Short term gap dynamics of the Canadian mixedwood boreal forests using multi-temporal lidar data

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1. Background

- Gap dynamics of boreal ecosystem is not well understood.
- Spatially explicit characterization of the dynamic processes of structure and function of the canopy can be complex using conventional methods, particularly in slow-growing boreal forests where stands may appear open and patchy.
- Multi-temporal lidar data spatial analysis has the potential to advance our knowledge on canopy gap dynamics.

2. Questions

- How best can lidar help in delineating recent canopy gaps of boreal forests?
- How are the gap processes, like random new gap, gap expansion, gap closure from the side and gap closure from below, occurring in these forests?
- Are the older stands maintaining equilibrium with regard to the structure compared to the younger stands in the boreal forests?

3. Study site

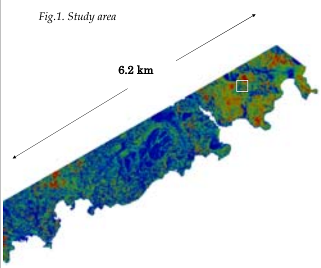
- 6 km^2 of the Conservation zone (Fig.1) in the Training and Research Forest of Lake Duparquet, Quebec (latitude 48.5 N)
- Largely mixed wood boreal forest with trembling aspen (*Populus*), white birch (*Betula*), white and black spruces (*Picea*), jack pine (*Pinus*)

4. Data

- Optimally constructed and co-registered 0.25 m resolution Canopy height models (CHMs) or vegetation surfaces of the medium density discrete lidar data* acquired in June, 1998 and August, 2003 (a sample window in Fig. 2).
- Reconstructed stand initiation maps.

* Independent assessment of both lidar datasets for maximum tree height with ground measurements showed r^2 of 0.88 and 0.86 respectively

Fig.1. Study area



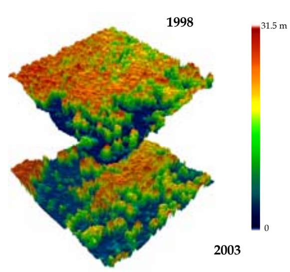


Fig.2 CHMs of parts (box) of the study area in 3-D

5. Defining canopy gap on lidar vegetation surface

Gaps are individual objects of contiguous binary grid cells determined by a gap indicator function (1) and that has a minimum size of 5m^2 represented by atleast 3 lidar vegetation returns. For a given grid cell at *(x,y)* on the CHMi , i = 1998 and 2003, a gap indicator function is:

$$G_i(x,y) = \begin{cases} 1 \;\; if \;\; CHM_i(x,y) < a \\ 0 \;\; otherwise \end{cases} \qquad (1)$$

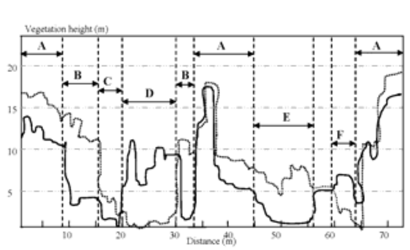
where a = 5 m in this study, CHMi(x,y) is the lidar height of the canopy surface in the ith year, (x,y) is a cell that does not belong to any open-ended system.

6. Field verification and accuracy

- Number of gaps and gap length measured along 4 transects of 980 m length on ground in September 2004.
- DGPS and compass were used to cruise and Vertex III to measure the distance.
- The percentage number of gaps and the proportion of the total gap length along the transects matched between the lidar derived and ground measured were compared.

7. Mapping gap dynamic characteristics

Using the definitions describe below, various combinatorics on gaps objects of 1998 and 2003 is applied to map different gap events, gap expansions, random new gaps, laterally closing gaps and regerenerating gaps.



Vertical profile (bold line : 1998; dotted line : 2003) along a random transect from the multi-temporal lidar CHMs showing the dynamical changes between 1998 and 2003. (A) represents a high canopy where canopy height, h > 5m; (B) Region where an old gap of 1998 is laterally closed in 2003 by the adjacent high canopy; (C) An old gap that is still open in 2003; (D) Gap expansion from the old gap; (E) Gap closure from below due to regeneration; (F) Random new gap

8. Results

Accuracy assessment

- Comparison of 29 field measured gaps with lidar derived gaps showed a good agreement.
- Overall, the number of matched gaps is 96.5% and matched gap legth is 73.05%.

