Chapter 15 - “Spacing, Density, and Excess”

In this chapter we'll talk about Spacing, Density, and Excess. We'll learn how these things are measured, and we'll understand why targets are set in silviculture prescriptions. We'll talk about compliance systems, and how, as a planter, you can leverage an understanding of these systems into increased productivity and higher earnings. If you have a proper understanding of what you can and can't get away with, with respect to spacing and density, your job will become a lot easier.

Your crew leader and quality checkers should carry tape measures, in order to help give proper guidance to planters about their intra-tree distances (especially during the first few weeks of any season).

What's In A Plot?

When a forester takes a plot, he or she is not just checking the quality of the trees. There's a lot of additional information gathered. In rough terms, the information collected in each plot includes:

1. The number of trees planted in the plot.
2. The number of plantable spots.
3. The number of excess trees.
4. The number of satisfactorily planted trees.
5. The number of unsatisfactorily planted trees, and reasons why they were unsatisfactory (this is the quality assessment part of the plot).
6. Any other comments about the plot in general.

As you can see, most of these measurements are not even directly concerned with quality!

Figure 15.01
Two Checkers Getting Ready to Start Work.

Quality and density assessments are done at the same time. There may be a few checkers working together to cover a block more quickly.

Plotted versus Planted Density

Density is a very important measurement that tells you the approximate number of trees *per area* on a block or a part of a block. Since we usually use the metric system, it's usually described as the number of seedlings, or "stems" per hectare. A hectare is 100m by 100m in size, or 10,000 square meters, and of course, it doesn't have to be a square. Earlier, I mentioned the fact that a plot within the 704 system is equal to 1/200th of a hectare. Because of this, if you know that you have a number of plots that average 8 trees each, and a plot is 1/200th of a hectare, then when you multiply the two numbers out, you'll realize that you have approximately 1600 trees per hectare. This density, which is determined by multiplying the average number of trees counted per plot by 200, is usually called the "plotted density." Sometimes it's called the "plot density" or "sample density" or "statistical density" of the block.

Figure 15.02
Throwing a Plot – 1/200th of a Hectare.

This checker is using a 3.99m plot cord, which means that the plot she throws will cover 50 square meters (π x r^2). Her plot will therefore be 1/200th of a full hectare.

There's another way to arrive at a slightly different density calculation: you can take the total number of trees that were actually planted on a block and divide it by the number of hectares. For instance, if you have a block on which you've planted 15,000 trees, and the size of the block is 10.0 hectares, then you have a density of 1500 trees per hectare. This density, calculated from the claimed planting totals, is usually called the "planted density." It may also be referred to as the "claimed density" or "theoretical density." Of course, if the planters made a mistake in their tallies, this number won't quite be correct.

It's important to understand right now that there's a significant distinction between the plotted density, which is a statistical measurement, and the planted density, which is the true density (if the planting totals are correct). Although each density is a measure of the number of trees per area of block, and although each may be "accurate" by itself, the two types of density measure slightly different items. It's possible for the plotted density be different than the planted density, and yet for each number to be "correct." A correct plotted density merely refers to a plotted density that is calculated correctly. It doesn't mean that the plotted density accurately reflects the true planted density of seedlings on the block. If you truly understand the distinction between plotted and planted densities, that distinction will form the basis for starting to understand a lot of other nuances of most quality systems. Understanding this distinction also helps you start to learn some advanced density management issues, including issues as varied as manipulating the system to improve your quality results as a planter, and for management, investigating the likelihood that planters are stashing trees.

Some planters, especially beginning planters, will focus entirely on their planting quality, and pay very little attention to the planting densities that they achieve. This is possibly one of the biggest mistakes that a beginning planter can make. I simply can't over-emphasize the importance that density will play in your planting career. Look at it this way: making a quality mistake is not "irrevocable." Planting a tree poorly, so it's considered a fault tree, will unquestionably reduce its chances for long-term survival. Even if it does survive, the tree may not achieve its maximum potential growth. However, a tree CAN recover from many types of quality faults. A quality fault simply means that the odds are stacked a bit higher against the tree. A tree in a dry area may not grow well until it gets heavy rains. A tree in a poor microsite may not grow as fast as one in a better microsite. A tree with non-vertical or "J" roots may not establish a strong root system as quickly as it could have. A leaning tree may take some time to straighten up. Despite all of these potential handicaps, a tree can often recover from a quality fault.

