# VOLUME AND WEIGHT CHARACTERISTICS OF A TYPICAL DOUGLAS-FIR/WESTERN LARCH STAND, CORAM EXPERIMENTAL FOREST, MONTANA

Robert E. Benson    and    Joyce A. Schlieter

BLOCK 11    TRT 3    PLOT 18    HABITAT TYPE

| TREE | SPP | DBH | HGT | CROWN LEN | CLS | VIG | 73 COND |
|---|---|---|---|---|---|---|---|
| 1 | 7 | 2.0 | 23 | 012 | 3 | 2 | 0550 |
| 2 | 8 | 3.8 | 26 | 017 | 2 | 3 | 0550 |
| 3 | 3 | 1.4 | 16 | 002 | 4 | 3 | 0550 |
| 5 | 3 | 1.9 | 16 | 003 | 4 | 3 | 0550 |
| 6 | 3 | 1.5 | 11 | 003 | 4 | 3 | 0550 |
| 7 | 3 | 2.7 | 20 | 005 | 3 | 2 | 0550 |
| 8 | 2 | 4.1 | 42 | 017 | 3 | 2 | 0200 |
| 9 | 7 | 4.0 | 48 | 030 | 2 | 2 | 0200 |
| 10 | 3 | 3.4 | 33 | 012 | 3 | 2 | 0550 |
| 11 | 7 | 7.2 | 29 |  | 0 | 0 | 1800 |
| 12 | 3 | 4.7 | 55 | 028 | 2 | 2 | 0550 |
| 13 | 3 | 3.5 | 36 | 007 | 3 | 2 | 0550 |
| 14 | 8 | 4.6 | 39 | 017 | 2 | 2 | 0550 |

26   SLOPE 3   ASPECT   37   DUFF DEPTH   20

| 75 COND | 77 COND | BLOW UP | DEFOL U | M | L | BUDWM TOPKL | UNSOUND A | B | C |
|---|---|---|---|---|---|---|---|---|---|
| 1700 | 50 |  |  |  |  |  |  |  |  |
| 1700 | 50 |  |  |  |  |  | 00 | 00 | 00 |
| 1700 | 50 |  |  |  |  |  |  |  |  |
| 1700 | 50 |  |  |  |  |  |  |  |  |
| 1700 | 50 |  |  |  |  |  |  |  |  |
| 1700 | 50 |  |  |  |  |  |  |  |  |
| 1700 | 50 |  |  |  |  |  | 00 | 00 | 00 |
| 1700 | 50 |  |  |  |  |  | 00 | 00 | 00 |
| 1700 | 50 |  |  |  |  |  | 00 | 00 | 00 |
| 1800 | 50 |  |  |  |  |  |  |  |  |
| 1700 | 50 |  |  |  |  |  | 00 | 00 | 00 |
| 1700 | 50 |  |  |  |  |  | 00 | 00 | 00 |
| 1700 | 50 |  |  |  |  |  | 00 | 00 | 00 |

# VOLUME AND WEIGHT CHARACTERISTICS OF A TYPICAL DOUGLAS-FIR/WESTERN LARCH STAND, CORAM EXPERIMENTAL FOREST, MONTANA

Robert E. Benson

and

Joyce A. Schlieter

# THE AUTHORS

ROBERT E. BENSON is a research forester assigned to the Forest
    Economics research work unit.  He has been with the Inter-
    mountain Forest and Range Experiment Station since 1961.  He
    was located at the Ogden Station from 1961 to 1964 and has
    been at the Station's Forestry Sciences Laboratory in Missoula
    since 1967.  His research includes studies in forest economics,
    wood products marketing, forest inventories, and resource
    analysis.


JOYCE A. SCHLIETER received her bachelor's degree in mathematics
    from Portland State University and her master's in statistics
    from Michigan State University. From 1975-1979 she was the
    mathematician/statistician for the Forest Residues Utilization
    Program, Missoula.

# RESEARCH SUMMARY

An overmature Douglas-fir/western larch stand on the Coram
Experimental Forest in Montana was skyline logged using three
different cutting methods and four different levels of utilization.

Prior to harvest, the total volume of wood averaged 7,300 ft$^3$/
acre (511 m$^3$/ha) and ranged from 4,400 to 15,000 ft$^3$/acre (308 to
1 042 m$^3$/ha) on the various cutting units. Fifty-seven percent
of this was sound green material, the rest was dead or rotten.
In addition, there was about 57 tons/acre (128 t/ha) of fine
material including tree crowns, duff, and litter.

After harvest, the volume of wood remaining ranged from about
40 percent of the preharvest volume in conventional saw log utili-
zation to under 20 percent where intensive utilization was practiced.
Type of material and size of residues also varied by utilization
treatment. Fine material increased from 3 to 10 tons/acre (7 to
22 t/ha) depending on utilization level.

The amount and condition of woody material and changes with
harvesting on this typical site provide a basis for evaluating
woody biomass conditions before harvesting is undertaken.

# CONTENTS

More detailed summary tables are available from the
Forestry Sciences Laboratory, Missoula, Mont.:

   Request:  "Appendix supplement to volume and weight
           characteristics of a typical Douglas-fir/
           western larch stand, Coram Experimental
           Forest, Montana."

# INTRODUCTION

Currently there is a great deal of interest in increasing utilization from forest stands. This interest stems from growing demands for wood products and from a concern over impacts of logging residues on esthetics, recreation, and wildlife. As utilization has increased over the years, forest managers have also had to take into account the effects of removing more of the wood material from the site. Whereas large volumes of residues can pose management problems, removal of too much material could adversely effect the ecosystem.

In 1973, a comprehensive study was begun in an overmature high risk Douglas-fir/western larch (*Pseudotsuga menziesii* [Mirb.]/*Larix occidentalis* [Nutt.]) stand on the Coram Experimental Forest. The objectives of the Coram study were to determine the impacts of various cutting methods, utilization levels, and postharvest treatments. Some aspects considered were regeneration, nutrients, water and hydrology, microclimate, logging systems, and costs.

The object of this report is to summarize information on woody material before and after harvest. It is intended to give managers information on the amount and kinds of material in a typical Douglas-fir/larch stand and on changes under different types of cutting and utilization. In addition, basic data are summarized for those concerned about the effects of woody material on other aspects of the forest, such as soil water, nutrients, and fauna.

Basic volume and weight summaries are included in this report. A more detailed data appendix is available upon request.

# DESCRIPTION OF STUDY
## Location and Harvesting Specifications

The study area is located in the Abbott Creek drainage of the Coram Experimental Forest. It consists of six blocks (total 100.3 acres, 40.6 ha), with each cutting method being used on two blocks, as follows:

Blocks

11 and 21    Shelterwood (SH) = leaving about half the volume and aiming toward good height and species diversity: 35.1 and 21.5 acres (14.2 and 8.7 ha).

12 and 22    Group selection (GS) cuts = all merchantable trees cut. Eight groups of 0.5 to 1.5 acres (0.2 to 0.6 ha) in each block: 7.5 and 6.0 acres (3.0 and 2.4 ha).

13 and 23    Clearcuts (CC) of 13.6 and 16.6 acres (5.5 and 6.7 ha).

The elevations range from about 3,900 feet (1 189 m) to 5,200 feet (1 585 m) and the aspect is generally east and southeast. Habitat type is mostly *Abies lasiocarpa/Clintonia uniflora*. Small sections of other types are also present. Control blocks were established adjacent to several cutting units (fig. 1). Each of the six blocks described was further divided into four utilization levels henceforth referred to as treatments.
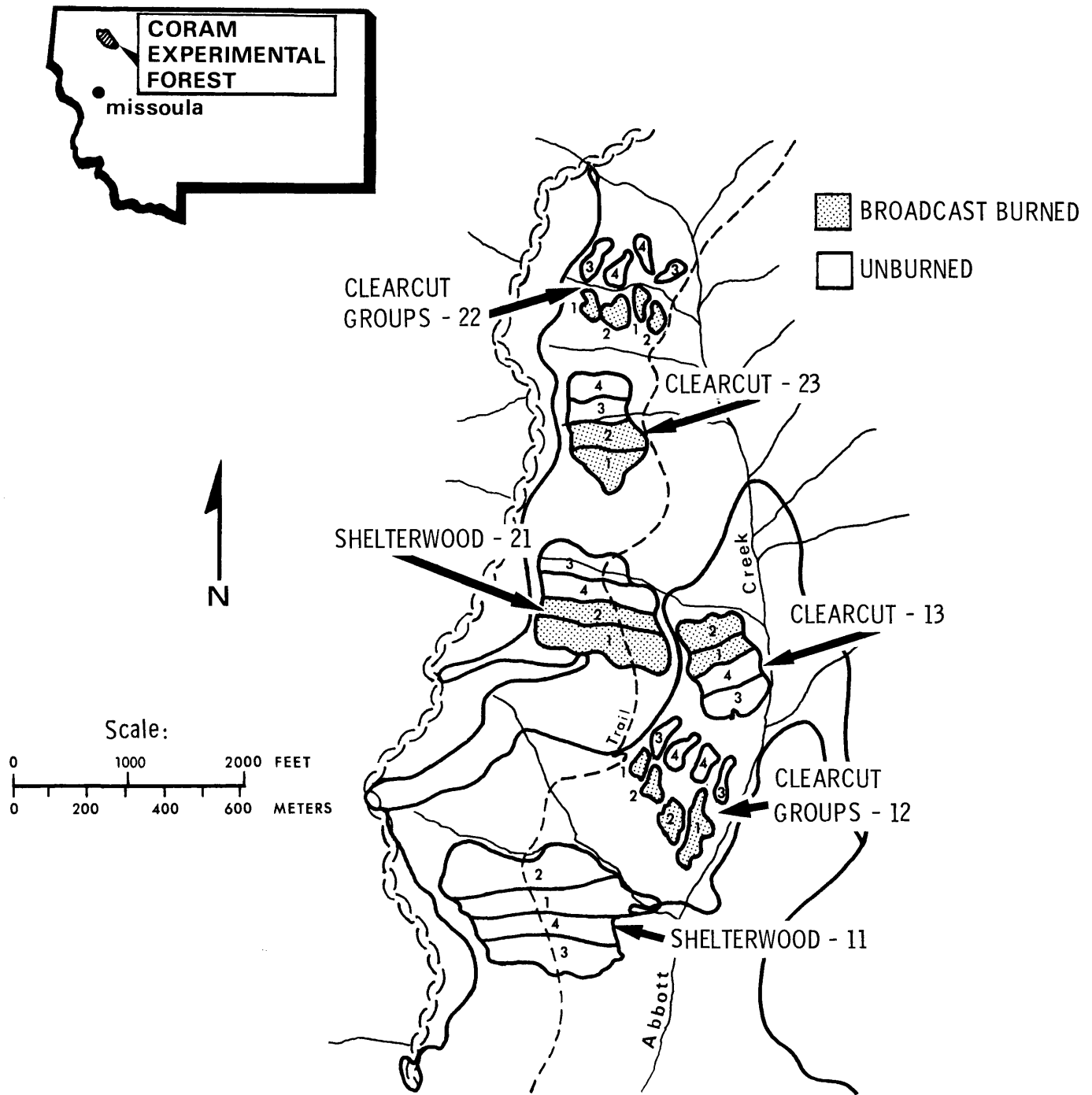
Figure 1.--Location of cutting blocks in Abbott Basin, Coram Experimental Forest. Timber harvested in 1974 and broadcast burned in Sept. 1975 (Artley and others 1978).

