CONCEPTS FOR MECHANIZED PRODUCTION OF WOODY FIBER

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INTRODUCTION

There has been a striking increase in the consumption of wood-based products over the past two or three decades, even in the face of very stiff competition from other materials. However, many of the traditional wood products are finding increasing competition from wood converted into new forms.

Consumption of wood made into pulp products has seen perhaps the most striking increase. Total pulpwood production in the United States was 44.7 million cords in 1963 and 64.2 million cords in 1970 (2), and the U.S. Forest Service projects the demand for pulpwood in 1985 as 119 million cords. As pulp products bear little resemblance in form to the material from which they are derived, an immediate question arises as to whether the material from which they are made must necessarily be the traditional pulp stick from a fairly mature tree. In 1963, round pulpwood accounted for 93% of production in the Northeast United States, by 1970 only 83% of the total was from round wood. Seventeen percent of the material originated from chipped waste materials recovered as byproducts from the manufacture of other forest products.

The present situation in wood production and use can be summarized as follows:

1. The bole is used, and this only of some species. This constitutes approximately 65% of the total tree (10). The top, branches, and roots are left in the forest.

2. Forest operations are 'labour-intensive' with over half the cost of producing logs being labour. What mechanization has taken place in forest operations has been evolutionary in nature. For example, the wheeled skidder replaced horses and teamsters as they became scarce resources. The wheeled skidder was quickly accepted because it performed no new function as a machine, and from the very outset had a high level of mechanical availability (7). Attempts at mechanization that have been revolutionary (for example, complete-tree harvesters) have by and large failed, after many millions of dollars were spent on development for very little profit return. Tree harvesters are very complex machines; they try to duplicate a number of separate functions and their reliability is often lowered because of this.

3. Total consumption of wood products is increasing rapidly and is in balance with growth in some areas of the world (4). Many companies traditionally thought of as paper companies are now adopting the stance that their base of operations is the land on which their product is grown. They are becoming mutliple product companies, branching off into sawmill operations and particle board manufacture, etc. There is a tendency to high-grade logs that years ago would have been pulped directly. This means that only the residue will go to the pulp mill.

4. More and more processed products are produced from wood, with the finished product being in a form very different to the original material.

Research Trends

Researchers are paying a great deal of attention to the situation as far as wood supply is concerned, and the present research picture might be summarzied as follows:

1. There is much interest in using more of the tree (1, 4, 5, 9). Young (10) summarizes findings on pulping, biomass, and nutrient studies as follows:

a. Regardless of size or species, the distribution of wood fiber is approximately: bole (65%); unmerchantable top (5%); branches (5%); stump (15%); and roots (10%).

b. Approximately 50% of the 15 essential elements in a tree are in the merchantable bole. About one-half of these are in the wood and the remainder in the bark.

c. Pulp made from the wood of the logging residue is similar in yield and physical properties to pulp made from the wood of the merchantable bole except for the branches, which have a lower yield and poorer physical characteristics.

d. Use of all of the logging residue would increase yield from the forest by 50%.

2. There is much interest in the possibility of using additional species for pulpwood and considerable work is being done on use of smaller trees, with all of the tree being utilized for some purpose. Hemck and Brown (5) have evaluated the possibility of 5-yr harvest cycles with sycamore in Georgia and foresee the possibility of annual yields of 20 tons of dry matter per acre. Chase et al. (3) have evaluated "puckerbrush" in Maine as a source of pulp and found overall yields of 30-35% from whole trees minus the leaves. Young (10) summarizes puckerbrush production and growth characteristics for Maine as follows:

a. Fully stocked puckerbrush stands, regardless of species or species composition, ranging from 5-45 ft in height above ground will produce (exclusive of leaves) about 1.2 tones of dry matter above ground per acre per year.

b. It appears that puckerbrush grows about the same amount as the commercial tree species, recognizing that a ton of dry matter is the equivalent of a cord and only the merchantable bole is included in current inventories.

c. In fully stocked puckerbrush stands, wood growth accumulates about 0.8 tons of dry matter per linear foot of average stand height.

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d. Regardless of species or species combination, puckerbrush produces about 1.0 ton of leaves (oven-dry basis) per acre per year without regard to stand age after the first few years.

MECHANIZING FOREST OPERATIONS

It is obvious that engineering will have to play a major role in development of any new utilization methods. Forest operations have appeared attractive to farm machinery companies for some time, as a large market appears to exist there. In 1967, Spanjer (8) indicated two areas ripe for mechanization. They were processing and movement of the wood between the stump and final landing (a composite of operations accounting for almost 50% of the cost of wood delivered to the mill); and the movement of the wood from the final landing to the mill, which then accounted for approximately 25% of the wood cost. However, with the exception of the wheeled skidder and other forwarding machines, very little successful equipment has been produced thus far.

