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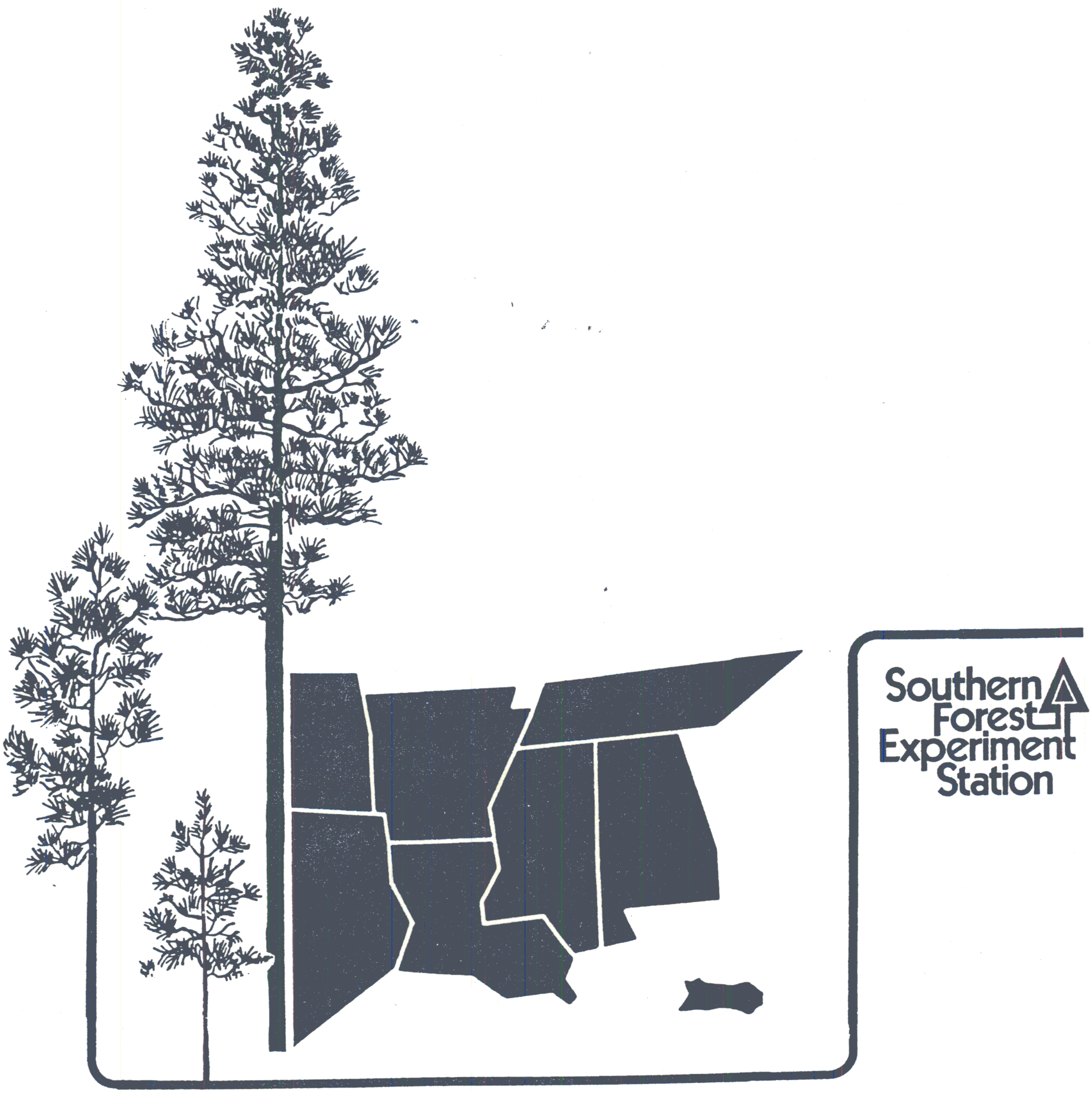

THE NICHOLSON-KOCH MOBILE CHIP HARVESTER SYSTEM

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Abstract

Development of the swathe felling Nicholson-Koch mobile chip harvesting system began early in 1977 with initial concept test of the swathe felling bar. The development has progressed through construction of a proto-type chip harvester that has advanced through several periods of field test and development modifications. Final modifications of the proto-type are being made and the supporting system machines (two chip forwards and a chip transfer machine) are now under construction for operational testing by mid-1982. The goal for the system remains that it be capable of producing 21 tons/hour (green) of harvested biomass delivered at road side.

