WRS-Canada: Web-accessible Landsat selection and stratification system

Mike Wulder, David Seemann, and Brian Low

Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, 506 West Burnside Rd.
Victoria, British Columbia, Canada, V8Z 1M5

Abstract

A system for image cataloguing and stratification at the national level is possible through the merging of the Landsat Worldwide Reference System (WRS) and Canadian national spatial data sets representing land cover, elevation, and population characteristics. The merging of the WRS grid system with other spatial data allows users to query the expected contents of each WRS frame and summarise these results nationally. Queries may also be nested to allow for insights to images appropriate for monitoring of forest change activities.

The information generated from adding spatial information to the WRS grid allows for improved image selection for various sampling designs to provide national or regional information. For large area Landsat mapping projects, the WRS system is an appropriate spatial cataloguing and query framework. In this communication, we present a brief summary of the data utilised and how each of these datum were created as well as the results of some queries. We also present the National Forest Information System as a means for accessing the WRS.

Introduction

The Worldwide Reference System[1] (WRS) is a global system facilitating the collection, organization, and cataloguing of Landsat data. The WRS partitions the globe into frames indicating the extents of Landsat imagery. Each frame is denoted by a sequential Path and Row determined by the scene latitude and longitude. Paths run north / south in direction and are determined by the 16-day repeat cycle of Landsat sensors which require 233 orbits. The Rows are generated by partitioning each Path into 23.92 seconds of spacecraft time in both directions at the equator resulting in 248 Rows per complete orbit. The Landsat sensors continuously collect data that are segmented post-collection on the ground, using telemetry ephemeris data, into individual framed scenes. The satellite orbit results in a coverage side overlap of a minimum of 7.3% at the equator increasing to approximately 85% at 80° latitude.

Reduction in the price of Landsat data, combined with increasing information requirements, has resulted in an unprecedented availability of satellite image data. This availability of image data has resulted in analyses being considered over larger areas than previously considered possible. As Canadians, we have the responsibility for the stewardship of the second largest national land mass in the world, containing 10% of the worlds forests (Westoby 1989). To meet this stewardship challenge, the Canadian Forest Service, in partnership with the Canadian Space Agency, has begun a long term project to monitor Canada's forests with space-based technology. As a component of this project, Earth Observation for Sustainable Development of Forests (EOSD) (Goodenough *et al*. 1998), the forest cover of Canada will be mapped with Landsat data. To aid in a national project of this magnitude a summarization of Canada's forest, topographic, and social conditions is of benefit. Summarization of Canada's characteristics by WRS frames may aid with issues such as, image selection, image cataloging, organization of processing, and the development of sampling techniques.

The National Forest Information System (NFIS)

The National Forest Information System (NFIS) is an information infrastructure that will

[1] http://edcwww.cr.usgs.gov/glis/hyper/guide/wrs.html

demonstrate the sustainable forest management practices within Canada. The Canadian Council of Forest Ministers (CCFM) agreed in 2000 to develop and deploy this technology framework. The framework is being designed to:

- provide ready access to current, consistent and reliable forest resources information,
- provide the transparent integration of information across jurisdictional boundaries,
- provide consistency in reporting thereby avoiding different answers being given to the same question,
- reduce costs through the sharing of information technology, and eliminate duplication in reporting, resulting in greater efficiency and reduced costs.

This information and service framework leverages on international standards such as those of ISO, OGC, FGDC, and W3C. With the adoption of open standards, the addition of new servers and services will be easily achieved. Governments, academics, industries, NGO's and eNGO's have already adopted many of these standards and open infrastructures.

The NFIS- PFC portal is one of many data stores and entry mechanisms to the NFIS infrastructure. The NFIS- PFC component is based on several key components. Currently the NFIS- PFC is deployed from a Sun Enterprise 450 Server with four 300 megahertz Ultrasparc CPU's and over 400 gigabytes of RAID disk storage. The software architecture is composed of a database layer (Oracle 8i), a spatial handling layer (CubeStor), a map server layer (CubeServ), and the web navigation application (CubeView).

