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# Differences in total stem value when merchandizing with a tracked processor versus a knuckle–boom loader in *Pinus taeda*


## Abstract

Using tracked processors over knuckle–boom loaders to increase total value per tree when merchandizing timber on the landing has become a topic of interest in the southeastern region of the United States. This study compared merchantability values, product classes, and product weights of loblolly pine (*Pinus taeda*) for both machines to determine if there was a significant difference between machines when processing the same tree. In order to process the same tree twice, the chains from the tracked processor had to be removed from the bottom saw bar. This allowed the processor to simulate the merchandising process without actually marking or cutting the tree for a more realistic comparison. Data were analyzed using paired t–tests and two–way ANOVA models. Results depicted that when diameter and total lengths are visually estimated by the knuckle–boom loader. A significant difference in value occurs, however, once diameter and total length are modified to match the tracked processors for more accurate measurements, no difference in value was seen. These results demonstrate that until mill specifications become more stringent, there is little incentive for loggers to purchase a tracked processor if their only motivation is to increase merchantability values.


**Keywords:** forest excavator, tracked processor, knuckle–boom loader, merchandizing

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## Introduction

Promotion towards using tracked processors to merchandize timber on the landing in place/in conjunction with knuckle–boom loaders has become a topic of interest in the southeastern region of the United States. Although this region is known for transporting full–length trees, also known as whole tree (WT), loggers are still required by mills to de–limb and cut the tops of each tree to a specific diameter depending on the product they are transporting. This process is currently conducted using a knuckle–boom loader with either a pull–through de–limber or a chain–flail de–limber for both pulpwood and chip and saw (CNS) logs. Loggers who are able to harvest plywood logs typically use a knuckle–boom loader with either a slasher saw attachment or a full–length log that is placed next to the loader. This log has been marked to identify the specific plywood lengths so the loader operator can simply lay the un–processed log next to the marked log to use as a cutting reference. In all the aforementioned cases, visual estimation is used to identify product classes, product lengths, diameter at breast height (dbh), and top dbh.

In addition to mills current demands for specific top dbh, a select number of mills are starting to require prime lengths on tree length material for more than just plywood. This request is forcing loggers to find alternative methods to process and merchandise their wood. One option is to use a tracked/wheeled processor which can merchandise either whole tree or dimension–length wood. In order to encourage the adoption and purchase of these processors, a few mills are providing incentives for loggers in their region with the mindset that by investing in the logger they are actually investing in their mill. If loggers purchased a processor to merchandise their wood this would result in fewer loads per unit time that results from inaccurate measurements. Additionally, they would potentially increase productivity at the landing, as well as producing less waste at the mill due to variable log lengths.

A processor is also said to be able to increase a logger's merchantability value per stem because of its technological advancements in computer software such as Waratah's TimberRite 30H & TimberRite 30Lite systems.[1,2] A logger can input market products into the machines computer system and prioritize them so that an operator simply pushes a button to determine product availability. With the use of the processor's software program, the TimberRite 30H system can learn typical stem profiles so it can make the most merchantable bucking choices, thereby in theory choosing the product with the highest value for the entire tree rather than one product.[1] At this time the TimberRite 30Lite is not capable of learning stem profiles, however, it is still capable of prioritizing products based on market value and market need. These value–added opportunities are in contrast to smaller dbh pulp or bioenergy feedstock's where good economies of scale are necessary.[3]

Merchandizing comparison studies are difficult because no two trees are exactly alike and a stem can only be truly merchandized once. For this reason, very few studies have been conducted to compare merchandizing abilities, and those that have occurred did not use the same tree more than once and were focused on productivity rather than merchandising.[4–9] The objective of this study was to determine if there was a difference between the tracked processor and knuckle–boom loader when merchandising the same loblolly pine stems with regards to products and value.

