

ARE CLEAR-CUT AREAS ESTIMATED FROM LANDSAT IMAGERY RELIABLE?

A-8

By Y. Jim Lee, Pacific Forest Research Centre, Canadian Forestry Service,
Environment Canada, 506 West Burnside Road, Victoria, B.C., Canada, V8Z 1M5.

ABSTRACT

N76-17477

The reliability of LANDSAT imagery for estimation of clear-cut areas was evaluated by comparison with data obtained from high-altitude photos and logging historical map and from field inspections.

A mature forest, owned by Pacific Logging Company, was selected as a test site because of its continuous clear-cut operation. The forest is about 50 km northwest of Victoria, British Columbia, Canada, and consists of 9092 ha. Ground truth was based on high-altitude photos and the Pacific Logging Company Logging History Map for 1973, with a scale of 1:63,360. LANDSAT imagery from band 5, recorded by multispectral scanner, was obtained on September 4, 1972 and on August 12, 1973.

Areas clear-cut within the past year were overestimated by 12.9% (105 ha), those clear-cut 1-year or more by 2.2% (76ha), whereas uncut mature timber was underestimated by 3.6%(176 ha). Three clear-cut areas were missed in the company map and two in the LANDSAT enhancement. The difference between area estimates was significant when all 26 areas were included but not when 2 overestimated areas were excluded from the analysis.

Some of the difficulties in using the technique are discussed, but the study indicates that LANDSAT imagery color enhancement is a useful tool in up-dating clear-cut areas for long-term planning in forest management.

INTRODUCTION

Logging has been a continuous operation in the Province of British Columbia since the earliest days of settlement. Accounting for the acreage logged annually is desirable for long-term planning, but it is also a tremendous task, expensive and time-consuming to carry out by conventional means. LANDSAT offers a new and unique periodic overview of forest lands and could facilitate economic collection of such useful data. Earlier studies indicated that some forest management operations can be monitored (Lee, 1974) and the technique of color additive viewer enhancement facilitated the interpretation of a dynamic event over time, such as clear-cut areas (Lee *et al.*, 1974). By adjusting the light intensity illuminating each band and the scale of each image on the color additive viewer, multi-date imagery can be superimposed to enhance the scene. This technique is especially useful for areas that have been clear-cut within the past year, where the LANDSAT signature responds to reflectance from exposed mineral soil. The purpose of this paper is to demonstrate that clear-cut areas and uncut mature timber can be identified and the acreage estimated, using LANDSAT imagery.

METHODS

The mature forest, owned by Pacific Logging Company, Victoria, British Columbia, was selected as a test site because of its continuous clear-cut operation. The forest is a typical old-growth type in the Pacific Northwest region, consisting of mainly Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), with western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and other coastal tree species as minor components. It is located about 50 km

northwest of Victoria, British Columbia, Canada, and consists of 9092 ha.

Ground truth was based on high-altitude color photography (scale 1:120,000) and the Pacific Logging Company Logging History Map for 1973, with a scale of 1:63,360, and field visits. The high-altitude color photographs were taken on August 6, 1972 and on July 19, 1973, from Falcon and CF-100 jet aircrafts, each equipped with RC10 and four Vinten 70-mm cameras. LANDSAT imagery from the 4 bands recorded by the multispectral scanner (MSS) was obtained on September 4, 1972 and on August 12, 1973.

Five steps were required in order to produce satisfactory data from multi-date LANDSAT imagery. The first step was to cut out the portion containing the test site from the 23 cm x 23 cm black and white MSS 5 imagery for both September 4, 1972 and August 12, 1973, and to mount them between "anti-Newton ring" lantern slide glass. The second step was to place the slides in a color additive viewer. The third step was to adjust the scale so that the multi-date images were superimposed. The fourth step was to give the right amount of light intensity, and to use a red filter for the September 4, 1972 imagery and a green filter for the August 12, 1973 imagery. The final step was to photograph the scene on the screen of the color additive viewer, using 35 mm color slide film.

A 35 mm slide projector was used to transfer the clear-cut information onto a map, comparable to the Pacific Logging Company Logging History Map for acreage estimation.

A systematic Dot-Area-Grid, 15.5 dots per cm², was used to estimate acreage of the forest types, totalling 26 areas (Figures 1 and 2).