CubeStor allows for the storage of spatially referenced objects within a relational database. Vast seamless multi-dimensional data can now be stored and retrieved easily. GIS data such as raster images, vectors, matrix, and points are stored and indexed efficiently within a database. Data is stored in any well defined map projection.

CubeServ is a fully OGC compliant cascading Web mapping server that allows for other servers to portray images and data over the Web. Many companies have adopted the OGC standards and have built their own servers. Web maps can be created from any number of servers that have varying map projections and varying data formats (ie. Shape, IGDS etc.). With this technology a user will be able to compose a map from different jurisdictions (provincial, municipal) and from differing GIS architectures. The adoption of public standards will allow the NFIS infrastructure to expand easily. Services and data will now be made available and reusable with fewer limitations. Access control and authentication modules will be used to ensure proper security measures are taken.

Achieving the NFIS vision will require the development and implementation of both a governance model and technical infrastructure. The governance model will address the needs for data, identify data availability, gaps, and other forest issues. The roles and responsibilities of members participating in NFIS will be key to governance. The governance model will address the need to provide information.

In this brief communication, we will provide background on the utility of web-based NFIS access to WRS-Canada, the methods applied to develop and populate the WRS, a description of the fields, and some example queries. A full description of the WRS-Canada database may be found in Wulder and Seemann (2001).

Methods

The Landsat WRS for the entire globe may be obtained by contacting the USGS - EROS Data Center. From this global information source Canada may be clipped. As there is overlap between each of the frames, a coverage of overlapping frames is sought; this is possible in the GIS by creating a coverage of *regions*, where each region is a Landsat frame (ESRI 1998). The overlap of images in southern Canada is approximately 40% increasing to over 80% in northern Canada. Due to the overlap of frames, which increases as latitude increases, there is an opportunity to thin the net. If the net is left un-thinned all queries would provide an overestimate of the number of scenes required to represent a particular area. The net was thinned to produce estimates of scene numbers that have limited overlap to aid in image selection and planning for provincial and national level remote sensing projects. A separate un-thinned net is used as the basis for an image cataloguing system. Un-thinned there are over 1200 image frames which intersect with a coverage of Canada's federal boundary. To thin the net, while maintaining exhaustive coverage, we sequentially removed images in an intensity related to the latitude. In so doing we reduced

the number of scenes to 712 to ensure complete coverage and to minimise redundant imagery.

For each of the 712 remaining frames the path, row, geographic location, province(s), ecozone(s), and frame identifier, are stored. The provincial and federal boundary information are from the Natural Resources Canada initiative GeoGratis[2]. Two attributes are created, one allowing for multiple provinces per scene, the other based on a majority rule where a scene is only given the provincial label with the greatest area in the frame. The Canadian terrestrial ecozones (Environment Canada 1996) were subject to the same methods and rational as for provinces, with a general ecozone label with a unique attribute, and a second attribute allowing for overlap, generated for each frame. To aid in geographic querying, the spatial extents and centres of each frame are also included with each frame. Land cover, elevation, and census data are also added to each frame. Descriptions of these data sources and the detailed methods to extract spatial information for each frame follows.

Through collaboration between the Natural Resources Canada sectors of the Canadian Forest Service and the Canada Centre for Remote Sensing a national land cover map from AVHRR data was produced (Cihlar and Beaubien 1998). The land cover map, a component of the Northern Biosphere Observation and Modelling Experiment (NBIOME), is derived from imagery collected from April to October of 1995. The AVHRR imagery is approximately 1.1 km spatial resolution at nadir and greater off nadir, resulting in a mosaic with an effective spatial resolution of approximately 4 km. The NBIOME map is composed of 1 by 1 km pixels. The NBIOME land cover classification system is composed of 31 classes, we summarised these into 10 classes (Table 1). The area of each cover type is recorded as a percentage cover found within a given frame (i.e. forest percentage in a frame is given as FOR_PER).

