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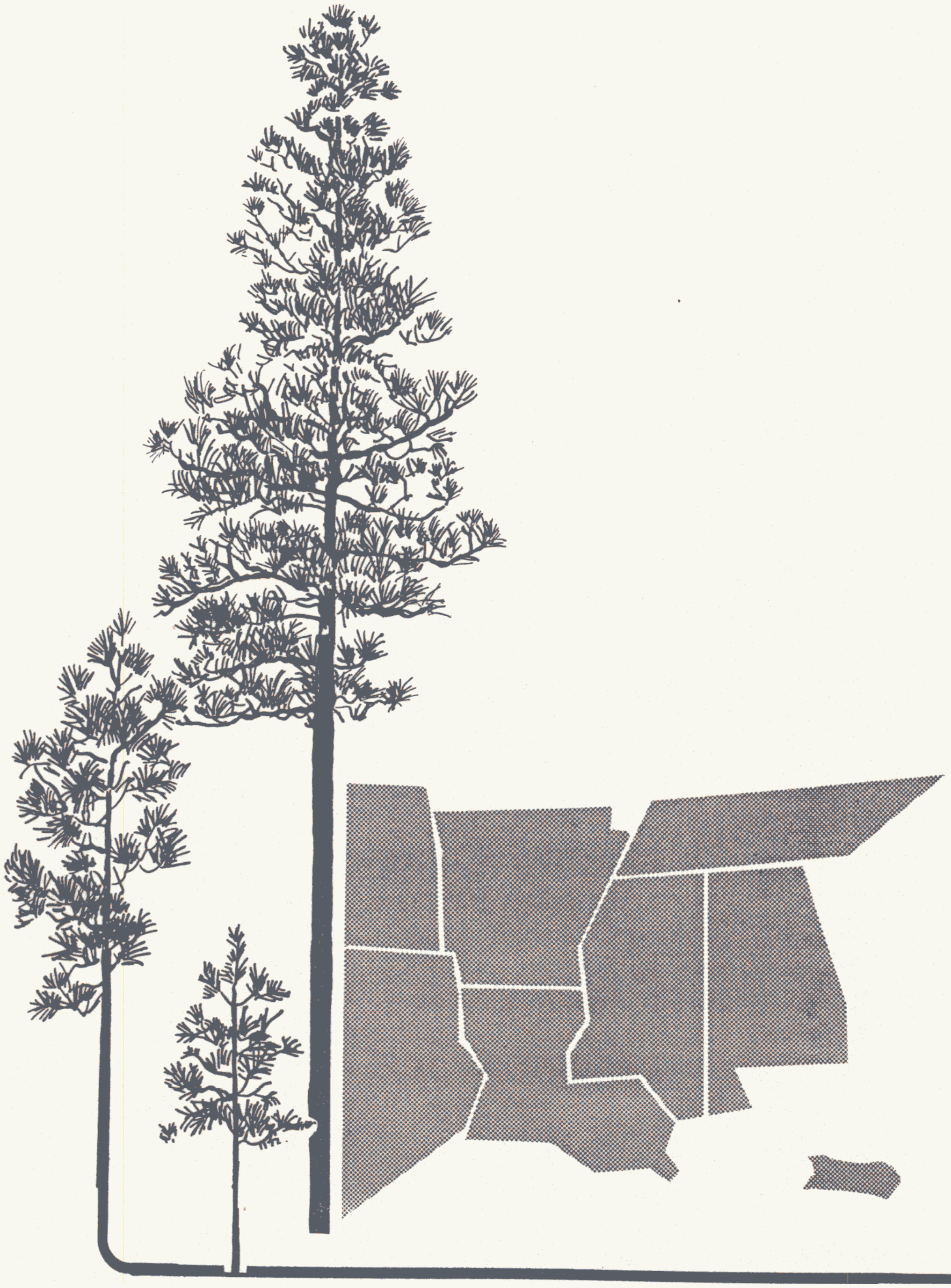

Southern Forest Experiment Station

RECOVERY OF FOREST RESIDUES IN THE SOUTHERN UNITED STATES'

by

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INTRODUCTION

In the mid 1970's, the accelerated price increases for petroleum products forced rapid exploration into and adoption of alternative energy sources. A viable option for the forest industry was the recovery of woody biomass from unmerchantable trees and logging residues. Several studies estimated that an abundance of such forest materials existed in the southeastern United States (GAO 1981, Ames and Ounavent 1984, Thomas et al. 1986). Other research concentrated on economical methods of converting forest residues into energy for industrial uses.

