BOREAS FOLLOW-ON DSP-01 LANDSAT TM LAND COVER MOSAIC OF THE BOREAS TRANSECT

Get Data

Summary

The objective of this land cover mosaic is to provide a data product that characterises the detailed land cover of a significant portion of the BOREAS Region. Seven Landsat-5 TM images have been assembled to completely cover the BOREAS Transect. Entire TM scenes were used to create this land cover map. A detailed classification scheme was employed, permitting the extraction of virtually all land cover information that can be discerned from digitally enhanced TM images. The data are provided in a binary image format file.

Note that some of the data files have been compressed using Zip compression. See Section 8.2 for details.

Data Citation

Cite this data set as follows (citation revised on October 29, 2002):

Beaubien, J., R. Latifovic, J. Cihlar, and G. Simard. 2001. BOREAS Follow-On DSP-01 Landsat TM Land Cover Mosaic of the BOREAS Transect. Data set. Available on-line [http://www.daac.ornl.gov] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A.

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1. Data Set Overview

1.1 Data Set Identification

BOREAS Follow-On DSP-01 Landsat TM Land Cover Mosaic of the BOREAS Transect

1.2 Data Set Introduction

This data set provides land cover description for a significant portion of the BOREAS Region, by employing 7 Thematic Mapper (TM) scenes that collectively span the BOREAS Transect between the Southern and the Northern Study Areas (Sellers et al., 1995). The land cover is characterised as belonging to one of 29 land cover classes (section 7.3.2).

A detailed classification scheme was employed, permitting the extraction of virtually all land cover information that can be discerned in digitally enhanced TM images. However, it should be noted that this classification does not include a separate category for wetlands. This is because wetlands in this region are generally composed of grass and/or shrub cover that can have very similar spectral reflectance characteristics to non-wetland shrub and grassland classes and it is extremely difficult to discern the two with single-date imagery.

1.3 Objective/Purpose

This classification was produced for BOREAS Follow-on investigators who needed a land cover data set with which to compare other measurements. It is an improved version of a 6-scene mosaic described by Beaubien et al (1999). The objective was to map land cover at the highest level of detail possible with TM data, especially for the forest. This was achieved by a series of pre-processing and classification steps, so that all the land cover detail discernible in digitally enhanced images could be retained for preparing the land cover map.

1.4 Summary of Parameters

Land cover type (refer to section 7.3.2 for a list of classes)

1.5 Discussion

The objective of this land cover map is to provide BOREAS regional scale modellers with a product that characterises the land cover for a significant portion of the BOREAS Region at the TM scale. An unsupervised classification technique was used, preceded by several pre-processing steps to facilitate the extraction of all relevant land cover information.

1.6 Related Data Sets

BOREAS Level-3b Landsat TM Imagery: At-sensor Radiance in BSQ Format
BOREAS TE-06 Biomass and Foliage Area Data
BOREAS TE-06 Allometry Data
BOREAS TE-13 Biometry Data
BOREAS TE-20 SSA Site Characteristics Data

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2. Investigators

2.1 Investigator Name and Title

Dr. Josef Cihlar

2.2 Title of Investigation

BOREAS Follow-on DSP-1 TM land cover and primary productivity in the boreal forest

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3. Theory of Measurements

Satellite sensors measure radiation reflected or emitted by land surface cover and its components. The assumption behind this approach to land cover mapping is that the reflected solar radiation is highly correlated with differences in land cover that are of interest to investigators studying land cover processes.

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4. Equipment

4.1 Instrument Description

The Landsat-5 Thematic Mapper (TM) sensor system records radiation in the visible, near-IR, and thermal wavelengths. See BOREAS TM documentation for additional details.

4.1.1 Collection Environment

Landsat-5 orbits the Earth at an altitude of approximately 705 kilometres.

4.1.2 Source/Platform

Landsat-5 satellite.

4.1.3 Source/Platform Mission Objectives

The mission of the Landsat-5 satellite is to measure reflected radiation from Earth's surface at a spatial resolution of 30 meters and to measure the temperature of Earth's surface at a spatial resolution of 120 meters.

4.1.4 Key Variables

Reflected radiation Emitted radiation Temperature

4.1.5 Principles of Operation

The TM is a scanning optical sensor operating in the visible and infrared wavelengths. It contains a scan mirror assembly that directly projects the reflected Earth radiation onto detectors arrayed in two focal planes.

4.1.6 Sensor/Instrument Measurement Geometry

The TM depends on the forward motion of the spacecraft for the along-track scan and uses moving mirror assembly to scan in the cross-track direction (perpendicular to the spacecraft). The Instantaneous Field of View (IFOV) for each detector from bands 1-5 and band 7 is equivalent to a 30-m square when projected to the ground; band 6 (the thermal-infrared band) has an IFOV equivalent to a 120-meter square.

