

Is This Stand Overstocked?¹

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The forestry profession exists to help people get the benefits they want from forests, but forests have limits. Like all living things, trees are restricted in what they can do. A tree species needing well-drained soils cannot survive in a marsh. If seeds require bare soil for germination, no amount of urging will get them to establish on a layer of leaves or tree needles.

Originating, growing, and tending stands of trees is called silviculture (silva is the Latin word for forest). Silviculture is one of the cornerstones of forestry. Someone who is trained and experienced in silviculture is called a silviculturist.

A silviculturist helps people understand what trees need, and how stands of trees could be managed to supply people with the forest benefits they want or need (to meet people's objectives).

Sometimes, what society wants from a forest is for the trees to be left alone to pursue their own destiny. But often, foresters are asked to deal with problems – stands that have been attacked by insects or diseases, stands that aren't providing the wildlife habitat that is desired, or stands that should produce more feed for cattle or sheep.

To grow well, a tree needs a place in the sun and some soil to call its own. When trees in a stand are crowded and standing too close together, they do not get enough sun or water to thrive. Trees without sufficient sun, water, and food (nutrients) become weak – and weak trees are more likely to be attacked by bark beetles or root diseases.

One thing that foresters have learned over the years is that many of the problems they deal with are related to how many trees are present in a stand. This concept is called stocking. Foresters take measurements in a stand to determine how many trees are present, and the number of trees is then related to stocking recommendations.

Your task is to take some measurements in Wildcat Unit 111 (this is your stand), and then use this information to figure out if the stand is overstocked (does it have too many trees?).

You can accomplish this task in five steps:

- ✓ First, the whole group will be split up into three teams, and each team will have a helper provided by the Forest Service.
- ✓ Second, each team will move into a portion of Wildcat Unit 111 and set up a circular plot, using the instructions provided below.
- ✓ Third, the team will use equipment provided by the Forest Service to measure trees occurring on the plot, and record your data on the plot sheets provided in this handout.
- ✓ Fourth, you will summarize your data to come up with an average for the whole plot.
- ✓ Fifth, you will compare your plot information with stocking charts to figure out if the stand (Wildcat Unit 111) is overstocked or not.

¹ This handout was prepared for the October 2008 Career Camp hosted by the Heppner Ranger District.

My experience is that many folks do not enjoy mathematics. But many jobs require good mathematics skills, and forestry is no exception. The exercises in this handout will show you some of the ways that foresters use mathematics in their work.

Foresters usually deal with large land areas. They need to know what kind of trees grow on their area, how many of them there are, and how big they are. Measuring every tree on a national forest covering one and half million acres and containing more than 500 million trees would not only be time consuming and expensive, but probably impossible!

For these and other reasons, foresters only measure part of the forest, a process called sampling. They assume that the measured (sampled) part represents the whole area, which is referred to as the population. Data collected from the sampled part is expanded to provide information for the unsampled portion.

Suppose we need to know the tree stocking levels for a 54-acre tree stand on the Heppner Ranger District. The entire stand (all 54 acres) is our population, but we can't measure every tree because it would take too much time. So the best way to determine the stand's stocking level is to sample it, which we'll do by establishing plots.

How can we figure out a plot size? By using some mathematical formulas, of course! Previous sampling experience shows that circular plots are easier to use than square ones, so we'll use circular plots for Wildcat Unit 111.

To lay out a plot in the shape of a circle, we must know its radius, which we'll figure out using this formula:

$$\text{Area} = \text{Pi} \times \text{Radius}^2$$

Note: if you don't know what pi is, here is a short description. Pi is the number you get when you divide the distance around a circle (its circumference) by the distance through its middle (the diameter). The distance around the outside of every circle is about three times the distance across it. But it's the "about" part that creates the puzzle of pi. Mathematicians call pi an irrational number because when you divide a circle's circumference by its diameter, the answer comes out in decimals that go on forever without any apparent pattern. Pi begins as 3.14159265, but it never ends. In 1999, a Japanese scientist used a super-computer to calculate pi to about 206 billion digits, and it still goes on from there. All those digits aren't really necessary to use pi, of course – using only the first ten decimals, you can measure the earth's circumference to within a fraction of an inch. Pi is often shown in textbooks or in formulas using this Greek symbol: π