2

| Treatments | Specification |
|---|---|
| 1. Intensive tree (IT) utilization: utilization of all trees with a 5-inch (12.7-cm) d.b.h. | All material at least 8 feet (2.4 m) long with at least a 3-inch (1.62-cm) small end diameter was removed (this included trees down to a 5-inch [12.7-cm] diameter breast height [d.b.h.]). The area was burned after harvest. |
| 2. Saw log (SL) utilization: saw log utilization standards | Trees down to a 7-inch (17.8-cm) d.b.h were cut, logs down to a 6-inch (15.2-cm) top diameter were removed, and the area was burned after harvest. |
| 3. Near complete (NC) removal: removal of all material | All trees down to a 1-inch (2.5-cm) d.b.h. were cut and removed. The area was left as it was after harvest. |
| 4. Intensive log (IL) utilization: close utilization of logs cut from trees 7 inches (17.8 cm) d.b.h. and larger | Trees down to 7-inch (17.8-cm) d.b.h. were cut, logs 8 feet (2.4 m) long with a diameter down to 3 inches (7.62 cm) were utilized. Remaining trees were protected as far as possible and left as advanced regeneration. |

The preharvest (spring) field measurements at Coram were made in 1973 and 1974; the harvest was in the summer of 1974. Postharvest (autumn) measurements were taken from 1975 through 1977.

# Measurement of Standing Trees

A 100 percent inventory of sawtimber trees (over 7.0 inches [17.8 cm] d.b.h.) was made on all cutting blocks before harvest and in shelterwood blocks after harvest. The preharvest tree data were processed by using the Region 1 (Northern Region) timber sale computer program to derive board foot volumes used in the timber sale preparation.

Smaller trees were measured on permanent plots, 10 plots per utilization level (40 per cutting block) and 50 plots per control area. Plots of 0.02 acre (0.0081 ha) were used to measure these smaller trees (poles, saplings, and seedlings).

# Measurement of Down Woody Material, Litter and Duff

The down woody material was measured along transects using procedures described by Brown (1974), as follows:

| Diameter at intercept of down material | Transect length |
|---|---|
| 3 inches (7.62 cm) and larger | 50 feet (15.24 m) |
| 1 inch (2.54 cm) to 3 inches (7.62 cm) | 10 feet (3.05 m) |
| 0 to 1 inch (2.54 cm) | 6 feet (1.83 m) |

In the preharvest inventory, two transects were established from each permanent plot for a total of 20 transects per treatment. For postharvest measurements, one transect was established at each permanent plot and 20 were established at randomized nonpermanent grid points, for a total of 30 transects per treatment.

Duff and litter depths were measured at three points along the transect (1 foot, 6 feet, and 10 feet from the origin). Duff included decomposed material above the mineral soil up to the litter layer. Litter included all foliage, leaves, and other organic material that was still identifiable. Woody material on the litter surface was tallied on the transect as described.

## Estimation of Crown Weights

Crown weights were calculated using equations developed by Brown (1978). These equations use tree species, diameter, and height to derive estimates of crown weight. Fractions of these crown weights in foliage and branchwood diameter size classes of 0 to 1/4 inch (0 to 0.63 cm), 1/4 to 1 inch (0.63 to 2.54 cm), and 1 to 3 inches (2.54 to 7.62 cm) were also determined using tables given by Brown and others (1977).

## Sampling Errors

Percent errors were calculated for various preharvest and postharvest volume and weight components. Percent error is the sample standard error divided by the sample mean and expressed as a percent. Errors based on total samples were quite low, ranging from 3.7 to 7.6 percent. These low errors were expected because of the large number of samples taken. For individual wood components within each subtreatment, the error was higher, but was usually within the range expected, given the limited number of samples that could be made within each subtreatment and each cutting unit.

# THE PREHARVEST STAND

The study site at Coram is typical of overmature Douglas-fir/larch sawtimber stands in western Montana. The stand reflects a history of factors such as fire, insects, disease, windthrow, and snow breakage. Over the 200 plus years of the stand these factors--plus topography and other site features--led to a patchy mosaic of different tree ages, sizes, and species. Number of trees and volumes vary considerably.

## Wood 3.0 Inches (7.62 cm) Diameter and Larger

The average volume for all woody material based on all samples in the study area was 7,318 ft$^3$/acre (512 m$^3$/ha). This is about the same volume as the average for overmature high risk stands in western Montana National Forests (table 1). There was considerable variation among individual cutting blocks and subtreatments, ranging from 4,400 ft$^3$/acre to nearly 15,000 ft$^3$/acre (308 to 1 042 m$^3$/ha). A summary of volumes for each cutting unit and subtreatment is presented in tables 2, 3, and 4.

Table 1.--*Volume of woody material for Douglas-fir and larch stands in western Montana National Forests, ft$^3$/acre (m$^3$/ha)*

| Type material | Coram study | Area | | |
|---|---|---|---|---|
| | | Western Montana National Forest high risk sawtimber | | |
| Standing green | | | | |
| Sawtimber | 3,706 | 3,927 | to | 4,510 |
| Other green | 340 | | | |
| Standing dead | | | | |
| Sound | 66 | 245 | to | 118 |
| Rotten | 1,409 | 101 | to | 858 |
| Down | | | | |
| Sound | 78 | 317 | to | 172 |
| Rotten | 1,719 | 616 | to | 1,380 |
| Total | 7,318 | 5,206 | to | 7,038 |
| | (512) | (365 | to | 493) |

Table 2.--*Preharvest volumes by component for shelterwood units, ft³/acre (m³/ha)*

| Block | Component | Treatment[1] 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 11 | Standing | | | | |
| | Green | 5,651 (395) | 3,663 (256) | 4,059 (284) | 3,414 (239) |
| | Sound dead | 382 ( 27) | 191 ( 13) | 67 ( 5) | 33 ( 2) |
| | Unsound dead | 0 | 0 | 448 ( 31) | 388 ( 27) |
| | Down | | | | |
| | Sound | 43 ( 3) | 32 ( 2) | 88 ( 6) | 16 ( 1) |
| | Unsound | 769 ( 54) | 87 ( 76) | 1,200 ( 84) | 1,429 (100) |
| | Totals | 6,845 (479) | 4,973 (348) | 5,862 (410) | 5,280 (369) |
| 21 | Standing | | | | |
| | Green | 4,330 (303) | 2,424 (170) | 3,031 (212) | 3,867 (271) |
| | Sound dead | 108 ( 7) | 39 ( 3) | 109 ( 8) | 85 ( 6) |
| | Unsound dead | 965 ( 65) | 495 ( 35) | 146 ( 10) | 280 ( 20) |
| | Down | | | | |
| | Sound | 35 ( 2) | 72 ( 5) | 33 ( 2) | 19 ( 1) |
| | Unsound | 1,282 ( 90) | 1,379 ( 96) | 1,237 ( 86) | 709 ( 50) |
| | Totals | 6,720 (470) | 4,409 (308) | 4,556 (319) | 4,960 (347) |

[1]See definition under Description of the Study.

Table 3.--*Preharvest volumes by component for group selection units, ft³/acre (m³/ha)*

| Block | Component | Treatment[1] 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 12 | Standing | | | | |
| | Green | 6,181 (432) | 4,502 (315) | 3,297 (231) | 4,650 (325) |
| | Sound dead | 10 ( 1) | 25 ( 2) | 16 ( 1) | 21 ( 1) |
| | Unsound dead | 2,272 (159) | 1,206 ( 84) | 2,854 (200) | 3,212 (225) |
| | Down | | | | |
| | Sound | 33 ( 2) | 20 ( 1) | 105 ( 7) | 73 ( 5) |
| | Unsound | 845 ( 59) | 1,275 ( 89) | 1,982 (139) | 1,963 (137) |
| | Totals | 9,341 (654) | 7,028 (492) | 8,254 (577) | 9,919 (694) |
| 22 | Standing | | | | |
| | Green | 3,846 (269) | 6,478 (453) | 4,572 (320) | 6,661 (466) |
| | Sound dead | 0 | 151 ( 11) | 31 ( 2) | 84 ( 6) |
| | Unsound dead | 2,846 (199) | 6,515 (456) | 1,399 ( 98) | 1,802 (127) |
| | Down | | | | |
| | Sound | 33 ( 2) | 177 ( 2) | 75 ( 5) | 25 ( 2) |
| | Unsound | 1,579 (110) | 1,570 (110) | 1,493 (104) | 1,643 (115) |
| | Totals | 8,304 (581) | 14,891(1 042) | 7,570 (550) | 10,215 (715) |

[1]See definition under Description of the Study.

Table 4.--*Preharvest volumes by component for clearcut units, ft³/acre (m³/ha)*

| Block | Component | Treatment[1] 1 | 2 | 3 | 4 |
|-------|-----------|-------|---|---|---|
| 13 | Standing | | | | |
| | Green | 3,538 (247) | 3,652 (253) | 2,468 (173) | 4,094 (286) |
| | Sound dead | 5 | 12 ( 1) | 1 | 5 |
| | Unsound dead | 1,837 (128) | 1,086 ( 76) | 789 ( 55) | 1,012 ( 71) |
| | Down | | | | |
| | Sound | 323 ( 23) | 143 ( 10) | 132 ( 9) | 48 ( 3) |
| | Unsound | 2,451 (171) | 1,811 (127) | 2,523 (176) | 1,752 (123) |
| | Totals | 8,154 (570) | 6,704 (469) | 5,913 (414) | 6,911 (483) |
| 23 | Standing | | | | |
| | Green | 4,136 (289) | 3,720 (260) | 1,717 (120) | 3,169 (222) |
| | Sound dead | 51 ( 4) | 90 ( 6) | 29 ( 2) | 42 ( 3) |
| | Unsound dead | 1,378 ( 96) | 1,545 (108) | 715 ( 50) | 630 ( 44) |
| | Down | | | | |
| | Sound | 133 ( 9) | 59 ( 4) | 43 ( 3) | 108 ( 8) |
| | Unsound | 3,123 (218) | 2,641 (185) | 3,034 (212) | 2,484 (174) |
| | Totals | 8,821 (617) | 8,055 (564) | 5,538 (387) | 6,433 (450) |

[1]See definition under Description of the Study.

