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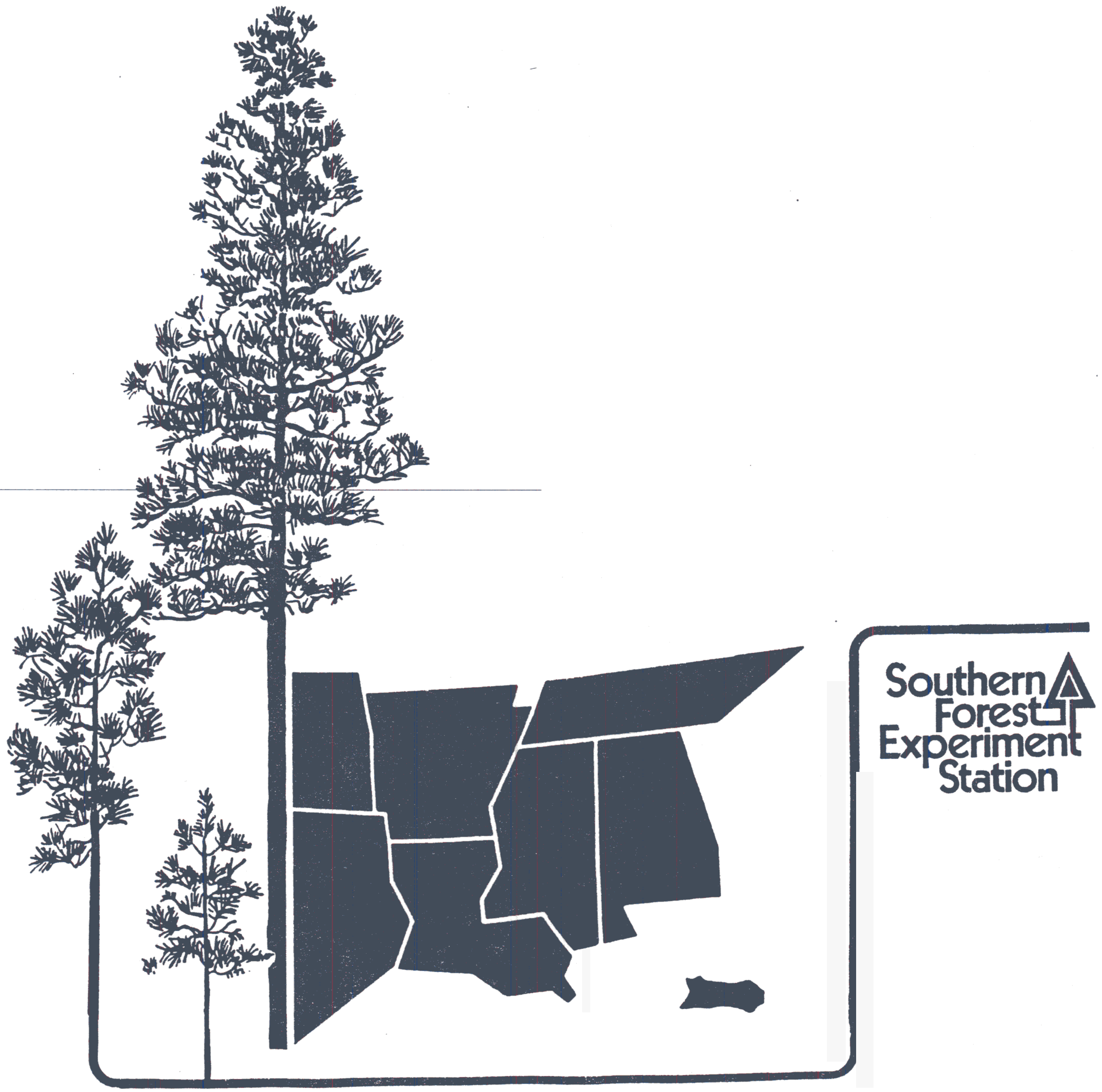

REDUCTION OF BIOMASS MOISTURE BY CRUSHING/SPLITTING - A CONCEPT[1/]

Paul E. Barnett, Donald L. Sirois, and Colin Ashmore[2/]

Abstract.-A biomass crusher/splitter concept is presented as a possible means of maintaining rights-of-way (ROW) or harvesting energy wood plantations. The conceptual system would cut, crush, and split small woody biomass leaving it in windrows for drying. A subsequent operation would bale and transport the dried material for use as an energy source. A survey of twenty southern power companies ROW's shows the potential applicability of a biomass harvesting systa. Drying characteristics and power requirements are presented for three southern tree species.

