United States
Department of
Agriculture

Forest
Service

**Northern
Research Station**

**General Technical
Report NRS-69**

MECHANIZED SYSTEMS FOR HARVESTING EASTERN HARDWOODS

Chris B. LeDoux

Abstract

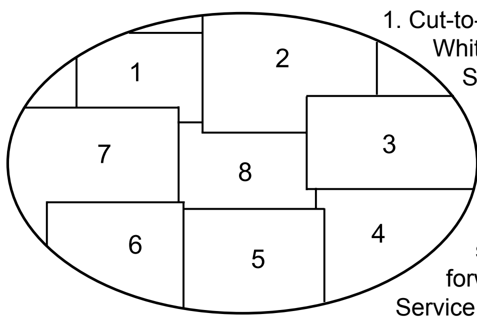
In the central Appalachian region, hardwoods traditionally have been harvested by chainsaw felling with trees and logs extracted from the forest to landings by rubber-tired skidders, bulldozers, and crawler tractors. In recent years, mechanized systems that include feller bunchers and cut-to-length (CTL) processors coupled with forwarders and clambunk and grapple skidders have been used increasingly to harvest Eastern hardwoods. Feller bunchers fell trees and pile stems or logs in bunches. CTL processors fell trees and delimb them, buck the stems into logs, and pile them in presorted bunches. Wood piles and bunches are transported to landings by a clambunk or grapple skidder or a forwarder. These system combinations for processing and transporting essentially eliminate the need for woods workers on the ground, a major advantage from a production and safety standpoint, and greatly reduce adverse effects on the site compared to chainsaw felling and conventional skidding. Feller buncher and CTL systems are reviewed, results of environmental impact studies are presented, and cost equations for a range of operating conditions in Eastern hardwoods are provided.

The Author

CHRIS B. LEDOUX is a research industrial engineer with the U.S. Forest Service's Northern Research Station at Morgantown, West Virginia.

Manuscript received for publication December 2009

Cover Photo



1. Cut-to-length processor (photo courtesy of Andrew Whitman, Manomet Center for Conservation Sciences); 2. Crawler dozer (photo courtesy of Caterpillar); 3. Rubber tired skidder (photo courtesy of Tigercat); 4. Track-mounted clambunk skidder (photo courtesy of Andrew Whitman, Manomet Center for Conservation Sciences); 5. Clambunk skidder (photo courtesy of Tigercat); 6. Small forwarder (photo by Neil Huyler, U.S. Forest Service, retired); 7. Track-mounted feller buncher processor (photo courtesy of John Umstead, West Virginia University); 8. Cut-to-length processor (photo by Kurt Gottschalk, U.S. Forest Service).

Published by:

USDA FOREST SERVICE
11 CAMPUS BLVD., SUITE 200
NEWTOWN SQUARE, PA 19073-3294

September 2010

For additional copies:

USDA Forest Service
Publications Distribution
359 Main Road
Delaware, OH 43015-8640
Fax: 740-368-0152

Visit our homepage at: **http://www.nrs.fs.fed.us/**

CONTENTS

INTRODUCTION

Mechanized systems that include feller bunchers and cut-to-length (CTL) processors coupled with clambunk and grapple skidders are used increasingly to harvest hardwoods in the Central Appalachian region (American Pulpwood Assoc. 1997, Long 2003). The trend toward increased mechanization is attributed to the need to address concerns related to productivity, safety, environmental, and cost concerns (LeDoux and Huyler 2001a, Wester and Eliasson 2003).

Daily production using machines to fell, delimb, cut to length, and bunch trees can exceed that achieved by crews of hand fallers. A study by the Forest Engineering Institute of Canada showed that a mechanized system (feller buncher/stroke delimber/grapple skidder) can produce a higher volume per hour at a lower cost per unit volume than a conventional system (hand faller/hand delimber/line skidder) (Phillips 1997). A study of CTL harvesting by LeDoux (2002) in New Hampshire, Vermont, and Maine showed that a substantial amount of the forest inventory would be profitable using this system.

