THE TIMBERLAND INVESTOR

How to Read Your FOREST

AN INTRODUCTION TO DIY FOREST MANAGEMENT

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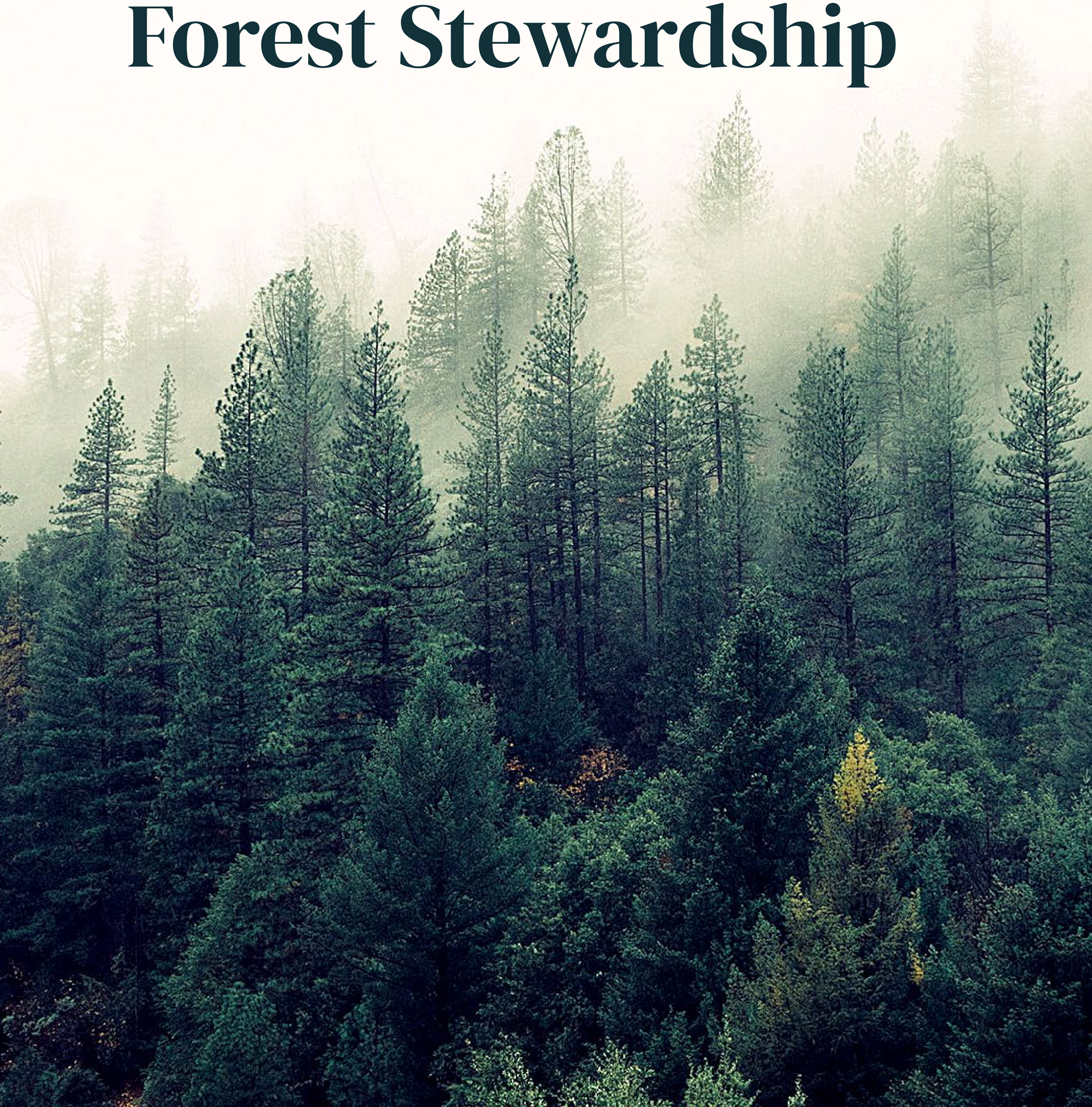
The Lost Art of Forest Stewardship



Forest land is an investment like no other. While higher-yielding assets may exist, I am confident in saying none can yield the owner the same value as timberland. A woodlot can be so much more than a means of generating income from growing and selling timber. It is a source of fuel in the form of firewood to heat a home during the long winter nights. It is a source of food as game big and small is harvested from meticulously managed and improved habitats. Above all, it is a source of immense satisfaction as one watches a young stand of low-value timber grow into a mighty forest. It then becomes a legacy as your family continues to manage the forest and watch it grow for generations. Unfortunately, not many woodland owners come to see these benefits.

For far too many, ownership of timberland is little more than “owning land.” It is a passive, non-income generating form of asset ownership that can be (and is) largely ignored and neglected. Most see it as not worth their time, and it has given birth to a popular, but misinformed sentiment: “Ain’t no money in the woods.” Thus, owners of forest land frequently fall into two categories. At best they sit on acreage for recreation or dreams of one day building a small cabin, unaware of the potential the land has. At worst, they use the asset as little more than a long-term bank account to park their money. They often see it as a speculative development endeavor, selling the timber to unscrupulous loggers who either cut the best trees and leave the rest (a degenerative practice known as “high grading”) or clear cut the land, robbing the forest of much (if not most) of its potential value.

After years of working in the field of forestry in the cold and vast timberlands of northern Maine, I’ve come to see the situation as a large-scale tragedy. Collectively, millions of acres of private forest lands are mismanaged, cut too hard in some instances and overgrown in others. In the worst situations, forests have been effectively destroyed through poor management, their production and value arrested for decades to come.

What’s worse, it is not usually caused by greed or malice, as some might expect. Usually, it is a matter of ignorance. Owners of forest land seldom have an understanding of sound forest management. Many do not even know what “forestry” is. If they do, it is usually an extremely rudimentary understanding. They do not have the ability to see a forest for its potential, and so the potential is never realized.

Who can blame them? Resources available to help landowners are scant. Too often, they are vague and simplistic or overwhelm with generalities devoid of enough context to properly convey the nuance inherent in forest management. Landowners are left with little more useful advice than to hire a consultant forester.

It is by no means bad advice to seek the counsel of a forester. In fact, I would also recommend it. But foresters are inherently limited in their expertise and utility to you and your land. Foresters don't own the land. They may have no connection to the land after a single harvest, and it is possible (if not likely) that a forester that is around for one harvest will no longer be practicing at the time of the second harvest. Moreover, a forester can only give recommendations given the values (income, recreation, etc) you convey. The management decisions are ultimately yours, and seeking the services of a forester to execute these decisions without having a solid grasp of forest management is like going to a car dealership having no knowledge of cars. Maybe it will work out well for you, but I would not recommend it.

Far better it is for the landowner to be a forester themselves–to develop an understanding of, connection to, and vision for their forest. That is the path to reaping the full joy, satisfaction (and of course profit) from a timberland asset and reclaiming the lost art of land stewardship. You must learn how to read your forest.

Becoming a Forester

That is the goal of this guide–to help you become a forester yourself and develop the skills necessary to manage your land to its fullest potential. However, forestry is as much art as science with enough nuance to support a lifetime of learning. Thus, this guide is not an end-all-be-all. Far from it. Instead, it is my intention only to lay a solid foundation and provide you with enough context to begin your journey to learn more. You will learn about your forest in relation to the broader forest economy and the physical, biological, and silvicultural components of a healthy forest. With that knowledge, you will be able to ask the right questions.

In time, and given the drive to learn, you will develop the knowledge, experience, and intuition that will rival any veteran woodsman, and the connection you build with your land will be a great source of pride and satisfaction in your life. But like all worthwhile endeavors, you must begin with the basics. Taking the time to understand the fundamentals will yield great dividends.

But first, a caveat: IIf you are a true beginner, barely able to differentiate a tree from a dandelion, it is wise to first familiarize yourself with the native tree species of your area, as this is the most basic skill required for reading and understanding your woodland.

Due to the sheer diversity of forests around the country and the wide array of materials on the subject that can be found elsewhere, it will not be covered here. However, you can find helpful tree identification videos on Youtube or find a field guide that is oriented toward your region. But once you have a solid grasp of species and their identification, you can truly begin practicing forestry.

What is Forestry?

From truck-driving, bud-sipping deer hunters to septum-pierced, tattooed urbanites who like crystals and astrology, everyone loves the forest. Even so, there are probably few ecological communities that are so misunderstood. When most walk through a forest, they see an ancient canvas painted by nature–a splendor of the world! But in most cases, forests are neither natural nor particularly old. In New England, for example, many forests are old farms from the 19th century that have since grown over. Elsewhere, particularly in forests with a long history of industry, forests have been harvested again and again for hundreds of years. The forests we see today, including their quality, species composition, and growth rates, are the direct result of human activity and influence.

This activity has been both intentional and unintentional. The effects have likewise been both positive and negative depending on the situation. But one truth is certain: Humans are largely responsible for the forests we see today. We are certainly capable of greatly influencing the growth of trees, and so when human activity in the forest is both intentional and targeted toward a larger goal, we call it **forestry**.

Over the years, and thanks to the efforts of many generations of woodsmen around the world, we have built the field of forestry around influencing and optimizing the growth of forests around various objectives, and we call this art and science **silviculture**. Broadly speaking, it is the goal of the silviculturist to take a vision for the forest (be it economic, financial, recreational, or ecological), and alter the trajectory of growth for that forest by tweaking the species composition, growth densities, and more.

With proper silviculture, forests can be improved overtime, turning a relatively low value parcel of land into a productive and high-value forest. These days, the forester has a well-equipped toolbelt full of means and methods toward this end, but successfully implementing these tools requires an understanding of the many nuances of silviculture, and central to this is the understanding of qualitative and quantitative management.

Quality Vs Quantity: The Fundamental Question

In forestry and silviculture, there is as much nuance as there are trees in the forest. Every species has different biological and economic characteristics that necessitate different management styles. If that isn't complicated enough, even *slight* changes in a region's topography, soil geology, or climate can impose new challenges and constraints while removing others. When I worked in the forest industry in northern Maine, it was always an adventure working with other foresters from the southern part of the state. Despite working in the same state and with (more or less) the same species, we often spoke in different languages, and many did not appreciate how limited their expertise was just three hours to the north, making for some entertaining conversations.

Clearly, navigating the nuances of a forest is a challenge even for seasoned professionals. But you need not worry about these nuances now. Like Maslow's hierarchy, they will come with time as you build a strong foundation and learn to recognize the context behind various management decisions. Merely understanding the nuance enables you to ask the right questions, which solves 90% of the problem at once. It might sound silly, but I stand by it.

For now, the most important dichotomy to understand to be able to properly read your forest and become a forester is the dichotomy between quality and quantity. Every commercial timber species is valued and managed either mostly for the quality of the wood or the quantity of wood it can produce, and virtually all management regimes revolve around maximizing one of the two. Understanding these regimes is critical.

Hardwoods Vs Softwoods

In general, hardwoods, which are used more for visible interior surfaces such as furniture, are valued more for quality and managed on a quality-based regime while softwoods, which are largely used to mill structural dimensional lumber, are valued and managed based on quantity. This is not universal, however. Certain hardwoods are grown mostly for pulpwood (such as aspen and (outside the U.S.) eucalyptus, and certain softwoods are grown and valued mostly for quality, such as white pine.

What's more, the management regimes aren't entirely mutually exclusive. Obviously, a higher quantity of high-quality wood is desirable, and ensuring at least a minimum quality for timber grown under a quantitative management regime aids in the logistics and milling, which ultimately enhances value. Instead, the dichotomous management of quality and quantity refers to what the primary objective is in the management of a given species. When managing sugar maples, for example, we want as much wood volume per acre as possible, but because a single high-value sugar maple can be worth 10x as much as a low value sugar maple, improving the quality of growth takes precedence.

Later on we will list the most common commercial timber species and their generally-accepted management regimes, but first let's discuss the specifics of qualitative and quantitative management, their primary considerations, and how decisions are made in each regime.

Quality

When we discuss the quality of timber, we are truly discussing the quality of the wood inside the tree, as this is the end product for the consumer and ultimately what determines the tree's value. Of course, we cannot see the actual quality of wood until a tree is harvested and milled, so instead, we look to external proxies that indicate the quality and soundness of the grain within. Chief among these are stem form, cracks, rot and other defects, and the tree's merchantable height and diameter.

Stem Form

Stem form is the most fundamental determinant of wood quality and thus tree and stand value. By stem form, we are referring to the general shape the tree has taken as it has grown, including how straight the main stem is and how it has branched out over time. WIth little exception, the highest quality trees are going to be as straight as possible and have a main stem (referred to as the bole) that is stem free for at least 16′ (the more of the stem that is branch free, the better).

