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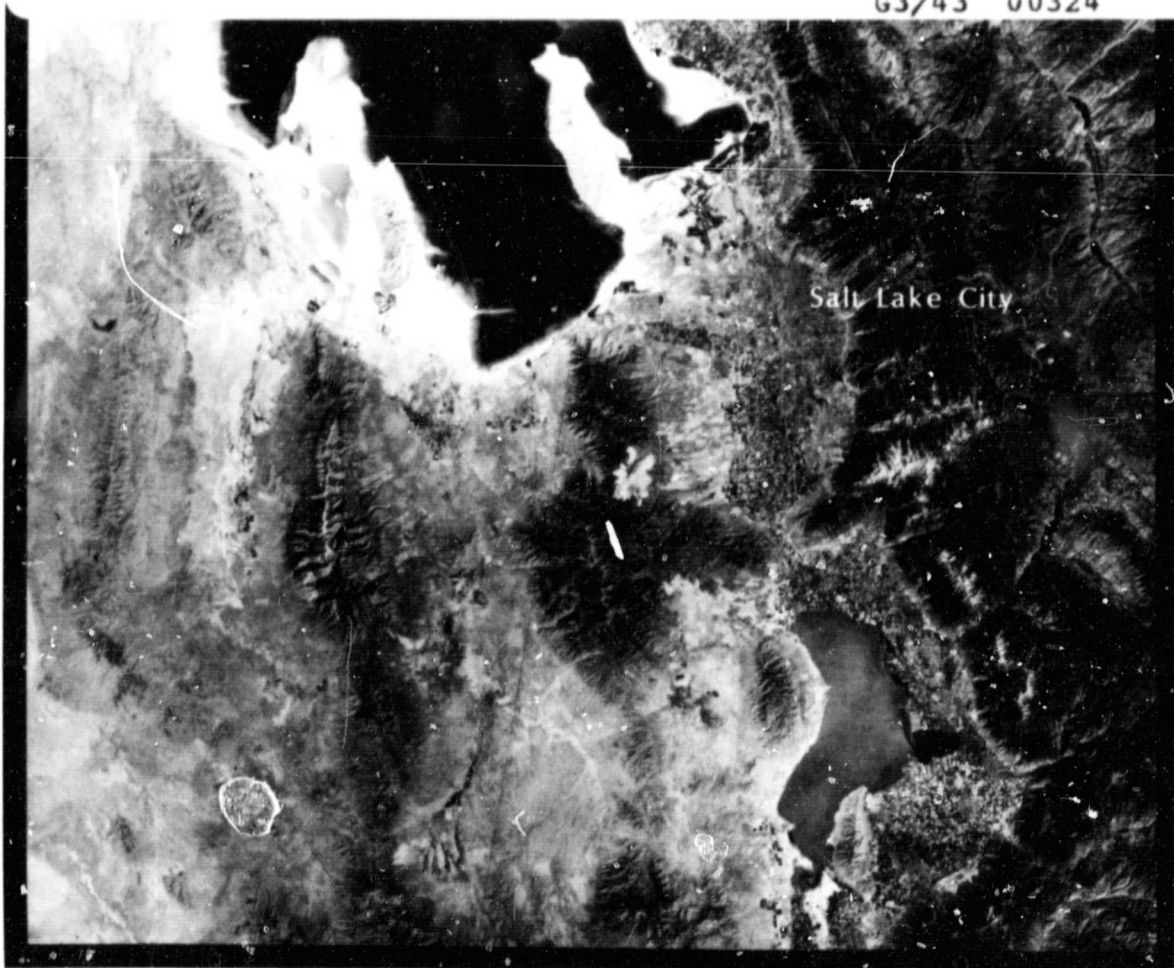
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DETECTION OF ASPEN/CONIFER FOREST MIXES