## Methods

The study was conducted on a 645–acre tract managed by Resource Management Services (RMS) five miles west of Rockford, Alabama. The tract had been planted approximately 30 years ago and was primarily comprised of loblolly pine (*Pinus taeda*). Although hardwood stems were being harvested and merchandized on this tract, they were not included in the study.

A 2154G John Deere Swing Machine with a 622B Waratah processing attachment head was used to represent the tracked processor and was compared against a 234B Tigercat knuckle–boom loader with a pull–through de–limber and slasher saw for the study. Both machines were set up on the same landing, close enough to pass stems between each other while still maintaining a safe working distance from one another. Samples were collected on two separate landings with 50 trees being merchandised on each landing for a total of 100 trees sampled. The chains were removed from the tracked processors top and bottom bars so the attachment could realistically simulate harvesting the tree without causing any damage to the tree before transfer to the knuckle–boom loader operator. TimberRite 30Lite, one of Waratah's software systems which displays stem information, was monitored for dbh, total length, product class, product length, and number of products per tree.[1] Similar measurements were recorded visually on the knuckle–boom loader as they were called out by the operator.

During the study, the skidder would drag a pull of trees and deposit them in front of the tracked processor. The tracked processor operator would grab a tree and go through the motions of processing the stem without the chains using the pre–assigned product class buttons to determine the ideal products for the tree. He would begin by attempting to cut a plywood log out of the butt. If the trees dbh and top merchantable height were found acceptable by TimberRite 30Lite then the cut would be made, otherwise, the attachment would automatically slide down to the next acceptable product. This process was followed for the entire length of the tree or until reaching a two–inch top, the minimum top dbh for pulpwood stem. Overall, the tracked processor operator's intentions were to maximize the total value received out of each tree.

The tree, now removed of all its branches after being run through the processor, was transferred to the knuckle–boom loader operator who would actually process the stem to later be loaded and transported to the mill. To make the study as realistic as possible, the loader operator called out his estimated dbh, product classes and product lengths for each stem. Total length was estimated by adding up all product lengths. The knuckle–boom operator merchandized stems based on current market needs for the day and what products would bring him the highest value rather than maximize the total value of the stem.

Out of the 100 trees sampled, 2 were removed from the dataset because they did not match the studies predetermined criteria of being loblolly pine. Data were recorded in Microsoft Excel initially. Clark & Saucier equations were used to find the number of pounds for each total tree, per ply log, per CNS log, and per pulpwood log for both the tracked processor as well as the knuckle–boom loader.[10] These weights were then converted into tons per product class and multiplied with a stumpage rate to determine the price per ton per product class as well as the total value of each tree for both machine types. Prices were found using Timber Mart South's 2017 third quarter's rates to demonstrate the total value of each tree when the study was conducted.[11]

Data was then input into MiniTab 18.0 where paired t–tests were conducted on dbh, total length, and total value per stem. Ideally, paired t–tests would have been conducted on all variables for comparison, however, since merchandizing each stem did not always result in the same products being included by both machines this was not feasible. Two–way ANOVA's were used to compare machine type (factor) against product classes, product class weight, product class values, and total value for a total of 13 variables (responses) being analyzed in the study with dbh and total length being used as covariates. Stepwise regression with significance of 0.05 was used to filter out the insignificant variables in the model.

## Results

Initial results from the paired t–tests depicted all three variables; dbh, total length, and total value to be statistically significant at the 95% level with the knuckle–boom loader having greater dbh, total lengths, and total values. As mentioned previously, all dbh and lengths were visually estimated by the knuckle–boom loader operator, indicating potential error and bias to the data analysis when continuing forward and testing differences in total values and tonnage. To alleviate this bias, the knuckle–boom loaders estimated dbh and total lengths were modified to match the processor's precise measurements. Because the knuckle–boom loader operator estimated dbh in two–inch dbh classes, the processor's dbh were modified to match this method. Differences in total length were added or subtracted from the pulpwood estimation on the knuckle–boom loader values. After these modifications were made the paired t–test resulted in no difference in total value between machine types.

