Mechanical Treatment

When fire alone is judged to be too risky or ineffective under acceptable prescriptions, partial mechanical treatments can be considered. Current treatment cost information is limited and site specific. Slope, stem diameter, stems per acre, and treatment objectives are just some of the factors that make it difficult to predict accurate costs. Cost per acre varies greatly. Appendix A includes some historical mechanical costs as reported in the initial field survey. There probably will be a need for some of the costlier mechanical preburn treatments presented in this section, especially at the residential/forest interface.

Using mechanical methods to rearrange the fuel profile can mitigate the risks of fire escape during prescribed fires. Only the vegetation that directly threatens the survival of the desirable leave trees (taller ladder fuels and concentrated fuel pockets), or vegetation that significantly increases the chance of fire escape, should be treated mechanically. Prescribed fire will kill the smaller standing ponderosa pine and the widely spaced Douglas-fir trees (stems less than 2 to 3 inches diameter).

To minimize preburn treatment costs, mechanically treat only the areas where the fire is most likely to go into desirable leave-tree crowns and perimeter areas surrounding the major area to be burned, especially any residential/forest interface. Once the perimeter areas have been fireproofed, the central area could be burned under a hotter prescription that would reduce the undesirable vegetation more quickly. Costs of the partial mechanical treatment should be spread through all the acres that are burned.

Tracks Versus Wheels

To meet the project's criteria, any machine used in the preburn treatments must not cause excessive soil disturbance (compaction, displacement, and so forth), must not damage leave trees, must be readily available, and must be reliable.

Because tracked machines typically have lower ground pressure and are more maneuverable on slopes, they meet the project's site disturbance concerns better than wheeled machines. (A potential exception may be some of the latest cut-to-length wheeled harvesters working on slash mats. This concept could use further study.) Soil compaction can be mitigated by working on snow or frozen ground, working on slash mats, or working when the soil is very dry. Although equipment with boom-mounted implements requires the operator to constantly reposition the machine, the overriding advantages are that the boom can reach over difficult areas the prime mover can not traverse. In addition, some ground is not compressed by the machine's weight. The boom can work in spaces tighter than the machine can travel through, but the operator must occasionally stop cutting and reposition the prime mover. In a telephone interview, Rick Toupin, a Logging Systems Specialist for the Pacific Northwest Region, mentioned that soil compaction is a significant issue there, and that using ground pressure exclusively to indicate soil compaction is misleading because of other interacting factors. Region 6 uses the amount of ground covered rather than pressure as an indicator of soil compaction during logging operations. This approach would favor a machine with a boom.

Some of the mechanized brush cutters commonly used to clear power line rights-of-way have wheels. Although the wheeled machines are very productive and usually less expensive to purchase and operate, they typically have higher ground pressures and are limited to gentler slopes than their tracked counterparts. Tracked machines would be more versatile in a typical forest setting. Exceptions may be wheeled vehicles equipped with over-the-tire tracks (see catalog section).

Methods to Modify Fuels Profile

Lop and Scatter

The most widely used slash treatment method for precommercially thinning pine stands in eastern California is lopping (with a chain saw) and scattering. Weatherspoon (1982) notes that this is one of the least expensive methods used, but it is also the least beneficial slash treatment for hazard reduction. Weatherspoon says that it can be an effective pretreatment, facilitating subsequent use of prescribed fire in certain stands. This approach will not work in stands of densely packed trees if the thinned slash will cause the fire to scorch leave trees and possibly start a crown fire (see *Project Constraints*). In more open areas lopped material could be scattered in openings. In such cases, the thinned slash might even be needed to carry the ground fire.

Cut With Chain Saw, Hand Pile, and Burn

When cutting the material with chain saws and hand piling it, quite a bit of large woody material can be left scattered onsite to meet guidelines for coarse woody debris. In many

cases only the tops and some branches need to be piled. Small winches could be used if larger materials are to be moved. The piles can be burned when convenient and when fuel moisture is too high to carry a ground fire. Some districts cover the piles with tarps to make them easier to ignite in really wet conditions. The use of chain saws should be considered and compared to any machine felling and piling systems before making a decision. Minimal preburn treatments may favor chain saws and hand piling. Extensive preburn treatments may favor heavy machinery. Using chain saws and hand piling may be the only option on steeper slopes. On the flip side, consideration should be given to the effects of pile burning on soil nutrient depletion.

Cut, Machine Pile, and Burn

A tracked machine with a boom can be used to cut and pile undesirable biomass, manipulating the fuel profile. Equipment should be sized to the vegetation. The feller-buncher is an attractive choice for brush cutting if the machine is already in the area and the saw head can be removed so that a brush head can be quickly installed. If all material is to be burned, the pile can be compacted with the machine, if desired, and left to cure.