Besides offering an alternative source of renewable energy the removal and utilization of forest residues has several intrinsic values. Forest residues can supplement a declining wood resource that is much in demand. Improved utilization, with less wasted biomass, can increase the fiber supply and yield from timberlands. With increased utilization of residues, site preparation costs can usually be reduced. This leads to lower regeneration costs and improved stocking and production from the forest land base.

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Many of the harvesting concepts and techniques developed for the recovery of forest residues in the Southern United States are summarized in this paper. The objectives are to define residues, describe developed technology, review harvesting techniques and speculate on the future of recovery and utilization of such residue:.

DEFINING FOREST RESIDUES

Logging residues are defined as unused portions of growing stock (pole timber and sawtimber) killed by timber harvesting (Stokes et al. 1989). Forest residues are the remaining woody biomass usually considered unmerchantable, left on site after harvesting merchantable stand and tree components. Forest residues include logging residues and residual stand components. Residuals are considered the by-products of an operation such as logging in general , or of a specific function such as delimbing. Residuals on the site include such material as standing trees and unremoved cut stems that are too small for merchantable products, have substandard specifications, or do not meet species requirements. Residues and residuals in the stand or at the landing are the limbs, tops, cull-bole portions, and stumps of the merchantable and unmerchantable trees. For the purpose of this paper, forest residues will include residuals from the harvesting operation. However, the classical definition of "forest residue" is an elusive term, dependent on the recovery efficiency of the harvesting system.

In theory, forest residues can be classified as any stand or stem component that would not be recovered during the harvesting operation given the level of utilization, system recovery efficiency, and range'of harvested products. For a conventional sawlog system, residues could include trees that are pulpwood size or less, unmerchantable sawtimber size trees, limbs, tops, unmerchantable portions of the removed sawlogs, and stumps. In a more intensive integrated harvesting system that produces roundwood and pulp chips, the only residues would be the limbs, tops and broken sections of the trees that were removed as roundwood the small trees too small for chipping, and stumps. In all cases, the residues are woody biomass components not recovered by the harvesting system. These materials (residues) do not necessarily have to be "left", but can be recovered in advance, during or after the harvesting of conventional products to the desired or economical level of utilization.

PROCESSING ALTERNATIVES

Residues are usually processed to reduce the material to a form that will allow easy and economically feasible removal, transport, and handling (Sirois and Stokes 1986). Because of the form of the raw materials, processing usually begins at the harvest site and may be completed after transportation to the mill.

The harvesting system is characterized by the type of products harvested. Trees and stem components are usually recovered in two basic forms, roundwood or chips. Roundwood may be the whole tree (complete except the stump) or processed bole wood. The bole wood may be either tree length, log length, or bolt length.

When the trees or residual material are chipped, with limbs, tops and bark attached, the chips have limited use for making paper pulp and composite panel products. Usually material with such a high bark content is only suitable as energywood to produce electricity and steam. Clean chips for pulping can be produced in the woods by delimbing and debarking before chipping.

Some methods have been developed to recover non-conventional products other than chips. Fuelwood can be recovered as shortbolts. This method is limited because of piece size and markets. Other concepts have been developed to handle a larger range of size and form. Many of these concepts have only advanced to the prototype stage and have not become operational. Examples of products are chunks, bales, modules, shreds, and ground materials.

Chipoinq

Harvesting forest residues economically is difficult because of the high cost of handling and transporting non-uniform small materials and because of the relatively low product value. Harvesting costs may be reduced by chipping whole trees or stem components at the site and using the material for boiler fuel. Four separate machine concepts have been identified for chipping forest residues at the site (Sirois 1982, Stokes and Sirois 1984):

Portable Chippers -- The chipper is mounted on a trailer frame and is designed to be set up on a landing. Wood is felled and skidded to the chipper for processing.