FROM MULTITEMPORAL LANDSAT DIGITAL DATA

CRSC Report 83-1
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By

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ABSTRACT

Aspen, conifer and mixed aspen/conifer forests have been mapped for a 15-quadrangle study area in the Utah-Idaho Bear River Range using Landsat multispectral scanner (MSS) data. Forest managers are interested in developing research techniques which combine the use of remote sensing technology and ground truth data to study and map the extent of stable and seral aspen forests in the Intermountain area. Conifer invasion of aspen produce distinctive spectral responses; the ability to detect such variations in aspen forests will be a valuable tool for inventorying aspen and associated range, wildlife and watershed attributes. The study objective has been to utilize Landsat digital MSS data to devise quantitative indices which correlate with apparently stable and seral aspen forests. This study has explored the extent to which a two-date Landsat MSS analysis may permit the delineation of different categories of aspen/conifer forest mix. The multitemporal analyses of Landsat MSS data performed in this study led to the identification of early, early to mid, mid to late, and late seral stages of aspen/conifer forest mixing.

INTRODUCTION

The study objective has been to utilize Landsat digital MSS data to devise quantitative indices which correlate with apparently stable and seral aspen forests, and use such indices to map and determine aerial coverage of several classes of stable/seral aspen forests in the Bear River Range of Idaho and Utah. Since aspen canopies tend to obscure understory conifers for early seral forests, a second date analysis, using data taken when aspen trees are leafless has been used to provide information about early seral aspen forests. This study explores the extent to which a two-date Landsat MSS analysis improves the detection of aspen/conifer forest mixes.

The overstory attributes of aspen forests in various successional phases and changes in understory characteristics produced by conifer invasion of aspen, can produce distinctive spectral responses; the ability to detect such variations in aspen forests will be a valuable tool for inventorying aspen and associated range, wildlife and watershed attributes. Forest managers need to have a means to assess the extent to which aspen stands are being converted to coniferous forests as part of the process of developing forest management plans. The application of Landsat digital processing methods suggests a relatively quick and inexpensive means to address the problems associated with the succession process on a forest, ranger district, or planning unit basis.

This paper is a report of the research and development done on the second phase of a two-phase mapping project. A report has been prepared on the first phase, CRSC Report 82-4 (Jaynes and Merola 1982). The first report contains detailed information on the data source, Landsat, data processing and methods not contained within this report. The first report

details the mapping of aspen/conifer forest mixes from a single date of Landsat data. It is suggested that the report (Jaynes and Merola 1982, also referred to herein as the "Phase I" study) be used in conjunction with this report.

STUDY AREA

This study has focused on the application of techniques for Landsat forest mapping on nearly 500,000 acres in the Bear River Range of Utah and Idaho.

The Bear River Range is part of the Middle Rocky Mountains located at the edge of the Great Basin. It is a north-south-trending range that makes up the Cache and part of the Caribou National Forests. Elevations of this mountainous area range from 5,000 to 9,980 feet. There is a steep western flank which is associated with the Wasatch Fault. The major peaks are located along the western flank with gentler slopes and round hills to the east. The major streams and rivers have large canyons which cut through the main range and allow drainage to the west.

The surface geology consists mostly of sedimentary rocks from the Quaternary Period. Predominant soils are the Mollisols. These soils have developed under the rangeland and forest vegetation and are dark, thick and relatively fertile soils.

The alpine and subalpine environments which characterize this range support extensive aspen and conifer forests, as well as rangeland. It also supports big game, such as mule deer, elk, and moose. Much of the area is also used for domestic sheep and cattle grazing. Recreation is an important use of this area, with peak use in the summer and substantial use all year round.

METHODS

Fall Scene Data Processing

The MSS data from the October 1978 or "Fall" Landsat scene was reformatted and then the raw data for all four bands were "filtered" prior to classification. The filter routine ("FILT") uses an unweighted moving average, or low pass filter. The FILT program is part of ELAS and allows the user to select a window size, in this analysis a 3x3 window was selected. FILT begins by averaging the nine pixels in the window and then assigns that value to the center pixel. The program then moves to the left one element, or column. When it reaches the end of that line, it moves down one line and back to the first element.

