Financial Aspects of Alternative Harvest Cutting Methods and Silvicultural Treatments: A Literature Review
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by

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SUMMARY

This report summarizes literature examining financial aspects related to clearcut and partial cut silvicultural treatments of forest stands in the Pacific Northwest. Partial cutting methods considered include both even- and uneven-aged regeneration cuts and intermediate harvests.

The following economic measures are compared for alternative silvicultural treatments:
1. costs and logging production identified with stump-to-landing harvest activities, and
2. net present value, soil expectation value, and net present amount related to costs and revenues of silvicultural treatments over a full rotation.

Although the reviewed literature reports economic measures linked with alternative silvicultural treatments, few studies isolate silvicultural treatment as the independent variable. It is therefore difficult to draw conclusions from the literature, except in a very general way.

Some of the research methods used in the reviewed literature, however, can be used in future studies. These methods isolate the effect of silvicultural treatment on the cost of harvesting activities and economic measures used to analyze long-term cash flows.
ACKNOWLEDGEMENTS

The author appreciates the assistance, experience, and enthusiasm of Bob Benson, retired research analyst, formerly with the U.S. Forest Service Intermountain Forest and Range Experiment Station. The comments of Ron Barger of the University of Montana School of Forestry are also appreciated.
# TABLE OF CONTENTS

SUMMARY ........................................................................................................ iii  

ACKNOWLEDGEMENTS ................................................................................ iv  

1 INTRODUCTION ......................................................................................... 1  
1.1 Objectives ............................................................................................. 1  
1.2 Harvest Cutting Methods ...................................................................... 1  
1.3 Economic Measures ............................................................................. 1  
1.4 Measures of Logging Production .......................................................... 2  
1.5 Summary ............................................................................................... 2  

2 APPROACH .................................................................................................. 3  
2.1 Organization .......................................................................................... 3  
2.2 A Basis for Comparison ......................................................................... 3  

3 TIME AND MOTION STUDIES: LOGGING PRODUCTION AND COSTS ...... 4  
3.1 Description ............................................................................................ 4  
3.2 Examples ............................................................................................... 4  

4 SIMULATION: LOGGING PRODUCTION AND COSTS ............................... 18  
4.1 Simulation Models ................................................................................. 18  
4.2 Simulation Examples ............................................................................. 18  

5 SIMULATION: FINANCIAL ANALYSIS OF A SERIES OF MANAGEMENT ACTIVITIES OVER TIME ........................................................................... 29  
5.1 Silvicultural Systems ............................................................................. 29  
5.2 Economic Measures ............................................................................. 29  
5.3 Examples ............................................................................................... 29  

6 APPRAISAL METHODS IN THE U.S. PACIFIC NORTHWEST ..................... 42  
6.1 USDA Forest Service Northern Region ................................................. 42  
6.2 USDA Forest Service Pacific Northwest Region ................................... 43  

7 OTHER SILVICULTURAL TREATMENTS ................................................... 44  
7.1 Slash Disposal and Site Preparation ................................................... 44  
7.2 Artificial Regeneration ......................................................................... 44  
7.3 Vegetation Management ....................................................................... 44  

8 FACTORS AFFECTING LOGGING PRODUCTION AND COSTS ................ 45  

9 SUMMARY .................................................................................................. 46  
9.1 Tractor and Cable Harvesting Costs .................................................... 46  
9.2 Costs and Revenues over a Full Rotation ............................................ 47  
9.3 Other Factors Affecting Economic Feasibility of Harvesting ............... 47  

10 RECOMMENDATIONS ............................................................................. 48  
10.1 Logging Production Studies ................................................................ 48  
10.2 Research Methods ............................................................................... 48  
10.3 Increasing Logging Production on Partially Cut Stands ....................... 48  
10.4 Other Silvicultural Considerations ..................................................... 49  

11 LITERATURE CITED ............................................................................... 50
**TABLES**

1. Planning/layout, felling, ground skidding, and total costs by silvicultural treatment and harvesting method ................................................................. 6
2. Planning/layout, felling, cable yarding, and total costs by silvicultural treatment ................................................................. 7
3. Felling, skidding, and total costs by cutting method, volume per acre logged, and tree size ................................................................. 9
4. Cost of felling, yarding, and swinging whole trees by harvest cutting method ................................................................. 11
5. Cost of felling, yarding, and swinging whole trees by harvest cutting method ................................................................. 12
6. Logging production by silvicultural prescription and site and stand attributes ................................................................. 14
7. Uphill live skyline yarding production by silvicultural method and site and stand attributes ................................................................. 16
8. Running skyline yarding production by silvicultural method and site and stand attributes ................................................................. 16
9. Running skyline yarding production by silvicultural method and site and stand attributes ................................................................. 17
10. Running skyline yarding production by silvicultural method and site and stand attributes ................................................................. 17
11. Felling, limbing, bucking, cable yarding, and total costs by cutting method and tree size ................................................................. 20
12. Felling, limbing, bucking, cable yarding, and total costs by cutting method and tree size ................................................................. 21
13. Felling, limbing, bucking, cable yarding, and total costs by cutting method and tree size ................................................................. 21
14. Felling, limbing, bucking, cable yarding, and total costs by cutting method and tree size ................................................................. 22
15. Total production costs by reproduction method ................................................................. 24
16. Total production costs by reproduction method ................................................................. 24
17. Present value of harvesting and loading costs by reproduction method ................................................................. 26
18. Uphill running skyline production by reproduction method ................................................................. 28
19. Uphill live skyline production by reproduction method ................................................................. 28
20. Net present value, soil expectation value, and net present amount by reproduction method ................................................................. 31
21. Net present value, soil expectation value, and net present amount by reproduction method ................................................................. 34
22. Net present value, soil expectation value, and net present amount by reproduction method ................................................................. 36
23. Present net worth and soil expectation value by reproduction method on a good site ................................................................. 38
24. Present net worth and soil expectation value by reproduction method on a poor site ................................................................. 39
25. Present net worth over one decade by cutting method on a good site ................................................................. 40
26. Present net worth over one decade by cutting method on a poor site ................................................................. 41
27. Appraised cost of skyline yarding by cutting method ................................................................. 43
28. Summary of harvest cost indices for alternative harvest cutting methods on tractor ground ................................................................. 46
29. Summary of harvest cost indices for alternative harvest cutting methods on cable ground ................................................................. 46
1 INTRODUCTION

1.1 Objectives

The primary objective of this project was to summarize forestry and economic literature pertaining to the relative logging production, costs, and other economic values associated with clearcut and partial cut harvesting of Pacific Northwest forests.

Each referenced study examines factors affecting the financial feasibility of alternative silvicultural systems. Most studies examine only the harvest production or costs. However, some studies go beyond the harvest activities and examine the financial implications inherent to silvicultural systems over whole rotations. A secondary objective was therefore to summarize literature that considers the relative financial aspects of silvicultural treatments over the course of clearcut and partial-cut rotations.

1.2 Harvest Cutting Methods

In this report, “partial cut” refers to harvest practices that are alternatives to clearcuts. The term “partial cut” is used in two ways in this report:

1. most often by the reviewer, in a generic sense, and
2. occasionally by the original authors (e.g., Fight et al. 1984) when developing harvesting costs for alternatives to clearcuts.

Other descriptors of harvest cutting methods examined in this summary of literature include:

- clearcut
- seed tree
- shelterwood
- group selection
- single tree selection
- commercial thin
- two-story

1.3 Economic Measures

In most of the examples in this report, the relative economic values (US$) of clearcut and partial cut methods are summarized and compared.

Some researchers analyze only the cost of harvesting activities such as felling, limbing, bucking, and yarding. They look at cost per unit of measure (stem, mbf, ton, and cubic feet) or present value (PV). Present value represents a dollar amount discounted back to the present.

Other researchers use economic measures that relate to a long-term view of both costs and revenues over a full rotation. Activities providing a mix of costs and revenues include harvesting, site prep/slash disposal, planting, pre-commercial thinning, and commercial thinning. Tesch and Mann (1991) define these economic measures as follows:

- net present value (NPV)
  - NPV represents the net difference between costs and revenues that have been discounted back to the present. This measure is used with existing stands or single rotations. The term “present net worth” (PNW) is sometimes used instead of NPV.
- soil expectation value (SEV)
  - SEV represents the NPV of an infinite series of similar future rotations starting from bare land.
• net present amount (NPA)
  - NPA is the sum of NPV and SEV. This measure makes comparison of management alternatives with different rotation lengths easier. The examples presented in this report sum the NPV of the existing stand and the SEV of future rotations.

1.4 Measures of Logging Production

Two studies provided harvest-related production figures (costs were not provided). In these studies, production rates of alternative silvicultural cutting methods are contrasted in volume or weight per hour.

1.5 Summary

The studies reviewed were designed to achieve a wide range of objectives. Since the pertinent literature involves a diversity of measures, and because the purpose of this summary is to describe relative cost or production differences between clearcut and partial-cut methods, a simplified means of reporting those relationships is described in the next section.

Several of the authors cited caution readers to consider local conditions and costs when developing specific silvicultural prescriptions. Nevertheless, the studies presented provide useful examples of trends and methods.
2  APPROACH

2.1 Organization

The literature reviewed can be organized into three main categories:

- *Time and motion studies:* These document observed harvesting activities and express them in terms of dollar cost or products produced per unit of time.

- *Simulations that model logging production or costs:* The models are usually based on time and motion data from previous studies.

- *Simulations that model a series of management activities over time:* A silvicultural system consists of a series of management treatments over the life of a forest stand. In the Pacific Northwest, the costs used in these models are often developed from U.S. Forest Service or Bureau of Land Management experience.

2.2 A Basis for Comparison

Units of measure in the pertinent literature vary widely. Most of the examples use board feet, although Dykstra (1978) summarizes the hazards of metrification of boardfoot measure. To facilitate comparison of economic values and logging production associated with clearcutting and partial cutting, these values are presented first as they were stated by the original author, and then as an index. Three samples follow:

- In the case of harvesting costs, the clearcut cost is assigned an index of 1.0. To determine a relative index for the partial cut, the cost of the clearcut is divided into the cost of the partial cut alternative (the units cancel).

  **Example:** Production cost of a partial cut is US$88.29/mbf
  Production cost of a clearcut is US$77.93/mbf
  The partial cut index is \[ \frac{US$88.29}{US$77.93} = 1.13 \]

  In this case, the cost of harvesting a partial cut is 1.13 times the cost of harvesting the stand by means of a clearcut.

- On the other hand, logging production on clearcut units usually exceeds that on partial cut areas. The clearcut index is set at 1.0. To determine the partial cut index, divide the partial cut value by the clearcut amount.

  **Example:** Logging production of a partial cut is 2.9 tons/worker hour
  Logging production of a clearcut is 3.7 tons/worker hour
  The partial cut index is \[ \frac{2.9}{3.7} = 0.78 \]

  In this case, logging production on the partial cut area is about three-quarters that of a clearcut area.

- In cases where NPV, SEV, or NPA are compared, the clearcut value is assigned an index of 1.0. To determine the partial cut index, divide the partial cut value by the clearcut amount.

