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Evaluation of a Conventional Harvesting System for a Hardwood Restoration Project on the George Washington and Jefferson National Forests

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Abstract

A conventional ground-based harvesting system was evaluated while implementing a shelterwood with reserves silvicultural prescription in a hardwood stand on the George Washington and Jefferson National Forests. The 16.3 acre study unit consisted predominately of chestnut oak (*Quercus montana*), scarlet oak (*Quercus coccinea*), and white oak (*Quercus alba*). Trees 6 inches Diameter at breast height (Dbh) and larger were measured in two felling plots. The mean Dbh was 11.8 inches with an average of 154 trees per acre (TPA). Machines evaluated included a drive-to-tree feller-buncher equipped with a saw head and a grapple skidder. Preliminary analyses revealed the feller-buncher averaged 52.8 green tons/Productive Machine Hour (gt/PMH), while the skidder averaged of 37.6 gt/PMH. Machine rate analyses resulted in an hourly cost of $150.44/PMH for the feller-buncher and $158.63/PMH for the skidder. Unit costs for the feller-buncher ranged from $2.50/gt to $3.44/gt and $4.22/gt for the skidder.

Introduction

Districts on the George Washington and Jefferson National Forests have planned an ambitious collaborative effort known as the Lower Cowpasture Restoration and Management Project. Restoration activities will be implemented on 117,500 acres of public and private lands over a ten year period (USDA Forest Service, 2016). The project will include an array of research activities in order to address issues considered a priority among its stakeholders. Activities will include timber management, transportation improvement, aquatic passage improvement, watershed improvement, wildlife habitat creation, non-native invasive species treatment, trail construction, dam stabilization, selected woody biomass removal, American chestnut progeny site development and planting of blight resistant seedlings, and prescribed fire projects USDA Forest Service, 2016).

It is envisioned that two-aged systems, mainly shelterwood with reserves, will be the primary harvest system utilized to achieve multiple use objectives and provide for a variety of wood products (USDA Forest Service, 2014). The traditional shelterwood method "involves the removal of the old stand in a series of cuttings, which extend over a relatively short portion of the rotation, by means of which the establishment of essentially even-aged reproduction under

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the partial shelter of seed trees is encouraged" (Smith, 1986). The goal is to establish a new even-aged crop of trees before the old one is completely removed (U.S. Forest Service, 1979).

The shelterwood with reserves, in contrast to a traditional shelterwood, is a two-aged regeneration method in which some or all of the shelter trees are retained, well beyond the normal period of retention, to attain goals other than regeneration (USDA Forest Service, George Washington National Forest, Revised Land and Resources Management Plan, 2018).

Study Site

The 16.3 acre study site was located on the Warm Springs Ranger District on the George Washington and Jefferson National Forests in Bath County, Virginia. Primary species on the site included chestnut oak (*Quercus montana*), scarlet oak (*Quercus coccinea*), and white oak (*Quercus alba*). Additional species included ash (*Fraxinus sp*.), black oak (*Quercus velutina*), northern red oak (*Quercus rubra*), red maple (*Acer rubrum*), tupelo (*Nyssa sylvatica*), and yellow-poplar (*Liriodendron tulipefera*). Depending on tree size, harvested trees were used for either tie logs or pulpwood.

Equipment

Harvesting machinery included a feller-buncher, a grapple skidder, and a knuckleboom loader. The feller-buncher was a John Deere[3] 843H drive-to-tree machine equipped with a Waratah FD22 sawhead and mounted on Firestone 28L-26 LS2 tires. A John Deere 748H machine mounted on 28L-26 TRS-LS2 tires was used for skidding. Logs were loaded using a John Deere 437D trailer mounted loader. A Caterpillar 650J dozer was used for building landings and maintaining haul roads.

Methods

Felling

To evaluate the performance of the feller-buncher, two felling plots were installed and located to capture a range of tree sizes. Within each plot, all trees 6 inches Diameter at breast height (Dbh) and larger were tallied. Trees less than 6 inches Dbh were considered unmerchantable but were cut by the feller-buncher to aid in accessing cut trees. Each merchantable tree was measured to the nearest 0.1-inch at Dbh and the species recorded. Total heights were measured to the nearest foot using an electronic hypsometer. Tree height measurements were sampled across all diameter classes present within each plot. Consecutive numbers were painted on two sides of each tree for identification purposes during data collection. Total individual tree volume (wood and bark) was calculated using equations from Clark et al. (1986). Total area of each plot was measured using a Garmin GPSmap 62s. A digital video camera was used to record the feller-buncher as it worked through each study plot.