One advantage of pile burning is that the piles can be burned during wet weather. This treatment should be done on the perimeter units where there is risk of fire escape. Once a safety buffer surrounding the main area has been mechanically treated and burned, substantially reducing the fire hazard, the main area can be burned. With a safety zone around the main area (either manmade or natural barriers), hotter prescriptions can be considered. For instance, ladder fuels could be thinned exclusively with fire in densely packed stands. Disadvantages to pile burning include the possible negative effect on soil nutrient depletion and collateral damage due to scorching of leave trees.

During the course of an interview with Steve O'Brien, a Northern Region logging engineer, discussion centered on a basal area reduction treatment that is being used by a large commercial logging company on some of its land in the Pacific Northwest. The following scheme is slightly outside the scope of this project but is included because it is a sensible approach if merchantable logs can be taken to offset costs during the course of the fuels treatment. The company's basic idea is to cut the merchantable and "weed" trees at the same time with a feller-buncher head mounted on a boom, and pile all trees (including weed trees). The use of this "hot saw" (continuously running disc saw with accumulator) significantly increases the logger's productivity compared to using a processing head. In another operation the merchantable material in the piles built by the hot saw is fished out and processed into cut-to-length pieces with a second machine equipped with a processor head. The merchantable material is taken out by a forwarder. The limbs and tops are left in the forwarder trail to be driven over.

After the forwarder removes the merchantable material, the unit is burned. The merchantable material provides income to help offset the cost of the preburn and burn treatments. This treatment thins the stand to increase site productivity and reduce the fire hazard.

The advantage to this company's approach is that the operator can work around the base of the leave trees with minimal damage and pile the burnable biomass a safe distance away. The hot saw can handle larger material with no problem. If equipped with a boom, the machine does not have to traverse every inch of ground, minimizing soil disturbance. The weed-tree piles could be concentrated and compacted with the machine if desired. Because the burning window is longer for pile burns, the piles could be burned when it's convenient. Firelines could be easily constructed around the piles if they began burning during a wildfire. Excavators and feller-bunchers are common machines, so this approach could be widely practiced. On gentle slopes, a tracked skid-steer or similar machine with a feller-buncher head may work.

Cut and Trample

A hot saw on a feller-buncher could cut down the trees. The machine could then move the cut material away from the base of the leave trees and run over the cut material. This approach eliminates the need to come back and burn piles before a prescribed fire, and helps break down the slash and put it closer to the ground. The resulting slash mat should also minimize soil disturbance by the machine traveling over it. This method raises questions about defense against wildfire while fuels are scattered on the forest floor. Trampling may reduce the hazard to acceptable levels. This possibility will have to be evaluated on a site-by-site basis. Prescribed burning of fuels that are crushed too finely and mixed with dirt may lead to incomplete combustion (smoldering) and smoke management problems. The amount of crushing must be carefully monitored. If burning later becomes prohibited, decomposition of the trampled slash will be slower on dry sites than on wet sites.

Crush and Chop

Another treatment method is to knock down the young standing trees, brush, and slash (logging and blow down) and crush or chop it up. When ladder fuels are removed or reduced, prescribed fires are easier to manage. The same equipment could be used for fuel augmentation. Weatherspoon (1982) notes that machine crushing can be an effective pretreatment for prescribed burning in some stands. Several papers on the use and productivity of chopping and crushing equipment were found and are referenced in Appendix B. (Anonymous 1967; Bryan 1970; Hopkins and Anderson 1960; Miyata and others 1983).

Crushers such as the Tomahawk in Figure 1 (Young Co., no longer made), the T.G. Schmeiser Co., Inc.'s Till n' Pak, or Hakmet USA's Meri Crusher should work between widely spaced leave trees. Rolling choppers (Figure 2) are commonly used for land clearing and site preparation in the Southeast (Marden Industries, Inc., Savannah Forestry Equipment Co., and Rockland Manufacturing Co.). None of these implements work very well with material that is supple, such as green seedlings. The equipment works better with dead material (slash) or during the winter months when material is frozen. This approach would probably also have to include a method or piece of equipment to get the standing material down. Large dozers with tree shearing blades (Savannah Forestry Equipment Co., Rockland Manufacturing Co., Rome, and Sharpco) have been used for land clearing operations. This equipment train would require a large turning radius, so tree spacing would be a consideration. Detrimental soil disturbance and damage to leave trees are also concerns with these machines (see the Catalog of Machines and Specialized Attachments).