Mobile Chip Harvester -- The chipper is mounted on a rubber-tired or tracked carrier with an integral device for clear felling small trees and brush in a continuous swath. Chips are discharged into a second vehicle for forwarding to the landing or other unloading point.

Mobile Chipper Harvester-Forwarder -- The chipper is mounted on a tracked or wheeled carrier that has an integral device for clear felling small trees and brush in a continuous swath. It also has an onboard provision for collecting the chips discharged from the chipper for forwarding to the landing or other unloading point.

Mobile Chipper-Forwarder -- The chipper is mounted on a rubber-tired or tracked carrier. Felled and bunched material is chipped at the pile and chips are discharged into an onboard container. When the container is full, the mobile chipper-forwarder travels back to the landing or other discharge point and unloads the chips.

Whole-tree in-woods chipping is an economical method of handling small stems and improving utilization. It became an important harvesting option for producing energywood in the late 1970's in the southeastern United States. Use has diminished somewhat because of current low oil prices, but use is expected to increase in the future. Most operational systems are composed of portable chippers, feller-bunchers and grapple skidders. Mobile chippers have been used on a very limited basis in the South and have not progressed beyond the prototype stage.

Chunking

Although chunking has not seen application in the southern United States, it should be mentioned as an alternative to chipping. The process, patented by the US Department of Agriculture Forest Service and still in the prototype stage, produces 5 to 11 cm long wood chunks instead of chips (Arola et al. 1983). The machine, originally a helical or spiral-head chipper, has evolved into an involuted disc chunker (Erickson 1976). Chunking requires less energy and produces a product suitable for energywood or other limited applications.

Crushing

The Canadian Forest Service developed a roller crusher/splitter test bench machine for biomass reduction and dewatering based on earlier work of the Tennessee Valley Authority (Jones 1982, Barnett et al 1986). The concept is to cut and process small diameter biomass by crushing, in one operation. After field drying, the crushed material would be collected and baled or modulized for transport. Further processing would probably be required. Potential advantages are lower energy requirements and transport costs, and improved heating value of dried wood.

Bal ins/Modulating

Baling of woody biomass is an alternative to whole-tree chipping (Swick et al. 1982). Baling is a promising option for limbs, tops and other segmented residues. The concept was first tested in 1975 at Virginia Polytechnic Institute and State University using a modified hay baler. A prototype baler completed in 1979 was an industrial compactor with a hydraulically powered ram and shear (Stuart et al. 1981). A separate knuckleboom loader was used to feed material into the baler.

Simulation studies on hypothesized baler systems were conducted by Jolley (1977) and Porter (1979). Both found baling to be comparable to chipping in cost and profit. According to Jolley the theoretical recovery of above-ground biomass may be as high as 99 percent.

Scheiss and Stuart (1981) conducted tests with the prototype baler. Expected production after modification was 2.3 to 2.7 tonnes/hour. Using the minimum times recorded for each baling function gave a theoretical maximum production of 3.6 tonne&per productive hour. Cost comparisons showed that the prototype baler was not competitive with whole-tree chippers. The researchers did hypothesize that a second generation baler, with a productive rate of 13.3 tonnes per productive hour, would be competitive.

Jenkins (1983) reports on several concepts for modulating agricultural biomass. Fridley and Burkhardt (1984) modified a round-bale hay baler to densify small diameter forest biomass. Stokes et al. (1988) completed similar tests on crushed trees.

Grinding/Shredding/Hogging

Although size reduction to particles smaller than chips is not a common in-woods function, some portable size reduction units have been evaluated for post-harvesting and integrated logging. Hammermills, hogs, shredders, and tub grinders are used to grind or chop residues into a product that can be used in boilers. These machines can process a much wider variety of raw materials than chippers or chunkers, including limbs, tops, and tree portions. Primary processing by shredders and grinders may be followed by additional processing by a hog at the boiler site.

Major advantages of these processes are the ability to handle a range of forest residue forms and to do so in an economical manner. A major disadvantage is their generally low productivity.

HARVESTING METHODS

Forest residues may be harvested: (1) after the conventional harvesting - post-harvesting, (2) before the conventional harvesting - pre-harvesting, and (3) as an integral part of the conventional harvesting operation. The first option usually recovers downed stems, and limbs and tops of previously processed stems. Some standing trees are recovered, depending upon their size and density. The second option is a specialized system using small equipment capable of handling small stems economically. The third option includes the felling and recovery of nearly all standing trees to a designated minimum diameter limit, sometimes as low as 2.5 cm DBH. This last option can be modified to include whole-tree harvesting and in-woods flail delimbing and debarking to increase product value.