  **Example:** NPV of a partial cut is US$8,766/acre
  NPV of a clearcut is US$13,165/acre
  The partial cut index is \[ \frac{8766}{13,165} = 0.67 \]

  In this example, the NPV of the partial cut is about two-thirds that of a clearcut.
3 TIME AND MOTION STUDIES: LOGGING PRODUCTION AND COSTS

This section features time and motion research examining relative harvesting production and costs for clearcut and partial cut prescriptions.

3.1 Description

Time and motion studies provide a basis for developing costs or production rates for work activities. In the case of timber harvesting activities, a researcher with stop-watch in hand may observe a sawyer and record both productive time (move between trees, fell tree, limb tree, buck tree) and non-productive time (saw maintenance, personal delays). Times for the various activities can be summarized and the number of logs produced during the shift tallied. The researcher can then determine an hourly or daily production rate.

Alternatively, the researcher can provide a form for the sawyer to complete at the end of the day; the worker estimates the productive and non-productive segments of the shift and the logs produced.

Similarly, productive and non-productive time for equipment (yarder, skidder) can be recorded.

If costs are to be a part of the time and motion study, hourly or daily worker wages and benefits are calculated. Equipment costs can also be determined, considering fixed and variable expenses and sometimes including overhead and profit.

In this way, time and motion studies provide either production or cost data.

3.2 Examples

Some of the following examples use a time and motion study to contrast clearcut and partial cut harvest costs (e.g., in US$/m$3); other studies use similar methods to determine harvest production (e.g., in m$3$/hour).
STUDY: Logging requirements to meet New Forestry prescriptions.

Discussion

This study contrasts planning and logging costs in clearcut, two-story, and group selection cutting units. A total of two snags and green trees per acre was retained on the clearcut; scattered and grouped snags were also retained with the other prescriptions. Each site was planted after harvest.

Cost centres identified

Planning, layout, felling, ground and cable yarding, equipment costs, labour costs, designated skidding on trails and random skidding, crew size.

Principal variables

- Dependent (response):
  Planning and layout costs
  Felling costs
  Yarding costs
  Total costs

- Independent (explanatory):
  Silvicultural prescription (clearcut, two-story, group selection)
  Harvesting method (ground skid, cable yard)

Analysis basis

- Production costs: Planning and layout (US$/mbf)
  Felling (US$/mbf)
  Yarding (US$/mbf)
  Total (US$/mbf)

- Index: Costs for clearcut set at 1.0

Characteristics common to the next two examples

These examples summarize harvesting costs under alternative silvicultural systems in second-growth Douglas-fir stands.

Location: Western Oregon
Cover type: Primarily Douglas-fir
Average dbh: 23 inches
Trees per acre: 60
Basal area per acre: 187 ft²
Volume per acre: 38.2 mbf
Example 1

Characteristics

Example 1 summarizes planning, layout, felling, and skidding costs on gentle terrain. Clearcut units were grapple-skidded without designated skidtrails. In two-story and group selection stands, logs adjacent to designated skidtrails were harvested with a grapple-equipped rubber-tired skidder. Other logs were winched to the skidtrails and taken to the landing by a flexible-track skidder.

Slope: Less than 30%
Skidding equipment: John Deere Model 648 grapple skidder; FMC Model 220 with winch; FMC Model 210 with winch
Total area harvested: Approximately 175 acres

| TABLE 1. Planning/layout (P/L), felling, ground skidding, and total costs (US$/mbf) by silvicultural treatment and harvesting method (from Kellogg et al. 1991) |
|--------------------------------------------------|------------------|------------------|
| Project attributes                              | Silvicultural method |                 |
|                                                  | Clearcut          | Two-story        | Group selection |
| Skidding method                                 | No trails, grapple | Designated skidtrails, winch | Designated skidtrails, grapple |
| Avg. vol/log (bf)                               | 372              | 261              | 335              |
| P/L cost ($) (index)                            | 0.14 (1.0)       | 0.72 (5.14)      | 2.66 (19.0)      |
| Fall cost ($) (index)                           | 6.64 (1.0)       | 7.43 (1.12)      | 5.67 (0.68)      |
| Skid cost ($) (index)                           | 25.89 (1.0)      | 29.88 (1.15)     | 24.93 (0.96)     |
| Total cost ($) (index)                          | 32.67 (1.0)      | 38.03 (1.16)     | 33.46 (1.02)     |

Notes

Adverse weather conditions, a larger crew, and smaller logs contributed to higher costs on the two-story harvest. The authors feel that if conditions and tree sizes were similar to those on the clearcut, skidding costs would have been a little lower but not as low as for the clearcut.

On group selection units, extensive (and relatively costly) planning and layout efforts increased felling and skidding fieldwork efficiency.
Example 2

**Characteristics**

This example condenses planning, layout, felling and yarding costs on cable ground. A crew of eight worked with a Thunderbird yarder. This harvesting system can lateral yard up to 125 ft on either side of the skyline and can be used for clearcut and partial cut units.

<table>
<thead>
<tr>
<th>Slope:</th>
<th>Greater than 30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yarding equipment:</td>
<td>Thunderbird TTY-50 slack skyline yarder with Danebo mechanical slackpulling carriage</td>
</tr>
<tr>
<td>Total area harvested:</td>
<td>Approximately 100 acres</td>
</tr>
</tbody>
</table>

**TABLE 2.** Planning/layout (P/L), felling, cable yarding, and total costs (US$/mbf) by silvicultural treatment (from Kellogg *et al.* 1991)

<table>
<thead>
<tr>
<th>Analysis basis</th>
<th>Silvicultural method (average gross volume/log)</th>
<th>Clearcut (391 bft)</th>
<th>Two-story (374 bft)</th>
<th>Group selection (391 bft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P/L cost ($)</td>
<td></td>
<td>0.38</td>
<td>2.52</td>
<td>2.40</td>
</tr>
<tr>
<td>(index)</td>
<td></td>
<td>(1.0)</td>
<td>(6.63)</td>
<td>(6.32)</td>
</tr>
<tr>
<td>Fall cost ($)</td>
<td></td>
<td>5.33</td>
<td>5.68</td>
<td>5.15</td>
</tr>
<tr>
<td>(index)</td>
<td></td>
<td>(1.0)</td>
<td>(1.07)</td>
<td>(0.97)</td>
</tr>
<tr>
<td>Yard cost ($)</td>
<td></td>
<td>39.92</td>
<td>48.13</td>
<td>49.33</td>
</tr>
<tr>
<td>(index)</td>
<td></td>
<td>(1.0)</td>
<td>(1.21)</td>
<td>(1.24)</td>
</tr>
<tr>
<td>Total cost ($)</td>
<td></td>
<td>45.63</td>
<td>56.33</td>
<td>56.88</td>
</tr>
<tr>
<td>(index)</td>
<td></td>
<td>(1.0)</td>
<td>(1.23)</td>
<td>(1.25)</td>
</tr>
</tbody>
</table>

**Notes**

Because lower volumes per acre were harvested on the partial cuts, a greater proportion of time was used in setting up the yarder along cable roads (and thus a smaller fraction of total time was spent yarding logs). This resulted in higher yarding costs. In the group selection units, parallel cable roads were laid (in part to facilitate future entries); this required the yarder to be moved more often and increased costs.

Planning and layout made felling and cable yarding operations easier in the group selection units.

Cable yarding costs (Example 2) are considerably higher than ground skidding costs (Example 1).

Discussion

Identifying that the cost effect of silvicultural harvesting methods is one of the least quantified variables in logging studies, these researchers undertook a comparison of four cutting methods. The authors provide production costs associated with clearcut, seed tree, group selection and single tree selection cutting methods in mixed conifer stands. The subject stands were relatively close together and had similar edaphic, biotic, and topographic attributes.

Separate studies documented harvesting costs associated with seed-tree and single tree selection (Atkinson and Hall 1963), group selection (McDonald 1965), and clearcut (Atkinson and Hall 1966). The McDonald et al. (1969) paper summarizes the findings of these earlier Research Notes.

Cost centres identified

Felling, limbing, bucking, lopping, ground skidding, crew size, defect, equipment costs, labour costs, volume per acre harvested, average log volume, silvicultural cutting method.

Principal variables

- Dependent (response):
  - Felling costs
  - Skidding costs
  - Total costs
- Independent (explanatory):
  - Silvicultural prescription (clearcut, seed tree, group selection, single tree selection)

Analysis basis

- Production costs:  Felling (US$/mbf)
  - Skidding (US$/mbf)
  - Total (US$/mbf)
- Index: Costs for clearcut set at 1.0
Example 1

**Characteristics**

This case summarizes the harvesting costs under alternative reproduction methods in a mixed-conifer stand.

- **Location:** North central California
- **Cover type:** Primarily ponderosa pine and Douglas-fir with other mixed-conifer
- **Defect:** 0 to 2.3% of gross volume
- **Slope:** 5–40%
- **Area harvested:** Clearcut 112 acres
  - Group selection approximately 10% of 36 acres
  - Seed tree approximately 204 acres
  - Single tree selection approximately 68 acres
- **Harvesting method:** Caterpillar D-7 or International TD-20
- **Skidding distance:** Averages ranged between 500 and 630 ft
- **Costs:** Adjusted to 1965 rates

---

**TABLE 3.** Felling, skidding, and total costs (US$/mbf) by cutting method, volume per acre logged, and tree size (from McDonald et al. 1969)

<table>
<thead>
<tr>
<th>Site/stand attributes</th>
<th>Clearcut</th>
<th>Seed tree</th>
<th>Group selection</th>
<th>Single tree selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vol/acre (mbf)</td>
<td>20.0</td>
<td>27.3</td>
<td>24.7</td>
<td>10.4</td>
</tr>
<tr>
<td>Net vol/log (bf)</td>
<td>314</td>
<td>367</td>
<td>304</td>
<td>355</td>
</tr>
<tr>
<td>Avg. skid (ft)</td>
<td>500</td>
<td>550</td>
<td>630</td>
<td>550</td>
</tr>
<tr>
<td><strong>Analysis basis</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fell costs ($)</td>
<td>3.86</td>
<td>3.86</td>
<td>3.86</td>
<td>3.86</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
<td>(1.0)</td>
<td>(1.0)</td>
<td>(1.0)</td>
</tr>
<tr>
<td>Skid costs ($)</td>
<td>4.42</td>
<td>4.40</td>
<td>4.31</td>
<td>5.16</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
<td>(1.0)</td>
<td>(0.98)</td>
<td>(1.17)</td>
</tr>
<tr>
<td>Total costs ($)</td>
<td>8.28</td>
<td>8.26</td>
<td>8.17</td>
<td>9.02</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
<td>(1.0)</td>
<td>(0.99)</td>
<td>(1.10)</td>
</tr>
</tbody>
</table>

**Notes**

The seed-tree figures reflect the costs of both the regeneration cut and the overstory removal cut.

Felling costs in all treatment areas were based on a rate negotiated with the sawyers. The authors felt that if an hourly wage were paid, cost differences among the cutting methods would likely result. Observed felling production was similar in the clearcut, single tree selection, and group selection, but higher in the seed tree. Seed-tree overstory removal raised the weighted average for seed-tree felling production.