Brush-Cutting, Thinning, and Shredding Machines

When a fire escape would be astronomically expensive, such as when residences are nearby or when the time required for sequential partial burns is not acceptable, mechanical treatments such as brush cutting, precommercial thinning, or shredding may be necessary. A wide selection of machines is available (see Catalog of Machines and Specialized Attachments). Many machines have been developed specifically to dispose of logging slash, but they can be costly to use.

If the objective is to reduce the vegetation in place, several mobile brush cutters and shredders can do the job. Mechanical brush-cutting equipment may have a vertical or horizontal shaft and the head may have fixed or free-swinging cutters. The heads may be machine mounted, boom mounted, or machine pulled. Some equipment manufacturers distinguish between an integrated machine and a specialized attachment, as we have done in the catalog section of this document. Many excellent publications on this subject are available (Karsky 1993; McKenzie and Makel 1991; Ryans and Cormier 1994).

A brush-cutter head mounted on a tracked excavator may offer a reasonable solution on slopes up to 35%. When a brush cutter head (many are commercially available) is mounted on a tracked feller-buncher with a self-leveling cab, the slope steepness may be increased to 50% or slightly more. The tree spacing must be considered. The tail swing on conventional excavators may damage leave trees, but it is negligible on zero-tail-swing feller-bunchers. Even if this equipment permits some kind of treatment on steep slopes, cost will be a factor. Some forests use the Slashbuster head

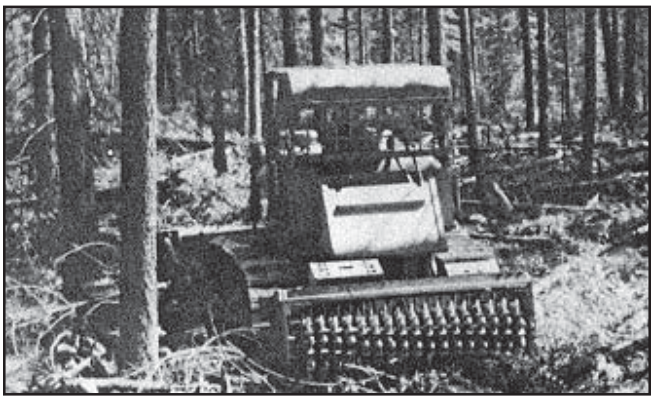


Figure 1—Tomahawk crusher.

Figure 2—Rolling chopper used for land clearing.

(D&M Machine Division, Inc.) on an excavator for fuel treatment and have indicated costs range from $220 to $270 per acre. One forest mounted the Slashbuster on a self-leveling-cab feller-buncher and estimated costs at $600 per acre. (Appendix A has additional information on equipment and techniques for this project as reported by forests.)

Vertical- Versus Horizontal-Shaft Machines

Most of the literature reviewed indicated that vertical-shaft machines are more productive than horizontal-shaft machines (Figures 3 and 4). Vertical-shaft machines produce a coarse, splintered stem and require a larger safety zone than the horizontal-shaft machines. Ryans and Cormier (1994) mention studies that show it is cheaper to cut stems with a vertical-shaft brush cutter and come back and stack the stems than it is to grind the stems with a horizontal-shaft machine. Some forests commented they thought there was more damage to leave trees when they used a vertical-shaft design with free-swinging cutters than when they used a drum shredder with free-swinging cutters. For equipment examples of both types, see the *Catalog of Machines and Specialized Attachments*. Table 1 compares the two designs.

Figure 3—The cutting head on the Kendall Cutter is a typical vertical shaft with free-swinging cutters.

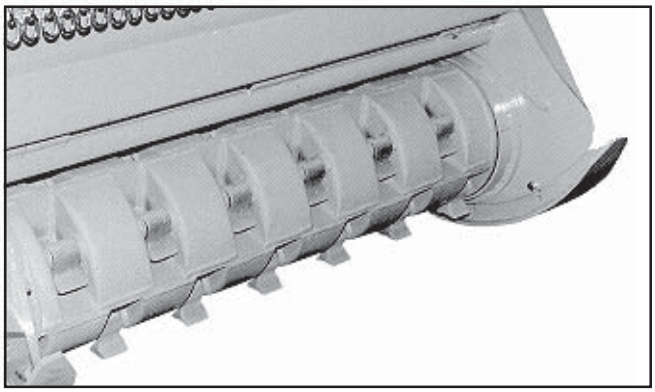


Figure 4—Seppi M drum shredder with free-swinging cutters.

