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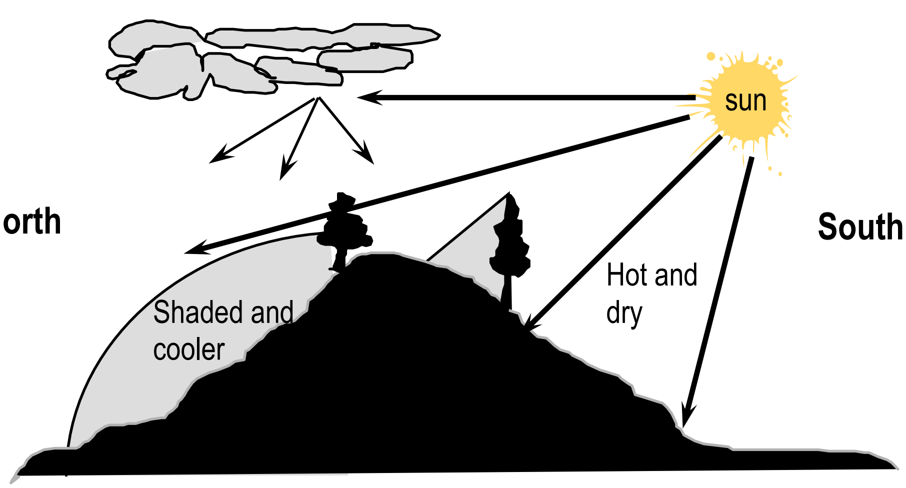
Alternative Forest Management Practices for Montana

The first step of any type of land management is to formulate a set of objectives and goals for the acreage in question. While these goals will reflect the personal needs of the landowner, which may include anything from minimizing human impacts to converting a forest into a pasture, they should also take into consideration the ecological capacity of the site. Throughout history, the biggest land management failures have occurred when managers tried to impose objectives that the land was incapable of supporting. With that in mind, all forested land management goals and objectives ultimately involve which trees should be left and which trees should be removed from a particular site. The most daunting challenge to the art and science of forestry is still represented by this basic decision making process, and can result in leaving all the trees or cutting every tree. To a forest landowner, setting objectives and goals for their land may be relatively simple compared to standing in the forest and trying to decide what actions to take.

Ecology

Montana forests are composed of a complex mosaic of ecologically distinct zones that were created by the interaction of topography, climate, soils and historic disturbance regimes on biological organisms. Depending on the location, this mosaic can occur across the landscape as an intricate puzzle of small 5-50 acre patches to larger 1000 – 10,000 acre patches. Within each patch, disturbances such as insects, disease, wildlife, wildfire, and historic Indian activities add complexity by having created numerous possible structural and species (successional) combinations. Although the numerical plant and animal species diversity is not as great in Montana as some other forested ecosystems such as tropical rainforests, the distribution of spatially fixed plant zones into a naturally fragmented mosaic creates a forest ecosystem that ranks among the most unique and complex on Earth.

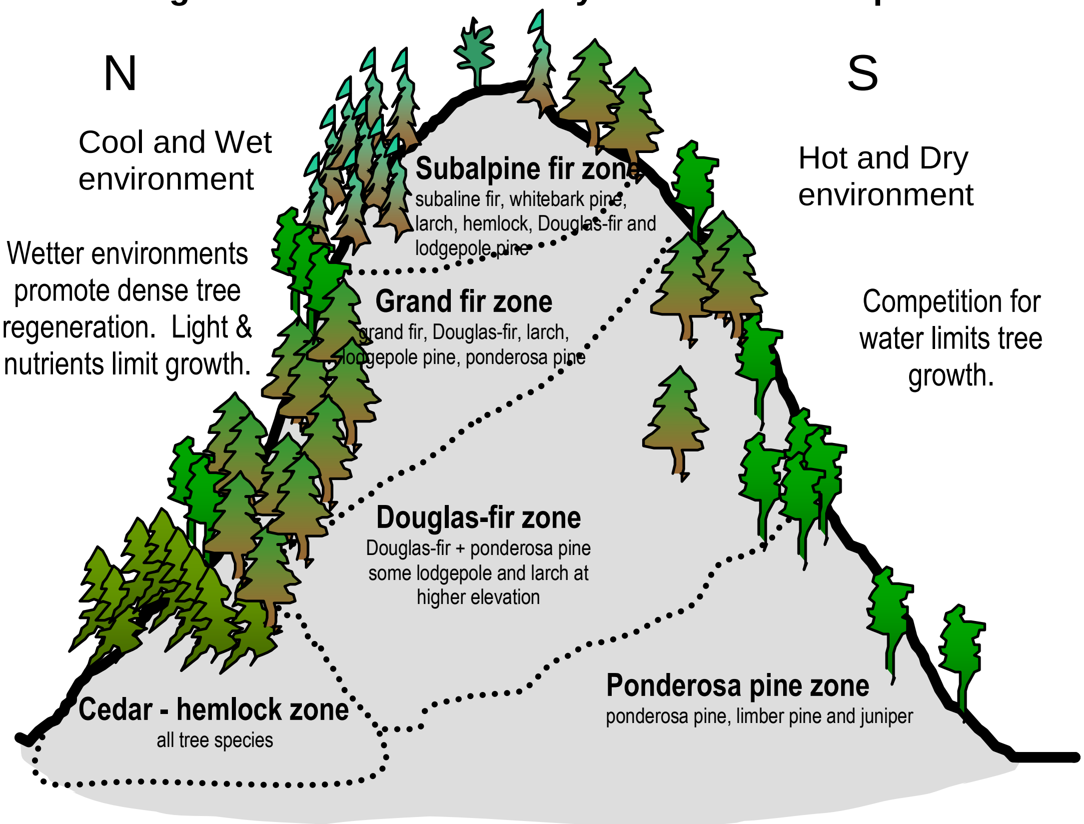
Topography affects how much energy from the sun is transferred to the plants and soil. South slopes intercept almost all the sun's energy and are hot and dry, where as north slopes receive most of their sunlight from light reflected off the atmosphere and are, therefore, cooler and often wetter. East and west slopes get equal energy from morning or afternoon sun, however, the air temperature is usually already at its highest point of the day in the afternoon, thus west slopes start getting direct sunlight when they are already warmed up, making them warmer and drier than east slopes. Typically, the temperature rating from hottest to coolest aspects follows a south, west, east and north pattern.



