## 6.2 Assessing Stands w/ "Plots" (or "Points") as Sample Units

The inventory sample unit most often used to obtain information about parameters of a stand or forest is some sort of sample *plot* centered on a sample *point*

Sample plots can have fixed area, in which sample trees in vicinity of a sample point are selected with constant and equal probability

Sample plots can have variable area, which results in sample trees being selected with *probability proportional to size* (pps)

Sample plots can be defined as an area encompassing the n nearest trees to a sample point, resulting in variable area plots of another sort

### Merits of the "Plot" System

1. Suitable for one-person cruising, though 2 or 3 persons can work efficiently
2. Pausing at each plot center allows more time to check vegetation dimensions, borderline cases, etc.
3. Measurements are separate for each plot, allowing summary by timber or habitat type, stand or compartment sizes, area or condition classes

### The Factor Concept

Inventory results are most useful when they are scaled up from the plot level to a unit area basis (an acre, say) and summarized for the average unit area

Sample measurements are scaled to a per unit area basis using a ratio of unit area to associated sample area:

$$TF_i = \frac{unit\ area}{sample\ area_i}$$

where $TF_i$ denotes the *Tree Factor* (expansion factor) of $i\text{-}th$ sample tree

$unit\ area$ denotes a standard unit of land area (e.g., 43,560 $ft^2$ per acre, or 10,000 $m^2$ per hectare)

$sample\ area_i$ denotes size of sample unit associated with $i\text{-}th$ tree

Any attribute of interest, X, can be thought of as having its own expansion factor (XF)

$$XF_i = TF_i \bullet X_i$$

Scaled up (per unit area) estimates for any attribute on a single plot can be found by summing the expansion factors for that attribute of every tree

$$\begin{aligned}\hat{X}/unit\ area &= XF_1 + XF_2 + XF_3 + \cdots + XF_n \\ &= \sum_{i=1}^{n} XF_i \\ &= \sum_{i=1}^{n} TF_i \bullet X_i\end{aligned}$$

## Fixed-Area Plots

Sampling units of fixed area can be any shape, either square, rectangular, triangular, or circular

Circular plots are most often used due to some advantages:

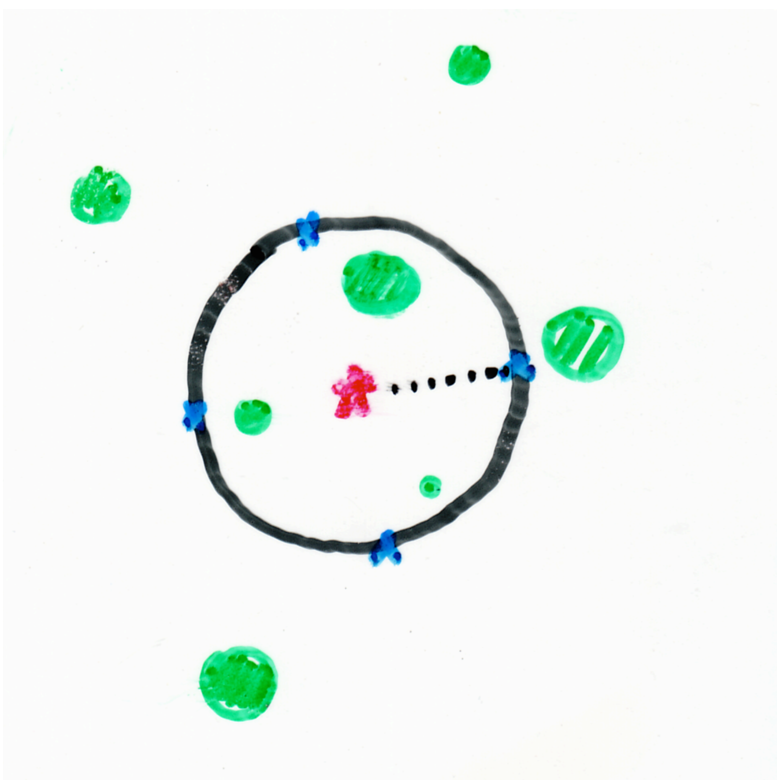
- A circle encloses a given area with minimum perimeter
- A circle has no pre-determined orientation
- Small, circular plots are favored as being most efficient in terms of measurement