Post-harvest

Post-harvest recovery of residues is probably the most difficult method. The site has stems with breakage, disorientation and entanglement. The limbs and tops may be scattered and remaining standing trees can be very small or very large, making them difficult to fell with conventional mechanized systems.

Post-harvest recovery of biomass energywood can decrease site preparation costs, but it is significantly less cost-effective than is pre-harvest or integrated (simultaneous) harvesting systems Its potential for biomass recovery falls between the other two methods.

Pre-harvest

Pre-harvesting usually involves using a specialized energywood harvesting system before the higher-valued merchantable products are harvested. Upper diameter limits and species to be harvested are dependent on markets, stand conditions, and management objectives. All stems within the specifications, usually pines less than 15 cm DBH and all non-sawtimber hardwoods, are cut by feller-bunchers. Skidding and chipping may take place at the same time as felling or may take place days or weeks later, allowing for transpirational drying. It may be more economical to segregate felling from skidding and chipping.

After the pre-harvest of small and undesirable trees, the more valuable products are harvested with little interference. This method has the advantages of (1) improving primary product harvesting productivity, (2) efficiently utilizing most of the unmarketable stems in a stand, and (3) leaving a nearly clean site requiring minimal site preparation before planting. The primary disadvantage is the inability to recover the limbs and tops of the primary product trees (Stokes et al. 1985).

Integrated Harvesting

The most economically advantageous biomass harvesting method is the modification of conventional harvesting systems by adding whole-tree chippers. For this process, the stand components are separated during harvest by size, species, quality, or tree segments. The separation may take place either before or after skidding. Limbs and tops of merchantable trees can be recovered and chipped along with non-merchantable trees.

Products may be separated by the feller-buncher operator during felling. The operator decides which stems should go to the loader and which go to the chipper. Where the product separation is accomplished after skidding, whole trees are skidded to the landing. The loader operator separates merchantable stems based on size, species or quality. The merchantable stem may be further processed and segmented into solid wood and chipwood components. The culled portions of these stems are chipped with the non-merchantable stand components (Stokes et al. 1985).

The recovery characteristics of a harvesting system are a function of: (1) the amount of energy biomass in a specific stand, (2) the market specifications for pulpwood chips, and (3) the local market for biomass fuels (Curtin and Czerspinski 1989).

Whole-tree Chipping - An alternative method for separating products is the whole-tree chipping of all trees in the stand and hauling chips to the mill. Screening to separate fiber chips from energywood and bark may be included as an intermediate phase in the woods or accomplished at the mill. Whole-tree chipping of pine trees has limited uses because the bark content is usually too high for many pulp processes even after special screening. The only usable product is energywood. Such operations are usually used to convert poor quality, stands of mixed species into productive pine stands.

Whole-tree Harvesting - An alternative to whole-tree chipping in the woods is transporting the whole tree (above ground biomass) to a processing facility. Trees are loaded onto special trailers that constrict the tops within legal highway load limits (Watson and Stokes 1987). Some trimming of limbs is required to make the loads legal on the highway. Conventional harvesting systems include feller-bunchers, skidders and a loader.

Certain modifications and requirements are needed for processing whole trees at a mill yard, including special handling and storage facilities. Large, straight conveyors are needed to transport bucked material to the drum debarker. The drum has to have special-sized slots for limb and bark removal. Specially designed large-sized drums are needed to maintain production and chip quality.

block

A significant advantage of whole tree processing at the mill is the efficiency of handling trees without any processing in the woods. This increases production and lowers harvesting costs, especially for small diameter stems. The major advantage is improved utilization of the above ground biomass. Disadvantages are the need for special trailers and for special mill receiving and processing facilities.

In-Woods Flail Processing - A conventional harvesting operation can be modified to harvest several additional products by including a flail delimber/debarker and chipper. Products, in addition to roundwood, may include clean chips and energy wood from merchantable stand components and forest residues.

