1-1-1972

Research Note, January 1972

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Research Note 10

Montana Forest and Conservation Experiment Station
School of Forestry/University of Montana/Missoula

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DETERMINING THE VOLUME OF CHIP PILES USING SMALL-CAMERA, VERTICAL AERIAL PHOTOGRAPHY

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Acknowledgments

We would like to thank the Hoerner-Waldorf Corporation of Missoula, Montana, for allowing us to test our ideas at their plant.

Special thanks go to R. A. Ainsworth of Ainsworth and Associates, Missoula, Montana; Dan Potts of the Hoerner-Waldorf Corporation; Norman Schwizer; and David McCleerey for their help and guidance during this project.

This project was supported in part by the Hoerner-Waldorf Corporation.

Introduction

The Hoerner-Waldorf Corporation of Missoula, Montana, maintains a large chip pile ranging in size from 200 to 400 thousand cubic yards of chips. The pile has two recognizable segments—the north one-third and the south two-thirds (see Figure 1). Approximately 80 percent of the total volume of chips is in the south two-thirds segment. At the present time the necessary elevations needed for volume determination are obtained by surveying engineers who physically climb over the pile.

Frequently, resource managers need current photographic coverage of small areas, but obtaining this coverage with conventional aerial photography cannot be justified economically. Small-camera aerial photography can be used as an economical solution to the problems of outdated information and lack of coverage on a small area. One situation where small-camera, vertical aerial photographs can be useful is in the volume determination of chip piles. This paper presents a technique for rapid, efficient determination of chip pile volume.

An aerial photographic system for volume determination would eliminate the need to climb the pile, decrease the total time spent in man-hours, and provide a permanent visual record of chip pile size and conformation.

The use of small-camera, vertical photographic techniques for chip pile measurement appears to be feasible. The accuracy is comparable to conventional methods, and the cost, once the investment in capital equipment is absorbed, is less than the cost of those methods. Companies having chip piles could benefit from frequent photographic coverage both as an inventory tool and as a basis for pile management.

Methods

To establish horizontal and vertical photographic control, targets which can be easily seen on photographs are placed on the ground to form a square around the pile. The longitude, latitude, and elevation of these positions are recorded. Once established, these positions can be used for all subsequent flights (see Figures 1 and 2).

Aerial photographs of the pile are then taken whenever volume determinations are desired. Because an inventory is frequently needed during a specific time period, the photography cannot be dependent upon clear weather but should be possible under cloudy conditions. Our flights were made under cloudy conditions which, in fact, may be preferable to clear skies because problems of shadow blackout are eliminated under diffuse lighting conditions.

In taking the photographs an attempt should be made to get the entire chip pile in one stereo-pair. The optimum photographic scale for complete coverage in one stereo-pair is approximately 1:12,000 for a pile coverage of 700,000 square feet photographed with a Hasselblad 500-C camera with a 2¼-by-2¼-inch format.

The resulting photographs are then enlarged four

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times and mounted on a stereographic plotter. The plotter used in this test was a Zeiss Stereotope which is a small, inexpensive instrument with an advertised accuracy of $\pm$ 2 percent.

The photographs are superimposed over a grid with a scale of 1 inch = 50 feet, and height measurements are taken at each grid intersection.

To establish an optimum sampling system we superimposed grid sizes of 1 inch = 50 feet, 1 inch = 25 feet, and 1 inch = 12.5 feet over a contour map of a chip pile whose estimated volume had been determined by conventional methods. Although all three of these scales yielded estimates of volume which varied less than one percent from the conventionally determined estimate, we used a spacing of 50 feet in the actual test because this scale requires the fewest measurements. We obtained a matrix of parallax readings at 50-foot intervals and used it as input to a computer program.

The program, written in CDC Fortran for a CDC 3100 computer system, determines cubic yard volume from parallax measurements. A cardreader, high-speed on-line printer, and 10,000 words of core storage are required for operation of the program. When the CDC 3100 is used with this program, the data points must be in a matrix no larger than 100 by 100. With larger capacity computers, however, the size of the matrix can be increased.

