DESIGNING THE BEND NURSERY TREE INVENTORY SYSTEM

Mahlon Hale

ABSTRACT: In 1979 the Bend Nursery recognized a serious problem with Its tree inventory projections. As a result, a review was made of seedling population characteristics and the inventory procedure was significantly revised. The new Inventory relied heavily on statistical analysis and seedling size measurements. The new system has significantly increased the reliability of the inventory as we'.. is providing needed information about seed lot sizes.

INTRODUCTION

For a number of years the Bend Pine Nursery had been using an Inventory system based on systematic plot sampling of Its tree lots using more or less typical nursery inventory procedures (Stoeckeler 1957). The original system, based on 1' x 4' (30.48-cm x 121.92-cm) rectangular sample plots, was calculated by hand. It did not use statistical evaluations. Adjustments to the inventory were based on past experience for species, seed bed density, and typical grading and cull rates.

The number of trees actually graded and packed would vary as much as !25 percent to ±50 percent per tree lot with an overall trend for all production to underrun appreciably. It was apparent that this inventory system was not reliable.

EVALUATING PAST INVENTORY DATA

In 1979, the Nursery began analyzing its population characteristics in order to design a new inventory system that would more accurately predict the trees available for shipment.

Population Characteristics

The Bend Nursery typically grows 5MM to 7MM shippable trees. Because of harsh, cold winters and the possibility for frost to occur in any month of the growing season, the Nursery can successfully grow only two conifer tree species--ponderosa pine, (Pinus ponderosa [Laws]), and lodgepole pine, (Pinus contorta [Dougl.]).

A review of past Nursery inventory records revealed that tree lots were frequently variable in size, ranging from 1,000 trees to 1.25M trees. The following bar graph (fig. 1) shows the skewedness of population sizes and frequency.

Trees were commonly sown 7 rows per 4-foot (1.2-meter) wide beds. Seedling density commonly ranged from 10 to 45 live trees per square foot (0.092 sq. meters). Seedling uniformity within seed beds and within drill rows fluctuated noticeably.

Samples of seedling lots revealed that tree count coefficients of variation ranged from 18 percent to 30 percent with 24 percent being about average. Sampling trials revealed that coefficient of variation could be reduced generally by reducing rectangular plot sizes from 1'x4' (30.48-cm x 121.92-cm) to 1/2' x 4' (15.24-cm x 121.92-cm).

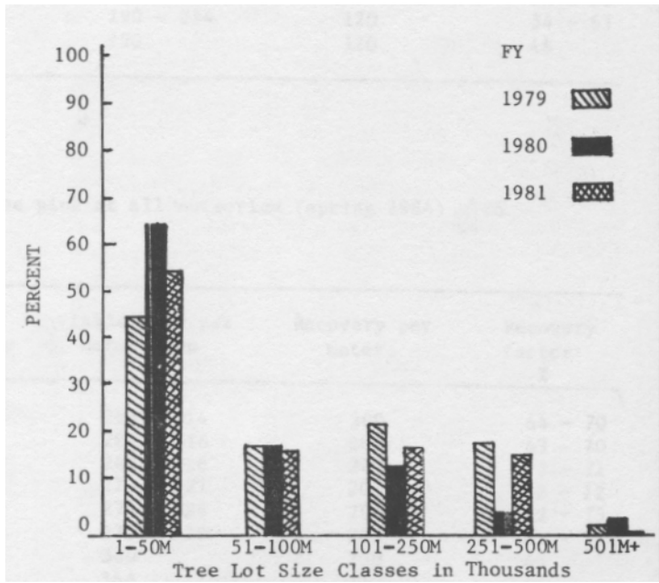

Figure 1.--Percentage of tree lots by size classes

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Tree caliper and height size measurement samples were being taken on every sixth tree counted. Statistical analysis showed resultant accuracies to commonly range from 3 percent to 10 percent at 1 Standard Deviation, which was considered adequate.

