Effect of Tire Size on Skidder Productivity

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ABSTRACT - During the Spring of 1996 a collaborative effort among Mead Coated Board. the Auburn University School of Forestry. and the Southern Research Station was initiated to evaluate skidder production performance as a function of tire size and soil condition (i.e. wet and dry season)_ The objective of the study was to determine production and cost differences among 28L-26, 30.5L-32, 67x34.00-25. and 66x43.00-25 tires. The first portion of the study was completed for dry sites and there proved to be no significant differences in productivities among the tires tested. Wider tires do not hinder productivity under dry conditions. Additional data for the same tires will be collected under wet conditions in order to make comparisons among the tires and between the seasons. The goal is to develop a strategy for optimal tire management.

INTRODUCTION

Rubber-tired skddding is the predominate method of wood extraction in the southern U.S. Grapple skidders combined with high-speed feller-bunchers, delimbing gates or mechanical delimbers, and knuckleboom tree-length loading offer high system production and relatively low harvesting costs. However, as with any ground base system, skidder performance is affected by wet site conditions and skidders can cause soil damage on such sites. Typically, skidders have been equipped with 71.4 cm (28 in) wide tires as a standard. In the last 10 years, there has been increased interest in wider tires to improve production and to reduce site impacts.

Many previous studies have concentrated on site and soil damage caused by varying tire sizes. Site damage is important. as it has been reported that natural recovery of soils in the southern U.S. can take as much as 50 years due to a lack of freezing and thawing (Drissi. 1975). Increasing tire width as a means to reduce ground pressure has been used by machinery manufacturers as machines have increased.in size and weight. These wider tires generally are perceived to reduce damage to sensitive soils.

However. there have been only a few studies which have evaluated the impact of tire size on productivity. Meek (1994) compared performance and soil impacts of 172.7 cm (68 in) tires and 127 cm (50 in) tires. 'In this study, the wider tires provided a 13 to 23 percent increase in productivity and produced less soil disturbance on firm and soft sites. Rummer and Sirois (1984) compared the productivity and site impacts of three tire sizes, 18.4-26, 23.1-26, and 6.7x34.00-26. They found no significant difference between the 46.7 cm (18.4 in) and 58.7 cm (23.1 in) tire widths, but found a 2.1 m^3/Productive Machine Hour (PM H), or 14.5 percent increase in productivity with the wider tires. There was no significant difference in productivity between the 58.7 cm (23.1 in) and 86.4 cm (34 in) tires, although the 86.4 cm (34 in) tires provided a 1.4 m^3/Productive Machine Hour increase in productivity.

Mclligan and Hcidersdorf (1984) studied high flotation tires and found productivity increases of 60 percent on wet ground and fuel savings of up to 40 percent. A 1984 study (Burt et al.. 1984) tested three tire sizes, 18.4-34, 24.5-32, and 30-5L-32, in a controlled test site. All three tires were tested at two travel reductions and two inflation pressures. In this study, tire size had little effect on skidder productivity on dry soil.

A cooperative study was initiated by Mead Coated Board, Auburn University. and the USDA Forest Service, to evaluate the effect of tire size on skidder productivity. With increased concern in meeting increasing environmental guidelines, a need was identified to determine optimal tire size for year-round operation to maximize productivity while maintaining environmental quality. The concept was to estimate grapple skidder productivity and costs for the various tire sizes over a range of conditions, and to use known environmental performance for the tires to develop a strategy for optimal tire management. The objectives of the study were to determine productivity and costs for selected tire widths for skidding as a function of wet and dry seasons. Four tire sizes were evaluated on two dry sites during the summer. Although an attempt was made to evaluate the same tires in wet sites in the late summer and early fall, the data were not collected because of dry conditions. This paper only reports the dry season portion of the study. Data remains to be collected for skidding during the wet season. A later paper will include the comparison between wet/dry season productivity and costs for the selected tire sizes and can be obtained from the authors.

