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MACHINE FOR ROW-MULCHING LOGGING SLASH TO ENHANCE SITE—A CONCEPT

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SUMMARY:

Proposes that stumps, tops, and branches residual after logging pine plantations be hogged to build mulch beds spaced on about 2.5-m centers, thereby eliminating pile and burn operations. Growth of seedlings planted through mulch beds should be accelerated because of moisture conservation, weed suppression, and minimum disturbance of topsoil.

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INTRODUCTION

In pine plantations throughout the world it is usual, after clear felling the final crop trees, to windrow and burn residual tops and branches, thereby diminishing the hazard from wildfire. Frequently the burning operation is followed by strip plowing to form beds and to control weed competition in rows that are to be bare-root planted. Although this procedure is in wide use, it has several disadvantages. First, burning of slash causes air pollution and diminishes nutrients—principally nitrogen—returning to the soil (Jorgensen et al. 1975). Second, fertility on some sites may be significantly reduced if bulldozer operators inadvertently blade off topsoil during piling operations (figs. 1 and 2). Third, burning of the slash removes material that could act as a mulch to slow moisture loss in rain-deficient areas. Finally, after piling and burning, weed control must be achieved by strip plowing.

Figure 1. High-site loblolly pine plantation in Southeast after pile and burn operations. (Trees show good growth rate where topsoil was undisturbed; reduced growth rate is evident in blade-scalped area in center.)

To reduce the hazard from fire, to return logging slash nutrients to the soil, and to conserve soil moisture while suppressing weed growth in planting beds, we propose a simple site preparation technique that obviates the necessity for burning and strip plowing on some sites. The concept calls for tops, branches, stumps, underbrush, and small trees residual after harvest (in short, all logging slash) to be hogged by a long cylindrical cutterhead horizontally mounted across the front of a prime mover. As this mobile mulching machine slowly traverses the acreage, hogged material would be collected from the cutterhead and

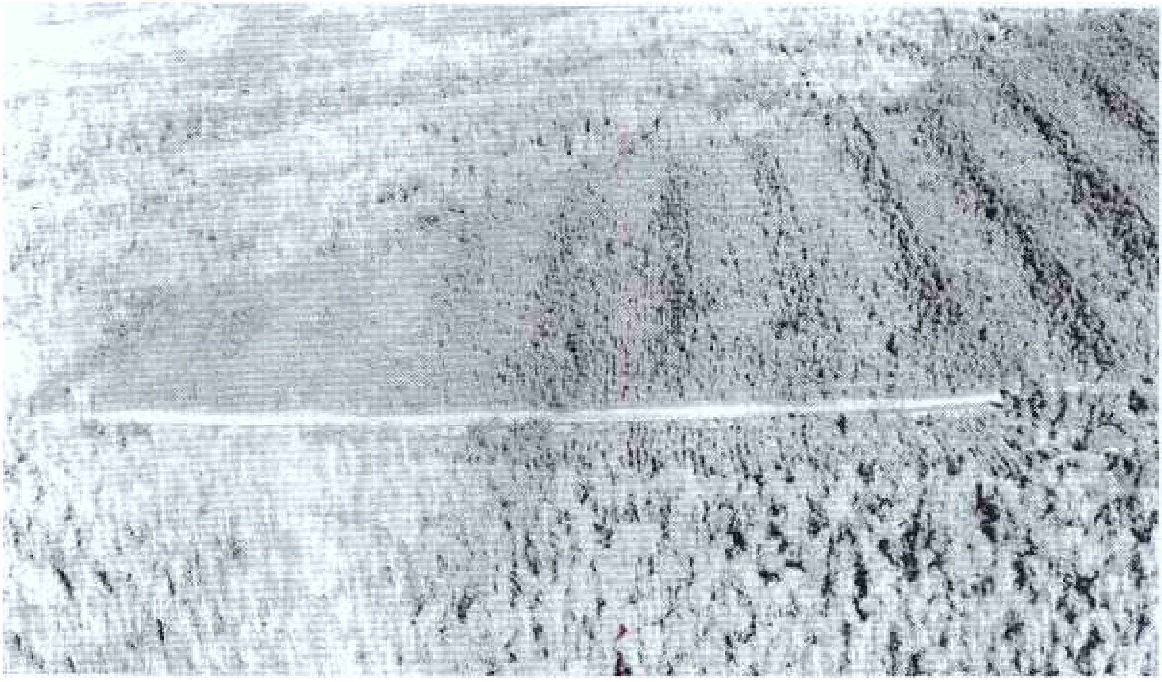

Figure 2. Significant reductions in growth rate, caused by blading off topsoil during pile and burn operations, are evident in this aerial view of a loblolly pine plantation in the Southeast. (Trees show good growth rate in rows where slash was piled and burned, and where bladed topsoil was concentrated.)

