Monitoring Riparian Leave Strips with Multi-Temporal RADARSAT C-Band Satellite Data

Peter A. Murtha
Forest Resources Management, University of British Columbia
2045-2424 Main Mall, Vancouver, BC, V6T 1Z4, Canada
murtha@interchg.ubc.ca

ABSTRACT

The British Columbia Forest Practices Code (FPC) requires protection of fish-bearing river and stream reaches through riparian reserve zone strips. This paper reports on the application of Fine 2 beam mode RADARSAT multi-temporal data to monitoring 65 riparian strips. Eleven Fine 2 beam mode RADARSAT images were acquired between 4 December 1996 and 24 March 1999; these were examined individually and as multi-temporal colour composites (MTCs) for strip-change detection. The 65 riparian strips have a total length of 24.4 km. Eighteen strips comprising 6.3 km (25.8%) are intact. The remaining 47 strips have holes of varying length. The measurement of holes shows that by November 1998, 5.56 km (30.5%) of the 18.2 km of the post-FPC strip length has been decimated by windstorms, and that overall, 7.785 km (31.85%) of the total strip length is decimated. Most decimated strips are found on till-based landforms.

Key words: clearcuts, Forest Practices Code, RADARSAT, riparian leave strips, Vancouver Island, windthrow.

The British Columbia Forest Practices Code (FPC) provides guidelines for forest operations and silvicultural prescriptions, and requires protection of fish-bearing river and stream reaches through a system of riparian reserve and management zones (collectively termed riparian leave strips; B.C. MOF and B.C. MELP 1993). Fish-bearing streams <1.5 m wide have a management zone 30 m wide, while non-fish-bearing streams <3 m wide have a management zone of 20 m. The riparian leave strips are found in or alongside new clearcuts. On northern Vancouver Island these strips are subject to severe wind and rain storms. Many of the strips are quickly decimated through windthrow (Fig. 1). Strips range in width from 20 to 70 m, and may be as short as 60 m

Figure 1. Riparian strip 16 as it looked on 20 August 1997. This strip was created in August 1995. Aerial photographs (Fig. 2) taken at the same time showed 55 codominant tree crowns in the strip. This strip was decimated by windstorms during the autumn–winter of 1995–96. The strip was 300 m in length. (Photo by P. Murtha.)

and as long as 700 m. RADARSAT Fine 2 beam mode data can image these strips, and their detectability depends on strip condition (Murtha and Mitchell 1998).

RADARSAT is a Canadian satellite that was launched in November 1995. It has a C-band (wavelength 5.3 cm) radar sensor, and multi-look and beam modes. Orbiting at an altitude of about 800 km, in a north–south polar orbit, it has a 24-day repeat cycle. Since it is radar, it is possible to obtain data from the same orbital position once every 24 days, regardless of darkness or weather conditions. More details about RADARSAT and radar can be found in Lillesand and Kiefer (1994), and on the Web. (For the satellite description see RADARSAT International at http://www.rsi.ca/home.htm.)

Murtha and Mitchell (1998) reported that all of the heavily damaged and decimated strips are not imaged (Figs. 2 and 3), and that all of the healthy to medium-damaged strips are easy or moderately easy to locate on multi-temporal colour composites (MTCs). The visibility of the strips is also dependent upon contrast with their background (Murtha 1998). On northern Vancouver Island all post-FPC clearcuts are imaged bright during the rainy winter–spring months. When the weather becomes drier in the summer, the clearcuts are imaged dark. Clearcuts on glacial till landforms, such as ground moraine, and till over bedrock remain brighter longer than do clearcuts on marine or lacustrine deposits (lake bed, lake bed terraces), glacial fluvial outwash deposits, or flood plains (Murtha 1998). The MTCs made the strips easier to interpret regardless of the season.

This paper reports on the RADARSAT monitoring of riparian leave strip decimation on northern Vancouver Island.

