locally seen on some small ridges or rocky areas. Generally the concave slopes have salts leached away or deeper.
	With an increase in elevation and percent slope: Similar soil type	Wyoming big sage, bluebunch grass. Shrub cover approximately 15-25%.	Loamy 10-13" ppt	With an elevation increase and higher up on the alluvial fans, this sage cover appears fairly dense and homogeneous. At both elevations, this class is seen locally on northerly facing hillsides.
7	Badland - highly calcic	Sparse shadscale	Calcareous restrictive 7-10" ppt	Generally representing the exposed Chalk Hills or Glenns Ferry formations which are highly eroded and lack dense vegetative cover. May also locally represent salt evaporites.

Class	Soil Type or Description (if known)	Major and Minor Plant Types Found	Ecological Site Name	Additional Remarks
 8	Badland - possibly Torriorthents	Shadscale with some cheatgrass, bud sage, rabbitbrush, or horse-brush.	Calcareous restrictive 7-10" ppt	Found on eroded lake sediments with generally less severe erosion as the previous class or less steep slopes. Some slight alluvial cover may give this a darker appearance. Also, this may locally represent an isolated salt patch.
 9	These soils may be calcareous throughout the profile and not have a single calcium restrictive layer. They may also be formed on silts or loess and represent Typic camborthids, coarse - loamy, mixed, mesic.	Indian ricegrass and winterfat with bud sage. Mainly grasses although some scattered shadscale was seen.	Loamy 7-10" Calcareous restrictive 7-10" ppt	Formed mainly on lake terraces which produce a generally light background. Also, locally found associated with drainages.
 10	Soils should generally be coarse sandy loams to loams, moderately deep to deep with some stones and gravel.	Wyomingensis in gullies, with winterfat bud sage, ricegrass, and shadscale on ridges. Some horse-brush and rabbitbrush are also present.	Loamy 7-10"	This class appears to be alternating between a Wyomingensis and marginal shadscale site.

Not as much time was spent in the mountain and plateau areas during this field period as was needed, but some samples and observations were made which aided in the interpretation of this classification. Lack of field time, helicopter time, accessibility and distance only permitted a few days of work in the high mountain and plateau areas. Some of the relationships observed between cover types and spectral classes in this region are given in Table 6.

The next objective of the field work was (2) to determine the factors that contributed to the spectral response in this environment. With the assumption that spectral classes within the study area have been made as separable or spectrally distinct as possible and these spectral classes represent certain cover types or combinations of cover types, a knowledge must now be gained of the factors causing or influencing these spectral signatures. It is only through this understanding of the environment and its spectral response that an accurate and intelligent interpretation can be made of the classification product. It is felt that the following key elements influence the spectral response in this area. These are:

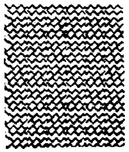
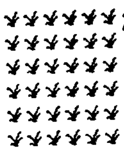
1. Plant Communities
   - a) type
   - b) density
   - c) underbrush
2. Landforms and Topography
   - a) elevation
     - slope
     - aspect
   - b) type and age
     - benches and terraces
     - alluvial fans
     - pediment and desert pavement
     - highlands, canyons, plateaus
3. Bedrock Type and Geology
   - a) stratigraphy or composition of the rocks (igneous, metamorphic, sedimentary)
   - b) weathering products
     - light or dark
     - weathered in place
     - eroded or transported, or resistant
     - rounding and size

It should be noted that the order of important of these elements will change depending upon the area one is analyzing. In the mountain and high plateau areas, the plant communities may play the dominant role in affecting the spectral signatures, while in the fan area or dissected lake sediments, factors 2 or 3 listed above may be most significant.

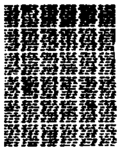
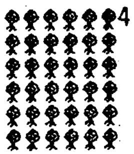
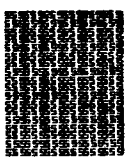
If one looks at each of these factors separately, an interdependence is seen where if one element is lacking another will dominate. Under Plant Communities, naturally if vegetation has a low density (usually on the order

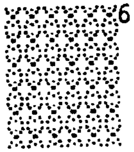
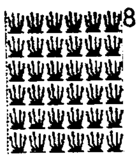
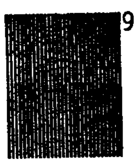
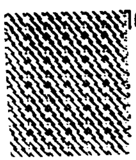
Mountain and Plateau Area Spectral Classes and Cover Types - p. 1

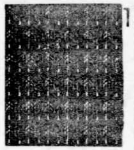
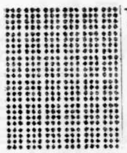
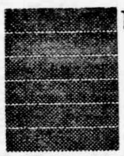
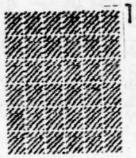
Table 6.

Class	Soil Type or Description (if known)	Major and Minor Plant Types Found	Ecological Site Name	Additional Remarks
 1	At lower elevations where the vegetative cover is Wyomingensis/bluebunch wheat grass, a deeper A horizon can be found. With higher elevation, steeper slopes or wind-swept ridges, the cover type becomes Arbuscula/Idaho fescue and the A horizon is shallow, rocky or gravelly, thin skeletal with a strongly developed clay B horizon. The root depth is usually less than 20" with a restrictive layer of rock or clay. One area sampled revealed a Typic Argixeroll soil type.	Wyomingensis sagebrush, bluebunch wheat grass at lower elevations, and Arbuscula (low sage) at elevations generally above 4500 ft. Idaho fescue was found to be the dominant grass type at elevations above 5500 ft. Some forbs seen were lupine, phlox, Indian paintbrush. There are some local inclusions of basin big sagebrush. Indian ricegrass may also be present.	Loamy 10-13" ppt Shallow 10-16" ppt Shallow 16+" ppt	Occurs on rolling foothills, mountains, and benchlands. Generally found as less dense sage in volcanics, although in the granitic terrain this class appeared to be a denser sage.
 2	Where Arbuscula occurs, the soils would be shallow with a strongly developed claypan; in areas covered by big sagebrush the soils would be loamy and deeper.	Locally, this class may represent basin big sage along drainages, and scattered mountain big sage at higher elevations. Where a burn or disturbance has occurred, this class may indicate a rabbitbrush vegetative cover. At higher elevations this class most likely represents low sage and grasses which may be Idaho fescue with abundant forb undercover.	Shallow 16+" ppt Loamy 10-13" ppt Loamy 13-16" ppt Loamy 16+" ppt	Generally light vegetation on volcanic plateau areas, and locally in granitic basins and along drainages.

Mountain and Plateau Area Spectral Classes and Cover Types - p. 2

Class	Soil Type or Description (if known)	Major and Minor Plant Types Found	Ecological Site Name	Additional Remarks
 3	Probably a deeper, moister soil; loamy	Denser sagebrush or green shrubs in drainages - may be Wyomingensis or basin big sage. This class may also locally indicate scattered rabbitbrush where a burn may have occurred. Mountain big sage could also be included in areas covered by this class.	Loamy 10-13" ppt Loamy 13-16" ppt Loamy 16+" ppt	Found on volcanics generally representing denser or darker vegetation in low areas or drainages. May also be found on some ridges with some vegetation and on the northwest slopes of hills.
 4	Loamy soil 18-40" deep; may possibly be classed as frigid or cryic.	Dense mountain big sagebrush (Vaseyana) with a lush undercover of forbs and grasses. May also include basin big sage and mountain mahogany. The dominant grass is Idaho fescue with forbs lupine and mint.	Loamy 16+" ppt Mountain brush 16+ ppt	May represent areas of fractured rock. Found in crevasses, depressions and on slopes usually at elevations greater than 4500 ft.
 5	Soil is shallow, rocky, less than 20" deep. This class may locally represent a rock outcrop. One sample indicated some of the soils may be Xerollic haplargids.	Sparse Arbuscula and bud sage with bluebunch wheat grass and/or Idaho fescue, and some Indian ricegrass.	Shallow 10-16" ppt Shallow 16+" ppt	Dark volcanic rocks or pebbles on the surface dominate the spectral response of this class. May represent some windswept areas. Usually associated with shallow soils and rock outcrops. Variations in the density of the vegetation will occur based on slope aspect and position. Windswept ridges will have less vegetation than sheltered slopes.

Class	Soil Type or Description (if known)	Major and Minor Plant Types Found	Ecological Site Name	Additional Remarks
 6	One soil sampled was loamy, skeletal, mixed mesic xerollic haplargid with 20% duranodes. It is slightly calcareous and an aridosol with an argillic horizon. In granites it may be a Typic Argixeroll.	Very sparse Arbuscula, some shadscale, and grasses at higher elevations. Cheat grass and sandberg bluegrass were the main grass types found. In granitic terrain this appears to represent Wyomingensis or Arbuscula depending upon elevation.		At lower elevations this class may represent sagebrush on alluvial fans or on granitic rocks. On rhyolitic plateaus it appears as shadscale, grasses, sparse Arbuscula. There is much rhyolitic gravel on the surface.
 7	At one locality the soil was described as a lithic xerollic haplargid, loamy, skeletal, mixed mesic haplargid; strong gravelly argillic horizon with 34% clay. Ground cover is approximately 60% rock and 30% vegetation. Soil is non-calcareous.	Sparse Arbuscula with some bud sage. Locally may represent Wyomingensis.	Generally an Arbuscula site.	Generally found on fairly level volcanic rocks. Observed at one locality with outcropping banded rhyolite and obsidian
 8	Similar to Class 4	Scattered mountain big sagebrush and green underbrush. Less dense than Class 4.	Loamy 16+" ppt Possibly loamy 13-16" ppt	Locally, this class may also represent a shallow soil typical of an Arbuscula site. This is generally found on higher rhyolitic plateaus. Some scattered Vaseyana may also be present.
 9	May be similar to Class 7 with more exposed rock and occurring more on sloping areas.	Arbuscula - probably less dense than Class 7.	Arbuscula site	Near volcanic rock outcrops. Rock exposed on slopes or in ledges.
 10	The class appears to represent basaltic rock in canyons or on slopes; also talus.			

Class	Soil Type or Description (if known)	Major and Minor Plant Types Found	Ecological Site Name	Additional Remarks
 11	Shadow			
 12	This cover type indicates deep soils, probably greater than 40". These soils are also moist, and can possibly be classed as frigid or cryic	Choke cherry, snowbrush ceanothus, some Vaseyana, some aspen, Idaho fescue, phlox and other forbs. Vegetation density is probably greater than 70%.	Mountain brush 16+"ppt	Generally isolated clumps of green trees located in canyons, on slopes, and sheltered crevasses. The slopes are usually steep with northerly and easterly aspects.
 13	This class is usually associated with granitic rock outcrops with little vegetation or soil. It is found representing light siliceous volcanics. Locally, it represents a flat playa.			
 14	Steeper slopes in granitic terrain representing an apron of light vegetation directly below Class 13. Also seen on southerly slopes with less dense vegetation and in siliceous volcanic rocks. Where the topography flattens in the fan area, this class locally represents shadscale-sage mixture.			
 15	Possibly locally represensing a Xerollic haplargid or a Typic Argixeroll.	In rhyolitic volcanic areas this appears similar to Class 6. Locally on lower alluvial fans this is possibly a mixture of shadscale and sage.		Generally found in granitic rocks or associated with siliceous volcanics.
 16	Possibly a Xerollic haplargid, fine-loamy mixed mesic, well drained, probably weathered in place; or a Typic Argixeroll.	Wyomingensis on fans. Sparse sage or sage and hop sage in granitic areas. In rhyolitic plateau areas this appeared to represent shadscale and grasses with some Arbuscula.	Possibly loamy 10-13" ppt	Generally found in drainage areas in granitic terrain; also in siliceous volcanics and on some rhyolitic plateaus.

of less than 15-20% total vegetative cover) then soil, bedrock alluvium, or desert pavement will be the dominant factor in influencing the spectral response. An interesting study may be to see at what percent total vegetative cover does the spectral curve begin to take on a vegetative or vegetation-soil mix curve in this arid environment. The type of plant is also important. Most varieties of sagebrush have been found to generally be non-reflective in the infrared, and the spectral properties of these types of plants warrants further study. Certain plants may have greater leaf area, a broader canopy, or contain more moisture or chlorophyll which may also affect the response. From this field work, and followed by a re-examination of certain spectral curves at selected sample sites, it has been observed that dense green underbrush in the form of grasses and forbs will contribute a strong vegetative spectral response. In certain sagebrush sites where a dense undergrowth of green forbs and grasses was found, the spectral curves and the ratio of VIS/IR reflectance indicated a definite green vegetation response which is generally not observed where sagebrush is found alone. Examples of the green underbrush found in a Vaseyana area (Alpine sagebrush) are shown in Figure 23. The sagebrush alone did not form spectral classes with a vegetative response, but where this undergrowth of grasses (Idaho Fescue) and forbs (Lupine) was present, there was a good vegetative response from these classes. The leaf structure of a sagebrush (Wyomingensis) is shown in more detail in Figure 24. Also in this figure is a close-up view of the leaves on a plant (Hawthorne?) found in a nearby drainage which probably causes the spectral class in this drainage to have a vegetative signature. When comparing the two plants, it can be noted the sagebrush leaves are a duller green, longer, more narrow, and thicker than the other plant. The shape of the plant leaf in the drainage is wider and flatter than the sagebrush leaf and the color is a bright shiny green. Both plants also vary in density with sagebrush being more scattered and, therefore, more soil being exposed.

