CHAPTER 3

SATELLITE LAND COVER MAPPING OF CANADA'S FORESTS: THE EOSD LAND COVER PROJECT

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ABSTRACT

Capture of land cover information is a key requirement for supporting forest monitoring and management. In Canada, provincial and territorial forest stewards use land cover information to aid in management and planning activities. At the federal level, land cover information is required to aid in meeting national and international reporting obligations. To enable improved monitoring of Canada's forests, the Earth Observation for Sustainable Developments of Forests (EOSD) project was initiated. EOSD is a partnership project between the Canadian Forest Service (CFS) and the Canadian Space Agency (CSA), with provincial and territorial participation and support. An element of EOSD is the development of a land cover map of the forested area of Canada reflective of circa 2000 conditions. Including image overlap outside of the forested area of Canada, over 475 Landsat-7 ETM+ images were classified, over 80% of Canada was mapped, and over 600 1:250,000 map sheet products were developed for unfettered sharing. The objective of this communication is to provide a brief project background, a summary of activities to enable product development, and an indication of the nature of the products and access.

Key words: *Large area land cover, Landsat, classification, EOSD, forest, Canada*

INTRODUCTION

Canada is a large country, approaching a billion hectares in size. With over 400 million hectares (Mha) of forested land contributing $37 billion dollars to the balance of trade, Canada is determined to be a responsible steward of this renewable resource. Ensuring effective resource management requires current and reliable forest information. In support of national and international reporting requirements, the Canadian Forest Service (http://www.cfs.nrcan.gc.ca/) (CFS), in partnership with the Canadian Space Agency (http://www.space.gc.ca/asc/index.html), with the support and participation of provincial and territorial agencies, is using space-based, earth observation (EO) technologies to monitor the sustainable development of Canada's forests through an initiative called Earth Observation for Sustainable Development of Forests (EOSD) (http://eosd.cfs.nrcan.gc.ca/). EOSD will contribute to meeting Canada's national and international reporting requirements related to climate change and sustainable forest management by mapping the forested areas of Canada. For example, the EOSD project is designed to provide land cover maps, methods for estimating biomass using satellite and inventory data (Luther et al. 2006; Hall et al. 2006), and techniques to identify and map disturbed areas (Wood et al. 2002). Implementation of the EOSD program for the purpose of monitoring forested land began in early 2002. Production of a land cover map of the forested area of Canada was the initial focus of the EOSD program.

The EOSD land cover map of the forested ecozones of Canada was produced using Landsat satellite data. A consortium of Canadian federal and provincial government agencies, led by the Center for Topographic Information (CTI) of Natural Resources Canada (NRCan), produced a Landsat ortho-image coverage for Canada (http://www.ctis.nrcan.gc.ca/). Through application of standardized methods and use of best available elevation data, this ortho-image coverage of Canada provided a consistent data source (temporally, spatially, and geometrically) for development of easy to integrate information products for Canada (Wulder et al. 2002). The short-term goal of EOSD was to complete a land cover map representing circa year 2000 forested area conditions by 2006 (Wulder et al. 2003), and this has been accomplished. Inputs from EOSD are an important data source in the National Forest Carbon Accounting Framework (http://carbon.cfs.nrcan.gc.ca/) and Canada's new plot-based National Forest

Inventory (http://nfi.cfs.nrcan.gc.ca/) (Wulder et al. 2004a). The National Forest Information System (http://nfis.org/) will be used to integrate and synthesize applicable data and products. In this communication we summarize the EOSD Land Cover program and indicate resources to provide additional detail for interested readers.

SUMMARY

Using single scenes of Landsat data to produce land cover information is not uncommon. However, combining several or even hundreds of Landsat scenes for the development of a large area land cover map remains relatively uncommon (Franklin and Wulder 2002). To cover the forested ecozones of Canada, approximately 800 Mha must be mapped requiring over 475 images (Figure 1). All of Canada's forests are mapped with EOSD; the only areas of Canada not mapped by EOSD are non-forested northern regions and agriculturally dominated areas in the south. The classification approach for EOSD is based upon a hyperclustering, cluster merging, and labeling approach (Wulder et al.