To understand why stem form is important, you must think of the tree as individual logs. Every log is going to be cut to a certain specification, and these specifications are going to place limits on defects and knots (branches) as well as the log's curvature, referred to as sweep. Higher grade logs are going to have more restrictions than lower grade logs, and so the more deflection there is in a stem, the more likely it is that the logs exceed the specifications for maximum sweep and get pushed into lower log grades, potentially failing to qualify as a sawlog entirely. Overly crooked stems that are sold as pulpwood fetch a fraction of the value of even the lowest-grade sawlogs in most markets. Likewise, boles that are covered in branches produce logs that are full of knots, which create the same problem in terms of the detriment to quality for the logs. As knots increase, the grades and values of the logs decrease.

Let's take a look at a few common stem forms below and discuss how value is affected.

1 2 3

Stem form one represents the highest value stem. Not only is the bole straight, but the portion of the stem that is free of branches or defects is long, allowing several high-grade logs to be cut from the tree.

Stem form two is also straight, but the clean portion of the stem is substantially smaller than stem form one. It is still a high-value stem, but it will likely only yield one log instead of several, so the total potential production is stunted.

In contrast to the first two, stem form three is very low value. Like stem form two, it branches off at a low height, but even on the branch-free lower portion, the stem is crooked and appears to have a substantial bulge or defect. Thus, the first log wouldn't be able to be sold as a sawlog and would be relegated to the lowest-value product class–pulpwood.

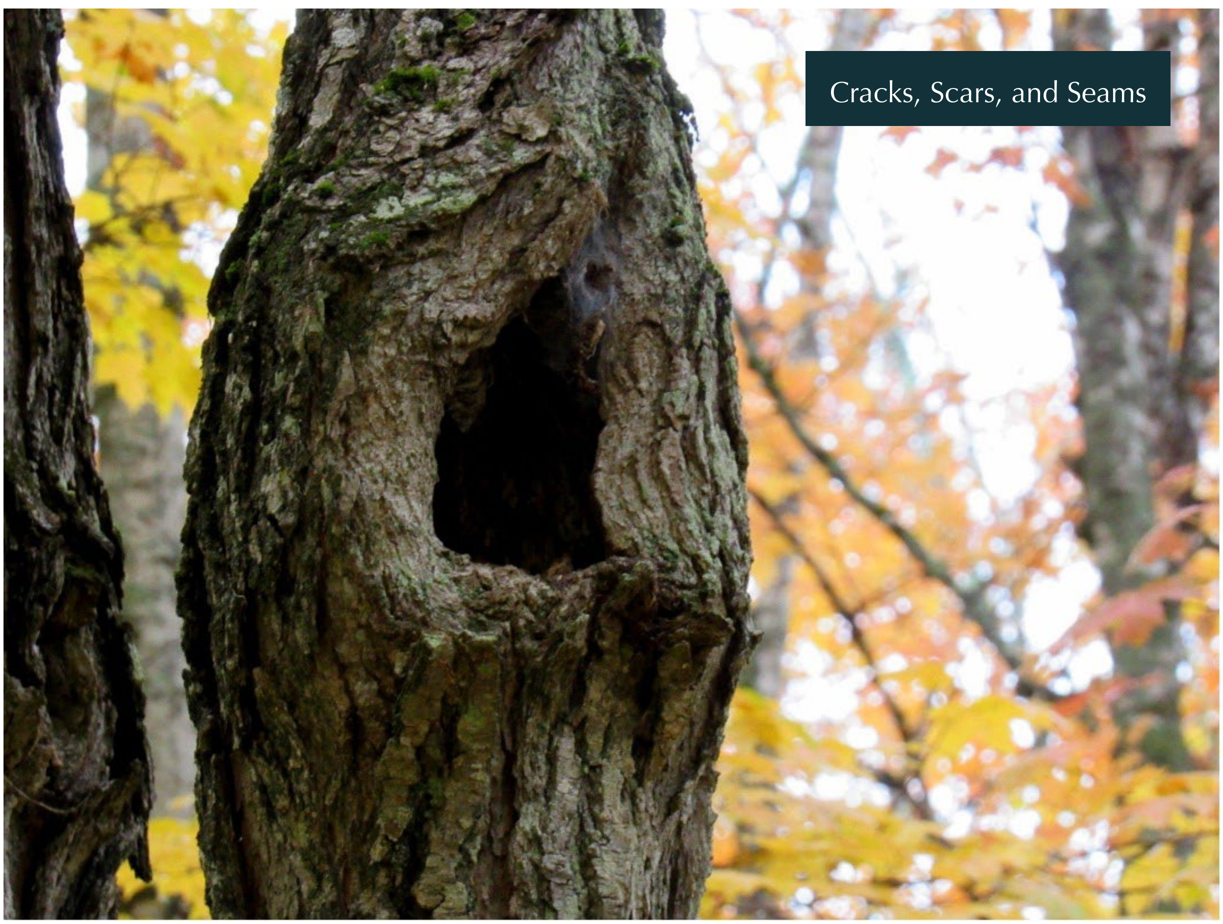
Note: *small defects on young stems do not necessarily mean the stem is worthless. Young trees still have the ability to grow over knots and dead branches and even straighten out slight crooks as the tree grows wider. In these situations, the tree will likely never make it to the highest value product class (veneer), but they can still become high-value stems with proper management. Take care when assessing the value of young stands of timber.*

Defects

Branchiness and sweep are not the only factors that lower the value of a tree. Even if a tree is gun-barrel straight and branch-free, it may be full of other defects that can dramatically lower the value. These defects include rot, cracks, scars, seams, disease, and even slight visual defects such as bulges.

Rot

It may not be too much of a shock, but rot decreases a tree's value, both by reducing the quality and net volume of the wood. Often, rot is obvious, manifesting as visual holes and punkiness in the wood, or the presence of fungi fruiting bodies, such as conks. In these situations, the rot is usually advanced, and the tree has lost its value as sawtimber. Other times, the rot may only be visible after the tree has been severed. In these situations, the tree may still be sold as sawtimber, depending on the species and total extent of the rot, suffering instead only a decrease in grade and yield.


Cracks, Scars, and Seams

Cracks, scars, and seams are all different names for essentially the same phenomenon: damage to the bole of the tree. Cracks can occur as the result of frost and lightning strikes and split the stem along the wood grain, which can dramatically reduce the possible yield from a tree.

Scars are the result of more blunt-forces that remove bark or cambium material, often as a result of harvesting equipment, falling trees, or pesky animals. Scars are often differentiated as being white face (fresh with sound wood) and black face (old and initiating rot). Black face scars are of course more of a serious detriment to value.

Seams refer to the seal a tree makes from growing over either cracks or scars. Like a scar on human skin, a scar will heal completely, covering the old wound with bark, but will forever bear a mark from the wound. Even if a seam looks ok from the outside, the wood on the inside never fully comes together as skin would, so it leaves a split in the wood that renders the area affected by the wound unusable as lumber. The deeper the seam goes, the more total volume is affected.

How Much is Too Much or Too Little?

Very seldom will one find a perfect tree. Even if slight and undetectable to the untrained eye, virtually all trees will have defects that can negatively affect its value. It is only a question of the limitations of acceptability. The answer will differ depending on the species in question and the specifications of the mill buying the logs, but there are still rules-of-thumb we can operate under to determine how much of a given defect is acceptable while still allowing the log to be sold as a sawlog, a more quality product

External Defect

To understand the limitations of external defect, imagine splitting the log vertically into quarters. Each quarter is a “face” of the log. To be sold as sawtimber, a log generally requires three clear faces along its stem, meaning that defect can only be found on one face. This is represented in the diagram below. Defect is only found along the stem in the quadrant marked in X, but the stems on the other three quadrants show no defect, so this log can still be sold as sawtimber, albeit at a lower grade.

Rot

Even if a log has rot, a modern sawmill can cut boards around the defect, so the log can still have value. Typically, rot will not disqualify a log from being sold as high grade until the diameter of the rot exceeds 30% of the total diameter of the log. This hypothetical maximum is represented by the red area in the diagram below.

Note, however, that deductions for the rot will be made when scaling the log, so aside from reducing grade, rot can have a detrimental effect on value.

Length

As one can imagine it is not economical to mill a log that is only one foot in length. Every mill has its limitations as to how short a log can be based on markets and their own efficiency. Typically, eight feet is the minimum. In some cases, the minimum might be as high as ten. In other situations where the product might be exceptionally rare, mills might drop their minimums to six feet in order to best utilize a constrained supply line. This is commonly the case with black walnut, for example.

Diameter

As length has economic minimums, so too does diameter. For hardwood sawlogs, sawmills typically require a ten inch minimum top end diameter. For softwood species from which 2x4 boards are a popular product, mills can usually accept down to a four inch top.

Qualitative Management

Thus far, we have discussed quality in such a way that allows only for retroactive analysis, which is to say examining the quality of timber as it is, but the purpose of this guide is of course to enable you to manage your forest for the future–to view and understand your forest as it could be. Thus, with the context of how quality timber is defined, let's examine how quality timber is grown with a discussion of qualitative forest management techniques.

Do understand, however, that the art and science of growing timber, known as **silviculture**, is a broad, nuanced, and complex field with considerations for every species, environment and market. As important as these are, It is simply not possible to cover these topics in sufficient depth, and so here we will only discuss broad techniques used by foresters to achieve specific elements of quality growth. These techniques are not mutually exclusive. It is both possible and in fact common to incorporate several if not all techniques in a given silvicultural regime.

Controlling Branchiness

Branchiness is going to be arguably the number one problem with growing quality timber because it often comes as an expense of silvicultural activities and often acts as a tradeoff to optimizing other values. Paradoxically, the more we as foresters and landowners meddle with the growth of a forest, the worse branchiness will be. But with proper planning and a solid understanding of what causes a tree to branch, we can greatly limit any ill-effects of silvicultural treatment.

Why Silviculture Causes Branchiness

A tree's foliage is its lifeline. Like an expansive network of solar panels, leaves are used to convert sunlight into energy for growth and respiration, and branches are the infrastructure connecting the whole network through the organism. But like any power grid, maintaining infrastructure is expensive, and trees are fairly efficient, at least by public utility standards. If leaves aren't getting enough sunlight to power the tree, the tree will abandon that line. The branch will die and eventually snap off. Conversely, if a given branch is particularly productive, the tree will continue to grow that branch further, slowly colonizing all the available light in an area until all available light is utilized. In short, the more light that is available to a tree, the more branches it will retain, and the bigger those branches will be.

This is the great paradox of silvicultural activities. As trees are thinned and harvested, more light is introduced for the tree. In most cases, this is the explicit goal of a silvicultural treatment. After all light and its availability or scarcity is the largest limitation to growth (at least in more humid parts of the country). But as light is introduced, trees stop self-pruning, existing branches get much larger and thicker, and new branches form. But there are methods used to either mitigate branchiness or balance it with other objectives.

Timing

Probably the most common method of controlling branching is using proper timing in treatment schedules. Thinking back to the elements of a quality stem, we want a clean stem for as much of the tree as possible, but most of the value of the tree is in the first two bottom logs. Thus, it is optimum to focus efforts on those first two logs. As long as the first two logs are of high quality, we can focus on growing out the tree and begin focusing on other silvicultural objectives. In practice, this means leaving the stand untouched and letting it grow in a dense environment (thus training stems to grow tall allowing for self-pruning from light scarcity) until around 20′ of the bole is clean of major branches. At that point, the stand can be thinned and timber stand improvement projects can be undertaken to allow these high-quality stems to grow out and put on diameter growth.

Pruning

Pruning, or the practice of manually cutting off branches along the bole, can also be used to limit branchiness. However, pruning is a difficult and time consuming process, and thus it comes at a great expense. Pruning is best used when the costs of growing trees densely (i.e, crown recession and slow growth) are unacceptable trade-offs for quality. For this reason, pruning is usually limited to use in softwood qualitative management (such as with white pine) and regimes where it is economical to maximize both quality and quantity of timber. That said, on a small, intensively-managed woodlot with less economic constraints, it can be a valuable addition to improvement operations.

Controlling Stem Form

There are near infinite events that can cause deformations on a growing tree. Ice, wind, falling neighboring trees, insects, and even moose or deer can have a substantial impact on the form a tree takes as it grows. Outside of controlling the more macro factors like tree density and not deliberately creating conditions conducive to insect outbreaks (which is more of a consideration when planting), there is little that can be done to effectively affect the shape trees take when growing. Luckily, we don’t have to.

In most North American forests, young stands are going to grow thousands of **trees per acre (TPA)**, and TPA naturally drops down as trees grow, leaving only a small fraction of the original individuals. Left to nature, pressures will usually select for the trees that grow the fastest and can catch the most light before being shaded out by its neighbors, but with active management, we can tip the scales of selection greatly in favor of quality stem form.

Out of the thousands of trees growing per acre, a certain percent will inevitably be straight and clean. Thus, average stem form for the stand can be effectively controlled by selecting these trees as crop trees and providing light and space for them to grow with pre-commercial thinning operations, commercial thinning operations, and considerations for quality in uneven age treatments such as selection cuts. However, as discussed in the previous section, thinning can create branchiness, so strategy and timing are paramount.

