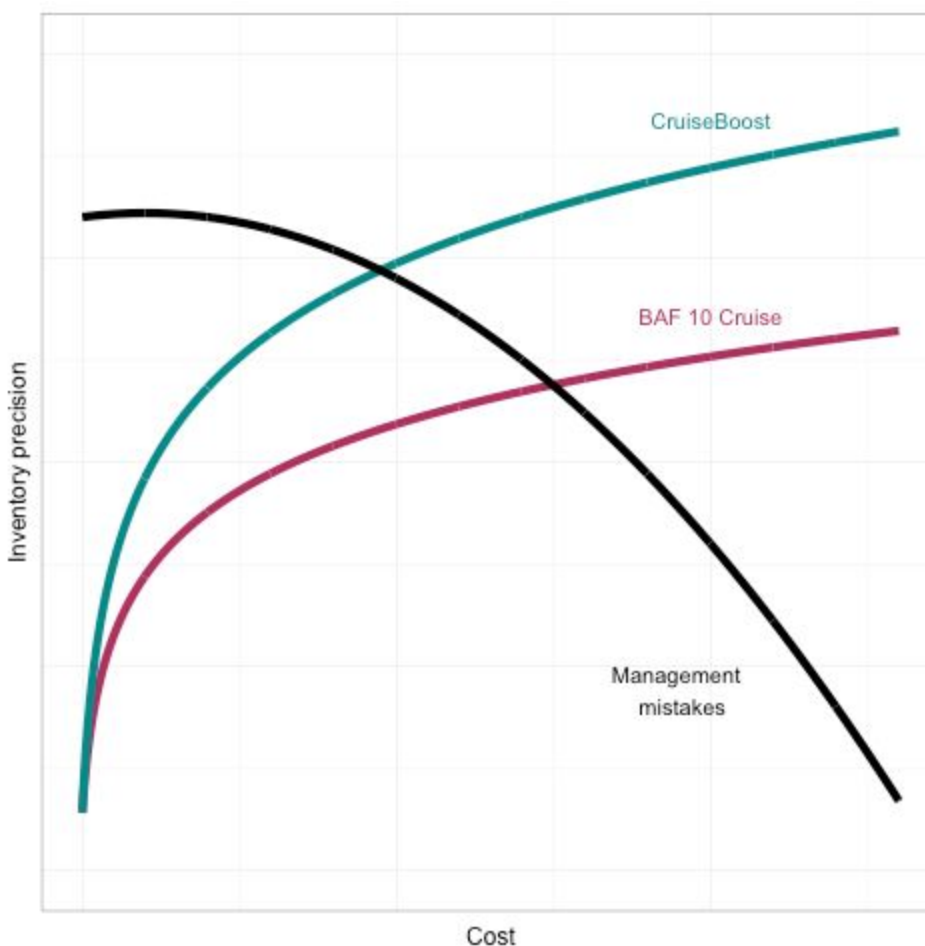




SilviaTerra's ForeCost service helps you optimize your forest inventory strategy and achieve maximum profitability. You know how much you're paying for forest inventory, but do you know how much you are losing due to suboptimal management decisions? The key is to identify the point at which spending an extra dollar on inventory doesn't result in avoiding more than a dollar of "mistakes" due to suboptimal management decisions.



ForeCost helps answer this question by simulating many different inventory sampling scenarios. We create a "virtual forest" similar to your ownership and then simulate cruising

it with many different plot types and many different intensities. We run each "cruise" through a harvest scheduler to develop a management plan. We then apply that management plan to the virtual forest and determine how much money you would have made in each case - and compare that to what the true optimal decisions are with perfect information about the virtual forest.

We also include SilviaTerra's CruiseBoost inventory method in the comparisons. CruiseBoost uses remotely-sensed imagery to get more accurate inventory information for less money than conventional cruises.

The tables included in this report show:

- For each iteration of a plot type / intensity: the estimated BA, mgmt decision, \$\$\$, and loss relative to the optimal
- For each plot type / intensity: the average inventory cost and average loss from imperfect information

TECHNICAL APPENDIX

ForeCost summary

The ForeCost analyses are performed using data from a simulated forest that represents a target forest condition of interest. This simulated forest is a stem map showing the location, size, and species of each stem in a 150-acre stand. Different inventory approaches are compared by sampling this forest with different plot types (fixed and variable radius plots) and cruise intensities. Each plot type and intensity combination is replicated in multiple simulations to capture the variation possible; the cost of each sampling method is calculated.