Let's say that we decide to use a plot covering $\frac{1}{4}$ of an acre. The total area of an acre is 43,560 square feet. Since we want to use a $\frac{1}{4}$ -acre plot, its area is $43,560 \div 4$ or 10,890 square feet. We now have enough information to use the formula above to figure out our plot radius.

$$\text{Area} = \text{Pi} \times \text{Radius}^2$$

$$10,890 \text{ square feet} = 3.1416 \times \text{Radius}^2$$

$$10,890 \text{ square feet} \div 3.1416 = \text{Radius}^2$$

$$3,466.39 \text{ square feet} = \text{Radius}^2$$

$$\sqrt{3,466.39} \text{ square feet} = \text{Radius}$$

$$58.9 \text{ feet} = \text{Radius}$$

Each $\frac{1}{4}$ -acre plot would be installed as a circle with a radius of 58.9 feet. For your exercise this afternoon, each group will use the same plot size, and a plot size will be selected during the field exercise.

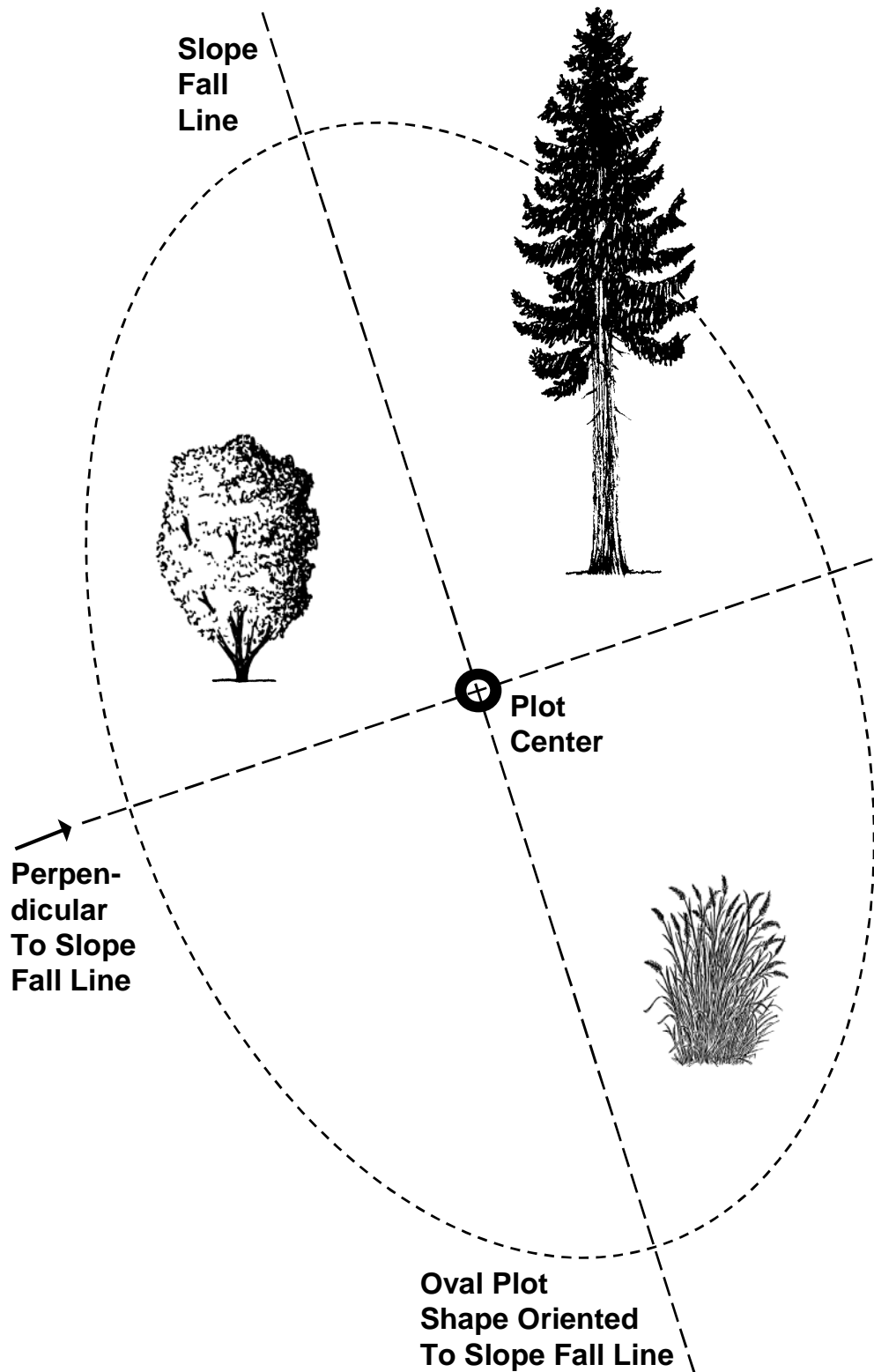
Each team will use a wooden stake to mark the plot center, and you will then use a measuring tape to determine the plot boundaries by measuring out a radius in several directions from the stake.

