

THE ESTIMATION OF LOGGING RESIDUES USING LARGE-SCALE AERIAL PHOTOGRAPHS

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INTRODUCTION

Large-scale photo (LSP) sampling systems have been developed to provide an adequate data base for forest management. The operational application of LSP sampling techniques has been made possible through the use of minicomputers and new and improved radar altimeters, which provide information on height of the aircraft above ground. Minicomputers with developed software can easily perform the many calculations associated with analytical photogrammetry. In addition, minicomputers can provide useful summaries of information for management.

The purpose of this paper is to show how LSP may be applied to the estimation of logging residues using the line-intersect sampling technique. The measurement of logging residues is of interest to

1. fire management personnel, for fuel loading and rates of accumulation
2. silviculturists, for site preparation for forest regeneration, and
3. individuals concerned with the utilization of forest residues as an energy source.

LINE-INTERSECT METHOD

Line-intersect sampling for estimating volume, weight, and number of pieces per unit area is well tested and ready for operational application. The method was first proposed by two New Zealanders (Warren and Olsen) in 1964 and was further developed by Van Wagner (1968). Since that time, the line-intersect method has been tested by a number of Canadians and Americans, including

Muraro (1970), Morris (1970), and Martin (1976), to name a few.

In application, the method requires only the length of the sample line, the diameter of pieces intersecting the line, and the use of a simple formula. Tallying rules can be found by referring to Van Wagner (1965, 1968). If the slash is oriented in a nonrandom fashion, potential bias can be avoided by multiple random starts and random orientation.

Simply stated, the formula for volume in cubic metres per hectare is

$$V = \frac{\pi^2 \sum d^2}{8L}$$

where: d = piece diameter (cm)
 L = length sample line (m)
 V = volume (m^3 /ha).

Multiplying the above formula by the specific gravity of the wood and the appropriate conversion factors can result in weight with units of tonnes per hectare.

LARGE-SCALE PHOTO SAMPLING SYSTEM

The Northern Forest Research Centre has developed an aerial camera and interpretation system (Kirby 1978) for large-scale photo sampling. The camera system consists of a Honeywell radar altimeter, two 70-mm Vinten aerial cameras, and an intervalometer (van Eck and Bihuniak 1978). The interpretation system consists of a Hewlett-Packard 9825A minicomputer interfaced to a Carl Zeiss-Jena Interpretoskop, with parallax measuring device and digitizer.

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The camera system has been used on fixed-wing aircraft (twin-engine Aztek) and on Jet Ranger (Bell 206B) helicopters. Figure 1 is a photograph of the aerial equipment under the 206B.

The intervalometer permits the cameras to be operating at different cycling rates. This, in combination with aerial camera lenses of different focal lengths, results in simultaneous localized and broader views of the terrain. Digital height information on light-emitting diodes is displayed through the secondary optics on one of the Vinten cameras. This results in the height above ground and exposure time to 1/100 s being recorded on the lower corners of each aerial photograph. Figure 2 is an aerial photograph with the digital information displayed.

The versatility of the system is its capability to provide two scales of photography with different films at the same time. With a multistage sampling approach, sample area stratification, plots, and sample lines are often located and delineated on photographs obtained with a wide-angle lens (77.45 mm) and Kodak color infrared (2443) film. Larger scale

photographs are then obtained with a telephoto lens (281.9 mm) and Kodak aero color negative (2445) film for measurements. The sampling option can be used to obtain bursts of several color photographs for stereo viewing and actual measuring of plots and sample lines.

METHOD AND RESULTS

A test was conducted on an intensively studied area in Hinton, Alberta, to indicate the use of large-scale color aerial photographs and line-intersect sampling. Color photographs at a scale of 1:220 were taken in a helicopter on May 19, 1978. The flying height was 60 m (200 ft) above ground. The area was photographed in the spring when the grass was dead and still down from the winter.

Fieldwork was done in the fall of 1978 in an area that was logged during 1966-67. The slash was approximately 11 years old at the time the photographs were obtained. Two 10-m sample lines were located on the ground and on the photos.