Cost Comparisons

Comparison of the cost of mechanical tree harvesting with the traditional 'man and chain saw' method throws some interesting light on the basic reason why tree harvesters have not gained full acceptance. Appendix I, Table I provides a comparison of approximate wood costs for the Beloit harvester (using Spanjer's estimate of performance potential for the harvester) with a chain saw operation. From the assumptions made (which seem reasonable), it appears that it would be necessary to work two shifts per day with the harvester to make any real cost saving over hand methods. Successful users of the Beloit machines have in many cases done this.

Another explanation of failure of equipment to provide successful duplication of the traditional tree harvesting process might be drawn from agricultural experiences. As crops were mechanized, the crop itself or the method of culture were almost always modified to suit the machine system. For example, the advent of grain combines in northwest Europe led to the development of short, stiff-strawed varities of grain that would remain erect and produce less straw to be passed through the combine. Row widths for crops such as sugar beets and potatoes were changed to allow room for large-wheeled tractors. A current example of the same process is the lowbush blueberry industry. A harvester for use on reasonably smooth land exists but has gained only limited acceptance, due to the reluctance of growers to give up traditional rocky hillsides sites for blueberry production.

Changing Methods of Harvesting

Some modification to the traditional tree harvesting process is reported from Finland, where in experimental work on utilization of roots, longer stumps are left after the felling process to make it easier to push over the stump and root combination. However, Hakkila (4) gives a number of reasons why utilization of roots will be difficult. Rainfall conditions in the Northeast United States and Eastern Canada may prevent any serious attempts at utilization of roots.

Some current methods of handling trees (i.e., with feller-bunchers and stationary processors) incidentally concentrate branches and tops, thus making disposal of such material necessary and utilization more feasible. If, in mechanization of full-tree harvesting we allow for the fact that different parts of the tree may go to different uses, it is probably as well to treat the tree as composed of sections. Each part has different handling characteristics and once separated, tree parts can be treated very differently. One might envision at least two devices necessary for such an operation; a machine to harvest the stem and a further machine to handle branches and tops. If the branches are to be removed from the forest, it will be important to return leaves and needles to the ground as a great deal of the nutrients available for tree growth will be removed from the area if the leaves and needles are taken away. The basic problem of mechanizing the harvest of a full tree still remains, in that a large piece of material has to be handled, necessitating a large and probably expensive machine.

Many attempts have been made to reduce the power requirements or simplify the individual operations of tree harvesters. The delimber described by Rowe and Huff (6) was designed to be part of a simplified tree harvester and was very successful at reducing power requirements. However, it is not a particularly simple or low cost mechanism.

The real push toward modification of tree harvesting systems may be due to the recreational uses of the forest. For example, in areas close to the Northeast megalopolis in some parts of Maine, wood may become only the secondary product of many forest areas and substantial changes may be made in the method of logging. There will always be a need for large logs, so mechanization of full-tree harvesting should certainly be considered, with serious attention given to methods of utilizing a greater portion of the tree.

Harvesting Small Trees

If the individual tree unit can be a smaller entity, a very different type of mechanization might be possible. Chase et al. (3) have shown that pulp produced from small trees and from hitherto undesirable species can give reasonable quality paper products with a yield approaching that of chips derived from full-grown trees. Incorporation of bark with wood chips is acceptable for many uses (1).

Young (10) has indicated that yield of dry fiber is approximately 0.8 tons per foot of height of part-grown wild stands in Maine. It is possible to envision a machine not unlike a grain combine handling a stand of young trees with stems approximately 1 to 1-1/2 inches in diameter at about the 3-inch level. Material like this would probably be 12-15 ft in height; hence the dry matter would be approximately 10 tons per acre. Such a stand would probably be composed mainly of hardwoods. Hardwood stumpage presently runs $3-5.00 per ton of dry matter and produces a value of approximately $18.00 per ton of dry matter delivered to the mill. Assuming a stumpage price for puckerbrush-type material around $2.00 per ton with a price for chips of this material of around $12.00 per dry ton at the mill, the harvesting and transportation process would have an added value to the product of $10.00 per ton. Transportation represents about 25% of the cost of delivered spruce pulpwood, so a transportation cost of around $6.00 per dry ton appears reasonable for chips, leaving an added value due to the harvesting process of $4.00 per ton.

Figure 1 illustrates a possible layout for a self-propelled machine to harvest brush stands, while Appendix II, Table II shows the economic potential of such machines. There are two main points to be made from these figures:

(1) The cost per unit for producing chips from youg trees appears to be considerably below the cost of producing pulp logs from mature stands.

(2) If the assumptions are correct, the machine would virtually pay for itself in 1 yr. There is sufficient margin between costs and returns on the operation such that even if some of the

assumptions are wildly in error, the basic concept appears well worth further study. All of the basic operations of the harvester have been performed previously, so actual design should not be too difficult.