Improvements in technology for flail debarking were made in the 1980's (Hammerstad et al. 1986, Lambert and Howard 1988, Stokes and Watson 1988). A dual-flail configuration improved productivity and delimbing/debarking quality. Wear-resistant chains are being developed for more economical flail operation.

In-woods flail processing has several advantages. Small diameter stems can be more economically processed into clean chips by flailing than by delimbing, topping, and hauling tree-length wood. More wood fiber can be recovered for pulp furnish. If the residuals from flailing are recovered, over 84 percent of the total tree biomass can be recovered as pulp fiber and energy wood (Stokes and Watson 1988).

Mobile Chipping - Land clearing and site preparation systems have been developed primarily for combining vegetation control with energywood recovery (Curtin and Barnett 1986). The result is a method that recovers undesirable vegetation and makes it available for fuel Some specific machine concepts were developed for biomass harvesting-or land clearing in recent years.

Georgia Pacific Biomass Harvester - The machine is classified as a mobile chipper harvester forwarder. Although its original design included forwarding to roadside, a final method of operation included inwoods dumping with a separate forwarding operation. Severing of small trees and brush is accomplished by two counter-rotating cutting disks. These cutters move the severed butts of the stems into the horizontal drum chipper.
The machine is comprised of two tracked carriers connected by an articulated joint. The rear unit carries the engine, hydraulic pumps and reservoir. The front unit carries the cutting head and chipping mechanism, the operator cab, and the chip container. The machine can hold 7.68 cubic meters of chips. All components are hydrostatically driven. This machine is neither currently in use nor being developed further.

Results have demonstrated the machine's capacity to harvest standing stems up to 12.7 cm DBH. Production rates in excess of 13 tonnes per PMH have been achieved.

Nicholson-Koch Mobile Harvester' (NKMH) - The NKMH was developed primarily to recover residues from conventional timber harvesting operations (Koch and Savage 1980) and is a mobile chip harvester It can also be used for harvesting standing timber. A horizontal felling bar cuts standing trees and lifts felled residues off the ground and feeds them toward a drum chipper. Two vertical rollers and a hydraulic arm, pivoted above the chipper opening, assist with the feeding of the chipper. Chips are blown directly into specially adapted forwarders. Sirois (1981) reported that on test areas the NKMH recovered approximately 76 percent of forest residues.

Biomass Combine (BC) - The BC was a prototype attachment to an agricultural tractor designed to harvest mesquite brush (Ulich 1983) and is classified as a mobile chip harvester-forwarder. It has a horizontal drum equipped with stirrup-shaped knives to reduce standing mesquite or other small woody biomass to chips. The chips are then conveyed by two augers to a basket with a 1.8 tonnes capacity for forwarding. Productivity of up to 5.4 tonnes per hour have been achieved.

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[2] Mention of firm or trade names is solely for the information of the reader and does not constitute endorsement by the U.S. Department of Agriculture or Mississippi State University.

FUTURE DEVELOPMENTS

With the current low oil prices, demand for wood for energy has decreased. Although new mills and facilities are installing wood-fired boilers, they have not had a problem finding wood sources mostly from mill residues and non-competitive wood from whole-tree chipping operations. There has been no impact on stand components currently having value as furnish for other forest products. The current situation is not expected to continue. For some time wood energy consumption has been expected to increase annually at rates of 10 to 15 percent and the increase will probably continue in the near future Increasing demand for energy wood must lead to increased utilization of stand and tree components. Developments such as flail delimbing/debarking may lead to competitive use of some of these components.

In the short-run, however, the southern United States has sufficient woody biomass for energy production without impacting other products. Forest residues from conventional logging operations, and growth of many weed species on unmanaged timberlands, could provide significant energy wood. The problem is to develop a technology to economically recover these residues and stands.

The many residue harvesting projects of the late 1970's produced several potential harvesting concepts and techniques. Their failure to become operational may be only a result of the lower oil prices making them uneconomical during the mid-1980's, and not their inability to efficiently recover forest residues. If needed, many of these concepts could provide viable alternatives and could be implemented with little delay. To meet the gradually expanding energywood markets, it may still be more economical to recover other, otherwise unmerchantable stand components as part of the conventional harvesting operation than to use specialized machines to recover residues as a separate operation.

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