Introduction

Since before recorded history wood has been a major source of energy for man. In many parts of the non-industrialized world, wood still is the dominant source of home energy. During the early development of the United States wood was the fuel that sustained homes and industry. More wood was consumed in the United States in the 1850s for energy than for lumber and other products. Consumption of wood fuel peaked in the 1870s at about three Quads (10^{16} BTUs) per year and declined fairly steadily through the early 1960s (5). The trend has reversed in recent years so that since the Arab oil embargo of 1974 there has been an increasing interest in the utilization of wood as a source of energy and chemicals (9).

In 1978 it was estimated that forest products were contributing about 1 1/2 percent or 1.1 Quads to the estimated 75 Quads of energy consumed by the United States annually (11). The estimate had increased to 1.2 to 1.3 Quads per year in 1980 with the greatest increase being within the pulp and paper industry (5). The use of energy wood by the pulp and paper industry increased nearly 6 1/2 percent, to 47 percent, of the total energy used by that industry during this period. New wood fired boilers presently under construction will further increase the industry's utilization of wood for energy. In addition, non-forest products companies are also showing a growing interest in use of wood as a source of energy. This is resulting in nearly all mill wood residues in the Southeast being committed to some form of utilization. Wood residual in the forest after commercial logging is virtually unutilized, however, and is therefore available for energy use if it can be economically harvested.

Presently, all fuel wood harvesting systems are based on some form of in-woods chipper. The use of these systems can be expected to continue because of high productivity capabilities and because a wide variety of raw materials can be processed into a fairly uniform commodity, whole tree chips, that is easy to load, transport, and handle at the use site. Four basic in-woods chipping machines that can be used for fuel wood harvesting have been identified by Sirois (11). These are: 1) portable chippers, 2) mobile chipper forwarders, 3) mobile chip harvesters, and 4) a mobile chip harvester forwarders. Presently, only the portable chippers are in commercial use. The other three machine types are all in the prototype stage. Each machine and its related system can be expected to have an area of application dependent on the forest stand and site conditions.

The present low commercial value of fuel wood chips and the availability of an abundance of non-commercial timber, primarily as logging residuals and residues, make these materials natural targets for energy uses. Berard (1) found that unused forest biomass available annually in the United States is about 600 million tons, ovendry basis, and that in Canada, about 121 million tons are available (Table 1).

Table 1. -- UNUSED FOREST BIOMASS IN CANADA AND THE UNITED STATES
(current estimates)

	United States	Canada
	(millions of dry tons)	
Excess growth & small trees	215	57
Logging residues	160	34
Rough, rotten & dead trees	115	22
Wood processing residues	20	8
Residues from land clearing[1]	20	
Urban wood residue[1]	70	
Total	600	121

[1]Data not available for Canada

For the state of Georgia, the average green tons of logging residues and residual trees left after conventional logging operations have been estimated for three stand types as follows(2):

Stand Type	Tons per acre, green-weight basis.
Pine	22
Pine-Hardwood	38
Hardwood	42

On two logging sites selected for testing the Nicholson-Koch Mobile Chip Harvester in east central Alabama, the measured tons per acre of logging residuals were found to be in close agreement with the Georgia values and are summarized by form in Table 2.