Mechanization also helps ensure a year-round supply of timber to mills because the machines cited can operate in poor weather (American Pulpwood Assoc. 1997). Some mills even help loggers acquire the necessary equipment. Using a feller buncher or CTL processor increases safety because the direction in which a tree falls can be controlled and the severed tree can be held securely and transported to the desired location, thus protecting operators from falling debris (Bell 2002, Shaffer and Milburn 1999). These machines also position felled trees such that hand delimbing and bucking is safer. Feller bunchers and CTL processors vary by type and size (Blinn et al. 1986; Greene and McNeel 1987, 1991) to accommodate different forest types, composition of primary tree species, topography, e.g., steep slopes and swamps (McDonald et al. 2000, Long 2003), site conditions, e.g., pine plantations (Aedo-Ortiz et al. 1997, McDonald et al. 2000) or products, e.g., pulpwood (Green et al. 1987, Greene and McNeel 1991). In this report we review feller buncher and CTL harvesting systems, present results of safety and environmental impact studies, and provide equations that can be used to estimate costs for a wide range of operating conditions in Eastern hardwoods.

FELLER BUNCHER AND CTL SYSTEMS

In harvesting the hardwood resource, CTL processors and feller bunchers (Figs. 1 and 2) can be fitted with different felling, delimbing, and debarking heads (Huyler and LeDoux 1996, 1997, 1998, 1999; LeDoux and Huyler 2000, 2001a,b), and generally are coupled with rubber-tired skidders with grapples (Fig. 3), dozers and crawlers with grapples (Fig. 4), clambunk skidders (Fig. 5), or forwarders (Fig. 6) to transport trees or logs to landings or central-processing areas. Such systems are best applied on gentle to moderately steep terrain. The CTL processor fells, delimbs, bucks a tree into logs, and debarks the stem. It can sort the wood as desired and build bunches according to the capacity of the machine used for skidding. Besides felling a tree, the feller buncher can accumulate multiple stems in the head, sort wood as required, and build bunches for transport by the skidding machine.

The machines that we studied were track-mounted with a self-leveling cab, and equipped with a boom that can extend the felling head a substantial distance beyond the machine itself. Track mounted machines are best suited for steeper, uneven and cut up terrain with ravines and rock outcrops. Such mechanized systems generally are ergonomic and highly maneuverable, and minimize soil disturbance and compaction and residual stand damage (LeDoux and Huyler 2001b, Wang et al. 2005). The CTL harvester can use limbs from the delimbing process to form a mat to travel on, further mitigating soil disturbance and compaction. A clambunk skidder is commonly used in association with CTL processors and feller bunchers (Fig. 5). It can be mounted on rubber tires or tracks and are equipped with a bunk and large grapple or clam attached to the back of the skidder. This machine generally is used to move bunched logs to a landing or central-processing area, and can be equipped with a boom with grapple attachment that can be used to build loads, sort logs, build decks, or maintain landings.

Although large volumes of wood can be moved in a short time and logs can be transported long distances, major trails used to travel to and from the landing and log-processing areas can be severely impacted. The maneuverability of a clambunk skidder is limited because of its size. One end of the log rests on the bunk and is held there while the other end is dragged along the ground.

Figure 1.—Large, self-leveling track-mounted, cut-to-length processor with felling and delimbing head (photo courtesy of Andrew Whitman, Manomet Center for Conservation Sciences).

Figure 2.—Large, self-leveling, track-mounted feller buncher with accumulating felling head (photo courtesy of John Umstead, West Virginia University).

Figure 3.—Rubber-tired skidder equipped with grapple and high-flotation tires (photo courtesy of Tigercat).

Figure 4.—Medium-size, track-mounted crawler dozer with grapple in back and blade in front skidding a turn of logs (photo courtesy of Caterpillar).

Figure 5.—Track-mounted clambunk skidder with boom attachment working on log deck (photo courtesy of Andrew Whitman, Manomet Center for Conservation Sciences).

Figure 6.—Small forwarder with rubber tires and chains in the front, tracks in the rear, boom, blade in the front, unloading and sorting at the landing (photo by Neil Huyler, U.S. Forest Service, retired).

A forwarder generally is used to transport logs and trees in association with a feller buncher and CTL processor (Fig. 6) when logs and trees have been prebunched in the woods. Forwarders are produced in various sizes and can handle a range of payloads. They are typically configured with rubber tires and chains or a track-based carrier and a boom with grapple attachment for self-loading and unloading. Because of the increased volume it can carry, the forwarder is a good alternative to a rubber-tired or dozer skidder when skid distances are long and the terrain is gentle to moderately steep (Erickson 1992).

