WOODLOT TECHNOLOGY
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# THE USE OF PILING RAKES ON WOODLOTS

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## Abstract

The raking of debris originated as an agricultural technique. In silviculture, the prime objective of this treatment is to push debris into piles to facilitate subsequent regeneration practices. Raking has a lower productivity than most site preparation treatments because of the alternate backing up and then pushing forward motions. Nevertheless, the simplicity of rakes, their low cost, and the ability to use a variety of prime movers makes raking a suitable technique for small-scale, site preparation operations. This report reviews numerous skidder-mounted piling rakes and their use on woodlots.

## The Origin and Evolution of Piling Rakes

Raking commonly is used in forestry to dispose of the slash on cutovers so as to improve access for subsequent silvicultural operations. It is an adaptation of methods used in agriculture for the conversion of forest and brush cover to farm land. Farmers use land clearing rakes, mounted on bulldozers, to remove and pile undesirable vegetation, stumps and other obstacles impeding the passage of ploughs (Figure 1).

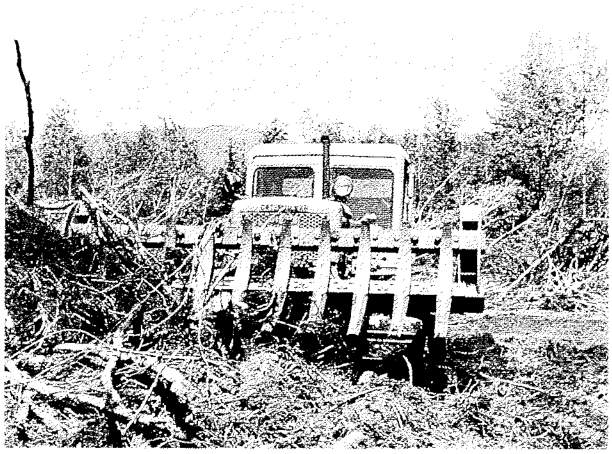

Figure 1. A 1950's bulldozer equipped with a clearing rake.

Since the objectives and intensity of the site preparation required for silviculture and agriculture are quite different, the equipment and methods used also tend to differ. *Clearing* rakes used in agriculture may occasionally be employed in silviculture for site preparation before planting, but are chiefly used for stand conversion and rehabilitation practices to remove and pile undesirable vegetation. The closely-spaced teeth on these types of rakes facilitates this practice. Moreover, such operations require a rake that is heavy and solid, mounted on a powerful and stable machine with good traction like a bulldozer.

When the objective is simply to *pile* logging debris, the rake should be kept above the soil. Such less-demanding operations, rarely involving the removal of standing trees, permit the use of lighter rakes with teeth more widely spaced. As a result, a mobile, faster prime-mover with good ground clearance, such as a skidder, may be chosen (Figure 2). This report provides a review of the use of skidder-mounted *piling* rakes on woodlots.

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KEYWORDS: Site preparation, Mechanical method, Slash piling, Piling rakes, Prime movers, Woodlots, Review, Productivity, Costs.

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Figure 2. A skidder equipped with a piling rake with retractable teeth.

## The Woodlot Scenario

Shortwood harvesting is the most common harvesting system on woodlots. Here the trees are delimbed and bucked at the stump leaving slash throughout the cutover area. In addition, harvesting of private land generally results in more complete utilization than that on Crown land because of the removal of residual trees for firewood. This results in fewer standing trees but increases the amount of slash, particularly the tops of hardwood species.

There are few alternatives to the piling of logging debris on woodlots. Prescribed burning over the area may seem an attractive alternative, but the organization required and the possibility of losing control of a fire close to peoples' homes often renders this option impractical. Other methods such as crushing the slash require large equipment rarely suitable for the small areas usually treated on woodlots.

Woodlot contractors treat areas that are typically small (< 10 ha) and widely dispersed. Even though there may be widespread areas of privately-owned forest in every province, it is broken into small parcels, divided among thousands of owners. The cost of transportation of equipment thus becomes an important consideration and tends to limit the choice of equipment available on a local scale. Small treatment areas also imply considerable manoeuvring on the site, favouring the use of more mobile prime movers such as skidders.

Highway regulations permit skidders to travel on public roads as long as the tire chains are removed on pavement. Bulldozers must be transported on a lowbed. Permits are required for prime movers exceeding 2.6 m in width (generally for skidders of more than 56 kW). These special permits cost less than ten dollars (no charge in New Brunswick).

Generally speaking, site preparation contracts on private land are accorded site by site, usually by verbal agreement. The contractor, therefore, has no assurance of being chosen for subsequent operations. The quantity of work to be done also depends on government funding programs, without which little silviculture would be conducted on woodlots. Modifications or interruptions to these programs thus have a direct impact on silvicultural contractors.

As such, piling rakes are an attractive option for the woodlot contractor. They are simple, inexpensive and permit alternate uses of the prime mover, thus giving the contractor flexibility to diversify his operations.