Nearly half the total volume of wood in the Coram study site is dead material, with a high proportion (over 25 percent) being down material, mostly rotten. In addition, a large proportion of the green material is in small trees and tops not normally utilized in ordinary sawing operations. This means that in a typical stand one-half or more of the volume represent a new utilization potential or a residue management problem when the stand is harvested.

# Tree Species

The species composition of the stand also reflects the stand conditions. Western larch along with Douglas-fir are the oldest and largest trees at Coram, but as the stand has developed, the larch, being intolerant of shade, has virtually disappeared from the understory. Alpine fir (*Abies lasiocarpa* [Hook.] Nutt.) and Engelmann spruce (*Picea engelmannii* Parry), both shade-tolerant species, and Douglas-fir make up most of the smaller trees, along with occasional western redcedar (*Thuja plicata* Donn.) and western hemlock (*Tsuga heterophylla* [Raf.] Sarg.). In total, there were about 1,282 stems per acre (519/ha), with 111 stems per acre 7 inches (17.8 cm) d.b.h. or larger (table 5). A detailed stand summary is provided in table 6.

Douglas-fir accounts for 58 percent of the volume. Western larch totals 20 percent, even though there are more spruce and alpine fir stems per acre than larch. In all species, one-third to one-half of the volume is rotten material (fig. 2). Very little of the dead material was sound enough to be utilized for products.

Table 5.--*Number of preharvest stems per acre (per ha), by species and d.b.h. class*

| D.b.h. class | Species[1] | | | | | |
|---|---|---|---|---|---|---|
| | DF | WL | AF | ES | Other | Total |
| *Inches* | | | | | | |
| <1 | 167 | 2 | 492 | 58 | 26 | 745 |
| 2 to 6 | 207 | 25 | 115 | 71 | 8 | 426 |
| 8 to 12 | 31 | 1 | 28 | 9 | 5 | 74 |
| 14 to 20 | 18 | 4 | 2 | 3 | 1 | 28 |
| over 20 | 5 | 5 | -- | -- | 0 | 10 |
| Total | 428 (1,057) | 37 (91) | 637 (1,573) | 141 (348) | 40 (99) | 1,283 (3,169) |

[1]Abbreviations:  DF = Douglas-fir
WL = western larch
AF = alpine fir
ES = Engelmann spruce

Table 6.--*Number of preharvest stems per acre (per ha), by diameter class and species*

| Diameter class | Species[1] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | WP | WL | DF | WH | WRC | LP | ES | AF | Other | Total |
| *Inches* | | | | | | | | | | |
| <1 | 3.9 | 2.0 | 166.9 | 18.5 | 3.3 | 0.2 | 58.1 | 492.1 | 0 | 745.0 |
| 2 | .2 | 13.3 | 124.0 | 2.0 | 0 | .4 | 39.8 | 57.1 | 0 | 236.8 |
| 4 | .2 | 7.2 | 54.8 | 1.4 | 0.1 | 1.4 | 20.6 | 36.5 | 0 | 122.2 |
| 6 | .3 | 4.2 | 27.8 | 1.5 | 0 | 1.5 | 10.9 | 20.8 | 0 | 67.0 |
| Subtotal | 4.6 (11.4) | 26.7 (65.9) | 373.5 (922.5) | 23.4 (57.8) | 3.4 (8.4) | 3.5 (8.6) | 129.4 (319.6) | 606.5 (1,498.1) | 0 | 1,171.0 (2,892.4) |
| 8 | 0 | 0.8 | 16.9 | .2 | 0 | 1.7 | 3.9 | 17.9 | 0 | 41.4 |
| 10 | 0.3 | .3 | 10.5 | † | † | .5 | 1.7 | 5.9 | † | 19.2 |
| 12 | .2 | .3 | 4.4 | † | † | .6 | 3.0 | 4.2 | 0.1 | 12.8 |
| 14 | .1 | .6 | 6.7 | † | † | .2 | 1.4 | 1.5 | † | 10.5 |
| 16 | .1 | .8 | 5.0 | .1 | † | .1 | .9 | .4 | † | 7.4 |
| 18 | .1 | 1.5 | 3.4 | 0 | † | 0 | .4 | .1 | 0 | 5.5 |
| 20 | † | 1.5 | 2.9 | 0 | 0 | 0 | .2 | † | 0 | 4.6 |
| 22 | 0 | 2.0 | 2.0 | 0 | 0 | 0 | .1 | † | 0 | 4.1 |
| 24 | † | 1.3 | 1.2 | 0 | 0 | 0 | .1 | † | 0 | 2.6 |
| 26 | 0 | .8 | .7 | 0 | † | 0 | † | 0 | 0 | 1.5 |
| 28 | 0 | .4 | .5 | 0 | 0 | 0 | † | 0 | 0 | .9 |
| 30 | 0 | .2 | .3 | 0 | 0 | 0 | † | 0 | 0 | .5 |
| 30+ | 0 | .1 | .3 | 0 | 0 | 0 | 0 | 0 | † | .4 |
| Subtotal | 0.8 (2.0) | 10.6 (26.2) | 54.8 (135.4) | 0.3 (0.7) | † | 3.1 (7.7) | 11.7 (28.9) | 30.0 (74.1) | 0.2 (0.5) | 111.5 (275.4) |
| Grand total | 5.4 (13.3) | 37.3 (92.1) | 428.3 (1 057.9) | 23.7 (58.5) | 3.4 (8.4) | 6.6 (16.3) | 141.1 (348.5) | 636.5 (1 572.2) | 0.2 (0.5) | 1,282.5 (3 167.8) |

†Averages less than 0.1 tree/acre.
[1]Species abbreviations:  WP = western white pine
WL = western larch
DF = Douglas-fir
WH = western hemlock
WRC = western redcedar
LP = lodgepole pine
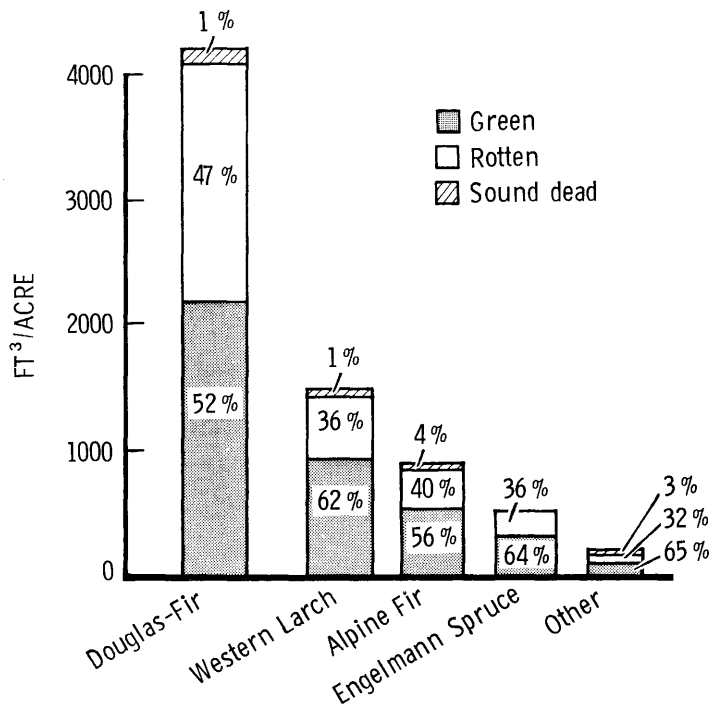ES = Engelmann spruce
AF = alpine fir

Figure 2.--Preharvest volume per acre of wood of 3.0-inch (7.62-cm) diameter and larger, by species and condition, Coram study units.

# Material less than 3.0 Inches (7.62cm) Diameter

In addition to the volume of wood standing and down, the smaller woody material is also an important part of the woody biomass, and is of particular interest to those concerned with fuels, nutrients, microclimate, and microsites for various species of fauna.

## MATERIAL 0 TO 3 INCHES (0 TO 7.62 CM) ON THE GROUND

Woody material under 3 inches (7.62 cm) on the ground prior to harvest averaged 4 tons per acre (9 t/ha), ovendry weight. Material in the 1- to 3-inch (2.54- to 7.62-cm) size class accounts for an average of 52 percent of the weight, with the 0 to 1/4-inch (0 to 0.63-cm) size class accounting for 11 percent (table 7). Detailed summary of this material is provided in table 8.

Table 7.--*Weight of woody material <3 inches, crowns, litter, and duff, tons/acre (t/ha)*

| Component | Fines | Woody material | | | Total |
| | | 0 - 1/4 inch | 1/4 - 1 inch | 1 - 3 inches | |
|---|---|---|---|---|---|
| Duff | 33.22(74.4) | -- | -- | -- | 33.22( 74.4) |
| Litter | 1.60( 3.6) | -- | -- | -- | 1.60( 3.6) |
| Wood on ground | -- | 0.45(1.0) | 1.48( 3.1) | 2.16( 4.8) | 4.09( 9.2) |
| Tree crowns | 5.12(11.5) | 3.17(7.1) | 4.95(11.1) | 4.42( 9.9) | 17.70( 39.7) |
| Total | 39.94(89.5) | 3.62(8.1) | 6.43(14.2) | 6.58(14.7) | 56.61(126.9) |

