Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)

Forrest G. Hall, Editor

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BOREAS TE-18 Landsat TM Physical Classification Image of the SSA

Forrest G. Hall, NASA Goddard Space Flight Center
David Knapp, Raytheon ITSS, NASA Goddard Space Flight Center
Greenbelt, Maryland
Summary

The BOREAS TE-18 team focused its efforts on using remotely sensed data to characterize the successional and disturbance dynamics of the boreal forest for use in carbon modeling. The objective of this classification is to provide the BOREAS investigators with a data product that characterizes the land cover of the SSA. A Landsat-5 TM image from 02-Sep-1994 was used to derive the classification. A technique was implemented that uses reflectances of various land cover types along with a geometric optical canopy model to produce spectral trajectories. These trajectories are used as training data to classify the image into the different land cover classes. These data are provided in a binary image file format.

Note that some of the data set files on the BOREAS CD-ROMs have been compressed using the Gzip program. See Section 8.2 for details.

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1. Data Set Overview

1.1 Data Set Identification

BOREAS TE-18 Landsat TM Physical Classification Image of the SSA

1.2 Data Set Introduction

This data set classifies the BOReal Ecosystem-Atmosphere Study (BOREAS) Southern Study Area (SSA) into 13 land cover classes. These classes include wet conifer, dry conifer, deciduous, mixed (deciduous and conifer), and fen, as well as various regeneration and other classes. The pixel resolution of this data set is 30 meters. This data set is georeferenced in the Albers Equal-Area Conic (AEAC) projection.
1.3 Objective/Purpose

The objective of this data set is to provide BOREAS investigators with a product to use for modeling the SSA. The technique that was used to produce this data set can also be used to determine the amount of canopy cover within the given class and makes it possible to derive other biophysical parameters from the imagery.

1.4 Summary of Parameters and Variables

In a joint meeting of the BOREAS Terrestrial Ecology (TE) modelers and the Remote Sensing Science (RSS) algorithm developers in Columbia, MD, July 1992, several land cover classes were identified as necessary inputs to the TE models. One exception to this is the fire-blackened class, which is a consequence of spectral distinctness. The classification was performed using bands 3, 4, and 5 of the Landsat-5 TM scene. The radiometric status of this scene was acceptable. The parameter being described in this data set is the land cover class for each 30-meter pixel. The classes that are used in this data set are:

<table>
<thead>
<tr>
<th>Image Value</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Conifer (Wet)</td>
</tr>
<tr>
<td>2</td>
<td>Conifer (Dry)</td>
</tr>
<tr>
<td>3</td>
<td>Mixed (Coniferous and Deciduous)</td>
</tr>
<tr>
<td>4</td>
<td>Deciduous</td>
</tr>
<tr>
<td>5</td>
<td>Fen</td>
</tr>
<tr>
<td>6</td>
<td>Water</td>
</tr>
<tr>
<td>7</td>
<td>Disturbed</td>
</tr>
<tr>
<td>8</td>
<td>Fire Blackened</td>
</tr>
<tr>
<td>9</td>
<td>New Regeneration Conifer</td>
</tr>
<tr>
<td>10</td>
<td>Medium-Age Regeneration Conifer</td>
</tr>
<tr>
<td>11</td>
<td>New Regeneration Deciduous</td>
</tr>
<tr>
<td>12</td>
<td>Medium-Age Regeneration-Deciduous</td>
</tr>
<tr>
<td>13</td>
<td>Grass</td>
</tr>
</tbody>
</table>

1.5 Discussion

The objective of this classification is to provide the BOREAS investigators with a data product that characterizes the land cover of the SSA. This data set can be used for modeling purposes. The technique that was used to produce this classification is based on the work of Dr. Forrest Hall. This technique involves the use of reflectances of various land cover types along with a geometric optical canopy model to model the amount of shadow. The reflectance data and the model are used to produce spectral trajectories of the various land cover classes. The trajectories are used in a way that is similar to training data. Each image pixel is compared to the various points of each trajectory. The pixel is assigned to the class of the point to which it is closest in red/near-infrared reflectance space.