After looking at the raw data and some preliminary classifications, it was determined that band four was contributing little or no information to aid in pattern recognition and it was decided that band four should be dropped from the analysis. In working with the preliminary classifications of small areas, using filtered and unfiltered data, it was determined that the patterns found in the second date most strongly correspond to terrain, and secondarily to land cover. This is due to the low sun angle on October 23, 1978 at 9:30 a.m.

In order to reinforce the patterns which were found in the data, principal components analysis was performed, using a program in ELAS called GASP (acronym for General Algorithm for Statistical Processing). All four bands were used in the analysis and an unrotated principal component was derived. The resulting principal component scores for each pixel can be thought of as a ratio of all four bands, with the attribute of being

contrast stretched. The principal component replaced band four in the
analysis. (See Figure 1.)

Study windows were then selected to be "searched" to generate spectral
signatures, MAXL was then used to classify the data. Once the data had
been classified, they were reclassified to reduce the number of classes to
the minimum needed for development of meaningful patterns that correspond
to the land cover patterns found in the study area. The first date was also
reclassified prior to the combined analysis of the two dates.

Combination of the two dates was performed by a program called "DBAS"
(abbreviated from Data Base Analysis). DBAS is part of ELAS, and it allows
the user to apply an algorithm, on a pixel-by-pixel basis, to as many as 20
channels of data, in matrix form. In this analysis, four channels were
used with the first two channels being classified data from the summer and
fall scenes respectively. The last two channels were used for indexing,
whose use is described below. All four channels were registered to one
another, pixel-for-pixel. Four channels are used in order to allow the
first two to be used for comparison and the last two channels are used for
indexing, through tables which contain the changes that are to be made.
For instance, in order to derive the "early seral" class, the algorithm
first looks at channel one and determines if the pixel is in the "stable
aspen" class; if it is, it then looks at channel two to see if the class
for that pixel is one that has been predetermined to indicate the change
to "early seral." If this test is passed, DBAS will then index channel
four through the first table for the change to the output map. The change
is made and then output to the first channel of the output map data file.
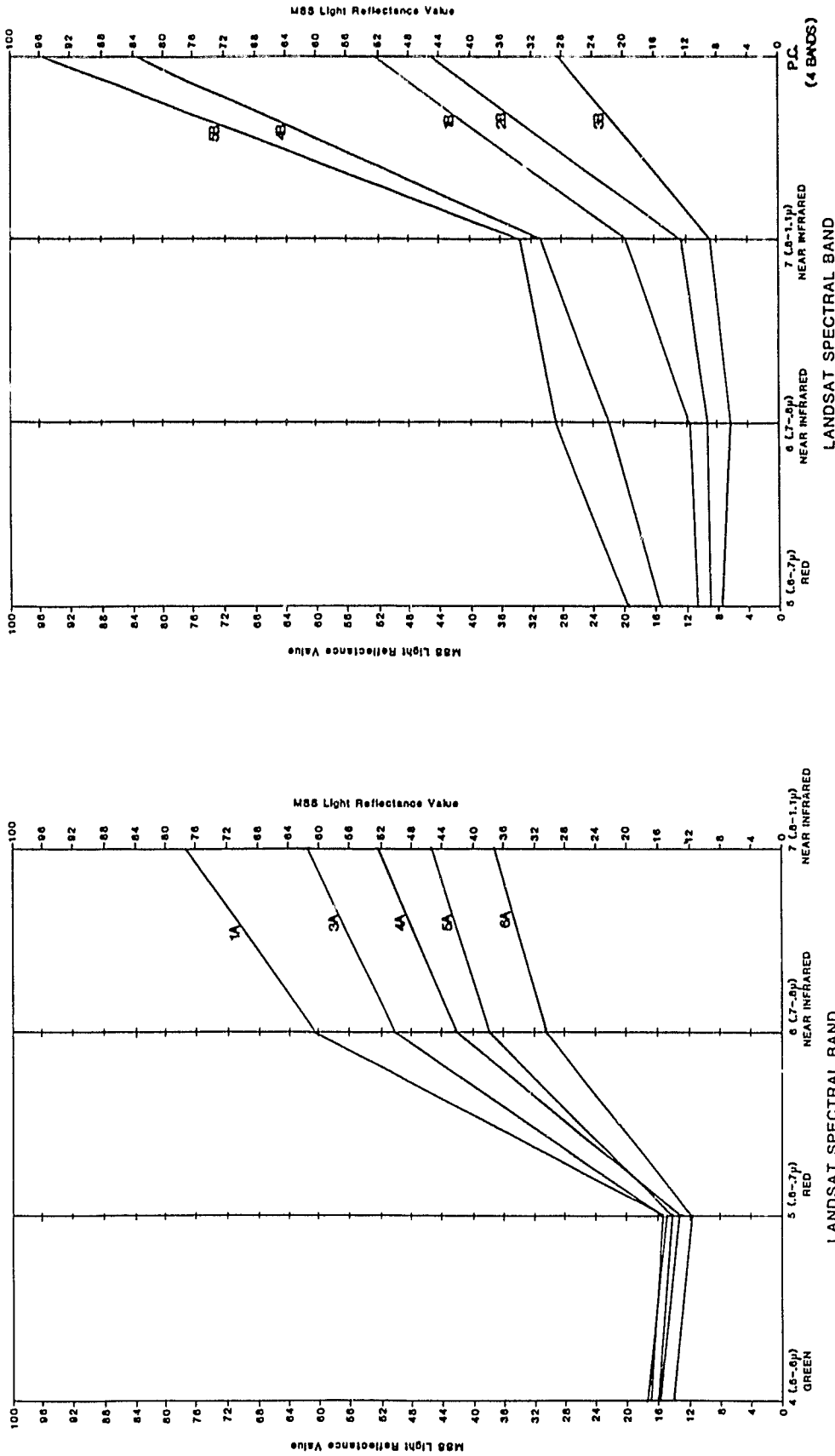The complete algorithm appears in flow chart form in Figure 2.