RESULTS AND DISCUSSIONS

Image interpretation

Image analysis of high-altitude photos (Figures 3 and 4) and confirmation from field visits indicate that progress of clear-cutting can be identified from LANDSAT imagery (Figures 5 and 6) and multi-date enhanced color prints (Figure 7). Three distinct forest types can be identified: (1) areas clear-cut within the past year, (2) areas clear-cut 1 year or more, and (3) areas of uncut mature timber. Areas clear-cut within the past year showed up much lighter in color or in tone (owing to fresh slash and exposure of mineral soil) than those areas clear-cut 1 year or more, with or without slash burn (owing to gray slash, planted trees plus grass and shrubs and burned slash), as seen in Figures 3, 4, 5 and 6 (see arrows). The differences in color among the 3 forest types as seen in the multi-date enhanced color print (Figure 7) are the most distinctive where areas clear-cut within the past year are red, areas clear-cut 1 year or more are yellow, and areas of uncut mature timber are dark gray. In areas where mineral soil or rocks are exposed for several years, the distinction between 1-year-old and older clear-cut areas may not be possible.

Transferring of Forest Types Onto Map

Obviously, the question will be asked, "How can the forest types best be transferred onto a map?" Initially, an attempt was made to use the August 12, 1973 black and white LANDSAT MSS 5 imagery and a 35 mm slide projector to transfer the forest types onto the map. This procedure was not successful because of the fuzzy forest type boundaries. However, when the multi-date enhanced 35 mm color slide (Figure 7) was used, the transformation was more successful because the type boundaries were quite clear. Some difficulty was encountered in the transferring process, possibly due to the distortion of the multi-date enhanced slide and the positioning of the 35 mm slide projector; so projection was done in small areas, 2 to 4 cm at a time. From experience, the author believes that if an Interpretoskop is available, this difficulty might be eliminated. Transformation of forest types can

probably be done directly, using LANDSAT color composite MSS bands 4, 5 and 7 or diazo color composites (Lee et al., 1974).

The map (Figure 1), produced by the process, is similar to the one provided by the Pacific Logging Company showing areas clear-cut in 1973 and before 1973.

Area Estimates

Ideally, area calculations should be done by overlaying the maps in a grid format on a digitizing machine. This machine was not available, hence area estimation was resolved by dot grids. Therefore, the error in area estimates from dot grids, if any, is vested in the process (Bonner, 1975). This error is not serious in the overall estimates between the 2 maps: 5 ha or 0.1%; but it may have some effect on each individual area estimate of the 26 areas. Table 1 is a summary of the two area estimates for each of the 26 areas and their differences.

In spite of this shortcoming, the resulting area estimates were satisfactory:

- (1) Areas clear-cut within the past year were overestimated by 105 ha or 12.9% only.
- (2) Areas clear-cut 1 year or more were overestimated by 76 ha or 2.2% only.
- (3) Areas of uncut mature timber were underestimated by 176 ha or 3.6% only.

A number of discrepancies, most of which were small, were found in the areas clear-cut within the past year. Area numbers 1, 2 and 11 were incorrectly classified by the company in its mapping process, while area numbers 7 and 14 were incorrectly classified in the LANDSAT mapping process. Area numbers 4 and 14 were significantly overestimated in the LANDSAT mapping process, 50.8% and 82.4%, respectively.

Significant differences were found to exist between area estimates from the company map and from the LANDSAT enhancement when all 26 areas were included (Chi-square: 80.80 with 25 degrees of freedom). However, the differences were not significant when area numbers 4 and 14 were excluded from the analysis (Chi-square: 40.99 with 23 degrees of freedom). In the LANDSAT mapping process, the total clear-cut area was overestimated by only 181 ha or 4.2%.

Attention should be drawn to the fact that the period for LANDSAT clear-cut area estimates was between September 4, 1972 and August 12, 1973, but the period for company clear-cut area estimates was the 1973 calendar year. Therefore, a slight discrepancy in area estimates was expected.

CONCLUSIONS

The ability to identify the status and to estimate the size of current and past clear-cutting activity has been definitely established. The acreages for clear-cut and uncut mature timber determined from LANDSAT imagery are reliable and the LANDSAT color enhancement technique is a useful tool in up-dating clear-cut areas for long-term planning in forest management.