The Slashbuster is a vertical-shaft design with fixed teeth (Figure 5). This head allows vegetation to be mulched in place. The head is also available with a “thumb” that allows vegetation to be piled. An excavator attachment called the VH Mulching Head (West-Northwest Forestry, Inc.) has an optional prototype tool head that uses replaceable carbide teeth and rotates very slowly compared to the Slashbuster. It also comes with a large thumb for piling vegetation. The Shar 20 by Shur Shar Manufacturing (Figure 6) is a specialized machine with a vertical-shaft, fixed-tooth disk, also available with free-swinging cutters on a disk. This machine and similar designs, such as the Lucky Logger (no longer available) and Timbermaster TM-20 (no longer available), have been used successfully on Forest Service lands in the past (McKenzie and Zarate give production data on several machines used for precommercial thinning and slash treatment in *Field Equipment for Precommercial Thinning and Slash Treatment—Update*, Project Record 8424-1204-SDTDC). Drawbacks include huge initial cost for the machine and the limited number of machines currently available. The machines are long and may have difficulty maneuvering in tight spots.

Table 1—Comparison of vertical- and horizontal-shaft reduction heads (McKenzie and Makel 1991).

	Advantages		Disadvantages	
VERTICAL-SHAFT HEADS—	• Low horsepower requirements • Cuts even when dull • High kinetic blade energy	• Low blade life • Low energy consumption per per ton of chips produced	• Can leave high stubs • Small bearing area at blade attachment points—can accelerate wear here.	• Large safety zones required • Can have poor operator visibility • Machine may be longer overall
HORIZONTAL-SHAFT HEADS—	• Capable of cutting close to ground • Can be closer-coupled machine • Can have good operator visibility • Can have large blade bearings	• Both ends of blades usually supported • Can have high kinetic drum energy (flywheel effect)	• Higher power needed to drive cutters • Usually low kinetic blade energy • Blades can be difficult to change	• Poor cutting when the blade is dull (low kinetic blade energy)

Figure 5—The Slashbuster has a vertical shaft and fixed teeth.

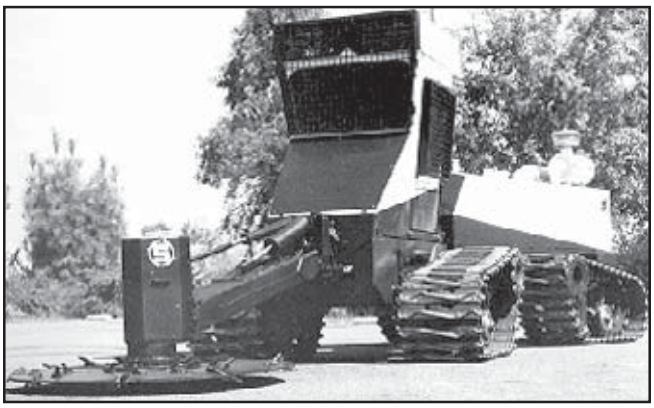


Figure 6—The Shar 20 has a vertical shaft and a fixed-tooth disk.

Tracked machines with booms and slashing heads like the Slashbuster, KDX mulching head (Kemp West, Inc.), Brushco (Figure 7, Quadco Equipment, Inc.), Pro Mac (Pro Mac Manufacturing, Ltd.), and Grizzly Tree Cutter (Alamo Industrial) can reduce fuels in place (see *Catalog of Machines and Specialized Attachments).* Some of these heads are available with a thumb to pile debris. This approach can be costly per acre unless it is used sparingly and the cost is spread over all acres to be burned. The Eldorado National Forest of the Pacific Southwest Region (R-5) has had good results using their Slashbuster in a variety of situations. They added a modified bar with cutting surface to the head, which helps to masticate smaller standing stems. Park-like effects can be achieved by a combination of machine work and successive burns. Park-like results may or may not be desirable from a cost standpoint.

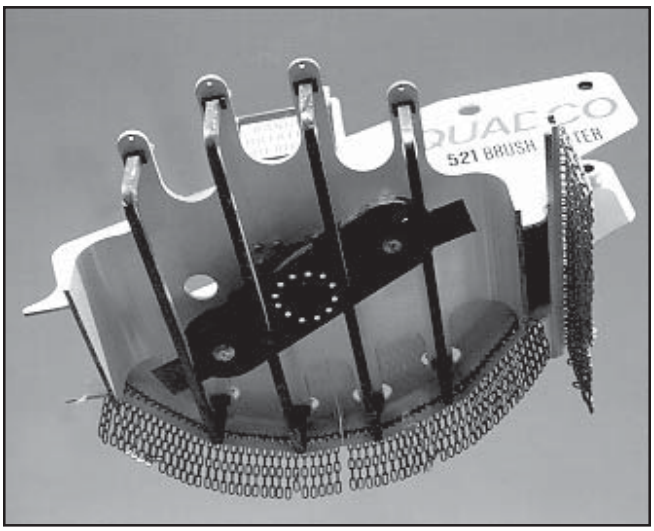


Figure 7—The Brushco brush-cutter attachment (made by Quadco) for excavators.