Figure 1a, on the left, and 1b, to the right, are light signature curves based on the group mean values. The vertical axis represents reflectance values for the different classes of pixels, as obtained from Landsat MSS data. The four points on the horizontal axis correspond to the spectral bands recorded by Landsat, with associated electromagnetic energy wavelengths in microns $(10^{-6}m)$.
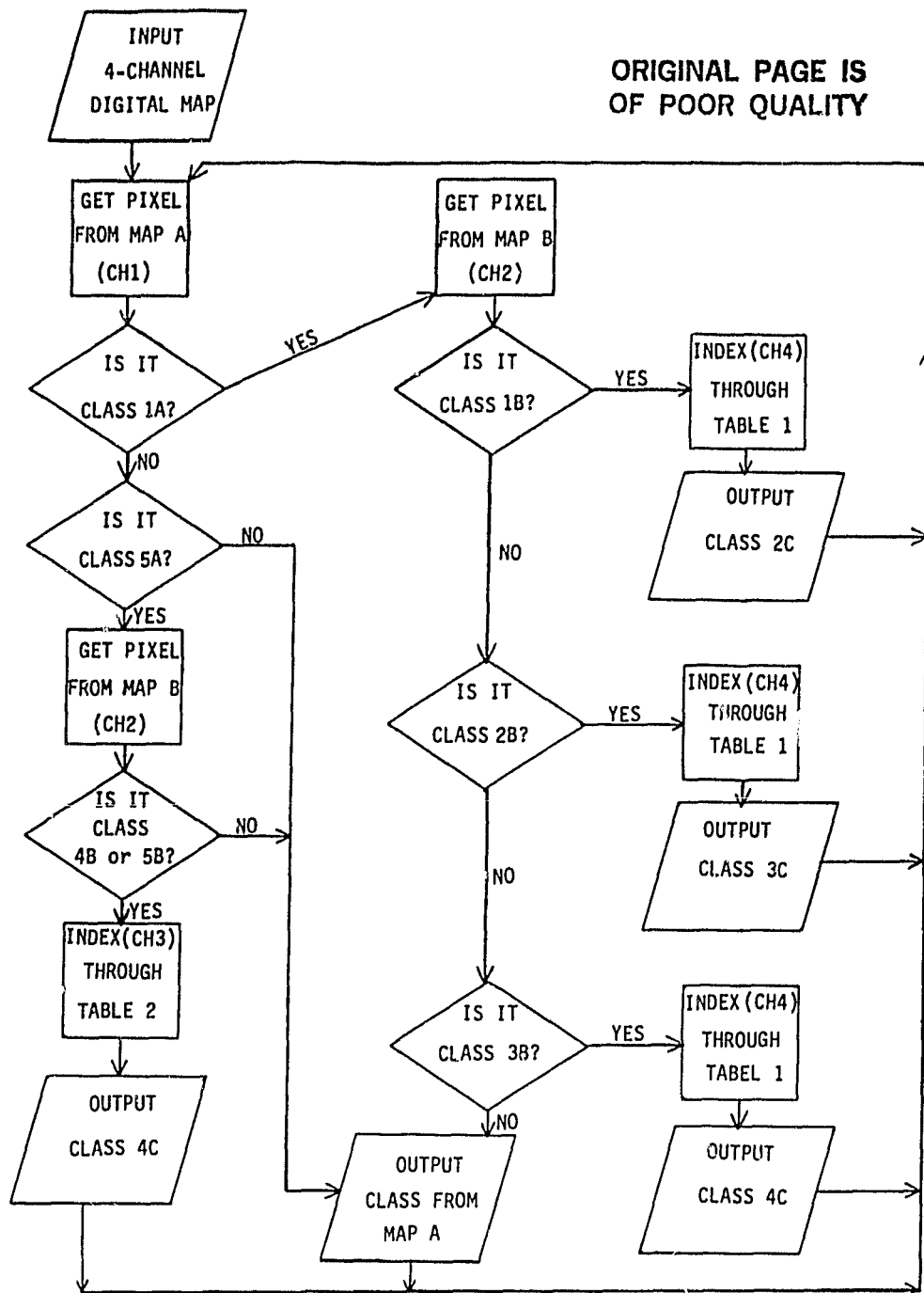
Figure 2. Flow chart representation of the logic applied through DBAS.
CH1 through CH4 are channel identifiers for the digital input map.