1.6 Related Data Sets

BOREAS Forest Cover Data Layers of the SSA-MSA in Raster Format
BOREAS TE-18 Landsat TM Maximum Likelihood Classification Image of the SSA
Prince Albert National Park Forest Cover Data in Vector Format
SERM Forest Cover Data of Saskatchewan in Vector Format
2. Investigator(s)

2.1 Investigator(s) Name and Title
Dr. Forrest Hall
Biospheric Sciences Branch
National Aeronautics and Space Administration (NASA)
Goddard Space Flight Center (GSFC)

2.2 Title of Investigation
TE-18 Regional Scale Carbon Flux from Modeling and Remote Sensing

2.3 Contact Information

Contact 1:
Dr. Forrest G. Hall
NASA GSFC
Code 923
Greenbelt, MD 20771
(301) 286-2974
(301) 286-0239 (fax)
Forrest.G.Hall@gsfc.nasa.gov

Contact 2:
David Knapp
Raytheon ITSS
NASA GSFC
Code 923
Greenbelt, MD 20771
(301) 286-1424
(301) 286-0239 (fax)
David.Knapp@gsfc.nasa.gov

3. Theory of Measurements

The Landsat-5 TM sensor collects imagery of Earth in seven spectral bands ranging from the blue to the thermal infrared portion of the electro-magnetic spectrum. This image was classified from Landsat-5 TM imagery using a technique described by Dr. Forrest Hall (Hall et al., 1997). In this technique, end member reflectances of canopy, background, and shadow are used with a geometric canopy model to compute simulated pixel reflectances for increasing amounts of canopy cover. These simulated reflectances can be plotted as a continuous trajectory for each class (e.g., wet conifer, deciduous, etc.) from 0% to 100% canopy cover. The imagery pixels were classified based on their proximity to the trajectories, with the pixel being assigned to the class of the closest trajectory.
4. Equipment

4.1 Instrument Description

The Landsat-5 TM sensor system records radiation from the seven bands described in Section 4.2.1. It has a telescope that directs the incoming radiant flux obtained along a scan line through a scan line collector to the visible and near-infrared focal plane, or to the mid-infrared and thermal infrared cooled focal plane. The detectors for the visible and near-infrared bands (1-4) are four staggered linear arrays, each containing 16 silicon detectors. The two mid-infrared detectors are 16 indium-antimonide cells in a staggered linear array, and the thermal-infrared detector is a four-element array of mercury-cadmium-telluride cells.

4.1.1 Collection Environment

The data that were used to produce this classification were collected by the Landsat-5 TM on 02-Sept-1994. Landsat-5 orbits Earth at an altitude of approximately 705 kilometers.

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. The TM achieves better imagery resolution, sharper color separation, and greater inflight geometric and radiometric accuracy for seven spectral bands simultaneously than the previous Multispectral Scanner (MSS). Data collected by the sensor are transmitted to Earth-receiving stations for processing.

4.1.6 Sensor/Instrument Measurement Geometry

The TM depends on the forward motion of the spacecraft for the along-track scan and uses a 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-meter 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 GSFC
Greenbelt, MD 20771

Hughes Aircraft Corporation
Santa Barbara, CA
4.2 Calibration

The internal calibrator, a flex-pivot-mounted shutter assembly, is synchronized with the scan mirror, oscillating at the same 7-Hz frequency. During the turnaround period of the scan mirror, the shutter introduces the calibration source energy and a black direct-current restoration surface into the 100 detector fields of view.

The calibration signals for bands 1-5 and band 7 are derived from three regulated tungsten-filament lamps. The calibration source for band 6 is a blackbody with three temperature selections, commanded from the ground. The method for transmitting radiation to the moving calibration shutter allows the tungsten lamps to provide radiation independently and to contribute proportionately to the illumination of all detectors.