Some disadvantages:

- A disadvantage is it is often tempting to “cheat” on measuring plot boundaries to determine if limiting trees are in the plot or out
- circular plots on slopes appear to be ovals when “traced” onto the ground surface, making plot boundary decisions more difficult

Steps to using a circular sample plot

- Choose plot area, determine the radius of a circle corresponding to that area
- Find a representative sample point in the forest
- Flag or otherwise mark plot boundaries at a distance of one radius in the four cardinal directions
- Measure every tree within a distance of one radius of plot center



- Scale up plot data to unit area basis and summarize

## Scaling up Plot data and summarizing

For fixed-area plots, the Tree Factor is constant for each tree, thus

$$\hat{X}/unit\ area = \sum_{i=1}^{n} TF_i \bullet X_i = TF \bullet \sum_{i=1}^{n} X_i$$

The most basic forest stand attributes (parameters) that are most ubiquitously useful are

- Number of trees per unit area (Stand density)
- Stand volume, mass, weight, etc. per unit area (stand Stocking)
- The distribution of density and volume across sizes of trees

## Stand density and its distribution (Stand Table)

The most easily obtainable size measurement on any tree is its DBH

The diameter (DBH) distribution can say much about the structure of the forest stand

The Stand Table provides diameter distribution information in tabular form

Example Total Stand Table

Species and number of stems according to DBH for the 10-inch class and up, for 518 acres of hardwood forest type on a 640-acre tract in northern New York.

(Table 11-3 in Husch, Miller, Beers. 1972)

| Dbh (inches) | Sugar Maple | Beech | Yellow Birch | Hemlock | Red Spruce | Total |
|---|---|---|---|---|---|---|
| 10 | 304 | 1018 | 160 | 15 | 1503 | 3000 |
| 12 | 752 | 1973 | 350 | 47 | 1149 | 4271 |
| 14 | 1279 | 1970 | 446 | 15 | 428 | 4138 |
| 16 | 1602 | 1429 | 461 | 5 | 98 | 3595 |
| 18 | 1662 | 1035 | 430 | | 15 | 3142 |
| 20 | 1148 | 562 | 415 | | | 2125 |
| 22 | 827 | 159 | 498 | | | 1484 |
| 24 | 420 | 77 | 364 | | | 861 |
| 26 | 241 | 21 | 256 | | | 518 |
| 28 | 47 | | 208 | | | 255 |
| 30 | 26 | | 150 | | | 176 |
| 32 | | | 110 | | | 110 |
| 34 | | | 36 | | | 36 |
| 36 | | | 20 | | | 20 |
| 38 | | | 15 | | | 15 |
| Total | 8308 | 8244 | 3919 | 82 | 3193 | 23746 |

Stand volume and its distribution (Stock Table)

The distribution of stand volume over diameter classes refines knowledge of stand structure

Example Average Acre Stock Table.
Data from 20.8 acres of pitch pine type in Central New Hampshire
(After Table 11-3 in Husch, Miller, Beers. 1972)

