LANDSAT IMAGERY FOR BANFF AND JASPER NATIONAL PARKS INVENTORY AND MANAGEMENT

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by

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ABSTRACT

Computer assisted classifications of LANDSAT digital magnetic tapes of Banff and Jasper National Parks were done using the General Electric "Image-100" of the Canada Centre for Remote Sensing in Ottawa. Themes of pine, spruce and poplar-shrub forest, water, snow and meadows were classified by their spectral signatures. From 70 to 80 percent of the four areas studied were classified with 80 to 90 percent accuracy using a supervised parallelepiped classification method. Extension of the classification from small training areas of 50 - 100 km^2 in each LANDSAT image to classification of 1200 km^2 areas at full resolution was done successfully on two LANDSAT images. The classifications produced were geometrically correct in color at a scale of 1:250,000 on an electron beam image recorder. Proposed applications of this work are in a biophysical inventory and in a National Park public education program. A limited number of LANDSAT photo-maps of Banff and Jasper Parks at a scale of 1:500,000 in color, and with national topographic map information on water resources and transportation, are available on request to the Northern Forest Research Centre.

INTRODUCTION

The first earth resources technology satellite (ERTS) was launched in July, 1972; a similar satellite was launched in January, 1975. These are now called LANDSAT and, together every nine days, they give coverage of all Canada that is cloud free. Applications of LANDSAT have been slow because the technology to utilize space imagery is well behind the capability to acquire it. Conventional photo interpretation techniques make it possible to use much of the information from space, but more accurate classification and favorable benefit-cost ratios are likely with the use of computers. To explore the possibilities of automated interpretation and mapping for the management of forested lands, a study was initiated by the Northern Forest Research Centre, Edmonton, in cooperation with the Canada Centre for Remote Sensing, Ottawa, and Parks Canada, Calgary. The objectives were:

1. To determine what cover types in Banff and Jasper National Parks and adjacent areas might be spectrally identified from LANDSAT images recorded on magnetic tapes.

2. To provide thematic maps of Banff and Jasper National Parks that show broad cover types and to evaluate the accuracy and usefulness of computer assisted interpretation.

LOCATION

The area of study is on the east slopes of the Rocky Mountains in Alberta, Canada. Elevations range from 900 to 3600 meters above sea level. Five forest regions of Canada are included in the study area (Rowe, 1972). They are as follows:

1. Lower Foothills - (900 - 1200 meters). The distinctive tree species is lodgepole pine (*Pinus contorta* Dougl. var *latifolia* Engelm.) which, with trembling aspen (*Populus tremuloides* Michx.) and balsam poplar (*Populus balsamifera* L.), has assumed a dominant position after extensive fires. In older forest stands white spruce (*Picea glauca*(Moench)Voss) is

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commonly found, while black spruce (*Picea Mariana* (Mill) B.S.P.) is seen on the wetter sites, especially on those adjacent to Jasper National Park.

2. Upper Foothills - (900 - 1800 m). This region is similar to the lower foothills, except that the forests are coniferous for the most part.

3. East Slope Rockies (1500 - 2100 m). This region is distinguished from the Upper Foothills by the presence of Engelmann spruce-white spruce hybrids *(Picea Engelmanni* x *P. glauca)* at the higher elevation.

4. Douglas fir-Lodgepole pine. This occurs only on small areas near Kananaskis, Banff and Jasper on slopes with warm exposures.

5. Alpine-Tundra. These are extensive areas of meadows, that are nearly treeless.

In this large and varied region are many potential land uses, some of which may conflict; for example: water, hydroelectric power, recreation, second homes, wood products, wildlife, coal mining, limestone quarries and oil and gas developments. It takes only a moment's reflection to realize that, while multiple uses of the east slopes are possible and even desirable, there is increasing need to establish priorities and integration of uses on the east slopes.

Resource inventory and information systems incorporating satellite imagery may provide information for:

1. Policy and Broad Regional Planning;

2. Resource allocation;

3. Resource management (intensive and extensive);

4. Monitoring and updating existing information because of changes in values, resource base, and disturbances caused by man and natural catastrophe.

METHODS

Five LANDSAT images were selected after close study of amount of cloud, shadow and the radiometric quality of the received data. The following images were judged to be most suitable for this project.

LANDSAT Number	Date Imaged	Location
E-1419 - 18233	Sept. 15, 1973	Jasper
E-1741 - 18042	Aug. 3, 1974	Jasper
E-1741 - 18045	Aug. 3, 1974	Banff
E-1344 - 18075	July 2, 1973	Kananaskis Forest Experiment Station
E-1310 - 18192	May 29, 1973	Cadomin Luscar

The digital tape for each image was recorded at 1600 bpi and produced by the Canada Centre for Remote Sensing (CCRS). Initial work was with tapes that were not radiometrically or geometrically corrected. The thematic maps produced for Banff and Jasper parks were from tapes that were corrected radiometrically and geometrically.

The computer assisted interpretation of LANDSAT magnetic tapes was done on the General Electric "Image 100" of CCRS. The system had been just installed, and this was the first operational project to be attempted on the system. It required considerable effort on the part of CCRS to bring the system to an operational state. This analysis, therefore, was restricted to two supervised classification methods incorporated in the software of the system at the time of delivery. These are described by Goodenough, 1975.

One method, known as 1-D training and classification involves the generation of four histograms, one for each multispectral band. FIGURE 1 shows the four histograms generated for a training site of Lodgepole Pine for LANDSAT frame E-1344-18075. The upper and lower bounds of each histogram are limits which are used to threshold each pixel in the scene. Pixels with intensity vectors falling within the four-dimensional parallelepiped defined by these limits are assigned to the same class as the training site. The user may interactively alter the histogram limits to optimize the resulting classification. This procedure was repeated for each of the classes of interest. Sometimes there was some overlap between similar ground classes. The pixels with class overlap are displayed in a bright red colour. When this project was begun in May, 1974, one could eliminate the overlap on the Image 100 in three ways:

(a) repeat 1-D classification for some classes using different histogram limits;

(b) perform n-D training and classification;

(c) perform logical and mathematical operations on the themes in conflict.

We used all of these methods to eliminate theme or class overlap.

The n-D or n-dimensional training and classification method is always preceded by 1-D training and classification. Within the rectangular parallelepiped defined by the histogram limits, the actual signature distribution of the training area is represented by the distribution of four-dimensional cells of unit volume (FIGURE 2). Each cell contains the number of pixels with intensity vectors corresponding to the coordinates of the cell. The cell counts are measures of the probability distribution for the given class. Cells with counts below a user-selected threshold may be deleted from the spectral distribution. The IMAGE 100 displays all pixels with intensity vectors corresponding to the cells with counts above the threshold. In this way, one can interactively alter the probability distribution to that best describing a class. Results of 1-D and n-D classifications are saved on theme tracks. Class conflicts or overlap were eliminated following the procedure previously described. Logical 'and' and 'or' operations, together with 'add' and 'subtract' operations were used on the theme tracks to force overlapped pixels to a particular class. At the time this work was carried out, the Canada Centre for Remote Sensing had not yet implemented any statistical decision scheme for deciding class assignments.