## The Objectives and Impacts of Piling Logging Debris

Piling of logging debris may be part of the process of returning cutover forest land to productive forest. While the principal objective is to remove the majority of slash from the cutover, other secondary factors may influence the scope of the work to be done. For example, where clearing is the only step before planting, the removal of tree tops, especially from hardwood species, is of prime importance since they most hinder the tree planters' movement and may actually prevent site access to planters.

Minimal site disturbance becomes an objective in fine-textured soils where the planted seedlings might be subject to frost heaving. Conversely, on sites where thick humus layers may compromise the survival of planted trees, the brush rake may be employed to reduce the thickness of the humus and expose mineral soil. Piling rakes are not designed for scarification and it is practically impossible to control the thickness of the material removed or the degree of mixing of the humus and the mineral soil. Furthermore, the removal of stumps may lead to excessive scalping and leveling of the terrain. Such removal of stumps and soil to the slash piles is undesirable as it may lead to depressions in the soil and air pockets and nutrient deficiencies which will ultimately reduce the survival and growth of planted trees.

The operator has a significant influence on the quality of work performed. Where the objectives are not clearly defined for the operator, there is a general tendency to clear the site excessively, causing unnecessary disturbance. The type of rake used also influences the work quality and the level of site disturbance.

Conventional root rakes, with teeth that are short and close together, tend to cause overexposure of mineral soil, remove rocks and stumps, and move quantities of the humus layer and the upper horizons of the mineral soil into the slash piles. The results are less severe than with a straight blade because part of the soil passes through the teeth and is redeposited. However, heavier, wet soils or fine-textured soils are less likely to be redeposited (Green 1977).

Piling rakes, with long teeth at wider spacing, tend to loosen and mix the soil, although the mixture of humus with mineral soil is not uniform. On sites where the humus layer is very thick, this loosening action tends to accelerate drying of the humus at the surface creating microsites unfavourable for seedling establishment. However, this type of rake does minimize the displacement of soil, stumps and rocks because of the decreased surface area pushing at ground level. Experience suggests that four or five teeth, distributed across the width of the blade, provide the best results.

Where scarification is necessary for planting success, raking must be justified by large quantities of slash making soil scarification impossible or at least difficult for the available scarification equipment to perform adequately. A preliminary treatment with a piling rake would facilitate the work of the scarifier and allow for the use of lighter, less-costly scarification equipment.

The slash windrows formed in piling operations result in losses in productive land area depending on the site conditions, the quantity of material piled, the operating procedure used, and the type of equipment utilized. Slash piles normally occupy between 10 and 20 percent of the total surface area treated (Figure 3) (Cormier and Ryans 1989).

The loss in area can be counteracted by decreasing the spacing between planted trees or by burning the windrows. The windrows may however be an advantage because they act as windbreaks which could theoretically provide benefit up to a distance of 15 times their height under optimal conditions (Baldwin and Johnston 1986).

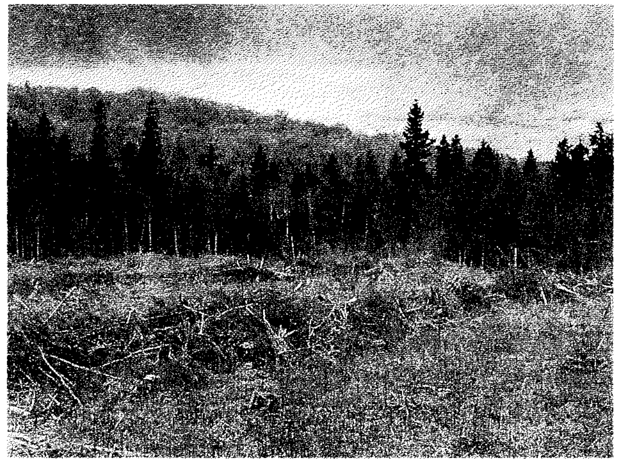

Figure 3. Slash piles generally occupy between 10 and 20 percent of the surface area treated.

Burning of the slash piles produced by raking is sometimes necessary when these piles occupy too much space or where rodents, finding refuge in the slash, would be a problem for future plantations. Burning may also be considered when aesthetic values are important to the woodlot owner or to the general public. In such cases, slash piles must be high, well oxygenated and free of soil to ensure combustion and reduce the risk of the fire flaming up again a few days or even weeks later (Green 1977). Burning the slash piles may not assure complete recovery of the area lost in terms of plantable microsites.

## Characteristics of Silvicultural Piling Rakes

Piling rakes consist of a partially-hollow frame on which are installed teeth of variable length and spacing depending on the model. The teeth are often curved to permit rolling of the debris being moved, and the rake may also be equipped with an accumulating bar on the upper part of the frame which increases the pushing surface and protects the tractor and operator against debris. These rakes are fastened to or may replace the blade of the prime mover. The force required to push a piling rake is less than that required with a straight blade.

