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Forestry Bulletin No. 6: Point-Sampling from Two Angles

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POINT-SAMPLING

FROM

TWO ANGLES

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AND LLOYD A. BISKAMP

DEPARTMENT OF FORESTRY

STEPHEN F. AUSTIN STATE COLLEGE

NACOGDOCHES, TEXAS

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INTRODUCTION

Point-sampling is a valuable tool in the kit of the practicing forester. It is employed for permanent and temporary sampling and for growth studies. Since the concept of point-sampling is new in American forestry, different approaches have been employed to explain its application. This bulletin employs two distinct methods.

Part I consists of a synthesis of point-sampling lectures and lesson plans developed at Stephen F. Austin State College and presented as a forestry short course in 1963. It explains these sampling techniques in a rigorous formal manner and suggests choices in methodology and computational procedures. As a series of lectures, it was written in outline form, and this form was retained because the organization and use of the ideas seemed to be facilitated in this way.

Part II is an operational case problem of a forest inventory employed by the Lutcher and Moore Lumber Company, Orange, Texas, written expressly for company use by L. A. Biskamp, graduate of the Department of Forestry, then Chief of the Records Division for the company. After careful consideration, he concluded that an intensive personnel training program and subsequent point-sample inventory of the company forests was the best solution to the immediate problem. His plan was submitted to selected officials of the U. S. Forest Service for review, some of whom suggested that, because of its simplicity, it was worthy of publication.

The authors gratefully acknowledge the generosity of The Lutcher and Moore Lumber Company for encouraging the publication of this material. Their action should inspire other companies to make the works of their foresters matters of public record when they are of significant educational value.

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PART I

POINT-SAMPLING FROM TWO ANGLES

ELLIS V. HUNT, JR., AND ROBERT D. BAKER

POINT SAMPLING—THEORY

I. Tally the selected trees at the point.
   - A. With the angle-gauge, tally all trees appearing larger than the angle.
   - B. With the prism, tally all trees that are not wholly offset.
   - C. Be sure to look at trees at dbh (diameter breast height, 4.5 feet above ground line).
   - D. Tally only every other marginal tree (those exactly coinciding with the angle or those just exactly offset by the prism).

II. Multiply the number of trees tallied per point by the BAF (basal area factor) that fits the instrument used, to obtain basal area per acre in square feet.
   - A. For an angle-gauge describing 104.18 minutes, the BAF = 10.
     1. A gauge 33 inches long with a cross arm 1 inch wide describes an angle of 104.18 minutes.
     2. A 3.03 diopter prism does the same job.
   - B. This is why it works—using a BAF of 10 as an example,
     1. The area of a circle is $0.7854\ D^2$.
        a. Area of a circle $= \frac{\pi D^2}{4} = \frac{3.1416\ D^2}{4} = 0.7854\ D^2$.
     2. The area of the "tree circle" is $66^2 \times$ BA (basal area) of the tree.
        a. The "tree circle" with the tree at its center, has a diameter $66 \times$ the diameter of the tree; it describes the boundaries within which one *must* stand if he is to tally the tree with an angle gauge of 104.18 minutes or a 3.03 diopter prism.
        b. These are examples of "tree circles" showing maximum distance one may stand from a tree and still tally it (radius of "tree circle").
           (1) For a tree of 1 foot dbh, one must stand not more than 33 feet away.
           (2) For a tree of 2 feet dbh, stand not over 66 feet away.
           (3) For a tree of 3 feet dbh, stand not over 99 feet away.

III. Now consider a tree which is 6 inches dbh, or 0.5 feet dbh.
   - A. BA (basal area) of the tree is $0.7854\ D^2 = 0.196$ square feet.
   - B. One could count such a tree if he stood not farther than 16.5 feet away from it.
   - C. The diameter of the "tree circle" for this tree is therefore $2 \times$ the radius, or 33 feet.
   - D. The area of this "tree circle" is $0.7854\ D^2$ or 0.7854×33^2 or 0.7854×1089 or 855.3 square feet.

E. Statement II.B.2. said the area of the "tree circle" was exactly the BA of the tree $\times$ 66^2; let's see if this is true for this 6-inch dbh tree.

1. BA of the tree = 0.196 square feet,
   area of the "tree circle" = 855.3 square feet,
   66 squared = 4356.
2. 855.3/4356 = 0.19630; this is the BA of the tree except for rounding off digits.
3. Therefore, the statement is proved.

IV. Then take a tree that has a BA of 1 square foot (approximately 13.55 inches dbh).

A. The "tree circle" for this tree has 1×66^2 square feet of area (as stated in II.B.2. and proved in III.E.) or 4356×1 square foot or 4356 square feet.

B. Visualize this tree in the center of its "tree circle," the latter being in the center of an acre of land (Figure 1).

1. Tree BA is 1 square foot.

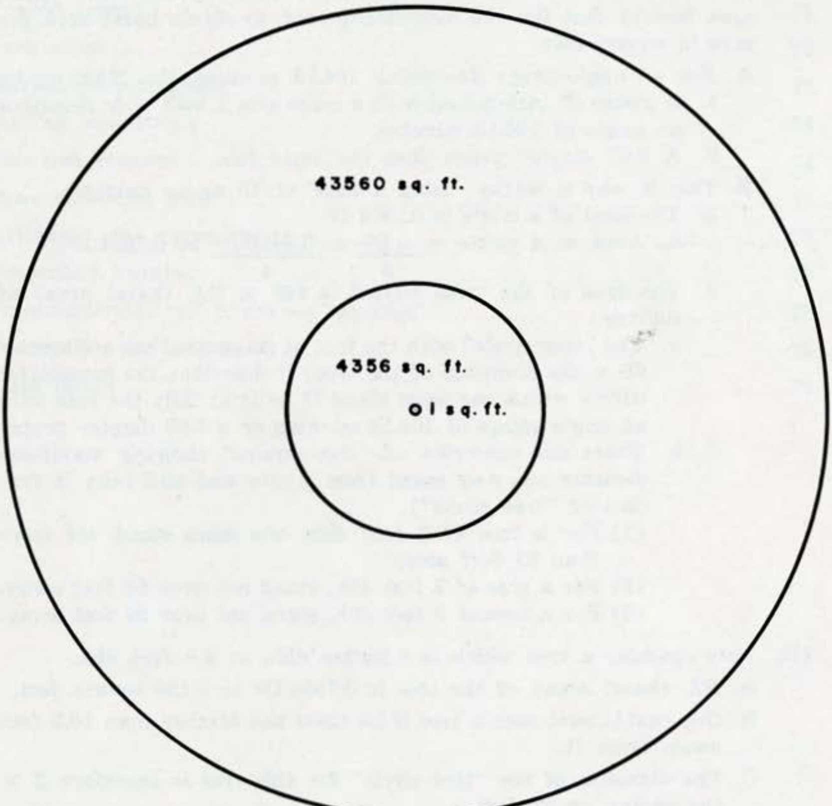


Figure 1. A one-square foot BA tree in its 4356-square-foot "tree circle" inside a circular acre of 43560 square feet.

2. "Tree circle" area is 4356 square feet.
3. Acre area is 43560 square feet.

V. If a cruiser stands at random inside this *acre*, what chance would he have of being inside the "tree circle" (i.e., close enough to the tree to count it with an angle gauge or prism defining an angle of 104.18 minutes)?

A. The chances are equal to the proportion of the areas of the "tree circle" and the acre, or 4356 to 43560, or 1 to 10.

VI. If we had a single tree on each of 100 such acres and each tree contained 1 square foot of BA, and if the cruiser were on each acre at random, the chances are 1 in 10 he would tally 10 trees in 100 chances.

VII. We change tally to total BA of trees by multiplying the tally by 10 because $10 \times 10 = 100$, and on 100 acres there would be 10 0square feet of BA.

VIII. We compute BA per acre from such a tally by multiplying the tally by 10 and dividing by the number of "points" the cruiser visited, or $10 \times 10 \div 100 = 1$ BA per acre.

IX. Conclusion: The BAF of an angle gauge or prism defining an angle of 104.18 minutes is 10, and the formula for computing BA in square feet per acre is:

$$\text{BA per acre} = \frac{\Sigma X}{N} \text{BAF},$$

where $X =$ sum of the trees tallied on all points,
$N =$ the number of points, and
$\text{BAF} =$ the basal area factor of the instrument.

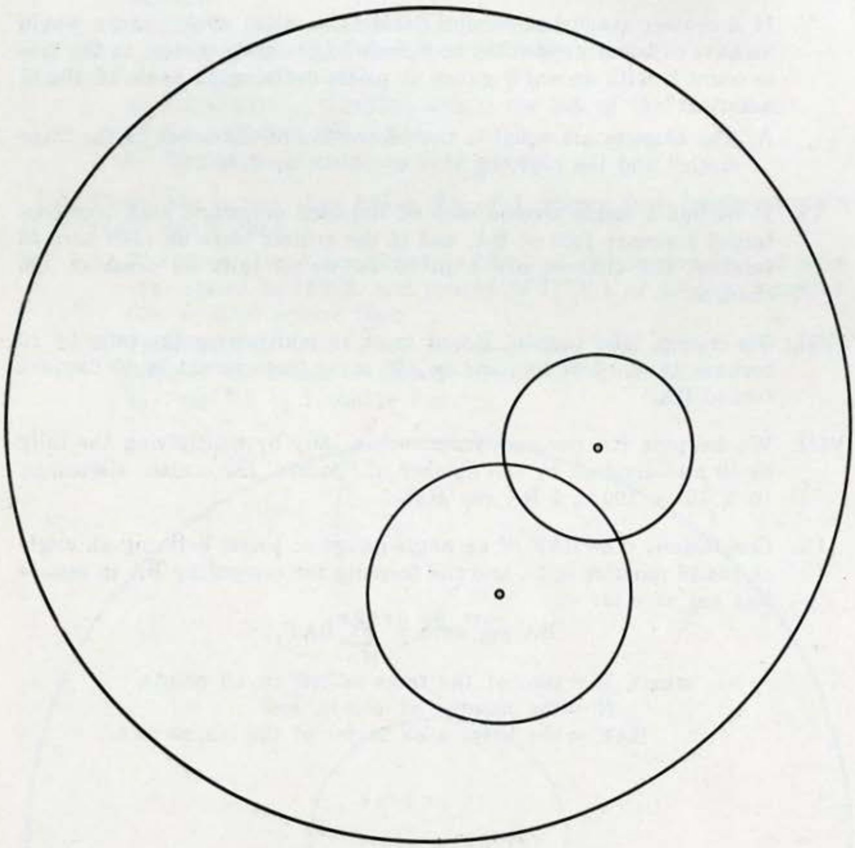
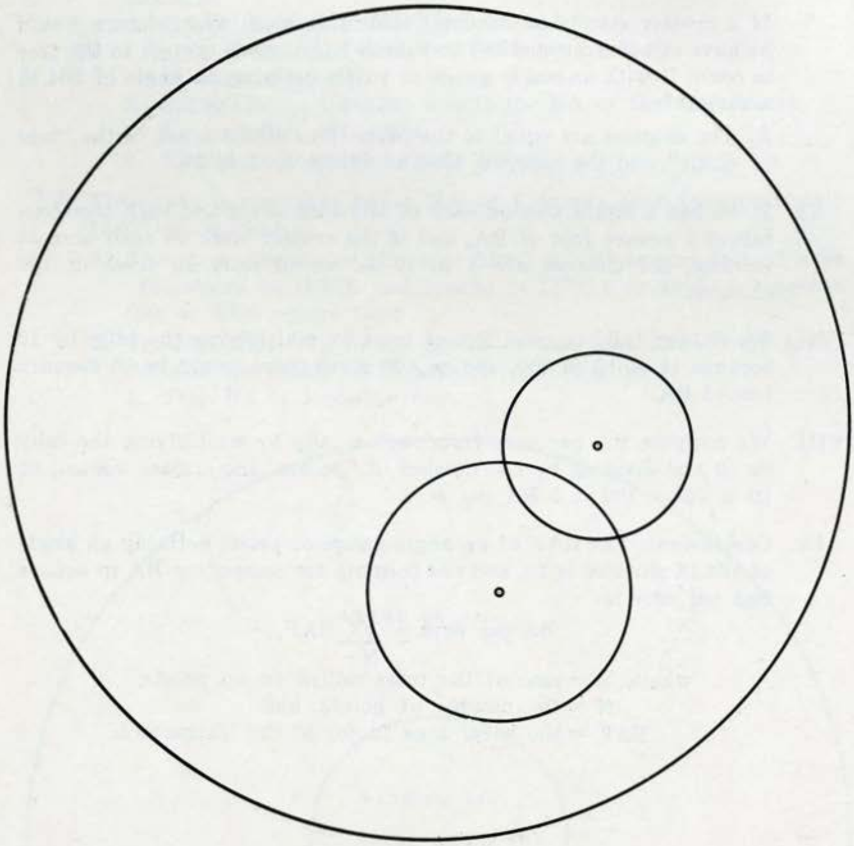


Figure 2. 10-BAF—Illustration of 3.03 Diopter Count. A 9.55-inch tree of BA=0.5 square feet has "tree circle" of (.05) $(66^2) = 2178$ square feet and a random tally chance in 1 acre of $\frac{2178}{43560} = \frac{1}{20}$ or 1 in 20. A 13.55-inch dbh tree has a BA = 1.0 square foot, a "tree circle" of (1) $(66^2) =$ 4356 square feet and a random chance of 1 in 10. The "tree circle" overlap area because of the position of trees is 871.5 square feet with a random chance of 1 in 50. In 100 random counts one would therefore get:

2 overlaps of count 2 each	total 4
8 other big tree counts of 1	total 8
3 other little tree counts of 1	total 3
	total 15 in 100 random-chances.

BA per acre is $\frac{\Sigma X}{N}$ (BAF) or $\frac{15}{100} \times 10$ or 1.5 square feet per acre.



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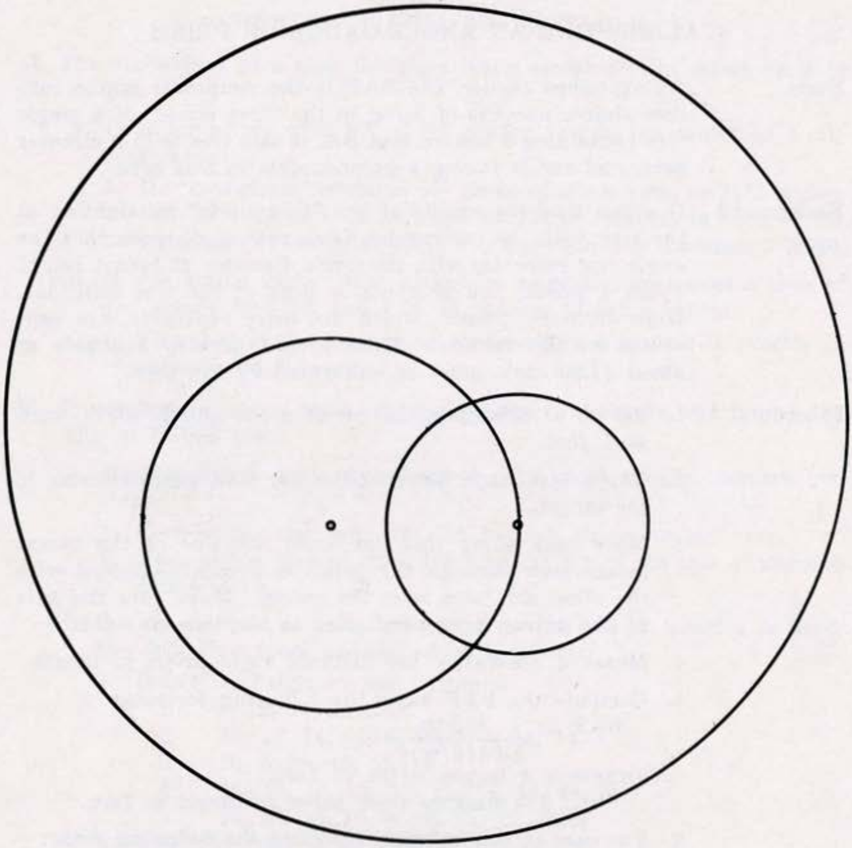

Figure 3. 5-BAF—Illustration of 2.14 Diopter Count. A 9.55-inch dbh tree of BA = 0.5 square feet has a "tree circle" of 37.14 feet radius or 4356 square feet and a random tally chance in one acre of 1 in 10. A 13.55-inch tree has a random cance of 1 in 5 and the "tree circle" overlap area is 1742.2 square feet for a random chance of 1 in 25. In 100 random counts one would therefore get:

4 overlaps of count 2 each	total 8
16 other big tree counts of 1 each	total 16
6 other little tree counts of 1 each	total 6
	total 30 in 100 random chances.

BA per acre is $\frac{\Sigma X}{N}$ (BAF) $= \frac{30}{100} \times 5 = 1.5$ square feet BA per acre.

EXERCISE NO. 1

CALIBRATING AN ANGLE-GAUGE OR PRISM

Basis As explained earlier, the BAF is the reciprocal of the random chance one has of being in the "tree circle" of a single tree containing 1 square foot BA, if this tree is in a circular acre, and one is taking a point-sample in this acre.

Background One can find the radius of the "tree circle" by sighting at the tree with the instrument from such a distance that the angle just coincides with the tree's diameter at breast height (with a prism, just so opposite sides of the tree coincide). High accuracy prisms, which are more expensive, are calibrated at the factory. Uncalibrated prisms, available at about $1.00 each, must be calibrated by the user.

Procedure

1. Set up a rectangular target of a convenient width, such as 1 foot.
2. Lay a steel tape along the center line, perpendicular to the target.
3. Move back along this line until one side of the target image seen through the prism is precisely aligned with the other side seen over the prism. Make sure the axis of the prism is perpendicular to the line of sight.
4. Measure accurately the distance from prism to target.
5. Compute the BAF using the following formula:

   $$BAF = \frac{43{,}560}{1+4(d/w)^2},$$

   where w = target width in feet,
   d = distance from prism to target in feet.
6. For ease in computation, complete the following form:

   Target width = 1.00 feet Distance from target = ... feet

   Ratio of d/w = ... $(d/w)^2$ = ...

   $$BAF = \frac{43{,}560}{1+(\ \ )} = \frac{43{,}560}{\cdots\cdots} = \cdots\cdots\cdots \text{(nearest tenth)}$$

As an alternate procedure, Dixon (1958) suggests using the same formula but measuring "the amount of deflection at a fixed distance.

1. Fix prism in position at one end of a long table.
2. At the other end, at right angle to face of the prism, set up a target of two vertical pins that can be moved in relation to each other.
3. Measure accurately (d) the distance between the target and prism.
4. Move pins until the displaced image of one pin coincides exactly with the image of the other. Measure the distance between the pins (w) precisely."

5. BAF "calculated using formula . . .above. It is essential that *d* and *w* be measured in the same units."

CONSTRUCTING A STAND TABLE

I. The probability of a tree dbh class being sampled is in direct ratio to its BA.

A. Consider a tree with BA of 0.5 square feet in the center of a circular acre.

1. Its "tree circle" contains 66^2 times as much area, or 2172 square feet, or 1/20 acre if an angle of 104.18 minutes is used.
2. Its chance of being tallied in any one sample is therefore 1 in 20.

B. It was stated earlier that under the same circumstances a tree of one square foot BA had 1 in 10 chances of being tallied.

1. The chance of a tree being contained in a sample is exactly in ratio to its BA.

II. To construct a stand table, it is necessary to measure and record the dbh of tallied trees.

A. Formulating a conventional stand table most simply requires two steps.

1. Convert the tree count to BA in each dbh class per acre.
2. Then divide each of these BA's by the BA of the tree at nominal class center.