The longer the trees grow, the greater the yield per acre, but there must be a point at which the size of each tree makes the material inconvenient to handle as a continuous flow. Possibly a machine capable of bulk handling material with stems up to 6 inches in diameter (i.e., from the overgrown farms which were given up from agriculture in the postwar period) might well be worthwhile also, as the impending shortage of woody material approaches. It is not hard to envision a paper mill which presently draws logs from a distance, having a good deal of that supply bled off by sawmills and veneer mills in the future. This would result in only a trickle of material coming from the traditional forest to supplement material that could be produced from woody fiber farms probably quite near the mill. Yields of 5 tons per acre per year are real possibilities even in northern USA and Canada, with good management and fertilization.

If woody fiber can also be an economical energy source, the concept of mechanized woody fiber farming may be very important in the future.

SUMMARY

Consumption of wood for fiber products has increased rapidly and to the point where sources of fiber such as branches and puckerbrush stands appear attractive. The advantage of harvesting small trees in a short-rotation forestry system is discussed and a cost analysis for operation of a "woody fiber harvester" is presented.

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APPENDIX I: COST COMPARISON – TREE HARVESTER VS. CHAIN SAW

Assumptions

Chain Saw

Producing tree-length wood: 8 minutes per tree; 10 trees per cord.
Saw cost: $1.00 per working day.
Operator: $4.50 per hour.

Harvesting cost for hand method: $6.10 per cord

Harvester

Purchase price (P)	$85,000
Life (L)	5 years
Salvage value (S)	$10,000
Interest rate (i)	8%
Taxes and insurance	2.5% of purchase price per year
Operator	$5.50 per hour
Fuel and oil	3 gallons per hour of fuel (total $1.00 per hour)
Repairs and maintenance	5% of purchase price per 1,000 hours work
Production rate	4 cords per hour

Costs

Fixed

Interest	$\left(i\left[\frac{P+S}{2}\right]\right)$	= $ 3,800
Depreciation	$\left(\frac{P-S}{L}\right)$	= $15,000
Taxes and insurance (.025 P)		= $ 2,175
		$20,975 per year

Operating (hourly)

Fuel and oil	$1.00
Labor	$5.50
Repairs	$4.25
	$10.75 per hour

APPENDIX II: POTENTIAL FOR A WOODY FIBER HARVESTER

Assumptions

1. A harvesting machine similar to a self-propelled grain combine capable of mowing and chipping 1.5 inch diam hardwood at 10 tons per hour and then winnowing out leaves, i.e., covers 1 acre per hour at 1 mph for 10-foot cut.
2. Machine weight 15,000 lb., 150 HP engine, using 3 gallons per hour at $1.00 per hour fuel and lubricant cost.
3. Machine cost $2.00 per lb. (i.e., Purchase price (P) – $30,000).
4. Life (L) – 5 yr; salvage value (S); – $4,000.
5. Interest rate (i) – 8%.
6. Taxes and insurance – 2.5% of purchase price per year.
7. Shelter (as cannot work in snow) – 1% of purchase price per year.
8. One operator – $5.50 per hour.
9. Repairs and maintenance – 5% of purchase price per 1000 hours work.
10. Value added to wood by harvesting process – $4.00 per ton.

Costs

Fixed

Interest	$\left(i\left[\frac{P+S}{2}\right]\right)$	= $1,400
Depreciation	$\left(\frac{P-S}{L}\right)$	= $5,200
Taxes and insurance (.025 P)		= $ 750
Shelter (.01 P)		= $ 300
		$7,650 per year

Operating

Fuel and oil	$1.00
Labor	$5.50
Repairs	$1.50
	$8.00 per hour

TABLE I TREE HARVESTER OPERATION COSTS

Cost	Hours use per year 1000	2000
Fixed	$20,975	$20,975
Operating	10,750	21,500
TOTAL	31,725	42,475
Per cord or per ton DM	7.93	5.31

TABLE II WOODY FIBER HARVESTER COSTS AND RETURNS

Cost	Hours use per year 1000	2000
Fixed	$ 7,650	$ 7,650
Operating	8,000	16,000
TOTAL	14,650	23,650
(Per torn or per cord)	1.46	1.18
Return in value added	40,000	80,000
Profit	25,350	56,350

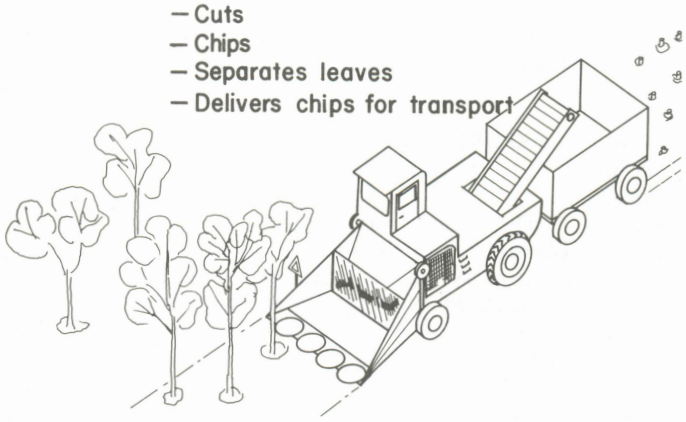

Figure 1. Woody fiber harvester.