Videos were analyzed using the time study software program TimerPro Professional from Applied Computer Services, Inc. Felling cycle elements observed and analyzed included move

[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.

to 1st tree, cut, move between trees, move to dump, dump, reposition head, cut unmerchantable trees, cut dead trees, delimb, align butts, push trees, and trim stumps. Production rates were determined by dividing total volume /cycle by total cycle time. No volume was included in those cycles where only unmerchantable trees or dead trees were cut, but the time was included as productive time. A complete felling cycle started with move to 1st tree and ended at the beginning of the next move to 1st tree cycle element.

Skidding

Skidder performance was evaluated using a stopwatch and recording the time required to travel from the landing to the woods (empty travel) and return to the landing (loaded travel). Elements that were timed in the woods included position and grapple, intermediate travel, and any delays observed. Trees skidded were classified by product type as either sawtimber or non-sawtimber. Merchantable volumes (cubic feet per tree) by product type were estimated from cruise information provided by the District. A mean weighted density (Miles and Smith, 2009) based on total removals and species as specified in the cruise was calculated for each product type to convert cubic feet to green tons. Travel distances were recorded using a Garmin GPSmap 62s.

Machine Costs

A machine rate analysis was used to determine hourly cost and unit cost for the feller-buncher and skidder (Miyata, 1980). Assumptions as outlined by Brinker et al. (2002) were applied to each machine (Table 1). Current purchase prices were estimated by inflating 2002 prices to current year prices. An off-road diesel price was determined from an average price of diesel fuel in the area and subtracting the tax rate of $0.20/gallon for the state of Virginia (Virginia Dept. of Motor Vehicles, 2018).

Table 1. Assumptions used for machine rate calculations.

Variable	JD 843H Feller-Buncher	JD 748H Grapple Skidder
Purchase price (PP, US$)[1]	309,000	327,000
Net Horsepower (hp)	170	169
Life (years)	5	5
Salvage value (% of PP)	20	25
Utilization rate (%)	65	60
Repair & maint. (% of annual depreciation)	100	90
Interest rate (%)	10	10
Insurance rate (% of average yearly investment)	4.5	5.0
Fuel consumption rate (gal/hp-hr)	0.026	0.028
Fuel cost ($/gal)	2.62	2.62
Lube & oil (% of fuel cost)	36.80	36.80
Operator wage & benefit rate ($15/hr plus 30%)	19.50	19.50
Scheduled machine hours (hrs/yr)	2000	2000

[1]Prices adjusted to current year dollars.

Results

Felling

A total of 92 felling cycles were collected from Plot 1 (0.62 acres) while 116 cycles were collected from Plot 2 (0.99 acres). Inventory data from the felling plots revealed Plot 1 had a mean density of 168.6 trees per acre (TPA) and contained 147.5 gt/acre. The maximum tree size observed was in the 16-inch diameter class. Plot 2 had a mean density of 138.0 TPA and contained 236 gt/acre. The maximum tree size observed was in the 22-inch diameter class. Stand density and stocking levels for both plots are displayed in Figures 1 and 2.

