by A. Jeff Martin

Suitability of the Line Intersect Method for Sampling Hardwood Logging Residues

USDA FOREST SERVICE RESEARCH PAPER NE-339
1976

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
6816 MARKET STREET, UPPER DARBY, PA. 19082
F. BRYAN CLARK, STATION DIRECTOR

The Author

A. JEFF MARTIN attended Michigan State University, receiving a degree in forestry in 1965, an M.S. degree in forest management in 1966, and a Ph.D. degree in forest management in 1969. He joined the Staff of the Northeastern Forest Experiment Station at the Forest Products Marketing Laboratory, Princeton, West Virginia, in 1969. He is conducting research in the marketing of primary wood products, the application of system-analysis procedures to the transportation of Appalachian roundwood products, and logging residue.

MANUSCRIPT RECEIVED FOR PUBLICATION 27 MAY 1975

Suitability of the Line Intersect Method for Sampling Hardwood Logging Residues

Abstract

The line intersect method of sampling logging residues was tested in Appalachian hardwoods and was found to provide unbiased estimates of the volume of residue in cubic feet per acre. Thirty-two chains of sample line were established on each of sixteen 1-acre plots on cutover areas in a variety of conditions. Estimates from these samples were then compared to actual volumes obtained from a 100 percent cruise of each plot. No consistent bias was found; and, when species, slope, cutting method, road influence, and piece length were examined, their effects were found to be nonsignificant.

From the average variance found with the line intersect method, a table of recommended sample sizes for several levels of precision was prepared. From the study, it was also learned that sampling time is directly related to residue volume per acre and type of cut; however, the relation is not as strong with the line intersect method as with fixed-area plots.

Introduction

ALTHOUGH LOGGING residues have always been a byproduct of timber harvesting, it has only been during the past few years that attention has really been focused on their utilization. In many parts of the country, logging slash has always posed problems by interfering with site preparation and increasing the danger of fire by fuel accumulation. However, the era of environmentalism (with greater concern for aesthetics, air and water quality, and additional energy sources) and the need for more raw materials in the paper, board, and sawn product industries have prompted a closer look at residue utilization.

Before marketing studies and economic analyses of the feasibility of residue utilization can be made, it is first necessary to learn something about the quantities, characteristics, and accessibility of the residue. Such information is now available for softwoods in the Pacific Coast states *(Dell and Ward 1971; Howard 1971, 1973)* and the Intermountain area *(Brown 1974)*; however, comparable data for other regions (particularly hardwood areas) is either lacking or limited in scope.

The West Coast estimates of logging residues were obtained by sampling cutover areas by the line intersect method. The use of this technique for sampling logging residues was pioneered in New Zealand *(Warren and Olsen 1964)* and refined and retested in the United States and Canada *(Bailey 1969, 1970a, 1970b; Howard and Ward 1972; Menard and Dionne 1972; Van Wagner 1968)*. The method was found to be quite accurate and efficient. All these tests, however, were in softwoods. Therefore, we felt that before surveying residue in Appalachia, we should verify the accuracy of line intersect sampling in hardwood timber.

The Line Intersect Method

Line intersect sampling uses a sample line, or a transect, that may be continuous or segmented, located systematically (with reference to a grid network) or randomly, and can be measured in any units.

When a continuous line is used, its direction is usually changed in either a fixed or a random manner after a predetermined distance has been measured. When the line is not continuous, the segments may be oriented unidirectionally, randomly, or in groups (for example, paired at a right angle to each other).

The method then requires that whenever a piece of residue crosses the line, its diameter be measured at the point of intersection. The volume of residue is then estimated by using the equation:

$$V = \frac{\pi \Sigma d^2}{8L} \cdot \frac{43{,}560}{144}$$

Where:

V = volume of residue per acre, in cubic feet.
d = diameter of residue at point of intersection, in inches.
L = length of sample line, in feet.

If the sample line is measured in chains, the equation becomes:

$$V = \frac{\Sigma(.005454d^2)}{N} \times 1037$$

Where:

N = the length of the sample line in chains.

When information on defect, length, and end diameters is desired, it is very easy to make a subsample of a portion of the sample line (for example, every fourth chain) and measure the desired characteristics of residue pieces in the subsample, and perhaps add a classification code, in addition to the diameter at point of intersection.