The effect of aspect on sunlight absorption and temperature regimes

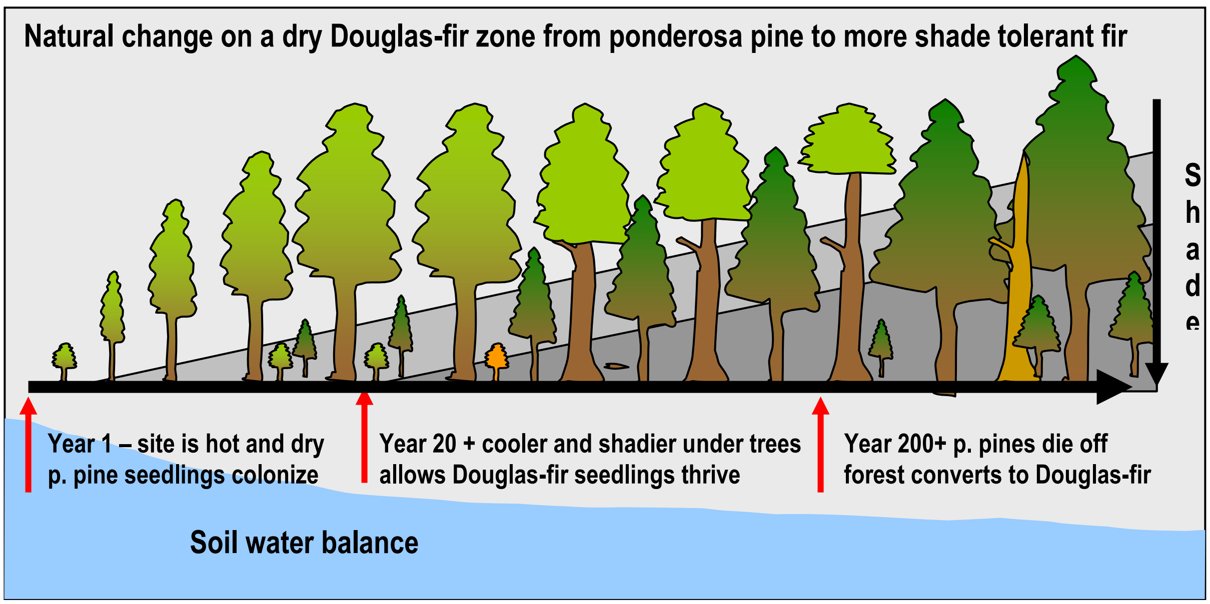
The sun's energy absorption and resulting temperature patterns are important because they control the moisture availability of the site, and the combined moisture and temperature regime determines the tree species and understory vegetation that can survive. Across Montana there are approximately 64 distinct tree-understory plant communities that reflect different temperature-moisture-soil combinations. These plant communities (also referred to as "Habitat Types") can be lumped into 5 major forest zones. A particular landscape may consist of only one of these zones, or a mosaic of all five. A simplified model of where these zones typically occur on a mountainous landscape, and the tree species that occupy each zone is illustrated below.

Vegetation zones created by elevation and aspect

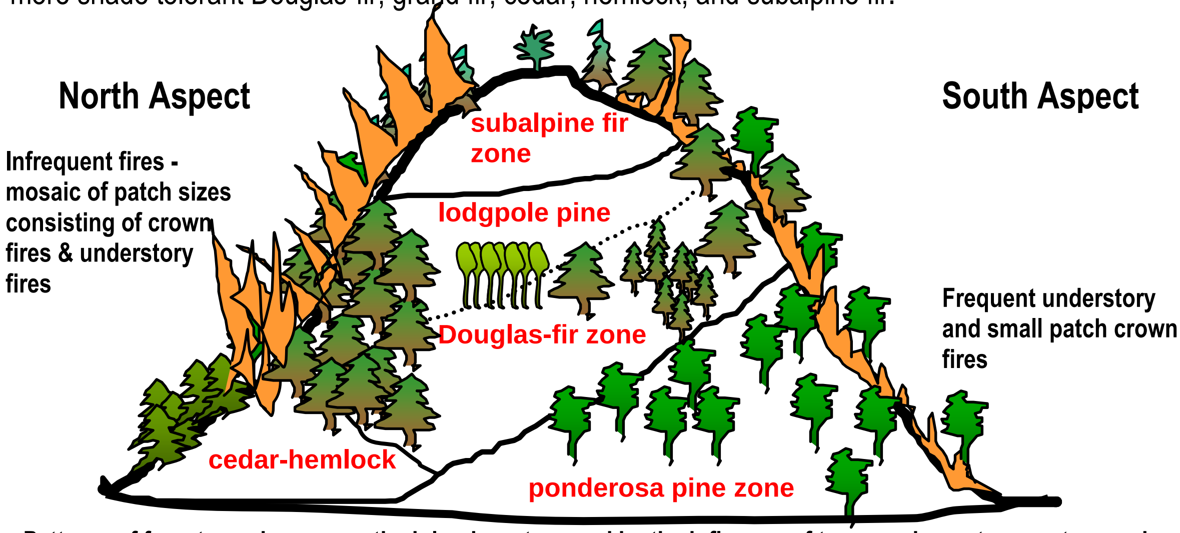


The North-Western portion of Montana, delineated by Missoula to the south and the continental divide to the east, is the only part of the state that receives adequate rain and snow to support all five forest zones. As east moving weather patterns cross the mountains they lose moisture, thus forested areas in central, southern and eastern Montana do not receive the precipitation needed to support the two wettest forest zones – grand fir and cedar-hemlock. In these areas the Douglas-fir zone expands to cover the lower elevation northern aspects and lodgepole pine becomes a unique zone just below subalpine fir.

