Computer Software to Estimate Timber Harvesting System Production, Cost, and Revenue

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ABSTRACT

Large variations in timber harvesting cost and revenue can result from the differences between harvesting systems, the variable attributes of harvesting sites and timber stands, or changing product markets. Consequently, system and site specific estimates of production rates and costs are required to improve estimates of harvesting revenue. This paper describes computer software developed to help perform these tasks: ECOST, PROFIT-PC, THIN, and GB-SIM. The applications discussed provide information needed to identify appropriate harvesting technology for specific applications and provide the cash flow information needed to evaluate forest management alternatives.

INTRODUCTION

Timber harvesting activities include felling and limbing trees, skidding or yarding stems to roadside, bucking stems into roundwood products, loading products onto trucks, and hauling roundwood to processing facilities. The total cost of these activities can represent a large part of the total cost of wood delivered to sawmills or pulp mills; especially the low-value wood from poor quality trees or undesirable tree species. For example, prices of delivered roundwood and average stump-to-mill harvesting costs reported for New Hampshire (Engalichev 1988) indicate that combined harvesting and transportation costs account for 20 to 40 percent of the delivered price of high-quality sawlogs, and 75 percent or more of the delivered price of low-value sawlogs or pulpwood. The remainder represents the price paid for standing timber. As a result, timber harvesting and transportation costs are important determinants of stumpage prices paid to landowners. Higher harvesting and transportation costs mean lower economic returns for forest-land owners and lower rates of returns on forest management investments.

It is important to recognize that harvesting costs are affected by the type of harvesting system employed, ground based skidders or cable yarders, as well as the capabilities and cost of specific machine models. Equally important determinants of costs are harvest site attributes that include tree diameter distributions, volume harvested per acre, and the harvest unit dimensions that dictate road spacing and yarding distance. Harvesting costs generally decrease with increasing volume per tree or volume cut per acre, and increase with increasing skidding or yarding distance. Site attributes such as terrain and soils also influence equipment selection decisions—cable yarders reduce soil disturbance on slopes and ground-based systems are most efficient on moderate to level terrain.

Accordingly, harvesting costs and stumpage receipts will be affected by the forest management or timber harvesting decisions regarding the selection of harvesting systems, attributes...

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of the cut stand, or the dimensions of the harvest unit. For example, the scheduling of thinnings affects numbers of trees harvested, average tree volume, and harvested volume per acre. Likewise, efforts to increase wood utilization by harvesting smaller trees affects harvesting costs and product yields and requires analysis of marginal revenues and costs to identify optimum wood utilization levels.

Harvesting costs were once a major concern of only timber harvesting and processing firms. However, the increasingly stringent constraints imposed on timber harvesting by environmental concerns have made harvesting cost and economic feasibility increasingly important issues with much broader ramifications. Efforts to lessen soil disturbance on steep slopes or wetlands may require use of cable yarding. Altering silvicultural methods to promote biodiversity, or diminishing the size of clearcut units to improve the aesthetic quality of harvest areas, can alter cut stand or harvest unit attributes and result in substantial changes in harvesting cost and stumpage returns. Efforts to evaluate the effects of environmental protection require estimates of harvest costs and revenue for each alternative considered. The sensitivity of harvesting cost and revenue makes it important to estimate economic returns as a function of harvest site and cut stand attributes. This information enables the forest manager to make informed choices regarding timber harvesting activities. The purpose of this paper is to provide an overview of four robust computer programs that are useful for estimating harvesting costs for a general set of inputs.

**Estimating Harvesting Costs**

The information required to estimate harvesting costs is generally developed from the results of logging machine time and motion studies. These studies measure and record machine cycle times and cycle attributes. Cycle time is the time required to make one complete production cycle. For a rubber-tired skidder this would include: travel empty, hooking and winching felled trees, travel loaded, and unhooking and deckling time. In this instance, cycle attributes could include travel distance, winching distance, number of logs, and volume skidded. Delay times and causes are also recorded. Through regression analysis, equations are developed to estimate machine cycle time as a function of cycle attributes. Estimates of cycle attributes and cycle times provide estimates of machine production rates and harvesting costs. Changes in cycle attributes related to changes in harvest site and cut stand attributes, such as skid distance or average tree volume, are reflected in estimated harvesting production and costs.

