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The Potential for Harvesting "Puckerbrush" for Fuel

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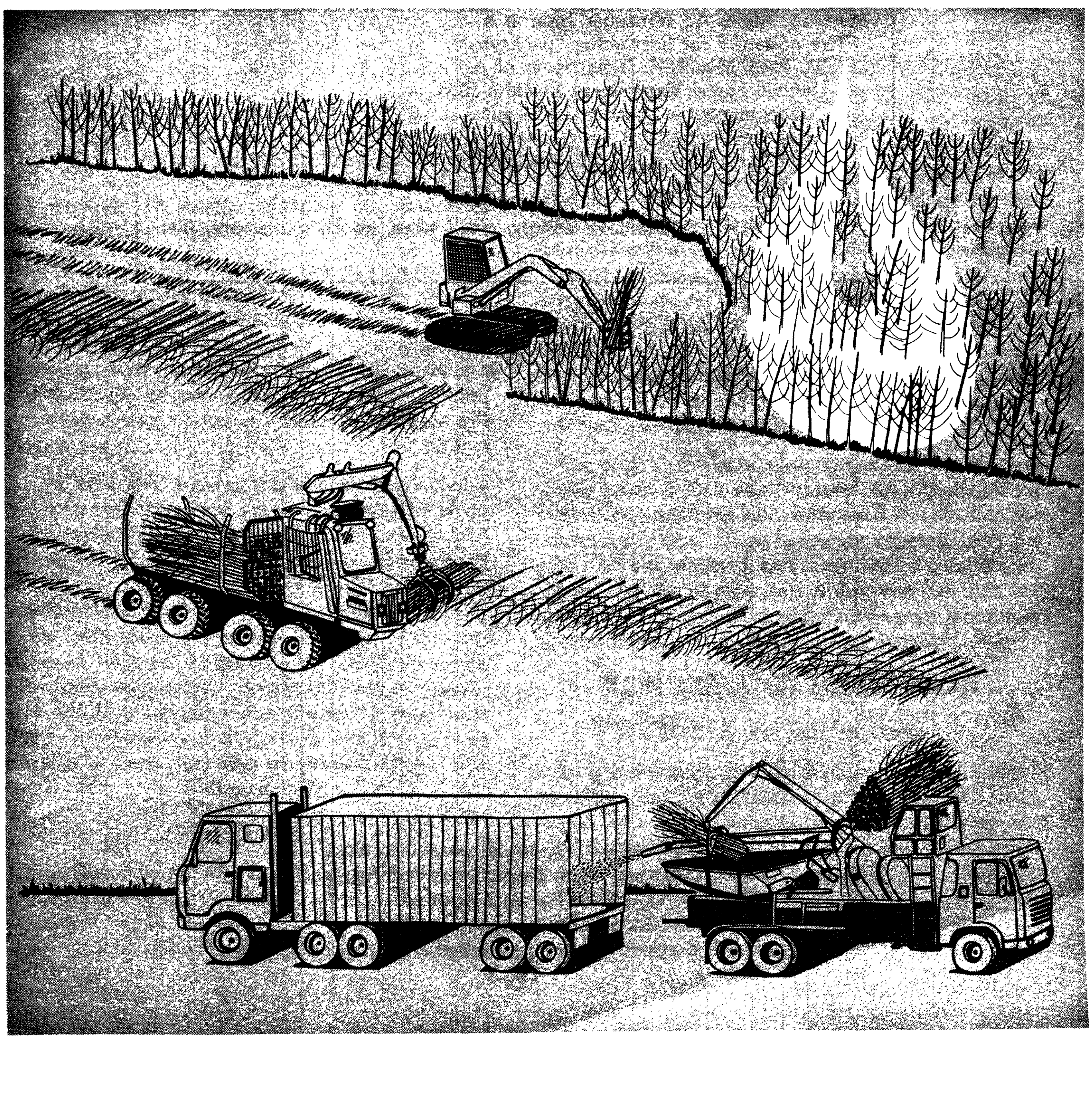

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Documents the biomass in 12 typical stands of puckerbrush and evaluates the feasibility of several potential systems to harvest these stands. Identifies areas of needed development for economically viable harvesting systems.