Forwarders can sort logs or trees by species or product type while loading in the woods or at the landing. They are slower than rubber-tired skidders but they can transport larger payloads than skidders and dozers. Wood is carried on bunks and not dragged along the ground. Overall impact on the site is relatively light, though soil disturbance and compaction can be significant on the most heavily traveled skid roads and trails.

Rubber-tired skidders (Fig. 3) or dozers and crawlers (Fig. 4) equipped with grapples transport bunched logs to landings or central-processing areas. The use of grapples is best matched with prebunched wood, i.e., bunched by the feller or CTL processor. Logs generally are dragged along the ground. As with forwarders, skidders and crawlers are best suited to gentle or moderate terrain and can increase soil disturbance and compaction on the most heavily used skid trails.

Seventy percent of current harvesting systems require the use of chainsaws to fell, buck, limb, and top trees[1]. They also are used to bump knots and clean and dress-up logs at the landing before hauling to processing plants. Unfortunately, the use of chainsaws in the woods has resulted in serious and even fatal injuries. In fact, the chainsaw is the largest contributor to logging accidents and injuries, according to the Occupational Safety and Health Administration (www.osha.gov). Where they are used, mechanized harvesting systems have dramatically reduced numerous risks associated with chainsaws by eliminating the need for chainsaw operators and other woods workers (Bell 2002, Shaffer and Milburn 1999).

[1] LeDoux, C.B. Harvesting systems for eastern hardwoods. Unpublished report on file at the Northern Research Station, 180 Canfield Street, Morgantown, WV 26505.

SITE IMPACTS

Despite the diligent use of “best management practices,” some harvesting systems create a certain amount of stand damage, including soil disturbance and compaction. Excessive disturbance along with severe rutting on moderate to steep slopes can be long-lasting and result in erosion and sedimentation. The use of mechanized harvesting systems can greatly minimize adverse impacts on residual stand because trees can be felled directionally, they are not dragged through the stand, and stems marked for cutting can be easily removed from within clumps or tangles with minimal damage to residual trees (LeDoux and Huyler 2001b). Delimbing occurs in front of the machines, so limbs and slash can be used as a mat upon which a machine can travel. As a result, the use of track-mounted feller bunchers and CTL processors cause less soil disturbance and compaction than traditional skidder-based systems. Although rubber tires are available for use on gentle terrain (McDonald et al. 2000), track-mounted machines operate primarily on moderate to steep slopes (Huyler and LeDoux 1996, 1997, 1998, 1999; LeDoux and Huyler 2000, 2001a,b; Long 2003; Wang et al. 2005).

These machines simply drive themselves from tree to tree where conventional logging systems would require skid trails to be built or logs to be winched through the stand to form a load. Studies have shown that mechanized, track-mounted systems resulted in less soil disturbance and compaction than conventional systems when operating in similar conditions (Wang and LeDoux 2005, Wang et al. 2007). The most heavily used skid trails should incur high levels of soil disturbance and soil compaction, particularly where multiple passes by loaded and unloaded machines are required in extracting trees and logs from the woods to landings (Wang et al. 2006).

ESTIMATING PRODUCTION AND COST

We developed equations[2] for estimating the cost of feller bunching, CTL harvesting, and forwarding based on results from time and motion studies and simulations. These equations were incorporated into the ECOST computer program. ECOST was developed by the author to estimate stump-to-mill costs related to logging Eastern hardwoods via cable, conventional ground-based skidding, mechanized harvesting systems, and small tractors. The program is available for downloading at: http://www.nrs.fs.fed.us/tools/software.

Cost equations are included for a Valmet 524 forwarder (Table 1), Timbco 425 and 445 feller bunchers (Table 2), Timbco T425 and JD 988 CTL harvesters (Table 3), and Timberjack 460 grapple skidder (Table 4). Note that cost estimates based on variables outside the limits listed in Tables 1-4 likely will be unreliable.

Suppose a logger wants cost estimates using a Timbco 425 feller buncher to cut timber and a Valmet 524 forwarder to transport wood to a landing. The travel distance for the forwarder is 800 feet (SYD)[3], the average diameter of the trees to be cut is 12 inches (DBH)[3], and the volume to be removed per acre is 2,000 cubic feet (VOAC)[3]. For the feller buncher, the equation is:

$$\$/ft^3 = \frac{119.17}{(1087.1828 + 38.0275 * TreeVol + 0.1865 * VOAC)}$$

$$TreeVol = -32.0924 + 5.529 * 12 = 34.25$$
$$VOAC = 2000$$

$$\$/ft^3 = \frac{119.17}{(1087.1828 + 38.0275 * 34.25 + 0.1865 * 2000)}$$

$$\$/ft^3 = .0431\ (\sim.04)$$

---

[2] LeDoux, C.B.; Wang, J. Development of general production and cost equations for feller bunchers in central Appalachian hardwoods. In preparation.