8

Table 8.--*Weight of small preharvest woody material on ground, by diameter class, tons/acre*
(t/ha)

| Treat-ment[2] | Size | Block[1] | | | | | | Average |
| | | 11(SH) | 12(GS) | 13(CC) | 21(SH) | 22(GS) | 23(CC) | |
|---|---|---|---|---|---|---|---|---|
| | *Inches* | | | | | | | |
| 1 (IT) | 0-1/4 | 0.43 | 0.37 | 0.33 | 0.55 | 0.47 | 0.33 | 0.41 |
| | 1/4-1 | 1.22 | 1.19 | 1.39 | 1.10 | 1.87 | 1.36 | 1.35 |
| | 1-3 | 2.46 | 1.72 | 1.50 | 1.80 | 1.95 | 3.37 | 2.13 |
| | Total | 4.11 | 3.28 | 3.22 | 3.45 | 4.29 | 5.06 | 3.90 |
| | | (9.21) | (7.35) | (7.22) | (7.73) | (9.61) | (11.34) | (8.73) |
| 2 (SL) | 0-1/4 | 0.28 | 0.72 | 0.42 | 0.44 | 0.34 | 0.63 | 0.47 |
| | 1/4-1 | .83 | 1.84 | 1.17 | 1.90 | 1.25 | 1.93 | 1.49 |
| | 1-3 | 1.73 | 2.02 | 1.87 | 3.38 | 2.08 | 2.27 | 2.22 |
| | Total | 2.84 | 4.58 | 3.46 | 5.72 | 3.67 | 4.83 | 4.18 |
| | | (6.36) | (10.26) | (7.75) | (12.82) | (8.22) | (10.82) | (9.37) |
| 3 (NC) | 0-1/4 | 0.42 | 0.50 | 0.49 | 0.44 | 0.54 | 0.31 | 0.45 |
| | 1/4-1 | 1.55 | 1.29 | 1.24 | 1.09 | 1.68 | 1.33 | 1.36 |
| | 1-3 | 2.71 | 1.69 | 2.09 | 1.76 | 2.64 | 1.43 | 2.06 |
| | Total | 4.68 | 3.48 | 3.82 | 3.29 | 4.86 | 3.07 | 3.87 |
| | | (10.49) | (7.80) | (8.56) | (7.37) | (10.89) | (6.88) | (8.67) |
| 4 (IL) | 0-1/4 | 0.47 | 0.60 | 0.48 | 0.57 | 0.39 | 0.44 | 0.49 |
| | 1/4-1 | 1.92 | 1.25 | 1.49 | 2.97 | 1.13 | 1.57 | 1.72 |
| | 1-3 | 2.68 | 1.79 | 2.33 | 1.45 | 3.24 | 1.61 | 2.19 |
| | Total | 5.07 | 3.64 | 4.30 | 4.99 | 4.76 | 3.62 | 4.40 |
| | | (11.36) | (8.16) | (9.64) | (11.18) | (10.67) | (8.11) | (9.86) |
| Block averages | | 4.18 | 3.75 | 3.70 | 4.36 | 4.40 | 4.15 | 4.09 |
| | | (9.37) | (8.4) | (8.29) | (9.77) | (9.86) | (9.30) | (9.17) |

[1]See definition of blocks under Description of the Study.
[2]See definition of treatments under Description of the Study.

## CROWN WEIGHT

The total crown weight of standing trees averaged about 18 tons per acre (40 t/ha). Foliage accounts for a substantial portion of this. The crown weights ranged from 9 to 25 tons per acre (20 to 56 t/ha) among the various subtreatment units. The detailed data are shown in table 9.

## DUFF AND LITTER

Estimates of the duff and litter weights were made prior to harvesting, using procedures described by Brown (1974). Duff consists of organic material above the mineral soil level that has decomposed to where individual particles are not identifiable. Litter is newly fallen material that has not decomposed. These components do not enter into wood removal, but are of interest for appraising fuel and nutrient conditions.

Weight of the duff averaged 38.22 tons/acre (86 t/ha) (table 7) and varied between 32 and 53 tons/acre (72 to 119 t/ha) among treatments. The weight was estimated by measuring duff depth and converting on a basis of 14.5 tons/acre per 1 inch of depth. This corresponds to a specific gravity of 0.13.

Table 9.--*Crown weights of standing trees, preharvest, tons/acre (t/ha)*

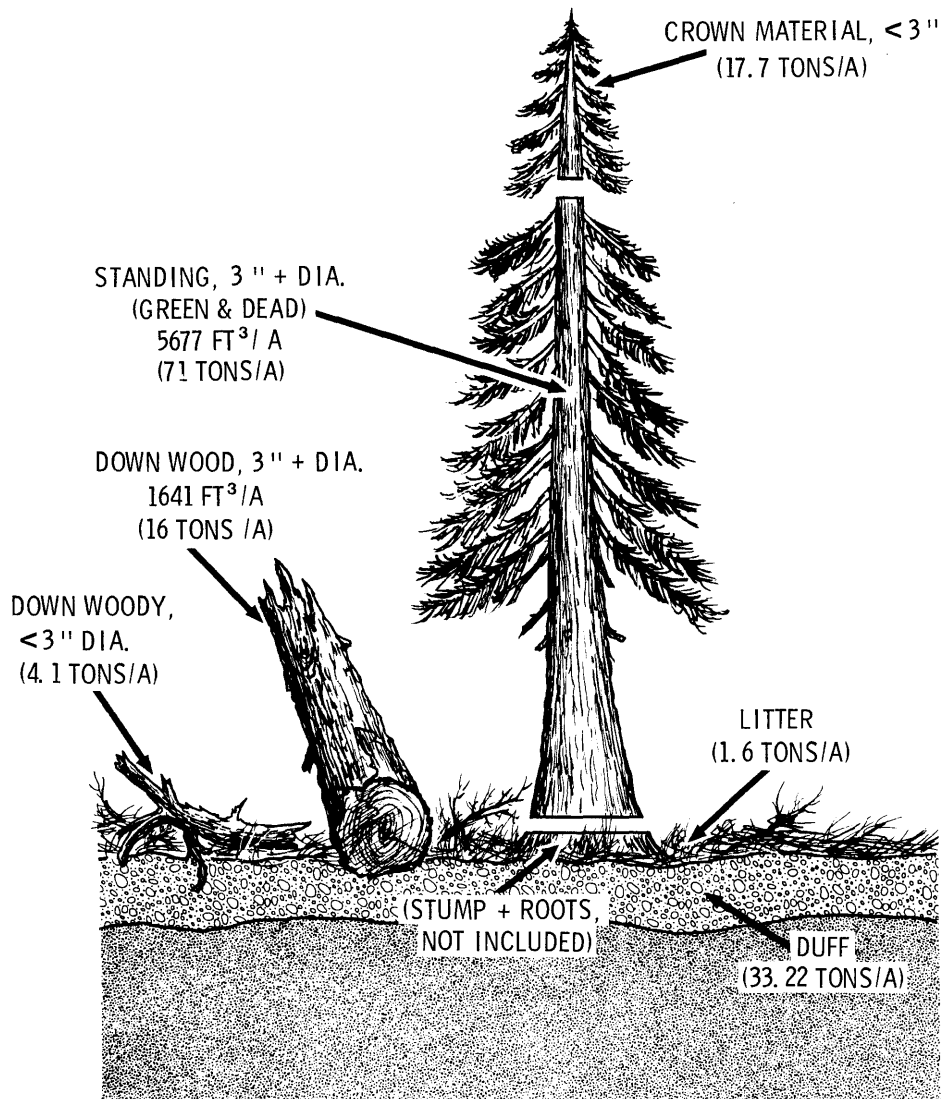| Treatment[2] | Size | Block[1] | | | | | | Treatment averages |
|---|---|---|---|---|---|---|---|---|
| | | 11(SH) | 12(GS) | 13(CC) | 21(SH) | 22(GS) | 23(CC) | |
| | *Inches* | | | | | | | |
| 1 (IT) | Foliage | 6.2 | 6.7 | 4.6 | 5.1 | 4.2 | 4.6 | 5.2 |
| | 0-1/4 | 3.8 | 4.2 | 2.7 | 3.3 | 2.6 | 2.8 | 3.2 |
| | 1/4-1 | 5.7 | 6.6 | 3.9 | 5.3 | 4.1 | 4.5 | 5.0 |
| | 1-3 | 6.1 | 6.1 | 3.3 | 4.6 | 3.2 | 3.1 | 4.4 |
| | Total | 21.8 | 23.6 | 14.5 | 18.3 | 14.1 | 15.0 | 17.9 |
| | | (48.9) | (52.9) | (32.5) | (41.0) | (31.6) | (33.6) | (40.1) |
| 2 (SL) | Foliage | 4.4 | 4.4 | 4.4 | 4.9 | 4.2 | 5.6 | 4.7 |
| | 0-1/4 | 2.7 | 2.7 | 2.7 | 3.1 | 4.2 | 3.4 | 3.1 |
| | 1/4-1 | 3.9 | 4.6 | 3.9 | 4.8 | 6.7 | 5.5 | 4.9 |
| | 1-3 | 4.1 | 3.7 | 3.8 | 4.1 | 8.1 | 4.5 | 4.7 |
| | Total | 15.1 | 15.4 | 14.8 | 16.8 | 23.2 | 19.0 | 17.4 |
| | | (33.8) | (34.5) | (33.2) | (37.9) | (52.0) | (42.6) | (39.0) |
| 3 (NC) | Foliage | 4.7 | 6.3 | 3.6 | 6.0 | 6.6 | 2.8 | 5.0 |
| | 0-1/4 | 3.0 | 3.7 | 2.2 | 3.5 | 4.0 | 1.7 | 3.0 |
| | 1/4-1 | 4.7 | 5.6 | 3.6 | 5.0 | 6.5 | 2.7 | 4.7 |
| | 1-3 | 5.8 | 5.9 | 3.1 | 4.9 | 4.4 | 1.9 | 4.3 |
| | Total | 18.2 | 21.5 | 12.5 | 19.4 | 21.5 | 9.1 | 17.0 |
| | | (40.8) | (48.2) | (28.0) | (43.5) | (48.2) | (20.4) | (38.1) |
| 4 (IL) | Foliage | 4.7 | 6.1 | 4.1 | 6.1 | 7.6 | 5.0 | 5.6 |
| | 0-1.4 | 2.8 | 3.6 | 2.6 | 3.8 | 4.5 | 3.0 | 3.4 |
| | 1/4-1 | 4.0 | 4.8 | 3.6 | 5.5 | 7.5 | 4.5 | 5.2 |
| | 1-3 | 4.3 | 4.8 | 3.4 | 5.5 | 5.0 | 2.9 | 4.3 |
| | Total | 15.8 | 20.8 | 13.7 | 20.9 | 24.6 | 15.4 | 18.5 |
| | | (35.4) | (46.6) | (30.7) | (46.8) | (55.1) | (34.5) | (41.5) |
| Block averages | | 17.7 | 20.3 | 13.9 | 18.9 | 20.9 | 14.6 | 17.7 |
| | | (39.7) | (45.5) | (31.1) | (42.4) | (46.8) | (32.7) | (39.7) |

[1]See block definitions under Description of the Study.
[2]See treatment definitions under Description of the Study.

The litter weights averaged 1.6 tons/acre (3.6 t/ha) (table 7), and varied from 1.2 tons/acre (2.7 t/ha) to 2.2 tons/acre (4.9 t/ha). Litter weight was estimated by measuring depth and converting to weight on the basis of 1.3 lb/ft$^3$ (20.8 kg/m$^3$) of undisturbed litter. Detailed summaries by unit for duff and litter are in tables 11-14 (appendix).

## TOTAL WEIGHT

The total of all material less than 3 inches is over 56 tons/acre (127 t/ha). The weight of standing and down woody material over 3 inches is approximately 85 tons/acre (190 t/ha) assuming about 24 lb/ft$^3$ ovendry weight of wood (sound wood will weigh more that this, rotten wood less). The total weight is about 141 tons/acre (316 t/ha) (fig. 3).