A - Summer scene
B - Fall scene
C - Combined map

Calibration and Verification

An additional and most vital dimension to the process of digital data analysis is calibrating spectral signatures with "ground truth." This is accomplished by assigning print symbols to each signature or signature group and printing maps which may then be registered to standard base maps or referenced to photographs and field study sites. In this study, digital print maps were prepared for the 15 U.S.G.S. 7½-minute quadrangles (scale 1:24,000) that cover the study area. Calibration of spectral signatures with actual land cover types was accomplished primarily by use of U.S.G.S. orthophoto quadrangles, high-altitude color-infrared photography (i.e., NASA and National High Altitude Program photography), and low-altitude Forest Service natural color photography. Photo sample sites selected mainly for aspen and aspen/conifer forest areas were located on the digital print maps; these same areas were identified on corresponding photography and interpreted with respect to forest type, canopy closure and understory vegetation (if the forest canopy was open or closed with forest openings). The above-described process of interpreting and combining spectral signatures based upon signature curve similarity, discriminant analysis of the signatures, and calibration of signature print symbols with photograph and ground observations is outlined in the Phase I study.

The calibration process resulted in the production of the digital print map overlays from which study plots were selected to be visited in the field. These study plots, 156 total, were selected randomly and visited in a helicopter for verification/calibration. The "ground truth" was collected from the helicopter while flying low and slow over each study plot. Three photos were taken of each plot from 400 ft. at approximately 40 m.p.h. in order to have two stereo pairs.

The conifer class was verified by randomly selecting 36 pixel groups. These groups were 2x2 pixels in size; classified as conifer. Air photo interpretation was then used to verify each pixel group. This gave us a total of 192 study plots.

The verification/calibration plots were selected randomly on a single-pixel basis, so that a selected pixel would very often occur with no other pixel in the same class touching it. This led to a verification/calibration of not only the spectral accuracy, but the spatial accuracy as well.