B. As an example, if an angle-gauge having 104.18 minutes is used, the following trees are tallied at 5 points:

1.

POINT	TALLY BY DBH—INCHES
1	6, 12, 16, 20
2	10, 18, 14, 6, 16, 10, 8, 8, 12, 14
3	10, 2, 20, 18, 12, 18
4	16, 10, 10, 12, 12, 10, 14, 14, 14, 8
5	14, 16, 18, 16, 8, 10, 12, 12, 10, 4

2. The total tally is 40 trees at 5 points.

C. In our example, abstracted from Grosenbaugh (*Journal of Forestry*, 1952), we have two 6-inch, one 4-inch, and one 2-tree tree.

1. To convert these to BA per acre, multiply by BAF and divide by the number of sample points.

2-inch dbh class	4-inch dbh class	6-inch dbh class
1 tree	1 tree	2 trees
2 sq.ft. per acre	2 sq.ft. per acre	4 sq.ft. per acre

2. To convert to trees per acre divide by BA of the tree of nominal class midpoint.

Tree diameter	2 inches	4 inches	6 inches
BA per tree	0.022 sq.ft	0.087 sq. ft.	0.196 sq.ft.
No. trees per acre	$= \frac{2 \text{ sq.ft.}}{0.022} = 90.90$	$\frac{2 \text{ sq.ft.}}{0.087} = 22.98$	$\frac{4 \text{ sq.ft.}}{0.196} = 20.40$

D. The entire stand table could be constructed in this manner from tree dbh's recorded for the trees counted as samples at the points.

III. In summary, to get (f) frequency per acre, multiply the tree count by the BAF, divide the product by N (number of points), and divide this quotient by BA of a tree at nominal diameter midpoint ($0.00545415\ D^2$). Putting this in equation form, we get:

$$f = \frac{\text{Count} \times \frac{BAF}{N}}{0.00545415\ D^2}\text{, or}$$

$$f = \frac{\frac{BAF}{N}}{0.00545415\ D^2} \times \text{Count,}$$

$$\text{so } \underline{\text{factor}} \text{ is } \quad \frac{\frac{BAF}{N}}{0.00545415\ D^2}\,.$$

COMPUTING BOARD FOOT AND CUBIC FOOT VOLUME

Note: The first step (as for any volume estimating) is to secure an appropriate volume table.

I. A suitable standard volume table in cubic feet or board feet may be modified (for instance, a Girard Form Class Volume Table).

A. To modify the table, divide each tree volume in the table by its tree BA. Enter these quotients, called bff [board foot factor] or cff [cubic foot factor], in a new table by tree dbh and height class.

1. This table may be used as follows:

a. Tally trees in each point sample by dbh and height.

b. Secure the sum of the bff or cff for the trees in the sample.

c. Divide this sum by the number of trees.

d. Multiply this quotient by BA per acre when:

$$\text{BA per acre} = \frac{\text{no. trees}}{\text{no. points}} \times \text{BAF.}$$

B. To further modify the tables of factors (described in I.A.) divide each value by 10 to reduce the size of the numbers for easy mental arithmetic, and round off all values to whole numbers.

1. This will not introduce any serious errors where samples of large numbers are to be collected and used to compute volume per acre.

2. This table may be used exactly as outlined before except that the quotient (I.A.1.d.) will need to be multiplied by ten before multiplying by BA per acre.

II. A different kind of table may be similarly produced giving a bff or cff. for height classes only, instead of dbh and height classes.

A. This is true because the height-tree volume relationship is *practically* a straight line.

1. Thus for Mesavage & Girard Form Class 80, Grosenbaugh (1952) showed these bff's divided by 10 (International ¼-inch log rule):

dbh	1 log	2 log	3 log	4 log
10	7	12	—	—
12	8	12	16	—
14	8	13	17	20
16	8	14	18	22
18	8	14	19	23
20	8	14	20	23

B. From the table, its can be seen, for instance, that if 2-log trees average 14 inches dbh, the Bff is 13.

C. Using the table, the following procedure for determining volume per acre is used.

1. Tally point sample trees by height classes.
2. Total the trees in each height class.
3. Multiply each sum by the appropriate Bff.
4. Total these products.
5. Divide this total by the number of points in the sample.
6. Multiply by BAF to get board feet per acre.

(Note that since Bff was obtained by dividing tree volume by BA $\times$ 10, it will be necessary as a final step to multiply final answer by 10.)

(Note, too, that the procedure above is simplified, but like I.A.1., where:

$$\text{Volume} = \frac{\Sigma\, \text{bff}}{\text{No. trees}} \times \frac{\text{No. trees}}{\text{No. points}} \times \text{BAF},$$

while here:

$$\text{Volume} = \frac{\Sigma\, \text{bff}}{\text{No. points}} \times \text{BAF.})$$

III. If no suitable volume table is present, the bff or cff may be determined by felling timber in each height class or, if preferred, each dbh-height class, and measuring it for volume.

A. The following procedure is used.

1. Fell the sample trees.
2. Secure suitable tree measures (usually dbh's at some regular interval).
3. Apply a suitable log rule to obtain log volume.
4. Total to obtain tree volume.
5. Calculate the average tree volume for each height-class or dbh-height class.
6. Divide tree volume by tree BA, or usually in case of Bff divide by 10 times BA.

IV. Appropriate factors for southern pine were suggested by Grosenbaugh (March, 1952).

A. Bff's based on Girard Form Class 80 (about average for reasonably well-stocked *second-growth southern pine*):

	Bff		
Merch. Length	International 1/4 inch	Scribner	Doyle
zero log	0	0	0
1	7	6	4
2	13	11	8
3	18	16	12
4	23	20	15
5	28	25	21

B. The cff's for reasonably stocked southern pine:

Merch. Length, feet	cff	Merch. Length, feet	cff
0	0	40	26
10	7	50	31
20	14	60	36
30	20	70	39

V. A formula suggested by Grosenbaugh (1955) for International board foot volume per acre in southern pine is:

$$\text{Board foot volume per acre} = \frac{(\Sigma L)\ (60)\ (BAF)}{N},$$

where L is merch. height of trees in 16-foot logs,
N is number of sample points.

A. The factor 60 is based on average southern pine and allows for an increase in tree dbh and form class with tree heights.

EXERCISE NO. 2

USING PRISMS OF VARIOUS DIOPTERS

FIELD TALLY

In order to illustrate the prism concept of sampling, a field tally under ideal conditions is useful. The stand to be used is clear of underbrush with only large trees occasionally obstructing the view.

Three locations are to be occupied, one each per crew. (A separate tally was made using a 5-BAF, a 10-BAF, and a 20-BAF prism. Since all trees in the 10- and 20-BAF prism samples were also in the 5-BAF prism sample, this one was done first.)

In the field, record tree number (clockwise from north), species, dbh, and merchantable height. Use the tally sheet shown in Figure 4.

In the laboratory, complete the computational portion of the tally sheets, as the appropriate procedures are explained.

The samples will be compared and pooled as a final step in the analysis.

COMPUTATIONAL STEPS—USE THE FIELD TALLY SHEET

1. From the volume table supplied, enter the volume of each tree on the tally sheet. Extrapolate for heights not on the table.
2. From a table of basal area, enter the BA per tree to 4 decimal places.
3. Total all columns where applicable.
4. Compute the stand table blowup factor for each tree.
5. Multiply the stand table blowup factor for each tree by its volume to get the volume per acre each tree represents.
6. For each tree, compute its bff.
7. Sum up the bff's for each point.
8. Calculate board feet per acre by the formula at the bottom of the tally sheet.
9. Complete the blank column on the field tally sheet by multiplying the BA of each tree by the stand table blowup factor; sum for the entire point sample.
10. Compare the results by the various methods.

The following example (Figure 5) was obtained by one crew attending the short course. The per acre estimates obtained using the three BAF prisms (and by the methods of compilation with the same prism) are quite different, as might be expected at any one location. However, with numerous independent samples, the average per acre estimates using the different factor prisms should be approximatly equal.

Point Sampling Short Course

Exercise No. 2

FIELD TALLY AND COMPUTATION SHEET

Date ____________________ Basal Area Factor of Prism ____________

Crew ____________________ Stand Table Blowup Factor $\frac{\text{BAF of prism}}{.00545415\ (\text{dbh})^2}$

Tree No.	Species	DBH Tenth Inch Class	Height in Logs	Bd. Ft. Volume	Basal Area (Sq.Ft.)	Bd. Ft. Factor	Stand Table Blowup Factor	Bd. Ft. Per Acre	B.A. per Ac.
	Totals								

Basal Area per Acre = Sum of Tree Count x Basal Area Factor ____________

Board feet per acre = Basal Area Factor x Sum of Bd. Ft. Factors____________

Figure 4. Tally sheet to illustrate some factors in Exercise No. 2.

SAMPLING TECHNIQUES

I. Point-sampling is tree sampling proportional to tree BA. This was made clear in the lecture concerning the construction of a stand table, where the following equation was presented for computing the stand table blow-up factor:

Point-Sampling Short Course

Exercise No. 2

FIELD TALLY AND COMPUTATION SHEET

Tree No.	Species	D.B.H. (inch class)	Height In Logs	Bd.Ft. Volume	Basal Area (Sq.Ft.)	5-BAF Prism Bd.Ft. Factor	5-BAF Prism Stand Table Blowup Factor	5-BAF Prism Bd.Ft. per Acre	10-BAF Prism Bd.Ft. Factor	10-BAF Prism Stand Table Blowup Factor	10-BAF Prism Bd.Ft. per Acre	20-BAF Prism Bd.Ft. Factor	20-BAF Prism Stand Table Blowup Factor	20-BAF Prism Bd.Ft. per Acre
1	Shortleaf	21.9	4.5	690	2.6159	263.77	1.911	1318.59	263.77	3.823	2637.87	263.77	7.646	5274.36
2	Shortleaf	18.2	5	450	1.8066	249.09	2.768	1245.60	249.09	5.536	2491.20	249.09	5.536	4982.40
3	Shortleaf	24.3	5	940	3.2206	291.87	1.553	1459.82	291.87	3.106	2694.04			
4	Shortleaf	30.7	4	1415	5.1405	275.27	0.973	1376.79	275.27	1.946	2725.30	275.27	1.946	5450.60
5	Shortleaf	27.3	4.5	1115	4.0649	274.30	1.230	1371.45						
6	Shortleaf	22.7	5	845	2.8105	300.66	1.779	1503.26	300.66	3.558	3066.52	300.65	3.558	6013.04
7	Shortleaf	19.6	5	590	2.0953	281.58	2.386	1407.74	281.58	4.772	2815.48	281.55	9.544	5630.96
8	Shortleaf	21.3	5	675	2.4745	272.78	2.021	1364.18	272.78	4.042	2728.36			
9	Shortleaf	24.5	5	1033	3.2739	315.53	1.528	1578.42	315.53	3.056	3156.84			
10	Shortleaf	22.7	5	845	2.8105	300.66	1.779	1503.26	300.66	3.558	3006.52			
11	Shortleaf	30.6	5	1715	5.1071	335.81	0.979	1678.98						
12	Shortleaf	15.9	5	330	1.3789	239.32	3.626	1196.58	239.32	7.252	2127.18	239.32	14.504	4254.36
13	Shortleaf	20.3	5	590	2.2476	262.50	2.225	1312.75						
14	Shortleaf	21.9	4	640	2.6159	244.66	1.911	1223.04	244.66	3.822	1934.08			
15	Shortleaf	22.4	4	640	2.7367	233.86	1.827	1169.28						
16	Shortleaf	24.7	5	1033	3.3275	310.44	1.503	1552.60	310.44	3.006	2278.80	310.52	6.012	4557.60
17	Shortleaf	23.2	5	845	2.9356	287.85	1.703	1439.04	287.85	3.406	2202.08	287.81	6.812	4404.16
18	Shortleaf	32.5	5.5	2135	5.7610	370.60	0.868	1853.18	370.60	1.736	3706.36	370.64	3.472	7412.72
	Totals		86.5			5110.55		25554.56	4004.08		37569.94	2578.62		47980.20
	Basal Area per Acre = Sum of Tree Count x BAF					18 x 5		= 90	14 x 10		= 140	9 x 20		= 180
	Bd. Ft. per Acre = BAF x Sum of Bd. Ft. Factors					5110.55 x 5 = 25,552.75			4004.08 x 10 = 40,040.80			2578.62 x 20 = 51,572.40		

Figure 5. Example of point sample of study by a student crew—Application of Exercise No. 2.

$$\text{Factor} = \frac{\frac{\text{BAF}}{\text{N}}}{0.00545415\ \text{D}^2}$$

A. The factors for three common values of BAF are:[1]

[1]Some values in the tabulation are slightly different from those which would be computed from values in Table 6, due to rounding off.

DBH Class Inches	Stand table blow-up factors 5-BAF	10-BAF	20-BAF
4	57.30	114.59	229.20
6	25.47	50.93	101.86
8	14.32	28.66	57.30
10	9.16	18.33	36.67
12	6.37	12.73	25.47
14	4.68	9.35	18.71
16	3.58	7.16	14.32
18	2.83	5.66	11.32
20	2.29	4.58	9.16
22	1.89	3.79	7.58
24	1.59	3.18	6.37

B. These are easily computed using the equation shown, as for instance the 10-BAF and dbh class of 4 inches:

$$\text{Factor} = \frac{\frac{10}{1}}{(0.00545415)(4^2)},$$

$$= \frac{10}{(0.00545415)\ (16)},$$

$$= \frac{10}{0.0872664},$$

$$= 114.5916.$$

C. So, the smaller the dbh class the smaller the percent of sample, and therefore the larger the multiplier must be to convert to per-acre values. This is an advantage over some other sampling methods since the bulk of counting or measuring labor is used on the more valuable larger size dbh classes.

II. Several other kinds of sampling (with which we are all familiar) are proportional to area, as for instance plot-sampling.

A. In plot-sampling, if one wanted to change count of sample trees on a 1/5-acre plot to trees per acre, the same multiplier (5) would be used for all dbh classes.

B. Generally speaking, the same principle applies to line sampling and to transect-sampling. Counts along a line or transect are related to the count for an area, and all dbh class counts are multiplied by a constant to obtain per acre counts.

C. Actually, as the typical uneven-aged stand table clearly shows, there are far more small trees than large trees in the forest; so a sampler really spends much more of his time than is warranted by volume or value in measuring or counting them. (For instance, on 110 circular 1/5-acre CFI plots established in Sabine County by the Department of Forestry, over half of the stems came from the 5- and 6-inch diameter classes.)

D. The same considerations would be valid for a mixture of small even-aged stands. One would expect, of course, to stratify and sample differently in even-aged stands large enough to be treated separately.

III. Some problems are perhaps best solved by a sampling method other than point sampling:

A. To determine survival of seedlings in plantings, sample-row counting is practicable.

B. In natural reproduction inventories, random quadrat counts or transect or line counts may be more reasonable.

C. For forage volume inventories, quadrat clippings may be desired.

D. When a count is not directly related to area, transect or line counts may suffice.

IV. There are many considerations involved when trying to devise a point-sampling scheme. Some of the most obvious are discussed, but many others are encountered in the field. One must be alert to note them and to make field time as productive as possible.

A. Random sampling principles should be used whenever reasonable because any measure which is averaged will be of limited value if not accompanied by a measure of variability or accuracy.

B. Systematic samples may be subjected to analyses suitable for random samples but the results must be accepted with reservation. Nevertheless, the systematic forest sample will generally be more precise than other kinds of samples of the same size, so systematic sampling does have some specific advantage.

C. Two-prism sampling may be advantageous when two arbitrarily defined populations occupy the same area.

1. A sawtimber population and a pulpwood population are present. To count the sawtimber trees with a 5-BAF prism would be too time consuming, but to count pulpwood size trees with a 10-BAF prism might admit too few trees for a good sample.
2. The obvious solution is to sample each arbitrarily defined population with the instrument best suited to measure it.

D. Combined plot and point-sampling may be suitable for some situations similar to that discussed above, or perhaps combined point and transect or line-sampling would be better.
   1. For timber volume and reproduction counts, one might use point-samples for volume and stocked quadrats for reproduction.
   2. For timber volume and thinning prescription, employing the Tennessee Valley Authority (1952) thinning system in young pine plantations, one could use row tree counts for prescribing, and point-sampling for timber volume estimating.

E. Subsampling (to save time) may be desirable in situations when some attribute with small variance is needed in combination with some other of larger variance, or where economics may dictate fewer measurements of a difficult nature.
   1. For estimating volume in pulpwood size plantations, use point-sampling to count trees, and randomly select trees out of the point-sample count for height measures (height is a time-consuming measure, and all the merchantable trees may be nearly the same height).
   2. The same kind of solution might apply if one were sampling to construct a stand table or to obtain volume when volume factors are based on dbh.
   3. Particularly, in IV.E.2., the *random* selection of individual sample trees for the measured subsample would be important (avoid the idea of measuring trees *you* select on the premise that a set number should be measured in each class).
   4. Because some size class may be limited by the nature of the stand (40-inch dbh trees for example), perhaps all individuals of some classes would be measured in the subsample. When this is done, computational procedures must take this into account.

F. Proportional sampling might be used in areas where stands can be stratified.
   1. Separate hardwood from pine stands or young timber from old timber, etc., then sample each stand optimally.
   2. This may involve not only variance of the populations, but also total stand area, value per unit, etc.

G. Cluster sampling may be better than the selection of a single sampling unit at each location.
   1. In 1957-58, an area was sampled using the average of two 10-BAF samples as a measure of BA per acre with the following results, compared to 1/5-acre plots also measured in 1957-58 and a subsequent single 10-BAF sample in 1962 at the same location:

Sampling Unit	BA per A (Sq. Ft.)	σm (Sq. Ft.)	C (Per Cent)
Avg. of 2 prism samples 1957-58	70.18	2.17	30.92
1/5-acre plot 1957-58	70.72	2.20	31.11
One prism sample 1962	62.87	2.8	44.53

2. The sampling scheme referred to above contained 110 sampling units so a σm of about $\pm$ 10% could have been obtained in the 1957-58 inventory with only about 10.52 or 11 points, but using only one prism count, as the sampling unit in 1962 would have required about 21 points for similar precision. (Note: The probability is 68 in 100 chances.)
3. Also, the 1957-58 point-sampling was as precise as 1/5-acre plot-sampling, showing that on this area it is just as efficient for BA data as the larger plot-sample.
4. Point-sampling is now employed in the Southern Forest Survey, where ten points, each a chain apart on varying azimuths, are used with limiting distances for a 37.5-BAF prism.

H. Prescription sampling with the prism may be done advantageously.

1. On pp. 10-11 of Southern Forest Experiment Station, Occasional Paper 145, Grosenbaugh described a method of prescribing and marking thinnings in southern forests. With a 50-BAF prism the count should *never* be 3 (over 2) when the "leave" BA target is about 83 square feet.
2. Similarly, where one-fourth or more points contain zero potential crop trees with 50-BAF prism, the area needs special attention for restocking or replenishing of stocking.
3. On the Texas National Forests, a 37.5-BAF prism is similarly used in sampling during pre-sale planning.
4. Seed tree marking, or checking of marked stands, may well be accomplished after marking standards have been formulated. For instance, if the goal is 7 large (average 19-20-inch dbh) trees per acre to be left as seed trees, then BA per acre of seed trees would be about 15 square feet; so with a 5-BAF prism, seed tree counts should average 3.

V. The choice of a point-sampling instrument (choice of a BAF) might make point-sampling somewhat comparable to plot-sampling in the concept of percent of sample.

