# COSTS ASSOCIATED WITH HARVEST ACTIVITIES FOR MAJOR HARVEST SYSTEMS IN MONTANA

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ABSTRACT

Comprehensive logging cost information has not been available in the Northern Rocky Mountains (Montana and northern Idaho) since 1982 when the USDA Forest Service Northern Region implemented a timber sale appraisal system that did not require harvest cost data. To establish updated harvest costs, the largest logging companies and processors of logs in Montana were surveyed to determine average 1991 costs for individual harvest activities (operator planning and administration, felling, limbing and bucking, skidding yarding, and loading). Operator planning and administration contributed least to total harvest costs, while the skidding yarding activity contributed most. Average costs for the individual activities were combined to estimate stump-to-loaded-truck harvest costs for eight harvest systems commonly used in Montana (three ground-based systems, four cable systems, and one aerial system). Stump-to-truck harvest costs for typical logging systems on tractor ground ranged from $87 to $123/thousand board feet (MBF) Scribner. Average cable system costs ranged from $131 MBF for a typical groundlead system to $164/MBF for a skyline system yarding downhill. Reported helicopter system stump-to-truck costs averaged $233/MBF. The biggest differences in activity costs among the various systems were found in the skidding/yarding component. Costs for this activity ranged from $25/MBF using a rubber-tired grapple skidder to $182/MBF for a helicopter system. Respondents were also asked to identify the primary factors influencing costs. Piece size, skidding/yarding distance, harvest volume per acre, and harvest unit layout were the factors most often cited as influencing logging costs.

Historically, the USDA Forest Service Northern Region's residual value appraisal system was the main source of logging cost data in Montana, northern Idaho, and western North Dakota. This method of selling timber was phased out between 1982 and 1987, and replaced by a transaction evidence system that did not require timber harvest cost data. Consequently, logging cost data were not collected by the agency after 1982.

Harvest cost information is of particular interest given the move toward New Forestry and ecosystem management, and the harvest prescription modifications that will accompany their implementation (1-3). The purpose in developing costs by overall harvest system and component activities was to provide a baseline for estimating the impact on harvest costs of modifying traditional silvicultural prescriptions. This information also provides operators a reference for comparing average activity costs of the systems they use with those of alternative systems used under similar conditions. Finally, it provides an updated source of harvest costs for forestry consultants and private forest landowners.

Specific objectives of this study were to:

1. Estimate costs of the major activities associated with moving timber from the stump to the truck.
2. Develop stump-to-truck costs for harvest systems commonly used in Montana.
3. Identify the primary factors that influence harvest costs.

## METHODS

The major harvest systems – and the primary activities that comprise them – were identified through discussions with timber processing companies in Montana. Costs associated with the key harvest activities were obtained through a follow-up survey of the same companies. These companies accounted for over 85 percent of the volume harvested in Montana in 1991 (6). Most of the harvest in 1991 was accomplished under traditional even-aged cutting prescriptions: clearcut, seed-tree, and shelterwood (6).

The following five activities were used to profile stump-to-truck costs for a given harvest system.

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• *Operator planning and administration*

• *Felling*: This component distinguished two methods, hand versus mechanical felling.

• *Limbing and bucking*: Under hand felling, limbing and bucking was to be done in the woods; under mechanical felling, costs were developed both for limbing and bucking in the woods and at the landing.

• *Skidding yarding*: Methods for moving the logs to the landing included tractors with chokers or grapples, rubber-tired skidders with chokers or grapples, log forwarders, groundlead and skyline cable systems, and helicopters.

• *Loading*

The discussions with logging and processing firms identified three ground-based systems, four cable systems, and one aerial system, which account for much of the volume harvested in Montana. While numerous variations of these systems exist, the identified systems were of primary interest for estimating harvest costs. The systems described are not always used to harvest the same kinds of timber under the same terrain and conditions. For example, mechanical felling systems are generally used to harvest smaller diameter material (e.g., 7 to 14 in. in diameter) on relatively gentle slopes. Cable and helicopter systems are used on steeper ground, and in 1991, generally for larger diameter timber.

The three systems identified for harvesting timber using ground skidding were: 1) a typical hand-felling system, in which the timber is felled by hand, limbed and bucked in the woods, and skidded by tractor with chokers to the landing; 2) a typical mechanical system, using a mechanical feller-buncher, a rubber-tired grapple skidder for skidding, with limbing and bucking at the landing; and 3) a typical forwarder system using a mechanical feller-buncher, with limbing and bucking in the woods and a cut-to-length forwarder for moving logs to the landing.

