

Machine To Harvest Slash, Brush, And Thinnings For Fuel And Fiber— A Concept

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ABSTRACT—It is proposed that biomass from non-commercial thinnings, and from logging slash residual after harvest, be hogged and recovered for fuel and fiber. Such a procedure might yield two dividends of biomass totalling as much as 90,000 kg per ha (40 tons per acre, green weight basis) from each rotation of southern pine. For sites deficient in organic matter, it is alternatively proposed that residual biomass be hogged and returned to the forest floor—either uniformly distributed or concentrated in bands.

Conversion of unmanaged forest land to pine plantations and cultivation of ensuing rotations call for repeated cycles of residual wood disposal. These cycles can be categorized as brush control, precommercial thinning, and logging slash disposal. In the South, brush control is usually achieved by periodic prescribed burning, by injection-deadening of unwanted species, or by foliar spraying with chemicals toxic to unwanted species. Precommercial thinning is accomplished by a variety of mechanical methods, all of which waste resultant tonnages of wood. After clear-felling of final crop trees, it is usual to windrow and burn tops, branches, stumps, and non-commercial trees in order to facilitate planting of the new stand.

This paper proposes an alternative method for performing these operations with a view toward recovering residues for fuel or fiber. In evaluating technical and economic feasibility of the proposal, it is useful to consider the tonnages of forest residues typically generated in management of pine plantations.

Residue Quantities

The amounts of residue from precommercial thinning and final harvest vary with the silvicultural system. In this discussion, comments will be restricted to procedures applicable to conversion of heavily stocked natural stands of southern pine and mixed hardwoods to fully managed pine plantations. Only two rotations will be considered: first, a 30-year minimum rotation yielding a full range of logs for lumber, veneer, and pulpwood; second, a 25-year rotation for pulpwood only.

In the first case, non-commercial thinning might be scheduled for year 6; a prescribed burn might be

scheduled for year 14, with boltwood commercial thinnings at year 15 and longwood thinnings at ages 20 and 25, followed by final harvest not sooner than year 30. After year 14, brush would not again be burned, but would be controlled during slash disposal following final harvest. Under these conditions, the final harvest could yield butt logs averaging perhaps 11 inches in diameter.

In the second case, non-commercial thinning might be accomplished at age 6, with no prescribed burns and only a light thinning of weak trees (in swaths plus selection) at about age 17; final harvest would be at year 25. Brush would be controlled during slash disposal operations prior to establishment of pines at a prescribed spacing.

During such rotations, what tonnages could be expected from retrieval of non-commercial thinnings and from slash following final harvest?

Precommercial thinning.—Stands of naturally or directly seeded southern pines vary greatly in density, but it is not unusual to find 12,000 to 40,000 stems per hectare. Such stands, if thinned at about age 6 by removing all stems in 2- to 3-meter swaths between narrow bands of residual trees, might yield 23,000 to 45,000 kg per hectare (10 to 20 tons per acre) of green wood, bark, and foliage¹.

Slash and brush disposal following final harvest.—Data on amounts of wood, bark, and foliage remaining after final harvest are limited. Quantities will vary greatly with species, nature of preceding and final harvests, density of stand, site, and fire history. For certain species and logging regimes, however, the quantity of slash is substantial. A brief sampling of the literature indicates the likely range of tonnages.

Simonsson (1974) reported on four stands of Norway spruce (*Picea abies* (L.) Karst.) and Scotch pine (*Pinus sylvestris* L.) logged by various mechanized methods, all of which included branch-trimming equipment. The quantity of slash varied from 41,000 to 57,000 kg per ha. It 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

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¹Private communication with B. M. Davis, International Paper Company, Mobile, Alabama, and with Gordon Condit, Boise Southern Corporation, De Ridder, Louisiana.



Figure 1. Prototype reduction head mounted on a Hydro-Ax model 1,000 to make up a Forestland Residues Machine.

residue remaining after harvest of a natural uneven-aged loblolly pine (*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 of dry wood and bark removed. Logging to a 10.2-cm top would reduce residue to 196 kg per 1,000 kg of wood and bark removed, 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.