A. This concept is totally disclaimed by all authorities contacted by the authors and by several in published material concerned with point-sampling or forest sampling in general.

B. Nevertheless, a case example from a Texas industrial forest is presented here, because it may have value for *some* situations.

1. Trees on company land average slightly over 12 inches dbh, and with a 10-BAF prism this size tree has a tree circle (or plot) of about 0.08 acre size; so plot size averages 0.08 acre.
2. 500 points will be located on 200,000 acres.
3. Equivalent acres tallied: (500) (0.08) = 40.00 acres.
4. Percentage cruise: 100 $\times$ 40.00/200,000 = 0.2 percent.
5. As noted above, there are good reasons for not accepting this line of reasoning, all revolving around the fact that sampling intensity varies as tree BA.

VI. Bias in point-sampling is just as important a consideration as in any kind of sampling. *It is to be avoided.*

A. Systematic instead of random samples may cause bias.

1. As a result of the coincidence of natural population clustering and sample point locations, all points could fall in high site class spots thus omitting all ridge tops and dry sites.
2. Bias could happen as a result of man's activities. By random selection of a starting point for a systematic cruise, one might select a spot 2 chains southeast of the northwest corner of each 160-acre square block of forest land, not knowing that 50 years ago a steam skidder yard was located in each of these spots, making each such spot non-representative of the *whole forest.*

B. Improper use of tools may cause bias.

1. If the prism is hand-held and by some quirk always 4-5 degrees out of horizontal (which would not be compensating) the count will be in error.
2. If the cruiser swings the prism around him instead of vice versa, the count will be wrong.
3. If one measures distance from point to borderline trees but to *nearest* edge of tree instead of to center of tree (note if one-half dbh is subtracted, then nearest edge of tree would be correct), the count will be incorrect.

C. Ignoring slope correction *may* be all right for *some* Southern forests; for many in East Texas it would not.

D. Borderline trees, if not properly handled, may be a source of bias.

1. As a result of reading or writing a rule the wrong way, bias may be introduced.
   a. The rule should be: "Include border trees on the west side, exclude those on the east side" or rephrased, "Count every borderline tree as ½ tree."
   b. The rule should not be: "At each point count the first borderline tree, omit the second, count the third, etc." (because borderline trees will be about 1 in 20 or so, and because ordinarily only one would be found on 2 or 3 plots, all would get counted.)
2. If borderline trees are not measured, to accurately determine in or out, an unconscious bias may develop wherein many "out" trees are counted or vice versa. This may not be compensating.
3. Looking at trees always at eye level or some place other than 4.5 feet above average ground line would not be compensating.

E. "Brush bias" (obscuring trees behind brush or other trees) may cause count to be low but never high.

1. Proper use of the prism and proper selection of BAF can *usually* whip this in Southern forests (this can be a problem in "Big Thicket" country).
2. In the Pacific Northwest this bias is controlled by looking at each tree at top of first 16 foot log instead of breast height (Bruce 1961).

EXERCISE NO. 3

A CHECK CRUISE OF TIMBER MARKING

A southern pine plantation has been marked for thinning. This problem is to determine:

1. Volume of cut and leave by species.
2. BA of cut and leave by species.

Several questions present themselves:

1. What BAF prism should be used?
2. What constitutes an adequate point sample, and is subsampling called for?
3. What volume tables are available, and which appears to be best?
4. How homogeneous is the plantation, or portions of it?
5. What maps, aerial photographs or supplemental data are available?

Design a field tally sheet to sample the stand and determine the required data. Perform the field work, prepare suitable summary data and include a statement of cost.

The following list shows the summaries from five separate crews' work on a particular stand:

Crew	Cords per Acre				BA per Acre			
	Loblolly		Shortleaf		Loblolly		Shortleaf	
	Leave	Cut	Leave	Cut	Leave	Cut	Leave	Cut
1	21.6	6.6	28.2	5.4	83	22	100	23
2	14.6	11.2	22.6	10.6	60	60	93	47
3	16.0	14.6	23.4	7.2	80	74	94	28
4	20.0	12.0	30.8	10.4	80	80	92	34
5	[1]	[1]	20.8	11.2	[1]	[1]	81	45
Average	18.0	11.2	25.2	9.0	76	59	92	35

[1]No sample.

BASIC POINT-SAMPLE STATISTICS

I. Statistical analysis of point-sample data is very easy. To show the principles involved, a point-sample tally sheet is presented (Figure 6).

II. No volumes were computed until the end of the problem. The primary tree variable that is correlated with volume is height, so total height per point was used as the variable from which the M and σm were computed.

III. The formulas used were modified from those presented by Grosenbaugh (1955), where:

A. International 1/4-inch bd. ft. volume per acre $= \frac{\Sigma L\ (60)(BAF)}{N}$,

B. Rough stacked cord volume per acre $= \frac{\Sigma F\ (0.005)(BAF)}{N}$,

when: L = tree merch. ht. in 16 foot logs,

F = tree total height in 10 foot units,
N = number of sample points,

Basal Area Factor 10

Point Sample Tally Sheet

Point	Pine Sawtimber: Height-Logs	L	L^2	Pine Pulpwood: Total Height-10 Feet	F	F^2
1	1, 0, 3, 1	5	25	6, 5	11	121
2	$2\frac{1}{2}$, $3\frac{1}{2}$, 1	7	49	3	3	9
3	4, 1, 2	7	49	2, 3, 4	9	81
4	4, 3, 2, 2	11	121		0	0
5	$2\frac{1}{2}$, 3	5.5	30.25	5	5	25
	Bd. Ft. Vol./Acre int. 1/4 in. Rule	SL 35.5	SL^2 274.25	Cord Vol./Acre	SF 28	SF^2 236

$$V = 600 \times \frac{SL\ 35.5}{N\ 5} \qquad V = \frac{SF\ 28}{2 \times N\ 5}$$

$$V = 600 \times 7.1 = 4260 \qquad V = \frac{28}{10} = 2.8$$

Standard Error of bd. ft. Volume

$$\sigma_M = 600\sqrt{\frac{SL^2\ 274.25 - \frac{(SL\ 35.5)^2}{N\ 5}}{N\ 5 \times (N\ 5 - 1)}}$$

$$\sigma_M = 600\sqrt{\frac{274.25 - \frac{252.05}{5}}{20}}$$

$$\sigma_M = 600\sqrt{1.11} \quad \text{OR } 1.0535$$

$$\sigma_M = 632.1$$

Standard Error of Cord Volume

$$\sigma_M = 0.5\sqrt{\frac{SF^2\ 236 - \frac{(SF\ 28)^2}{N\ 5}}{N\ 5 \times (N\ 5 - 1)}}$$

$$\sigma_M = 0.5\sqrt{\frac{236 - \frac{784}{5}}{20}}$$

$$\sigma_M = 0.5\sqrt{4.46} \quad \text{OR } 2.11$$

$$\sigma_M = 0.5 \times 2.11 \text{ OR } 1.055$$

Figure 6. A field tally computational form for point-sample volume estimates showing analysis of a sample.

BAF = basal area factor of the instrument.

IV. When the BAF is 10, the factors multiplied by it will be 600 and 0.05 respectively. When tree height in pulpwood is also recorded in units of 10 feet, the conversion factor will then become 0.5, or, is changed to a divisor, it will be 2.0. It is used in the form easiest to apply (Figure 6).

V. Point-sampling statistical analysis is similar to any sampling analysis, particularly where one is working with relatively large samples wherein the variable is continuous. Actually, tree counts, as in BA estimation with point samples, are discrete, but this should not be a barrier to the use of normal statistical analysis for continuous variables.

VI. Statistical analysis uses variance as measured in a sample. If X is the measured variable, then its value must be ascertained for *each* sample point. The variance is computed with the equation:

$$V = \frac{\Sigma X^2 - \frac{(\Sigma X)^2}{N}}{N - 1},$$

where: V = variance of X,
X = measurement at a point,
N = number of points.

VII. Other statistical values normally needed from point sample cruises are:

A. Standard deviation $= \sigma = \sqrt{V}$.

B. Standard error of the mean $= \sigma m = \sqrt{\frac{V}{N}}$.

C. Coefficient of variation $= C = \frac{\sigma}{M}(100)$.

D. Proportional limit of errer = Ple. $= \frac{2\,\sigma m}{M}(100)$.

E. Number of observations for 68 percent confidence in $\sigma m = N = \frac{V}{\sigma m^2} = \frac{\sigma^2}{\sigma m^2}$.

Number of observations for 95 percent confidence in $\sigma m = N = \frac{4V}{\sigma m^2}$.

F. Sampling error of mean in percent $= S = \frac{C}{\sqrt{N}}$.

G. Combined sampling error in percent = Se.%, where $Se\% = \sqrt{(S \text{ of bff (or cff)})^2 + (S \text{ of Tree Count})^2}$.

CONSTRUCTING POINT-SAMPLE VOLUME FACTORS

I. There are many ways of computing timber volumes from point-samples. Four are illustrated:

A. The first is similar to the standard volume table approach in plot cruising, sample trees being classified on height and diameter.

B. The second is based on local volume tables as used in conventional plot cruising, sample trees being classified by diameter only.

C. The next is *like* the local volume table approach except that sample trees are classified on height rather than dbh, with a volume factor for each height class.

D. The last method is like I.C. except that a single average factor is used for all height classes.

II. The system wherein sample trees are classified by height and dbh is simple, easy and direct.

A. To begin with, a *good standard volume* table is needed. To illustrate the procedure, a volume table developed for an area on the Sabine National Forest for loblolly pine is shown in Table I.

B. Each tree volume in the table is divided by the BA of the dbh class to which it belongs.

1. For instance, for 10-inch dbh, 1 log, from Table 1, the volume is 23 bd. ft., and

$$\text{bff} = \frac{23}{(3.1416)\ (10)^2/144},$$
$$= 23/0.545,$$
$$= 42.$$

2. As a further refinement, each of the basal area factors thus derived is commonly divided by 10 to reduce the size of the numbers involved; thus

$$\text{Bff} = \frac{\text{bff}}{10},$$
$$= 42/10,$$
$$= 4.2 \text{ which is frequently rounded off to 4.}$$

C. Table 2 was made in that manner from Table 1.

D. A three-step procedure then determines volume per acre from point samples.

1. Tally sample trees by dbh and height at the sample points.

2. For each tree tallied, extract the appropriate Bff from the table.

3. Sum the Bff's, divide by the number of points, and multiply by 10 × BAF to obtain board foot volume per acre.

E. Suitable tally sheets for this system are shown as Figures 7 and 8.

TABLE 1. LOBLOLLY PINE GROSS BOARD FOOT VOLUMES (SCRIBNER LOG RULE), SABINE NATIONAL FOREST

F.C.	74	76	77	79	80	82	83	84	84	84
					Log Length					
D.B.H.	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5
10	23	31	39	50	53					
11	30	41	52	68	74					
12	38	52	65	88	93	106	119			
13	47	65	83	112	119	137	151			
14	56	77	101	136	144	166	183			
15	66	93	119	163	174	201	225			
16	76	110	138	190	205	236	267			
17	88	127	162	222	239	279	311			
18	101	144	186	254	273	322	354			
19	114	163	212	291	312	365	407			
20	128	182	238	327	351	410	460	506	537	
21	142	203	266	368	394	461	522	574	612	
22	157	225	293	409	437	511	583	642	686	
23	174	250	327	456	488	570	644	716	768	
24	191	274	362	503	537	630	705	791	851	
25	208	302	396	550	592	693	781	871	938	

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Point-Sample Tally Sheet

Tree dbh	Tree Height in 16 Foot Logs					
(inches)	1	1.5	2	2.5	3	3.5
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						

Line __________ Type __________ Date __________

No. of Points __________ Estimator __________

Figure 8. A tally sheet for use when all point-samples in a line or unit are tallied together as a single unit.

III. The system wherein the sample trees are tallied by dbh class only, simplifies field work.

A. A good local volume table is used without modification.

B. Stand blowup factors, one for each dbh class, are computed as follows:

$$\text{Stand blowup factor} = \frac{\text{BAF}}{\text{basal area per tree}},$$

where: BA per tree is in square feet,
and BAF is determined by the prism.

C. For the 5-inch class and for a 3.03 diopter prism, for instance:

$$\text{stand blowup factor} = 10/0.1364, \\ = 73.3.$$

D. With the local volume table and the stand blowup factor, to get volume per acre in each dbh class, multiply sample tree count by stand blowup factor, then multiply that product by volume per tree (Figure 9).[1]

IV. When sample trees are classified by height only, field time is saved.

A. To develop the factors needed for this point-sampling, start with a curve of dbh over height and a standard volume table, as for instance Table 1 from which Table 2 could be developed.

B. Then for each height class from the curve, determine average dbh, and from Table 2 extract the proper Bff for that height class.

C. If a suitable volume table is not available, derive the factors from basic data.

D. The necessary tree measures by height classes will be:
1. Tree volume,
2. Tree dbh.
Note: To show the procedure, Table 3 presents some data from the Sabine National Forest.

E. Compute a bff for each height class by dividing average volume by average BA in each height class (See Table 3).

F. Make a good curve of bff over height. This may be done graphically or mathematically. From Table 3 the mathematical equation for this line was $y = 15.2 + 2.9x$ (When y was bff and x was height class).

G. For each height class take from the curve (or compute by the equation of the curve) the bff for each height class.
1. The equation from Table 3 gave these:

Ht. Logs	bff	Ht. Logs	bff
0	0	3	154
0.5	38	3.5	178
1	62	4	201
1.5	85	4.5	224
2	108	5	247
2.5	131	5.5	270

H. To use these in point-sampling, tally sample trees by height classes and determine the sum of bff by multiplying the number of trees in each class by the appropriate bff.

I. Then compute volume per acre with the equation:

$$\text{Vol., bd.ft. per acre} = \frac{\Sigma \text{ bff}}{\text{no. points}} (\text{BAF}).$$

J. A suitable field tally sheet is shown in Figure 10.

K. Table 4 shows similar basic data and Table 5 the cff's from cubic foot volume material obtained from the Sabine National Forest.

[1]This form has been used for several years by sophomore summer camp mensuration students at Stephen F. Austin State College.

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TALLY SHEET -- FOR POINT-SAMPLES ONLY
(For Use on Special Use Area Only)

Line ______________ Type ______________ Date__________

Point ______________ Estimator ______________

Diameter Class	Field Tally	Stand Table Blowup Factor	Trees per Acre	Cubic Foot Volume Blowup Factor	Board Foot Volume Blowup Factor	Cubic Foot Volume per Acre	Board Foot Volume per Acre
Shortleaf Pine							
5		73.3		1.44			
6		50.9		2.57			
7		37.4		4.28			
8		28.6		6.09			
9		22.6		8.49			
10		17.3			49.4		
12		12.7			84.5		
14		9.4			140.7		
16		7.1			203.1		
18		5.7			281.5		
20		4.6			353.6		
22		3.8			448.7		
24		3.2			548.0		
26		2.7			664.8		
28		2.3			790.8		
30		2.0			922.0		
Total							
Loblolly Pine							
5		73.3		1.43			
6		50.9		2.63			
7		37.4		4.36			
8		28.6		6.20			
9		22.6		8.69			
10		17.3			49.3		
12		12.7			82.0		
14		9.4			130.7		
16		7.1			203.4		
18		5.7			280.1		
20		4.6			384.9		
22		3.8			457.7		
24		3.2			559.0		
26		2.7			678.1		
28		2.3			808.6		
30		2.0			940.4		
Total							

Sawtimber Volume by Scribner Log Rule

Figure 9. A tally sheet for use when point-sample tree dbh only will be measured and local volume table volumes applied.

V. The system where one single average factor is used to compute volume in board feet when sample trees are classified by height only is explained by Grosenbaugh (1955). Hunt (1961) said that the bff (a number normally near 60 for average southern pine timber volumes based on International 1/4-inch log rule) could be derived from tree height, and stock and stand tables usually available.

A. When the bff (a number near 60) has been obtained, board foot volume may be computed by the equation:

$$\text{Vol., bd. ft. per acre} = \frac{(\Sigma L)\,(BAF)\,(\text{a number near } 60)}{N},$$

where: N is the number of points, and
ΣL is the sum of sample tree heights in 16-foot logs on those points.

B. A suitable field form when using a factor like this is shown as Figure 11, where the bff is 55 for hardwood and 60 for pine and the local cord volume factors are given.

Note: Throughout this lecture, bff and board foot volumes generally have been used, but cff's are similarly computed.

TABLE 3. LOBLOLLY PINE SAWTIMBER TREE MEASUREMENTS FROM SABINE NATIONAL FOREST, 1958 (300 trees).

Ht. Class (feet)	Trees (number)	Avg. dbh (inches)	Avg. Vol. (bd. ft. scrib.)	Ht. Class (feet)	Trees (number)	Avg. dbh (inches)	Avg. Vol. (bd. ft. scrib.)
12	1	10.3	36.4	46	21	16.3	220.0
16	3	9.8	37.9	48	16	16.8	240.1
18	6	10.7	46.6	50	12	16.4	231.3
20	5	10.9	51.3	52	13	17.3	273.0
22	4	11.1	55.8	54	8	16.7	258.9
24	12	11:4	61.0	56	12	16.7	270.6
26	9	11.0	60.3	58	9	17.5	308.4
28	9	11.5	69.4	60	8	17.7	323.8
30	19	11.9	78.1	62	4	20.4	456.5
32	23	11.5	74.9	64	4	17.6	335.9
34	20	13.2	107.2	66	5	18.1	377.7
36	13	13.5	115.8	68	5	17.6	354.6
38	23	12.8	110.0	70	2	18.1	384.6
40	13	14.6	149.1	72	3	20.1	506.8
42	7	14.2	143.0	76	1	19.2	477.9
44	10	15.1	176.8	Total	300	----	-----

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TALLY SHEET -- FOR POINT-SAMPLES ONLY

Type ________ Estimator ________ Date ________

Point No.	Number of 16-Foot Logs: 1	1.5	2	2.5	3	3.5	4	4.5	Total
Sums									
Bd.Ft. Factor									
Product									
								$\frac{\text{Total}}{N}$	
								Total Bd. Ft./Acre = $\frac{\text{Total}}{N}$ x BAF	

Figure 10. A tally sheet suitable for use when point-sample trees will be tallied by height class, only.

TABLE 4. LOBLOLLY PINE PULPWOOD TREE MEASUREMENTS FROM SABINE NATIONAL FOREST, 1958 (437 trees).

Ht. Class (feet)	Trees (number)	Avg. dbh (inches)	Avg. Vol (cu. ft.)	Ht. Class (feet)	Trees (number)	Avg. dbh (inches)	Avg. Vol. (cu. ft.)
8	15	4.9	.95	28	7	8.2	7.33
10	27	5.1	1.18	30	21	7.9	7.31
12	54	5.4	1.55	32	20	8.2	8.36
14	53	5.9	2.06	34	8	8.2	8.79
16	54	5.9	2.39	36	7	8.5	9.95
18	46	6.5	3.16	38	3	9.2	11.98
20	30	6.8	3.79	40	3	9.3	12.84
22	34	7.1	4.40	42	2	8.4	11.49
24	23	7.5	5.38	44	1	9.1	13.62
26	28	7.3	5.55	48	1	9.3	15.32

TABLE 5. LOBLOLLY PINE CUBIC FOOT VOLUME FACTORS FOR POINT-SAMPLING, FROM THE EQUATION—CFF = 1.98 + 0.65 H.