4.1.7 Manufacturer of Sensor/Instrument

NASA Goddard Space Flight Center
Greenbelt, MD 20771

Hughes Aircraft Corporation
Santa Barbara, CA

4.2 Calibration.

The absolute radiometric calibration between bands on both sensors is maintained by using internal calibrators that are physically located between the telescope and the detectors and are sampled at the end of a scan.

4.2.1 Specifications

The TM sensor is sensitive to the following spectral bands:

Channel	Wavelength (um)	Primary Use
1	0.451 - 0.521	Coastal water mapping, soil vegetation differentiation, deciduous/coniferous differentiation.
2	0.526 - 0.615	Green reflectance by healthy vegetation.
3	0.622 - 0.699	Chlorophyll absorption for plant species differentiation.
4	0.771 - 0.905	Biomass surveys, water body delineation.
5	1.564 - 1.790	Vegetation moisture measurement, Snow cloud differentiation.
6	10.450 - 12.460	Plant heat stress measurement, Other thermal mapping.
7	2.083 - 2.351	Hydrothermal mapping.

4.2.1.1 Tolerance

None given.

4.2.2 Frequency of Calibration

The absolute radiometric calibration between bands on both sensors is maintained by using internal calibrators that are physically located between the telescope and the detectors and are sampled at the end of a scan.

4.2.3 Other Calibration Information

Relative within-band radiometric calibration, to reduce "striping", is provided by a scene-based procedure called histogram equalisation. The absolute accuracy and relative precision of this calibration scheme assumes that any change in the optics of the primary telescope or the "effective radiance" from the internal calibrator lamps is insignificant in comparison to the changes in detector sensitivity and electronic gain and bias with time and that the scene-dependent sampling is sufficiently precise for the required within-scan destriping from histogram equalisation. Each TM reflective band and the internal calibrator lamps were calibrated prior to launch using lamps in integrating spheres that were in turn calibrated against lamps traceable to calibrated National Bureau of Standards lamps. Sometimes the absolute radiometric calibration constants in the "short-term" and "long-term parameters" files used for ground processing have been modified after launch because of inconsistency within or between bands, changes in the inherent dynamic range of the sensors, or a desire to make quantized and calibrated values from one sensor match those from another.

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5. Data Acquisition Methods

These data were acquired from the Landsat-5 TM sensor and received from the Canada Centre for Remote Sensing (CCRS). As received, the image had been processed from raw telemetry to a systematically corrected product within the CCRS MOSAICS system (Friedel and Fisher, 1987). The calibration coefficients equations incorporating 1994 calibration updates not included in the IGARSS '94 are as follows, where D = days since launch (01-March-1984), L* = (DSL - Offset)/G, and DSL = digital signal level:

```
TM          Calibration gain         Characteristic    Solar irradiance
Spectral    (counts/(W/m**2/         wavelength        (W/m**2/
Band        sr/micrometre))          (micrometre)      micrometre)
--------    ---------------------    ------------      -----------
1           G=(-3.58E-05)*D+1.376    0.4863            1959.2
2           G=(-2.10E-05)*D+0.737    0.5706            1827.4
3           G=(-1.04E-05)*D+0.932    0.6607            1550.0
4           G=(-3.20E-06)*D+1.075    0.8382            1040.8
5           G=(-2.64E-05)*D+7.329    1.677              220.75
7           G=(-3.81E-04)*D+16.02    2.223               74.960
```

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6. Observations

6.1 Data Notes

In general, the data quality was acceptable from the atmospheric transparency viewpoint, except for scene Path 33/Row 31 which appeared to be hazy over its SW part. Significant radiometric differences were also apparent as a result of seasonal (day of acquisition) and interannual differences, most likely due to varying precipitation regimes. These differences were dealt with at the classification and labelling stages.

6.2 Field Notes

Field observations were collected as part of the accuracy assessment procedure (refer to section 10.2.1).

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7. Data Description

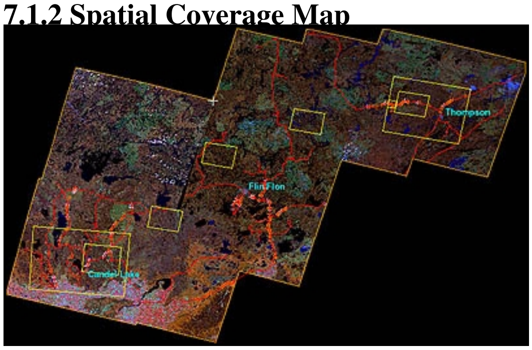
7.1 Spatial Characteristics

7.1.1. Spatial Coverage

The seven images cover an area of 142854.15 km^2, over 159 million pixels, 30 metres by 30 metres in size, and include both the BOREAS Southern and Northern Study Areas. Because of the orbital geometry, a small area between images Path/Row 37/21 and 35/21 was omitted when the images were selected.

