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Contents

Efficiency of the 1-2-3 Selection Cutting Method in Hardwood Forests

Keywords

Selection cut, Tree selection procedure, Hardwood forest, Productivity, Hardwood Initiative, Harvesting costs.

Abstract

The 1-2-3 selection cutting method was originally designed as a low-cost and practical silvicultural alternative for efficiently managing softwood harvests. Through the FPInnovations Hardwood Initiative, two operational trials were conducted in predominantly sugar maple stands to measure the efficiency of the 1-2-3 method when applied to hardwood forests. In both trials, feller-buncher operators were able to rapidly apply the method's specific trail design and tree selection rules after a brief training period. By comparing pre- and post-treatment stand characteristics and composition, as well as tree vigour, crown release, and growing conditions, the method showed it was able to improve overall stand quality. The method's harvest system also resulted in high machine productivity at a competitive cost. While only extensive implementation could truly reveal the method's full potential, both trials suggest that the 1-2-3 selection cutting method is well suited to hardwood forest harvests.

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and
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Introduction

In recent years, FPInnovations' research program has allowed the development of non-clearcut harvesting approaches that meet sophisticated silvicultural objectives at a reasonable cost. Among them, the 1-2-3 selection cutting method was designed by FPInnovations to allow single tree harvesting operations under the concept of a "continuous cover forestry" system marked by periodic stand entries (Meek and Cormier 2004). Successfully maintaining an uneven-aged stand depends on three main criteria: 1) the harvest of poor-vigor mature trees, 2) significant crown release to allow accelerated growth of residual intermediate trees, and 3) suitable conditions for the regeneration of shade tolerant or semi-tolerant species. The 1-2-3 method has been developed with these objectives in mind.

As part of the FPInnovations Hardwood Initiative (FPInnovations 2011), the method was adapted and transferred to hardwood stands where traditional selection cutting pre-harvest requirements were not met. After some preliminary trials in the fall of 2009, FPInnovations collaborated with Northern Pulp Nova Scotia Corporation (Nova Scotia) and Port Hawkesbury Paper (PHP, NewPage at the time of the study) (Nova Scotia) to test and implement the 1-2-3 method using a three-machine cut-to-length system. The two main goals of these trials were:

1) to test how the tree selection procedure would improve the stand, and
2) assess the method's productivity and cost effectiveness.

Harvesting system and equipment

Both trial harvests were performed using a three-machine cut-to-length system composed of a feller-buncher, a processor and a forwarder. Figure 1 shows the feller-buncher and processor working in the Northern Pulp block studied. In both locations, predominately sugar maple stands were selected to conduct trials. The sites were located in Colchester County and in Antigonish County for Northern Pulp and Port-Hawkesbury Paper respectively.

Description of the 1-2-3 selection method

As its name suggests, the 1-2-3 method relies on three basic steps:

1) implement a repetitive pattern of trail, selection and untouched zones that allows a rotation of four entries into the stand,
2) establish simple tree selection guidelines based on target end product, removal intensity and vigour management, and
3) continuously control harvests by regularly providing feedback to machine operators.

Trail network

The trail network in the blocks studied was based on 5 m wide trails spaced at 30 m. Width of trail and selection cutting

Figure 1. Feller-buncher and processor working on two trails in the Northern Pulp block studied.

zones were set to meet standard harvesting equipment specifications: a feller-buncher's overall width varies from 2.5 to 3.4 m and its effective boom reach may measure up to 7.5 m. Operators were first asked to clear cut a straight 5 m wide trail that also would accommodate the two other machines (in dark brown in Figure 2). On each side of the trail, 5 m wide selection zones were selectively cut removing 50 % of standing trees according to specific selection guidelines (in light beige in Figure 2). Considering the combined width of the trail (5 m) and of both selection zones (2 x 5 m), a 15 m zone was left untouched along each selection zone (in dark green in Figure 2). Along the trails, pairs of trees form the gates. Their crowns are marked in yellow. Those trees are chosen by the operator because they are approximately separated by 5 m and they are left standing as a structure helping to maintain appropriate trail width.

