Cutblock Update With High Resolution Satellite Images

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Abstract

Increasing demands on the forest resource and the high costs of re-inventory is driving the need for methods by which cost-effective update can be accomplished. The India IRS-1C/D panchromatic sensors with 5.8 m pixel resolution is the satellite with the highest spatial resolution next to the recent launch of IKONOS. The objective of this study was to compare photogrammetrically-derived cutblocks with those interpreted from IRS-1C/D images that were geometrically rectified using two methods: orthorectification and rubber sheeting. Aerial photographs at a scale of 1:20,000 were digitally aero-triangulated and displayed on a stereo photogrammetric workstation (DiAP viewer) from which cutblock information was derived. Although cutblock accuracy from the orthorectified IRS image was higher than from the rubber sheeted image, they were not statistically different. Cutblock areas were on average, within 2 ha and boundary placements ranged from 16 to 20 m of photogrammetric ground truth values. An assessment of individual cutblock delineations identified factors such as terrain shadow, residual snow cover and low density trees and vegetation will influence the spatial integrity of cutblock delineations.

Introduction

One objective of a forest inventory is to provide current information on the status and extent of forest resources within a managed land base (Teuber 1990). Changes in the forest land base will occur from harvesting, access and geophysical activities, and from other causes such as fire and pest damage. Maintaining a current forest inventory is required by those in resource management, fire protection, and forest health. With increasing demands on the forest resource and the high costs of reinventory (Birdsey 1990), the ability and procedures by which cost-effective update can be made to the inventory database are critical (Gillis and Leckie 1996).

The requirements for an inventory update include their cartographic mapping accuracy (eg., area and boundary placement), detection accuracy to a specified minimum size, frequency (eg., how often) and timing (eg., when required during the year) (Gillis and Leckie 1996). Although cartographic accuracies of about about ± 20 m (eg., ± 1 mm a 1:20,000 map scale) are often cited, there is a desired trend for finer levels of precision.

Various remote sensing approaches for inventory update have been evaluated using satellite and airborne data from Landsat (Archibald and Ahern 1985; Ahern and Leckie 1987; Hall et al. 1989), SPOT (Hall et al. 1991), airborne Radar (Yatabe and Leckie 1995), and Radarsat (Ahern et al. 1997). The potential advantages of satellite technology include lower-cost images in digital format that cover a larger area than aerial photographs, and the opportunity to automate the mapping procedure (Leblon 1999). A major factor that has limited the use of satellite data for update applications, however, has been the pixel size that has been too coarse for operational update.

With digital images, a pixel size must be no larger than 1/4 to 1/5 of the size of object to be represented. With a target cartographic accuracy of 20m, this translates to a maximum pixel size of 4 to 5m. The India IRS-1C and D satellites launched in 1995 and 1997, respectively, has a panchromatic sensor with 5.8m spatial resolution (http://www.spaceimaging.com/aboutus/satellites/IRS/IRS.html) that was the highest available until the recent launch of IKONOS. The objective of this study was to determine the accuracy by which recent forest cutblocks could be mapped from India IRS-1C/D images that have been geometrically rectified using digital orthorectification or rubber sheeting methods.

Study Area

The study area was located near Whitecourt, Alberta within Townships 58 and 59, Ranges 15 and 16, west of the 5th Meridian. This area is bounded by 54.15°N, 116.55°W on the northwest and 53.98°N, 116.08°W on the southeast. The study area is within the Lower Foothills Natural Region (Achuff 1992) that is dominanted by pure stands of lodgepole pine, white spruce (*Picea glauca* (Moench) Voss), trembling aspen (*Populus tremuloides* Michx.), balsam poplar (*Populus balsamifera* L.) and mixtures of these species in varying proportions. Pure stands of black spruce (*Picea mariana* (Mill) B.B.P.) in varying densities may also occur in poorly drained areas. Cutblocks and extensive geophysical activity such as well sites, seismic lines and pipelines occur frequently, which provided excellent conditions to test the mapping of disturbance activities.