Controlling Stem Damage and Rot

Like stem form, stem damage and rot are often the result of more or less random forces, and they can be out of our control aside from careful stem selection, but this comes with a substantial caveat. More than ice storms, hurricanes, or insect damage, there is one event that holds the potential for the greatest amount of damage (and thereby rot) to a forest: A timber harvest. That is not to say that a timber harvest will destroy any residual timber, only that it has the potential to. Luckily, the damage of harvest can greatly be mitigated by understanding how damage occurs and how to strategize around limiting its potential. Damage from harvest is broken down into two main categories: damage caused by falling trees, and damage caused by harvesting equipment.

When trees fall, they can sever branches, scrape stems, and crush regeneration, potentially decimating the stand's future value. This damage can be mitigated by choosing the proper equipment for the stand condition. Feller bunchers can retain much more control of falling trees, for example, whereas harvesters have little control of where and how trees fall. We will discuss equipment in more detail later. Just as important as the machine is the operator. A skilled operator that treats the forest with care can substantially increase a forest's future value as a result of the mitigated damage, regardless of the machinery used. This is especially true with conventional chainsaw harvests where every tree presents unique challenges.

Root damage is the second mechanism of residual stand damage and is more a function of ground condition and machinery weight. Softer ground combined with heavier machines is going to result in more root damage. The potential for damage can be limited with small equipment and operating in dryer seasons or in the winter when the ground is frozen.

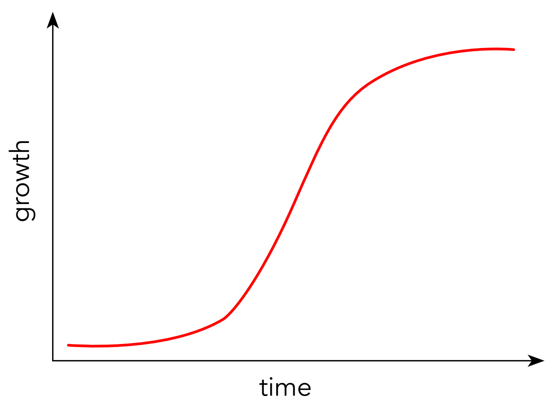
While it is controversial among foresters, there is merit to designing silvicultural regimes around limiting entry to the stand when managing for quality as a means of mitigating stem damage. For example, I prefer a binary regime where harvests are either extremely light (less than 30% of volume including trails) or extremely heavy, necessitating a long period of time without disturbance to allow quality stems to grow.

Quantity

In contrast to focuses on quality, considerations of quantity revolve around maximizing the growth rate of the forest and hence the production of value for specific species. Luckily, qualitative management is more standard, mathematical, and generally more predictable than qualitative management, but it comes with just as much nuance. Let's discuss some of the factors of growth maximization and quantitative management.

Forest Growth Dynamics

The growth of a forest is not constant throughout its life. Instead, the growth of a tree (and an even-aged forest stand by extension) follows the shape of a sigmoid-shaped curve. When a tree is young, its growth in terms of volume is incredibly slow. As it gains foliar area, its growth rate increases and reaches its peak at approximately middle age. After that point, growth gradually slows until it hits a crawling pace, eventually reaching the age of mortality. You can see this pattern visualized in the graph below.



Forests that are middle-aged are thus the most productive, and optimizing forest growth requires consideration of this dynamic.

The Growth Ring Illusion

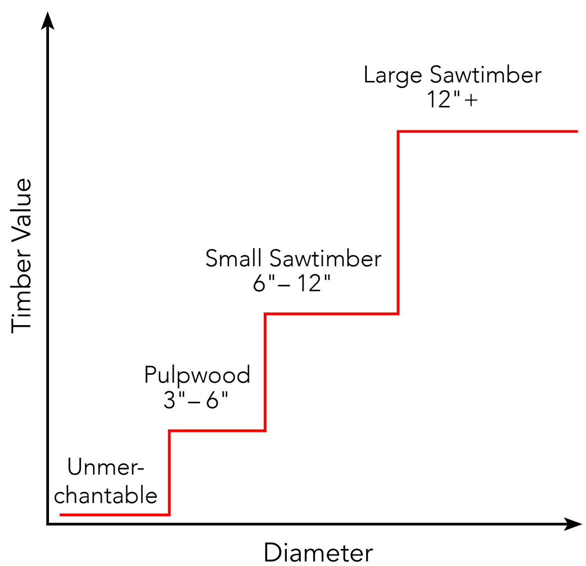
When analyzing your forest to determine its growth rate and stage of growth, it can be a common error (even for experienced foresters) to focus on the growth rings. If you cut down a tree or use an increment borer to count rings, you will probably see the annual increment (the width of every new ring) decreasing. However, diameter growth is NOT the growth of the tree. The diameter growth could very well be increasing rapidly despite the diameter growth appearing to decrease or stall. This is simply due to the mathematics of how the volume of a cylinder is calculated.

The formula for determining the volume of a cylinder **is** $\pi R^2 * L$. The two variables in this equation are radius and length. When you look at the growth rings, you only look at one of these variables, radius, but you look at it out of context. In the formula, it is squared, so constant radial increments will lead to exponential growth. If the level of the increment diminishes, however, the growth rate can still be linear or resemble a lesser exponential function. And then of course, you have the entire variable of length that can greatly increase volume.

Of course, trees aren't perfect cylinders. They taper greatly, so such a formula will overestimate these effects. Nonetheless, you can see how one must be careful when examining only the annual increment of growth rings.

Tree Size and Product Class

When maximizing the quantity of growth in a forest, foresters often speak in terms of "cords per acre per year" or another low-resolution figure that describes growth as a whole, but that is often a limited metric, as it does not show the true picture of growth. Like in qualitative management, not all growth is equal. Wood that comes from larger stems is often more valuable for reasons relating to quality, of course, but also the efficiency of harvest and milling and the necessary dimensions of a log required to mill or manufacture valuable wood products. Thus, as a tree grows and hits various height and diameter thresholds, all its growth becomes retroactively more valuable per unit of volume. This process is illustrated in the graph below.



Timber Value Intervals

Small Trees from which boards cannot be sawn can only be sold as pulpwood or biomass and thus command the lowest price per unit of volume. Medium-sized trees can be sold for sawtimber and command a dramatically higher price. The largest trees can be sold as veneer or higher-grade logs and command an even higher price (though this is still a minority of trees). Thus, it often makes sense to optimize growth in such a way that recognizes these value thresholds.

Quantitative Management

While techniques for maximizing quality can often resemble art–choosing the best specimens to grow based on almost arbitrary and imperceptible differences–quantitative management is more a science. It involves careful consideration of the biology of forest growth and the silvics of individual species to produce the best outcome possible. Variables of growth are controlled to the greatest extent possible, with specific species, TPA densities, and treatment timings chosen based on real data collected over generations. While it not possible to cover the complexity of quantitative management in sufficient detail here, let's discuss the basics, which will do well to provide sufficient context.

Foliar Area and Growth

Fundamentally, quantitative management is about maximizing growth, and the growth of a forest is directly correlated with the forest's foliar area, or the amount of green leaves and needles on the trees. The more leaves are in a forest, the faster the growth will be. But controlling foliar area can be difficult, as the forest is not a single organism, but rather a collection of trees competing for light.

Recall our discussion of controlling branchiness under a qualitative management regime: As trees grow densely, the imperative is for the trees to grow up toward the sun to avoid their own mortality. As their lower branches are shaded out, the lower branches are discarded to conserve energy and focus resources toward limbs that are productive. Thus, A dense stand will have many trees, but the crown on each tree will be smaller. The size of these crowns is expressed as the **Live Crown Ratio or LCR**. While the total growth of a dense stand with low individual LCRs may still be adequate, the growth per tree will likely be miniscule as the trees have limited foliar resources to grow. When the economic effects of tree size thresholds and harvest efficiency are considered, the distribution of growth creates a major problem, as the majority of growth is locked in low-value stems, many of which may reach mortality before becoming merchantable. Thus, quantitative management often focuses on optimizing both LCRs and total growth per acre.

Optimizing LCRs can be tricky business: Once a crown recedes, the only way for the LCR to recover is for the tree to grow taller. Leaves and branches don't grow back from the base, so it is critical that efforts are focused on preventing crown recession in the first place. Timing and consistency is crucial.

Thinning

A key component of controlling LCR is thinning. Trees are systematically cut to allow selected crop trees to grow in open light. Free from shade, their crowns will persist for longer, preventing the volume growth per tree from decelerating. With proper density, such a regime can optimize growth per tree with growth per acre. While there are many styles of thinning, they can be broken down temporally by two categories: Pre-commercial and commercial.

Pre commercial

Pre-commercial thinning (**PCT**) is conducted in stands of very young regeneration. As the name suggests, these trees are too small to be sold commercially, so they are cut manually with brush saws and left on the ground.

In the world of thinning, pre-commercial thinning is one of the most effective means of maximizing growth for two main reasons. Because the operation is performed at such a young age, the treatment is most effective at preventing crown recession and allowing the tree to have as high an LCR as possible. Second, the younger the stand is, the higher the TPA, and so the more options the forester has in terms of crop tree selection. There are more individuals to choose from in a younger stand, and so crop trees will be higher quality on average than if thinning were initially delayed until a later age when otherwise high-value species and individuals might be outcompeted.

The benefits come with a real cost, of course. Unlike other thinning operations where costs can be offset by timber revenues, no wood is sold during a PCT operation. It is solely an investment and so requires substantial upfront cost. However, the equipment needed is much less than with a commercial harvest, so it is extremely accessible for small landowners for whom the largest investment may simply be time. In many cases, brush saws can even be rented from local equipment rental shops.

Commercial

In contrast to pre commercial thinning operations, commercial operations are, well, commercial. Wood has reached a sufficient size to sell to sawmills or paper mills, and while the harvest may not be as profitable as later entries, it does usually yield the landowner a positive return.

Precommercial thinning and commercial thinning are not mutually exclusive. In fact, they are best used in tandem. A stand can first be pre-commercially thinned and later undergo a second commercial thinning when stems are both merchantable and at risk of excessive crown recession. If stands are grown naturally and do not originally undergo PCT, the LCRs will be lower by the age of the first commercial thinning, and subsequent growth will be slower, thereby reducing the efficacy of the thinning.

Planting

The most ubiquitous and effective means of managing growth is planting. Compared to more natural means of growth optimization, planting offers two primary benefits: Total control over species and growing stock and more control over the conditions in which those trees are grown, including site quality and density. Because of these huge advantages, plantations commonly offer substantially higher gross yields than natural stands. They do, however, come at great cost.

Planting is not a simple business. It requires substantial upfront investment for trees, planting labor, and even proper infrastructure to prevent seedlings from drying up in the sun. The costs don't end there. Planted trees may require follow-up herbicide treatments to prevent the ingrowth of competition, and PCT may still be required prior to a commercial thinning. The exact treatments are highly dependent on region and species, as well as site-specific attributes, but properly implemented, plantations offer substantial financial rewards for a landowner.

Tree improvement

As mentioned, a primary advantage of planting is the control over species composition it offers. Of course, there naturally exists significant differences in growth rates between species, so being able to choose what species to grow will improve growth. But the benefits planting has on growth go beyond the genetics of the species. Modern forest growing stock is often genetically-improved, which offers substantial growth advantages over naturally produced individuals of the same species.

Genetic improvement is not genetic modification, mind you. Instead of splicing and inserting new genes into trees, scientists merely select trees with superior attributes and inter-breed them. The offspring tends to carry on those traits. Over the course of generations, the resulting individuals grow at rates that would otherwise not be seen in nature. They may also present other beneficial characteristics like disease resistance.

The effect of these efforts can be seen clearly through the course of human history. Bananas, wheat, and corn all began as vastly different organisms with lower utility prior to human intervention. Today they power our world and provide us with needed sustenance at scales previously unimaginable. The decades-long span of time it takes for a tree to reach maturity means the genetic improvement process is necessarily slower, but the results will likely be similar. Planting and tree improvement will certainly play a larger role in forest management in the years, decades, and centuries to come.

Species Value and Utility

Once more, quantitative and qualitative management are not mutually exclusive, and wise forest management necessitates an attention that synthesizes both elements, especially in diverse forests. Nonetheless, it is a useful dichotomy that helps us differentiate and understand two fundamental styles of management. And of course, hardwoods are typically managed qualitatively while softwoods are typically managed quantitatively, but this is not always the case, and even where it is, it provides no information in regards to which trees should be selected as crop trees during thinning, selection, or improvement operations in either regime.

This is a complex and nuanced question that requires an understanding of local market dynamics. That will come in time with study and experience. For now, and for the purposes of this guide, we will provide a list of important timber species in the United States, as well as their relative value and typical management regime.