Piling rakes may be grouped into two categories: Fixed-tooth rakes and; retractable-tooth rakes. Table 1 provides specifications for some commercially-available models. The simplicity of piling rakes and the lack of lightweight commercial models suitable for small skidders (< 75 kW) has prompted many contractors to make their own. Homemade rakes are variable in concept, limited only by the ingenuity and the technical and financial resources of their numerous inventors. Normally, they have four or five teeth and their width is usually limited to that of the skidder's blade. Generally lighter than the manufactured equivalent, their reliability varies. They are rarely neat in design but represent, more importantly, a minimum investment to the user. For example, a fixed-tooth rake can be made for as low as a few hundred dollars.

## Table 1. A description of some commercial piling rakes

| Piling Rake | Young Brush Blade 31BB and 40BB | Mann Skidder Pin-on Rake MSR-1 to MSR-4 | Fleco BL 518 | Eden | Force | 1. Raumfix<br>2. C.F.E.<br>3. MacDonell Welding |
|---|---|---|---|---|---|---|
| Number of teeth | 6-7 | 7-8 | 6 | 4-9 | 5-6 | 4-6 |
| Tooth retraction mechanism | fixed teeth | fixed teeth (hinged to blade) | fixed teeth (hinged to blade) | hydraulic | hydraulic | mechanical |
| Total width (m) | 2.7 or 3.0 | 2.3-3.0 | 2.0 | 2.5 or 3.0 | 2.5 or 3.0 | 2.5-3.5 |
| Weight (kg) | 750 or 1295 including blade arms | 310-460 | 323 | 900-1500 | 1100 or 1650 | 850-1700 |
| Required power (kW) | made for CAT skidders 518 (97 kW) and 528 (130 kW) | >70 | made for CAT 518 skidder (97 kW) | 75-112 | 82-112 | 75-112 |
| Comments | replaces blade | | | | - available with grapple for use on a loader<br>- replaces blade optional arms | - accumulating bars<br>- replaces blade, (MacDonell only) |
| Approximate price (1987) | $5750-$7950 FOB Seattle, Washington | $3000-$4500 | $2500 FOB Montreal | $15 000 | $30 000 | $10 000-20 000 |
| Manufacturer | - Young Corporation Ltd. Washington, USA | - Mann Corporation (Washington, USA)<br>- Craig's Machine Shop Ltd. (N.B.) | - Balderson Inc. (Florida, Kansas, USA) | - Cazes & Heppner Forest Services Ltd (British Columbia) | - Forest Country Engineering Inc. (Michigan, USA) | 1. Hans Wahlers (West Germany)<br>2. C.F.E. (Ontario)<br>3. MacDonell Welding (Nova Scotia) |
| Distributor | - Caterpillar distributors | - heavy machinery dealers | - Caterpillar distributors | - KBM - Thunder Bay, Ont. | - C.F.E. (Canadian Forestry Equipment) - Montreal, Que.; Mississauga, Ont.; Edmonton, Alberta. | 1. Afortek - Thunder Bay, Ont.<br>2. C.F.E. (Canadian Forestry Equip.) - Mtl, Que.; Mississauga, Ont.; Edmonton, Alberta<br>3. MacDonell Welding and Metal Working - Elmsdale, N.S. |

## Fixed-tooth Rakes

This type of rake is the most simple. They require no hydraulic system, nor any mechanism for retracting the teeth. The current models manufactured generally are designed for bulldozers, except for certain models produced by Young Corporation Ltd., Mann Corporation and Fleco Corporation (Figures 4, 9 and 10) which are suitable for skidder mounting.

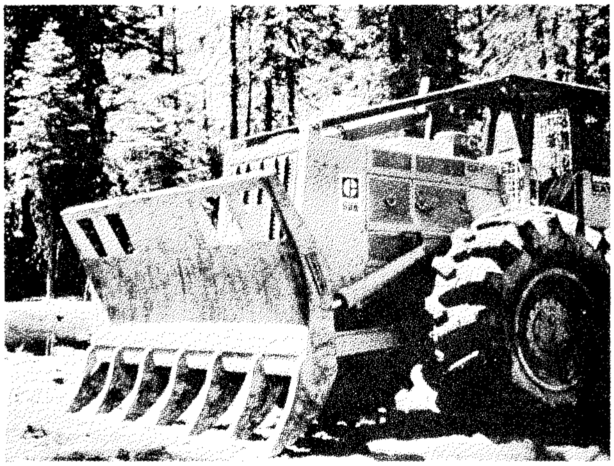

Figure 4. A fixed-tooth rake manufactured by Young Corporation Ltd. (made in the U.S.A.) on a Caterpillar 528 skidder (130 kW). *Note*: This rake is not to be confused with Young's teeth commonly used for scarification.

Figure 5 shows a homemade piling rake with fixed teeth made from mine rails, 10.2 cm (4 in.) high. It is entirely supported and reinforced by T-1 type steel plates. According to the inventor, the type of steel used is not crucial. The rake is fixed to the blade of a John Deere 540 skidder by six bolts, the same type used for bulldozers (grade 12). These bolts are tightened at the beginning of the season and no unusual wear of the threads has been observed.