Skidding production was highest in the group selection and lowest in the single tree selection, but the production variation among the cutting methods was not statistically significant.

Even though the volume harvested per acre varied widely, the authors concluded that tractor logging costs in these young-growth mixed-conifer stands did not change significantly with the silvicultural cutting method, and that forest managers can choose a cutting method based on other management objectives.
STUDY:  Thinning on steep terrain with low-cost cable yarders.  
Goetz, H. and F. Maus (1986)

Discussion
The project was designed to demonstrate the feasibility of full-tree thinning operations on steep terrain. The yarders and skidders considered in the study are relatively small and inexpensive, and are meant to represent the type of equipment that a small operator or landowner might use when harvesting small timber.

The researchers recorded production rates and costs identified with harvesting and processing small-diameter trees in western Montana stands. Though several stands were pre-commercially thinned, the following tables focus only on cable-yarded clearcut and commercial thin areas on which revenues exceeded costs.

Cost centres identified
Felling, whole-tree cable yarding, swinging, volume per stem, crew size, equipment costs, labour costs.

Principal variables
- Dependent (response):
  Felling costs
  Yarding costs
  Swing costs
  Total costs
- Independent (explanatory):
  Silvicultural prescription (clearcut; commercial thin)
  Harvesting method (equipment)

Analysis basis
- Production costs:
  Felling (US$/stem)
  Yarding (US$/stem)
  Swinging (US$/stem)
  Total (US$/stem)
- Index: Costs of clearcut set at 1.0

Characteristics common to the next two examples
Location:
Western Montana
Cover type:
Predominantly lodgepole pine, minor component of western larch
Pre-harvest trees/acre:
644–669
Residual trees/acre after commercial thin:
Approximately 80
Average dbh:
6.3–6.8 inches
Slope:
32–45%
Area harvested:
Clearcut approximately 4 acres
Commercially thinned approximately 0.75 acres
Costs:
Local rates for equipment and labour
Revenues:
[Then] current market values for products removed
Example 1

*Characteristics*

This case summarizes costs attributed to felling, yarding, and swinging whole trees. The Bitteroot Miniyarder is well suited to thinning small diameter (<10-inch dbh) trees. A grapple-equipped John Deere farm tractor was used to swing trees from the yarder to the landing.

Harvesting method: Bitteroot Miniyarder; grapple-equipped John Deere Model 2240 farm tractor for swinging

TABLE 4. Cost of felling, yarding, and swinging whole trees (US$/stem) by harvest cutting method (from Goetz and Maus 1986)

<table>
<thead>
<tr>
<th>Analysis basis</th>
<th>Harvest cutting method (average volume/stem)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clearcut (7.5 ft³)</td>
</tr>
<tr>
<td>Fell costs ($)</td>
<td>0.406</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
</tr>
<tr>
<td>Yard costs ($)</td>
<td>0.885</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
</tr>
<tr>
<td>Swing costs ($)</td>
<td>0.132</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
</tr>
<tr>
<td>Total ($)</td>
<td>1.423</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
</tr>
</tbody>
</table>
Example 2

Characteristics

This case summarizes the logging costs associated with different harvesting equipment. The Clearwater yarder, more powerful than the Bitterroot Miniyarder, is suitable for logging larger diameter trees and has the capacity to handle large overstory trees sometimes found in thinning operations. (The yarding capacity of a Christy yarder, a machine more commonly used in interior forests, is similar to that of the Clearwater.) A John Deere skidder was chosen because its production rate closely matched that of the Clearwater yarder.

Harvesting method: Clearwater yarder; John Deere Model 440 grapple rubber-tired skidder for swinging

TABLE 5. Cost of felling, yarding, and swinging whole trees (US$/stem) by harvest cutting method (from Goetz and Maus 1986)

<table>
<thead>
<tr>
<th>Analysis basis</th>
<th>Clearcut (8.3 ft³)</th>
<th>Commercial thin (8.03 ft³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fell costs ($)</td>
<td>0.278</td>
<td>0.451</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
<td>(1.6)</td>
</tr>
<tr>
<td>Yard costs ($)</td>
<td>0.76</td>
<td>0.969</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
<td>(1.28)</td>
</tr>
<tr>
<td>Swing costs ($)</td>
<td>0.135</td>
<td>0.23</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
<td>(1.7)</td>
</tr>
<tr>
<td>Total ($)</td>
<td>1.173</td>
<td>1.65</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
<td>(1.41)</td>
</tr>
</tbody>
</table>

Notes

Larger trees, the larger payload Clearwater yarder, and minimally sized crews contributed to favourable net revenue. Silvicultural prescriptions also affected logging costs. Clearcut treatments and widely spaced commercial thin prescriptions enhanced logging production and reduced costs.
**STUDY:** Production and product recovery for complete tree utilization in the Northern Rockies. 
Mandzak, J.M., K.S. Milner, and J. Host (1983)

**Discussion**

This time and motion study examined the feasibility of a mechanized harvesting system under a variety of site conditions and silvicultural prescriptions. These researchers recorded production rates and costs identified with whole-tree felling, bunching, skidding, and processing (system productivity) of small-diameter stands in western Montana.

Feller-bunchers harvested 6- to 18-inch dbh trees; larger trees were felled by a sawyer. Skidders took the whole trees to a landing where a tree processor and whole-tree chipper (both grapple equipped) prepared products for logging trucks and chip vans.

**Yarding production factors identified**

Equipment production (feller-bunchers, skidders, tree processor, whole-tree chipper), machine utilization, crew size, site and stand attributes, silvicultural method.

**Principal variables**

- Dependent (response):
  - Logging production
- Independent (explanatory):
  - Silvicultural prescription (clearcut, shelterwood, commercial thin)
  - Site and stand conditions

**Analysis basis**

- Logging production: (tons/net worker hour of hog fuel and logs)
- Index: Logging production for clearcut set at 1.0
Example 1

**Characteristics**

The upper portion of Table 6 displays site and stand attributes associated with each cutting area. The lower portion of the table provides production data.

<table>
<thead>
<tr>
<th>Location:</th>
<th>Western Montana</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area harvested:</td>
<td>Clearcut nominally 13 acres</td>
</tr>
<tr>
<td></td>
<td>Shelterwood nominally 20 acres</td>
</tr>
<tr>
<td></td>
<td>Light commercial thin nominally 4.5 acres</td>
</tr>
<tr>
<td></td>
<td>Shelterwood (+ commercial thin) nominally 43 acres</td>
</tr>
<tr>
<td>Tree felling:</td>
<td>International Model 3966-B track-mounted feller-buncher; Melroe Bobcat Model 1079 feller-buncher</td>
</tr>
<tr>
<td>Whole-tree skidding:</td>
<td>Two John Deere Model 640 rubber-tired skidders (one with a grapple, the other with chokers)</td>
</tr>
<tr>
<td>Tree processor:</td>
<td>Hahn Tree-length Harvester</td>
</tr>
<tr>
<td>Whole-tree chipper:</td>
<td>Trelan Model DL-18</td>
</tr>
<tr>
<td>Log loading:</td>
<td>Truck-mounted hydraulic Husky Brute</td>
</tr>
</tbody>
</table>

**TABLE 6.** Logging production (tons/worker hour) by silvicultural prescription and site and stand attributes (from Mandzak et al. 1983)

<table>
<thead>
<tr>
<th>Silvicultural treatment</th>
<th>Clearcut</th>
<th>Shelterwood</th>
<th>Light commercial thin</th>
<th>Shelterwood (+ commercial thin)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site/stand attributes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td>Lodgepole pine</td>
<td>Ponderosa pine (western larch)</td>
<td>Western larch</td>
<td>Ponderosa pine--Douglas-fir</td>
</tr>
<tr>
<td>Trees/acre</td>
<td>452</td>
<td>363</td>
<td>558</td>
<td>290</td>
</tr>
<tr>
<td>Vol/acre (ft³)</td>
<td>5114</td>
<td>1197</td>
<td>4440</td>
<td>3556</td>
</tr>
<tr>
<td>BA/acre (ft²)</td>
<td>137</td>
<td>99</td>
<td>147</td>
<td>155</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>0-25</td>
<td>4</td>
<td>25</td>
<td>5</td>
</tr>
<tr>
<td>Max. skid (ft)</td>
<td>800</td>
<td>800</td>
<td>500</td>
<td>1000</td>
</tr>
<tr>
<td>Log size (bf)</td>
<td>62</td>
<td>50</td>
<td>97</td>
<td>84</td>
</tr>
<tr>
<td><strong>Analysis basis</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labour production</td>
<td>3.7</td>
<td>2.9</td>
<td>2.8</td>
<td>4.3</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
<td>(0.78)</td>
<td>(0.75)</td>
<td>(1.16)</td>
</tr>
</tbody>
</table>

**Notes**

Higher production was achieved on those units with a larger proportion of sawlogs (rather than chippable stems). Also, on the units with lower production, an overabundance of small stems tended to clog the landing (the chipper could not keep up) and limit the productivity of other equipment.

The authors concluded that the cutting method had little impact on the profitability of this logging system on these sites.
Study: Skyline logging productivity under alternative harvesting prescriptions and levels of utilization in larch-fir stands.

Discussion
This study examines skyline yarding productivity under a range of wood utilization options and silvicultural prescriptions. Silvicultural methods examined are clearcut, shelterwood, and group selection.

Three utilization levels are used in the following comparisons:
1. conventional sawlog;
2. close log utilization, trees (7-inch dbh); and
3. a more intensive close log utilization (5-inch dbh).

The following examples summarize skyline yarding productivity on steep slopes (45–60%) in larch-Douglas-fir stands in northwestern Montana. The examples used represent a harvested area of approximately 79 acres.

The author cautions that production comparisons between silvicultural methods should not be made due to differences in timber size and composition, stand density, landing conditions, and uphill and downhill yarding. He does not therefore draw conclusions about yarding productivity between silvicultural prescriptions.

Yarding production factors identified
Yarder production, cable configuration (live skyline, running skyline), machine utilization, external yarding distance, lateral yarding distance, slope, number of logs or weight or volume per turn, wood utilization, volume per acre harvested, average log volume, silvicultural cutting method.

Principal variables
- Dependent (response):
  Yarding production
- Independent (explanatory):
  Silvicultural prescription (clearcut, group selection, shelterwood)
  Level of utilization (conventional, intermediate, intensive)
  Site and stand conditions

Analysis basis
- Yarding production: (m³/hr)
- Index: Yarding production for clearcut set at 1.0
Example 1

**Characteristics**

This case summarizes uphill yarding production under alternative reproduction methods, using a Link Belt 78 rigged with a live skyline and a gravity return carriage.