Economics of Energy Wood and the Nicholson-Koch Mobile Harvester

With the preponderance of logging residuals in the forms of cull and small trees and downed materials such as pieces and tops, conventional logging systems that might be used to feed portable chippers have low production and high cost (1, 6). Depending on average tree size and stand density, harvest cost (including transportation) can range from $6.00 per green ton for 11-inch average d.b.h. trees to $53.91 for 2-inch average d.b.h. trees. The Georgia Forestry Commission reported in 1979 that it cost (excluding transportation) $23.89 per green ton for harvesting a stand of 3-inch average d.b.h. trees with a 60 sq. ft. basal area stocking. These high costs with conventional harvesting systems (feller-buncher, skidder and portable chipper) have stimulated the search for new machines that will be more efficient for the harvesting of small trees and residues. The Nicholson-Koch Mobile Chip Harvester is a result of this search.

Unlike feller-bunchers, that can generally fell only one tree at a time, used with conventional whole tree chipping systems, the Nicholson-Koch Mobile Harvester can achieve high production in dense stands of small trees as well as fell large trees. This capability is provided by the machine's felling bar. The felling bar is approximately 8 feet long and is capable of felling trees in a continuous swathe and feeding them into the chipper along with downed materials such as limbs and tops that may be present on the harvest site. The felling bar and the machine have been well documented in other writings (7, 8, 11) and will not be presented here.

The concept of the complete system used in the economic analysis is illustrated in Figure 1. Presently only the mobile harvester has been undergoing developmental field testing since early 1980. Final development modifications are being made to the mobile harvester. Three other prototype machines, two chip forwarders and a chip transfer/utility machine, have been designed and built for operational testing starting in mid-1982.

Past field tests of the mobile harvester have indicated that the machine is capable of achieving the performance goals of harvesting 21 tons of green forest biomass per productive hour on sites containing at least 25 tons/acre. This and the assumption of a harvesting efficiency of 85 percent (15 percent of material not harvested or lost in the transfer/transport system) was used by Koch and Nicholson (7) in their economic analysis that showed in expected cost of $13,57 per green ton delivered to a mill. The analysis included a 30 percent pre-tax

Table 2. -- LOGGING BIOMASS RESIDUAL ON TWO SITES IN EAST CENTRAL ALABAMA IN GREEN TONS/ACRE.

Site	Diameter Class-inches	Hardwood			Pine		
		Standing	Downed	Pieces	Standing	Downed	Pieces
I	1-2	.3	1.9	2.5	0	.7	1.3
	3-4	4.0	1.0	0	0	1.0	1.7
	5-6	0	1.8	0	0	0	0
	>6	4.7	0	0	0	0	0
Site Total	20.9	9.0	4.7	2.5	0	1.7	3.0
II	1-2	4.4	.1	.9	.4	0	2.3
	3-4	5.8	1.3	1.0	0	1.1	.3
	5-6	4.8	0	0	0	0	0
	>6	14.0	0	0	0	0	0
Site Total	36.4	29.0	1.4	1.9	.4	1.1	2.6

profit and the application of a $74 credit per harvested acre for preparing the site for forest regeneration on 1,500 harvested acres. Because of inflation Koch and Savage (8) revised the cost upward to $18 per ton (green basis). This cost estimate compared favorably with the price paid for fuel chips, $16 to $18 per ton green paid in the Southeast (10). Timber Mart South (12) reported a southwide hardwood pulp chip price of $16.08 per ton green FOB mill in January 1982. These prices, if compared to recent fuel oil prices, are low. The February 15 issue of Energy Users News (3) reported a refiner's fuel oil price of $28.27 per barrel (42 gallons) for No. 6 oil at Mobile, AL and a refiners price of $32.24 per barrel for No. 4 high sulfur oil at Charleston, NC. A barrel of oil can generally be equated to the heating value of a ton of green wood chips of about 5.7 million BTU. On this basis of BTU content, it would be reasonable to say that fuel wood chips should be of a higher value--closer to $30 per ton (green). Taking into account possible higher handling and storage cost of chips it would still seem that the present low prices of $16 to $18 per ton of chips at the mill is an energy bargain.

Mobile Harvester Cost Analysis Update

Based on the experience gained from the developmental tests of the mobile harvester, system costs were analyzed over a range of possible operating conditions. Miyata's (9) methods for calculating fixed and operating cost of logging equipment were used in the analysis. Therefore, it is not possible to make direct comparisons of costs with the earlier analysis (7) that did not follow a standard method. Although not directly comparable with the earlier cost analysis some of the changes in assumptions should be noted.