delivered via belt to spaced planting beds about 60 cm in width and perhaps 5 to 7 cm in depth; centerline distance between beds might range from 2 to 3 m. Using average bed dimensions and spacing, this would call for 144 m^3 of mulched material per hectare; at 320 kg per m^3, about 46 000 kg of green mulched chips would be required per hectare.

In attempting to evaluate the merit of the concept, it is pertinent to note that two knowledgeable silviculturists in the South (E. Shoulders and J. Burton) have voiced some reservations about the idea. They comment that, while nitrogen is released to the atmosphere by burning of slash, most other nutrients remain in the ash and are quickly returned to the soil—much more rapidly than if the slash were allowed to decompose naturally, and that the literature contains some evidence that the loss of nitrogen poses no serious problem in site deterioration (Boyle et al. 1973; Shoulders and McKee 1973). They further observe that chips mulched in beds immediately under planted trees may constitute more of a fire hazard than the slash *in situ*. Also, there is some question whether a mulch bed of the thickness contemplated will control competitive sprouts from hardwood rootstocks.

Another reviewer questions whether southern pine plantations yield sufficient logging slash to form the proposed mulch beds. Indeed, the whole issue of the merit of complete-tree harvest of southern pines (e.g., as proposed by Koch and Coughran 1975) versus less intensive harvest, as here described, has yet to be elucidated.

In spite of these reservations, the concept appears to the authors to have sufficient advantages to merit a trial. To promote such a trial, additional data follow on quantity of slash available, experience with mulched pine, and progress on machine design.

QUANTITY OF AVAILABLE SLASH

If the concept is to be workable, sufficient wood, bark, and foliage must be residual on the site to build the mulch beds to the required width and depth. Quantities available will vary greatly—depending on species, nature of preceding and final harvests, density of stand, site, and fire history on the acreage. Some data are available indicating that for certain species and logging regimes the quantity of slash is sufficient. Simonsson (1974) reported on four stands of Norway spruce (*Picia abies* (L.) Karst.) and Scotch pine (*Pinus sylvestris* L.) logged by various mechanized methods, all of which included branch-trimming equipment; he found that the quantity of slash varied from 41 000 to 57 000 kg per ha. He noted that the slash accumulated in heaps or swaths, covering 20 to 45 percent of the felling area to a depth greater than 10 cm; the rest of the area remained virtually clear.

Clark and Taras (1974) used regression equations to estimate the dry weight and composition of logging residue remaining after harvesting a natural unevenage loblolly (*Pinus taeda* L.) stand to various merchantable tops. Results indicated that, if the sale trees were harvested to a 15.2-cm top, 263 kg of dry logging residue would remain for every 1 000 kg (dry) of wood and bark removed. Logging the sale to a 10.2-cm top would reduce logging residue to 196 kg per 1 000 kg of wood and bark logged, and logging to a 5.1-cm top (plus utilizing limbs larger than 5 cm in diameter) would leave only 100 kg of residue per 1 000 kg of wood and bark logged.

Chappel and Beltz (1973) evaluated clearcut southern pine acreage in Alabama and observed that about 46 000 kg (green basis) per ha were left in residual trees, tops of cut trees, unused bole sections, and above-ground portions of stumps.

C. J. Storch (1975), in an evaluation of hogged slash residual from clear-felled Monterey pine (*Pinus radiata* D. Don) in South Australia, found that it yielded a mulch about 2-cm thick over the entire felling area. If this amount was concentrated in the rows described, mulch depth would likely have averaged about 7 cm.

From these limited data, and from observations in the field, it would seem that many logging sites would have residues sufficient to build the proposed mulch beds. However, where intensive utilization of tops, or whole-tree or complete-tree harvesting is practiced, the concept would not be applicable.

