

P-3-P VARIABLE PLOT CHECK CRUISE PROCEDURE

By [Dr Kim Iles](#) and [Ken Lucas](#),
with field work contributed by [Doug Maxey](#)

December, 2003

This is a rough draft

The purpose of this paper is to present an alternative method to conventional check cruising. This paper attempts to offer a variant of P-3-P, the sample method originally suggested by Lew Grosenbaugh and explained in Dr. Iles's book, "[A Sampler of Inventory Topics](#)", as a method to check an experienced timber cruiser's field-work.

The conventional way of checking cruises, which is commonly employed by government agencies and some large timber companies, attempts to verify the exact tree measurements taken previously on a cruise plot by the original cruiser.

Advantage: makes it easier to identify specific tree measurement problems, which could be leading to volume error. We feel that this method should still be employed when attempting to train new cruisers.

Disadvantages:

1. Requires an unacceptable amount of time, because of the need to-
 - 1) Match the original cruiser's plot tree list measurements exactly to the trees on-plot in the field. Some time can be wasted trying to figure out which measurements go with which trees; to re-create the original cruiser's moves on-plot.
 - 2) Double or triple-check measurements that could cause the original cruiser to receive an error penalty. Individual tree measurements can vary greatly among different cruisers, due to unusual tree or ground conditions; these conditions can result in a lot of "inconclusive" quality check results. This amounts to wasted time and frustration for the check cruiser.
2. In the event that we find quality control problems using this method, the only way to "fix" the sub-standard plot work is to force the cruiser, or his company, to redo all of the plots; a time consuming and costly effort that is rarely done. In many cases, all of the original cruiser's work is simply dumped and another cruise effort is made. Costs in money, time, and loss of credibility can be significant.

Our suggested P-3-P method. We are essentially proposing to make a re-cruise of the ground, using the same plot centers as the original cruise.

Since time is limited and our cruise can only be done on a percentage of the original plots, we require an **unbiased method** that will select some of the original cruiser's plots to use as sample plots.

3-P, which is "Probability Proportional to Prediction", is a method that can be used to make unbiased selections of samples for any population.

3-Ps advantage is its ability to make a weighted, but still unbiased, selection of a few individuals in a population. Estimates must first be made for all individuals in a population and then careful measurements taken on those individuals selected by the 3-P method. We can then compare the estimate answer with the sample answer to calculate an **error ratio**, which we can evaluate and even use later to correct all of the original individual estimates.

We can use 3-P at many levels in timber cruising, including the tree, plot, and polygon levels. When we use 3-P to make selections at the plot level or above, we call it Point-3-P. The goal of any sampling effort, including timber cruising, is to take enough samples to insure our cruise figures are acceptably close to the real figures. We should strive for low sampling errors (SE's) when we calculate our sample statistics, which indicate that we took enough samples to have a level of confidence in a our figures.

We've found that for P-3-P to help us get low sampling errors, the estimates have to be fairly close to the measured samples. Therefore, we prefer to make our P-3-P selections on the **tree counts** made on every plot when employing the variable plot cruising method; since most experienced cruisers can make very accurate tree counts, using a prism or relaskop.

We've also found that most tree count mistakes will tend to occur on the higher count plots, so we want our 3-P program to weight the higher count plots more for selection.

