Virginia Cooperative Extension
Virginia Tech • Virginia State University
EXPERT REVIEWED
CNRE-180P

# Appreciating Uncertainty in Timber Cruising

*Authored by Corey Green, Assistant Professor, Forest Resources and Environmental Conservation, Virginia Tech*

## Introduction

A common task when managing forestland is quantifying the resource. When a forester is providing guidance to a landowner, information such as stand (a group of trees growing together that are being managed as a single unit [Nyland 2002]), volume, tree heights, and basal area (a common measure of density used by foresters) are important for informed decisions. For example, basal area and tree heights are important factors to consider when scheduling thinnings or final harvests. Having a reliable estimate of stand volume and product proportions is critical to forming a bid for a timber sale that is competitive to the landowner and also provides sufficient profit to the timber buyer. If a landowner is interested in managing for carbon, an accurate estimate of the different carbon pools is necessary for ensuring the sequestration and storage are properly accounted for.

While a forester could set out to measure every tree in a given stand, that is often impractical given the substantial time it would require. For example, in a 100-acre stand, it could very possibly involve measuring more than 20,000 trees! In practice, foresters often sample the forest through a practice commonly known as a timber cruise. Timber cruises consist of establishing smaller sample plots throughout the stand of interest. Only the trees captured with these plots are used to estimate the characteristics of the entire stand.

In figure 1, the process is illustrated with fixed area plots. Only the trees falling inside the boundaries of the plots are measured.

Figure 1. A stand of timber (white-bounded area) with randomly distributed fixed-area plots represented as yellow circles. (Image credit: Maxar Technologies.)

A key assumption of a timber cruise is that the plots sampled are selected without bias. That is, they are not located only in the "good" or "easy-to-measure" areas. Notice in figure 1 that the conditions captured by the sample plots vary significantly. There are several ways to select the locations, but assuming they are selected in an unbiased manner, any two timber cruises in a stand at a specific time will almost certainly give different results. On the surface, this is a rather unsettling statement. In actuality, this is an unavoidable property of sampling when any variability exists (which is always the case with forests due to natural differences in site productivity, stem density, etc.). In stands with lots of variability (e.g., a mixed-age, hardwood stand), the differences can be quite large. With lower variability stands, one can expect smaller differences.

# A Computer Simulation Example

To help illustrate this, hypothetical natural hardwood and planted pine stands were created, each with a mean basal area of 120 square feet per acre. The difference between the stands is their variability (fig. 2). The hardwood stand was created with three times the variability of the pine stand. Generally, planted stands are much more uniform due to the controlled species, number of trees, and age composition, as well as more intensive management practices, such as site preparation and chemical competition control.

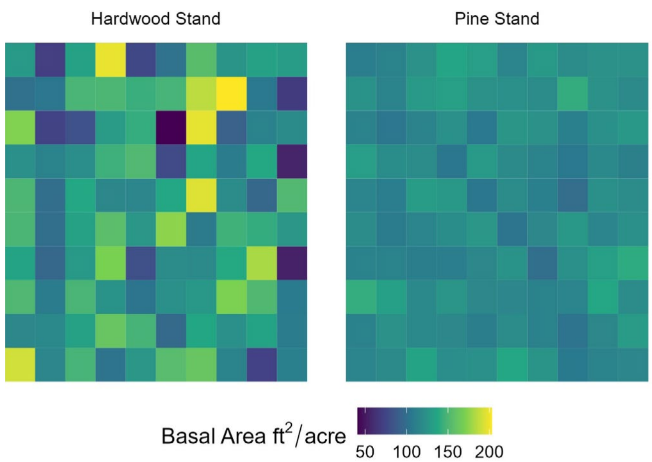


Figure 2. Two computer-generated, hypothetical timber stands were used for the simulation example. The hardwood stand had three times the variability of the pine stand.

In each stand, ten 0.1-acre sample plots were randomly selected through a computer simulation. The estimate of basal area was then calculated by averaging the per-acre values from each sample plot.

The process was repeated for a total of 1,000 hypothetical timber cruises. When the averages from all the cruises are plotted in a histogram, the range of possible estimates is quite surprising (fig. 3).

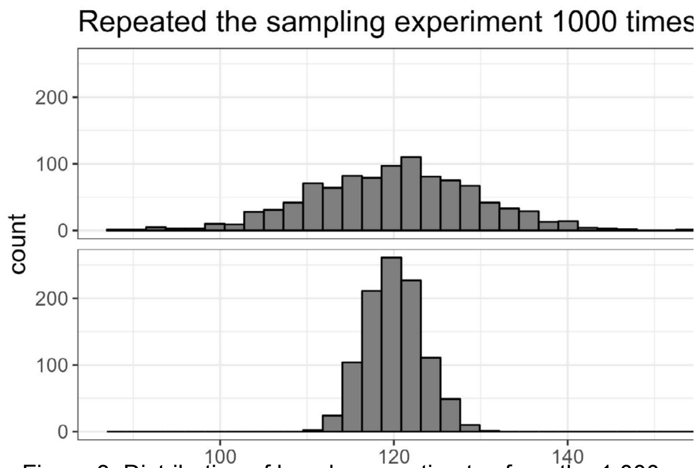


Figure 3. Distribution of basal area estimates from the 1,000 repeated computer timber cruises for the hardwood and pine stands.