CROWN MATERIAL, < 3"
(17.7 TONS/A)

STANDING, 3" + DIA.
(GREEN & DEAD)
5677 FT³/ A
(71 TONS/A)

DOWN WOOD, 3" + DIA.
1641 FT³/A
(16 TONS /A)

DOWN WOODY,
< 3" DIA.
(4.1 TONS/A)

LITTER
(1.6 TONS/A)

(STUMP + ROOTS,
NOT INCLUDED)

DUFF
(33.22 TONS/A)

Total = 142 tons/acre
(318 metric tons/ ha)

Figure 3.--Average preharvest volume and weight of various forest
components, Coram study area.

# POSTHARVEST CHANGES IN WOODY MATERIAL

The amount of woody material that remains as residue after harvesting depends on the
cutting prescription and the level of utilization specified, and also on the extent to which
utilization specifications are followed during logging. Residue volume is also related to
preharvest conditions and these vary widely among cutting units and subtreatments. If
residues are expressed as a percentage of volumes, however, this variation can be removed to
show more clearly the effects of cutting and utilization.

# Volume of Residues 3.0 Inches (7.62 cm) Diameter and Larger

Based on the four utilization treatments specified, we would expect residues remaining after harvest to be arrayed as follows, from most to least:

> Conventional saw log utilization,
> Intensive tree utilization, understory slashed,
> Intensive log utilization, understory protected,
> Near-complete removal.

The volume of residues that remained after logging averaged from 873 ft$^3$/acre (61 m$^3$/ha) in the shelterwood-near complete utilization treatment to 2,950 ft$^3$/acre (206 m$^3$/ha) in the clearcut-conventional saw log utilization treatment (table 10). In general, the total volume of residues follows the expected pattern, but there were substantial differences in the preharvest stand that affect volume of residues. (See detailed summary in tables 15-20 [appendix].)

Table 10.--*Volume of postharvest residues by cutting method and utilization treatment, ft$^3$/ acre (m$^3$/ha)*

| Cutting method | Conventional saw log utilization | Intensive tree utilization | Intensive log utilization | Near-complete utilization |
|---|---|---|---|---|
| **Shelterwood** | | | | |
| Green | 476 | 314 | 83 | 29 |
| Sound dead | 412 | 252 | 126 | 98 |
| Unsound | 1,049 | 733 | 1,295 | 746 |
| Total | 1,937 | 1,299 | 1,504 | 873 |
| | (135) | (91) | (105) | (61) |
| **Group selection** | | | | |
| Green | 877 | 506 | 168 | 66 |
| Sound dead | 246 | 112 | 139 | 101 |
| Unsound | 827 | 1,286 | 858 | 796 |
| Total | 1,950 | 1,904 | 1,165 | 963 |
| | (136) | (133) | (81) | (67) |
| **Clearcut** | | | | |
| Green | 415 | 186 | 95 | 37 |
| Sound dead | 614 | 390 | 149 | 134 |
| Unsound | 1,929 | 1,483 | 1,428 | 1,301 |
| Total | 2,958 | 2,059 | 1,672 | 1,472 |
| | (206) | (144) | (117) | (103) |

The total volume of residue expressed as a percent of total preharvest volume is illustrated in figure 4. Here the proportion of the total preharvest stand left as residues generally decreases as the level of utilization increases. The relationship is somewhat erratic, however, because of the large and variable volume of rotten material.

When sound residues are compared to sound preharvest volume, however, there is a consistent and smooth trend (fig. 5). Sound residues in conventional saw log utilization were as high as 46 percent of the preharvest sound volume in shelterwood units. In contrast, sound residues were less than 10 percent in the near-complete utilization treatment in all cutting units.
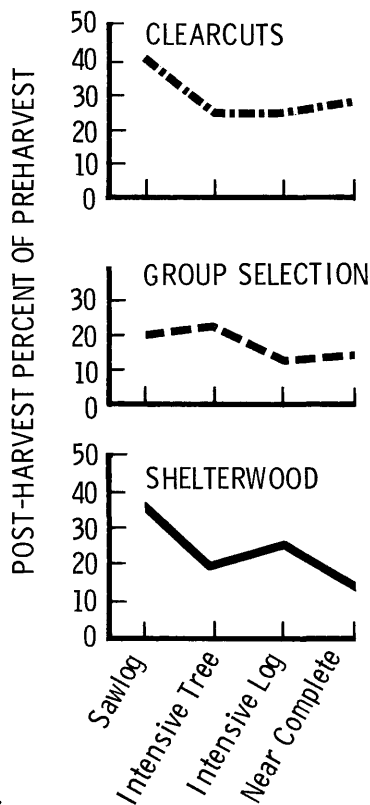
Figure 4.--Total
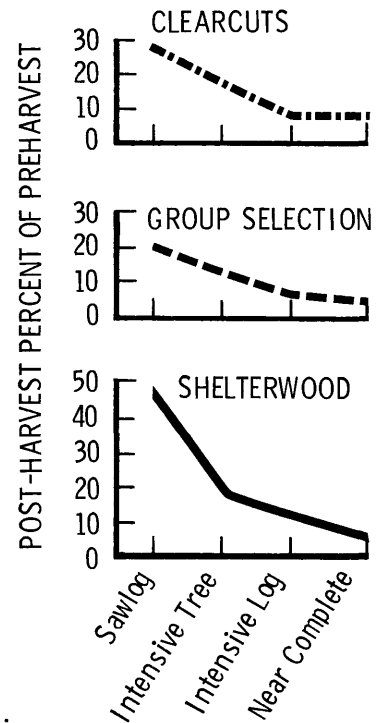  residue as a
  percent of total
  preharvest volume.



Figure 5.--Sound
  residue volume as
  percent of sound
  preharvest volume.

From the standpoint of utilization of wood fiber, figure 5 indicates that conventional saw log utilization leaves a substantial volume of sound material, but there was not much difference in the proportion of sound residues among the three more intensive treatments. There also was a lower proportion of sound residues in the shelterwood units than in the group selection and clearcut units. This was probably because protection of leave trees made it more difficult to remove sound pieces that might have been taken in clearcut units.

Although some sound material remained in all units, some unsound material was also removed, even in treatments where it was not required. In the clearcut and group selection units, the volume removed ranged from about 15 percent to over 100 percent more than the estimated sound volume. A considerable amount of unsound material was removed.

To some extent this was expected since in some treatments utilization specifications required removal of pieces that were one-third or more sound. Also, a good market for pulp chips at the time contributed to removal of defective material.

## Characteristics of Residues

The utilization potential of the residues depends in part on the number and size of residue pieces and on their condition.

The total number of pieces remaining after logging averaged from about 411/acre (1,015/ha) in shelterwood near-complete utilization to 1,240/acre (3,063/ha) in group selection with intensive tree utilization. The total number of pieces per acre of residue is tabulated below.

|  | Conventional saw log utilization | Intensive tree utilization | Intensive log utilization | Near-complete utilization |
|---|---|---|---|---|
| Shelterwood | 763 | 825 | 471 | 411 |
| Group selection | 904 | 1,240 | 690 | 580 |
| Clearcut | 932 | 1,043 | 864 | 677 |

As might be expected, fewest pieces were left in the near-complete treatment. There was not much difference between near-complete and intensive log utilization because in the intensive log treatment, the understory was not slashed. Conventional saw log utilization usually had fewer pieces than the intensive tree utilization treatment, probably because in bucking to required sizes in intensive treatment utilization, some additional residue pieces were created.

Many of these pieces were too small, in length or diameter, or were not sound enough to be used. There were, however, some potentially usable pieces. The tabulation below shows the number of individual sound pieces[1] per acre that could have been derived from the residues:

|  | Conventional saw log utilization | Intensive tree utilization | Intensive log utilization | Near-complete utilization |
|---|---|---|---|---|
| Shelterwood | 257 | 129 | 50 | 20 |
| Group selection | 338 | 245 | 91 | 63 |
| Clearcut | 112 | 88 | 59 | 27 |

### Residues Less than 3.0 Inches (7.62 cm) Diameter

The amount of fine residues under 3.0 inches diameter about doubled after harvest. The actual weights ranged from 6.44 tons to 13.49 tons per acre (16 to 33 t/ha) as shown below:

|  | Conventional saw log utilization | Intensive tree utilization | Intensive log utilization | Near-complete utilization |
|---|---|---|---|---|
| Shelterwood | 10.22 | 9.26 | 9.45 | 6.44 |
| Group selection | 11.01 | 13.49 | 12.13 | 8.30 |
| Clearcut | 10.97 | 9.55 | 10.20 | 8.24 |

On an actual weight basis, there does not appear to be much difference among treatments except for near-complete removal, where whole trees were removed. The amount of fine residues, however, is determined in large part by preharvest conditions. In figure 6, the increases in fine residues are plotted for each utilization treatment by block. In general, shelterwood had less increase in weight and the near-complete utilization treatment less increase in fine material than the other treatments because small stems were removed, not left as slash. Generally, however, there is not a strong relationship of fine residues to utilization treatment.

No postharvest measurements were made of duff and litter. This material is pushed around during logging, but does not change in amount. As needles dry and fall from slash, presumably there will be some increase in litter weight.

The role of duff and litter in regeneration following logging is discussed in other reports.

---

[1]Estimated as number of sound pieces 8 feet or more long (2.4 m) and over 3 inches (7.62 cm) small end.
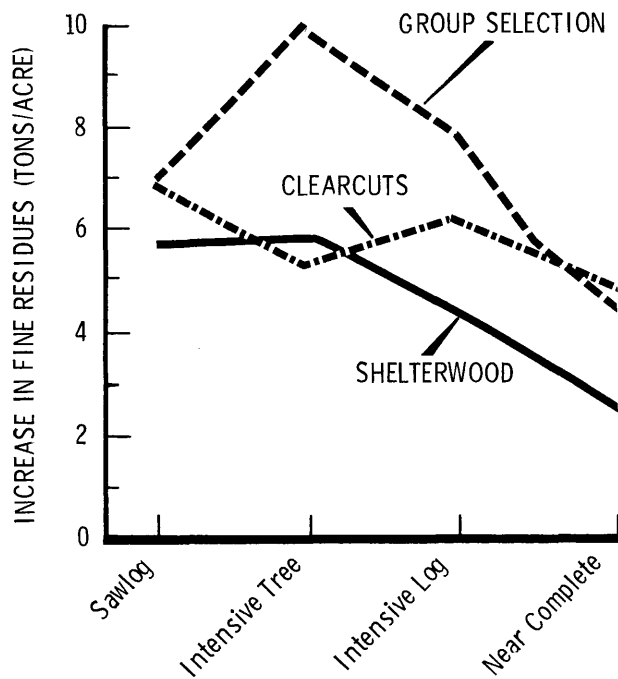
Figure 6.--Increase in fine postharvest residues < 3.0 inches diameter (7.62 cm).