4.2.1 Specifications

The following spectral bands are collected by the TM sensor:

<table>
<thead>
<tr>
<th>Channel</th>
<th>Wavelength (µm)</th>
<th>Primary Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.45 - 0.52</td>
<td>Coastal water mapping, soil vegetation differentiation, deciduous/coniferous differentiation.</td>
</tr>
<tr>
<td>2</td>
<td>0.52 - 0.60</td>
<td>Green reflectance by healthy vegetation.</td>
</tr>
<tr>
<td>3</td>
<td>0.63 - 0.69</td>
<td>Chlorophyll absorption for plant species differentiation.</td>
</tr>
<tr>
<td>4</td>
<td>0.76 - 0.90</td>
<td>Biomass surveys, water body delineation.</td>
</tr>
<tr>
<td>5</td>
<td>1.55 - 1.72</td>
<td>Vegetation moisture measurement, snow cloud differentiation.</td>
</tr>
<tr>
<td>6</td>
<td>10.4 - 12.5</td>
<td>Plant heat stress measurement, other thermal mapping.</td>
</tr>
<tr>
<td>7</td>
<td>2.08 - 2.35</td>
<td>Hydrothermal mapping.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Band</th>
<th>Radiometric Sensitivity [NE(dP)]*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.8%</td>
</tr>
<tr>
<td>2</td>
<td>0.5%</td>
</tr>
<tr>
<td>3</td>
<td>0.5%</td>
</tr>
<tr>
<td>4</td>
<td>0.5%</td>
</tr>
<tr>
<td>5</td>
<td>1.0%</td>
</tr>
<tr>
<td>6</td>
<td>0.5 K [NE(dT)]</td>
</tr>
<tr>
<td>7</td>
<td>2.4%</td>
</tr>
</tbody>
</table>

Ground IFOV 30 m (Bands 1-5, 7)
120 m (Band 6)
Avg. altitude 699.6 km
Data rate 85 Mbps
Quantization levels 256
Orbit angle 8.15 degrees
Orbital nodal period 98.88 minutes
Scan width 165 km
Scan angle 14.9 degrees
Image overlap 7.6 %

* N.B. The radiometric sensitivities are the noise-equivalent reflectance differences for the reflective channels expressed as percentages [NE(dP)] and temperature differences for the thermal-infrared bands [NE(dT)].
4.2.1.1 Tolerance
The TM channels were designed for a noise-equivalent differential represented by the radiometric sensitivity shown in Section 4.2.1.

4.2.2 Frequency of Calibration
The absolute radiometric calibration between bands on both sensors is maintained by using internal calibrators that are 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 equalization. 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 equalization. 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.

5. Data Acquisition Methods
These data were acquired from the Landsat-5 TM sensor and received from the Canadian Centre for Remote Sensing (CCRS), who purchased them from the Earth Observation Satellite Company (EOSAT). As received from CCRS, the image had been processed from raw telemetry to a systematically corrected product within the CCRS MOSAICS system. After original delivery to the BOREAS data system, CCRS reprocessed these data, which produced minor differences in the pixel values. The data that were used to produce this data product are from the original data delivery, not the TM image product that currently exists in the BOREAS data set.

6. Observations

6.1 Data Notes
This imagery was collected on 02-Sep-1994. This scene is Path 37, Row 22-23 (shifted) in the Landsat Worldwide Reference System (WRS). The solar elevation angle at the time of image acquisition was 40.1 degrees. The solar azimuth angle was 146 degrees. The radiometric quality of this imagery was acceptable. The TM image from which this classification was produced was atmospherically corrected using aerosol optical thickness data measured by sunphotometers in the study area. These optical thickness data were used in the Second Simulation of the Satellite Signal in the Solar Spectrum (6S) program to determine the spherical albedo, path radiance, gaseous transmission, and scattering transmission. These parameters were used to determine surface reflectance based on equations 4a and 4b of Markham et al. (1992).

6.2 Field Notes
Not applicable.
7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage
The classified image covers an area that is approximately 144 km by 114 km and includes areas just north of Prince Albert, Saskatchewan. The corners of the data set are as follows. These coordinates are in the BOREAS Grid projection.