Relative Species Value and Management Style

SPECIES	VALUE	MANAGEMENT REGIME
Sugar Maple	High	Quality
Red Maple	Low	Quality
Yellow Birch	Mid	Quality
White Birch	Low	Quality
Black Cherry	High	Quality
Black Walnut	Very High	Quality
Hickory	High	Quality
White Oak	Very High	Quality
Red Oak	High	Quality
Aspen	Mid	Quantity
Yellow Poplar	Mid	Quantity
White Ash	High	Quality
Red Cedar	High	Quality
White Cedar	Mid	Quality
White Pine	High	Quality
Ponderosa Pine	Mid	Quanitity
Lodgepole Pine	Mid	Quantity
Loblolly Pine	Mid	Quantity
Yellow Pine	Mid	Quantity
Spruce	High	Quantity
Balsam Fir	High	Quantity
Hemlock	Low	Quanitity
Douglas Fir	High	Quanitity

Silvicultural Systems

To many in the modern world, “logging” is a dirty word. It conjures up imagery of men with chainsaws deforesting a landscape and destroying the environment. Nothing can be farther from the truth. While both chainsaws and clearcuts are still tools used in modern forestry, in reality logging can be a powerful silvicultural tool to help promote the health, sustainability, and value of a forest in both the quantitative and qualitative regimes mentioned previously.

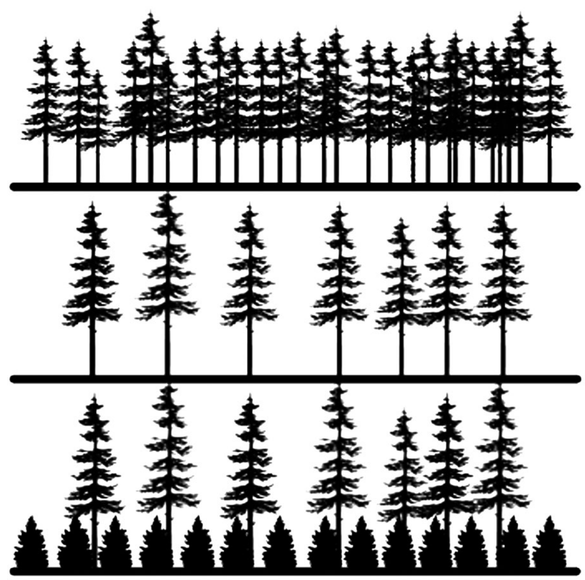
Logging can be used to accomplish a wide range of goals, including regeneration, growth enhancement, and quality improvement. In modern forestry, the type of harvest and objective of the harvest is referred to as a **silvicultural prescription**, and we break these prescriptions down into five general systems: Shelterwood, seed tree, clear cut, selection, and thinning.

Though you may not be planning to harvest your property on your own, it is still important to familiarize yourself with the concepts behind these silvicultural systems.

Shelterwood

A shelterwood system aims to harvest a portion of standing timber and regenerate the stand by allowing retained trees to spread seed while creating enough gaps in the canopy for light to reach new seedlings.

Once seedlings have sprouted, the retained canopy continues to put on growth for future harvests while providing shelter to the new seedlings in the form of shade from harsh sun and protection from ice, winds, and any other environmental hazard that may pose a threat to seedling survival. This is why it is called a “shelterwood.” You can see the progression of a shelterwood harvest in the illustration below.



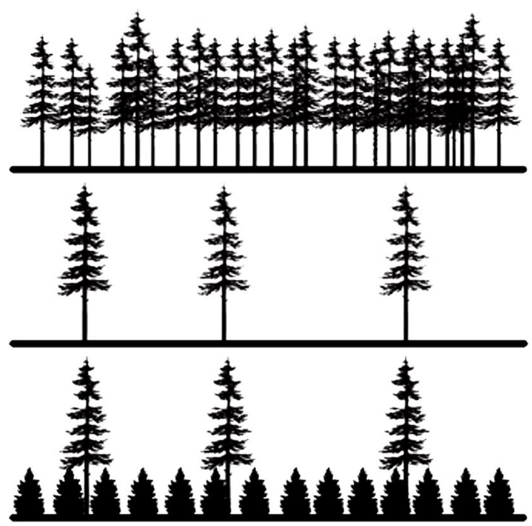
Shelterwood

With this type of logging, there are typically two timber harvests: the establishment cut, which creates gaps in the canopy and allows for the stand to regenerate, and the shelterwood removal (or overstory removal), which removes the remaining mature trees once the understory is healthy and established. Eventually, the understory matures into a new stand of timber, and another establishment cut can be implemented, continuing the cycle. While these are separate harvests, they together represent a shelterwood silvicultural system.

The benefit of this system is that it allows for the natural regeneration of a stand without the need for expensive planting operations or other treatments. Unfortunately, spacing out the canopy enough to regenerate the stand can lead to blow down risks, and excessive stand entries can lead to damage of both the understory and residual timber, which, as expressed earlier, is a concern particularly when managing for quality. Despite these downsides, shelterwood cutting remains a mainstay of modern forestry practices and is one of the favored types of logging for managing well-suited species in the right stand types.

Seed Tree

Similar to a shelterwood, a seed tree cut is a type of timber harvest that aims to mimic natural stand regeneration. However, there are a few key differences. In a seed tree harvest, far fewer trees are retained. The trees that are left for seed may just number a couple per acre, depending on the circumstances. At this level, retained trees do not offer any "shelter" to new seedlings. Their only purpose is to spread seed. In fact, because the density of these trees is so low, it is, in most circumstances, not even worth it to come back to harvest these trees. Instead, they are left as legacy trees for the benefit of wildlife, particularly birds of prey. This is a goal many harvests seek regardless. In many ways, these trees are sacrificial, but the sacrifice is not in vain! Thanks to the seed proliferation of these trees, foresters and loggers can keep the forest healthy and productive for generations to come.

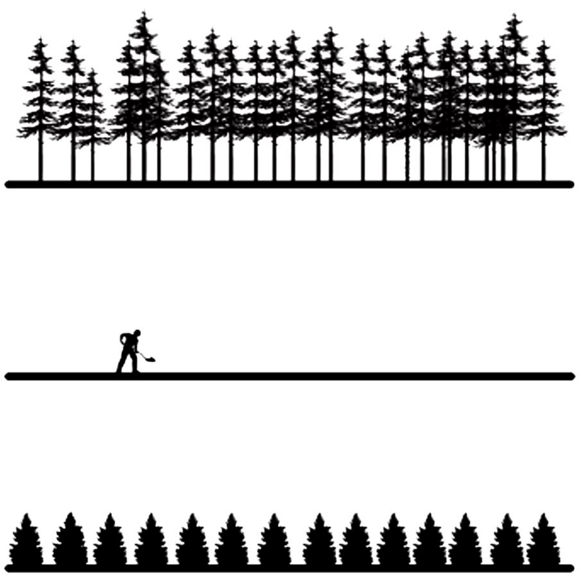


Seed Tree

Because these trees must have healthy enough crowns to spread seed far and wide and be strong enough to support itself out in the open against harsh winds, ice, and snow, individuals are often hand-selected by foresters, so proper seed tree harvests require careful planning.

Clearcut

By far the most famous (or infamous) of the types of logging, clearcutting is a silvicultural system that removes all standing timber from an area. In some cases, this can also be a method of natural regeneration, especially for species like aspen that can regenerate through stump sprouts and root suckers after a disturbance. In other situations (usually on smaller acreage), clearcuts may be left to seed in over time. Even if there are no seed trees or shelter, seeds will fall in from the edges, and the wind will blow lighter seeds like samaras into the cut. Additionally, certain pioneer species like aspen and cottonwood are designed to disperse seeds far away into natural disturbances, including recent burns and man-made disturbances like clearcuts!



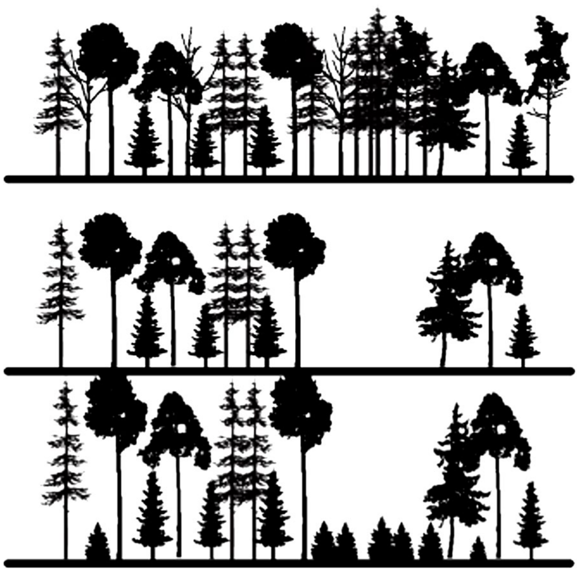
Clearcut

In most cases, however, clearcutting is used in conjunction with planting. In these situations, clearcutting has the benefit of giving land managers much better control over the future trajectory of the forest. Species, density, and even vigor can be controlled for, allowing for optimum growth. Unfortunately (though unsurprisingly) these operations come at great expense, so they must be planned carefully. Contrary to popular belief, there is a large amount of consideration that goes into every clearcut.

Selection Cut

All of the previously mentioned systems fall under a label known as "even-aged management." In other words, they are generally used when trees in a stand are of the same age class, or when it is the objective of the harvest to create an even-aged stand over time. However, forests are nothing if not variable, and so often "uneven aged management" must be used. Most prominent in this class is the selection cut.

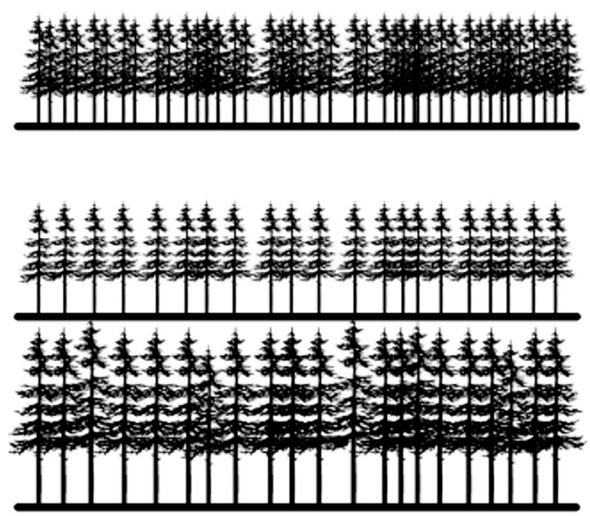
A selection cut is arguably one of the most complicated types of logging if only because it is less a system and more a methodology. While there are many variations, broadly speaking, selection cuts focus on selecting for harvest trees or groups of trees based on their own merits of species, quality, and growth potential with the aim of enhancing growth of desirable individuals and proliferating regeneration of valuable species. Over time, these cuts will create multi-aged stands in perpetuity, and the acreage will always be well-stocked with a certain percentage of mature and immature growing stock. You can see this process illustrated in the diagram below.



Selection Cut

Thinning

Not all timber harvests have to be a means of regenerating a stand. There are certain types of logging, known as intermediate treatments, that primarily focus on improving growth or quality of standing timber. Primary among these harvests is thinning, which we discussed a bit earlier. As a group of trees grows larger, they begin to compete with each other more and more. Their limbs shade each other from the sun, and their roots fight with each other for nutrients and space. They cannibalize each other and hinder the growth of the entire stand. Thinning focuses, as you may have guessed, on thinning out these dense stands, leaving the best, most healthy and desirable individuals plenty of room to grow. The result is a faster growing stand and one that will be much more healthy and vigorous for far longer. Additionally, if a regenerating cut like a shelterwood is to be done at a later date, thinning helps prepare stands for these treatments and reduces the risk of blow down from canopy gaps, as larger trees and better crowns makes trees better able to withstand wind and stress.



Thinning

Thinning is one of the most versatile types of logging because of its wide range of benefits. Not only does it create financial return for the landowner, but it allows for faster growth and gives land managers more silvicultural options when the stand is ready for a final harvest. Done properly, there are few downsides. The only caveat is that you need the right harvest system to be able to maneuver through tight, small trees.

Harvest Systems

Almost as important as the prescription itself is the harvesting system used. While often overlooked, modern forestry machines are extremely diverse in their functions, strengths, and weaknesses, and selecting the right equipment and operator for the job can make an extraordinary difference in the success of a harvest. Below is a list of common harvest systems and their attributes.

The conventional logging system is one of the oldest and most classic types of logging. Trees are felled with a chainsaw and yarded with a cable skidder, which uses a winch to drag trees across the ground out to the road. Traditionally, the feller manually limbs and bucks trees with a saw, but some conventional systems utilize a delimber to buck and delimb faster.

Conventional systems are ideal for smaller woodlots and sensitive sites. They have lower production rates than more mechanized systems, but the small equipment is gentle on the soil and minimizes damage to residual timber. They are a mainstay of low-impact logging.

