United States
Department of
Agriculture

Forest Service

Southern Forest
Experiment Station

New Orleans,
Louisiana

Proceedings Reprint

EVALUATION OF CHIPPER-FORWARDER BIOMASS HARVESTING CONCEPT

B. J. Stokes and D. L. Sirois

In: Rockwood, Donald L., ed. Proceedings of the 1985 Southern Forest Bianass Workshop; 1985 June 11-14; Gainesville, FL. Gainesville, FL: Institute of Food and Agricultural Sciences, University of Florida; 1986: 23-26

EVALUATION OF CHIPPER-FORWARDER BIOMASS HARVESTING CONCEPT[1/]

8. J. Stokes and D. L. Sirois[2/]

Abstract. -A chipper-fonuarder system offers an alternative for biomass hawcstfng. Components are a small feller buncher for felling and bunching. and a chipper-forwarder that chips at the pile and transports the chips to roadside. In a case study on a mixed pine and hardwood site in Georgia after conventional harvest-ing, production rates and cost estimates for a prototype chipper-forwarder were developed. At a forwarding distance of 153 m the cost of chipping and forwarding was estimated to be between $15 and $25 per dry tonne depending on initial investment assumptions.

INTRODUCTION

As demand for forest biomass increases, more importance is being given to utilizing small-diameter, unmerchantable trees as well as resi-duals left after hawestfng. To offset the high cost of harvesting this resource, the technology and methods used are being improved. Major advances have occurred in the hanesting of woody biomass for energy and several concepts are being developed or have been implemented.

Since the early 1970's. the accelerating price of petroleum products has forced an explora-tion into alternative energy sources. One alternative is the potential use of unmer-chantable trees and logging residues. These by-products of traditional -logging operations could be used to fuel boilers in the forest products industry.

In 1976. about 3.9 million cubic meters of residues from growing stock were left on the harvested sites with perhaps two to four times as much left in tops. branches, and small stems (USDA Forest Service, 1982). There is an abun-dance of unmerchantable forest materials in the southeastern United States alone. Understocked stands with abundant low-volume hardwoods have been increasing in the southeast by an estimated one million acres per year (Sirois, 1981). These stands are usually harvested pine-stands left to regenerate naturally.

Harvesting this energy wood economically is made difficult by the high cost of handling and transporting low-volume trees. One solution lies in chipping the wood at the site and shipping it in vans to the'mill boiler. Four separate con-cepts are presently being evaluated for chipping at the site (Sirois, 1981):

Portable Chippers

Chipper fs 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 Hawester

Chipper is mounted on a rubber-tired or tracked carrier with an integral device for clear felling small trees and brush fn a continuous swath. Chips are discharged into a second vehicle for fonardfng to the landing or other unloading point.

Mobile Chipper Harvester-forwarder

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-Fomarder

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.

Harvesting unmerchantable stands economical-ly is one advantage of whole tree field chipping systems (Plummer, 1974). Deal (1976) stated that use of total-tree chipping systems to improve utilization and reduce costs in harvesting small-diameter stands was growing in the south-eastern United States. Actually use has dimi-nished somewhat because of the current low oil prices. but is expected to increase in the future. Most such systems are made up of Porta-ble (used at the deck) chippers combined with

---

[1/] Paper presbnted at Seventh Annual Southern Forest Biomass Workshop, Gainesville, Florida. June 11-14, 1985.

[2/]Research Engineer and Project Leader, USDA Forest Service, Southern Forest Experiment Station. Auburn, AL.

conventional skfddfng operations. Mobile (used in the woods) chippers am just now befng developed and evaluated.

One of the advantages of a mobile chipper is the elimination of the skidding cycle; this feature yields chips that am essentially free of dirt (Koch and Savage, 1980). One concept befng developed is a swath-fellfq mobile chipper; a prototype has been tested in the south The mobile chipper-fonwder also eliminates the skfddfng cycle, thus contributing to cleaner chips and easier handling of small wood.

The chipper-forwarder concept has been developed and implemented fn Scandinavia.. Hakkila et a?. (1979) reports that one disadvantage of the chipper-forwarder system is total output reduction, because the chipping unft is used to fonard chfps. Productivity is also affected by forest haul-distance and forest terrain; fntcractfons with felling are important as well. Lillandt (1976) points out that a chipper-forwarder should have a large enough chip bin to insure that the chipping share of the total work time wf 11 be greater than the forest transportation share. However, the larger- bin size would require stronger frame structures and larger power systems, thus increasing operatfng costs that may not be offset by the higher pmductfon.

A pmposed system uses a machine to Chip felled and bunched trees fn the stand and forward the chfps to a loading point. Little production data collection or cost analysis has been completed for such a system. however. A prototype machine capable of chipping fn the stand and then forwarding the chips to the deck was developed by a private logger. The unit (Figure 1) consists of an eighteen-fnch Morbark[3] chipper mounted on a salvaged W-6 military undercarriage. A large dumping hopper fabricated on the rear of the unit is used to collect chips and transport them to the roadside. where the machine dumps the chips into an open-top van. This prototype was used for preliminary evaluation of the chipper-forwarder concept,

METHODS

Productron of the prototype chipper-forwarder was detetmined fn a case study. Some preliminary data were co??ected and used to analyze the concept. Cost estimates were made for an economic evaluation.