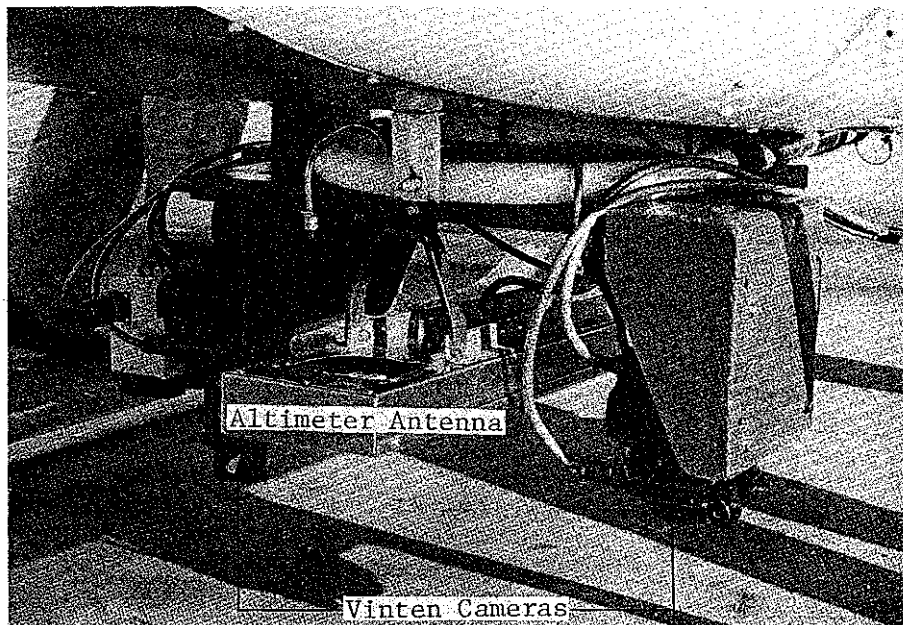


Figure 1. Cameras under the 206B helicopter.

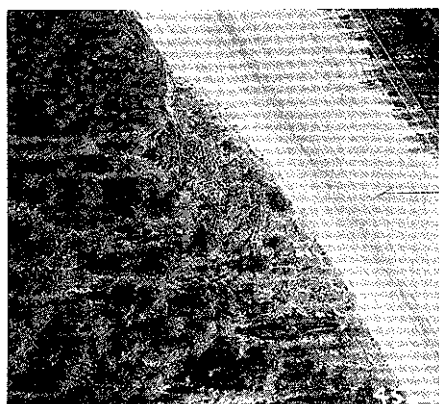


Figure 2. Black-and-white aerial photograph from aero color negative. Lower left corner: exposure time (min/s/1/100 s). Lower right corner: height above ground (ft).

As can be seen in Table 1, the volume estimates of residue calculated for the two sample lines from the photos and ground were found to be remarkably close. Sample lines 1 and 2 showed a volume difference between photo and ground of only +1% and -7%, respectively.

The mean percentage missed for pieces tallied on photos to those on the ground was 14. This difference occurred from partial coverage by regeneration and slash, which affected detection and measurement. These factors will be mentioned in greater detail later.

The piece diameter range for both sample lines was 2.5-15 cm on the ground and 2.5-17 cm on the photo. A simple linear regression was performed to determine the relationship between piece diameters from the photo estimating and the ground diameters (Figure 3). The results showed mean ground and photo diameters of 6 cm (SD ± 3) and 6.1 cm (SD ± 2.6), respectively. The data showed a high correlation of 87.6%, and at two standard errors the ground diameter could be estimated from the photos to ± 2.5 cm.

An important fact to note is the bunching of data at several common photo diameters for a range of ground diameters, which can be seen from the plotted regression line in Figure 3. This bunching occurred because of the limitations in measuring photo diameters. The smallest distance detectable on the contact prints was 0.1 mm, which at the scale of the photos was to the closest 2.2 cm. Ground measurements, on the other hand, could be taken to the closest millimetre (± 1 mm) with a metric diameter tape.

Problems

There were three problems which affected this particular study:

1. Slash on the ground may have been partially covered by grass, soil, or other slash.
2. Slash may have been partially or entirely hidden on the photos by forest regeneration or its shadow.

Table 1. Results of the line-intersect method in sampling logging residues.

Plot No.	Volume of residue		Percentage diff. with ground	Ground diameter range	No. pieces measured		Percentage missed on photo ¹
	Ground	Photo			Ground	Photo	
1	1568.3	1584.3 ft ³ /ac	+1	1.1- 5.9 in. 2.8-15.0 cm	25	21	16
	109.7	110.8 m ³ /ha					
2	1964.7	1822.4 ft ³ /ac	-7.2	1.0- 5.0 in. 2.5-12.7 cm	25	22	12
	137.5	127.5 m ³ /ha					

