Evaluation of a Tracked Feller-Buncher Harvesting Plantation Loblolly Pine

John Klepac[1] and Dana Mitchell[2]

Abstract

A Tigercat 845D[3] swing-to-tree tracked feller-buncher was evaluated while operating on four sites located in Butler, Covington, Crenshaw, and Monroe counties in south Alabama. Study sites were comprised of loblolly pine (*Pinus taeda*) and ranged in age from 14 to 16 years with a mean tree size of 6.2 to 7.6 inches at Diameter Breast Height (DBH). The feller-buncher incorporated several new design features which included a high-speed shear head, a high capacity accumulating head, an adjustable shear opening, and an improved boom and swing system to increase fuel efficiency. The feller-buncher was observed while operating in stands that ranged from 486 to 777 trees per acre (TPA). Total cycle times ranged from 59 to 73 seconds. The majority of cycle time was spent accumulating trees in the head and ranged from 54.7% to 68.8% of total cycle time. Production rates ranged from 77.9 to 113.7 green tons/Productive Machine Hour (gt/PMH).

Keywords: Productivity, felling, time study,

Introduction

Providing wood products to the U.S. has been a major role of the of the South's forests for the past several decades. With increased demand for lumber and paper products to meet the needs of consumers, management of plantation pine has become the common practice to help meet these demands. Harvesting pine in the southeastern US, specifically the Coastal Plain, Delta, and Lower Piedmont physiographic regions has improved over the last thirty years in terms of productivity and efficiency. Pine planting has increased from <50,000 acres per year in 1945 to about 2M acres per year in 2006 (Taylor et al., 2014). Harvesting plantations is more profitable to the landowner if two thinnings can be accomplished before final harvest. Pulpwood products are removed from the first thinning, followed by pulpwood and chip-n-saw from the second thinning, and sawtimber during the final harvest. Alternatively, plantations can be clearcut when trees become large enough to provide a marketable biomass product.

Genetic improvements in seedlings coupled with intensive management practices have resulted in harvesting stands at a younger age. Over time, this has resulted in a decrease in average tree diameter. These smaller diameter trees resulted in the design of high production machines. The flat and gently rolling topography in the physiographic regions of the southeastern U.S. are favorable for rubber-tired, drive-to-tree feller-bunchers equipped with high-speed disc saws.

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[1] General Engineer, USDA Forest Service, 521 DeVall Dr., Auburn, AL 36849, jklepac@fs.fed.us
[2] Project Leader, USDA Forest Service, 521 DeVall Dr., Auburn, AL 36849, danamitchell@fs.fed.us
[3] The use of trade or firm names in this publication is for reader information and does not imply endorsement of any product or service by the U.S. Department of Agriculture or other organizations represented here.

The objective of this study was to evaluate production rates for an alternate machine design, a Tigercat 845D tracked swing-to-tree feller-buncher equipped with a shear-head, while performing clearcut operations. Also, to determine which cycle elements have the most significant impact on machine performance.

Machine Overview

A Tigercat 845D tracked swing-to-tree feller-buncher was evaluated. The feller-buncher incorporated new design features for the purpose of enhancing productivity while working in smaller diameter pine plantations. The feller-buncher was powered by a Cummins QSB 6.7 L 260 hp (horsepower) engine which met Tier 4i emissions requirements. A specifically designed DT1802 shear-head was incorporated into the design to reduce initial capital investment and decrease maintenance costs. The head capacity was increased to approximately 3.73 ft^2. The shear head was designed to complete a cycle (open and close) in 1.5 seconds and was capable of being adjusted for harvesting a specific tree size (Taylor et al. 2014). Other features included Tigercat's patented ER® technology boom system, an energy recovery swing system, and a 340 degree head rotation capability.

Methodology

Study Sites

The Tigercat 845D feller-buncher was observed while operating at the four study sites located in the Coastal Plain of Alabama as indicated on the map in Figure 1. All sites were comprised of plantation loblolly pine (*Pinus taeda*) which ranged in age from 14 to 18 years. Site 1 was located in Butler County, Site 2 in Covington County, Site 3 in Crenshaw County, and Site 4 in Monroe County.

