PRODUCTIVITY AND COST ESTIMATORS FOR CONVENTIONAL GROUND-BASED SKIDDING ON STEEP TERRAIN USING PREPLANNED SKID ROADS

Michael D. Erickson
Research Associate

Curt C. Hassler
Assistant Professor and Leader of the
Appalachian Hardwood Center
Division of Forestry
West Virginia University

Chris B. LeDoux
Industrial Engineer and Project Leader
USDA Forest Service
Northeastern Forest Experiment Station
Morgantown, West Virginia

ABSTRACT

Continuous time and motion study techniques were used to develop productivity and cost estimators for the skidding component of ground-based logging systems, operating on steep terrain using preplanned skid roads. Comparisons of productivity and costs were analyzed for an overland random access skidding method, verses a skidding method utilizing a network of preplanned designated bladed skid roads. Productivity levels decreased while costs increased as the amount of winch line cable needed to be pulled to choke logs increased. Although estimated skidding costs were higher when the designated skid roads were used, the increased costs may be offset by a reduction in adverse stand and site impacts, and a reduction in the safety hazards often associated with ground-based skidding on steep terrain.

Keywords:
Ground-based harvesting, harvesting costs, productivity.

INTRODUCTION

In the eastern United States, most timber producers transport felled timber from the stump to the landing by skidding. Skidding is defined as the moving of whole trees or tree sections from one location to another by connecting a cable or chain or a grapple to one end and dragging them with a skidder or other suitable machine to a location where they can be loaded onto trucks for transport to the mill (Matthes and Watson, 1981). Rubber-tired skidders with their advantages of cost, flexibility, and modest skill requirements are currently the most economical means of removing timber from level to moderately steep terrain, and will likely remain the method of choice from an operational standpoint (Stuart and Carr, 1990).

Increased environmental concerns coupled with increased harvesting costs have renewed interest in the impacts of ground-based harvesting systems on steep terrain. Harvesting impacts include such things as erosion risk, soil and site disturbance, residual stand damage, and unfavorable aesthetics. When ground-based systems are used, these adverse impacts become increasingly severe as slopes become steeper and logging difficulty increases.

Traditional skidding practices typically involve a random entry/exit overland skidding method. The greatest single advantage of overland skidding is its simplicity. The method requires little if any preplanning since the skidder operator simply travels whatever random route he chooses to reach and skid timber to the landing. Disadvantages with the method arise when slopes become moderately steep (30-40%) and begin to limit the mobility and efficiency of rubber-tired skidders, at which time the potential for adversely impacting the site increases (Sloan, 1990). When slopes increase to the point where skidding in an overland fashion becomes too hazardous, alternative methods must be used.

An alternative skidding method that can be used on steep slopes is one which utilizes a system of designated preplanned bladed skid roads. When using designated roads the operator travels the constructed trails to points where timber can be choked by pulling winch line to the felled trees while the skidder remains on the trail. Skid road spacing is crucial as it determines the cable pull distances necessary in the log choking process, which can have a major impact on system productivity. Advantages with this type of skidding include: reduced damage to residual trees since the machine is not operating within the stand; a reduction in total forest floor area disturbed; reduced soil compaction within the stand; better control over drainage and sensitive area crossings; and increased safety since the operator is not required to negotiate steep side slopes which can increase the hazard of machine rollover. Disadvantages include skid road construction and maintenance costs, and reduced productivity due to the additional time required to pull cable from the skid roads to the felled timber to be choked. Bladed skid roads have the potential of being a major source of erosion and adverse aesthetics, although these can be alleviated through careful pre-harvest road planning and layout, and post-harvest use of proper best management practices for skid road closure, including installation of water bars and other erosion control structures.

There is currently little information available for assessing the productivity and costs of steep slope skidding with conventional ground-based equipment. Such information would be useful in preparing National Forest timber sales, private commercial sales, and could be used by loggers in determining operating costs. The information may also be useful in comparing the productivity and costs associated with ground-based harvesting systems versus those of traditional steep slope cable operations (Fairweather, 1991, Fight *et al*, 1984, LeDoux and Baumgras, 1990). A more complete understanding of operating ground-based systems on steep terrain using preplanned skid roads may also help to capitalize on an existing work force that is familiar with the method, while avoiding the expensive retraining and layout required in cable yarding systems.