Figure 6 is another example of a homemade piling rake that replaces the blade of a Timberjack 230D skidder. It is made from a hollow cylinder, 3.2 cm (1 1/4 in.) thick and 2.9 metres (9.5 feet) long. The holding arms are made from ordinary steel. The teeth are cut from a 3.2 cm (1 1/4 in.) thick, T-1 type steel plate. The outer teeth had to be doubled to withstand the extra stress placed on them. The accumulating bars (at the top of the rake) are made of steel, 1.9 cm (3/4 in.) thick, which did not prove to be sufficient; the central bar is missing. This piling rake costs approximately $2000.

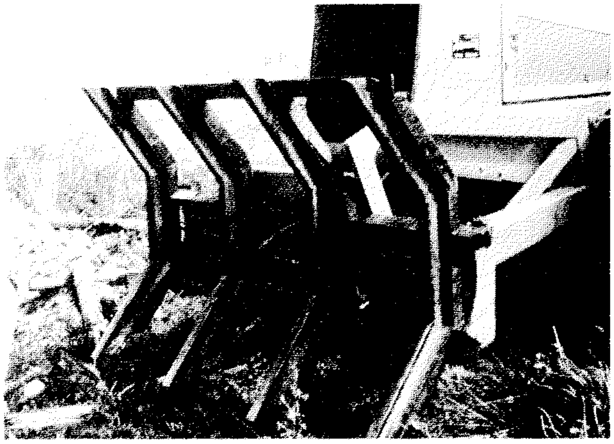

Figure 5. A homemade piling rake with fixed teeth (Société d'exploitation des ressources de la Vallée, Québec).

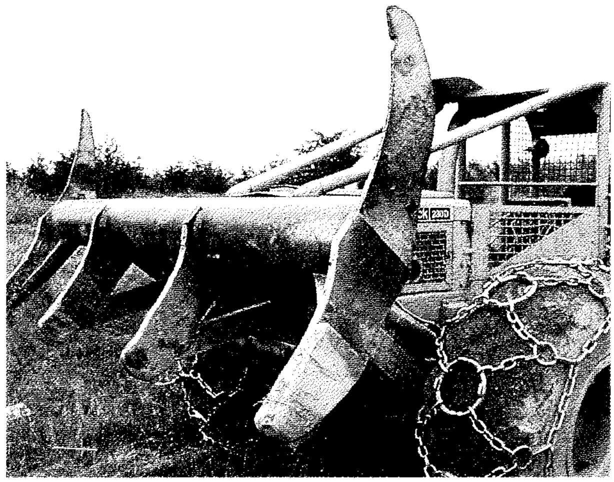

Figure 6. A homemade fixed-tooth piling rake (Société Sylvicole de Mistassinni, Québec).

Figure 7 shows the most simple version of a homemade piling rake. The teeth are cut from a T-1 steel plate, 5 cm (2 in.) thick, and are then welded directly to the skidder blade. The weight of one tooth is approximately 34 kg (75 lb). This rake costs about $200.

Figure 8 illustrates a homemade rake with removable teeth, mounted on a Timberjack 240 skidder. The upper part, in which the teeth are inserted, remains permanently on the blade. The teeth are made of squared tubes of metal, 10.2 cm (4 in.) wide and 1.9 cm (3/4 in.) thick. Each tooth is fastened by two regular bolts (1.9 cm or 3/4 in. diameter), and weighs only about

27.2 kg (60 lb), so as to be manually transportable. This rake is made of standard steel and has been operating for two seasons. A slight wearing of the teeth, the only problem noted, could be overcome by using the teeth of a CAT 966 loader made of a more resistant magnesium alloy. This piling rake costs approximately $800 to $1000 for four to six teeth.

Figure 7. A homemade piling rake with fixed teeth that are welded directly to the skidder blade (Quebec).

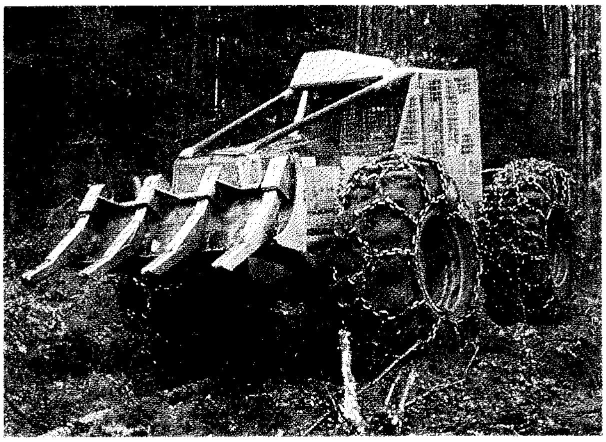

Figure 8. A homemade piling rake with removable teeth (Société Sylvicole de l'Outaouais, Quebec).