Merch. Ht. (feet)	Cu. Ft. Factor	Merch. Ht. (feet)	Cu. Ft. Factor
0	-----	28	20.18
8	7.18	32	22.78
12	9.78	36	25.38
16	12.38	40	27.98
20	14.98	44	30.58
24	17.58	48	33.18

S. F. Austin State College — Department of Forestry

POINT-SAMPLE TALLY SHEET

Type ______ Area ______ acres Crew ______ Date ______

Point	Pine Logs	Total	Hardwood Logs	Total	Pine Pulp Height	Total	Hardwood Pulp Height	Total
	L=		L=		H=		H=	
	$V = \frac{60 \times BAF \times L}{\text{Total Points}}$		$V = \frac{55 \times BAF \times L}{\text{Total Points}}$		$V = \frac{H \times .0050 \times BAF}{\text{Total Points}}$		$V = \frac{H \times .0045 \times BAF}{\text{Total Points}}$	
	V = Bd.Ft./ac.		V = Bd.Ft./ac.		V = Cds./ac.		V = Cds./ac.	

Figure 11. A tally sheet for use when point-sample tree heights are tallied and a single factor for each product is applied in computing volume per acre.

MISCELLANEOUS VOLUME FACTORS

I. Using shortleaf pine tree measurement averages from the Sabine National Forest, and the procedure illustrated for board feet by Hunt (1961), a cff of 0.7 was computed for use as follows:

$$\text{Cubic feet per acre} = \frac{\text{(sum tree merch. ht. in feet)}\,(0.7)\,(\text{BAF})}{\text{number of sample points}}$$

II. Grosenbaugh (1955) offers the following equation for computing southern pine cord volume per acre using an instrument with BAF = 10:

$$\text{Volume per acre in rough stacked cords} = \frac{\text{sum of total tree height in feet all sample trees}}{(20)\,(\text{number of sample points})}$$

A. If a locally correct factor other than 20 is desired, it can be calculated and usually is between 18 and 21.

B. The procedure:

1. Select several small representative areas.
2. On each, measure to determine individual tree BA and total height in feet.
3. Determine sum of (BA × height) for each area.
4. Cut the trees into pulpwood, stack and measure cords for each area.
5. Compute the factor for each area with the equation:

$$\text{factor} = \frac{\text{sum of } [(\text{BA})\ (\text{height})]}{\text{sum of cords volume}}.$$

III. Grosenbaugh (1955) rewrites his equation so that it may be used for any instrument with a known BAF in sampling southern pines:

$$\text{Volume per acre in rough stacked cords} = \frac{(\text{Sum total tree hts.})\,(0.005)\,(\text{BAF})}{\text{number of sample points}}$$

A. This is really the same equation as in II, with the BAF inserted and the values re-arranged.

B. If a locally more accurate factor than 0.005 is desired, it may be computed in the same manner as described for the 20-factor above except that the right side of the equation is inverted to read:

$$\text{factor} = \frac{\text{sum of cords volume}}{\text{sum of } [(\text{BA})\,(\text{hts.})]}.$$

IV. Using the procedure in III., and values from yield tables, classes at Stephen F. Austin State College devised factors for three southern pine species in varying localities:

Virginia pine in East Tennessee	0.0047,
Longleaf pine in Georgia	0.00524,
Shortleaf pine plantation of low form class in East Tennessee	0.0045.

A. Note that some of these are significantly different from 0.005 and therefore a locally derived factor *may* be of some importance.

V. If we re-write Grosenbaugh's equation in II., to include the BAF, it could become:

$$\text{Volume per acre in rough stacked cords} = \frac{(\text{no. trees})\,(\text{BAF})\,(\text{avg. total tree ht.})}{(10)\,(20)\,(\text{no. sample points})}$$

A. Rearranged, this equation could be shown thus:

$$\text{Volume per acre in rough stacked cords} = \frac{(\text{no. trees})\,(\text{BAF})}{100\,(\text{no. sample points})} \times \frac{\text{avg. total tree ht.}}{2}$$

B. But $\frac{\text{no. trees}}{\text{no. points}}$ (BAF) = BA per acre,

so, BA per acre in 100 square feet units × half the average total tree height = volume per acre in rough stacked cords.

THE STAND TABLE BLOW-UP FACTOR

I. The stand table blow-up factor (S.T.F.) gives the stand table values when multiplied by point-sample tree counts tallied by dbh class at one point.

A. Therefore, for each dbh class:
Trees per acre = (S.T.F.) (Point sample tree count).

B. A stand table may be made in this manner.

C. As an additional point, if the count came from N points then the product must be divided by N.

II. The S.T.F. for each dbh class and BAF can be computed by the equation

$$\text{S.T.F.} = \frac{\text{BAF}}{\text{BA per tree}}.$$

A. It would be easier to compute for any particular BAF, however, if multiplication by the constant BAF could be performed.

B. This can be accomplished if the equation is changed to:
S.T.F. = (BAF) (reciprocal of BA per tree)

C. Table 6 is a list of these reciprocals; the values may be used in the above equation to produce the appropriate S.T.F.'s for any BAF.

CONSTRUCTING PLOT RADIUS OR "LIMITING DISTANCES" TABLE

I. A diopter is 1 centimeter of displacement of a light ray at a distance of 100 centimeters from the optical lens—in our case a prism.

II. A wedge or triangular prism is a piece of optical glass which refracts a light beam, the refraction (or deflection) being a factor of the rate of convergence of its non-parallel sides.

A. Therefore, with a 10-BAF prism, which is 3.03 diopters, a 12-inch dbh (wide) tree would be on the borderline at 33 feet:

$$\frac{12 \times 100}{3.03} = 12 \times 33 \text{ inches} = 33 \text{ feet.}$$

B. By like reasoning, a 12-inch dbh tree viewed through a 20-BAF prism, having 4.29 diopters, would be borderline at 23.3 feet:

$$\frac{12 \times 100}{4.29} = 23.3 \text{ inches} = 23.3 \text{ feet.}$$

C. For ease in computation, derive a multiplying factor for inches of dbh to get the borderline, or limiting, distance. For a 10-BAF prism 12 inches of dbh has 33 feet to its borderline and therefore the "tree circle" factor is 2.75:

$$\frac{33}{12} = 2.75 \text{ the "tree circle" factor.}$$

TABLE 6. RECIPROCALS OF BASAL AREA (SQUARE FEET) BY .1 INCH INCREMENT OF DIAMETER BREAST HEIGHT FROM 1 INCH TO 25.9 INCHES

DBH	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
1	181.8182	151.5152	126.5822	108.6956	93.4579	81.3008	71.4286	63.2911	56.4972	50.7614
2	45.8716	41.4938	37.8788	34.6021	31.8471	29.3255	27.1003	25.1256	23.3645	21.7865
3	20.3666	19.0840	17.8891	16.8350	15.8479	14.9701	14.1443	13.3869	12.6904	12.0482
4	11.4548	10.9051	10.3950	9.9206	9.4697	9.0580	8.6655	8.2986	7.9554	7.6336
5	7.3314	7.0472	6.7797	6.5274	6.2893	6.0606	5.8480	5.6433	5.4496	5.2659
6	5.0942	4.9285	4.7687	4.6189	4.4763	4.3403	4.2088	4.0850	3.9651	3.8506
7	3.7411	3.6377	3.5373	3.4400	3.3478	3.2595	3.1746	3.0921	3.0139	2.9377
8	2.8645	2.7949	2.7270	2.6617	2.5988	2.5374	2.4789	2.4225	2.3674	2.3148
9	2.2635	2.2139	2.1664	2.1200	2.0751	2.0317	1.9893	1.9486	1.9091	1.8706
10	1.8335	1.7973	1.7621	1.7283	1.6952	1.6631	1.6318	1.6015	1.5718	1.5432
11	1.5152	1.4881	1.4616	1.4360	1.4108	1.3864	1.3626	1.3394	1.3168	1.2947
12	1.2732	1.2523	1.2318	1.2118	1.1925	1.1734	1.1549	1.1368	1.1191	1.1018
13	1.0848	1.0684	1.0523	1.0365	1.0211	1.0060	0.9913	0.9768	0.9627	0.9489
14	0.9355	0.9223	0.9093	0.8966	0.8842	0.8721	0.8601	0.8485	0.8370	0.8258
15	0.8149	0.8041	0.7936	0.7832	0.7731	0.7631	0.7534	0.7438	0.7344	0.7252
16	0.7162	0.7073	0.6986	0.6901	0.6817	0.6734	0.6654	0.6574	0.6496	0.6419
17	0.6344	0.6270	0.6197	0.6126	0.6056	0.5987	0.5919	0.5852	0.5787	0.5722
18	0.5659	0.5597	0.5535	0.5475	0.5415	0.5357	0.5300	0.5243	0.5188	0.5133
19	0.5079	0.5026	0.4974	0.4922	0.4872	0.4822	0.4773	0.4724	0.4677	0.4630
20	0.4584	0.4538	0.4493	0.4449	0.4406	0.4363	0.4321	0.4279	0.4238	0.4197
21	0.4157	0.4118	0.4079	0.4041	0.4004	0.3966	0.3930	0.3894	0.3858	0.3823
22	0.3788	0.3754	0.3720	0.3687	0.3654	0.3622	0.3590	0.3558	0.3527	0.3496
23	0.3466	0.3436	0.3406	0.3377	0.3348	0.3320	0.3292	0.3264	0.3237	0.3210
24	0.3183	0.3157	0.3131	0.3105	0.3080	0.3054	0.3030	0.3005	0.2981	0.2957
25	0.2934	0.2910	0.2887	0.2864	0.2842	0.2820	0.2798	0.2776	0.2754	0.2733

D. The "tree circle" factor for a 20-BAF prism is 1.944:

$$\frac{23.3}{12} = 1.94$$

E. In like manner, by knowing the BAF of the prism and its diopter power, we can calculate the multiplying factor for dbh to convert to feet for the borderline distance (Hovind and Rieck, 1961).

III. Tables 7 through 10 give the borderline distances by tenth-inch dbh classes for 5-, 10-, 20-, and 37.5-BAF prisms. Actually, by chaining to each tree and measuring its diameter, we can perform point sampling without a prism.

EXERCISE NO. 4

PRISM VERSUS "LIMITING DISTANCE" POINT-SAMPLING

Since many factors involved in using a prism make point sampling less accurate than it theoretically could be, it is wise to recognize just how these errors influence the accuracy of the sample at a point.

Using the tables of limiting distances, return to the 5-, 10-, and 20-BAF point-samples in Exercise No. 2.

Calculate the percent error in per-acre board foot volume made while using the prism instead of chaining to each tree to determine if it was "in" or "out."

Note: The crew whose results are shown in Figure 5, added 2 trees to its 5-BAF sample when it employed the "Limiting Distance" table. This increased its per acre acre board foot estimate to 28,269.35 bd. ft. per acre.

TABLE 7. LIMITING DISTANCES FOR 5 FACTOR PRISMS—HORIZONTAL

DBH	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
					FEET					
5	19.44	19.83	20.22	20.61	21.00	21.39	21.78	22.17	22.56	22.95
6	23.33	23.72	24.11	24.50	24.89	25.28	25.67	26.06	26.45	26.83
7	27.22	27.61	28.00	28.39	28.78	29.17	29.56	29.95	30.33	30.72
8	31.11	31.50	31.89	32.28	32.67	33.06	33.45	33.83	34.22	34.61
9	35.00	35.39	35.78	36.17	36.56	36.95	37.33	37.72	38.11	38.50
10	38.89	39.28	39.67	40.06	40.45	40.83	41.22	41.61	42.00	42.39
11	42.78	43.17	43.56	43.95	44.33	44.72	45.11	45.50	45.89	46.28
12	46.67	47.06	47.45	47.83	48.22	48.61	49.00	49.39	49.78	50.17
13	50.56	50.95	51.33	51.72	52.11	52.50	52.89	53.28	53.67	54.06
14	54.45	54.83	55.22	55.61	56.00	56.39	56.78	57.17	57.56	57.95
15	58.34	58.72	59.11	59.50	59.89	60.28	60.67	61.06	61.45	61.84
16	62.22	62.61	63.00	63.39	63.78	64.17	64.56	64.95	65.35	65.72
17	66.11	66.50	66.89	67.28	67.67	68.06	68.45	68.84	69.22	69.61
18	70.00	70.39	70.78	71.17	71.56	71.95	72.34	72.72	73.11	73.50
19	73.89	74.28	74.67	75.06	75.45	75.84	76.22	76.61	77.00	77.39
20	77.78	78.17	78.56	78.95	79.34	79.72	80.11	80.50	80.89	81.28
21	81.67	82.06	82.45	82.84	83.22	83.61	84.00	84.39	84.78	85.17
22	85.56	85.95	86.34	86.72	87.11	87.50	87.89	88.28	88.67	89.06
23	89.45	89.84	90.22	90.61	91.00	91.39	91.78	92.17	92.56	92.94
24	93.34	93.72	94.11	94.50	94.89	95.28	95.67	96.06	96.45	96.84
25	97.22	97.61	98.00	98.39	98.78	99.17	99.56	99.95	100.34	100.73
26	101.11	101.50	101.89	102.28	102.67	103.06	103.45	103.84	104.23	104.61
27	105.00	105.39	105.78	106.17	106.56	106.95	107.34	107.73	108.11	108.50
28	108.89	109.28	109.67	110.06	110.45	110.84	111.23	111.61	112.00	112.39
29	112.78	113.17	113.56	113.95	114.34	114.73	115.11	115.50	115.89	116.28
30	116.67	117.06	117.45	117.84	118.23	118.61	119.00	119.39	119.78	120.17

TABLE 8. LIMITING DISTANCES FOR 10 FACTOR PRISM—HORIZONTAL

DBH	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
					FEET					
5	13.75	14.02	14.30	14.57	14.85	15.12	15.40	15.67	15.95	16.22
6	16.50	16.77	17.05	17.32	17.60	17.87	18.15	18.42	18.70	18.97
7	19.25	19.52	19.80	20.07	20.35	20.62	20.90	21.17	21.45	21.72
8	22.00	22.27	22.55	22.82	23.10	23.37	23.65	23.92	24.20	24.47
9	24.75	25.02	25.30	25.57	25.85	26.12	26.40	26.67	26.95	27.22
10	27.50	27.77	28.05	28.32	28.60	28.87	29.15	29.42	29.70	29.97
11	30.25	30.52	30.80	31.07	31.35	31.62	31.90	32.17	32.45	32.72
12	33.00	33.27	33.55	33.82	34.10	34.37	34.65	34.92	35.20	35.47
13	35.75	36.02	36.30	36.57	36.85	37.12	37.40	37.67	37.95	38.22
14	38.50	38.77	39.05	39.32	39.60	39.87	40.15	40.42	40.70	40.97
15	41.25	41.52	41.80	42.07	42.35	42.62	42.90	43.17	43.65	43.72
16	44.00	44.27	44.55	44.82	45.10	45.37	45.65	45.92	46.20	46.47
17	46.75	47.02	47.30	47.57	47.85	48.12	48.40	48.67	48.95	49.22
18	49.50	49.77	50.05	50.32	50.60	50.87	51.15	51.42	51.70	51.97
19	52.25	52.52	52.80	53.07	53.35	53.62	53.90	54.17	54.45	54.72
20	55.00	55.27	55.55	55.82	56.10	56.37	56.65	56.92	57.20	57.47
21	57.75	58.02	58.30	58.57	58.85	59.12	59.40	59.67	59.95	60.22
22	60.50	60.77	61.05	61.32	61.60	61.87	62.15	62.42	62.70	62.97
23	63.25	63.52	63.80	64.07	64.35	64.62	64.90	65.17	65.45	65.72
24	66.00	66.27	66.55	66.82	67.10	67.37	67.65	67.92	68.20	68.47
25	68.75	69.02	69.30	69.57	69.85	70.12	70.40	70.67	70.95	71.22
26	71.50	71.77	72.05	72.32	72.60	72.87	73.15	73.42	73.70	73.97
27	74.25	74.52	74.80	75.07	75.35	75.62	75.90	76.17	76.45	76.72
28	77.00	77.27	77.55	77.82	78.10	78.37	78.65	78.92	79.20	79.47
29	79.75	80.02	80.30	80.57	80.85	81.12	81.40	81.67	81.95	82.22
30	82.50	82.77	83.05	83.32	83.60	83.87	84.15	84.42	84.70	84.97

TABLE 9. LIMITING DISTANCES FOR 20 FACTOR PRISMS—HORIZONTAL

DBH	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
					FEET					
5	9.72	9.92	10.11	10.30	10.50	10.69	10.88	11.08	11.28	11.47
6	11.66	11.86	12.06	12.25	12.44	12.64	12.83	13.03	13.22	13.42
7	13.61	13.81	14.00	14.19	14.39	14.58	14.78	14.97	15.17	15.36
8	15.56	15.75	15.94	16.14	16.33	16.53	16.72	16.91	17.11	17.31
9	17.50	17.69	17.89	18.08	18.28	18.47	18.67	18.86	19.06	19.25
10	19.44	19.64	19.83	20.03	20.22	20.42	20.61	20.81	21.00	21.19
11	21.39	21.58	21.78	21.97	22.17	22.36	22.56	22.75	22.95	23.14
12	23.34	23.53	23.72	23.92	24.11	24.31	24.50	24.70	24.89	25.08
13	25.28	25.47	25.67	25.86	26.06	26.25	26.45	26.64	26.83	27.03
14	27.22	27.42	27.61	27.81	28.00	28.20	28.39	28.58	28.78	28.97
15	29.17	29.36	29.56	29.75	29.95	30.14	30.33	30.53	30.72	30.92
16	31.11	31.31	31.50	31.70	31.89	32.08	32.28	32.47	32.67	32.86
17	33.06	33.25	33.45	33.64	33.83	34.03	34.22	34.42	34.61	34.81
18	35.00	35.20	35.39	35.58	35.78	35.97	36.17	36.36	36.56	36.75
19	36.95	37.14	37.33	37.52	37.72	37.92	38.11	38.31	38.50	38.70
20	38.89	39.08	39.28	39.47	39.67	39.86	40.06	40.25	40.45	40.64
21	40.83	41.03	41.22	41.42	41.61	41.80	42.00	42.20	42.39	42.58
22	42.78	42.97	43.17	43.36	43.56	43.75	43.95	44.14	44.33	44.53
23	44.72	44.92	45.11	45.31	45.50	45.70	45.89	46.08	46.28	46.47
24	46.67	46.86	47.06	47.28	47.45	47.64	47.83	48.03	48.22	48.42
25	48.61	48.81	49.00	49.20	49.39	49.58	49.78	49.97	50.17	50.36
26	50.56	50.75	50.95	51.14	51.33	51.53	51.72	51.92	52.11	52.31
27	52.50	52.70	52.89	53.08	53.28	53.47	53.67	53.86	54.06	54.25
28	54.45	54.64	54.83	55.03	55.22	55.42	55.61	55.81	56.00	56.20
29	56.39	56.58	56.78	56.97	57.17	57.36	57.56	57.75	57.95	58.14
30	58.34	58.53	58.72	58.92	59.11	59.31	59.50	59.70	59.89	60.09

TABLE 10. LIMITING DISTANCES FOR 37.5 FACTOR PRISMS—HORIZONTAL

DBH	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
					FEET					
5	7.13	7.26	7.39	7.52	7.66	7.79	7.92	8.12	8.25	8.38
6	8.51	8.65	8.78	8.98	9.11	9.24	9.37	9.50	9.64	9.77
7	9.97	10.10	10.23	10.36	10.49	10.63	10.82	10.96	11.09	11.22
8	11.35	11.48	11.62	11.81	11.95	12.08	12.21	12.34	12.48	12.61
9	12.80	12.94	13.07	13.20	13.33	13.46	13.66	13.79	13.93	14.06
10	14.19	14.32	14.45	14.65	14.78	14.92	15.05	15.18	15.31	15.51
11	15.64	15.77	15.91	16.04	16.17	16.30	16.50	16.63	16.76	16.90
12	17.03	17.16	17.36	17.49	17.62	17.75	17.89	18.02	18.15	18.35
13	18.48	18.61	18.74	18.88	19.01	19.14	19.34	19.47	19.60	19.73
14	19.87	20.00	20.20	20.33	20.46	20.59	20.72	20.86	20.99	21.19
15	21.32	21.45	21.58	21.71	21.85	22.04	22.18	22.31	22.44	22.57
16	22.70	22.84	23.03	23.17	23.30	23.43	23.56	23.69	23.83	24.02
17	24.16	24.29	24.42	24.55	24.68	24.88	25.01	25.15	25.28	25.41
18	25.54	25.67	25.87	26.00	26.13	26.27	26.40	26.53	26.73	26.86
19	26.99	27.13	27.26	27.39	27.52	27.72	27.85	27.98	28.12	28.25
20	28.38	28.51	28.71	28.84	28.94	29.11	29.24	29.37	29.57	29.70
21	29.83	29.96	30.10	30.23	30.36	30.56	30.69	30.82	30.95	31.09
22	31.22	31.42	31.55	31.68	31.81	31.94	32.08	32.21	32.41	32.54
23	32.67	32.80	32.93	33.07	33.20	33.40	33.53	33.66	33.79	33.92
24	34.06	34.25	34.39	34.52	34.65	34.78	34.91	35.05	35.24	35.38
25	35.51	35.64	35.77	35.90	36.10	36.23	36.37	36.50	36.63	36.76
26	36.89	37.09	37.22	37.36	37.49	37.62	37.75	37.88	38.08	38.21
27	38.35	38.48	38.61	38.74	38.94	39.07	39.20	39.34	39.47	39.60
28	39.73	39.93	40.06	40.19	40.33	40.46	40.59	40.79	40.92	41.05
29	41.18	41.32	41.45	41.58	41.78	41.91	42.04	42.17	42.31	42.44
30	42.57	42.77	42.90	43.03	43.16	43.30	43.43	43.63	43.76	43.89

SLOPE CORRECTIONS IN POINT SAMPLING

I. Sloping land complicates point-sampling just as it complicates plot-sampling. If slope is neglected the errors will be of significant magnitude when slope is more than about 10 percent.