<table>
<thead>
<tr>
<th>Corner</th>
<th>BOREAS Grid X</th>
<th>BOREAS Grid Y</th>
<th>NAD83 Long.</th>
<th>NAD83 Lat.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northwest</td>
<td>297.810</td>
<td>392.490</td>
<td>106.401W</td>
<td>54.438N</td>
</tr>
<tr>
<td>Northeast</td>
<td>441.810</td>
<td>392.490</td>
<td>104.190W</td>
<td>54.333N</td>
</tr>
<tr>
<td>Southwest</td>
<td>297.810</td>
<td>278.490</td>
<td>106.515W</td>
<td>53.417N</td>
</tr>
<tr>
<td>Southeast</td>
<td>441.810</td>
<td>278.490</td>
<td>104.357W</td>
<td>53.314N</td>
</tr>
</tbody>
</table>

7.1.2 Spatial Coverage Map
Not available.

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

7.1.4 Projection
The area mapped is projected in the BOREAS Grid projection, which is based on the ellipsoidal version of the AEAC projection. The projection has the following parameters:

- Datum: North American Datum of 1983 (NAD83)
- Ellipsoid: Geodetic Reference System of 1980 (GRS80) or Worldwide Geodetic System of 1984 (WGS84)
- Origin: 111.000°W 51.000°N
- Standard Parallels: 52° 30' 00"N
- 58° 30' 00"N
- Units of Measure: kilometers

7.1.5 Grid Description
The data are referenced to the projection described in Section 7.1.4.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage
This imagery was collected on 02-Sep-1994. This scene is Path 37, Row 22-23 (shifted) in the Landsat WRS. The solar elevation angle at the time of image acquisition was 40.1 degrees. The solar azimuth angle was 146 degrees. The radiometric quality of this imagery was acceptable.

7.2.2 Temporal Coverage Map
Not applicable.

7.2.3 Temporal Resolution
This data set represents the land cover as it appeared on 02-Sep-1994.

7.3 Data Characteristics
7.3.1 Parameter/Variable
Land cover type.

7.3.2 Variable Description/Definition
Each pixel in the classification image contains a number between 0 and 13. This number represents one of the following land cover classes:

<table>
<thead>
<tr>
<th>Pixel Value</th>
<th>Class Name</th>
<th>Class Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Data</td>
<td>This area is not covered in the classification. This area is most likely blank fill on the edges of the image frame.</td>
</tr>
<tr>
<td>1</td>
<td>Conifer (Wet)</td>
<td>Primarily black spruce and jack pine on three major different soil substrates: (i) moderately well drained soils with feather moss over clay, (ii) poorly drained soils with sphagnum on clay, and (iii) sparsely treed fens with a very deep moss layer. Overstory biomass density varies considerably within this class.</td>
</tr>
<tr>
<td>2</td>
<td>Conifer (Dry)</td>
<td>Dry Conifer is an area that contains coniferous trees (primarily jack pine) with a lichen (cladina) background. These areas have sandy soils that are well drained. Areas of permafrost supporting conifers with a lichen background are also included in this class.</td>
</tr>
<tr>
<td>3</td>
<td>Mixed Deciduous and Coniferous</td>
<td>Mixed deciduous and coniferous contains coniferous and aspen/birch (Populus tremuloides/betula papyrifera) trees. The composition of this class contains less than 80% of the dominant species.</td>
</tr>
<tr>
<td>4</td>
<td>Deciduous</td>
<td>The Deciduous class contains primarily aspen/birch. The composition of this class is generally greater than 80% deciduous trees.</td>
</tr>
<tr>
<td>5</td>
<td>Fen</td>
<td>The Fen/Bog class is characterized by areas with a water table very near or at the surface. Fens experience lateral water transport whereas bogs are enclosed landforms experiencing only vertical transport. Fens typically contain sedges, moss, and bog birch associated with sparse to medium dense tamarack (Larix laricina) stands. Bogs are usually treeless.</td>
</tr>
<tr>
<td>6</td>
<td>Water</td>
<td>Water bodies such as ponds, lakes, and streams.</td>
</tr>
<tr>
<td>7</td>
<td>Disturbed</td>
<td>The Disturbed class consists of areas that are dominated by bare soil, recently logged areas, or rock outcrops. This class also includes roads, airports, and urban areas.</td>
</tr>
<tr>
<td>8</td>
<td>Fire Blackened</td>
<td>Areas that have been burned in the last 5 or 6 years. Distinguishable for their charred sphagnum background they are usually areas of very intense burn where little or no vegetation survived.</td>
</tr>
<tr>
<td>9</td>
<td>New Regeneration Conifer</td>
<td>This class consists primarily of conifers that are regrowing after a burn. It may also include conifer stands where there are a few remaining trees after a low- to medium-intensity burn.</td>
</tr>
<tr>
<td></td>
<td>Class Description</td>
<td></td>
</tr>
<tr>
<td>----</td>
<td>----------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Medium-Age Regeneration Conifer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Areas that are predominantly young jack pine or young black spruce. This class</td>
<td></td>
</tr>
<tr>
<td></td>
<td>typically occurs in stands that were cleared or burned and have been growing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>back for approximately 10 years.</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>New Regeneration deciduous</td>
<td></td>
</tr>
<tr>
<td></td>
<td>This class consists of aspen that is starting to regrow after a recent clearing.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>This class is younger than the young aspen class. The aspen in this class may</td>
<td></td>
</tr>
<tr>
<td></td>
<td>also include grasses or other herbaceous vegetation.</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Medium-Age Regeneration deciduous</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The class consists of areas that were cleared or burned and have been growing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>back as aspen. These stands typically contain 10 year old aspen where the</td>
<td></td>
</tr>
<tr>
<td></td>
<td>background is almost completely obscured and thinning has not yet taken place.</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Grass</td>
<td></td>
</tr>
<tr>
<td></td>
<td>This class consists primarily of grasses, agricultural fields that have</td>
<td></td>
</tr>
<tr>
<td></td>
<td>been planted, or shrub-like vegetation.</td>
<td></td>
</tr>
</tbody>
</table>