At one time, the San Dimas Technology and Development Center proposed a concept machine that had a horizontal-shaft drum with fixed teeth (McKenzie 1991). The head was an integral part of the machine, which was intended to thin and mulch trees in strips. The concept machine was never built and tested. Since that time, two companies, Fecon and Rayco, have each developed this type of machine (see Catalog of Machines and Specialized Attachments).

Chip

Another approach is the use of a self-propelled whole-tree chipper (Morbark Mountain Goat and Bandit Industries' Track Bandit in Figure 8, see Catalog of Machines and Specialized Attachments) to reduce fire hazard. Although this may be a feasible approach if a chip or hog fuel market is viable or if burning is prohibited, there are some drawbacks. A self-propelled whole-tree chipper can chop trees at the stump. A machine that cuts the trees must precede the chipper. The use of a felling machine or manual felling in addition to the chipper increases the cost of the operation. If a market for chips is present, provisions must be made to get the chips off the landing or out of the forest. Leaving chips spread out in the forest (assuming they could not be sold) would be a very expensive option, but it may be advantageous from a soils management perspective. The cost of the specialized chipping machines and the number that are available are also concerns. Although the Beckwourth Ranger District, Plumas National Forest in R-5, liked the concept of a feller-buncher working ahead of the Morbark Mountain Goat, they indicated that the Mountain Goat experienced a large percentage of downtime during a demonstration. Concerns about availability and dependability of the self-propelled whole-tree chippers make this approach less than ideal.

Figure 8—Track Bandit Model 1900 self-propelled whole-tree chipper.

Chipping has been done on a limited basis in the residential/forest interface on the Gila National Forest (R-3), Dixie National Forest (R-4), and the Bridger-Teton National Forest (R-4). On the Dixie National Forest, chipping was also used in conjunction with a project to reduce the spruce beetle infestations in camping areas where fire was not an option. Although tied to larger objectives, the projects were still costly. For chipping operations on landings, trailer-mounted whole-tree chippers should be considered.

Remove Biomass

Removing the undesirable biomass from a site involves handling every piece more than once, driving up treatment costs. Even though this report assumes material on the site has no current commercial value, for the sake of a broad discussion let's assume a viable chip or hog-fuel market is present, or that we want to move the biomass to a landing and wait for the market to become more favorable. In this case we need to consider options to get the material to the landing. When terrain permits, skidding material offsite with a rubber-tired skidder is more cost effective than using other logging systems such as cut-to-length and cable yarding. The cost of cable-yarding systems typically runs three times the cost of ground-based systems, according to interviews conducted for this project.

Whole-Tree Skidding

Whole-tree skidding (where the limbs are still attached) is especially cost effective and gets more of the biomass out of the unit. But whole-tree skidding at times has been found to cause undesirable soil disturbance and compaction. The Weyerhaeuser Company has reduced soil impact from rubber-tired skidders by using super-wide tires and studded chains rather than ring chains. Skidding over snow or frozen ground can also mitigate this problem. Whole-tree skidding increases the potential for damage to leave trees. In addition to skidding costs, the material must be cut in a separate operation.

A concern with this technique is nutrient recycling. Weatherspoon (1982) notes that "most nutrients contained in trees are concentrated in foliage and small branches. Removal only of material larger than 3 inches in diameter, therefore, removes relatively little of the nutrient capital of the site." With whole-tree skidding, all branches and tops are taken off the site where the nutrients would not be available for future forests.

Foresters on the Eldorado National Forest have been practicing whole-tree skidding on a number of sales over the past few years and report no adverse effects to date. The forests in the region have a relatively rich litter layer that remains intact when whole trees are removed. Limbs and debris that fall off during the thinning process are not cleaned up afterward. With repeated treatments, detrimental effects might be measurable. However, it was noted that with a 120-year rotation and thinning once every 20 years, trees will continue to produce, and nutrient stores should be maintainable or even increased. Pines hold their needles for 3 years, leaving 17 years for the needles to add to nutrient stores.

Although whole-tree skidding can be one of the cheapest ways to get the material out of the unit, it is often rejected because of soil disturbance, potential leave-tree damage, and additional handling costs. If there is no chip or hog-fuel market, the removed biomass will have to be piled and burned on the landing. The landing might need expansion to make room for the large piles.

Cut-to-Length Systems

Another harvesting technique gaining popularity is the cut-to-length system. This method causes less site damage than traditional rubber-tired skidding. The harvester lays the branches and tree tops in the forwarder's travel path to minimize soil disturbance. The forwarder crushes the branches and tops to reduce fire hazard. The shorter log lengths also reduce damage to leave trees. This approach is popular with some because it leaves more nutrients onsite. Drawbacks include equipment expense and lack of a high-value commercial product.