Corner	Longitude	Latitude
Upper Left Corner	106°46'55.71" W	56°51'25.89" N
Upper Right Corner	96°06'30.92" W	56°51'25.89" N
Image Centre	101°26'43.32" W	54°50'25.87" N
Lower Left Corner	106°46'55.71" W	52°49'25.86" N
Lower Right Corner	96°06'30.92" W	52°49'25.86" N

7.1.2 Spatial Coverage Map



7.1.3 Spatial Resolution

Each pixel represents a 30-meter by 30-meter area on the ground.

7.1.4 Projection

The projection is defined by the following parameters:

Georeference Units	:	LONG/LAT
Projection	:	Geographic (geodetic)
Datum - Ellipsoid	:	WGS 1984 (Global Definition) - WGS 84

7.1.5 Grid Description

The data are referenced to the projection described in section 7.1.4.

Pixel Size (in Degrees)	:	0.00046 Lon	0.00029 Lat
(Equivalent Deg,Min,Sec)	:	0° 00' 01.65"	0° 00' 01.03"

7.2 Temporal Characteristics

7.2.1 Temporal Coverage

See section 7.2.2.

7.2.2 Temporal Coverage Map

The data that were used to produce this classification were collected by the Landsat-5 TM on the following dates:

Path	Row	Date and time of acquisition	Scene centre
33	21	June 12, 1992 16:50:20	55° 54' 46" N / 97° 59' 49" W
34	21	August 06, 1992 16:56:30	55° 54' 42" N / 99° 32' 24" W
35	21	August 11, 1991 17:06:50	55° 54' 48" N / 100° 59' 16" W
37	21	August 28, 1998 17:36:24	55° 24' 44" N / 104° 18' 19" W
35	22	August 11, 1991 17:06:50	54° 29' 37" N / 101° 43' 48" W
36	22	July 30, 1996 17:00:42	53° 46' 34" N / 103° 26' 37" W
37	22	August 09, 1991 17:14:50	53° 59' 30" N / 105° 06' 43" W

7.2.3 Temporal Resolution

Each TM scene was collected at a single point in time as indicated in section 7.2.2.

7.3 Data Characteristics

7.3.1. Parameter/Variable

Land cover type.

7.3.2 Variable Description/Definition

The classification scheme was designed to meet three objectives: 1) retain as much information about land cover in the Region as possible, especially regarding forest types and conditions; 2) be compatible with other classifications employed by boreal ecosystem investigators; and 3) be applicable to Landsat TM (i.e. all the necessary information to differentiate between the classes should be available in a single-scene TM image).

Class Descriptions

Two sets of pixel values are shown for each class. The number preceding the class name refers to the final classification, each class having a unique identifier. The second set of numbers (after the name) refers to spectral clusters that have been agglomerated to produce the final class; they thus provide additional (spectral) information. Note that the file "tm_mosaic_cls1" (section 8.2.1) contains the first set of pixel identifiers, and the file "tm_mosaic_cls2" contains the second set.

```
Pixel    Class
Value    Name
------------------
  7 - Coniferous high crown density black spruce (includes spectral
      clusters 6, 7)
 11 - Coniferous high crown density black spruce and Jack pine (11, 12, 15, 18)
 21 - Coniferous high crown density black spruce younger (21, 19, 17, 31)
 22 - Coniferous medium crown density jack pine (22)
 32 - Coniferous medium crown density black spruce, jack pine (33, 32, 34, 29,
```

```
      10)
 25 - Coniferous medium crown density black spruce (20, 25, 28)
 43 - Coniferous low crown density black spruce, jack pine (43, 41)
 59 - Coniferous low crown density jack pine (59, 37, 49)
 55 - Coniferous very low density (55, 52, 50, 65)
 79 - Deciduous high crown density (83, 79, 78, 88, 86, 93)
 80 - Deciduous medium crown density (80, 75, 68, 66)
 99 - Deciduous low broadleaf cover (99, 111)
 39 - Mixed coniferous high density (39)
 36 - Mixed coniferous medium density (36)
 69 - Mixed deciduous forest (69, 73, 62)
 53 - Mixed forest (53, 48)
 85 - Shrubs and grassland (85, 72, 71, 126)
 13 - Burn recent bare area (13)
 35 - Burn recent sparse vegetation cover (35, 30, 54, 63, 47)
113 - Burn rock outcrops (51, 113, 130, 131)



 81 - Older burns shrub-grass cover (81, 106, 84, 109)
 64 - Old burns mixed regeneration cover (64, 77)
134 - Bare disturbed area (134, 143)
112 - Bare disturbed areas sparse vegetation cover (133, 112, 120, 123, 118,
      149)
160 - Cropland high biomass (160)
161 - Cropland medium biomass (161)
162 - Cropland low biomass (162)
  1 - Water (1, 2, 3, 4, 5, 9)
150 - Clouds (150, 128, 127)
```

The class descriptions follow below. Note that the sole purpose of the numbering scheme used here is to indicate the hierarchy among the categories.