Landforms and Topography also are factors in determining the spectral response in this area. Elevation, slope, and aspect may be interrelated to vegetative communities. Denser vegetation and different species were found on some northerly slopes, and at different elevations (see Figure 25). Areas of steeper slopes may be more susceptible to erosion, and windswept slopes may exhibit less dense vegetation and more rocks at the surface. The type of landforms and their age are also factors. Flat benches or terraces which are windswept may have a thin veneer of pebbles on the surface which is referred to as desert pavement. Where this material is coated by MnO or FeO, sometimes called desert varnish, a general dark smooth texture may be observed and this overshadows any response from the vegetation that may be present on the surface (see Figure 26). In this study area, the vegetative type found on these pediment surfaces was generally in the shadscale community with a density of approximately 15%. As expected, the desert pavement is the dominant factor controlling the spectral response, and this particular response is unique. In this instance, this combination of factors leads to a very good description of expected soil characteristics and spectral mapping of these areas is highly accurate.

Finally, the bedrock type and geology may also contribute to the observed spectral response. Sedimentary, igneous, and metamorphic rocks weather differently producing different landforms. Igneous rocks may weather to different textures and different degrees depending upon the composition. Generally, rocks high in quartz and feldspar will be more resistant while those containing more ferromagnesium minerals will weather quicker. Where a regolith forms,

Figure 23. This is an example showing an area of Vaseyana (Alpine sage)(top) with green grasses and forbs growing at the base of these plants. The bottom photo shows these forbs (Lupine) and grasses (Idaho Fescue) in more detail.

Figure 24. The leaves from two different plants are shown here. Hawthorne(?) in the top photo is found along drainages and exhibits more of a vegetative response than does the Wyomingensis (below) which gives very little, if any, vegetative spectral response.

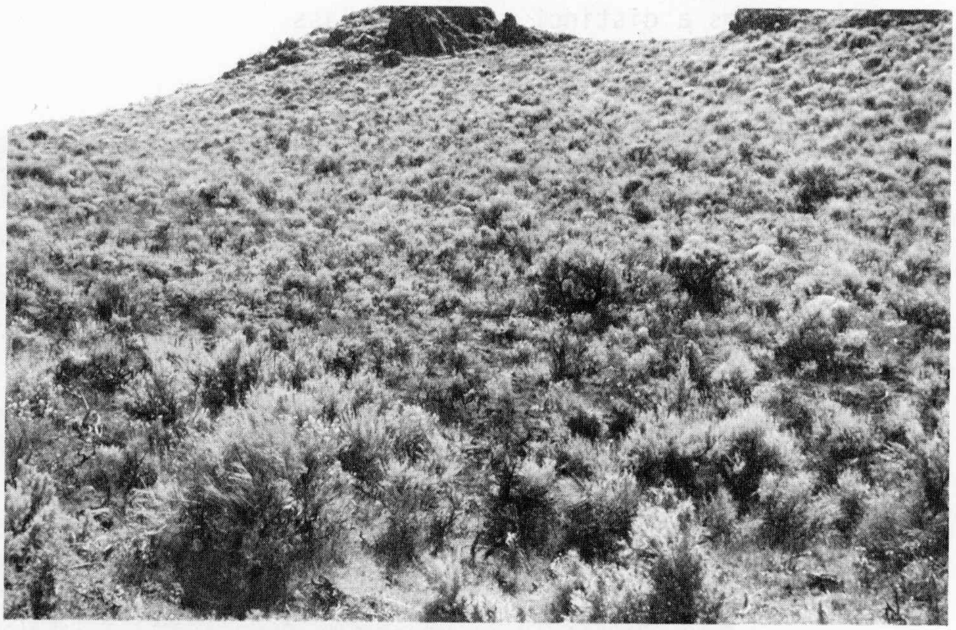


Figure 25. These photos were taken within the same canyon at one locality showing the south facing slope (top) and the north facing slope (bottom). The south facing slope exhibits more rock exposure and less dense vegetation while the north facing slope shows denser and greener vegetation. It should also be noted that on the north facing slope some shadows are present at the base of the plants which may also influence the spectral response.

Figure 26. Desert pavement along with scattered shadscale found on a pediment surface. The desert pavement dominates the spectral response and forms a distinct spectral class.

Figure 27. A shallow soil forming on a granitic fan area. Pieces of parent material can be seen in the soil removed from the hole. This soil was described as a Xerollic Haplargid, coarse loamy mixed mesic, very well drained. Depth is about 20-30" to weathered granite.

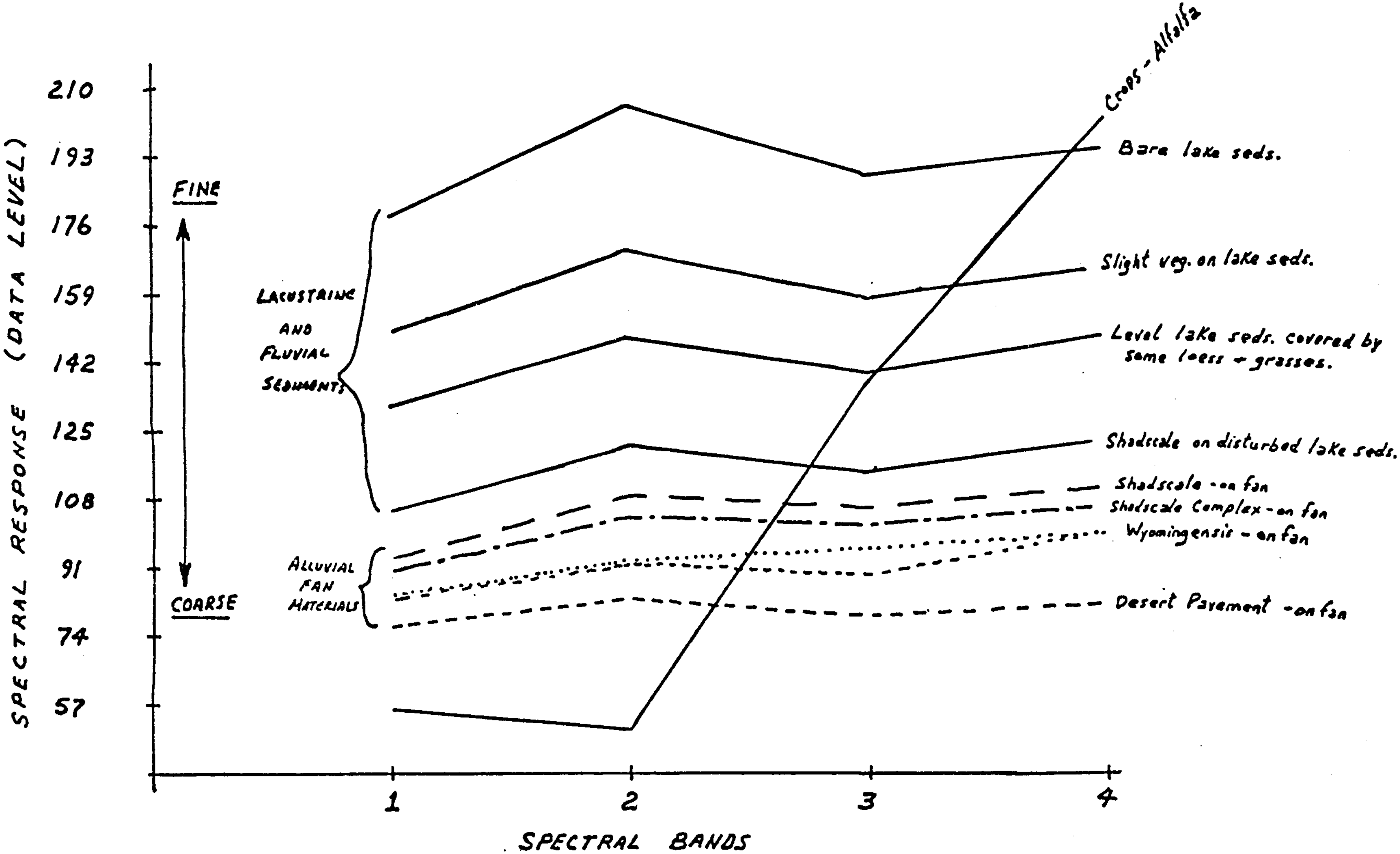


Figure 28. Spectral curves of various cover types within the Alluvial Fan classification area.

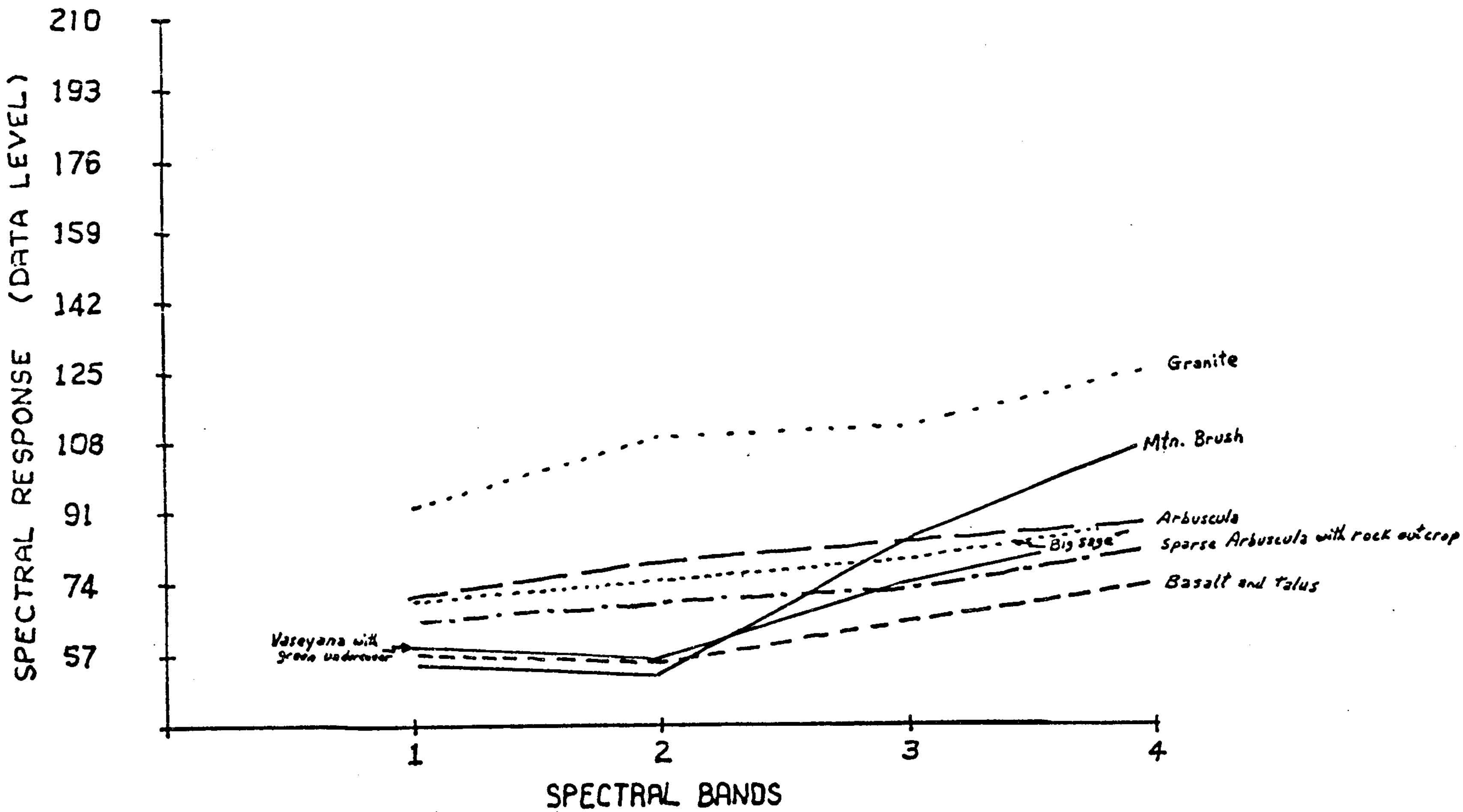


Figure 29. Spectral curves of selected cover types within the Mountain and Plateau area.

a direct correlation can be found with soil types. Where this material is transported, the more resistant and finer components will travel farthest and thus influence the spectral response. Such areas may be at the foot of alluvial fans. If this area is interfingered with sediments deposited along the flanks of streams as they meandered through a valley in the past, the resulting soil forming this zone may be highly silty and easily eroded. This type of zone could form a distinctive spectral response. The composition of rocks contributing to the soil profile will definitely be a prime factor influencing the response. Certain limestones may cause local soils to be highly calcareous while minerals eroding from metamorphic rocks may promote the formation of clays. Soils forming on granites are generally found to be sandy in nature (see Figure 27).

The factors just discussed are thought to be important in causing the types of spectral response observed within this study area. It is felt that a good understanding of the elements contributing to the spectral response is important where inferences must be made in the determination of soil characteristics. It will most likely be found in future work that as the understanding of the spectral nature of this arid environment increases, the accuracy and reproducibility of soil spectral maps within this and similar regions will also increase.