**TABLE 7. Uphill live skyline yarding production (m$^3$/hr) by silvicultural method and site and stand attributes. Utilization: close log, trees (7-inch dbh) (from Gardner 1980).**

<table>
<thead>
<tr>
<th>Site/stand attributes</th>
<th>Silvicultural method</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clearcut</td>
<td>5.1–5.5</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>Group selection (2 blocks)</td>
<td>0.44</td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td>Shelterwood</td>
<td>155</td>
<td></td>
</tr>
<tr>
<td>Vol/acre harvested (mcf)</td>
<td>2.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log size (m$^3$)</td>
<td>0.37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg. yard (m)</td>
<td>149</td>
<td>98 and 160</td>
<td>155</td>
</tr>
<tr>
<td><strong>Analysis basis</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yarding production (m$^3$/hr)</td>
<td>14.2</td>
<td>13.3</td>
<td>9.1</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
<td>(0.94)</td>
<td>(0.64)</td>
</tr>
</tbody>
</table>

**Characteristics common to the next three examples**

These examples summarize yarding production for clearcut, group selection, and shelterwood regeneration methods using a running skyline on a Skagit GT-3 yarding uphill. The three tables abstract site and stand attributes and yarding production under three levels of wood utilization.

Example 2

**TABLE 8. Running skyline yarding production (m$^3$/hr) by silvicultural method and site and stand attributes. Utilization: conventional sawlog (from Gardner 1980).**

<table>
<thead>
<tr>
<th>Site/stand attributes</th>
<th>Silvicultural method</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clearcut</td>
<td>5.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Group selection</td>
<td>0.44</td>
<td>0.40</td>
<td>0.41</td>
</tr>
<tr>
<td></td>
<td>Shelterwood (2 blocks)</td>
<td>160</td>
<td>155 and 170</td>
<td></td>
</tr>
<tr>
<td>Vol/acre harvested (mcf)</td>
<td>3.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log size (m$^3$)</td>
<td>0.42</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg. yard (m)</td>
<td>146</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Analysis basis</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yarding production (m$^3$/hr)</td>
<td>28.0</td>
<td>14.2</td>
<td>13.6</td>
<td></td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
<td>(0.51)</td>
<td>(0.49)</td>
<td></td>
</tr>
</tbody>
</table>
Example 3

TABLE 9. Running skyline yarding production (m³/hr) by silvicultural method and site and stand attributes. Utilization: close log, tree (7-inch dbh) (from Gardner 1980).

<table>
<thead>
<tr>
<th>Site/stand attributes</th>
<th>Silvicultural method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clearcut</td>
</tr>
<tr>
<td>Vol/acre harvested (mcf)</td>
<td>5.8</td>
</tr>
<tr>
<td>Log size (m³)</td>
<td>0.42</td>
</tr>
<tr>
<td>Avg. yard (m)</td>
<td>146</td>
</tr>
<tr>
<td><strong>Analysis basis</strong></td>
<td></td>
</tr>
<tr>
<td>Yarding production (m³/hr)</td>
<td>17.6</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
</tr>
</tbody>
</table>

Example 4

TABLE 10. Running skyline yarding production (m³/hr) by silvicultural method and site and stand attributes. Utilization: close log, tree (5-inch dbh) (from Gardner 1980).

<table>
<thead>
<tr>
<th>Site/stand attributes</th>
<th>Silvicultural method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clearcut</td>
</tr>
<tr>
<td>Vol/acre harvested (mcf)</td>
<td>3.3</td>
</tr>
<tr>
<td>Log size (m³)</td>
<td>0.42</td>
</tr>
<tr>
<td>Avg. yard (m)</td>
<td>146</td>
</tr>
<tr>
<td><strong>Analysis basis</strong></td>
<td></td>
</tr>
<tr>
<td>Yarding production (m³/hr)</td>
<td>24.1</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
</tr>
</tbody>
</table>

Notes

The author draws no conclusions about the effect of silvicultural prescription on yarding productivity. As might be expected, yarding production is generally reduced where:

- group selection and shelterwood are the prescribed harvest cutting methods;
- volume per acre harvested is lower;
- smaller diameter trees are harvested;
- more intense wood utilization is prescribed; and
- yarding distance is greater.
4 SIMULATION: LOGGING PRODUCTION AND COSTS

4.1 Simulation Models

Simulation models enable an analyst to use relatively easily obtained information (such as external yarding distance and ground slope) to estimate harvesting costs or production. These models commonly use tables, equations, or computer spreadsheets to allow a user to simulate harvest costs on a given cutblock or timber sale. The logging production or cost data embedded in the simulation models come from experience gained during prior logging production studies.

To update harvest production costs, the USDA Forest Service and other agencies use either new time and motion studies (if available) or broad price indices such as the price deflator for the gross national product (Fight et al. 1984).

4.2 Simulation Examples

Authors featured in this section provide either procedures for simulating harvest costs or examples of harvesting costs using simulation methods:

1. Procedures for developing representative examples of logging costs: Fight et al. (1984) provide methods by which an analyst can use variables such as volume harvested per acre and average tree dbh to determine an estimate of harvesting costs.

2. Examples of simulated harvesting costs: Kramer and Conan (1985) and Brush¹ provide examples of harvest-related costs.

In most of these examples, cost components are made up of stump-to-truck harvest activities. One study (Kramer and Conan 1985) also features post-harvest cost centres such as slash disposal and erosion control.

---

STUDY: Logging costs for management planning for young-growth coast Douglas-fir.

Discussion

These researchers assembled equations, tables, and adjustment factors to assist silvicultural planners to estimate logging costs for representative stands. The methods are designed to work for clearcut and partial cut prescriptions for young-growth coast Douglas-fir stands.

The authors assembled equations that use independent variables (harvest cutting method, tree dbh, and volume per acre removed from a stand) to arrive at the dependent variable (yarding costs). They determined yarding costs using the THIN cable harvesting simulation model (LeDoux and Butler 1981). The costs simulated by this model are based on analysis of a Koller K300 harvesting logs up to 16 inches dbh, and a Washington 078 harvesting larger logs.

The researchers provide estimates of delays (non-productive time) associated with clearcut logging activities. To facilitate comparison, equations (or tables) can be used to estimate delays attributed to partial cut prescriptions.

According to the authors’ analyses, cutting method (clearcut versus partial cut) does not affect branding and loading costs; they ascribe increases in branding and loading costs to decreasing log diameter. Though the cost of branding, loading, moving-in, moving-out, rigging, and corridor changes are included in the cited study, they are not included in the simulations developed here.

Logging costs developed with this approach can be used in other simulators such as DFSIM with economics (Fight et al. 1984) and FORPLAN.2

According to Fight (pers. comm., 1992), Table 12 on page 7 (Fight et al. 1984) contains errors. Consequently, this particular table was not used in developing the examples shown below.

Cost centres identified

Felling, limbing, bucking, dbh, volume harvested per acre, external cable yarding distance, yarding equipment, delays.

Principal variables

- Dependent (response):
  - Felling cost
  - Yarding costs
  - Total costs

- Independent (explanatory):
  - Silvicultural prescription (clearcut, partial cut)
  - Average size of cut trees (dbh)
  - Average volume per acre removed from the stand (mcf)
  - Slope yarding distance (ft)

Analysis basis

- Simulated production costs: Felling (US$/mcf) Yarding (US$/mcf) Total (US$/mcf)

- Index: Costs for clearcut set at 1.0

---

Characteristics common to the next four examples

With the procedures described in Fight et al. (1984), estimated costs for clearcuts and partial cuts were established for this review and are portrayed in tables below. The following examples show logging costs for a range of log sizes and harvest volumes. The first two examples summarize the cost of logging 8- and 14-inch dbh trees; harvest volume per acre is 2 mcf in one table and 5 mcf in the other. Examples 3 and 4 summarize costs for harvesting bigger trees with a larger yarder.

Location: Western Oregon and Washington
Cover type: Young-growth Douglas-fir
Yarding distance: Average 500 ft; maximum 1200 ft
Costs: 1983 dollars

Example 1

Characteristics

In this simulation, 2 mcf/acre have been harvested from the stand. The trees harvested have a relatively small dbh; yarding costs are based on using the Koller K300.
Harvesting method: Koller K300 yarding uphill, gravity carriage

TABLE 11. Felling, limbing, bucking (F/L/B), cable yarding, and total costs (US$/mcf) by cutting method and tree size (simulations created following procedures developed by Fight et al. 1984)

<table>
<thead>
<tr>
<th>Analysis basis</th>
<th>Harvest cutting method</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Clearcut (8 in. dbh)</td>
<td>Partial cut (8 in. dbh)</td>
<td>Clearcut (14 in. dbh)</td>
<td>Partial cut (14 in. dbh)</td>
</tr>
<tr>
<td>F/L/B costs ($)</td>
<td>96</td>
<td>104</td>
<td>47</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
<td>(1.09)</td>
<td>(1.0)</td>
<td>(1.09)</td>
<td></td>
</tr>
<tr>
<td>Yard costs ($)</td>
<td>321</td>
<td>355</td>
<td>163</td>
<td>203</td>
<td></td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
<td>(1.13)</td>
<td>(1.0)</td>
<td>(1.10)</td>
<td></td>
</tr>
<tr>
<td>Total costs ($)</td>
<td>417</td>
<td>459</td>
<td>230</td>
<td>254</td>
<td></td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
<td>(1.10)</td>
<td>(1.0)</td>
<td>(1.10)</td>
<td></td>
</tr>
</tbody>
</table>
Example 2

In this example, 5 mcf/acre have been cut and yared from the stand. Again, costs are based on a Koller K300 yarding the relatively small trees in this example.

TABLE 12. Felling, limbing, bucking (F/L/B), cable yarding, and total costs (US$/mcf) by cutting method and tree size (simulations created from material provided by Fight et al. 1984)

<table>
<thead>
<tr>
<th>Analysis basis</th>
<th>Clearcut (8 in. dbh)</th>
<th>Partial cut (8 in. dbh)</th>
<th>Clearcut (14 in. dbh)</th>
<th>Partial cut (14 in. dbh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F/L/B costs ($) (index)</td>
<td>96 (1.0)</td>
<td>96 (1.0)</td>
<td>47 (1.0)</td>
<td>47 (1.0)</td>
</tr>
<tr>
<td>Yard costs ($) (index)</td>
<td>316 (1.0)</td>
<td>319 (1.0)</td>
<td>178 (1.0)</td>
<td>180 (1.0)</td>
</tr>
<tr>
<td>Total costs ($) (index)</td>
<td>412 (1.0)</td>
<td>415 (1.0)</td>
<td>225 (1.0)</td>
<td>227 (1.0)</td>
</tr>
</tbody>
</table>

Example 3

**Characteristics**

In this simulation, 2 mcf/acre have been harvested. Average tree sizes are relatively large and the simulation bases its costs on the Washington 078 yarder.