[3] Acronyms are defined in Tables 1 and 2.

Table 1.—Simulated delay-free cost equation for forwarder[a].

Forwarder	Equation	Variable limit
Valmet 524	$/ft³ = 110 / (408.9482 + 0.00241 * TP * SYD – 0.0006 * SYD²)	TP: Constant at 400 SYD : 50 to 1627.4

[a]TP = turn payload (ft³) = 400; SYD = slope travel distance (ft).

Table 2.—Simulated delay-free felling and bunching cost equations for two feller bunchers[a].

Feller buncher	Equation	Variable limit
Timbco 425	$/ft³ = 119.17 / (1087.1828 + 38.0275 * TreeVol + 0.1865 * VOAC)	DBH: 4 to 30 VOAC: 334 to 10600
Timbco 445	$/ft³ = 138.33 / (633.3737 + 63.9942 * TreeVol + 352162.052 * (1 / VOAC))	DBH: 4 to 30 VOAC: 334 to 10600

[a] TreeVol = tree volume (ft³); DBH = average diameter breast height (inches); VOAC = volume cut per acre (ft³). NOTE: If DBH = 4, TreeVol = 1.76; if DBH = 5, TreeVol = 2.37; if DBH = 6, TreeVol = 4.72; otherwise TreeVol = –32.0924 + 5.529*DBH.

Table 3.—Simulated delay-free cut-to-length cost equations for two CTL harvesters[a].

CTL harvester	Equation	Variable limit
Timbco T425	$/ft³ = 146.7 / (7830 + 270.77 * DBH – 1.88 * DBH * HT – 642.51 * DC + 11.44 * DC²)	DBH: 5 to 20 DC: Constant at 22
JD 988	$/ft³ = 115.0 / (–440.25 + 201.74 * DBH – 1.85 * DBH * HT)	DBH: 5 to 14

[a]HT = total height (ft) = 34.95428248+2.672088601*DBH; DC = average ground travel distance of harvester/cycle (ft) = 22; DBH = average diameter at breast height (inches).

Table 4.—Simulated delay-free cost equation for grapple skidder[a].

Grapple skidder	Equation	Variable limit
Timberjack 460	$/ft³ = 0.65 * ((82.17 / (466.49 – (0.13*SYD) + (3.76*Pl) – (0.003*Pl²) – (0.36*BS) + (0.003*BS²))))	SYD: 400 to 1800 Pl: 50 to 250 BS: 30 to 270

[a]SYD = slope yarding distance (ft); Pl = pay load (ft³); BS = bunch size (ft³).

For the forwarder the equation is:

$$\$/ft^3 = \frac{110}{408.9482 + 0.00241 * TP * SYD - 0.0006 * SYD^2}$$

$TP = 400$
$SYD = 800$

$$\$/ft^3 = \frac{110}{408.9482 + 0.00241 * 400 * 800 - 0.0006 * 800^2}$$

$\$/ft^3 = .1382\ (\sim.14)$

Felling and extracting using both machines would cost about $0.18/ft^3, or about $17.64/cord. Be advised that these estimates are "delay free", that is, theoretical production for a given machine and stand condition with no idle time or delay. Another way to think of "delay free" estimates is that these are the production levels we observed during our time and motion studies when the respective machines were in full production mode with no delays and idle time. Although these production levels are possible, they are unlikely over the course of a longer production cycle. Thus, all estimates must be adjusted for delays and down/idle time. In this example, if we assume that the logger expects about 18 percent delay/down/idle time for both the felling and forwarding operations, our estimates of $17.64/cord would be adjusted such that $17.64/(1–.18) = 17.64/.82 = $21.51/cord. The equations also can be adjusted for various combinations of machines, sites, and delay times.

CONCLUSION

Mechanized feller buncher and CTL systems have major advantages over ground-based skidders in that they allow sustained productivity, increase safety, and reduce site impacts (Wang et al. 1998, Wang and LeDoux 2003). They can be highly productive in cold and windy weather, rain and snow, and on muddy and swampy sites (American Pulpwood Assoc. 1998). The need for chainsaws and woods workers is virtually eliminated, thus reducing safety risks and hazards. Damage to the residual stand also is reduced, and soil disturbance and compaction are minimized compared to conventional systems.