Conventional
Felling: Chainsaw
Yarding: Cable Skidder

More on the modern and mechanized side of the spectrum, we have the cut-to-length harvest system utilizing harvesters for felling, limbing, and bucking, and forwarders for yarding. Trees are limbed and processed in the woods, and wood is brought out to the yard already cut to specification, hence the name "cut-to-length." Unlike conventional logging systems, these systems are fully

Cut-to-Length
Felling: Harvester
Yarding: Forwarder

mechanized with all functions fulfilled in the seat of a cab.

As far as mechanized systems go, the harvester has the unique advantage of incredibly articulate machinery, allowing it to reach in hard places that most larger equipment can't get to. By limbing trees in the woods, it also creates for itself a bed of protective slash to drive over, allowing for better waste disposal and more protection for sensitive soils. Unfortunately, these machines have little control over felling direction, and moving trees around to limb can be a problem, so these machines don't always protect regeneration and residual timber all that well.

Similar to cut-to-length systems, whole tree systems are fully mechanized, but that is where the similarities end. Whole tree systems harvest trees with feller-bunchers and drag the "whole tree" out to the yard using a grapple skidder. A delimber then removes

branches and stacks wood without cutting logs to length. Trucks then bring the wood to the mill where it is processed further.

Feller-bunchers may not have the articulation of harvesters, but by being able to pick trees up off the stump, fell-buncher offer a great deal more control, protecting regeneration and residual timber. Unfortunately, grapple skidders apply more pressure to the ground, making the system unfit for sensitive sites. The differences and advantages of whole tree and cut-to-length systems are complex, so if you are interested, we have a separate article about it here.

All the aforementioned systems have one profound weakness: Steep slopes. In the western United States and Canada, where steep slopes are the rule and not the exception, a different system is needed. That is where cable logging comes in. Cable logging is similar to the conventional system in that it uses a sawyer and cable to fell timber and pull it out of the woods, but unlike a cable skidder, which uses a small winch affixed to a vehicle that ultimately does the pulling, cable yarders use cables affixed to semi-stationary towers that pull trees up and away from above.

Hybrid and Experimental Systems

While the aforementioned are the standard equipment mixes one will find, they are by no means the only equipment mixes available. A plethora of different types of equipment and methods exist depending on the area and the economics of a harvest. Personally, I harvest my woodlot with a hybrid cut-to-length/conventional system, cutting logs by chainsaw and moving them out of the woods with a forwarder-equipped tractor. Ive also worked with several logging crews that have utilized a hybrid cut-to-length/whole tree system, where a feller-buncher cuts trees ahead of a harvester, letting the harvester focus solely on processing the wood. The woods industry is governed by what Iike to call "soft economics." economies of scale in one area are usually matched by diseconomies of scale in another. As a result, no single system of production is inherently superior, and efficiency falls on the creativity of the operator to match the equipment mix with the situation.

Tools of the Trade

To effectively utilize the aforementioned concepts, you need to know when to use them , how much to cut, and so on. You can only make these decisions with proper measurements, and so, and so crucial to understanding forest management and making decisions regarding your land is learning how to measure the forest and interpret the data. Let us begin by covering the tools necessary to take proper measurements and readings of the physical attributes of your forest. While simply using your eyes and developing a sense of intuition can accomplish much, this intuition can only be developed after learning how and when to take measurements, understanding how to interpret them, and then taking those measurements hundreds of times. There are no shortcuts here.

Luckily for you, in comparison to most other trades and skill sets, the tools used in forestry are economical to purchase and easy to use. Moreover, their function is extremely simple. With the exception of a few modern technologies like GPS, the tools used to measure forests have been used for over a century, and they are designed to withstand the harshest conditions of field work, including pouring rains and sub-zero temperatures. As such, you can expect your tools to last a lifetime (especially with light use) and work in all conditions.

Here are the essentials:

Angle Gauge/Prism Gauge:
Perhaps the most fundamental tool of the forester is the angle gauge and prism gauge. These measure Basal area by allowing the user to count trees based on both their size and distance from the data collector. The estimation of basal area provides an estimate of the density of wood volume along a horizontal plane, which, when combined with height measurements, can give an estimate of the total volume on a given parcel of land.
Both the angle gauge and prism gauge measure the same metric and can be used interchangeably. However, an angle gauge can generally measure several basal area factors, while a prism gauge can only measure one. Moreover, prism gauges are substantially more fragile.

You can find an angle guage here and a prism gauage here.

We will discuss basal area more in depth later.

D-Tape

A D-tape is a flexible tape measure that measures diameter based on the tree's circumference. Unlike a standard tape measure, a D-tape the markings on a diameter tape are pre-calculated to convert the circumference to diameter, eliminating the need for further calculations.

You can find a D-tape here.

Scaling Stick

A tree and log scale stick (which may be called by several names with slightly differing functionality, including a **Biltmore Stick** *or* **Merritt Hypsometer***) is a measuring stick that can measure diameter, merchantable height, and the board feet of both standing timber and processed logs.*

You can find a scaling stick here.

Increment Borer

An increment borer is a specialized tool that bores into a tree and extracts a core to allow a forester to examine and analyze a tree's growth patterns through the rings without need to cut down a tree. By looking into the past and seeing the history of a tree's and forest's growth, a forester can infer much about the likely trajectory and value of a forest.

Increment borers are not what I would call a "core" tool of the forester's tool belt. They are more of an auxiliary device, and they are one of the more expensive tools on the list. However, if your budget allows, I highly recommend buying one. Forests grow slowly, and so it can be difficult to learn patterns of growth over time.

An increment borer lets us cheat and see past patterns, allowing for more observation and faster learning. And I'll be honest: They are fun to use

You can find an Increment borer here.

Compass
Best known for aiding hikers, hunters, and other outdoorsmen in navigating the backcountry reliably, a compass serves as an indispensable tool for the small landowner as well, even if they know the property like the back of their hand. A compass can help you locate property boundaries and search for evidence of boundary markers, properly navigate to points when conducting a timber inventory cruise, and aid in laying out a stand for timber harvest. Additionally, modern baseplate compasses come equipped as a Swiss army knife of tools and functions, which usually include a ruler, magnifying glass, and clinometer to measure heights and slopes. A seasoned forester never walks into the woods without his compass.

You can find a decent, utilitarian forester's compass here.

GPS
These days, everyone knows what a GPS is, so I won't waste paper (or your phone's battery) explaining them. Suffice to say, they are an integral component of modern forest management, allowing you to delineate your property into manageable units and navigate accordingly. You don't need to go out and buy a dedicated GPS unit, however. What most people don't realize is that they already carry a sophisticated GPS with them on their phone. With special apps (Tracklia being my current preference and recommendation) you can take points and create tracks using a standard Google Maps base map. You can then take your points and upload them onto Google Earth or any GIS platform. Alternatively, another app called Avenza can be used to import your own custom base maps using georeferenced PDFs. However, doing so requires a bit of technical knowledge, so it is best to stick to Tracklia unless you have GIS experience. Whatever your preference, download the app and familiarize yourself with its functions.

Forest Mensuration: Understanding How to Use Your Tools

As important as familiarizing yourself with the tools themselves is understanding how and when they are used. What good is a hammer if you have never heard of a nail? Of course, hammers and nails are both simple and ubiquitous. Virtually everyone around the world understands "hammer theory," if you really want to pretentiously refer to it as such: Hammer goes ***bang*** and nail gets real stuck. The tools outlined in the previous section are not as ubiquitous. While they mechanically and functionally may be as simple as a hammer, an angle gauge being little more than a single piece of aluminum on a chain, for example, the outputs of these tools are incredibly complex, abstract, and theoretical. It is crucial to understand them.

In fact, forestry has an entire subfield dedicated to the use of these tools and the interpretation of their data. We call this field "forest mensuration." In truth, an entire book could be written on this subject, and many books have been written. But you need not have a masters in the subject to be a proficient forester. We will leave the bulk of the theory to the academics and forest modelers and instead focus only on the essentials. Namely, we will discuss the fundamental measurements of a forest, what they represent, and how to use your tools to derive them.

Diameter

The diameter of a tree, also known as "**Diameter at Breast Height**" or "**DBH**," is one of the most essential and basic measurements in forestry. While the diameter of a circle or circular object is a measurement everyone understands, DBH has a specific definition as to the location of the measurement and rules for how it is taken. When you read academic or industry materials that reference "tree diameter," this is the specific measurement they refer to. Here are the steps to properly find the diameter of a tree:

Step 1: Find "Breast Height" at 4.5′ High

Diameter at Breast height is specifically defined as being 4.5′ above the ground, and this is where one must measure the diameter of a tree. It can be overly cumbersome and inefficient to measure this height on every tree, so to make life easier, you must familiarize yourself with where 4.5′ lands on your body and use that mark to determine where to measure diameter on a tree.

Being 6′ tall myself, 4.5′ lands perfectly at my breast, as you can see in the photo below, so DBH holds particularly true–as well as being easy to remember. Everyone's "breast height" will be different, however, so it is important to measure for yourself.

Step 2: Carefully Wrap the Tape Around the Tree

For the next step you will need a D-Tape as mentioned in our outline of common tools. Alternatively, a flexible tape measure (such as one used in tailoring) will work at the expense of an extra calculation. I do, however, highly recommend buying yourself a proper D-tape, particularly if you are serious about managing your forest. Not only will a D-tape come with a specialized hook for grabbing into bark, making it much easier to measure large diameter trees, but it will automatically convert circumference into diameter, saving you a step later on and decreasing the possibility of error.

Whichever tool you choose to use, wrap the tape around the tree at 4.5′, keeping it as straight (perpendicular to the tree's vertical axis) as possible, avoiding any sag in the tape in the back. Avoid measuring over any defects or protrusions. If you do find there is a protrusion in the tree at 4.5′ that will affect the measurement, simply measure directly

above the defect. If the tree is on a slope, try to measure on the uphill side of the tree. Remember, trees taper slightly as you go up the trunk, so whenever there is any doubt about where exactly to measure, it is best to move the tape upward slightly to avoid overestimation. Underestimated data leaves us with happy surprises. Overestimations leave us with disappointment.

If the tree shape is irregular or oblong in some fashion, don't worry about it. Because we are deriving diameter from a circumferential measurement, we are automatically creating a sort of average of the tree's shape.

Step 3: Take the Reading

After taking the tape completely around the tree, bring it back and match up the end of the tape with zero. My D-tape reads in centimeters, so this tree is 60.3 centimeters in diameter, or about 23.7 inches. There you have it. That's the diameter. There are D-tapes that are double sided with one side measuring diameter and the other measuring nominal length, so be sure you are reading the correct side before recording your information.

If you are using a regular tape measure, the number you derive here is only the circumference of the tree, and **further calculation is necessary to measure the true diameter**.

Step 4: Convert the Measurement as Necessary

A forester's D-tape is designed to automatically measure diameter from circumference, but if you use a standard measuring tape, you will have to do this yourself. Luckily, it isn't too difficult.

To convert your circumference into diameter, simply divide by 3.14 or pi. That's it.

To use the above tree as an example, if you were to measure the diameter with a standard tape measure, it would read 74.4 inches, which would be the circumference. Divide 74.4 by 3.14, and you get the real diameter: 23.7 inches.

The Purpose of Measuring Diameter

Taking tree diameters (especially when combined with height measurements) is the only way to get high-resolution inventory and growth data of a forest. Measuring diameters of trees over time also can give us exact data on growth trends and impart valuable insights into the health and condition of the forest. For smaller-scale management styles, diameter can also allow us to estimate the volume of a single tree, which is crucial for planning firewood and other small harvests.

Alternative Tools:

DBH can also be measured with calipers and scaling sticks. However, calipers can be cumbersome to lug around the woods, and scaling sticks, while extremely convenient, do not provide the most precise measurement, so I do not recommend using them for recording data for long-term monitoring or when precision is needed. In most cases, D-tapes are the best tool for the job.

Tree Height

Tree height is exactly what you would expect–the total height of the tree from the top of the crown to the base of the stump. Though a simple and conceptually easy measurement, it can be one of the trickier pieces of data to measure due to the obscured crown views in the forest and the myriad of methods (some overly complicated) of measurement. Nonetheless, total height is important for both taking high-resolution data of individual trees and coarser stand-level data of average tree height.

I advocate measuring heights with the "stick method" for its simplicity and accuracy.

To measure tree heights with the stick method, you will only need two tools: An arms-length stick and a 100′ tape for precise and accurate data. For coarser estimates, you can also pace distance in place of using a tape.

1. Hold the Stick Straight Up With the Bottom Level with Your Eye

Next, grab on to the base of the stick and hold your arm out fully extended in front of you, **being sure to keep your hand at eye level**. Ensure the stick is just long enough to reach your eye from this position. Adjust your grip as necessary to get just the right length. Once you are sure the stick is at the right length, **hold the stick straight up at 90 degrees**, being sure once more that your hand is still held up at eye level.