A. A slope factor (s.f.) may be easily determined using the average slope at each point, because:

s.f. = secant of angle and slope.

B. With this factor, point-sample tree counts may be corrected by merely multiplying:

Corrected count = (tree count) (s.f.)

C. Using this method, the correction can be made for any slope situation although in some Western states cruisers have encountered a great deal of difficulty and noted some significant inaccuracies in its actual application.

D. Grosenbaugh (1955) gives correction factors for most slopes and a copy of his table is attached as Table 11. Note also the equation presented at the foot of the table.

II. Slope may also be corrected for by rotating the prism through a vertical angle equal to the angle of the slope.

A. Certain prisms are manufactured with a rounded top to facilitate use in the rotated position.

B. This is perhaps the best solution of the slope problem.

C. It has been used extensively throughout the United States satisfactorily, and in some western point sampling wherein the tree is *always* viewed at the top of the first 16 foot log, as a hedge against brush-bias, every tree is on a slope—in a manner of speaking (Bruce 1961).

TABLE 11. APPROPRIATE CORRECTION FACTORS FOR BA OR VOLUME PER ACRE CALCULATED FROM UNADJUSTED ANGLE-GAUGE TALLIES TAKEN ON A SLOPE, WHERE SLOPE PERCENT IS MEASURED AT RIGHT ANGLES TO CONTOUR.

Limits of Percent Slope	Slope Correction Factor	Limits of Percent Slope	Slope Correction Factor	Limits of Percent Slope	Slope Correction Factor
10.0		55.8		80.7	
	1.01		1.15		1.29
17.4		57.8		82.3	
	1.02		1.16		1.30
22.5		59.8		83.9	
	1.03		1.17		1.31
26.7		61.7		85.4	
	1.04		1.18		1.32
30.4		63.6		86.9	
	1.05		1.19		1.33
33.6		65.4		88.4	
	1.06		1.20		1.34
36.6		67.2		89.9	
	1.07		1.21		1.35
39.5		69.0		91.4	
	1.08		1.22		1.36
42.1		70.8		92.9	
	1.09		1.23		1.37
44.6		72.5		94.3	
	1.10		1.24		1.38
47.0		74.2		95.8	
	1.11		1.25		1.39
49.3		75.8		97.2	
	1.12		1.26		1.40
51.5		77.5		98.7	
	1.13		1.27		1.41
53.7		79.1		100.1	
	1.14		1.28		1.42
55.8		80.7		101.5	

Correction factor for steeper slopes is:

$$\sqrt{1 + \left(\frac{\text{Slope percent}}{100}\right)^2}$$

Source: Grosenbaugh, L. R. "Better Diagnosis and prescription in southern forest management." U. S. Forest Service, Southern Forest Experiment Station, Occasional Paper 145, 1955.

CONTINUOUS FOREST INVENTORY WITH POINT-SAMPLING

I. Point-sampling techniques are just as suitable for continuous forest inventory (CFI) as are plot sampling techniques.

A. Point sampling has the special advantage of taking a smaller percent sample of the many small stems in uneven-aged forests, while sampling the fewer large stems in much the same proportion as in fifth-acre plot-sampling.

B. This is illustrated as follows from the experience with CFI in the Sabine National Forest:

DBH Class	Number of Trees Tallied—110 Locations	
	1/5-Acre Plots (1957-58)	10-BAF Point Samples (1962)
9 - 8	1782	239
10 - 14	601	211
15 - 19	248	184
20 - 24	55	50
25+	2	5

II. The techniques of point-sampling, and the resulting calculation manipulations, are as easy for electronic machines as the mechanics of plot-sampling.

A. U. S. Steel in Alabama (University of Georgia, 1959) used point-sampling in its CFI plan and measured six to eight stems at each point. They measured all trees due to the small number at each location, and so have a permanent record of trees from seedling size up.

B. The Southern Forest Survey, a large-scale CFI system, now employs point sampling as its inventory technique. Samples are on a 3 x 3 mile grid. As mentioned previously, clusters of ten 37.5-BAF samples are collected at each survey location.

III. Several problems not assessed to plot-sampling present themselves when point-samples are used in continuous forest inventory.

A. First, trees grow into the sample according to their size *and* distance from the point, not just according to their size. In other words, a 20.0-inch tree 79.34 feet from the point will come into the sample when it grows to 20.4 inches dbh, if the sample is being taken with a 5-BAF prism. Since its total volume is really not ingrowth, the volume per acre and the number of stems per acre it represents, will be used for future growth determination, but will not necessarily figure in past growth calculations.

B. Second, unless dbh and distance are both remeasured, omitted or extra trees will severely affect stand and stock tabular values. In brushy areas obscured trees may be omitted completely by accident in the point sample.

C. Since a CFI sample is exceedingly small and blowups are large, extreme care must be exercised in taking the CFI point sample.

EXERCISE NO. 5

A GROWTH-PROJECTION POINT-SAMPLE

Point-sampling can be applied to growth projection studies (Fender and Brock, 1963) for future volume or basal area as well as to determine actual current volume or basal area.

To show the principle involved, in an exceedingly simplified method, return to the southern pine plantation, bore several trees to determine average projected 5-year diameter growth. Using a table of limiting distances for the new diameters, "tally" the projected stand 5 years hence. Compare this with the current stand.

Prepare suitable tally sheets and summary data to fit this application of point sampling.

Doing this exercise, the class obtained the following results:

Southern Pine Plantation—Growth Projection

(Crew Summary Sheet)

Present		Future	
Count	BA/Acre	Count	BA/Acre
8	160	9	180
9	180	10	200
9	180	13	260
9	180	10	200
6	120	8	160
Average	164	Average	200

NUMBER OF POINTS TO ACHIEVE STATED PRECISION

I. The forester, contemplating a point-sample cruise, must know how its accuracy compares with that of a conventional plot cruise he has employed for so long. He needs to know the total number of points to take on a property of given acreage to yield the precision he requires. The literature on point sampling is deficient in this respect. The authors were able to find some references to this subject, however. They are presented below. No conclusions are rendered.

   A. Bruce (1961) says that in western timber, point-sampling requires about the same number of points as 1/4- or 1/5-acre plots to achieve a stated precision of volume estimate, if the prism is properly matched to tree size in the stands sampled. This means that counts per point must average about 5 trees.

   B. Discussing Southern forests, Grosenbaugh (1955) wrote, "The reconnaissance would require a minimum of about 20 unbiased sample points well distributed throughout the record unit for a standard error of about ± 25 percent in volume per record unit. A volume total of 25 such record-units would have a standard sampling error of only about ± 5 percent for the ownership or working circle as a whole."

   C. Bell and Alexander (1957) said, "Considerable research will be necessary to determine what sampling intensity is necessary in a given stand. However, present experience shows that the same intensity as that used for one-quarter acre plots will result in a statistically better sample than given by the one-quarter acre plot method."

D. Putnam, et al. (1960), wrote, "The reconnaissance preceding the first managed cut should ordinarily be an inexpensive affair. An inspection and sight estimate (with supporting notes, as previously discussed) may suffice for experienced men, though a more formal approach will be necessary for most foresters. The point-sampling technique makes it possible to get approximate estimates of volume with very little effort. If a prism or angle gauge with a basal area factor of 10 is employed to select sample trees, 25 sample points distributed systematically over a management unit will usually give a sampling error for board-foot volume of less than 23 percent. The aggregate volume on four management units will ordinarily be estimated within twelve percent. The goal is not extreme accuracy but rather rough estimates obtained as quickly and cheaply as possible.

"If a more intensive survey is needed, the following tabulation may be used to obtain approximate and usually conservative sampling errors as a percent of the total volume.

Points (number)	Error (percent)
25	23
50	17
100	12
200	8
400	6
1600	3

"For cruises of the specified intensity, differences between sample volume and volume by 100-percent tally will be exceeded, on the average, in only one cruise in three. Five percent of the time, the difference might be twice the chosen limit, but 50 percent of the time the difference will be less than 68 percent of the tabulated error.

"This means, for example, that a cruiser choosing 12 percent as his limit of sampling error may be wrong by more than this amount on one cruise out of three. In fact, one time in twenty his actual error may be more than 24 percent, but half the time his error will be less than 8 percent. In the rare cases where a sample of low intensity might deviate from the true mean considerably, an experienced cruiser will suspect the lack of representativeness and intensify the sampling accordingly.

"Whether sample points are located systematically or at random, the area of the tract has little effect on the number of points required for a given sampling error. The important thing is the variability among the aggregate volumes sampled at various points. The tabulation is based on average variation over a large portion of an entire southern state. Errors may be larger in extremely irregular stands and smaller where stands are relatively uniform."

E. Kendall and Sayn-Wittgenstein (1959) said, ". . . The number of point samples required to give a precision equal to that from conventional 1/5-acre plots varied with the type of stand and averaged 2.8.

NUMBER OF POINT SAMPLES (N) EQUIVALENT TO 1/5 ACRE PLOT

(basal area factor = 10)

Location	Type of Stand	Stocking (trees per acre)	Diameter Range (inches)	Modal Diameter (inches)	N (by random selection)
Eagle Depot	even-aged pine	340	1-25	5	3.1
Forbes Depot	pine-spruce	760	1-14	4	2.3

"Although no detailed time study was undertaken, it is estimated that with the relascope, BA was sampled to a given precision in one-half or one-third the time required when 1/5-acre plots were used. In the tests carried out in the Forbes Depot and Eagle Depot areas in 1957, the number of trees tallied for volume calculations in the point samples numbered 1,290, whereas 12,301 were tallied in the corresponding 1/5-acre plots. This is partly due to the fact that with the relascope each tree size is sampled on a land area which is proportional to its BA. A greater proportion of large trees is therefore sampled, and the time consuming measurement of small trees is largely eliminated."

F. The lecture "Sampling Techniques" shows that for 110 double sample points the error of BA would be only about ± 3.1 percent and for 110 single points the error would be about ± 4.5 percent on a pine-hardwood area in the Sabine National Forest.

G. None of the above, of course, is applicable to your forest, but in the lecture "Basic Point-Sample Statistics," the equations to compute the number of points needed are given.

COMPARING METHODS OF PER ACRE POINT-SAMPLE VOLUME ESTIMATES AT SELECTED POINT LOCATIONS

I. The Department of Forestry, Stephen F. Austin State College, maintains 110 permanent continuous forest inventory plots on the Sabine National Forest, Texas. These were measured in 1957-58 and remeasured in 1962. At the time of the remeasurement, a point-sample using a 10-BAF prism was made in addition to the fifth acre plot-sample. As an indication of the various answers of per acre volume one would determine, using various methods and factors in computation, the following data are presented from *ten* of the 110 point samples. The authors suspect that the range of per acre volumes would be less if data from the entire array of 110 points were presented (See Tables 12 and 13).

TABLE 12. POINT SAMPLES FROM THE SABINE NATIONAL FOREST. 1962

Tree No.	Species Code	D.B.H. (inches)	Height (feet)	Tree No.	Species Code	D.B.H. (inches)	Height (feet)
(Point no. 12)				(Point no. 52)			
5	99	8.4	27.1	4	22	7.0	22.2
12	11	11.9	34.0	5	11	7.2	25.0
14	22	9.5	30.1	8	22	13.0	25.0
15	11	20.0	50.1	10	11	13.7	38.6
19	11	20.8	50.9	11	22	15.8	43.4
(Point no. 42)				14	88	15.7	43.2
3	99	11.2	32.0	18	22	11.5	32.9
8	77	15.4	42.4	21	22	8.1	26.2
24	11	6.2	18.9	24	22	9.7	20.0
(Point no. 2)				26	55	16.3	44.3
5	77	5.5	15.9	27	88	14.2	39.8
9	22	12.8	36.2	(Point no. 63)			
20	22	18.8	48.6	1	11	5.2	14.7
(Point no. 22)				11	11	7.2	23.0
6	55	5.6	16.4	12	22	17.3	46.2
15	77	8.9	28.5	18	22	17.2	46.0
24	99	7.8	25.2	24	11	7.0	22.3
33	66	10.3	32.1	41	11	8.1	26.2
34	77	15.1	41.8	49	11	4.6	14.0
(Point no. 82)				(Point no. 32)			
1	11	8.0	25.9	12	22	6.3	19.3
2	11	12.2	34.8	14	22	6.6	20.5
3	33	5.0	13.9	5	11	5.3	15.1
7	33	5.8	17.3	8	11	6.5	20.1
34	22	10.1	30.0	19	22	7.7	24.8
43	22	6.0	14.0	33	22	13.2	37.3
(Point no. 92)				36	22	11.1	31.8
1	11	11.5	32.9	37	11	8.8	28.2
3	22	21.8	51.7	(Point no. 72)			
12	11	7.0	22.3	3	22	18.2	47.7
27	11	6.8	21.3	6	11	19.1	49.0
28	11	6.3	19.3	8	22	20.1	50.2
29	11	14.2	39.8	10	11	15.7	43.2

Total sawtimber stems - 29
Total pulpwood stems - 29

TABLE 13. SUMMARY OF THE FACTORS BY POINT USED TO COMPUTE VOLUMES IN THE VARIOUS WAYS, FROM DATA IN TABLE 12.

Point	Σ Bff Sawtimber (1)	Σ bff Sawtimber (2)	Σ Logs Sawtimber (3)	Σ Bd. Ft. Sawtimber (4)	Σ Cu. Ft. Pulp Trees (5)	Σ cff Pulp Trees (6)	Σ Feet Pulp Trees (7)
2	27.9	193.0	3.5	2677.70	105.552	12.38	15.9
12	42.5	416.8	8.0	4326.71	366.048	42.96	57.1
22	10.8	131.2	2.5	1442.01	701.001	72.92	102.2
32	20.0	239.2	4.5	2395.73	893.298	95.08	128.0
42	19.1	239.2	4.5	2515.16	120.813	14.98	18.9
52	84.0	980.2	18.5	9972.11	494.318	55.34	73.4
63	30.4	308.8	6.0	3209.10	705.422	77.50	100.2
72	60.2	594.4	11.5	6299.68	0	0	0
82	17.3	216.0	4.0	1927.77	541.352	49.52	71.1
92	38.8	393.6	7.5	4100.79	450.957	47.54	62.9
10	351.0	3712.4	70.5	38866.32	4388.761	468.02	629.7

(1). Using the standard volume table type of approach:

$$\text{Vol. bd. ft. per acre} = \frac{\Sigma\ Bff}{N}(BAF)(10) = \frac{351.0}{10}(10)(10) = 3510.0$$

(2). Using the board foot factor per height class method:

$$\text{Vol. bd. ft. per acre} = \frac{\Sigma\ bff}{N}(BAF) = \frac{3712.4}{10}(10) = 3712.4$$

(3). Using the 60 factor and sum of logs method:

$$\text{Vol. bd. ft. per acre} = \frac{(\Sigma\ L)(60)(BAF)}{N} = \frac{(70.5)(60)(10)}{10} = 4320.0$$

(4). Using the stand table approach with volume for each d.b.h. class:

$$\text{Vol. bd. ft. per acre} = \frac{\Sigma[(T)(S.T.F.)(Vol)]}{N} = \frac{38,866.32}{10} = 3886.6$$

(5). Using the stand table method for cubic foot volume of pulpwood:

$$\text{Vol. cu. ft. per acre} = \frac{\Sigma[(T)(S.T.F.)(Vol)]}{N} = \frac{4388.761}{10} = 438.9$$

(6). Using the c.f.f. for each height class in pulpwood trees:

$$\text{Vol. cu. ft. per acre} = \frac{\Sigma\ cff}{N}(BAF) = \frac{468.02}{10}(10) = 468.02$$

(7). Using the cubic foot factor 0.7052 and merchantable pulp tree height in feet method:

$$\text{Vol. cu. ft. per acre} = \frac{(\Sigma\ H)(.7052)(BAF)}{10} = \frac{(629.7)(.7052)(10)}{10} = 444.06$$

For comparison: 1958 volumes of 10 fifth-acre plots at same location:

410.02 cu. ft. per acre and 4806.8 bd. ft. per acre.

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Tennessee Valley Authority Thin your pine plantation for fence posts. Norris, Tennessee. 1952.

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ABBREVIATIONS

BA	basal area
BAF	basal area factor
bff	board foot factor
Bff	modified board foot factor
C	coefficient of variation
CFI	continuous forest inventory
cff	cubic foot factor
d	distance between target and prism
D	tree diameter in inches
dbh or DBH	diameter at breast height
f	frequency
F	tree total height in 10 foot units
H	total height of tree in feet
ht.	height
L	merchantable height of trees in 16-foot logs
M	mean
N	number of points or observations
Ple.	proportional limit of error
S	sampling error of a mean in percent
Se.	combined sampling error in percent
s.f.	slope factor
S.T.F.	stand table blowup factor
T	tree count in a diameter class
V	variance
w	target width, or distance between pins
Σ	sum of
σ	standard deviation
σm	standard error of the mean

PART II

POINT-SAMPLING CRUISE

LLOYD A. BISKAMP[1]

THE PROBLEM

We need to gather information giving the current condition of Company forest acreage.

The Chief Forester of the Company is to report to the Board of Directors in January. His report will include recommendations for work on Company forest acreage during the five years immediately ahead.

The Forestry Department is charged with the responsibility of investigating Company forests. The Department must accurately collect sound information to confidently recommend specific action. We must answer the question, "What actions should be taken on the Company's forest lands during the next 5-year period?"