Of the two–way ANOVA models that were run on the original 13 variables, six of these variables were found to have a statistical difference between the factor, machine type, and the response it was tested against at the 0.05 significance level. Total value was not found to be statistically significant through the ANOVA. The significant responses included: plywood logs, pulpwood logs, CNS tons, pulpwood tons, CNS value, and pulpwood value. Plywood 2 was the variable used when more than one plywood log was merchandized from a single stem. It should be noted however that CNS tons and pulpwood tons had the exact same p–values, F–value, and $R^2$ as CNS value and pulpwood value, only coefficients were different.

Both covariates assisted in explaining the Plywood logs ANOVA model in addition to machine type (p–value 0.006). These variables, dbh (p–value <0.0001) and total length (p–value 0.036), were associated with the changes in the number of feet of plywood logs that were produced. This model had an adjusted $R^2$ of 36.70%. Regression equations for the machines were as seen above in Table 1 indicating that the tracked processor produced approximately 4 foot longer lengths of plywood logs.

Pulpwood logs ANOVA had a p–value of 0.039 for machine type. The two covariates, dbh (p–value <0.0001) and total length (p–value 0.006), were associated with changes in the number of feet of pulpwood that was produced. This model had an adjusted $R^2$ of 31.05%. Regression equations for the machines were as seen above in Table 1 indicating that the knuckle–boom loader produced approximately 5 foot longer lengths of pulpwood.

**Table 1** List of all variables tested in the two–way ANOVA models comparing the knuckle–boom loader against the tracked processor with equations for significant variables.

| Variable | Significant difference at p–value <0.05 | Equations if significant | $R^2$ | F–Value | P–Value | n |
|---|---|---|---|---|---|---|
| Plywood Logs (ft) | Yes | (TP) Ply Logs (ft) =–4.93+2.201*DBH+0.1750*TL (KBL) Ply Logs (ft) =–8.31+2.201*DBH+0.1750*TL | 0.381 | 2.86 | 0.003 | 133 |
| Plywood 2 Logs (ft) | No | | | | | |
| CNS Logs (ft) | No | | | | | |
| Pulpwood (ft) | Yes | (TP) Pulp (ft) =36.49–3.084*DBH+0.367*TL (KBL) Pulp (ft)=47.12–3.084*DBH+0.367*TL | 0.321 | 6.78 | < 0.00001 | 196 |
| Plywood Weight (tons) | No | | | | | |
| Plywood 2 Weight (tons) | No | | | | | |
| CNS Weight (tons) | Yes | (TP) CNS (tons) = 0.0061+0.002289*TL (KBL) CNS (tons) =–0.1071+0.002289*TL | 0.256 | 3.2 | < 0.00001 | 196 |
| Pulpwood Weight (tons) | Yes | Pulp (tons) = 0.1867–0.0489*TP+0.0489&KBL | 0.109 | 7.94 | < 0.00001 | 196 |
| Value of Plywood ($) | No | | | | | |
| Value of Plywood 2 ($) | No | (TP)$CNS = 0.092+0.0348*TL (KBL)$CNS =–1.626+0.0348*TL | 0.256 | 60.93 | < 0.00001 | 196 |
| Value of CNS ($) | Yes | | | | | |
| Value of Pulpwood ($) | Yes | $Pulp = 1.5607–0.4088*TP+0.4088&KBL | 0.109 | 23.67 | < 0.00001 | 196 |
| Total Value of Stem ($) | No | | | | | |

CNS tonnage ANOVA had a machine type p–value of 0.001 to assist in explaining the model in addition to the covariate total length (p–value 0.019). This model had an adjusted $R^2$ of 24.85%. Regression equations for the machines were as seen above indicating that the tracked processor produced 0.05656 tons more of CNS than the knuckle–boom loader. The pulpwood ANOVA had a p–value of <0.0001 for machine type which was it's only signficant variable. The model had an adjusted $R^2$ of 10.41% and the regression equation depicted that the knuckle–boom loader produced 0.0489 more tons of pulpwood over the tracked processor. Both the CNS value and pulpwood value ANOVA's resulted in the exact same p–values and adjusted $R^2$ as CNS and pulpwood tons. Regression equations however, differed. The knuckle–boom loader was able to produce $0.41 more per tree in pulpwood value; however, the tracked processor was able to produce $0.86 more per tree than the knuckle–boom loader for CNS value.