For this analysis, the number of scheduled hours was reduced to 50 hours per week from 66.7 hours. The system is scheduled to work 50 weeks per year for a total schedule time of 2,500 hours per year. No change was made in the utilization factor of .468 for the system so the estimated productive hours for the system was 1,170 hours per year. Because the forwarders and the chip transfer/utility machine are not required to be operating for the full time the mobile harvester is working, adjustments were made in the operating times and cost for these machines. It was estimated that the two rubber-tired forwarders would need to operate only 75 percent of the mobile harvester time, or 878 hours, and the chip transfer/utility machine only 50 percent of the time, or 585 hours. The adjustments affected only machine operating cost. All labor costs are based on the total scheduled time of 2,500 hours per year. A summary of the basic cost analysis and machine rates per scheduled hour are shown in Table 3. The crew for the system is assumed to be three machine operators, a mechanic and a mechanic's helper/operator. In this cost analysis it is assumed that chips will only be delivered to roadside and loaded into open top vans. No costs have been included for the vans or trucks required to take the chips to the use site.

Table 3 -- SYSTEM COST ANALYSIS AND MACHINE RATES

Machine	Investment	Economic Life	Scheduled Time	Productive Time	Repair Cost Multiplier	Machine Rate[1] Fixed[2]	Operating
	Dol.	Yrs.	Hr./Mi.	Hr.	Percent	Dol./Hr.	
Chipper	325,000	5	2,500 hr	1170	150	38.50	44.03
Forwarder	87,500	5	2,500 hr	878	40	10.58	16.31
Forwarder	87,500	5	2,500 hr	878	40	10.58	16.31
Transfer/ Utility	50,000	8	2,500 hr	585	50	4.67	2.83
Crew Truck	10,000	5	20,000 mi	--	25	.16	.30
Mech. Truck	15,000	6	15,000 mi	--	25	.28	3.91
Full & Lub Truck	18,000	8	15,000 mi	--	25	.55	.40

[1] All machine rates are based on 2,500 scheduled hours per year and include labor.
[2] Interest rate = 14 percent, Insurance = 3 percent, Taxes = 3 percent. License fees for trucks are: Crew Truck = $50 per year, Mechanic's Truck = $100 per year, and Fuel Truck = $100 per year. Diesel fuel cost $1.20/gal., Gasoline cost $1.40/gal.

To determine a possible rage of costs for the chips at roadside several production rates were explored. Since the mobile harvester can harvest biomass across an 8-foot swathe, it can be assumed that it can harvest approximately one acre per hour at a ground speed of one mile per hour. The original design criteria and cost analysis (7) assumed that the harvesting operations would be at least 85 percent efficient. That is, of the total above ground harvestable biomass on a site no more than 15 percent of the biomass would remain on the site after harvest. Figure 2 is a graphical presentation of system production in tons per hour for five average operating rates over a range of 0 to 50 tons of forest biomass per acre on the site.

Because of the high degree of removal of harvesting residuals during biomass harvesting during the developmental test of the mobile harvester it appears that very little additional site preparation would be required before regeneration of the site to pine. the additional site work required before machine planting may need to be only a broadcast burn and aerial chemical application for weed control. On one small 2.5 acre study, site measurements indicated that only 32 percent of the area was significantly compacted by the mobile harvester with little movement of top soil (4). Therefore, the benefits of reduced site preparation cost could be credited toward reducing biomass harvesting cost. A credit of $85 per acre was assumed in the cost analysis; however, it is believed that a credit of up to $120 could be assumed where a site contains high volumes of residues and intensive mechanical treatment would be required.

Using the above information, three cost curves were developed for the system (fig. 3) using three levels of production from what might be considered favorable to less favorable. Since actual data for the system are not available, it is not possible to state actual costs. Operational tests are planned for mid-1982 that will provide production and cost data that will provide a comparison for the estimated cost. The three curves of Figure 3 are all based on an annual cost of $469,075 (sum of fixed and operating cost) for the system, including crew and maintenance trucks, using 2,500 scheduled hours and a utilization factor of .468.