Some selected spectral curves of various cover types within the study area are shown in Figures 28 and 29. In the Alluvial Fan classification area spectral curves of soils developed on the lacustrine and fluvial sediment areas are distinctly brighter than those formed on the alluvial fans. Also materials deposited closer to the mountain fronts are generally coarser than those transported further, so possibly a relationship may also be seen between texture and spectral response. The variation seen in the two Wyomingensis curves which were plotted in Figure 28 may either be caused by plant density or a grass undercover. The curve showing the weak vegetative response may reflect these possibilities, while the lower curve of the two which appears more like a soil response is probably a factor of low plant density. As was mentioned earlier, sagebrush was found to be non-reflective in the infrared when growing alone. Table 7 lists some ratios and magnitudes of these classes. It can be seen that all of the classes except the alfalfa growing in the canyons, have ratios greater than 1.0. This seems to indicate that the non-vegetative surface materials dominate the spectral response in the alluvial fan and lowland areas, and even where sagebrush stands appear fairly dense the non-IR channels dominate. Most likely the variability seen in the Wyomingensis ratios may be a reflection of plant density. Note also that magnitude values significantly reflect changes in cover types.

The spectral curves showing the response of some of the cover types in the mountain and plateau area appear to have more of a vegetative signature. Note the difference between the big sage curve and the Vaseyana curve with green underbrush. This is also shown in the ratios listed in Table 8.

The final objective of the field work in southwestern Idaho was to determine how these spectral classes, and their associated cover types, would aid in defining soil characteristics which might reduce the manpower and time needed in the field by the soil scientist and possibly increase the accuracy of his product which would be a third order soils survey. It should be

Table 7. Alluvial Fan Area.

	Ratio vis/IR	Magnitude
Shadscale - Fan (Calcareous)	1.093	177
Shadscale Mix - Fan	1.091	169
Wyomingensis - Fan	1.133	152
	1.097	153
	1.053	157
Desert Pavement - Fan	1.154	135
Bare Lake SEDS.	1.170	323
Slight veg. on dissected lake seds.	1.163	292
Level lake seds covered by some loess and grasses.	1.153	252
Shadscale on disturbed lake seds.	1.125	194
CROPS-Alfalfa	0.394	170

Table 8. Mountain and Plateau Area.

	Ratio VIS/IR	Magnitude
Granite	1.007	183
Basalt and Talus	0.954	104
Sparse arbuscula with rock outcrop	1.027	121
Arbuscula	1.015	135
Big Sage	1.014	130
Vaseyana with green undercover	0.851	113
Mountain Brush	0.669	120

emphasized that it is not the intent of this project to directly make a third order soils survey map from Landsat data. Instead the intent is to produce a tool to facilitate and aid in the construction of this map by the soil scientist. (It should be noted that highly detailed soils maps have been produced using Landsat data and are currently being field checked by the SCS in the midwest. Also more sophisticated equipment will be aboard Landsat-D in 1981 which will increase the number of spectral bands available and provide better clues to soil characteristics. In addition the resolution will be finer and the amount of data should be increased.)

Many of the relationships of spectral classes to cover types and soil characteristics have been noted in Tables 5 and 6. Some of these relationships have already been alluded to in previous discussion. As was mentioned before, vegetative communities generally have been found to be consistent indicators of soil characteristics in this area, and where major changes occur in the natural vegetation, changes in soil type are also usually found. A very general and abbrebiated list has been made indicating some of these relationships. This is shown in Table 9.

The overall distribution of sagebrush species is related to soil development, moisture, and temperature.

In addition to vegetation, landforms and geologic materials and processes may indicate soil characteristics. Some of their relationships to soil characteristics was discussed in the previous section. Within this study area the following non-vegetative divisions were noted which could indicate changing soil characteristics:

1. Lacustrine and fluvial sediments
    a. terraces
    b. badlands
    c. slightly covered with loess or alluvium
2. Fan material
    a. derived from siliceous rocks
    b. derived from darker volcanic rocks
    c. flat pediment
        - desert pavement
    d. slight slope
    e. steeper slope
3. Granitic rocks
    a. steep and rocky
    b. less steep
    c. basins and drainages
4. Volcanic rocks
    a. steep and rocky
    b. less steep
    c. drainages
5. High flat volcanic plateaus
    a. rhyolitic
    b. basaltic

Table 9.

Plant Type (Major and Some Minor)	Soil Characteristic
Shadscale Bud sagebrush	Calcareous restrictive; poorly leached - high in salts and calcium; generally associated with a shallow root barrier such as gravels, duripan, or durinodes; pH > 8.6 and root depth < 16"; dry conditions; found more on flat ridges or mounds, and on some southerly slopes.
Greasewood	Generally follows the water table; found more on bottomlands or in drainage; saline soils, highly calcareous.
Russian thistle Cheat grass Horsebrush Rabbitbrush	Indicates disturbance, possibly by man, overgrazing, or fire.
Wyoming bigsage Spiny hopsage Indian ricegrass Bluebunch wheatgrass (at higher elevations) Winterfat Rabbitbrush (similar environment as Wyomingensis but indicates disturbance)	Generally found in depressions or on northerly slopes; the salts are leached away; may be indication of moister conditions; pH < 8.6 and root depth usually greater than 16"; loamy; may extend to elevations of 6000'
Basin bigsage - Tridentata	Generally indicates deeper soil, moister conditions, and is found along drainages; may also occur where precipitation is between 13-18", and on northerly facing slopes; loamy
Mountain bigsage - Vaseyana Bluebunch wheatgrass (deeper A horizon) Idaho Fescue (where precipitation > 16" - shallow A horizon) Lupine Phlox	Found generally above 4500 feet where precipitation > 18" although it has been described where precipitation > 13"; soil depth is medium to deep - approximately 20-40".
Mountain Brush Choke cherry Snowbrush ceanothus Lupine Phlox Idaho Fescue	Found in moist crevasses and pockets at higher elevations; indicates deep soils, generally > 40"

Table 9. (Continued)

Plant Type (Major and Some Minor)	Soil Characteristic
Low sagebrush - Arbuscula Bluebunch wheatgrass (precipitation 10-16") Idaho Fescue (precipitation > 16")	Indicates shallow soils (less than 20" root depth) with restrictive layers of rock or clay; generally found at elevations > 4000'; very rocky or shallow soils, windswept ridges and exposed aspects will decrease the density of this plant; soil may be thin skeletal and have a strongly developed clay B horizon.

These five major divisions could also be considered stratum upon which separate classifications could be made. While generally good spectral delineations were made and confirmed during this field period, and this study site has been stratified into three major classification areas for this project, stratification made on the basis of the five divisions just listed could reduce most of the confusion or questionable classes present. It is felt that any future classification efforts in this region should be stratified along these lines, and possibly incorporating digital terrain data in the analysis using certain elevations and slopes as additional stratum could prove helpful. This stratification in addition to a knowledge of the vegetative communities and their spectral responses should help produce a product of dependable quality which would be extremely useful to the Bureau in its current soils effort by saving manpower, time, and money.

Some vegetative types which may indicate certain soil characteristics are shown in the following figures.

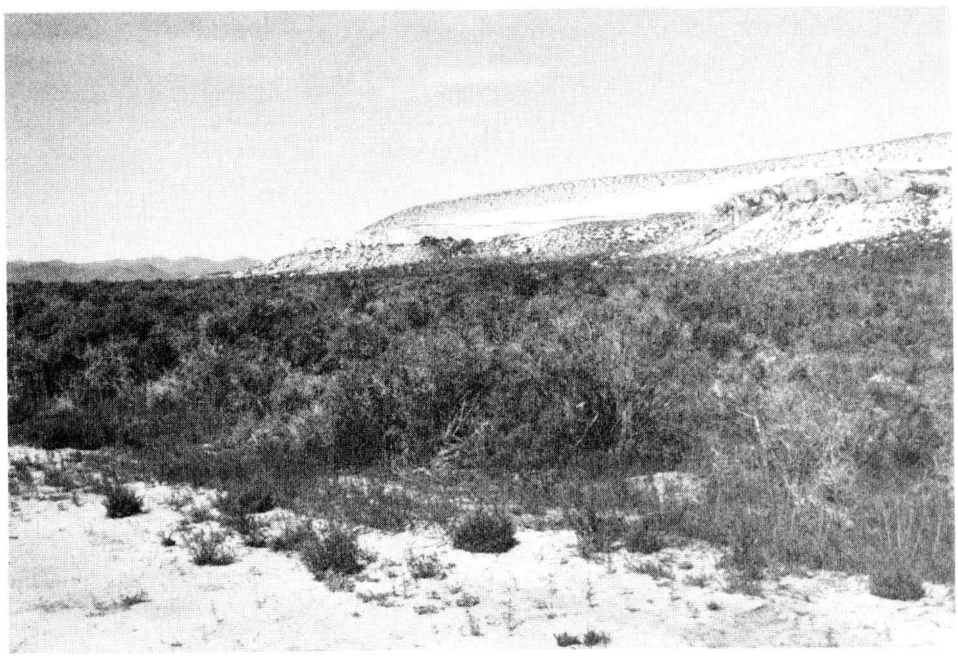


Figure 30. This is dominantly a greasewood site with exposed lake sediments in the background. The slight vegetation on the slopes of the lake sediments is shadscale which grows in a calcareous and restrictive environment. The greasewood generally follows the water talbe and is found more on bottom lands or in drainages indicating saline and highly calcareous soils.

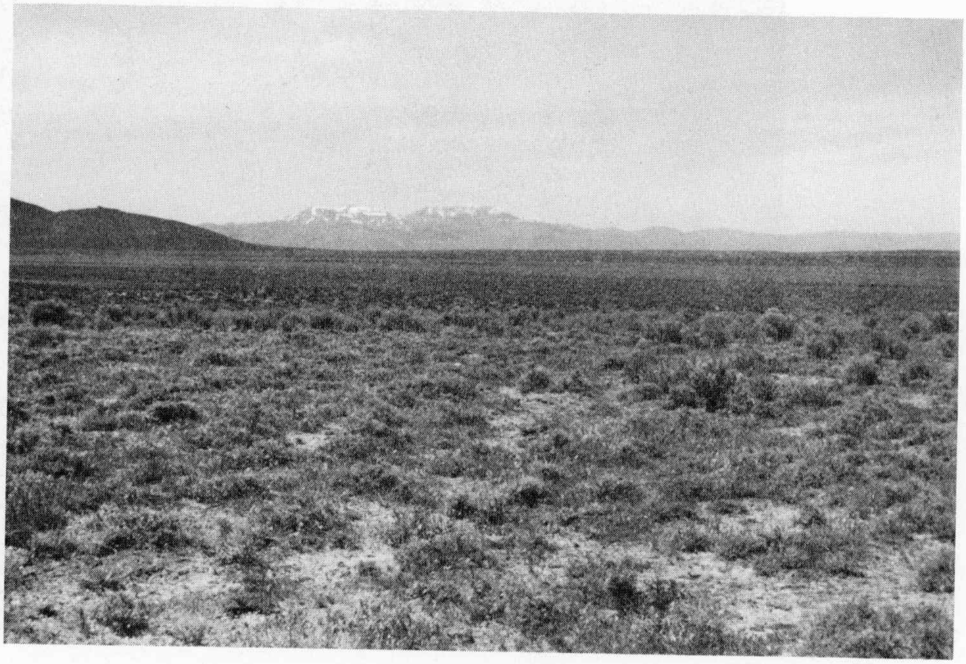


Figure 31. In the foreground and on the ridges is shadscale with some bud-sage which is generally indicative of a calcareous restrictive environment. In the lower areas or depressions and showing up as darker areas in the distance is Wyomingensis (Wyoming bigsage) which indicates a loamy site where salts are leached away. These alternating loamy and calcareous restrictive zones, along with transition zones are spectrally distinct and show up quite well in the Landsat data.

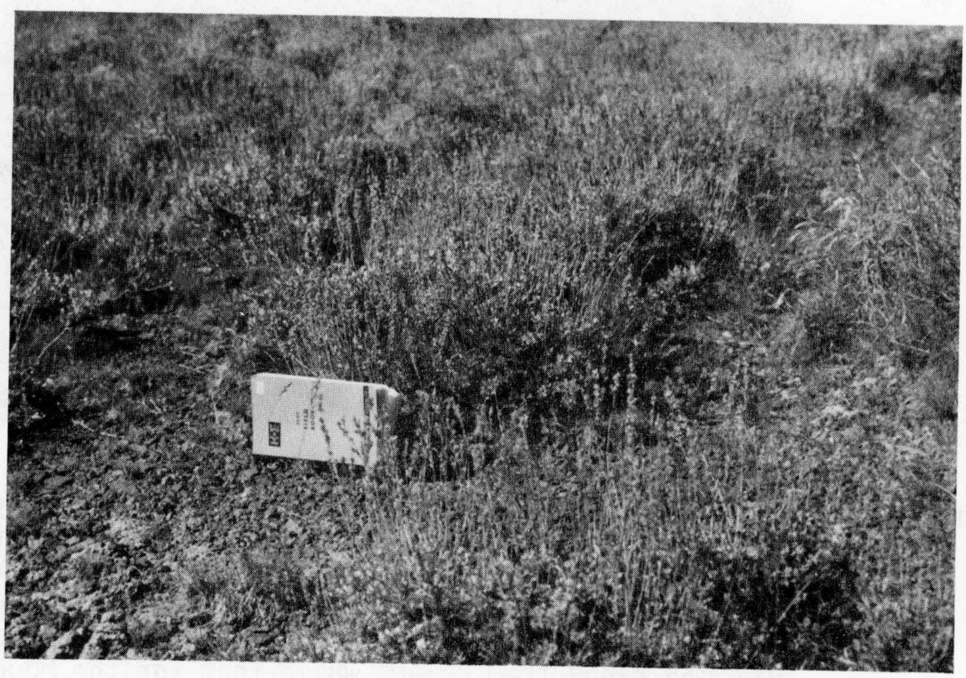


Figure 32. Arbuscula or low sage sites indicate soil depths are generally less than 20" with restrictive layers of rock or clay.