There also are disadvantages in using mechanized harvesting systems. Feller bunchers and CTL processors are expensive to purchase and maintain and present challenges when moving from site to site due to their size. They are larger and wider than conventional equipment, so moving these machines might require special permits, the use of flag vehicles, and oversize, lowboy mule trains. Also, on some roads and bridges, dismantling of some equipment may be necessary to meet safety standards and/or weight limits.

Our intent is not to promote mechanized systems but to provide information that can be used in selecting equipment for use in alternate harvesting operations. An even flow of wood year round is imperative to generate profits, meet payrolls, and purchase equipment. The use of mechanized systems that include feller bunchers and CTL processors coupled with forwarders, rubber-tired or tracked grapple skidders, or clambunk skidders can help loggers meet this objective.

LITERATURE CITED

Aedo-Ortiz, D.M.; Olsen, E.D.; Kellogg, L.D. 1997. **Simulating a harvester-forwarder softwood thinning: a software evaluation.** Forest Products Journal. 47(5): 36-41.

American Pulpwood Association. 1997. **Active cut-to-length equipment in northern New England.** Rockville, MD: American Pulpwood Association. 33 p.

American Pulpwood Association. 1998. **In-woods processing—tree characteristics that impact production.** Rockville, MD: American Pulpwood Association. 35 p.

Bell, J.L. 2002. **Changes in logging injury rates associated with use of feller bunchers in West Virginia.** Journal of Safety Research. 33(4): 463-471.

Blinn, C.R.; Sinclair, S.A.; Hassler, C.C.; Mattson, J.A. 1986. **Comparison of productivity, capital, and labor efficiency of five timber harvesting systems for northern hardwoods.** Forest Products Journal. 36(10): 63-69.

Erickson, M.D.; Hassler, C.C.; LeDoux, C.B. 1992. **Economic comparisons of haul road construction versus forwarding versus longer skid distances.** In: 1992 International American Society of Agricultural Engineers winter meeting; 1992 December 15-18; Nashville, TN. ASAE Pap. 92-7513. St. Joseph, MI: American Society of Agricultural Engineers. 17 p.

Greene, W.D.; Lanford, B.L.; Mykytka, E.F. 1987. **Stand and operating effects on feller buncher productivity in second thinnings of southern pine.** Forest Products Journal. 37(3): 27-34.

Greene, W.D.; McNeel, J.F. 1987. **Productivity, costs, and levels of butt damage with a Bell Model T feller buncher.** Forest Products Journal. 37(11/12): 70-74.

Greene, W.D.; McNeel, J.F. 1991. **Productivity and cost of sawhead feller bunchers in the South.** Forest Products Journal. 41(3): 21-26.

Huyler, N.K.; LeDoux, C.B. 1998. **Application of cut-to-length harvesting in a small suburban woodlot in Vermont.** Northern Logger. May: 26-36.

Huyler, N.K.; LeDoux, C.B. 1996. **Cut-to-length harvesting on a small woodlot in New England: a case study.** In: Joint Meeting of the Council On Forest Engineering and International Union of Forest Research Organizations: planning and implementing forest operations to achieve sustainable forests; 1996 July 29 - August 1; Marquette, MI. Gen. Tech. Rep. NC-186. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 102-108.

Huyler, N.K.; LeDoux C.B. 1997. **Logging technology for managing northern hardwoods.** In: Ball, John J.; Starnes, Lawson W., eds. Proceedings, 20th annual meeting of the Council on Forest Engineering; 1997 July 28-31; Rapid City, SD. Corvallis, OR: Council on Forest Engineering: 12-16.

Huyler, N.K.; LeDoux, C.B. 1999. **Performance of a cut-to-length harvester in a single-tree and group-selection cut.** Res. Pap. NE-711. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 6 p.

LeDoux, C.B. 2002. **Assessing the feasibility and profitability of cut-to-length harvests in Eastern hardwoods.** In: Wagner, Robert G., comp. Eastern CANUSA forest conference proceedings; 2002 October 19-20; Orono, ME. Orono, ME: University of Maine: 53 p.