EXPERIENCE WITH MULCHED PINE

As noted previously, a major objective of the concept is to eliminate windrowing and burning because of fertility diminution from the loss of topsoil during bulldozing and the loss of nutrients during burning. What about other effects?

Loblolly Pine in East Texas

Bilan (1960), in a study of the effects of root development in modified environments—i.e., naturally sodded ground, a 5.1-cm mulch of pine needles (both unshaded and 50 percent shaded), bare ground (both unshaded and 50 percent shaded), and bare sand—examined the roots of loblolly pine seedlings that had been bar-planted at age 1 on 61-cm spacing in east Texas during February 1957 and then allowed to grow an additional year before excavation. His conclusions follow.

On plots protected by mulch, shade, or sod, more than half the root growth was in the uppermost 7.6 cm of soil, and over 70 percent of the root weight was in the top 15.2-cm layer. On an ovendry basis, the root systems weighed about as much as stems and needles combined; root weight was generally less than 90 g per seedling.

Scalping sites before seedlings were planted increased the total dry weight of the roots by more than four times, increased the temperature at the soil surface, and caused a general downward shift of the entire root system. Mulching of scalped soil favored root development very close to the soil surface, probably by improving moisture conditions and mitigating temperature extremes. About 70 percent of ovendry root weight on mulched plots was in the uppermost 7.6 cm of soil. Mulching increased the length of lateral roots, but decreased root branching and lignification; the total biomass on scalped and mulched plots was somewhat less than on scalped plots with no mulch.

Monterey Pine in South Australia

In 1974, while traveling near Tarpenna, South Australia, it was the senior author's privilege to see an impressive response in Monterey pine that had been mulched. C. G. Stephens and C. J. Storch (1975), foresters responsible for the experiment, have provided some response data. The experiment consists of 14 rows of 25 trees each. Planting with 1-year-old nursery stock took place in August and September 1969, at which time the mulch was also applied. Rows 1, 6, 10, and 14 are controls and received a "normal" fertilizer treatment of 113 g of superphosphate per tree. Rows 2, 3, 4, 5, 7, 8, and 9 received a variety of other treatments. Rows 11, 12, 13, and 14 were involved in the mulching experiment and received the treatments indicated in table 1.

Table 1. Treatment of four rows of Monterey pine in mulching experiment.

ROW	TREATMENT
11	113 g of superphosphate plus 71 g of potassium sulphate per tree; no mulch.
12	Fertilizer as in row 11 (above), plus a mulch of pine bark for half the row length and pine chips for the balance.
13	113 g of superphosphate per tree, plus mulches of bark and chips as in row 12 (above).
14	113 g of superphosphate per tree; no mulch.

A basal dressing of 82 kg of ground rock phosphate was spread uniformly over the whole area of the 14 rows. The other fertilizers were spread over the space around each tree within a circle 0.9 m in diameter. The bark and chip mulches were applied to a depth of about 10 cm after planting and application of fertilizer; the mulch completely covered the ground between trees in rows 12 and 13 and extended halfway towards rows 11 and 14 (fig. 3). The bark mulch came from the sawmill log skids and was quite variable in size, with larger pieces measuring about 10-cm square by 2-cm thick. The chips came from the sawmill hog and were somewhat less variable in size, with the largest pieces measuring about 15 by 5 by 1¼ cm (fig. 4).

Figure 3. Virtually weed-free rows of wood-chip mulched Monterey pine, about 15 months after planting.

In the experimental area, groundwater lies in polyzoal Miocene limestone about 9.1 m below ground level. Observations repeated in dry weather each summer show dry soil in the control plots and moist soil below bark and chip mulches, with lower levels of the mulches also moist. Annual rainfall in the area averages about 84 cm.

Wood chips provided almost complete weed control (figs. 3 and 4); bark was slightly less effective; but with early canopy closure, weeds in the bark mulch were much reduced by July 1975. Unmulched control plots had a full covering of weeds soon after planting.

Data taken 1 through 5 years after planting indicate that the mulched trees responded immediately to

Figure 4. Typical Monterey pine, about 15 months after planting.

Table 2. Mean dimensions of Monterey pine in mulching experiment.