HARVEST SYSTEMS

Two contractors on two sites participated in the study. The first logging contractor normally hauled chips from this site, but during the tests the contractor was restricted to hauling only roundwood. The harvesting method was a final harvest of a pine plantation. Skidders performed gate delimbing, Trees were topped to approximately 5. l cm with a chainsaw at a staging area. From the staging area trees were then skidded to a deck and loaded onto trucks. Firestone' 28L-26 and 66x43.00-25 tires (Table 1) mounted on Timberjack 450C grapples skidders were evaluated on this site.

The second contractor also hauled roundwood. The harvesting method was a final harvest of a natural stand. Trees were skidded to a deck where they were processed with a CTR pull-thru delimber. During some observations delimbing was performed using a gate before trees were skidded to the deck. Firestone 30.5L-32 and 67x34.00-25 tires were tested on this site. These tires were also mounted on Timberjack 450C grapple skidders.

Table 1. Specifications of tires tested.*

Tire Size	Overall Width (cm)	Overall Diameter (cm)	Static Loaded Radius (cm)
28L-26	71.4	163.8	74.2
30.5L-32	77.5	188.0	84.3
67x34.00-25	85.6	175.8	76.9
66x43.00-25	105.4	172.2	76.9

* Specifications taken from Bridgestone/Firestone brochure.

STAND/SITE CONDITIONS

Site 1 was a loblolly pine (*pinus taeda*) plantation located on a Lower Piedmont site in Georgia. Slopes on this site ranged from ten to fifteen percent grades with some localized areas exceeding 20 percent. Soil moisture content, dry basis, was 13.6 percent in undisturbed areas and 11.5 percent in skid trails. Average DBH of trees skidded was 18.8 cm for the 28L-26 tires and 16.6 cm for the 66x43.00-25 tires (Table 2).

The second site was a natural stand of mixed pine and hardwood on an Upper Coastal Plain site in Alabama. Slopes on this site ranged from zero to ten percent. Soil moisture content was 16.5 percent in undisturbed areas and 11.9 percent in skid trails. Average DBH of trees skidded was 20.0 cm for the 30.5L-32 tires and 18.6 cm for the 67x34.00-25 tires.

METHODOLOGY

Each skidder tested had different, but experienced operators that were assessed to have comparable skills. Standard production-time study techniques were used to measure the elements: travel empty, position, grapple, intermediate travel (bunching), gate delimbing, travel loaded, and ungrapple. Travel distances were measured with a rolotape distance wheel. Butt diameters were measured on all trees. DBH and total length for pine were sampled and regression equations were developed to estimate these variables for unsampled trees. Weights were calculated using appropriate weight equations (Clark and Saucier, 1990). For hardwood trees, DBH and length to a 10.2 cm top were sampled and regression equations were developed to estimate these variables for unsampled trees. Hardwood weights were calculated using equations provided by Mead Corporation. Soil samples were taken in undisturbed areas and in skid trails for each skidder for determining percent moisture content during the time study (Table 3).

RESULTS AND DISCUSSION

The summary of trees skidded by site and tire size combination is shown in Table 2. There were significant differences for average tree diameter and weight per tree by tire size on each site. There were also significant differences among the average weight per tree for each tire tested. The tree differences translated into significant differences among the average trees per cycle and pay load for the different tire sizes (Table 3).

The extent to which tree size was confounded with tire size in skidder production is not known. However, even with differences between average tree weight, there were not significant differences between average load size within a site, but only between sites. This indicates that there were site differences, and the skidder operators adjusted for site differences and not tire differences.

A summary of the means of each time study element is shown in Table 3. Time per cycle (travel empty, position, grapple, travel loaded, and ungrapple) is essentially the same for the tires on each site, although the travel loaded distance was much less for the 28L-26 tires. Since intermediate travel and staging did not occur during every skidder turn for each skidder, that time was not included in the calculation of time per cycle. Also, time per cycle was calculated with and without gate delimbing. With gate delimbing, time per cycle increased over 17 percent for each skidder on site 1 and over 13 percent for the skidder mounted with the 30.5L-32 tires on site 2.

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[1]Use of firm or trade names is solely for the information of the reader and does not constitute endorsement by Auburn University, the U.S. Department of Agriculture, or Mead Coated Board.

Table 2. Summary of mean values of tree measurements/weights of skidded trees.