The final results of the classifications were displayed on the colour CRT and directly photographed. Subsequently, we were able to generate the saved results geometrically corrected on color film using an electron beam image recorder.

Spectral Signatures

The spectral signatures of ground classes are not easily determined directly from LANDSAT multispectral scanner data. The LANDSAT radiance measurements depend in a complicated fashion on atmospheric properties which are, in general, not well known. There has appeared in the literature a number of excellent articles on methods of atmospheric correction (Rogers, Peacock, and Shah, 1973; Turner, Malia, Nalepka, and Thompson, 1974) and spectral signature extension (Henderson, Thomas, and Nalepka, 1975).

On the ground there are many possible errors in the measurement of incoming and reflected radiation and these are well documented by Hulstrom (1974). With appropriate ground data obtained at the time of the satellite overflights it is possible to calibrate the LANDSAT spectral signatures. We did not have such data at the time this paper was written. We therefore relied upon relative radiance values from the LANDSAT multispectral scanner.

Presented in Tables 1 and 2 are the gray level means and variances for various classes observed in two frames with the LANDSAT multispectral scanner. The maximum grey level value in each band is 63. Classes with small variances in each band were used to generate regression lines for each band between the two frames. The equation representing these regressions is:

$$I(1,i)=a(i)\cdot I(2,i)+b(i) \qquad (1)$$

where $I(1,i)$ is the intensity in band i ($i=4,5,6,7$), frame 1 (E-1344-18075); and $I(2,i)$ is the intensity in band i, frame 2. The coefficients of equation (1) obtained for the two frames are given in TABLE 3 along with the linear-correlation coefficients, $R(i)$ (Bevington, 1969).

The intensity values in frame two were corrected by the inverse of these regression lines. The 1-D intensity limits of frame one were then used to generate rectangular parallelepipeds for classification of frame two. In TABLE 4 are tabulated the original acreages derived from supervised classification of frame two and the acreages obtained by extending spectral signatures of frame one. The large variation in acreages is indicative of a considerable error in this procedure. The errors were:

(a) radiometric errors in frame two between detectors enhanced by scaling frame two intensities;

(b) linear signature extension (equation 1) too simple;

(c) non-parametric classifications not suitable for signature extension.

These results led us to classify each frame, independent of any other classifications on other frames.

Ground Truth

Ground truth was based on photo interpretation of small-scale (1:100,000 and 1:60,000) infrared ektachrome aerial photography obtained from jet aircraft of CCRS. This aerial photography was supplemented by the Northern Forest

Research Centre using a Cessna 320 and Bell 306B helicopter to obtain color and infrared ektachrome 70 mm aerial photographs at scales from 1:500 to 1:60,000. In addition verification of photo interpretation was obtained by ground samples and from previously published inventory reports by Kirby and Ogilvie (1969) and Kirby (1973).

RESULTS

Thematic Maps

Thematic maps at full resolution for sections ($1200\ km^2$) of images E-1419-18233 and E-1741-18045 at a scale of 1:250,000 have been produced for Banff and Jasper National Parks. One thematic map from image E-1344-18075 was produced for Kananaskis and one thematic map from the Cadomin Luscar area was produced from image E-1310-18192. The classification of each section is based on one training set for each of the images. Examples of this work are shown in FIGURES 3, 4, 5 and 6 along with accompanying ground truth. In addition, all of image E-1419-18233 was classified in one pass at 1:1,000,000 resolution (25% of the pixels). (See Fig. 7).

Color Composite Satellite Photo Maps with N.T.S. Overlay

Color composites at a scale of 1:250,000 were obtained from the National Air Photo Library in Ottawa. Line detail from 1:250,000 National Topographic Map Sheets (NTS) showing roads, streams, lakes and place names was transferred to a clear plastic overlay. These color composites of spectral bands 4, 5 and 6 or 7 (blue, green, red respectively), with NTS line detail, have been lithographed in color at a scale of 1:500,000. The maximum position error is reported as 10 km, but for small areas of $1000\ km^2$ the error is much less. The summer photo-maps indicate water with various sediment loads, hardwood, spruce and pine forests, barren lands (rock, buildings, roads), forest burnovers, forest damage (red belt). To distinguish these various themes requires the perception of slight tonal changes in color, a feat more accurately accomplished by computer than by the naked eye. A limited number of satellite photo maps will be available on request from the Northern Forest Research Centre.

A winter mosaic from 1973-74 images of Banff and Jasper Parks and surrounding area was prepared by the National Air Photo Library in Ottawa (Map Sheet 2185). The winter mosaic shows the snow pack areas. Geologic structure, forest cutovers, and drainage patterns are highlighted by the snow background and shadows. Corrections for the low sun angle and resulting long shadows are required in interpretation of this winter mosaic.

EVALUATION

Portions of the $1200\text{-}km^2$ areas where training signatures were developed were evaluated as to accuracy of the thematic classifications. The areas evaluated were larger than the areas upon which training of the computer was done.

Kananaskis

On this test site of approximately $50\ km^2$, forest cover-type maps at a scale of 1:15,840 were available. Line transects 1 pixel wide (70 m) and approximately 1 km apart running north and south on the maps were compared with a similar grid on a 1:25,000 pixel printout from a line printer of the "Image 100". The coded printout was hand-coloured to facilitate the evaluation. Additional ground truth in the form of aerial photographs at scales of 1:500 to 1:120,000 were used to supplement the ground truth map which had a 10-ha limit for the smallest discernible cover type. That is, the ground truth map had types less than 10 ha in size included in other larger types and it was necessary to use aerial photographs to get 0.4 ha units for comparison with the pixel printout. Table 5 presents the results of this evaluation. Eighty-two percent of the test area was classified. The classification of spruce, pine and poplar forests had an average accuracy of 76 percent; water was 90 percent correct with three categories; barren lands which included dolomite rock, gravel, buildings and mineral soil had 70 percent accuracy; while grassland which included cut-over forest and alpine meadows was only 30 percent correctly classified.

The 76 percent accuracy achieved with the "Image 100" classification of spruce and pine forests is notable. The classification of water with 90 percent accuracy was possible when three classes of water were used to classify the test site. Improved accuracy in the classification of grasslands could no doubt have been achieved if additional themes for grasslands, herb-shrub and cut-over forest were defined. The electron beam image recordings of the "Image 100" color composite and the classified test area are shown in FIGURE 3.