Year measured	Dimensions measured	Row 11* (No mulch)	Row 12 (With mulch)	Row 13	Row 14 (No mulch)
1970	Height (cm)	53	78	74	55
1971	Height (cm)	103	158	154	104
1972	Height (cm)	140	260	245	155
	Diameter**(cm)	3.6	7.8	7.3	3.9
	Volume (cm^3)	721	5 130	4 163	983
1973	Height (cm)	268	429	405	274
	Diameter (cm)	6.0	10.9	10.1	6.0
	Volume (cm^3)	3 097	15 097	12 394	3 978
1974	Height (cm)	470	634	619	470
	Diameter (cm)	8.2	13.5	13.2	8.7
	Volume (cm^3)	10 688	36 962	32 132	12 722

*See table 1 for details on fertilizer and mulch (if any) used on each row.

**Diameters measured 15 cm above ground level.

exceed the unmulched trees in height and diameter (table 2). To determine if the rapidly growing mulched trees might become nitrogen deficient, P. DeVries of the Australian Commonwealth Scientific and Industrial Research Organization, sampled and analyzed the needles from trees in rows 10, 11, 12, 13, and 14. He found that needles from the mulched trees had greater content of nitrogen than the unmulched trees. In short, under conditions of the experiment, mulching accelerated growth. Because this exploratory study did not include replication, a follow-up experiment of more rigorous design and larger size is now underway in Australia (Stephens and Storch, 1975). In areas of water surplus, it is doubtful that mulched trees would differ so markedly from unmulched trees.

EVOLUTION OF ROW-MULCHING MACHINE

In response to a need for equipment to hog logging slash and broadcast it more or less uniformly over an area, a number of commercial machines have been manufactured. The literature contains evaluation of some of these machines (e.g., USDA Forest Service, 1970; Lambert, 1974; and Harrison, 1975). For one reason or another none of these commercially available machines appear capable of row mulching in the manner we visualize.

Development of Cutterhead

To evaluate cutterhead designs for brush and slash disposal, the Forest Service's San Dimas Equipment Development Center constructed a test stand for both horizontal- and vertical-axis hogging cutterheads (fig. 5). After testing commercially available heads, a development effort on a horizontal-axis cutterhead began. This evolved into a configuration of two individual cutters, mounted at opposite ends of a support member (fig. 6), which pivot about hinge bars. Each stirrup-like cutter is about 26-cm long from its pivot point to cutting edge and the cutting circle diameter is 119.4 cm.

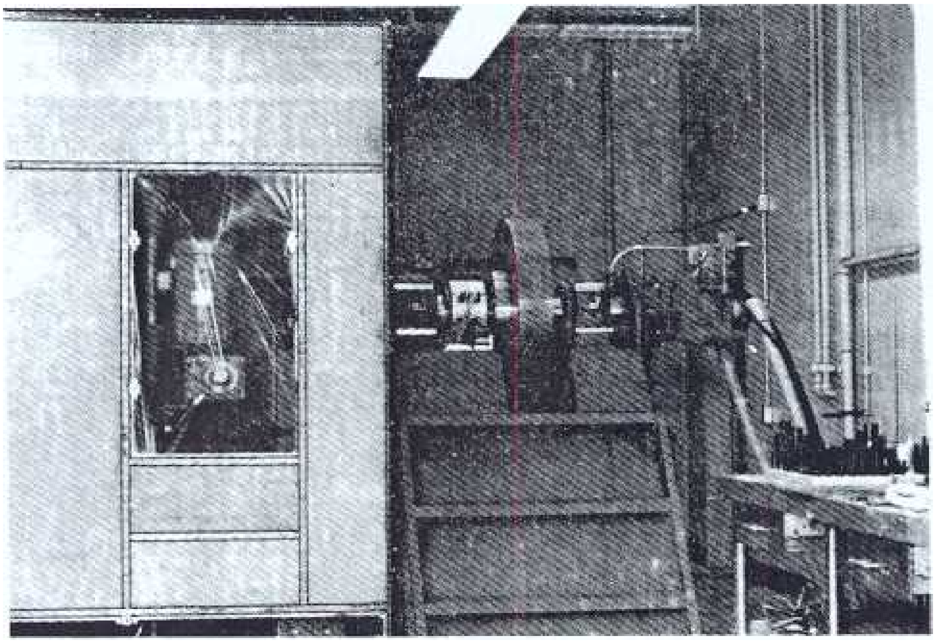

Figure 5. Test stand for evaluating cutters designed for slash treatment/utilization equipment.