Stephens and Storch², in an evaluation of logged 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.

Lidburg (1975) reported that logging slash chipped 1 year after clear-felling a mixed-species coniferous forest in Sweden amounted to 51m³ (loose volume) of chips per ha.

From these limited data, and from observation in the field, it would seem that green weight of brush and logging slash following final harvest of many natural stands might amount to 45,000 kg per ha (20 tons per acre).

Evolution of Mobile Hog

To utilize these tonnages for fiber and fuel (or as mulch), a machine is required to reduce the residues to chips or chunks. 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 evaluations of some of them (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 hogging and collecting in the manner we visualize. To more adequately solve the problem, researchers at the Forest Service's San Dimas Equipment Development Center conceived of a general-purpose mobile hog which they have named *Forestland Residues Machine*. Their

²Stephens, C. G. and C. J. Storch. 1975. Private communication, Southern Australia Perpetual Forests Limited. (18 July)

studies centered about design of the rotating hogging head, because this element is the key to the machine's operation. They have named the element a *reduction head* because it carries flails rather than knives.

Development of reduction head.—To evaluate reduction-head designs for brush and slash disposal, the center constructed a test stand for both horizontal- and vertical-axis heads. After commercially available heads had been tested, a development effort on a horizontal-axis model began. The result was a configuration of two stirrup-like flails which pivot about hinge pins at opposite ends of a support member.

Guided by data from test runs with various wood types and head designs, the center built a prototype head and mounted it on a Hydro-Ax model 1,000 prime mover (fig. 1). The 15.9-cm-wide flails (fig. 2) with relatively blunt cutting edges were assembled in a nine-stirrup-wide arrangement of 18 flails 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 provide support and limit the depth of bite. Each individual flail can pivot on its axis through an arc of 232 degrees. Geometry and dynamics of the flails are such that, after being folded back during impact, they return to their operating positions by the time the head has made a revolution. Thus, the flails are always available to engage the wood being hogged.

When the head is driven at 900 rpm, about 150 hp is required to break wood up to 20 cm in diameter; chips and chunks produced measure up to 15 cm in the largest dimension. Specific cutting energy expended when the reduction head produces such softwood chips is about 3.0×10^{-4} kw-hr per kg (i.e., 0.36 hp-hr

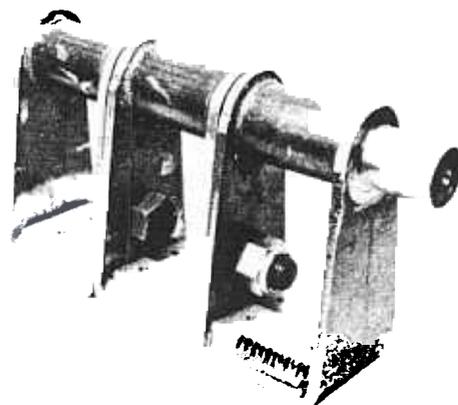


Figure 2. Stirrup-type flails.



Figure 3. Chipped wood produced with sharper flails having greater rake and less negative clearance angles than flails illustrated in figure 2.

per ton). By varying rake and clearance angles of the flails, average size of the chips can also be varied. The smaller chips shown in figure 3 would be more acceptable for mulch. Specific cutting energy for such chips is about 8.2×10^{-4} kw-hr per kg (or 1 hp-hr per ton).

Proposed commercial machine.—The commercial machine proposed will carry an improved 8-foot-wide reduction head on the front of a 200- to 400-horsepower prime mover in such a fashion that retrieval of hogged slash, cull trees, stumps, brush, or thinnings is possible (fig. 4). The machine will travel at 1 to 5 km per hr and should be able to reduce standing softwood trees up to 20 cm in diameter and residual hardwoods up to 15 cm in diameter.

The difficulty of successfully building this machine is recognized. Foremost among the problems is that of designing a reduction head capable of hogging energy-absorbing material such as hickory stumps or white oak cull trees. Moreover, the reduction head must be able to withstand occasional impacts with rocks.

Given a successful reduction head, the dirt that will inevitably be picked up by the cutterhead must either be tolerated in the product or removed before transit to the mill. Removal would, of course, be preferable.