Harvesting method: Washington 078 running skyline yarding uphill

TABLE 13. Felling, limbing, bucking (F/L/B), cable yarding, and total costs (US$/mcf) by cutting method and tree size (simulation developed from data provided by Fight et al. 1984)

<table>
<thead>
<tr>
<th>Analysis basis</th>
<th>Clearcut (18 in. dbh)</th>
<th>Partial cut (18 in. dbh)</th>
<th>Clearcut (24 in. dbh)</th>
<th>Partial cut (24 in. dbh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F/L/B costs ($) (index)</td>
<td>32 (1.0)</td>
<td>35 (1.09)</td>
<td>20 (1.0)</td>
<td>22 (1.1)</td>
</tr>
<tr>
<td>Yard costs ($) (index)</td>
<td>174 (1.0)</td>
<td>192 (1.14)</td>
<td>129 (1.0)</td>
<td>142 (1.10)</td>
</tr>
<tr>
<td>Total costs ($) (index)</td>
<td>206 (1.0)</td>
<td>227 (1.10)</td>
<td>149 (1.0)</td>
<td>166 (1.11)</td>
</tr>
</tbody>
</table>
Example 4

The following table summarizes simulated logging costs when 5 mcf/acre are cut and yarded from the stand. In this simulation, relatively large trees are harvested with the Washington 078 yader.

TABLE 14. Felling, limbing, bucking (F/L/B), cable yarding, and total costs (US$/mcf) by cutting method and tree size (simulation developed from material presented in Fight et al. 1984)

<table>
<thead>
<tr>
<th>Analysis basis</th>
<th>Harvest cutting method (average tree dbh)</th>
<th>Clearcut (18 in. dbh)</th>
<th>Partial cut (18 in. dbh)</th>
<th>Clearcut (24 in. dbh)</th>
<th>Partial cut (24 in. dbh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F/L/B costs ($)</td>
<td></td>
<td>32 (1.0)</td>
<td>33 (1.03)</td>
<td>20 (1.0)</td>
<td>20 (1.0)</td>
</tr>
<tr>
<td>(index)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yard costs ($)</td>
<td></td>
<td>156 (1.0)</td>
<td>157 (1.01)</td>
<td>111 (1.0)</td>
<td>112 (1.01)</td>
</tr>
<tr>
<td>(index)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total costs ($)</td>
<td></td>
<td>188 (1.0)</td>
<td>190 (1.01)</td>
<td>131 (1.0)</td>
<td>132 (1.01)</td>
</tr>
<tr>
<td>(index)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes

The authors provide ranges (volume per acre harvested and dbh) within which the logging cost equations and tables are valid.

Observe that the cost index of partial cutting approaches that of clearcutting when the volume cut per acre is 5 mbf. The authors attribute the same yarding costs to clearcuts and partial cuts when the volume harvested per acre exceeds 5.4 mcf/acre. Felling, limbing, and bucking costs for clearcut and partial cut units are the same when the volume harvested per acre is greater than 4.3 mcf/acre.

Discussion
Kramer and Conan (1985) developed appraisals that simulate costs of treatments on clearcut and shelterwood cutting units. The authors follow cost appraisal procedures detailed in USDA Forest Service Timber Sale Appraisal Handbook 2409.26. The shelterwood harvesting costs reflect a weighted average of the regeneration cut and the overstory removal cut.

Cost centres identified
Felling and bucking, aerial and ground skidding, loading, equipment depreciation, slash disposal, erosion control, temporary roads, regeneration costs.

Principal variables
• Dependent (response):
  Production costs
• Independent (explanatory):
  Silvicultural prescription (clearcut, shelterwood)
  Harvesting method (cable, tractor)

Analysis basis
• Simulated: Production costs (US$/mbf)
• Index: Cost of clearcut set at 1.0

Characteristics common to the next two examples
Location: Southwest Oregon
Gross volume per acre: 42 mbf
Area harvested: Clearcut 30 acres
Shelterwood 30 acres
Costs: USDA Forest Service Timber Sale Appraisal Handbook 2409.26
Example 1

**Characteristics**

Table 15 contrasts the cost of logging typical steep southwest Oregon cutting units by clearcut and shelterwood reproduction methods. The Madill 071 yarder is capable of harvesting large logs found in southwest Oregon.

Slope: 45%

Harvesting method: Madill 071 skyline yarder

**TABLE 15.** Total production costs (US$/m$) by reproduction method. This case simulates cable yarding (from Kramer and Conan 1985).

<table>
<thead>
<tr>
<th>Analysis basis</th>
<th>Reproduction method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clearcut</td>
</tr>
<tr>
<td>Production costs ($)</td>
<td>90.73</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
</tr>
</tbody>
</table>

Example 2

**Characteristics**

This case contrasts the cost of harvesting on gentle slopes by clearcut and shelterwood reproduction methods.

Slope: 20%

Harvesting method: Caterpillar D-7

**TABLE 16.** Total production costs (US$/m$) by reproduction method. This example simulates tractor skidding (from Kramer and Conan 1985).

<table>
<thead>
<tr>
<th>Analysis basis</th>
<th>Reproduction method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clearcut</td>
</tr>
<tr>
<td>Production costs ($)</td>
<td>77.93</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
</tr>
</tbody>
</table>

**Notes**

The authors feel that the logging cost trend shown by these skyline and tractor examples will remain constant.
STUDY: Estimator for clear-cut and shelterwood yarding cost difference.
Brush, L. (1984)³

Brush contrasts the logging costs identified with clearcut and shelterwood cutting methods and provides a summary of the present value (PV) of harvesting costs. In the following example, the author used tables detailing production costs for clearcut and partial cut logging. The tables reflect USDA Forest Service Pacific Northwest Region cost data adapted for local use by the Bureau of Land Management, Medford District.

Cost centres identified
Cable yarding, external yarding distance, volume per acre harvested, number of landings required, loading, yarder move-in, rig landing, yarding equipment, loading.

Principal variables
- Dependent (response):
  PV - harvesting and loading costs
- Independent (explanatory):
  Silvicultural prescription (clearcut, shelterwood)
  Harvesting method (highlead, skyline)

Analysis basis
- Simulated: PV - harvesting and loading costs (US$/acre)
- Index: Cost of clearcut set at 1.0

Example 1

Characteristics

This example compares the PV of the harvesting costs of a one-entry clearcut with that of a two-entry shelterwood (the overstory trees are removed after 5 years). The shelterwood and clearcut regeneration cuts required five landings. To protect the advanced regeneration, the shelterwood overstory removal required 11 landings.

The highlead cable system is commonly used on clearcut units; a skyline system is required to harvest partially cut stands. The Madill 071 used in this simulation can be rigged as either a highlead or skyline system.

<table>
<thead>
<tr>
<th>Location:</th>
<th>Southwest Oregon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cover type:</td>
<td>Primarily Douglas-fir</td>
</tr>
<tr>
<td>Volume/acre harvested:</td>
<td>40 mbf in clearcut; same in shelterwood after the shelterwood overstory is removed in year 5</td>
</tr>
<tr>
<td>Average dbh (range):</td>
<td>29 inches (28–60 inches)</td>
</tr>
<tr>
<td>Slope:</td>
<td>Steep</td>
</tr>
<tr>
<td>Area harvested:</td>
<td>Clearcut 28 acres</td>
</tr>
<tr>
<td></td>
<td>Shelterwood 28 acres</td>
</tr>
<tr>
<td>Harvesting method:</td>
<td>Madill 071 yarder</td>
</tr>
<tr>
<td>Interest rate:</td>
<td>7.875%</td>
</tr>
<tr>
<td>Costs:</td>
<td>Bureau of Land Management, Medford District production costs</td>
</tr>
</tbody>
</table>

TABLE 17. Present value (US$/acre) of harvesting and loading costs by reproduction method

<table>
<thead>
<tr>
<th>Analysis basis</th>
<th>Reproduction method (cable system)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clearcut (highlead)</td>
</tr>
<tr>
<td>PV of costs ($)</td>
<td>1256</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
</tr>
</tbody>
</table>

*a Brush, 1984.*
STUDY: Estimating production rates and operating costs of timber harvesting equipment in the Northern Rockies.

Discussion
This paper summarizes logging system information gathered by the Intermountain Forest and Range Experiment Station over a period of 15 years. Using this data, Gardner has assembled tables, equations, and procedures for analysts to estimate the harvest production of yarding systems (running skyline, live skyline) associated with alternative silvicultural methods.

Examples that use Gardner’s methods and tables to estimate uphill yarding production are shown below.

Cost centres identified
Running skyline yarding, live skyline yarding, yarding distance, piece size, lateral yarding distance, weight per turn of logs, number of logs per turn, productive time of the yarder, silvicultural method.

Principal variables
- Dependent (response):
  Turn time
- Independent (explanatory):
  Silvicultural prescription (clearcut, shelterwood, group selection)
  Lateral yarding distance
  External yarding distance
  Weight per turn of logs
  Number of logs per turn
  Slope
  Volume per log

Analysis basis
- Simulated: Yarding production (turn time)
- Index: Yarding production of clearcut set at 1.0

Characteristics common to the next two examples
Location: Northern (U.S.) Rockies
Average yarding distance: 500 ft
Average lateral yarding distance: 50 ft
Average piece size: 0.37 m³
Average weight per turn: 1361 kg
Average logs per turn: 4.5
Yarder productivity: 0.67
Average slope: 52%
Example 1

TABLE 18. Uphill running skyline production (time/turn) by reproduction method (from Gardner 1982)

<table>
<thead>
<tr>
<th>Analysis basis</th>
<th>Silvicultural method</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clearcut</td>
<td>Group selection</td>
<td>Shelterwood</td>
</tr>
<tr>
<td>Yarding turn time (min)</td>
<td>5.661</td>
<td>6.026</td>
<td>5.962</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
<td>(1.06)</td>
<td>(1.05)</td>
</tr>
</tbody>
</table>

Example 2

TABLE 19. Uphill live skyline production (time/turn) by reproduction method (from Gardner 1982)

<table>
<thead>
<tr>
<th>Analysis basis</th>
<th>Silvicultural method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clearcut</td>
</tr>
<tr>
<td>Yarding turn time (min)</td>
<td>6.331</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
</tr>
</tbody>
</table>
5 SIMULATION: FINANCIAL ANALYSIS OF A SERIES OF MANAGEMENT ACTIVITIES OVER TIME

Previous sections have focussed on costs and production related to only the harvesting of stands. Section 5 is not limited to harvesting costs alone.

5.1 Silvicultural Systems

The studies featured in this section contrast relative cash flows associated with partial cut and clearcut silvicultural treatments over a full rotation. Researchers set up schedules of management treatments (such as harvesting, site preparation, and thinnings) during the life of stands used in the examples. Treatment costs and harvest revenues are derived from local Pacific Northwest experience.

5.2 Economic Measures

Research featured in this section uses NPV, SEV, and NPA to describe and compare relative economic values of clearcut and partial cut alternatives.

5.3 Examples

Tesch and Mann (1991) and Brodie (1985) provide a diverse range of examples examining cash flows over time.
STUDY: Clearcut and shelterwood reproduction methods for regenerating southwest Oregon forests.
Tesch, S.D and J.W. Mann (1991)

Discussion

Tesch and Mann (1991) provide detailed analyses of the cash flows associated with clearcut and shelterwood silvicultural systems. Three examples examine the effect of reproduction method and a series of silvicultural treatments on NPV, SEV, and NPA over full rotations.

The authors assume: the management objective is timber production; artificial regeneration is used with both clearcut and shelterwood prescriptions; and both reproduction systems are ecologically and physically feasible on the site.