KEY WORDS: Biomass, energy, small trees, swath harvesters, fuel drying.

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THE POTENTIAL FOR HARVESTING "PUCKERBRUSH" FOR FUEL

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Millions of acres of land in the northeastern United States are stocked with "puckerbush," a collection of small tree and brush species of no conventional commercial value (Young 1971). Puckerbrush is a rapidly growing commodity in terms of tons of biomass per acre per year. Young found that fully stocked puckerbrush stands in Maine produce more than 1 ton of dry matter per acre per year, exclusive of leaves. The rapid increases in fossil fuel prices in recent years make this material an attractive renewable energy source. Its increased value as a fuel source could also make puckerbrush worth managing on poor sites where it naturally occurs.

Utilization of puckerbrush for fuel is hampered by a lack of appropriate harvesting equipment for this type of material. The small tree sizes, large numbers of trees per acre, and poor form of the stems make it impractical to use conventional harvesting equipment. Unless suitable harvesting equipment and techniques are developed, this potentially valuable resource will go unutilized.

As the first step toward this end we conducted a study with two objectives: (1) to document the physical characteristics of those stands that have the best potential for being harvestable--that is, those stands in which the stems average more than 1 inch in diameter and that cover at least 2 acres; and (2) to evaluate the technical and economic feasibility of systems that could be used to harvest typical puckerbrush stands. Systems ranging from manual to highly mechanized and from combinations of existing equipment to the merely conceptual and not yet available may be applicable to harvesting this material. Each of these systems needs to be evaluated.

METHODS

In the Lake States region, speckled alder (*Alnus rugosa*) is a commonly occurring puckerbrush species. It frequently occurs in almost pure stands of an acre or more on both upland and lowland sites, and is the most likely candidate among the local puckerbrush species for increased utilization. This study initially concentrated on alder with the intent of later expanding into other puckerbrush species and mixed stands.

Previous studies have documented the weight of various puckerbrush species (Ribe 1973). The results of that work--regression equations relating the weight of stem, branches, and leaves to diameter at breast height (d.b.h.)--were used to estimate biomass weights on the sampled plots. This minimized weighing, greatly simplifying field work. Available data indicated that plots of 1/100 acre would be sufficient to develop reasonable estimates of the pertinent stand characteristics. Three plots per stand were taken in each of 12 stands scattered throughout the Upper Peninsula of Michigan and northern Wisconsin to obtain a regional distribution. Typical stands were identified by contacting various industrial and public agency cooperators who are familiar with the various areas.

On each 1/100-acre plot, the d.b.h. of all trees greater than 1 inch was recorded. As a check on the regression equations that were used to calculate the biomass per plot, three randomly selected trees per plot were cut, weighed, and measured for total height, d.b.h., and stump diameter. A disc was cut from the stump of each sampled tree for subsequent laboratory determination of age and moisture content.

RESULTS AND DISCUSSION

Biomass Estimates

Data from the 12 sampled stands verifies the general description of puckerbrush stands. There were many stems per acre--an average of about 5,000 stems per acre for the sampled plots--and the average stem was small. The average d.b.h. was 1.53 inches for trees greater than 1 inch. Many stems less than 1-inch d.b.h. were found on each plot, so the estimates of total biomass per plot are conservative.

Basal area ranged from 29 to 99 feet²/acre for trees greater than 1 inch d.b.h. in the sampled stands, reflecting the range of stand densities and tree diameters. More than 80 percent of the stems were less than 2 inches d.b.h.