Class 1.0 Coniferous (>80% coniferous trees)
Class 1.1 High crown density (>60%)
Class 1.1.1 Black spruce (DN = 7) This class, especially prevalent in the Northeast portion of the mapped area, contains older black spruce (BS) forest (older than ~40 years).
Class 1.1.2 Black spruce, Jack pine (DN = 11) This class is also dominated by old black spruce forest, like 1.1.1, but is more widely spread in the region and commonly includes jack pine (JP) trees; if desirable, 1.1.1 and 1.1.2 may be merged.
Class 1.1.3 Black spruce, younger (DN = 21) As most of this region was repetitively burned in the past, this class is particularly dispersed in the area. It may contain a small proportion of broadleaf species (<20%) and some jack pine stems; ëyoungerí refers to approximately 20-40 years.
Class 1.2 Medium crown density (40-60%) In this region, medium crown density forests are generally young (~ 20-40 years). It should be noted that the species (BS or JP) may influence the apparent density. For example, a dense (>60%) jack pine stand may be part of a medium density class because of the foliage pattern and the influence of the ground cover (particularly lichens) more easily apparent then under a dense black spruce stand.
Class 1.2.1 Jack pine (DN = 22) Typically, a jack pine forest on a drier site with lichen commonly present in

the understory.

Class 1.2.2 Black spruce, Jack pine (DN = 32)
Lichens may also be present, but generally has a green understory; this class is particularly widespread in the region.

Class 1.2.3 Black spruce (DN = 25)
Generally located on more humid sites, this class can include a small proportion of broadleaf species.

Class 1.3 Low crown density (25-40%)

Class 1.3.1 Black spruce, Jack pine (DN = 43)
Commonly located on wet sites with a proportion of broadleaf vegetation (mostly shrubs); occasionally young tree canopy after older burns (> 10 years).

Class 1.3.2 Jack pine (DN = 59)
Lichens commonly present in the understory; occasionally this class is located in burned areas with mixed cover (dead stems, bare soil, rock outcrops); an understory with abundant lichens seems to lower the apparent density. There is confusion in this class with some dried-up wetlands.

Class 1.4 Very low crown density (10-25%) (DN = 55)
Commonly located on wet sites with a proportion of broadleaf vegetation (mostly shrubs) in the southern portion of the region; in the northern areas, some regenerating cover after burns.

Class 2.0 Deciduous (>80% deciduous trees)

Class 2.1 High crown density (> 60%) (DN = 79)
Almost exclusively in the southern part of the area; elsewhere some rare younger, dense broadleaf cover (or high shrubs) can be in this class.

Class 2.2 Medium crown density (40-60%) (DN = 80)
Mainly in the southern part of the area in the vicinity of high-density deciduous forest; transitions between high and medium densities may frequently occur locally; the density values refer mainly to the dominant broadleaf trees; some conifers may be present in lower strata. After perturbations (fires), this class may combine young and short broadleaf cover with possible conifer regeneration.

Class 2.3 Low broadleaf cover (DN = 99)
Mostly in the southern part of the area, after perturbations such as previous cut-overs, burns, and cropland areas with shrub cover.

Class 3.0 Mixed forest (20-80% coniferous or deciduous trees)

Class 3.1 Mixed coniferous (> 60% coniferous trees)

Class 3.1.1 High crown density (>60%) (DN = 39)
Mainly among southern mixed forest, some patches exist in northern old burns (>10 years).

Class 3.1.2 Medium crown density (40-60%) (DN = 36)
Mainly young forest cover in northern old burns.

Class 3.2 Mixed deciduous forest (> 60% deciduous, density > 60%) (DN = 69)
Mainly located in the southern part of the area within high crown density deciduous forest class of high crown density.

Class 3.3 Mixed forest (40-60% coniferous/deciduous, density > 60%) (DN = 53)
Among southern broadleaf and mixed forest cover, but also numerous patches of young forest cover after old burns in northern areas.

Class 4.0 Open land (tree crown density <10%)

Class 4.1 Shrubs and grassland (DN = 85)
Typically contains wetlands in southern areas; very few patches after more or less recent burns; some trees can be present.

Class 4.2 Burns
Note that some TM scenes predate fieldwork by up to seven years; during this period, vegetation on burns has regenerated.