The researchers point out that site-specific economic analyses must be conducted for any series of prescribed treatments. The methods described by Tesch and Mann provide one tool for such an analysis.

Principal variables

- Dependent (response):
  - NPV – existing stand
  - NPV – first rotation (in one example)
  - SEV – future rotations
  - NPA

- Independent (explanatory):
  - Silvicultural prescription (clearcut, shelterwood)
  - Harvesting method (cable, tractor)

Analysis basis

- Simulated: NPV (US$/acre)
  SEV (US$/acre)
  NPA (US$/acre)
- Index: NPV, SEV, and NPA of clearcut are set at 1.0

Characteristics common to the next three examples

Location: Southwest Oregon
Costs: USDA Forest Service District experience
Example 1

Characteristics
This case simulates a financial analysis of a USDA Forest Service prescription (McCrimmon 1986, cited by Tesch and Mann 1991) for a 60-acre uneven-aged stand that will be converted to even-aged management. In this example, both the clearcut and the shelterwood will be clearcut and planted at the end of the rotation. The NPV of the first rotation has therefore been included in Table 20 below.

Cover type: Uneven-aged mixed conifer
Volume/acre harvested: 16.4 mbf from clearcut; 18.5 mbf from shelterwood includes the overstory removal at year 6
Slope: Relatively flat
Harvesting method: Tractor
Interest rate: 4%
Rotation length: Both the clearcut and shelterwood will be clearcut in year 83
Revenues: Timber values are assumed to increase at 1% per year for the next 50 years

Cost and revenue centres identified
Clearcut: Year 0 regeneration cut, post-logging survey, slash plant, release (backpack spray), survey stocking
1 pre-commercial thin
13 commercial thin
50 clearcut
83
Shelterwood: Year 0 regeneration cut, post-logging survey, slash plant, release (backpack spray), survey stocking
1 remove overstory, post-logging survey
6 replant, survey stocking
7 pre-commercial thin
13 commercial thin
50 clearcut
83

TABLE 20. Net present value, soil expectation value, and net present amount (US$/acre) by reproduction method (from Tesch and Mann 1991)

<table>
<thead>
<tr>
<th>Analysis basis</th>
<th>Reproduction method</th>
<th>Clearcut</th>
<th>Shelterwood</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPV existing stand ($)</td>
<td></td>
<td>1853</td>
<td>1905</td>
</tr>
<tr>
<td>(index)</td>
<td></td>
<td>(1.0)</td>
<td>(1.03)</td>
</tr>
<tr>
<td>NPV first rotation ($)</td>
<td></td>
<td>-8</td>
<td>-8</td>
</tr>
<tr>
<td>(index)</td>
<td></td>
<td>(1.0)</td>
<td>(1.0)</td>
</tr>
<tr>
<td>SEV future rotations ($)</td>
<td></td>
<td>-254</td>
<td>-392</td>
</tr>
<tr>
<td>(index)</td>
<td></td>
<td>(1.0)</td>
<td>(0.65)</td>
</tr>
<tr>
<td>NPA ($)</td>
<td></td>
<td>1591</td>
<td>1505</td>
</tr>
<tr>
<td>(index)</td>
<td></td>
<td>(1.0)</td>
<td>(0.95)</td>
</tr>
</tbody>
</table>
Notes

The NPV of the existing stand is higher for the shelterwood alternative than for the clearcut. Logging costs (and stumpage) were assumed to be the same for both alternatives because designated skidtrails were used with the clearcut and the shelterwood regeneration cut. The shelterwood overstory trees are assumed to grow and increase in stumpage value until they are removed during year 6.

It was assumed that 20% of the unit would require replanting after the shelterwood overstory removal. Thus the NPV of the first rotation is more negative for the shelterwood than for the clearcut.

Costs incurred early in a rotation have a large impact on the economic results. Replanting after shelterwood overstory removal is the primary reason for favouring clearcut over shelterwood in Example 1. However, the authors note that if the clearcut also needs replanting (due to the harshness of the site), the financial advantage exhibited by this alternative might be depleted.

Because both alternatives revert to clearcut-and-plant scenarios after the first rotation, the SEV for the first rotation is the same.
Example 2

**Characteristics**

Table 21 summarizes a financial analysis of a USDA Forest Service prescription (Craig 1980, cited by Tesch and Mann 1991) for an old-growth stand. This example assumes that at the end of the next rotation, the clearcut will again be clearcut, and that the site harvested by shelterwood will again be prescribed for harvesting by that method.

- **Cover type:** Primarily Douglas-fir
- **Volume/acre harvested:** 36 mbf from clearcut; 36 mbf from shelterwood includes the overstory removal at year 6
- **Slope:** 50%
- **Harvesting method:** Cable
- **Interest rate:** 5%
- **Rotation length:** Regeneration cut on shelterwood and clearcut in year 90; shelterwood overstory removal in year 96
- **Revenues:** Assumes no increase in value of the overstory shelterwood trees during the 6 years they remain standing. Timber values for future stands are assumed to increase at 2% per annum for the next 60 years

**Cost and revenue centres identified**

<table>
<thead>
<tr>
<th>Clearcut:</th>
<th>Year</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>regeneration cut, broadcast burn</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>plant with animal protection</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>release (aerial spray)</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>pre-commercial thin, treat slash</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>thin, treat slash</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>thin, treat slash</td>
</tr>
<tr>
<td></td>
<td>75</td>
<td>thin, treat slash</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>clearcut, broadcast burn</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shelterwood:</th>
<th>Year</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>regeneration cut, underburn</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>plant with animal protection</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>remove overstory, treat slash</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>replant</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>release (aerial spray)</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>pre-commercial thin, treat slash</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>thin, treat slash</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>thin, treat slash</td>
</tr>
<tr>
<td></td>
<td>75</td>
<td>thin, treat slash</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>shelterwood regeneration cut, underburn</td>
</tr>
<tr>
<td></td>
<td>96</td>
<td>remove overstory, treat slash</td>
</tr>
</tbody>
</table>
TABLE 21. Net present value, soil expectation value, and net present amount (US$/acre) by reproduction method (from Tesch and Mann 1991)

<table>
<thead>
<tr>
<th>Analysis basis</th>
<th>Reproduction method</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clearcut</td>
<td>Shelterwood</td>
<td></td>
</tr>
<tr>
<td>NPV existing stand ($)</td>
<td>13,165</td>
<td>8,786</td>
<td></td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
<td>(0.67)</td>
<td></td>
</tr>
<tr>
<td>SEV future rotations ($)</td>
<td>+477</td>
<td>+288</td>
<td></td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
<td>(0.60)</td>
<td></td>
</tr>
<tr>
<td>NPA ($)</td>
<td>13,642</td>
<td>9,074</td>
<td></td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
<td>(0.67)</td>
<td></td>
</tr>
</tbody>
</table>

Notes
The NPV of the shelterwood is lower than that of the clearcut because shelterwood costs are higher for cable-logging, burning, and handpiling and replanting after overstory removal.
Example 3

**Characteristics**

This example summarizes the financial analysis of a USDA Forest Service prescription (Teubner 1983, cited by Tesch and Mann 1991). The case assumes that at the end of the next rotation, the area clearcut will again be clearcut and that the site harvested by shelterwood will again be prescribed with a shelterwood regeneration method.

- **Cover type:** Primarily Douglas-fir and white fir
- **Volume/acre harvested:** 33.8 cunits in clearcut; same in shelterwood after overstory is removed in year 8
- **Slope:** 40%
- **Harvesting method:** Cable
- **Interest rate:** 4%
- **Rotation length:** Shelterwood and clearcut regeneration cuts in year 117; shelterwood overstory removal in year 125
- **Revenues:** Future revenues are based on current values

**Cost and revenue centres identified**

<table>
<thead>
<tr>
<th>Clearcut:</th>
<th>Year</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>regeneration cut</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>broadcast burn</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>plant, bait gophers</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>release (aerial spray)</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>pre-commercial thin, handpile slash</td>
</tr>
<tr>
<td></td>
<td>57</td>
<td>thin, handpile slash</td>
</tr>
<tr>
<td></td>
<td>77</td>
<td>thin, handpile slash</td>
</tr>
<tr>
<td></td>
<td>97</td>
<td>thin, handpile slash</td>
</tr>
<tr>
<td></td>
<td>117</td>
<td>clearcut</td>
</tr>
<tr>
<td></td>
<td>119</td>
<td>broadcast burn</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shelterwood:</th>
<th>Year</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>regeneration cut</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>underburn</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>plant, bait gophers</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>release (aerial spray)</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>remove overstory, handpile slash</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>pre-commercial thin, handpile slash</td>
</tr>
<tr>
<td></td>
<td>57</td>
<td>thin, handpile slash</td>
</tr>
<tr>
<td></td>
<td>77</td>
<td>thin, handpile slash</td>
</tr>
<tr>
<td></td>
<td>97</td>
<td>thin, handpile slash</td>
</tr>
<tr>
<td></td>
<td>117</td>
<td>shelterwood regeneration cut</td>
</tr>
<tr>
<td></td>
<td>119</td>
<td>underburn</td>
</tr>
<tr>
<td></td>
<td>125</td>
<td>remove overstory, handpile slash</td>
</tr>
</tbody>
</table>
TABLE 22. Net present value, soil expectation value, and net present amount (US$/acre) by reproduction method (from Tesch and Mann 1991)

<table>
<thead>
<tr>
<th>Analysis basis</th>
<th>Reproduction method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clearcut</td>
</tr>
<tr>
<td>NPV present stand ($)</td>
<td>3278</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
</tr>
<tr>
<td>SEV future rotations ($)</td>
<td>-213</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
</tr>
<tr>
<td>NPA ($)</td>
<td>3065</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
</tr>
</tbody>
</table>

Notes

The main differences between the alternatives are:

- The most valuable shelterwood trees were retained as overstory and discounted to the present.
- Burning costs were higher for the shelterwood.
- Planting costs were higher for the clearcut.
- After the shelterwood overstory removal, handpiling of slash was required.

In Examples 2 and 3, note that the shelterwood alternatives are given longer rotations (6–8 years until the shelterwood overstory is removed). Since there are significant costs early in the rotation (such as pre-commercial thinning), the shelterwood is obviously going to be at an economic disadvantage when analyzing NPV and SEV. It would be interesting to compare these prescriptions if the shelterwood and clearcut both had the same rotation length.
STUDY: Economic analysis of shelterwood versus clearcut decisions. 
Brodie, J.D. (1985)

Discussion

Brodie used a stand simulator (Curtis et al. 1981), a subsequent economic version of that simulator (Fight et al. 1984), and a 4% interest rate to compare PNW and SEV for shelterwood and clearcut regimes over full rotations. The method is replicated on a good site and a poor site in south coastal Oregon Douglas-fir stands.

Brodie then compared the stumpage netted by the single harvest clearcut and the double-harvest shelterwood. This compares the PNW of the immediate clearcut harvest with the PNW of the shelterwood regeneration cut and the overstory removal 10 years later. Brodie discusses the implications of examining the cash flow in these distinct manners.