Rather than have each group figure out the size of your plot radius by using calculators and the formula for a circle (like the example above), I have done these calculations for you and the plot areas and plot radiuses are provided in this table:

Table 1: Plot size, area, and radius

| Plot Size (Acres) | Plot Area (Square Feet) | Plot Radius (Feet) |
|------------------------------|------------------------------------|-------------------------------|
| 1/4 | 10,890 | 58.9 |
| 1/5 | 8,712 | 52.7 |
| 1/10 | 4,356 | 37.2 |
| 1/20 | 2,178 | 26.3 |
| 1/50 | 871 | 16.7 |
| 1/100 | 436 | 11.8 |
| 1/250 | 174 | 7.5 |
| 1/300 | 145 | 6.8 |
| 1/500 | 87 | 5.3 |
| 1/1000 | 44 | 3.7 |

If the ground near your plot center is absolutely flat, then the plot is a perfect circle with a radius as it was calculated in the table above. The problems start when you are working on a hill because the plot's radius then varies, depending on the steepness of the hill. By projecting a plot's radius on a steep hillside, we see that it becomes oval in shape, not circular:



On sloping ground, plots have an oval shape with their long axis parallel to the slope (called the “slope fall line”). Note that a line perpendicular to the slope forms a right angle with the slope fall line. Plots on sloping ground need to have their radius adjusted using a factor that converts slope distance to what is called horizontal distance.

How do we adjust the radius of a plot that occurs on sloping ground? Well, you could figure out the adjusted radius using trigonometry (secants), but most foresters just carry around something called a slope correction table.

Here is part of the slope correction table for slopes ranging up to 61 percent:

Table 2: Slope correction factors

| Slope Percent | Correction Factor |
|----------------------|--------------------------|
| 0 – 9 | 1.00 |
| 10 – 17 | 1.01 |
| 18 – 22 | 1.02 |
| 23 – 26 | 1.03 |
| 27 – 30 | 1.04 |
| 31 – 33 | 1.05 |
| 34 – 36 | 1.06 |
| 37 – 39 | 1.07 |
| 40 – 42 | 1.08 |
| 43 – 44 | 1.09 |
| 45 – 47 | 1.10 |
| 48 – 49 | 1.11 |
| 50 – 51 | 1.12 |
| 52 – 53 | 1.13 |
| 54 – 55 | 1.14 |
| 56 – 57 | 1.15 |
| 58 – 59 | 1.16 |
| 60 – 61 | 1.17 |

Now, let's use table 1's slope correction factors to figure out if some trees near our plot edge are "in or out" (inside or outside the plot radius). These trees near the plot edge are referred to as *borderline* trees. Here is a way to measure borderline trees:

1. Use an instrument called a clinometer to measure the slope percent from the center (side) of a borderline tree to the plot center (let's say that it is 30 percent).
2. Find a slope correction factor in table 1 for the slope percent you just measured (the correction factor is 1.04 for 30 percent).
3. Multiply the correction factor by the plot radius. This is called the corrected radius. For a ¼-acre plot, the result is: 58.9 feet × 1.04 = 61.3 feet.
4. Measure the slope distance from the center (side) of the tree to the plot center. If the measured distance is less than the corrected radius (61.3 feet in this example), then the tree is in; if the measured distance is more, the tree is out.