Tree size was determined by measuring Diameter at Breast Height (DBH) from either felling plots or inventory plots installed prior to harvest. Total tree heights were sampled using an electronic hypsometer. Trees within a felling plot were identified by either a number or color code by diameter class. Tree weights were calculated using a local weight equation developed from weighing trees in the field using an electronic digital scale. Weights of trees over 11-inches DBH were calculated using an equation for plantation pine in the Southeast (Clark and Saucier, 1990).

Soil types for the Butler county site consisted predominately of a Halso fine sandy loam, 1 to 3% slopes and also included a Lynchburg sandy loam, 0 to 2% slopes (USDA, 2016). The Crenshaw county site included an Arundel fine sandy loam, 2 to 8% slopes (USDA, 2016), while the Covington county site consisted of an Orangeburg sandy loam, 5 to 8% slopes (USDA, 2016). The Monroe county site was a Bama sandy loam, 1 to 5% slopes and also included a Saffel very gravelly sandy loam, 8 to 15% slopes (USDA, 2016).

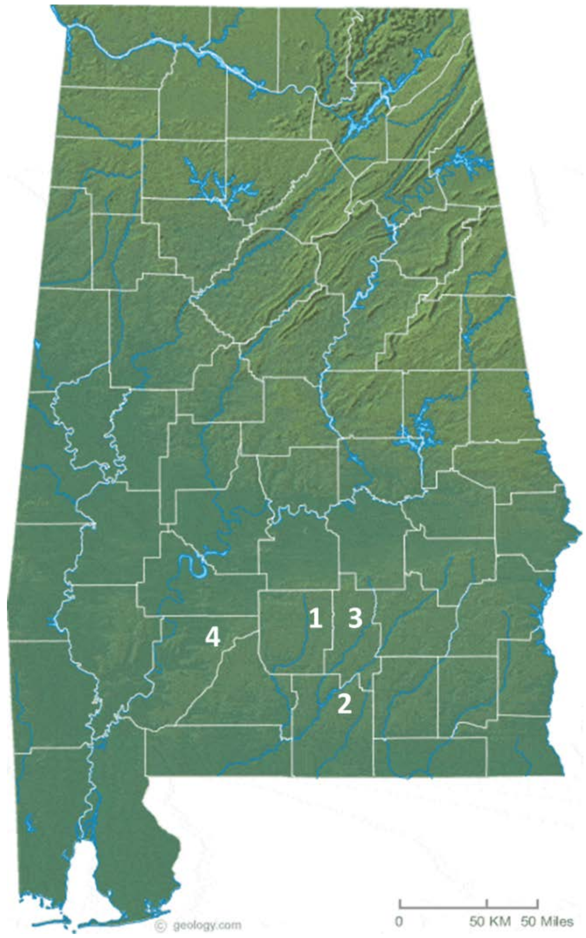

Figure 1. Site location map.

Felling

The Tigercat 845D feller-buncher was observed on each study site while performing a clearcut operation. The same equipment operator was used on all sites. Productive time of the machine was recorded onto digital video while it operated within each study plot. Tree numbers or color codes were recorded verbally during felling.

Videos were analyzed using the software program Timer Pro Professional (Applied Computer Services, Inc., 2015). Cycle elements were defined in the program and the time required to perform each element was recorded. A compete observation, or cycle, of the feller-buncher began after trees in the head were dumped and the machine initiated travel or a swing to cut the first tree and ended when trees in the head were dumped. Cycle elements consisted of move-to-1^{st}-tree, reach-to-1^{st}-tree, accumulate, move-between-trees, move-to-dump, and dump.

Tree weights were calculated using local weight equations to determine productivity. To test for differences in measured variables among sites and mean time for each element among sites, Tukey's Studentized Range Test (SAS Institute Inc. 1988) was used. This test controls the Type I experimentwise error rate. A Type I error occurs when the null hypothesis is incorrectly rejected.

Results and Discussion

Study Sites

Diameter distributions from inventory data and felling plot data are displayed in Table 1. Stand densities ranged from 486 to 777 trees per acre (TPA). Tree sizes encountered ranged from 2 inches to 12 inches DBH and averaged 6.2 inches to 7.5 inches across all sites.

Site 1 had a mean density of 581 trees per acre (TPA) in the 2 to 11-inch diameter classes with a mean DBH of 7.6 inches. Sixty percent of trees were contained in the 6 to 8-inch diameter classes. Only 2.5 percent of trees were included in the 2 and 11-inch diameter classes. Total tree height averaged 53.2 feet.

