Inventory Methods

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There are three primary inventory methods practiced in our southeast 13-pine belt states (Texas to Virginia) which are overviewed as follows:

1) **Plot Cruise (fixed plots)**
2) **Prism Cruise (variable plots)**
3) **100% Tree-Count (Marking)**

The three dominant practiced methods are compared below:

Comparison	100% Tree-Count	Plot Cruise	Prism Cruise
Fixed Plots Installed	No	Yes	No
Variable Plots Installed	No	No	Yes
All Trees Counted	Yes	No	No
Sampling Error	No	Yes	Yes
Human Error	Yes	Yes	Yes
Stand Variation Influences Accuracy	No	Yes	Yes
Percent Error for less than 120 plots	0% Error	10% to 50%	10% to 50%
Percent Error for more than 120 plots	0% Error	2% to 10%	5% to 15% (dbh dependent)
Intensity	Higher	Lower	Varies with dbh
Accuracy	Highest	Lower	Lower (dbh dependent)
Management Use for Planning	No	Yes	Yes
Estate Planning Use for Taxes	No	Yes	Yes
Inventory Thinning Use for Selling	Yes	No	No
Inventory Final Harvest Use for Selling	High Use	Medium Use	Low Use
Procurement Use	Seldom	High use	Low Use
Ease of Use in Field	Simple	Simple	Simple
Time Involved	High	Medium	Low
Calculation Complexity	Simple	Medium	Complex
Seasoned Experience Improves accuracy	Yes	Yes	Yes

An overview of each method follows:

1) Plot Cruise (fixed plots):

Plot cruises are popular for procurement, appraisals and estate planning. A cruise is conducted to estimate the number of trees in a forest by species, diameter, height, form class and grade. All fixed plot cruises have statistical sampling error which is important to know and understand before relying on the data.

A plot cruise simply consists of counting and classifying all trees in a series of circular sample plots. Circular plots are usually 1/10-acre in size (37.2 feet radius). The plots are evenly spaced throughout the stand to provide an equal sampling of all forest types across all topographic changes. The plot information is then extrapolated to one acre and then multiplied by the total acres as illustrate in the two examples below:

One plot on 1-acre:

Plot size	1/10-acre
Plot radius (feet)	37.2
Average trees/plot	8
Factor to 1-acre	10
Number of trees/acre	8 x 10 = 80

40 plots on 60-acres:

Plot size	1/10-acre
Plot radius (feet)	37.2
Cumulative trees in all fixed plots	320
Total number of plots	40

Average trees/plot	320/40 = 8
Factor to 1-acre	10
Number of trees/acre	8 x 10 = 80
Number of acres	60
Total trees on 60-acres	60 x 80 = 4,800

In addition to the tree count, the following information is ordinarily collected in the plots:

a. Pine Sawtimber.
b. Pine Pulpwood.
c. Red Oak Sawtimber.
d. White Oak Sawtimber.
e. Miscellaneous Pulpwood.
f. Hardwood Pulpwood.
g. Diameter at breast height (4.5 feet above the ground; dbh).
h. Merchantable height in 16 feet logs (to set top end diameter or where limbs excessive).
i. Form Class (degree of taper in a tree).
j. Grade (quality of the timber based on straightness, soundness and knots).

An example of a volume report produced from cruise field data is as follows:

Refer to insert #1: "Volume Report"

Determining the appropriate number of plots to install in a cruise is very important. Unfortunately, few landowners, consultants, or procurers appropriately determine the right number of plots to install. We tend to install too many plots creating unnecessary costs or do not install enough plots causing unnecessary risk.

The adequate numbers of plots to install in a cruise are based on three variables:

1) Desired Percent Error (selected by landowner or forester; preferably 5% - 10%).
2) Set Probability (selected by landowner or forester; preferably 90%).
3) Tree variation in each forest (tree uniformity or lack of uniformity in each stand).