DESIGNING THE INVENTORY SYSTEM

Ranger districts needed more information about the percentage of trees by size classes in order to match the stock to planting sites and to recommend changes in grading specifications. Also the Nursery needed this information to predict the number of trees to be shipped. Through trial and error, the Nursery designed a tree inventory size-class tally form to record this information. (Refer to the tree inventory tally forms in the Appendix for details.) Also, the size class measurements could be used to predict net shippable trees.

Selecting Inventory Reliability and Accuracy Standards

Experience with previous inventory design problems showed that trial inventories based on 1 Standard Deviation would be too weak (67 chances out of 100 for success) while at 2 Standard Deviations (95 chances out of 100 for success) they would be too labor intensive for a large scale operation. Therefore, 1.6 Standard Deviations (89 chances out of 100 for success) was selected for the initial trial. Next, accuracy standards were selected based on a series of trial-and-error calculations comparing the approximate cost to Inventory to probable impact of tree volume errors to district planting programs. The following accuracy standards were used:

Inventor Target Accuracy Standards

Tree Lot Size	Min. Accuracy Standard
1-50M	10%
51-250M	7%
251-500M	5%
501-1MM	4%
1MM plus	3%

Inventory sampling intensities were calculated based on the standard sampling formula (Dilworth 1955).

$$N = \frac{n\,t^2\,c^2}{n\,A^2 + t^2\,c^2}$$

Inventory Procedures

Rectangular plots of 1/2' x 4' (30.48-cm x 121.92-cm) were systematically distributed throughout the tree lot. Live trees were counted and every sixth tree per plot was measured for caliper and height. No grading was done. Crews were instructed to write narrative statements on the inventory form to alert the Nursery personnel to any unusual tree lot characteristic.

Refer to the inventory procedural instructions in the Appendix for additional details.

Computational Procedures

The net shippable volume per tree lot was derived from the gross volume computations times a shipping factor adjustment. The following formulas were used:

Gross volume.

$$\frac{\text{Total Trees on Plots}}{\text{Total Plots} \times \text{No. Plots/BF}} \times \text{Total Lineal Footage (meters) sown}$$

Shipping factor.-(Adjustment of gross volume to net volume)-

1. Percentage of trees currently shippable from size class measurement array. See Figure 2.

TREE LOT # 14-8352
PERCENT OF GROSS TREES BY DIAMETER AND HEIGHT

SIZE CLASSES * caliper in mm							
ht. cm. (in)	1.2	2 1/2	3	3 1/2	4-6	7+	
1-6 (<2 1/2)	0.0	0.0	0.0	0.4	0.8	0.0	
7-9 (3-4)	0.4	0.0	1.2	1.2	5.2	0.0	
10-20 (4-8)	0.0	0.0	2.8	2.0	78.3	1.6	
21+ (8+)	0.0	0.0	0.0	0.0	5.6	0.4	

Figure 2.--Size class measurement array

2. Ingrowth allowance from size class measurement array for undersized trees.

3. Cull factor. Experienced culling rates for cull roots, top damage, disease, etc.

Shipping Factor - [(1)+(2)]x(3)

Net shippable trees.--Gross volume x shipping factor

For actual computer calculations and printout refer to Appendix.

MONITORING THE INVENTORY RESULTS

During the trial inventory, each tree lot was analyzed statistically to assure it met prescribed accuracy standards. If minimum accuracy was not achieved, additional plots were taken.

Occasionally on problem tree lots, it was necessary to Increase plot size to 1' x 4' (30.48-cm x 121.92-c7l to overcome coefficient of variation problems. In unusual cases where mortality created extreme coefficient of variation, populations were stratified and resampled to improve the accuracy.

Initial Findings

The initial inventory showed a number of significant operational problems, such as:

1. Bed footage measurements contained errors. The inventory crew was instructed to measure accurately between plots and determine the correct bed footage for each tree lot.

2. Plot sampling intensities were initially excessive for the accuracy needed. Based on the 1-0 age inventory results, the 2-0 age inventory sampling intensity was reduced. The Proposed sampling intensity for 1-0 age trees is as follows:

Size of Tree Lot	Target Accuracy	Recommended Percent Sample
0.5-10M	10%	10.0
11-30M	7%	4.0
31-100M	5%	2.0
101-250M	4%	1.5
251-500M	3%	1.5
501-1MM	2%	1.0
1.1 + MM	1%	1.0

3. Tree size measurement sampling procedures were too slow. The procedure was revised from sampling every sixth tree to measuring the first and last tree in each drill row within the plot (typically 14 trees per plot for seven-row beds). Inventory time was speeded up and accuracy was increased.