Roughly, we have the month of August scheduled for training and the months of September and October for field work. November and December will be spent organizing the inventory facts, and placing them in a form that can be readily understood by management.

The Company has less than 500,000 acres, broken into five blocks, in Texas and Louisiana.

The information can be provided best by a one-shot cruise. Although a cruise is an expense which, in itself, yields no return, it does provide a base for other activities which do. The method of cruising should yield information which can be depended upon, the cruise must be economically feasible, and available manpower must be taken into account.

Considering the above situation, point-sampling, using the wedge-prism, meets our requirements and remains within our limitations.

In order to benefit most from our cruise we need a standard pattern to follow, which will establish the current characteristics of the forest properties. We want to determine, by individual trees, which should be cut and which should be left, taking into account those trees which are entitled to the growing space available. We want to diagnose the situation in regard to reproduction, determine the amount of cull trees, and assess control burning needs.

Thus, we want accurate volume figures, a basic diagnosis of the properties, and a prescription for Company lands. Our prescriptions should be guided to management for the next five years.

Points will be located on the block maps with the use of a 70.7 by 70.7 chain grid overlay. This divides the properties into 500-acre squares.

The Company has five blocks of land and five foresters available to carry out the field work. Five crews, consisting of a forester and a field assistant, will be employed. Each two-man crew is assigned specific points to visit. It is anticipated that all field work can be completed by early November if the crews spend two to three days each week in the field.

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[1]International Petroleum Company, Limited.

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S.T.F.	stand table blowup factor
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V	variance
w	target width, or distance between pins
Σ	sum of
σ	standard deviation
σm	standard error of the mean

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The information can be provided best by a one-shot cruise. Although a cruise is an expense which, in itself, yields no return, it does provide a base for other activities which do. The method of cruising should yield information which can be depended upon, the cruise must be economically feasible, and available manpower must be taken into account.

Considering the above situation, point-sampling, using the wedge-prism, meets our requirements and remains within our limitations.

In order to benefit most from our cruise we need a standard pattern to follow, which will establish the current characteristics of the forest properties. We want to determine, by individual trees, which should be cut and which should be left, taking into account those trees which are entitled to the growing space available. We want to diagnose the situation in regard to reproduction, determine the amount of cull trees, and assess control burning needs.

Thus, we want accurate volume figures, a basic diagnosis of the properties, and a prescription for Company lands. Our prescriptions should be guided to management for the next five years.

Points will be located on the block maps with the use of a 70.7 by 70.7 chain grid overlay. This divides the properties into 500-acre squares.

The Company has five blocks of land and five foresters available to carry out the field work. Five crews, consisting of a forester and a field assistant, will be employed. Each two-man crew is assigned specific points to visit. It is anticipated that all field work can be completed by early November if the crews spend two to three days each week in the field.

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[1]International Petroleum Company, Limited.

POINT-SAMPLING

Through the efforts of a handful of foresters, variable radius sample plots (point-sampling) are now accepted for selecting sample trees for forest inventory and management. This is a method of obtaining information about forest lands without using fixed radius plots. The method, providing an on-the-spot estimate of basal area per acre, avoids the inevitable tendency of conventional plot-sampling to disproportionately oversample small trees. In conventional plot-sampling, probability of tree selection is proportional to tree frequency. In point-sampling, the probability of tree selection is proportional to basal area.

Let's look at a fixed radius 1/10-acre plot for illustrative purposes. The forester establishes the plot center, then measures and tallies every tree within 37.2 feet of the center of the circular plot. He measures and tallies many small trees and a few large ones, producing a tally proportional to tree frequency.

Now, consider a variable radius plot. The forester goes to the location on the ground and establishes the center "point." However, he is not interested in a boundary of a plot. From the point, he measures sample trees selected with an angle-gauge, which guarantees, or nearly so, that a sample tree is within a plot that has a radius determined by the particular tree's dbh. The instrument selects trees by sampling with probability proportional to size. That is, the bigger the tree, the larger the sampling plot in which it lies. A small tree is measured on a small plot; a large tree is measured on a large plot—the larger the tree the larger the plot and the greater the intensity of cruise. In effect, the point that the forester is standing upon is the center of an infinite number of circles or plots of variable radius.

ANGLE-GAUGE

In point-sampling, an angle-gauge optically measures a known angle. The instrument places the vertex of the angle at the eye of the person using the gauge.

In constructing an angle-gauge, obtain a stick 33 inches long, a small piece of metal with a small hole drilled in it, and a piece of metal exactly 1" square. Attach the piece of metal with a hole in it to one end of the stick so that the hole becomes a peepsight, allowing one to look down the length of the stick. Next, attach the 1" wide metal to the other end of the stick, making sure that the sides of the square are perpendicular to the long axis of the stick (Fig. 1).

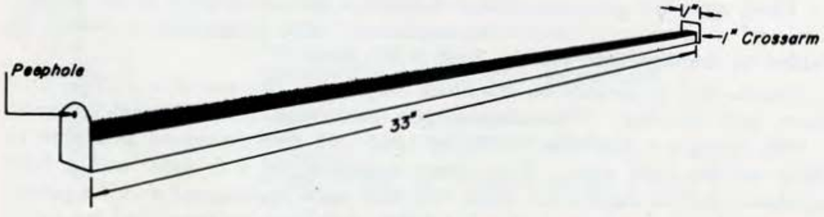

Figure 1. A sketch of the angle-gauge.

Now, hold the stick up, look through the peephole, and 33" away you should see the 1 inch wide metal crossarm.

What kind of an angle does it gauge? Thus far, we know the stick is 33" long and the crossarm is 1" wide. By looking through the peephole we can gauge the same angle each time by using the 1" crossarm as bounds of the angle.

A mensuration formula is used to determine the size angle we are dealing with (Fig. 2):

$$\text{Sin } 1/2\, \Theta = \frac{\text{Length of chord subtending angle } \Theta}{2 \times \text{Radius}}$$

In our case, the radius is 33" and the chord is 1". What is the angle Θ?

$$\text{Sin } 1/2\, \Theta = \frac{1}{2 \times 33}$$
$$= \frac{1}{66}$$
$$= .015151515$$

By transposing the 1/2:

$$\text{Sin } \Theta = 2 \times .1515$$
$$= .0303$$

Referring to a table of natural functions of angles, find the angle having a Sin of .0303:

.0303 = Sin 104.18 minutes, or Sin 1 degree and 44.18 minutes.

We have constructed an angle-gauge that defines an angle of 104.18 minutes. In point-sampling, the 104.18 minute angle is called the "critical angle." In this example .0303 is referred to as the "crossarm length factor."

This particular angle has proven adaptable to point-sampling, or variable radius plot cruising.

BASAL AREA OF A TREE

The basal area of a tree is defined as the area, in square feet, of a cross-section of the stem at a point 4½ feet above the ground, or at breast height.

The basal area for a 10" dbh tree would be determined as follows:

Basal area = area of a circle = $\pi \times r^2$

Diameter = 10" = .8333'

Radius = $\frac{.8333'}{2}$ = .4167'

$\pi = 3.1416$

Basal area = $3.1416 \times .4167^2$

Basal area = $3.1416 \times .1736$

Basal area = .5454 sq. ft.

The basal area of a 12" dbh tree would be as follows:

Diameter = 12" = 1'

Radius = 0.5'

Basal area = 3.1416×5^2

Basal area = $3.1416 \times .25$

Basal area = .7854 sq. ft.

PLOT RADIUS

We learned earlier that an angle of 104.18 minutes involves a ratio of 1" of cross-sectional width for each 33" of length along the axis of the angle. Using the above ratio, at a point 330" from the vertex of the angle, the cross-section measures 10" wide.

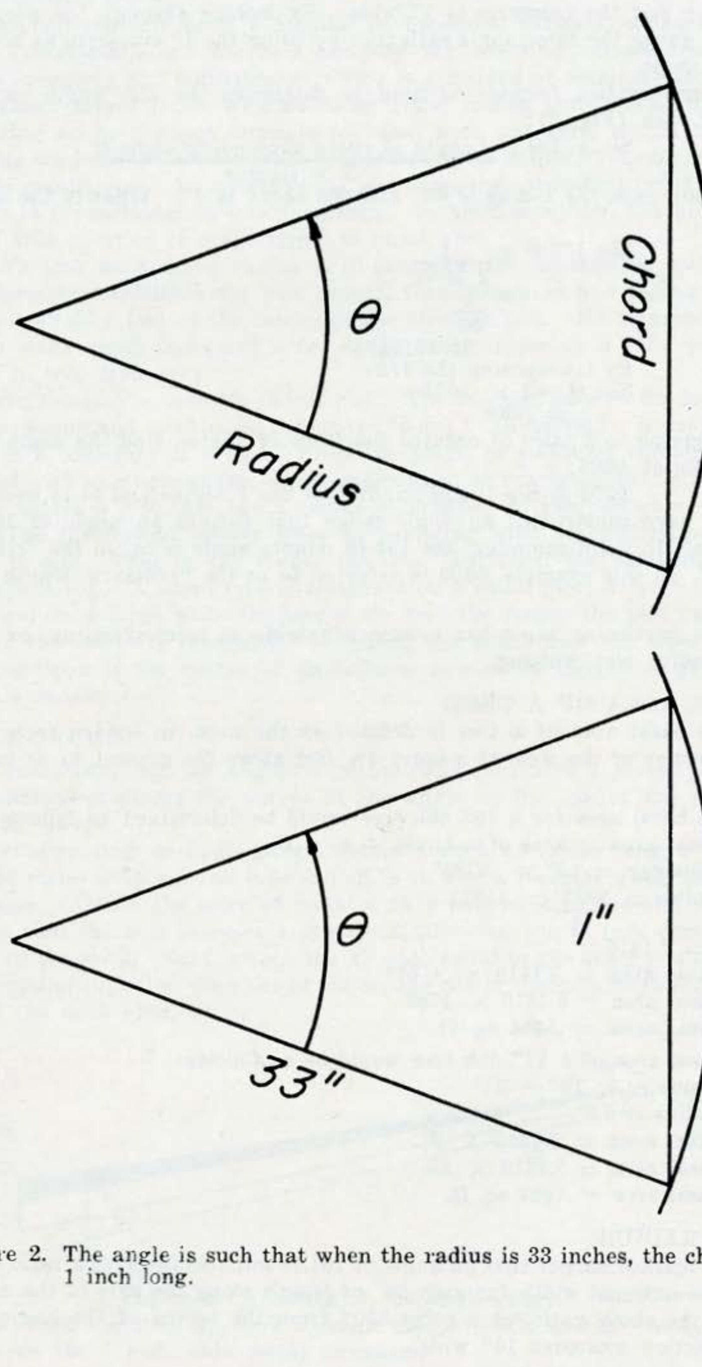

Figure 2. The angle is such that when the radius is 33 inches, the chord is 1 inch long.

In forestry, we use feet, rather than inches, when considering the radius of a plot and inches, rather than feet, when dealing with tree diameter.

From this point on, use tree dbh rather than cross-section widths of our critical angle and refer to the distance along the angle as the "plot radius." A 12" cross-section width amounts to a 12" dbh tree. A point 33 feet from the vertex of the angle is the plot radius.

To convert from inches to feet, divide the 33' of plot radius by 12" to obtain a "plot radius factor" in feet per inch of tree diameter.

$$\frac{33'}{12''} = 2.75' \text{ per inch of tree diameter}$$

Thus, for each 1" of tree dbh we have 2.75' of plot radius.

A 10" dbh tree has a plot radius of 10 × 2.75' = 27.5'.

A 12" dbh tree has a plot radius of 12 × 2.75' = 33'.

To look at things a different way, what dbh size tree has a plot radius of 38.5'? (Fig.3)

$$\text{Tree dbh size} = \frac{38.5'}{2.75'} = 14''.$$

Finally, it should not be confusing to state that the 104.18-minute angle-gauge tallies all trees closer to the sampling point than 33 times tree dbh.

FIELD MEASUREMENT OF PLOT RADIUS (with ½ dbh deduction)

We can define plot radius as being the distance from a sample point to the HEART of a sample tree.

As an example, a 10" dbh sample tree with a plot radius factor of 2.75' falls on a sampling plot with a radius of 27.5'. This 27.5' measurement is the distance from the sampling point to the HEART of the 10" dbh tree.

With a tape, we can measure the distance from the sampling point to the estimated heart of the sample tree. This is done by holding one end of the tape at the sampling point, and stretching the tape past the side of the sample tree, guessing where the middle of the tree is, and taking a reading.

Another method of measuring the plot radius is to measure the distance from the sampling point to the near side of the sample tree. This method requires a deduction of ½ dbh from the maximum allowable distance for each size sample tree.

For instance, a 10" dbh tree can be up to 27.08' from the sampling point and be included as a sample tree. This 27.08 figure is derived as follows:

A 10" dbh tree = .8333' dbh tree

½ of .8333' = .4166' which is ½ of dbh

10 × 2.75' = plot radius to heart of tree = 27.5'.

27.5' minus .4166' = 27.08' = Plot radius from sampling point to near side of tree at dbh.

If a 10" dbh tree falls at a distance of 27.08', as measured from the near side of the tree to the sampling point, the plot radius would actually be 27.5' to the heart of the sample tree.

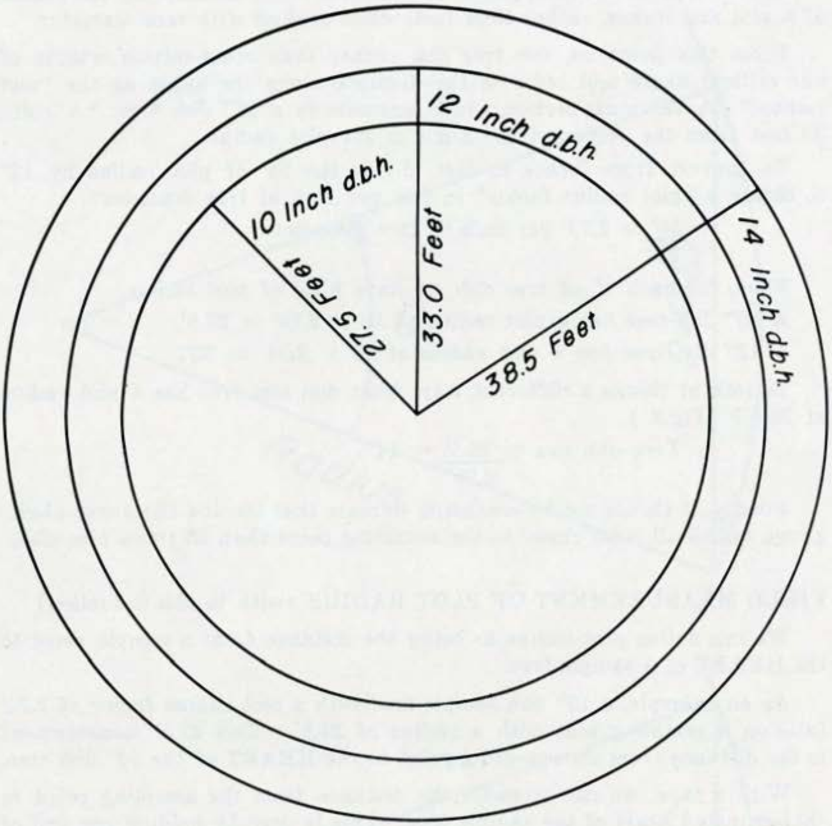

Figure 3. For each one inch of tree dbh, there is 2.75 feet of plot radius.

CORRECTING FOR SLOPE

In cruising timber, volumes and other data are on a per acre basis—a level acre. In rolling or hilly terrain, some consideration should be given to slope. Failure to correct for slope can cause serious errors.

"Slope" can be defined as the difference in elevation of two points in a horizontal distance of 100'. For our purpose, the answer obtained is considered to be a percentage figure.

Example 1

If there is a 2-foot drop in elevation in 100 horizontal feet, the slope is 2%.

Example 2

If there is a 10 foot rise in 100 horizontal feet, the slope would be 10%

Slope percent is not in degrees. A 1% slope equals an angle from the horizontal of 34.4 minutes. A 10% slope is 5 degrees and 42.6 minutes.

We have previously established a plot radius factor of 2.75 feet for level ground. Let's see what our plot radius factor will be for 20% slope and at the same time try to picture why our plot radius factor is different.

First, recall that for a right triangle the square of the two short sides equals the square of the longest side. (Figure 4)

$$C^2 = A^2 + B^2$$

Now, with a 20% slope, we have this right triangle relationship:

$$C^2 = (20)^2 + (100)^2$$

To maintain the same ratio of slope to horizontal with factors as with distance, since our plot radius factor on level ground is 2.75, we can substitute this for the 100, and find our factor substitute for the 20. Then C will be our plot radius factor for the 20% slope.

$$\frac{20}{100} = \frac{A}{2.75}$$

$$A = \frac{2.75 \times 20}{100}$$

$$= \frac{55}{100}$$

$$= .55$$

$$\text{Therefore: } C^2 = (.55)^2 + (2.75)^2$$

$$= .3025 + 7.5625$$

$$= 7.8650$$

$$C = 2.80$$

On a 20% slope the plot radius factor is 2.80'. A 20" dbh tree has a plot radius, on a 20% slope, of 20 × 2.80, or 56.0'.

A table giving plot radius factors for the various slopes is in the appendix.

When measuring plot radius on doubtful sample trees, the lead end of the tape is held at dbh on the near side of the sample tree. If the tape can be held horizontal there is no need to determine slope.

When establishing slope from the sampling point to a sample tree, the following procedure will be used:

> The field assistant gives the Haga to the forester, who picks out a position on his field assistant that is level with the forester's eyes. The field assistant stands by the sample tree. The forester, remaining at the sampling point, shoots the slope from his eye to his eye-level on the field assistant, and then reads the percentage scale on the instrument. He then applies the proper plot radius factor.

PLOT SIZE

We have already established the fact that a 10" dbh tree is tallied and measured on a plot that has a radius of 27.5'.

The area of the plot that a 10" dbh tree is tallied upon can be calculated by using the formula for the area of a circle.

Area of a circle $= \pi \times r^2$

$\pi = 3.1416$

$r = 27.5$ feet

Plot area $= 3.1416 \times (27.5)^2$

Plot area $= 3.1416 \times 756.25$ sq. ft.

Plot area $= 2375.835$ sq. ft.