**COMPUTER SOFTWARE**

Examples of computer programs that apply the results of harvesting machine time and motion studies include: THIN, GB-SIM, ECOST, and PROFIT-PC. All except THIN have been developed specifically for eastern hardwood harvesting conditions. THIN and GB-SIM are stochastic simulation programs that simulate timber harvesting operations, using cycle-time equations to estimate production rates and harvesting costs. ECOST and PROFIT-PC use a deterministic approach to estimating stump-to-mill harvesting costs. PROFIT-PC also estimates product yields and net revenue. A brief description of each program and program applications follows.

**GB-SIM**

GB-SIM is a stochastic simulation model developed for conventional ground-based harvesting systems that include: manual chainsaw felling, a rubber-tired skidder, and either manual or mechanized tree bucking (Baumgras 1990). This program was principally developed to estimate harvesting cost and revenue for a wide range of forest management and wood utilization alternatives. Forest management alternatives that affect harvesting cost and revenue include the timing and intensity of thinnings as well as rotation length. Wood utilization alternatives include minimum merchantable tree diameter, minimum stem top diameter, and the types of roundwood products utilized.

Inputs to GB-SIM include numbers of trees to be harvested per acre by tree species and dbh class. Other inputs include harvest unit dimensions and skid trail spacing, minimum merchantable tree dbh and top diameter. Machine cycle time equations and delay time distributions also can be modified to represent specific machines and operators. The program randomly assigns X and Y coordinates, dbh, and species to each tree harvested based on input stand attributes. Harvesting activities are modeled as a function of tree locations and attributes by tracking each tree through the entire harvesting process. Production cycle times are estimated from simulated cycle attributes, cycle time equations, and randomly sampled delay times that included all delays except those resulting from system interactions. By monitoring the inventory of standing trees, felled trees, and skidded stems, the program models interactions between system components. GB-SIM also uses a system of equations to estimate the yield of pulpwood, sawbolts, and factory grade sawlogs by log grade.

The more important simulation results include total scheduled time to harvest the specified unit, operating time for each machine, and product yields—information essential to estimating cash flows. Applications of GB-SIM have included the economic analysis of forest management alternatives (Baumgras 1990), and identification of wood utilization alternatives that maximize harvesting revenue (Baumgras and LeDoux 1991).
the PC and mainframe versions of GBSIM are written in Fortran 77.

**THIN**

THIN, written in Fortran IV to simulate cable yarding operations, combines Monte Carlo and system simulation techniques and uses subroutines of the GASP IV simulation language to collect and report data (LeDoux and Butler 1981). Specifically, the model evaluates how alternative diameter classes, stand densities, harvesting efficiencies, external and lateral yarding distances, spatial log distributions, and prebunch-and-swing strategies affect production rates and related direct costs. THIN assumes that the cutting unit is a rectangle of given dimensions. The spatial distribution of logs in the cutting unit is determined by dividing the unit into a rectangular grid. Each rectangle in the grid is approximately square, and exactly one log is assigned to each square. The hooking and yarding of logs is then simulated, and descriptive statistics collected turn by turn with the hourly production rates summarized by parameter of interest.

THIN allows for detailed evaluation of the effects on production of alternative log sizes and distributions, silvicultural prescriptions, stand conditions, and equipment configurations. It should provide a quantitative tool to help forest managers assess the best ways to harvest the young-growth, intensively managed stands of the future. THIN has been applied by research to evaluate thinning cost (LeDoux and Starnes 1986), development of stump-to-truck estimates for West Coast conditions (LeDoux 1989), and development of stump-to-mill estimates for eastern hardwood conditions (LeDoux 1987). THIN also has been used by the Norwegian and Yugoslavian Forest Research Institutes to estimate cable logging production and costs for their respective operating conditions.