A seralness scale, derived from the relative amount of aspen to conifer canopy cover, was developed based on an analysis of variance of the classes developed from the MSS classification. These classes were verified with the 192 study plots and the seralness scale was then calibrated based on the ability of the MSS data to define the classes of seralness as follows:

Map Symbol	Seralness Class	% Aspen Cover
S	Stable aspen	96 - 100
E	Early seral	90 - 95
M	Early to mid seral	50 - 89
M	Mid to late seral	20 - 49
L	Late seral	5 - 19
C	Conifer	0 - 4

RESULTS AND DISCUSSION

Summer Scene Analysis

The process of generating representative spectral signatures by SEARCH produced 67 signatures. Each pixel within the study was then classified into one of the 67 signatures that had been generated. After these 67 signatures were reduced from four mean band reflectance values to two components, and clustered according to signature factor score similarity,

a discriminant analysis was performed which created the scatter plot in
Figure 3. The discriminant analysis provides information, besides Figure 3,
which is helpful in the process of understanding relationships among
signatures; the analysis quantitatively assesses the integrity of the
signature groups created by the cluster analysis which helps in the process
of deciding whether to combine signatures into a group, leave them separate,
or to combine groups.

Preliminary digital print maps were produced for portions of the study
area, with a unique pixel classification symbol assigned to each signature
in Figure 3. As such print maps were compared with available field data
and interpretations from aerial photographs and spectral curves, it was
possible to partition the 67 signatures in Figure 3 into six major regions,
only one of which is the focus of this study.

Once Figure 3 was partitioned into regions, further study focused
exclusively on Region I. Examination of field sites and photo sites match-
ing the individuals signatures within Region I of Figure 3, in addition to
the study of signature shapes and results from the discriminant analysis,
led to the creation of subregions within Region I. Once a decision was
made to combine two or more signatures into one group, a class number was
assigned through the reclassification of all signatures in a group. Figure
3 shows the signatures included in subregions selected and the class
number assigned. Note that the process of combining signatures does not
merge the signature statistics in any way, but simply involves assigning a
common class number to more than one signature. Thus, the curves in Figure
1, where more than one signature is included for a given class, represent an
average of the individual signature mean values; the mean band values for
the signatures have been combined in this manner to simplify the graphical
presentation of the signatures.

Figure 3. Graphic representation of the discriminant analysis conducted to detect spectral similarities and differences among 67 light signatures.

○ MAP CLASS

--- GROUP BOUNDARY

Canonical Discriminant Function #1 (increasing visable light reflectance)