The four cable systems were: 1) a typical groundlead system (a cable system that does not have a vertical lift capability); 2) a typical uphill skyline system (a system employing a carriage to vertically lift logs and move them along a cable stretched between two spars); 3) an uphill skyline system with intermediate supports, which allows transport of logs over long distances and on slopes with deflection problems; and 4) a downhill skyline system, which also lifts logs off the ground but moves them downhill rather than uphill.

The aerial system was based on mid-sized helicopters with lift capabilities from 3,000 to 5,000 pounds.

For a given system, average costs for the five harvest activities (and specific felling, limbing and bucking, and skidding/yarding methods associated with that system) were summed to estimate total stump-to-loaded-truck harvest costs.

## Results and Discussion

### Costs of Harvest Activities

Operator planning and administration was the least expensive of any of the five harvest-related activities. Average costs by system for this activity ranged from $7 to $11 MBF (**Table 1**).

The key component of any harvest system, the actual felling activity, accounts for a rather minor amount of overall harvest costs. The average cost of the hand felling method was cheaper than mechanical felling ($13 vs. $18/MBF), a difference respondents attribute to the larger average diameter of trees felled by hand (15 in. vs. 10 in.).

Costs associated with the limbing and bucking activity varied widely

*TABLE 1.— Activity costs for logging systems in Montana in 1991.*

| Activity | Tractor system | | Cable system | | Helicopter system | |
|---|---|---|---|---|---|---|
| | Average | Range | Average | Range | Average | Range |
| | ($/MBF) | | | | | |
| Operator planning and administration | 11 | 5 to 20 | 8 | 5 to 11 | 7 | 5 to 10 |
| Felling | | | | | | |
| Hand | 13 | 7 to 20 | 13 | 7 to 20 | 13 | 7 to 18 |
| Mechanical | 18 | 8 to 30 | | | | |
| Limbing and bucking | | | | | | |
| Hand | 19 | 13 to 25 | 17 | 8 to 25 | 19 | 13 to 25 |
| Mechanical at the landing | 20 | 7 to 30 | | | | |
| Mechanical in the woods | 37 | 19 to 54 | | | | |
| Skidding | | | | | | |
| Tractor w grapple | 28 | 13 to 45 | | | | |
| Tractor w choker | 33 | 14 to 44 | | | | |
| Rubber-tired w grapple | 25 | 15 to 35 | | | | |
| Rubber-tired w choker | 32 | 20 to 44 | | | | |
| Forwarder | 44 | 38 to 50 | | | | |
| Yarding | | | | | | |
| Ground lead | | | 81 | 42 to 150 | | |
| Skyline uphill | | | 98 | 69 to 175 | | |
| Skyline uphill w supports | | | 106 | 74 to 180 | | |
| Skyline downhill | | | 114 | 90 to 180 | | |
| Helicopter | | | | | 182 | 155 to 200 |
| Loading | 13 | 9 to 15 | 12 | 9 to 25 | 14 | 11 to 20 |

*TABLE 2. — Average 1991 costs for various timber harvest systems.*

| Harvest system | Activity | | | | | |
|---|---|---|---|---|---|---|
| | Operator planning and administration | Felling | Limbing & bucking | Skidding/yarding | Loading | Total stump to truck cost |
| | ($/MBF) | | | | | |
| Ground system | | | | | | |
| Typical mechanical system | 11 | 18 | 20 | 25 | 13 | 87 |
| Typical hand felling system | 11 | 13 | 19 | 33 | 13 | 89 |
| Typical forwarder system | 11 | 18 | 37 | 44 | 13 | 123 |
| Cable system | | | | | | |
| Groundlead | 8 | 13 | 17 | 81 | 12 | 131 |
| Uphill skyline | 8 | 13 | 17 | 98 | 12 | 148 |
| Uphill skyline w/ intermediate supports | 8 | 13 | 17 | 106 | 12 | 156 |
| Downhill skyline | 8 | 13 | 17 | 114 | 12 | 164 |
| Helicopter system | 7 | 13 | 17 | 182 | 14 | 233 |

among methods, from a low of $17/MBF for hand limbing and bucking in the woods, to a high of $37/MBF for in-woods mechanical processing using either a stationary or slide boom processor. However, mechanical limbing and bucking using this equipment at the landing was only about half as costly as in-woods processing ($20 vs. $37/MBF).

The skidding/yarding activity was the most expensive among the five phases comprising a harvest system. The largest differences in activity costs among the various systems were also found in this component, where costs ranged from $25/MBF using a rubber-tired grapple skidder to $182/MBF for aerial yarding.

The average skidding/yarding distances varied by system. The average skidding distance for tractor and rubber-tired skidders was 500 to 700 feet, while the average for systems using forwarders was 1,000 to 1,200 feet. The average yarding distance for cable systems was 500 to 600 feet, and the average yarding distance for helicopters was 1,000 to 1,200 feet.

