LiDAR Mapping as an Aid to Partial Cutting in Heterogeneous Stands

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This presentation shows how Canopy Height Models (CHM) derived from LiDAR (lidar, LIght Detection And Ranging) can facilitate implementation of partial cutting in a Maple and Yellow birch forest in New-Brunswick (Canada). Partial cutting with selection and shelterwood silvicultural systems are commonly used in tolerant hardwood forests in Eastern Canada. Cost savings are possible when the trees to be felled are selected by the machine operator rather than by a tree marker in a separate phase of the work. FPInnovations and Natural Resources Canada have developed an innovative approach as a tree selection aid for machine operators in heterogeneous stands. The innovative approach called the multiple-treatment approach (Lussier and Meek, 2014) is an operational tool designed to help the implementation of this silvicultural treatment. It recognizes that a heterogeneous stand is composed of a mosaic of micro-stands and each micro-stands needs to be harvested with its own selection rules. The CHM from Lidar should help the operator to easily analyse the stand structure in close proximity around the machine.

In most situations, the stand composition and the history of past disturbances (mortality caused by insect outbreaks or unmanaged cuts) are similar through the stands. The tree species and the stand structure are causing the micro-stand variations. The process by which the micro-stands are classified results generally in 3 or 4 microtypes covering most cases within the stands. Such classification is based on low density sampling and also helps to define the different sets of guidelines for tree selection. is the individual selection rules must be coherent with the overall silvicultural goal defined for the entire stand. The operators are asked to recognize the stand conditions surrounding the machine, to select the appropriate set of guideline and to perform the harvesting. The use of Lidar to facilitate this process was validated in a test area with 3 treatment variants.

From Lidar data covering the tested area, a Canopy Height Model (CHM) derived from the Digital Surface Model (DSM, interpolated using the first returns of laser) and the Digital Terrain Model (DTM, interpolated using last returns classified as ground) allows approximating the importance of the large tree (mature) level and mid-sized (immature) tree level in the canopy for each surface unit (pixel or tile). The assumption is that the density of the first returns over 16 m on the CHM is closely related with the density of large (mature) trees detected by the pre-treatment sampling.

Figure 1 present a synthesis of the metrics used to sort the 30m X 30 m tiles into the 3 treatment variants. This is based on the percentage of hits reaching the mature tree height class and the percentage of hits reaching the immature tree height class. When the returns indicate that the canopy is mainly occupied by large trees, the risk of excessive removal is high and the selection rules propose a partial removal of large trees. When the canopy is composed of a more even mix of mature and immature trees, the cutting rule can direct that most large trees can be removed, since it is assumed that the immature trees will develop into an appropriate future stand. When there are no strong indication of the presence of mature trees (the darker zone), no felling is expected. The determination of the critical canopy height on the CHM and the setting of the limits between the different cutting rules zones are the real challenge of the trials.

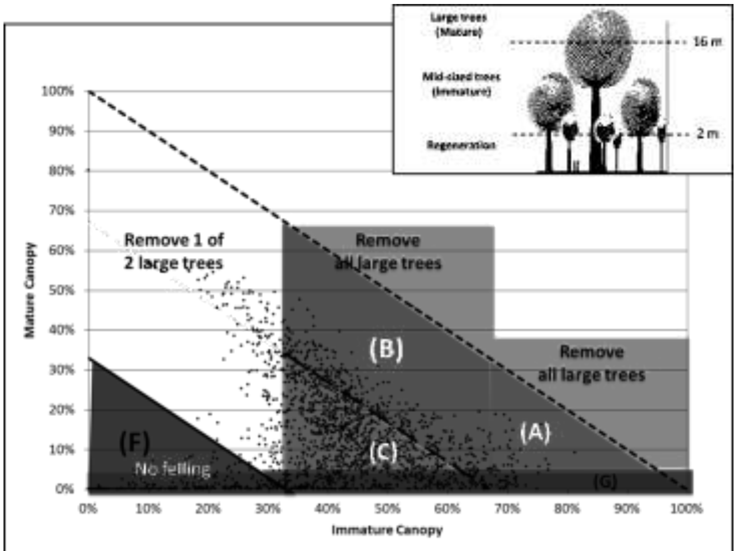

Figure 1 . Upper-rigth corner : Classification of heights from the CHM. Distribution of the tiles according to their relative content of hits into the mature and immature classes.