With density problems, the story is different. Once a tree is planted in a particular microsite, it can never move. Quality faults, if they don't kill the tree, may only be temporary setbacks in the total life of the tree. But trees can't move by themselves, so density problems are permanent. The vast majority of foresters are very intelligent, and any forester with any common sense recognizes the importance of density, and will be far more tolerant of a few minor quality issues than they will be of density issues.

Another thing to consider is that most common quality systems are designed so that when a planter's density starts to get really out of line, it also starts to have a negative effect on your quality percentage. For instance, under the FS 704 system, planting low density will eventually result in missed spots, which are automatic quality faults. Under the same system, planting high density will usually result in an excess fine, which again is not good.

Target Spacing & Minimum Spacing

Ok, now that you understand the basics of density, I'm going to explain two new issues: target spacing, and minimum spacing. Sometimes, target spacing is called the "contract" spacing. On any given contract, a forester will have come up with an assessment of how many trees they want planted in an area. If the area is rich and non-competitive and the trees are expected to do well, a "low" density of 1200 stems/Ha may be a good goal. In areas with poor soil, or high competition from existing vegetation, a higher density of 2400 stems/Ha may be a better goal. On some contracts, the density that the forester wants to see may not be a single number for the entire contract, but may vary from block to block, or may even vary from section to section within a block. No matter what the desired density is, it's very difficult for a forester to get good results by telling a planter to go out and, "plant about 2000 trees per hectare." This instruction is too vague, unless you understand how to apply that number to the immediate area that you're currently planting in. Even after all the years that I've spent planting, I can't tell you exactly how big a hectare is at a glance, nor could I do a very good job of just guessing how far apart the individual trees need to be in order to fit exactly 2,000 trees into a hectare. I need a more tangible and achievable immediate measure to aim for.

Depending on the target density, it's fairly easy to use a chart to determine what the average inter-tree spacing needs to be to achieve the desired density. Once you have a tangible inter-tree distance to aim for, you have a realistic chance of meeting the forester's goals for density. For example, if every tree were 2.4 meters away from every other tree in a perfect grid, the resulting density would be 2000 stems/Ha. If every tree were 2.7 meters apart in a perfect grid, the resulting density would be 1600 stems/Ha. Your crew leader can tell you the average spacing that will result in the target density that the forester is looking for. Crew leaders and supervisors have charts to help us know what our target spacing needs to be. Let me show you a couple of common numbers right now:

2000 stems/Ha = 10 trees per plot = 2.4m average between trees
1800 stems/Ha = 9 trees per plot = 2.5m average between trees
1600 stems/Ha = 8 trees per plot = 2.7m average between trees
1400 stems/Ha = 7 trees per plot = 2.9m average between trees
1200 stems/Ha = 6 trees per plot = 3.1m average between trees
1000 stems/Ha = 5 trees per plot = 3.4m average between trees
800 stems/Ha = 4 trees per plot = 3.8m average between trees

For a first year planter in the northern BC Interior, you're probably not going to see low density numbers very often. Those are typically target densities for coastal contracts. A planting density of 1200 stems/Ha or less is quite rare in the Interior. Trees are much less expensive to plant in the Interior than on the coast, so foresters there prefer to aim for higher densities, to maximize the chance of meeting Free Growing survey requirements. In the Interior, you're most likely to see target densities of 1400 stems/Ha and above, and sometimes as high as 2400 stems/Ha in pine plantations.

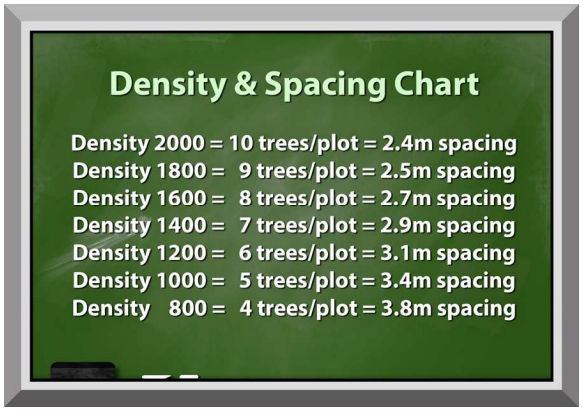

Figure 15.03
Spacing Chart.

