United States Department of Agriculture

Forest Service

Southern Forest Experiment Station

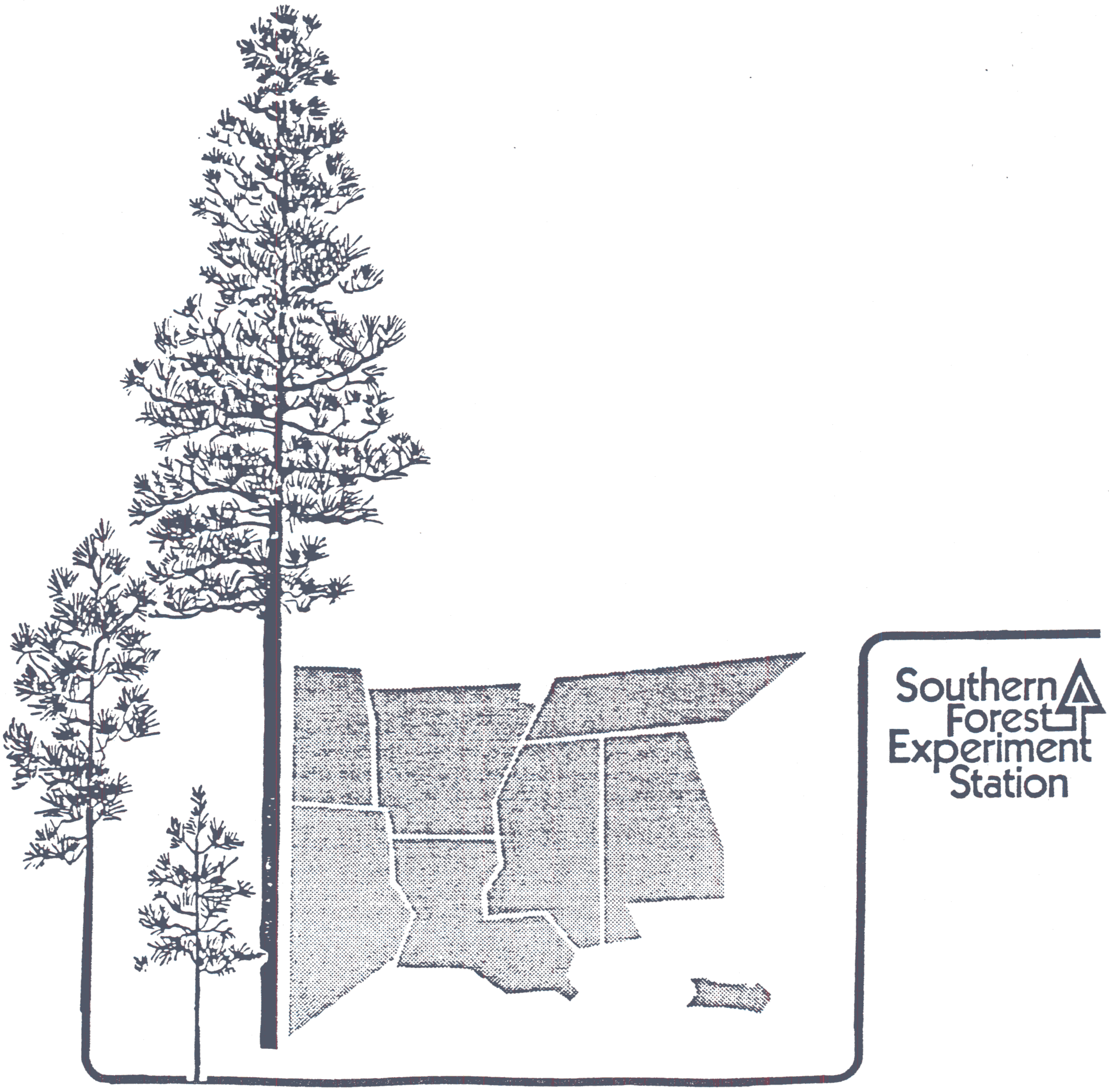
New Orleans, Louisiana

Proceedings Reprint

PRODUCTIVITY OF IN-WOODS CHIPPERS PROCESSING UNDERSTORY BIOMASS

W.F. Watson, Robert F. Sabo, and B.J. Stokes

In: A Proceedings of the Council on Forest Engineering, Improving Productivity through Forest Engineering; 1986 September 29 - October 2; Mobile, AL. Mobile, AL: Council on Forest Engineering; 1986: 69-72.