The data from each inventory simulation are grown forward for ten years under a variety of possible management scenarios - varying both harvest intensity and year of entry. The values of the removals and standing timber at the end of ten years are calculated and compared so that the apparent best management solution, given imperfect inventory information, can be determined. The 'true' return from each possible management operation is determined from growing forward the full stem map of the entire forest and calculating its value. This information is used to determine the expected loss from each inventory methodology, calculated as the difference between the returns from the optimal management decision selected using the sample and the returns that can be expected of the actual optimal management decision determined from the full stem map.

Cost-plus-loss analysis

The stumpage values of standing and removed forest volume for each sampling method, management scenario, and management year are used to determine what the financially optimal management decision would have been using each sampling technique. The net present value at year 10, including harvesting revenues,

standing timber, premerchantable timber values, and cruising costs, is calculated using a specified discount rate.

The optimal selection, that with the highest estimated NPV, is compared to the true financially optimal management scenario made using perfect information, drawn from the census data. The expected loss for each replication is the difference in NPV of the selected management scenario and the NPV of the optimal management scenario. The loss calculation is performed using the numbers from growing the simulated forest, so that it reflects the total possible realized value, and the realized value from an alternate management scenario, rather than the value expected using information from an imperfect real-world sample.

CruiseBoost

The ForeCost analyses also facilitate a comparison of SilviaTerra's CruiseBoost system and traditional inventory techniques. CruiseBoost is a remote sensing-assisted inventory approach, in which measured plot data are paired with remotely sensed data to generate an estimate of stocking for the entire stand, including areas not visited during plot measurements. Typically, CruiseBoost estimates of basal area and trees per acre have higher precision (smaller standard errors) than traditional sampling estimates. For ForeCost simulations, the gains in precision are estimated based on observed gains from CruiseBoost predictions in real stands of the same forest type and similar stocking levels. The cost of using CruiseBoost includes both the cruising cost with a given sampling methodology and cruise intensity plus a fixed, per-acre cost charged by SilviaTerra.

The benefits of the CruiseBoost system vary by sampling intensity and plot type. In general, CruiseBoost results in a smaller cost-plus-loss than many of the traditional sampling procedures. The cost per acre is slightly higher, but the improved

accuracy and precision of the stocking estimates allow for optimized management decisions.

User-Specified Inputs

Forest conditions

The user specifies a state, forest type and target forest conditions for which an ForeCost report will be generated. Target conditions include stocking levels (trees per acre, basal area, and stand age) as well as stand origin. The specified target conditions are more influential on the final results than the state in which the plot is located; these results are largely extensible to other similar forests within the region.

This information is used to select a USFS Forest Inventory and Analysis (FIA) plot similar to the specified conditions. This FIA plot serves as the basis for a simulated stem map of a 150-acre forest, with species distributions, size distributions, and spacing resembling the selected FIA plot.

Cruise protocols

ForeCost reports currently facilitate comparison of up to three cruise protocols—variable radius plots using BAF 10 and BAF 20, and a 1/10th acre fixed radius plot. Cruise intensities of one plot per 5 acres, one plot per 10 acres, or both can also be compared. An ForeCost report also includes a comparison of SilviaTerra's CruiseBoost technology paired with each unique cruise protocol. Each cruise is repeated for a specified number of replications, with the location of plot centers shifted in each replication.

In addition to select the sampling methodology, individual components of plot measurement protocols can also be defined by the user. The time to make each

measurement is estimated from internal SilviaTerra data, and generalized by region and forest type. The cost of an inventory is determined based on the estimated time to sample each plot multiplied by an hourly rate, plus a base cost that is also user-determined.

The cruise components that can be specified include:

- Walking Speed (mph, defaults to 1.5 miles per hour, or 40 minutes per mile)
- Number of Recorded Heights per Plot (defaults to 2)
- Percent of Grades Recorded (defaults to 100%, or grade on all trees)
- Number of Increment Cores Taken per Plot (defaults to 0)
- Time for high-precision GPS reading (defaults to yes, adds 1 minute to plot time)
- Hourly Rate (defaults to \$30 per hour)
- Fixed Travel Costs (defaults to \$250)

Management

The US Forest Service Forest Vegetation Simulator was used to project stand growth based on user-defined management scenarios. FVS is an individual-tree growth and yield model. Region-specific variants of FVS exist for all of the United States, making it a flexible choice for this tool. Any consistent growth and yield model could be used, however, because the relative valuations are of greater interest than specific values of growth and yield.