Class 4.2.1 Bare areas, recent burns (DN = 13)
Dead standing stems are commonly present. Confusion exists with some patches of medium density jack pine cover class with lichen understory, class 22.

Class 4.2.2 Rock outcrops (DN = 113)
Rock outcrops with very sparse vegetation after burns.

Class 4.2.3 Recent burns, sparse vegetation cover (~ < 10 years) (DN = 35)
Conifer regeneration can be present; also some patches of open land with partial green vegetation, like some wetlands.

Class 4.2.4 Older burns, shrub-grass cover (DN = 81)
Conifer regeneration can be present; also some patches of similar cover within wetlands.

Class 4.2.5 Old burns, mixed regeneration (DN = 64)
Also mixed low cover in wetland areas.

Class 4.3 Bare disturbed areas (DN = 134)
Very sparse vegetation cover, mainly located in areas recently disturbed by cut-overs in the southern portion of the area.

Class 4.4 Disturbed areas, sparse vegetation cover (DN = 112)
This class with sparse vegetation cover is located mainly in areas recently disturbed by cut-overs in the southern part of the area; a few exceptions are some patches in burned areas; conifer regeneration can be present (recall the acquisition dates of the imagery).

Class 5.0 Cropland
No attempt was made to differentiate crop types, because the primary interest is forest cover, and the varying acquisition dates make crop identification difficult. The categories below refer broadly to different crop types, but the phenological differences cause large confusion.

Class 5.1 High biomass (DN = 160)

Class 5.2 Medium biomass (DN = 161)

Class 5.3 Low biomass (DN = 162)

Class 6.0 Non-vegetated land

Class 6.1 Water bodies (DN = 1)
This class contains some cloud shadows

Class 6.2 Clouds (DN = 150)

7.3.3 Unit of Measurement

Land Cover type - coded but unitless value.

7.3.4 Data Source

Landsat-5 TM (refer to section 4.).Forest cover maps of the area were acquired to identify training fields. The following basic source maps were used:

- Manitoba Department of Natural Resources, Provincial Forest Inventory Maps. These maps are compiled from aerial photographs at a scale of 1:15,840. Each map covers an area of about 93 km^2. Maps identify stands by number, assigned within each map;

a separate legend sheet for each map provides details about each stand.

- Saskatchewan Department of Tourism and Renewable Resources, Inventory Maintenance Maps. These maps are compiled from aerial photographs at a scale of 1:12,500. Each map covers a 10x10 km area. Stand information code on the map include stand number, species age, height, and canopy information.

7.3.5 Data Range

Pixel values of 0 to 162, stored as 8-bit integers.

7.4 Sample Data Record

Not applicable for image data.

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8. Data Organisation

8.1 Data Granularity

The smallest amount of data that can be ordered from these data is the entire data set.

8.2 Data Format

8.2.1 Uncompressed Data Files

The classification product contains two image files, each are unsigned 8 bit binary files, with a size of 23341 pixels by 14139 lines.

- tm_mosaic_cls1.img: Classified image with values from 1 to 150 with zero values (0) used as fillers for non-image (no data) areas of the image: contains a unique identifier for each final class (refer to section 7.3.2).
- tm_mosaic_cls2.img: Classified image with values from 1 to 150 with zero values (0) used as fillers for non-image (no data) areas of the image: contains a unique identifier for each spectral cluster; one or more clusters were merged to form the final classes (refer to section 7.3.2).

The image files have been compressed with the MS Windows-standard Zip compression scheme. These files were compressed using Aladdin's DropZip on a Macintosh. DropZip uses the Lempel-Ziv algorithm (Welch, 1994), also used in Zip and PKZIP programs. The compressed files may be uncompressed using PKZIP (with the -expand option) on MS Windows and UNIX, or with StuffIt Expander on the Mac OS. You can get newer versions from the PKZIP Web site at http://www.pkware.com/download-software/ [Internet Link].

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9. Data Manipulations

9.1 Formulae

Not applicable.

9.1.1 Derivation Techniques and Algorithms

None given.

9.2 Data Processing Sequence

9.2.1 Data Processing Steps

A. Image selection and pre-processing

The intent was to obtain land cover classification compatible with the BOREAS experimental period (1994-1996). Given the limitations of data availability (primarily due to cloud cover), images from several years were used. For the most part, the resulting classification is representative of land cover during BOREAS because of the low rate of land cover change during the 1990's. The selected images are listed in section 7.2.2.

A new radiometric normalisation procedure was used to establish radiometric consistency among the seven TM scenes. The principle of the method is to employ overlapping sections among the scenes, assuming that there are at least some areas within these whose reflectance properties have not changed between the imaging dates (Du et al., 2000). The procedure avoids any loss of radiometric detail during the normalisation, and ensures consistency across the entire mosaic, regardless of the sequence of scenes in the mosaicking.