This paper presents the results of an investigation undertaken in part to compare productivity and costs for ground-based skidding on steep terrain using random entry/exit overland skidding from stump to landing, versus skidding on a system of preplanned bladed skid roads. The discussion and results reported will focus on an analysis comparing system productivity and costs as influenced by the variable degrees of winch line pulling necessary to skid felled timber in a commercial thinning operation. These comparisons will help to explain the magnitude of the cost differentials between the random access overland skidding method where the operator generally positions the skidder as close to the felled timber as possible to minimize the length of line to be pulled in the choking process, versus the method used in this study where the skidders remained on the designated skid roads and cable was pulled to the felled timber.

STUDY AREA

Data for the study was collected from a commercial logging operation on the West Virginia University Experimental Forest, Preston County, West Virginia. The harvested area was approximately 30 acres in size. Terrain varied with slopes ranging from moderately steep to steep slopes of 20 to 40 percent with varying degrees of rock outcropping and shelf rock. Terrain characteristics found on the study area are common to Appalachia, extending the usefulness of the study results to other harvesting operations in the region.

Initial stand characteristics consisted of mixed Appalachian hardwoods averaging 84 square feet of basal area per acre and 10,632 board feet per acre in trees 12 inches DBH and larger. Average stand diameter was 16.5 inches in trees 12 inches and larger. Species composition included white oak, red oak, chestnut oak, scarlet oak, soft maple and yellow-poplar along with a few other species of lesser importance (Table 1).

Marking of the timber to be harvested in the thinning was done following recommendations based on the initial timber cruise. Average diameter of marked timber was 19.3 inches DBH, ranging from 12 to 40 inches, with an average of 45.3 ft^2 of basal area per acre marked for harvest. Total marked volume was estimated at 166,397 board feet, or 5547 board feet per acre (Table 1).

METHODS

Skid Road Layout

Following the timber mark, a single centrally located landing and a network of skid roads spaced 150 to 200 feet apart were flagged in, center staked, and surveyed for bearing, distance, slopes, and side slopes. The skid roads, consisting of two main and 8 variable length spurs totaling 7577 feet in length, were constructed with a dozer prior to logging. Skid roads were located to take advantage of natural terrain features, while avoiding sensitive areas as much as possible. Slopes were kept under 15 to 20 percent whenever possible. By maintaining the narrow spacing between skid roads, it was intended that all skidding activities be limited to the roads, which should minimize the adverse soil and site disturbances, while keeping the winch line pull distances to a tolerable and cost effective level in the log choking process.

Table 1. Initial conditions and marking summary for study unit.[a]

Trees/Acre initial	Trees/Acre marked	BA/Acre (ft^2) initial	BA/Acre (ft^2) marked	Vol./Acre[b] initial	Vol./Acre[b] marked	Mean DBH initial	Mean DBH marked
56	22	84.1	45.3	10632	5547	16.5	19.6

[a] Includes only trees 12-in dbh and greater.
[b] Board feet International 1/4-in rule.

Skidding

Felling and skidding of the marked timber was done in the early spring of 1990. Trees were chain saw felled and skidded tree-length to the landing where they were either decked or loaded directly onto trucks. Although three machines were used in the operation, the analysis and discussion reported here will focus only on a John Deere 440C[1] cable skidder in order to simplify discussion. This skidder was the primary machine used in the harvest operation and skidded nearly 65 percent of the total volume removed in the thinning.

Persons stationed both in the woods and at the landing recorded continuous time and motion data for all skidding elements, both productive and nonproductive, with electronic stopwatches. Additional turn parameters including maximum skid slope distance, number of trees skidded per turn, winch line pull distance, pull slope, and several other variables were also recorded and used in the productivity and cost analysis.

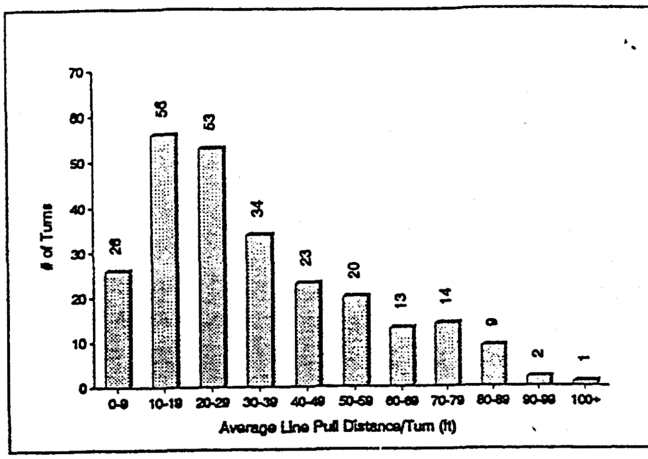

Figure 1. Actual total line pull distances per turn for 28.2 skid cycles, mean pull distance = 34 feet.