Productivity of In-Woods Chippers Processing Understory Biomass[1]

W. F. Watson, Robert F. Sabo, and B. J. Stokes[2]

Abstract: Productivity and cost per ton are predicted for two in-woods chippers (Morbark 20 and 27) where DBH, species groups, and moisture content are varied.

Keyword: Transpirational drying

Typical logging operations in the South average removing less than 45% of the aboveground biomass (USFS 1983). The bulk of the biomass produced must be dealt with in site preparation and re-establishment of the stand. If a market for this residue biomass is available, a case can be made for harvesting this material that is normally left on the site. The cost of recovering this residue or potential residue, minus the value of the residue to a utilizing facility must be less than the cost of re-establishment when the material is left on the site.

Two types of residue are found on a site following clearcut logging. There are the tops of merchantable stems and the understory stems which do not meet the specifications for the material being harvested. We have observed natural pine stands with up to 60 tons of understory material per acre and pine plantations with as much as 40 tons of this material.

The key to the cost effectiveness of any intensive utilization operation is the economical handling of small stems. Our previous work has shown that skidding can be cost effective when utilizing small stems if there is a sufficient quantity of these stems available on the site to make a full load for each skidder turn (Stokes et al. 1984, Miller et al. 1985, Watson et al. 1986). This was true for a preharvest operation when only the understory stems were taken as well as for an operation in which the merchantable overstory and the understory stems were taken in a single pass.

Felling the small stems economically is possible with some of the currently available equipment and if large quantities of understory material are available on the site. Feller-bunchers with high speed heads, which are highly maneuverable, and have a fast travel speed, can perform very well when harvesting the understory. The cost of felling understory has been found to be reasonable provided there is ample quantity of material to be felled (Watson et al. 1986). However, the felling costs become prohibitive when there is less than 15 green tons of material to be cut per acre (Miller et al. 1985). The feller-buncher spends much more of its time in traveling cycle when there is low volume of this material on the site.

Chipping is the predominant method of handling the small stems once they have been moved to a loading area. Chipping allows for the reduction in airspace that is necessary for the economical transport of small stems. The sole current use of this understory material is for fuel, thus chipping or hogging the material would be necessary in preparing the stems for burning. The results of a study that was conducted to investigate the economies and productivity of chippers in processing small stems are reported in this paper.

The power required for converting small stems to chips should not be as great as for the conversion of large stems to chips. Most companies producing chips in the South are using chippers in the 650 horsepower class. We first set out to determine if these larger chippers were necessary if only small stems were being processed.

Some companies are using transpirational drying to reduce the moisture content of wood for fuel. By felling the trees and allowing the stems to dry for several weeks, one can gratly increase the net Btu yield from the wood. However, processing the dried material requires that the knives be changed more often and it was felt that the chippers were losing productivity on a productive hour basis when handling this drier material. Thus, the impact of moisture content of the stems processed on productivity was also examined.

PROCEDURES

The study site (near Range, Alabama) was chosen so that a wide variety of species were available for processing. Felling of stems began 6 weeks prior to the chipping tests. Stems were segregated into separate piles by DBH and species group as they were felled. Species groups were hard hardwoods, soft hardwoods, and pines. The hard hardwoods found on the site included oaks, hickories, ashes, and dogwood. The soft hardwoods species included sweetgum, blackgum, red maple, holly, sweetbay, magnolia, and yaupon. DBH classes were the odd numbered classes from the 1 inch class to the maximum sized stem on the site for the hard and soft hardwoods and were 1, 3, and 5 inches for the pine.

Preparing a bundle sufficiently large for a chipper test would require several days. Thus, the bundles were labeled according to the week in which the trees were felled. This information was used to determine the length of time the trees had dried before being chipped.

On the day of the chipper test, the bundles were weighed. A converted prehauler was used to lift the stems from the ground. A load cell attached to the boom on the prehauler was used to determine the weight. The digital readout on the load cell was mounted at eye level on the rear of the prehauler.

Two chippers were used in this study. Models 27 and 20 Morbark chippers were utilized. The model 27 had a 650 horsepower power supply and 27

[1] Presented at the 9th Annual Council on Forest Engineering Meeting, Mobile, AL, September 29 - October 2, 1986.