INTRODUCTION

The principal focus of biomass harvesting in the past has typically relied on the use of portable chipping machines to reduce a wide variety of woody materials to smaller sited pieces for easier handling and franspurting. In-woods chipping systems have been successful because of technology and equipment available from the forest products industry. However, chipping systems have several shortcomings such as high investment and fuel costs. and limited applicability to many operational environments where harvestable biomass exists.

An alternative to chipping at the harvesting site could be to process small diameter stems, up to 13 cm diameter at breast height (DBH), by crushing and splfttfng them. Through this concept, a harvester would cut and process the stems and then deposit them on the gmund in windrows for drying (Figure 1). After drying, the crushed and splft material can then be picked up by a separate machine and modulized for low cost transport to a final processing point. such as a permanent boiler facility. The potential advantages of this system are: 1) lower energy requirements for mobile operations, 2) separation of the harvesting and processing phase from the moduling and ● -=r:p'?r?rg operatfon, 3) lower transport cost per megajoule, and 4) higher heating value of the dried fuelwood.

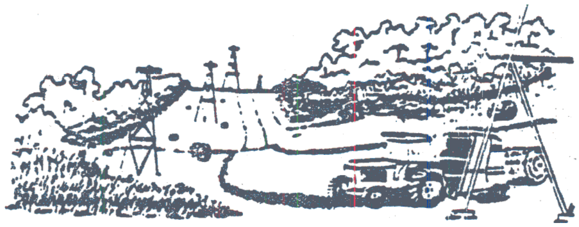

Figure 1. Conceptual crusher/splitter biomass harvesting systa.

The crushing/splitting concept has features suited for harvesting biomass growing on utility ROW and harvesting other sites containing small trees. These features are low energy requirements, reduced normal maintenance (i.e., no knife changing), and reduced damage from foreign objects. Other advantages include a harvesting system where the felling and processing phase is independent of the forwarding and transporting operation, material that fs dried and densified for the subsequent transportation operations, and modulized material suitable for storage in the field or at the use site.

Earlier work by the Tennessee Valley Authority (TVA) showed feasibility for the development of a fiberizer machine designed to reduce small logs to long fiber particles. The Canadian Forest Service's Energy From the Forest (ENFOR) program began a project (P-28) that included the development of a roll crusher/splitter test bench machine for biomass rite reduction and dmatering (Jones. 1982). This work was based on TVA's fiberizer concept. The purpose of the Canadlan test bench machine was to exolore engineering design parameters, roller configuration forces, and power requirements for reducing large diameter (uo to 30 an) forest biomass into crushed, dewatered fibers or strands for baling' and then later processing for boiler fuel. This paper presents preliminary test results of the Canadian test bench machine for roll splitting and dewatering small southern woody biomass for energy use.

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The primary intent of this work is to determine the feasibility of harvesting and processing biomass growing on utility ROW in the southeastern United States.

LITERATURE REVIEW

As current supplies of wood residues In the forms of chips and sawdust become more fully utilized for fuel and other wood products, more woody biomass wi 11 need to be harvested specifically for energy use. The harvested biomass will generally be live, green wood if harvested from an energy plantation. forest rite. or utility ROW. Typically. live woody biomass will have moisture contents ranging from a la of approximately 50 percent to a high of over 120 percent on a dry might basis (Sirois, 1993). These high moisture contents can have *three* effects that increase the net cost per megajoule. First. hauling cost are high because of the cost of transporting the green wood. Schiess and Yonaka (1983) show about a 40 percent increase in the cost for hauling wood residues at 50 percent moisture when compared to wood at 30 percent moisture content (over a 81 km haul distance). Second is a higher degradation during storage and third, lower boiler efficiency during combustion if pm-drying is not done. When pre-drying is done by use of hot hogs and conveyors or rotary drum driers, the energy input can often exceed the net energy obtained (Haygreen, 1981); however, this can be acceptable if low quality waste heat can be used in the drying process. Haygreen (1982) also reports that mechanical dewatering can produce energy gains of between 67 and 240 times the input energy. but that compression drying is only ● ffutlve for wood chips with high initial moisture contents. To accoarplfsh this, he determined that pressures on the chips would have to be near 46.3 MPa.

RIGHTS-OF-WAY FACTORS

A survey was made in 1984 to determine the ootentiai use of a biomass harvester that would incorporate roll crushing for ROW maintenance. Almost all of the 20 southern-based utility companies surveyed maintain their ROWs on a five-year or shorter rotation period. Nearly 48 percent of the ROWs have small trees. under 13 cm DBH, growing on tha and about 13 percent have growing shrubs. The remaining 39 percent are covered by grasses and herbaceous materials. The average width of a ROU is 29 m and is 0.8 km from an access point to an improved surfaced mad. The comoanies surveyed maintain an average of 9,370 km of ROWs. Eighty-four percent of the ROWs are maintained by mechanical equipment with only 13 percent being treated with herbicides and about three percent are cleared by hand.