RESULTS

Cycle Time Model

Forest engineers responsible for making estimates of ground-based skidding productivity have commonly used techniques based on analysis of time and motion data (Olsen and Gibbons, 1983). Multiple regression techniques were used to develop a regression model which would estimate an average productive cycle time as a function of the skidding parameters recorded during the time study. The model was developed using data from 282 skid cycles containing complete and valid data records for the JD440C skidder. Significant variables in the regression equation included skid distance, turn volume, number of trees per turn, amount of winch line pulled, whether or not an operator sets his own chokers, and a function of the amount of adverse slope encountered during a skid. Average values from the 282 turns used to develop the model for one way skid distance and turn volume were 833 feet and 81.3 ft^3, respectively. Frequency distributions for total length of winch line cable pulled per turn and line pulls by slope class (referenced from the skidder to the felled tree) for the 282 turns are given in Figures 1 and 2.

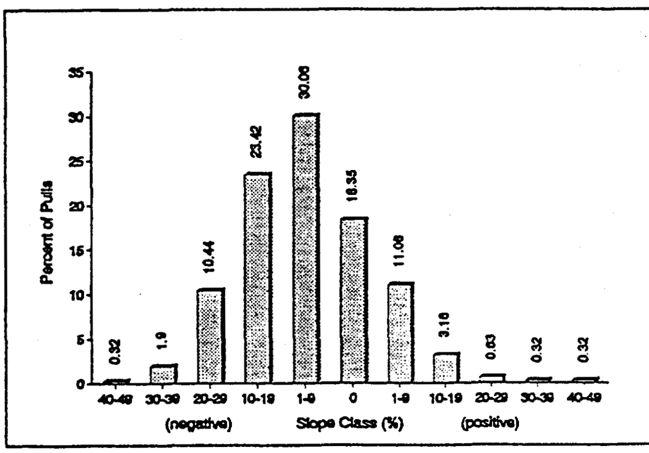

Figure 2. Proportional distribution of pulls by slope class (referenced from skidder to felled tree) for 28.2 skid cycles.

Preplanned Roads vs Random Access Skidding

The regression model was used to perform a sensitivity analysis based on differing levels of average line pull distance per turn. By varying the total line pull distance while keeping all other variables constant, the influence of this single parameter on skidding productivity and costs could be evaluated.

In an overland random access skidding method one can assume that total line pull distances will average out to negligible levels, since the operator will generally position the skidder as close to the felled timber as possible before choking. In the discussion we will assume an average pull distance of zero feet for the overland skidding method.

[1] The use of trade, firm, or corporation names in this paper is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

When using a designated skid trail system to skid timber, line pull distances will average out to higher values which will vary depending on skid road spacing and the amount of directional felling utilized. For comparison purposes a range of average line pull distances from 0 to 70 feet will be used, which are well within the range of data used to develop the regression model.

Productivity. Machine productivity levels were based on the actual 295 turns that were required for the JD440C to skid 23814 cubic feet of timber, for an average volume of 80.7 ft^3 per turn. Using this average turn volume with appropriate total line pull distances, along with mean values for the other skidding parameters in the regression model yields an estimate of average productive cycle time. Multiplying the estimated cycle time by the total number of turns gives the number of productive hours the skidder was used in the harvest operation for the average total line pull distance selected. Hourly machine productivity for the different levels of line pulling were then calculated by dividing the total volume skidded by the estimated number of productive skidding hours for each level of line pulling.

Under the overland method of skidding, where a total line pull distance of zero feet is assumed, productivity is estimated at 413 cubic feet of wood skidded per productive machine hour. This value can be used as a baseline figure for comparisons of productivity when different levels of total line pull distance are used.

Under the preplanned designated road skidding method, productivity decreases as line pull distance increases. For example, when an average line pull distance of 70 feet per turn is used in the model, productivity is estimated at 339 cubic feet of wood skidded per productive machine hour. With an average line pull distance of 70 feet per turn, productivity is reduced by 17.9 percent as compared to the overland skidding method. A graphical representation of productivity levels per productive machine hour for incremental line pull distances of 10 feet is included in Figure 3.

Skidding Costs. A machine rate calculation method was used to estimate equipment costs for skidding (Matthews, 1942, Miyata, 1980, Burgess and Cubbage, 1990). Published rates and cost factors (Anonymous, 1981, Brinker *et al* 1989, Miyata, 1980, Werblow and Cubbage, 1986) altered to fit the needs of this study where necessary, were used to determine hourly machine rates, both fixed and operating. Based on these calculations, fixed costs per scheduled machine hour were estimated to be $7.35, while operating costs per productive machine hour, exclusive of labor, were estimated at $8.56 for the JD440C skidder.