# SUMMARY AND CONCLUSIONS

The total preharvest volume of wood 3 inches diameter (7.62 cm) and larger on the units logged in the Coram study averaged 7,318 ft$^3$/acre (512 m$^3$/ha). About 57 percent of this was live green material, and over 40 percent was unsound (table 21, appendix). The material less than 3 inches (crowns, litter, duff) averaged about 56.6 tons/acre (127 t/ha). Because of the patchy nature of the forest, these weights and volumes varied widely among cutting units and utilization treatments.

Despite this wide variation, the amount of residue material remaining after logging was related to the utilization level. Under conventional saw log utilization (the least intensive of the utilization treatments), from 20 percent to over 40 percent of the sound material remained, but under near-complete utilization, less than 10 percent of the sound material remained. On the more intensive utilization treatments most of the sound material was too small to be used.

Measurements were made of all phases, which provide a detailed picture of various components in the woody biomass of an overmature Douglas-fir/larch forest, showing how these components changed under different cutting methods and utilization levels.

The study indicates that despite great variation in preharvest stand conditions, the amount and kinds of residue remaining can be influenced by the utilization level prescribed. The impact of these different levels of residue on other physical and biological systems, such as soil nutrients, hydrology, and regeneration, is being followed through a series of other Coram studies.

The variations in woody material at the Coram site are probably typical of fir/larch forests throughout the Northern Rockies. Therefore, while there may not be other cutting units exactly like those at Coram, these data should provide managers with a useful insight of the composition of the woody material and changes occurring from logging under similar circumstances.

15

Various sampling schemes and measurement methods were used in estimating the preharvest and postharvest components reported here. Percent errors (the sample standard error divided by the sample mean, expressed as a percent) for all samples were quite low (tables 22, 23, appendix). To achieve a similar percent error in the individual subtreatment units, a much more intensive sampling scheme would be required.

# PUBLICATIONS CITED

Artley, Donald K., Raymond Shearer, and Robert W. Steele.
  1978. Effects of burning moist fuels on seedbed preparation in cutover western larch forests. USDA For. Serv. Res. Pap. INT-211, 14 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.
Brown, James K.
  1974. Handbook for inventorying downed woody material. USDA For. Serv. Gen. Tech. Rep. INT-16, 24 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.
Brown, James K.
  1978. Weight and density of Rocky Mountain conifers. USDA For. Serv. Res. Pap. INT-197, 56 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.
Brown, James K., J. A. Kendall Snell, and David L. Bunnell.
  1977. Handbook for predicting slash weight of western conifers. USDA For. Serv. Gen. Tech. Rep. INT-37, 35 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

# APPENDIX

Table 11.--*Weight of litter on ground, preharvest,*[1] *tons/acre (t/ha)*

| Block[3] | Treatment[2] | | | | | |
| | 1 IT | 2 SL | 3 NC | 4 IL | 5 Control | Average |
|---|---|---|---|---|---|---|
| 11 SH | 1.44 | 1.65 | 1.01 | 1.27 | | 1.34 (3.00) |
| 12 GS | 1.56 | 2.24 | 1.79 | 1.98 | | 1.89 (4.23) |
| 13 CC | 1.39 | 1.53 | 1.04 | 2.12 | | 1.52 (3.41) |
| 14 Control | | | | | 1.56 | 1.56 (3.50) |
| 21 SH | 1.30 | 1.63 | 1.79 | 1.39 | | 1.53 (3.43) |
| 22 GS | 2.34 | 2.27 | 2.12 | 2.03 | | 2.19 (4.91) |
| 23 CC | 0.97 | 1.42 | 1.60 | 0.71 | | 1.18 (2.64) |
| 24 Control | | | | | 1.63 | 1.63 (3.65) |

[1]Based on 1.3 lb/ft$^3$ (20.8 kg/m$^3$) of undisturbed forest litter.
[2]See definition of treatments under Description of the Study.
[3]See definition of blocks under Description of the Study.

Table 12.--*Average litter depth, preharvest, inches (cm)*

| Block[2] | Treatment[1] | | | | |
| | 1 IT | 2 SL | 3 NC | 4 IL | 5 Control |
|---|---|---|---|---|---|
| 11 SH | 0.61 (1.55) | 0.70 (1.78) | 0.43 (1.09) | 0.54 (1.37) | |
| 12 GS | .66 (1.68) | .95 (2.41) | .76 (1.93) | .84 (2.13) | |
| 13 CC | .59 (1.50) | .65 (1.65) | .44 (1.12) | .90 (2.29) | |
| 14 Control | | | | | 0.66 (1.68) |
| 21 SH | .55 (1.40) | .69 (1.75) | .76 (1.93) | .59 (1.50) | |
| 22 GS | .99 (2.51) | .96 (2.44) | .90 (2.29) | .86 (2.18) | |
| 23 CC | .41 (1.04) | .60 (1.52) | .68 (1.73) | .30 ( .76) | |
| 24 Control | | | | | .69 (1.75) |

[1]See definition of treatments under Description of the Study.
[2]See definition of blocks under Description of the Study.

Table 13.--*Weight of duff on ground, preharvest,*[1] *tons/acre (t/ha)*

| Block[3] | Treatment[2] | | | | | Average |
| | 1 IT | 2 SL | 3 NC | 4 IL | 5 Control | |
|---|---|---|---|---|---|---|
| 11 SH | 43.10 | 33.69 | 30.98 | 46.80 | | 38.64 ( 86.59) |
| 12 GS | 37.68 | 30.64 | 53.09 | 32.96 | | 38.59 ( 86.48) |
| 13 CC | 39.95 | 50.36 | 51.92 | 41.60 | | 45.96 (103.0) |
| 14 Control | | | | | 28.17 | 28.17 ( 63.13) |
| 21 SH | 37.27 | 45.79 | 41.45 | 41.02 | | 41.38 ( 92.63) |
| 22 GS | 49.63 | 39.54 | 37.53 | 38.79 | | 41.37 ( 92.71) |
| 23 CC | 33.11 | 39.37 | 50.02 | 43.51 | | 41.50 ( 93.00) |
| 24 Control | | | | | 30.18 | 30.18 ( 67.63) |

[1]Based on ovendry weight of 14.5 tons/inch (82.54 t/cm) depth of duff (this corresponds with a specific gravity of 0.13).
[2]See definition of treatments under Description of the Study.
[3]See definition of blocks under Description of the Study.

Table 14.--*Average duff depth, preharvest, inches (cm)*

| Block[2] | Treatment[1] | | | | |
| | 1 IT | 2 SL | 3 NC | 4 IL | 5 Control |
|---|---|---|---|---|---|
| 11 SH | 2.97 (7.54) | 2.32 (5.89) | 2.13 (5.41) | 3.22 (8.18) | |
| 12 GS | 2.59 (6.58) | 2.11 (5.36) | 3.66 (9.30) | 2.27 (5.77) | |
| 13 CC | 2.75 (6.98) | 3.47 (8.81) | 3.58 (9.09) | 2.86 (7.26) | |
| 14 Control | | | | | 1.94 (4.93) |
| 21 SH | 2.57 (6.63) | 3.15 (8.00) | 2.85 (7.24) | 2.82 (7.16) | |
| 22 GS | 3.42 (8.69) | 2.72 (6.91) | 2.58 (6.55) | 2.67 (6.78) | |
| 23 CC | 2.28 (5.79) | 2.71 (6.88) | 3.44 (8.74) | 3.00 (7.62) | |
| 24 Control | | | | | 2.08 (5.28) |

[1]See definition of treatments under Description of the Study.
[2]See definition of blocks under Description of the Study.

19

Table 15.--*Postharvest volumes by component for shelterwood units, ft$^3$/acre (m$^3$/ha)*

| Block | Component | 1 IT | | 2 SL | | 3 NC | | 4 IL | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Treatment[1] | | | | |
| 11 | Standing green | | | | | | | | |
| | Leave trees | 2,526 | (177) | 1,598 | (112) | 1,724 | ( 21) | 1,619 | (113) |
| | Other | 31 | ( 2) | 10 | ( 1) | 0 | | 280 | ( 20) |
| | Down green | | | | | | | | |
| | Sound | 422 | ( 29) | 542 | ( 38) | 34 | ( 2) | 61 | ( 4) |
| | Unsound | 34 | ( 2) | 13 | ( 1) | 0 | | 1 | |
| | Down dead | | | | | | | | |
| | Sound | 253 | ( 18) | 484 | ( 34) | 80 | ( 6) | 69 | ( 5) |
| | Unsound | 583 | ( 41) | 1,023 | ( 71) | 925 | ( 65) | 1,617 | (113) |
| | Totals | 3,849 | (269) | 3,670 | (257) | 2,763 | (193) | 3,647 | (255) |
| 21 | Standing green | | | | | | | | |
| | Leave trees | 1,922 | (134) | 1,962 | ( 37) | 1,201 | ( 84) | 1,839 | (129) |
| | Other | 19 | ( 1) | 0 | | 2 | | 694 | ( 48) |
| | Down green | | | | | | | | |
| | Sound | 205 | ( 14) | 410 | ( 29) | 24 | ( 2) | 105 | ( 7) |
| | Unsound | 18 | ( 1) | 53 | ( 4) | 1 | | 3 | |
| | Down dead | | | | | | | | |
| | Sound | 251 | ( 18) | 341 | ( 24) | 116 | ( 8) | 183 | ( 13) |
| | Unsound | 1,448 | (101) | 1,010 | ( 71) | 566 | ( 40) | 969 | ( 68) |
| | Totals | 3,863 | (270) | 3,777 | (264) | 1,910 | (134) | 3,793 | (265) |

[1]See definition of treatments under Description of the Study.

Table 16.--*Postharvest volumes by component for group selection units, $ft^3$/acre ($m^3$/ha)*

| Block | Component | 1 IT | | 2 NC | | 3 SL | | 4 IL | |
|---|---|---|---|---|---|---|---|---|---|
| 12 | Standing green | 1 | | 0 | | 0 | | 154 | ( 11) |
| | Down green | | | | | | | | |
| | Sound | 639 | ( 45) | 682 | ( 48) | 59 | ( 4) | 238 | ( 17) |
| | Unsound | 23 | ( 2) | 6 | | 0 | | 4 | |
| | Down dead | | | | | | | | |
| | Sound | 65 | ( 4) | 237 | ( 16) | 57 | ( 4) | 176 | ( 12) |
| | Unsound | 1,027 | ( 72) | 338 | ( 24) | 483 | ( 34) | 740 | ( 52) |
| | Totals | 1,755 | (123) | 1,263 | ( 88) | 599 | ( 42) | 1,312 | ( 92) |
| 22 | Standing green | 34 | ( 2) | 0 | | 0 | | 31 | ( 2) |
| | Down green | | | | | | | | |
| | Sound | 374 | ( 26) | 1,072 | ( 75) | 74 | ( 5) | 99 | ( 7) |
| | Unsound | 7 | | 5 | | 0 | | 0 | |
| | Down dead | | | | | | | | |
| | Sound | 160 | ( 11) | 255 | ( 18) | 146 | ( 10) | 103 | ( 7) |
| | Unsound | 1,515 | (106) | 1,305 | ( 91) | 1,109 | ( 78) | 973 | ( 68) |
| | Totals | 2,090 | (146) | 2,637 | (184) | 1,329 | ( 93) | 1,206 | ( 84) |

[1]See definition of treatments under Description of the Study.