Finally, potential machine operators are wary of ex-

cessively massive machines that may be too heavy and awkward to navigate easily over southern terrain.

The retrieval machine as it ultimately develops may or may not resemble the one depicted in figure 4. For example, an 8-foot-long felling bar might be attached across the front of the machine to sever all wood an inch or two above ground level before the reduction head engages the wood; this would simplify reduction of stumps and standing trees, and the bar would level some surface irregularities. Moreover, further analysis may indicate that a series of machines can do the job better than a single one. For example, the hogged wood might be deposited in a narrow bed between the wheels of the prime mover; a second machine could then move along the bed in the manner of a corn picker and load the hogged wood into a piggy-back bin or pallet. Finally, a third machine—a forwarder—could shuttle between pickup machine and highway transport truck. Alternatively, the reduction machine might deliver hogged material to a pair of self-powered forwarders that would trail it until loaded and then shuttle between the reduction machine and a highway transport truck.

Should silvicultural prescription call for return of biomass to the forest floor, the problem is much simpler. The mobile hog could be designed to distribute

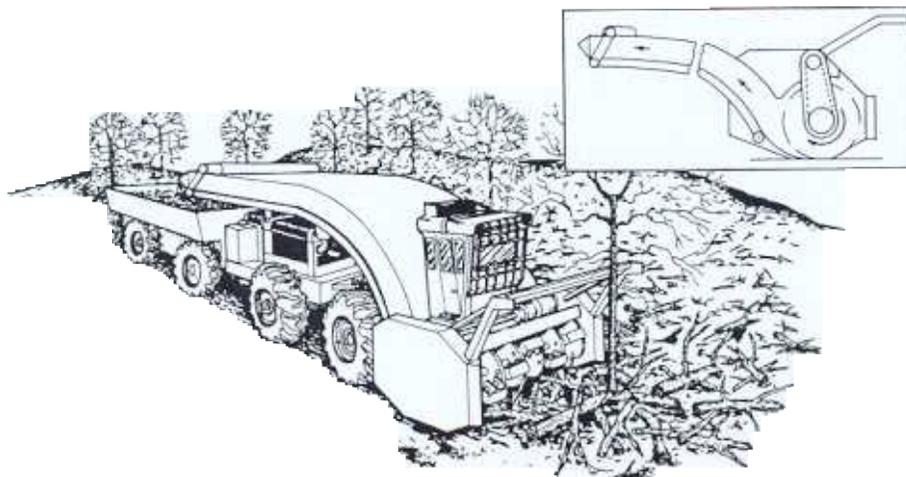


Figure 4. Concept of mobile machine to hog and retrieve logging slash or standing trees to be removed by row thinning.