Reliability Trend

The following graph (fig. 3) shows the reliability trend for the Bend Nursery inventory system.

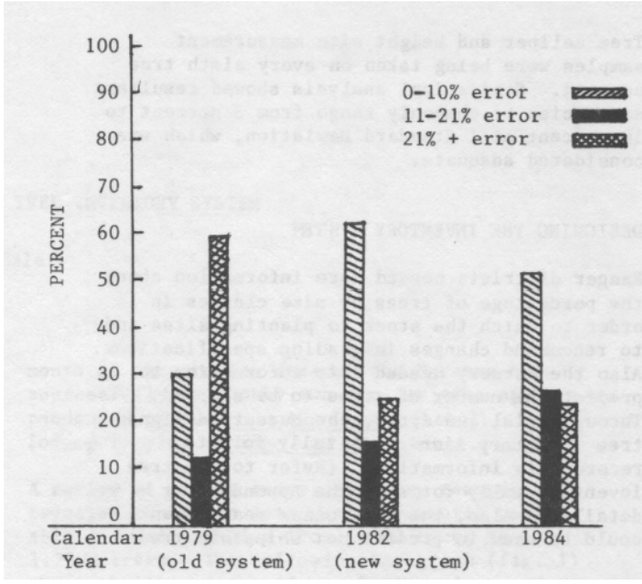

Figure 3.--Inventory error* rates based on number of tree lots

* The percentage of overrun or underrun that the inventory failed to predict based on the actual amount of trees packed.

DISCUSSION

The reliability of a nursery inventory is ultimately gauged by its ability to consistently predict the actual amount of trees packed for shipment. This reliability can be significantly affected by factors not related to either the inventory design or process. These factors would be items not measured or that occurred after the inventory, such as:

1. Damage to trees from weather, animals, disease, or by mechanical means;

2. Changes in farming or cultural practices that alter typical growth patterns;

3. Short-notice changes in grading specifications.

As shown in the preceding bar graph, the new Bend Nursery inventory system has significantly reduced the frequency and magnitude of large errors but further improvement is needed. Ranger districts are reporting that inventory size class arrays are providing needed information about their Nursery stock. And, the Nursery is using the inventory statistics and size array to identify problem seed lots as well as to guide cultural operations and influence management decisions.

Since the original inventory design, the Bend Nursery system has been revised slightly to improve monitoring of data and improve convenience. The computer program now monitors the inventory number of plots taken and the bed footages measured and compares them to the prescribed inventory amounts. When the recorded inventory input data exceeds prescribed accuracy standards, the computer prints out a discrepancy message to alert the reviewer. Also, the accuracy standards have been tightened for the statistics to be run at 1 Standard Deviation. See the appendix computer printouts for details.

REFERENCES

Dilworth, J.R. Log Scaling and Timber Cruising. OSU Cooperative Association; 1955.

Stoeckeler, J.H. Forest Nursery Practices in the Lake States. USDA Forest Service; 1957.

APPENDIX

INSTH'CTIONS TO INVENTORY CREW-1984 TREE INVENTORY

Jim Schmahl will supervise all tree inventory operations this season. The prescribed procedures are described below.

1. Equipment Needed: /'x4' and l'x4' plot frame, 100 foot tape, tally sheets, caliper gauge.

2. Measure the specified distance between plots as listed in the heading. Avoid taking plots in both the first and last 5' of each bed. Next to the last plot in the bed, record the total bed length measured. Be sure to include the ends in your total figure.

3. On all 1-0, 2-0 tree lots, use /'x4' plot. Count all live trees, unless the tree is obviously dying and is not expected to survive until winter. Record all count data without totaling. On 2-0 trees, do not count any 1-0 trees found. Take a minimum of 2 plots per lot and at least 1 plot for each seed bed.