B. Image classification

A modified version of the Enhancement-Classification Method (ECM) (Beaubien et al., 1999) was used to classify the image mosaic. The ECM procedure is intended to capture most of the information visible in an enhanced image by converting the image into a classification through various generalization steps. It was designed to be as reproducible as possible for an interactive classification. The main modification to the original methodology is the use of an unsupervised classifier in step #2 below instead of image quantization. Image filtering, employed to help in the selection of the more important image mean values (signatures), was also modified. In summary, the modified ECM consists of the following phases:

1. Image contrast enhancement

   The purpose of the enhancement is to bring out the distinctions among various classes of interest so that they can be more easily viewed in the subsequent steps. It is carried out in three steps: viewing of the data, sampling of cover types with low and high values in each spectral band, and digital stretch.
2. Unsupervised classification

   The purpose of this part of the process is to produce a first classification, which captures most of the information visible in the initial enhanced image. A K-Means method (Tou and Gonzales, 1974) was used to classify the stretched image into 150 clusters. After computing a pseudo colour table (PCT) for the enhanced image, the classified image closely resembles the enhanced input image.
3. Minimum distance re-classification

A second level of generalization is reached by a re-classification from a selection of the more significant signatures generated by the unsupervised classifier. This is carried out in three steps, first, by image filtering (mode and sieve filters) to "flatten" the image by making classes more uniform over groups of spatially adjacent pixels. The next step includes selection of all visible (thus more significant) cover types. Lastly, a minimum distance classification on the initial enhanced image according to the signatures of the selected cover types. To reduce the number of clusters before manual agglomeration, those three steps are optionally repeated. After each iteration, the classification results are carefully compared to the initial unsupervised classification, using the same pseudo-colour table. Other signatures may be added if suitable.

4. Cluster agglomeration and labeling

The purpose of this step is to group spectral clusters representing the same ground cover types. Since the last classified image closely resembles the original image, where image colours associated with the basic cover types are known, a substantial degree of agglomeration can be completed on the basis of colour patterns. Additional tools may include examination of the cluster mean digital value through a distance table, and spatial proximity values between clusters. For the remainder, independent knowledge of ground conditions in specific areas is required, as in other classification methods. **9.2.2 Processing Changes**

None.

9.3 Calculations

9.3.1 Special Corrections/Adjustments

None.

9.3.2 Calculated Variables

Refer to PCI CSG and MLC programs.

9.4 Graphs and Plots

The area occupied by individual classes is as follows:

Pixel Number	Area [km2]	Percent
7	4551.1461	3.1859%
11	11184.5817	7.8294%
21	12431.7315	8.7024%
22	3377.6496	2.3644%
32	16748.0874	11.7239%
25	10621.206	7.4350%
43	7990.4637	5.5934%
59	5389.1595	3.7725%
55	13722.4071	9.6059%
79	3908.4408	2.7360%
80	5158.6686	3.6111%
99	1160.6319	0.8125%
39	2958.075	2.0707%

```
36          2026.5147       1.4186%
69          3308.2668       2.3158%
53          4043.7774       2.8307%
85          4177.5588       2.9244%
13           861.1092       0.6028%
35         10667.6442       7.4675%
113         1683.2673       1.1783%
81          5954.6016       4.1683%
64          4617.3114       3.2322%
134          363.4947       0.2545%
112         1016.1828       0.7113%
160         2315.1312       1.6206%
161          799.0407       0.5593%
162         1818.0036       1.2726%
----------------------------------
Total     142854.15          100%
```

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10. Errors

10.1 Sources of Error

This classification does not include a separate category for wetlands. This is because wetlands in this region are generally composed of grass and/or shrub cover with different heights, densities, and the ratios of live-to-dead leaf biomass. Consequently, they can have very similar spectral reflectance characteristics to shrub, grassland, and some burn classes. It might be possible to use late spring images as an additional data source because surface water should have a stronger influence on the spectral reflectance. Alternatively, radar images might be helpful. However, such differentiation does not appear to be feasible with a single-date TM image taken during the growing season. Thus, most wetland cover types are in the shrub and grassland class (85), and some are contained within the burn classes (81, 64, 35). A similar situation is present in the southern part of the mosaic where grass fields in agriculture area are classified as class 81.

10.2 Quality Assessment

10.2.1 Data Validation by Source

The classification was checked qualitatively using aerial photographs, and quantitatively using field data. Three types of field sites were used:

a. BOREAS auxiliary sites 'B': these sites were carefully documented using aerial photographs, and described in the field using forest mensuration and site description methods (Halliwell and Apps, 1997). A total of 55 sites were documented in this manner.
b. Additional sites: in late September and early October of 1998, a field survey was undertaken to obtain additional data for accuracy assessment. Due to access limitations and the large area to be covered, the criteria for site locations were the representativeness of the various forest classes and conditions, sufficiently large patch size (to compensate for potential geolocation uncertainties), and proximity to the existing road network. This was accomplished by pre-processing the mosaicked TM image to locate spectrally homogenous patches, overlaying the road network, and printing the result at a large scale for use in the field. The above procedure resulted in a somewhat uneven distribution of test sites, as indicated in the table below, but further improvements were not feasible with the available resources.