Valuation

Stumpage prices and product rules are specifiable by the user, but must follow the broad product breaks which are built into the FVS variant for the region. The prices and rules can be set for individual species, species groups, or for all stems of a certain size. If no values are provided then defaults of \$30.99 for hardwood sawtimber, \$25.60 for softwood sawtimber, and \$10 for all pulpwood will be used. The ability to set prices allows the user to compare the change in relative value of

different sampling methods and decisions under different current or future markets, by running the ForeCost analysis changing only the stumpage prices for one or more products.

Details of Simulation

Simulating forest structure

The simulated forest stem map was created using a marked point process, with spatial pattern models fit using the FIA plot stem map. The diameters for the simulated forest are sampled from a Gaussian (normal) distribution with mean and standard deviation computed from the FIA plot. Species are assigned to each mapped stem using a model predicting species from diameter, with additional rare species added proportionally to ensure complete representation of the species distribution recorded in the FIA plot.

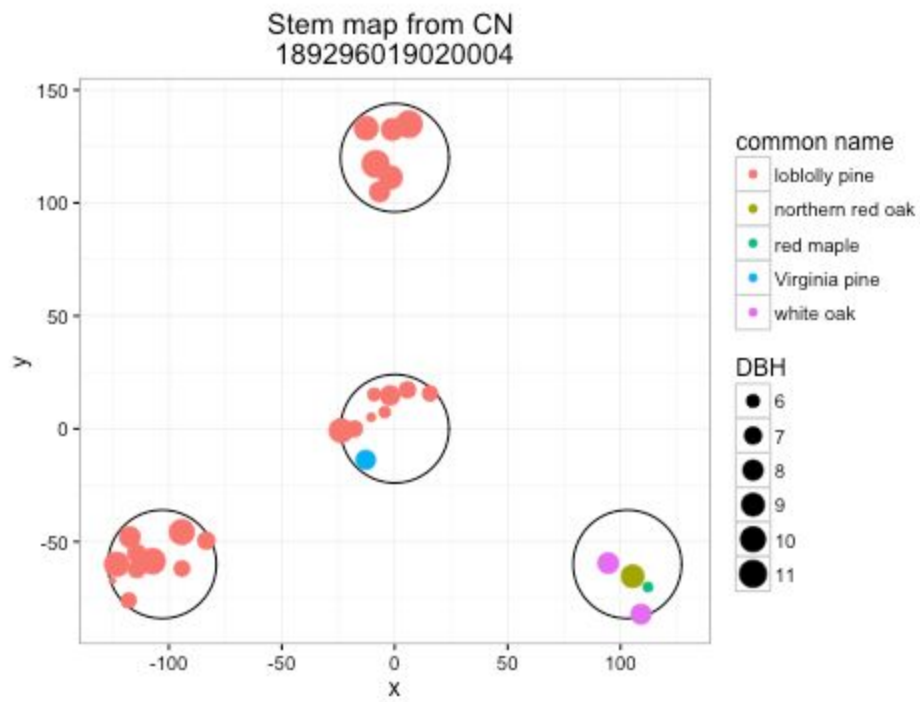


Figure A1: Example of stem map built from USFS FIA plot data.