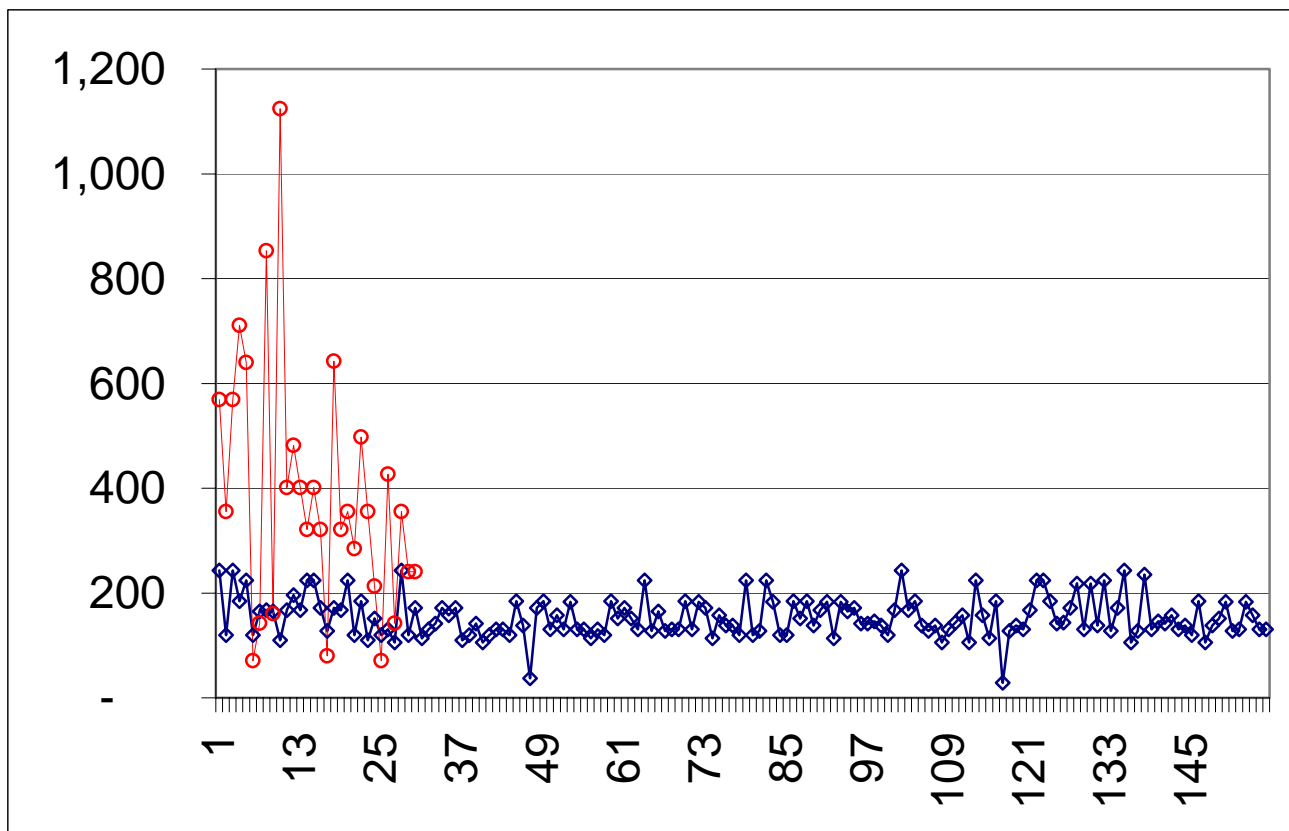
Since it is rarely feasible to take measurements in a timber cruise to precise levels, we need to recognize that a cruiser needs the flexibility to make estimates and judgments when taking cruise measurements. We should only be interested in weather the sum of a cruiser's measurements "balance out" during a cruise and get us an accurate cruise volume. Rather than wasting time trying to judge each one of an original cruiser's measurements, we should examine a number of his **final cruise volumes** to judge his overall accuracy. To check a cruiser's overall accuracy, we need to evaluate the two types of measurements that made up his variable plot cruise:

1. **V-BAR**, volume to basal area ratio. This is calculated from the full tree measurements taken during the cruise, including species, DBH, form factor, and bole height. Since we also want to judge how accurate the cruiser's log

sort/grade estimates are, along with the V-BAR measurements, we need to use **\$value as the unit of measurement** to judge his work. It's not enough to get an accurate stand volume, the original cruiser needs to be close on the \$value as well.