Figure 33. This shows a comparison of Arbuscula on the left with Wyomingensis on the right.

Figure 34. In the foreground is Vaseyana (Alpine sage) with Idaho Fescue (grass), while in the background, lacking leaves in mid-May, is mountain brush consisting of Choke Cherry and Snowbrush Ceanothus. These sites at the higher elevations (generally above 4500') may give an indication of soil depth. The depth for the Vaseyana area may range from 20-40" while that for the Mountain Brush area is generally greater than 40". In the analysis of the June 5 scene, these classes have been separated.

Results

In the previous two sections on analysis and field procedure, many observations were made concerning technique and results. It should be seen that every step in the analysis procedure should be considered important, and each step builds upon the other.

The end product from this procedure, after preliminary classifications have been field checked, will be the final classification map. The applicability of this product to meeting the needs of the resource specialist must now be demonstrated. Unless this product can be used with positive results, then the time and effort involved in making spectrally distinct classes in the laboratory will have little meaning.

In the next section entitled Landsat Data and Soil Surveys, the applicability of this technology to current soil survey efforts in the West is discussed. Part of the objective of this work was to determine which factors contributing to a third order soil survey can be addressed using Landsat technology. As mentioned in the previous section, due to the experimental nature of this research, it was found that additional techniques could have aided in producing the final classification for this area. Factors considered important would be boundary digitization on geology and geomorphology, more field time and sampling, and a thorough analysis of the spectral classes in relation to soils information needs by an experienced soil scientist.

It is felt that the results of this work show the capability for using Landsat data as a stratification tool in soils investigations, thereby reducing the number of transects and on-site observations necessary during the survey. In certain cases, spectral information will also reveal subtleties and inclusions which could better define unit boundaries and increase description detail. Spectral classes may also be refined by the incorporation of geological information such as two spectral classes being similar but lying on different geological units. Where they may have been given the same informational names before, their descriptions would now be refined based upon the difference in parent materials.

It is felt that limitations to classification dependability will result where the terrain being classified is extremely rugged. Then again, extremely rugged terrain could limit field survey accuracy also. In this mountainous terrain shadowing, slope, and aspect could all prove to reduce spectral classification accuracy. Again, geological information could aid in class interpretation in these areas as could topographic or terrain data. Incorporating digitized terrain data and elevation contours was not performed during this project, but work has been done in this area by other researchers with mixed results. The contour interval and contour line registration may be limiting factors in the use of digitized terrain data in certain areas for soil survey work. On the other hand, this information when incorporated into an analysis could prove quite useful for stratification purposes. Currently, research is also being conducted on developing techniques to eliminate topographic or shadowing effects, thereby determining which spectral responses are being caused by non-shadow elements such as denser vegetation growing on northerly aspects.

Where vegetation is dense and the spectral response is dominated by certain vegetative types, alteration in natural vegetative growth by nature or man could lead to misclassification. Such alteration or change in native species may occur as a result of fire, overgrazing, or chaining and reseeding and so forth. Invader species will usually follow, and their spectral characteristics must be determined. While these native vegetation alterations were not found to be significant in this study site (there were local areas), work done in other regions may reveal more alteration of the native plant species. The use of Landsat data as an image analysis may prove to be helpful in delineating these areas. RBV (Return Beam Vidicon) data may also help in locating areas of disturbance before beginning an analysis. This type of imagery, which has a greater resolution than other Landsat data, may also aid in preliminary stratification or selection of cluster sites.

While the complete classification maps could not be attached to this report, portions of these maps have been included in this section as figures. The Varian plotter output is displayed because it is felt that patterns can be recognized easier visually on this than on other forms of output. Acreages and class percentages have also been tabulated for each sample area. It should be noted that accurate acreage, hectare, and class percent calculations can easily be made, and this information may be used in determining dominant soil units which would aid in a more accurate description of the area. Rangeland in poor condition, badland areas, or agricultural acreages may all be accurately tabulated for resource planning purposes. This could reduce errors caused by the tedium or uncertainty involved in visual approximation techniques.

In addition to the sample classification output and acreage tables, photographs are included in the figures which show specific cover types as they appear on the ground. Copies of the aerial photographs covering each sample area are also included for comparison. These air photos were taken in late July of 1976. The Landsat data was obtained on June 5, 1976. Tables 5 and 6 should also be referred to for a more accurate description of the spectral classes represented by different symbols.

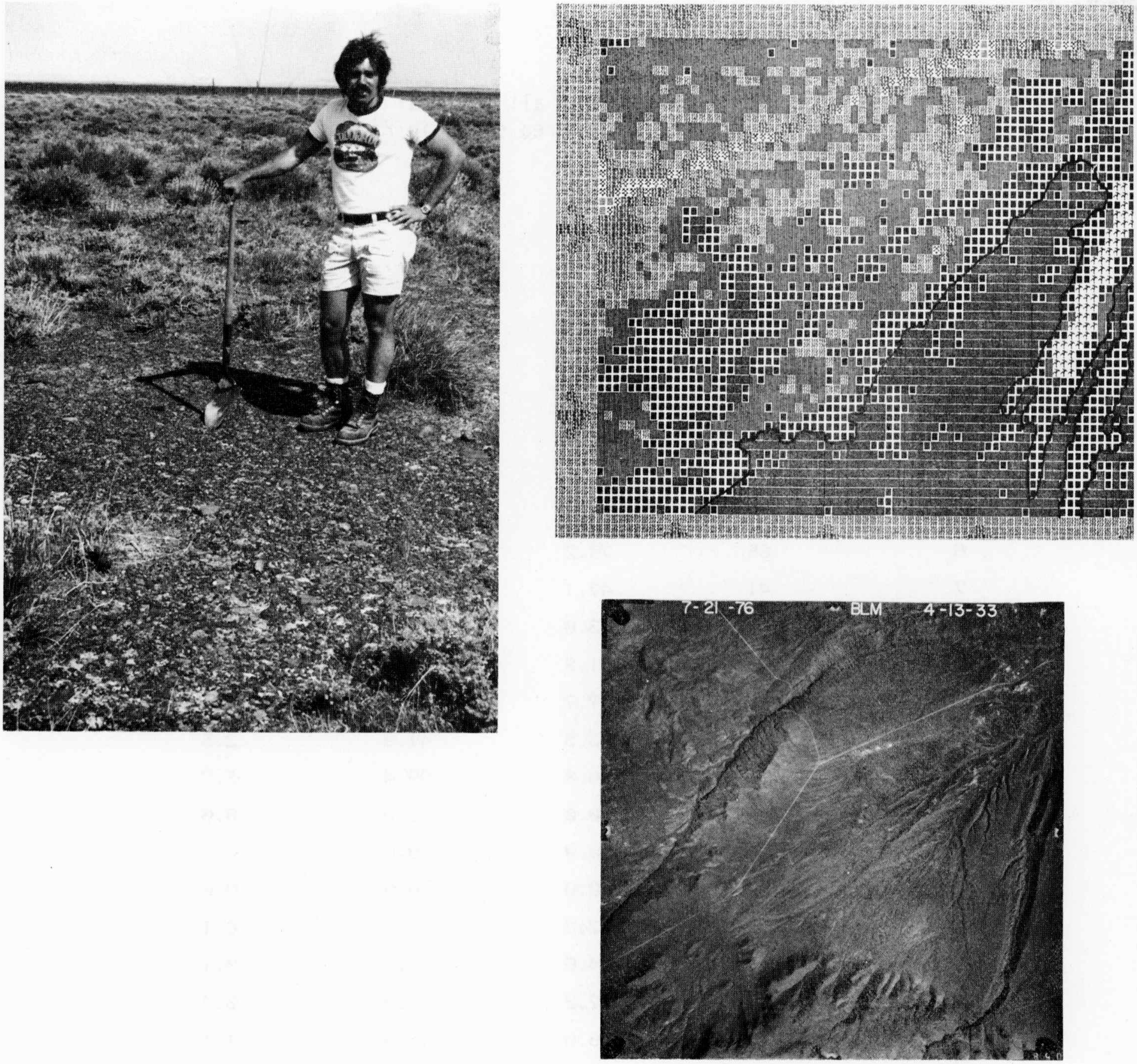


Figure 35. The classification map above represents Cluster Area 1. The class outlined represents a pediment surface covered with desert pavement. The photo to the left shows an example of this area in the field which is calcareous restrictive and dominated by a shadscale community. A description of all the classes within this area is given in Table 5. The air photo shown below corresponds to this classification area. The agricultural field observed in the drainage on the right side of the air photo can be seen on the classification map and used for registration as can the road which crosses the classification map in the upper left corner. It should be noted that the area outlined on the classification map and delineated as desert pavement also corresponds to older alluvial fan material. This area may also be stratified to aid in the designation of areas which show soils formed under a certain set of conditions.

Table 10. Acreages calculated for all spectral classes within the sample classification area shown in Figure

GROUP	POINTS	ACRES	HECTARES	PERCENT
1	863	992.4	401.8	23.8
2	137	157.5	63.8	3.8
3	490	563.5	228.1	13.5
4	571	656.6	265.9	15.8
5	18	20.7	8.4	0.5
6	68	78.2	31.7	1.9
7	41	47.1	19.1	1.1
8	620	713.0	288.7	17.1
9	132	151.8	61.5	3.6
10	198	227.7	92.2	5.5
11	90	103.5	41.9	2.5
12	192	220.8	89.4	5.3
13	0	0.0	0.0	0.0
14	0	0.0	0.0	0.0
15	0	0.0	0.0	0.0
16	2	2.3	0.9	0.1
17	4	4.6	1.9	0.1
18	15	17.2	7.0	0.4
19	40	46.0	18.6	1.1
20	141	162.1	65.6	3.9
TOTAL	3622	4165.3	1686.4	100.0

EACH DATA POINT REPRESENTS 1.15 ACRES
0.47 HECTARES

TOTAL POINTS IN CLASSIFICATION = 3622

Table 11. These classes were grouped and symbols were combined to form 10 classes which are listed and described in Table 5. Acreages calculated for these combined classes are given below.

Group	Points	Acres	Hectares	Percent
*1	863	992.4	401.8	23.8
2	137	157.5	63.8	3.8
3	490	563.5	228.1	13.5
4	969	1114.3	451.3	26.8
5	59	67.8	27.5	1.6
6	1043	1199.4	485.6	29.0
7	0	0.0	0.0	0.0
8	0	0.0	0.0	0.0
9	6	6.9	2.8	0.2
10	55	63.2	25.6	1.5

*Represents the amount of desert pavement indicated within this classification area.

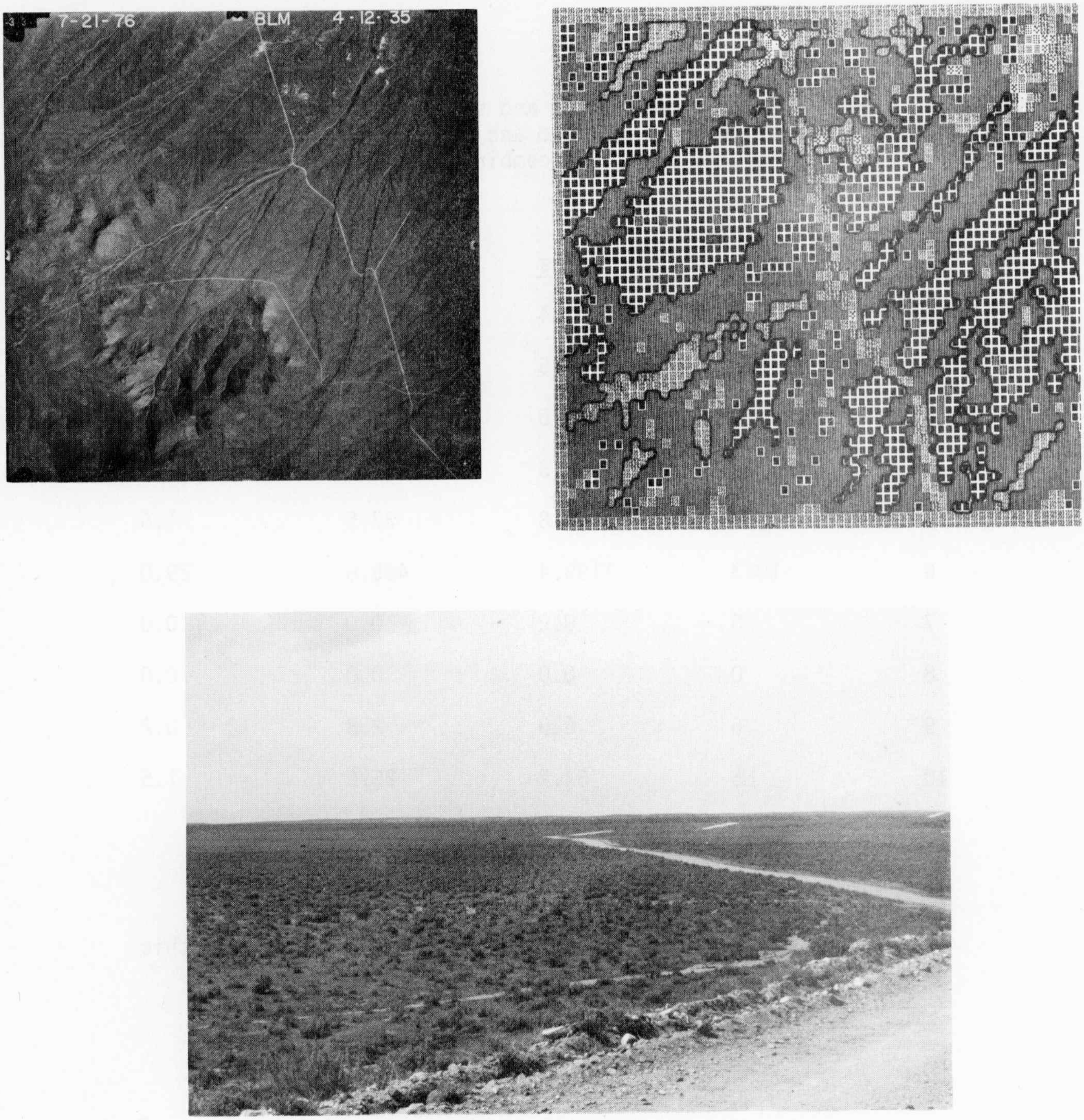


Figure 36. An example of a loamy sage site found in depressions alternating with a shadscale (calcareous restrictive) - transition area. These classes are outlined in the sample block above. Descriptions of these symbols can be found in Table 5. The road appearing in the photo can also be seen in the classification map. The air photo covering this area is also shown next to the classification map. These classes are lying on alluvial fan material.