Girdle

A preburn treatment concept suggested to MTDC was to girdle undesirable trees. Girdled Douglas-fir trees would shed their needles after about 1 year. Ponderosa pines would do so after about 2 to 3 years. A prescribed fire on the wetter end of the prescription could remove the needle layer. Periodic prescribed fires would be passed through the unit as dead trees toppled over in a period of years. Youth crews could perform the work. Manual girdling equipment would have to be used because many youth crews are not allowed to use chain saws.

The girdling concept was discussed with fire researchers who thought the girdled trees would add to the fire hazard. When the needles were cured and still on the tree, ladder fuels would be extremely flammable. After the needle layer was burned off, it would be harder to get subsequent ground fires to carry through the unit, especially on the cooler prescriptions. During subsequent prescribed fires, standing dead trees become burning snags that could cast sparks across containment lines.

Some Equipment Options to Minimize Soil Disturbance on Steeper Slopes

Cut With Chain Saw and Hand Pile

Manual cutting with chain saws and hand piling may be the only feasible mechanical treatment possible on some steep slopes. Refer to the previous discussion in Methods to Modify Fuels Profile. Any other treatment considered should be compared to this one.

Multipurpose, Low-Ground-Pressure, Rubber-Tracked Machines

Some new, smaller, rubber-tracked machines may warrant a closer look. One is ASV, Inc.'s Posi-Track (Figure 9). It is reputed to be very stable on side slopes, but does not have a boom. The manufacturer rates it at 33% gradability on a sidehill. It has very low ground pressure (2 psi for the MD 70 with front loader, 3 psi for the HD 4500 and HD 4520 with front loaders). The Posi-Track can use any skid-steer implement. A feller-buncher head can be mounted, but the machine does not have enough power to operate the larger brush-cutting heads. LMC Corporation makes a similar machine, the Trackmaster 85 rubber-tracked crawler, that also has very low ground pressure (less than 2 psi with a bucket.) The Trackmaster's power source is smaller than the Posi-Track (88.5 hp compared to 115 hp). Davco Manufacturing, Inc. makes a 14-inch cutting-capacity hot saw for the Posi-Track. New Dymax, Inc. makes a 14-inch tree shear with accumulator for skid-steer machines. Hahn Machinery, Inc. and Davco Manufacturing, Inc. make small processor heads that could be used with the Posi-Track. A small nonpowered tree cutter with accumulator (E-Z Implements, Inc.) is available that can handle a maximum tree diameter of 8 inches (see the *Catalog of Machines and Specialized Attachments* for more small tree-cutting equipment options and skid-steer attachments). A grapple and stacking forks are just two of the implements that can be used to create piles in the unit.

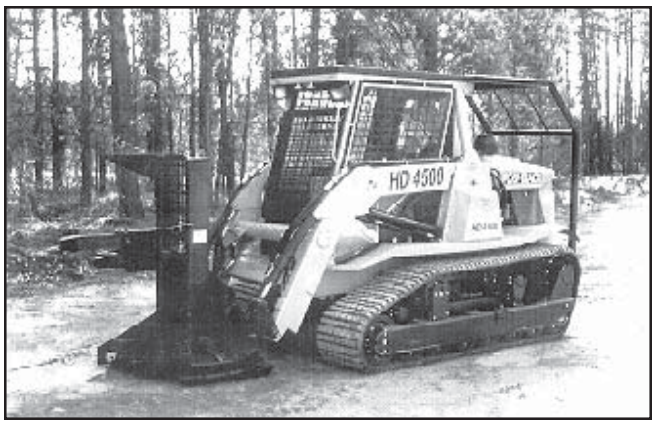


Figure 9—The ASV Posi-Track is a smaller, rubber-tired machine that shows good stability on slopes.

Feller-Bunchers With Self-Leveling Cabs

The private logging company's approach discussed earlier (see Cut, Machine Pile, and Burn under Mechanical Treatment, Methods to Modify Fuels Profile) could be expanded to steeper slopes (up to 50%) by using a feller-buncher with self-leveling cab (Timbco, Prentice, and Timberjack; see Catalog of Machines and Specialized Attachments). Even though common excavators can operate brush-cutting equipment on slopes up to 50%, the self-leveling cab feature is necessary when using a felling head so that there is proper tree orientation when cutting, and stability while moving with

a cut tree on steep slopes. These machines also make excellent platforms for mounting brush-cutting heads. The performance of the early model Timbco feller-buncher (Figure 10) is documented in Stokes and Lanford (1983).