Among the wheeled or tracked systems, moving logs to the landing by forwarder was substantially more expensive than any of the alternatives ($44/MBF vs. $25 to $33/MBF).

The costs of loading are a relatively minor component of the overall stump-to-truck costs of a harvest system. The average cost for this activity ranged from $12 to $14/MBF.

## HARVEST COST BY LOGGING SYSTEM

Average stump-to-truck harvest costs for identified ground-based systems ranged from $87 to $123/MBF (**Table 2**). Costs vary based on whether the operation employs hand- or mechanical-felling, where the limbing takes place, and how the timber is skidded.

Costs per MBF for a typical mechanical system on gentle ground are $11 for planning and administration, $18 for felling, $20 for limbing and bucking at the landing, $25 for rubber-tired grapple skidding, and $13 for loading, for an average on-truck cost of $87.

Harvest costs for a typical hand-felling system on tractor ground were nearly the same as for the mechanical system ($89 vs. $87/MBF). In contrast, on-the-truck costs for the log forwarder system were approximately one-third higher ($123/MBF).

Average logging costs for cable systems ranged from $131/MBF for a typical groundlead system to $164/MBF for a downhill skyline system. Differences in stump-to-truck harvest costs among cable systems are due entirely to differences in yarding costs, reflecting the increased complexity of yarding associated with the move from uphill skyline to downhill skyline systems.

Reported stump-to-truck costs for helicopter logging averaged $233/MBF. Higher overall harvest costs for this system are due almost entirely to higher yarding costs.

## FACTORS INFLUENCING COSTS

The factors that operators use to estimate the cost of major harvest activities — planning and administration, felling, bucking and limbing, skidding/yarding, and loading — are shown in **Table 3**.

For the operator planning and administration activity, more firms consider harvest unit layout than any other factor when estimating costs.

All respondents cited piece size and harvest volume per acre as important factors in estimating hand felling costs. Nearly all consider these two factors plus slope when estimating mechanical felling costs.

Piece size is the most important factor in considering hand limbing and bucking costs. All respondents use piece size in estimating costs of mechanical limbing and bucking at the landing. While there were few respondents for the category of mechanical limbing and bucking in the woods, all factors were considered important in estimating costs for this activity.

Four factors – piece size, skidding/yarding distance, harvest volume, and slope – are used by more than 90 percent of the firms to estimate costs of skidding with either a tractor or rubber-tired skidder (chokers or grapples). Slope, skidding/yarding distance, and harvest volume/acre were important factors affecting costs to respondents using forwarders to move logs.

Piece size, yarding distance, and harvest volume per acre were important considerations in estimating yarding costs to virtually all respondents using cable and helicopter yarding systems. In addition to these factors, landing size/design, utilization specifications, and elevation (not shown in **Table 3**) were cited by all respondents using helicopter systems as significant factors affecting costs.

Only two factors, piece size and landing size/design, are seen as impor-

TABLE 3.—Factors used to estimate cost per unit produced.

| Activity | Number of firms | Harvest unit layout[a] | Utilization specifications | Skidding/yarding requirements | Volume per harvest method | Leave volume per acre | Post harvest treatment |
|---|---|---|---|---|---|---|---|
| | (Number who use each factor) | | | | | | |
| Operator planning and administration | 16 | 15 | 12 | 14 | 14 | 11 | 12 |

| | Number of firms | Piece size | Harvest volume per acre | Leave volume per acre | Slope | Season/seasonal constraint | Utilization specification | Limbing and bucking requirements |
|---|---|---|---|---|---|---|---|---|
| Felling | | | | | | | | |
| Hand felling | 14 | 14 | 14 | 9 | 10 | 8 | 10 | 11 |
| Mechanical felling | 15 | 13 | 14 | 9 | 14 | 10 | 9 | 7 |
| Limbing and bucking | | | | | | | | |
| Hand limb and buck | 12 | 10 | 7 | 3 | 8 | 6 | 7 | 6 |
| Mechanical limb and buck at the landing | 15 | 15 | 6 | 2 | 6 | 5 | 10 | 10 |
| Mechanical limb and buck in the woods | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |

| | Number of firms | Piece size | Skidding/yarding distance | Harvest volume per acre | Leave volume per acre | Slope | Utilization specification | Slash/top treatment | Season/seasonal constraint | Ground condition | Landing size and design |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Skidding | | | | | | | | | | | |
| Tractor w/ grapple | 14 | 13 | 14 | 14 | 7 | 14 | 7 | 10 | 9 | 11 | 7 |
| Tractor w/ choker | 12 | 12 | 12 | 12 | 8 | 11 | 7 | 9 | 7 | 10 | 7 |
| Rubber-tired w/ grapple | 13 | 13 | 13 | 13 | 9 | 13 | 8 | 9 | 9 | 11 | 9 |
| Rubber-tired w/ choker | 12 | 12 | 12 | 12 | 8 | 12 | 7 | 9 | 7 | 10 | 8 |
| Yarding | | | | | | | | | | | |
| Forwarders | 4 | 2 | 3 | 3 | 2 | 4 | 1 | 2 | 1 | 2 | 2 |
| Groundlead | 5 | 5 | 5 | 4 | 4 | 3 | 3 | 4 | 5 | 2 | 4 |
| Skyline uphill | 10 | 10 | 10 | 9 | 7 | 6 | 5 | 8 | 7 | 7 | 7 |
| Skyline uphill w/ supports | 8 | 8 | 8 | 8 | 7 | 6 | 5 | 7 | 7 | 6 | 6 |
| Skyline downhill | 7 | 7 | 7 | 7 | 7 | 7 | 5 | 6 | 7 | 6 | 7 |
| Helicopter | 5 | 5 | 5 | 4 | 4 | 2 | 5 | 4 | 4 | 3 | 5 |

| | Number of firms | Piece size | Landing size and design | Seasonal constraints |
|---|---|---|---|---|
| Loading | 20 | 16 | 14 | 5 |

[a] Includes spatial distribution of harvest units and harvest methods.

tant considerations when estimating loading costs.

The results presented here are a first step in developing an approach to estimate the influence of new silvicultural and harvest prescriptions on logging costs. This paper provides average costs of the major harvest systems used in Montana under more traditional silvicultural prescriptions, and identifies the major factors influencing costs of individual harvest activities.

Because many variables can potentially influence costs, researchers have historically had problems developing models that are both parsimonious and explain significant amounts of variation (4,8). Results of this study indicate that modeling will likely become even more challenging as harvest prescriptions become more complex.

Respondents indicated that the more complex the logging system, the more expensive it was, and the more factors that must be considered in estimating costs. For example, all seven of the firms providing information on downhill cable yarding indicated that piece size, yarding distance, harvest volume per acre, leave volume per acre, slope, seasonal constraints, and landing size were important factors influencing costs; six of seven also included slash treatment and ground condition. Building equations that can accurately predict harvest costs for complex harvest systems is a daunting task because of the difficulty of accurately measuring or quantifying some independent variables, and because of potential correlation or interaction among them.

It is also clear that harvest prescriptions modified to accommodate the visual and biological impacts of logging have the potential to substantially influence costs. This influence may come in the form of operability constraints on the area to be harvested, specific requirements associated with individual harvest systems, or through changes in the size and quantity of timber available for harvest from a given site. For example, the need to mitigate visual impacts and eliminate roads in scenic travel corridors in the West commonly requires the use of helicopter systems in place of cable systems, despite their greater costs.

Modified (New Forestry) silvicultural prescriptions will also affect the major factors influencing costs, regardless of the harvest system used. For example, most New Forestry prescriptions call for leaving more stems per acre (including some larger trees) than traditionally were left (3). This modification affects both piece size and harvest volume per acre, two of the most important variables affecting costs. Other changes accompanying New Forestry, such as leaving clumps of understory trees (5) and reduced road building (7), have potential to impact skidding and yarding distance and choice of harvest system.

The choice of harvest system is influenced primarily by timber characteristics and terrain. For example, a system consisting of a mechanical harvester and rubber-tired skidder is designed for relatively small timber on gentle ground (generally slopes < 35%), and cannot be used to harvest large-diameter timber on steep slopes. However, the land manager can exert substantial influence on harvest costs by prescribing the size and quantity of timber harvested, and setting harvest system requirements.

## Conclusions

Stump-to-truck harvest costs were developed for harvest systems that account for >85 percent of the timber harvest in Montana. Of the eight systems examined, a system including mechanical-felling, limbing and bucking at the landing, and rubber-tired grapple skidding was the cheapest ($87/MBF); while a helicopter system with moderate lift capability was the most expensive ($233/MBF). Of the five activities comprising a harvest system (operator planning and administration, felling, limbing and bucking, skidding yarding, and loading), operator planning and administration contributed least to total stump-to-truck costs, and yarding contributed most. Yarding was also the activity cost that varied most among harvest systems ($25 to $182/MBF). Harvest unit layout is the factor that most affects operator planning and administration costs; piece size and harvest volume/acre most affect felling costs; piece size most affects limbing and bucking costs; piece size, skidding yarding distance, and harvest volume/acre most affect skidding yarding costs; and piece size most affects loading costs.

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