The case study site was a mixed pine and hardwood stand in central Geoqia. The site had been conventionally harvested, but large volumes of unmerchantable stems suitable for fuel-wood remained on the site. No data were collected on the felting portion of the operation. The fieid test consisted of obtaining pile and stem measurements and time data. All butt diameters were measured for each tree in the pile. Species

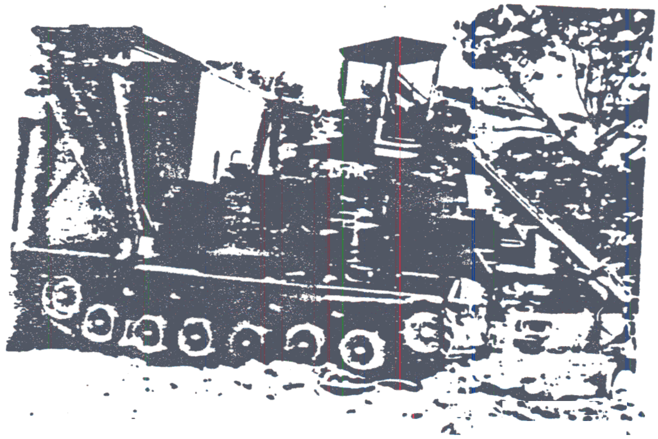

Figure 1. Purcel 1 Chipper-Forwarder.

were recorded; DBH and total height were sampled. Each pile was numbered for correlation of pile fnfoneatfon with the production data. Stem measurements were converted to total biomass weight per pile. If a complete pfle was not chipped during a single cycle. the weight MS proportioned by stem count.

RESULTS

Production data am summarized in Table 1. The study covered eight cycles at an average forwarding distance of 99 m (325 ft) The chipped stems averaged 12.7 an (5.0 in) DBH for pine and 9.6 cm (3.8 in) DBH for hardwood Chipping time per pile averaged 8.6 minutes. with approximately two piles per cycle. Each cycle averaged 4,358 kg (9,600 lb) (green weight). Four cycles were required to ff 11 an open-top van at the deck. Even though data were limited, a preliminary evaluation of production was still obtainable. The data analysis documents some simple characteristics of the production cycles and forms a basis for evaluation of the total concept. Only the means were used for the analysis.

An average empty and loaded travel speeds of 95 m/min (312 ft/min) and 69 m/min (227 ft/min), respectively, were used for the travel elements in the analyses. The other times used are shown in Table 2. Assumptions of two piles per cycle and an average of 4.4 green tonnes per cycle were used to develop production rates for the chipper-forwarder. Chip weights were converted to -bone ary tonnes (bdt) using 50 percent moisture content. Production rates were developed for forwarding distances from 92 m to 275 m (Table 3).

3/ The use of trade names in not an endorsement by the USDA Forest Service.

Table 1. Production data for prototype chipper-forwarder on harvested site, usfng piled material.

Item	Unft	Observations	Mean	St. Dev.	Min.	Max.
Tfa:						
Travel empty per cycle	afn	8	1.300	0.403	0.839	1.907
Travel loaded per cycle	min	8	1.433	0.498	0.788	2.128
Pile position time	min	19	0.092	0.198	0.0	0.658
Travel to pile	min	11	0.586	0.191	0.371	0.691
Chip time per pile	min	19	a.568	2.631	5.208	12.43
Deck posftfon time	afn	8	0.526	0.196	0.337	0.828
Lift bin time	min	8	I.356	0.180	1.076	1.622
Dump time	mfn	8	2.468	0.511	2.054	3.663
Other:						
Empty distance	m (ft)	8	124 (405)	61 (200)	72 (235)	185 (607)
Loaded distance	m (ft)	8	99 (326)	73 (240)	43 (140)	177 (580)
Distance between piles	m (ft)		19.6 (64.4)	7.0 (22.8)	14 (46)	35 (114)
Weight per pile	kg green (lb green)		2315 (5100)	910 (2000)	13x7 (2900)	4131 (9100)
Total stems per pile			36.1	10.2	23	49
Pfnc stems per pile	pct		27.7	20.5	0.0	77.8
Pine DBH	cm (in)	48	12.7 (5.0)	4.1 (1.6)	5.6 (2.2)	22.4 (8.8)
Hardwood DBH	cm (in)	37	9.6 (3.8)	5.1 (2.0)	3.3 (1.3)	21.1 (8.3)
Weight per cycle	kg green (lb green)	a	4358 (9600)	545 (1200)	3632 (8000)	5221 (11500)

Table 2. Time required for average production cycle of prototype chipper-forwarder.