Methods

Collection of photogrammetric ground truth

Cutblock ground truth was derived using a softcopy photogrammetric stereo viewing system (DiAP-Viewer) that operates as an extension to Microstation marketed by Integrated Mapping Technologies (http://www.askism.com/index4.html). The stereophoto data set consisted of 85, 1:20,000 6 inch black and white aerial photographs (Agfa Pan 50) that were flown August 3 1998. The photographs were scanned in a 8 bit grey scale format at 10um that resulted in a pixel size of 0.2 metres. Aerotriangulated control points were extracted from the Alberta provincial triangulation network based on 1:60,000 survey photography. Integrated Mapping Technologies who undertook the photogrammetric compilation reported an internal block fit error of ± 0.25 metres in X/Y and ±0.5 metres in Z. Absolute errors were 3 to 5meters X/Y and 1.5 to 3.0 metres in Z. Integrated Mapping Technologies also provided a 0.5m/pixel digital geotif orthophoto that was used as a source for locating ground control points on the India IRS satellite image.

The DiAP-Viewer system provides heads up 3D visualization for interpreter delineation of cutblock features using a computer mouse for data input. Interpretation was first conducted on hardcopy photos, and the interpreted line work was verified by two Level 3, Alberta Vegetation Inventory certified interpreters. This exercise was used to develop an interpretation protocol that guided the on-screen delineation of the photogrammetric ground truth.

Cutblocks were delineated using 3D line segments to form closed shapes that were subsequently imported in 2D to Arcview for comparison with delineations from the satellite image.

India IRS-1C/D acquisition and preprocessing

An April 20th 1998, 23kmx23km IRS-1D-Pan image was acquired in super structure format from which two image rectification methods were implemented. The image was extracted and processed using PCI version 6.3 imaging software and the IRS satellite orthoimage module add-on. The software provides an integrated environment for importing, correcting for ephemeris, collecting ground control and image rectification through either polynomial transformation (rubber sheeting) or ortho rectification using differential rectification methods (Cheng and Toutin, 1995). The difference between the two methods is that rubber sheeting procedures does not utilize an elevation model, and does not correct for relief displacement (Butler 1999).

Ground control points for both image rectification methods consisted of the same 9 evenly spaced points with coordinates derived from the 0.5m/pixel digital orthophoto. A 5m pixel size was defined for both methods. Results from the orthorectification were compared to a 2nd order polynomial transformation based upon ordinary least squares.

The orthorectified and rubbersheeted image histograms were compared and a linear contrast stretch enhancement was used to improve the apparent grey level difference between the bright cutblocks and the darker forested areas. This caused a small proportion of pixels in cutblocks to become saturated. A 5x5 sharpening filter was applied to further enhance texture especially along the cut edge and in the forested areas. These enhanced images were subsequently imported into ArcView for cutblock interpretation.

Statistical analysis

Cutblock delineations were undertaken in Arcview using the processed IRS images in geotif format. Thirty-six clearcut blocks were interpreted and digitized by one interpreter on the IRS orthorectified image, and a different interpreter on the IRS rubber sheeted image. The use of different interpreters for the photogrammetric ground truth and IRS rectified images were important to ensure training biases did not occur from interpreting the same block twice. The accuracy of cutblock mapping was assessed for area and boundary placement.

Cublock areas were calculated and a percent error and accuracy was determined:

$$\% \ error = \left| \frac{Interpreted - Actual}{Actual} \right| \times 100$$

$$\% \ accuracy = 100 - \%error$$

Descriptive statistics, scatterplots and an analysis of covariance (ANCOVA) using cutblock area differences were undertaken to compare the area accuracies attained from the image interpretations. The ANCOVA consisted of a one-way analysis of cutover differences with actual cutover area as a covariate.