Each of the 5 forest zones supports several tree species. The wetter the zone, the more tree species can occur with cedar-hemlock having the potential to support every conifer native to Montana. As water becomes limiting fewer tree species have the adaptations to survive, ultimately resulting in the driest zone, ponderosa pine, supporting only 3 tree species. Within each zone, different tree species can only coexist with the help of tree-killing disturbances such as insects, diseases, wildfires, and……humans! One of the most important within-zone site characteristics that influences tree species occurrence is sunlight availability. Specifically, tree species have varying abilities to regenerate in either sun or shade. Open areas with bare soil, such as may occur following a wildfire, can experience high soil surface temperatures (above 150° F) from sunlight. Most tree species seedlings perish from heat and moisture stress. Some species such as ponderosa pine, larch, and lodgepole pine have seedlings with needles and root systems uniquely adapted to survive such conditions. Long, thin, needles that reflect sunlight and are easily cooled by air movement, combined with rapidly growing taproots that find deeper water sources keeps them alive in a hot sun environment. These same adaptations, however, make for poor survival under shaded conditions where light for photosynthesis is limiting and soil water is most available on the surface, away from the deeper established roots of the overstory trees. Other species such as Douglas-fir, grand fir, subalpine fir, western red cedar and hemlock have seedlings with needles designed to absorb 100% of the light they receive and shallow root systems that can take advantage of surface water and nutrient rich soil surface organic layers. These adaptations allow them to grow best in shaded environments. Alternatively, shade adapted seedlings exposed to the intense sunlight on an open southern aspect would die from heat and moisture stress. Species with seedlings that have full sun tolerance are often termed "pioneer" or "seral" species because they are the first to occupy a disturbed site. As they mature and shade the soil, temperatures tend to be less extreme, and seedlings of shade tolerant tree species gain the advantage for growth. Since these are the only species able to regenerate under a forest leaf canopy, over time and without a major disturbance, the shade tolerant species dominate the site, which is why they are also labeled the "climax" species. For seral species to remain a component of the forest, disturbances that create sun filled openings are necessary. A simplified model of forest change in the dry portion of the Douglas-fir zone is shown below.



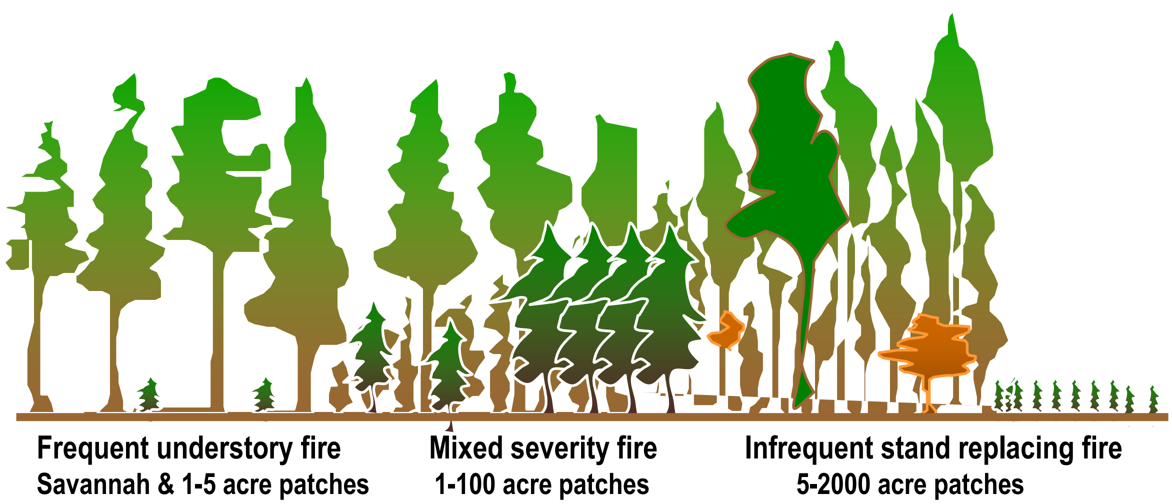
Wildfire has been the single largest disturbance force that forests in the inland western United States have evolved with and in some cases are dependant on. In a general sense, the pattern of fire history is closely related to landscape topography. Hot and dry southern and western aspects are more apt to carry fire during the average summer, and historically burned more frequently than northern and eastern aspects. Tree species, understory vegetation, and forest structures often reflect those differences in wildfire occurrence. Forests that experienced frequent fires (every 3 – 15 years) supported an open forest structure with a predominance of ponderosa pine at lower elevations and Douglas-fir at higher elevations. Those areas that supported a combination of frequent and infrequent fires (every 10 – 100 years) are characterized by a patchwork of stand structures including multi-aged and even-aged stands with species that include ponderosa pine, Douglas-fir, larch, aspen and lodgepole pine. This fire regime typically occurs at higher elevation south slopes, intermediate elevations on east and west slopes and widely across north aspects. North slopes, which are typically cooler and wetter than other aspects require a drought coinciding with a lightning strike in order for a fire to get started. They also support faster tree growth, which allows dense stand conditions and large amounts of fuel to develop. When fires did occur they typically burned in large forest stand replacing patches 100's and 1000's of acres in size intermixed with other patches where the fire slowly burned over the surface with minimal tree injury. Fire frequencies on northern and wetter cedar-hemlock, grand fir, subalpine fir and even the wetter portions of the Douglas-fir zone ranged from100 to 500+ years. Landscapes in this wildfire regime are dominated by large irregular shaped stands of same aged lodgepole pine, larch, aspen and occasionally ponderosa pine trees that eventually are replaced by more shade tolerant Douglas-fir, grand fir, cedar, hemlock, and subalpine fir.



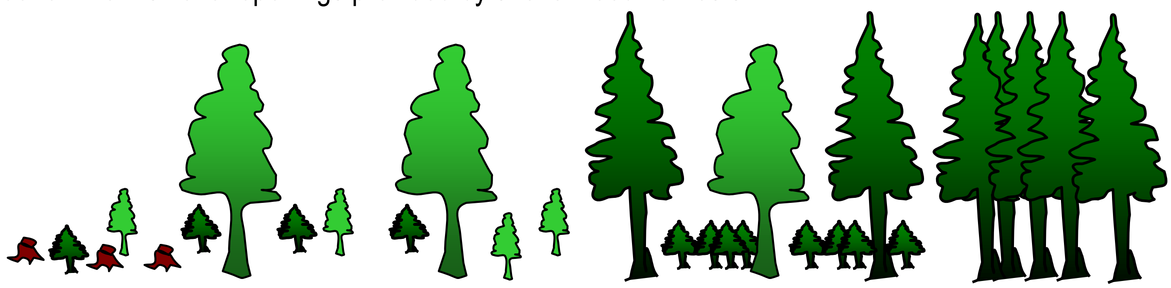
Patterns of forest species across the inland west caused by the influence of topography on temperature and soil water availability has also created different patterns of fire disturbance across the landscape.