Table 12. Acreages for all spectral classes shown in Figure 36.

GROUP	POINTS	ACRES	HECTARES	PERCENT
1	4	4.6	1.9	0.1
2	77	88.5	35.9	2.3
3	315	362.2	146.7	9.6
4	627	721.0	291.9	19.1
5	0	0.0	0.0	0.0
6	271	311.6	126.2	8.2
7	0	0.0	0.0	0.0
8	261	300.1	121.5	7.9
9	341	392.1	158.8	10.4
10	406	466.9	189.0	12.3
11	242	278.3	112.7	7.4
12	536	616.4	249.6	16.3
13	3	3.4	1.4	0.1
14	1	1.1	0.5	0.0
15	3	3.4	1.4	0.1
16	2	2.3	0.9	0.1
17	5	5.7	2.3	0.2
18	4	4.6	1.9	0.1
19	18	20.7	8.4	0.5
20	172	197.8	80.1	5.2
TOTAL	3288	3781.2	1530.8	100.0

EACH DATA POINT REPRESENTS 1.15 ACRES
0.47 HECTARES

TOTAL POINTS IN CLASSIFICATION = 3288

Table 13. These classes were grouped and symbols were combined to form 10 classes which are listed and described in Table 5. Acreages calculated for these combined classes are given below.

Group	Points	Acres	Hectares	Percent
1	4	4.6	1.9	0.1
2	77	88.5	35.9	2.3
3	315	362.2	146.7	9.6
4	1645	1891.6	765.9	50.0
5	0	0.0	0.0	0.0
*6	1211	1392.6	563.9	36.8
7	3	3.4	1.4	0.1
8	4	4.5	1.9	0.1
9	7	8.0	3.2	0.3
10	22	25.3	10.3	0.6

*Indicates the acreage tabulated for spectral classes representing loamy sites covered by Wyomingensis; generally found in depressions on alluvial fan material.

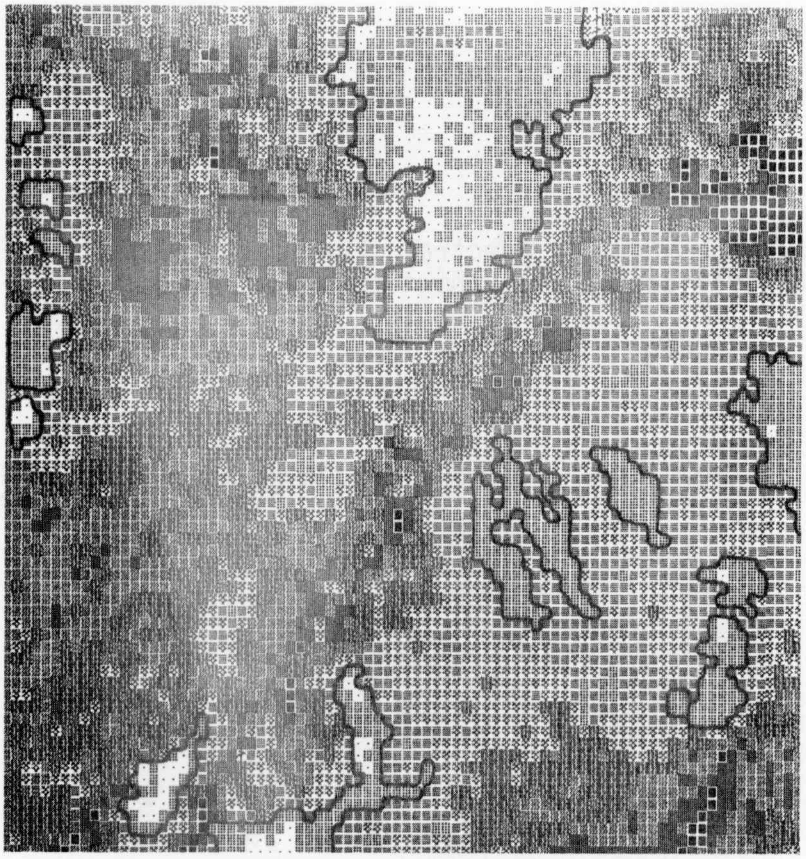


Figure 37. This classification map shows an area with classes formed mainly on lake sediments, some loess and alluvial fan material, and also alluvium deposited along the drainage of the creek seen running on a diagonal from the lower left to the upper right. The areas outlined on the classification map represent exposed lacustrine and fluvial sediments. The air photo representing this area is also shown.

Table 14. Acreages for all spectral classes within the sample classification area shown in Figure 37.

GROUP	POINTS	ACRES	HECTARES	PERCENT
1	2	2.3	0.9	0.0
2	1068	1228.2	497.2	18.6
3	1076	1237.4	501.0	18.7
4	276	317.4	128.5	4.8
5	4	4.6	1.9	0.1
6	48	55.2	22.3	0.8
7	1	1.1	0.5	0.0
8	24	27.6	11.2	0.4
9	82	94.3	38.2	1.4
10	18	20.7	8.4	0.3
11	4	4.6	1.9	0.1
12	23	26.4	10.7	0.4
13	151	173.6	70.3	2.6
14	320	368.0	149.0	5.6
15	445	511.7	207.2	7.7
16	539	619.8	251.0	9.4
17	502	577.3	233.7	8.7
18	524	602.6	244.0	9.1
19	604	694.6	281.2	10.5
20	40	46.0	18.6	0.7
TOTAL	5751	6613.6	2677.6	100.0

EACH DATA POINT REPRESENTS 1.15 ACRES
0.47 HECTARES

TOTAL POINTS IN CLASSIFICATION = 5751

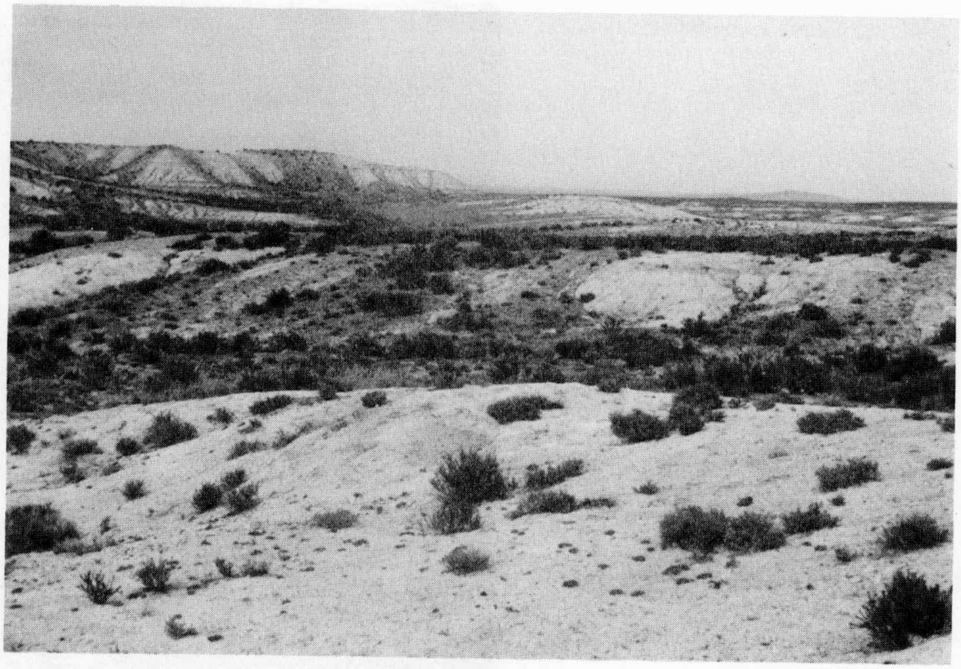
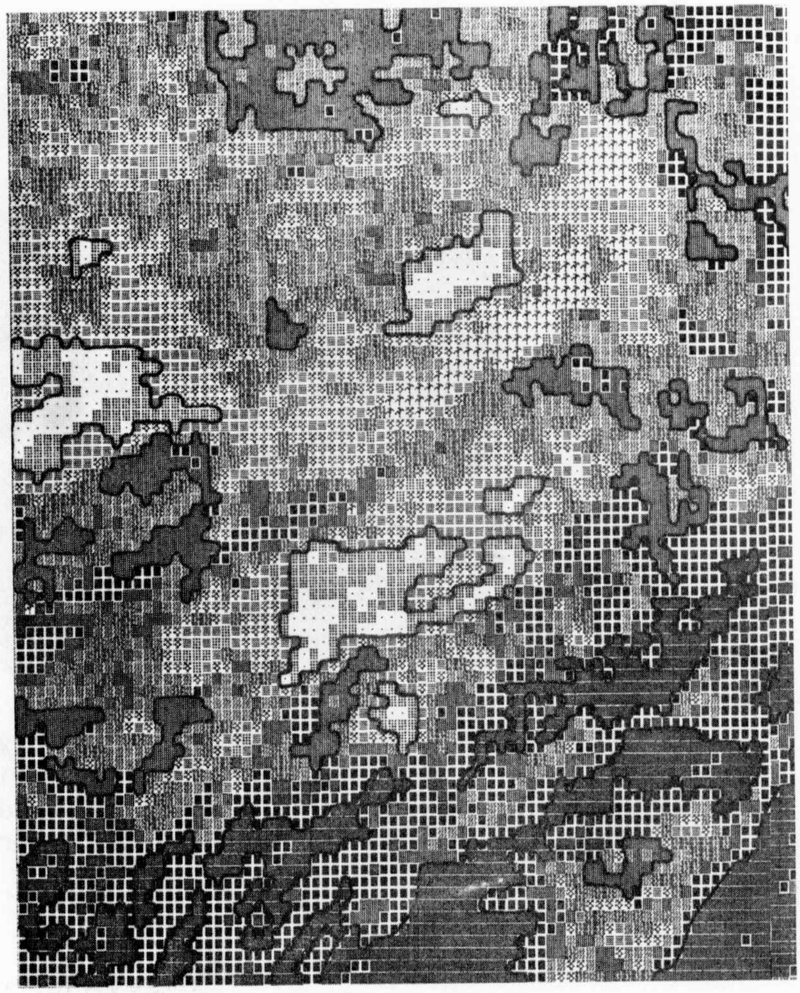


Figure 38. The above photo shows an example of the areas classified as dissected lake and fluvial sediments or badlands. Acreages for this class and others found within the sample block shown in Figure 37 are given below in Table 15.

Table 15.

Group	Points	Acres	Hectares	Percent
1	2	2.3	0.9	0.0
2	1068	1228.2	497.2	18.6
3	1076	1237.4	501.0	18.7
4	424	487.6	197.4	7.3
5	5	5.7	2.4	0.1
6	91	104.6	42.4	5.2
*7	151	173.6	70.3	2.6
*8	765	879.7	356.2	13.3
9	1041	1197.1	484.7	18.1
10	1128	1297.2	525.2	19.6

*Classes 7 and 8 represent the exposed lake sediments.



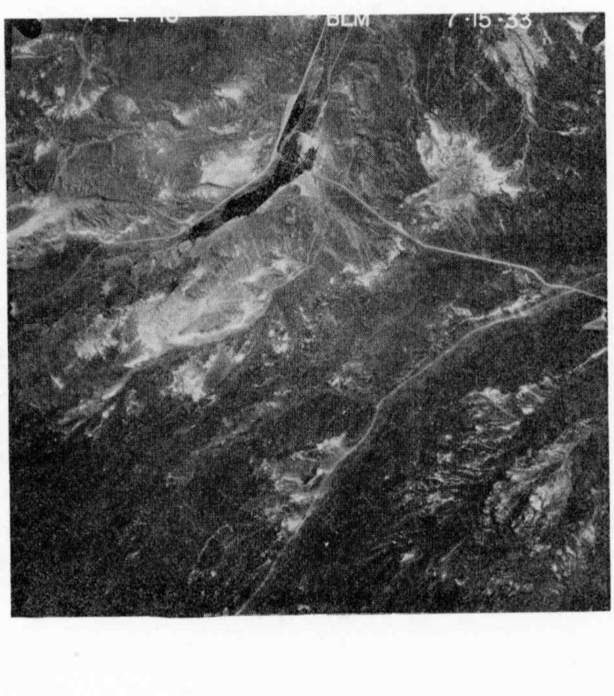


Figure 39. The classification map at the top shows some classes which were outlined in previous figures. Here, classes representing desert pavement areas, loamy sites, and exposed lake sediments are outlined. Calcareous restrictive sites and other classes shown are described in Table 5 which also gives the symbol legend. Below this map is the air photo for this area which can be used to spot various features such as the alfalfa fields and the exposed lake sediments. It should be noted that in the lower portion of this area the classes are formed on alluvial fan and pediment material, but the upper portion lies on lacustrine and fluvial formations. Therefore, while similar symbols, such as loamy sites, are seen on both areas, their description may be refined for a more accurate soils interpretation.