The second entry will recreate the same trail and selection zones pattern offset to the 15 m wide zone left untouched at the first entry (Figure 3). The two last entries will eventually target the areas between the first two sets of trails. The time interval between two entries corresponds to a fourth of a full rotation required to produce a mature tree and depends on target wood product and species. Systematically sliding the pattern's position to harvest regenerated stand areas addresses the concept of "perpetual forest cover" by allowing the development of four tree cohorts.

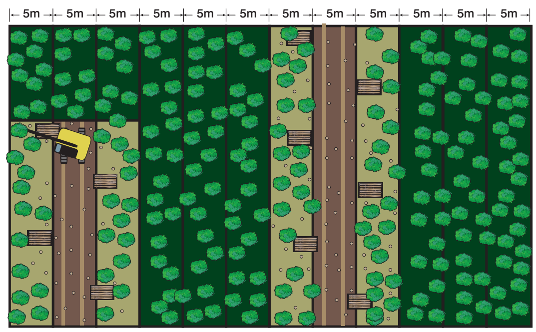


Figure 2.
The 1-2-3 single tree selection cutting method (first entry).

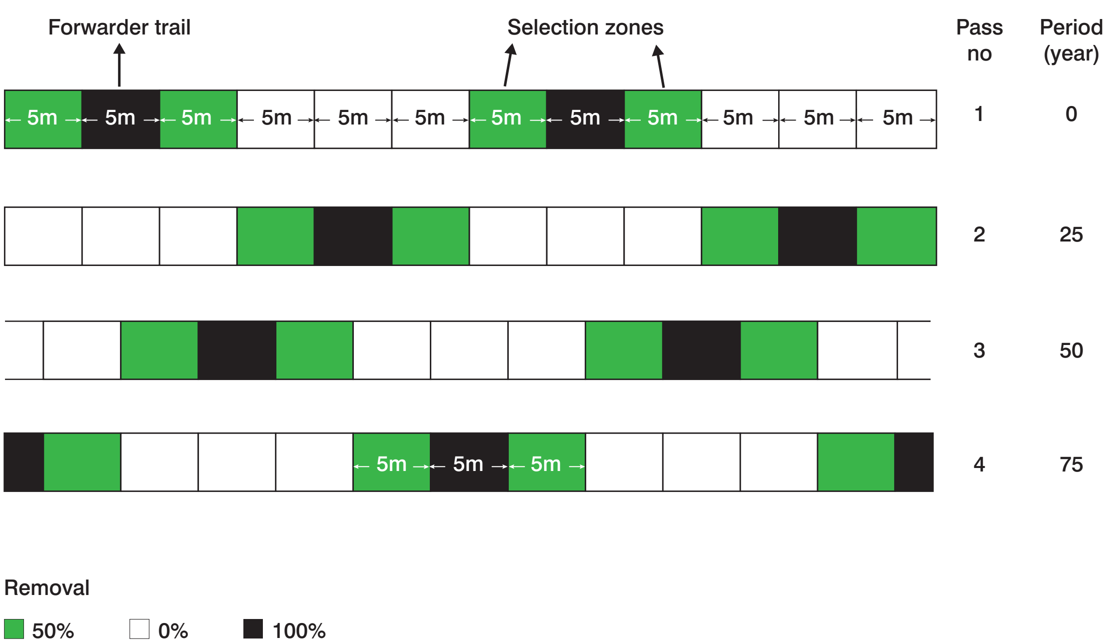


Figure 3.
The trail and partial removal zone locations for the four entries per rotation.