Boundary placement errors were calculated using a method developed by Archibald and Ahern (1986) which used interpretation displacements based upon radial differences along 25 (15 degree) sector lines radiating from a centroid point within each cutblock. The mean of all 25 displacements was used as an indicator of the average boundary displacement for each cutblock. To remove the effects due to inside (negative) and outside (positive) displacements, only the average absolute value was reported under the assumption that displacements were equally important regardless of direction.

Results

The root mean square error of a second-order polynomial fit based upon 114 test points was 1.56 pixels (7.8m) in X and 1.21 pixels (6m) in Y directions. A subset of 26 pts from the above produced an error of 5.8 metres in X and Y on the orthocorrected image. The resulting planimetric accuracies were similar to what has been previously reported (Cheng and Toutin 1998).

Cutovers areas ranged between 1 to 52 hectares. IRS interpreted areas from both the orthorectified and rubbersheeted images were generally larger than those derived photogrammetrically (Table 1). Cutblocks were on average, within 2 ha of the photogrammetric ground truth, and smaller differences appears to have occurred from cutblocks interpreted on the IRS orthoimages (Table 1). Average area accuracies from both geometric correction images were similar and approached 90 percent

There was no significant difference in cut over areas derived from either the satellite orthorectification or rubber sheeting procedures ($p = 0.12$) for the sample of blocks used in this study.

Boundary placement errors were within the 20 metre provincial specification for cutblock mapping, and boundary delineations were on average, more variable than for the rubber sheeted image (Table 2). Boundary displacements varied widely regardless of whether the images were orthorectified or rubbersheeted, suggesting that other factors such as interpretation issues influence cutblock delineations.

Discussion

Comparison of the image rectification results suggest there were minimal displacement differences among control points located within the imagery, and the magnitudes were well within the errors expected for object recognition at this resolution. The lack of large differences as a function of position from nadir implies linear displacements due to view angle effects were minimal for the types of terrain encountered in the study area.

Cutblock area accuracies from both image rectification methods were similar which suggests for mapping cutblocks, the improvements due to incorporation of terrain was minimal for the study area. IRS rectification utilizing a 2^{nd} order polynomial transformation may suffice in areas of relatively flat or rolling terrain, or where the features of interest are not located on steep and undulating terrain. This has operational implications due to the reduced reliance for an accurate and precise DEM that is not always available. Cutblock boundary delineations were on average, within the maximum 20m boundary displacement error specified by the province, and approximately 5 to 10 m smaller than what has been previously reported (Hall et al. 1989, 1991).

Based on the empirical results generated, we may conclude cutblock mapping from India IRS panchromatic images would be operationally feasible. A visual comparison of delineated cutblocks between the digital air photo and the IRS image, however, resulted in identifying several factors that influence the spatial integrity of the cutblock polygon. The factors that influenced boundary delineations included terrain shadowing, snow cover and surrounding vegetation. Cutblock tone and texture varied greatly depending upon slope, cover type and wetness. Streams resembled roads in tone but were distinguished by their geographic shape and pattern. Low density vegetated areas such as open black spruce, and deciduous stands along cutblock edges were often incorporated into the block due to reduced contrast between the cutblock and the surrounding stand. Similarly, low brush areas with non-treed vegetation were usually incorporated into the block. The timing of image acquisition was also considered important since winter and early season images with snow cover may confuse the discrimination of cutblock edges.

Conclusions

Cutover areas from IRS orthorectified and rubbersheeted images were statistically similar with smaller differences from the IRS orthorectified image. Boundary placement values were also within the 20 m tolerances established as a cartographic function of map scale. These are encouraging results from the perspective of operational inventory update. Assessment at the individual cutblock level, however, identified that interpretation issues greatly affected the integrity of the delineated polygon. The results suggest that cutblock information from the India IRS 1-C/D panchromatic sensor would be well suited for monitoring harvesting activity at the landscape level and for creating a depletion coverage. When the spatial positioning of boundaries are critical such as for operational update of a forest inventory, however, higher resolution data is needed to mitigate the influences of terrain shadow and low density vegetation on detection and delineation of cutblock edges.

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Table 1. Cut over descriptive area statistics.