Banff

A test area of $460\ km^2$ (FIGURE 4) was selected near the townsite of Banff. Seven broad themes of meadows (grassland alpine meadows);

water (various sediment loads and depths); barren lands (limestones, shales, quartzites, roads, townsite, coal mines and mineral soil); pine forest: spruce forest; poplar-deciduous forest; and snow and cloud. A comparison (TABLE 6) of percentage distribution of five themes as classified by the "Image-100" and by photo interpretation of 1:100,000 aerochrome infrared aerial photography was made on a 100 km^2 test area. The percentage distributions were obtained from dot counts placed over the pixel map and the interpreted photograph. Spot checks on the "Image 100" classification at various points indicated that the Vermilion Lakes area near Banff portrays a vast array of spectral signatures reflecting vegetation associations so detailed as to defy classification at a pixel size of 70 m^2. Further difficulties were encountered in separating spectral signatures of open grassland areas from those with an abundance of shrubs. Yet the "Image-100" system was able to classify the larger fairways of the Banff Springs Hotel golf course as meadow. No attempt was made to map the distribution of alpine larch or Douglas fir in the training area. While the extent of Douglas fir was limited within the training area, the larch occupies the upper fringe of several valley systems. There was some confusion (as in the Kananaskis test) with pine forests on north-facing slopes and in shadow being classified as spruce.

The spectral signatures developed on the Banff test site were used to classify other 1200 km^2 areas within image E-1741-18045. One area classified by the "Image 100" where no training was done is presented in FIGURE 6. A comparison of the "Image-100" classification with the 1:100,000 infrared aerial photography at points that have been numbered on FIGURE 6 indicate the "Image-100" classification is nearly 100 percent correct, but approximately only 80 percent of the area could be classified. The geometric accuracy is close to that found on a 1:250,000 national topographic map sheet.

By combining the classification done by the "Image-100" with other information obtained from aerial photographs and topographic maps, such as presented in FIGURE 6, a great deal of information useful for Park management is assembled at little cost. By digitizing information from other sources, such as topographic maps and aerial photos, it may be combined with the "Image-100" classification.

Cadomin-Luscar

A comparison of the "Image-100" classification of "red belt" with a map prepared by the Alberta Forest Service from 1:60,000 infrared aerochrome photographs supplied by CCRS is shown in FIGURE 5. Red belt in lodgepole pine forests on the east slopes is a problem related to physiological damage of the trees, and is associated with rapid changes in temperature from thawing to freezing. A comparison of the "Image-100" classification against the map based on photo interpretation of infrared aerochrome photographs indicates a high degree of correlation, but some cut-over areas with dead slash and along streams are misclassified as red belt by the "Image-100". (See FIGURE 5). Some high meadow areas where the shrub-herb-grass vegetation appears to be damaged by frost are also classified as red belt.

Jasper

This evaluation was based on 1:60,000 70 mm infrared ektachrome aerial photography obtained by the Northern Forest Research Centre using a Cessna 320 flying at 21,000 ft. above sea level. Evaluations on five 10-km^2 areas were made by comparing the 1:25,000 pixel printout of the "Image-100" classification with interpretations of the 70 mm aerial photography. The 1:60,000 70 mm aerochrome infrared photography was enlarged to a scale of 1:25,000 to match the pixel printout. The results indicated that the Image-100 classification of five broad themes of water, barren, meadow, hardwood shrub forest, coniferous forest was 80 percent correct. The main problem is the omissions in the "Image-100" classification, and only 70 to 80 percent of the areas tested could be classified. The lower sun angle when this image was obtained on September 15 definitely caused more shadow problems than in Kananaskis on July 2 and in Banff on August 3. The alpine meadows are better defined on the LANDSAT image of September 15, 1973 with no snow than they are on 1:60,000 aerial photographs obtained in July 1975 when there was snow. (See FIGURE 7.) The training of the "Image-100" on the Jasper test site was used to classify all of image E-1419-18233 with one-quarter resolution (25 percent of the pixels). The thematic map for nearly all of Jasper National Park appears to have no large unclassified areas.

DISCUSSION

The results obtained are encouraging and are comparable to those obtained by Driscoll *et al.* (1974), Root et al. (1974) and Kalensky (1974). Very little overlap in classification by the "Image-100" was indicated. From our test areas it appears that in all cases our classification could be improved if more than 6 to 8 themes were used. Additional themes for mixed forest of various classes, meadow, rock and water are required to achieve more complete classification. The use of LANDSAT images displaying various phenological changes will also improve classification of specific themes. The classification of larch forest may be possible by taking advantage of the fall change in color of the needles.

Statistically sound evaluation of the Banff-Jasper interpretations can be done when all of the "Image-100" classification has been completed. It will then be possible to grid the "Image-100" classification and randomly select test points throughout Banff and Jasper Parks in sufficient numbers to give precise estimate on the classification accuracy. The ground truth for this test would be 1:60,000 infrared aerochrome and color photography and thermal imagery obtained for most of Banff and Jasper National Parks in July, 1975, by the Canada Centre for Remote Sensing. In addition to the thematic maps presented in this report, binary coded theme maps are now available and can be produced at various scales. These may be used in further evaluating the classification and in applying the LANDSAT classification in a biophysical survey.

APPLICATION

Of particular interest to this meeting are the development of the multi-stage biophysical inventory program and an evaluation of the potential role of LANDSAT imagery in such a program.

The biophysical mapping program developed for Banff and Jasper Parks (Day, 1975), an area of 17,000 km^2, is an application of procedures suggested by Lacate, 1969. Lacate describes four levels of mapping which can be summarized as:

Level 1 - The "Land Region" is an area of land characterized by a distinctive regional climate as expressed by vegetation - an aggregation of several distinctive contiguous landscapes. Mapping scale is 1:1,000,000 or smaller.

Level 2 - The "Land District" is an area of land characterized by a distinctive pattern of relief, geology, geomorphology and associated regional vegetation. The "Land District" is a subdivision of the Land Region based primarily on the separation of major physiographic and/or geologic patterns which characterize the region as a whole. Mapping scale is 1:500,000 to 1:1,000,000.

Level 3 - The "Land System" is an area of land throughout which there is a recurring pattern of land forms, soils and vegetations. Mapping scale is 1:125,000 to 1:250,000.

Level 4 - The "Land Type" is an area of land, on a particular parent material, having a fairly homogeneous combination of soil and vegetation. Mapping scale is 1:10,000 to 1:60,000.

The stated objectives of the Banff/Jasper inventory program are:

- To define the physical and biological environment of Banff and Jasper National Parks in terms of "Land Systems"; that is, in terms of recurring patterns of landforms, soils and vegetation, and
- To separate those "Land Types" that are large enough to be indicated within the constraints of the final mapping scale of 1:50,000.

The multi-stage characteristic of biophysical land classification can be of significant value to land management agencies such as Parks Canada. LANDSAT provides a ready means of conducting low-cost, small-scale inventories of several parks or park areas lacking a comprehensive data base. Such inventories are assured a position of permanent value because they constitute the framework on which more detailed inventory mapping is laid. Depending on the specific planning objectives, Land Region and Land District classifications can provide an adequate data base for preliminary land-use planning or resource allocation (Bull, 1974). Additional information is, of course, required for master planning of parks.