Table 16. A tabulation of all spectral classes classified within the sample block in Figure 39. A grouping of these classes conforming to the 10 symbols seen on the map is listed in Table

GROUP	POINTS	ACRES	HECTARES	PERCENT
1	780	897.0	363.2	11.9
2	764	878.6	355.7	11.6
3	1032	1186.8	480.5	15.7
4	524	602.6	244.0	8.0
5	81	93.1	37.7	1.2
6	158	181.7	73.6	2.4
7	30	34.5	14.0	0.5
8	797	916.5	371.1	12.1
9	239	274.8	111.3	3.6
10	71	81.6	33.1	1.1
11	36	41.4	16.8	0.5
12	142	163.3	66.1	2.2
13	126	144.9	58.7	1.9
14	150	172.5	69.8	2.3
15	173	198.9	80.5	2.6
16	178	204.7	82.9	2.7
17	217	249.5	101.0	3.3
18	329	378.3	153.2	5.0
19	460	529.0	214.2	7.0
20	274	315.1	127.6	4.2
TOTAL	6561	7545.1	3054.7	100.0

EACH DATA POINT REPRESENTS 1.15 ACRES
0.47 HECTARES

TOTAL POINTS IN CLASSIFICATION = 6561

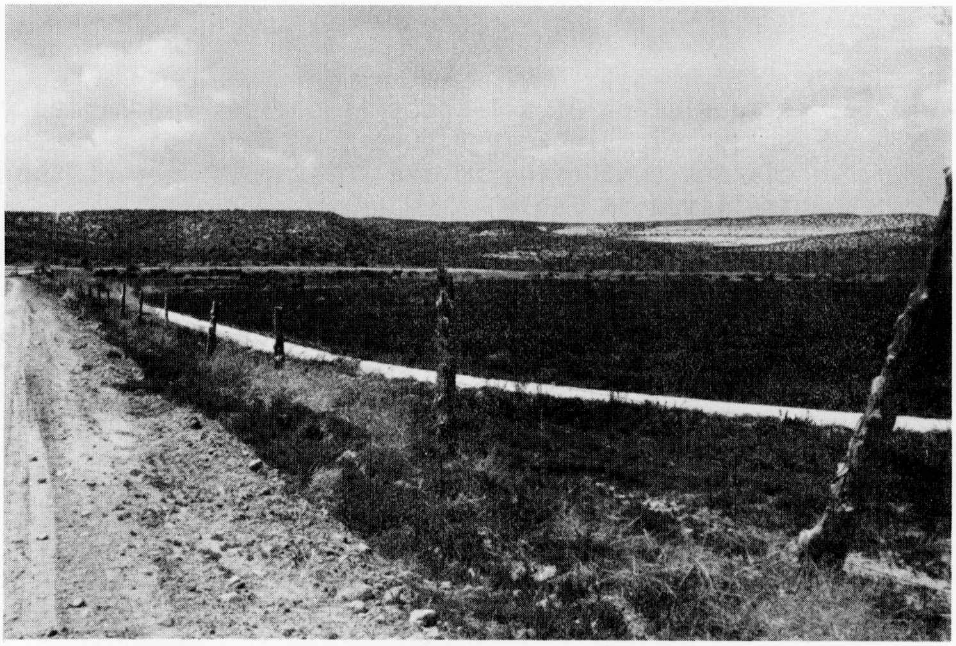


Figure 40. This shows the alfalfa field which is seen in the classification map. Acreages for this classification area are also given below. These 10 classes represent the 10 different symbols on the classification map.

Table 17. Acreages for the grouped classes within the sample block shown in Figure 39.

Group	Points	Acres	Hectares	Percent
1	780	897.0	363.2	11.9
2	764	878.6	355.7	11.6
3	1032	1186.8	480.5	15.7
4	992	1140.7	462.0	15.1
*5	111	127.6	51.7	1.7
6	1249	1436.3	581.6	19.0
7	126	144.9	58.7	1.9
8	323	371.4	150.3	4.9
9	395	454.2	183.9	6.0
10	789	907.3	367.4	12.0

*Represents the agricultural fields seen within this classification.

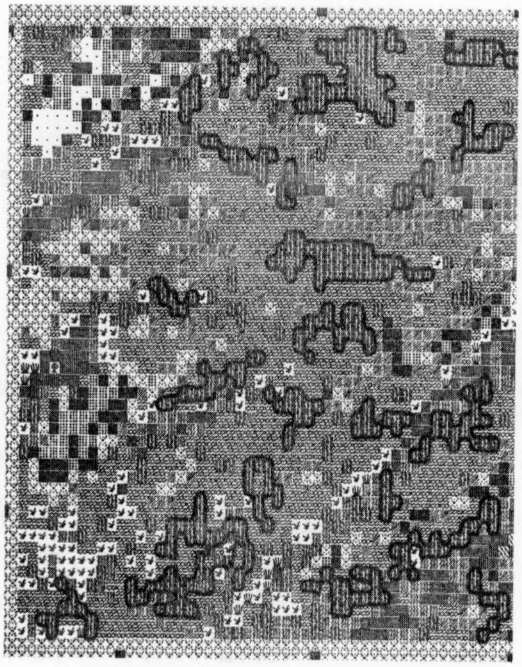


Figure 41. The top photo shows a classification map for a sample area with spectral classes outlined which appear to represent shallow or rocky soils with local rock outcrops. The lower photo shows some of these areas on the ground with exposed volcanic rock.

Table 18. A listing of all spectral class acreages found within the sample block shown in Figure 41.

GROUP	POINTS	ACRES	HECTARES	PERCENT
1	571	656.6	265.9	21.5
2	128	147.2	59.6	4.8
3	199	228.8	92.7	7.5
4	1	1.1	0.5	0.0
5	430	494.5	200.2	16.2
6	298	342.7	138.7	11.2
7	164	188.6	76.4	6.2
8	116	133.4	54.0	4.4
9	8	9.2	3.7	0.3
10	23	26.4	10.7	0.9
11	2	2.3	0.9	0.1
12	0	0.0	0.0	0.0
13	176	202.4	81.9	6.6
14	7	8.0	3.3	0.3
15	1	1.1	0.5	0.0
16	0	0.0	0.0	0.0
17	24	27.6	11.2	0.9
18	60	69.0	27.9	2.3
19	57	65.5	26.5	2.1
20	71	81.6	33.1	2.7
21	316	363.4	147.1	11.9
TOTAL	2652	3049.8	1234.7	100.0

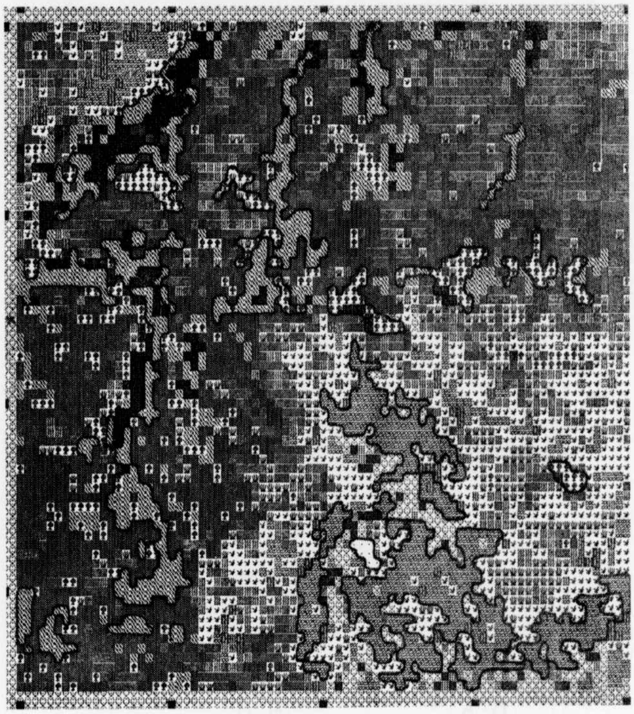
EACH DATA POINT REPRESENTS 1.15 ACRES
0.47 HECTARES

TOTAL POINTS IN CLASSIFICATION = 2652

Table 19.

Group	Points	Acres	Hectares	Percent
1	1001	1151.1	466.1	37.7
2	128	147.2	59.6	4.8
3	199	228.8	92.7	7.5
4	1	1.1	0.5	0.0
*5	474	545.1	220.6	17.8
6	164	188.6	76.4	6.2
7	116	133.4	54.0	4.4
8	16	18.3	7.5	0.6
9	23	26.4	10.7	0.9
10	2	2.3	0.9	0.1
11	0	0.0	0.0	0.0
12	0	0.0	0.0	0.0
13	24	27.6	11.2	0.9
14	60	69.0	27.9	2.3
15	128	147.1	59.6	4.8
16	316	363.4	147.1	11.9

*This class represents shallow or rocky soils with local rock outcrops and is seen outlined on the classification map in Figure 41.



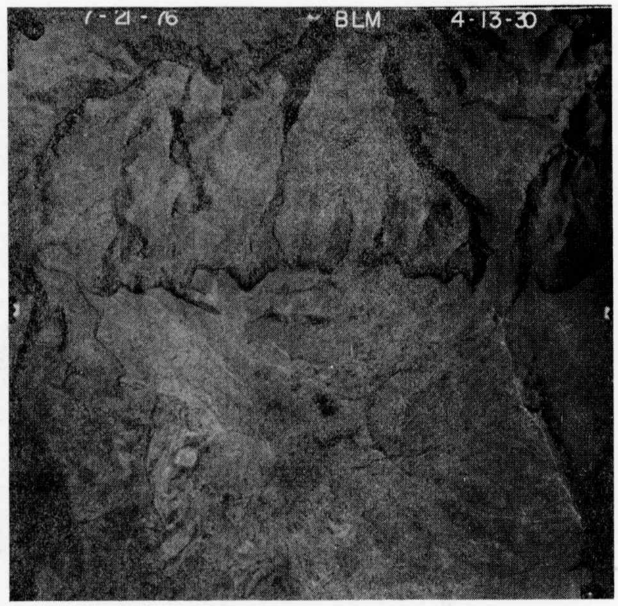


Figure 42. Classification map of a sample site in the mountain and plateau area. The air photo representing this area is also shown. The white circular playa seen on the air photo can also be seen as a white symbol in the lower center part of the classification map. This, along with the canyons can be used to register the classification map with the air photo. Classes such as basaltic rock canyons, shadows, flat Arbuscula and grassy areas, Alpine sage and Mountain Brush are seen. The legend for these symbols and their description is given in Table 6. The photo shows some of the terrain within this area.

Table 20. Acreages for all spectral classes within this sample site (Figure 42) representing a mountain and plateau area.

GROUP	POINTS	ACRES	HECTARES	PERCENT
1	488	561.2	227.2	8.5
2	587	675.0	273.3	10.2
3	349	401.3	162.5	6.1
4	338	388.7	157.4	5.9
5	80	92.0	37.2	1.4
6	68	78.2	31.7	1.2
7	153	175.9	71.2	2.7
8	943	1084.4	439.0	16.4
9	218	250.7	101.5	3.8
10	1479	1700.8	688.6	25.7
11	620	713.0	288.7	10.8
12	174	200.1	81.0	3.0
13	5	5.7	2.3	0.1
14	144	165.6	67.0	2.5
15	8	9.2	3.7	0.1
16	28	32.2	13.0	0.5
17	7	8.0	3.3	0.1
18	7	8.0	3.3	0.1
19	18	20.7	8.4	0.3
20	14	16.1	6.5	0.2
21	23	26.4	10.7	0.4
TOTAL	5751	6613.6	2677.6	100.0

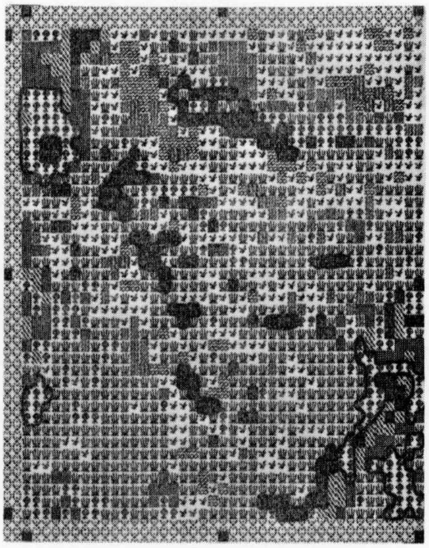
EACH DATA POINT REPRESENTS 1.15 ACRES
0.47 HECTARES

TOTAL POINTS IN CLASSIFICATION = 5751

Table 21. Acreages grouped from Table 20 into 16 classes.