Element	Mfnutes
Pile position (2 piles)	0.092
Travel to pile[1/]	0.586
Chip time (2 piles)	17.136
Deck sosition	0.526
Lift bin	1.356
Dump	2.488
Total[2/]	22.184

[1/] Travel to second pile only; travel to first pile is part of empty travel time.
[2/] Does not include travel empty and loaded.

Table 3. Estimated production rates for chipper-forwarder by distance.

One-way Distance m/(ft)	Travel Empty	Travel Loaded	Total Travel	Total[1/]	Dry tonnes/hr (dry tons/hr)
	-------------min-------------				
92 (300)	0.962	1.322	2.284	24.468	5.33 (5.88)
(500)	1.603	2.203	3.806	25.990	5.03 (5.3)
214 (700)	2.244	3.084	5.328	27.312	4.74 (5.23)
(900)	2.885	3.965	6.850	29.030	4.50 (4.36)

[1/] Includes all cycle elements: travel, position, chip, and dump.

These production rates were analyzed in greater detail to determine the percentage of each element in the cycle. At a 92-m fonardfng distance, the total. travel time was Only 9 percent of the total cycle, but this increased to 24 percent at 275 m:

Element	Percent of Cycle Tfme by Distance	
	92 m (300 ft)	275 m (900 ft)
Trave 1	9	24
Chip	73	61
Dump	18	15

Chipping element. which includes travel between piles. positioning, and actual chipping, was the largest portion of the cycle at all distances. This element also included the time to idle the chipper drum down In order to engage the transmission. A different power transfer unit for the machine that would allow the chfpper-forwarder to travel with the chfpper under full power would reduce chipping time per cycle by removing the need of Idling the chipper darn between moves. Some technical improvements in the dump mechanism could also reduce the total cycle; dumping accounted for at least 15 percent of the cycle.

Little cost information was available on this machine. Actual manufacturing price would dffer significantly from the price of the prototype. An estimated purchase price for a comparable chipper-fomarder would be a minimum of $200.000. The estimate used in the analysis was $250,000. Owning and operating costs were developed from the prototype model. With these assumptions. a new machine could be operated for approximately $115 per productive hour. Because estimates are based on limited data. a range of $75 to $125 per operating hour was determined for the chipper-forwarder. Estimated chipper-forwarder production costs to roadside, not including felling costs. am given (fable 4) for both low and high machine cost estimates.

Table 4. Estimated production cost to roadside for chipper-forwarder.

One-way Distance	Cost Per Operating Hour	
	$75/hr	$125/hr
m/(ft)	------$ dry tonne------	
	-----(S/dry ton)------	
92 (300)	14.36 (12.76)	23.43 (21.26)
152 (500)	14.93 (13.54)	24.87 (22.56)
214 (700)	15.81 (14.34)	26.34 (23.90)
275 (900)	16.67 (15.12)	27.70 (25.20)

SUMMARY

Although this study provided only limited production data, it allowed general evaluation of the chipper-fonarder for comparison with other sys teals. An estimated 5.37 bone dry tonnes per hour of small tree biomass was harvested at an average fonardfng distance of 153 m (500 ft). at an estimated cost of 514.92 per dry tonne (513.54 per dry ton) for low machine rate and $24.86 per dry tonne ($22.56 per dry ton) for the high machine rate for chipping, forwarding. and dumping into vans at the landing.

More evaluation of this concept is needed to determine the potential of a chipper-fomarder biomass harvesting system. More study is required to determine the effect of stand and terrain conditions on productivity and cost. Because the concept offers some unique advantages over other biomass harvesting systems, the development of such a system could be continued In the future.

LITERATURE CITED

Deal. E. L. 1976. Whole-tree harvesting by chipping methods in North America. FAO/ECE/ILO Symposium on the Harvesting of a Larger Part of the Forest Biomass. Vol. 2. Hyvinkaa. Finland; p. 170-182.

Hakkila. P., M. Leikola and M. Salakarf. 1979. Production, hawestlng and utilfzation of small-sized trees. The Finnish National Fund for Research and Development, Helsinki; p. 62-74.

Koch; P. and T. Savage. 1980. Development of swath-felling mobile chipper. J. Forestry 78(1):17-21.

Llllandt. M. 1976. Whole-tree harvesting by chipping methods (including transport in the forest) in Northern Europe. FAO/ECE/ILO Symposium on the Harvesting of a Larger Part of the Forest Biomass. Vol. 2. Hyvfnkaa, Finland; p. 205-215.

Plummer, G. M. 1974. Total-tree field chipping. Southern Lumberman 228(2834):16-17.

Sirois, D. L. 1981. A mobile harvester for utilization of weed trees and residues. In: Weed Contorl in Management: Proceedings of the 1981 John S. Wright Forestry Conference. Purdue University; West Lafayette, IN; p. 177-191.

USDA Forest Service. 1982. An analysis of the timber situation in the United States: 1952-2030. U.S. Dept. Agri. For. Res. Rpt. 23; p. 264.