Beyond the applications of LANDSAT imagery as a mapping and dynamic monitoring tool are a variety of special-purpose applications currently being evaluated by diverse user groups. Such groups are often perceived by the research and academic communities as peripheral to the mainstream of remote sensing; however, they may have the greatest potential for familiarizing the general public with satellite, and other remotely sensed, imagery. Two potential applications of LANDSAT imagery being evaluated by Parks Canada are for visitor orientation and nature interpretation within National Parks. The geometric accuracy of LANDSAT imagery as a planimetric base provides orientation in large Parks such as Banff and Jasper. The low cost of a wide variety of photographic products further increases the potential of LANDSAT imagery for application to visitor orientation and nature interpretation. Satellite imagery is a new "media" for the naturalist, enabling him to relate ecological units to larger systems. This program has a potential audience of three million visitors annually. The interest generated by the biophysical inventory program, notably ecological awareness groups as well as by individual visitors, requires that this program be demonstrated to the public.

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TABLE 1

MEAN INTENSITIES AND STANDARD DEVIATIONS FOR VARIOUS CLASSES

KANANASKIS (E-1344-18075; July 2, 1973)

CLASS \ MSS BAND	4	5	6	7
Lodgepole Pine	14.2±1.5	11.0±0.7	24.8±2.3	16.3±3.0
Poplar	16.0±2.2	13.1±2.8	36.3±4.6	30.2±4.8
Barrier Lake	20.9±1.8	12.3±1.1	7.4±0.8	1.1±0.3
Chiniki Lake	13.1±1.6	9.1±2.6	8.0±3.1	1.7±1.2
Bow River	20.6±1.5	16.5±1.0	14.1±12.8	4.4±7.9
Barrier Mountain	27.4±26.6	29.2±30.7	34.1±29.2	22.0±25.8
Gravel Pit	22.1±1.1	21.9±3.1	29.7±1.5	19.8±1.1
White Spruce	13.4±1.1	10.6±1.1	21.3±2.0	12.1±1.1
Grassland	18.8±2.5	18.3±2.6	29.2±1.8	20.1±3.6

TABLE 2

MEAN INTENSITIES AND STANDARD DEVIATIONS FOR VARIOUS CLASSES

BANFF-JASPER NATIONAL PARK (E-1419-18233, Sept. 15, 1973)

CLASS \ MSS BAND	4	5	6	7
Poplar	11.3±1.1	9.2±1.1	25.5±3.2	18.7±2.0
Pine	10.9±0.9	9.0±0.7	19.7±1.8	11.6±0.7
Spruce	9.5±1.2	7.2±0.7	14.7±2.7	7.8±0.7
River	21.1±4.0	18.1±2.8	13.6±6.2	3.8±2.4
Grassland	14.8±2.4	15.0±1.4	29.6±19.0	24.9±14.5
Rock-1	22.0±4.3	24.2±4.9	26.3±10.2	13.0±3.4
Rock-2	28.1±6.6	31.1±4.2	34.6±9.7	24.0±4.2

TABLE 3

INTENSITY REGRESSION LINES BETWEEN
FRAME 1, E-1344-18075, and FRAME 2, E-1419-18233

$$I(1,i)=a(i)\cdot I(2,i)+b(i)$$

i	a(i)	b(i)	R(i)
4	1.38	-9.22	0.99
5	1.28	-5.64	0.98
6	0.57	4.69	0.97
7	0.58	1.28	1.00

TABLE 4

COMPARISON OF RESULTS OBTAINED BY EXTENDING SPECTRAL SIGNATURES WITH THE REGRESSION LINES OF TALBE 3

COMPARISON OF E-1 ACREAGES

Class	Original Acreages	Signature Extended Acreages	Percentage Difference
Spruce	42482	31278	-26.4%
Pine	53472	69365	+22.9%

TABLE 5

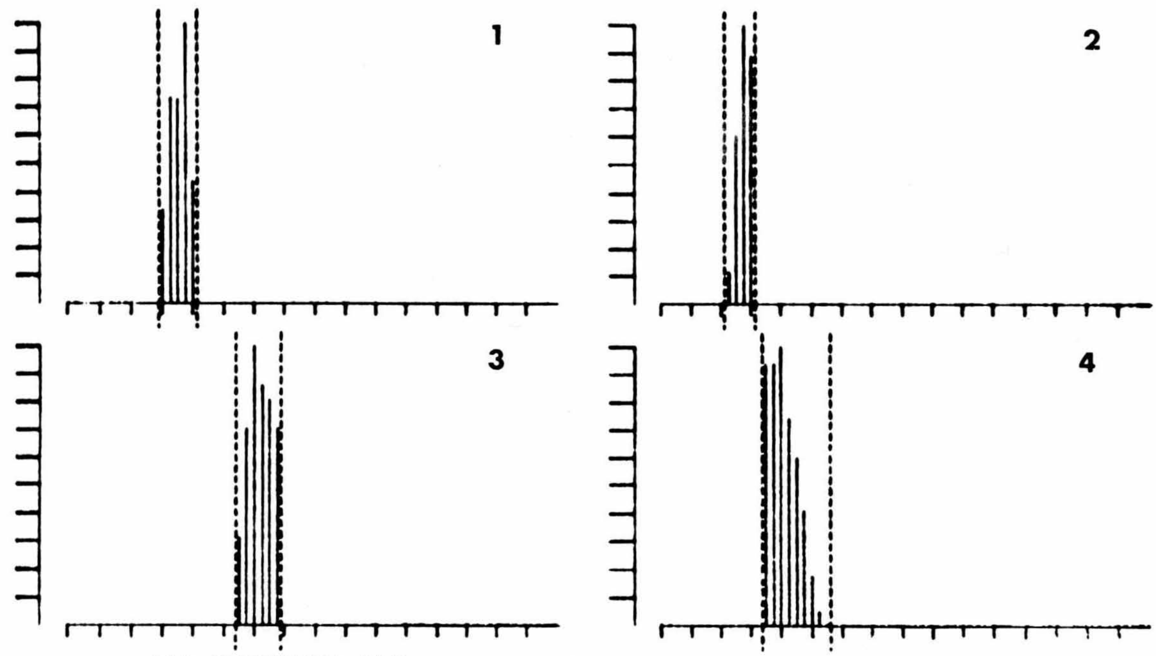
A COMPARISON OF THE "IMAGE 100" CLASSIFICATION WITH GROUND TRUTH SHOWING ERRORS OF OMISSION AND COMMISSION ON THE KANANASKIS TEST SITE (IMAGE E-1344-18075)

"Image 100"	Ground Truth							%
Classification	Spruce	Pine	Poplar	Grass	Barren	Water	Totals	Correct
Spruce	66	15			6		87	76
Pine	43	224	13	5	9	3	297	75
Poplar			24		7		31	77
Grass	3	6	2	16	15	1	43	37
Barren	8	7		4	45		64	70
Water					3	26	29	90
Unclassified	51	36	3	5	30		125	
	171	288	42	30	115	30	676	
%	Classified						82	