Stand height ranged from 12.4 to 19.9 feet, and the age was between 9 and 17 years, reflecting a preponderance of large and therefore old trees in the sample stands. Moisture content of the sampled trees was uniform and averaged 52 percent (green basis).

Total green biomass in trees larger than 1-inch d.b.h. was estimated to average 29.1 tons/acre for all the stands: 19.8 tons of stems, 5.5 tons of branches, and 3.8 tons of leaves. The biomass estimates were based on a regression equation for speckled alder (Ribe 1973). The equations used for the biomass estimates were checked against the 108 sample trees actually weighed in the sample plots to determine if there were any regional differences. Weights of the sample trees fell close to the regression estimates; therefore the estimates of biomass are expected to be reasonably accurate (fig. 1).

Trees on old field sites generally grew faster than those on forest sites, suggesting a significant site difference. Abandoned farms are likely to be better for growing puckerbrush than forest sites.

Harvesting Trial

We felt that a harvesting concept developed in Finland might be suited to selected puckerbrush stands. The technique involves manual felling with a small chain saw attached to a unique frame that allows the operator to remain upright while severing the stems (fig. 2). Experience in Finland has shown that this system makes bunching easy because the operator has only to direct the fall of the tree and not actually individually lift and pile each tree. If such a felling technique were used to fell and accumulate the small stems in a puckerbrush stand, we felt that conventional forwarding and chipping equipment could then be used to recover the trees.

An additional advantage of this system is that trees to be used for fuel could be stockpiled whole and allowed to dry before chipping. Trees stored in whole-tree form will dry to a lower moisture content than if stored in chip form, because of the easier air passage through the piles of whole trees.