"Cutting upslope and bunching to the front was the single most productive pattern, and cutting downslope and bunching to the rear was the least productive," reported Stokes and Lanford. "To have continuous cutting the most productive pattern involved cutting across-slope and bunching uphill with the butts facing downhill."

Figure 10—Timbco T445C feller-buncher with the Quadco 22-inch disk saw.

Cable Yarders

Slash can be cable yarded on steep slopes with skyline grapples (Figure 11) or rakes (Krischuk and Miyata 1986). Once the material is on a landing, it can be piled and burned, or chipped. Unfortunately, the only commercial skyline grapple-rake designs that MTDC was aware of have been discontinued. An interesting option found in the literature is open-pit burning with a wind-generating machine called an air curtain destructor (Lambert 1972). This machine caused the material to burn so hot that smoke emissions were reduced substantially. Although it is possible to reduce the biomass in the unit using this approach, it would be extremely expensive to yard all the material to a landing.

Another possibility on steeper slopes is to concentrate the slashed trees into corridors and use a small cable yarder to yard the material to the landing for pile burning. If a market for small wood develops, small yarders like the Bitterroot Mini-yarder, a double-drum skyline and mainline yarder (Figure 12), or a monocable yarder can be considered. One commercial monocable system is the Howe-Line Monocable System (imported under the name Truckhowe, CC), which is not yet widely available in the United States, shows promise (Figure 13). It has a distinct advantage over zigzag-style monocables because it can yard in straight lines using specialized blocks and doubletrees to suspend the cable (see *Catalog of Machines and Specialized Equipment*).

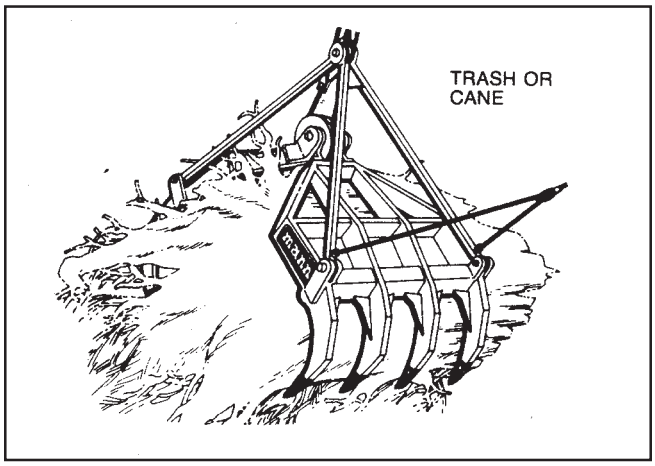


Figure 11—A skyline grapple rake can yard slashed trees that have been collected into corridors. (This model no longer available.)

Cable Chippers

Extra handling of the biomass drives costs up. One variation would be to cable a chipper around the unit and chip the biomass as you go. (See On-Site Chipper for Reduction of Forest Residues, Technical Report 8451-1207-SDTDC.) Drawbacks include the need to cut the material before it goes into the chipper and the possibility that nitrogen will be used by organisms that decompose the wood chips rather than being available for plants if the chips are left in concentrated piles.

Figure 12—The Bitterroot Miniyarder would be suitable for yarding smaller wood.

Figure 13—Eucalyptus clearfell harvesting with Howe-Line monocable system. (Photo courtesty of Professor Loren Kellogg, Oregon State University.)

Extreme Machines

Few machines will allow the operator to comfortably operate a mechanized shredder/brush cutter on slopes steeper than 50%. The Kaiser Spyder, Schaeff Climbing Backhoe, Menzi Muck, and Allied Systems' ATH 28 can operate on these steeper slopes, but they are very expensive to purchase and maintain and are not available in quantity (Figure 14). Johnson (1992–1993) reports spending $987 per acre on 2.4 acres to shred slash with a Kaiser Spyder on slopes steeper than 60%. When the cost was spread over the entire 14-acre burn unit, it was $161 per acre (see Catalog of Machines and Specialized Attachments for specifications on these extreme machines).

Figure 14—The Menzi Muck with a feller-buncher head is one of few machines that can operate brush cutters on slopes greater than 50%. They are cost prohibitive to run and are not readily available.