Management

Different patterns of disturbance result in unique adaptations of species and distinct patterns of forest stand structures and composition. By knowing which types of structures and disturbance patterns have historically occurred, we can tailor our forest management to simulate past disturbances in a more controlled fashion than occurred by wildfires. This will provide the necessary habitat for all of the organisms that over the centuries have become dependant on these unique forest patterns and structures, and provide the best environment for healthy native trees.



Forest management practices of the past typically focused on the ecosystems where large stand replacement fires shaped the forests. The practice of clearcutting, seed tree and shelterwood cuts, all of which are referred to as "evenaged" management practices because they result in stands of same-aged trees, are well suited for simulating stand replacement or crown fire events. The harvest used depends largely on the species mixtures and individual tree characteristics in a stand. Where individual trees of desirable species have stem and crown dimensions that suggest their ability to withstand the shock of a more open environment, a seed tree or shelterwood cut is recommended to promote natural regeneration. Stands that are dominated by sick or suppressed trees may benefit greatest from a series of clearcuts, where planting seedlings of desired species may be needed. Tree species that require full sunlight (shade intolerant) such as ponderosa pine, larch, lodgepole pine and aspen will benefit from the larger openings of small clearcut or seedtree harvests. Species that prefer intermediate shade (shade tolerant) such as Douglas-fir, grand fir, western red cedar, spruce, and subalpine fir will benefit from smaller openings provided by shelterwood harvests.



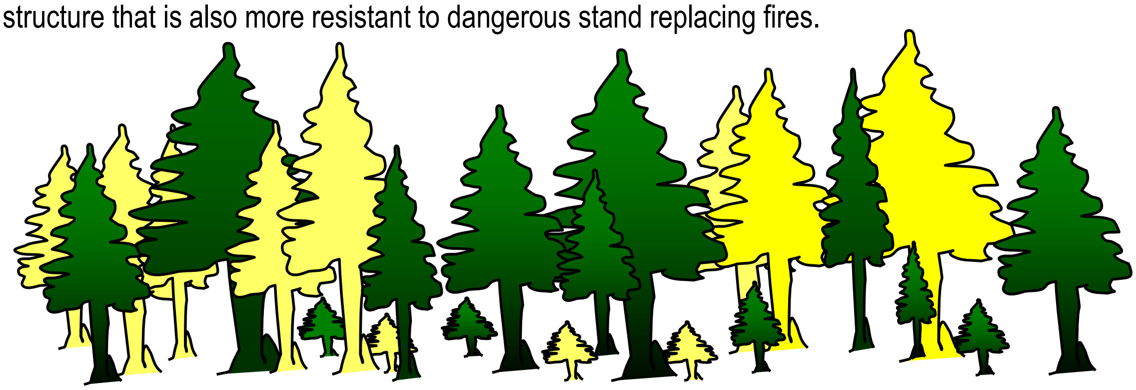
Clearcut **Seed tree *(for shade intolerants)*** **Shelterwood *(for shade tolerant)***

Sites that typically had mixed severity fires provide for the greatest options in forest management practices, partially because past disturbances maintained a high degree of species diversity. Simulating mixed severity fires often calls for a variety of management practices including traditional clearcutting, seedtree and shelterwood harvests. Often the stand of trees itself will indicate what naturally would have occurred. For example, an area that has dense standing trees with large amounts of down woody debris would have led to a crown fire, burning all trees in that area and creating a large clearing. Stands that have a random spacing of dense and open grown trees would have burned in clumps creating small opening while leaving the more open spaced trees intact. Areas that are composed of large well spaced trees would have supported a fire that stayed on the ground with an occassional tree burning up. Mosaics such as these provide multistructural forests and are often also the most productive wildlife habitats. Harvesting patterns can mimick this natural variation using a combination of thinning, individual tree selection and group or "patch cuting". It is important to recognize that many different treatments can be used within the same stand of trees.

Single tree selection and group selection (*light color are cut trees*)

What is often refered to as group selections or "patch cutting" is in essence the same as a small clearcut. Openings are created by harvesting all the trees within a specified area. Smaller openings (<1/4 acre) will promote shade tolerant species to regenerate where as larger openings will promote more sun loving species. As a general rule, and opening must have a diameter equal to the height of the tallest surrounding trees to allow for sunb loving tree regeneration. It is necessary to take into account the less light of northern aspects where openings need to be bigger verus southern aspects where smaller openings will suffice.

The ponderosa pine and drier Douglas-fir zones historically supported frequent fires that kept most of the stands in an open savanah- like composition. Quite often these areas are also used extensively by deer and elk for winter range because of the lush bunchgrass understory that was promoted by frequent fires. In the absence of fire, prolific tree regeneration can occur resulting in dense and often stagnant stands of small diameter pine and fir trees. These stands not only represent a significant fire danger, but lose their bunchgrass understory to shading resulting in loss of wildlife habitat. Overgrazing or excessive soil disturbances from harvesting operations in the ponderosa pine and Douglas-fir zones will accelerate the development of dense tree regeneration. Land managers are often challenged in their efforts to restore such situations because they require labor intensive pre-commercial thinning. Thinning combined group selection is a good management alternative for these sites and prmotes a more natural unevenaged forest structure that is also more resistant to dangerous stand replacing fires.