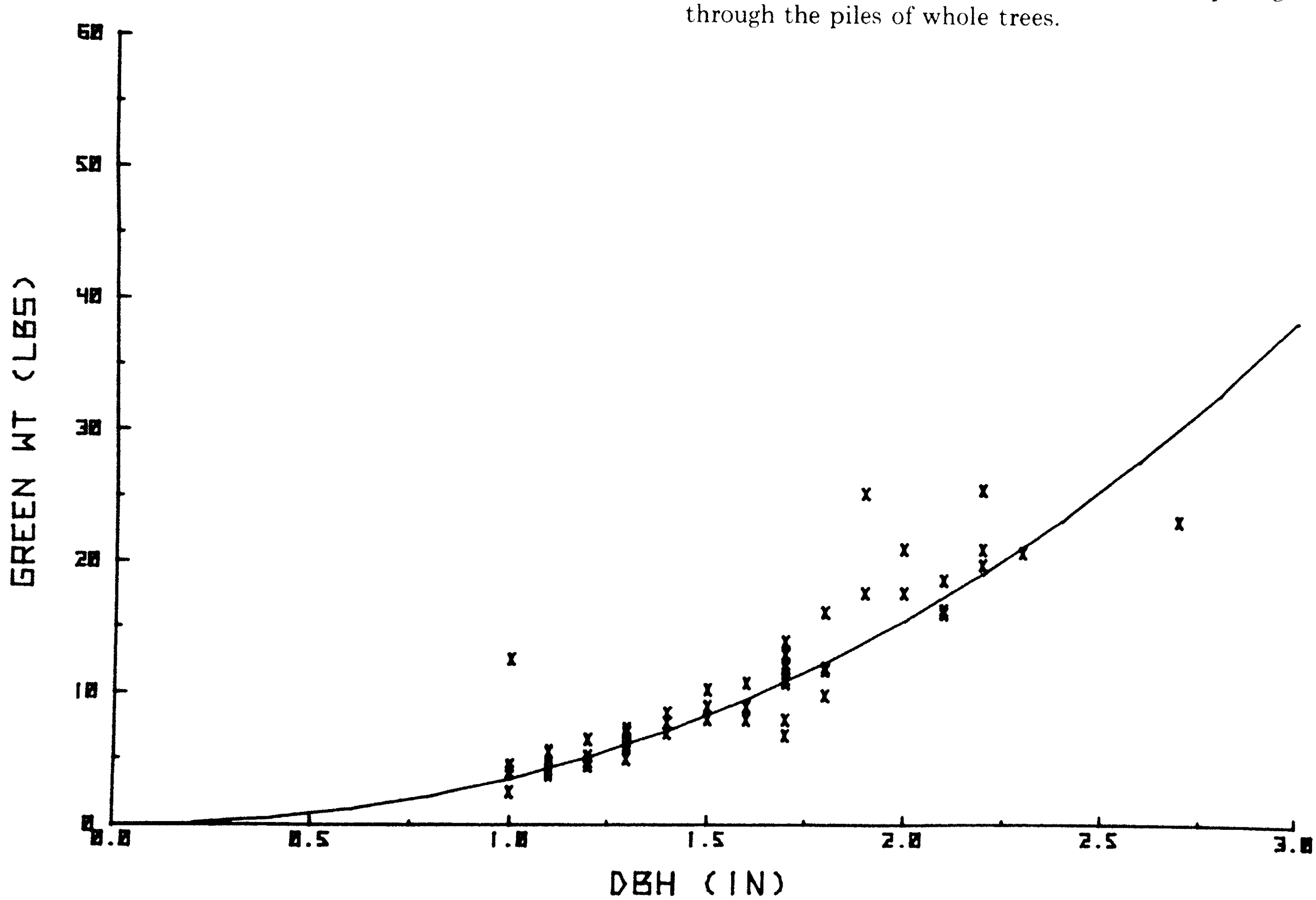

Figure 1.--*Correlation of sample tree weights to regression equation used to estimate biomass.*

Figure 2.--*Illustration of felling and accumulating small trees with the Finnish felling frame.*

We tested the technical and economic feasibility of the system in a stand located near Tomahawk, Wisconsin, where the equipment and weighing facilities of the Owen-Illinois, Inc. mill were readily available.

A commercially available felling frame suitable for mounting on a Husqvarna model 44 chain saw[1] was obtained from a manufacturer in Finland. The chain saw was equipped with a 13-inch bar for this trial. The fellers were equipped with shin protectors and safety boots designed for chain saw work.

The two individuals who did the cutting practiced for several days in another stand before starting on the test stands. A total time of 18.9 hours was spent cutting in the test stand. Forty-eight hundred stems were cut and piled in 149 bunches (table 1). Total production, 14.6 tons of greenwood, was estimated from the amount of material that was subsequently chipped. The cutting was done December 12-16, 1982, during which time only a few inches of snow was on the ground, so working conditions were good.

The material was moved to roadside with a standard Gafner Iron Mule pulpwood forwarder (fig. 3). Sixteen loads were hauled an average distance of 440 feet. The average load was 0.9 ton and 2.2 tons were hauled per productive hour. Forwarding was done on January 6, 1983. The stockpiled material was then left through the following summer to dry. Four randomly selected sample trees were analyzed at the time of forwarding to obtain an original moisture content. The average moisture content of the green material was 50.8 percent (green basis).

Table 1.--*Productivity for tag alder harvesting trial*

	Felling	Forwarding	Chipping
Total time (hours)	18.9	6.8	2.6
Productive time (hours)	14.8	6.5	1.6
Total stems	4,788		
Number of bunches	149		
Total loads		16	
Total green tons	14.6	14.6	
Total seasoned tons	9.7	9.7	8.2[1]
Green tons/productive hour	1.0	2.2	
Seasoned tons/productive hour	.7	1.5	5.1

[1]9.7 tons of seasoned material was calculated to be in the pile, 85 percent of which was chipped.

The seasoned material was chipped on November 4, 1983, with a Morbark Super Beaver chipper (fig. 4). All told, material weighing 8.2 tons was chipped in 1.6 hours of productive time. Average moisture content was 25.6 percent on a green-weight basis. Approximately 85 percent of the stockpiled material was chipped, so the total material harvested from the plot was calculated to be 9.7 tons of seasoned wood or 14.6 tons of green wood.

