CALIFORNIA DIVISION OF FORESTRY
DEPARTMENT OF NATURAL RESOURCES

STATE FOREST NOTES

Office of the State Forester
Sacramento 14, California

No. 7 February, 1961

A TEST OF VARIABLE PLOT CRUISING IN YOUNG GROWTH REDWOOD

R. J. Malain *

INTRODUCTION

This note deals with cruising results on a 76 acre area on the Jackson State Forest in Mendocino County. The test area lies four miles inland from the coast on the north-facing slope of a short coastal drainage. Slopes vary from very steep (85%) to gentle.

The timber stand (fig. 1) in the test area is mixed Douglas-fir (*Pseudotsuga menziesii*) and coast redwood (*Sequoia sempervirens*) with smaller amounts of grand fir (*Abies grandis*) and western hemlock (*Tsuga heterophylla*). The stand is essentially even-aged young growth, 85 years old, with occasional residual old growth trees which comprise about 5 percent of the board foot volume. Average d.b.h. is 22.6 inches. Young growth trees range up to 40 inches d.b.h., and old growth residuals as large as 72 inches d.b.h. are encountered. This cruising test was a portion of a harvesting experiment on the same area.

METHOD

A conventional 10 percent cruise of the 76 acres was designed. This design was 38 one-fifth acre rectangular cruise plots installed on a 4 x 5 chain spacing. Boundaries of the rectangular plots were determined with staff compass and chain. Diameter to the nearest one inch d.b.h. class and height to the nearest 16-foot log were recorded for all trees.

Two variable plots, one with a basal area factor 40 and one with a basal area factor 54.44, were installed at the same center point used for the conventional one-fifth acre plot. Thus, three different cruise plots were established at each of the 38 center points. Only one height and one d.b.h. measurement were taken for trees common to more than one type of plot. This eliminated the chance of getting two different

* Forest Technician, California Division of Forestry; Assistant Forest Manager, Jackson State Forest, Fort Bragg, California.

Fig. 1. Scene in the young growth redwood stand cruised.

Fig. 2. Cruiser using a Spiegel-Relaskop; redwood sucker clump in background.

estimates for the same tree. All the trees on each 54.44 factor plot would also fall in the 40 factor plot with the common center point.

Bitterlich's "Spiegel-Relaskop" was used (fig. 2) as an angle gauge. This instrument was chosen because of its ready and accurate slope correction and because various basal area factors are available on one scale. Use of the prism was rejected because of less certain slope correction, although the prism might have advantages under conditions of low available light if mounted in a slope correcting device such as that described by Gould (1957).

Board foot volumes for the variable plots were computed by the method suggested by Afanasiev (1957) and Morrow (1958). That is, the "conversion factor" or number of trees per acre respresented by each tree tallied, was calculated for each one-inch diameter class. The board foot volume for each tree tallied on the variable plot was obtained from the same unmodified volume tables (U.S.F.S., 1955 and Wallen and Reveal, 1947) that were used for the one-fifth acre plots. The product of the volume table volume and the "conversion factor" for the appropriate d.b.h. class gave the volume per acre represented by each tree tallied on the variable plots. The sum of the volumes per acre represented by all trees tallied on each variable plot equalled the total volume per acre represented by that plot. This total volume per acre for each variable plot was then treated statistically in the same manner as per-acre plot volumes obtained for each of the one-fifth acre plots.

RESULTS

Cruise results and statistical analysis are summarized in table 1. Because it was not possible to make a 100 percent cruise of the 76 acre area, cruise results were compared statistically.

Mean volumes per acre for the three systems varied considerably as follows. Board foot estimates for the 40 and 54.44 factors were respectively 7 percent and 11 percent higher than those obtained by the one-fifth acre plot cruise. Board foot volume precision at the 95 percent level of probability was ± 9.7 percent for the 40 factor cruise and ± 12 percent for the 54.44 factor cruise. Although precision of the variable plot estimates was less, far fewer trees were cruised than in the conventional 10 percent cruise.

In order to have attained the same degree of precision with the variable plot factor 40 cruise as that attained by the 10 percent plot cruise, an additional 34 points would have been needed, but 287 fewer trees would have had to be cruised (table 1).

In order to attain a precision of ± 10 percent at the 95 percent level of probability (a common minimum precision goal) the 40 factor cruise would have necessitated 16 more points (an 84 percent increase) but 152 fewer cruised trees (a 31 percent decrease) than the one-fifth acre plot cruise (table 1).

A similar analysis of basal area (not tabulated here) closely parallels the board foot results shown in table 1, the basal area estimates for each type of cruise being slightly more precise.

Table 1. Results of cruise with 1/5th acre plots and Spiegel-Relaskop plots basal area factors 40 and 54.44 from the same 38 locations in a young growth redwood stand on Jackson State Forest.

Item	Plot Size		
	1/5 acre rectangular	BAF 40 Sp'Relaskop	BAF 54.44 Sp'Relaskop
Mean volume per acre (f.b.m.)	70,419	75,058	78,122
Standard deviation (f.b.m.)	±15,084	±22,220	±29,006
Standard error of mean (f.b.m.)	± 2,447	± 3,605	± 4,706
Percent accuracy (at 95% probability)	±7.0	±9.6	±12.0
Number of trees cruised	985	368	287
Average number of trees cruised per plot location	25.9	9.7	7.6
Number of plots necessary for 7% accuracy a/	38	72	112
Number of trees necessary for 7% accuracy a/	985	698	851
Number of plots necessary for ±10% accuracy (95% probability)	19	35	55
Number of trees necessary for ±10% accuracy (95% probability)	492	340	418

a/ Note that this is the accuracy originally attained with the 1/5 acre plot cruise and that,

$$\text{number of plots (trees)} = \left(\frac{\text{standard dev.}}{\text{mean} \times \frac{\text{S.E.\%}}{2}}\right)^2$$