As illustrated below, the increased number of plots installed in a cruise desirably lowers percent error. While on the other-hand, increased tree variation (lack of tree uniformity, for example each plot has a large difference in the number of trees counted) increases percent error thereby requiring additional plots to counter the variation's negative impact. Greater tree variation increases the need for more plots, while uniform stands require fewer plots to achieve the same or lower percent errors. Tree variation is simply measured by the varying number of trees occurring in adjacent plots. If three plots respectively had 2 trees, 9 trees, and 5 trees; then this stand has higher variation and will need 75-plots to achieve a 10% error (based on 90% probability). If three plots respectively had 7 trees, 5 trees and 3 trees; then this stand has a lower variance and will require only 28-plots to achieve a 10% error (based on 90% probability).

Over 50% of landowners and professionals mistakenly interchange "cruise percent" for "percent error", which are crucially two different things (illustrated below). Cruise percent is simply the amount of surface acres sampled by the cumulative plots and is not the same as "percent error". As illustrated in the table below, a cruise percent of 10% with 40 plots produced a 14% percent error and a cruise percent of 20% with 80 plots produced a 10% percent error (40 1/10th-acre plots on 40-acres = 4 acres sampled on 40 acres = 10% sampled surface area = cruise percent). Unlike cruise percent, "percent error" is based on tree variation, number of plots, and selected probability.

"Refer to insert #2: "Percent Error Table"

Another important factor to remember is the number of acres involved in a cruise does not influence percent error. Percent error is determined by the number of installed plots combined with stand variation (acres are not included). For example, if two stands are identical in variation and only differ in number of acres and plot ratio to acres, which of the following cruises is more accurate:

Stand #1	**1-plot per 1-acre**	40 plots	40 acres	Tree variation same as #2 below
Stand #2	**1-plot per 2-acres**	50 plots	100 acres	Tree variation same as #1 above

Over the past 10-years in presenting this question, less than 5% of landowners and practicing professionals answer correctly. 1-plot per 1-acre appears more intensive, while in reality it is not because it only produced 40 plots, while the 1-plot per 2-acres produces 50 plots achieving a higher intensity with greater representation and resultantly less percent error.

A “cruise or appraisal” without a stated “percent error” is as valuable as one shoe.

This mathematical phenomenon has yielded many procurers and landowners richer or poorer. Consequently, the best margins for financial gain based on percent error in procurement are experienced in sales less than 120 acres, which lack uniformity and are advertised by a cruise. There are two solutions, increase the number of plots until an acceptable percent error is achieved and/or 100% tree-count (mark) all stands less than 120 acres and greater if adequate dependable staff are available.

Human error is an additional factor that plays an important role in the accuracy of inventories. I have witnessed and personally experienced 100% tree-count (marked) sales and cruise sales where the purchaser reaped considerable over-cuts. Consistent over-cuts exceeding the statistical percent error can often be traced to:

1) Inexperienced markers and cruisers. A college degree does not rank as experience. Also, years in the woods does not rank as experience. Only a marker or cruiser’s actual cut-out report from the mill determines their personal accuracy (the question is do they have 10-years experience, or 1-year experience 10-times).
2) Improper cruise layouts. Cruises should cross all drains and topographic elevation changes to ensure maximum cross-section of all forest types and sizes.
3) Forestry consultants sub-contracting contract cruises to third parties. For example:
   > “A landowner or company contracts a cruise to an established consultant who contracts the field work to a third party; the original consultant will prepare the reports with their letterhead, but the field data collection was performed by an unassociated third party for a lesser price.”