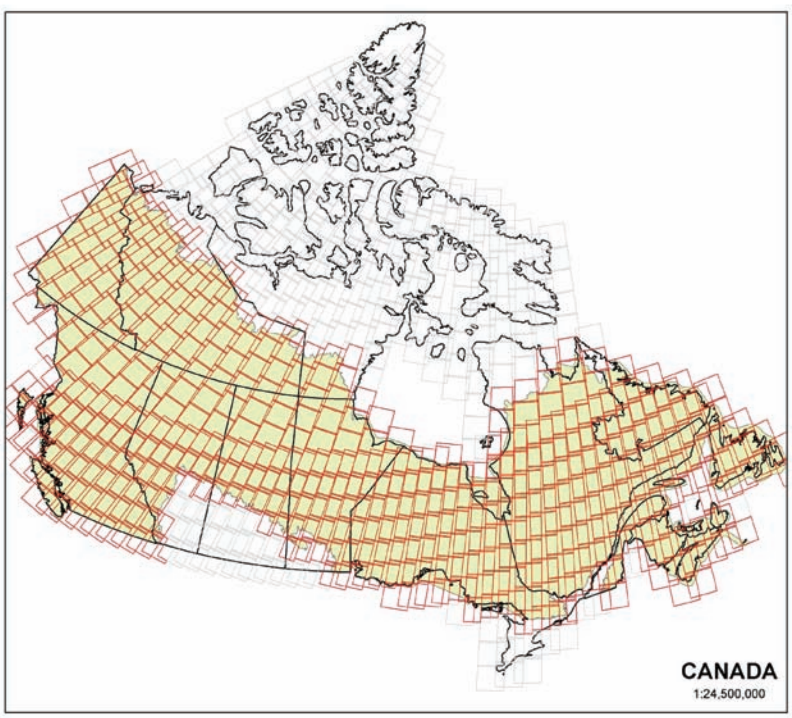

Figure 1. WRS-2 frames (red) corresponding to the forested land area of Canada. More than 475 Landsat scenes were used in the production of the EOSD land cover product.

2004b). Many more spectral groupings are created through the k-means clustering approach than can be expected to be unique classes, requiring a merging of similar groups, and then labeling of the spectral groupings into meaningful classes conforming to the closed 21 class legend. The legend used for EOSD was developed to fit with the hierarchical classification of the NFI (Wulder and Nelson 2003). Additional information on the methods and legend are available on-line:
(http://eosd.cfs.nrcan.gc.ca/cover/legend_e.html).

EOSD land cover products are based upon the national topographic database's (NTDB) national topographic system (NTS) map sheet framework (there are 986 1:250,000 map sheets covering Canada's landmass), with 630 maps sheets required to cover Canada's forested ecozones. The EOSD land cover products are available for download on a NTS map sheet basis (Figure 2). Each map sheet represents an area of approximately 14,850 km^2. The products are available in a paletted GeoTIFF format, with a disabled TIFF world file, and United States Federal Geographic Data Committee (FGDC)

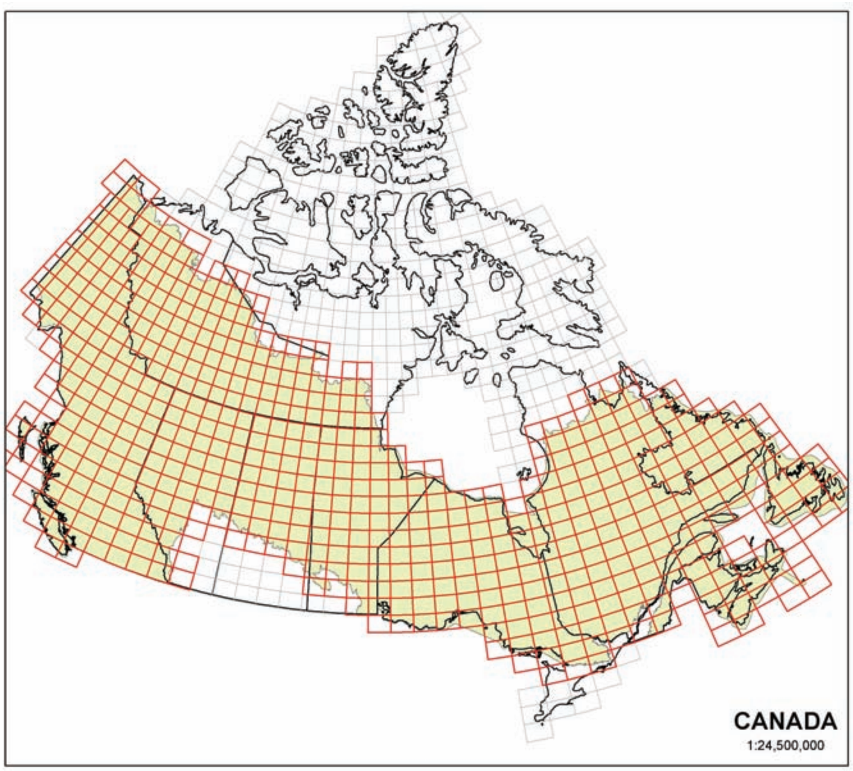

Figure 2. The EOSD land cover product is delivered by 1:250,000 NTS map sheet (red); there are more than 630 NTS map sheets (red) covering the forested area of Canada.