STUDY AREA

The study area is located on northern Vancouver Island, B.C., between the communities of Port Hardy and Port McNeill (Murtha and Pollock 1996). It is located in the Nahwitti Lowlands ecosection and in the Coastal Western Hemlock (CWH) biogeoclimatic zone (Klinka et al. 1991, Krajina 1965). The surficial geology has been mapped

Figure 2. August 1995 aerial photograph showing intact riparian strip 16 bisecting the cutblock. When viewed stereoscopically, 55 codominant tree crowns can be counted. (Aerial photography by Foto Flight Surveys, Calgary, AB.)

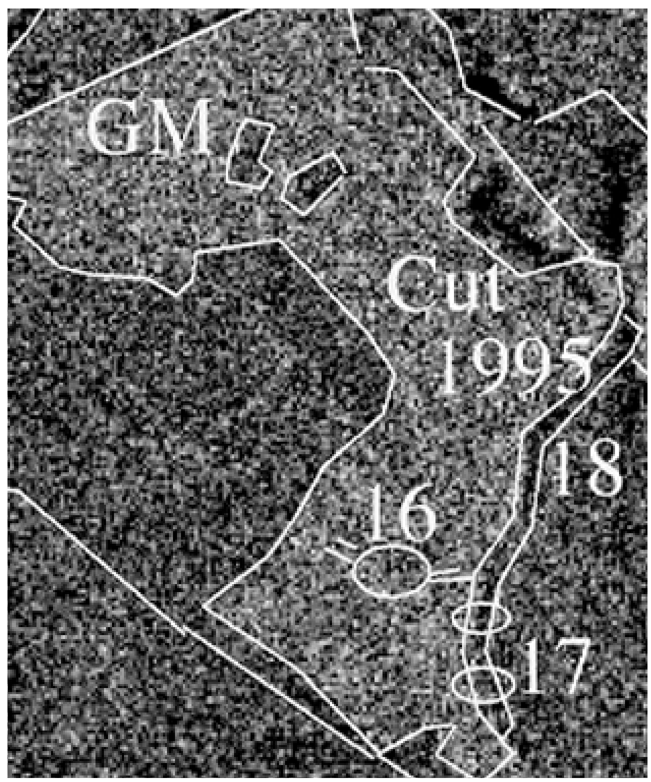

Figure 3. The first RADARSAT Fine 2 beam mode images showed no trace of riparian strip 16. Even though the image data were acquired at night during rainstorms, riparian strips 17 and 18 on the right side of the cutblock are clearly evident. Decimated riparian strips do not show on the RADARSAT images. (RADARSAT images copyright Canadian Space Agency, 1996, 1997, and 1998.)

according to textures, genetic materials, surface forms, and modifying processes (Lewis 1985). The dominant tree species are Sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*), and amabilis fir (*Abies amabilis*; Klinka et al. 1991). The study area borders the Port Hardy airport, where Environment Canada maintains a weather station.

METHODS

Eleven Fine 2 (F2) beam mode RADARSAT images were acquired between 4 December 1996 and 24 March 1999 (Table 1). All F2 RADARSAT data were acquired at 0221 hr UTC. F2 beam mode images are 50 km on the side, and have a nominal of 8-m pixel resolution and an incidence angle of about 40°. Thirteen 512 X 512 pixel subscenes were selected from each RADARSAT Fine 2 scene using ER Mapper 5.5 software. The subscene image pixel display resolution is 7.60 X 7.60 m. Each subscene was registered to NTS map sheet 92L/11, then each of the remaining 10 dates for each subscene were co-registered in order to create MTCs.

