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A TEST OF VARIABLE PLOT CRUISING IN MIXED STANDS ON LATOUR STATE FOREST

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Tests of variable plot cruising in which prisms were used were conducted in 1957 on the Latour State Forest, administered by the California Division of Forestry. This property consists of about 9,000 acres located in eastern Shasta County, California, in the southern end of the Cascade Mountain Range. The timber cruised was a Site II (Dunning, 1942) stand in the Beal Creek Unit of the Forest at about 5,200 feet elevation. The timber is a "mixed conifer" stand consisting of sugar pine (*Pinus lambertiana*), ponderosa pine (*Pinus ponderosa*), white fir (*Abies concolor*), red fir (*Abies magnifica*), Douglas-fir (*Pseudotsuga menziesii*), and incense cedar (*Libocedrus decurrens*). The virgin timber in the unit was cut in 1953. About 45 percent of the merchantable volume was removed by cutting with a "unit area" management system (Hallin, 1954). The silvicultural system used in cutting was mostly group selection with provision for natural seeding of clear-cut openings requiring regeneration. The area to which the cruise figures apply was 175 acres.

PROCEDURE

The experiment was designed to test the feasibility of using variable plot (prism) methods of cruising for volume and growth to be used in management decisions regarding the State Forest. The volume portion of the cruise was designed by conventional methods. The growth portion of the cruise developed data to fit the Clements growth prediction charts (Roy, 1955).

The cruise was designed as a 10 percent cruise using systematically spaced one-fifth acre circular plots. The plot spacing was 5 chains by 4 chains. For the particular area under consideration 88 one-fifth acre plots were required for the 10 percent cruise. A plot center was established for each one-fifth acre plot. From each plot center a three-diopter prism plot was established. A tree count using the prism was made from each plot center. Forty-four plots, where the trees "in" the plot were measured for DBH, height, and crown class, were established at all the even numbered plots. That is, one half of the plots were "control plots."

After testing with the three-diopter prism on 88 plots it was discovered that use of prisms with higher basal area factors would be more economical in accomplishing the desired results.

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From 22 of the previously established plot centers, where one-fifth acre and three-diopter prism plots had been taken, additional four-diopter and five-diopter prism plots were established. These 22 plots were systematically located. Every other plot served as a control plot. The methods of Bell and Alexander (1957) were used to establish the plots and lay out the cruise. Basal area factors of the prisms were determined by field measurement on a target course. The prisms were only approximately 3, 4, and 5 diopters.

Volumes were computed from the Region 5 Volume Tables for Site II (USFS, 1948). Trees that occurred on more than one type of plot were assigned the same measurements so that no bias was introduced. The method of Bell and Alexander (1957) was used to compute the cruise volume. In this method the average number of count trees per plot is multiplied by the basal area factor for the prism used to give basal area per acre. Basal area per acre is then multiplied by the average board foot per square foot ratio determined from the trees measured on the "control" plots. The result gives board feet per acre. The board foot per square foot ratios were taken from Site II tables prepared by the Forest Service (1957). Similar tables have been prepared by the Division of Forestry (1957) for Sites I and III.

RESULTS AND DISCUSSION

Test of 3d, 4d, 5d Prisms and One-fifth Acre Plots (22 Plots)

The results of the 22 plot cruise, comparing three different prisms and one-fifth acre plots, from the same center point are shown in table 1. The sampling errors shown for prism points were calculated by Bell and Alexander's (1957) method, and by analysing plot volumes in the conventional manner for the one-fifth acre plots.

Table 1. Results of cruise with 3, 4, and 5 diopter prisms and one-fifth acre plots from same centers (22 plots total, with 11 prism points used as control plots).

Item	Plot size			
	3d	4d	5d	1/5th acre
Basal area factor	9.372	17.62	27.37	...
No. of trees counted (22 plots)	389	193	129	235
Basal area per acre (sq. ft.)	166	155	160	...
No. of trees measured (11 plots)	191	89	58	235 a/
Average bd. ft.-Basal area ratio (bd. ft./sq. ft.)	165	167	180	...
Volume per acre (bd. ft.)	27,280	25,870	28,810	26,170
Percent sampling error b/	± 8.4	± 10.9	± 14.8	± 16.0

a/ 22 Plots
b/ By Method of Bell and Alexander (1957) for variable plots, standard method for 1/5th acre plots.

As shown, all the prism estimates resulted in cruises with lower sampling errors. The economies in tree measurement are striking. The five-diopter prism, which has a sampling error comparable to the one-fifth acre plots, required measurement of only 58 trees compared with 235 trees measured on the fixed area one-fifth acre plots.

It was estimated from a rough time study that one-fifth acre plots took about twice as long to establish as five-diopter prism points. Time spent actually measuring trees was four times as great for the regular circular plots, but due to the fixed time walking between plots, resting, etc., the over-all saving was only two times. The reason for the time savings are in the method. No area measurements are required with prisms. Also with variable (prism) plots large trees are sampled in proportions greater than their number per acre. As large trees are the most important trees with respect to board foot volume the variable plot is more efficient. This is demonstrated in table 2 which shows the average diameter of the trees measured for the different type plots used in this cruise.

Table 2. Average diameter (b.h.) of trees measured on 11 plots.