It's a good idea to post this chart in all of the trucks if you're on a contract where the density requirements are not very consistent from block to block. You can find a digital copy of this chart, which you may share freely, at the following link: www.replant.ca/spacingchart

Of course, when you're planting a block, the trees are not going to end up in a perfect grid. Nor would you want to try to plant them in a perfect grid, because to get it exactly right would mean having a tape measure and measuring the distance between each tree. That would slow you down, and you'd plant less, which means that you'd make less money. The great thing is that your trees don't need to be exactly the same distance apart every time. If some are closer to each other, and some are further away from each other, you can still get the right overall density by making sure that ON AVERAGE, the trees are the proper target distance from each other. So to make your life easy, think of the "target spacing" as the optimum average distance between trees that is required for you to hit the correct overall density. You can plant some closer together, and some further apart, so long as the average is correct.

There are two benefits to being allowed to vary your distance between trees. The first is a benefit for the trees. Since you have a variance, you can select the best microsites for the trees. The forester wants you to put the trees in the best microsites, to maximize the long-term crop yield on the plantation, so it's in his or her best interests to allow you this variance in spacing. The second benefit is for the planter, and it's a very obvious one. If you're allowed some leeway in picking and choosing the spots to put your trees, you can select the easiest spots to plant each tree. You want to find the easy spots to plant in. As much as being successful at tree planting means a lot of hard work, you shouldn't be doing unnecessary work.

Of course, there are limits on how much variance you're allowed. That's where the minimum spacing comes into play. You won't be allowed to plant two trees closer together than the minimum spacing, or one of them will be faulted. So for instance, if you have a contract or block where the target spacing is 2.7 meters and the minimum is 2.1 meters, then you'll want to plant your trees about 2.7 meters apart on average, with no two trees ever being closer than 2.1 meters together.

Many planters at this point will ask an intelligent question: "If there's a minimum spacing, is there also a maximum spacing?" There isn't, at least, not exactly. Instead, there's a different measurement which effectively mimics the effect of having some sort of maximum spacing. It depends on the quality system you're working under, but it usually relates to having a "missed spot" rather than "wide spacing." I'll explain that in more detail in a few minutes.

When it comes to density, you need to learn quickly to get it right the first time. Density problems cannot be "fixed" by replanting, unless you pull every tree up from an area and start again, which is unthinkable. Once you start moving some trees, you have to start moving other trees around them. It's a domino effect, and it takes a lot of effort to fix the area. Avoid getting yourself into this kind of a situation. It only takes a minute or so for a planter to quickly throw a plot on himself or herself, and to count the number of trees in the plot. If you want to be a good planter, or if you already consider yourself to be a good planter, you're only fooling yourself if you think that you don't need to throw plots on yourself to check your density throughout the day. I personally recommend that all planters take at least four quick plots on themselves every day. I do it. In the long term, it's worth my while.

Figure 15.04
Planter Throwing a Plot on Himself.

This planter, who has just bagged out, knows that it's worth thirty seconds of his time to walk around and throw a quick plot to double-check his density. He doesn't want to run the risk of having to go back and fix poor density.

Excess

Many planters find the concept of density to be fairly easy to grasp, but they have much more difficulty with excess. Some planters mistakenly think that the two are the same thing, and that high density is the same as excess. However, this is another area where understanding the fine distinction between the two concepts will help a good planter become a great planter. High density and excess are somewhat similar. But high density happens when you have too many trees planted throughout the block consistently. Excess happens when you have too many trees through just some parts of the block, specifically where the plots land. For the mathematicians out there, let me give you a better definition: excess penalizes you if you have a high standard deviation.