MEASURING TREE DIAMETER

Now that we know how to figure out which trees are in or out of the plot, we need to learn how to measure the size of trees that are in on the plot. Tree size has two dimensions – how big around they are, and how tall they are.² For this field exercise, we need to find out how big around each tree is.

There are two main ways we can describe the size of round objects like tree stems:

- ◆ We can measure the circumference, the distance around the outside of their trunk, or
- ◆ We can measure the circumference and convert it to diameter, which is the distance through the middle of a tree's trunk.

Foresters use special measuring tapes that show a tree's circumference on one side, and its equivalent diameter on the other side. How is this done? Actually, it's easy to do because circumference and diameter are closely related:

$$\text{Circumference} = \text{Pi} \times \text{Diameter}$$

$$\text{Diameter} = \text{Circumference} \div \text{Pi}$$

One final thought about measuring tree diameter. By historical convention, diameter is measured at “breast height”, which is defined as 4½ feet above the ground surface on the uphill side of the tree. It will hereafter be referred to as DBH (diameter at breast height) – welcome to the world of forestry jargon!

CALCULATING BASAL AREA

Tree count tells us how many trees are present in an area, but a tree count does not do a good job of accounting for differences in tree size. If a count shows 500 trees per acre, do they occur as 1-foot-tall seedlings or as 40-foot-tall trees? It makes a huge difference! Having 500 1-foot seedlings per acre might be okay, but having 500 large trees per acre almost always presents a problem.

To get around this size issue, foresters use a measurement called basal area, which is getting at the “bulk” of a tree. Basal area is a hard concept to understand. It is the cross-sectional area of a tree at breast height (DBH), in square feet, as though we cut down the tree at DBH and then wanted to calculate the surface area of the top of the stump (the flat part).

Here is the formula for calculating the basal area (BA) of a single tree, in square feet:

$$\text{BA} = \text{Pi} \times (\text{DBH}/24)^2$$

[Have you noticed yet that most mathematical formulas pertaining to circles use pi?]

² Many tasks require foresters to measure tree height. To evaluate stocking, tree height is not needed, so how to measure height will not be described in this handout.

Rather than have you use the formula to calculate basal area for each tree that is sampled on your plot, I will make your life easier by providing you with basal area values in a table:

Table 3: Basal area by DBH

| DBH (Inches) | Basal Area (Square Feet) |
|-------------------------|-------------------------------------|
| 1 | 0.0 |
| 2 | 0.0 |
| 3 | 0.0 |
| 4 | 0.1 |
| 5 | 0.1 |
| 6 | 0.2 |
| 7 | 0.3 |
| 8 | 0.3 |
| 9 | 0.4 |
| 10 | 0.5 |
| 11 | 0.7 |
| 12 | 0.8 |
| 13 | 0.9 |
| 14 | 1.1 |
| 15 | 1.2 |
| 16 | 1.4 |
| 17 | 1.6 |
| 18 | 1.8 |
| 19 | 2.0 |
| 20 | 2.2 |
| 21 | 2.4 |
| 22 | 2.6 |
| 23 | 2.9 |
| 24 | 3.1 |
| 25 | 3.4 |
| 26 | 3.7 |
| 27 | 4.0 |
| 28 | 4.3 |
| 29 | 4.6 |
| 30 | 4.9 |

So, here's the process you will use to sample a stand and figure out if it is overstocked:

1. Locate a plot area and pound in a stake to mark its center.
2. Decide which plot size will be used, and find the radius for that plot in table 1.
3. Is a tree in the plot? Stretch out a measuring tape from the plot center stake in a full 360° circle to determine which trees are in your plot. Trees in the plot are called sample trees. Each sample tree is recorded individually on the plot form, and each sample tree is numbered. Note: if your plot occurs on sloping ground, don't worry about correcting for slope: we probably won't have enough time to worry about this issue.
4. What is the species of tree? For all sample trees, record the species on the plot form.
5. What is the DBH? For all sample trees, measure their diameter with a diameter tape (round off to the nearest whole inch), and record the value on the plot form.
6. What is the basal area of each sample tree? For all sample trees, record their basal area on the plot form (hint: look up the basal area value, by DBH, in table 3).
7. What is the plot's total basal area? Use your calculator to add up the values in the basal area column on the plot form, and then record the answer in the space provided.
8. How many trees per acre does the stand have? Here's how to do this: take the number of sample trees and multiply it by the plot expansion factor.

Note: when you sample (measure) a fraction of an acre, and then later want to expand the sample data so it represents a whole acre, the sample values must be multiplied by the denominator of the plot size. Examples: for a 1/10-acre plot, each sample tree represents 10 trees (the denominator value); for a 1/20-acre plot, each sample represents 20 trees, etc. This denominator value is referred to as the "plot expansion factor."

9. What is the stand's basal area? Here's how to do this: take the plot's total basal area answer and multiply it by the number of sample trees.
10. Calculate an average stand diameter. Here's how to do this: take the square root of stand basal area divided by stand trees per acre, and multiply the answer by 13.54 (each team should ask their helper to assist with this calculation).

Formula: $\sqrt{(\text{Stand BA}/\text{Stand TPA})} \times 13.54 = \text{Average stand diameter (QMD)}$

11. Now, finally, you are ready to decide if the stand is overstocked or not! Take the average stand diameter answer, and the stand basal area answer, and use them with the stocking charts (at the end of this handout) to find where your stand falls on the charts.
12. Here's how to interpret the chart position:
 - Between the blue and green lines: not overstocked; life is good and trees are happy!
 - Between the green and red lines: moderately overstocked; stand is crowded and the trees are cranky!
 - Between the red and black lines: greatly overstocked; stand is very dense and the trees are stressed out!

EXAMPLE PLOT (Plot size = 1/10 acre; radius = 37.2 feet)

| Tree Number | Species | Diameter (Inches) | Basal Area (Square Feet) |
|--------------------|----------------|--------------------------|---------------------------------|
| 1 | Ponderosa pine | 22 | 2.6 |
| 2 | Ponderosa pine | 27 | 4.0 |
| 3 | Western larch | 18 | 1.8 |
| 4 | Douglas-fir | 29 | 4.6 |
| 5 | Western larch | 12 | 0.8 |
| 6 | Douglas-fir | 8 | 0.3 |
| 7 | Western larch | 14 | 1.1 |
| 8 | Ponderosa pine | 9 | 0.4 |
| 9 | Ponderosa pine | 15 | 1.2 |
| 10 | Douglas-fir | 16 | 1.4 |
| | Total | | <u>18.2</u> |