## Discussion

Total value per tree was found to be statistically significant when using the visually estimated dbh and total lengths recorded by the knuckle–boom loader operator. These results indicated that knuckle–boom operators could actually be losing money if they are under–estimating the dbh and lengths of stems rather than over–estimating or being precise with their measurements. Although visual estimation is currently the common practice for merchandizing trees in the southeastern region of the United States, some mills are beginning to demand more specific product specifications from the loggers which could make visual estimation a technique of the past. Utilization of a processing attachment head on either a tracked or wheeled machine would guarantee product specifications if calibrated correctly, allowing loggers to inadvertently decrease the number of trucks that were turned away from the scale house due to imprecise visual estimates when merchandizing trees.

Total value per tree was not found to be statistically significant once dbh and total length were adjusted to match the tracked processors measurements indicating that using the processing head did not actually increase the logger's total merchantability value on a per stem basis as previously believed. The differences seen in the CNS and pulpwood values, however, do represent the difference between the knuckle–boom operator who merchandized stems based on current market needs for the day and what products would bring the highest value in that area rather than maximize the total value of the stem. During the study, the knuckle–boom operator discussed how the CNS mills were on quota but plywood mills were not restricted so he tried to optimize each stem to get the highest value of plywood logs out rather than CNS. This resulted in having four stems which had plywood 2 logs whereas the tracked processor had none. If the knuckle–boom operator wasn't able to make a plywood log out of the stem he inferred that he gained more value out of putting the log into pulpwood rather than CNS when considering trucking distances to mills. Overall, the knuckle–boom operator had less overall CNS logs which were found to be statistically significant with regards to weight but not feet.

Plywood logs and pulpwood logs were found to be statistically significant with regards to the number of feet merchandized by each machine. In both cases, although the knuckle–boom loader harvested more total products than the tracked processor, the processor was able to get additional feet out of each product which aided to its significance. The additional feet once again tie back having the precise measurements from the processor versus having to visually estimate where the top dbh is on each product. Since plywood is purchased in prime lengths, the additional four feet was only significant in this variable rather than carrying through to tonnage and value. There was potential however, for not only plywood value, but total value per stem to be found statistically significant if plywood length distance were to have had a couple more feet added to the tracked processors final ANOVA coefficient.

Ideally, this study would be repeated using the TimberRite 30H software system to determine if the ability to learn whole stems profiles increases total value for a tracked processor. The TimberRite 30H software system was not originally installed in the 2154G John Deere Swing machine. Although the 30H system can be installed to override the 30Lite system it was not done for this study.

In general, it is not completely surprising that total value was not statistically different between the two machines. Prices per ton per product class are the same regardless of whether merchandising is conducted by maximizing the total value of the stem or current market needs for the day. Due to the site characteristics, a majority of the trees were merchandized with a single plywood log with the additional tree length classified as pulpwood. This left minimal opportunity for the tracked processor to demonstrate its technological capability. The site was however typical of the region indicating that tree height and quality should be taken into consideration for any person interested in purchasing a processor.

## Conclusion

Unless mills in the southeastern United States become more stringent with their product specifications, there is little motivation for loggers to invest in a processing head to increase value when merchandising. Future studies may reveal that the tracked processor increases productivity on the landing giving the logger the opportunity to haul more loads in a day which increases his profit, however, at this time no additional value is gained by the logger when merchandizing his trees with the tracked processor over a knuckle–boom loader.

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## Conflict of interest

Author declares there is no conflict of interest.

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