Table 17.--*Postharvest volumes by component for clearcut units, $ft^3$/acre ($m^3$/ha)*

| Block | Component | Treatment[1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 IT | | 2 SL | | 3 NC | | 4 IL | |
| 13 | Standing green | 0 | | 0 | | 0 | | 26 | ( 2) |
| | Down green | | | | | | | | |
| | Sound | 146 | ( 10) | 499 | ( 35) | 25 | ( 2) | 149 | ( 10) |
| | Unsound | 0 | | 101 | ( 7) | 4 | | 0 | |
| | Down dead | | | | | | | | |
| | Sound | 298 | ( 21) | 512 | ( 36) | 135 | ( 9) | 166 | ( 12) |
| | Unsound | 1,284 | ( 90) | 1,269 | ( 89) | 787 | ( 55) | 675 | ( 47) |
| | Totals | 1,728 | (121) | 2,381 | (167) | 951 | ( 66) | 1,016 | ( 71) |
| 23 | Standing green | 43 | ( 3) | 0 | | 10 | ( 1) | 42 | ( 3) |
| | Down green | | | | | | | | |
| | Sound | 226 | ( 16) | 331 | ( 23) | 49 | ( 3) | 42 | ( 3) |
| | Unsound | 0 | | 68 | ( 5) | 0 | | 0 | |
| | Down dead | | | | | | | | |
| | Sound | 483 | ( 34) | 716 | ( 50) | 134 | ( 9) | 132 | ( 9) |
| | Unsound | 1,682 | (118) | 2,421 | (169) | 1,812 | (127) | 2,182 | (153) |
| | Totals | 2,434 | (170) | 3,536 | (247) | 2,005 | (140) | 2,398 | (168) |

[1]See definition of treatments under Description of the Study.

22

Table 18.--*Total volume per acre (hectare) of standing and down wood, 3-inch (7.62-cm) diameter and larger, preharvest and postharvest, and volume removed, by block and treatment, ft³/acre (m³/ha)*

| Block | Number | Intensive tree utilization 5-inch d.b.h. 1 | Conventional saw log utilization 7-inch d.b.h. 2 | Near-complete removal 3 | Intensive log utilization 7-inch d.b.h. 4 |
|---|---|---|---|---|---|
| | | Preharvest | | | |
| Shelterwood | 11 | 6,845 (480) | 4,973 ( 348) | 5,862 (410) | 5,280 (369) |
| Shelterwood | 21 | 6,720 (470) | 4,409 ( 308) | 4,556 (319) | 4,960 (347) |
| Group Selection | 12 | 9,341 (654) | 7,028 ( 492) | 8,254 (577) | 9,919 (694) |
| Group Selection | 22 | 8,304 (581) | 14,891 (1,042) | 7,570 (530) | 10,215 (715) |
| Clearcut | 13 | 8,154 (570) | 6,704 ( 469) | 5,913 (414) | 6,911 (484) |
| Clearcut | 23 | 8,821 (617) | 8,055 ( 563) | 5,538 (387) | 6,433 (450) |
| | | Postharvest | | | |
| Shelterwood | 11 | 3,849 (269) | 3,670 (257) | 2,763 (193) | 3,647 (255) |
| Shelterwood | 21 | 3,863 (270) | 3,777 (264) | 1,910 (134) | 3,793 (265) |
| Group Selection | 12 | 1,755 (123) | 1,263 ( 88) | 599 ( 42) | 1,312 ( 92) |
| Group Selection | 22 | 2,090 (146) | 2,637 (184) | 1,329 ( 93) | 1,206 ( 84) |
| Clearcut | 13 | 1,728 (121) | 2,381 (167) | 951 ( 66) | 1,016 ( 71) |
| Clearcut | 23 | 2,434 (170) | 3,536 (247) | 2,005 (140) | 2,398 (168) |
| | | Volume Removed | | | |
| Shelterwood | 11 | 2,996 (210) | 1,303 ( 91) | 3,099 (217) | 1,633 (114) |
| Shelterwood | 21 | 2,857 (200) | 632 ( 44) | 2,646 (185) | 1,167 ( 82) |
| Group Selection | 12 | 7,586 (531) | 5,765 (403) | 7,655 (536) | 8,607 (602) |
| Group Selection | 22 | 6,214 (435) | 12,254 (857) | 6,241 (437) | 9,009 (630) |
| Clearcut | 13 | 6,426 (450) | 4,323 (302) | 4,962 (347) | 5,895 (412) |
| Clearcut | 23 | 6,387 (447) | 4,519 (316) | 3,533 (247) | 4,035 (282) |

Table 19.--*Crown weights on standing trees, postharvest (prior to slash burning in treatments 1 and 2), tons/acre (t/ha)*

| Treatment[2] | Size | Block[1] 11 SH | 12 GS | 13 CC | 21 SH | 22 GS | 23 CC | Treatment averages |
|---|---|---|---|---|---|---|---|---|
| | | *Inches* | | | | | | |
| 1 IT | Foliage | 2.4 | 0.01 | | 2.2 | 0.2 | | |
| | 0-1/4 | 1.5 | .01 | | 1.4 | .1 | | |
| | 1/4-1 | 2.4 | .01 | | 2.2 | .1 | | |
| | 1-3 | 1.6 | .04 | | .9 | .1 | | |
| | Total | 7.9 | 0.07 | | 6.7 | 0.5 | | 2.5 |
| | | (17.7) | (0.16) | | (15.0) | (1.1) | | (5.6) |
| 2 SL | Foliage | 1.3 | | | 1.9 | | | |
| | 0-1/4 | .8 | | | 1.2 | | | |
| | 1/4-1 | 1.4 | | | 2.0 | | | |
| | 1-3 | .8 | | | 1.1 | | | |
| | Total | 4.3 | | | 6.2 | | | 1.7 |
| | | (9.6) | | | (13.9) | | | (3.8) |
| 3 NC | Foliage | 1.7 | 0.02 | 0.02 | 1.8 | | 0.1 | |
| | 0-1/4 | 1.1 | .01 | 0 | 1.0 | | .1 | |
| | 1/4-1 | 1.9 | .01 | .01 | 1.7 | | .1 | |
| | 1-3 | 1.0 | .01 | .03 | .9 | | .1 | |
| | Total | 5.7 | 0.05 | 0.06 | 5.4 | | 0.4 | 1.9 |
| | | (12.8) | (0.11) | (0.13) | (12.1) | | (0.9) | (4.3) |
| 4 IL | Foliage | 3.1 | 0.5 | 0.4 | 4.8 | 0.3 | 0.3 | |
| | 0-1/4 | 1.9 | .4 | .2 | 3.0 | .2 | .2 | |
| | 1/4-1 | 2.6 | .5 | .2 | 4.2 | .2 | .2 | |
| | 1-3 | 2.8 | 1.0 | .3 | 3.4 | .3 | .3 | |
| | Total | 10.4 | 2.4 | 1.1 | 15.4 | 1.0 | 1.0 | 5.2 |
| | | (23.3) | (5.4) | (2.5) | (34.5) | (2.2) | (2.2) | (11.7) |
| Block averages | | 7.1 | 0.6 | 0.3 | 8.4 | 0.4 | 0.3 | 2.9 |
| | | (15.9) | (1.3) | (0.7) | (18.8) | (0.9) | (0.7) | (6.5) |

[1]See definition of blocks under Description of the Study.
[2]See definition of treatments under Description of the Study.

Table 20.--*Weight of small woody material on ground, by diameter class, postharvest, tons/acre*
*(t/ha)*

| Treat-ment[1] | Size | Block[2] | | | | | | Treatment averages |
|---|---|---|---|---|---|---|---|---|
| | | 11 SH | 12 GS | 13 CC | 21 SH | 22 GS | 23 CC | |
| | *Inches* | | | | | | | |
| 1 IT | 0-1/4 | 1.50 | 2.10 | 1.72 | 1.44 | 1.95 | 1.45 | |
| | 1/4-1 | 3.48 | 6.38 | 3.24 | 3.99 | 5.09 | 3.74 | |
| | 1-3 | 4.24 | 7.89 | 4.51 | 3.85 | 3.57 | 4.45 | |
| | Total | 9.22 | 16.37 | 9.47 | 9.28 | 10.61 | 9.64 | 10.77 |
| | | (20.66) | (36.68) | (21.22) | (20.80) | (23.78) | (21.60) | (24.13) |
| 2 SL | 0-1/4 | 2.03 | 1.86 | 2.00 | 1.43 | 2.01 | 2.09 | |
| | 1/4-1 | 3.83 | 4.80 | 3.64 | 3.61 | 3.59 | 3.78 | |
| | 1-3 | 5.37 | 6.10 | 6.09 | 4.18 | 3.67 | 4.35 | |
| | Total | 11.23 | 12.76 | 11.73 | 9.22 | 9.27 | 10.22 | 10.74 |
| | | (25.17) | (28.59) | (26.29) | (20.66) | (20.77) | (22.90) | (24.07) |
| 3 NC | 0-1/4 | 1.41 | 1.06 | 1.05 | 1.27 | 1.40 | 1.25 | |
| | 1/4-1 | 2.05 | 3.34 | 5.70 | 1.75 | 2.73 | 1.59 | |
| | 1-3 | 3.60 | 3.90 | 3.19 | 2.81 | 4.16 | 3.70 | |
| | Total | 7.06 | 8.30 | 9.94 | 5.83 | 8.29 | 6.54 | 7.66 |
| | | (15.82) | (18.60) | (22.27) | (13.06) | (18.58) | (14.66) | (17.17) |
| 4 IL | 0-1/4 | 1.64 | 1.65 | 1.70 | 1.26 | 1.94 | 1.53 | |
| | 1/4-1 | 2.34 | 4.55 | 4.46 | 2.55 | 3.40 | 2.15 | |
| | 1-3 | 5.81 | 5.70 | 6.25 | 5.30 | 7.03 | 4.32 | |
| | Total | 9.79 | 11.90 | 12.41 | 9.11 | 12.37 | 8.00 | 10.60 |
| | | (21.94) | (26.68) | (27.81) | (20.41) | (27.72) | (17.93) | (23.75) |
| Block averages | | 9.33 | 12.33 | 10.89 | 8.36 | 10.14 | 8.60 | 9.94 |
| | | (20.91) | (27.63) | (24.40) | (18.73) | (22.72) | (19.27) | (22.29) |

[1]See definition of treatments under Description of the Study.
[2]See definition of blocks under Description of the Study.