2. Stand in a Position Where the Top of the Stick Is Visually Aligned With the Top of the Tree

From here, get a visual of the tree you wish to measure and adjust your physical distance from the tree until, from your visual perspective, **the top of the stick you hold is perfectly aligned with the top of the tree**. Try to stay on the same ground level as the tree while moving around. The final position should resemble something like the diagram below.

3. Measure Your Distance From the Base of the Tree

From here, **your physical distance is roughly equal to the height of the tree!** All that is left to do is to measure that distance, which you can do either by physically measuring the distance with a 100′ tape or estimating the distance using pacing.

Measuring With a 100′ Tape

Measuring your distance from the tree with a 100′ tape is the most accurate way to do so, but it is also fairly inconvenient. First, you will need to get yourself a tape if you don't have one. Then, take one end of the tape and secure it to the tree and walk back to your previous position (hopefully you marked it). All that is left to do then is to record the measurement.

Estimating by Pacing

The less accurate but more convenient method of estimating distance is by using pacing. Measuring distance with pacing is simple. All you need to know is the average distance of your pace (one pace is defined as two steps. Every time your right foot touches the ground is one pace, for example). Count how many paces it takes you to walk to the tree from your position and multiply that number by your average pace length.

If you don't know your pace length, you can use the table below to estimate it based on your height:

HEIGHT	WOMEN'S PACE (FEET)	MEN'S PACE (FEET)
5 ft. 0 in.	4.2	4.2
5 ft. 1 in.	4.2	4.2
5 ft. 2. in.	4.3	4.3
5 ft. 3 in.	4.3	4.3
5 ft. 4 in.	4.3	4.5
5 ft. 5 in.	4.5	4.5
5 ft. 6 in.	4.5	4.5
5 ft. 7 in.	4.7	4.5
5 ft. 8 in.	4.7	4.7
5 ft. 9 in.	4.7	4.7
5 ft. 10 in.	4.8	4.8
5 ft. 11 in.	4.8	4.8
6 ft. 0 in.	5	5

Remember: **A single pace is equal to two steps!**

Note: *Pacing is a convenient and ever-useful skill in forestry and outdoor sports. If you find yourself using it frequently, find your own unique pace by measuring out 100 yards on flat ground and counting how many paces it takes you to walk the distance, walking as normally as possible. Divide 300 (feet) by the number of paces. Do this five times and average your results. When you use your own unique pace for estimates, you will be surprised how accurate it can be.*

5. Make Final Adjustments to Your Calculation to Get the Final Tree Height

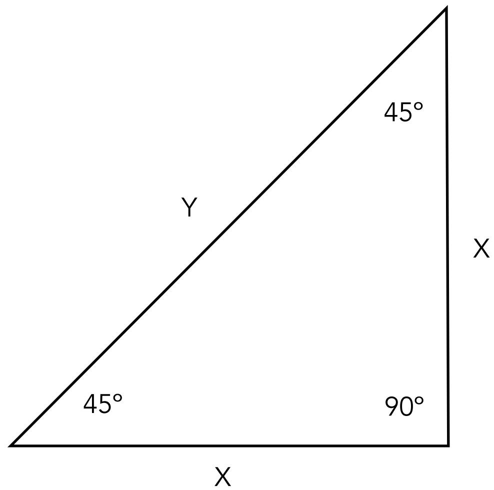
The last step needed is to make a few adjustments based on the circumstances. First, because you were holding the stick at eye level, it is likely the base of the stick was aligned with eye level on the tree as well. To adjust for that, add on your eye height (generally your total height minus six inches) to the distance measurement in step 4. **That leaves you with the final answer**.

There may also be times when you are unable to stay on the same level as the tree, maybe going a bit downslope or upslope from its base. If that's the case, simply make a heuristic adjustment. If you went downslope, subtract the approximate elevation decline. If you went upslope, add the approximate elevation gain.

Why it Works

While it may seem odd, **this method works by essentially doing pre-calculated trigonometry**. If you recall from your high school geometry class, the internal angles of a triangle must equal 180 degrees. When we measure trees, we know the tree stands at roughly 90 degrees from the ground, which gives us 90 more degrees to work with. If we ensure the bottom angle is 45 degrees, we can guarantee the top angle is 45 degrees also, and if that is true then the adjacent side (bottom) and opposite side (right) of the triangle must be identical. X=X.

When we hold a stick to our eye and flip it up, we are creating a small triangle with two equal sides to be able to sight-in 45 degree angles on a much larger triangle, ensuring once more that the opposite and adjacent sides are equal. When we pace our distance to the tree, we are measuring X, which measures simultaneously two sides of the triangle, including the height of a tree!



Note: *This method of height measurement can also be used to measure the height of the stem to the base of the crown, which can then be used to find the liver crown ratio, as discussed earlier.*

Basal Area

Basal area per acre is likely the most utilitarian and important measurements in forestry. It is also a bit complicated to understand and appreciate. **Basal area is the total amount of surface area occupied by wood on a horizontal plane**. If we imagine a horizontal plane at DBH (4.5 feet off the ground) spanning an entire acre and intersecting all trees on that acre, what would be the total surface area of the log faces that were intersected by that plane? That surface area is the basal area per acre.

Basal area is a special measurement because it neither strictly measures density like trees per acre, nor measures mean tree size like DBH. Instead, it provides a mix of those two attributes and provides a little information on both. Combined with other details like tree height, basal area per acre can be a reliable way of estimating total wood volume on an acre, making it a crucial measurement for inventory, management, and timber value analysis. It can also be used in conjunction with stocking guides to better advise silvicultural decisions based on the density and size of trees. Learning how to measure basal area is thus essential for understanding forest management and becoming a proficient forester.

The Basics of Measuring Basal Area Per Acre

The only way to know the true basal area of a given acre is to measure every single tree and sum the total area each tree represents. Clearly, that is far too impractical, so foresters developed means of estimating basal area through **point sampling**.

In point sampling, foresters use tools (an **angle gauge** or **prism gauge**) designed to simultaneously measure the distance and diameter of a tree to judge whether that tree is representative of a given amount of basal area per acre, known as the **basal area factor** or **BAF**. Each tree is determined to be "in" or "out" of a plot, and the total tally of trees "in" the plot are multiplied by the basal area factor. Thus, such a plot (also known as a variable radius plot) will follow these steps:

1. Find plot center
2. Go around the plot center using an angle gauge or prism gauge and count trees in the plot based on the parameters of the respective gauge (more on that later).
3. Multiply the total tally by the BAF of the gauge used.
4. Repeat this process for multiple plots and average the results.

That's it. That's the process. The rub, however, is in the proper use of the angle and prism gauges, deciding on a proper BAF, as well as designing the overall cruise. Let's go into detail for each step

Choosing the Basal Area Factor

When it comes to choosing a proper BAF for a point sample, it is important to remember that a larger BAF will tally fewer trees. The goal is to be able to measure as few trees as possible while still getting a representative sample of the stand. Thus, a larger BAF can be used for a stand with larger trees and a smaller BAF can be used for a stand with smaller trees.

In the US northeast, where trees are generally smaller, 10 BAF is considered standard. However, 20 BAF is used for stands of larger saw logs. Out in the western US, where larger trees are the norm, even 40 BAF can be used. While there are no clear rules, a good rule of thumb is to choose a BAF that will tally around seven trees per plot. When in doubt, use a smaller BAF. **It is better to tally too many trees than too few**.

On an angle gauge, BAF can be chosen freely, as each instrument comes with usually four different slots for four different BAF measurements. On a prism gauge, however, it is limited to one BAF per prism, so there is less optionality.

Remember**, the BAF you choose is the basal area per acre each tree represents in a plot**, so if you tallied seven trees using 20 BAF, that plot would represent 140 BA/Acre.

Taking a Plot With an Angle Gauge

An angle gauge measures basal area per acre by measuring the angle a tree's width relative to your eye. The narrower the angle, the less likely a tree is to be counted in a plot.

To use an angle gauge, start (as always) by finding plot center. Once found, stand directly on plot center. It is important to note when using an angle gauge that **the person taking the measurements (the cruiser) acts**

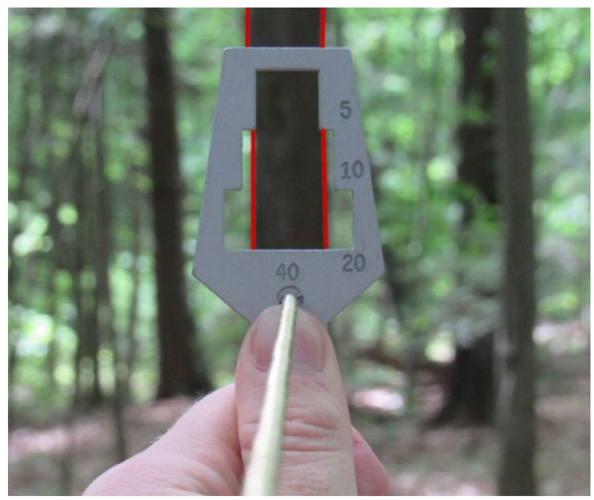
as plot center, and while counting trees, the cruiser spins around from a single point.

To begin measuring, pick a starting point. It is best to use a starting point that can be easily remembered. I recommend tying a ribbon to a branch to mark where you start. After a starting point is determined, place the loose end of the gauge's chain in your mouth and fully extend the gauge away from your eyes, as seen in the image below.

turning around in a circle, carefully get a clear sight picture of every tree around you and determine if each tree fits within the slot (of the specified BAF, as marked on the side) or extends past the slot.

If the tree extends past the slot, as seen in the picture below to the left, **the tree is counted in**. If, however, the tree fits within the edges, as seen in the photo below to the right, the **tree is counted out**.

Tree is counted in



Tree is counted out

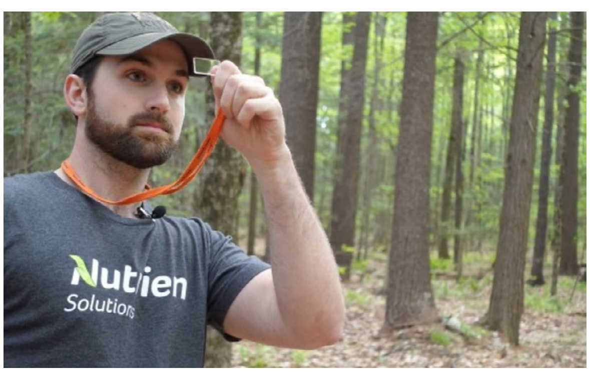
Continue this process with every tree around you and stop at your starting point. Be sure not to double count trees! Take your total tally and multiply the number by your chosen BAF. That will give you the total basal area per acre that plot represents.

Taking a Plot With a Prism Gauge

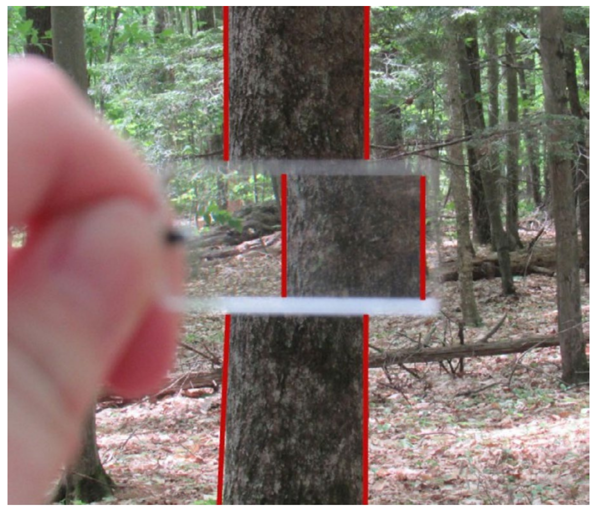
Determining basal area with a prism gauge is similar to the process for an angle gauge, with a few key differences. Prism gauges measure basal area by creating an offset image of every tree bole. The narrower the tree, and the farther away it is, the greater the offset. Trees that are sufficiently offset are counted out.

Similar to the angle gauge, begin a prism gauge plot by finding plot center. However, unlike an angle gauge, the center of a prism gauge plot is the prism itself. It is necessary for the cruiser to rotate around the prism while holding the prism over plot center.

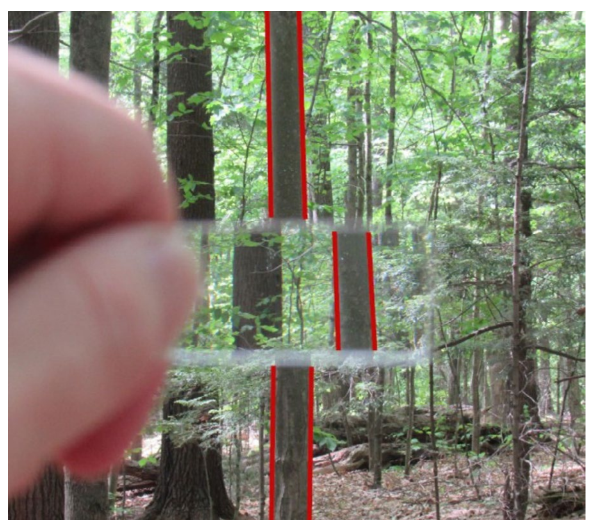
Find your starting point (marking it, ideally) and view every tree around you through the prism, such as in the photo below. Note that the distance of the prism from your eye is irrelevant, though a matter of personal preference and visibility.