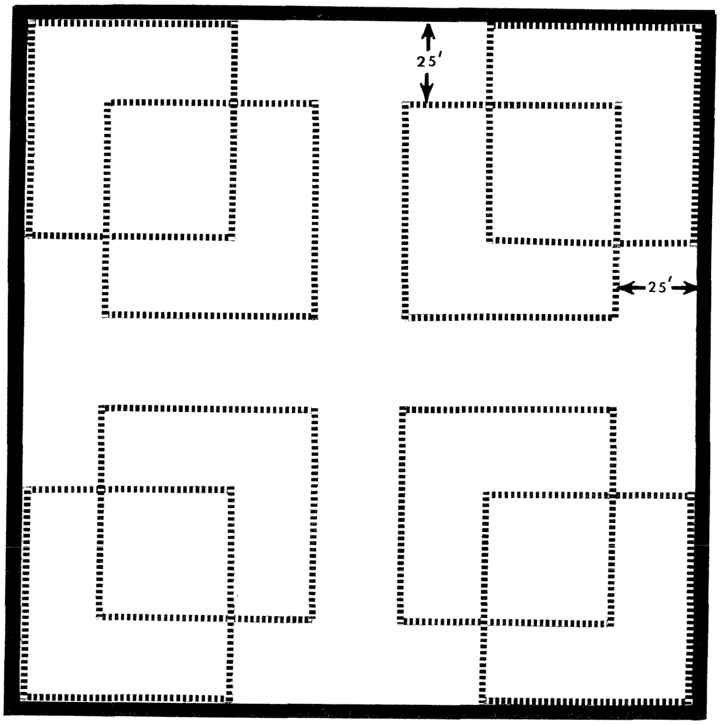
Study Methods

The objectives of this study were to see whether any characteristics of hardwood logging residues would cause bias in the line intersect method, and to determine what amount of sampling would be required to estimate residue volume to a given degree of precision.

To accomplish this required a means of ascertaining "actual" residue volumes for comparison with the estimates provided by the line intersect method.

In this study, actual volumes were obtained from a 100 percent tally of all residue pieces ($\geq$ 4.0 inches dob at the small end, and $\geq$ 4 feet in length) within a square 1-acre plot. Sixteen plots were established in different parts of West Virginia and measurements were taken between May of 1973 and May of 1974. Each plot was treated as a limited population of residue material. Hence, the tabulated volume for each plot will be referred to as the true or actual volume per acre. Volumes in gross cubic feet were calculated with Smalian's formula, using both end diameters and the length of each piece. Pieces that crossed one-

Figure 1.—A 1-acre plot (208.7 feet on each side) showing the arrangement of lines for the line intersect sample.



▮▮▮▮▮▮▮▮▮▮▮ Intersect lines for the sample of 32 chains half of the plot's boundary were tallied; pieces crossing the remainder of the boundary were ignored.

Next the plots were sampled by the line intersect technique. Each plot was sampled along 32 intersect lines, each one chain in length. Figure 1 illustrates the arrangement of sample lines within one of the plots. As recommended by Bailey *(1969, 1970b)*, we subsampled 25 percent of the chains (8 chains per plot) to obtain measurements of end diameters and length.

Results

The volumes estimated by the line intersect sampling method are compared with the actual tallied volumes in table 1.

The mean percentage difference between the estimated and actual volumes was 8 percent. The 95 percent confidence interval about the mean percentage difference was 8 percent ± 11 percent. Therefore, we may be 95 percent confident that, if there is a consistent bias when the line intersect method is used with hardwood logging residues, it is between − 3 and + 19 percent. The fact that this interval includes zero means that we can't reject the hypothesis that there is no bias.

Table 1.—Actual gross volume of residue and that estimated from the sample (in ft.^{3}/acre) for the 16 plots

Plot no.	Volume of residue		Difference between estimated and actual volume
	Actual	Estimated	
	Cubic feet		*Percent*
1	290	231	−20
2	655	814	24
3	204	176	−14
4	805	831	3
5	672	868	29
6	761	808	6
7	264	360	36
8	169	134	−21
9	1,297	1,638	26
10	354	398	12
11	925	916	− 1
12	397	443	12
13	222	327	47
14	150	172	15
15	199	195	− 2
16	102	83	−19
Mean	467	525	8

BIAS IN DIFFERENT SITUATIONS

In general the line intersect method was reliable. But are there situations in which it is biased? To provide at least a partial answer to this question, we divided the 16 plots according to various characteristics.

- Oak plots versus nonoak plots (a plot with more than 50 percent of the pieces from oak species was considered an oak plot).
- Plots with roads versus plots without roads (a plot with one or more skid trails or haul roads intersecting its boundaries was considered to be a plot with roads).
- Plots in partially cut areas versus plots in clearcut areas.
- Flat plots versus steep plots (a flat plot was one with an average slope $\leq$ 20 percent ($\bar{x}$ = 9%); a steep plot, $\geq$ 30% ($\bar{x}$ = 38%)).
- Plots with short residue pieces versus plots with long pieces (a plot was in the "short" category if fewer than 50 percent of the pieces were over 12 feet long).