Group	Points	Acres	Hectares	Percent
1	568	653.2	264.4	9.9
2	587	675.0	273.3	10.2
3	349	401.3	162.5	6.1
4	338	388.7	157.4	5.9
5	73	83.9	34.0	1.3
6	153	175.9	71.2	2.7
7	943	1084.4	439.0	16.4
8	370	425.5	172.2	6.4
9	1479	1700.8	688.6	25.7
10	620	713.0	288.7	10.8
11	174	200.1	81.0	3.0
12	28	32.2	13.0	0.5
13	7	8.0	3.3	0.1
14	7	8.0	3.3	0.1
15	32	36.8	14.9	0.5
16	23	26.4	10.7	0.4

(b)



(a)

(c)

Figure 43. The classification map (a) shows the spectral classes identified as Mountain Brush and dense Vaseyana. These classes (c) are shown with the darker Mountain Brush surrounded by Vaseyana (Alpine sage). The elevation in this area is about 6000'. Some of the canyons (b) that appear in the classification within the Mountain and Plateau areas are illustrated.

Table 22. Acreages for all classes within the sample classification area of Figure 43.

GROUP	POINTS	ACRES	HECTARES	PERCENT
1	78	89.7	36.3	4.6
2	311	357.6	144.8	18.5
3	75	86.2	34.9	4.5
4	218	250.7	101.5	13.0
5	4	4.6	1.9	0.2
6	18	20.7	8.4	1.1
7	0	0.0	0.0	0.0
8	46	52.9	21.4	2.7
9	308	354.2	143.4	18.3
10	59	67.8	27.5	3.5
11	47	54.0	21.9	2.8
12	13	14.9	6.1	0.8
13	3	3.4	1.4	0.2
14	254	292.1	118.3	15.1
15	123	141.4	57.3	7.3
16	122	140.3	56.8	7.3
17	0	0.0	0.0	0.0
18	0	0.0	0.0	0.0
19	2	2.3	0.9	0.1
20	0	0.0	0.0	0.0
21	0	0.0	0.0	0.0
TOTAL	1681	1933.1	782.7	100.0

EACH DATA POINT REPRESENTS 1.15 ACRES
0.47 HECTARES

TOTAL POINTS IN CLASSIFICATION = 1681

Table 23. Represents a grouping of classes to form the 16 symbols seen in the classification map in Figure 43.

Group	Points	Acres	Hectares	Percent
1	82	94.3	38.2	4.8
2	311	357.6	144.8	18.5
3	75	86.2	34.9	4.5
*4	218	250.7	101.5	13.0
5	21	24.1	9.8	1.3
6	0	0.0	0.0	0.0
7	46	52.9	21.4	2.7
8	685	787.7	319.0	40.7
9	59	67.8	27.5	3.5
10	47	54.0	21.9	2.8
11	13	14.9	6.1	0.8
+12	122	140.3	56.8	7.3
13	0	0.0	0.0	0.0
14	0	0.0	0.0	0.0
15	2	2.3	0.9	0.1
16	0	0.0	0.0	0.0

*This class represents dense Alpine sage with Idaho Fescue underbrush.

+This class represents Mountain Brush as seen outlined in the classification map in Figure 43.

Table 24. A tabulation of acreages from all classes within the entire study site. This represents results from the Layered Classifier with boundaries digitized separating classification areas. Group A represents Mountain and Plateau area classes; Group B represents Alluvial Fan area classes; and Group C represents Agricultural area classes.*

GROUP	POINTS	ACRES	HECTARES	PERCENT
A1	5949	6841.3	2769.8	2.7
A2	5059	5817.8	2355.4	2.3
A3	8793	10111.9	4093.9	4.0
A4	3088	3551.2	1437.7	1.4
A5	4847	5574.0	2256.7	2.2
A6	7219	8301.8	3361.1	3.3
A7	5738	6598.7	2671.5	2.6
A8	5780	6647.0	2691.1	2.6
A9	2261	2600.1	1052.7	1.0
A10	6077	6988.5	2829.4	2.7
A11	2372	2727.8	1104.4	1.1
A12	1148	1320.2	534.5	0.5
A13	3637	4182.5	1693.3	1.6
A14	2070	2380.5	963.8	0.9
A15	581	668.1	270.5	0.3
A16	605	695.7	281.7	0.3
A17	1711	1967.6	796.6	0.8
A18	1863	2142.4	867.4	0.8
A19	1459	1677.8	679.3	0.7
A20	2591	2979.6	1206.3	1.2
A21	4161	4785.1	1937.3	1.9
B1	15443	17759.4	7190.1	7.0
B2	16055	18463.2	7475.0	7.3
B3	18172	20897.8	8460.6	8.2
B4	12127	13946.0	5646.2	5.5
B5	520	598.0	242.1	0.2
B6	2901	3336.1	1350.7	1.3
B7	893	1026.9	415.8	0.4
B8	14807	17028.0	6893.9	6.7
B9	3117	3584.5	1451.2	1.4
B10	3046	3502.9	1418.2	1.4

Table 24. (Continued)

B11	2220	2553.0	1033.6	1.0
B12	4065	4674.7	1892.6	1.8
B13	1399	1608.8	651.4	0.6
B14	1945	2236.7	905.6	0.9
B15	2442	2808.3	1137.0	1.1
B16	3222	3705.3	1500.1	1.5
B17	3446	3962.9	1604.4	1.6
B18	5238	6023.7	2438.7	2.4
B19	6910	7946.5	3217.2	3.1
B20	5376	6182.4	2503.0	2.4
C1	5649	6496.3	2630.1	2.6
C2	2294	2638.1	1068.1	1.0
C3	3187	3665.0	1483.8	1.4
C4	3525	4053.7	1641.2	1.6
C5	2820	3243.0	1313.0	1.3
C6	1511	1737.6	703.5	0.7
C7	940	1081.0	437.7	0.4
C8	730	839.5	339.9	0.3
C9	432	496.8	201.1	0.2
MOUNT	0	0.0	0.0	0.0
FAN	0	0.0	0.0	0.0
AG	0	0.0	0.0	0.0
LAVA	0	0.0	0.0	0.0
TOTAL	221441	254655.3	103099.2	100.0

EACH DATA POINT REPRESENTS 1.15 ACRES
0.47 HECTARES

TOTAL POINTS IN CLASSIFICATION = 221441

*It should be noted if these classes were grouped in each area representing the 10 classes described in Table 5 for the Fan Area and the 16 classes described in Table 6 for the Mountain Area, the following combinations would be made in determining acreages for the spectral classes symbolized on the classification maps: Mountain -1(A1,A5), 2(A2), 3(A3), 4(A4), 5(A6,A13), 6(A7), 7(A8), 8(A9,A14,A15), 9(A10), 10(A11), 11(A12), 12(A16), 13(A17), 14(A18), 15(A19,A20), 16(A21). Fan - 1(B1), 2(B2), 3(B3), 4(B4, B6,B9,B10), 5(B5,B7) 6(B8,B11,B12,B20), 7(B13), 8(B14,B15), 9(B16,B17), 10(B18,B19).

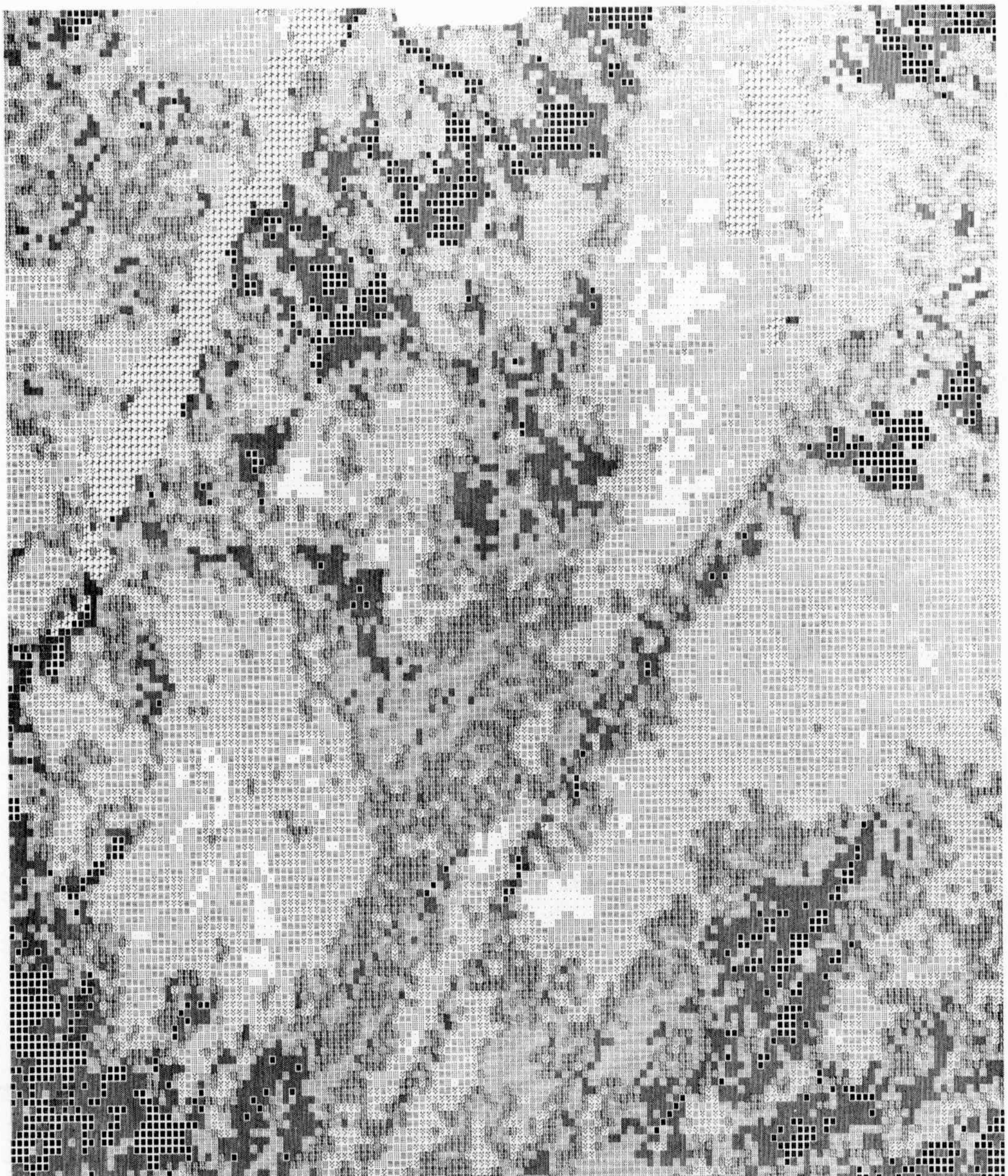


Figure 44. A portion of the MINIMUM DISTANCE classification map in the Fan Area. Refer to Table 5 for a description of the symbols.

Figure 45. A portion of the MINIMUM DISTANCE classification map in the Mountain Area. Refer to Table 6 for a description of the symbols.

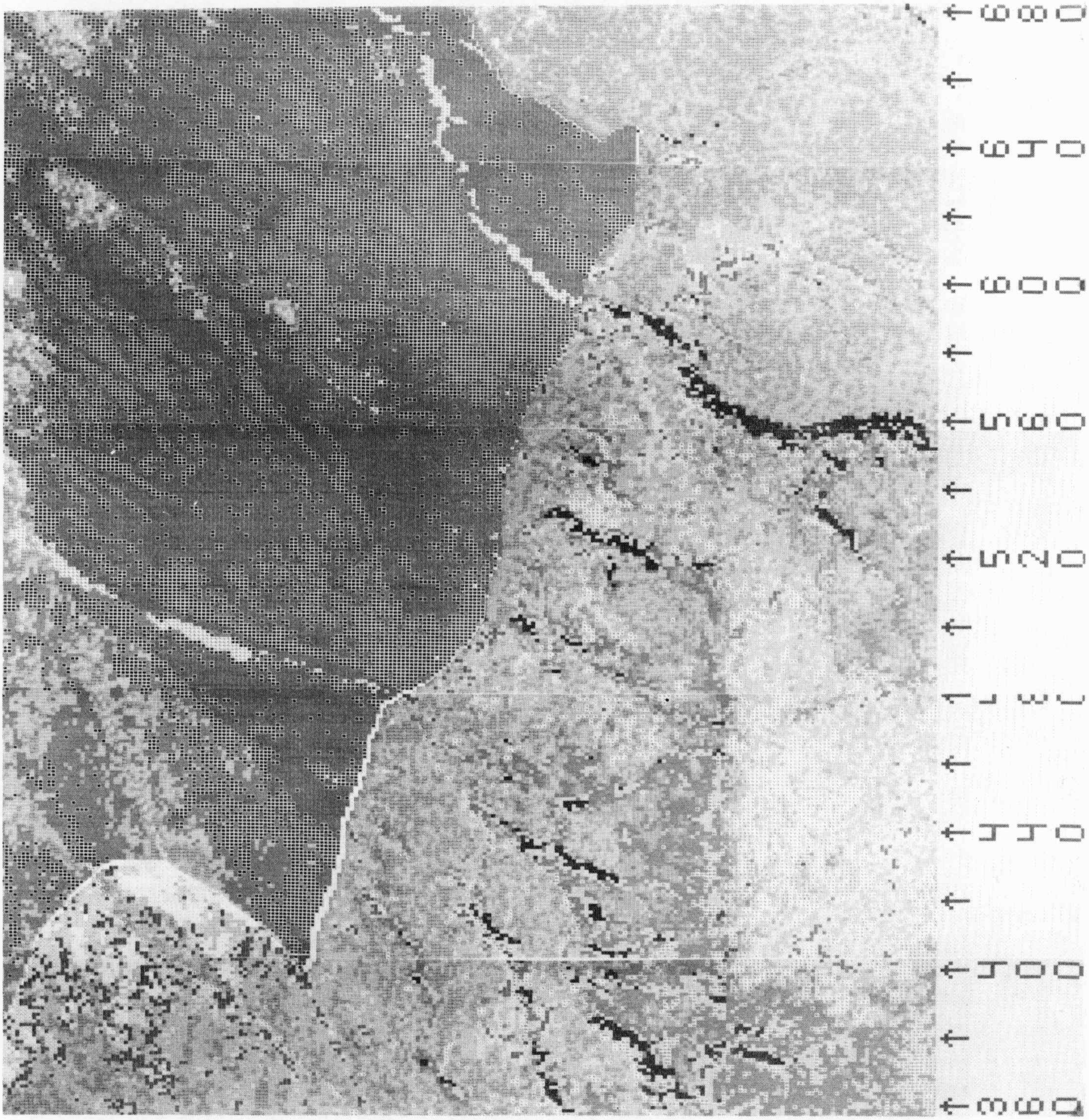


Figure 46. Part of the Layered Classification map showing the mountain area below separated from the fan area above. Refer to Tables 5 and 6 for a description of the symbols.