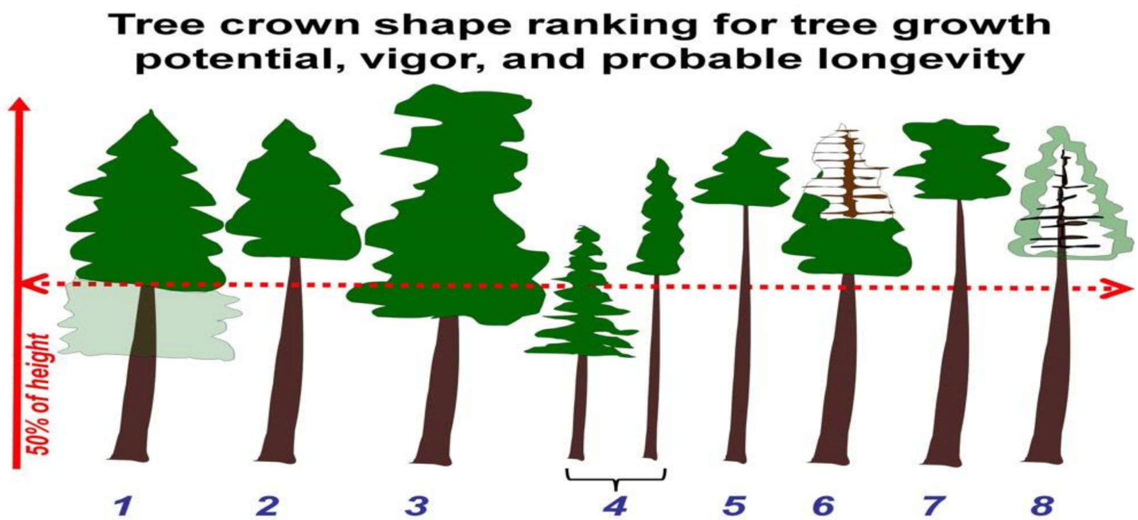
Unevenaged management (*light color indicates cut trees*)

Thinning is a useful technique to reduce the overall density of a stand of trees. The rationale is to provide individual trees with adequate light, soil water and nutrients to grow bigger and remain vigorous. Pre-commercial thinning refers to removing excess trees before they are of any commercial value. Commercial thinning consists of harvesting trees that have a monetary value. Forests that are intensively managed for wood fiber production often have several thinnings prior to final harvest. Typically this type of intensiv management is only cost effective on the more productive wet Douglas-fir, grand fir, and cedar-hemlock zones. Ponderosa pine and dry Douglas-fir zones benefit tremendously from thinning but it is often challenging to make this practice pay for itself in the short term. Long term benefits include healthier trees and lower wildfire danger.

The issue of optimal spacing between trees has been extensively studied for most tree species. Smaller trees (<12 ft tall) can be spaced closer together at an approximate 8 x 8 ft spacing leaving 680 trees per acre. As trees grow taller their crowns widen and they start to compete with each other for light. Additionally an overly dense tree canopy intercepts rain and snowfall which evaporates back into the atmosphere, adding to the problem of competition for soil water. Spacings of 15, 20, and 30 feet between trees are have been used for most commercial forest operations. Although the tendency is for managers to use one spacing uniformly across a stand of trees, it has been shown that spacing based upon individual tree crown characteristics provides for a healthier residual forest. Essentially this means that trees with wide full crowns are given more space than trees with smaller narrow crowns. This is also refered to as “variable density thinning”. As a general rule, spacing trees with the goal of providing 5 to 20 feet between the outer edges of the crowns will give individual trees adequate space to grow.

Tree selection criteria for vigorous high value trees

The criteria used for determining which individual trees to cut or leave are usually based upon their crown characteristics. Since the green needles are the food producing part of the tree, the more needles a tree has, the better the growth rates will be. In general, if less than a third of the entire tree height supports green needles, the tree is a poor choice as a leave tree. Optimal tree crowns occupy between 60 and 40 % of the tree height. Greater than 60% crown area results in a healthy tree, however one that also requires more water, nutrients and space relative to the amount of stem wood it produces. Less than 30% crown indicates a senescent tree that is top heavy and subject to wind breakage, slow growing, and often reflects a poor root system that may be inadequate to supply the tree with enough water during dry periods. Trees of lesser quality may eventually recover if left, however, it often takes them over 10 years to develop a more vigorous crown. Crown shape is another indicator of recovery potential. A flat toped crown indicates the tree has reached its maximum height. If it has more than 30% crown it can remain healthy for another century, on the other hand if it has less than 30% crown it has a poor chance for any longevity. Most native conifers can't regrow lower branches and can only develop a bigger crown by growing taller. If the tree has reached its maximum height, it will be unable to develop a larger crown.



1) & 2) Best form **3)** Mature tree, good growth and survival -knotty wood **4)** Supressed but can recover if given space - risk of wind breakage if too much space **5)** Pointy top indicates some hieght growth potential– very high risk of wind breakage – can be thinned but leave denser stands
6) Evidence of top kill by bark beetles, moderate chances of survival though poor form and growth
7) Overmature, low vigor, little recovery with thinning – high risk of mortality with any disturbance
8) Diseased, low vigor, evidence typical of root disease or damage, poor survival.

Insect and disease criteria

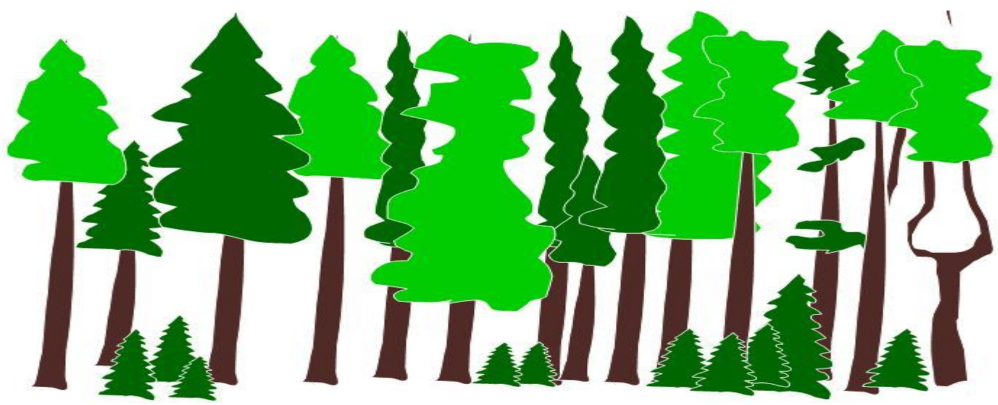
Most insects and diseases prefer specific tree species. Observing which tree species is suffering in a stand of trees will often indicate which species to select more heavily against. It is easy to overreact, however. Some degree of tree mortality is normal and necessary as insects are an important food source for a variety of wildlife species. Maintaining a healthy population of insect predators is the best way to keep pests in balance. Selecting for a diversity of tree species will keep any one insect or disease from devastating an entire stand of trees.