2. **Basal Area.** In the event that the original cruiser's \$value is off, we can use this second type of measurement to determine if the error is, possibly, the result of a poor effort in determining "in/out" trees on the plots.

The following graph was done on data collected from a variable plot cruise with 30 plots and clearly illustrates basal area being way more variable in the cruise; which means that basal area has a much greater effect on the accuracy of a cruise than V-BAR.



Notice the extreme "peaks" and "valleys" on the red graph (the different basal areas, or tree counts, graphed for all 30 plots). Major variability from plot to plot. Now notice how relatively stable the blue graph (the average V-BAR of each plot). The combined standard error was calculated using "Bruce's equation. The combined SE is 11.1%. Notice something interesting when we break the SE down:

V-BAR Standard Error= 2%

Basal Area Standard Error= 9%

The basal area is clearly contributing way more error to the cruise than the V-BAR (full tree measurements). These data results indicate that we need to be more concerned about cruiser error resulting from poor plot tree counts.

Since manpower and time for check cruising is often very limited, we'd like the flexibility to take samples whenever its possible, or convenient for us and "bank" these samples for such a period of time until we have enough samples for a statistically-supported judgment of an original cruiser's work. Therefore, a **check cruise period** needs to be designated at the outset of a check cruise effort. We should decide the length of our check cruise period on factors such as how many sample plots we could complete in a week, the end of a cruise contract, etc....

Our P-3-P method:

Disadvantage: not effective if trying to train new cruisers, who require correction of poor tree measurement techniques. The most effective method for correcting new cruisers is "hot" checking; staying one or two plots behind them and correcting their error as soon as possible after it is noticed.

Advantages:

1. saves considerable time, otherwise spent trying to exactly verify the original cruiser's work on plot; much of which could be wasted getting inconclusive results.
2. **The error ratio, later calculated, can be used to "correct" all of the original cruiser's plots done during the check cruise period; instead of having to throw the data out for the poor work and redoing it.**
3. Permits the calculation of a check cruise sampling error that can give all parties involved confidence that enough P-3-P samples were done to constitute a "fair" check of the original cruiser, should a penalty need to be assessed later.

Which ever check cruise method is used, tree measurement data collected during the check cruise effort should be added to the original cruise file to improve the accuracy of the final cruise report.

P-3-P check cruise procedure.

We've developed this procedure to be used with the Atterbury SuperAce cruise compiler, but any cruise compiler will work if it can generate the following cruise reports:

1. the original cruiser's plot measurements, with all data entry errors corrected for all plots done. We'll refer to this report as a "plot tree list". The report should indicate the BAF used on each plot, as well as which plots were "half plots".
2. Net volume for each plot done by the original cruiser. Some compilers may not report volume per plot.

Initial office work:

Since basal area(tree counts) contributes way more variability to a cruise than V-BAR(full tree measurements), we want the P-3-P program to make an unbiased selection of the higher count plots; which we feel have a greater chance for tree count error, due to the screening effect of the closer trees.

Any 3-P program should work for this method; it does not even have to be installed on a hand-held data collector, since the selection takes place in the office.

Determining the approximate amount of samples to set the 3-P program to select should be decided by how many plots you estimate you can find and re-cruise in a single work session; such as 6 hours, not including travel and office time. If the original cruiser used a 2-chain plot spacing, you should be able to find, and complete the work for, 1.5 sample plots per hour. So, for a 6-hour work session you could reasonably expect to complete 9 sample plots. If you have less time available for the work session then set the program to select less plots. Since finding the old plots in the field is the greatest challenge in check cruising, we recommend you set the 3-P program to **select triple** the amount of plots you have time to sample, or in this case, 27(assuming there were that many plots done in the cruise unit).