We chose to use the public domain GTOPO30 DEM[3], available from a consortium of organisations led by the United States Geological Survey (Gesch *et al*. 1999), to categorise imagery based upon the internal elevation within each WRS frame. Elevations in the GTOPO30 model are spaced 30 arc seconds apart, which coincides with an approximately 1 km spacing. The elevations from the GTOPO30 DEM result in more than 60,000 data points per Landsat frame to be summarised. The elevation data is summarised by mean, minimum, maximum, standard deviation, and range.

In Canada population is aggregated in terms of census subdivisions. For the 1996 Statistics Canada census there were 5984 census subdivisions to represent the nation. Some fragmented census subdivisions are located within larger subdivisions, resulting in a polygon coverage composed of 8358 polygons. For each census subdivision we have computed population totals. To aid in the selection of Landsat imagery, based upon population characteristics, we have summarised each frame with total expected population. The field NEWPOP captures the population expected within an individual frame.

Results and Discussion

To view the WRS-Canada database go to http://www.pfc.forestry.ca/profiles/wulder/wrs/ using your web browser. In Figure 1 we present a view of the NFIS-PFC portal. Information on the data store may be viewed by selecting the "Details" button. As can be seen in Figure 1 a variety of user options are available, from setting the extents of the viewed area, panning of the viewable area, selection of themes and layers, as well as a query tool.

A nested data storage structure is utilised. For instance, the Data Stores identify where the information is being provided, Themes are groups of available data, and Layers are the actual information that may be viewed. In the case of Figure 1 the Data Store is NFIS-PFC, the Theme is CA_MAPREFERENCES, and the Layer is Landsat WRS.

Selected layers may be included for viewing by using the "Add →" button. In the Selected Layers box, the layers are ordered for viewing and the layers are drawn as listed, i.e. Provincial Boundaries under Landsat WRS layers. The "Up" and "Down" buttons may be used to alter the order of layers. The order of the layers is also important when building where clauses (to query the database). The where clause (see Figure 1) searches for the identified criteria in the first (or top listed) layer as the default. With

[2] http://geogratis.cgdi.gc.ca/frames.html
[3] http://edcdaac.usgs.gov/gtopo30/gtopo30.html

the Landsat WRS layer first in the Selected Layers box where clauses may be written directly, such as:

FOR_PER > 10
- forest percentage greater than 10% of frame

FOR_PER > 50 and NEWPOP > 100000
- forest percentage greater than 50% of frame and an expected population in the frame of greater than 100000

If the Landsat WRS layer is not listed first in the Selected Layer box, a comma may be placed before the where clause to advance through the list of layers. For example if the Selected Layer box was filled first with Provincial Boundaries then Landsat WRS, then the query for all frames with greater than 10% forest cover from above would look like:

, FOR_PER > 10

More commas may be added to accommodate additional layers. As identified above, with the search for forest cover and population criteria, Boolean operations are permitted. For example, following SQL rules, a variety of queries may be formed,

for_per > 10 and (prov_ab = 1 or prov_sk = 1 or prov_mb = 1)
- Prairie province images with greater than 10% forest cover expected

Conclusions

The WRS-Canada database, accessible through NFIS, provides the remote sensing community with a means for selection of Landsat imagery based upon an expectation of image contents from a variety of landscape and social characteristics. For example, trends in land cover, population, elevation may be nested within ecozones to aid in regional specific image selection. Image selection may also be stratified within individual provinces. The description of database characteristics will allow users to form queries based upon project specific concerns. The use of NFIS as a framework for storing and querying the database allows for broad access to the information and linkages to other resource information sources describing Canada.

References

Cihlar, J. and J. Beaubien, 1998; *Land cover of Canada Version 1.1. Special NBIOME Project*, Produced by the Canada Centre for Remote Sensing and the Canadian Forest Service, Ottawa, Ontario, Canada.

ESRI, 1998; ArcInfo, Version 7.2.1 Patch 1, On-line digital manual.

Environment Canada, 1996; *A national ecological framework for Canada*, Minister of Supply and Services, Ottawa, ON, Canada.

