CRUISE DESIGN AND LAYOUT

Sample plots or points can be installed in a forest either randomly or systematically. Random location is just that: plots or points are placed in the forest in a completely random fashion. Modern GIS is particularly well suited to do this. This is the best method, statistically speaking, but it can cost more to install random plots because travel costs between plot/point centers is typically higher than with systematic samples. In a systematic sample, plots/points are located at fixed intervals along lines that are arranged in some type of square or rectangular grid pattern. Systematic samples run the risk of being biased if they somehow pick up periodic variation in the sample (e.g., run parallel to rows in a plantation). To minimize this possibility of bias, these transects, or “cruise lines”, should be run perpendicular to any variability gradients (e.g., creeks, ridges, valleys) in the stand. The lines should be anchored to a “baseline” (e.g., road, fence, property boundary, etc.) with a starting point that can be easily located in the field. The starting point can be randomly located to ensure that some level of randomness is met (this is a systematic sample with a random start), or it can be located systematically at some fraction of the sampling grid. Foresters mostly prefer a systematic sample over a random sample, but they will often use a random starting point to add some randomness to the sample. This will often result in a more precise confidence interval than a random sample. A systematic sample also ensures that the sample is collected evenly across the stand. Random samples can possibly be clumped, which can result in large gaps of the stand that are not sampled.

Once you decide on a sampling method, you next need to calculate the number of plots or points needed to reach your statistical objective. A statistical objective defines the level of confidence you have that your sample estimates the true population value within some acceptable bounds on
error. For example, calculate the number of plots needed to be 95 percent confident that we are within 15 percent of the true tons per acre. The simple random sample formula can be used to determine the sample size necessary to achieve this statistical objective:

Given: $CV_{\text{Tons/A}} = 35\%$

Then: 

$$n = \frac{t^2 \cdot CV^2}{A^2} = \frac{2^2 \cdot 35^2}{15^2} \approx 22 \text{ plots}$$

An estimate of CV for the variable of interest is needed to make this calculation. CV can be found in a preliminary cruise, historical records of prior cruises, a cruise of a similar stand, or best professional judgment from an experienced cruiser. The next step is to locate these plots on the stand map.

**How to systematically locate plot centers along cruise lines**

1.) **Obtain a scaled map of your stand.**

2.) **Determine the number of acres per square inch from the map scale.**

   For example, if your map scale is: 4 inches = 1 mile, then

   $$16 \text{ in}^2 = 1 \text{ square mile} = 1 \text{ section} = 640 \text{ acres}$$

   $$1 \text{ in}^2 = 640 \text{ acres} / 16 \text{ in}^2 = 40 \text{ acres}$$

3.) **Using a dot grid, determine the number of acres in your stand.**

   A dot grid is a transparency that has a grid of dots. You lay the dot grid over a map of your stand and count the number of dots falling within the stand’s boundary. Since a dot grid has a known number of dots per square inch, you can use the conversion created in Step 2 to determine the acreage of your stand. Continuing with our example, if we counted 128 dots on our dot grid (with a grid size = 64 dots/in$^2$), then the stand’s acreage is: 128 dots / 64 dots per in$^2$ = 2 in$^2$ * 40 acres per in$^2$ = **80 acres**. There are other ways to determine stand acreage (such as GIS or a
planimeter), but we will only cover the dot grid in this lecture. Dot grids are easy to use and adequate for placement of sample plots/points in a stand.

4.) **Determine the grid spacing for your plot centers.**

Now, you want to determine the grid for your cruise lines and plot centers. In our example, the stand size is 80 acres and the number of plots needed is 22. We also know that 1 chain = 66 feet and 10 square chains = 1 acre. So,

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\text{Acres per plot} = \frac{80 \text{ acres}}{22 \text{ plots}} = 3.6 \text{ or } 4 \text{ acres per plot.}
\]

\[
4 \text{ acres / plot} \times 10 \text{ square chains / acre} = 40 \text{ square chains per plot.}
\]

This translates to a 6 x 6 or 7 x 6 chain grid; both grids are approximately 40 square chains. You would arrange this grid of plots on the map of your stand. You would then have cruise lines to follow in the field using either compass and pacing, or a GPS. I recommend that you know your pace and how to use a compass in the event that your GPS fails in the field.

**OTHER CONSIDERATIONS**

**BOUNDARY PROBLEM**

How do you handle plots that fall on the stand boundary? We will consider two methods to handle this problem:

1.) **Mirage Technique**: When the plot is not fully contained within the stand boundary, measure the distance to the boundary edge along your cruise line. Measure this same distance outside the stand, continuing on your cruise line, and install another plot center. On this new plot, tally the trees that fall inside the stand. These are the trees that you measured on the original plot; thus, you are tallying them twice (see picture on page 221 of Avery and Burkhart).
2.) If the adjacent stand is similar to your stand, you can move the plot backwards along your cruise line until the plot is fully contained within your stand. This is not recommended if the adjacent stand is drastically different from your stand.

**NESTED PLOT DESIGNS**

Sometimes in a cruise, you have different objectives that require you to measure different sized trees. For example, you might be cruising for a timber sale, plus evaluating the regeneration. In this example, point sampling would adequately sample the large trees but not the small trees. To alleviate this problem, you can use point sampling for the large trees AND a fixed-area plot for the small trees. You would use the same center points and use a diameter break point for tallying trees on the two plots. Nested plots should be considered separately; do NOT double count trees!

Here’s another example of a nested plot design that uses three “plots” to sample trees:

- Large Trees (≥ 6 inch dclass) ⇒ use point sampling
- Small Trees (1 to 5 inch dclass) ⇒ use fixed-area plot (e.g., 1/100th to 1/50th acre circular plot).
- Regeneration (1 foot to 0.5 inch dbh) ⇒ use fixed-area plot (e.g., 1/250th or 1/300th acre circular plot).