TABLE 6

A COMPARISON OF THEME DISTRIBUTION AS OBTAINED BY THE I-100 CLASSIFICATION AND FROM INTERPRETATION OF 1:100,000 INFRARED AEROCHROME AERIAL PHOTOGRAPHY

Theme	Percent Distribution of Area	
	Image-100	1:100,000 Photos
Meadows	0.5	1.2
Water	1.7	5.3
Barren	14.2	21.2
Coniferous Forest	63.0	55.0
Hardwood - Shrub Types	21.0	17.0



*** OVERVIEW *** +

#	LB	UB	DEL	PEAK	MEAN	VAR	
1	12	16	5	8756	14 1	1 5	+
2	9	12	4	10301	11 0	0 7	+
3	22	27	6	6460	24 7	2 3	+
4	14	22	9	5827	16 3	3 2	+

TRAINING AREA= 28328 PIXELS +
ALARMED AREA= 34662 PIXELS(13.2%)+
TYPE CHANNEL # OR E(X)IT

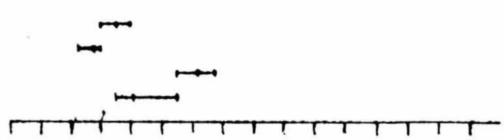


FIGURE 1: The number of Lodgepole Pine picture elements (pixels) of a given intensity are shown plotted against intensity for E-1344-18075 for the four multispectral scanner bands. The 1-D limits are shown as dashed lines and are tabulated below as lower bounds (LB) and upper bounds (UB). Also listed are the largest number of pixels in the histogram and the means and variances for each channel. The graph in the lower right shows the means and 1-D limits for each channel and is, in effect, a plot of wavelength against mean intensity.

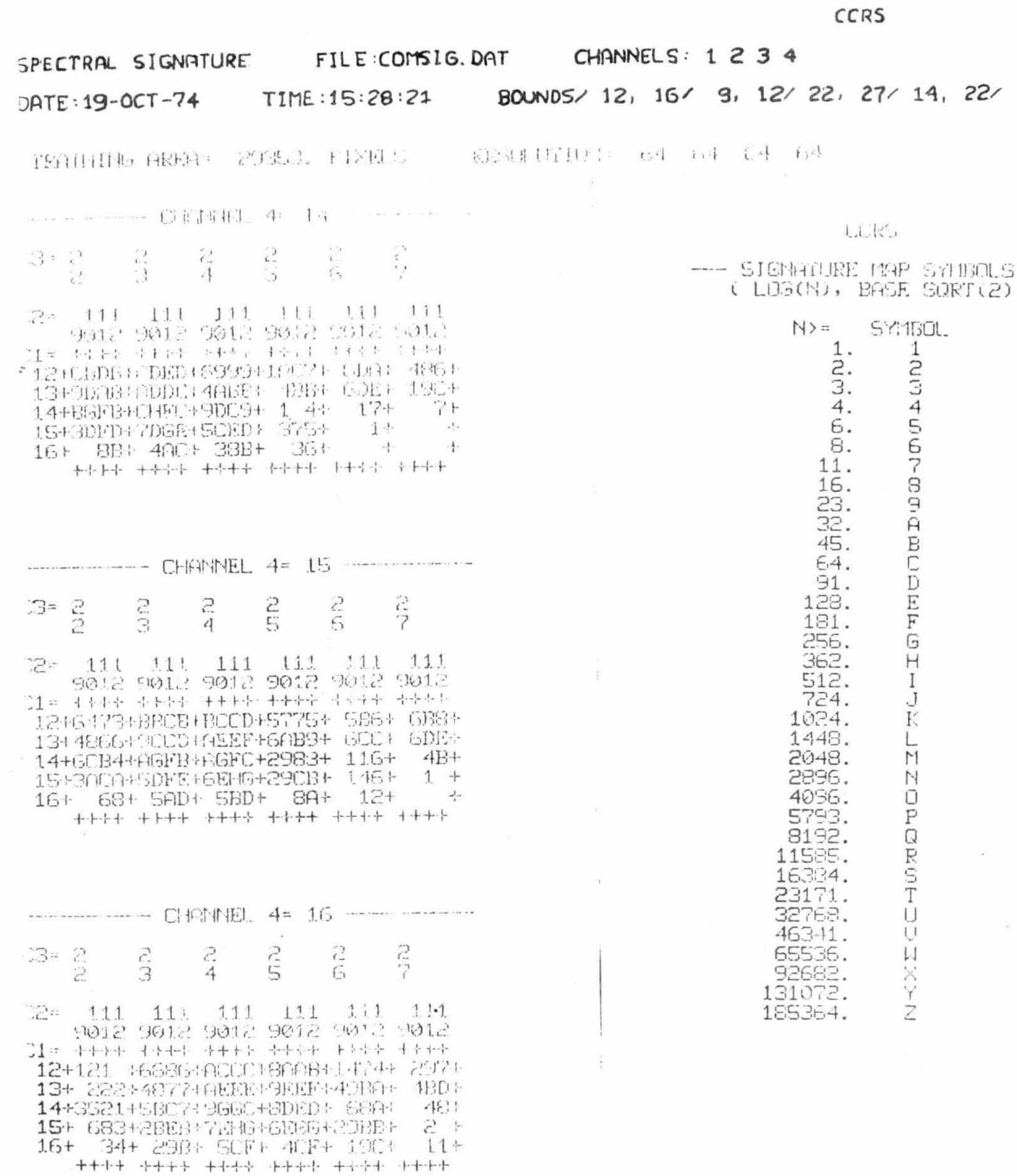


FIGURE 2: A portion of the four dimensional space for Lodgepole Pine (E-1344-18075) is shown. Each row of six sub-panels corresponds to different channel 4 (MSS band 7) values. Each sub-panel is a cut-through the space at different channel 3 (C3) intensities. The individual sub-panels are two dimensional plots of the channel 1 and 2 intensities. The symbols in these plots represent the powers of square-root-of-2 which best match the actual cell count. This type of printout is used to examine the detailed structure of the four dimensional spectral space.