*Blade* rakes are a variation of fixed-tooth rakes, designed for rapid installation and detachment on the original blade. Two sets of mounting brackets must be welded to the top of the skidder blade before installing the rake. With the brackets in place on the blade, the rake can be attached with two pins. It takes about 15 minutes to install or detach these rakes. They are particularly useful where the prime mover is used alternately for raking and other applications. These rakes are lighter and are generally used for less demanding operations than are fixed-tooth rakes.

Figures 9 and 10 illustrate two commercial models of blade rakes mounted on skidders.

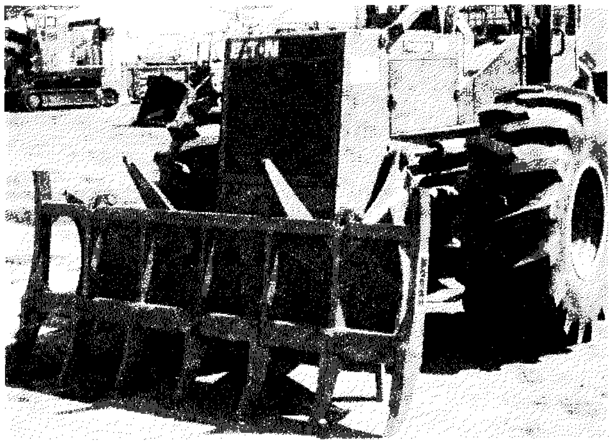

Figure 9. A blade rake manufactured by Mann Corporation (U.S.A.)

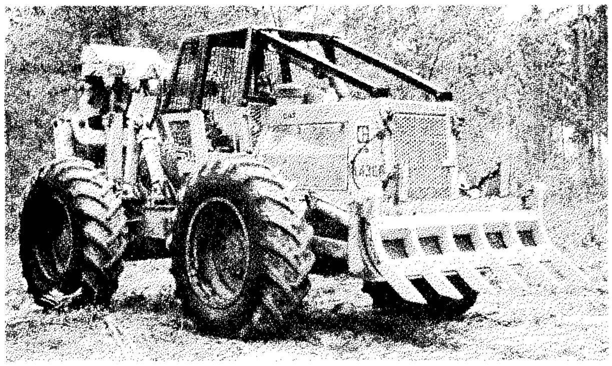

Figure 10. A Fleco BL-518 blade rake mounted on a Caterpillar 518 skidder (97 kW).

## Retractable-Tooth Rakes

Retractable-tooth rakes are capable of following the ground micro-relief. Their teeth are designed to move upward or backward when obstacles are encountered, then to return to their original position via either a hydraulic or mechanical system. This serves to reduce soil disturbance, the quantity of soil displaced to the slash piles, the shocks transmitted to the chassis, and the amount of power demanded of the prime mover. Less frequent and less violent jarring improves operator comfort and should improve the machine availability. However, the rake itself is more susceptible to breakage given the number of moving parts. Because of their greater weight, retractable-tooth rakes are mounted on more powerful skidders ( > 75 kW).

### Hydraulic System

The hydraulic retracting system consists of a closed circuit in which a regulated pressure is applied to maintain the teeth in their vertical position. This hydraulic system is separate and independent even though it is charged by the vehicle's hydraulic system. When a tooth encounters an obstacle which induces a force greater than that of the hydraulic pressure, it retracts to the rear and then returns to its initial position having passed the obstacle (Figure 11).

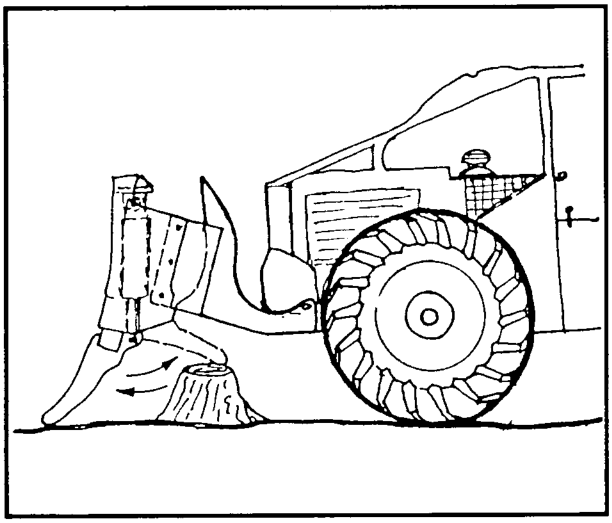

Figure 11. Hydraulic retraction mechanism.

### Mechanical System

The most commonly-used mechanical retracting system consists of large metal teeth which slide upwards, inside guides, when they encounter obstacles. Springs are installed at the upper end of each tooth, applying more downward pressure than the weight of the teeth alone (Figure 12).