[2] The authors are Associate Professor and Research Assistant, Department of Forestry, Mississippi State University, and Research Engineer, USFS Andrews Forest Sciences Lab, Auburn, AL.

inch throat while the model 20 had a 350 horsepower power unit and 20 inch throat.

After a bundle of stems was weighed, the bundle was skidded up to the chipper. The chipper operator would take a grapple full of the stems and feed the stems into the throat of the chipper. Timing of an observation would begin at this point. Timing of an observation would continue as the remainder of the stems in the bundle were fed into the chipper. Timing of the observation ended when the last chips were blown from the chip spout for the bundle. Chipper knives were changed after loading each van so that knife sharpness would not influence productivity.

A sample of chips was taken for each bundle for moisture content determination. A joint of schedule 40, 4" PVC pipe with a 90° elbow glued to the end was used for catching the sample. The elbow end of the pipe was moved in front of the chip spout to catch a sample of the chips as the bundle was being processed. Several random samples were taken during the processing of a bundle so that an unbiased estimate of moisture content could be made. The sampled chips were placed in a plastic bag immediately and were returned to a lab for drying and weighing.

ANALYSIS

An observation for this study consisted of the following information for use as independent variables:

1. species group of the bundle,
2. moisture content of the stems,
3. DBH class for the bundle,
4. chipper model, and
5. chipper operator.

The dependent variable was productivity in tons per productive hour which was derived from the bundle weight and the time to process the bundle. Productivity was predicted for both green tons and bone dry tons.

First, productivity was determined to be significantly different for the two models of chippers; thus, separate predictors were developed for each model. Productivity was found to be significantly different among the species groups for the model 27 chipper but the differences among the species groups were not significantly different for the model 20 chipper.

Model 27

The best predictors for the productivity of the model 27 chipper are given below:

1. For pine:

   A. $GPROD = 35.5 + 0.430\ (DBH)^3$ $(n = 16,\ R^2 = 66.6$ percent)

   B. $DPROD = 22.7 + 0.211\ (DBH)^3$ $(n = 16,\ R^2 = 56.6$ percent)

2. For hard hardwood:

   A. $GPROD = 29.4 + 4.66\ DBH$ $(n = 40,\ R^2 = 45.2$ percent)

   B. $DPROD = 20.7 + 2.68\ DBH$ $(n = 40,\ R^2 = 38.4$ percent)

3. For soft hardwood:

   A. $GPROD = 9.48 + 10.1\ DBH - 0.530\ (DBH)^2$ $(n = 37,\ R^2 = 55.5$ percent)

   B. $DPROD = 7.35 + 6.13\ DBH - 0.321\ (DBH)^2$ $(n = 37,\ R^2 = 52.0$ percent)

where

GPROD = productivity in green tons per productive hour
DPROD = productivity in bone-dry tons per productive hour
DBH = diameter at breast height
n = number of observations
R^2 = coefficient of determination (from regression analysis).

Productivity estimates derived from these predictors are reported in Tables 1 and 2.

An interesting occurrence in this data is that moisture content had no impact on productivity. This is especially interesting in the green tons productivity since as much as 50 percent of the weight of wood chipped would be moisture.

The productivity of the chipper processing soft hardwoods exhibited traits that were expected. Productivity increased rapidly as DBH is increased from the 1 inch class and was at a maximum at the 9 inch class. The maximum productivity when processing hard hardwoods was the largest class observed which means that we did not test enough stems in the higher diameter classes to adequately predict an optimum stem size.

Model 20

Two operators were used on the model 20 chipper during this study. No significant differences were found in the productivity when

Table 1—Predicted green productivity and cost of the Morbark Model 27 chipper for each species group.

	Pine		Hard Hardwood		Soft Hardwood	
DBH	Tons/ Prod. Hour	Cost/ Ton	Tons/ Prod. Hour	Cost/ Ton	Tons/ Prod. Hour	Cost/ Ton
1	35.9	$2.64	34.1	$2.78	19.1	$4.96
3	47.1	2.01	43.4	2.18	35.0	2.71
5	89.3	1.06	52.7	1.80	46.7	2.03
7			62.0	1.53	54.2	1.75
9			71.3	1.33	57.5	1.65
11			80.7	1.17	56.5	1.68
13			90.0	1.05	51.2	1.85
15			99.3	0.95		

Table 2--Predicted bone-dry productivity and cost of the Morbark Model 27 chipper for each species group.