ACKNOWLEDGMENT

Thanks are due to Canada Centre for Remote Sensing, Ottawa for making available a Color Additive Viewer. The cooperation of Mr. W. J. Bruce Devitt of the Pacific Logging Company, Victoria, British Columbia, Canada in making available information for the test site is gratefully acknowledged.

REFERENCES

- Bonner, G.M. 1975. The Error of Area Estimates From Dot Grids. Canadian Journal of Forest Research 5(1): 10-17.
- Lee, Y.J. 1974. Monitoring Forest Management Operations. Canadian Surveyor, 28(2): 135-141.
- Lee, Y.J., E.T. Oswald and J.W.E. Harris. 1974. A Preliminary Evaluation of ERTS Imagery For Forest Land Management in British Columbia. Second Canadian Symposium on Remote Sensing, Univ. of Guelph, Guelph, Ontario April 29, 30 and May 1, pp. 87-101.

TABLE I SUMMARY OF AREA ESTIMATES

Forest Type	Type No	Pacific Logging Co. Logging History, ha (A)	LANDSAT Color Additive Viewer Enhancement Logging History ha (B)	Difference ha (C)	$\frac{(C)}{(A)} \times 100\%$
Logged in 1973	1	60	60	0	0
	2	57	75	-18	-31.6
	3	39	44	- 5	-12.8
	4	65	98	-33	-50.8
	5	52	54	- 2	- 3.8
	6	134	132	2	1.5
	7	11	13	- 2	-18.2
	8	13	11	2	15.4
	9	44	44	0	0
	10	77	75	2	2.6
	11	106	101	5	4.7
	12	44	49	-5	-11.4
	13	75	98	-23	-30.7
	14	34	62	-28	-82.4
	Subtotal	811	916	-105	-12.9
Logged before 1973	15	98	98	0	0
	16	477	502	-25	-5.2
	17	300	321	-21	-7.0
	18	495	538	-43	-8.7
	19	1580	1531	49	3.1
	20	534	570	-36	-6.7
	Subtotal	3484	3560	-76	- 2.2
Uncut Mature Timber	21	3496	3401	95	2.7
	22	28	36	- 8	-28.6
	23	75	73	2	2.7
	24	476	476	0	0
	25	660	583	77	11.7
	26	62	52	10	16.1
	Subtotal	4797	4621	176	 3.7
Total		9092	9097	-5	-0.1