The easiest way to explain the difference between excess and high density is probably with a very simple mathematical example. First, let me explain how excess is calculated. In most systems, each plot on a block is considered individually. If the plot that you're looking at has more planted trees than the target density, then each "extra" tree above the target density will be considered to be an "excess" tree. Once the forester knows how many excess trees there are in total in the series of plots, that number is divided by the total number of planted trees in the set of plots to come up with the excess percentage. Let's look at an example:

- First, assume that the target density is 2000 stems/Ha. This means that if you divide by 200, because a plot is 1/200th of a hectare, you should be hoping to get a total of exactly ten trees in each plot.
- Let's assume that we have two blocks. Each is two hectares, and to keep things simple, we'll say that each block needs two plots. Under the FS 704 system, a block which is that small actually needs a minimum of five plots, but we're going to ignore that rule for this example. Two plots per block.
- On block "A" we get 10 trees in the first plot and 10 trees in the second plot.
- On block "B" we get 8 trees in the first plot and 12 trees in the second plot.
- Let's assume that we've been told that 4000 trees were planted in block "A" and 4000 trees were also planted in block "B."
- Although it isn't important to this example, I'm going to tell you that the trees in block A were planted with fairly even spacing, hence the reason that each of the two plots got 10 trees, while the spacing on block B was a lot more varied, with some sections having closer or "tighter" spacing than other parts of the block.

Block "A" Calculations:

- The total number of trees in the plots is 20. There are two plots. Therefore, there's an average of 10.0 trees per plot. Multiply this by 200 and you get a plotted density of 2000 stems/Ha.
- The total number of excess trees in the plots is 0. The first plot had 10 trees, and you don't get an excess tree until you go "one tree over" the target. Therefore, that plot did not have an excess tree. The second plot was exactly the same: no excess trees. Therefore, the total excess for the block is 0 trees out of 20 trees planted, or 0.0%.

Block "B" Calculations:

- The total number of trees in the plots is 20. There are two plots. Therefore, there's an average of 10.0 trees per plot. Again, multiply this by 200 and you get a plotted density of 2000 stems/Ha.
- The first plot had 8 trees, so there are no excess trees in that plot. However, the second plot had 12 trees, which is two trees higher than the target number of trees per plot, or two excess trees.
- With no excess in the first plot, and two excess trees in the second plot, the total excess for the block is 2 trees. You then divide that number by the total trees planted, which was twenty, and you get an excess percentage of 10.0%.

Hopefully this numerical example starts to illustrate the concept. The planted density on each of the two blocks is exactly the same, because each had 4000 trees planted over 2.0 hectares, or 2000 stems/Ha. The plotted density on each of the two blocks is exactly the same, because each block had 20 trees total between the two plots, or 10.0 trees per plot, which when multiplied by 200 gives you 2000 stems/Ha.

By the way, in this particular example, the planted density is exactly equal to the plotted density. Remember that it doesn't always turn out this way, depending on where the plots fall and how many

trees are in each plot. In fact, it's most common for these two numbers to be different, although they are usually quite close to each other.

Even though the plotted density of both blocks is the same, and the planted density is also the same on each block, the excess on each block is NOT the same. The first block was planted with very consistent spacing, and did not end up having any excess trees. The second block had inconsistent spacing, and ended up getting a few excess trees in the plots, resulting in an excess percentage of 10.0%.

Under the FS 704 system, a company is not penalized for excess charges on a block if the overall excess percentage is less than 7%. In other words, you can have a small amount of excess and not get penalized for it. This is fair, because even the best planters will be forced to deal with a small amount of variety in their spacing. And to be honest, the foresters are ok with a bit of variance in your spacing too, because they want to see you looking for the best spots for the trees.

Missed Spot – A Quality Fault

Earlier we learned that wide spacing is not necessarily a quality fault. This is especially true if the spacing is consistently just a bit wider than the target spacing. Wide spacing only becomes a problem when it gets to be too extreme. There's a point when your spacing between two trees becomes so wide that you could have fit another tree in without it being too close to either of the other trees. At that point, it's considered to be a missed spot rather than just wide spacing. This is equivalent to a fault on the plot sheet. There's no specific code for this. You'll still get penalized though, because you don't have enough "satisfactorily planted trees" to match the number of "plantable spots." These are two terms that we'll look at later.