Standard logging machinery cost-estimating procedures were used to estimate cost for each phases of this harvesting trial (Miyata 1980). Cost per productive hour for each phase of the operation for both the equipment and personnel is based on the percent of total scheduled time that the equipment is actually doing productive work. We estimated these to be 50 percent for the felling, 64 percent for the forwarding, and 75 percent for chipping. Combining these costs with the production rates in table 1 gives costs per green ton of $19.82 for felling, $15.80 for forwarding, and $4.07 for chipping for a total

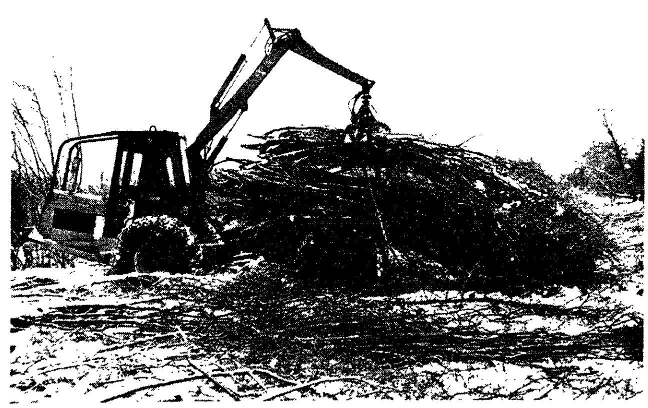

Figure 3.--***Forwarding bunched alder to roadside.***

[1]*The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. It does not constitute an official endorsement or approval of any product or service by the United States Department of Agriculture to the exclusion of others which may be suitable.*

Figure 4.--*Chipping from the stockpile of seasoned alder.*

production cost of $39.69 per green ton or $57.46 per ton of seasoned wood (table 2).

The effect of seasoning becomes significant when the fuel value of the harvested biomass is considered. A total of 7.2 tons of ovendry wood was harvested. At an assumed energy content of 17 million BTU's per ton, this amounts to 122.4 million BTU's. However, it takes 2 million BTU's to remove a ton of water in the combustion process. So, considering that the green material contained 7.4 tons of water and the seasoned material 2.5 tons, the available energy content of the green wood would be reduced to less than 108 million BTU's (7.4 million per ton) and that of the seasoned material to about 117 million BTU's (12.1 million per ton) (Arola and Sturos 1981). Applying the production costs shown above then gives a total harvesting cost per million of BTU's of $5.36 for the green wood and $4.79 for the seasoned wood.

Seasoning the wood may also have other benefits. In this small study, about 5 tons of water were removed during seasoning--weight that didn't have to be transported to the use point. Dry wood is also easier to store and handle and it burns more efficiently (Riley and Drechsel 1983).

Table 2.--*Estimated cost for tag alder harvesting trial*

(In dollars)

	Felling	Forwarding	Chipping	Total
Cost per productive hour	19.82	34.76	30.52	
Production				
Green tons/hour	1.0	2.2	7.5	
Seasoned tons/ hour	.7	1.5	5.1	
Cost per ton				
Green	19.82	15.80	4.07	39.69
Seasoned	28.31	23.17	5.98	57.46

Our results show that although it is technically feasible to harvest puckerbrush with this manually intensive system, the cost is not competitive with other harvesting systems. Conventional, whole-tree chipping can deliver wood fuel for about $15 per green ton compared to $40 per green ton in this study. The major problem centers on the need to handle large numbers of very small stems. Felling and bunching accounted for about half the total production cost in this trial, primarily because it was still necessary to individually handle each small stem. A definite need exists to develop more economical, combine-type equipment that can continuously sever and collect all the stems in a swath of the stand. This would eliminate the individual handling of each stem and permit greater, most cost-effective production rates to be achieved.