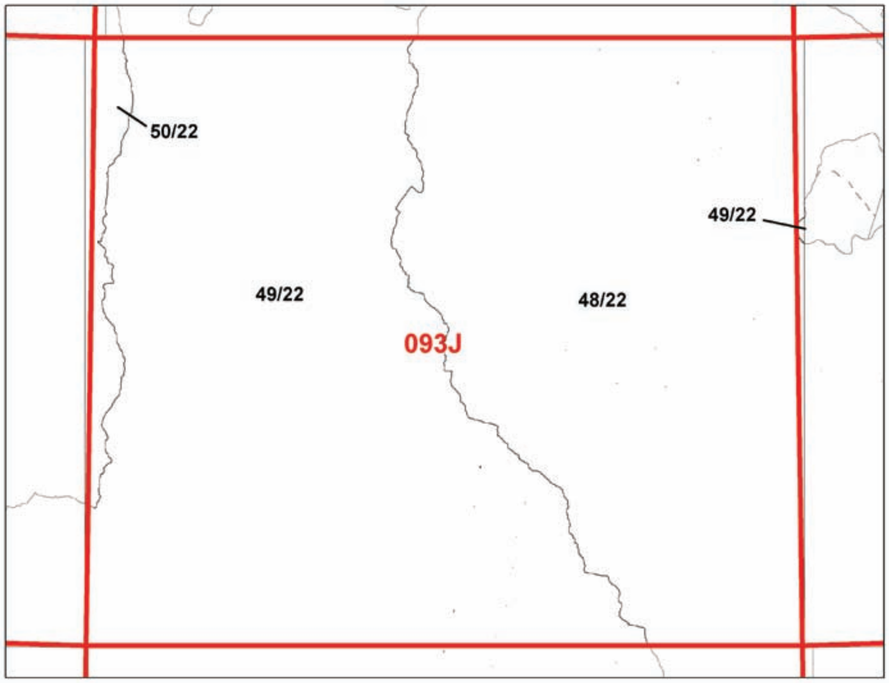

Figure 3. A sample of a 1:250,000 NTS map sheet (093J). Mosaic lines are shown, along with the source path and row of the corresponding Landsat image used to fill each portion of the NTS map sheet. This information is delivered with the product as an ESRI shape file, enabling the user to know the source image (the image date is also provided).

compliant metadata (http://www.fgdc.gov/). Final products are resampled to a 25m spatial resolution. As a single EOSD product tile may have been generated from a number of images, ESRI shape files are provided to spatially communicate source image information and actual mosaic lines (Figure 3).

To date, all of the 630 NTS map sheets required to cover the forested ecozones of Canada are complete and available for download through the National Forest Information System (NFIS) and the System of Agents for Forest Observation Research with Automation Hierarchies (SAFORAH).

SAFORAH is a networking data grid that enables distributed data storage and access (http://www.saforah.org). FTP download of bundled and compressed collections of entire provincial or territorial coverages is also accommodated by SAFORAH (http://www4.saforah.org/eosdlcp/nts_prov.html).
Identifying appropriate validation sources for large area land cover products is complicated by logistical constraints that frequently necessitate the use of pre-existing data sources. Many concerns emerge when comparing polygon (vector-based) data sets to raster imagery, including: geo-locational

mismatches; differences in features or classes mapped; disparity between the scale of polygon delineation and the spatial resolution of the image; and temporal discrepancies. As a result, when and where feasible the use of purpose collected validation data is recommended for the accuracy assessment of maps derived from remotely sensed data. If pre-existing vector-based data is judged as the only option for map validation, approaches accounting for the heterogeneity of land cover classes within a given polygon (in the pre-existing data to be used for validation) are recommended (Wulder et al. 2006a). Goodchild et al. (1994) outlined three possible approaches for evaluating map accuracy against a pre-defined target accuracy. The approach most suitable for large area land cover products involves identification of the minimum map accuracy that would cause the null hypothesis (associated with a specified target accuracy) to be rejected (Aronoff 1985). This approach supports the use of smaller sample sizes and allows a one-sided z-test statistic to identify the range of minimum map accuracies that would not cause rejection of the null hypothesis (Wulder et al. 2007).