*Variables**	*Mean (ha)*	*Std.dev. (ha)*	*Min. (ha)*	*Max. (ha)*	*C.V. (%)*
Cutover Areas N= 36					
Photo truth	22.4	12.0	1.2	51.7	53.7
IRS-ortho	23.6	12.9	1.2	55.8	54.5
IRS-rubber sheet	24.3	12.6	1.2	56.9	51.9
Cutover area difference with interpreted photographs					
IRS Ortho - Photo Truth	1.2	2.3	-9.4	6.3	187.2
IRS-rubber sheet - Photo Truth	2.0	1.6	-0.6	6.4	83.5

* Std. dev. (standard deviation), Min. (minimum), Max. (maximum), C.V. (coefficient of variation)

Table 2. Summary statistics for polygon line displacement.

*Variables**	*Mean (m)*	*Std. dev. (m)*	*C.V. (%)*
Abs (IRS ortho - Photogrammetric Truth)	16.3	8.5	52.0
Abs (IRS rubber sheet - Photogrammetric Truth)	19.7	11.9	60.3

* Std. dev. (standard deviation), C.V. (coefficient of variation)

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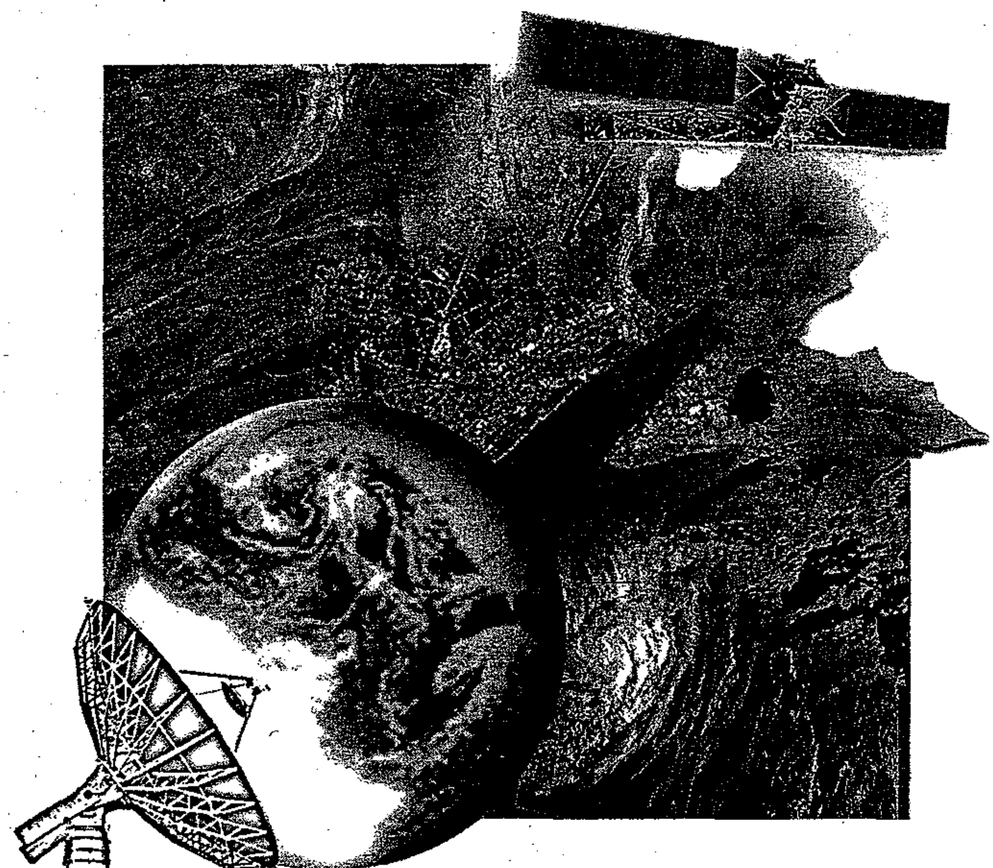

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