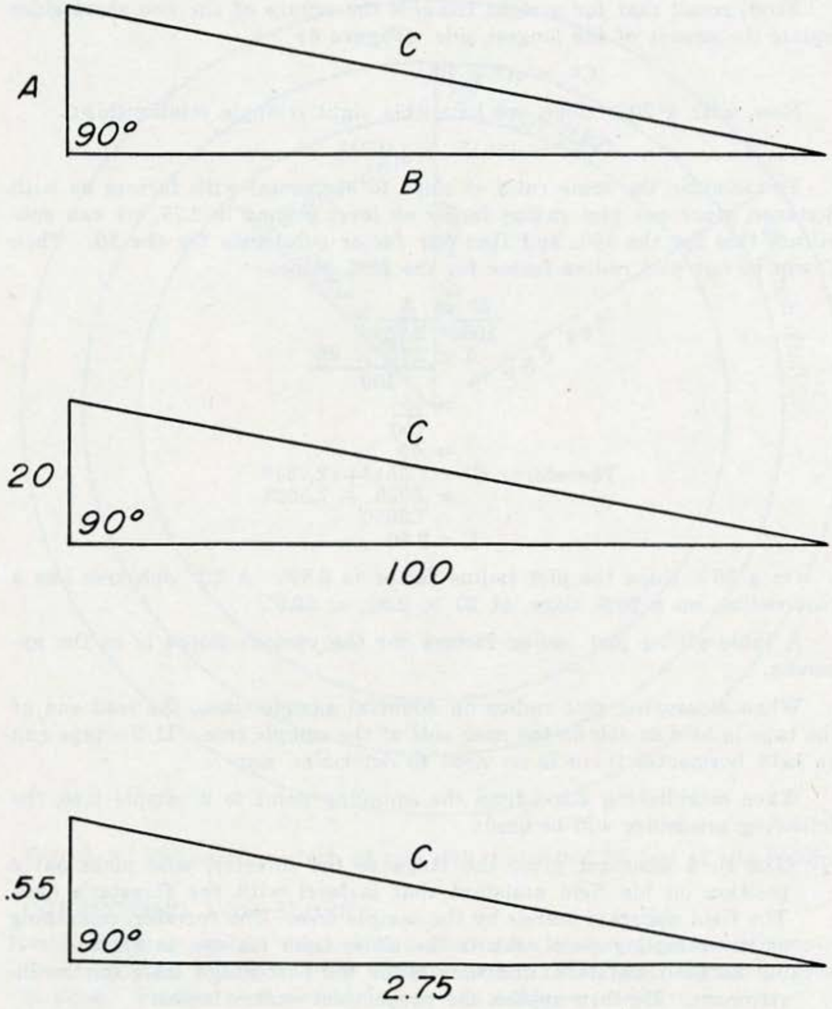

Figure 4. The square of the length of the hypotenuse is equal to the sum of the squares of the lengths of the other two sides.

To change square feet to acres, divide by 43,560, the number of sq. ft. in one acre.

$$\text{Plot area in acres} = \frac{2375.835 \text{ sq. ft.}}{43{,}560 \text{ sq. ft.}}$$
$$= .05454 \text{ acres}$$

Incidentally, a 10" dbh tree has a basal area of .5454 sq. ft.

Thus, the plot area of a tree, in acres, is exactly 1/10 of the basal area for the same tree, for example:

A 10" dbh tree has a basal area of .5454 sq. ft. and is included in a plot that is $.5454 \times 1/10 = .05454$ acres.

A 12" dbh tree has a basal area of .7854 sq. ft. and is included in a plot that is $.7854 \times 1/10 = .07854$ acres.

This calculation works because we are using a critical angle of 104.18 minutes. The plot area, in square feet, is $(66)^2$ times the basal area of the tree, in square feet.

The basal area of a 10" dbh tree is .5454 sq. ft.

$$\begin{aligned}\text{Plot area in sq. ft.} &= .5454 \times (66)^2 \\ &= .5454 \times 4356 \\ &= 2375.762 \\ \text{Plot area in acres} &= \frac{2375.762 \text{ sq. ft.}}{43{,}560 \text{ sq. ft.}} \\ &= .05454\end{aligned}$$

Perhaps you noticed that we multiplied tree basal area by $(66)^2$, or 4356, and then divided by 43,560. By elimination:

$$\begin{aligned}\text{Plot area in acres} &= \frac{.5454 \times (66)^2}{43{,}560} \\ &= \frac{.5454 \times 4356}{43{,}560} \\ &= \frac{.5454}{10} \\ &= .05454\end{aligned}$$

Trees on Company forest lands average slightly larger than 12" dbh. Average plot size will be slightly larger than

$$.7854 \times 1/10 = .07854 \text{ acres.}$$

We will assume that most of our measurements and tallies will be made on trees that fall on plots of .08 acres, or between 1/12 and 1/13 acre.

BASAL AREA FACTOR

An angle-gauge with a critical angle of 104.18 minutes has a basal area factor of 10. To see why, let's go back to the 10" dbh tree, which has a basal area of .5454 sq. ft. The 10" dbh tree is tallied on a plot that is .05454 acres in size. This gives us the relationship of having .5454 sq. ft. of basal area on .05454 acres.

If we want to know the basal area on a per acre basis, we must determine how many plots of .05454 acres fit into one acre.

$$\begin{aligned}.05454 \times (?) &= 1 \text{ acre} \\ .05454 \times 18.34 &= 1 \text{ acre}\end{aligned}$$

The number of .05454-acre plots in one acre is therefore 18.34.

Thus, we can multiply the plot size by 18.34 and arrive at one acre. Similarly, we can multiply the sq. ft. of basal area by 18.34 and determine basal area on a per acre basis.

$$\begin{aligned}\text{Basal area per acre} &= .5454 \text{ sq. ft.} \times 18.34 \\ &= 10 \text{ sq. ft.}\end{aligned}$$

Let's look at a 12" dbh tree. Its basal area is .7854 sq. ft. It is tallied on a .07854-acre plot.

$$\begin{aligned}.07854 \text{ acres} \times (?) &= \text{one acre} \\ .07854 \text{ acres} \times 12.73 &= \text{one acre}\end{aligned}$$

Point-sampling requires common sense and care. Doubtful trees must be checked using tree dbh and the plot radius factor. Make sure that all qualified trees are tallied.

CALIBRATING THE WEDGE PRISM

Although our prisms are precision-made, we can check the basal area factor very easily. First, find a level area. Next, set up a target at eye-level height. The target should be exactly one foot wide. Then lay a tape along the ground on a line bisecting, and perpendicular to, the target. A jacob staff is placed vertically at a point 33' from the target, and from this you should be able to align one side of the target seen through the prism with the other side of the target seen over the prism. The prism can be moved toward or away from the target 1" and still be considered to have a basal area factor of 10.

After the prism has been moved to a position where the target is exactly deviated, mark the exact position with the jacob staff. Record the distance measured from the staff to the target.

This procedure should be repeated at least 10 times and the average distance should be used.

After the average distance is determined, the basal area factor may be found from the following tabulation:

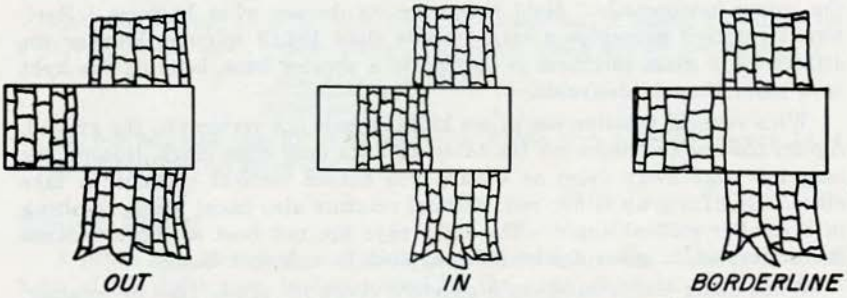

Figure 5. Observe the tree at dbh both through and over the prism.

LIMITS OF DISTANCE (feet)	BASAL AREA FACTOR
33.42-33.25	9.8
33.26-33.08	9.9
33.09-32.91	10.0
32.92-32.75	10.1
32.76-32.59	10.2

The formula below can be used to calibrate a prism. The distance from the target to the prism is X.

$$\text{Basal area Factor (Sq. Ft. per acre)} = \frac{43{,}560}{1 \text{ plus } 4X^2}$$

This equation is used when the distance from the target to the prism is measured in feet and the width of the target is one foot.

A close approximation of the basal area factor of a prism can be made employing the following formula:

$$\text{Basal Area Factor (approximate)} = \frac{10890}{(X)^2} \quad \text{(X is in feet).}$$

This formula is a short cut devised as follows:

In the original formula, $BAF = \dfrac{43{,}560}{1 \text{ plus } 4X^2}$; the 1 in the denominator is eliminated, giving

$$BAF = \frac{43{,}560}{4X^2} = \frac{43{,}560}{4} \times \frac{1}{X^2} = 10{,}890 \times \frac{1}{X^2} = \frac{10{,}890}{X^2}$$

In our case, $X = 33.0$ feet

$$BAF = \frac{10{,}890}{(33)^2} = \frac{10{,}890}{1089} = 10$$

VOLUME AND FREQUENCY

The volume for all sawtimber will be based on Mesavage and Girard's "Tables for Estimating Board-Foot Volume of Timber." The Doyle Rule is used. The volume for all pulpwood trees is based on "Form Class Volume Tables for Use in Southern Pine Pulpwood Timber Estimating," by Charles O. Minor.

We have already established the frequency of a 10" dbh tree as 18.34 trees per acre for each 10" dbh tree selected as a sample tree. With reference to Mesavage and Girard's Form Class 77 Table for the Doyle Rule, a 10" dbh one-log tree has a volume of 14 bd. ft.

The volume represented by each 10" dbh, one-log, sample tree on a per acre basis = (Volume of one tree) × (Frequency)

= 14 bd. ft. × 18.34
= 256.76 bd. ft.

Each 10" dbh one-log sample tree tallied at a point represents 256.76 bd. ft. per acre, Doyle Rule, Form Class 77.

VOLUME-BASAL AREA RATIO

The volume-basal area ratio is a convenient method of obtaining the volume that each selected sample tree contributes on a per acre basis.

The volume represented by each sample tree on a per acre basis $= \dfrac{\text{Volume of the tree in bd. ft.}}{\text{Basal area of tree in sq. ft.}} \times$ basal area factor

Mesavage & Girard Volume for 10" dbh, one-log, FC 77, Doyle Rule = 14 bd. ft.

Basal area of a 10" dbh tree = .5454 sq. ft.

Basal area factor = 10

The volume represented by each 10" dbh, one-log, FC 77, Doyle Rule, sample tree on a per acre basis $= \dfrac{\text{14 bd. ft.}}{\text{.5454 sq. ft.}} \times 10$

= 25.669 bd. ft. × 10
= 256.69 bd. ft.[1]

[1]This figure and the figure 256.76 in the example under the previous heading differ due to rounding of digits.

Volume tables for this cruise have been developed using the volume-basal area ratio. All figures have been rounded off to the nearest whole number of board feet. In the case of cord volume for pulpwood, values have been carried out to the hundredth, or two decimal places of a cord of pulpwood.

HOW MANY POINTS TO VISIT?

It is very practical to determine, in advance, the number of points to sample. The location of sample points using systematic grid squares gives more accurate estimates of error than in the discussion that follows. These formulas are for random samples. At present, there is no formula available for estimating the error where systematic sampling is employed.

To begin with, the Company has no valid local coefficient of variation on forest acreage. The "coefficient of variation" is a measure, in percentage form, of the amount of dispersion of volume per acre in relation to the average volume per acre. When using an angle-gauge of 104.18 minutes in point-sampling and working with an infinite number of unstratified points, a random coefficient of variation of 50% is considered valid. We want our information to be accurate enough for the Chief Forester to be able to make sound recommendations to the Board of Directors. If our volume is within 5% of the true situation 19 times out of 20, our needs should be satisfied.

If we use a coefficient of variation of 50% in the following calculations, our volume should be within the desired limits 2 times out of 3. However, by doubling our coefficient of variation and using 100%, our sample volume should lie between the desired limits of error 19 times out of 20.

$$\text{Number of samples or points, to be taken} = \frac{(\text{Coefficient of variation in } \%)^2}{(\text{Specified limit of error in } \%)^2}$$

Coefficient of variation = 100%
Limit of error = 5%

$$\text{No. of points} = \frac{(100)^2}{(5)^2} = \frac{10{,}000}{25} = 400$$

From this, 400 sampling points are needed to place our volume within plus or minus 5% of the true volume 19 times out of 20.

If a property were 350,000 acres, and one point per 500 acre block were used, we would have $\frac{350{,}000}{500} = 700$ points to cruise. What accuracy would this give us? Instead of saying our accuracy is going to be 5%, we will call our accuracy "X."

The equation was:

$$400 = \frac{(100)^2}{(5)^2}$$

Now let's substitute 700 for the 400, and X for the 5.

$$700 = \frac{(100)^2}{(X)^2}$$

$$X^2 = \frac{10{,}000}{700}$$

$$X^2 = 14.29$$

$$X = 3.8\%$$

Our cruise volume should be within 3.8% of the true volume 19 times out of 20, which is better than our 5% tentative goal.

INTENSITY OF CRUISE

Various writers believe that the overall intensity of a point-sample cruise cannot be determined. However, the sampling intensity of any specific dbh tree class can be determined. As shown earlier, trees on Company land probably tend to be slightly larger than 12 inches dbh, giving us a plot of about .08 acres on the average.

Total acres, assummed	= 350,000
Plot size	= .08 acres
No. of plots, assumed	= 700
Acres actually inventoried or sampled	= Plot size × No. of points (plots)
	= .08 × 700
	= 56.00 acres
Percentage of Cruise	$= \frac{\text{Acres in sample}}{\text{Total acres}}$
	$= \frac{56{,}000}{350{,}000}$
	= .000160
	= .0160% (about 1/60 of 1%)

CREWS AND FIELD WORK SCHEDULE

Each of the five two-man crews consists of a forester and a field assistant. Each forester is responsible for meeting the scheduled requirements by submitting the specified number of point tallies each Friday to the headquarters office. Headquarters keeps track of our progress as we proceed through the schedule.

SAMPLE SCHEDULE FIRST FIVE WEEKS—NUMBER POINTS

Week of:	Crew 1	Crew 2	Crew 3	Crew 4	Crew 5
Aug. 29-Sept. 2		12	12	12	12
Sept. 6-9		10	10	10	10
Sept. 12-16		12	12	12	12
Sept. 19-23		12	12	12	12
Sept. 26-30	12	12	12	12	12

SAMPLING POINT DISTRIBUTION

Company lands are to have sample point at each intersection of a 70.7-chain grid. This particular size grid gives a weight of 500 acres to each sample point. Each intersection falling in a permanent opening is omitted. Only those locations falling in forest acreage are retained. Therefore, the ratio of forested acres per point varies for different blocks.

Block	Actual Acres per Point
A	411
B	470
C	470
D	519
E	521

TOOLS AND EQUIPMENT

The following tools and equipment are needed by each crew:

Equipment	Cost
One Haga Altimeter	$40.50
One Tip Top Wyteface Diameter Tape	4.30
One Lufkin 20' Diameter Tape, with Hook	6.95
One Hand Compass graduated in azimuths	13.95
One Range Pole	7.00
One Wedge Prism with Basal Area Factor of 10	5.95
One 100' Steel Tape graduated in tenths	13.75
One Note Book	1.50
One 4' stick with Red Flag	.35
One 4½' dbh and Brush Stick	.30
One 30' Cord with Chain Arrow on each end	2.40
Two Dozen Yellow Paintstiks, with one Holder	4.40
One Bark Gauge	20.00
One field Bag for Note Book and Tools	2.75
Three Dozen Eagle Mirado #2½ Pencils	2.03
Control Map	1.50
Tally Sheets	3.65
Scratch Pad	.50
Paper Clips	.15
Ladder, 16 ft. metal	36.94
	$168.87

CONTROL MAPS

Two complete sets of control maps are available, with points dotted, circled and numbered. Each crew has an area map with all points shown that fall within crew responsibility.

Each forester should color in the circle around a sampling point after completing its field measurements.

One set of control maps is retained at headquarters.

LOCATING POINTS

Written descriptions are provided for locating each point in the field.

Courses are set with a hand compass graduated in azimuths. Distances to sampling points are paced. At least once a week a measured distance should be paced to check accuracy. Sample points SHOULD NEVER be moved. All points are either *in* forest acreage or they are *not in* forest acreage.

When a point is located in a permanent opening (any area that is not forest acreage) the Tally Sheet is briefed in and a note is written across the face explaining the land use of the point location. The Tally Sheet must be turned in to account for the point. All points are supposedly situated in forest acreage. Examples of permanent openings are firelanes, roads, improved pastures, agricultural fields, pipelines and tenant house leases; as such they are not available to grow timber during the next five years.

TREE NUMBER

Upon arrival at the sampling point, the forester sticks his range pole at the point. The field assistant plants the 4 ft. stick with the red flag on it in the ground about 50 feet north of the point.

Beginning at the red flag, the forester (standing at the sampling point) sweeps the point from left to right, in a clockwise direction. Except at boundary points, he makes a full 360° sweep.

At each sampling point, all trees selected with the prism will have a number assigned, whether they are of commercial size or not. As the forester picks up each tree in the sweep, the field assistant numbers the tree on the side of the stem facing the point. Tree numbers are painted with a Markall Paintstik.

Doubtful, or borderline trees, are checked by a plot radius measurement before assigning a tree number or continuing the sweep. The plot radius table provided gives distances by one inch dbh classes. In very doubtful borderline cases, take dbh to the nearest one-tenth of an inch, and calculate the exact plot radius distance.

Within each block a consecutive record is kept on exact borderline trees selected. All odd numbered borderline trees are tallied, all even numbered exact borderline trees are not tallied. The "Exact Borderline Tree Record" is maintained on the sheet provided each crew.

After numbering each tree the field assistant measures dbh and calls it to the forester.

If a selected tree is not of commercial size, the tree number, dbh and tree class are all that is recorded. A tree class of 1 or 4 (to be explained later) is assigned to each tree.

The tree number of a forked sample tree is discussed in "Forked Trees."

The 360 degree sweep returns to the place of beginning at the red flag.

At points which fall near the boundary of Company lands or next to permanent openings, the usual 360 degree sweep is not made. A partial sweep of the point can be made by using the range pole and red flag for alignment. If a 180 degree sweep is made, each selected tree has two tree numbers. Enter two trees on the tally sheet for each tree selected, duplicating every entry except tree number. If a 90 degree sector is swept, assign each selected tree four tree numbers, duplicating the other entries four times. For a 60 degree sweep, assign six tree numbers to each selected tree, duplicating the entry six times.

DIAMETER BREAST HIGH (dbh)

The diameter breast high (dbh) measurement employed in this cruise is outside the bark, as measured with a diameter tape, at a point 4½ feet above the average ground level.

A pulpwood tree must measure at least 4.6" dbh. A pine must measure 9.6" dbh or more in order to be classified as a sawlog tree. A hardwood tree must measure 11.6" dbh or more in order to be classified as a sawlog tree.

Tree diameters will be classified by inch classes, each class extending from 6 tenths through 5 tenths, inclusive: for instance, the 5-inch class is from 4.6 through 5.5 inches and the 20-inch class is from 19.6 through 20.5 inches.

The 4½' stick previously mentioned is used to establish dbh at 4½' above the average ground level.

Tree diameter (as a substitute for dbh) of swell-butted species and forked trees is measured or estimated 18" above pronounced swell or abnormal configuration. When the tree bole at breast height is deformed by turpentine chipping, tree diameter is measured just above the highest face.

FORM CLASS

Company policy includes one bark thickness in log diameter measurements. Hence, form class is defined as the ratio between the diameter, inside bark, plus one bark thickness, at a point 17 feet above average ground level and the diameter outside bark at breast height.

For example, a tree is 16.0" diameter inside bark at a point 17' above the ground, has a single bark thickness of 0.4" at this height, and a dbh of 20.5". The form class is computed as follows:

$$\text{Form Class} = \frac{16.0'' + 0.4''}{20.5''} = \frac{16.4}{20.5} = 80\%$$

In the absence of a local volume table, we measure or estimate the form class of each merchantable tree, and use Form Class Volume Tables.

In order to make accurate estimations, each crew should have several trees of known form class conveniently located and refer to them before beginning field work each day.

It is helpful to remember that one form class percentage change amounts to 3% volume change.

In determining the form class of swell-butted species and fork trees, tree diameter is measured 18" above the pronounced swell or abnormal configuration. Top measurements remain at 17' above ground level.

When the tree bole at breast height is deformed by turpentine chipping, tree diameter is measured just above the highest face. Top measurement remains at 17' above ground level. Although the chipped portion of the tree might be cull, the same top height is used for calculating the form class.