Variable	Units	Site 1		Site 2					
		28L-26	66x43.00-25	30.5L-32			67x34.00-25		
				Pine	Hw	Both	Pine	Hw	Both
DBH	(cm)	18.7a+	16.6b	20.8	13.5	20.0c	20.1	12.4	18.6a
Total length	(m)	15.8	14.1	17.4		- -	17.6		- -
Length to 10.2 cm top	(m)	-	-		6.8	-		5.9	-
Tree weight	(t)*	0.22a	0.15b	0.37	0.12	0.34c	0.34	0.08	0.29d

+ Means with the same letter are not significantly different at α=0.05 using Tukey's Studentized Range Test.
* t = metric tons (tonnes)

The production summary is also shown in Table 3. As mentioned, average tonnes per cycle for each site is approximately equivalent. The average productivities were 36.1, 46.8, 43.2, and 43.0 tonnes per PMH for the 28L-26, 30.5L-32, 67x34.00-25, and 66x43.00-25 tires, respectively. With skidders performing gate delimbing, average productivity decreased by 17.5 percent for the 28L-26 tires, 10.5 percent for the 30.5L-32 tires, 3.0 percent for the 67x34.00-25 tires, and 23.3 percent for the 66x43.00-25 tires.

The skidder with the 66x43.00-25 tires had significantly more trees per cycle than the skidders with the other tire sizes. This was most likely due to the tree size differences and different bundle sizes built by the feller-buncher operators. On average, the number of trees skidded by the 66x13.00-25 tires was over 35 percent greater than that of the XL-26 tires.

There were significant differences in tonnes per cycle between sites, but not between skidders on the same site. The skidders on site 1 had a decrease of over 25 percent in average load size than the skidders on site 2.

Since our main objective was to determine production differences among the tires, certain elements were evaluated more closely. Tukey's Studentized Range Test was used to compare means of the independent variables studied for differences among the tire sizes (Table 3). It was thought that increased tire width might hinder machine maneuverability and increase *time* to position the machine or reduce travel speed on the dry site conditions. The 30.5L-32 tired skidders had significantly less position time than the other skidders equipped with various tire sizes which had about the same average position time. This may have been due to having smaller diameter trees and fewer trees per cycle, which could account for less position time. In any case, there was no strong indication that position time was affected by tire width on the dry sites.

The skidder with the 28L-26 tires had uncommonly high travel empty speeds and low travel loaded speeds. This was due to a slope factor in the area where the skidder was operating. After gate delimbing. the skidder had to travel up a 20 to 30 percent grade, resulting in low travel loaded speeds. Since the skidder traveled down the grade during the travel empty element back to the woods, this caused an increase in travel empty speeds. Although the skidder with the 66x43.00-25 tires was on the same site, it skidded from a different area that was not as steep. There were significant differences among the travel speeds for the different tires, but there was not a trend to indicate a relationship with tire size.

Travel speed, empty or loaded, did not appear to be directly influenced by tire width. However, the preponderance of the data shows differences, but not conclusive trends. It can be surmised that in dry conditions when traction is not a problem and loads are comparable, that tire width within range tested does not increase/decrease speed. However, additional, more detailed data would be needed to verify this conclusion. Additional data is also needed for wet site conditions to compare productivities across the seasons and help to develop guidelines for optimal tire size selection and management.

A linear regression analysis using SAS (1988) was conducted to model the total time per cycle. The only variable found to be correlated with total cycle time was total distance. A model was developed that included all the tire treatments (Figure I). Since tire size was not significant, the final model was based only on total travel distance:

$$TOTTIME = 2.551144759 + 0.005054510(TD); R^2 = 0.5105;$$
C.V. = 29.94

where: TD = total distance (m).