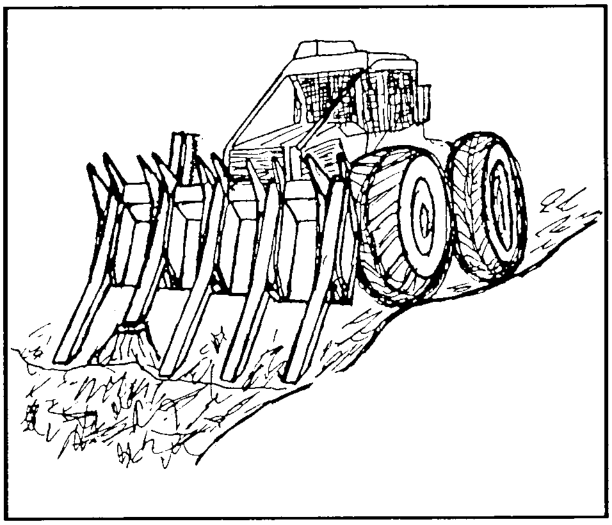

Figure 12. Mechanical retracting system.

# Prime Movers

The majority of prime movers used for silviculture in eastern Canada are not specifically designed for silviculture work. Bulldozers, built initially for pushing gravel and leveling terrain for road construction, are stable and strong but may cause unneccessary ground disturbance when used in the forest environment. Since bulldozers have no suspension, operators tend to remove stumps and level terrain for their own comfort. However, bulldozers do operate more effectively than certain skidders do on steep slopes and on soft ground.

On the other hand, skidders work more rapidly in most cases, and are less costly to operate and transport from site to site. The coordination of operations is facilitated since the same contractor may carry out both the skidding operation and the slash piling. While more mobile, skidders are designed to pull loads, not to push. As a result, they tend to be front heavy which is further compounded by the addition of a piling rake. This leads to additional stress on the front axle, less uniform traction, a decrease in the flotation for a given weight (Cormier and Ryans 1988), and an increased risk when climbing hills in reverse (Jeannotte and Beauchesne 1986). Installing a counterweight in the rear improves this imbalance and reduces the risk of component failure.

Skidders with hydrodynamic transmissions (torque converters) are easier to manoeuvre. However, there is a risk of overheating since the torque converter is often required to function in a low efficiency range (Ryans 1984), particularly when the engine comes close to stalling because of obstacles or large loads. A standard transmission with a range of gear ratios adapted to this type of work would prevent overheating. It would however make the operator's job more tedious and would increase the risk of more rapid wear from the severe shocks transmitted to the drive train.

The piling of slash usually involves a back-and-forth movement of the prime mover. Thus, the machine is normally working under load 60% of the time and spends 40% of the operating time manoeuvring (Cormier and Ryans 1989). Slash piling has a less intense duty cycle than scarification, but is more demanding than the skidding for which the machines were designed. During forest harvesting, skidders are under load for a maximum of 40% of the productive cycle (Ryans 1984). Manufacturers naturally design machine components based on the anticipated duty cycle, and thus problems can occur if the machine is put to alternate use. For example, frequent cases of skidder engine overheating may be attributable to the more intense duty cycle incurred in slash piling. In fact, the time during slash piling when the machinery is manoeuvring but not actually piling (backing up, for example), does not constitute a rest period for the engine since heat is continually building up. The capacity of the cooling system might therefore be exceeded and must be upgraded if the prime mover is to meet the demands of this increased intensity of operation.

According to a study done in Newfoundland by Brake (1985), the fuel consumption of skidders was 60 to 75 percent higher for raking than for normal skidding operations. Brake also notes more than a 50 percent reduction in tire life, down to about 700 machine hours. This can be explained by the work requirement during slash piling. The skidder is constantly passing over obstacles when loaded and is often pushing piles of slash to the point where the tires are spinning. When skidders are used for raking, higher costs for maintenance and repair are to be expected.

# The Use of Piling Rakes in Eastern Canada

Table 2 shows the use of piling rakes on private land in each of the provinces in eastern Canada, comparing the area treated by piling rakes to the total area that was mechanically site prepared in 1986*. The table illustrates that raking is most popular in Quebec and Nova Scotia.

In Newfoundland, the first piling rakes were introduced in 1984. Their use largely involved the rehabilitation of forests damaged by insect infestation. No funding for silviculture on woodlots was available before November 1987, so the first mechanical site preparation treatments are projected for 1988. These all involve the use of piling rakes.

**Table 2. Mechanical site preparation on private land in eastern Canada (1986)**

| | Area Treated (ha) | | |
|---|---|---|---|
| | With piling rake | Total | Comments |
| Newfoundland | 0 | 0 | - program beginning in 1987. |
| Prince Edward Island | 362 | 940 | - 2/3 of the area by piling rake on skidder. |
| Nova Scotia | 3919 | 5688 | - stand rehabilitation — mostly with bulldozer.<br>- raking logging debris — mostly with skidders, having mainly retractable-tooth rakes. |
| New Brunswick | 98 | 830 | - 94% by piling rakes on skidders. |
| Quebec | ≈8300 | ≈9000 | raked with skidders, mostly equipped with fixed-tooth rakes. |
| Ontario (partial data, 1987) | 500 to 800 | 6500 to 10 500** | - **about 70% being scarification with Young's teeth. |

* Internal FERIC survey.