Table 2.—Comparison of estimated volume to actual volume for selected "treatment" categories

Category	Average volume per acre		Difference between estimated and actual volume
	Actual	Estimated	
	Cubic feet		*Percent*
Oak (n=10)	392	415	6
Nonoak (n=6)	592	707	19
Road influence (n=8)	430	514	20
No road influence (n=8)	504	535	6
Partial cuts (n=10)	605	694	15
Clearcut (n=6)	236	242	3
Flat (n=10)	328	362	10
Steep (n=6)	698	795	14
Short pieces (n=9)	276	311	13
Long pieces (n=7)	712	799	12

The results of these comparisons are shown in table 2. To evaluate them, a modified analysis of variance was performed. It showed that none of the interaction terms or main effects was significant. In other words, we could not reject the hypothesis that all differences were due to chance (random variation).

SAMPLE SIZE

The desired sample size can be computed from the mean variance within the plots for various levels of precision. Sample sizes were computed by the standard formula; the results are presented in table 3. When these recommendations are followed, we may be 95 percent confident that the final volume-per-acre estimate will have at least the specified degree of precision with the number of chains given.

Table 3.—Length of sample line needed for various degrees of precision (in chains)

Degree of precision	Length of sample line
Percent	*Chains*
±10	680
±15	302
±20	170
±25	109
±30	76
±35	55
±40	42
±45	34
±50	27

$$n = \frac{t^2 CV^2}{DP^2}$$

Where: n = required number of sampling units (chains)
t = "student's" t-value at the 95 percent confidence level
CV = coefficient of variation in percent
DP = desired degree of precision in percent

Since these are guidelines based on average coefficient of variation found in this study (133 percent), they should be tempered by the characteristics of the residue to be sampled. For example, areas where the pieces vary greatly in size and the residue is noticeably clumped should be sampled more intensively than areas where the residue is uniform in size and distribution.

SAMPLING TIME

When field measurements were being collected, a record was kept of the time spent by a two-man crew. On the average, 3.7 hours were required to measure a 1-acre plot (this excluded lunch breaks but included any other rest periods). Sampling with the line intersect method (with a 25 percent subsample), required an average of 5 minutes per chain (excluding lunch breaks but including rest periods and walking between sampling units).

We also found that the time required was related to volume per acre and to the type of cut (clearcut areas required more time than partially cut areas). As can be seen in figure 2, the effect of volume per acre was more pronounced when an entire 1-acre plot was measured than when the line intersect method was used.

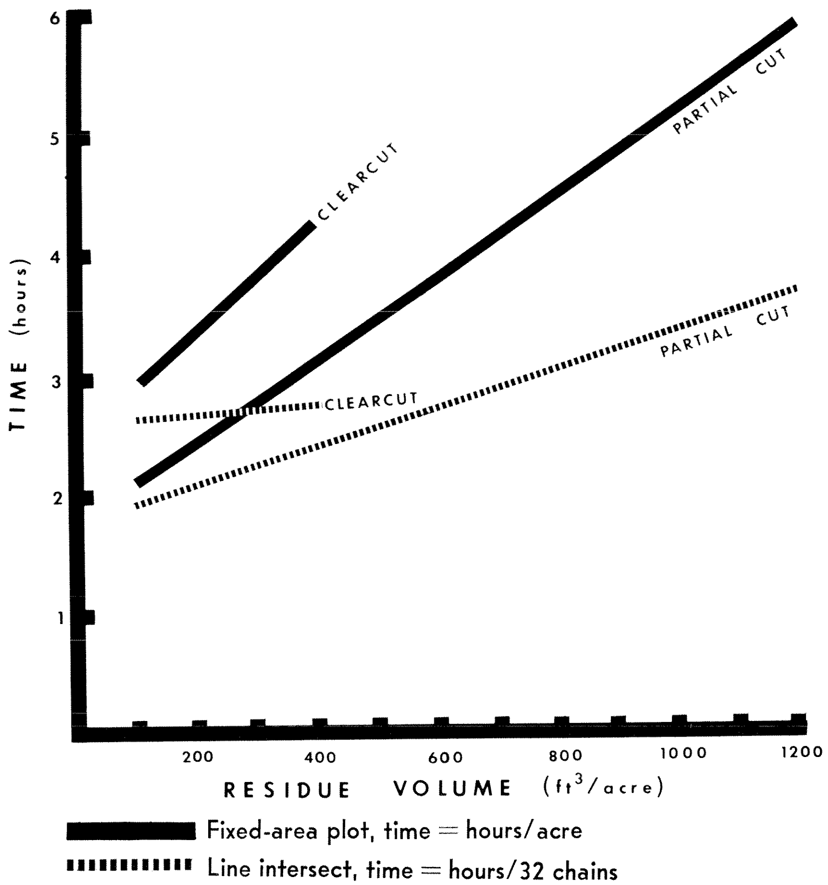
The effect of slope on sampling time was also examined, but very little relationship was found. Measurement time for the fixed 1-acre plots increased slightly as slope increased from 0 to 45 percent; however, there was no noticeable increase in the time required for line intersect sampling.