Bell and Alexander (1957) present a method where d.b.h. and height measurements are taken on only one-half to one-fourth of the variable plots established. Only the number of trees by species is then recorded on intervening plots. Board foot per square foot ratios, established for each species from the "cruised" points, can then be applied to trees on variable plots where tree counts only are made. This procedure was tested by dropping tree measurement data from one-half of the variable factor 40 plots. Results were encouraging. When the board foot per square foot ratio was taken from the odd numbered plots, mean calculated volume (72,872 f.b.m.) per acre was 2.9 percent lower than the mean volume per acre (75,058 f.b.m.) based on diameter and height measurement on all plots. When the board foot per square foot ratio was taken from the even-numbered plots, mean calculated volume per acre (76,637 f.b.m.) was 2.1 percent higher than the mean volume based on measuring all the trees. These differences are well within the standard error of the estimate and should become even smaller as sample size increases.

DISCUSSION

Some of the variation in mean volumes and basal areas per acre between the three cruises can be attributed to error in application of the plotless method. When the mean volumes and basal areas per acre from the variable plot methods were compared to those from the one-fifth acre plot cruise the probability in all cases was over 68 percent (i.e. "t" was greater than 1) that the means came from different populations. In one case the difference between the means was quite significant. The standard error of the difference between the mean basal areas obtained from the one-fifth acre plots and the 54.44 factor variable plots was significant at the 95 percent level. (i.e. "t" = 2).

It is quite probable that some of the higher estimate given by the variable plot methods was due to the inclusion of borderline trees that were not actually "in" the plots.

Some methods by which these borderline trees could be more accurately placed are:

1. Measure the distance to the tree from the center point and measure d.b.h. with calipers at right angles to viewer. Determine distance at which the tree would be "in" by formula, previously prepared tables, or a device such as that described by Stage (1959).

2. Mount the Spiegel-Relaskop (in this test it was hand held) or other instrument on a staff for added stability.

3. Target the tree in question by wrapping a red flag around the tree at d.b.h. This accurately delimits edges of the tree when lighting and/or background gives poor contrast, and locates d.b.h. which is important on trees with rapid taper.

It should be noted that these borderline trees become more and more important when larger basal area factors are used. In this test the difference in basal area per acre between the 40 factor cruise and the one-fifth acre plot cruise would be eliminated if 0.67 trees per plot were deducted from the count.

CONCLUSIONS

The variable plot cruise with basal area factor 40, on a 76 acre area, was the most efficient of the three cruises tested based on the number of trees measured. Cruise data analysis indicates that it is necessary to measure 31 percent fewer trees (on 84 percent more plots) with the variable plot factor 40 cruise than with the one-fifth acre plot cruise, in order to get ± 10 percent accuracy at the 95 percent level. Good accuracy is still maintained with the factor 40 cruise when height and d.b.h. measurements are taken on only one-half of the variable plots so even greater efficiency is possible.

Use of the variable plot system, rather than the fixed plot system, could result in greater plot location time because of the 84 percent increase in points needed. However, if cruise design allows for insertion of added points without increasing ground travel distance, this possible additional plot location time would be negligible.

The status of borderline trees must be accurately determined. If errors in determination of these trees are not cancelling large bias is introduced.

SUMMARY

This is a test of the reliability and the applicability of the variable plot cruise method for use in dense young growth stands of coast redwood and Douglas-fir.

Basal area and board foot volume results from three cruises were analyzed and compared. These were a 10 percent one-fifth acre plot cruise, and two variable plot cruises, one using a basal area factor of 40, and one using a basal area factor of 54.44.

Results indicated that the variable plot cruise using the basal area factor 40 was the most efficient of the three cruises for this tract. In order to attain ± 10 percent accuracy with the variable plot method factor 40 it would be necessary to take tree measurement data on 31 percent fewer trees than with the standard one-fifth acre plot cruise. Even further economies should be possible in cruises of large areas.

Accurate determination of borderline trees when using the variable plot method is very important. Distance to borderline trees should be taped and d.b.h. calipered at right angles to the line of sight when the angle gauge or prism leaves doubt about their status.

BIBLIOGRAPHY

AFANASIEV, Michael, 1957. The Bitterlich method of cruising - why does it work? Journal of Forestry 55: 216-217.

_______________, 1958. Some results of the use of the Bitterlich method of cruising in an even-aged stand of longleaf pine. Journal of Forestry 56: 341-343.

BELL, John F. and ALEXANDER, Lucian B., 1957. Application of the variable plot method of sampling forest stands. Research note #30. Oregon State Board of Forestry.

DEITSCHMAN, Glenn H., 1956. Plotless timber cruising tested in upland hardwoods. Journal of Forestry 54: 844-845.

GOULD, Jr., E. M. 1957. The Harvard forest prism holder for point-sampling. Journal of Forestry 55: 730-731.

MORROW, Jr., Robert R., 1958. Computation of volume in the Bitterlich method of cruising. Journal of Forestry 56: 41.

STAGE, Albert R., 1959. A cruising computer for variable plots, tree heights, and slope correction. Journal of Forestry 57: 835-836.

U. S. FOREST SERVICE, 1955. Volume tables for Pacific Northwest trees. USDA Agric. Handbook No. 92: table 15, Douglas-fir young growth board foot (Scribner) volume table.

WALLEN, A. F. and REVEAL, J. L. 1947. The redwood forest handbook: second growth redwood board foot (Spaulding) volume table, pp. 130, 131. California Division of Forestry.

From
CALIFORNIA DIVISION OF FORESTRY
301 State Office Building No. 1
Sacramento 14, California

TO