Basically, let's take a quick example where the target spacing is 2.7m and the minimum spacing is 2.0m. To keep things simple, let's work in just one dimension, ie. going in a straight line, although of course on the block you also have to think of trees beside you, not just the ones ahead and behind. Let's assume that as you're planting along in a line, you plant two trees that are 3.8m apart. This is wider than the target spacing of 2.7m. But wide spacing is not a fault.

Now let's try to figure out if we have a missed spot. Let's see if we can stick an extra tree between the two trees. We'll put it in the exact center of those two trees, so the new tree is as far as possible away from the original two trees. Since they were 3.8m apart, the tree in the exact middle will be 1.9m away from each of the other two. That's under the minimum spacing of 2.0m. In other words, it's not possible to legally put another tree between your first two trees without it being closer to an existing tree than permitted. If you can't legally add that tree, it's not a missed spot. The spacing is just wide spacing, no penalty.

Let's look at a second example, where you plant two trees that are 4.8m apart. That's really quite wide, if the target is only 2.7m. Once again, let's try to put a tree between the first two. If you put it exactly in the middle, then the new tree is 2.4m away from each of the other two. This is above the minimum. In fact, it's close to the proper target spacing. Since another tree can legally be added in the middle without causing Minimum Spacing problems, you'll be considered to have a Missed Spot. There should have been a tree between the original two trees, so you're faulted.

Of course, in considering whether or not you have a missed spot, the forester also looks at other factors. Is the spot that was missed good enough to allow for a tree to be planted properly? If not, say for example there was a huge puddle right there, then the forester will not penalize you for missing the spot. The rationale in this example is that you skipped the spot because you had no choice, so you shouldn't be penalized.

Penalties

So overall, there are three different ways that you can be penalized for planting either too many trees or not enough trees in an area:

- Missed Spots
- Excess
- Low Density

Missed spots come into play when your spacing is wide and erratic, because you'll end up leaving gaps that should have had trees. For a planter, that's not good. If you walk over a spot where you should have planted a tree, you just missed out on an opportunity to make a bit of money. You don't get paid just to walk around. You need to be planting at the same time.

Excess comes into play when your spacing is erratic, and you put too many trees into a small area that a plot lands in. Now to be honest, it's usually good for planters to have slightly higher density than the target, and if a little bit of excess is the result, that's fine. So long as your crew's excess on the block is under 7%, your company isn't penalized.

Low density isn't something that I've mentioned yet. I did say that wide spacing wasn't a quality fault. But because foresters want to see a sufficient number of trees in their blocks, they often add a clause to the contract that gives a minimum acceptable density tied to payment. This is often a number like 200 stems/Ha under the target density, or alternatively, it could be a percentage amount such as ten percent under. So for example, a contract might say that the target density on a block is 1800 stems/Ha, but if the final density is under by more than 10%, or less than 1620 stems/Ha, there is no payment. If your crew does end up planting less than 1620 stems/Ha, there's a simple solution: You'll be sent back to add some more trees, until the density is brought up over the minimum.

If you have a smart crew leader, he or she will probably do a quick calculation as soon as the block is done to see what the planted density is. If it's low, say around 1590 stems/Ha or slightly lower (on our block with 1800 target and 1620 minimum), that will indicate that the block is likely going to be a problem, because the plotted density will probably be very similar. In that case, it would be smart for the crew leader to tell the crew to go back out and put in a few more trees as a precautionary measure. It's easier to add more trees to a block when you're already there, instead of coming back later. If your planted density for the block is obviously low, it's smart to just fix the problem before the plots are even taken.

Is there a High Density penalty? Not really. Foresters get you on the excess charge, so they don't worry about it. Many foresters are Ok with you planting slightly higher density than the target (and many encourage slightly high density of perhaps 2% to 5%), so long as it's consistent. They just don't like inconsistent high density, which is why the excess calculation meets their needs as a way of making sure you don't plant far more trees in an area than you're supposed to. Even density that is perfectly consistent can still give you an excess charge if the density starts to get too high.