Landsat Data and Soil Surveys

Soil surveys in Idaho are currently being mapped by the Bureau of Land Management at a high level 3rd order on mountainous rangeland and at 2nd order on potentially irrigable areas with a minimum mapping unit delineation of 10 and 6 acres respectively for highly contrasting areas, and areas significantly different in use and management. The Soil Conservation Service is assisting in the mapping of the irrigable areas. The information from these surveys will be used in the Bureau's planning system, grazing environmental impact statements, and as a basis for any other land use activity on public lands. The SCS currently estimates that one man can map, at a 3rd order level, approximately 120,000 acres per year in these arid and semi-arid areas. This figure will vary depending upon weather, terrain, field season, and so forth.

In order to assess the potential contribution Landsat data can make toward this soils effort, the factors that go into the making of a 3rd order soil survey should be mentioned.

In a 3rd order soil survey the soils in each delineation are identified by transecting and traversing. Mapping unit boundaries are plotted by observation and by interpretation of remotely sensed data with some observations. Field observations should be frequent enough to locate and plot areas of dissimilar soils that are significant to the purposes of the survey. The minimum size delineation for this type of survey ranges from 6 acres to 640 acres. Although, in southwest Idaho, the survey crews are generally not mapping anything less than 10 acres in size unless highly significant, and usually mapping is on the order of 10's to 100's of acres. Mapping scales range from 1:24,000 to 1:250,000. The current field mapping scale is being carried out using air photos at 1:31,680 and publication will be at a 1:24,000 scale. Mapping units are usually designed to separate segments of the landscape that, because of the location or other physical factors, will be used in the same or similar manner as recognized for the purposes of the survey. The kind of map units would consist of associations and some consociations and complexes.

Some elements which can be obtained using Landsat data and which may contribute to the 3rd order survey are:

1) scale - maps can be generated directly at a 1:24,000 scale
2) map unit size - because of the approximate 1.1 acre resolution of Landsat data, the 10 acre mapping unit minimum size can easily be attained and smaller inclusions may also be observed within these larger units if desired. Also, acreages of mapping units or classes can easily be tabulated along with their percentages.
3) boundary delineation - more detailed boundaries may possibly be delineated using Landsat data. Subtleties not visually observed on aerial photography may be seen on the Landsat map because of the additional portion of the electromagnetic spectrum sensed by the satellite scanners. These boundaries may then serve to delineate areas for intensive mapping, or for locating sample sites for broader mapping. The synoptic view of Landsat would also facilitate mapping by eliminating the piecing together of numerous air photos and also providing a complete view to better interpret the landscape for the determination of soil forming processes or other physiographic factors.

4) transects and sample sites - the classification map produced from Landsat data could reduce the number of transects a soil scientist will have to make, and also possibly reduce the number of on-site observations. By using a Landsat map which has been constructed to show distinct and separable spectral classes, knowing the factors that contribute to the spectral response of the cover types within the study area, and where terrain is diverse incorporating topographic and geologic information, on-site inspection can be limited to a few select sites. Current use of Landsat spectral maps for soils studies in central Indiana have been found to increase the productivity of SCS soil survey crews by approximately 1/3 to 1/2.
5) soil characteristics - it has been emphasized throughout this report that it is not the intent of using Landsat data to directly make a 3rd order soil survey map, but rather to create a spectral map which may infer certain soil properties, and thus increase soil crew efficiency and accuracy. When the topography, geology or parent material, and spectral response of certain vegetation types are known, soil characteristics such as drainage, texture, depth and pH may be inferred. In addition, heavily eroded areas and rocky areas may be mapped directly from Landsat data.

A comparison was made between the Landsat map generated during this study and a soils map published at a scale of 1:126,720 covering this area. It should be noted that the published soils map was made for assessment of the potential of irrigable lands, and not for rangeland evaluation. The alluvial fan and lowland areas were the only areas used for comparison, and the boundaries of the spectral classes were generally found to conform to the boundaries delineated on the published soils map. In all cases more than one spectral class was found to be included within the larger mapping units of the soils maps. This would seem to imply that more detail could be obtained from the Landsat data. Where the same spectral classes were found within different soils mapping units, it was seen that geology determined the location of the soils mapping unit. Therefore, geologic information would have to be incorporated into the spectral data to have the resulting classification conform more accurately to certain soils mapping units.

In addition to rangeland, soils information gained by using Landsat can be applied to other BLM projects. An example might be to delineate heavily eroded areas which would be avoided in a transmission line right-of-way. A map showing just these areas along with acreages could be generated from the classification data quite easily.

A brief word should be mentioned about just the utilization of Landsat imagery itself. A Landsat image can be generated showing one spectral band or a combination of spectral bands such as in a false color composite. An image analysis can be made by viewing one band, having two scenes showing one visible and one infrared band, or using a color composite of two or more bands. Images obtained at different dates can also be compared. With this synoptic view, multiband and multitemporal capability, broad resource information can be mapped. Such mapping could represent the extent of vegetation, location of springs, drainages and surface water, geology and lineaments, and so forth. Broad physiographic boundaries can be delineated for soils studies. Return Beam Vidicon (RBV) data is also being found useful in analyzing areas for soils studies.

It must be remembered that the objective of using this satellite data is to be able to increase the efficiency of the soils field crews. This would include increasing productivity and accuracy. In order for this tool to be used effectively it must provide information which will meet the needs of the project at hand. The data must be specific but yet not be so detailed that it will cause confusion. The analyst must keep the purpose of the soil survey in mind. The expertise and skill of the analyst will be important in obtaining a correct product. Each area will be different and a different analysis approach will have to be used. Accuracy will also depend upon the kind and amount of ancillary data available, adequate sample and ground truth, and most important the full cooperation of the soils staff working in that particular area.

Finally, a decision must be made on the economic feasibility of generating a computer classification of a particular area for a soils project. The complexity and size of the area must be considered. While it is not felt that precision registration is a necessity for Landsat analyses for soils, a complex area may require boundary digitization, or multitemporal data, or the incorporation of terrain data. These processes would add a considerable amount of cost to the analysis. (Refer to the section on Analysis Methods and Procedures.) Although an economic study was not made comparing costs of conventional soils surveys to those utilizing computer processed Landsat data, it is felt that where boundary digitization is required or where the study site is complex an area no smaller than 250,000 acres should be analyzed. Possibly, if the terrain is level, and only low order surveys are required for broad planning purposes, this figure could be lowered. The use of this technology would be most cost effective where the acreages to be surveyed are large such as on the order of hundreds of thousands to millions of acres.

Conclusions

It is felt that as a result of this work, it can be shown that Landsat data can be used as a tool for stratifying large areas into smaller units which can be sampled more efficiently in the field. Limited field time did not permit adequate sampling to determine the accuracy of the classification map products. The areas that could be sampled did allow generalized descriptions of all spectral classes. These descriptions and field observations have been presented in this report, and it is hoped that future work in this area will permit this product to be more adequately examined. It was shown in the previous section that several of the elements that go into the making of a third order soils survey can be addressed using Landsat information. Not only can digitized data be used, but also Landsat images in different spectral bands or RBV images may prove useful in pre-analysis examination or for certain resource investigations. Multitemporal Landsat data may also prove useful, especially when determining the extent of green vegetation in arid areas.

Concerning the date of Landsat data used, it is felt that in semi-arid areas where native vegetation has not been altered, mid to late spring data may prove useful. Where there has been much chaining and reseeding, or fire damage, certain vegetation patterns may be deceiving and thus a latter summer date may be more advantageous. Naturally, topography and elevation may also determine optimum dates for image analysis.

It has been seen that every step in the analysis procedure is important, each step building upon the other. One cannot perform a careless analysis and then expect a reliable product, nor can a deliberate analysis be performed followed by inadequate field work, lack of understanding of the spectral nature of the environment or resource objectives, or production of an output product having little meaning or utility. It was shown that any available ancillary data should be used which would help in determining sample site or cluster block locations. All cover types should be represented with an adequate number of classes being selected. Many points must be considered during the critical pooling period. The resource needs or objectives must be kept in mind during this period. Sample classifications should first be made on the cluster sites. If these sites do not appear correct, then it is useless to continue classifying the entire area until the problem is corrected in the sample blocks. Even the selection of symbols is important. Certain symbols may enhance certain cover types while other symbols may not appear as distinct and thus cause the output to appear quite heterogeneous. The correct combination of classes under one symbol will also be critical and depend upon the needs of the resource specialist. In this study it was found that having 20 spectrally distinct classes in one area may only tend to confuse the user when the objective is to map units on the order of 10's to 100's of acres in size; but, a certain amount of detail is also needed, so symbol combinations must be made with care.

Concerning classification algorithms, it was seen that MINIMUM DISTANCE was comparable in accuracy to the more expensive classifiers but yet cost much less. It is felt that in the western states where there is great diversity of topography and heterogeneity of cover types, boundary digitization would be necessary, and thus, the Layered Classifier would be used. This was found especially true in analyses for soils because of the importance of delineating different parent materials and land forms. It is not felt that precision registration is necessary for third order soil survey work on western rangeland. The geometric correction of data appears to be adequate, and the expensive precision registration process does not seem necesary for the needs of this work.

Based on the field experiences during this project, and in addition to points already mentioned in this report, the following points may also prove useful for field personnel:

1. Visit the area during the clustering process in addition to after the preliminary classification;
2. Become thoroughly familiar with the cover types and any variations in the resource of interest; try to identify all of the classes selected within each cluster block, and be sure enough classes were selected, or if too many know which are redundant;
3. During field investigations, have all ancillary information available such as geologic maps, vegetative site descriptions, and air photos;
4. Examine both the air photos and computer output in the field transferring significant landmarks to the output as accurately as possible;
5. Have air photos made to the same scale as the computer output before field investigations, and overlay clear mylar on the photos for plotting points; this mylar can then be overlaid on the computer output directly;
6. If field time is limited, sample and describe at least one good homogeneous area of a certain spectral class, doing this for each class. Where different types of pixels are present, trying to pick one of these to sample may not give an accurate picture of the class due to uncertainty in location and the possibility of a transition zone;
7. Photograph all cover types and record all notes in detail while in the field; do not rely on memory in the office; it was found that the macrolens was most useful in photographing all resources because of the potential for close-up detail.
8. If infrared film is available, also take IR photographs of selected cover types to determine their response characteristics.

It must be remembered that the basic assumption throughout this whole process is that the cover types of interest are spectrally separable. For soils, this separability may result from different vegetative cover types, density, or a difference in the spectral response of the soil itself. The factors causing these spectral differences must then be analyzed so that their relationship to soil characteristics may be understood. Texture, color, drainage, composition, and depth are just a few factors which may determine different spectral signatures. Knowing these factors, along with a knowledge of parent materials, soil forming processes, and landscape effects may contribute to the identification of various soils units in a given area. Then, with the assumption that spectral classes inferring certain characteristics in one area infer similar characteristics where they are seen in a different area, on-site sampling and field transects may be reduced thereby increasing the productivity and efficiency of field survey crews. The subtleties observed in the Landsat spectral data and not observed visually on air photos along with the synoptic view offered by Landsat may also increase the accuracy of the third order soil survey which they shall produce. Therefore, knowledge and understanding of the spectral nature of the environment being analyzed and the factors contributing to the spectral response of the cover types will be most important in accurately relating spectral information to useful resource information.

Finally, it must be noted that the use of spectral data for soils studies in this region is still experimental, and much remains to be learned about the spectral nature of this environment. Only through the use of this information in the field by the soils survey crews can its value be fully assessed. Analysis procedures may differ depending upon the area being studied, and additional techniques could be applied that might permit greater spectral separation and accuracy. Some of these might consist of the incorporation of digital terrain data, the digitization of boundaries and classification based on elevation, slope, aspect, geology, or geomorphology, and the use of multitemporal data. While all these techniques could not be used in this study, it is hoped that the potential contribution of this technology to the construction of a third order soil survey will be realized. The man in the field will never be replaced, but it is hoped that these and future space-age tools will allow him to look at his environment more efficiently and accurately.