Tree selection for wildlife

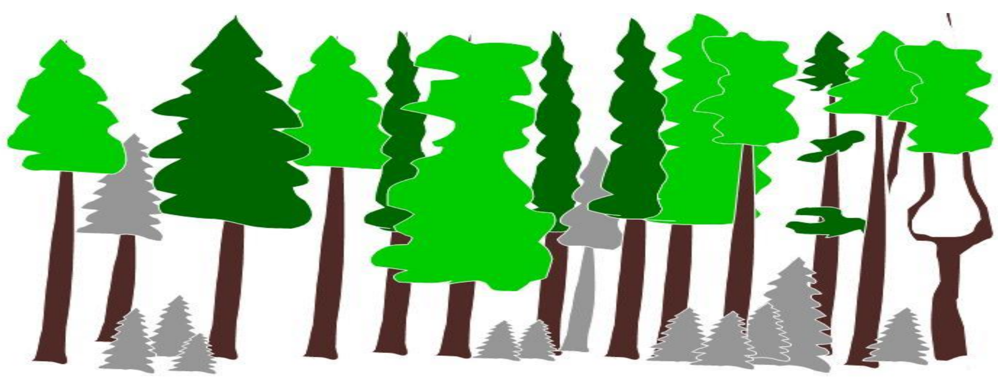
Wildlife requires food sources and hiding cover. Tree structural and species diversity are the most common desired components for wildlife. Tree selection criteria should favor size and crown diversity. A spindly tree with a small crown may be favored by an owl or eagle whereas a dense bushy shrub is preferred by nesting warblers. Large snags, vigorous trees, odd shaped trees all contribute to wildlife habitat. For diversity, clumps of dense, evenaged trees can also be left in a mosaic with savannah-like openings. Wildlife species are especially sensitive to changes in their historical forest enviroment. It is important to match the patch size of the management areas, as well as the tree species diversity to that which wildfires historically created.

Alternative harvesting scenarios.

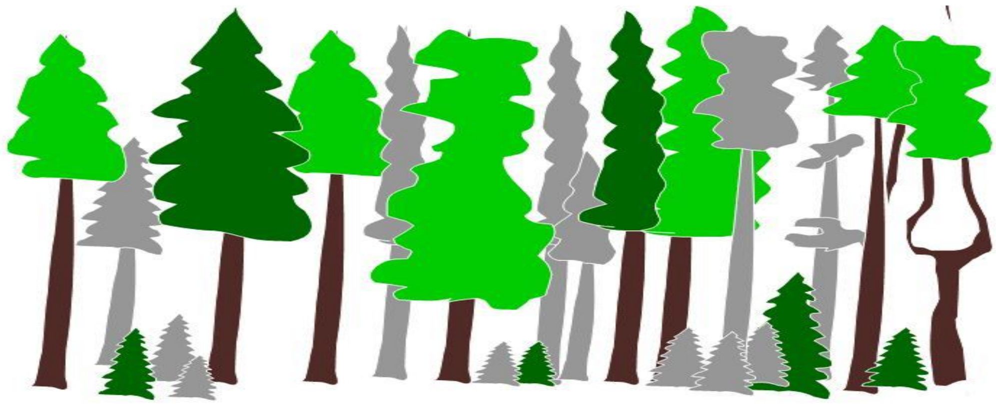
Every stand of trees has a mixture of thin, wide, forked and diseased crowns. "V" shaped crowns are inherited and are structurally weaker, "U " crowns are the result of prior tip damage and other than some defect for sawmilling are healthy and can make good live wildlife trees.



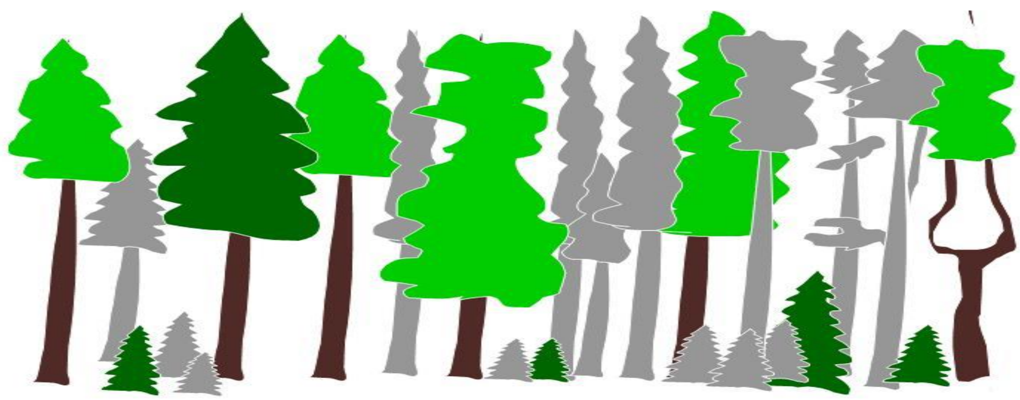
The original forest



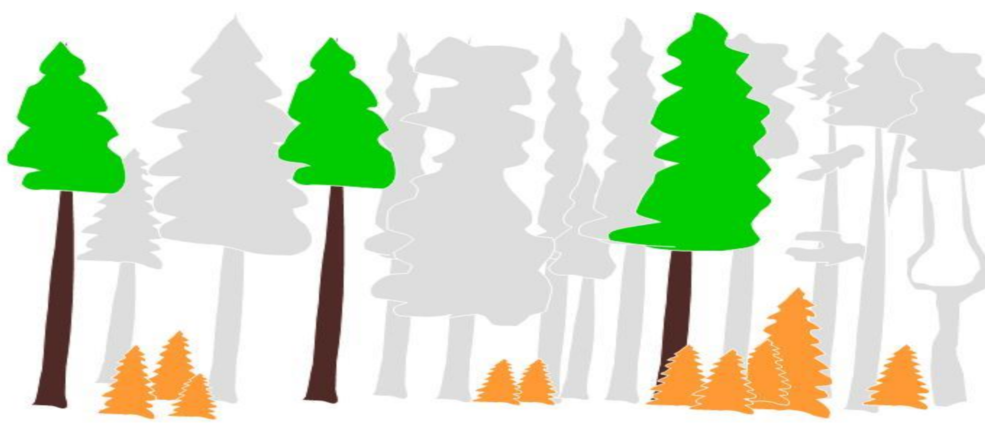
Thin from below – fire hazard removal, no merchantable trees are removed.