The treatment proposal as shown in figure 2 is being displayed on the machine's GPS navigation screen. Individual tiles of the grid (30m X 30m) are proposing one of the three cutting rules to select the trees to fell. During our first test of the concept, a harvester (Tigercat H822C with a Waratah 622 head) was observed during 16 hours in two similar areas, one with the assistance of the map and one block without. The harvester operator was asked to navigate in the stand in order to create 5 m wide trails spaced at 20 m. On each side of the trail, the operator observed around the machine, within the crane reach, and selected the appropriate set of cutting rules in order to harvest 50 % of the volume (priority to the valuable products), maintain an uneven-aged stand structure and to facilitate the regeneration of yellow birch, a mid-shade-tolerant specie.

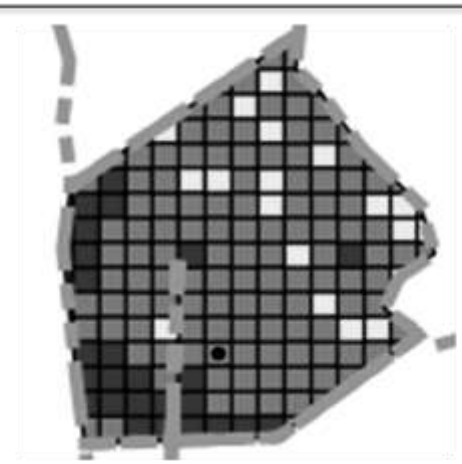

Figure 2. The block dot indicates the position of the harvester on the 30 m X 30 m grid. The dark tiles means no harvesting; the gray ones suggest the removal of half of the big trees (40 cm +); the white ones suggest the felling of all the big trees.

The three set of cutting rules were:

a- If there is 1 large tree (40 cm +) in the machine operating area, fell the tree. Leave standing all immature trees.

b- If there are 2 large trees (40 cm +) or more in the machine operating area, cut one with the priority to the most valuable (less defect).

c- If there is no large trees, no felling.

Two blocks were prepared for the harvesting and were surveyed before treatment and after treatment. In each sample plots (100 m² or prism-variable surface), the forester evaluated the stand conditions and selected which set of cutting rules to be applied.

Table 1 shows the surface distribution for the sets of cutting rules as evaluated by the field evaluations and by the Lidar processing. The two field evaluations present variations up to 10 % of the surface coverage. The Lidar estimates provided clear over-estimates of the “cut all big trees” set of rules. This occurred despite an extra validation of the treatment map before the installation of the map into the harvester navigation system.

Table 1 . Relative importance of treatments as estimated for the two blocks treated during the trials.

	With map assistance			Without map assistance		
Cutting Rules	Field Before	Lidar Map	Field After	Field Before	Lidar Map*	Field After
Sampled surface (m²)	300	900	200	300	900	200
No cutting	25%	17%	17%	17%	17%	28%
Cut 1 of 2 large trees	30%	11%	27%	42%	16%	36%
Cut all large trees	45%	72%	56%	41%	67%	36%
Total	100%	100%	100%	100%	100%	100%

*Not used by the machine operator

This important difference was analysed and a plausible explanation can be provided. The concept of the multitreatment applies on small surface units where a machine operator can apply the rules: the crane reach. It corresponds to a surface that varies from 100 to 200 m². In such a small area, it is less obvious to find a stand structure with a vertical arrangement of mature and immature stand. With larger reference areas, such as the Lidar mapping process involves, close to unevenaged structure are more easily found.. This is an important learning of the present project as there is a need to identify the metrics that would better align with the capabilities of the operators to apply the cutting rules. Factors like the height criteria, the size of the pixels, and the use of multiple return hits all need to be revaluated for example. This approach is nonetheless quite promising because the overall performance evaluation of the harvesters was very positive:

- The machine productivity was good into the two tested block;
- The application of the cutting rules was appropriate;
- The overall silvicultural objectives (% removal, product value, regular trail network) were fairly well achieved;
- The map showed the concentrated areas of “no cutting” allowing the harvesters to avoid them.

The successful development of this mapping & decision process will be very beneficial when the system will permit the harvesting of the appropriate trees within very heterogeneous forest without negatively affecting the silvicultural development of the stands.

Reference : Lussier, J.-M. and P. Meek (2014) *Managing Heterogeneous Stands Using a Multiple-Treatment Irregular Shelterwood Method*, J. For. 112(3):287–295