The form of the equation used is:

$$V = \Sigma[A(I,J) + A(I+1,J) + A(I,J+1) + A(I+1, J+1)]/4 * X^2/27$$

where:

V = volume in cubic yards
$A(I,J)$ = elements of matrix
$I = 1,N$ and $J = 1,M$
N and $M \leq 100$
X = grid size in feet

The computations provide for multiplying the matrix (area) by a C-factor to convert the parallax readings into feet. The program is flexible enough to take any number of data and run any number of jobs consecutively.

We tested the system design on May 1, 1970. On the same day Ainsworth and Associates of Missoula, Montana, measured the chip pile, thereby providing conventional volume data for comparison purposes.

To evaluate the accuracy of the photographic height determination, we superimposed the grid system over the contour map of the pile, produced by Ainsworth and Associates. At each elevation location indicated by Ainsworth, we estimated the height of the pile using the grid. These values were then compared with a paired-difference statistical test.

Results

Approximately 80 percent of the total chip volume was in the south two-thirds of the pile. Over this area the stereotope heights compared significantly at the 95 percent level with height measurements obtained on the ground by Ainsworth and Associates. The paired-difference test for the north one-third, however, revealed a significant discrepancy between the height values obtained by the two methods. This disparity may have resulted from a photographic error introduced by tilting the camera. Such an error could be offset by rectifying the photographs during the printing process or by measuring the height of the pile on the ground in four or five places and then applying a correction factor for height during the actual plotting process. The other possibility is that both methods were in error on this section of the pile and that the actual volume of the pile lay somewhere between the two figures.

The following is a breakdown of the time spent during the actual test and the approximate cost of equipment and supplies:

Travel time	45	minutes
Flying time	38	minutes
Darkroom time	60	minutes
Stereotope preparations	135	minutes
Plotting	221	minutes
Computer time	0.77	minutes
Total time (man hours)	8.3	hours

Hasselblad 500-C	\$ 500
Zeiss Stereotope	\$5000
Film	\$ 2
Airplane (with pilot)	\$ 30 per hour
Developing and printing	\$ 10-25

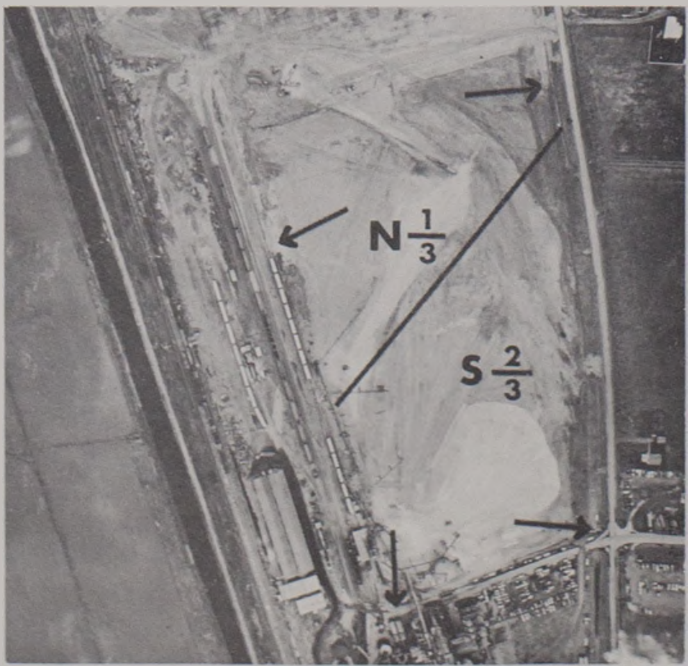

FIGURE 1. Photograph of Hoerner-Waldorf chip pile showing north one-third and south two-thirds. The arrows indicate target positions.

FIGURE 2. Aerial target used for control in the stereo model.