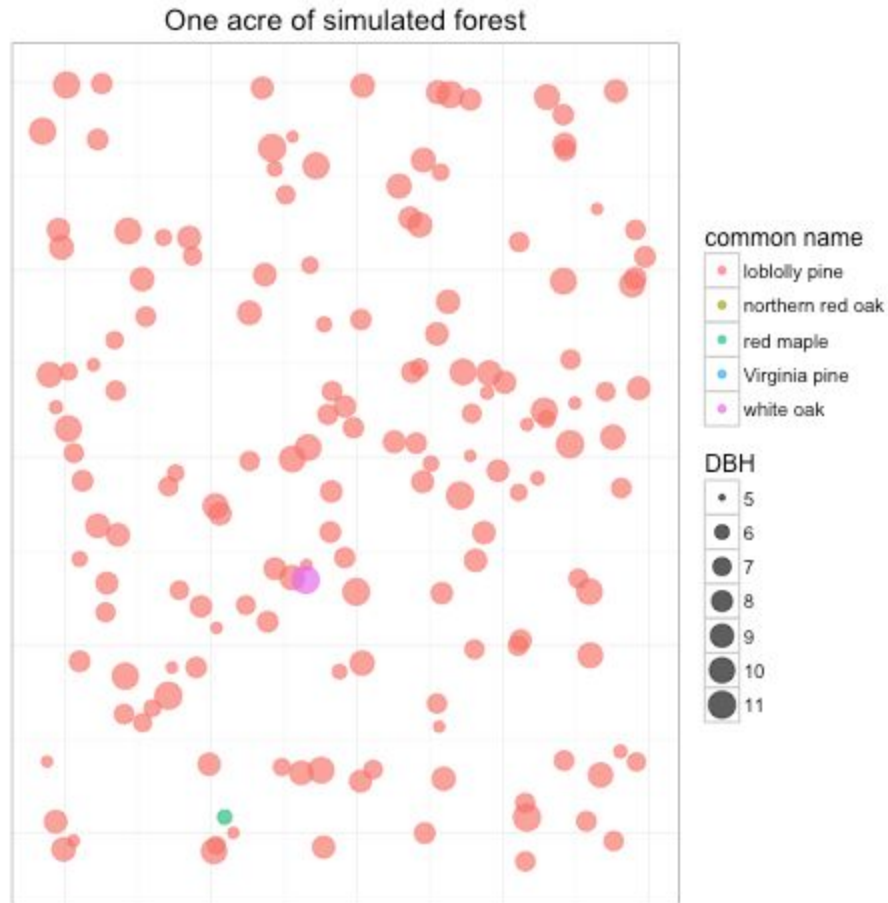


Figure A2: Portion of simulated forest stem map.

Plot measurement

Plots are laid out on an evenly spaced grid throughout the stand, based on the specified intensity for the cruise. Plot locations are then 'jittered'- shifted slightly along the x and y-axes - so that each replication of a given cruise methodology results in a different sample from the simulated forest. Figure A3 (below) shows the location of plots from 5 replications of a cruise.



Figure A3: Simulated plot locations for five cruises.

The stems sampled from a given plot are determined based on the simulated plot type. For a fixed radius plots, sampled stems are those that fall within the specified radius. For a simulated variable radius plot, the limiting distance for each stem close to the plot center is calculated using the specified basal area factor, and used to determine which stems are sampled from that plot center.

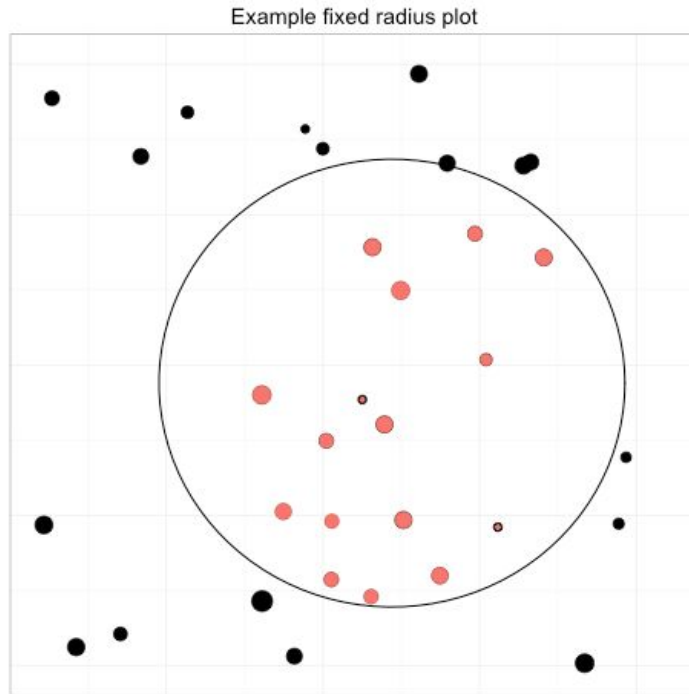


Figure A4: Simulated fixed radius plot location and sample trees (red indicates 'in' trees).