Two types of sites were used: 'S', sites with photographs (overstory, understory, horizontal view) and physiognomic descriptions (overstory, understory); and 'M', sites with a photograph (horizontal view) and vegetation class identification. The location of each 'S' site was established with a GPS, and each 'M' site by landmarks on the TM enhancements. A total of 94 'M' sites and 89 'S' sites were located across the region. In addition, high-resolution GPS point measurements were taken to facilitate accurate registration of the TM mosaic. For the accuracy assessment, each site from the BOREAS auxiliary site set and the additional set was assigned to one of the 29 classes, based on a consensus of two interpreters. The corresponding class on the map was defined to be the majority class occurring in the 3x3 window centred on the site.

10.2.2 Confidence Level

Based on the qualitative and quantitative accuracy assessments (section 10.2.1, 10.2.3), we have high confidence in the accuracy of the classification. As noted above, the main limitation is absence of a wetland class. In addition, accuracies could be lower in areas from which no field sites were located, e.g. areas farther from the existing road network.

10.2.3 Measurement Error for Parameters and Variables

The following tables and statistics were derived in assessing the classification accuracy:

A. Number of sites by category and agreement

No.	Class Name	'M' Sites No.	'M' Sites Match	'S' Sites No.	'S' Sites Match	'B' Sites No.	'B' Sites Match	All Sites No.	All Sites Match	Pct Match
7	CHD BS	6	5	3	3	3	3	12	11	0.917
11	CHD BS/JP	1	1	1	1	4	4	6	6	1.000
21	CHD BSY	7	5	14	14	6	6	27	25	0.926
22	CMD JP	5	5	4	4	2	2	11	11	1.000
32	CMD BS/JP	4	4	8	7	10	8	22	19	0.864
25	CMD BS	3	3	8	7	3	1	14	11	0.786
43	CLD BS/JP	1	1	1	1	0	0	2	2	1.000
59	CLD JP	6	6	7	7	3	3	16	16	1.000
55	CVLD	4	4	3	2	5	2	12	8	0.667
79	BHD	8	8	7	7	6	6	21	21	1.000
80	BMD	5	5	3	2	0	0	8	7	0.875
99	BLD	3	3	0	0	0	0	3	3	1.000
39	MCHD	0	0	3	3	0	0	3	3	1.000
36	MCMD	2	2	2	2	2	2	6	6	1.000
69	MB	5	3	4	2	5	4	14	9	0.643
53	MIX	2	1	6	6	4	3	12	10	0.833
85	SHR/GRASS	3	3	2	2	0	0	5	5	1.000
13	B-recent	1	1	0	0	0	0	1	1	1.000
35	B-recent	4	3	1	1	0	0	5	4	0.800
113	B-rock-out-crops	2	2	1	1	0	0	3	3	1.000
81	B-old shrub/grass	11	11	6	6	1	1	18	18	1.000
64	B-old mixed regeneration	7	6	3	3	1	1	11	10	0.909
134	Bare disturbed	2	2	1	1	0	0	3	3	1.000
112	Bare disturbed sparse	2	2	1	1	0	0	3	3	1.000
160	CROP/HB*									
161	CROP/MB*									

```
162   CROP/LB*
1     WATER*
150   CLOUD*
-------------------------------------------------------------------------
TOTAL            94    86      89    83      55    46     238  215       0.903

* no auxiliary sites available for this class
```

B. Confusion matrix

The following confusion matrix shows results of the accuracy assessment. It is evident that the overall accuracy is quite high. The confusion that did occur was mostly between adjacent density classes or the proportions of coniferous and deciduous classes.

Error Matrix of the Classification Map BOREAS MOSAIC V3

Land Cover	7	11	21	22	32	25	43	59	55	79	80	99	39	36	69	53	85	13	35	113	81	64	134	112	160	161	162	1	150	
7	11					1																								12
11		6																												6
21			25	2																										27
22				11																										11
32				3	19																									22
25				1	1	11			1																					14
43							2																							2
59								16																						16
55				2		1			8							1														12
79										21																				21
80											7						1													8
99												3																		3
39													3																	3
36														6																6
69										2	1		1		9							1								14
53															1	10						1								12
85																	5													5
13																		1												1
35																			4			1								5
113																				3										3
81																					18									18
64										1												10								11
134																							3							3
112																								3						3
160																														
161																														
162																														
1																														
150																														
	11	6	25	19	20	13	2	16	9	24	8	3	4	6	10	11	6	1	4	3	18	13	3	3						238

Summarising the classes into major groups, the classification accuracy was as follows:

```
Class           % Correct
-------------------------
Coniferous        90.0%
Deciduous         96.9%
Mixed             80.0%
Disturbed/other   95.9%
------------------------
Overall Correct   90.7
```

The overall kappa value (Congalton, 1991) was 0.8977 or 89.8% better than chance agreement.