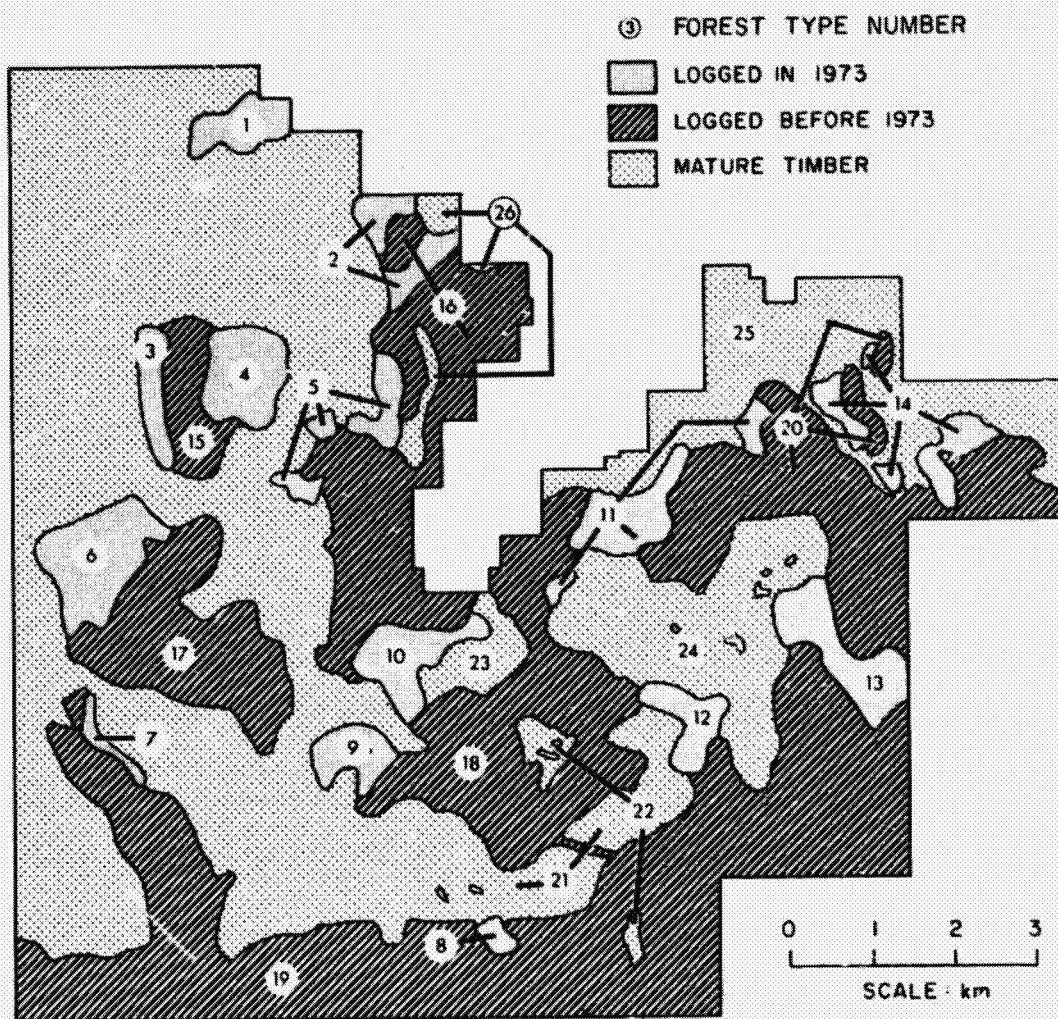


Figure 1. Logging history map produced from LANDSAT imagery Color Additive Viewer enhancement. (Forest type numbers also correspond to type numbers in Table I).