Fifty strips were located on 1:20,000 colour aerial photographs from 1995. Seventeen strips were pre-FPC (before 1994). The landform of the clearcuts was interpreted from the 1995 aerial photographs (Kesser 1976, Mollard 1978). The RADARSAT F2 images were examined individually and, after receipt of the first 3 images, as MTCs. The known riparian strips looked like sinuous, dark noodles in or alongside the bright cutblocks (Figs. 2 and 3). Fifteen new strips were found on the RADARSAT images. The length, width, and direction of the original 50 strips were measured on 1995 colour aerial photos. The RADARSAT F2 MTCs were used to measure the strips created after August 1995.

Holes in strips were measured on the aerial photographs and on the RADARSAT MTCs. As strips become more damaged, trees go down in groups, creating the holes. These holes are seen on the RADARSAT MTC images as strips that should have shadows, but don't, or the MTC-colour of the

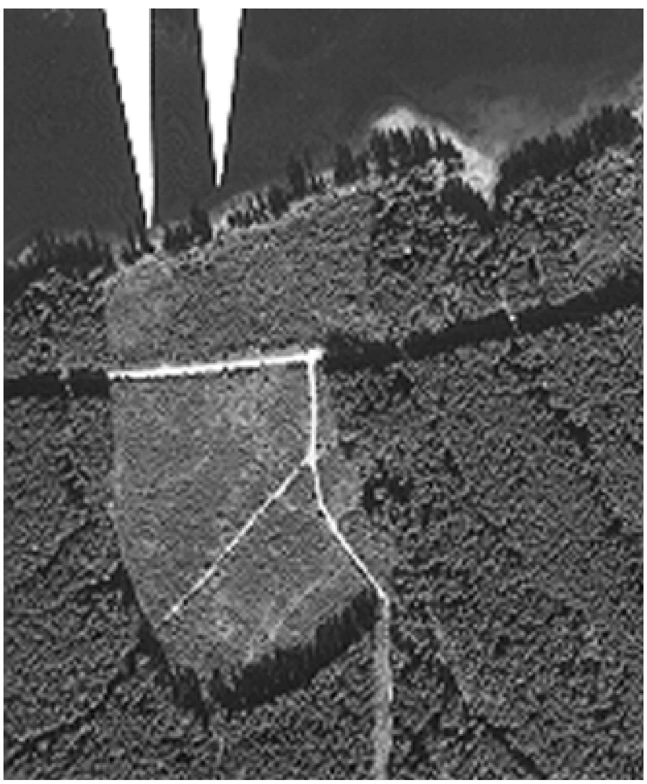

Figure 4. August 1995 aerial photograph showing riparian strip 31b. Pointers indicate holes, which measure a total of 4 mm in length. Stereoscopically, a windthrown tree is visible by the left-hand hole. At the original scale of 1:20,000, the lineal distance of holes equals 80 m. (Aerial Photography by Foto Flight Surveys, Calgary, AB.)

Figure 5. The holes in riparian strip 31b are circled in this RADARSAT image, acquired at night during rainstorms, from 800 km in space. Using ER Mapper image analysis software, the measured holes totalled 88 m. (H9S1–1982 indicates the cutblock was planted to 90% hemlock and 10% spruce.) (RADARSAT images copyright Canadian Space Agency, 1996, 1997, and 1998.)

Table 1. RADARSAT data acquired over northern Vancouver Island, B.C. from 4 December 1996 to 24 March 1999.

Date	RADARSAT data	Daylight	Weather
4 Dec 96	Fine 2	No	heavy rain, strong winds
11 Dec 96	Standard 4	No	heavy rain
14 Feb 97	Fine 2	No	heavy rain, windy
3 Apr 97	Fine 2	No	gale force winds, drizzle
8 Jul 97	Fine 2	Yes	drizzle
15 Jul 97	Standard 4	Yes	overcast, scattered drizzle
1 Aug 97	Fine 2	Yes	overcast, no rain for 6 hr
25 Aug 97	Fine 2	Yes	light rain
5 Nov 97	Fine 2	No	rain
12 Nov 97	Standard 4	No	rain
29 Nov 97	Fine 2	No	heavy rain
6 Dec 97	Standard 4	No	overcast, no rain
20 Aug 98	Fine 2	Yes	overcast, no rain
24 Nov 98[a]	Fine 2	No	rain
24 Mar 99[b]	Fine 2	No	frontal rains

[a] Image courtesy of British Columbia Ministry of Environment, Lands and Parks.