¹ $\bar{X} = 14$

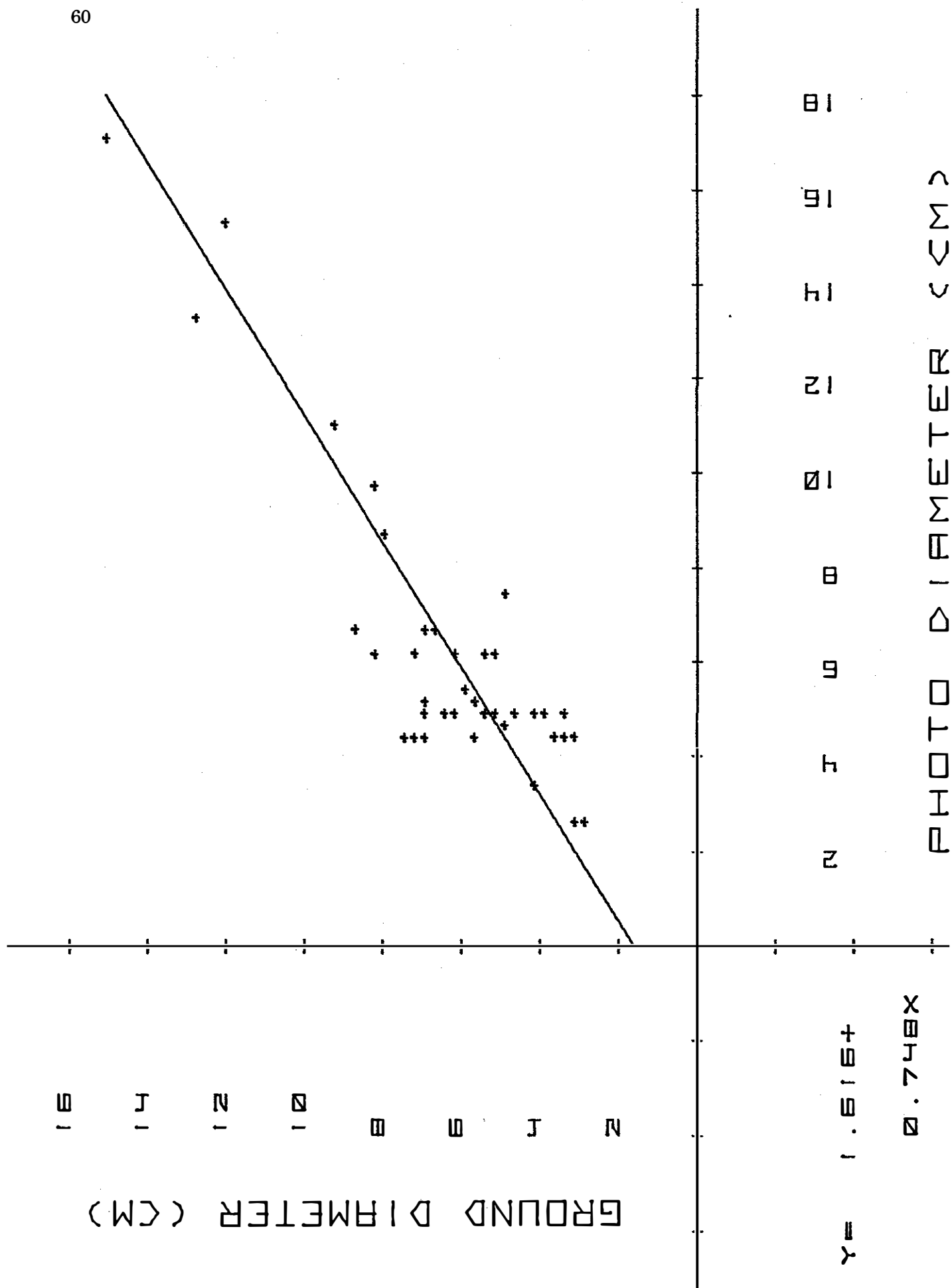


Figure 3. Photo-ground results ($r^2 = 0.767$, $SE = 1.25$, $N = 43$).

3. A slight loss in image sharpness occurred from the photos being slightly out of focus due to the low altitude from which the photos were being taken.

These problems affected the resultant piece count and the ability to obtain accurate photo measurements. Other possible problems were variations in photo scale due to steeply sloping ground (>40%) or large tips and tilts.

DISCUSSION AND CONCLUSIONS

From our studies of different scales and aerial films, we have concluded that using aero color negative film (with its high film speed and wide exposure latitude) in the spring before tree leafout and under high overcast conditions is most satisfactory at a scale of 1:500, with 1:2000 color infrared being obtained simultaneously. With a multi-stage sampling design, the smaller scale (1:2000) would be used for stratifying sampling units and for sample location. The larger scale (1:500) would then be used as the secondary sampling medium in actual sampling at the prescribed intervals.

Grass and tall regeneration (up to 1.5 m) were problems in that some measurements were hampered. Slight image fuzziness was also a problem that could have been rectified by flying at a higher elevation to obtain slightly smaller scale photographs (i.e., 1:500 instead of 1:220). Another solution would be to refocus the lenses for altitudes lower than 100 m.

Aircraft ferrying, the amount of area to be flown, the sampling plan, and the precision desired will greatly affect the cost of photography. At Hinton, Alberta, where no ferrying was required, the estimated cost of photography (including air time, aerial films, film processing, equipment charge, and wages plus expenses) would be approximately \$36/line km for 50 line km (30 line mi)¹. This

cost was based on a flying altitude of 150 m above ground with sampling groups of four photos at 200-m intervals. With sampling groups representing photo plots, the cost of photography alone would be approximately \$9/photo plot¹.

A hypothetical example showed the photo measurement rate for a photogrammetrist to be approximately 51 m/h¹. Based on contract field work, production was calculated to be roughly 36 m/h^{1,2}. Note that consideration must be given to fuel type, fuel loading, and the number of pieces to be tallied, since these will affect the production figure. As such, these figures must be taken only as estimates. The figures do seem to indicate, however, that large-scale photo sampling could be an efficient alternative to ground sampling.

The results have shown potential in wood volume estimation using low-level aerial photographs. Further testing and application are warranted and will be carried out in the near future.

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¹ More detailed breakdowns of cost and production figures are available by enquiry.

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