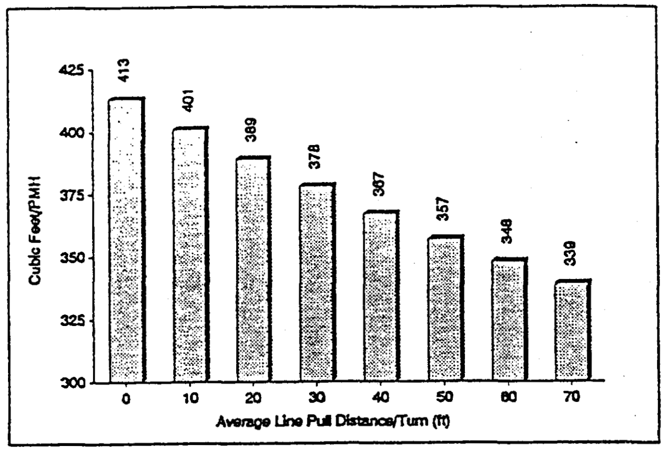

Figure 3. Estimated skidding productivity per productive machine hour by variable average total line pull distances per turn.

Labor rates were based on a machine operator, and 50 percent utilization of a choker setter. In addition to a base wage, labor rates included employer contributions for Workmen's Compensation, Social Security, Unemployment Insurance, and employee benefits and totaled $13.91 per scheduled machine hour. All costs reported in the following discussion will include labor.

A unit production cost analysis similar to the one presented by Miyata and Steinhilb (1981), was used to calculate total skidding costs under a range of average total line pull distances. Total skidding costs for the tract increased by $60.81 for each additional 10 foot increment of average line pull distance per turn. Based on the total volume skidded by the JD440C skidder, total skidding cost for the tract ranged from a low of $1925.72 when a line pull distance per turn of zero feet was assumed, to a high of $2351.36 when a line pull distance per turn of 70 feet was assumed. A graphical representation of total skidding costs for incremental line pull distances of 10 feet is included in Figure 4.

In addition to the increased costs of skidding due to pulling cable when designated skid trails are used, the cost of skid road construction and maintenance must also be included to get reliable estimates of total skidding costs. The cost to blade in and maintain skid roads will vary depending on soil and terrain characteristics, as well as the size of dozer used for construction.

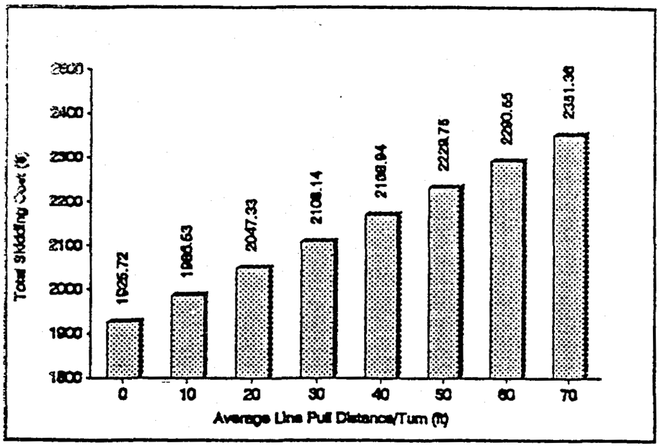

Figure 4. Estimated total skidding costs for skidding 23814 ft^3 of timber by variable average total line pull distances per turn.

CONCLUSION

Productivity and cost estimators for two ground-based skidding methods are provided which may be useful for a variety of applications. These estimators include costs for the skidding component of a harvest operation, the component that is traditionally the weak link and least productive function in ground-based harvesting (Hassler *et al*, 1983, Lawrence and Dyson, 1967). By using the productive cycle time model developed from the time and motion data, it was possible to show how skidding productivity and costs are affected by variable degrees of line pulling. The results of this case study indicate that productivity is clearly influenced by the amount of line pulling required to choke a turn of logs. As line pull distances increase productive cycle times increase, which in turn reduces productivity and results in a corresponding increase in skidding costs. The extent of the reduction in productivity and increase in costs when using designated skid roads will depend on road spacing and the amount of directional felling used. Although skidding on a network of preplanned skid roads results in higher skidding costs, increased environmental concerns over the impacts of harvesting on steep terrain may force the use of such skidding practices to minimize the extent of adverse stand and site impacts in the future.

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