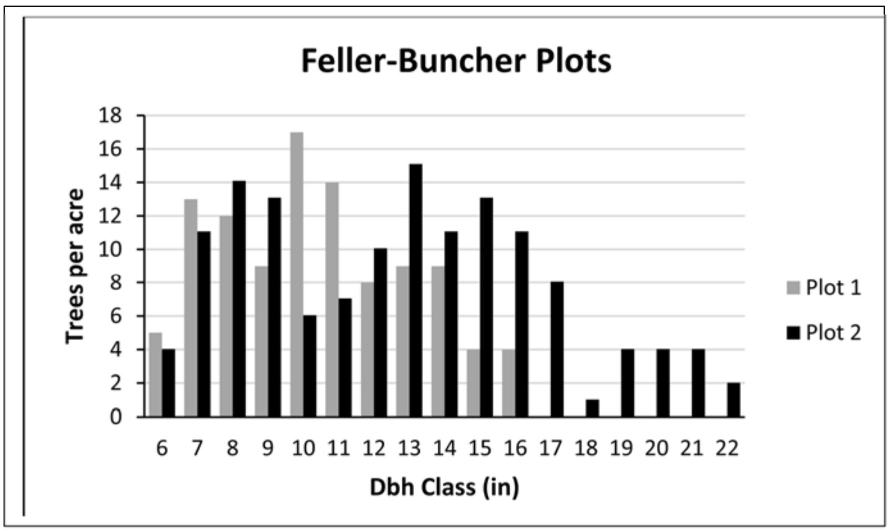

Figure 1. Diameter distributions in felling plots.

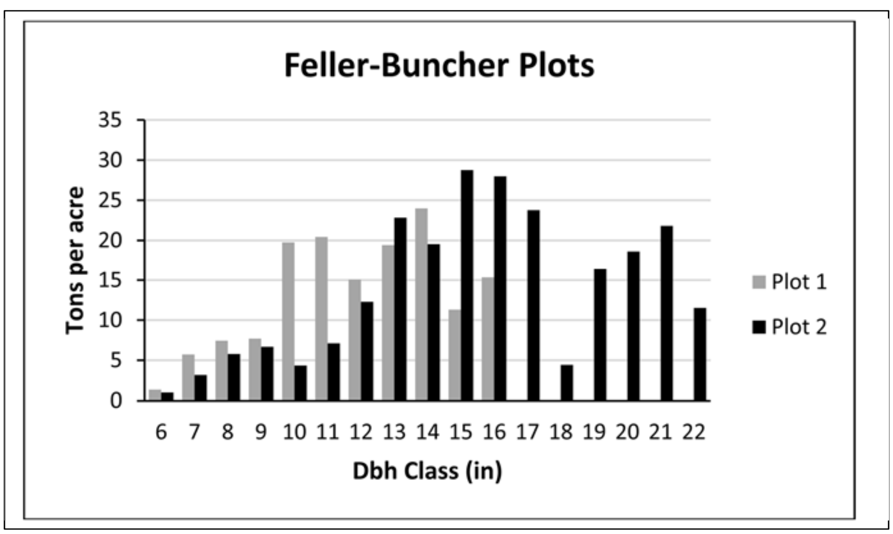

Figure 2. Stocking levels by diameter class.

Elemental cycle time was analyzed on a per plot basis due to the variability between the plots (Table 2). For Plot 1, delimbing accounted for the majority of total cycle time (43%) followed by moving to 1st tree (26%). For Plot 2, moving to 1st tree accounted for the majority of total cycle time (34%) followed by delimbing (28%). Mean delimbing time between the two plots (86 seconds for Plot 1 and 137 seconds for Plot 2) was significantly different ($\alpha = 0.05$) as indicated by Duncan's Multiple Range Test (SAS, 1988). The feller-buncher spent less time moving to 1st tree in Plot 1 than in Plot 2 ($\alpha = 0.05$). This difference was due to the larger tree sizes in Plot 2. These larger trees required multiple cuts to become completely severed. However, the operator did not complete all cuts during one visit to a tree that required multiple cuts, but made the first cut and then traveled to other trees to cut. This method of operation required the operator to make multiple visits to the same tree, which resulted in more move to 1st tree element observations and more total felling time performed in this element. Percent of total cycle time for each element is displayed in Figures 3 and 4.

When the feller-buncher moved to dump (7-8% of total cycle time), it did not result in bunching. Trees were generally felled with the tops oriented downhill. After several trees were dumped, the feller-buncher would straddle individual stems with the sawhead tilted forward to delimb the branches.

The cut unmerchantable trees cycle element accounted for over 25% of the felling time in each of the plots. This cycle element included those complete cycles that contained only unmerchantable stems and portions of those cycles that included both merchantable and unmerchantable trees. Fifteen cycles (7 in Plot 1 and 8 in Plot 2) felled only unmerchantable trees. All elements of these 15 cycles, from move to 1st tree to dump, were assigned to the cut unmerchantable trees cycle element. For cycles that included both unmerchantalbe and merchantable stems (10 cycles in each plot), the cut unmerchantable stems element only includes those elements that are associated with move between trees and cut.