Procedure for setting up and doing the P-3-P selection:

1. Sum the tree counts for all of the plots done by the original cruiser in the cruise unit (get these tree counts from the plot tree list). This tree count sum becomes the 3-P SumKPI figure.
2. Calculate the 3-P selection trigger, known as the KZ, with the formula- $\text{SumKPI} / (3 * (\text{the approximate number plots you have time to sample in the cruise unit}) * \text{the average tree count per plot [get this figure from one of the reports offered by the cruise compiler]}) = \text{KZ}$
3. Enter the KZ into the 3-P program.
4. Begin entering total tree counts for each original cruiser plot; these become the 3-P KPI figures. When the program selects a plot, use a simple random number generator, such as a 6-sided die roll. On a die roll of 1-4 the plot should be designated an "insurance" plot. On a die roll of 5 or 6 the plot should be designated as primary sample plot. Write these selected plots

down immediately, as most 3-P programs are “live”, that is the formerly selected plots change as more KPIs are entered.

In the field:

Insure that you take a copy of the original cruiser’s plot tree list, so that you can use the same BAF, identify which trees he did full measures on, and note any half-plots. Since there are several ways to do half plots, you need to know and use the same procedure the original cruiser used. If a reasonable effort to locate a selected plot fails, proceed with looking for an insurance plot nearby from the P-3-P list of selected plots. Once on the selected plots-

1. check the tree count, including doing **complete limiting distance checks**, as necessary for all trees in the vicinity of the plot.
2. Re-estimate form factor and measure DBH, log sort, & bole heights for all of the full tree measures done by the original cruiser on each sample plot.

Complete as many sample plots as your field time allows. Since we’re intending to evaluate a cruiser’s work over a period of time, it’s less critical to complete a lot of sample plots in a specific work session.

Back in the office.

Do the calculations for the \$value check:

1. Calculate the dollar value per acre for each sample plot, using the **data** just collected **from the check cruise** with the formula-
((full tree measure net volume/1000) * \$ value of tree specie[\$value per MBF]) / basal area of the full tree measure= **\$BAR** or “\$ value-basal area ratio”.
2. Repeat this formula calculation for each full tree measure done on the sample plot.
3. Average all of the \$BARs on the plot.
4. Calculate the average dollar value per acre, using the formula-
Ave \$BAR * tree count on plot * BAF used on plot =
Ave \$Value per acre
5. Calculate the dollar value per acre for each sample plot, using **the original cruiser’s data** from the **actual sample plots only** with the formula-
((full tree measure net volume/1000) * \$ value of tree specie) / basal area of the full tree measure= **\$BAR** or “\$ value-basal area ratio”.
6. Repeat this formula calculation for each full tree measure done on the plot.

7. Average all of the \$BARs on the plot.
8. Calculate the average dollar value per acre with the formula-

$$\text{Ave \$BAR} * \text{tree count on plot} * \text{BAF used on plot} =$$
Ave \$Value per acre
9. Calculate the original cruiser's value for each of the cruise units that check cruise samples were completed in with the formula-

$$\text{Ave \$Value per Acre} * \text{unit acreage} = \text{\$value of the cruise unit}$$
10. Calculate the error ratio for **each sample plot** with the formula-

$$\text{Ave \$value per acre check cruise} / \text{Ave \$value per acre original cruiser} =$$
the error ratio
11. Average all of the error ratios available for the check cruise period to get an **overall average error**.
12. Determine the overall dollar value error with the formula-

$$\text{Average overall error} * (\text{sum of the \$values of all of the units [get these figures from step \#9] cruised by the original cruiser in the check cruise period}) =$$
the \$value error incurred by the original cruiser
13. Calculate a **sampling error** for the check cruise effort by doing statistical calculations, using all of the error ratios collected during the check cruise period and an appropriate "t" value.