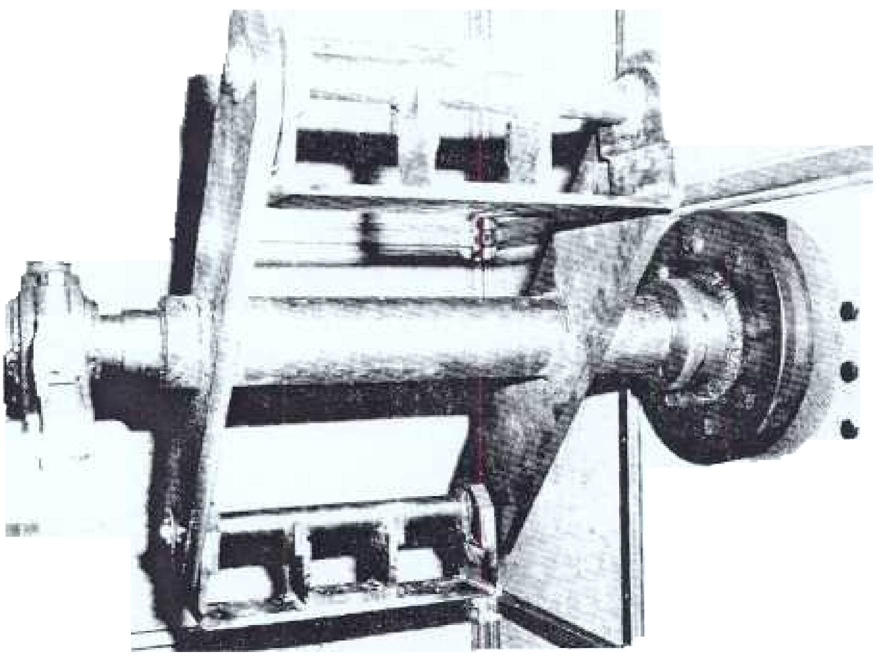

Figure 6. Mounting of cutters that make up the test bed cutterhead.

Guided by data obtained from a series of test runs using various wood types and cutter design concepts the engineers and technicians at the Equipment Development Center built a prototype cutterhead that was mounted on a Hydro-Ax model 1 000 prime mover (fig. 7). The 15.9-cm wide cutters (fig. 8) with relatively blunt cutting edges were assembled in a 9-stirrup-wide arrangement of 18 cutters having a total length of about 1.5 m and a cutting circle diameter of 121.3 cm. Steel discs were placed after every third stirrup assembly to support these assemblies and limit the depth of the cutter's bite. Each individual cutter can swing through a limited arc of 232 degrees. The geometry and dynamics of the cutters are

Figure 7. Prototype cutterhead mounted on a Hydro-Ax model 1 000.

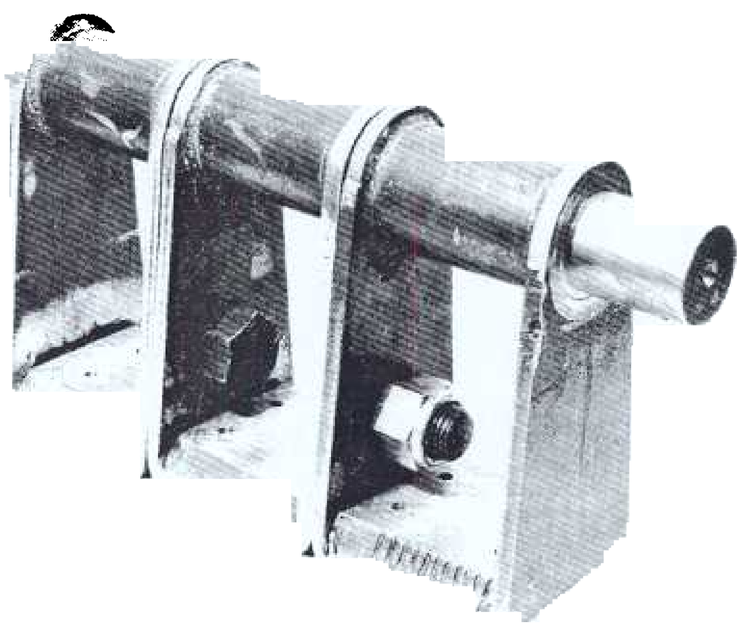

Figure 8. Stirrup-type cutter.

such that, after being folded back during a cut, they return to their cutting position by the time the cutterhead has made a revolution. Thus the cutters are always available to engage the wood being hogged.