Fuel Reduction During Harvest

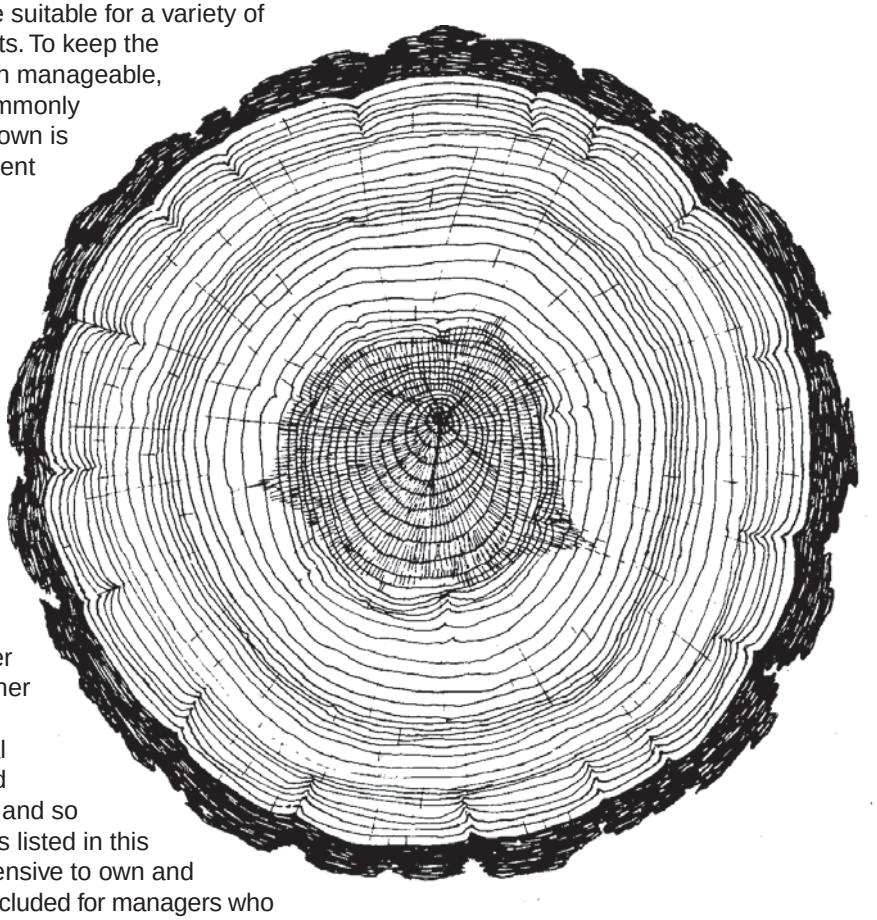
Although timber harvest is outside the present scope of this project, harvest offers a good opportunity to reduce the fuel loading as part of logging activities. Weatherspoon (1982) notes that the "National Forests in California have for a number of years included yarding unmerchantable material (YUM) provisions in many of their timber sale contracts. One purpose is to increase utilization." Utilization of residual small wood or biomass may become economically viable long after the main harvesting activity is over.

John Waverek, fire management officer at the Missoula Ranger District (Lolo National Forest), was interviewed in the early stages of this project. His District is near a cardboard linerboard manufacturing plant that uses wood chips and operates a hog-fuel burner. The District includes a clause in some harvesting contracts that requires extraction of all chippable material down to a 3-inch diameter. To help loggers cope with the sometimes volatile pulp market, the District allows a longer completion time on contracts so that material may not have to be removed from landings while the pulp market is unhealthy. The sale of the pulp-quality chips and hog fuel currently pays for processing and transporting up to 50 miles. Chip prices and market windows can fluctuate widely and the value of chips varies, depending on whether they are clean (destined for the pulp market) or dirty (destined for hog fuel).

Some areas in need of a preburn treatment were logged long ago or may never have been logged. A simplistic approach would be to harvest as much of the undesirable biomass as possible as merchantable products during fuel treatment. Districts would essentially trade the products to help offset the fuel-treatment expense. Posts, poles, chips, hog fuel, and firewood are some of the possible uses for the smaller material. Some larger trees—especially mature Douglas-fir—could be added if needed. Use of this approach may involve contractual issues beyond the scope of this publication. The primary benefit would be a sharp reduction in the tons per acre of fuel loading on the site.

Catalog of Machines and Specialized Attachments

This catalog is a compilation of specifications for equipment suitable for reducing excess biomass in areas before prescribed burns. It is designed to help forest managers make informed decisions. The catalog profiles a variety of lesser known, small, and large pieces of equipment that are suitable for a variety of situations and budgets. To keep the amount of information manageable, equipment that is commonly available and well known is not included (equipment such as chain saws, winches, skidders, excavators, loaders, non-selfleveling feller-bunchers, harvesters, and so forth).



When looking at machine specifications, forest managers will also want to consider how the equipment relates to such factors as: terrain, soil, timber characteristics, weather and climate, fiscal restraints, silvicultural systems, endangered species, regulations, and so forth. Some machines listed in this section are very expensive to own and operate. They were included for managers who might have some high-value acres to guard against wildfire (such as residential/forest interface) and substantial working budgets. Contact information for manufacturers and sources is in Appendix C.