Do the calculations for the basal area check:

1. Maintain a running total of all trees counted "in" on all plots **actually sampled** during the check cruise period. Calculate the tree count error with the formula-

$$\text{Total check cruiser tree count} / \text{Total original cruiser tree count} =$$
tree count error
2. Calculate the tree count difference with the formula-

$$\text{check cruiser total tree count} - \text{original cruiser tree count} =$$
tree count difference
3. Calculate the weighted average, by acres, of the V-BARs for all of the units cruised by the original cruiser during the check cruise period.
4. Calculate the weighted average, by acres, of the BAFs used by the original cruiser for all of the units cruised by him during the check cruise period.
5. Calculate the amount of gross volume the original cruiser is off by with the formula-

$$\text{tree count difference} * \text{average BAF} * \text{average V-BAR} =$$
original cruiser gross volume error.

The step #5 formula assumes an average cruise spacing of 1 plot per acre. If the plot spacing is different, then calculate the correct multiplier with the formula-

$$\text{Plot Spacing}^2 / 43,560 = \text{acres per plot multiplier}$$

Example- plot spacing of 330' = 2.5 acres per plot.

Multiply the gross volume error figure from step #5 by the acres per plot multiplier to get the original cruiser gross volume error.

At this point a judgment needs to be made about what is **reasonable error**. Evaluate both the \$value and basal area errors; if one, or both of these checks have an error deemed unacceptable, then the original cruise plot volumes for **all of the plots** done by the cruiser during the check period should be adjusted by a correction multiplier. You could use the unmodified \$Value or basal area % error as a correction multiplier, you could weight the average of the errors from the 2 checks, or just “split the difference” and use just half of the error. In any case, correcting the original plot volumes will tend to move the figures closer to the actual figures. A contract penalty could be also be assessed, possibly based on a percentage of the \$value or basal area that the original cruiser is off by.

Following is a test we did using a slightly different P-3-P selection procedure on an actual 16-acre timber stand.

Test Procedure:

- We selected a previously cruised harvest plan unit that was in the process of being logged, because there were doubts by the loggers that the original cruise volume was accurate. The quality of the original cruise was one of several issues, one of which was an accurate acreage determination for the unit, that had to be examined to fully address the concerns. The unit was about 1/3 logged at the time of the test. 16 cruise plots had originally been done, using a ratio of cruise one / take DBHs only on two. 8 of the original plots had been logged through by the time of the test.
- The cruise had been originally compiled on the Atterbury SuperAce cruise compiler. We entered the **net volume per acre** data from the Ace original cruise plot tree list-volumes report as estimate values into a 3-P program to select specific plots for re-measure. We set our 3-P program to select approximately 10 plots to sample, because we were not sure how many of the original plots had been logged and how many we would be able to locate in the field. The 3-P program selected 7 plots for sampling. This 3-P selection step would always be done in the office and a list generated showing which plots to visit during the field phase, along with back-up insurance plots.
- We could not locate 2 of the 7 selected plots in the field. We were able

to sample 5 of the original plots, including 4 that were DBH-only and 1 where full measurements had been taken on all of the trees. Doug Maxey and Ken Lucas worked together to make it easier to find the plots.

- At each plot we took full measurements of all trees determined to be “in” on the plot, using the same BAF as the original cruise. Limiting distance checks were done as necessary. In a few cases we did not take bole heights, as we could not clearly see the bole height top.
- We then followed the procedures explained earlier to calculate the \$Value and basal area error ratios.

• **Our \$Value Check.**

We’ve tabulated the Net Volume and \$Value per acre figures for both the check and original cruises for the 5 sample plots:

Plot	Plot Type	Original Volume	Check Volume	Volume Error Ratio	Orig \$ Value/Ac	Check \$ Value/Ac	Value Error Ratio
14	DBH Only	124,523	115,627	0.929	105,897	98,133	0.93
19	DBH Only	197,233	140,901	0.714	167,520	125,769	0.75
20	DBH Only	157,125	166,292	1.058	133,425	155,567	1.17
25	DBH Only	52,800	61,711	1.169	44,965	57,767	1.28
18	Full Meas.	79,725	84,270	1.057	82,004	84,885	1.04
	Averages=	115,273	113,760	0.985	106,762	104,424	1.03
	Standard Deviation=	54,139	42,067	0.174	45,111	37,648	0.232
	Standard Error=	12	17	8	11	16	9