If we look at what could be accomplished in an 8-hour day (on partial cuts only, using "curved" values from figure 2) we find:

	Amount sampled in an 8-hour day	
Volume/acre (ft^3)	*Fixed plots (acres)*	*Line intersect (chains)*
200	3.3	122
400	2.6	107
600	2.1	95
800	1.8	85
1000	1.5	77
1200	1.4	70

Our study was not designed to compare sampling time for fixed-area plots against that with the line intersect method, but other studies *(Warren and Olsen 1964, Van Wagner 1968, Bailey 1969, Menard and Dionne 1972)* all report that the line intersect method requires only one-fifth to one-third the time normally spent with fixed-area plots.

Figure 2.—Residue sampling time plotted against volume per acre for clearcuts and partial cuts.



OTHER CONSIDERATIONS

There are considerations other than accuracy, time, and cost that affect the choice of a sampling method. For example, with fixed area plots, there must be some criteria for pieces that overlap the plot's boundary, and they must be easily interpreted by the field crew. With line intersect sampling, there is no boundary; therefore, no guidelines are needed.

Another factor of considerable importance to the field crew is the ease of determining what has been measured. With fixed plots, we found it necessary to mark each measured piece to avoid missing some and remeasuring others. When the line intersect method is used, there is no problem because measuring proceeds systematically along the sample line.

Thus, in general, line intersect sampling is a boon to the field worker because there is less ambiguity and decision-making is held to a minimum. There is also a psychological benefit in being able to see readily what has been accomplished and what lies ahead, and in having confidence that the completed work is up to standard.

Conclusions

- The line intersect method will provide a reliable and unbiased estimate of the volume of hardwood logging residues with a minimum expenditure of time and money.
- Reliability of the line intersect method is little affected by species, type of cut, slope, road influence, or length of residue pieces.
- Sampling time is directly related to volume per acre and type of cut, and the advantage of line intersect sampling over the fixed-plot design is greater at the higher volumes.

- The line intersect method is attractive to field personnel because it requires fewer decisions and gives them greater confidence than the fixed-plot method.

Literature Cited

Bailey, G. R.
1969. AN EVALUATION OF THE LINE INTERSECT METHOD OF ASSESSING LOGGING RESIDUES. Can. Dep. Fish. & For., Forest Prod. Lab., Inf. Rep. VP-X-23, 41 p.

Bailey, G. R.
1970a. A SIMPLIFIED METHOD OF SAMPLING LOGGING RESIDUE. For. Chron. 46(4): 289-294.

Bailey, G. R.
1970b. SPEEDIER ESTIMATES OF LOGGING RESIDUE. Can. For. Ind. 90(12): 32-33, 35.

Brown, James K.
1974. REDUCING FIRE POTENTIAL IN LODGEPOLE PINE BY INCREASING TIMBER UTILIZATION. USDA For. Serv. Res. Note INT-181, 6 p.

Dell, John R., and Franklin R. Ward
1971. LOGGING RESIDUES ON DOUGLAS-FIR REGION CLEARCUTS—WEIGHTS AND VOLUMES. USDA For. Serv. Res. Pap. PNW-115, 10 p.

Howard, James O.
1971. VOLUME OF LOGGING RESIDUES IN OREGON, WASHINGTON, AND CALIFORNIA—INITIAL RESULTS FROM A 1969-70 STUDY. USDA For. Serv. Res. Note PNW-163, 6 p.

Howard, James O.
1973. LOGGING RESIDUE IN WASHINGTON, OREGON, AND CALIFORNIA—VOLUME AND CHARACTERISTICS. USDA For. Serv. Resour. Bull. PNW-44, 26 p.

Howard, James O., and F. R. Ward.
1972. MEASUREMENT OF LOGGING RESIDUE—ALTERNATIVE APPLICATIONS OF THE LINE INTERSECT METHOD. USDA For. Serv. Res. Note PNW-183, 8 p.

Menard, Mario, and Jules Dionne.
1972. ESSAI D'UNE METHODE PAR TRANSECTS POUR ESTIMER LE VOLUME DE BOIS NON UTILISE LORS D'UNE EXPLOITATION FORESTIERE. Gov. Quebec, Minis. Terres et Forets, Serv. Rech. Note 2, 9 p.

Van Wagner, C. E.
1968. THE LINE INTERSECT METHOD IN FOREST FUEL SAMPLING. For. Sci. 14(1): 20-26.

Warren, W. G., and P. F. Olsen.
1964. A LINE INTERSECT TECHNIQUE FOR ASSESSING LOGGING WASTE. For. Sci. 10(3): 267-276.