[b] These data were received too late to include strip analysis in this paper, however initial analysis shows continued decimation of the riparian strips.

cutblock bleeds through the strip when it shouldn't. The accuracy of the measurements was compared with the aerial photographs. For example, strip 31B had holes clearly evident on the aerial photographs (Fig. 4), with a cumulative length of 4 mm, or 80 m at a scale of 1:20,000. The same holes measured on the RADARSAT composites (Fig. 5) with ER Mapper software gave a length of 88 m. These tests indicate that measurements made on the RADARSAT MTC are within ±10% of measurements made on the aerial photographs. Holes in all strips were measured on images from 25 August 1997, 29 November 1997, 20 August 1998, and 24 November 1998.

RESULTS

Data on year of creation of the strips, landform of the cutblock, total strip length, and decimation (holes in strips) are presented in Tables 2 and 3. The 17 pre-FPC decimated strips are found primarily on ground moraine. Table 3 indicates that the newly decimated strips created since the implementation of the FPC are also found on ground moraine, or till with bedrock close to the surface. Better drained and having better site conditions, the till deposits support CWH climax species (western hemlock) because of their mesic site attributes. Rooting depth is more restricted on the till deposits. Thus when the adjacent forest is cut, the tall (30–50 m) hemlock are more predisposed to windthrow than are the cedar

Table 2. Pre-Forest Practices Code (before 1994) riparian strips classified according to year of cutting, landform, total length, and length of holes measured on the RADARSAT images.

Strip #	Year of cutting	Land- form[a]	Total length (m)	Length of holes (m)			
				25 Aug 97	29 Nov 97	20 Aug 98	24 Nov 98
04	1984	LB	160				20
10	1992	GM	240	240	240	240	240
11	1992	GM	100	100	100	100	100
12	1991	LB	580				40
14	1991	LB	800				224
19	1993	LB	800				
20	1993	LB	200				
22	1993	LB	200				
28	1985	LB	500				
29	1985	LB	320	320	320	320	320
30	1991	LB	400				
31B	1982	LB	400	88	88	141	199
32A1	1992	GM	300				
32A2	1992	GM	200	105	105	105	105
32B	1992	GM	180	180	180	180	180
32C	1992	GM	400	400	400	400	400
32D	1992	GM	400	400	400	400	400

[a] LB = lakebed; GM = ground moraine.

Table 3. Post-Forest Practices Code (1994 and later) riparian strips classified according to year of cutting, landform, total length, and length of holes measured on the RADARSAT images.

Strip #	Year of cutting	Land- form[a]	Total length (m)	Length of holes (m)			
				25 Aug 97	29 Nov 97	20 Aug 98	24 Nov 98
01	1995	GM	100	100	100	100	100
02	1995	GM	300	26	26	26	26
03	1995	GM	220				
05	1996	GM	400	20	20	20	20
06	1996	GM	200				
07	1996	GM	460	20	20	48	48
08	1996	GM	480				30
09	1994	LB	80				
13	1994	LB	320		30	30	57
16	1995	GM	300	300	300	300	300
17	1995	GM	400	94	94	134	176
18	1995	GM	440	95	95	153	202
21	1994	LB	100				
23	1994	LB	160				
24	1994	GM	300	300	300	300	300
25	1994	LB	1200	175	310	398	472
26A	1994	LB	200				
26B	1994	LB	200				
31A	1996	GM	440		60	80	113
33	1995	GM	280	280	280	280	280
34	1995	GM	140	140	140	140	140
35	1995	GM	400				
36	1995	T/R	800				230
36A1	1997	T/R	380		131	380	380
36A2	1997	T/R	320		60	320	320
37	1994	LB	900				146
38	1994	LB	220				
39	1995	T/R	500	82	82	82	80
40	1995	T/R	600			74	74
41	1995	T/R	500				
42	1995	T/R	300				
43	1995	T/R	260				
44	1995	T/R	300	90	90	90	90
45	1995	T/R	480			145	172
46A	1995	T/R	200	60	60	60	60
46B	1995	T/R	80	80	80	80	80
47	1995	T/R	300	167	167	167	167
48	1995	T/R	650	160	160	160	160
49A	1995	T/R	360	360	360	360	360
49B	1995	T/R	200	200	200	200	200
50	1997	GM	920		60	60	94
51	1997	LB	640				
52	1997	LB	560				50
53	1997	T/R	450				450
54	1997	T/R	200				45
55	1997	T/R	320				50
56	1997	T/R	380				44
7A	1996	GM	280				41