From the curves of Figure 3, it can be seen that there needs to be a balance of operating conditions for both harvestable tons of biomass per acre and acres per scheduled hour of production. It would be unwise to try to operate the system on sites with anything less than about 20 tons/acre of above ground biomass, even under the more favorable production rate of one acre per hour. Working on sites containing 30 or more tons of harvestable biomass per acre, the acreage production of the system becomes less critical for economical operation. And, the system should be able to produce fuel chips to roadside for $15 or less per ton (green) without any allowance for profit or transportation cost to the mill.

Conclusions

With the increasing cost of fossil fuel prices since the mid-1970s there has been a growing interest and use of the abundant supply of noncommercial forest residuals as a source of energy for both commercial andnoncommercial use. With fuel oil prices of about $30 per barrel, wood fuel chips at $16 to $18 dollars a ton green appear to be an energy bargain. The Nicholson-Koch Mobile Chip Harvester that is presently under development appears to be able to produce fuel chips from forest residuals and residues at reasonable cost under the present assumptions of system cost and production rates.

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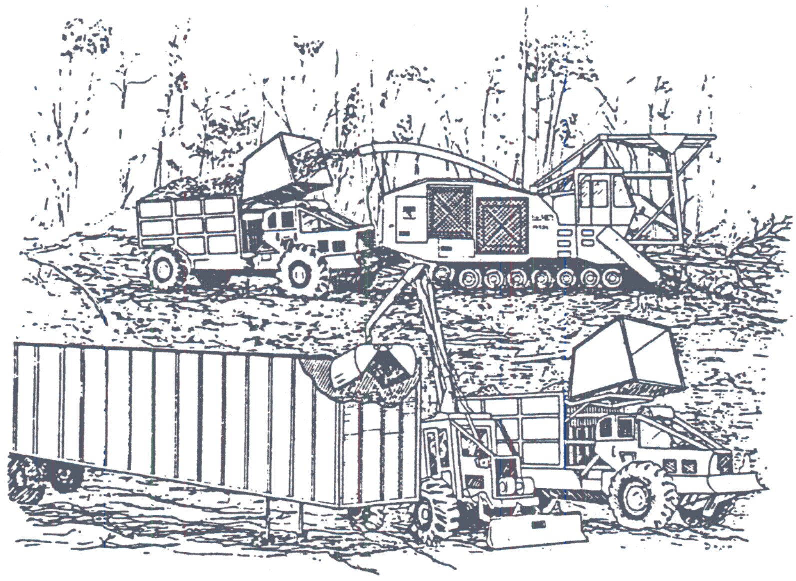
Figure 1.



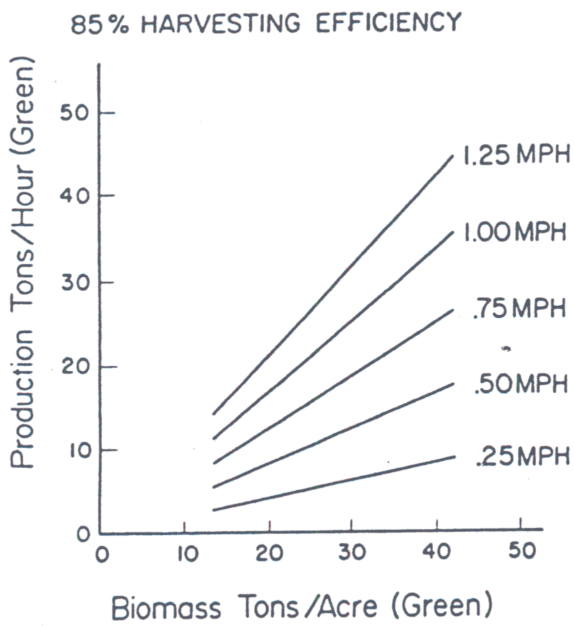


Figure 2.

Figure 3.