Forwarding was expensive in this trial because the carrying capacity of the machine used was not fully utilized. The average load hauled was less than 1 ton. Several modifications could be made to standard forwarders that could increase the productivity and bring down this cost. A wider-opening clam on the loader would allow the operator to work on a larger bunch while still remaining within the weight limits of the loader. A smaller number of cycles to load the machine would greatly increase efficiency. Also, the load space on the forwarder could be easily increased to permit a larger volume of material to be carried on each trip without overloading the forwarder. Such modifications along with increased operator experience would bring the costs of forwarding within reasonable limits.

The chipping portion of the operation was reasonably efficient with standard equipment. The Morbark Super Beaver was able to take adequate amounts of material from the stockpile and keep the chipper operating at an efficient rate. Small changes, such as adding a funnel-shaped section in front of the chipper to help direct the stems into the feed would increase productivity. Some problem was encountered with removing the stems from the stockpile. The numerous small trees tend to tangle. This creates a problem for the chipper operator as he is trying to form a bunch for feeding into the chipper.

Working a "hot" operation, that is, chipping the material as it is being forwarded, would probably increase the productivity of the chipper. But, this would require more forwarding equipment feeding the chipper and eliminate the advantage of stockpiling the material to allow for seasoning. The material could be allowed to season at the stump, but then problems with machinery working in the stand at times other than winter could arise. Many of the sites where puckerbrush grows are very wet and may not be workable except in winter when the ground is frozen.

Other Possibilities

Fully mechanized harvesting may be one way to solve some of these problems. Computer simulation was used to study the feasibility of mechanized harvesting techniques in puckerbrush stands. One typical stand of alder was described in greater detail to use in simulation studies. A plot of 30-foot radius was randomly located in an old-field stand, and all stems within the plot were measured for d.b.h. and plotted on a map. The map was then used to model the distribution of stems that a harvester would encounter as it worked through a typical stand. The stand consisted of 10,354 stems per acre averaging 1.22 inches d.b.h. (97.2 square feet of basal area). Green weight totaled 38.7 tons per acre; 24.3 tons of stems, 8.4 tons of branches, and 6.0 tons of leaves.

A light machine mounted on tracks might be suitable for negotiating the wet sites on which puckerbrush typically grows in the Lake States area. If such a carrier were equipped with a rotatable deck and boom, a felling and accumulating head might be developed that would cut and gather the stems as it was repeatedly swept through the stand while the machine moved intermittently forward (fig. 5). Conventional forwarding equipment could then be used to move the material to roadside for further processing or transportation.

Several combinations of boom radius and cutter head width were simulated on the computer, and the number of stems and biomass weight collected for a number of sweeps through this typical stand were

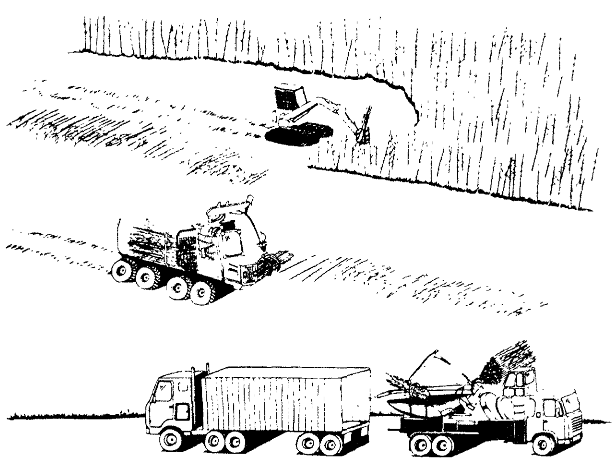

Figure 5.--*Concept of a sweeping harvester for puckerbrush.*

Table 3.--*Simulated average production rates for a swinging-type puckerbrush harvester by swing radius and width of cut*