Table 1. Inventory data summary for study sites.

DBH Class (in)	Trees per Acre			
	Site 1	**Site 2**	**Site 3**	**Site 4**
2	3	2	0	0
3	0	32	0	37
4	17	94	33	83
5	37	125	51	116
6	110	162	110	173
7	130	125	124	169
8	110	50	88	105
9	97	14	57	73
10	67	4	14	21
11	10	0	4	0
12	0	0	5	0
Avg. DBH	**7.6**	**6.2**	**6.9**	**6.4**
Total TPA	**581**	**608**	**486**	**777**

Site 2 had a mean density of 608 TPA in the 2 to 10-inch diameter classes with a mean DBH of 6.2 inches. Sixty-eight percent of trees were contained in the 5 to 7-inch diameter classes. Only 1 percent of total trees were in the 2 and 10-inch diameter classes. Total tree height averaged 42.0 feet.

Site 3 had a mean density of 486 TPA in the 4 to 12-inch diameter classes with a mean DBH of 6.9 inches. Sixty-seven percent of trees were contained in the 6 to 8-inch diameter classes. Only 7.9 percent of total trees were in the 4 and 12-inch diameter classes. Total tree height averaged 48.6 feet.

Site 4 had a mean density of 778 TPA in the 3 to 10-inch diameter classes with a mean DBH of 6.4 inches. Fifty-nine percent of trees were contained in the 5 to 7-inch diameter classes. Only 7.6 percent of total trees were in the 4 and 10-inch diameter classes. Total tree height averaged 51.0 feet.

Elemental Time Study

A summary of time study variables for each site is shown in Table 2. Time study data showed Sites 1 and 3 had the lowest total cycle times and lowest stand densities. These two sites also had the largest mean tree diameter, which suggests less time was required to reach the capacity of the felling head, resulting in lower cycle times. Alternatively, Sites 2 and 4 had the highest total cycle times and the highest stand densities. With higher stand densities mean tree diameters were smaller, which required more time to fill the felling head to capacity.

Table 2. Summary of time study variables for each site.

Variable	Site 1 Butler Co.	Site 2 Covington Co.	Site 3 Crenshaw Co.	Site 4 Monroe Co.
Total time (sec)	58.9b[1]	71.3a	59.6b	73.3a
No. of Obs.	65	44	52	38
Trees/cycle	5.8c	7.8b	7.2b	9.0a
Time/tree (sec)	10.1c	9.1b	8.3a	8.1a
Mean DBH/cycle (in)	7.3c	6.2b	7.0a	6.5a
Green tons/cycle	1.81a	1.51b	1.80a	1.89a
Green tons/PMH	113.7a	77.9c	112.8a	95.6b

[1]Means with the same letter are not significantly different ($\alpha = 0.05$) using Tukey's Studentized Range Test.

Mean time moving to 1st tree (Figure 2) ranged from 5.65 sec to 8.47 sec with significant differences indicated by letters. Stand densities are shown in parenthesis on the horizontal axis next to the site name. Number of observations are displayed in parenthesis at the top of each bar next to the mean. There was a significant difference between Sites 1 and 2, where Site 2 was 33 percent faster in this cycle element.

Mean reach to 1st tree time (Figure 3) ranged from 3.71 sec to 6.80 sec, where Site 4 was significantly different from the other sites. This could be attributed to the higher stand density which decreased the distance required to extend the boom while reaching for the first tree after dumping.

Accumulate time (Figure 4) ranged from 32.59 sec to 49.06 sec for the four sites. Sites 1 and 3 were statistically the same while Sites 2 and 4 were statistically the same. Sites 1 and 3 had larger average tree sizes as compared to Sites 2 and 4. With larger size trees, fewer trees would be needed to reach head capacity, resulting in less time spent accumulating. Alternatively, with smaller trees, more trees are required to fill the head which results in more time accumulating.

Mean time moving between trees was statistically the same among all sites and ranged from 6.93 sec to 10.27 sec (Figure 5). Utilization of a boom allowed the operator to harvest multiple trees from a single location, which resulted in less time performing this element as compared to a rubber-tired machine.