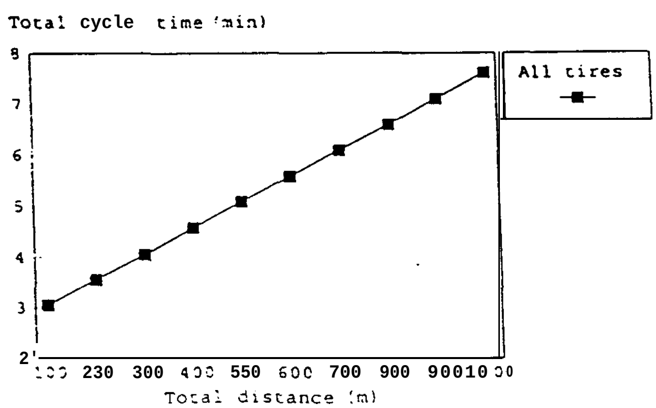

Figure 1. Regression line for all tires combined

Table 3. Summary of mean values of study elements.

Element	Units	Site 1-28L-26				Site 2-30.5L-32				Site 2-67x34.00-25				Site 1-66x43.00-25			
		Obs.	Mean	S.D.	Range	Obs.	Mean	S.D.	Range	Obs.	Mean	S.D.	Range	Obs.	Mean	S.D.	Range
Travel empty	(min)	22	0.71	0.12	0.50-0.92	24	1.81	0.55	0.83-3.31	25	1.70	0.88	0.75-2.97	35	1.99	1.51	0.40-5.17
Position	(min)	22	0.34a*	0.22	0.12-0.98	24	0.19b	0.09	0.05-0.36	25	0.30ab	0.16	0.10-0.77	35	0.25ab	0.23	0.06-1.45
Grapple	(min)	22	0.43a	0.26	0.10-1.05	24	0.37a	0.22	0.13-0.81	25	0.39a	0.26	0.11-1.00	35	0.37a	0.28	0.11-1.45
Int. travel	(min)	0				5	0.62	0.30	0.29-0.93	4	0.93	0.22	0.69-1.16	1	1.80		1.80-1.80
Gate delimb	(min)	22	0.79a	0.57	0.21-2.57	21	0.49a	0.29	0.17-1.15	7	0.61a	0.33	0.22-1.07	35	0.81a	0.37	0.13-1.X6
Travel loaded	(min)	22	3.08	1.40	1.49-5.38	24	2.18	0.85	0.92-4.47	25	2.77	0.95	1.61-4.95	35	1.98	1.05	0.56-4.25
Ungrapple	(min)	10	0.04a	0.01	0.03-0.06	2	0.49a	0.65	0.03-0.95	7	0.59a	0.81	0.03-1.96	15	0.05a	0.03	0.02-0.13
Stage	(min)	22	0.48	0.12	0.34-0.77	0				0	-			21	0.21	0.04	0.16-0.30
Travel empty distance	(m)	22	149.7	25.4	107-193	24	278.1	71.9	156-369	25	189.8	85.1	100-325	35	260.0	206.7	54-539
Travel loaded distance	(m)	22	151.0	26.1	107-194	24	240.8	62.2	72-351	25	251.7	39.2	190-328	35	225.0	164.1	54-451
Total distance	(m)	22	300.7	51.4	214-387	24	518.9	126.7	228-679	25	441.5	122.2	317-653	35	485.1	370.4	10X-986
Trees/cycle		22	10.8a	3.3	5-21	24	9.1a	3.8	3-19	25	10.7a	3.6	5-21	35	14.6b	4.6	6-26
Tonnes/cycle	(t)	22	2.3%	0.59	1.66-4.29	24	3.13b	0.96	1.68-5.34	25	3.14b	0.96	0.76-4.59	35	2.27a	0.58	1.18-3.82
Time/cycle+	(min)	22	4.58	1.52	2.36-6.X1	24	4.12	1.04	2.69-6.85	25	5.00	1.90	2.80-8.43	35	4.61	2.61	1.81-8.78
Time/cycle w/gate	(min)	22	5.37	1.45	2.80-7.37	21	4.67	1.12	2.88-7.46	7	4.22	0.68	3.73-5.51	35	5.42	2.63	2.42-9.56
Productivity	(t/PMH)++	22	36.1	20.3	17.5-108.9	24	46.8	13.1	18.7-77.9	25	43.2	20.9	6.1-86.4	35	43.0	29.0	8.3-114.9
Productivity w/gate	(t/PMH)	22	29.8	16.2	14.9-91.8	21	41.9	10.2	16.3-63.2	7	41.9	17.7	18.4-62.2	35	33.0	19.4	7.7-71.5
Travel empty speed	(km/hr)	22	12.8a	1.48	8.2-15.5	24	9.5b	1.8	5.4-13.9	25	7.1c	1.3	4.0-10.2	35	7.8c	1.9	3.3-11.5
Travel loaded speed	(km/hr)	22	3.4a	1.12	1.9-5.5	24	7.4b	2.9	2.0-12.6	25	5.8c	1.4	3.0-8.2	35	6.3bc	2.2	3.2-9.X
Moisture content (%)																	
Undisturbed		2	17.5	6.Y	17.5-22.4	3	13.6	12.1	5.9-27.7	3	19.4	3.7	15.5-22.9	4	11.7	3.9	6.0-15.0
Trail		2	14.0	2.0	12.6-15.4	3	10.7	7.7	5.7-19.6	3	13.1	7.x	5.7-21.2	4	10.3	4.5	5.0-14.6