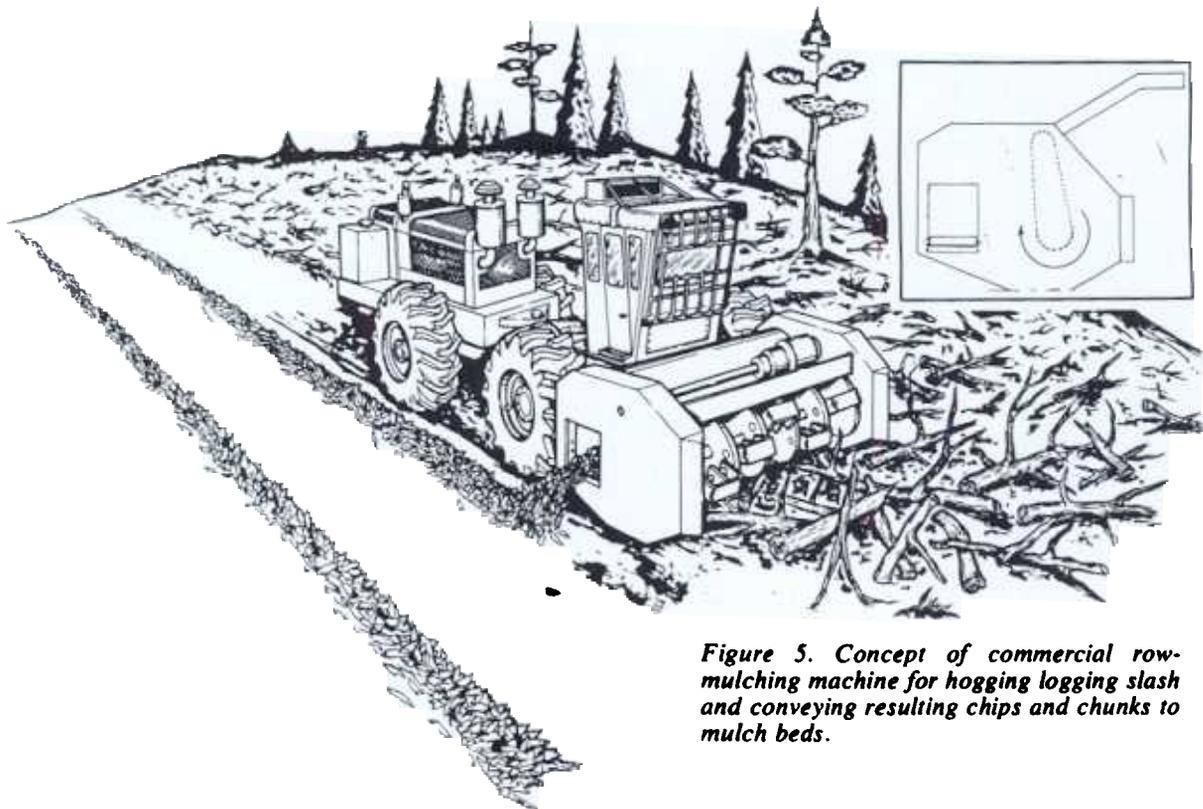


Figure 5. Concept of commercial row-mulching machine for hogging logging slash and conveying resulting chips and chunks to mulch beds.

wood chunks uniformly over the acreage (fig. 3) or to deposit them in bands or rows of concentrated mulch (fig. 5).

Toward a Practical Machine

To bring the concept to fruition, design proposals have been requested from a couple of dozen leading manufacturers of harvesting equipment. Adequacy of submitted proposals will be evaluated by a panel composed mostly of industrial land managers and loggers from the South. It is hoped that the design winning the competition will be converted to operational hardware by late 1977 or early 1978. If successful, the equipment should be of interest to forest managers throughout the South as a means of reducing logging slash and accomplishing pre-commercial thinning of thicket stands.

The equipment will be designed primarily to retrieve the biomass for use as fiber or fuel. Koch (1976) has outlined a utilization system that calls for initial particle sizing followed by processing to separate clean wood from bark and dirt. Erickson (1976) has described one such cleaning operation; others are working on different techniques.

As visualized in Koch's process, clean, sized, chips and chunks would proceed to ring flakers and be converted for use in structural exterior flakeboard. Bark and fines would be freed of dirt and burned to supply energy for plant operation. By this series of operations, perhaps half the residue tonnage would end as usable fiber and half would be burned for energy.

Alternatively, the equipment to be built can be arranged to return all biomass to the forest floor by broadcasting it over the entire site or by concentrating it in beds of mulch according to silviculturists' prescriptions. In the latter circumstance, the mobile hog would slowly traverse the acreage and hogged material would be collected and delivered via belt to

spaced planting beds about 60 cm in width and perhaps 5 to 7 cm in depth (fig. 5); centerline distance between beds might range from 2 to 3 m. For average bed dimensions and spacings, 144 cu m of mulched material would be needed per ha; at 320 kg per cu m, about 46,000 kg of green mulched chip would be required per ha. No effort has been made to abstract the large body of literature on mulching, but an account of one Australian firm's success in mulching Monterey pine is pertinent and has been described by Koch and McKenzie (1975). Likely benefits of mulching with hogged logging slash would include reduction of fire hazard, return of nutrients to the soil, diminution of topsoil disturbance and air pollution resultant from windrow-and-burn operations, conservation of soil moisture, and suppression of weed growth. ■

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