Mean move-to-dump time (Figure 6) was statistically the same among Sites 1, 3, and 4 and ranged from 5.4 to 11.1 sec. The statistical test for this element should be interpreted with caution due to the limited number of observations. No occurrences of move-to-dump time were

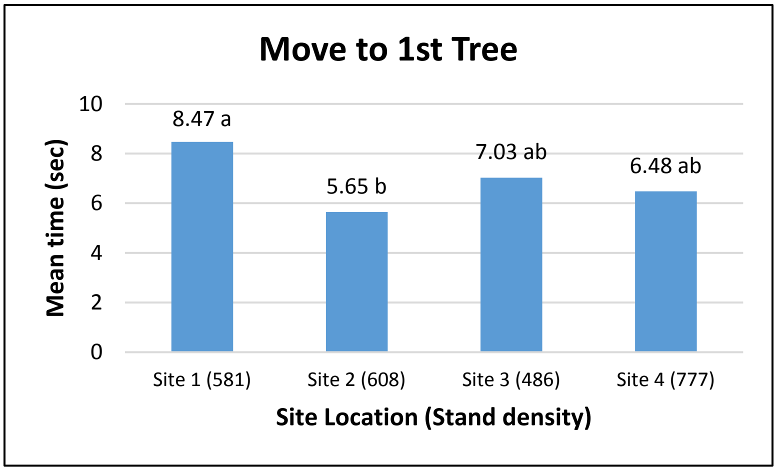

Figure 2. Mean time moving to 1st tree for the Tigercat 845D feller-buncher. Means with the same letters are not significantly different (p=0.05).

observed for Site 2. The ability to extend the boom to dump trees from the head, coupled with moving while accumulating, reduced the number of instances where the operator was required to travel to dump.

Dump time ranged from 7.84 to 11.87 sec (Figure 7) and was statistically the same among Sites 1, 2, and 3. Dump time on Site 4 may be explained by the significantly higher number of trees per cycle.

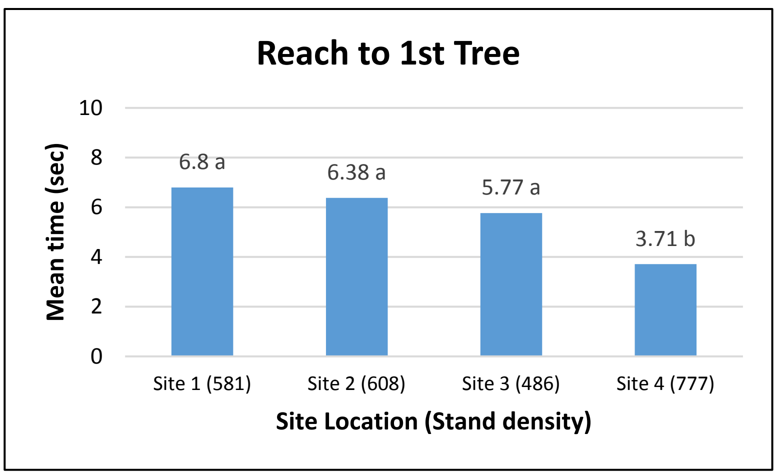

Figure 3. Mean time reaching to 1st tree for the Tigercat 845D feller-buncher. Means with the same letters are not significantly different (p=0.05).

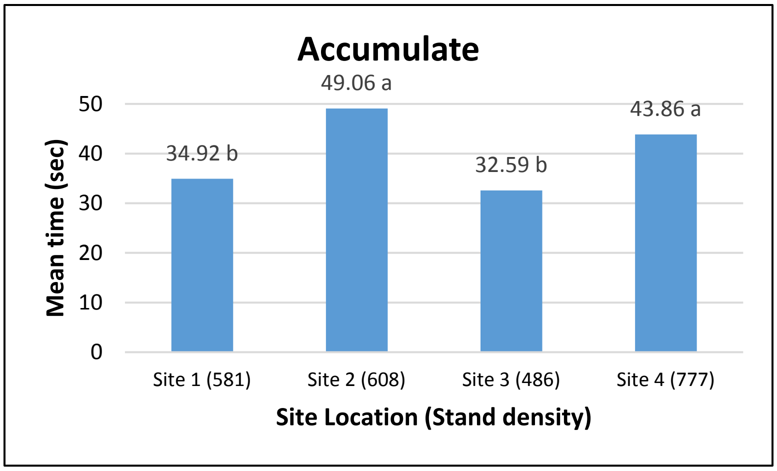

Figure 4. Mean time accumulating for the Tigercat 845D feller-buncher. Means with the same letters are not significantly different (p=0.05).