| | Cubic Feet Per Acre | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| DBH (inches) | Pitch Pine | Balsam Fir | Red Spruce | White Pine | Red Pine | Red Maple | White Birch | Amer. Elm | Total |
| 6 | 17.6 | 2.5 | 5.0 | 3.9 | | 14.5 | 4.3 | | 39.6 |
| 7 | 37.9 | 4.0 | 4.0 | | | 12.9 | | | 67.0 |
| 8 | 27.6 | 22.4 | | | | | | | 50.0 |
| 9 | 25.5 | 20.1 | 13.4 | | | 13.4 | 7.6 | | 80.0 |
| 10 | 60.8 | 18.8 | 18.8 | 27.0 | | 10.6 | | | 136.0 |
| 11 | 40.2 | | 13.3 | 13.3 | | | 14.0 | | 80.8 |
| 12 | 48.0 | 16.4 | | | | | | 14.1 | 78.5 |
| 13 | 61.3 | 17.6 | | | | | | | 78.9 |
| 14 | 17.4 | | | | 18.4 | | | | 35.8 |
| 15 | 21.8 | | | | | | | | 21.8 |
| 16 | 82.3 | | | | | | | 18.1 | 100.4 |
| 17 | | | | | | | | | |
| 18 | 158.8 | | | | | | | | 158.8 |
| 19 | | | | | | | | | |
| 20 | 37.7 | | | | | | | | 37.7 |
| Total | 363.9 | 101.8 | 54.5 | 44.2 | 18.4 | 51.4 | 25.9 | 32.2 | 965.3 |

Important features of fixed-area plot analysis

- Each tree on the plot has a constant Tree Factor, i.e., every tree represents the same number per unit area
- Contribution to stand basal area depends on tree size
- Trees are sampled with probability proportional to frequency of occurrence, therefore, fixed-area plot sampling is optimal for estimating structure such as trees per acre, size distributions (height, diameter or stand tables), etc.

## Choosing fixed area plot size

Effect of plot size on variability (precision)

- large plots are less variable than small, $S^2 = k \bullet P^{-b}$

So, given a plot size of $P_1$, which exhibits variance $S_1^2$, we can calculate the expected variance $S_2^2$, of a new plot size $P_2$.

$$S_1^2 = k \bullet P_1^{-1/2} \qquad \Rightarrow \qquad S_1^2 \bullet P_1^{1/2} = k$$

$$S_2^2 = \left(S_1^2 \bullet P_1^{1/2}\right) P_2^{-1/2}$$

Example. A survey of n = 24 random 1/40-ac plots exhibited a variance of $S_1^2 = 201.39 \ \left(\text{CV4/acre}\right)^2$; we want to find the variance of 1/5-ac plots.

$$S_2^2 = \left(S_1^2 \bullet P_1^{1/2}\right) P_2^{-1/2}$$

$$S_2^2 = (201.39)(0.025)^{1/2}(0.20)^{-1/2} = 71.20$$

## Forest Edge Effects

Trees and vegetation near forest / stand boundaries will likely be different from interior individuals, especially when forest is bordered by non-forest or other land-use classes

Forest edges must be properly represented in the sample, especially if the forest area near the perimeter is a large proportion of the total forest area

Also, plot centers may fall so near the forest / stand edge that a portion of the plot will fall outside the stand

Several methods have been proposed to correct for “edge bias” – none work perfectly