As mentioned previously, The prism will create an offset image. Look carefully at the bole (stem) of each tree. If the offset is still within the edges of the real position of the tree, as seen in the image to the left below, the tree is counted in. If however, there is no intersection between the offset image and the real tree, and the edges do not meet, such as in the image to the right, the tree is counted out.



Tree is counted in



Tree is counted out

As with an angle gauge, this process is repeated for every tree around you, and the final tally is multiplied by the BAF of the prism. Once more, be careful not to double-count trees!

Which Is Better, an Angle Gauge or a Prism Gauge?

Both are perfectly acceptable to use. Prisms can be easier to see through, but in low light conditions, it can be more difficult than an angle gauge. Prism gauges are also limited to a single BAF, whereas angle gauges have more options, as previously mentioned. Ultimately, it comes down to preference.

For beginners, I recommend an angle gauge to start, if only because it is more intuitive to treat yourself as plot center than to circle around the gauge.

Trees Per Acre

Trees per acre, also known as TPA, is one of the most important metrics for determining the timber density of a forest. To calculate trees per acre, simply use a fixed radius plot to count trees within a given area and multiply the number of trees by the denominator of the fraction of an acre the plot represents. If that sounds confusing, don't worry: It's actually quite simple. We'll explain how to do it in depth in this article. But first, let's explain the fundamentals of what exactly a fixed radius plot is and how they can be used to calculate trees per acre.

What Is a Fixed Radius Plot?

Fixed Radius plots are a method of sampling in which every individual within reach of a specified, consistent radius is tallied or measured. The area of the circles created by the radius represents a given fraction of a larger area, such as a 1/100th of an acre circle, and this is the sample area. By measuring trees within that plot, we can then extrapolate and estimate data about the population of the larger area. By sampling enough of these plots and averaging them, we can get a decent idea of the true numbers across large areas that are otherwise impractical to measure.

Using Fixed Radius Plots to Calculate Trees Per Acre

Using fixed radius plots properly is more than just drawing circles and counting trees, however. It requires good, consistent technique, an appropriate radius, and a non-biased sampling method. Let's take a closer look at every step of the process.

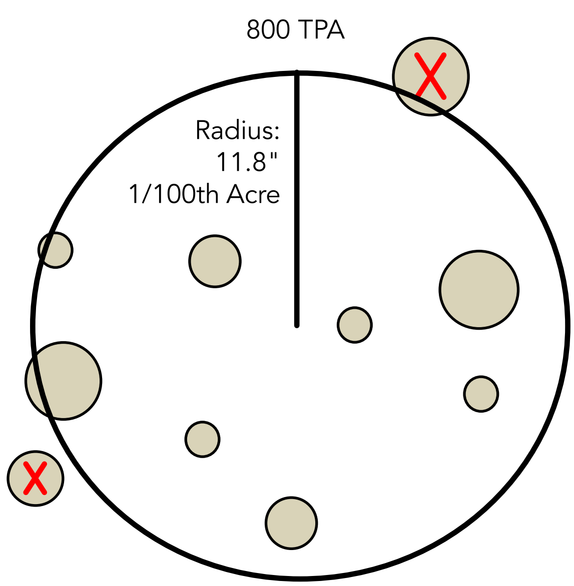
How to Take a Plot

To take fixed radius plots to calculate trees per acre, you need only three materials:

- A tape measure

- Rope or cable
- Sturdy wooden stake or metal rod
- A notepad or digital recording device
- (**Optional**) Laser Distance Measure

To begin, place the stake or rod firmly in the ground so it does not easily move from side to side. This is your plot center. Next, affix a cable or rope to the plot center in such a way that it moves freely around the rod and does not wind (looping it around the stake, for example). Measure the rope to the desired length and cut it or mark it at the correct length (for now, we will use 11.8’, or 1/100th of an acre). Now we are ready to begin tallying.



Example of a TPA tally. Trees with centers that fall outside the plot are not counted. Eight trees counted in a 1/100th of an acre plot equates to a total of 800 TPA.

1. Find a place to begin. Hold out the rope, and begin moving clockwise.
2. Any tree with a center that lands within reach of the rope falls within the plot and should be tallied. If the center falls outside of reach, the tree should not be counted. reference the diagram above to see what trees should and should not be counted.
3. Once you count your first tree, be sure to mark it with a ribbon or paint so you don’t lose track of where you started counting.
4. Proceed to move in a complete circle and tally every single tree that falls within the plot. Stop Counting when you return to your starting point.

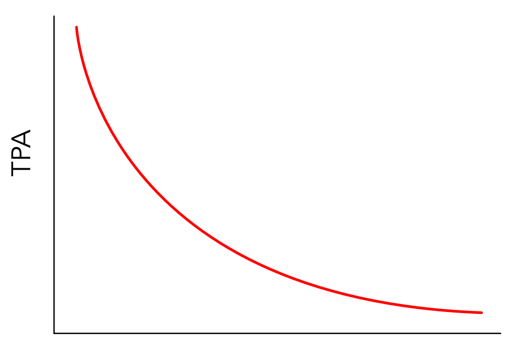
When you are done, multiply the tally by the denominator of the fraction of acreage your plot represents. This number represents the total trees per acre. for example, in the diagram above, the 8 trees tallied in a 1/100th acre plot represent 800 trees per acre, as 8*100=800. However, 8 trees tallied in a 1/50th of an acre plot represent only 400 trees per acre.

Alternative Method

If you are dealing with larger radius plots, it can be easier to use a laser distance measure instead of a rope or cable to find distances. Simply stand at the plot center and shoot a laser at trees, going around in a circle. Trees that fall within the specified distance, such as 11.8′, are tallied. Using this method can be a much faster and more convenient way to calculate trees per acre.

Choosing Plot Radius

How do you know what plot radius to use? Generally, the larger the trees on a given plot of land, the larger the radius needed. As trees grow, they outcompete smaller trees, and so TPA decreases as mean diameter increases. The relationship is demonstrated with the graph below.



When trees are fewer and farther between, a larger plot is needed to ensure enough trees are counted to generate useful data. If a plot size is too large, however, collecting data can be difficult and needlessly tedious.

It is important to choose the proper size plot. Below is a table of three common plot sizes and the type of timber they should be used for.

ACREAGE OF PLOT	PLOT RADIUS	OPTIMUM TIMBER TYPE
1/100	11.8'	Regeneration
1/10	37.2'	Small Sawtimber and pulpwood
1/5	52.7'	Large Sawtimber

Why Is It Important to Calculate Trees Per Acre?

Trees per acre is one of the most important measures to use to determine the density of a forest. Trees per acre can be used to help determine spacing for pre-commercial thinning regimes to maximize the amount of timber growing on each acre and ensure trees have enough room to grow. Additionally, TPA can be useful when timber is being grown on a small-tree-specific basis, and trees are selected for harvest individually, such as for individual firewood consumption.

When to Use Trees per Acre and When to Use Basal Area

Trees per acre has limitations as a useful metric, however. It is a measurement of the density of individual trees only. It has no relation to total timber volume. Thus, TPA is best used in even-aged stands with more or less uniform timber. In such cases, each tree can be assumed to contain a certain amount of volume, and TPA can be more easily used to make management decisions or make assumptions about timber inventory, especially when following specific plans, as is often the case with softwood plantations. Where this is not the case and trees are uneven-aged, non-uniform, and variable, basal area, a measurement of timber area per acre, is a much more useful metric. So if you decide to calculate trees per acre, be sure it is a metric that suits your needs. However, there are also certain tools, such as stocking charts, which require use of both metrics to make decisions.

Using a Scaling Stick to Merchandize and Measure Yield

It may occasionally be necessary (especially when planning a tree-specific selection harvest), to take high-resolution data on specific trees. For this, we use the scaling stick. A scaling stick allows us to measure the likely **board foot** yield of sawlogs inside of a given stem, so they are important for taking estimates of the value of specific trees or the expected return of a timber harvest. Here is how you can use a scaling stick to merchandize and measure yield.

Step 1: Take Position and Sight-in the Tree

The first step is to stand 66′ from the base of the tree, and hold out the stick 25′ from your eye, as seen below

Step 2: Determine the Number of Logs

Holding it from this position, you can see markings on the right side of the stick indicating the number of logs. If you are standing 66′ from the tree as you are supposed to, these markings indicate individual 16′ lengths. Determine how much of the tree is usable as sawtimber and use these markings to determine how many usable logs can be obtained from that length. Be sure to account for stump height!

If you are having trouble determining what qualifies as a log, refer back to our discussion about quality and limits to defect.

Step 3: Find Diameter

The scaling stick also comes with markings that you can use to visually measure diameter. Same rules apply as when using a D-tape: measure 4.5 feet off the ground, but this time, the tool must also be held 25 inches from your eye. At this distance and height, the markings can measure diameter accurately.

Step 4: Find the Board Feet

Using the diameter and number of logs, you can find the board feet using the 1/4′ International log rules printed on this stick (other scaling sticks may use different rules) . In this case, we have an 11′ diameter and 2 logs, which gives us 75 board feet!

Designing a cruise

In most cases, these measurements are never taken just once. Taking a single plot for basal area or TPA, for example, could give you extremely misleading data, if the area happened to be anomalously under or over stocked. Instead, these points are taken as part of a systematic process of measuring a forest known as a timber cruise.

The design of a cruise is going to be crucial for the accuracy of your numbers. If one is not careful, it is easy to unintentionally pick and choose the location of your plots. This will greatly bias your data and give you inaccurate results, likely over-estimating the data. Particularly if a cruise has management or financial consequences, it is crucial to create a cruise that is as unbiased as possible.

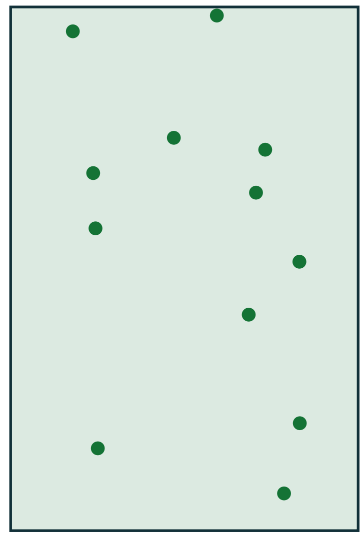
Toward that end, one must pick a system for picking plots. Here we will focus on two popular systems: random sampling and systematic sampling.

In random sampling, plots are chosen (you guessed it) randomly prior to beginning the cruise and plotted on a map. Plots must then be navigated manually with help of a GPS, map, and compass.

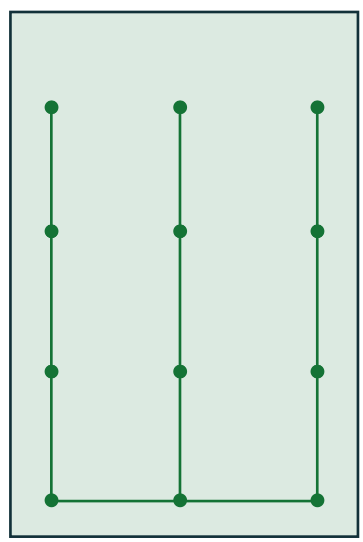
In systematic sampling, plots are chosen using a specified system, such as walking along northerly lines and taking a plot every 250 feet.

Examples of both systems can be seen in the visuals below.

Random Sampling



Systematic Sampling



How Many Plots Should Be Taken?

How many plots you incorporate in your cruise depends on how intense you want the sampling to be. However, a good rule of thumb is to do one plot for every five acres or five plots minimum.

Recording Your Data

Along with defining a cruise system, it is important to develop a system for recording and tallying your data. If all you need is a gross measure of basal area per acre or TPA, for example, averaging your totals from each plot will work fine. However, it may be wise and useful to break down the data further and tally trees by species and, if your experience allows, product class. Take, for example, this Basic cruise data sheet available for free download here.

BASIC BASAL AREA TIMBER CRUISE						BAF:	10
Species Tally						# OF PLOTS	1
PLOT #	SPECIES 1	SPECIES 2	SPECIES 3	SPECIES 4	SPECIES 5	TOTAL BA	AVG HEIGHT
Plot 1	0	0	0	0	0	0	0
Plot 1	0	0	0	0	0	0	0
Plot 2	0	0	0	0	0	0	0
Plot 3	0	0	0	0	0	0	0
Plot 4	0	0	0	0	0	0	0
Plot 5	0	0	0	0	0	0	0
Plot 6	0	0	0	0	0	0	0
Plot 7	0	0	0	0	0	0	0
Plot 8	0	0	0	0	0	0	0
Plot 9	0	0	0	0	0	0	0
Plot 10	0	0	0	0	0	0	0
Plot 11	0	0	0	0	0	0	0
Plot 12	0	0	0	0	0	0	0
Plot 13	0	0	0	0	0	0	0
Plot 14	0	0	0	0	0	0	0
Plot 15	0	0	0	0	0	0	0
Plot 16	0	0	0	0	0	0	0
Plot 17	0	0	0	0	0	0	0
Plot 18	0	0	0	0	0	0	0
Plot 20	0	0	0	0	0	0	0
Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0

By breaking down the basal area per acre by species, we can get a more clear picture of the composition of the stand. This can be crucial for cruises for purchasing property or preparing a timber sale. If one only needs to know stocking levels, or if a stand is largely dominated by a single species, such detail may be unnecessary.