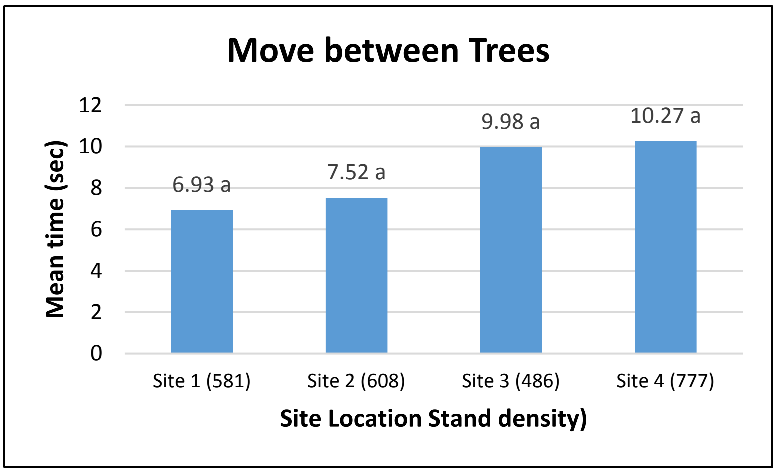

Figure 5. Mean time moving between trees for the Tigercat 845D feller-buncher. Means with the same letters are not significantly different (p=0.05).

Percent of total cycle time the feller-buncher spent performing each element is shown in Figures 8 to 11. The majority of cycle time for all sites was spent accumulating, with a minimum of 54.7% for Site 3 and a maximum of 68.8% for Site 2. Following accumulation, time to dump occupied the majority of cycle time for Sites 1, 2, and 4 and ranged from 11.0% to 15.4%. Site 3 had a higher percentage of cycle time in the move between trees element as compared to percent of time dumping, which could be a function of the lower stand density (486 TPA) on the site. Percent of time moving between trees for Sites 1, 2, and 4 ranged from 7.7% to 12.9%. Move-to-dump was less than 1% for all sites and ranged from 0.0% to 0.8% of total cycle time. Dump time was similar among sites and ranged from 11.0% to 15.4% of total cycle time.

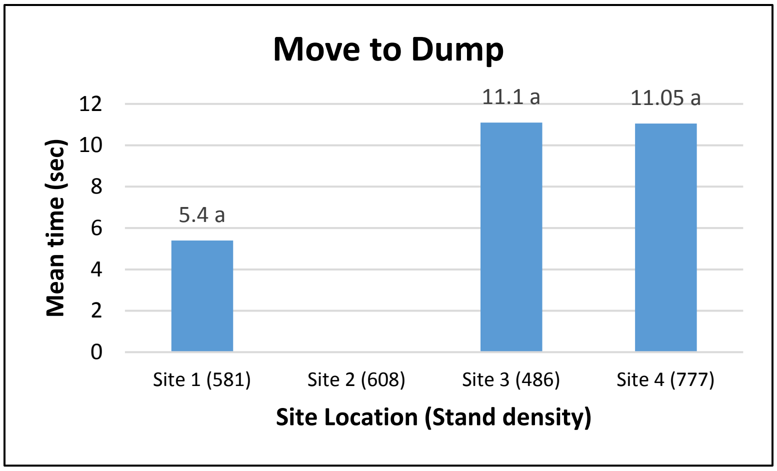

Figure 6. Mean time moving to dump for the Tigercat 845D feller-buncher. Means with the same letters are not significantly different (p=0.05).