In Prince Edward Island, two Eden piling rakes mounted on skidders and four conventional root rakes mounted on bulldozers are used. The latter are used on sites with poor bearing capacity or on steeper slopes. The Eden piling rakes, which have retractable teeth, are owned by the Department of Energy and Forests and are rented to contractors. The government chose this type of rake after previous bad experiences using fixed-tooth rakes. This had resulted in excessive levels of soil disturbance.

In Nova Scotia, there are more than 40 piling rakes in operation, most having retractable teeth. On private land, most of the work is done with Eden and Raumfix rakes. Retractable teeth are even found on some homemade models. The use of piling rakes having retractable teeth is favoured in Nova Scotia because the humus layer is typically thin, and because about 85% of the slash piles are burned to reduce area losses and rodent problems. In the northern and eastern regions of the province, fixed-tooth rakes mounted on bulldozers are used. Their objective is to rehabilitate insect-and disease-killed stands which can not entirely be commercially salvaged, physically or economically.

In New Brunswick, only one homemade piling rake on a forwarder, one Raumfix on a skidder, and one conventional root rake on a bulldozer were used for site preparation on woodlots in 1987. This limited use can be explained in part by the usage of other equipment that is available locally, even though it may not be best suited for the job. Work is often done on woodlots using large equipment (like anchor-chains or Marden choppers) by contractors who are in the area working on company or Crown land. An increase in the use of piling rakes is expected in New Brunswick as their positive results become more well known.

In Quebec, more than 50 piling rakes are working on private land. Most are homemade with fixed teeth and more than half are mounted on skidders. Their use is varied from region to region. The use of retractable teeth is less favoured because these piling rakes are more expensive than the homemade models and require more powerful prime movers.

In Ontario, three Eden piling rakes, four Raumfix rakes and 15 others of various makes are operating on Crown and private land. In addition, there are 166 sets of detachable Young's teeth mounted on bulldozers. Though they look like a rake, Young's teeth are intended to be used as a scarification tool more than for slash piling. As a result, their use in Ontario is centered largely in the north and northeast where the soils are deep and the consequences of excessive scarification are reduced. Most of the areas to be reforested in the south consist of abandoned farm land where there are few obstacles and the use of ploughs, brush cutters and scarifiers (700 ha in total in 1987) is more common than the use of piling rakes (500 ha in 1987 of which 90% consisted of Young's teeth).

# Operating Layout

There are two basic methods for piling slash, piling in windrows or in circular piles (Figure 13).

Piling in windrows is simple and more easily accomplished. Debris is pushed from both sides, using a back-and-forth action, into long central piles, preferably perpendicular to the road. With this method, the operator maintains better orientation and sees the progression of his work.

Although not as effective as the furrows resulting from scarifiers, the windrows nevertheless provide a guide-line for the tree planting crews during subsequent reforestation and facilitate supervision of the planters. However, the windrows should occasionally be broken to permit passage between corridors.

A variation of the windrow method is possible where the operator progresses continually forward, piling the slash when loaded and then passing over that windrow and working towards the next pile. However, this method is not recommended because it halves the distance between windrows. Furthermore, the piles that are formed are less uniform, not as high, take up more surface area, and appear untidy when compared with those created with the back-and- forth technique. In terms of productivity, there is little difference between the techniques (Jeannotte and Beauchesne 1986).

With the second method, creating circular piles, the operator tends to become turned around and disoriented. The piles are scattered, and their creation involves shorter, overlapping passes, making the entire operation less efficient.

Despite the potential problems when creating circular piles, this method may prove advantageous if used in combination with the windrow method so as to take advantage of the prevalent slash distribution and terrain conditions (Cormier and Ryans 1989). The circular pile method has greatest application where the site contour is irregular, where there are existing slash concentrations, or where the slash can be pushed into inaccessible spots or into existing depressions in the terrain.