In the hardwood stand, approximately 30% of timber cruises resulted in a basal area estimate that was more than 10 square feet per acre away from the true value, and approximately 10% of the cruises were more than 15 square feet per acre away from the true value! It's important to note that these differences are purely due to chance and can have significant implications on management decisions, especially if the values are used to predict future conditions. Conversely, the pine stand is much more uniform and has much less variability from sample to sample.

A question that naturally comes to mind is, What can be done to reduce the uncertainty? The simplest answer is to increase the number of sample plots in a given cruise. When the number of plots in the hardwood stand was increased from 10 to 30, another computer simulation revealed that approximately 90% of the values in the resampling experiment were within 10 square feet per acre of the correct answer. While increasing the number of plots seems like an obvious solution, more plots come at a financial cost. There are other statistical methods that can be employed. However, in many cases, increasing the sample size or using other techniques is not possible or practical.

No matter the number of plots or the statistical sampling technique used, it is important to have some way of expressing the amount of unavoidable uncertainty when conducting a timber cruise (Shiver and Borders 1996). One method is the confidence interval. This provides an interval around the mean estimate from your timber cruise that contains a range of plausible values for the stand characteristic being estimated.

Confidence intervals have a confidence level associated with them. The most common is the 95% confidence interval. In practice, statistical software is used to calculate confidence intervals (a spreadsheet example is included in supplemental material), and it's the interpretation that is most important. For example, figure 4 shows a confidence interval that was created for a single hypothetical timber cruise.

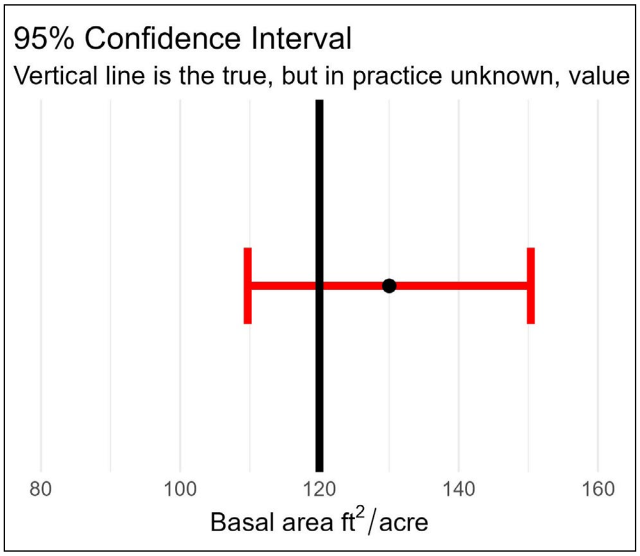


Figure 4. A single 95% confidence interval for a hypothetical timber cruise. The basal area estimate is plotted as a point and the confidence interval is in red.

In this case, the confidence interval captures the true value (represented by the bold vertical line) we are trying to determine. If this were repeated for all 1,000 hypothetical timber cruises, 95% of the intervals would capture the true value. This leads to the interpretation of the confidence interval in the context of a single timber cruise: We are 95% confident that the timber cruise produced a confidence interval that captured the true basal area per acre that we are trying to determine.

The confidence interval gives us a range of values to work with rather than just one value. If the confidence interval is very wide compared to the mean, it indicates low confidence that the mean from our single timber cruise is near the actual value we are after. Conversely, a narrow confidence interval gives us more confidence that our estimate from the timber cruise is close to the true value.

It is important to note that the confidence interval does not account for errors in measurements. If poor quality data are collected, the procedure described does not take these errors into account. Also, a confidence interval cannot be calculated if only one sample plot is measured. In practice, a forester should always install multiple sample plots to capture the inevitable variability present in every timber stand. Further, in the case of a 100% inventory (i.e., every tree in the stand is measured), there is no need for a confidence interval because the true population mean and the totals are assumed to be known, and there is no uncertainty in the mean due to sampling.

# Implications

Now that a range of plausible values is available, different management scenarios can be explored within the bounds of the confidence interval. If a forester is working with a landowner to determine future timber volumes, the range of values within the confidence interval can be used to explore future scenarios. Additionally, it can provide a landowner or forester with a plausible range of expected financial returns from a timber sale. For example, if a confidence interval around total stand value were created, the forester and landowner could use the range to determine a bid that is acceptable to both parties.

From a landowner's perspective, it is recommended that you ask your forester to describe their timber cruising process and include a confidence interval around their estimates of forest characteristics, such as timber value. If the level of uncertainty is unacceptably large, consider requesting that the forester perform additional sampling. From a forester's perspective, confidence intervals are a helpful method to express the unavoidable uncertainty when using timber cruise data to make management and financial decisions with more information than just a single-point estimate.

In summary, confidence intervals are a useful follow-up analysis from a timber cruise. Some level of uncertainty is unavoidable in timber cruising, and confidence intervals can be used to approximate how much uncertainty exists (Shiver and Borders 1996). They provide foresters and landowners with additional information that can be used to inform management decisions and value standing timber.

# References


Nyland, Ralph D. 2016. *Silviculture: Concepts and Applications*, 3rd ed. Long Grove, IL: WavelandPress.

Shiver, Barry D., and Bruce E. Borders. 1996. Sampling Techniques for Forest Resource Inventory. New York: Wiley.



Visit our website: www.ext.vt.edu

Produced by Virginia Cooperative Extension, Virginia Tech, 2024





VT/0724/CNRE-180P