In determining form class by ocular estimate, avoid estimating diameters. It is more accurate to study the taper in the first log and then to estimate form class.

Board foot form class volume tables have been developed for classes 76 through 85. Additional form class volume tables will be made if necessary. Pulpwood form class volume tables have been developed for classes 67, 72, 77, 82, and 87. When recording form class for pulpwood trees, use one of the five classes that we presently have. (See the appendix.)

MERCHANTABLE HEIGHT OF SAWLOG TREES

Merchantable height of sawlog trees is tallied by increments of four feet.

No tree can qualify as a sawlog tree unless it has 10.6' or more of merchantable stem—that portion of a tree from stump height to a point where merchantability for saw timber is limited by branch deformity or minimum diameter.

On swell-butted trees (tupelo gum and cypress) and turpentine-chipped pine trees, stump height is where the tree will actually be cut.

Normal stump height for all pine trees is 12", and for all hardwood trees is 24".

The minimum merchantable top diameter for pine sawlogs is 7.6" outside bark, and for hardwood sawlogs is 9.6" outside bark.

Cull is deducted from the tree, and the adjusted merchantable height recorded.

The field assistant measures merchantable height with the Haga Altimeter, using distances established by using the 30-foot cord. Make sure the proper scale is exposed in the Haga. All measurements are taken twice. In the event the two sets of readings put the sample tree into two different height classes, a third set of measurements is made. On all sawlog trees, the field assistant selects the upper limit of merchantability and describes this point to the forester. Each time a shot is made with the Haga, the assistant takes the reading and calls it off to the forester. The forester keeps track of the readings on scratch paper, figures the proper height class, and makes an entry on the tally sheet. The merchantable height figure is followed by the letter "M."

Board foot volume tables have been developed through the 72-foot height class. If a sample tree has a merchantable height greater than 74.5 ft., record the actual class the tree falls within, and individual volumes will be developed later.

The board foot volume tables are developed through the 36 in. dbh class. If a sample tree has a dbh larger than 36 in., record the actual dbh class, and volumes will be computed later.

TOTAL HEIGHT OF PULPWOOD TREES

Total height of pulpwood trees is tallied in increments of 10 feet.

No tree can qualify as a pulpwood tree unless it has a dbh greater than 4.6". If a sample tree qualifies as nothing but pulpwood, any portion that is greater than 20" in diameter is considered cull and deducted from the total height before recording.

All cull is deducted from the total height, and the adjusted total height recorded.

The procedure for measuring the height of pulpwood trees is the same as that for measuring height of sawtimber trees. Height is followed by a capital letter "T," e.g. 30T. The "T" denotes pulp total height, as measured from the ground to the tip of the tree.

Cord volume tables have been developed through the 80-foot height class. If a sample tree has a total height of 85.6 or more, record the actual height class and individual volumes will be computed later. The same holds true with dbh's of 17 in., 18 in., and 19 in.

FORKED TREES

Sample trees with more than one principal stem, are handled in the following manner: If the stem below the fork meets sawlog specifications, the dbh, form class, merchantable height, tree class and market product grade are recorded for that portion of the sample tree below the fork. Each stem above the fork is recorded separately. The measured or estimated dbh, form class, height, tree class and market product grade for each separate stem are recorded individually.

If the stem below the fork is merchantable, but not of sawlog size, it is included with one stem above the fork, all measurements determined and recorded on the combined above and below portion. Other stems above the fork, as with the sawlog size tree, are handled individually.

Only the first portion of the forked tree that is tallied shows a tree number; other stems, entered in spaces below the first entry, are not numbered. This indicates that a forked tree has been selected and measured as a sample tree, with only one basal area involved in later calculations.

Some trees have a merchantable stem above the fork, with the stem below the fork being unmerchantable. In such cases, the cull portion below the fork is deducted by omitting an entry for that portion of the sample tree.

TREE CLASS

Each sample tree has one of four classifications. Deciding which classification to give a tree takes into account overcrowding, wasted space and which trees are best entitled to the growing space available. Age and vigor enter the picture. Insects and disease always call for class 2 or 4.

Code No.	Tree Class	Description of Class
1	Leave Tree	Trees definitely should be left in the stand.
2	Cut Tree	Trees should be cut. No Pine Seed Trees placed in this category unless there is a satisfactory sapling stand of pre-commercial pine in the area.
3	Leave or Cut Tree	A borderline class. In some cases, a tree could be cut without hurting the stand, but it is still healthy and vigorous and earning money. These trees may be marked in order to make the operation economically possible.
4	Cull Removal Tree	Trees are unmerchantable but should be removed for the benefit of the remaining stand.

MARKET PRODUCT GRADE

The following Market Product Grades are governed by current markets. Each merchantable sample tree is assigned one Market Product Grade. Do not upgrade trees. If there is any doubt as to whether a tree should go into a certain grade, put it in the next lower grade. Each sample tree is graded for the product which returns the most profit.

Code No.	Market Product Grade	Description of Grade
1	Pine Sawlog Tree	Includes all species of pine and cypress. Minimum dbh is 9.6", minimum log length 10.6', minimum top diameter 7.6" outside bark, and normal stump height 1'.

2	Pine Pole & Piling Tree	All species of pine and cypress. Minimum dbh is 9.6", minimum top diameter 7.6" outside bark, normal stump height 1'. A minimum length of 24' must be straight and reasonably clear of knots, limbs, and defects. No over-size trees are included.
3	Pine Pulpwood and Fence Post Tree	All species of pine and cypress. Minimum dbh is 4.6". Total height, from ground to tip of tree, recorded in increments of 10 feet (no stump height on normal trees). No portion of a tree greater than 20 in. diameter can be included as pulpwood. If a sample tree qualifies as pulpwood, only, any portion of the tree greater than 20 in. diameter is considered cull and deducted from the total height before recording total height on the Tally Sheet. All pulpwood trees 4.6 in. dbh or greater, and having a total height of less than 25.6 ft., are included in the 30 ft. height class.
4	Good Quality Soft Hardwood Log Tree	Includes all species of gum, magnolia, bay, soft elm, soft maple, red birch, cottonwood, basswood, sycamore, ash, willow, holly and hackberry. Minimum dbh is 11.6", minimum log length 10.6', minimum top diameter 9.6" outside bark, and normal stump height is 2'.
5	Good Quality Hard Hardwood Log Tree	All species of oak, hard maple, hard elm, pecan and cherry. Minimum dbh is 11.6", minimum log length 10.6', minimum top diameter 9.6" outside bark, and normal stump height is 2'.
6	Low Quality Merchantable Hardwood Log Tree	All species in codes 4 and 5 above and all other merchantable hardwood species. If a tree is included in one of the species listed in code 4 or 5, but is of low quality, it is included here. Minimum dbh is 11.6", minimum log length 10.6', minimum top diameter 9.6" outside bark, and normal stump height is 2'.
7	Soft Hardwood Pulpwood Tree	All species listed under code 4. Size specications are the same as for code 3.
8	Hard Hardwood Pulpwood Tree	All species listed under code 5. Size specications are the same as for code 3.
9	Cull Removal Tree	All trees that are unmerchantable but definitely should be removed for the benefit of the remaining stand.

CUTTING OPERATIONS

The Company is currently employing nine types of cutting operations. Eight of these operational types could be described as thinning or improvement cuts, while the ninth is clear-cutting; they are based on volume per acre available for harvest.

On the tally sheet, enter one or more recommended cutting operations for each sampling point. If no cutting operation is recommended, enter Code 10.

Code No.	Type of Cutting Recommended
1	Pine Sawlog
2	Pine Pole and Piling

3	Pine Pulpwood and Fence Post
4	Qood Quality Soft Hardwood Sawlog
5	Good Quality Hard Hardwood Sawlog
6	Low Quality Merchantable Hardwood Sawlog
7	Soft Hardwood Pulpwood
8	Hard Hardwood Pulpwood
9	Clear-cut
10	No Cutting

It is not necessary to enter volumes on the tally sheet while in the field. If volumes have not been entered on the tally sheet, recommended cutting oprations can be checked closely at a later date, after volumes have been entered on the tally sheet. A Code 9 canont be marked later, however.

CULL TREE REMOVAL

Observe the area around cull sample trees and make a decision concerning why a cull tree removal operation is recommended.

CODE NO.	CLASSIFICATION
1	Release of Reproduction
2	To Establish Reproduction
3	No cull tree removal operation recommended

PRE-COMMERCIAL PINE

At each sampling point a 1/100th acre plot is established for checking the stocking of pre-commercial pine. This size plot has a radius of 11.78 feet.

Pine is marked in two ways on each plot. The first distinguishes between planted pine and natural reproduction; if both are present, both are checked. The second classifies according to the degree of stocking on the plot and takes into consideration two size classes.

"Seedlings" are defined as being established trees, one year or older, and less than 4.5' in height. "Saplings" are defined as being trees that are 4.5' tall, or taller, and less than 4.6" dbh.

If both seedling and sapling stands are present, tally in the Mixed Classifications, two seedlings equalling one sapling.

CODE NO.	CLASSIFICATION
1	Satisfactory Seedling Stand. Five or more reasonably well-spaced and free-to-grow stems.
2	Unsatisfactory Seedling Stand. One through four present on the plot.
3	Satisfactory Sapling Stand. Three or more reasonably well-spaced and free-to-grow stems.
4	Unsatisfactory Sapling Stand. One or two saplings present.
5	Mixed Satisfactory Pre-commercial Pine. One sapling and four seedlings, reasonably well-spaced and free-to-grow. Two saplings and two or three seedlings, reasonably well-spaced and free to grow. Any combination with more than these two conditions.
6	Mixed Unsatisfactory Pre-commercial

	Pine. One sapling and one to three seedlings present. Two saplings and one seedling present.
7	No reproduction due to pine overstory.
8	No reproduction due to hardwood overstory or brush.
9	No reproduction due to other causes, or causes unknown.

ARTIFICIAL PINE REGENERATION

The degree of stocking of pre-commercial pine is determined on the 1/100th acre plot. If stocking on the 1/100th acre plot merits planting within the next five years, determine which type of regeneration would be most feasible. If planting is necessary, the type employed is based on conditions on a ¼ acre plot, with the sampling point as plot center. A ¼ acre plot has a radius of 58.9 feet.

CODE NO.	TYPE OF PLANTING OPERATION
1	Machine Planting
2	Hand Planting
3	Direct Seeding
4	No pine tree planting recommended.

PRESCRIBED BURNING

Control burning depends on conditions on a ¼ acre plot. If a burn is recommended, classify into one of the four categories listed below.

Slash or Loblolly Satisfactory Seedling Stand areas are not recommended for prescribed burning

CODE NO.	TYPE OF BURN
1	Brush Control Burn
2	Fire Hazard Reduction Burn
3	Seed Bed Preparation Burn
4	Brown Spot Needle Blight Control
5	No burn recommended.

PRE-COMMERCIAL CULL HARDWOOD SAPLINGS

A stem count of pre-commercial cull hardwood saplings is made on the 1/100 acre plot. Pre-commercial cull hardwood saplings are 4.5' tall or taller and less than 4.6" dbh. The number of stems actually counted on the 1/100 acre plot is entered on the tally sheet. If no stems are present, write a "O."

COMPLETING THE TALLY SHEET

Upon arrival at the sampling point, enter the date and sampling point number (Figures 6 and 7).

In Texas, enter the survey number and abstract number. In Louisiana enter section, township, and range.

Sweep the point and assign each selected tree a tree number. If more than 10 trees are selected with the prism, two tally sheets are needed. When two tally sheets are used, complete the top of the second sheet, and number the sheets. On the first sheet, directly below Tree No. 10, write "continued on page 2." Codes at the bottom of the tally sheet are entered on page 2, only. Clip or staple the two sheets together, with page 2 on top, before submitting to Headquarters.

Complete the data for each tree by entering dbh, form class, height and tree class. Next, place a big dot in the upper left hand corner of the rectangle for the Market Product Grade of the sample tree. The forester may enter the volume of the tree while at the sampling point if he desires. Otherwise, volumes are entered in the headquarters office. In any case, it is desirable to calculate volumes occasionally just to see what certain per acre volumes look like on the ground.

If volumes are not entered, the code for Cutting Operations can be omitted for office-entry. However, a Clear-Cut (Code 9) cannot be entered later.

Enter the Cull Tree Removal code.

TALLY SHEET

POINT-SAMPLING CRUISE

Page 1

POINT NO. 1-47

DATE 22 Aug. '60

SURVEY OR SECTION A. Calder A-56 (36-4-11)

TREE NO.	DBH	FORM CLASS	MERCH or TOTAL HEIGHT	TREE CLASS	MARKET PRODUCT GRADE 1 PINE LOGS	2 PINE POLES	3 PINE PULP	4 GOOD QUAL SOFT HWD LOGS	5 GOOD QUAL HARD HWD LOGS	6 LOW QUAL MERCH HWD LOGS	7 SOFT HWD PULP	8 HARD HWD PULP	CULL REMOVAL
1	14	80	32M	1	767								
2	18	77	24M	4									730
3	4		—	1		—							
4	9	77	50T	2			2.65						
5	15	84	40M	1		1125							
6	20	80	12M	2				495					
7	16	82	32M	1				967					
8	15	81	16M	2						546			
9	8	72	40T	1			2.09						
10	7	72	40T	1							2.02		
CLASS TOTALS	LEAVE			1		Continued On Page 2							
CLASS TOTALS	CUT			2									
CLASS TOTALS	LEAVE OR CUT			3									
CLASS TOTALS	CULL REMOVAL			4									
TOTALS													

GRAND TOTAL BD. FT. VOL. PINE______ HWD.______

GRAND TOTAL CORD VOL. PINE______ HWD.______

	CODE	
CUTTING OPERATIONS		1-8 Same as Market Product Grade; 9. Clear-Cut; 10. No Cut
CULL TREE REMOVAL		1. Release; 2. Establish; 3. No Removal
PRECOMMERCIAL PINE NAT.____ PLANT.____		1. Sat Seed; 2. Uns Seed; 3. Sat Sap; 4. Uns Sap; 5. Mix Sat; 6. Mix Uns; 7. No-Pine; 8. No-Hwd; 9. No-Unknown
PINE TREE PLANTING		1. Mach; 2. Hand; 3. Direct; 4. No Plant
PRESCRIBED BURNING		1. Brush; 2. Hazard; 3. Seed Bed; 4. Brown Spot; 5. No Burn
PRECOMMERCIAL CULL HARDWOOD SAPLINGS		Number actually counted

Figure 6. The first page of a completed two-page tally sheet.

TALLY SHEET

POINT-SAMPLING CRUISE

POINT NO. Page 2 1-47 DATE 22 Aug. '60

SURVEY OR SECTION A. Calder A-56 (36-4-11)

TREE NO.	DBH	FORM CLASS	MERCH or TOTAL HEIGHT	TREE CLASS	MARKET PRODUCT GRADE 1 PINE LOGS	2 PINE POLES	3 PINE PULP	4 GOOD QUAL SOFT HWD LOGS	5 GOOD QUAL HARD HWD LOGS	6 LOW QUAL MERCH HWD LOGS	7 SOFT HWD PULP	8 HARD HWD PULP	CULL RE-MOVAL
11	18	80	24M	1					•815				
12	16	77	32M	4									•788
13	26	78	12M	2	•541								
	17	81	32M	2	•1002								
	15	80	24M	2	•684								
14	16	84	56M	1	•1461								
CLASS TOTALS	LEAVE			1	2228	1125	2.09	967	815		2.02		
	CUT			2	2227		2.65	495		546			
	LEAVE OR CUT			3									
	CULL REMOVAL			4									1518
TOTALS					4455	1125	4.74	1462	815	546	2.02	—	1518

Example of Forked Tree (trees 13 and the two following rows)

GRAND TOTAL BD. FT. VOL. PINE 5580 HWD. 4341

GRAND TOTAL CORD VOL. PINE 4.74 HWD. 2.02

	CODE	
CUTTING OPERATIONS	1, 6	1-8 Same as Market Product Grade; 9. Clear-Cut; 10. No Cut
CULL TREE REMOVAL	1	1. Release; 2. Establish; 3. No Removal
PRECOMMERCIAL PINE NAT.____ PLANT____	1	1. Sat Seed; 2. Uns Seed; 3. Sat Sap; 4. Uns Sap; 5. Mix Sat; 6. Mix Uns; 7. No-Pine; 8. No-Hwd; 9. No-Unknown
PINE TREE PLANTING	4	1. Mach; 2. Hand; 3. Direct; 4. No Plant
PRESCRIBED BURNING	5	1. Brush; 2. Hazard; 3. Seed Bed; 4. Brown Spot; 5. No Burn
PRECOMMERCIAL CULL HARDWOOD SAPLINGS	0	Number actually counted

Figure 7. The second page of a 2-page tally sheet.

Next, establish the 1/100th acre plot. Check pre-commercial pine and cull hardwood sapling on the 1/100 acre plot.

Make a prescription for Pine Tree Planting and Prescribed Burning on a ¼ acre plot. Enter each recommended action on the tally sheet.

Use a 2.5 pencil to avoid smears.

FIELD TABLES

PLOT RADIUS BY DBH

dbh	Plot Radius	1/2 dbh	Corrected Plot Radius 0-6% Slope
(inches)	(feet)	(feet)	(feet)
5	13.75	.21	13.54
6	16.50	.25	16.25
7	19.25	.29	18.96
8	22.00	.33	21.67
9	24.75	.38	24.37
10	27.50	.42	27.08
11	30.25	.46	29.79
12	33.00	.50	32.50
13	35.75	.54	35.21
14	38.50	.58	37.92
15	41.25	.63	40.62
16	44.00	.67	43.33
17	46.75	.71	46.04
18	49.50	.75	48.75
19	52.25	.79	51.46
20	55.00	.83	54.17
21	57.75	.88	56.87
22	60.50	.92	59.58
23	63.25	.96	62.29
24	66.00	1.00	65.00
25	68.75	1.04	67.71
26	71.50	1.08	70.42
27	74.25	1.13	73.12
28	77.00	1.17	75.83
29	79.75	1.21	78.54
30	82.50	1.25	81.25
31	85.25	1.29	83.96
32	88.00	1.33	86.67
33	90.75	1.38	89.37
34	93.50	1.42	92.08
35	96.25	1.46	94.79
36	99.00	1.50	97.50

PLOT RADIUS FACTOR BY SLOPE

Slope Class Limits (%)	Plot Radius Factor (feet)
0-6	2.75
7-10	2.76
11-13	2.77
14-15	2.78
16-18	2.79
19-20	2.80
21	2.81
22-23	2.82
24-25	2.83
26	2.84
27	2.85
28-29	2.86
30	2.87

DIAMETER BREAST HIGH CLASSES

Class Limits (Inches)	Diameter Class (Inches)	Class Limits (Inches)	Diameter Class (Inches)
4.6-5.5	5	20.6-21.5	21
5.6-6.5	6	21.6-22.5	22
6.6-7.5	7	22.6-23.5	23
7.6-8.5	8	23.6-24.5	24
8.6-9.5	9	24.6-25.5	25
9.6-10.5	10	25.6-26.5	26
10.6-11.5	11	26.6-27.5	27
11.6-12.5	12	27.6-28.5	28
12.6-13.5	13	28.6-29.5	29
13.6-14.5	14	29.6-30.5	30
14.6-15.5	15	30.6-31.5	31
15.6-16.5	16	31.6-32.5	32
16.6-17.5	17	32.6-33.5	33
17.6-18.5	18	33.6-34.5	34
18.6-19.5	19	34.6-35.5	35
19.6-20.5	20	35.6-36.5	36