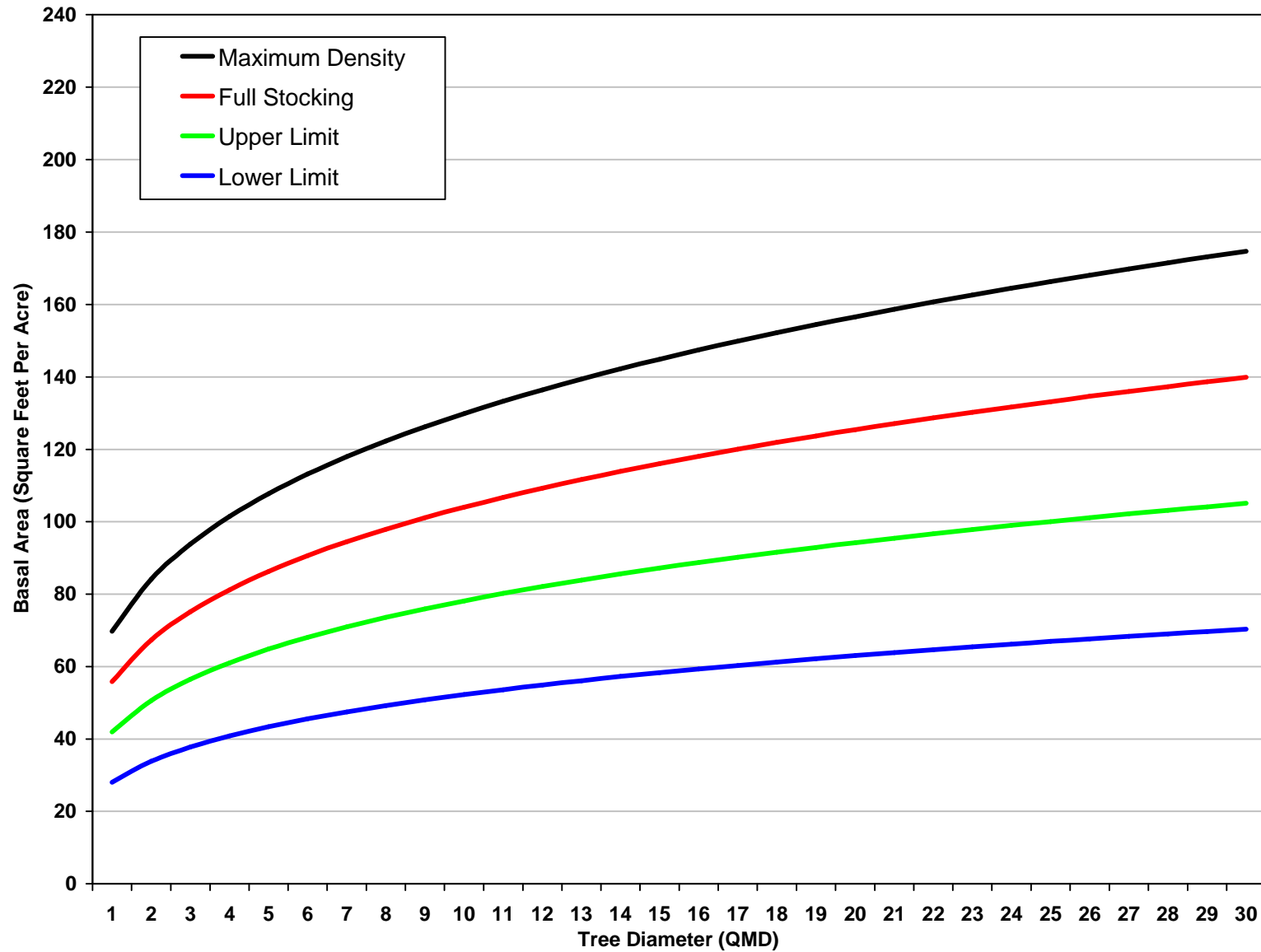
1. Trees per acre: 100 (number of sample trees × expansion factor) (10×10)
2. Basal area per acre: 182 (total plot BA × expansion factor) (18.2×10)
3. Average stand diameter (QMD): 18 (use formula in item #10 above)
4. Stocking status for Western Larch: **greatly overstocked**
5. Stocking status for Ponderosa Pine: **greatly overstocked**
6. Stocking status for Douglas-fir: **greatly overstocked**