Rationale behind Density Variations

Planters often wonder why prescribed densities can vary so widely from contract to contract, and even from block to block within a specific contract. I've even seen blocks where one side of the block is prescribed for 1800 stems/Ha, and the other side is prescribed for 1200 stems/Ha. Although this may seem odd, there's usually some justifiable rationale behind these prescriptions.

Some trees develop best when growing in close proximity to each other. Various pine species (especially lodgepole) often prefer close spacing. The high density of natural regen forces trees to compete against each other in terms of height, because pine trees like direct sunlight. That's why many juvenile pine stands are extremely dense, with tons of closely packed thin but tall trees reaching for the sky. When planting pine seedlings, foresters often lean toward higher densities to mimic this natural growth.

Density variations can also affect the spread of diseases through a stand. For some pathogens, wide spacing of trees is useful. For example, pathogens that are slowed down by sunlight can be controlled by wide spacing in a plantation. Conversely, some pathogens can only spread readily through tightly packed stands, so if this is a risk, a forester may prescribe a low stand density to keep a specific disease from spreading widely. Foresters have to take dozens of factors into account when picking target densities for our blocks.

Figure 15.05
Post-Wildfire Pine Regeneration.

Lodgepole pine (and some other pine species such as Jack pine) have a genetic predisposition to grow well at high densities. It is typical to see very high natural regen densities after a wildfire.

What Now?

I'm sure that at this point, many of you are sitting there with your eyes glazed over, completely lost. That's understandable. This is the sort of material that you should revisit a couple times per season for your first couple years, until you fully understand the math behind everything. Unfortunately, there are multi-year vets that haven't bothered to learn the ins and outs of understanding the nuances of density measurement. Understanding exactly how spacing variations affect your overall density will ultimately make you a much stronger planter.

To be honest, what we've just covered here is barely scratching the surface of a proper understanding of spacing and density management considerations. For a first-year planter though, it's enough to get you started. The key take-away lesson here is that you need to get your density right, and in order to do that, you need to make sure your spacing between trees is accurate and consistent. Instead of using a measuring tape to measure between pairs of trees, throwing a quick plot on yourself is the best two-dimensional way to see if you're on the right track. Even if you don't check the quality of each tree in your plot thoroughly, a quick density plot can be thrown in less than a minute. If you have the right number of trees in your plot, you'll feel more confident in proceeding at full steam ahead.

Your instructor and your crew leader will throw some plots with you, to make sure you completely understand how to take plots quickly and accurately. Taking a quick plot will ultimately save you time, rather than just costing you a minute or two, because it'll let you know if your density is either on track or all whack.

Some vets don't recognize the value of throwing two or three very quick density plots on themselves each day. Let me give you a numerical example to show why throwing plots on yourself is a good idea. Let's say that you're a fast, experienced planter and you think you have great spacing. Let's say that you're planting 4k per day, and your target spacing is 2.0 meters. That means that you're covering 8,000 meters during the day. Now lets say that you don't realize, but you're going slightly wide. To be more exact, you're planting 10% wider than you need to. This means that you're going to have to take 800 extra steps during the day to plant the same number of trees. Wouldn't you rather

throw three quickly plots during the day (1 minute each) and catch this problem, instead of taking 800 extra steps with loaded bags? Or in a different scenario, what if you're planting 10% too close? In that case, many of your trees may get called as quality faults for being too close together. In that case, three minutes of throwing plots on yourself might avoid a massive replanting situation. I throw plots on myself constantly, and I look at the few minutes spent as "insurance" on making sure I can meet the planting specs while maximizing my potential earnings.

Figure 15.06
Throwing a Plot.

One of the reasons that density is so important is because trees can't get up and move. If you make a mistake with your density, that mistake will still be obvious eighty years from now, when your trees are fully mature. Unless, of course, they die from overcrowding.

By the way, if you're working in Ontario, the industry there often works with feet instead of meters. I'm fairly certain that Canada has used the metric system since the late 1970's, so to help you out, here are some useful conversions:

7 feet = 2.1 meter spacing
8 feet = 2.4 meter spacing
9 feet = 2.7 meter spacing

For more photo and video resources associated with this chapter of the book, visit:
www.replant.ca/training/density