In all cases, the author assumed no regeneration cost at the beginning of the rotation. At the end of the analysis, Brodie contemplated planting expenditures for the clearcut. He considered the per-acre PNW dollar difference between the clearcut and the shelterwood to be the funds that could be used for planting the clearcut. This difference he referred to as the “planting bonus.”

Principal variables for the first two examples

- Dependent (response):
  PNW of a regime of treatments over a full rotation
  SEV
- Independent (explanatory):
  Prescribed (clearcut, shelterwood) treatments over a full rotation
  Site quality (site index in feet at 100 years)

Analysis basis

- Simulated: PNW (US$/acre) of cash flows over a full rotation
  SEV (US$/acre)
- Index: PNW and SEV of clearcut are set at 1.0
- “Planting bonus” (US$/acre)
Example 1

**Characteristics**

Table 23 contrasts the PNW and SEV of alternative silvicultural regimes on a good site.

| Site index: | Site 115 (mid-site III, a favourable growing opportunity in southern Oregon) |
| Rotation length: | Clearcut and shelterwood regeneration cuts in year 70; shelterwood overstory removal in year 80 |

**Cost and revenue centres identified**

<table>
<thead>
<tr>
<th>Clearcut:</th>
<th>Year</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>pre-commercial thin</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>commercial thin</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>clearcut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shelterwood:</th>
<th>Year</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>pre-commercial thin</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>commercial thin</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>shelterwood regeneration cut</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>remove overstory</td>
</tr>
</tbody>
</table>

TABLE 23. Present net worth and soil expectation value (US$/acre) by reproduction method on a good site. This case uses a full rotation for comparison (from Brodie 1985).

| Analysis basis | Reproduction method |
| --- | --- | --- |
| | Clearcut | Shelterwood |
| PNW ($) | 839.80 | 764.65 |
| (index) | (1.0) | (0.91) |
| SEV($) | 897.52 | 799.37 |
| (index) | (1.0) | (0.89) |
| Per acre *planting bonus*($) | 91.85 | — |
Example 2

**Characteristics**

This case contrasts clearcut and shelterwood cash flows, PNW, and SEV for a regime of treatments over a full rotation on a poor site.

Site index: Site 70 (mid-site V, a harsh marginal site in southern Oregon)

Rotation length: Clearcut and shelterwood regeneration cuts in year 90; shelterwood overstory removal in year 100

**Cost and revenue centres identified**

<table>
<thead>
<tr>
<th>Clearcut: Year</th>
<th>0</th>
<th>—</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15</td>
<td>pre-commercial thin</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>commercial thin</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>clearcut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shelterwood: Year</th>
<th>0</th>
<th>—</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15</td>
<td>pre-commercial thin</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>commercial thin</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>shelterwood regeneration cut</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>remove overstory</td>
</tr>
</tbody>
</table>

TABLE 24. Present net worth and soil expectation value (US$/acre) by reproduction method on a poor site. This example compares shelterwood and clearcut over a full rotation (from Brodie 1985).

<table>
<thead>
<tr>
<th>Analysis basis</th>
<th>Reproduction method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clearcut</td>
</tr>
<tr>
<td>PNW ($)</td>
<td>149.66</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
</tr>
<tr>
<td>SEV($)</td>
<td>154.17</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
</tr>
<tr>
<td>Per acre &quot;planting bonus&quot;($)</td>
<td>22.31</td>
</tr>
</tbody>
</table>

**Principal variables for the next two examples**

- Dependent (response):
  - PNW of net stumpage
- Independent (explanatory):
  - Silvicultural cutting prescription (clearcut, shelterwood)
  - Site quality (site index in feet at 100 years)

**Analysis basis**

- Simulated: PNW (US$/acre) of cash flows over the next 10 years
- Index: PNW of clearcut is set at 1.0
- "Planting bonus" (US$/acre)
Example 3

Characteristics

Table 25 contrasts the PNW of the net stumpage derived from alternative cutting methods over a 10-year period on a good site.

Site index: Site 115 (mid-site III, a favourable growing opportunity in southern Oregon)

Rotation length: Not considered in this case

Revenue centres identified

| Clearcut: | Year | 0 | clearcut |
| Shelterwood: | Year | 0 | shelterwood regeneration cut |
| | | 10 | remove overstory |

TABLE 25. Present net worth (US$/acre) over one decade by cutting method on a good site (from Brodie 1985)

<table>
<thead>
<tr>
<th>Analysis basis</th>
<th>Clearcut</th>
<th>Shelterwood</th>
</tr>
</thead>
<tbody>
<tr>
<td>PNW ($) (index)</td>
<td>9380 (1.0)</td>
<td>8209 (0.88)</td>
</tr>
<tr>
<td>Per acre “planting bonus” ($)</td>
<td>1171</td>
<td></td>
</tr>
</tbody>
</table>
Example 4

*Characteristics*

This case contrasts the PNW of the net stumpage of alternative cutting methods over a 10-year period on a poor site.

Site index: Site 70 (mid-site V, a harsh marginal site in southern Oregon)

Rotation length: Not considered in this case

*Revenue centres identified*

<table>
<thead>
<tr>
<th>Clearcut:</th>
<th>Year</th>
<th>0</th>
<th>clearcut</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shelterwood:</td>
<td>Year</td>
<td>0</td>
<td>shelterwood regen.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>remove overstory</td>
</tr>
</tbody>
</table>

TABLE 26. Present net worth (US$/acre) over one decade by cutting method on a poor site (from Brodie 1985)

<table>
<thead>
<tr>
<th>Analysis basis</th>
<th>Clearcut</th>
<th>Shelterwood</th>
</tr>
</thead>
<tbody>
<tr>
<td>PNW ($)</td>
<td>6720</td>
<td>5936</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
<td>(0.88)</td>
</tr>
<tr>
<td>Per acre &quot;planting bonus&quot;($)</td>
<td>784</td>
<td></td>
</tr>
</tbody>
</table>

*Notes*

The first two examples show the "planting bonus" to be less than would be required to regenerate a clearcut by planting. The third and fourth examples consider the PNW only over the first 10 years. In these cases, the "planting bonus" is sufficient to regenerate the clearcut by planting.
6 APPRAISAL METHODS IN THE U.S. PACIFIC NORTHWEST

6.1 USDA Forest Service Northern Region

The USDA Forest Service Northern Region (R-1) uses a Transaction Evidence (TE) appraisal model. (The region consists of Montana, northern Idaho, and North Dakota.) The model equation predicts the high bid value for timber sales, based on such independent variables as the size of the sale offered, yarding method, lumber prices by species, tree size, uncut volume currently under contract to buyers, adjustments for each National Forest, and other less significant variables (Hedges and Niccolucci 1992).

Although analysts in the Northern Region have examined the influence of partial cutting and clearcut prescriptions on predicted bid prices, the magnitude of this effect is statistically insignificant. Thus, the current TE model does not specifically address the impact of partial cutting on bid prices. In preparation for a TE update, analysts will watch for this effect (J. Hedges, Valuation Assistant, USDA Forest Service, Northern Region, pers. comm., 1992).

Although the Residual Value Appraisal approach is used only in special circumstances, current procedures used in the Northern Region make no adjustments for partial cutting prescriptions (USDA Forest Service 1991b). Northern Region stump-to-mill costs are determined for broad average conditions and are then adjusted to the conditions being appraised. These broad regional costs are first adjusted considering the number of logs/mbf. Subsequent cost adjustments relate to:

- felling and bucking (adjustments for tree size, tree density, slope, and defect)
- tractor skidding (adjustments for net volume/acre, log size, average external skidding distance, and scaling defect)

A 1986 amendment of the Northern Region Timber Appraisal Handbook (USDA Forest Service 1986) included a formula to adjust constructed operating costs for timber sales containing partial cuts. A regression equation was developed by sampling skyline operations; the equation yielded what was referred to as an “F” factor (known colloquially as a “fudge” factor). The “F” factor was a function of the gross logs per mbf and the proportion of merchantable trees cut from the stand. The resulting value was entered into an equation that incorporated scaling defect, skyline costs for the zone, and depreciation costs.

An example illustrating use of the “F” factor is in the 1986 Handbook:

Example 1

**Principal variables**

- Dependent (response):
  - Appraised costs
- Independent (explanatory):
  - Silvicultural prescription (proportion of merchantable trees cut from the stand)
  - Harvesting method (yarding or skid method)
  - Log size (no. of logs/mbf)
  - Defect
  - Operating cost for the zone
  - Depreciation

**Analysis basis**

- Appraised costs (US$/mbf)
- Index: Costs of clearcut are set at 1.0
Characteristics
This example contrasts the appraised cost of skyline logging a clearcut and a partial cut. The results are constructed from formulae in the 1986 Timber Appraisal Handbook. Move-in, move-out, rigging, and hauling costs are not included in this example.

Zone location: Northern Idaho, western Montana
Log size: 14 logs/mbf
Harvesting method: Single span skyline
External yarding distance: plus or minus 2000 ft
Scaling defect: 8%
Costs: 1986 USDA Forest Service Northern Region, Timber Appraisal Handbook

TABLE 27. Appraised cost of skyline yarding by cutting method (from USDA Forest Service 1986)

<table>
<thead>
<tr>
<th>Analysis basis</th>
<th>Clearcut (all 100 merch. trees/acre cut)</th>
<th>Partial cut (60 of 100 merch. trees/acre cut)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appraised cost ($)</td>
<td>58.62</td>
<td>69.83</td>
</tr>
<tr>
<td>(index)</td>
<td>(1.0)</td>
<td>(1.19)</td>
</tr>
</tbody>
</table>

6.2 USDA Forest Service Pacific Northwest Region

Though the Pacific Northwest Region (R-6) has considered switching to a TE method, it still uses a Residual Value Appraisal approach (J. Hedges, pers. comm., 1992). The current amendment of the R-6 Timber Appraisal Handbook makes no adjustments on the basis of partial cutting prescriptions. The handbook does, however, refer to partial cuts for helicopter sales. If a helicopter timber sale meets several key criteria, and if the volume removed exceeds 50% of the stand to be cut, the cost/mbf of a partial cut is the same as for a clearcut (USDA Forest Service 1991a).
7 OTHER SILVICULTURAL TREATMENTS

In examining alternative silvicultural regimes, few researchers have compared the relative cost differences of treatments such as slash disposal, site preparation, planting, and vegetation management that may be needed during a full rotation.

7.1 Slash Disposal and Site Preparation

Not many researchers mention the relative cost differences for slash disposal and site preparation associated with alternative silviculture treatments.

Tesch and Mann (1991) cite underburning and broadcast burning costs from the Bureau of Land Management and the USDA Forest Service Pacific Southwest Region (R-5). Broadcast burning costs on clearcuts range between US$175 and 400 per acre; costs for underburning beneath a shelterwood overstory range from US$195 to 400 per acre (1982–1990 estimates). Though underburns require slow ignition, broadcast burn costs have been increasing due to air-quality regulations and mop-up concerns. Earlier estimates by Shepard and Larsen (1985) indicate that underburning increases costs (over broadcast burning) by about US$100 per acre.