Tree selection guidelines

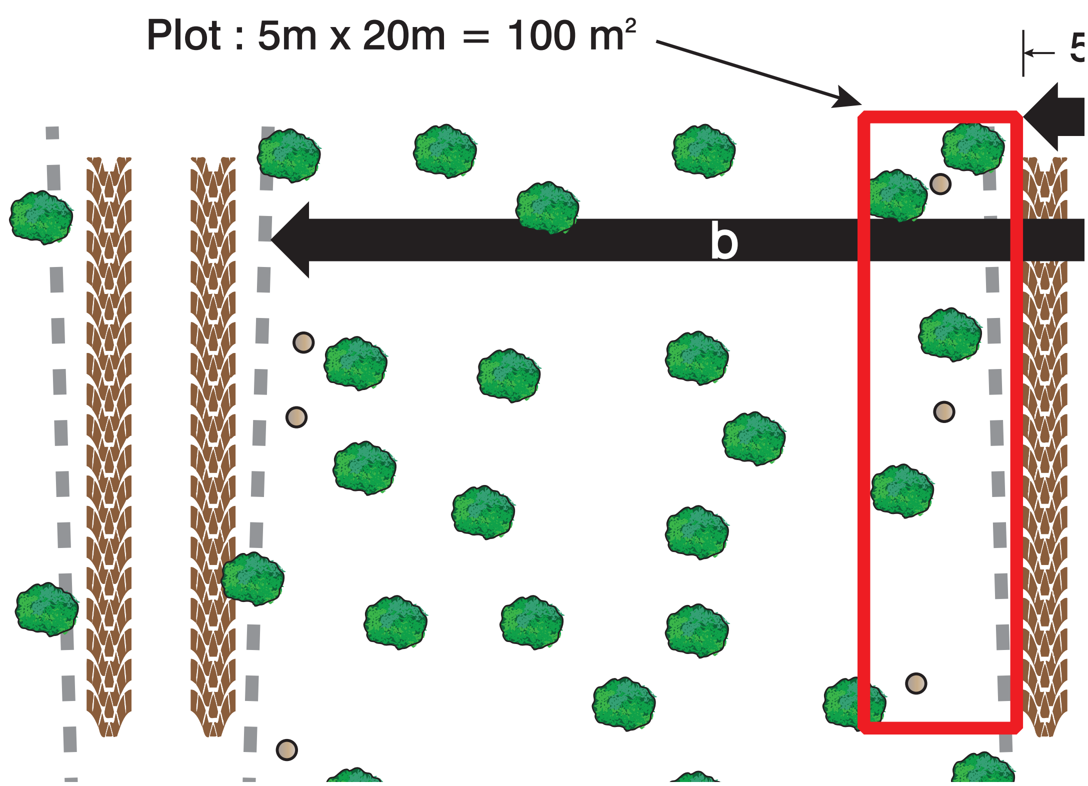
The second part of the 1-2-3 method refers to tree selection guidelines. These guidelin es are established by the operations supervisors during a preliminary stand assessment to address local silvicultural issues and facilitate their implementation by operators. They must provide the means of controlling removal intensity and vigour management when applied from a machine cab perspective. This explains why a simple tree count process (e.g. remove one tree out of three or out of four) and an operational tree vigour classification are used. Supported by the pre-treatment inventory, the tree count aims to harvest 50% of the volume in the two selection zones neighbouring the trail. Such removal in these zones provides an overall removal rate of 32% in the stand, including trails and untouched areas. Size classes and/or vigour classes are used to determine removal priority. For example, the operator could be asked to count three trees in the selection zone and fell the largest. From experience, the removal rate in the selection zones varies typically between 40% and 60%. However, if the diameter range is very wide as is often the case in a tolerant hardwood stand, removing one out of four trees would be more appropriate for achieving 50% target.

In both trials, the vigour classification developed by FPInnovations used three classes:

Q1: A tree with no noticeable defects,
Q2: A tree with a noticeable defect on one or two faces of the trunk and
Q3: A tree with a noticeable defect on three or more faces.

"Noticeable defects" should account for local conditions and market tolerances. The operator had to analyze the lowest 6 m of the stem and look for defects such as any type of fork, seam, canker, curve, or general damage on the tree. The supervision crew had to develop a list of major defects to

Figure 4.
Shape and location of a control plot in the selection zone. Trail width (a) and trail spacing (b) are also evaluated.



confirm that not all trees were bad or a rare component of the stand. When operators know how to sort the worst 33% of trees, they may apply the guidelines.

In the Northern Pulp trials, it was easy to establish selection guidelines since the small diameter at breast height (DBH) class (DBH = 10-22 cm) presented the highest Q1 proportion (46%) of all classes. Removing all the large trees (≥ 40 cm) and half of the mid-sized trees (24-38 cm) bearing noticeable defects would let vigorous small and mid-sized trees develop at an accelerated rate. Pre-treatment sampling results indicated that those guidelines would result in a 50% removal rate. In the NewPage trial, the selection guidelines first called for "cutting the largest of four trees," assuming large trees (with DBH ≥ 40 cm) would be felled. However, the wide variation of small DBH stems in the stand resulted in many mid-sized trees being harvested. The selection guidelines were then changed to cut the less vigorous of two large trees (DBH ≥ 36 cm). This increased the proportion of Q1 trees and maintained a regular residual canopy while favoring crown release.