   There are reasons why third party contractors are in positions to accept lower rates for their work (often they are between jobs, attempting to start companies, moonlighting, dabbling, part-time, or struggling to develop a direct clientele base). The field cruiser is as important as your attorney, managing forester and accountant. You waited 25 – 50 years for the investment return, and the field data collection (cruise) determines the accuracy of all following reports, decisions and returns.
4) Low wages for field foresters and technicians resulting in low effort.
5) Hot, tired, chigger-infested, hungry markers and cruisers late in the day.
6) Utilizing summer student interns.
7) Poor supervision and accountability.
8) Too much ocular estimation (ocular estimations should be periodically checked with instruments).
9) Utilizing prism cruises in brushy stands (prisms can only accurately be used in clear, open stands).
10) Out-dated or cheap forestry equipment. Lasers are available that adjust all distance measurements to horizontal distance for accurate plot radius measurement (enables measuring over brush).
11) Working too fast.
12) Falsified data recording (make-up tree counts in truck to avoid extreme weather, brush, briars and chiggers).
13) Lack of general drive for excellence.
14) Staff turn-over and training.
15) Companies understaffed and/or lacking sufficient working environment.
16) Insufficient software and computers. The following software is imperative: Excel, Access, ArcView for mapping and Avenue.
17) Computer illiteracy in many practicing foresters.
18) Out of shape. It is difficult to maintain field accuracy when out of shape (short cuts become inviting).
19) General form class selection.
20) Incorrect utilization standards (calls to top end log diameter and merchantability).
21) Accidental mis-recording of data in the field (entering data in wrong columns or rows).
22) Field data transfer errors by office personnel during report preparation.
23) Consultants not determining the correct number of plots to install in order to achieve an acceptable percent error. The human error lies in simply not determining the percent error and/or not knowing how.
24) Improper volume and weight calculation programs and tables (for example, Doyle Log Rule Board Feet grossly underestimates pine trees between 10” to 20” dbh).
25) Incorrect acreage calculated for cruise. The correct acreage needs to be determined before being multiplied or extrapolated by the average weight or volume per acre (correct acres are the total stand acres minus excluded acres in roads, power lines, well sites, pasture, buffer strips, etc.). The most accurate way to calculate the correct

acreage is through digital orthographic quadrangle aerial photographs in ArcView software or by on ground GPS (global positioning system).

The above examples can be overcome and monitored for accountability, imperative improvement, and minimal error; but never entirely eliminated.

Not included above is the green weight in tons, because the average accumulated mill reports signify otherwise, and the problem is not human error. Green weight does vary by tree and fluctuates by seasons. Pine trees tend to weigh more with sap drop in the fall and sap rise in the spring. Pine trees generally weigh more in the summer and less in the winter. Stressed pine trees naturally over pruned to less than 1/5-crowns on top of sandy ridges in the middle of dry winters, experiencing minimal transpiration, weigh least of all comparable stands and conditions. Reason, pine has a lower specific density than water (dry pine floats on water). The greater ratio of water to wood, the heavier green pine weighs. However, weight typically balances over the whole stand, but there are occasions where natural water to wood ratios in unique conditions bias cut-out reports.

2) Prism Cruise (variable plots)

A prism cruise is well suited for gathering in-house management data and verifying current stocking for thinning and harvest decisions (management decisions and planning). The prism cruise has the same statistical sampling error as plot cruises, which is important to know and understand before relying on the data (refer to plot cruise). However, the prism's accuracy additionally varies beyond fixed-plots based on the average diameter of the sampled trees, thereby unnecessarily complicating its application and accuracy for selling and/or procuring timber. The prism works through viewing the subject trees through a glass prism from a point location and spinning 360° around that point location to view all trees. The light refracts the trees' image shifting it to the left or right. Whether the refracted image is displaced to where it is completely out of line with the un-refracted portion of the tree, determines whether the tree is in or out at that point location. Resultantly, as tree dbh increases, prism accuracy increases (and vice versa). This phenomenon provides fluctuating error based on each dbh, which renders the prism a poor choice for most pine timber sales. Different factor prisms can simultaneously be used to minimize variability, but such is seldom done. The 10-factor prism is the most popular used prism for management-based cruises.