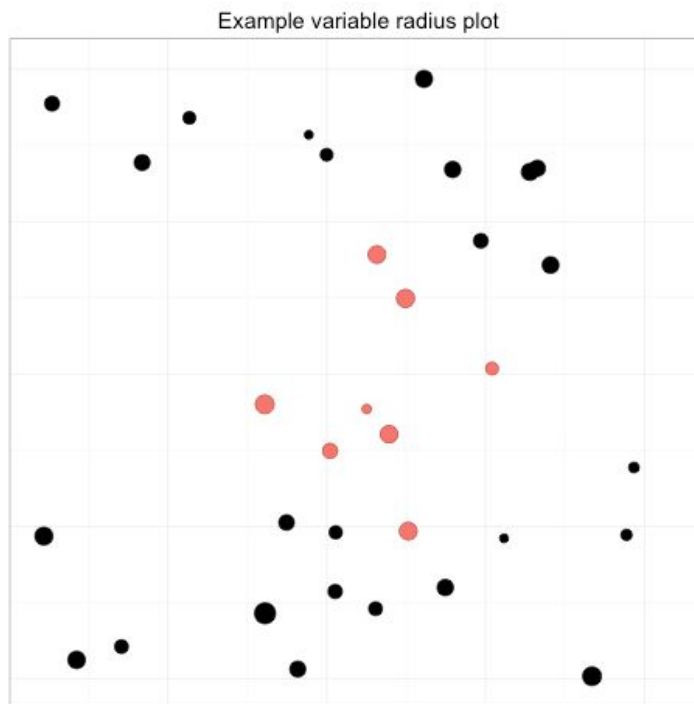


Figure A5: Simulated variable radius plot location and sample trees (red indicates 'in' trees).

Worked example

A worked example of the calculations and comparisons used are shown in the following sequence of tables. The first table shows partial results of two replications of one sampling approach. Note that the two samples result in different stocking estimates for the stand, which in turn influences the calculations of value generated by each management approach.

Table A1. Sampling results.

Replication	Sampling approach	Sample basal area	Management	Year	Total estimated value (\$/acre)
1	BAF 10; 1 plot per 5 acres	117 ± 8 ft ²	Thin to 80 ft ²	3	\$1301
1	BAF 10; 1 plot per 5 acres	117 ± 8 ft ²	Thin to 80 ft ²	5	\$1343
2	BAF 10; 1 plot per 5 acres	124 ± 12 ft ²	Thin to 80 ft ²	3	\$1325
2	BAF 10; 1 plot per 5 acres	124 ± 12 ft ²	Thin to 80 ft ²	5	\$1315

The stem map for the entire simulated stand is also grown forward and the value of each possible management scenario is calculated and compared. This represents

the 'true' potential for the stand. From the valuation of the stem map, we calculate both the maximum value possible for the stand, and the true value realized from each alternative management approach.

From this the expected loss of each management approach can also be calculated- expected loss being the difference between the maximum value attainable from the stand, and the value of selecting other management approaches.

Table A2. Census growth

Inventory	Year	Total estimated value (\$/acre)	Expected loss from management decision (\$/acre)
Thin to 80 ft2	3	\$1290	\$75
Thin to 80 ft2	5	\$1365	\$0

These values are used together with the management approaches selected from each inventory replication to determine the expected loss for each replication and methodology (Table A3) and the average cost and loss associated with each inventory methodology (Table A4).

Table A3. Calculation of expected loss

Replication	Sampling method	Selected management approach	Optimal management decision from census	Realized value (\$/acre) from census for selected management	Expected loss from management decision (\$/acre)
1	BAF 10; 1	Thin to 80	\$1365	\$1365	\$0

	plot per 5 acres	ft2, Year 3			
2	BAF 10; 1 plot per 5 acres	Thin to 80 ft2, Year 5	\$1365	\$1290	\$75

Table A4. Final comparison of sampling approaches

Sampling approach	Total Replications	Average cost to inventory (\$/acre)	Average expected loss (\$/acre)
BAF 10; 1 plot per 5 acres	10	\$3.25	\$11
BAF 20; 1 plot per 5 acres	10	\$2.65	\$72

Further Reading

Additional information about cost-plus-loss analysis and forest inventory precision and efficiency can be found in:

Borders, B. E., Harrison, W. M., Clutter, Shiver, B. D. and R.A. Souter. 2008. The Value of Timber Inventory Information. *Can. J. For. Res.* 38: 2287-2294.

Lund, H. G. and C.E. Thomas. 1989. A primer on stand and forest inventory designs. Gen. Tech. Rep. WO-54. Washington, DC: U.S. Department of Agriculture Forest Service. 96 p.