This information tends to support the idea that ROWs could be suitable candidates for biomass production as a result of normal maintenance activities or as an area for cultivated energy piantatfons. This is further supported by the fact that over 61 percent of the ROY kilometers reported by the utility companies were on slopes of less than 15 percent, so mechanical harvesting is feasible on these lands. In addition, the companies reported high costs related to their present maintenance programs. Average costs reported were $445/ha for mechanical treatment, $300/ha for chemical control, and $865/ha for hand cutting. It seems reasonable that harvestfng biomass from ROWs could reduce these costs and that under highly favorable conditions. actually produce income.

CRUSHER/SPLITTER CONCEPT

The feasibility of developing a crusher/splitter biomass harvester is presently being investigated through these objectives: 1) conducting a literature review of biomass harvesting research for small woody biomass; 2) surveying and characterizing ROW biomass, area, terrain conditions, and average spacing between access roads; 3) developing engineering, production, and cost criteria for detenaining design and economic feasibility; and 4) test an exfstfnq bench teat machine to determine power requirements and improve performance of the crushing rolls.

To be successful. the concept of a biomass harvester based on crushing and splitting biomass would have to show advantages over present energy wood harvesting systems using conventional logging machines and portable chippers. One area of application could be ROW maintenance where it is generally impractical for conventional energy wood chipping systems to operate. Some of the problems of conventional systems that a crushing concept would have to overcome are: 1) high costs of severing and handling large numbers of wall trees; 2) the handling problems associated with moving trees to the chipper: 3) dependency of chipper on chip van availability and 4) Cost of transporting water in the form of wood moisture. Another area of application could be harvesting of short rotation energy plantations. In these areas, a roll crusher harvester would need the capabilities for: 1) cutting large numbers of small stems, under 13 cm DBH, in rows or random distributions and 2) be highly maneuverable with good speed control over a range of site and biomass conditions.

It is still too early in the project to develop the design and economic feasibility criteria. however, experience and data being gained through operation of the test unit is providing vdluable insight toward a future design, particularly in the areas of roll design and -their related control and drive systems. York is just getting underway for testing, but some significant results are being obtained from the experimental roll crusher/splitter test bench.

TEST BENCH RESULTS

The crusher/splitter test bench is comprised of ii trailer frame, two sets of 46 cm diameter rolls, hydraulic motors with speed reducing gear drives to power the lower crush rolls, and a 130 kW gasoline engine with three gear driven hydraulfc pumps that supply power to the various components. The crushing force is provided by four hydraulic rams that act on the movable upper crush rolls. Control valves permit control of the degm and speed of crushing. During a test, the speed of the rolls would be set;. the upper rolls raised to permit feeding of the stems to be processed;' then the gap between the rolls would be adjusted to provide the desired degree of crushing and splitting.

For testing; green stems were harvested and bucked into approximately P-meter bolts. Bolts were cut to a standard 1.7 meter length, with disk samples 3- to 6-a thick being collected for moisture content determination.

After weighed bolts were processed by the crusher/splitter, the bolts and all solid particles (bark and splinters) were gathered and weighed to determine the weight of water removed during the process. Then. the splft bolts and particles were set on pallets and weighted daily to determine moisture loss rates. Table **1** and Figure 2 fllustrate moisture loss rates for the three species tested.

Another test was conducted to determine the power required to process small trees. Pressure transducers and tachometers were connected to the crusher/splitter and the data was recorded usfng a multichannel recorder. The digitized data was used to calculate power requirements. In the tests, three species were used: 1) hybrid poplar (*Populus x spp*.); 2) red maple (*Acer rubrum*); and 3) chestnut oak (*Quercus rinus*). Complete stems were crushed while stem diameter hydraulic pressures, and feed rates were monitokd for each of the two sets of rolls. Stems of each species were crushed singly, in pairs, and three at a time. Table 2 represents part of the findings of the power tests.

The preliminary findings Indicate that by applying minimal **power** during the harvesting phase by a machine similar to that in Figure 3, small diameter bianass (less than 13 cm) may be, adequately processed using a crushing and splftting technique to accomplish a significant amount of drying in the field. Though the physical **characteristics** of processed material have not been evaluated. it seems feasible that a satisfactory level of flexibility can be achieved to allow baling or modulating using modified agricultural equipment. Research by others (Schiess, and Yonaka, 1983) has shown that green forest biomass can be baled to a density of 336 kg/m^3 using an average of 0.83 kW·hr/tonne.