*Plot displacement* – most questionable method, edges are under-represented

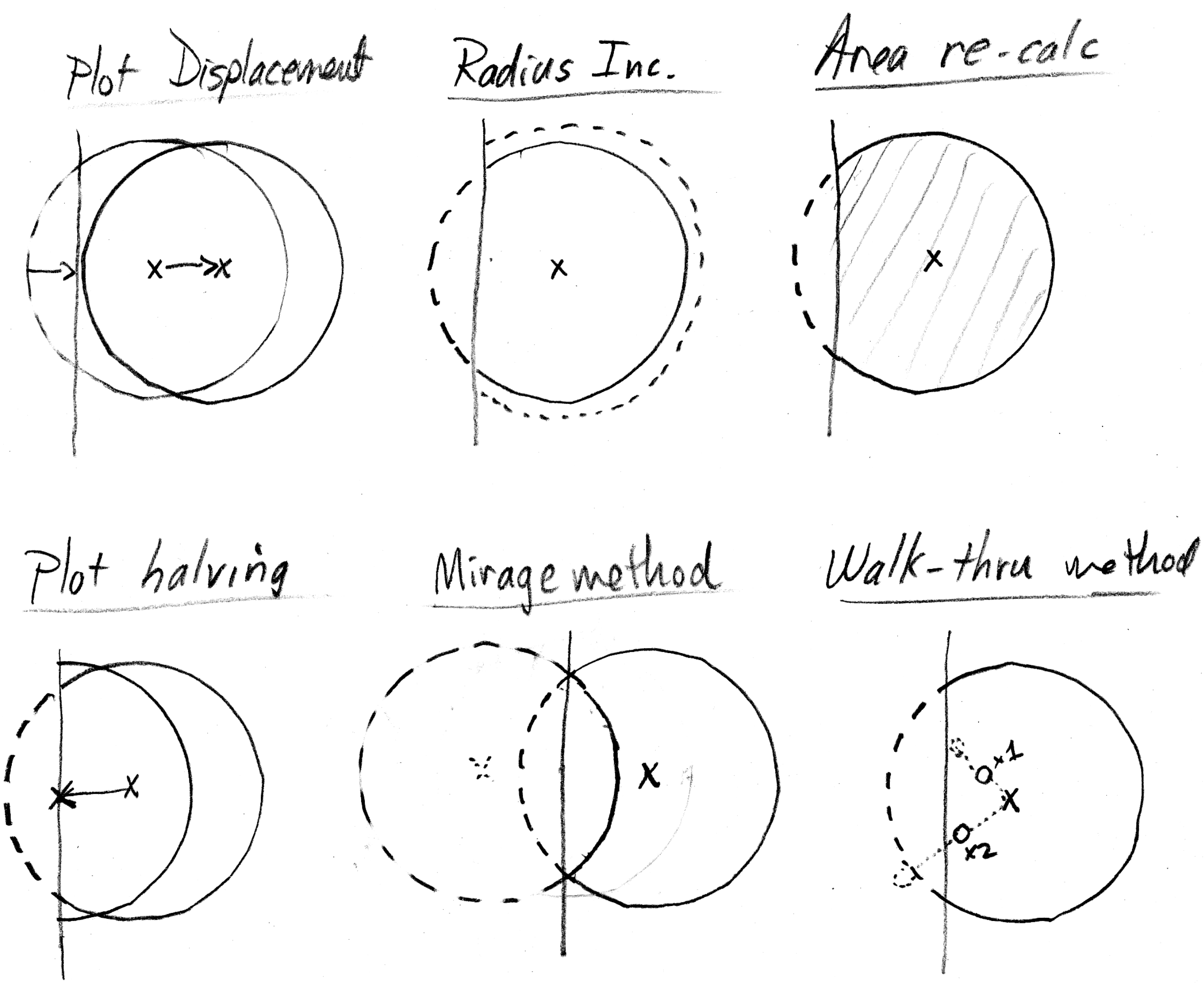
*Plot radius increase* – better than displacement, but edge representation still biased

*Plot area recalculation* – very time consuming, complex; affects variance of estimates

*Plot halving* – places a half-plot against the stand border, over-represents edges

*Mirage method* – plot center is “reflected” over the stand boundary, and vegetation falling inside the reflected plot are counted twice – method is exact only for straight edges