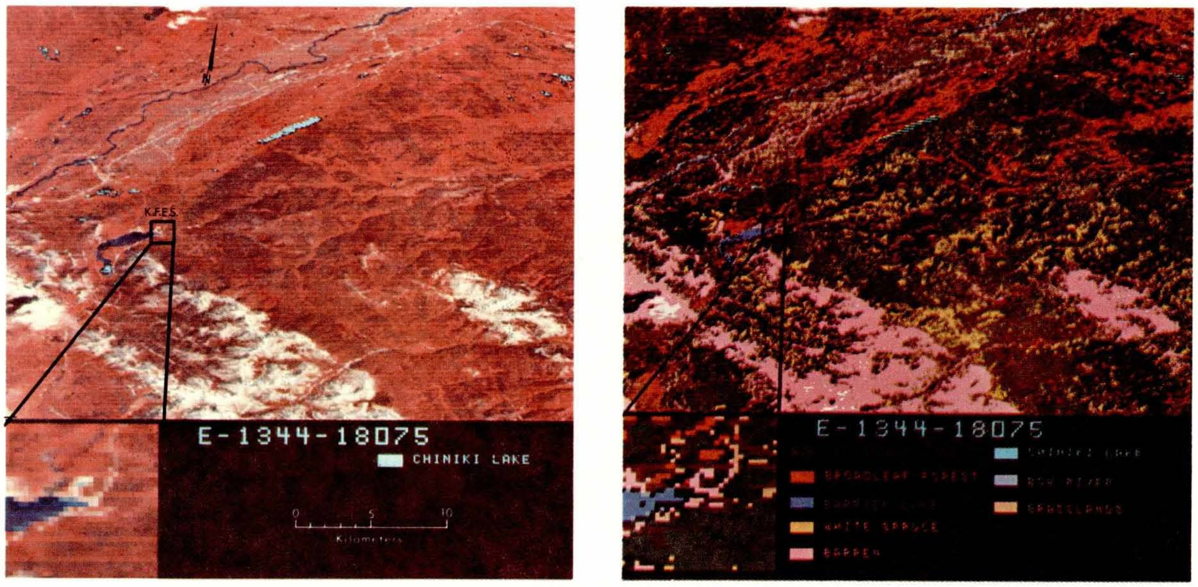


Figure 3: The Kananaskis test site showing "Image-100" output, not geometrically or radiometrically corrected, produced on the electron beam image recorder: (a) one theme (water) classified on a color composite with a background of bands 4, 5 and 6 in blue, green and red respectively, (b) thematic map as produced for the test site.

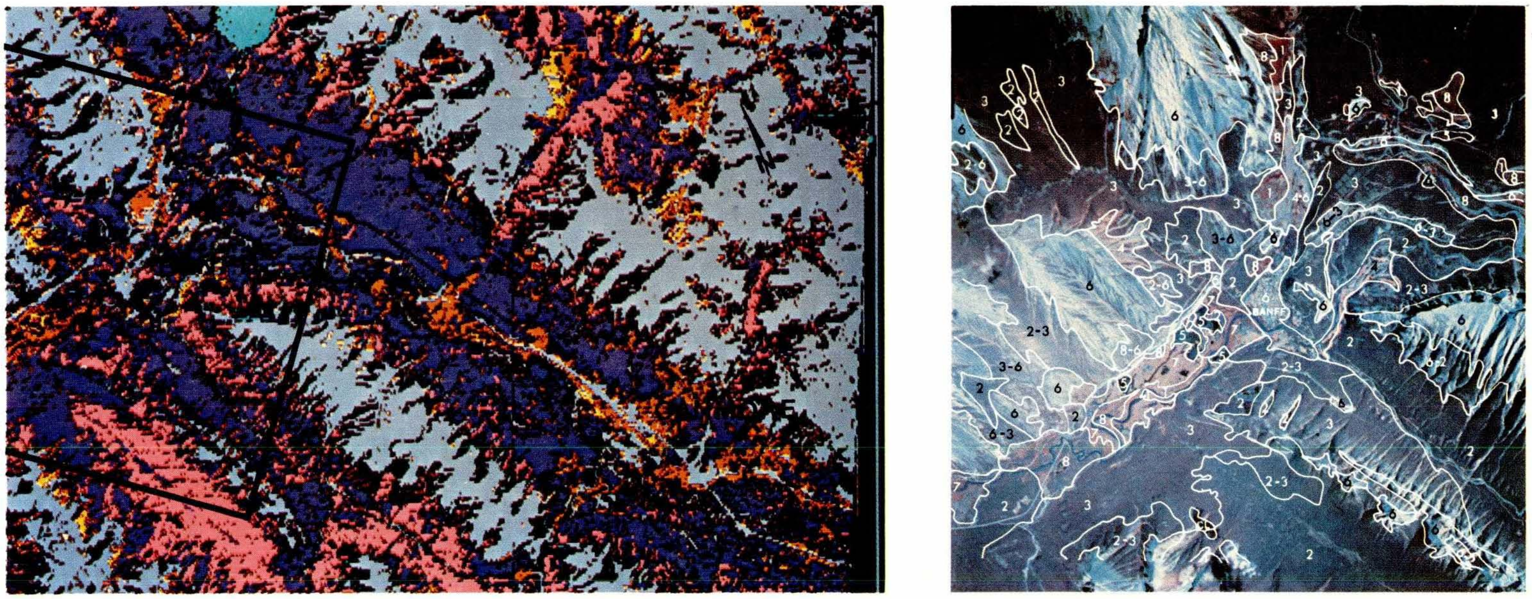


Figure 4: The Banff test site showing a comparison of (a) a portion of the 1:250,000 "Image-100" thematic map; with (b) an interpretation of a 1:100,000 aerochrome infrared aerial photograph reduced to a scale of 1:250,000.

Legend fig. 4a

Orange = Poplar/deciduous shrub

Pink = Spruce

Blue = Pine

Yellow = Alpine meadows or grasslands

Turquoise = Water

Grey = Barren lands (rock, townsite, roadways)

White = Snow or cloud

Black = Unclassified

Legend fig. 4b

1. Poplar/deciduous shrub
2. Spruce
3. Pine
4. Alpine meadows or grasslands
5. Water
6. Barren lands (rock, townsite, roadways)
7. Wetlands
8. Mixed poplar-spruce/pine

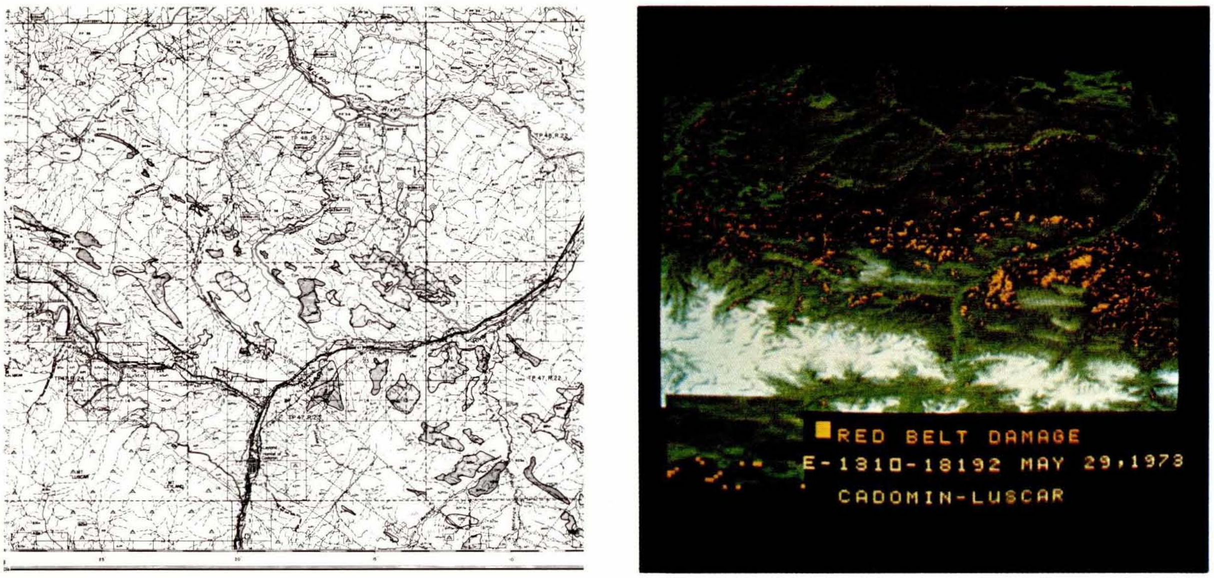


Figure 5: "Red belt" damage in the Luscar area, as interpreted from (a) 1:60,000 aerochrome infrared aerial photographs and (b) as a thematic Image-100 output.