LeDoux, C.B.; Huyler, N.K. 2001a. **Comparison of two cut-to-length harvesting systems operating in Eastern hardwoods.** Journal of Forest Engineering. 12(1): 53-59.

LeDoux, C.B.; Huyler, N.K. 2000. **Cost comparisons for three harvesting systems operating in Northern hardwoods.** Res. Pap. NE-715. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 4 p.

LeDoux, C.B.; Huyler, N.K. 2001b. **Light impact logging technology for achieving future desired conditions.** In: Barras, Stanley J., ed. Proceedings: national silviculture workshop; 1999 October 5-7; Kalispell, MT. RMRS-P-19. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Abstract.

Long, C. 2003. **Production and cost analysis of two harvesting systems in central Appalachia.** Morgantown, WV: West Virginia University. 80 p. M.S. thesis.

McDonald, T.P.; Rummer, R.B.; Taylor, S.E. 2000. **Automated time study of feller bunchers.** In: Proceedings, 23rd annual meeting of the Council on Forest Engineering; 2000 September 11-14; Kelowna, BC. Corvallis, OR: Council on Forest Engineering: 1-4.

Phillips, E.J. 1997. **Comparison of conventional and mechanical harvesting for the Prince Albert Model Forest.** Publ. SR-000121. Vancouver, BC: University of British Columbia, Forest Engineering Research Institute of Canada. 17 p.

Shaffer, R.M.; Milburn, J.S. 1999. **Injuries on feller buncher/grapple skidder logging operations in the southeastern United States.** Forest Products Journal. 49(7/8): 24-26.

Wang, J.; Greene, W.D.; Stokes, B.J. 1998. **Stand, harvest, and equipment interactions in simulated harvesting prescriptions.** Forest Products Journal. 48(9): 81-86.

Wang, J.; LeDoux, C.B. 2003. **Estimating and validating ground-based timber harvesting production through computer simulation.** Forest Science. 49(1): 64-76.

Wang, J.; LeDoux, C.B.; Edwards, P.; Jones, M. 2005. **Soil bulk density changes caused by mechanized harvesting: a case study in central Appalachia.** Forest Products Journal. 55(11): 37-40.

Wang, J.; LeDoux, C.; Vanderberg, M.; Li, Y. 2006. **Effects of soil compaction on residual stand growth in central Appalachian hardwood forests: a preliminary case study.** In: Proceedings, 29th annual meeting of the Council on Forest Engineering; 2006 July 30-August 2; Coeur d'Alene, ID. Corvallis, OR: Council on Forest Engineering: 333-341.

Wang, J.; LeDoux, C.B.; Edwards, P. 2007. **Changes in soil bulk density resulting from construction and conventional cable skidding using preplanned skid trails.** Northern Journal of Applied Forestry. 24(1): 5-8.

Wang, J.; LeDoux, C.B.; Li, Y. 2005. **Simulating cut-to-length harvesting operations in Appalachian hardwoods.** International Journal of Forest Engineering. 16(2): 11-27.

Wester, F.; Eliasson, L. 2003. **Productivity in final felling and thinning for a combined harvester-forwarder (Harwarder).** International Journal of Forest Engineering. 14(2): 45-50.

LeDoux, Chris B. 2010. **Mechanized systems for harvesting eastern hardwoods.** Gen. Tech. Rep. NRS-69. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 13 p.

In the central Appalachian region, hardwoods traditionally have been harvested by chainsaw felling with trees and logs extracted from the forest to landings by rubber-tired skidders, bulldozers, and crawler tractors. In recent years, mechanized systems that include feller bunchers and cut-to-length (CTL) processors coupled with forwarders and clambunk and grapple skidders have been used increasingly to harvest Eastern hardwoods. Feller bunchers fell trees and pile stems or logs in bunches. CTL processors fell trees and delimb them, buck the stems into logs, and pile them in presorted bunches. Wood piles and bunches are transported to landings by a clambunk or grapple skidder or a forwarder. These system combinations for processing and transporting essentially eliminate the need for woods workers on the ground, a major advantage from a production and safety standpoint, and greatly reduce adverse effects on the site compared to chainsaw felling and conventional skidding. Feller buncher and CTL systems are reviewed, results of environmental impact studies are presented, and cost equations for a range of operating conditions in Eastern hardwoods are provided.

KEY WORDS: Feller buncher; cut-to-length processor; forwarder; production cost; safety; site impact

www.nrs.fs.fed.us