More advanced methodologies may pair diameter measurements or merchandizing estimates for every tree within a plot.

Translating Your Data

Raw data from a cruise can then be used to estimate more readily-usable information, such as cords per acre, MBF per acre, and even growth rate. As you probably guessed, these estimates include a lot of assumptions and depend on models that may or may not be accurate. A plethora of volume tables exist for specific regions and species, and there exists complex models, such as the US Forest Service's Forest Vegetation Simulator, that can give sophisticated inventory data and growth estimates from a collection of the above data. However, in my experience, sophistication is no guarantee of accuracy.

Below is a collection of simple, but useful volume tables, charts, and log rules that you can use to interpret collected data. However, these are based on data from the Northeastern US, so they may not be useful elsewhere. Nonetheless, they can help you learn how to use your collected data, and you can later find volume tables more relevant to your region and species mix elsewhere.

Volume Per Acre

VOLUME PER ACRE (CORDS)

Combined Softwood Species, Whole Tree

BA/Acre	Average Total Tree Height in Feet					
	15	30	50	65	80	95
5	0.7	1.1	1.7	2.1	2.6	3.0
10	1.4	2.2	3.4	4.2	5.2	1.5
15	2.1	3.4	5.0	6.4	7.6	8.9
20	2.8	4.5	6.7	8.5	10.2	11.8
25	3.5	5.6	8.4	10.6	12.7	14.8
30	4.2	6.7	10.1	12.7	15.2	17.8
35	4.9	7.8	11.8	14.8	17.8	20.7
40	5.6	9.0	13.4	17.0	20.3	23.7
45	6.3	10.1	15.1	19.1	22.9	26.6
50	7.0	11.2	16.8	21.2	25.4	29.6
55	7.7	12.3	18.5	23.3	28.0	32.6
60	8.4	13.4	20.2	25.4	30.5	35.5
65	9.1	14.6	21.8	27.6	33.0	38.5
70	9.8	15.7	23.5	29.7	35.6	41.4
75	10.5	16.8	25.2	31.8	38.1	44.4
80	11.2	17.9	26.9	33.9	40.6	47.4
85	11.9	19.0	28.6	36.0	43.2	50.3
90	12.6	20.2	30.2	38.2	45.7	53.3
95	13.3	21.3	31.9	40.3	48.3	56.2
100	14.0	22.4	33.6	42.4	50.8	59.2

VOLUME PER ACRE (CORDS)

Combined Hardwood Species, Whole Tree

BA/Acre	Average Total Tree Height in Feet					
	15	30	50	65	80	95
5	0.5	1.0	1.6	2.1	3.3	3.0
10	1.1	2.0	3.2	4.1	6.5	5.9
15	1.6	3.0	4.8	6.2	9.8	8.9
20	2.2	4.0	6.4	8.2	13.1	11.9
25	2.7	5.0	8.0	10.3	16.4	14.8
30	3.3	6.0	9.6	12.3	19.6	17.8
35	3.8	7.0	11.2	14.4	22.9	20.8
40	4.4	8.0	12.8	16.4	26.2	23.7
45	4.9	9.0	14.4	18.5	29.5	26.7
50	5.5	10.0	16.0	20.5	32.7	29.6
55	6.0	11.0	17.6	22.6	36.0	32.6
60	6.5	12.0	19.2	24.7	39.3	35.6
65	7.1	13.0	20.8	26.7	42.5	38.5
70	7.6	14.0	22.4	28.8	45.8	41.5
75	8.2	15.0	24.0	30.8	49.1	44.5
80	8.7	16.0	25.6	32.9	52.4	47.4
85	9.3	17.0	27.2	34.9	55.6	50.4
90	9.8	18.0	28.8	37.0	58.9	53.3
95	10.4	19.0	30.4	39.1	62.2	56.3
100	10.9	20.0	32.0	41.1	65.5	59.3

MBF PER ACRE

Medium Sawtimber - International Rule - Form Class 78

BA/Acre	Average # of 16' Logs in Each Tree						
	1	1.5	2	2.5	3	3.5	4
5	0.4	0.5	0.7	0.8	0.9	1.0	1.1
10	0.8	1.0	1.3	1.6	1.8	2.0	2.1
15	1.2	1.6	2.0	2.3	2.7	2.9	3.2
20	1.5	2.1	2.6	3.1	3.6	3.9	4.2
25	1.9	2.6	3.3	3.9	4.5	4.9	5.3
30	2.3	3.1	4.0	4.7	5.3	5.9	6.4
35	2.7	3.6	4.6	5.4	6.2	6.8	7.4
40	3.1	4.2	5.3	6.2	7.1	7.8	8.5
45	3.5	4.7	5.9	7.0	8.0	8.8	9.5
50	3.9	5.2	6.6	7.8	8.9	9.8	10.6
55	4.2	5.7	7.3	8.5	9.8	10.7	11.7
60	4.6	6.2	7.9	9.3	10.7	11.7	12.7
65	5.0	6.8	8.6	10.1	11.6	12.7	13.8
70	5.4	7.3	9.2	10.9	12.5	13.7	14.8
75	5.8	7.8	9.9	11.6	13.4	14.6	15.9
80	6.2	8.3	10.6	12.4	14.2	15.6	16.9
85	6.5	8.8	11.2	13.2	15.1	16.6	18.0
90	6.9	9.4	11.9	14.0	16.0	17.6	19.1
95	7.3	9.9	12.5	14.7	16.9	18.5	20.1
100	7.7	10.4	13.2	15.5	17.8	19.5	21.2

Volume Per Tree

INTERNATIONAL 1/4-INCH RULE TREE VOLUME (Ft 78)

Board Foot Volume By Number of Usable 16-Foot Logs

DBH	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6
10	20	36	48	59	66	73						
11	25	46	61	76	86	96						
12	31	56	74	92	106	120	128	137				
13	37	57	90	112	130	147	158	168				
14	43	78	105	132	153	174	187	200				
15	51	92	124	156	182	208	225	242				
16	58	106	143	180	210	241	263	285				
17	67	121	164	206	242	278	304	330				
18	75	136	184	233	311	314	344	374				
19	85	154	209	264	348	358	392	427				
20	94	171	234	296	391	401	440	480	511	542		
21	105	191	262	332	434	450	496	542	579	616		
22	116	211	290	368	478	500	552	603	647	691		
23	127	231	318	404	523	605	608	663	714	766		
24	138	251	346	441	574	665	664	723	782	840		
25	151	275	380	484	626	725	732	800	865	930		
26	164	299	414	528	680	788	801	877	949	1021		
27	178	323	448	572	733	850	870	952	1032	1111		
28	191	347	482	616	794	920	938	1027	1114	1201	1280	1358
29	206	375	521	667	854	991	1016	1112	1210	1308	1398	1488
30	222	403	560	718	921	1070	1094	1198	1306	1415	1517	1619
31	238	432	602	772	988	1149	1184	1299	1412	1526	1640	1754
32	254	462	644	826	1053	1226	1274	1400	1518	1637	1762	1888
33	271	492	686	880	1119	1304	1360	1495	1622	1750	1888	2026
34	287	521	728	934	1196	1304	1447	1590	1727	1864	2014	2163
35	305	555	776	998	1274	1394	1548	1702	1851	2000	2156	2312
36	324	589	826	1063	1351	1485	1650	1814	1974	2135	2298	2461
37	342	622	873	1124	1428	1578	1752	1926	2099	2272	2444	2616
38	361	656	921	1186	1514	1670	1854	2038	2224	2410	2590	2771
39	382	694	976	1258	1514	1769	1968	2166	2359	2552	2744	2937
40	402	731	1030	1329	1598	1868	2081	2294	2494	2693	2898	3103

CORDS PER TREE (WHOLE TREE)

Total Tree Height in Feet

DBH	15'	30'	50'	65'	80'	95'
4"	0.01	0.02	0.03	0.04		
5"	0.02	0.01	0.04	0.06	0.07	
6"	0.03	0.04	0.07	0.08	0.10	
7"	0.03	0.05	0.09	0.11	0.13	0.16
8"	0.04	0.07	0.11	0.13	0.17	0.21
9"	0.05	0.09	0.14	0.18	0.22	0.26
10"	0.06	0.11	0.17	0.23	0.27	0.32
11"	0.07	0.13	0.21	0.27	0.33	0.39
12"	0.08	0.16	0.25	0.32	0.39	0.47
13"	0.10	0.18	0.29	0.38	0.46	0.55
14"	0.11	0.21	0.34	0.44	0.53	0.63
15"	0.13	0.24	0.39	0.50	0.61	0.72
16"		0.31	0.44	0.57	0.69	0.82
17"			0.50	0.64	0.79	0.93
18"			0.56	0.72	0.88	1.04
19"			0.62	0.80	0.98	1.16
20"				0.88	1.08	1.28
21"				0.97	1.19	1.41
22"					1.31	1.55

Values for combined hardwoods only. Based on data for New York State.
Converted From tons using 2.75 tons/cord.

The Next Steps

It is my earnest hope that after reading this brief guide, you have far more questions than before you started. Such a state indicates you are approaching the subject with the necessary humility and curiosity. Now, with context and an appreciation of the many nuances and complexities of the forest economy, you can begin your journey to become a true forester. In time, you can gain the skills necessary to manage your forest to its fullest potential and create a real asset for yourself, your family, and future generations.

Toward this end, be sure to check out our resources for small landowners at thetimberlandinvestor.com, but right now, the most important thing you can do is get out in the woods. Buy the necessary tools, download this guide onto your phone, and go out to your property (or public land if you are considering purchasing timberland) and start practicing taking measurements. Be observant. Pay attention to the cold hard data as well as the small, nearly imperceptible qualities of the forest. Take note of the differences between species as well as differences in the quality of growth in different areas on your property. Along with reading proper literature, these observations will make up a bulk of your forestry education.

I highly recommend journaling your observations, making note of any changes, patterns, or anomalies you see. Doing so helps train your brain to pay attention to these qualities and keeps records, which you (or even your kids) will find useful and entertaining years down the line. You can also use this journal to document measurements so you can have data-based records of the changes in your forest.

Additionally, it is important to get involved in your local forestry community. The field of forestry highly values public relations, and there are usually local and state groups to help landowners big and small. Often these groups or organizations will host conferences or tours, which are great events for you to learn the nuances of the science as well as connect with other like-minded and experienced individuals. In fact, there are likely foresters in your area that would be more than happy to offer a ride along for a day or two. The woods can be a lonely place, and speaking from experience, it can be nice to share a few days with an appreciative and curious person. Don't be afraid to ask!

Above all, don't be intimidated. There is much to learn, but you will catch on sooner than you think. Be patient, but be consistent. Your forest will show its appreciation in valuable timber, abundant wildlife, and countless memories. Good luck, and welcome to a new lifetime addiction!

Forestry Units and Conversions

Wood Volume Measurements:

Cord: A cord is a unit of wood volume defined as a stack of wood measuring 4′x4′x8′, or 128 cubic feet. This measurement includes the empy space in between logs.

Cubic Foot: Cubic feet (or meters) is a measurement of the solid wood volume, expressed in units measuring 1′x1′x1′

Board Foot/MBF: Board feet (or MBF for Thousand Board Feet) is a measurement of yield. It is an estimate of the amount of green, rough boards measuring 12″x12″x1″ a tree or log can produce. Because it is an estimate of yield, it is usually used for sawtimber, and it is governed by different formulas, known as log rules, that estimate this yield based on different assumptions. The three main rules are the Scribner rule, Doyle rule, and international ¼″ rule. Each has different strength and weaknesses, and different regions may use different rules based on customs and local timber attributes.

Ton: SImply, tons are a measurement of weight. This might be specified as green tons or dry tons to denote the wood's moisture content at the time of weighing.

"Rule of Thumb" Conversions

While these are all commonly used units to express volume of wood, there are technically entirely inconvertible because they measure very different things. Nonetheless a few "rule of thumb" conversions can be used unofficially to give you an idea of how they relate.

1 softwood cord = 2.5 tons

1 hardwood cord = 2.75 tons

1 cord = .5 MBF

Area Measurements:

Acre: An imperial measurement of land area measuring 43,560 square feet or .41 hectares.

Hectare: A metric measurement of land area measuring 10,000 square meters or 2.47 acres.