Control

As the harvest proceeds, stand supervisors must monitor the effects of the treatment guidelines on the stand by examining control plots after felling. In both trials, 100 m^2 control plots (5 m x 20 m) were established in the selection zones (Figure. 4). The number of trees and stumps in each DBH class was noted. The residual trees are classified and their proportion is compared with the pre-treatment results. Trail width and trail spacing are also assessed. Operator compliance to guidelines is evaluated using these indicators with the appropriate tolerance and rapid feedback is provided to the operators to adjust his removal intensity.

Results and discussion

Stand conditions and treatment effects

Stand description

The characteristics of the two stands studied are described in Table 1. On average, there were fewer trees per hectare in Northern Pulp's stand, but they were larger on average than those in the PHP stand. The stands were typically uneven-aged with a large number of small trees that were not distributed uniformly.

		Northern Pulp	PHP
Stand density	(stem/ha)	468	766
Basal area	(m^2/ha)	17.6	24
Volume density	(m^3/ha)	108	162
Average stem volume	(m^3/stem)	0.231	0.211
Average DBH	(cm)	21.9	20
Quality 1 trees in proportion of basal area	(% m^2/ha)	30	33

Table 1. Pre-treatment stand inventory characteristics

Removal rate and stand improvement

In the Northern Pulp study, 80% of the large trees and 38% of the mid-sized trees were felled in the selection zones, indicating that the operator was meeting the removal guideline targets. The average size of trees harvested was 32.7% larger than the pre-harvest average. From a harvesting economics perspective, this is one of the method's major benefits. The larger trees not only generally provide a more valuable product basket, but also contribute to keeping harvesting costs low, close to the conventional clearcutting costs.

Before treatment, 41% of the stems received a Q1 rating whereas this proportion increased to 45% after treatment, indicating that the operator was able to avoid harvesting many of the future crop trees. In the selection zones, the proportion of Q1 increased to 60%, demonstrating the stand improvement aspect of the 1-2-3 selection cutting method. During the trials, no quality increase goal was set, but this could easily be integrated into the treatment quality monitoring procedure.

In the Port Hawkesbury trial, a 27% reduction in stem density represented a 33% volume removal per hectare. Also, the average harvested tree volume was 0.262 m^3, which was 24% higher than the average stem volume for that stand (0.211 m^3/tree). It is well known that machine productivity will benefit from this increase.

The proportion of Q1 rated trees in terms of basal area (m^2/ha) before and after harvesting increased from 33% to 38%, indicating that the 1-2-3 method effectively led the operator to cut defective trees in priority. These observations all indicate that the 1-2-3 method is appropriate to control tree removal without having to mark trees or trails.

Changes in growing conditions in residual stands

In the PHP operation, crown release was measured as an indicator of growth conditions. This variable was measured with a five-class system that considered that any tree may have between zero and four neighbouring trees with crown competition. The canopy before treatment was considered to be closed where 2/3 of the basal area was composed of trees with 4/4 crown competition. After treatment, the proportion of the basal area trees with 4/4 crown competition decreased to 38%. These improved growing conditions were achieved despite the fact that felling was concentrated on only 50% of the stand's area in the selection zone. After treatment, 23% of Q1 rated basal area had lost at least one competing tree and 11% had lost at least two competing neighbors. The 1-2-3 selection cutting method therefore, demonstrated its ability to specifically improve growing conditions of the best trees in the canopy by combining vigour and crown release analysis.