DBH	Pine Tons/ Prod. Hour	Pine Cost/ Ton	Hard Hardwood Tons/ Prod. Hour	Hard Hardwood Cost/ Ton	Soft Hardwood Tons/ Prod. Hour	Soft Hardwood Cost/ Ton
1	22.9	$4.14	23.4	$4.05	13.2	$7.18
3	28.4	3.34	28.7	3.30	22.9	4.14
5	49.1	1.93	34.1	2.78	30.0	3.16
7			39.5	2.40	34.5	2.75
9			44.8	2.12	36.5	2.60
11			50.2	1.89	35.9	2.64
13			55.5	1.71	32.8	2.89
15			60.9	1.56		

each operated the machine; thus, the data gathered on both operators could be pooled.

The best predictors for productivity are given below:

1. $GPROD = 11.2 + 0.488\ (DBH)^2 - 0.00140\ (DBH)^4 + 0.00186\ (MC\ percent)^2$
   $(n = 97,\ R^2 = 62.6\ percent)$

2. $DPROD = 6.41 + 2.57\ DBH$
   $(n = 97,\ R^2 = 59.4\ percent)$

where

GPROD = productivity in green tons per productive hour
DPROD = productivity in bone-dry tons per productive hour
DBH = diameter at breast height
MC percent = percent moisture content
n = number of observations
R^2 = coefficient of determination (from regression analysis)

Productivity predictions derived from these equations are reported in Table 3.

Note that moisture content was significant in explaining the variation in green ton productivity for the model 20 chipper. As would be expected, productivity decreased as moisture content decreased.

Cost Analysis

Cost estimates were developed for the models 27 and 20 chippers (Sabo 1986). These costs are given below:

	Model 27	Model 20
Machine rate	$78.83	$44.13
Rental rate	94.83	60.13

The rental rate (operating per productive hour including labor) of each chipper was used to calculate the cost per ton of production in Tables 1, 2, and 3.

Table 3--Predicted green and bone-dry productivity[a] and cost of the Morbark Model 20 chipper.

DBH	Green Tons/ Prod. Hour	Green Cost/ Ton	Bone-dry Tons/ Prod. Hour	Bone-dry Cost/ Ton
1	16.9	$3.56	9.0	$6.68
3	20.7	2.91	14.1	4.27
5	27.7	2.17	19.3	3.12
7	37.0	1.63	24.4	2.46
9	46.7	1.29	29.5	2.04
11	55.0	1.09	34.7	1.73
13	58.9	1.02	39.8	1.51

[a]Productivity at mean percent moisture content of 52.9 percent.

CONCLUSIONS

Note that the model 27 chipper was more productive and more cost effective in almost all diameter classes for the pines and hard hardwoods. Further, the model 27 chipper was more cost effective than the model 20 chipper in the smaller diameter classes. This means that in the smaller stems throat size is more important than power. However, these results are not definitive for the case of purchasing the larger chipper. Other considerations could sway the case for either size machine.

Reduced moisture content did not reduce the productivity per productive hour of the larger chipper. Sharp knives were always used in this study, thus the more powerful chipper was not overloaded with harder dry stems. One should realize that this study did not take into account the fact that drier stems will require more knife changes. (We have observed situations where a set of knives will last for only 3 van loads of chips in dry material but will last through 10 or more van loads when chipping green material.) More knife changes will reduce productive time and drive the cost per productive hour and cost per ton of chips up further.

LITERATURE CITED

Miller, D. E., W. F. Watson, T. J. Straka, R. K. Matthes, and B. T. Stokes. Productivity and cost of conventional understory biomass harvesting systems. Paper No. 85-1598 presented at 1985 Winter Meeting of Am. Soc. of Ag. Eng. 19 p.

Sabo, R. F. Productivity and cost of in-woods chippers processing understory biomass. Unpublished Master's thesis, Miss. State Univ. 1986. 25 p.

Stokes, B. J., W. F. Watson, and I. W. Savelle. Alternative biomass harvesting systems using conventional equipment. Proc. 1984 Southern Forest Biomass Workshop. p. 111-114.

U.S.F.S. Forest statistics for West Central Alabama Counties. U.S.F.S. Sou. For. Exp. Sta. Bul. SO-93. 1982. 15 p.

Watson, W. F., B. J. Stokes, and I. W. Savelle. Comparison of two methods of harvesting biomass for energy. For. Prod. Jour. 1986. 36(4):63-68.