10.2.4 Additional Quality Assessments

None.

10.2.5 Data Verification by Data Center

This image was viewed to make sure that it matched the product description and appeared to be a classification image of a part of the BOREAS region.

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11. Notes

11.1 Limitations of the Data
The user should keep in mind that the original images were taken in different years. The class descriptions and the map accuracy should also be considered in using this product.

11.2 Known Problems with the Data
None

11.3 Usage Guidance
Users should be aware of accuracy limitations as well as problems listed in Section 10.

11.4 Other Relevant Information
None.

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12. Application of the Data Set

This land cover map was created to provide BOREAS regional scale modelers with a driver data set that characterises the land cover for a significant portion of the BOREAS region at a relatively fine scale.

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13. Future Modifications and Plans

None given .

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14. Software

14.1 Software Description
Various proprietary programs in the EASI/PACE image processing software from PCI, Inc. were used to classify the image. Zip uses the Lempel-Ziv algorithm (Welch, 1994) used in the zip and PKZIP commands.

14.2 Software Access
EASI/PACE is a proprietary software package developed by PCI, Inc. Contact PCI for details.

PCI, Inc.
50 West Wilmot St.
Richmond Hill
Ontario, Canada L4B 1M5
(905) 764-0614
(905) 764-9604 (fax)

Zip software is available from many Web sites across the Internet. You can get newer versions from the PKZIP Web site at http://www.pkware.com/download-software/ [Internet Link]. Versions of the decompression software for MS Windows, Mac OS, and several varieties of UNIX systems are included on the CD-ROMs.

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15. Data Access

15.1 Contact for Data Center/Data Access Information

These BOREAS data are available from the Earth Observing System Data and Information System (EOS-DIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC). The BOREAS contact at ORNL is:

ORNL DAAC User Services
Oak Ridge National Laboratory
(865) 241-3952
ornldaac@ornl.gov
ornl@eos.nasa.gov

15.2 Procedures for Obtaining Data

BOREAS data may be obtained through the ORNL DAAC World Wide Web site at http://www.daac.ornl.gov/ [Internet Link] or users may place requests for data by telephone or electronic mail.

15.3 Output Products and Availability

Requested data can be provided electronically on the ORNL DAAC's anonymous FTP site or on various media including, CD-ROMs, 8-MM tapes, or diskettes.

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16. Output Products and Availability

16.1 CD-ROM Products

These data can be made available on CD-ROM.

16.2 Film Products

None.

16.3 Other Products

None.

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17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation

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17.2 Journal Articles and Study Reports

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Tou, J.T., and R.C. Gonzales. 1974. Pattern recognition principles. Addison-Wesley Publishing Co.

17.3 Archive/DBMS Usage Documentation

None.

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18. Glossary of Terms

None.

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19. List of Acronyms

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ASCII      - American Standard Code for Information Interchange
BOREAS     - BOReal Ecosystem-Atmosphere Study
BORIS      - BOREAS Information System
BPI        - Bytes Per Inch
CCRS       - Canadian Centre for Remote Sensing
CD-ROM     - Compact Disk-Read-Only Memory
DAAC       - Distributed Active Archive Center
EOS        - Earth Observing System
EOSAT      - Earth Observing Satellite Company
EOSDIS     - EOS Data and Information System
GMT        - Greenwich Mean Time
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GPS       - Global Positioning System
IFOV      - Instantaneous Field of View
LCC       - Lambert Conformal Conic projection
MSA       - Modeling Sub-Area
MSS       - Multispectral Scanner
NAD83     - North American Datum of 1983
NASA      - National Aeronautics and Space Administration
NSA       - Northern Study Area
ORNL      - Oak Ridge National Laboratory
PANP      - Prince Albert National Park
SSA       - Southern Study Area
TE        - Terrestrial Ecology
TM        - Thematic Mapper
URL       - Uniform Resource Locator
UTM       - Universal Transverse Mercator
WGS84     - World Geodetic System of 1984
WRS       - Worldwide Reference System
WWW       - World Wide Web
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20.5 Document Curator:

webmaster@daac.ornl.gov

20.6 Document URL:

http://daac.ornl.gov/BOREAS/FollowOn/guides/dsp01_tm_landcover_doc.html

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