Figure 9. Prototype cutterhead.

When driven at 900 rpm, about 150 hp is required to chip wood up to 20 cm in diameter; chips and chunks produced measure up to 15 cm in the largest dimension (fig. 10). Specific cutting energy expended when the cutterhead produces such softwood chips is about 3.0 x 10^{-4}kw-hr per kg (i.e., 0.36 hp-hr per ton). By varying the rake and clearance angles, etc. of

Figure 10. Chipped wood produced by prototype cutterhead.

the cutters, the average size of the chips can also be varied (fig. 11). The chips shown in figure 11 would be more acceptable for use as site enhancement planting mulch. Specific cutting energy for such chips is about 8.2×10^{-4} kw-hr per kg (or 1 hp-hr per ton).

Figure 11. Chipped wood produced with sharper cutters having greater rake and less negative clearance angles.

Production Machine Concept

The success obtained with the 1.5-m prototype has encouraged us to proceed with concept drawings for a commercial machine. The cutterhead will carry cutters of the design shown in figure 8, arranged as shown in figure 9; its length will be 2.6 m. The cutterhead, together with a chip hood and an integral conveyor belt (fig. 12), will be carried on the front end of an articulated wheeled prime mover. This longer cutterhead, powered by a hydraulic motor, will demand about 260 hp and will rotate at 900 rpm. The conveyor belt will catch the chips as they are formed and will deposit them in 60-cm wide, 5- to 7-cm deep beds, spaced as desired alongside the prime mover as it moves slowly along its traverse path. In addition to the slash on the ground, the machine will be able to chip standing softwood trees up to 20 cm in diameter and residual hardwoods up to 15 cm in diameter.

On level terrain, under conditions typical after final felling of a southern pine plantation, travel speed will likely be in the range of from 1 to 5 km per hour. Spacing of mulch beds will be determined by the spacing of the traverse lines of the prime mover; if the traverse lines are spaced in excess of 2.6 m, some residual will escape mulching.

The concept appears promising and development work is continuing.