The 10-factor prism works from the mathematical formula of 0.005454 x [dbh(inches)]^2 = cross-sectional area (square feet) in the tree trunk. Each tree at the prism point that is not completely refracted is counted. The counted number of trees is then multiplied by ten, for a ten factor prism, which provides the number of square feet (called basal area) in the stand (more plots are installed for greater accuracy as in the plot cruise). For example:

1-plot on 1-acre:

Prism type	10-factor
Average trees/plot	8
Factor to 1-acre	10
Basal Area or square feet per acre (not # of trees)	8 x 10 = 80
Average dbh of plot trees (inches)	13
Square feet for average dbh tree	0.005454 x (13 x 13) = 0.92
Average trees per acre	80 / 0.92 = 87

40-plots on 60-acres:

Prism type	10-factor
Cumulative trees in all variable plots	320
Total number of plots	40
Average trees/plot	320/40 = 8
Factor to 1-acre	10
Basal Area or square feet per acre (not # of trees)	8 x 10 = 80
Average dbh of plot trees (inches)	13
Basal Area for average dbh of plot trees	0.005454 x (13 x 13) = 0.92
Average trees per acre	80 / 0.92 = 87
Number of acres	60
Total trees on 60 acres	60 x 87 = 5,220

As mentioned, the strength of a prism lies in its management use for planning appropriate thinning levels for pine stands illustrated as follows (thin down to the following basal area levels):

Management Type	Basal Area	Trees Counted per 10-Factor Spin
Intensive Plantations	60 - 70	6 - 7
Light Intensive Plantations	70 – 80	7 - 8
Natural Stands	80 – 90	8 - 9

During marking selection and logging, a simple spin of the prism will verify accountable stocking.

3) 100% Tree-Count (Marking):

Marking provides the highest accuracy and is the inventory preference for timber sales by sellers for lump sum bids. Marking is simply counting every tree in the stand. The probability in marking is 100% and the statistical percent error is 0% because every tree is counted. The only error that exists in marking is human error (which equally exists in cruises as outlined above). Marking is laborious, but well justified based on eliminating risk by providing accurate tree counts.

Ordinarily, marking is conducted by spraying blue paint on each tree while simultaneously recording species, dbh, and height. Blue paint signifies the tree has already been counted. When marking a thinning, two marks are placed on the tree, one at ground level and the other between 5 – 6 feet high. The high mark aids the logger in identifying trees to harvest, while the stump mark aids the landowner and forester in verifying only pre-selected trees were harvested. For additional security, a tracer can be used in marking paint fluorescing in a select nanometer spectrum to change paint colors when checked with ultra-violet light. This prevents the possibility of trees being added to the thinning after sale.

Due to its intensive nature, marking is not used in general management planning or procurement, but simply reserved for use by sellers in accounting and representing timber sales.

A combination of marking and a 1/10-acre plot cruise can also be blended to improve accuracy and accountability, in the stand's highest value product, by illuminating ocular estimation in dbh and tree heights. This unique blend is performed in the following manner:

> All pine sawtimber trees greater than 9.1" dbh are 100% marked for tree count (eliminating probability and percent error). Fixed plots are overlaid for pine sawtimber diameters and heights. Each 1/10 acre plot radius of 37.2 feet is "laser" measured, each dbh individually taped, every height individually laser measured and all data individually recorded on each flagged tree (eliminating ocular estimation and creating accountability via verification by the procuring bidders).
>
> The pulpwood and hardwood volumes are derived from the same fixed plots (in a pine stand that usually comprises less than 5% of the total sale). This method allows you to focus the majority of your time, consequential accuracy and accountability on the highest valued products.
>
> The pine sawtimber tree-counts are then pro-rated to the percentile occurrence of dbh and heights. This method can only be used in final harvest sales.

Summary

There are three dominant methods practiced for inventorying timber in our southeast 13-pine belt states:

1) Fixed Plot Cruise (1/10-acre radius plots).
2) Variable Plot Cruise (prism).
3) 100% Marking.

Plot cruises are popular for procurement, appraisals and estate planning. A prism cruise is well suited for gathering in-house management data and verifying current stocking for thinning and harvest decisions. The prism cruise has the same statistical sampling error as plot cruises, which is important to know and understand before relying on the data. The prism's accuracy additionally varies beyond fixed-plots based on the average diameter of the sampled trees.

Marking provides the highest accuracy and is the inventory preference for timber sales by sellers for lump sum sales. Due to its intensive nature, marking is not used in general management planning or procurement, but simply reserved for use by sellers in accounting and representing timber sales.