Table 2.
Stand description pre- and post-treatment

		Northern Pulp				PHP			
		Pre	Post	%[1]	Harvested	Pre	Post	%[1]	Harvested
Density	(stems/ha)	731	551	-25	180	766	559	-27	207
Volume	(m^3/ha)	165	111	-33	54	162	108	-33	54
Avg. volume	(m^3/stem)	0.225	0.202	-10	0.298	0.211	0.192	-9	0.262
Proportion Q1		41[2]	45[2]	+4	34[2]	33[3]	38[3]	+5	20[3]

[1] Harvested percentage compared with pre-treatment value
[2] % stems/ha
[3] % m^2/ha

Trail networks

Complying to the designated trail network is critical to success using the 1-2-3 method. The operator's ability to meet trail width and trail spacing was assessed in the control plots during both trials. In the Northern Pulp and PHP studies, the average trail width was 5.0 and 5.1 m respectively, while it never or almost never exceeded 6 m. This demonstrated that operators were able to reach the target trail width and spacing using the "gate" approach proposed by FPInnovations (Meek 2006). The spacing between trails averaged 30.8 and 28.7 m and measured between 26 and 34 m in 84% and 85% of the cases respectively in each trial. One of the operators used a GPS navigation system (an FPDat system developed by FPInnovations) whereas the other operator had to visually gauge the spacing. As a training tool, some trail ribboning helped the operators evaluate the appropriate spacing.

Productivity and cost

Felling

At Northern Pulp, the felling was done with a Tigercat 860C feller-buncher. Productivity was good in both the clearcut and selection cutting zones, indicating that the operator quickly understood the rules of the 1-2-3 selection cutting method (Table 3). The 15% drop in productivity (m^3/PMH) is largely explained by the increase in moving time associated with the selection cutting harvest. The operator's need for a clear line of sight when deciding which trees to select increased the amount of time spent brushing. The average stem harvested was smaller by 4% in the selection cut compared with the clearcut block, mostly due to fewer large softwood trees available in the selection zones. Many of the large and least vigorous (Q3) trees left standing at clearcut were cut during the selection portion of the harvest. The calculated 18% increase in felling costs is similar to that observed in other case studies.

Table 3. Productivity and cost for the feller-buncher in the 1-2-3 selection cutting method trials

Activity parameters		Northern Pulp		PHP	
		Clearcut	Selection	Selection 1	Selection 2
Study duration	(PMH)	2.1	5.3	7.7	7.4
Average stem volume	(m^3)	0.310	0.296	0.343	0.274
Productivity	(stem/PMH)	202	182	167	184
Productivity	(m^3/PMH)	62.6	53.9	57.9	50.4
Direct operating cost[1]	($/PMH)	120	120	121	121
Felling cost	($/$m^3$)	1.92	2.22	2.08	2.40
Work cycle elements Time distribution					
Move	(%)	14	27	39	40
Brush	(%)	10	16	14	11
Cut	(%)	43	37	29	22
Move to bunch	(%)	0	2	2	1
Arrange bunch	(%)	0	0	1	1
Bunch	(%)	27	12	9	19
Operational delays[2]	(%)	6	6	6	6

[1] Cost including direct operational cost
[2] Adjusted operational delays

At PHP, overall harvest results were collected during the first and second week the method was implemented. The average harvested tree volume was 20% lower in the second week (Table 3). This reduced the volume per PMH by 13% despite the fact that stem productivity increased by 10%. It shows that the operator was already productive during the first days with the new selection cut using the 1-2-3 method. Overall, the costs are very competitive. The detailed time distribution for the work cycle elements indicates the 1-2-3 method was more efficient than the conventional single tree selection previously studied in the Ottawa River Valley (Meek, 1997) where trees were marked for removal, which increased machine travel away from the main trail.

Processing

Processing in the Northern Pulp operation was done with a Tigercat carrier equipped with a Hornet processor head. The measured productivity of 15 m^3/PMH was considerably lower than what would be expected on a clearcut operation for the same average stem volume (Table 4). This can be explained in part by the effort of the operator to maximize fibre recovery, yielding insufficient volume for the effort. Another negative factor was the use of the cumbersome butt-plate processing head combined with a wide machine tail swing. Particular care was required to avoid damaging adjacent residuals or gate trees. An alternate working pattern (half-moon) allowing clearcutting within the selection zone was tried briefly before the trial ended, which appeared to reduce some of the difficulties related to maneuvering the processing head. Overall, the \$8.61/m^3 processing cost can be expected to decrease as operators become more proficient. However, this type of head will likely be a limiting factor to further improvements. While the processor was not observed in

Table 4. Productivity and costs for the processor in the 1-2-3 selection cutting method trials