As expected, the check cruise has a significantly higher SE than the original 16-plot cruise, since the check cruise is based on only 5 plots. We can get a better idea of the accuracy of original cruise \$Value per acre figure if we make a combined statistical calculation, using “bruce’s equation” as specified in Dr. Kim Iles book, “**A Sampler of Inventory Topics**”-

$$\text{Square Root of } ((\text{original cruise SE})^2 + (\text{check cruise error ratio SE})^2)$$

The Original \$Value per Acre, **if corrected by the check cruise**, will have a Standard Error= 14%. The 14% standard error means that we are predicting an **error** of 14% for the corrected original \$Value figure; there is a 68% chance that the **actual** \$Value figure is within 14% of the corrected figure and a 32% chance that actual \$Value off more than 14% of the corrected figure. So the actual average \$Value per acre for this unit is probably \$106,762, plus or minus \$9,609.

- **Our basal area check.**

We noted the following plot count discrepancies: On plot #19, the original cruiser had one less tree “in” on the plot than the check count and on plot # 14 the original cruiser had one extra tree “in” on the plot than the check count. Both of the plots where the tree counts were off had 8 or more “in” trees on them; this confirms the need for a 3-P selection that weights the higher count plots. Not surprisingly, for this small amount of sample plots, the tree counts balanced to 0.

Summary points.

- The 3% difference in the \$value between the original and the check cruise error alone does not tell us how much of the error is due to the original cruiser and how much is due to how the cruise compiler, SuperAce, calculates volumes per plot with a significant amount of DBH-only measurements in the cruise file. In order to complete our evaluation of the original cruise error, it would be helpful to know the accuracy of the compiler to calculate volumes, using a cruise data set file that includes a significant amount of “DBH-only” trees/plots. We could then isolate this cruise compiler error from our calculated check cruise error with the formula-

Cruise error – compiler error = actual cruise error.

We did some research and made some calculations to compute a rough SuperAce “DBH-only compilation error of 4%. So, since the our check cruise showed only a 3% error and the cruise compiler could be responsible for up to 4%, we can conclude, with the data from sample plots we got, that-

1. That the original cruise is acceptably accurate.
2. There is no way to confirm that we would not be moving the original \$Value further away from the actual figure by using a correction ratio.

So, we can, with confidence, let the original cruiser “off the hook”; this time...

- If it would have been possible to have a check cruiser on-site to measure all of the felled and bucked trees on some of the sample plots for this unit, we could have calculated a much more accurate \$Value per acre with the formula-

original cruise \$Value per acre * the check cruise error ratio * the average F & B Ratio (check cruise \$Value per acre / F & B \$Value per acre)=

The more corrected \$Value per plot

- We'd ideally like to do enough sample plots to gain a combined SE of less than 5. To determine how effective our method might be over a month period, we extrapolated, using some production assumptions and the statistics from our example check cruise. We used the STAR_BAR program from Dr Iles book, "A Sampler of Inventory Topics", to calculate the combined SE, if we used the same CVs from our example check cruise for a hypothetical one-month check cruise period. The assumptions for this problem are:

- The original cruiser does 18 plots per day for 20 days = 360 plots done during the check cruise period.
- A single check cruiser has time to do at least one field session per week and can complete an average of 9 plots per field session, including office and travel time= 36 sample plots completed during the period.

The "STAR_BAR" program calculated a very acceptable **4.4% SE** for this effort.

With an investment of 4-man days of check cruise effort per month, using this 3-P method; we could maintain unbiased, statistically-based quality control for one experienced cruiser. So, a single dedicated check cruiser could, theoretically, maintain **adequate quality control** for up to 5 cruisers at once.