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INNOVATING CLEAR-FELLING TECHNIQUE TO IMPROVE HARVESTING OF BRANCHES IN MARITIME PINE FOREST

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Abstract: *The use of biomass to produce energy has been strongly encouraged since the signature of the agreements of Kyoto by the European countries. Industries try to decrease their impact on greenhouse effect and to substitute the consumption of fossil energy by renewable energies. In such a context, the pulp and paper companies in South West of France want to find cost-effective solutions to recover slashes after the clear-cuts in the local forest of maritime pine (Pinus pinaster) without compromising the harvest and the supply of pulpwood. They asked FCBA to perform some experimentation to find an operational forest residues bundling scheme, without disturbing the wood supply chain for the pulp mills in the area.*

We seek how to improve the productivity of bundling without decreasing the clear-felling productivity. A new technique of felling was assessed. The operator of the harvester used a directional felling method instead of the traditional crosswise felling method. This new method makes it possible to group the crowns besides the caterpillars of the harvester (an excavator base), to avoid their crushing in too small pieces.

From the results, we can recommend to use the optimized alternative method of "directional felling" instead of the conventional one. The productivity of the harvesting operation is slightly reduced (4%) but the bundling productivity increases significantly (+11%), and the quantity of biomass recovered too (+50%). As far as economics is concerned, the gain with the alternative method will be significant too because the bundler cost is higher than the harvester cost. Knowledge transfer and dissemination toward loggers has to be done now to develop this new technique in the maritime pine forest.

Figure 1: Traditional crosswise clear-felling (on the left) and directional clear-felling (on the right)

1. Introduction

The use of biomass to produce energy has been strongly encouraged since the signature of the agreements of Kyoto by the European countries. Industries try to decrease their impact on greenhouse effect and to substitute the consumption of fossil energy by renewable energies. Moreover, public policies sustain particularly the use of forest biomass for energy production and some concurrence between the different uses of wood (energy / pulp) appeared.

In such a context, the Pulp and Paper companies in South West of France look for cost-effective solutions to recover slash after the clear-cuts in the local forest of maritime pine (*Pinus pinaster*) without compromising the harvest and the supply of pulpwood (Fraysse 2005). They asked FCBA to perform some experimentation on innovating techniques such as bundling for harvesting forest residues, and in particular branches.

Preliminary tests of the Scandinavian harvesting method for preparing the bundling of forest residues, resulting in a row of logs besides a row of branches, both rows being on one side of the harvester tracks (Figure 2), took place in 2003. These tests showed that this Nordic method was not adapted to maritime pine forest, because the quantity of biomass available in such stands after a clear-cut is about 30 to 50 tons of branches per hectare (Cuchet, Roux and Al 2003), which is very low compared to other species as spruce, chestnut or poplar (100 tons per hectare or more). This low quantity of biomass is clearly a limiting factor to make the bundling operation profitable in maritime pine stands.

Of course, with a larger top end cutting diameter for the logs, quantity of biomass for bundling would be more important and the productivity of the bundler would increase directly. Nevertheless, this option is not a solution because it would destabilize the supply of wood to the pulp industries by reducing the volume of pulpwood harvested. Harvesting methods permitting synergy between the harvest of wood energy and pulpwood have to be found.

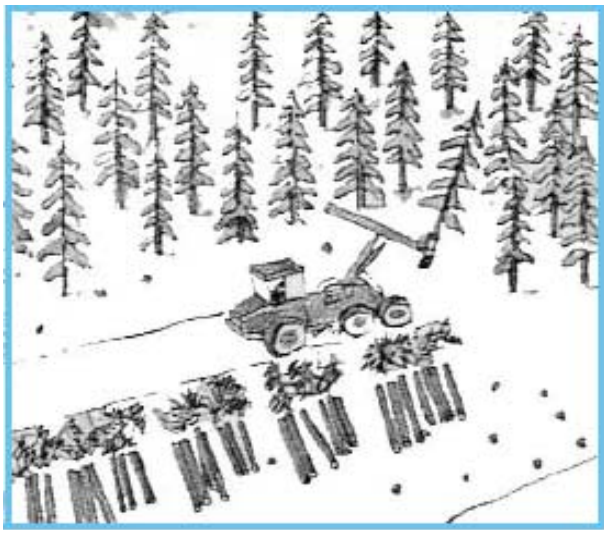

Figure 2: Scandinavian harvesting method for preparing forest residues harvest (source: Skogforsk).