After a shelterwood overstory removal, if slash disposal is necessary, handpiling or handpiling and burning may be required. Handpiling estimates range from US$30 to 685 per acre; burning the piles ranges in cost from US$30 to 60 per acre (Tesch and Mann 1991). Tesch and Mann (1991) discuss techniques that can be implemented after the shelterwood regeneration cut, thus minimizing slash abatement costs following the overstory removal.

7.2 Artificial Regeneration

Brodie (1985) projects and compares the PNW of clearcut and shelterwood regimes over a full rotation on two different sites. By assuming a zero regeneration cost for both silvicultural treatments, he is able to infer (by subtracting the PNW of the shelterwood from that of the clearcut) the amount of money available for planting the clearcut. His simulation indicates that, on both the poor site and the good site, the funds available for planting are insufficient for regenerating the clearcut.

Then, instead of assuming a whole rotation, Brodie changes the rules and estimates near-term (10-year) scenarios. In these cases, the clearcut and plant options are very attractive.

7.3 Vegetation Management

Though there has been an injunction against the use of herbicides by public agencies on federal lands since 1982, Shepard and Larsen (1985) indicate that, with the exception of aerial application of herbicides, vegetation management costs and effectiveness are about the same on both clearcut and shelterwood sites. Helicopter application of herbicides over a shelterwood overstory is costlier, more dangerous for the pilot, and possibly less effective around leave trees.

Labour-intensive backpack spraying is an alternative to aerial application, but is about 2.5 times as expensive per acre (Shepard and Larsen 1985). On steep terrain, backpack spraying is commonly used instead of aerial application; costs of backpack application may be 1.5–3 times more expensive than aerial (Tesch and Mann 1991). Herbicides may be applied beneath shelterwood overstories on gentle terrain using tractor-mounted spray mechanisms. The cost of a tractor application of herbicide is between that of aerial and backpack methods (Tesch and Mann 1991).
8 FACTORS AFFECTING LOGGING PRODUCTION AND COSTS

Analysis of the relevant literature reveals the most commonly cited stand, site, and operational variables affecting logging production and costs.

- **Stand variables:**
  - volume per acre harvested
  - dbh of harvested trees

- **Site variables:**
  - slope
  - slope profile (concave, convex)

- **Operational variables:**
  - harvesting method (ground skid, cable yard)
  - external yarding distance
  - lateral yarding distance
  - logs/turn, volume/turn, weight/turn
  - silvicultural method
  - crew size and experience
  - equipment balance (e.g., fell-bunch, yard/skid, swing, process, chip)
  - factors affecting machine mobility/flexibility (e.g., spacing of residual trees, landing size)

Factors occasionally mentioned that can affect logging productivity and costs include ground obstacles (brush, down timber, boulders), weather conditions, and soils.
9 SUMMARY

This literature review summarizes various financial considerations associated with alternative silvicultural prescriptions. Stump-to-truck costs cited include planning and layout, felling activities, and yarding operations. The largest portion of harvest costs are attributed to ground or cable yarding operations. Tables 28 and 29 show the total costs associated with alternative cutting methods. The relative indices displayed in the tables are from examples shown in greater detail in Sections 4 and 5.

9.1 Tractor and Cable Harvesting Costs

Table 28 features relative harvest costs on tractor ground. The basic cost index for clearcut is set at 1.0; cost indices for partial cut harvesting methods range between 1.0 and 1.16.

<table>
<thead>
<tr>
<th>Harvest cutting method</th>
<th>Clearcut</th>
<th>Seed tree</th>
<th>Shelterwood</th>
<th>Group selection</th>
<th>Single tree selection</th>
<th>Two-story</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total logging costs</td>
<td>1.0</td>
<td>1.0</td>
<td>1.13</td>
<td>0.99–1.02</td>
<td>1.10</td>
<td>1.16</td>
</tr>
</tbody>
</table>

McDonald et al. (1969), studying tractor logging in second-growth forests, concluded that volume per acre harvested does not significantly affect the cost of logging. Tables developed by Brush\(^4\) show no difference in the stump-to-truck logging costs between partial cut and clearcut cutting methods on tractor ground. Brush assumed that both prescriptions require use of designated skidtrails.

McDonald et al. (1969) and Mandzak et al. (1983), while analyzing harvesting costs on tractor ground, considered silvicultural method to affect economic feasibility only in a very minor way.

Table 29 summarizes cost indices on cable harvested ground. Again, the harvest cost index for clearcut is set at 1.0; cost indices for partial cut methods range from 1.01 to 1.41.

<table>
<thead>
<tr>
<th>Harvest cutting method</th>
<th>Clearcut</th>
<th>Shelterwood</th>
<th>Group selection</th>
<th>Two-story</th>
<th>Commercial thin</th>
<th>Partial cut</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total logging costs</td>
<td>1.0</td>
<td>1.06–1.39</td>
<td>1.06–1.25</td>
<td>1.23</td>
<td>1.31–1.41</td>
<td>1.01–1.19</td>
</tr>
</tbody>
</table>

Fight et al. (1984) consider that if volume per acre cable-harvested exceeds 5.4 mcf/acre, then partial cut skyline yarding costs are similar to those of clearcut.

With tractor logging, regardless of whether the cutting unit is clearcut or partial cut, the equipment must cover the area to bring logs to the landing(s). However, with cable yarding, on a particular corridor setting, fewer logs will be gathered in a partial cut than in a clearcut. Since moving and rigging the cable system are non-productive activities, the proportion of total time spent yarding logs (productive time) is lower in a partial cut than in a clearcut. Therefore, cable yarding costs are generally higher in partially cut units than clearcut blocks.

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Just two case studies contained in this review focus on harvest production exclusively. Gardner (1980) investigated logging costs associated with different intensities of use. Harvest methods on the cutblocks included both clearcut and partial cut. However, Gardner (1980) warned that because site, stand, and operational conditions varied considerably, production comparisons should not be made between the cutting methods. Mandzak et al. (1983) also measured harvest system production. Site and stand conditions varied with this study also, though not as much as in the Gardner (1980) study. In this review, these two logging production studies are not summarized in a table.

9.2 Costs and Revenues over a Full Rotation

The works reviewed included several examples examining financial aspects related to silvicultural alternatives over full rotations. However, the types of management treatments used in the examples vary widely.

Brodie (1985) provided one example that includes only three management treatments (pre-commercial thin, commercial thin, and clearcut). Tesch and Mann provided more complex examples, one of which included 19 treatments over a 125-year rotation.

Tesch and Mann (1991), in a section on economic considerations, conclude with general statements. Financial returns under shelterwood regimes on gentle terrain can approximate those of clearcut (assuming skidtrails are built for both shelterwood and clearcut). On steeper slopes, however, where logging costs escalate, clearcut returns are generally higher than those of shelterwood systems.

The method of examining relative cash flows over time, as shown by Tesch and Mann (1991) and Brodie (1985), is a useful tool for scrutinizing the long-term financial implications of alternative silvicultural treatments over full rotations.

9.3 Other Factors Affecting Economic Feasibility of Harvesting

According to Mandzak et al. (1983), the market price of forest products has the greatest effect on economic feasibility of harvesting operations. The Transactions Evidence Appraisal Model (Hedges and Niccolucci 1992) also indicates that market prices for forest products are of prime importance to USDA Forest Service timber sale bidders.

Planning and layout costs are worthy of note: Kellogg et al. (1991) point out the relatively labour-intensive planning required for partial-cut blocks. Time spent planning makes harvest implementation easier (Kellogg et al. 1991). In addition, field planning and layout time allows silviculturists (and technical support workers) to be more aware of specific forest resource conditions on a given cutblock.
10 RECOMMENDATIONS

10.1 Logging Production Studies

McDonald et al. (1969) noted a lack of study on the relationship between silvicultural cutting methods and harvesting production or costs. Their study of costs relating to clearcut and partial cut prescriptions was restricted to tractor ground in second-growth stands in the 1960s. Kellogg et al. (1991) examined the cost effect of clearcut, two-story, and group selection harvest methods on both ground-skidded and cable-yarded cutting units. So far their research is restricted to coast Douglas-fir.

More information is needed on the cost effect of harvest cutting methods in a diverse range of site and operational conditions for stands in the coastal and inland Pacific Northwest. Not only has ground-skid harvesting technology changed since the 1960s, but ecological, economic, and social issues related to steep-ground harvesting have increased in relative importance.

This information need can be addressed in three ways. The first two procedures use data gathered in the field; the third requires study of appraisal documents.

1. Logging activities on clearcut and partial cut units can be examined through detailed time and motion studies of productive and non-productive stump-to-landing logging activities.
2. With a broader approach, logging production for clearcut and partial cut cutting prescriptions can be recorded under a range of site, stand, and operational conditions. More cutting units could be examined in the field using a broad approach, rather than through a detailed time and motion study. First, the logging system, site, stand, and operational conditions can be described; then stump-to-landing production can be summarized on a daily basis.
3. U.S. Pacific Northwest National Forest timber sale cost appraisal records can be examined to establish the relative harvesting costs attributed to a range of cutting prescriptions. (The U.S. appraisal system assumes a prudent logging operator using an appropriate harvesting system.) Appraisal records up to 10 years old could be included in the sample (some of the contracts for these timber sales are still active).

Recommendation: Use techniques (2) and (3) described above.

10.2 Research Methods

Researchers have developed means for analyzing alternative treatments of Pacific Northwest forests. The methods used by these researchers can be replicated on stands in British Columbia.

Tesch and Mann (1991) examined the relative cash flows of alternative silvicultural systems. The methods for deriving NPV, SEV, and NPA are useful for analyzing treatment options.

The methods used by McDonald (1969) and Kellogg et al. (1991) have been designed to isolate the cost effect of alternative harvest cutting prescriptions. Kellogg et al. point out other harvest-related factors that need to be considered: planning and layout, snag and green-tree retention, and future entries.

Ficht et al. (1984) assembled regression equations and tables so that planners and other analysts can estimate harvest costs for clearcut and partial cut cutting methods.

Recommendation: Isolate alternative harvest cutting methods in future studies.

10.3 Increasing Logging Production on Partially Cut Stands

Harvesting production on thinned stands has been the focus of many studies in the Pacific Northwest. Initially, research was undertaken to increase harvest efficiency while thinning small-stem stands. Increasingly, silviculturists, logging engineers, and other forest professionals need information about harvest techniques that address issues such as increased second-growth (smaller average dbh) stands, steep ground, partial cutting prescriptions, ecosystem stewardship, and social concerns.
Though much study of commercial thinning has occurred in the Pacific Northwest, that literature has not been summarized in this report. Such a summary should be undertaken to increase knowledge of appropriate partial cutting harvesting techniques.

**Recommendation:** Summarize existing knowledge of commercial thinning techniques.

### 10.4 Other Silvicultural Considerations

Information is needed about the effects of clearcut and partial cut prescriptions on growth and yield, site capability, and the cost of silvicultural treatments throughout a rotation.

Existing growth and yield models might be adapted for use with forest stands in British Columbia.
11 LITERATURE CITED