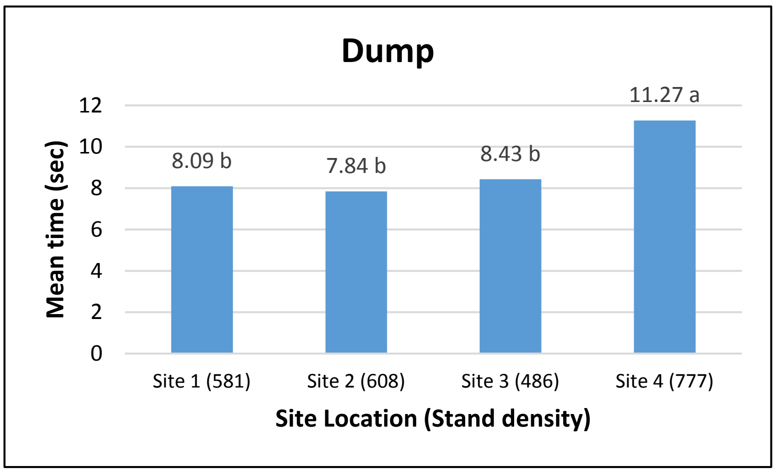

Figure 7. Mean time dumping for the Tigercat 845D feller-buncher. Means with the same letters are not significantly different (p=0.05).

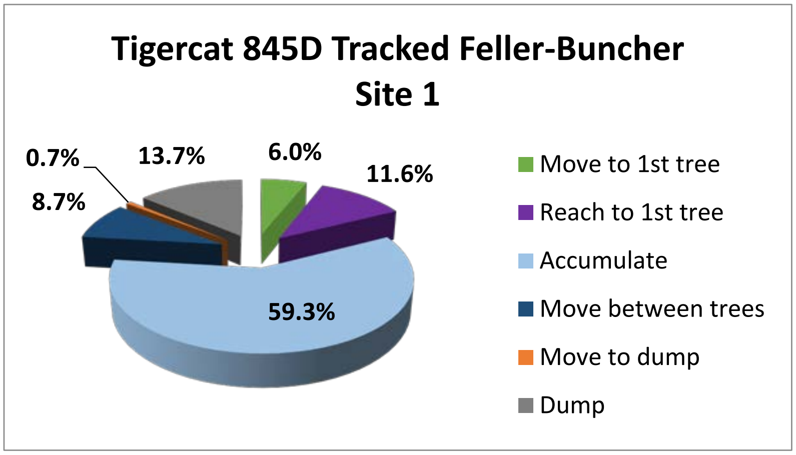

Figure 8. Percent of total cycle time by element for the Tigercat 845D feller-buncher.

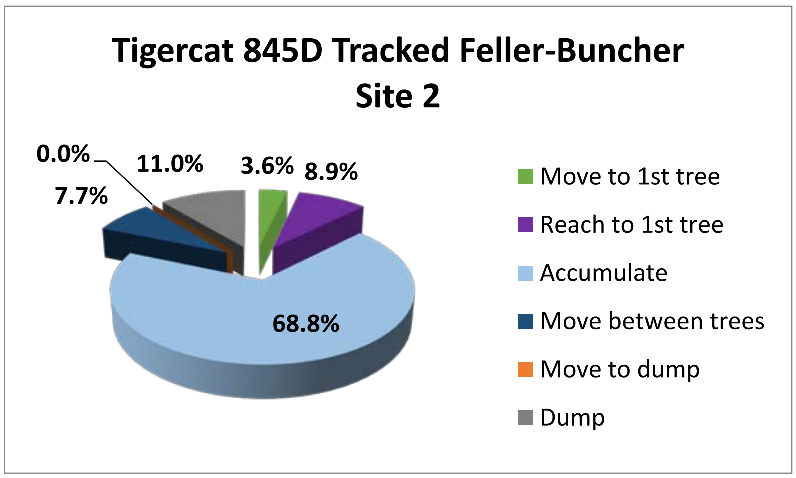

Figure 9. Percent of total cycle time by element for the Tigercat 845D feller-buncher.

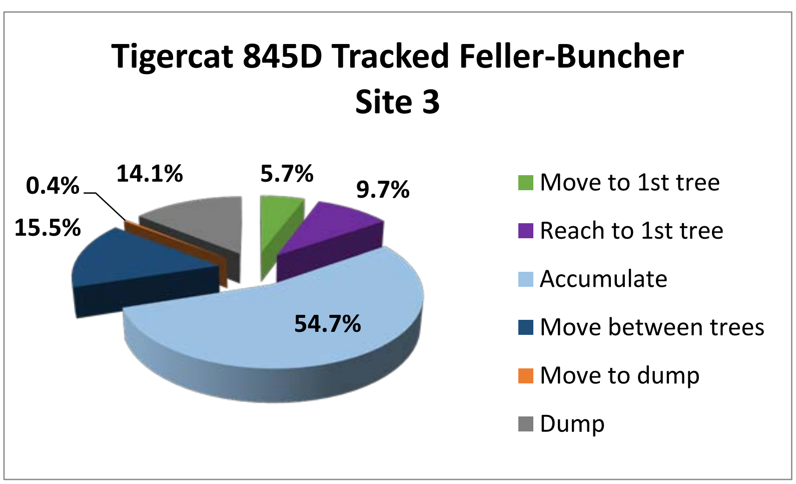

Figure 10. Percent of total cycle time by element for the Tigercat 845D feller-buncher.