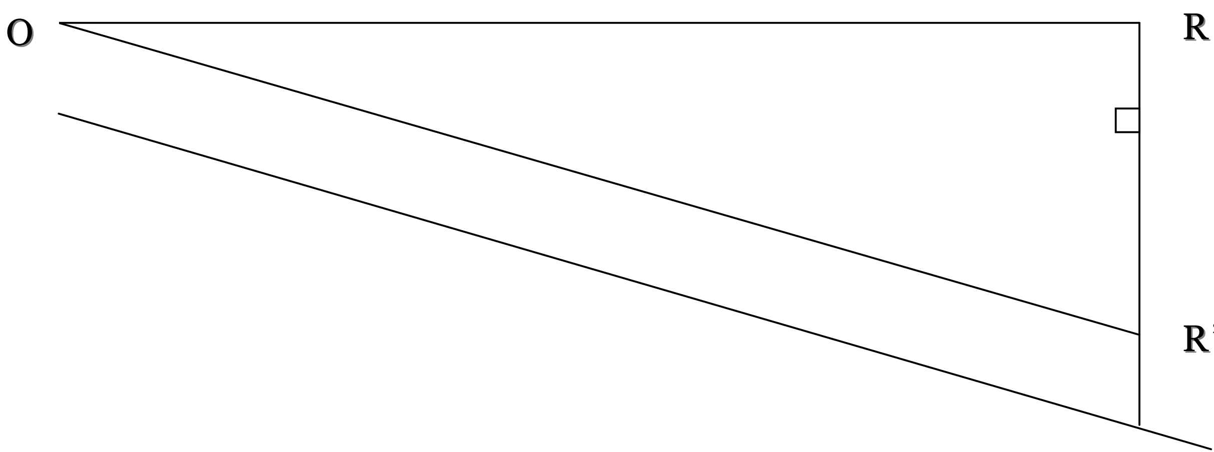
*Walkthrough method* – walk straight from plot center to the center point of the population element, then beyond it an equal distance. If forest edge is encountered before the walk is complete, the element is counted twice. This most closely mimics the mirage method and works in forests of any shape



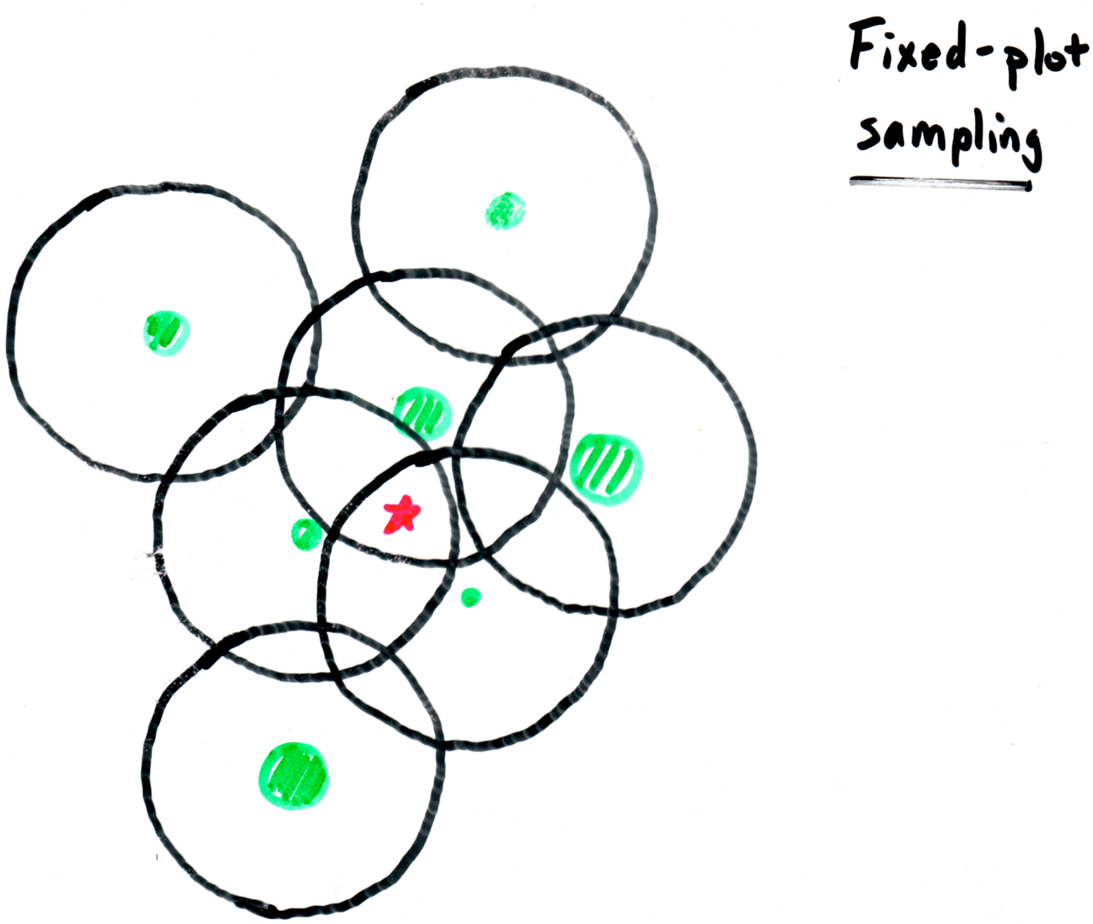
Fixed-area Plot Establishment on Sloping Ground