		Northern Pulp		PHP
Activity parameters		**Selection**	**Half-moon**	**Selection 1**
Study duration	(PMH)	2.5	0.9	3.4
Average log volume	(m^3)	0.106	0.154	0.075
Average stem volume	(m^3)	0.316	0.471	0.33
Productivity	(stem/PMH)	49.2	91.6	59.8
Volume Productivity	(m^3/PMH)	15.5	43.2	19.7
Direct operating cost[1]	(\$/PMH)	130	130	130
Processing cost	(\$/m^3)	8.37	3.01 (4.40[2])	6.59
Work cycle elements				
Time distribution				
Move	(%)	10	14	10
Load	(%)	14	28	22
Arrange pile	(%)	5	0	1
Process	(%)	65	52	61
Operational delays[3]	(%)	6	6	6

[1] Cost including direct operational cost
[2] With comparable tree volume to the Selection
[3] Adjusted operational delays

a clearcutting operation during this trial, the half-moon can serve as a benchmark. After adjustments for the larger tree size, the processing costs in clearcutting were estimated at $4.36/m³.

During the first study week at PHP, the detailed time distribution for work cycle elements performed by the Tigercat 845B processor were not found to be different from those for processing another type of partial cut where the trees are selected individually. Productivity and the estimated felling and processing costs were normal.

Forwarding

At Northern Pulp, although forwarding was studied for a few cycles, the loads were not complete and productivity estimates were meaningless considering the travel distances and short loading and unloading times. The observations at PHP were much more conclusive. The average volume per cycle observed was 11.2 m³/trip (Table 5). The forwarding distances were adjusted to reflect productivity over an average distance of 150 m, typically forwarding cycles with a distance ranging from 0 to 300 m. Productivity was 16.2 m³/PMH, and estimated cost was $7.40/m³. The cycles observed involved mostly pulpwood logs and loading was efficient considering the size of the piles near the trail.

Based on previous observations and assuming comparable forwarding costs, the total direct costs using the 1-2-3 selection cutting method at Northern Pulp and PHP were evaluated at $19.46/m³ and $17.87/m³ respectively (including a 10% profit margin for the contractor). These costs reflect the fact that the study was done in the early in the implementation period and are expected to decrease once operators become more experienced.

Based on the study results, we estimate the cost difference between clearcutting and the 1-2-3 selection cutting would be about $7 to $11/m³ in the study conditions.

Table 5. Productivity and cost of forwarders operated in the 1-2-3 selection cutting method trials.

Activity parameters		PHP Selection 1
Trips		9
Study duration	(PMH)	6.2
Average forwarding distance	(m)	150
Average volume per cycle	(m³)	11.2
Average volume per cycle	(m³/PMH)	16.2
Direct operating cost	($/PMH)	120
Forwarding cost	($/m³)	7.40
Work cycle elements Time distribution		
Travel empty	(%)	6
Maneuver	(%)	5
Load	(%)	36
Move loaded	(%)	11
Travel loaded	(%)	9
Unloading	(%)	28
Operation delays	(%)	5

This hypothetical difference is significant and assumes that harvested trees are of similar average size in both clearcutting and selection cutting. A more realistic assumption would be to expect the average size of harvested trees in the clearcut to be smaller than that of trees in the selection cutting, reducing the cost gap between both types of treatment.

Conclusions

The 1-2-3 selection cutting method was developed to facilitate its implementation in the field by production-oriented machine operators. A key benefit of the 1-2-3 method is its operator-friendliness with an easy-to-follow trail lay-out, simple tree selection guidelines and easy to monitor progress. Both trials demonstrated that a basic set of rules can be successfully followed by operators on their first try. In addition, the method seems to meet the objective of maintain fairly reasonable costs and the cost difference should drop over time from operator experience. Even though different guidelines were established at both sites, the method showed it was able to improve the growing conditions of the residual stand.. Although the costs and the effects on the stands may vary with changing conditions, both trials showed that selection cutting using the 1-2-3 method is viable to manage tolerant hardwood forests. Extensive implementation and observations on a wider range of stand conditions would allow documenting its full potential at larger scales.