Canonical Discriminant Function #2 (increasing IR light)
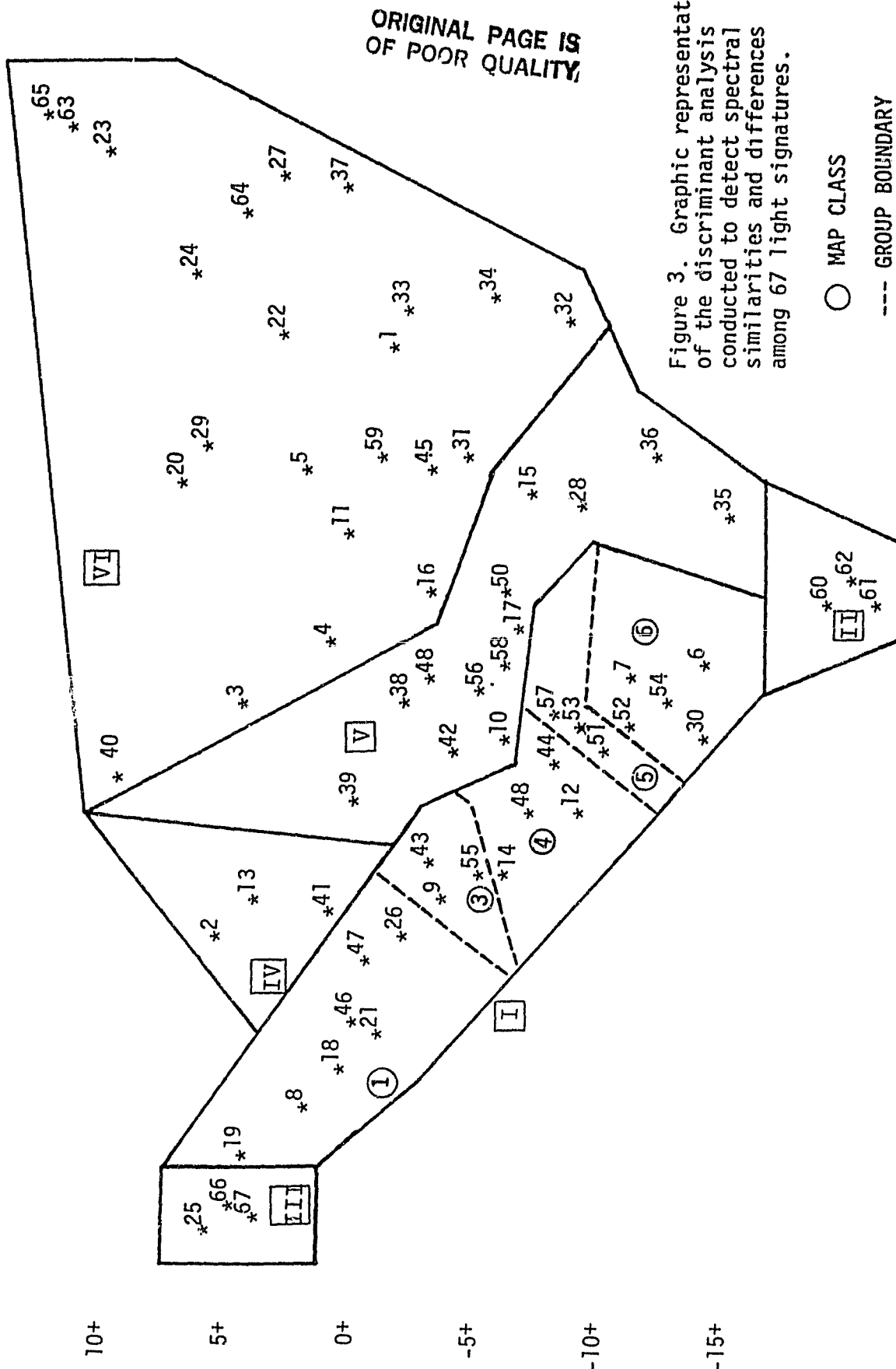
Light signature curves for the classes in Region I of Figure 3 are presented in Figure la. These signatures reflect a gradient of changing signature shape from class 1 to class 6. Examination of aerial photographs and available field site information support the conclusion that this spectral gradient corresponds with a forest gradient which begins with aspen forests and proceeds to coniferous forests, with various aspen/conifer mixes in between.

Fall Scene Analysis

The logic applied in the algorithm to utilize the information in the fall scene, as illustrated in Figure 2, is presented below. The primary objective was to map a successional stage of aspen, which would correspond to "early seral." The objective in using the fall scene was an attempt to map aspen with understory conifers present. But, as stated previously, the fall scene primarily contained information about terrain. There is but one study plot that can be said to have been correctly changed, using the fall scene to early seral, based on understory conifer alone.

In scrutinizing the field data, it was discovered that misclassifications in the "stable aspen" class also included "early to mid" and "mid to late" aspen seral classes as well as "early seral." This could be due to the presence of vigorous and healthy aspen obscuring the conifer that is also present. It was also discovered that misclassifications in the "late seral" class with field sites being "mid to late seral" was occurring. This could be due to shadowing from the trees themselves. This led to a modification of the objective, to not only map "early seral" aspen, but to improve the mapping of other seral stages.

The decisions made in the final algorithm were based on the verification/calibration field data collected from the helicopter and

independent air photo verification. Representative spectral signatures for the classes used from the summer scene (hereafter A), appear in Figure 1a; Figure 1b is a representation of the classes used from the second date (hereafter B). Class 1A is the "stable aspen" class, while class 1B, when found with class 1A, changes 1A to the "early seral" class. Class 2B, when found with class 1A, changes 1A to "early to mid seral," and when class 1A is found with class 3B, 1A is changed to "mid to late seral."