* Means with the same letter are not significantly different among sites at $\alpha=0.05$ using Tukey's Studentized Range Test.

\+ Time/cycle reflects sum of travel empty, position, grapple, travel loaded and ungrapple times.

++ t/PMH = tonnes/Productive Machine Hour.

Although there were no significant differences among tire sizes, models were developed for each tire size for demonstration purposes (Figure 2). The final models were:

28L-26: TOTTIME = 0.0154045839(TD);
R^2 = 0.9498; C.V. = 24.10
30.5L-32: TOTTIME = 0.0077409441(TD);
R^2 = 0.9468; C.V. = 24.28
67x34.00-25: TOTTIME = 0.0114967697(TD);
R^2 = 0.9724; C.V. = 18.11
66x43.00-25: TO-l-TIME = 1.354942574 + 0.006708371(TD);
R^2 = 0.9094; C.V. = 17.27

where: TD=total distance (m). R-square values for the 28L-26, 30.5L-32, and 67x34.00-25 tires are not corrected for the mean.

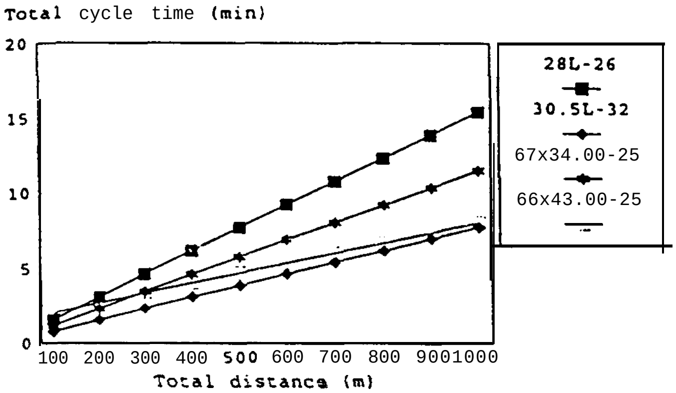

Figure 2. Regression lines for each tire size.

ECONOMICS

Costs for each tire size are listed in Table 4. These costs include tires. wheels, tubes, and mounting.

Skidder tire life has decreased over the years due to heavier, higher horse powered skidders. Ten years ago, skidders averaged 8,000 kg and had 67.1 kW engines and a logger could get 2 to 3 years tire life operating in the South. Today, skidders average over 12.000 kg with 89.5 kW engines. This extra weight and horsepower results in a tire life of about 18 months (Titus, 1996).

Table 4. Tire costs.*

Tire Size	Cost per Assembly (US$)	cost to Equip Machine (US$)
28Lx26	2,160	8.640
30.5L-32	2.916	11,664
67x34.00-25	3,469	13,876
66x43.00-26	4,058	16,232

* Cost Information provided by Beard Equipment Company

SUMMARY AND CONCLUSIONS

The primary objective of this study was to determine productivity and costs for selected tire widths for skidding as a function of wet and dry seasons. Only the dry season data has been collected to date. Productivity was not affected by tire size in the study. There were no indications of trends in the evaluated elements as related to tire size.

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