Swing radius (feet)	Width of cut	Trees cut	Weight per cycle
	Feet	*Number*	*Pounds*
10	1	5.6	39
15	1	7.6	55
20	1	9.9	74
10	2	11.2	78
15	2	14.7	111
20	2	19.8	148

calculated (table 3). Increasing boom radius and cutter width increased the production per sweep, as would be expected. If we assume that such a machine with a 20-foot boom and 2-foot cutter could make an average of 30 sweeps per hour, the hourly production would be merely 2¼ tons per hour. Production is low because so much time is spent swinging the boom back and moving the machine forward. A more productive machine would be a swath harvester that would move continuously through the stand cutting everything in its path. If such a machine could cut an 8-foot swath through the stand at a speed of 1 mph, estimated production would be about 37 tons per hour or about 1 acre per hour.

Several prototype machines have been developed around the swath harvester concept. Koch and Nicholson (1978), Hakkila and Kalaja (1980), and Smith and O'Dair (1980) all have reported trials with swath harvesting machines designed to recover small trees and/or logging residues. The basic operational concepts of the machines have been shown to be workable, but two concerns exist about their applicability to harvesting stands of puckerbrush. So far, all such machines include chippers, adding to the horsepower required and the weight of the machine. This increased weight may preclude operating such machines in typical puckerbrush stands, such a tag alder where soil-bearing conditions are typically poor. Moreover, the machines developed to date are expensive due to their size and complexity. The cost of such equipment would require a high production rate to make them economically feasible, difficult in the small, scattered stands of puckerbrush.

CONCLUSIONS

This initial study has shown that a significant amount of biomass is available in puckerbrush stands. Twelve typical stands measured in this study averaged about 29 green tons of biomass per acre. The high current costs of fossil fuels makes this material valuable as a fuel source. Currently available systems do not appear to be economically feasible for harvesting this material. Felling and bunching the large numbers of small stems per acre is the major problem. Initial emphasis should be put on further study of equipment and systems that can efficiently sever and collect the numerous small stems into bunches ready for forwarding from the stand. As in any wood fuel harvesting situation, the means of producing a dry fuel should also be included in the harvesting system to maximize the value of the harvested material.

LITERATURE CITED

Arola, Rodger, A.; Sturos, John A. How to compare fuel values. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1981.

Hakkila, Pentti; Kalaja, Hannu. Harvesting fuel chips with the Pallari swath harvester. Folia Forestalia 418. Helsinki, Finland: Finnish Forest Research Institute; 1980. 24 p.

Koch, P.; Nicholson, T. W. Harvesting residual biomass and swathfelling with a mobile chipper. In: Proceedings, Complete-tree utilization of southern pine symposium; 1978 April 17-19; New Orleans, LA. Madison, WI: Forest Products Research Society; 1978: 146-154.

Miyata, Edwin S. Determining fixed and operating costs of logging equipment. Gen. Tech. Rep. NC-55. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1980. 16 p.

Ribe, John H. Puckerbrush weight tables. Misc. Rep. 152. Orono, ME: University of Maine, Life Sciences and Agriculture Experiment Station; 1973. 92 p.

Riley, John G.; Drechsel, Carl S. Drying and storage of woody biomass fuels. ASAE Pap. 83-3560. Paper presented at 1983 winter meeting of American Society of Agricultural Engineers, 1983 December 13-16; Chicago. 19 p.

Smith, Fred M.; O'Dair, James R. A total harvester. In: Proceedings, 1980 annual meeting; Atlanta, GA. Atlanta, GA: Technical Association of Pulp and Paper Industries; 1980: 391-400.

Young, H.E. Biomass sampling methods for puckerbrush stands. In: Young, H. E., ed. Forest biomass studies of the working group on forest biomass, section 25, International Union of Forestry Research Organizations. Orono, ME: University of Maine, School of Forest Resources; 1971: 179-190.