LET'S SUMMARIZE

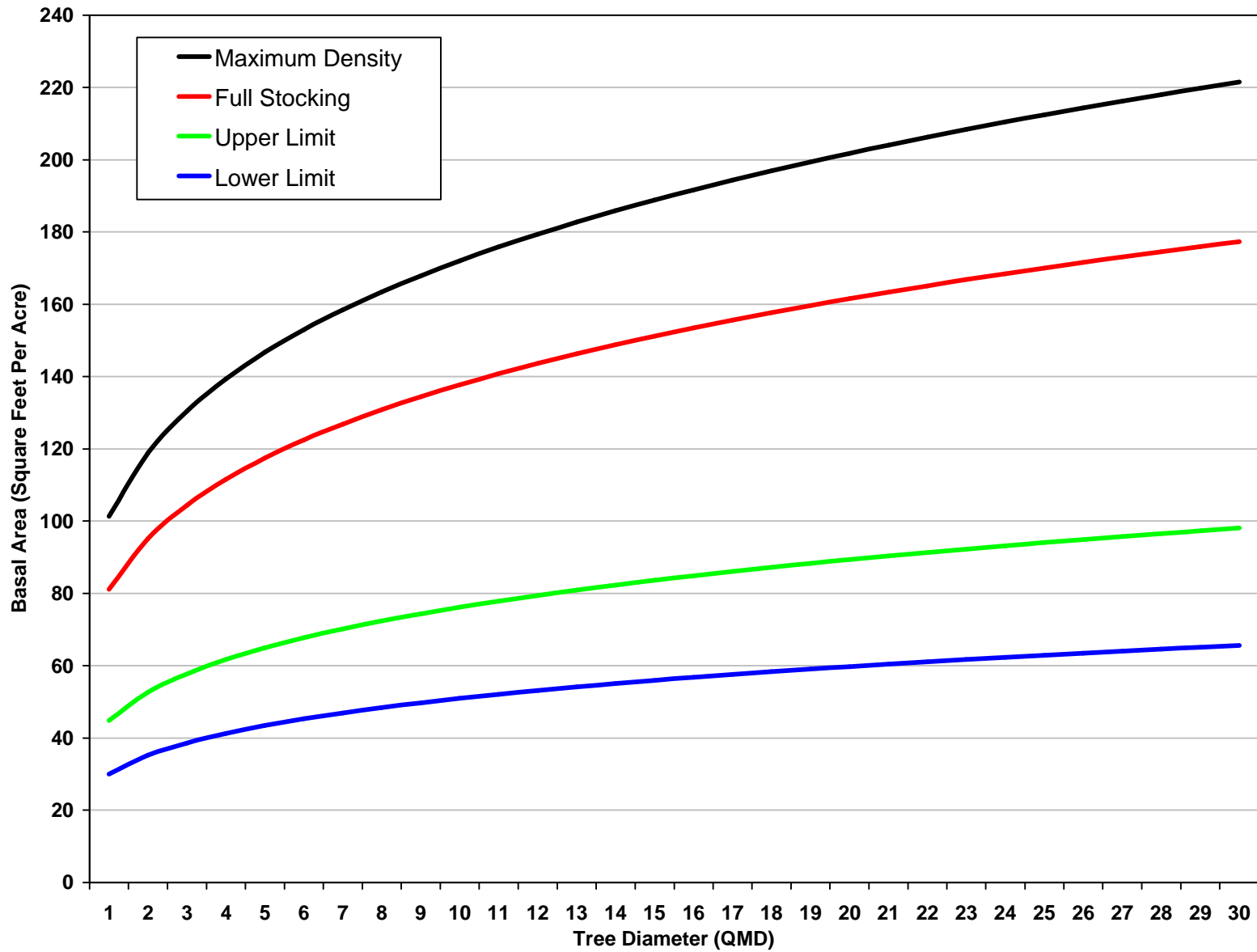
What have you learned from this exercise?

- ◆ How forestry and silviculture serves society.
- ◆ How to figure out the radius of a circular plot after being given its area.
- ◆ How to adjust a plot radius to account for sloping ground.
- ◆ That many mathematical formulas involving circles use pi, a special constant that we round off to 3.1416.
- ◆ How to measure the diameter of trees.
- ◆ How to calculate basal area.
- ◆ How to establish and measure a sample plot.
- ◆ How to use stocking charts to figure out if a stand is overstocked or not.

Stocking Chart for Western Larch on the Douglas-fir/Common Snowberry Plant Association



Stocking Chart for Ponderosa Pine on the Douglas-fir/Common Snowberry Plant Association



Is This Stand Overstocked?

Stocking Chart for Douglas-fir on the Douglas-fir/Common Snowberry Plant Association