7.3.3 Unit of Measurement
Unitless but coded value.

7.3.4 Data Source
Landsat-5 TM scene on 02-Sep-1994 from the CCRS.

7.3.5 Data Range
Land Cover type: 13 different land cover classes (pixel values from 0 to 13).

7.4 Sample Data Record
Not applicable for image data.

8. Data Organization

8.1 Data Granularity
The smallest amount of data that can be ordered is the entire data set.

8.2 Data Format

8.2.1 Uncompressed Data Files
The SSA classification product contains two files as follows:
- File 1: (80-byte American Standard Code for Information Interchange (ASCII) text records) Text file listing the files on tape
- File 2: (3,800 records of 4,800 bytes each) (1 byte per pixel) Classified image with values from 0 to 13

8.2.2 Compressed CD-ROM Files
On the BOREAS CD-ROMs, file 1 listed above is stored as ASCII text; however, file 2 has been compressed with the Gzip compression program (file name *.gz). These data have been compressed using gzip version 1.2.4 and the high compression (-9) option (Copyright (C) 1992-1993 Jean-loup Gailly). Gzip (GNU zip) uses the Lempel-Ziv algorithm (Welch, 1994) used in the zip and PKZIP programs. The compressed files may be uncompressed using gzip (-d option) or gunzip. Gzip is available from many Web sites (for example, ftp site prep.ai.mit.edu/pub/gnu/gzip-*) for a variety of operating systems in both executable and source code form. Versions of the decompression software for various systems are included on the CD-ROMs.
9. Data Manipulations

9.1 Formulae
Not applicable.

9.1.1 Derivation Techniques and Algorithms
The techniques that were used to classify this image are described in Sections 1.5, 3, and 6.1.

9.2 Data Processing Sequence

9.2.1 Processing Steps
- The imagery was converted to surface reflectance before the classification was performed. Atmospheric correction coefficients were computed using optical depths from a sunphotometer in conjunction with 6S (Markham et al., 1992).
- End member reflectances were collected or compiled.
- Trajectories were computed based on end member reflectances, solar geometry, tree height to width ratio, and tree form (i.e., cone or cylinder).
- Additional trajectories for regeneration classes were added using sample reflectances from the image. No end member reflectances were used to characterize the regeneration and water classes (classes 6 through 13).
- The trajectories were used as input to the image classifier.
- Post-processing techniques to classify any remaining null-classed pixels were applied.
- The classification image was mapped into the AEAC projection using nearest neighbor resampling.
- The classification image was written to tape.
- BOREAS Information System (BORIS) staff copied the ASCII and compressed the binary files for release on CD-ROM.