**ECOST**

ECOST is a program for estimating stump-to-mill timber production costs for cable logging eastern hardwoods (LeDoux 1987). The program uses data from stand inventory, cruise data, and the logging plan for the tract in question. The program produces detailed stump-to-mill cost estimates for proposed timber sales. Yarding cost estimates are derived from equations developed through simulation of yarding operations with the THIN model. Other harvesting costs are estimated from equations developed from published results of time and motion studies (LeDoux 1985). These estimates are then utilized, in combination with specific landowner objectives, to assess the economic feasibility of cable logging a given area. The manager, logger, or planner can use the estimates in their cable logging planning efforts. ECOST can provide cost comparisons between alternative harvesting machines for making equipment selection decisions; or cost comparisons between alternative silvicultural treatments for making forest management and harvesting decisions. When linked with a suitable forest growth and yield model, ECOST also can facilitate the cash flow analyses required to identify entries that break-even and forest management options that maximize economic returns over an entire rotation.

The program output is summarized in tabular format by harvesting component, and input parameters are also echoed in a summary table. ECOST operates on an individual stand or harvest block basis, providing stump-to-mill cost estimates that are specific to each stand or block. The tabular estimates can be arranged by stand or harvest block so that individual stands can be combined into a total timber sale cost data base that provides a powerful tool for cable-logging cost estimation. ECOST provides cost estimates for six types of cable yarders and five truck classes. Cost estimates are also provided for hauling over the following road class/design speeds: 35, 25, 16, 8, and 4 miles per hour. The five truck and road classes provide estimates for most eastern hardwood conditions.

**PROFIT-PC**

PROFIT-PC is an interactive program for personal computers that estimates roundwood product yields, determines the product mix required to maximize revenue, provides detailed estimates of stump-to-mill harvesting costs, and estimates net harvesting revenue (LeDoux and others 1989). Program inputs include numbers of trees per acre to be harvested by dbh class and tree species group, mill prices by product class and tree species, haul distance by road class to each roundwood market, truck type, and average yarding or skidding distance. Users also select one of 10 yarders or skidders to estimate system-specific harvesting costs. PROFIT-PC applies equations developed for estimating product yields from thinnings in central Appalachian hardwood stands (Baumgras 1984). Harvesting and transportation costs are estimated with routines adopted from the ECOST program. From mill prices, estimated haul costs, and roundwood product diameter and quality constraints, the program determines the allocation of available roundwood to product markets that will maximize net revenue. This allocation process compares the equivalent unit value of each product to determine if net revenue can be increased by allocating roundwood to markets with lower quality requirements, but higher value (delivered price - haul cost).

Primary applications of PROFIT-PC are harvest site and system-specific economic analyses of multiproduct harvesting opportunities for thinning in Appalachian hardwood stands. Options include evaluation of alternative harvesting systems, assessing the economic feasibility of harvesting operations for specific stands and market conditions, and evaluating multiproduct harvesting opportunities.
SOFTWARE

Profit-PC is written in MS-DOS (Version 3.2) GW-BASIC for IBM compatible personal computers.

SUMMARY

The software described provides the capability to assess the cost and economic feasibility of harvesting specific sites and stands with a variety of yarders or skidders. Equally important, this software permits experimentation with variable inputs reflecting the changing harvest site and timber stand attributes or different harvesting machines. The results from these experiments can illustrate the economic effects of ongoing efforts to lessen the environmental impacts of timber harvesting.

Except for GB-SIM, the above programs are now available on request with the understanding that the U.S. Department of Agriculture, Forest Service, cannot ensure their accuracy, completeness, reliability, or suitability for any other purpose than that reported. The recipient may not assert any proprietary rights thereto nor represent them to anyone as other than Government-produced computer programs. For further information regarding all programs described, write: John E. Baumgras or Chris B. LeDoux, USDA Forest Service, Northeastern Forest Experiment Station, 180 Canfield Street, Morgantown, WV 26505. For copies of available software, send a blank double-sided, double density 5.25-inch floppy disk.

REFERENCES


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