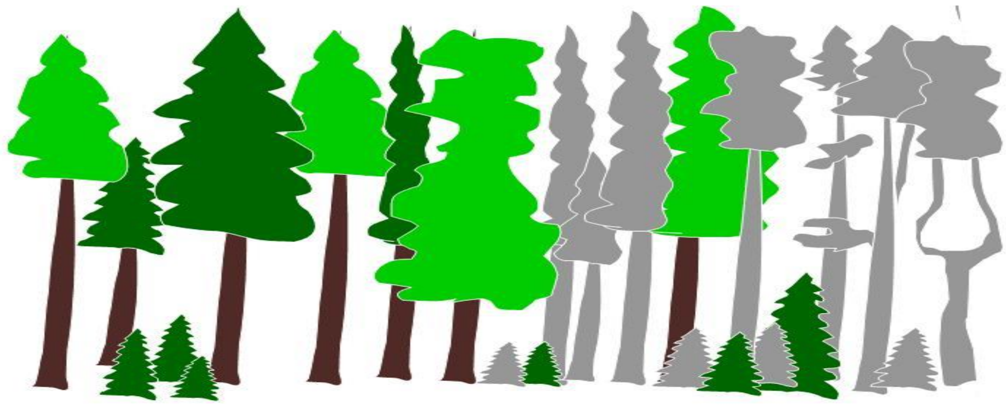
Comprehensive thinning- dominant trees left for growth and longevity as well as natural seedling production. This treatment usually pays for itself but can generate a surplus income.



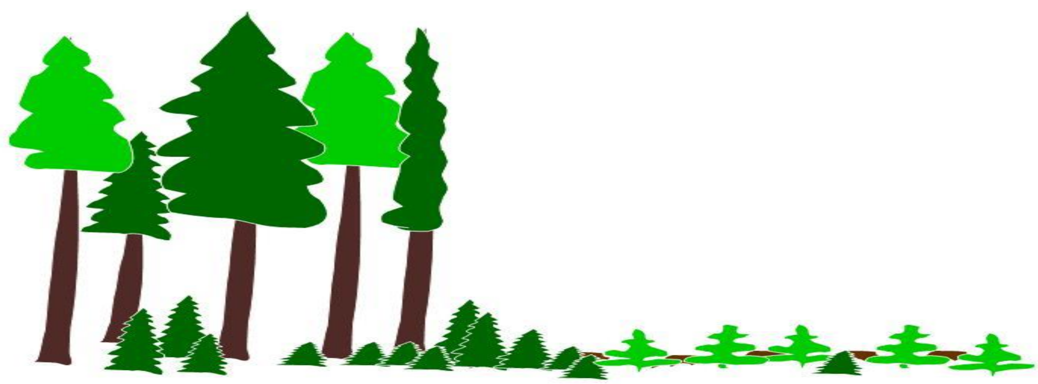
Shelterwood harvest – the purpose is to create a more protected environment for seedling recruitment. Often this treatment results in high percentage of seedlings from shade tolerant species



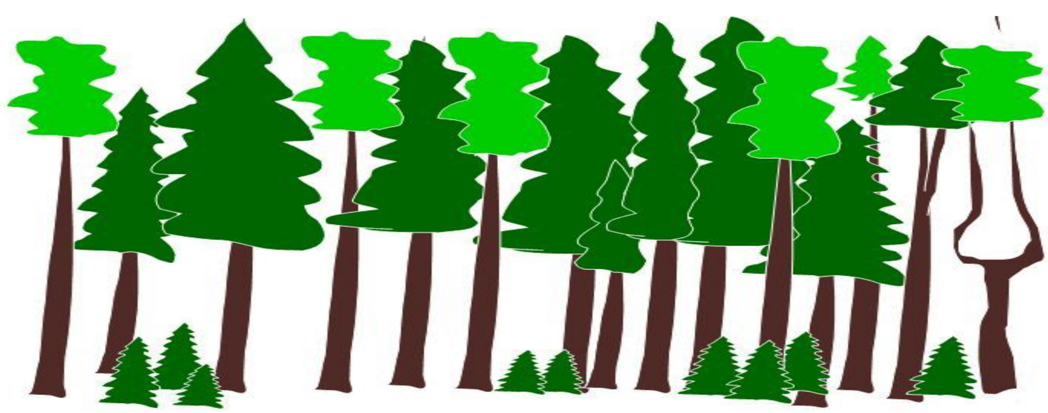
Seed tree cut – residual trees must be vigorous, seed producing, and able to regenerate in sun environments if located on south or west aspects. Only ponderosa pine, white pine and larch are well suited for this type of harvest.



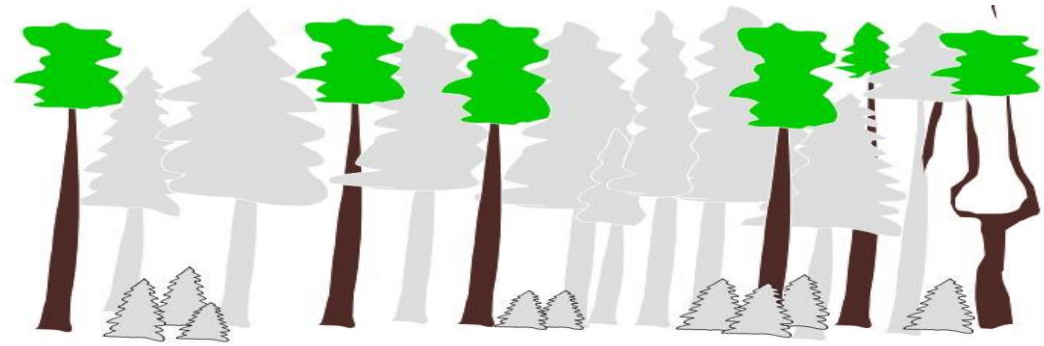
Group selection cut – offers many options and works reasonably well for trees with crowns less suitable for wider spacing. Crowns prone to wind breakage are left in tighter groups for mutual protection. As crowns recover, more trees can be harvested for a wider spacing if desired.