9.2.2 Processing Changes
None.

9.3 Calculations

9.3.1 Special Corrections/Adjustments
None.

9.3.2 Calculated Variables
None.

9.4 Graphs and Plots
None.

10. Errors

10.1 Sources of Error
The sources of error in this classification can be attributed to several factors. In many cases, the reflectance of one feature could be similar to the reflectance of another feature, resulting in confusion. The similarity in reflectances could be the result of similar background components and variations in tree density. Error could also be a result of spectral mixing of various features that fall within a 30-meter pixel.

10.2 Quality Assessment
10.2.1 Data Validation by Source
The imagery was spot checked at various locations, and the image class was compared to the forest cover map. An error assessment was performed on the classification. The auxiliary sites and a few randomly selected sites were used as ground truth. The location of each ground truth site was identified on the georeferenced image as a 3- by 3-pixel area. Each of the 9 pixels in these areas represents a test point. Some classes were not represented by the auxiliary sites or the randomly selected sites.

10.2.2 Confidence Level/Accuracy Judgment
Although efforts have been made to make this classification as accurate as possible, there is bound to be some confusion between classes. In some areas, new regeneration conifer can be confused with fen because of differences in canopy density. Also, many of the age classes within the deciduous or conifer classes can be confused because of minor variations in background.

10.2.3 Measurement Error for Parameters
The following tables and statistics were derived in assessing the accuracy of the classification.

Accuracy Assessment Confusion Matrix

<table>
<thead>
<tr>
<th>Truth</th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
<th>Class 4</th>
<th>Class 5</th>
<th>Class 6</th>
<th>Class 7</th>
<th>Class 8</th>
<th>Class 9</th>
<th>Class 10</th>
<th>Class 11</th>
<th>Class 12</th>
<th>Class 13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet Conifer</td>
<td>115</td>
<td>1</td>
<td>6</td>
<td>0</td>
<td>33</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Dry Conifer</td>
<td>5</td>
<td>9</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mixed</td>
<td>13</td>
<td>0</td>
<td>19</td>
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<tr>
<td>Fire Blackened</td>
<td>83 %</td>
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<tr>
<td>New Regen. Conifer</td>
<td>78 %</td>
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Med. Age
Regen. Con.  44 %
New Regen.
Decid.  100 %
Med. Age
Regen.
Decid.  0 %
Grass  67 %
Overall  75 %

Kappa = 0.70 or 70% better than chance agreement (Campbell, 1987).

10.2.4 Additional Quality Assessments
None.

10.2.5 Data Verification by Data Center
The imagery was spot checked at various locations, and the image class was compared to the forest cover maps from Saskatchewan Environment and Resource Management (SERM).

11. Notes

11.1 Limitations of the Data
This data set is based on an image that was collected on 02-Sep-1994 and represents the land cover only as it existed on that day. Please see Section 10.2.3 to determine how the amount of error in this product may affect your results.

11.2 Known Problems With the Data
Clouds in this classification show up in the disturbed class, and cloud shadows show up in the water class. The scene is mostly clear, so this problem has a very limited impact.

11.3 Usage Guidance
Before uncompressing the Gzip files on CD-ROM, be sure that you have enough disk space to hold the uncompressed data files. Then use the appropriate decompression program provided on the CD-ROM for your specific system.

11.4 Other Relevant Information
None.

12. Application of the Data Set
This data set may be used for modeling purposes. It can also be used to analyze measurements from aircraft to determine the land cover that was under the aircraft at locations along the aircraft’s path.

13. Future Modifications and Plans
None.
14. Software

14.1 Software Description
Programs written at NASA GSFC to run under EASI/PACE image processing software from PCI, Inc., were used to classify the image. The trajectories were computed using Microsoft Excel (Version 4.0), a spreadsheet program. Questions related to the specific details of the software written to process this data set should be addressed to David Knapp (see Section 2.3). Gzip (GNU 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)

Microsoft Excel is a proprietary software package that is widely available in the commercial software market. Gzip is available from many Web sites across the Internet (for example, ftp site prep.ai.mit.edu/pub/gnu/gzip-*.*) for a variety of operating systems in both executable and source code form. Versions of the decompression software for various systems are included on the CD-ROMs.