Plot size	Basal area factor	Average diameter of measured trees
3 diopter	9.4	27.9
4 diopter	17.6	28.0
5 diopter	27.4	29.5
1/5 acre	....	20.6

Test of 3 Diopter Prism and One-fifth Acre Plots (88 Plots)

The results of the 88 plot test with only the three diopter prism compared with one-fifth acre circular plots were similar to those shown in table 1. In the 88 plot test the 3 diopter prism gave an average volume per acre of 24,290 board feet per acre ± 1,287 board feet (± 5.3%). The one-fifth acre plots gave an average volume per acre of 27,862 board feet ± 1,922 board feet (± 6.9%). On the 3 diopter prism points 619 trees were measured and an additional 647 trees were "counted" only. The one-fifth acre plots included 858 trees that were measured. As shown in table 1 for the 22 plot test the 3 diopter prism (basal area factor 17.62) included more trees than necessary to give results comparable to one-fifth acre plots. Prisms with a basal area factor of 25-30 (about 5 diopters) should be used in this type of all-aged timber to give results comparable to one-fifth acre plots.

Sampling Error

Considerable discussion has centered around the methods of calculating the accuracy of variable plot cruises statistically. Bell and Alexander (1957) describe a method which fits their method of calculating the cruise where:

$$\text{Sampling Error of volume per acre (percent)} = \sqrt{SE_x^2 + SE_y^2}$$

where SE_x is the percent error due to variation in the number of trees per sampling point and SE_y is the percent error due to variation of the board foot per square foot ratios of the measured trees.

Table 3 shows the results of calculating sampling error of the mean by the method of Bell and Alexander compared with the standard method of computing sampling error where the variation in volume of each plot is compared separately. This table shows data for 11 plots on which all the trees were measured.

Table 3. Sampling error of the mean for 11 "control" plots by two methods

Item	Plot size			
	3d	4d	5d	1/5th acre
Mean volume per acre (board feet)	26,790	23,860	25,900	27,200
Standard Method				
Standard deviation (board feet)	± 9,440	±14,300	±16,800	±22,440
Sampling error of the mean (percent)	± 10.6	± 18.1	± 19.5	± 24.9
Bell and Alexander (1957) Method				
Standard deviation of tree count (no. trees)	± 5.3	± 3.6	± 2.6	± 4.7 a/
Standard deviation of ratios (bd. ft. per sq. ft.)	± 86	± 93	± 98	± 87 a/
Sampling error of the mean for combined tree count and ratio (percent)	± 10.0	± 14.5	± 16.7	± 20.7 a/

a/ The 1/5th acre plot cruise was calculated by multiplying average number of trees per acre times average board foot volume per tree and the results treated statistically similar to Bell and Alexander (1957) method.

As shown, Bell and Alexander's method underestimates the sampling error calculated by conventional methods in this particular example of 11 plots. Bell and Alexander (1957 pg. 17, footnote) indicate that they have found a correlation between average tree count and average board foot per square foot ratio. This was tested for 44 prism plots. The correlation coefficient was determined to be, r = .001. Therefore no correlation between tree count per plot and average tree ratio per plot could be shown in this case.

Palley (1960) has presented a formula which can be used to closely approximate sampling error for cruises which are designed so that only certain points are control points on which trees are measured; and the remainder of the points are "count" points where the basal area is determined, but the volume factors for the trees are not measured. This method is claimed to be more exact than that proposed by Bell and Alexander (1957). However, the method of Bell and Alexander might find favor as a method of determining approximate sampling errors while crews are still in the field. Oftentimes a field approximation of sampling error is desirable so that the number of plots required may be adjusted in the field without recourse to office procedures.

Use of Variable Plots for Growth Studies

It was found that the variable plot method is adaptable to the Clements alinement charts for growth prediction (Roy, 1955). The savings in time of cruising through use of variable plots may allow greater use of similar growth study methods for determining growth of stands.

The result of applying data from 88 one-fifth acre plots and 3-diopter prism points from the same centers to the Clements alinement charts is shown in table 4.

Table 4, Comparison of growth calculated by the Clements method (Roy, 1955) for a 3 diopter prism and one-fifth acre plot cruise of 88 locations.

Item	Plot size	
	3d	1/5 acre
	(fbm/acre/year)	
Gross Growth	320	330
Ingrowth	98	100 1/
Mortality	185	210
Net Growth	233	220

1/ Based on 1/25th acre plots.

The economy of the prism method can be pointed out in the measurements required to determine the number of poles per acre. This is an input variable required to determine ingrowth. For the conventional pole cruise, 1/25 acre plots were used and 479 poles were cruised. For the 3 diopter prism only 335 poles were cruised. The sampling error of the determinations was nearly equal, the 3 diopter points being more accurate. Similar savings in time have already been shown for volume per acre, another input variable.

The only difficulty encountered adapting the Clements method (Roy, 1955) to the prism cruise was in the office calculations. Some of the input variables required are in terms of "number per acre" or "percent of number per acre." Variables in these terms are laborious to calculate in the prism method because each diameter class is sampled proportionately to its size. Therefore, a separate multiplier is required for each diameter class to determine number of trees per acre. If growth prediction methods would have the variables in terms of "basal area per acre" or "percent of basal area" they could be more easily adapted to the variable plot method of cruising.

CONCLUSION

The experience gained by this study at Latour State Forest has led to increased use of prisms and other variable plot methods on this Forest. Most cruises have been converted to the variable plot method. The saving in time by using variable plots instead of fixed area plots has resulted in more area being cruised and more accurate inventories on which important management decisions can be based.

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