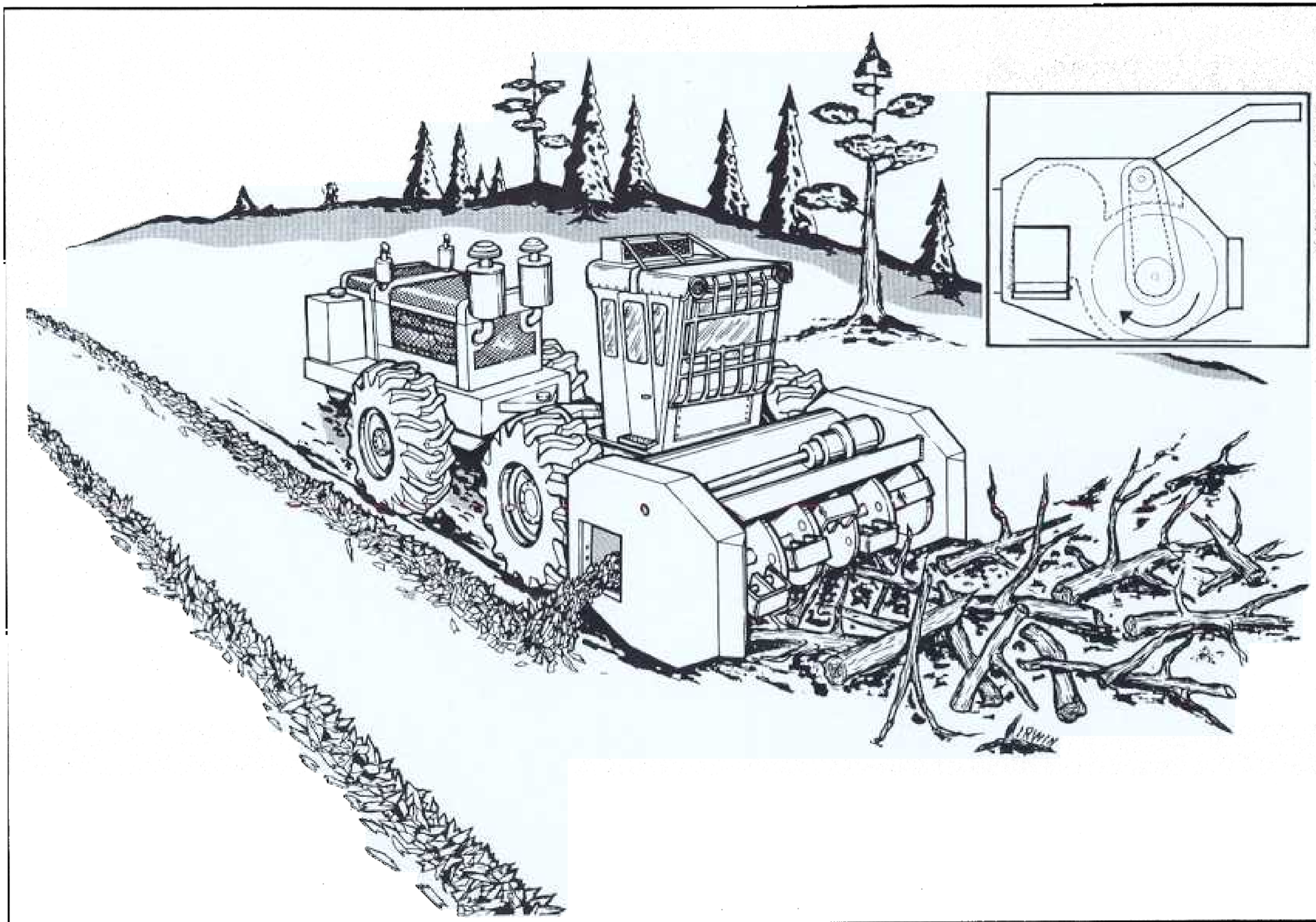

Figure 12. Concept of commercial row-mulching machine for hogging logging slash and conveying resulting chips to mulch beds.

LITERATURE CITED

Bilan, M. V.

1960. Root development of loblolly pine seedlings in modified environments. Stephen F. Austin Coll. Forest. Dep. Bull. 4.

Boyle, J. R., J. J. Phillips, and A. R. Ek.

1973. "Whole tree" harvesting: Nutrient budget evaluation. J. For. 71(12):760-762.

Chappel, T. W., and R. C. Beltz.

1973. Southern logging residues: an opportunity. J. For. 71:688-691.

Clark, A., III, and M. A. Taras.

1974. Effect of harvesting to various merchantable limits on loblolly pine logging residue. For. Prod. J. 24(6):45-48.

Harrison, R. T.

1975. Slash: equipment and methods for treatment and utilization. Equip. Dev. and Test Rep. 7120-7, USDA Forest Serv., San Dimas, Calif.

Jorgensen, J. R., C. G. Wells, and L. J. Metz.

1975. The nutrient cycle: key to continuous forest production. J. For. 73(7):400-403.

Koch, P. and S. J. Coughran.

1975. Development of a puller-buncher for harvesting southern pines with taproot attached. For. Prod. J. 25(4):23-30.

Lambert, M. B.

1974. Evaluation of power requirements and blade design for slash cutting machinery. ASAE Paper No. 74-1570. USDA Forest Serv. Equip. Dev. Ctr., San Dimas, Calif.

Shoulders, E. and W. H. McKee, Jr.

1973. Pine nutrition in the West Gulf Coastal Plain: a status report. Gen. Tech. Rep. SO-2. USDA Forest Serv., South. For. Exp. Stn., New Orleans, La.

Simonsson, N.

1974. The distribution of slash after mechanized final felling. Ekonomi, Forsknings-stiftelsen Skogssarbeten. No. 5.

Stephens, C. G., and C. J. Storch.

1975. Private communication, Southern Australia Perpetual Forests Limited. (18 July)

USDA Forest Service.

1970. Results of field trials of the Tree Eater: a tree and brush masticator. Equip. Dev. and Test Rep. 7120-1, USDA Forest Serv., San Dimas, Calif.