15. Data Access

The SSA physical classification data are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

15.1 Contact Information
For BOREAS data and documentation please contact:

ORNL DAAC User Services
Oak Ridge National Laboratory
P.O. Box 2008 MS-6407
Oak Ridge, TN 37831-6407
Phone: (423) 241-3952
Fax: (423) 574-4665
E-mail: ornldaac@ornl.gov or ornl@eos.nasa.gov

15.2 Data Center Identification
Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics http://www-eosdis.ornl.gov/.

15.3 Procedures for Obtaining Data
Users may obtain data directly through the ORNL DAAC online search and order system [http://www-eosdis.ornl.gov/] and the anonymous FTP site [ftp://www-eosdis.ornl.gov/data/] or by contacting User Services by electronic mail, telephone, fax, letter, or personal visit using the contact information in Section 15.1.
15.4 Data Center Status/Plans

The ORNL DAAC is the primary source for BOREAS field measurement, image, GIS, and hardcopy data products. The BOREAS CD-ROM and data referenced or listed in inventories on the CD-ROM are available from the ORNL DAAC.

16. Output Products and Availability

16.1 Tape Products

These data can be made available on 8-mm, Digital Archive Tape (DAT), or 9-track tapes.

16.2 Film Products

None.

16.3 Other Products

These data are available on the BOREAS CD-ROM series.

17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation


Markham, B.L., R.N. Halthorne, and S.J. Goetz. 1992. Surface reflectance retrieval from satellite and aircraft sensors: Results of sensor and algorithm comparisons during FIFE. FIFE Special Issue. American Geophysical Union. 18785-18795.


17.2 Journal Articles and Study Reports


17.3 Archive/DBMS Usage Documentation
None.

18. Glossary of Terms
None.

19. List of Acronyms

6S - Second Simulation of the Satellite Signal in the Solar Spectrum
AEAC - Albers Equal-Area Conic
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
DAT - Digital Archive Tape
DEM - Digital Elevation Model
EOS - Earth Observing System
EOSAT - Earth Observation Satellite Company
EOSDIS - EOS Data and Information System
GIS - Geographic Information System
GMT - Greenwich Mean Time
GRS80 - Geodetic Reference System of 1980
GSFC - Goddard Space Flight Center
IFOV - Instantaneous Field of View
MSA - Modeling Sub-Area
MSS - Multispectral Scanner
NAD27 - North American Datum of 1927
NAD83 - North American Datum of 1983
NASA - National Aeronautics and Space Administration
NSA - Northern Study Area
20. Document Information

20.1 Document Revision Dates
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Last Updated: 01-Mar-1999

20.2 Document Review Dates
BORIS Review:
Science Review: 09-Jan-1998

20.3 Document ID

20.4 Citation
When using these data, please include the following acknowledgment as well as citations of relevant papers in Section 17.2:
This classification image was produced for the BOREAS project as part of the research of Dr. Forrest Hall of NASA GSFC. Please contact Dr. Hall or David Knapp before using these data in a publication.

If using data from the BOREAS CD-ROM series, also reference the data as:

Also, cite the BOREAS CD-ROM set as:

20.5 Document Curator

20.6 Document URL
Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)
BOREAS TE-18 Landsat TM Physical Classification Image of the SSA

Forrest G. Hall and David Knapp
Forrest G. Hall, Editor

Goddard Space Flight Center
Greenbelt, Maryland 20771

National Aeronautics and Space Administration
Washington, DC 20546-0001

D. Knapp: Raytheon ITSS, NASA Goddard Space Flight Center, Greenbelt, Maryland

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The BOREAS TE-18 team focused its efforts on using remotely sensed data to characterize the successional and disturbance dynamics of the boreal forest for use in carbon modeling. The objective of this classification is to provide the BOREAS investigators with a data product that characterizes the land cover of the SSA. A Landsat-5 TM image from 02-Sep-1994 was used to derive the classification. A technique was implemented that uses reflectances of various land cover types along with a geometric optical canopy model to produce spectral trajectories. These trajectories are used as training data to classify the image into the different land cover classes. These data are provided in a binary image file format.