Table **1.** Roll splitting bolt tests, selected variable means and lfrits (preliminary analysis).

Variable	wean	Minimum	Maximum
---------Yellow-poplar - n-177-------------			
Diameter of bolt (cm)	10.4	6.7	16.6
Green weight (kg)	13.6	4.4	35.3
Green moisture content (% OD basis)	**118.5**	**84.1**	146.8
Water removed during splitting (% OD basis)	7.3	0.0	24.7
Cumulative water loss after 7 days (% OD basis)	76.8	-	-
---------------Red maple - n= 178---------------			
Diameter of bolt (cm)	9.8	6.1	18.2
Green weight (kg)	12.8	4.5	36.4
Green moisture content (% OD basis)	75.9	55.0	117.1
Water removed during splitting (% DD basis)	4.6	-	16.8
Cumulative water loss after 7 days (% DD basis)	50.0	-	-
--------------Loblolly pine - n=82-------------			
Diameter of bolt (cm)	10.9	**6.1**	16.5
Green weight (kg)	15.0	4.7	30.3
Green moisture content (% DD basis)	144.4	95.9	202.1
Water removed during splitting (% OD basis)	6.D	-	-
Cumulative water loss after 7 days (% DD basis)	107.7	-	-

CONCLUSIONS

The developments to date need significantly more • Valuation from the engineering, productivity. and cost' standpoints to determine system feasibility. Advantages and disadvantages may occur over present harvesting systems as a result of any of the systems operations. The objectives of the land managers, existing site/biomass conditions. and the characteristics of the final system will determine actual feasibility.

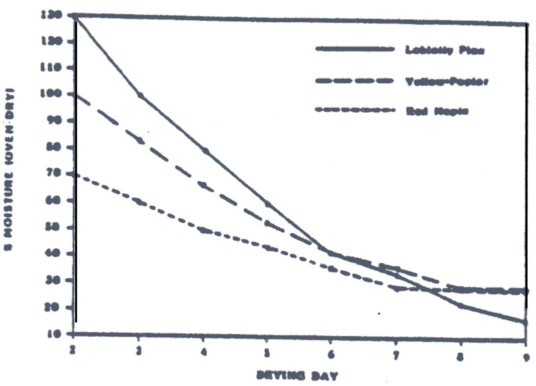

Figure 2. Percent moisture vs. drying time.

Table 2. Mean powr (kW) requirements by species, diameter, and number of stems for the small tree tests.

	1 stem			3 stems		
Diameter (cm)	First Roll	Second Roll	Total	First Roll	Second Roll	Total
	-	-	-	-	-	-
- - - - - - - - - - - - Hybrid				Poplar - - - - - - - - -		
2.5						2.4
5.1	1.4	1.0 1.8	3.2 1.6	5.0 1.5	0.9 1.9	6.9
	3.6	2.2	5.7	6.8	1.9	8.7
7.6	5.4					
10.2	5.2	2.9 2.2	8.3 7.8			
15.2	5.2	17.	.69			
17.8		1.9	7.2			
- w2.5 - m a - - - - - Chestnut				Oak - - - - - - - - - - -		
5.1	0.7	0.8 1.1	2.9 1.6	3.6	• 2.0	• •
	1.8					5.6
7.6	3.6	1.6	5.3	5.1	2.8	8.0
10.2	3.6	1.2	4.8	4.2	2.3	6.6
12.7	3.1	1.3	4.3	4.8	2.2	7.0
15.2	3.6	1.4	5.1			
17.8	4.3	0.8	5.1			

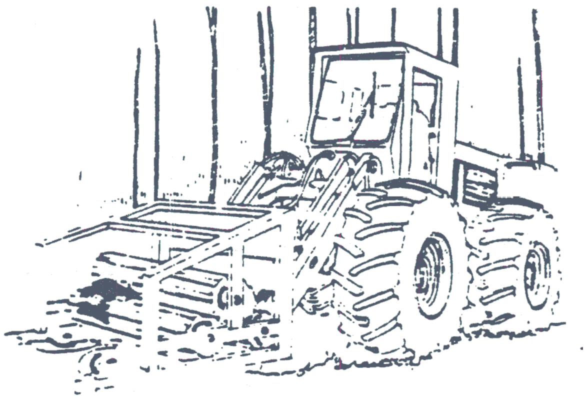

Figure 3. Artist's concept of roll crushing/splitting machine.

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