[a] LB = lakebed; GM = ground moraine; T/R = till/rock.

Table 4. Summary of data on length of holes measured in riparian strips from before and after implementation of the Forest Practices Code (FPC), as shown on RADARSAT F2 images.

Year of cutting	Total length of strips (m)	Length of holes (m) and % of total strip length			
		25 Aug 97	29 Nov 97	20 Aug 98	24 Nov 98
Before 1994 (pre-FPC strips)	6,180	1,833 / 29.66%	1,833 / 29.66%	1,886 / 30.5%	2,228 / 36.05%
1994 and later (post-FPC strips)	18,220	2,699 / 14.81%	3,225 / 17.7%	4,187 / 22.98%	5,557 / 30.5%
Total	24,400	4,582 / 18.78%	5,058 / 20.72%	6,073 / 24.88%	7,785 / 31.85%

on the wetter sites. These riparian strips are habitats at risk.

The 65 riparian strips, found in or beside 35 clearcuts, have a total length 24.4 km (Table 4). They also have an average length of 375 m, and an average width of 50 m. Of the 48 strips created since the implementation of the FPC in 1994, 30.5% of the total strip length has been decimated by windstorms. In the first images assessed, the total length of holes in all 65 strips combined was about 19% of total strip length. A year later (20 Aug 1998), the combined length of holes had increased by 6%, and at last measurement (24 Nov 1999) had increased by an additional 7%, for a total increase of 31.85%, or 7.78 km covering 38.92 ha (Table 4). (A RADARSAT F2 image acquired on 24 March 1999 shows further decimation of the strips I have been watching. The winter of 1998–99 has seen major windstorms. Undoubtedly strip decimation will have taken another jump when all the strip holes are remeasured.)

DISCUSSION

The riparian reserve zone and management zone leave strips on northern Vancouver Island are a by-product of the Forest Practices Code, and their numbers are increasing. The greater the numbers, the more difficult it is to monitor using traditional ground-based approaches. Clearly the riparian strips are being damaged by windstorms and are habitats at risk. The terrain is remote and somewhat difficult to access, which makes ground surveys slow and time-consuming, and thus very costly. Helicopter surveys cost about $1,000/hr, and leave no permanent record. Cloudy weather makes optical remote sensing questionable on a continually repetitive basis. Scheduling commercial aerial photography, and acquisition of aerial photographs on a continuing basis is currently not a option because of weather and the cost of aerial photography (>$50,000 for the Aug 1995 aerial photography). The Landsat thematic mapper (TM) can image the strips at a 25-m pixel resolution (which for some strips is inadequate resolution), but cloud cover precludes frequent imaging. The past 5 years of TM images illustrates the depth of the problem (see http://ceocat.ccrs.nrcan.gc.ca/cdql/landsat5/track-51/frame-25/); during the last 5.5 years about 18% of the images were cloud-free. The alternative is the Fine 2 beam mode of RADARSAT with an 8-m pixel resolution. The satellite turnaround time is remarkable. The image ordered from the 24 March 1999 satellite pass at 0221 hr UTC (= 23 Mar, 1921 hr PST, when a frontal storm system was passing over northern Vancouver Island) was acquired, processed, and delivered to the FIRMS lab in the Faculty of Forestry, University of British Columbia, then loaded into the computers prior to noon on 25 March: 38 hours between acquisition and application.