A protocol for addressing the accuracy of the national EOSD product, based upon a stratified random sample, has been proposed (Wulder et al. 2006b). An operational trial of the suggested methodology has been undertaken over the contiguous landmass of Vancouver Island (Wulder et al. 2007). In this trial, agreement between the EOSD product and the airborne video data was defined as a match between the mode (most frequent) land cover class of a 3 by 3 pixel neighborhood surrounding the sample pixel and the primary or secondary choice of land cover for the interpreted video. The overall accuracy for the EOSD product covering Vancouver Island met the target accuracy of 80%, with a result of at 77% (with 90% confidence intervals: 74 – 80%) for level 4 (excludes vegetation density) of the classification hierarchy (13 classes). The coniferous land cover classes, which represented 71% of Vancouver Island, had a user's accuracy of 86%. Rather than using possibly ill-suited pre-existing information, purpose acquired video was found to be a useful and cost-effective data source for validation of the EOSD land cover product. The impact of using multiple interpreters was also tested and documented. Over 60% of the disagreement between interpreters resulted from differences in estimation of the vegetation density classes, suggesting greater effort must be made to calibrate interpreters and improve consistency in estimation of density classes. Improvements to the sampling and response designs that emerged from this trial will benefit a full-scale accuracy assessment of the EOSD product. A sample of a completed EOSD map sheet is provided in Figure 4. As the EOSD class legend (closed) is based upon the hierarchical NFI classification scheme (Wulder and Nelson 2003), knowledge of the EOSD class enables generalizations to more broad depictions, such as forest / non-forest (Figure 5).

CONCLUSIONS

The goal of EOSD land cover project was to produce a land cover map of the forested area of Canada with Landsat-7 ETM+ data, using proven methods, to provide timely and useful information for use within, and external, to Canada. EOSD products are being used by the Canadian NFI, with update of the EOSD land cover product envisioned to produce information on forest cover change over time. The potential for biases in the NFI photo plots can also be tested with EOSD land cover data and can also be used to determine if the NFI sampling adequately captures forest characteristics. Other applications, not yet envisioned for the EOSD land cover data, continue to emerge as awareness of the product increases.

The completion of the EOSD product has required the support and concerted effort of many partners. Cooperation and communication both within and between various levels of government provide an opportunity to share resources and work towards common objectives. Products generated from this project will be an integral component of Canada's new forest measuring and monitoring system and will assist the public and interested organizations in understanding the composition, distribution, and dynamics of Canada's forests.

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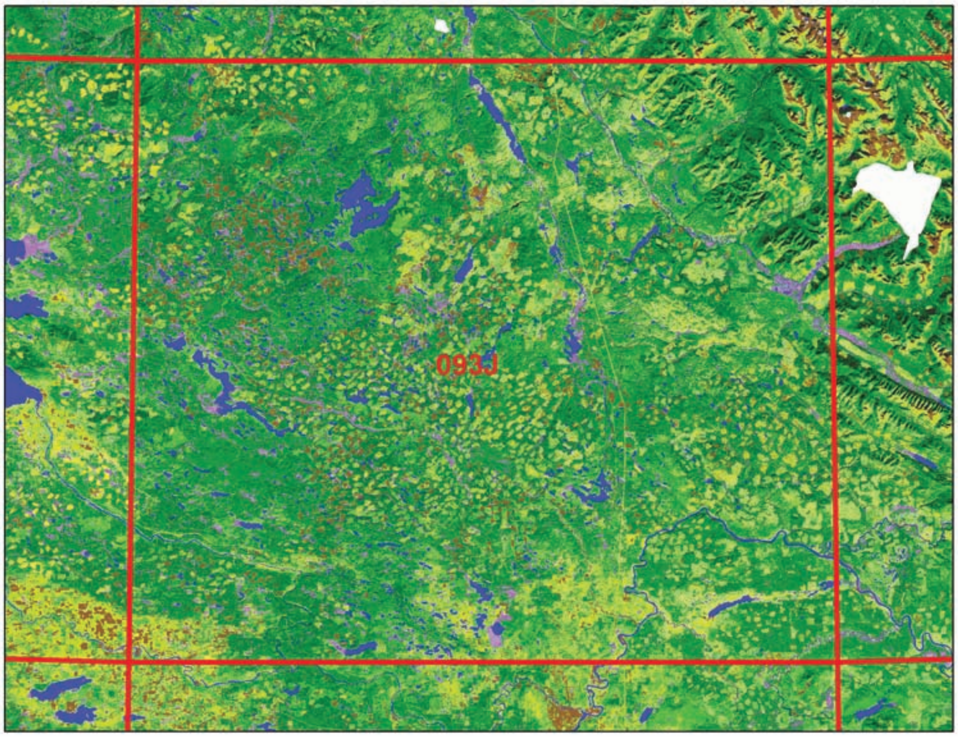

Figure 4. The classified EOSD product for NTS map sheet for 093J (and adjacent maps).

Figure 5. The classified EOSD product from Figure 4 shown generalized to forest (green) and non-forest (no colour). Such generalizations may prove useful for applications such as stratification for statistical sampling.

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