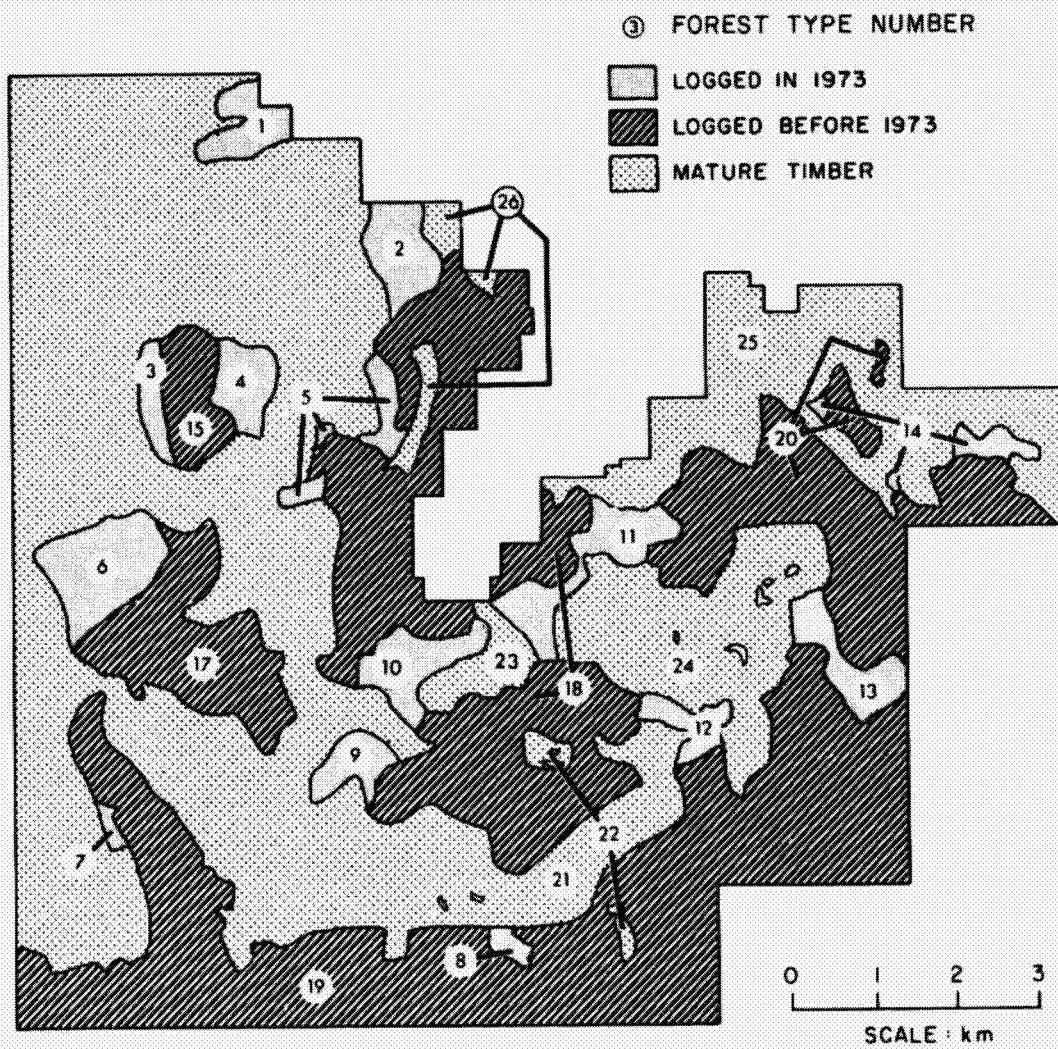


Figure 2. Pacific Logging Company logging history map. (Forest type numbers also correspond to type numbers in Table I).

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR



Figure 3. Part of a 23 cm x 23 cm high-altitude color photo taken on August 6, 1972, showing the test site. Arrows point to timber to be logged in 1973.



Figure 4. Part of a 23 cm x 23 cm high-altitude color photo taken on July 19, 1973, showing the test site. Arrows point to area logged in 1973.

**REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR**



Figure 5. An enlargement of LANDSAT-1 imagery from frame 1043-18370 MSS-5 (September 4, 1972), showing the test site. Arrows point to timber to be logged in 1973.

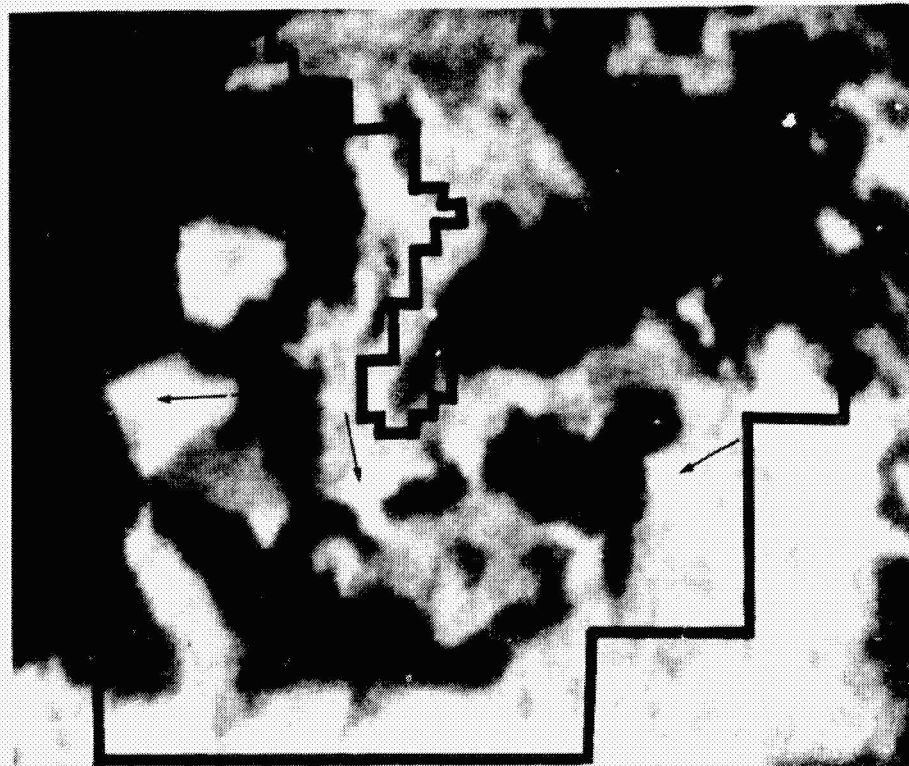


Figure 6. An enlargement of LANDSAT-1 imagery from frame 1385-18365 MSS-5 (August 12, 1973), showing the test site. Arrows point to area logged in 1973.

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR



Figure 7. Color Additive Viewer enhancement of logged areas (in red color, see arrows), using LANDSAT frame 1043-18370 MSS-5 (September 4, 1972) with red filter superimposed on frame 1385-18365 MSS-5 (August 12, 1973) with green filter.