Measure angle ROR' with clinometer in deg.

$$\frac{OR}{OR'} = \cos(\angle ROR') \quad \Rightarrow \quad \frac{OR}{\cos(\angle ROR')} = OR'$$




Another way to look at fixed-area plots



## Example Fixed-Area plot Summary Calculations

A particular forest was surveyed using 1/40-acre circular plots. An estimate of CV4 per acre with confidence interval and Stand and stock tables. Avg. tarif = 33.6

**Plot 1**

| DBH | CV4 |
|---|---|
| 8 | 9.6 |
| 10 | 16.9 |
| 12 | 25.7 |
| 12 | 25.7 |
| | 77.9 |

**Plot 2**

| DBH | CV4 |
|---|---|
| 8 | 9.6 |
| 8 | 9.6 |
| 10 | 16.9 |
| 14 | 36.1 |
| | 72.2 |

**Plot 3**

| DBH | CV4 |
|---|---|
| 12 | 25.7 |
| 12 | 25.7 |
| 8 | 9.6 |
| | 61.0 |

**Plot 4**

| DBH | CV4 |
|---|---|
| 8 | 9.6 |
| 8 | 9.6 |
| 10 | 16.9 |
| 8 | 9.6 |
| | 45.7 |

let y = CV4 per plot. $n = 4$

$\Sigma y = 256.8$ , $\bar{y} = 64.2$ , $\Sigma y^2 = 17{,}090.74$

$$s_y^2 = \frac{\Sigma y^2 - (\Sigma y)^2/n}{n-1} = 201.39$$

$$s_y = \sqrt{s_y^2} = 14.19$$

presuming four plots is very low intensity we will ignore the f.p.c.

$$s_{\bar{y}} = \frac{s_y}{\sqrt{n}} = 7.10$$

If we desire a 95% confidence interval we'll need $t_{0.05,3} = 3.182$

95% CI: $64.2 \pm (3.182)(7.10) \Rightarrow (53.9, 86.8)$ CV4

PER ACRE:

$40(95\%CI) \Rightarrow (2178.6, 3472.0)$

Unless we're unlucky, true CV4 per acre lies here.

Stand Table Calculations

DBH ranges from 8 to 14 inches

We have seven (7) 8-inch trees on our plots, for a total of 40 x 7 = 280 trees

We have three (3) 10-inch trees, for a total of 40 x 3 = 120 trees

We have four (4) 12-inch trees, for a total of 40 x 4 = 160 trees

We have one (1) 14-inch trees, for a total of 40 x 1 = 40 trees

These are totals for all the representative acres we measured, so we must divide each of these numbers by 4 (number of plots) to arrive at per acre estimates

| DBH | Trees / ac. | Total |
|---|---|---|
| 8 | 70 | 70 |
| 10 | 30 | 30 |
| 12 | 40 | 40 |
| 14 | 10 | 10 |
| Total | 150 | 150 |

The stock table should be derived from the satnd table for consistency. Therefore, with 30 stems per acre in the 10" class and 16.9 CV4 in a single 10" tree, we have 16.9 x 30 = 507 CV4 per acre in 10" trees. Following this process for each DBH-class we derive the stock table as follows:

| DBH-class | CV4 per acre | Total |
|---|---|---|
| 8 | 672 | 672 |
| 10 | 570 | 570 |
| 12 | 1028 | 1028 |
| 14 | 361 | 361 |
| Total | 2568 | 2568 |