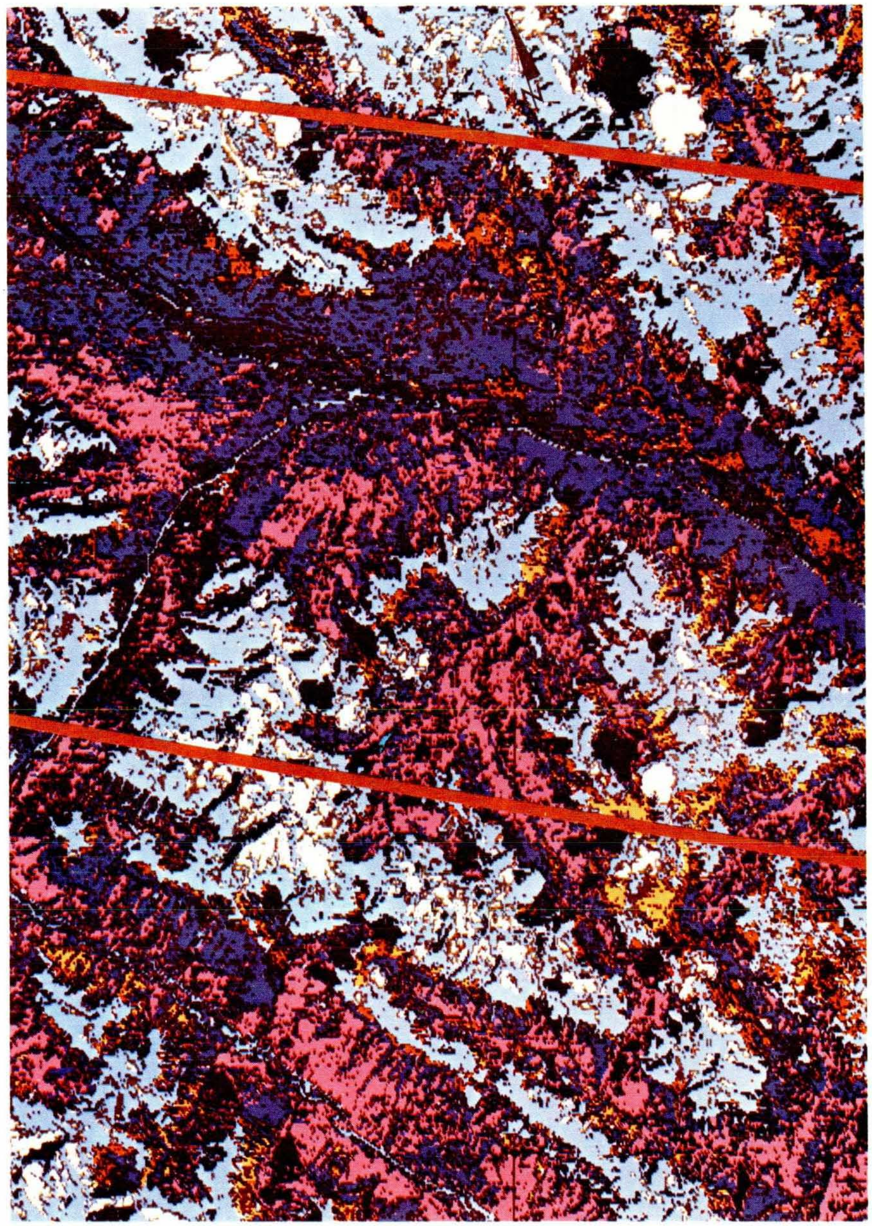
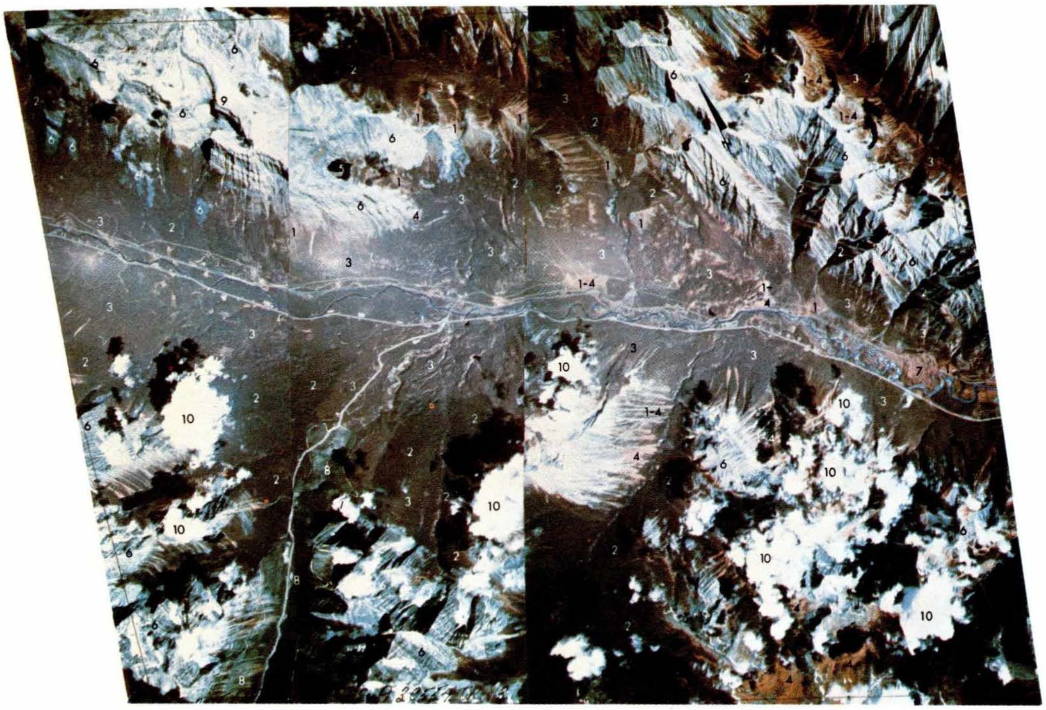


Figure 6: An extension of the classification developed on the Banff test site (Figure 4) to a 1200 km^2 area around Mount Eisenhower: (a) Image-100 output, (b) 1:110,000 aerochrome infrared photo mosaic reduced to 1:250,000, (c) national topographic map information 1:250,000.