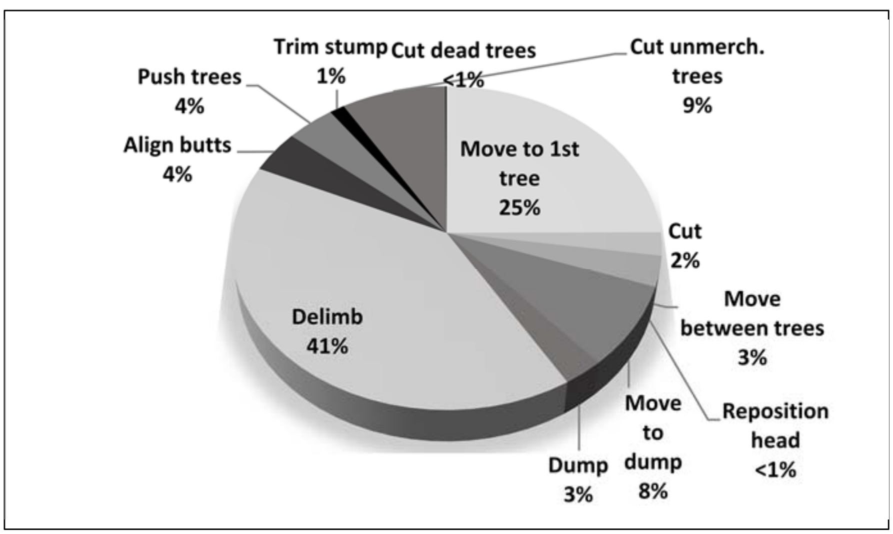

Figure 3. Percent of total cycle time for the feller-buncher in Plot 1.

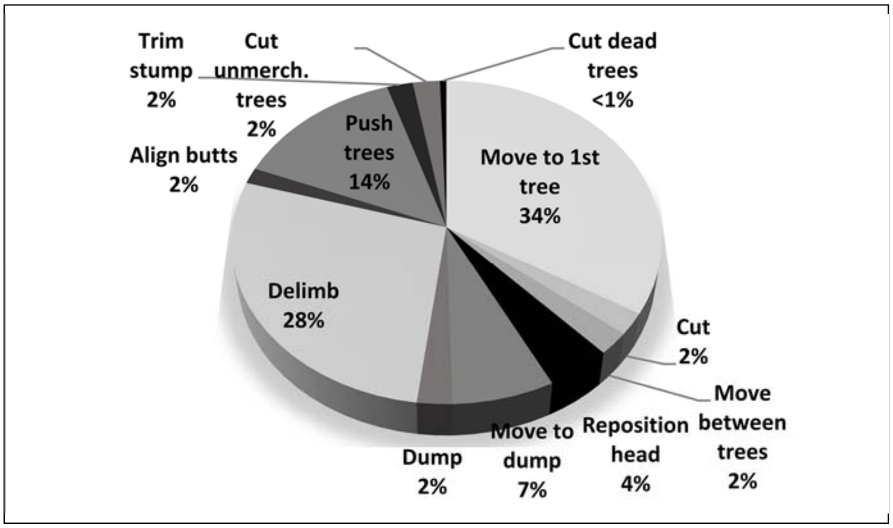

Figure 4. Percent of total cycle time for the feller-buncher in Plot 2.

Table 2. Time study summary for the feller-buncher.

Variable	Plot 1	Plot 2
No. of observations	92	116
Dbh (in)	10.9a[1]	13.1b
Merchantable trees/cycle	1.17a	1.09a
Cuts/tree	1.33a	1.64b
Tons/cycle	1.04a	1.85b
Total cycle time (sec)	122.5a	163.1b
Productivity (tons/productive machine hour)	43.7a	60.1b

[1]Values in a row with the same letter are not significantly different ($\alpha = 0.05$).

Skidding

A total of 30 observations were collected for the grapple skidder while working in the felling plots. Duncan's Multiple Range Test showed there was no significant difference in production rates between the two plots, therefore, plot data were combined for the skidder. Percent of total cycle time for each element is displayed in Figure 5. Travel time (empty and loaded) accounted for 66% of total cycle time at a mean total distance of 753 ft. After trees were skidded to the landing and ungrappled, the operator would push trees with the blade into a pile (pile trees) to consolidate them near the loader. This element occurred 57% of the time and accounted for 7% of the total cycle time. A summary of time study data is shown in Table 3.