4. On 2-0 and 1-1, 2-1 tree lots, measure-plot ratio is shown in the heading. On measure plots, measure the first and last tree in each of the seven rows in each plot to be measured. On each tree, measure the total height from the root collar to the tip of the bud and record to the nearest centimeter. Measure tree caliper near the root collar, preferably just above the collar swelling. Measure to the nearest half millimeter. °ecord as on the tally form in a dot format according to the tree size. Use additional tally sheets as needed to keep the dot tally legible.

5. The prescribed number of plots shown in the heading is the minimum needed. Should you be unable to get the minimum plots, advise Jim Schmahl. If you have taken all the required plots and have some remaining uninventoried ground, continue taking additional plots at the prescribed rate.

   If for any reason it becomes apparent that there is a large error in the prescribed number of plots or the indicated total seed bed length, stop all work and bring the problem to Jim Schmahl's attention.

6. On 1-1 transplanted trees, use a 1' x 4' size plot! Measure and record as instructed for 2-0 age trees. There will only be 6 rows of trees per bed for measuring.

7. Turn in tally sheets daily once the seed lot is fully Inventoried. If you observe unusual characteristics for a seed lot, such as high mortality, above average number of double tops, or spindly and stunted trees, please record your observations in narrative form on the bottom of the tally page.

7/25/84

2-0 AGE SEEDLING INVENTORY Names L.H. & J.R.P
Tree Lot #14-8352, Lot BF 231, Sample 4 %, Size Plot ½'x4'
Blk 15, No.Plots 18, Plot Spacing 23.5, M Trees
Source Code 22-14-851-04000-55-81 SIARea(M) 18 Avail (M)18

Bed Sub. Tot.	Plot No.	Sec	Bd	Live Tree Count	Bed Footage	Bed Sub. Tot.	Plot No.	Sec	Bd	Live Tree Count	Bed Footage
5	1	3	1	29 22			21				
	2			30 14			22				
	3			46 22			23				
	4			39 22			24				
	5			36 30			25				
	6			38 30			26				
	7			33 26			27				
	8			38 25			28				
	9			35 22			29				
	10			23 32			30				
	11			36 25			31				
	12			29 19			32				
	13			32 24			33				
	14			30 18			34				
	15			36 15			35				
	16			40 19			36				
	17			42 27			37				
	18			36 30	230		38				
	19						39				
	20						40				
	Totals						Totals				

REMARKS:

Figure 4.--Field tally form #1

TREE MEASUREMENT DOT TALLY FORM

BLK #15 Sec. #3 Bd. #1

L.H. & J.R.P.

DATE 7/25/84

TREE LOT #14-8325

SOURCE CODE

REMARKS

Ht in cm	Caliper Measurements								
	1-2mm	2½mm	3mm	3½mm	4mm	5mm	6mm	7mm	8+mm
1-6			1	1	3				
7	1		2	1	4				
8				1	3	1			
9			1	1	4	4			
10			3	3	5	2	1		
11			3	1	4	4			
12			1	1	6	4			
13				1	5	6	4		
14			3		5	6	3		
15					5	6	4		
16					3	6	4		
17					4	6	5		
18					3	6	3	1	
19					3	5	4	3	
20					1	4	4	1	
21						5	4		
22						1	1		
23						1			
24						1	1		
25								1	

Figure 5.--Field tally form #2

RJL

1-0 SEEDLING INVENTORY CALCULATIONS

PLOT SIZE
1' × 4' = 1
1/2' × 4' = 2

TL# 14-8416 DATE 08/01/84
108-14-863-03000-55-77 SIA

TREE VOL. REQUESTED 15 (M)
ADJUSTED REQUEST 15 (M)

BLK:SEC:BED	TREES/PLOTS	× PLOT SIZE =	LT/BF × BF	= GROSS VOL.)
10: 10: 3	151/ 10	2	30.300 48.0	1.4
10: 10: 4	534/ 46	2	23.217 219.0	5.1
TOTAL	685/ 56	× 2 =	24.5 × 267	= 6.5