The critical time is during the winter storm period (Oct–Apr). This time is coincident with the best imaging period to obtain adequate contrast of strips against the bright background of the recent cuts. Riparian strips in the correct situation, like the Nahwitti Lowlands ecosection, can be monitored for the price of data acquisition and image processing. In the case of the 24 March 1999 image, it took less than half an hour to document further decimation of strips.

CONCLUSIONS

1. RADARSAT Fine 2 beam mode data can be used to assess decimation of riparian leave strips in clearcuts on northern Vancouver Island.
2. Thirty-five clearcuts had 65 riparian strips with a total length of 24.4 km.
3. 30.5% (5.6 km) of post-FPC strip length has been decimated.
4. The 7.78 km of strip decimated since 1990 covers 38.9 ha.
5. Post-FPC decimated strips are found on till-based landforms (till/rock, ground moraine).
6. Without the RADARSAT Fine 2 images, these data on damage to riparian leave strips would not have been readily available to this author or these proceedings. This report suggests a link between riparian strip decimation and the landform of the clearcut.

ACKNOWLEDGEMENTS

Cooperators in the study include Western Forest Products Ltd., RADARSAT International, the Canadian Space Agency, and the British Columbia Ministry of Environment, Lands and Parks. Special thanks are given to K. McGourlick (Western Forest Products Ltd., Port McNeill, B.C.). Image analysis and interpretation was done in the FIRMS Remote Sensing/GIS lab, Faculty of Forestry, University of British Columbia. Canadian Space Agency ADRO 384 funding is gratefully acknowledged.

LITERATURE CITED

British Columbia Ministry of Forests (MOF), and British Columbia Ministry of Environment, Lands and Parks (MELP). 1993. British Columbia Forest Practices Code rules. Victoria, BC. 128pp.

Kesser, N. 1976. Interpretation of landforms from aerial photographs. Res. Div., B.C. Minist. For., Victoria, BC. 215pp.

Klinka, K., J. Pojar, and D. V. Meidinger. 1991. Revision of biogeoclimatic units of coastal British Columbia. Northwest Sci. 65(1):32–47.

Krajina, V. 1965. Biogeoclimatic zones in British Columbia. Ecol. Western N. Amer. 1:1–17.

Lewis, T. 1985. Ecosystems of the Quatsino Tree-Farm Licence (TFL 6). Western Forest Products Ltd., Vancouver BC. 77pp.

Lillesand, T. M., and R. W. Kiefer. 1994. Remote sensing and image interpretation. 3rd ed. Wiley and Sons, Toronto, ON. 750pp.

Mollard, J. 1978. Landforms and surface materials of Canada: a stereoscopic airphoto atlas and glossary. 6th ed. J. D. Mollard, Regina, SK.

Murtha, P.A. 1998. Weather or not: monitoring riparian strips in forest clearcuts with multi-temporal fine 2 mode RADARSAT data. [on CD-ROM] Proc. Twentieth Canadian symposium on remote sensing. Can. Aeronaut. and Space Inst., Ottawa, ON.

_____, and S. J. Mitchell. 1998. Riparian leave strip monitoring with multi-temporal fine 2 mode RADARSAT data. [on CD-ROM] Proc. American Society for Photogrammetry and Remote Sensing 1998 annual meeting. Amer. Soc. for Photogrammetry and Remote Sensing, Bethesda, MD.

_____, and R. J. Pollock. 1996. Airborne SAR studies of North Vancouver Island rainforests. Can. J. Remote Sensing 22:175–183.