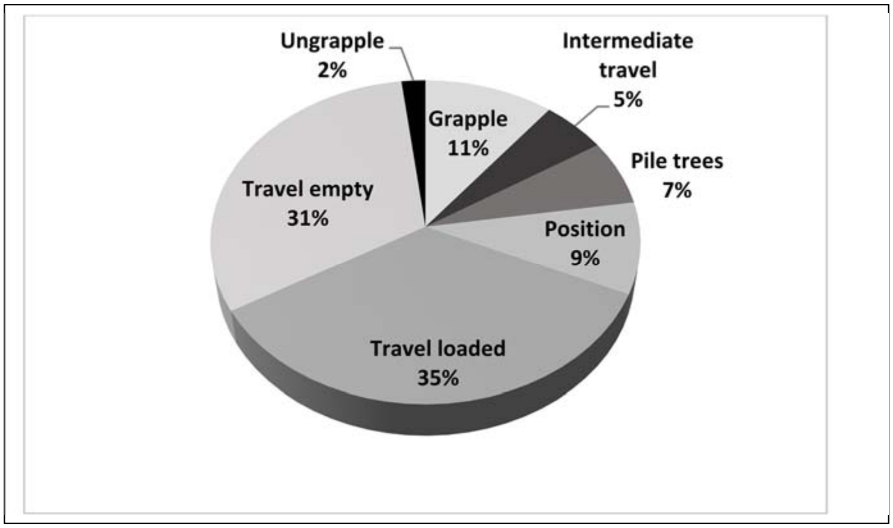

Figure 5. Percent of total cycle time for the grapple skidder.

Table 3. Time study summary for the skidder.

Variable	Mean
No. of observations	30
Trees/cycle	6.4
Tons/cycle	4.95
Total time (min/cycle)	8.33
Total distance (ft)	753
Productivity (tons/PMH)	37.6

Machine Costs

Felling cost was determined to be $150.44/PMH using the assumptions in Table 1. The production rate for the feller-buncher in Plot 1 was 43.7 tons/PMH, which resulted in a cost of $3.44/ton. For Plot 2, the feller-buncher had a production rate of 60.1 tons/PMH, or $2.50/ton. The feller-buncher performed some activities that negatively impacted its productivity, one of which was delimbing. This activity accounted for 41% of total cycle time in Plot 1 and 28% of total cycle time for Plot 2. The traditional method of in-woods delimbing of hardwoods, manual delimbing with chainsaws, could be employed which would allow the feller-buncher to devote more time to felling trees. However, placing a person on the ground to delimb may result in additional cost in terms of insurance and workers' compensation.

Skidding cost was estimated at $158.63/PMH. The overall production rate for the skidder was 37.6 tons/PMH, which resulted in a cost of $4.22/ton.

Analysis indicated that one feller-buncher and one skidder were balanced for the operation. The limiting machine in terms of productivity was the skidder at 22.6 tons/SMH (Table 4).

Table 4. Cost summary for the feller-buncher and skidder.

Machine	No. of Machines	tons /SMH	System tons/SMH	System $/SMH	System $/ton
John Deere 843G Feller-Buncher	1	33.7	22.6	180.44	8.00
John Deere 748H Grapple Skidder	1	22.6			

Conclusions

A shelterwood with reserves silvicultural prescription was implemented in a 16-acre hardwood stand on the George Washington and Jefferson National Forests. A traditional ground-based system consisting of a rubber-tired drive-to-tree feller-buncher equipped with a disk saw and a grapple skidder were used to harvest the stand. The feller-buncher averaged 43.7 tons/PMH in Plot 1 where the average Dbh was 10.9 inches. In Plot 2, the feller-buncher averaged 60.1 tons/PMH where the average Dbh was 13.1 inches. The grapple skidder averaged 37.6 tons/PMH with 6.4 trees/cycle.

The feller-buncher and skidder production rates were similar, which made using one of each machine the most cost effective and balanced system. Cost from woods to landing was estimated to be $180/SMH or $8.00/ton.

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