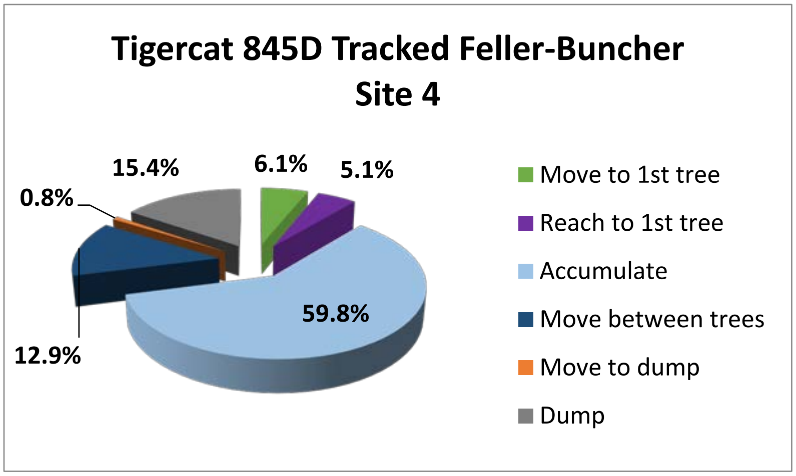

Figure 11. Percent of total cycle time by element for the Tigercat 845D feller-buncher.

Conclusions

A Tigercat 845D track mounted swing-to-tree feller buncher with a shear head was observed while performing clearcut operations in four young southern pine plantations. Stand densities ranged from 486 to 777 TPA, while tree size ranged from 2 to 12 inches DBH. The largest difference in move to 1st tree time was between Sites 1 and 2, even though these two sites had similar stand densities. Site 4 had the fastest reach to 1st tree time (3.71 sec), which was possibly a function of the higher stand density (777 TPA) and closer tree spacing. Across all sites, the operator spent over half of the total cycle time accumulating trees in the head. Accumulate time was longer for Sites 2 and 4. These two sites had the smallest average tree size, which required more time acquiring a full head of trees. Move between tree times were statistically the same among sites. Although a range of stand densities were examined, the use of a boom resulted in similar times for this element. Move to dump time element had a low frequency of occurrence. Site 2 had no observations for this element. Using the boom to extend to the dump location, coupled with the clearcut silvicultural prescription, reduced the time spent performing this element. Dump times were statistically the same for Sites 1, 2, and 3, while Site 4 had the longest average dump time which was significantly different. The longer dump times on Site 4 may be explained by the significantly higher number of trees per cycle.

References

Applied Computer Services. (2015). Timer Pro Professional Video Analysis Software, Version 11.4.17.2014. Applied Computer Services, Inc., Englewood, CO.

Clark III, A. and Saucier, J.R. (1990). “Tables for Estimating Total-Tree Weights, Stem Weights, Volumes of Planted and Natural Southern Pines in the Southeast.” Research Paper SE-79, USDA-Forest Service, Southeastern Forest Experiment Station, Asheville, NC.

SAS Institute Inc. (1988). *SAS/STAT*® User’s Guide, Release 6.03 Edition, Cary, NC: SAS Institute Inc., 1028 pp.

Taylor, S.E., T.P. McDonald, O.O. Fasina, T. Gallagher, M. Smidt, D. Mitchell, J. Klepac, J. Thompson, W. Sprinkle, E. Carter, J. Grace, R. Rummer, F. Corley, and G. Somerville. (2014). High Tonnage Forest Biomass Production Systems from Southern Pine Energy Plantations. Final Report, DOE-EE0001036. United States Department of Energy.

USDA Natural Resources Conservation Service. Web Soil Survey. https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htr. [Date accessed: October 20, 2016.