The rationale behind these changes is that the classes 1B through 3B are progressively darker or reflect less light. After it was discovered that the combination of 1A and 1B could allow the mapping of an "early seral" class, other possibilities were investigated, with the resulting progression from 1B to 3B. It is believed the dark classes 2B and 3B indicate the presence of conifer on slopes and aspects most favorable to conifer growth.

A similar logic was used in making changes in class 5A, "late seral," to "mid to late seral" based on the association of class 5A with 4B and 5B. The rational is that the high response of classes 4B and 5B, when found with 5A indicates there is less conifer than a "late seral" class would require. In addition, the fact that in the summer scene classification some aspen was found to be present, the change seemed to be logical. This procedure has been found to be the most significant improvement to the final maps.

Final Maps

The improvement to the final maps is illustrated in Tables I and II. These tables are error matrices, Table I being the summer scene only and Table II being the combination of the summer and fall scenes. The overall

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Map Class	VERIFIED CLASSES						Total	Percent Correct	Percent Commission
	1	2	3	4	5	6			
1	_4_	6	4	2			57	79	21
2*									
3	7	2	_11_	3			23	48	52
4	1	1	6	_29_	6	1	44	66	34
5				15	_12_	2	29	41	59
6					6	_33_	39	85	15
Total	53	9	21	49	24	36	192		
Percent Omission	15	100	48	41	50	8	Overall Accuracy: 68%		

Table I. Summer Scene

*Class 2 was not mapped using the summer scene.

Map Class	VERIFIED CLASSES						Total	Percent Correct	Percent Commission
	1	2	3	4	5	6			
1	_38_	1	3				42	90	10
2	7	_3_					10	30	70
3	7	4	_12_	4			27	44	56
4	1	1	6	_41_	7	1	57	72	28
5				4	_11_	2	17	65	35
6					6	_33_	39	85	15
Total	53	9	21	49	24	36	192		
Percent Omission	28	67	43	16	54	8	Overall Accuracy: 72%		

Table II. Combined Map

Map Classes:

1 - stable aspen   4 - mid to late seral
2 - early seral   5 - late seral
3 - early to mid seral 6 - conifer

improvement by including the fall scene is only 4%, from 68% to 72%. The relatively small improvement in map accuracy by adding the second date analysis brings up the question of cost effectiveness. The increased cost of using the fall scene is from 15% to 20% over the cost of analyzing only one scene. But the 4% increase in accuracy does not represent all improvements in the maps. The value of having an "early seral" class must be considered as well as the improvement to particular classes, such as the "late seral" class, which was improved by 24%. The "stable" class was improved by 11% and the "mid to late" class was improved by 6%, while the accuracy of the "early to mid" class dropped by 4%.

It should be noted that 15% of the field sites contained maple. Only 8% of these had greater than 50% maple cover and 83% of these field sites contained less than 20% maple cover. Maple has been treated as if it were aspen in this analysis. We feel there is not much difference between the two types from a land manager's point of view.

CONCLUSION

Aspen, conifer and mixed aspen/conifer forests have been mapped for a 15-quadrangle study area in the Utah-Idaho Bear River Range using Landsat multispectral scanner data. Digital classification of Landsat data allowed the identification of four groups of signatures which reflect different types of aspen/conifer forest mixing. The four groups of signatures are indicative of "early" to "late seral" aspen forest, when two dates of Landsat digital data are analyzed together. For a single date, three groups of signatures are indicative of "early to mid seral," "mid seral," and "late seral."

After analyzing the field data of 156 sites, collected from a helicopter, it appears the digital terrain data could be added to the analysis for improvement. This has been indicated by analysis of variance performed on the field data. Significant differences between the aspen/conifer mixes occurred in elevation, slope, and a synthetic variable which was created by multiplying slope by aspect.

In the light of the growing importance of aspen as a cover type for watershed, wildlife habitat, and recreation, the techniques developed in this study should significantly improve mapping of aspen/conifer forest mixes.