Hence, in order to ensure the profitability of the fuel wood harvesting operation in the maritime pine forest without compromising the supply of the pulp industry, we investigated how to better aggregate slash while limiting the time dedicated to this operation, which is the key point for a satisfying bundling productivity.

We tested two different working methods for mechanizing the clear-cut (the conventional “crosswise felling” and the alternative “directional felling”) and we studied their impact on bundling productivity and quantity of biomass recovery.

2. Material and Methods

2.1 Logging site

The study has been carried out on a 1,8 hectare clear-cut in a maritime pine stand of 55 years. The ground, on a sandy soil, was clean and flat.

In the stand, There were 126 stems per hectare, and the average tree volume was 1,25 cubic meter (average diameter at breast height 42 cm ; average height 22 m). As in any other maritime pine stand, all trees bent in the direction of the predominant wind, e.g. from West to East. The top end cutting diameter was fixed at 7centimeter on bark.

2.2 Machines and operators

The harvester was a 30-tons tracked excavator Case 1288 with a harvesting head Silvatec 665. This equipment had approximately 7 000 machine hours. The operator on the harvester had a lot of experience with the conventional working method (see below) while he was unfamiliar with the alternative method.

The bundling machine was a PIKA 828/2000 forwarder of more than 6 000 machine hours with a telescopic crane of 10 meters. The bundling unit PINOX 330 was installed on the loading space. The operator of the bundling machine was an experienced Finnish contractor used to work in forwarding and bundling operation. He worked according to the Scandinavian working method: he did not seek to collect all the forest residues and thus left a significant part of them on the ground.

Both logs and bundles have been extracted by a forwarder, a Valmet 860. However, extraction of logs took place before the bundling operation.

2.3 Harvesting methods

The mechanized harvesting have been carried out according to 2 different working methods: the conventional one (crosswise felling) and the alternative one (directional, that is to say longitudinal felling).

- Conventional crosswise felling:
The machine advances in a perpendicular axis to the lean of the trees, on a 10 meters working strip. Generally, only trees on the front and the right side of the machine are fallen, and they are bucked frontward on the left side while slashes fell in front of the machine where they are crushed with the further progression of the machine (Figure 2). When the harvester comes to the end of the line, it travels back to start working on a new line.

- Alternative directional felling:
The machine moves parallel to the lean of the trees, on a 14 meters working strip. Trees in the front of the harvester, both on its left and right sides are fallen frontward but hired on the left side. Meanwhile, the excavator cab turns of 90° in order to buck the logs parallel to the caterpillars (Figure 4) and leave slashes also on the left side.

With such a method, forest residues and logs alternate on a single row (Figure 5). This lets less freedom to the operator on where to lay the logs. But, only small quantities of forest residues are left under the tracks of the machine. As in the conventional method, when the harvester comes to the end of the line, it travels back to start working on a new line.

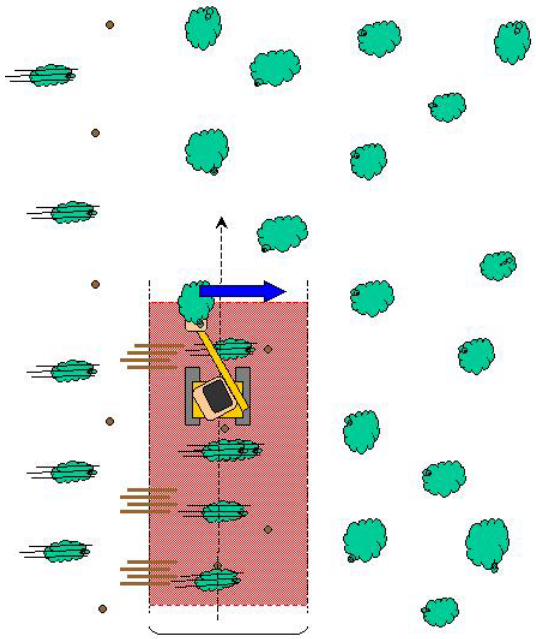

Figure 3: Conventional crosswise felling method (the blue arrow represents the felling direction)