Implementation

The 1-2-3 selection cutting method was designed to be easy and quick to implement in the field. It was designed to be adaptable to any operating system or machinery in use. The success of the system depends on:

1) Constant width of trail, selection, and no-harvest zones by using FPInnovations "gate trees" system and GPS navigation (or trail pre-marking) as per the lay-out proposed in Figures 2 and 3. The assignation of the different machines and the monitoring of the activities are easier when a map (Figure 5) the progressing trail network;
2) Suitable tree selection guidelines that can be understood by the operators without tree marking by using pre-established DBH and vigour criteria based on a preliminary stand assessment in randomly distributed plots;
3) Adaptable tree selection guidelines set jointly by operators and managers for improved overall stand quality by considering targeted end product and local density, vigour and regeneration issues (specific visual vigour criteria should be included in the pre-established guidelines);
4) A higher average harvested tree volume per stand and increased volume productivity compared with clearcut or traditional selection cut with advance tree marking according to specific guidelines.

5) The 1-2-3 method implies also a supervision process that allows the first line supervisors to detect rapidly any deviance of the trail layout or defective tree selection. A control system using post-treatment plots is defined in Meek (2006). It is using descriptive variables that can be estimated formally for auditing purposes or informally to provide numerous feedbacks to the feller-buncher operators. The forest conditions are always changing from one block to the next one or within the same block. The proposed process allows continual adjustments and assures that the treatment quality is maintained.

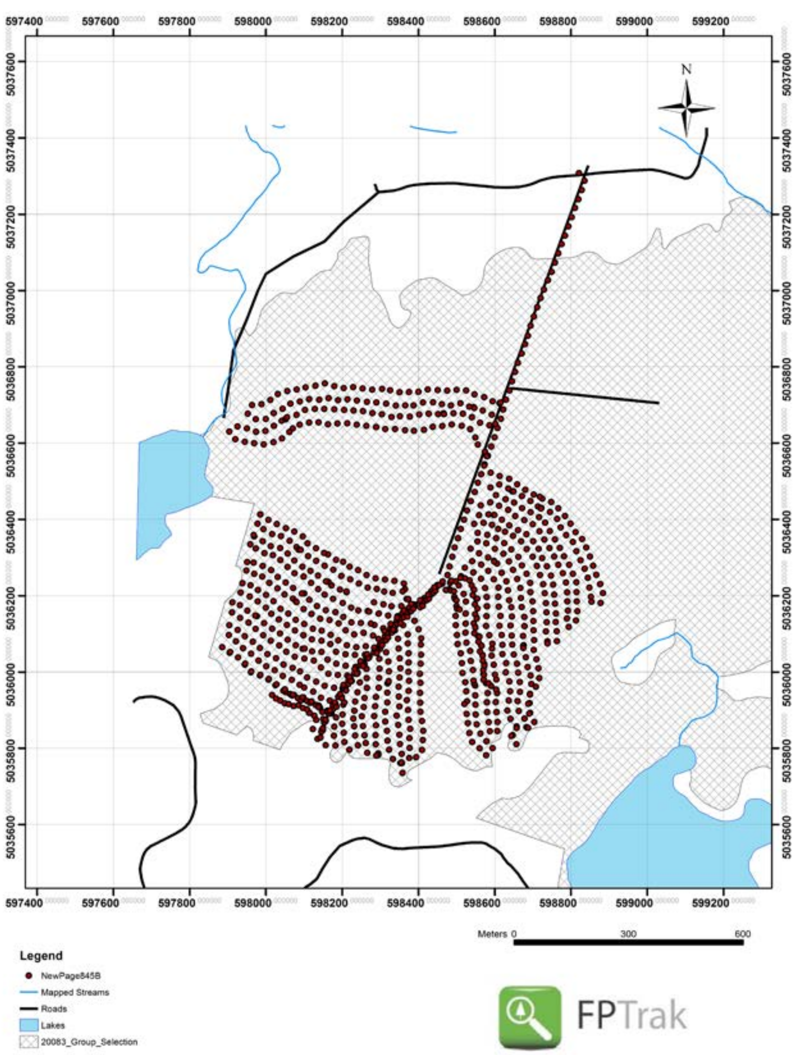


Figure 5. GPS locations as reported by the FPDat unit installed on the feller-buncher during the PHP trial.

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