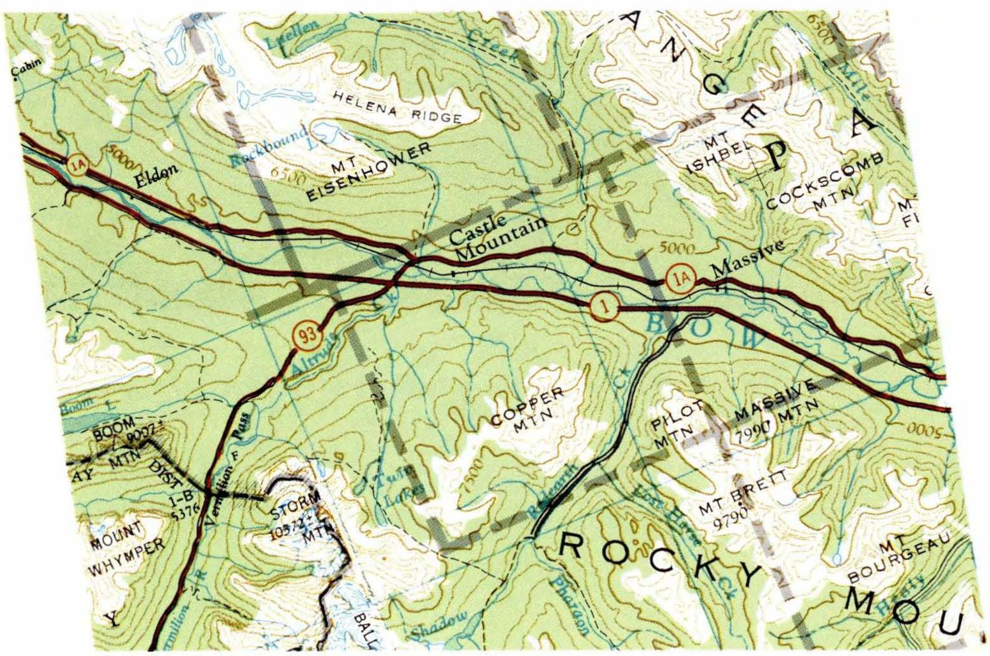
Legend fig. 6a

Orange	= Poplar/deciduous shrub	Turquoise	= Water
Pink	- Spruce	Grey	= Barren lands (rock, roads)
Blue	= Pine	White	= Snow or cloud
Yellow	= Alpine meadows or grasslands	Black	= Unclassified



Legend fig. 6b

1. Poplar/deciduous shrub
2. Spruce
3. Pine
4. Alpine meadows or grasslands
5. Water
6. Barren lands (rock, roadways)
7. Wetlands
8. Fire
9. Snow
10. Cloud



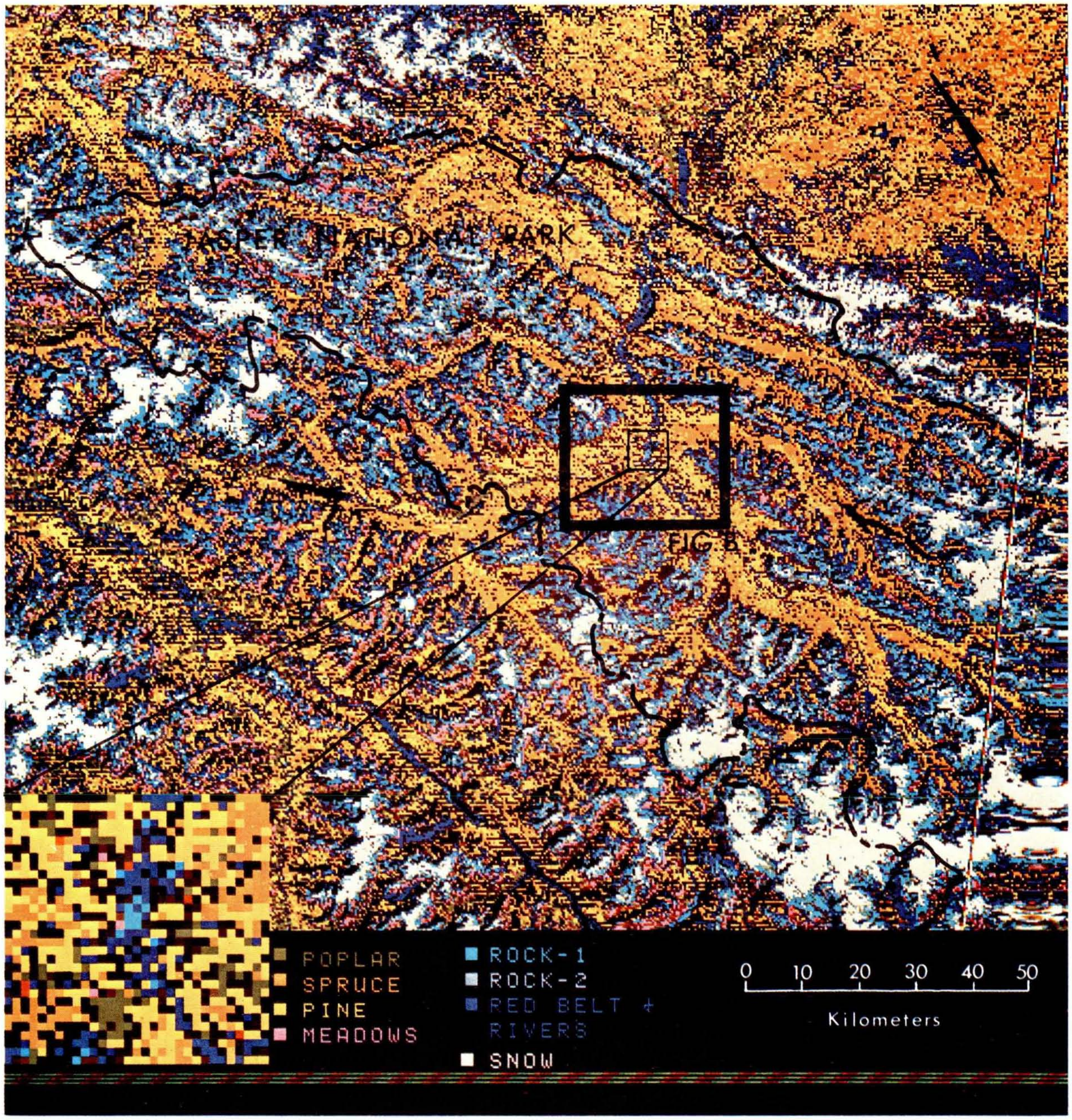


Figure 7: The Image-100 classification of (a) a complete LANDSAT image at 1/4 resolution

(b) the Jasper test area at full resolution, and a

(c) 1:60,000 aerochrome infrared photograph