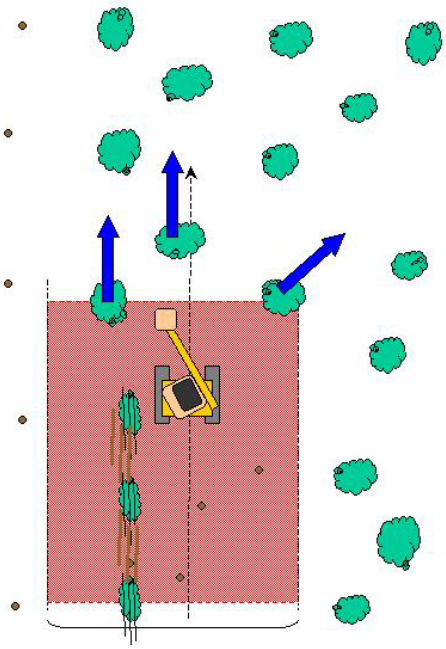

Figure 4: Alternative directional felling method (the blue arrows represent the felling direction)

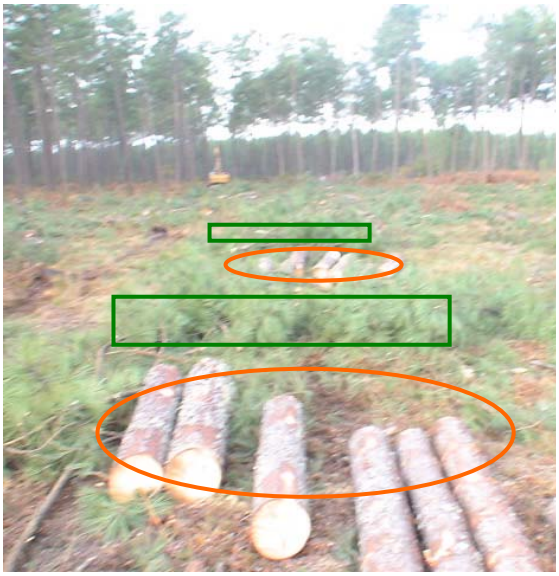

Figure 5: Alternative batches of logs and forest residues

2.4 Measures

Time studies have been carried out tree by tree according to ARMEF protocol (Laurier J.P 1992) for mechanized harvesting. Cycle time is divided into elementary phases: machine movement (including crane movement until it grips the tree), crane movement to transfer the tree (and particularly from the right side of the machine to the left one, for the bucking), delimbing-bucking, forest residues collection.

Time study protocol for the bundler (Figure 6) comes from the FORENEGY project (Martin S. 2002). The bundling work cycle is composed by: machine movement, empty crane movement, forest residues collection, loaded crane movement, bundler feeding, bundles bucking.

Figure 6: Bundler in loading phase

Time elements were recorded with a DAP Microflex hand-held field computer running with the dedicated SDI time study software. Measured surfaces came from a Thalès Mobile mapper GPS with 12 channels.

Quantity of biomass remaining on the ground after the bundling has been assessed through a survey. Biomass has been collected on 90 plots of 1 square meter and weighted. Bundlers have been weighed too

3. Results and discussion

3.1 Time studies on harvester productive work

The only significant difference found between the two harvesting methods concerns the machine movement, which is significantly longer in the alternative felling technique (Table 1). This difference is partly due to the fact that it is a new working method for the operator: he "wastes" some time to approach and grip the tree. This difference should hopefully be reduced when the operator will be more experienced. Moreover, as the work strip is wider in the alternative method than in the conventional one, the proportion of time dedicated to the travel back of the harvester should be more limited in the alternative method.

Table 1: Times per tree for the working phases in the 2 different methods

phases	Convention--nal Method. (Cmin)	Alternative method. (Cmin)	Difference (Cmin))
Delimbing-bucking	79.7	79.8	n.s.
Machine movement	28.1	37.5	*
Crane transfer movement	0.0	3.4	n.s.
Collecting forest residues	0.0	4.7	n.s.
Total time	**107.8**	**125.4**	*****

**significant difference (α = 5 %)*

The two working phases specific to the alternative method (crane transfer movement and forest residues collection) are statistically non significant and they could be even more reduced.

- Transfer movement could probably be divided by two with a more "optimized" working method (Figure 7), consisting in felling and bucking the trees both on the left and on the right side of the machine, depending on where the trees stand.
- Concerning the collecting of forest residues, the operator should concentrate on the collection of the whole crowns, and should not waste time (as he did) in picking up small branches fallen sometimes in front of the machine.