Live Trees/Sq.Ft. 6

DISCREPANCY-ACTUAL BF 267 VS. PROJECTED BF 277*
DISCREPANCY-ACTUAL PLOTS TAKEN 56 VS. PROJECTED PLOTS OF 22*

*(Program detected discrepancies to be checked out by field crew)

STATISTICS

MEAN	12.2321
STANDARD DEVIATION	6.3
STANDARD ERROR OF EST.	6.9%
COEFFICIENT OF VARIATION	51.5%
ACTUAL % SAMPLE	10.49
SUM OF X'S	685
SUM OF X 2'S	10549

INVENTORY DESIGN NEEDS

DESIGNED ACCURACY STD.	5 %
COEFFICIENT OF VARIATION	51.5%
PERCENT SAMPLE NEEDED	16.85
NUMBER OF 1/2'×4' PLOTS NEEDED	90
PLOT SPACING	3 ft.

TREELOT #14-8416

Figure 6. -- Computer printout for 1-0 seedling inventory calculations

RP

2-0 SEEDLING INVENTORY CALCULATIONS

PLOT SIZE
1' × 4' = 1
1/2' × 4' = 2

TL# 14-8352 DATE 07/31/84
122-14-851-04000-55-81 SIA

TREE VOL. REQUESTED 18 (M)
ADJUSTED REQUEST 18 (M)

BLK:SEC:BED	TREES/PLOTS	× PLOT SIZE	= LT/BF	× BF	= GROSS VOL. (M)	× SHIPPING FACTOR	= NET VOL.(M)
15: 3: 1	915/ 16	2	114.375	230.0	26.3	79%	20.8
TOTAL	915/ 16	× 2	= 114.4	× 230.0	= 26.3	× 79%	= 20.8

Live Trees/Sq.Ft. 29

STATISTICS

MEAN	57.1875
STANDARD DEVIATION	7.3
STANDARD ERROR OF EST.	3.2%
COEFFICIENT OF VARIATION	12.8%
ACTUAL % SAMPLE	3.48
SUM OF X'S	915
SUM OF X 2'S	53133

INVENTORY DESIGN NEEDS

DESIGNED ACCURACY STD.	7 %
COEFFICIENT OF VARIATION	12.8%
PERCENT SAMPLE NEEDED	.65
NUMBER OF 1/2'×4' PLOTS NEEDED	3
PLOT SPACING	115 ft.

AVERAGE HEIGHT OF ALL TREES	14.7 cm
AVERAGE HEIGHT OF SHIPPABLE TREES	15.2 cm
AVERAGE DIAMETER OF ALL TREES	4.9 mm
AVERAGE DIAMETER OF SHIPPABLE TREES	5 mm

SHIPPING FACTOR
[87.9 + 1/2 (10.44)] × .85 = 79%

TREE LOT #14-8352
PERCENT OF GROSS TREES BY DIAMETER AND HEIGHT

ht. cm. (in)	1.2	2½	3	3½	4-6	7+
1-6 (2 ½)	0.0	0.0	0.0	0.4	0.8	0.0
7-9 (3-4	0.4	0.0	1.2	1.2	5.2	0.0
10-20 (4-8)	0.0	9.9	2.8	2.9	78.3	1.6
21+ (8+)	0.0	0.0	0.0	0.0	5.6	0.4

TREELOT # 14-8352

Figure 7.--Computer printout for 2-0 seedling inventory calculations

TREE SIZE STATISTICS
TL # 14-8352

MEAN (GROSS)	4.9 mm	MEAN (GROSS)	14.7 cm
STD. ERROR OF ESTIMATE	1.1%	STD. ERROR OF ESTIMATE	1.7%
ACTUAL % SAMPLE TAKEN	.95	ACTUAL % SAMPLE TAKEN	.95%
COEFFICIENT OF VARIATION	17.6	COEFFICIENT OF VARIATON	26.4
NUMBER OF TREES SAMPLED	249	NUMBER OF TREES SAMPLED	249

DISCREPANCY - # OF TREES ENTERED IS 249*
SHOULD BE IN THIS RANGE: 184 - 225.6*

*Key punching error detected by program)

Figure 8.--Computer printour for tree size calculations