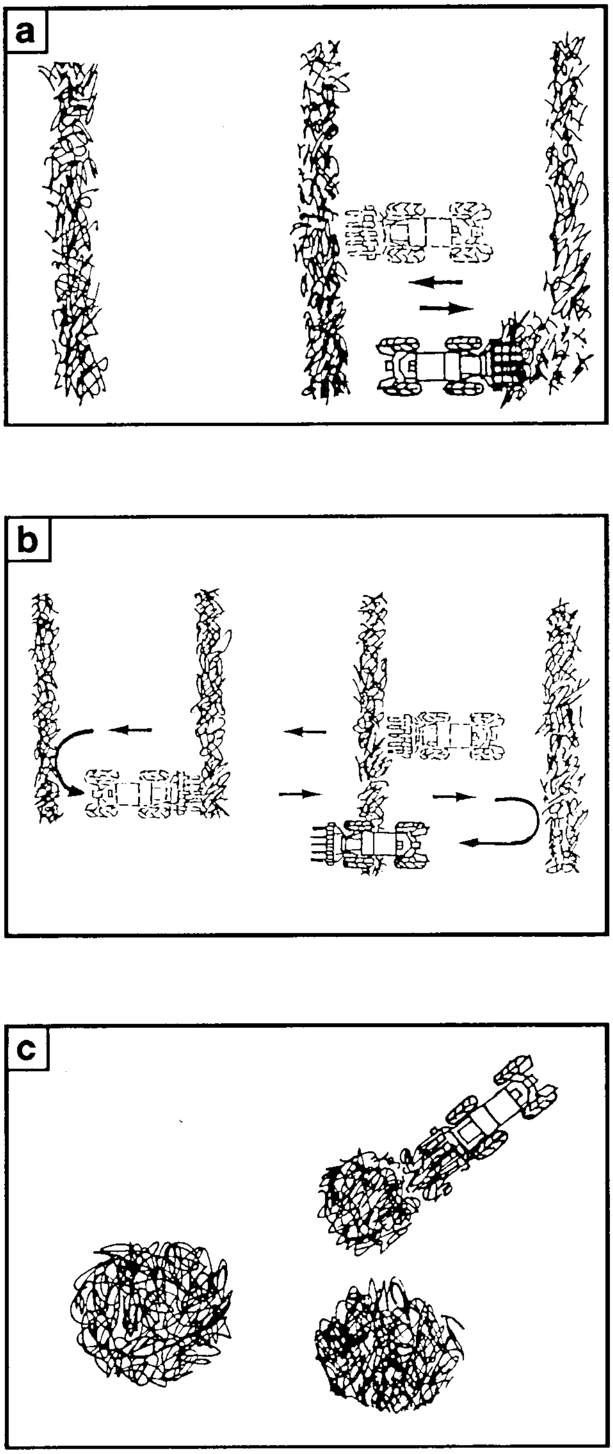


Figure 13. Methods of operation: a) the windrow method, operating back-and-forth, b) the windrow method, operating continually in a forward progression and c) circular piles.

## Productivity And Operating Costs

Studies conducted by FERIC show that the productivity for slash piling in clearcuts, using rakes mounted on skidders, is between 0.4 and 0.8 ha per productive machine hour (PMH) (Cormier et Ryans 1989). However, when slash from roadside delimbing is being treated, undesirable vegetation is being removed, or bulldozers are being used, the productivity is reduced to between 0.2 and 0.4 ha per PMH (Plante 1987; Weatherland 1979). Productivity will be affected by site conditions, block configuration, slash density, the treatment prescribed, the size and type of piling rake, and by the type of prime mover used. These factors will also influence the costs involved though possibly to a different degree. According to Cormier and Ryans (1989), the cost of mechanized raking using a skidder ranges between $65 and $175 per PMH, based on a utilization rate between 60 and 80 percent and a cost of $16 per hour for labour. This cost includes the direct costs attributable to the rake itself, normally about $1 to $2 per PMH for homemade fixed-tooth rakes; $10 per PMH for the Eden and Raumfix rakes and; $17 per PMH for the Force (Cormier 1987). Using, for example, an operating cost of $100 per PMH and a productivity of 0.5 ha per PMH, the treatment cost for raking amounts to $200 per ha. Where retractable-tooth rakes are used, their higher cost per hour is generally offset by their greater productivity.

## Conclusion

Even though rakes were originally used in agriculture, they have evolved to meet the specific requirements for use in silviculture. This evolution has changed rakes in a number of ways: adaptation for use on skidders; wider spacing of teeth to reduce the extraction of soil from the site; quickly removable rakes which maintains the versatility of the prime mover; and retracting teeth which improves the rake's ability to deal with variable micro-relief and minimizes soil disturbance. Because private land characteristically is inhabited and broken into small parcels there are few alternatives to slash piling when dealing with a logging debris problem since the size of the usable equipment available is limited.

Contractors are rarely assured of work other than by verbal agreement, site by site. This does not encourage the acquisition of expensive equipment. The greatest number of homemade rakes with fixed teeth are found in Quebec. They are not expensive to make and are suited to smaller skidders. The largest number of retractable-tooth rakes are found in Nova Scotia. Some of these are homemade.

Skidders are being used more often for raking instead of bulldozers because of their lower operational cost and better mobility. However, slash piling places a heavy duty cycle on a skidder, and the extra weight of the piling rake may require the installation of a counterweight at the rear, particularly where cable skidders are used in conjunction with retractable-tooth rakes.

The use of bulldozers is still fairly common because they perform well on steeper slopes, on soft ground and where standing trees must be removed. Nevertheless, it is most often the local availability of equipment that dictates the choice of method and equipment.

Windrowing is the most common method of slash piling. It is practical, simple, and results in less overlapping than forming circular piles. However, in some cases, the site configuration and relief, and the slash distribution pattern may lend themselves to a combination of the two methods.

Raking is an operation where low productivity inherently results from the constant forward-backward movement involved. Despite this, it remains a solution to the problem of handling slash left on cutovers.

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