Table 21.--Preharvest volume components, in percent, for Coram study site

Percent - - - (Total volume, ft³/acre)

| Component | 11[2]:1 | 11:2 | 11:3 | 11:4 | 12:1 | 12:2 | 12:3 | 12:4 | 13:1 | 13:2 | 13:3 | 13:4 | Average all treatments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Standing** | | | | | | | | | | | | | |
| Green | 82.6 | 73.7 | 69.2 | 64.6 | 66.2 | 64.1 | 39.9 | 46.9 | 43.4 | 54.5 | 41.7 | 59.2 | 56.6 |
| Sound dead | 5.6 | 3.8 | 1.1 | .6 | .1 | .4 | .2 | .2 | .1 | .2 | .0 | .0 | 1.0 |
| Unsound | .0 | .0 | 7.6 | 7.4 | 24.3 | 17.2 | 34.6 | 32.4 | 22.5 | 16.2 | 13.3 | 14.6 | 16.5 |
| **Down** | | | | | | | | | | | | | |
| Sound | .6 | .6 | 1.5 | .3 | .3 | .3 | 1.3 | .7 | 4.0 | 2.1 | 2.2 | .7 | 1.0 |
| Unsound | 11.2 | 21.4 | 20.5 | 27.1 | 9.1 | 18.1 | 24.0 | 19.8 | 30.1 | 27.0 | 42.7 | 25.3 | 24.8 |
| Total volume | (6,845) | (4,973) | (5,862) | (5,280) | (9,341) | (7,028) | (8,254) | (9,919) | (8,154) | (6,704) | (5,913) | (6,911) | (7,314) |

Block

Percent - - - (Total volume, ft³/acre)

| Component | 21:1 | 21:2 | 21:3 | 21:4 | 22:1 | 22:2 | 22:3 | 22:4 | 23:1 | 23:2 | 23:3 | 23:4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Standing** | | | | | | | | | | | | |
| Green | 64.4 | 55.0 | 66.5 | 78.0 | 46.3 | 43.5 | 60.4 | 65.2 | 46.9 | 46.2 | 31.0 | 49.3 |
| Sound dead | .6 | .9 | 2.4 | 1.7 | .0 | 1.0 | .4 | .8 | .6 | 1.1 | .5 | .6 |
| Unsound | 14.4 | 11.2 | 3.2 | 5.6 | 34.3 | 43.7 | 18.5 | 17.6 | 15.6 | 19.2 | 12.9 | 9.8 |
| **Down** | | | | | | | | | | | | |
| Sound | .5 | 1.6 | .7 | .4 | .4 | 1.2 | 1.0 | .2 | 1.5 | .7 | .7 | 1.7 |
| Unsound | 19.1 | 31.3 | 27.1 | 14.3 | 19.0 | 10.5 | 19.7 | 16.1 | 35.4 | 32.8 | 54.8 | 38.6 |
| Total volume | (6,720) | (4,409) | (4,556) | (4,960) | (8,304) | (14,891) | (7,570) | (10,215) | (8,821) | (8,055) | (5,538) | (6,433) |

[1]See definition of blocks under Description of the Study.
[2]See definition of treatments under Description of the Study.

Table 22.--*Percent errors[1] for various preharvest components*

| Block-treatment[2] | Number of standing green trees <7" | Number of standing dead trees <7" | Weight of small woody material | | | Duff load | Total down volume >3" |
|---|---|---|---|---|---|---|---|
| | | | 0"-1/4" | 1/4"-1" | 1"-3" | | |
| | | | | *Percent errors* | | | |
| | (n=10) | (n=10) | | (n=20) | | (n=20) | (n=20) |
| 11-1 | 17.1 | 23.1 | 14.5 | 14.5 | 17.2 | 9.8 | 22.0 |
| 2 | 16.1 | 21.5 | 12.4 | 16.0 | 25.4 | 22.4 | 20.7 |
| 3 | 17.9 | 29.1 | 15.7 | 16.5 | 24.4 | 29.7 | 26.1 |
| 4 | 12.7 | 24.2 | 18.8 | 20.8 | 25.4 | 24.2 | 18.4 |
| 12-1 | 21.0 | 41.3 | 9.6 | 12.2 | 24.7 | 36.4 | 17.0 |
| 2 | 18.8 | 20.9 | 10.7 | 12.0 | 22.3 | 49.3 | 26.4 |
| 3 | 12.3 | 31.3 | 11.5 | 14.1 | 17.7 | 29.8 | 20.0 |
| 4 | 13.8 | 30.3 | 11.7 | 16.9 | 18.7 | 58.6 | 14.3 |
| 13-1 | 17.9 | 34.0 | 23.0 | 21.8 | 25.1 | 51.6 | 18.0 |
| 2 | 15.1 | 30.6 | 9.9 | 16.1 | 21.6 | 43.3 | 23.7 |
| 3 | 15.8 | 37.3 | 16.2 | 11.9 | 22.6 | 51.0 | 17.4 |
| 4 | 16.7 | 47.5 | 9.9 | 18.9 | 20.1 | 59.9 | 22.2 |
| 21-1 | 15.1 | 24.5 | 16.4 | 12.7 | 26.8 | 71.8 | 18.5 |
| 2 | 14.9 | 29.3 | 19.8 | 16.6 | 17.0 | 60.6 | 29.6 |
| 3 | 16.8 | 37.9 | 17.7 | 14.2 | 18.1 | 69.6 | 18.7 |
| 4 | 15.5 | 17.7 | 16.4 | 51.3 | 30.0 | 72.4 | 24.2 |
| 22-1 | 13.8 | 54.1 | 14.9 | 16.0 | 26.8 | 64.3 | 16.3 |
| 2 | 17.5 | 51.1 | 14.0 | 11.5 | 26.1 | 83.1 | 21.8 |
| 3 | 20.4 | 53.6 | 14.7 | 19.0 | 23.0 | 89.6 | 18.6 |
| 4 | 21.6 | 95.0 | 15.5 | 13.0 | 25.1 | 88.1 | 19.3 |
| 23-1 | 15.2 | 37.1 | 15.4 | 15.6 | 37.2 | 104.8 | 14.4 |
| 2 | 21.2 | 34.6 | 14.1 | 18.6 | 36.4 | 89.3 | 15.5 |
| 3 | 29.3 | 51.1 | 18.9 | 25.5 | 21.7 | 72.2 | 15.7 |
| 4 | 27.3 | 65.8 | 17.4 | 17.1 | 24.4 | 84.9 | 20.8 |
| | (n=30) | (n=30) | | (n=40) | | (n=40) | (n=40) |
| 14-5 | 14.9 | 21.2 | 8.9 | 15.3 | 18.8 | 45.7 | 14.7 |
| | (n=20) | (n=20) | | | | | |
| 24-5 | 12.2 | 31.0 | 10.0 | 26.0 | 16.1 | 62.1 | 12.2 |
| | (n=290) | (n=290) | | | | | (n=558) |
| All samples | 3.7 | 7.6 | | | | | 4.1 |

[1]Percent error is the sample standard error divided by the sample mean.
[2]See definition of blocks and treatments under Description of the Study.

Table 23.--*Percent errors[1] for various postharvest components*

| Block-treatment[2] | Weight of small woody material | | | Total down volume |
|---|---|---|---|---|
| | 0"-1/4" | 1/4"-1" | 1"-3" | >3" |

- - - - - - - - - - - - - *Percent errors* - - - - - - - - - -

| Block-treatment[2] | 0"-1/4" | 1/4"-1" | 1"-3" | >3" |
|---|---|---|---|---|
| | | (n=30) | | (n=30) |
| 11-1 | 11.6 | 11.2 | 15.4 | 17.6 |
| 2 | 7.0 | 12.3 | 15.0 | 13.1 |
| 3 | 7.5 | 10.2 | 17.0 | 25.6 |
| 4 | 11.5 | 16.4 | 9.5 | 16.1 |
| 12-1 | 11.2 | 13.6 | 11.8 | 17.8 |
| 2 | 7.4 | 8.8 | 16.1 | 13.2 |
| 3 | 12.0 | 9.2 | 15.6 | 18.2 |
| 4 | 9.4 | 10.5 | 12.1 | 11.5 |
| 13-1 | 9.3 | 11.1 | 13.6 | 15.1 |
| 2 | 9.3 | 12.0 | 13.7 | 15.0 |
| 3 | 7.3 | 37.4 | 19.1 | 13.3 |
| 4 | 17.1 | 16.0 | 11.6 | 15.6 |
| 21-1 | 14.1 | 14.9 | 13.6 | 19.4 |
| 2 | 13.3 | 14.9 | 17.4 | 10.4 |
| 3 | 10.0 | 13.5 | 17.9 | 21.9 |
| 4 | 10.7 | 14.9 | 14.3 | 19.0 |
| 22-1 | 8.8 | 8.6 | 13.2 | 19.2 |
| 2 | 8.7 | 12.2 | 15.9 | 19.8 |
| 3 | 10.2 | 13.8 | 15.2 | 20.7 |
| 4 | 11.9 | 13.9 | 13.4 | 12.1 |
| 23-1 | 12.4 | 16.1 | 15.2 | 17.3 |
| 2 | 8.2 | 10.6 | 16.7 | 13.0 |
| 3 | 12.2 | 13.9 | 15.8 | 18.9 |
| 4 | 11.9 | 13.7 | 14.9 | 17.9 |
| | | | | (n=720) |
| All samples | | | | 3.9 |

[1]Percent error is the sample standard error divided by the sample mean.
[2]See definition for blocks and treatments under Description of the Study.

Benson, Robert E., and Joyce A. Schlieter.
1980. Volume and weight characteristics of a typical Douglas-
fir/western larch stand, Coram Experimental Forest, Montana.
USDA For. Serv. Gen. Tech. Rep. INT-92, 28p. Intermt.
For. and Range Exp. Stn., Ogden, Utah 84401.

An overmature Douglas-fir/western larch stand on the Coram
Experimental Forest in Montana averaged about 7,300 ft$^3$/acre
(511 m$^3$/ha) of wood over 3 inches (7.62 cm) in diameter, and
an additional 57 tons/acre (128/ha) of fine material, before
harvest. After logging, using three different cutting methods
and four different levels of utilization, wood residues ranged
from 600 ft$^3$/acre (43 m$^3$/ha) under intensive utilization to over
3,500 ft$^3$/acre (245 m$^3$/ha) where only saw logs were removed.
Fine residues increased under all treatments.

KEYWORDS: biomass, forest residues, Douglas-fir/western larch

The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station includes the States of Montana, Idaho, Utah, Nevada, and western Wyoming. About 231 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

Field programs and research work units of the Station are maintained in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)