Accuracy assessment of lidar canopy gap delineation

Transect Number	Transect length (m)	Field		Lidar		% match	
		# gaps	Gap length (m)	# gaps	Gap length (m)	# gaps	Gap length (m)
1	300	7	149.96	7	158.5	100.00	105.69
2	160	8	84.99	8	78.8	100.00	92.72
3	240	6	73.01	5	71.8	83.33	98.34
4	280	8	115.2	8	69.06	100.00	59.95
Total	**980**	**29**	**423.16**	**28**	**309.1**	**96.55**	**73.05**

Gap characterisation

- Gap size distributions varied significantly in both years (Kolmogorov Smirnov test, p<0.01), but both followed log normal distribution.
- The total area under gaps decreased as the annual rate of gap closures (1.25%) is twice that of the new gap openings (0.66%)
- These forests consistently maintain an open area of about 23%
- Of the existing gaps in 1998, 49% of them closed mostly due to regeneration, 21.3% expanded and 19.7% partially closed and opened by 2003
- The estimated turnover times are 144 and 80 years respectively for new gap opening and closures.

Fig.4 Mapping of dynamic gap characteristics

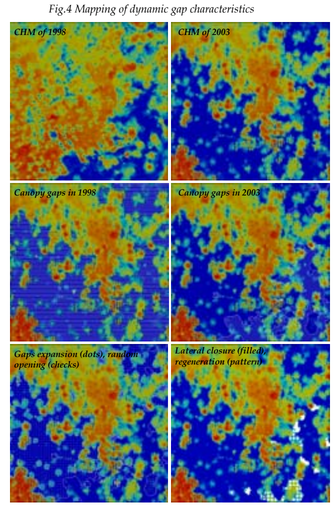
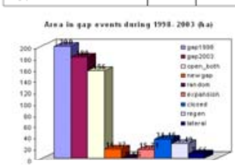
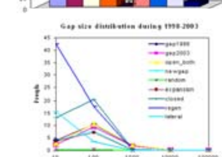


Table 2. Comparing gap characteristics of 1998 and 2003

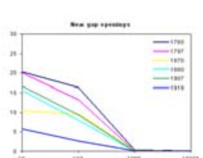
Statistic	*1998*	*2003*
Max vegetation height (m)	31.15	33.5
Total number of gaps	9466	7857
Minimum gap size (m^2)	5	5.01
Maximum gap size (ha)	9.8	9.2
Mean gap size (m^2)	156.37	202.28
Median gap size (m^2)	19.6	24.46
Total area under gaps (ha)	200	180.08
Percentage frequency of gaps < 100m 2	86.7	85.1
Number of gaps of size > 1ha.	23	30
Gap fraction	0.38	0.32

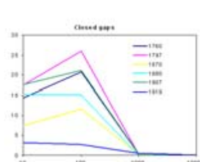


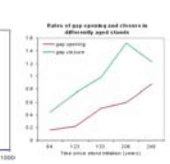


Gap dynamics in different aged stands

- New gaps are opening more frequently in the oldest than in the youngest stands.
- Mean new gap size increased from 17.77 m2 to 22.88m2 as the stand age increased from 84 to 243 years.
- Annual rate of opening as well as closure is increasing with stand age, while the oldest stands are coming closer to equilibrium.







9. Conclusions and Prospects

- The study of this large contiguous area confirms that gap disturbances do determine the structure and processes of the mixedwood boreal forests.
- Lidar is an excellent tool for delineating gaps formed by single to multiple tree falls even in a complex canopy structure.
- Multi-temporal lidar data analysis helped in rapidly acquiring their short-term dynamics a new dimension to our current understanding of the role of canopy gap disturbances.
- With a potential to extend to a long-term combining lidar and photogrammetry, we should be able to improve our knowledge of role of gaps in successional dynamics, especially in maintaining mixedwoods.
- This new insight will also have direct implications where natural disturbance is used as a template for management practices

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