Gesch, D., K. Verdin, and S. Greenlee, 1999, New land surface digital elevation model covers the earth, *Eos, Transactions, American Geophysical Union*, v. 80, no. 6, p. 69-70.

Goodenough, D., A. Bhogal, R. Fournier, R. Hall, J. Iisaka, D. Leckie, J. Luther, S. Magnussen, O. Niemann, and W. Strome, 1998; Earth observation for sustainable development, *Proceedings of the 20th Canadian Symposium on Remote Sensing*, Calgary, Alberta, pp. 57-60.

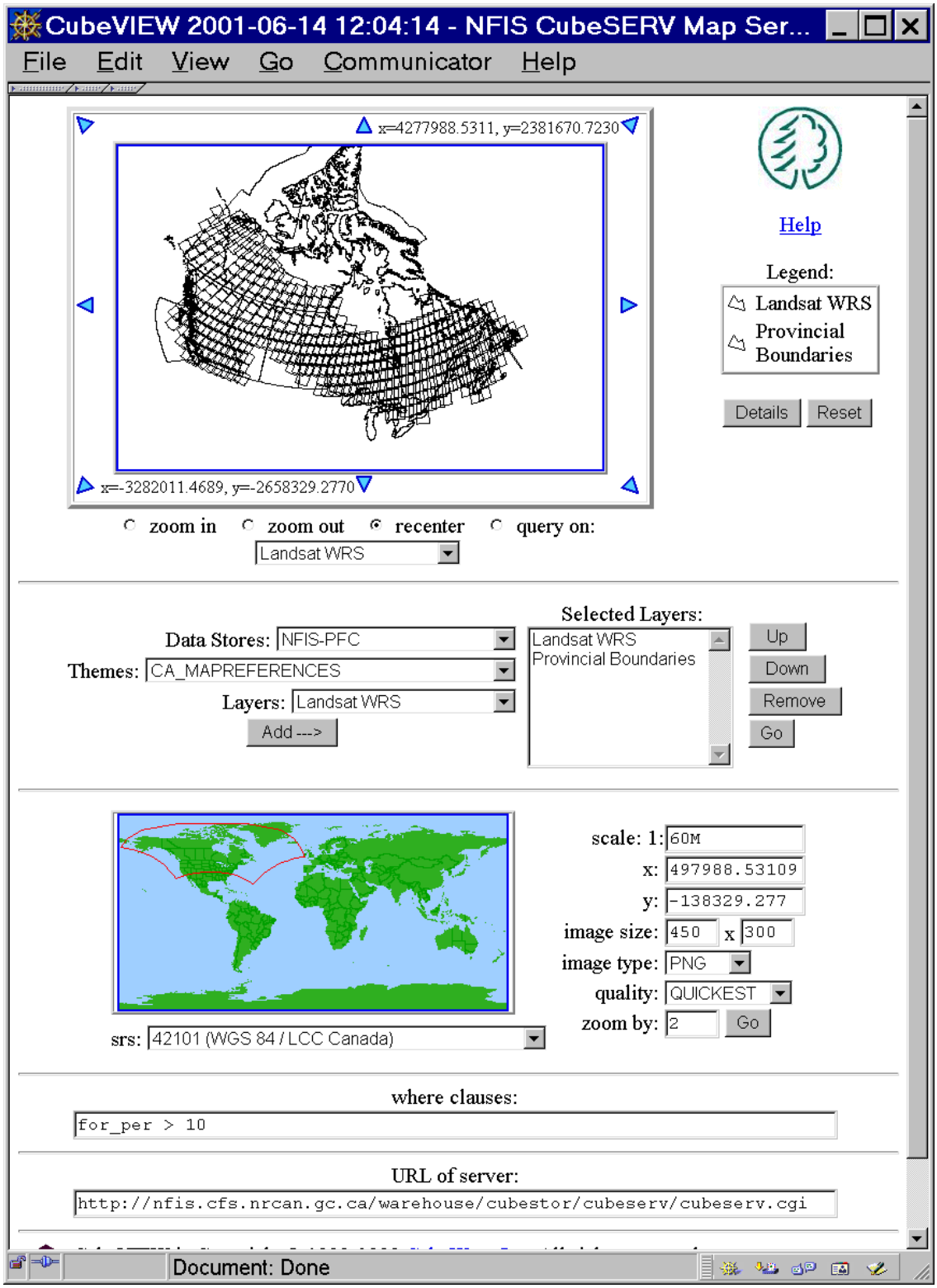
Westoby, J, 1989; *Introduction to world forestry*, (Basil Blackwell Ltd., Oxford, 228p.)