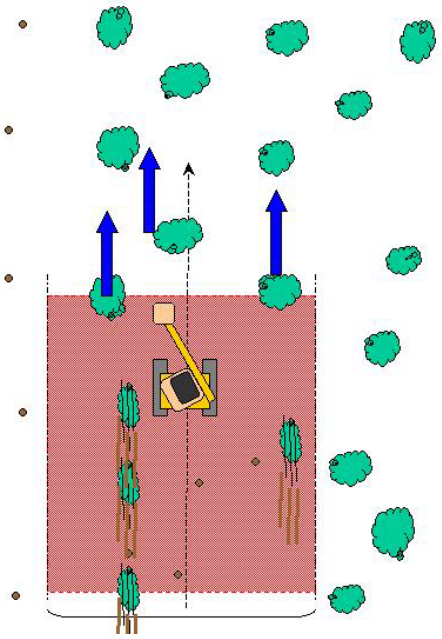

Figure 7: Optimized directional felling

With such improvements, we calculated that the difference on the harvesting time per tree, between the traditional crosswise felling and the alternative directional felling, would fell from 17% to 4% (Table 2).

3.2 Study of the bundling productivity

The study concerned 302 bundles in total. We observed a significant gain of productivity (+ 11%) on the bundling productivity in the area harvested by the alternative method (Table 3).

The fine study of the productive working time shows that "forest residues collection" is the main working phase, even in the area harvested by the alternative method: it takes 38 % of the time (Table 4).

Table 2: Calculation of the potential difference of productivity per tree between the conventional method and the optimised alternative method

phases	Conventional method (Cmin)	Optimized alternative method (Cmin)
Delimbing-bucking	79.7	79.8
Machine movement	28.1	28.1
Crane transfer movement	0.0	1.7
Collecting forest residues	0.0	2.4
Total time	**107.8**	**112.0**

Table 3: Bundling productivity

	Area harvested by the alternative method	Area harvested by the conventional method
Productivity (number of bundlers per Productive Machine Hour)	26.0	23.4

Table 4: Working phases of bundling productive work in the area harvested by the alternative method

phase	percentage
Machine moves	16%
Empty crane moves	7%
Forest residues collection	38%
Loaded crane move	7%
Bundler feeding	26%
Bundles bucking	6%

3.3 Quantity of biomass left on site

The weighing of bundlers and biomass remaining on site after the extraction of the bundlers reveals that only 33% of the forest residues biomass are recovered in the area harvested with the conventional harvesting method, but 53 % in the area harvested with the alternative harvesting method. (Figure 8). The quality of the site preparation, during the harvesting operation, is then crucial.

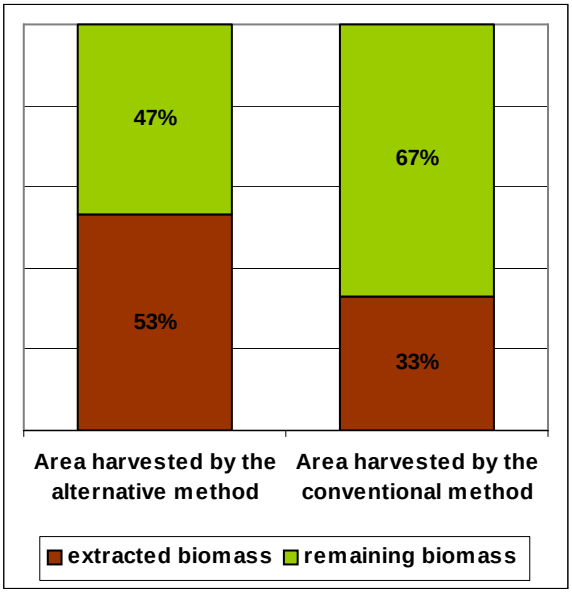

Figure 8: Total forest residues distribution

4. Conclusion

It was already known that only clear-cuts in maritime pine stands can provide sufficient volumes of forest residues to make the bundling of these residues profitable. Bundling should not be done in thinning.

Our experiments showed that even in clear-cuts, site preparation during the felling is crucial to obtain a satisfying productivity in the bundling process and to extract a more important quantity of biomass. If forest residues are too small, too much crashed, the bundling productivity is weak.

From our results, we can recommend to use the alternative optimized method of “directional felling” instead of the conventional “crosswise felling”. The productivity of the harvesting operation may be slightly reduced but the bundling productivity will increase significantly, and the quantity of biomass recovered too.

As far as economics is concerned, the gain with the alternative method will be significant too because the bundler cost is higher than the harvester excavator base cost.

Knowledge transfer and dissemination have to be done now to develop this new technique in the maritime pine forest. Setting up a support action for informing and training the operators is necessary.

5. Acknowledgments

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6. References

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