Wulder, M., and D. Seemann, 2001; Spatially partitioning Canada with the Landsat Worldwide Referencing System, *Canadian Journal of Remote Sensing*, Vol. 27, No. 3, pp. 225-231.

Table 1. description of WRS-Canada fields and related characteristics

Name	Description
TM_PATH	Landsat Path
TM_ROW	Landsat Row
PROV_BC PROV_AB PROV_SK PROV_QC PROV_NS PROV_NB PROV_PE PROV_YT PROV_NT PROV_NF PROV_ON PROV_MB	Those frames which contain a 1 (versus a 0) are situated at least in-part in the province or territory indicated. Multiple provinces may be identified (as opposed to the PROV field noted below).
AC	Ecozone: Arctic Cordillera
NA	Ecozone: Northern Arctic
SA	Ecozone: Southern Arctic
TP	Ecozone: Taiga Plains
TS	Ecozone: Taiga Shield
BS	Ecozone: Boreal Shield
AM	Ecozone: Atlantic Maritime
MP	Ecozone: Mixed Wood Plain
BP	Ecozone: Boreal Plain
P	Ecozone: Prairies
TC	Ecozone: Taiga Cordillera
PM	Ecozone: Pacific Maritime
MC	Ecozone: Montaine Cordillera
HP	Ecozone: Hudson Plain
CB	Ecozone: Boreal Cordillera
	Those frames which contain a 1 (versus a 0) are situated at least in-part in the ecozone indicated. Multiple ecozones may be identified (as opposed to the ECO field noted below).
PROV	Frames indicated here are entirely within the province identified (use two letter provincial codes (BC, AB, SK, QC, NS, NB, PE, YT, NT, NF, ON, MB)
ECO	Frames indicated here are entirely within the ecozone identified (use two letter ecozone codes (AC, NA, SA, TP, TS, BS, AM, MP, BP, P, TC, PM, MC, HP, CB)
FOR_PER	NBIOME: expected percentage of forest in a frame
BURN_PER	NBIOME: expected percentage burned land in a frame
WET_PER	NBIOME: expected percentage wetland in a frame
OPEN_PER	NBIOME: expected percentage of open areas in a frame
GRASS_PER	NBIOME: expected percentage grass land in a frame
BARE_PER	NBIOME: expected percentage bare land in a frame
CROP_PER	NBIOME: expected percentage crop land in a frame
URBAN_PER	NBIOME: expected percentage urban land in a frame
WATER_PER	NBIOME: expected percentage water in a frame
ICE_SNOW_PER	NBIOME: expected percentage ice and snow in a frame
ULLONG ULLAT URLONG URLAT LRLONG LRLAT LLLONG LLAT	Upper Left, Upper Right, Lower Left, and Lower Right geographic boundaries of each frame.
MIN_ELEV	GTOPO 30: minimum elevation
MAX_ELEV	GTOPO 30: maximum elevation
MEAN_ELEV	GTOPO 30: mean elevation
STD_ELEV	GTOPO 30: standard deviation of elevation values
ELEV_RANGE	GTOPO 30: elevation range
NEWPOP	Canadian census data: expected population within a frame

Figure 1. Screen capture of NFIS rendition of WRS-Canada* (example query, forest percentage > 10%).



* Note access through: http://www.pfc.forestry.ca/profiles/wulder/wrs/