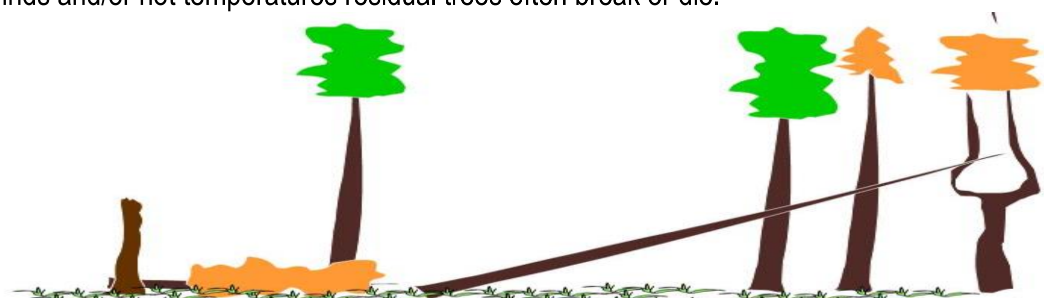
Clearcut or patch cut – if a high percentage of the trees have poor crowns and insect and disease issues this is a viable alternative. Planting of nursery grown seedlings may be needed. This is a very suitable environment for pioneer (sun loving) tree species.



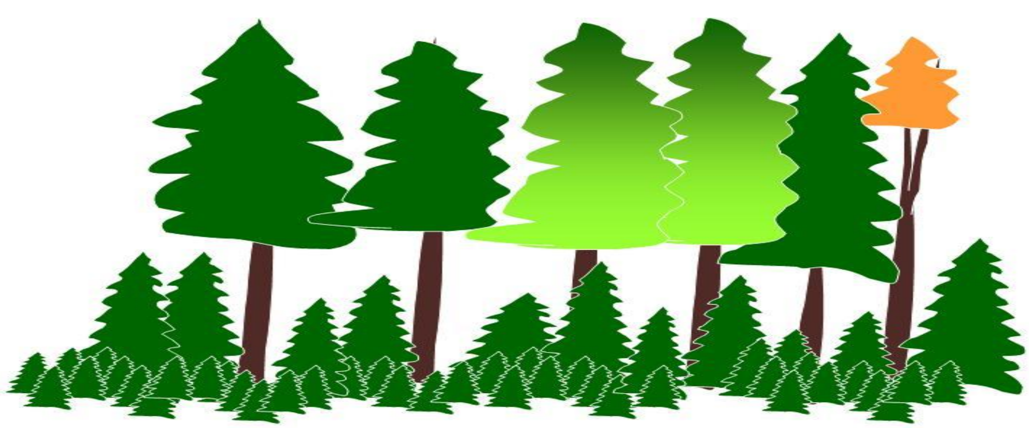
A typical Montana forest structure where pioneer species have less optimal crowns and shade tolerant species have become codominant.



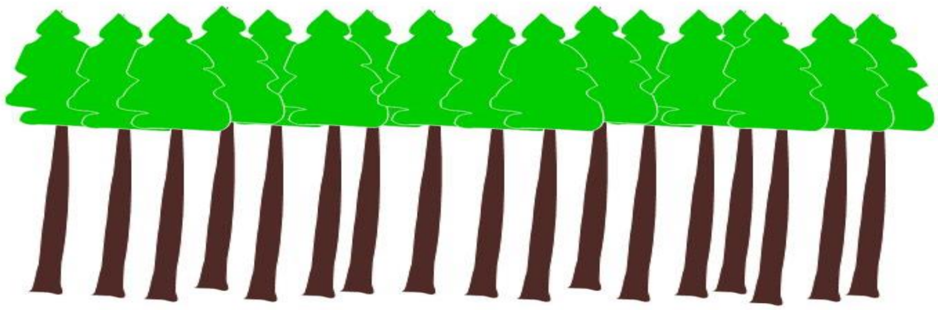
Attempting to create a seedtree effect by leaving less optimal crowns is risky. On exposed sites with high winds and/or hot temperatures residual trees often break or die.



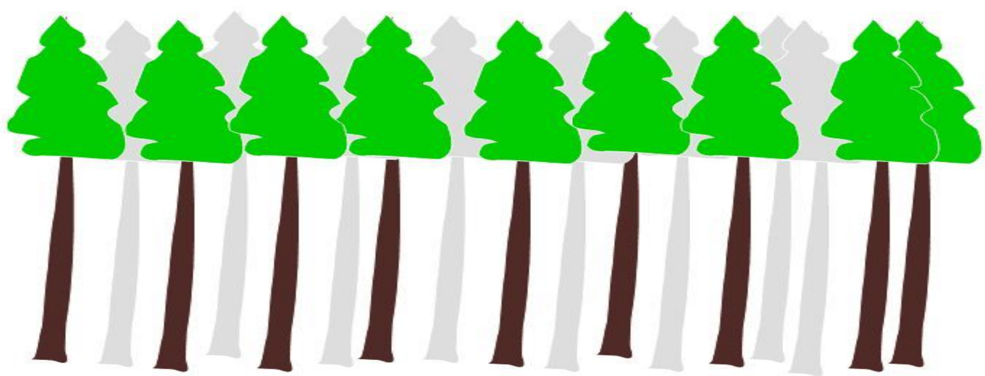
Leaving shade tolerant species is an alternative provided spacing between trees is not to wide. Trees need time to acclimate to a more open environment with more wind and sun. On south aspects heating of the soil surface can adversely affect shallow root systems of shade tolerant species. Typically the longevity of shade tolerant species is not as great as pioneer species. One must therefore expect a greater pest and pathogen occurrence. Shade tolerant species will also have the tendency to regenerate prolifically underneath themselves.



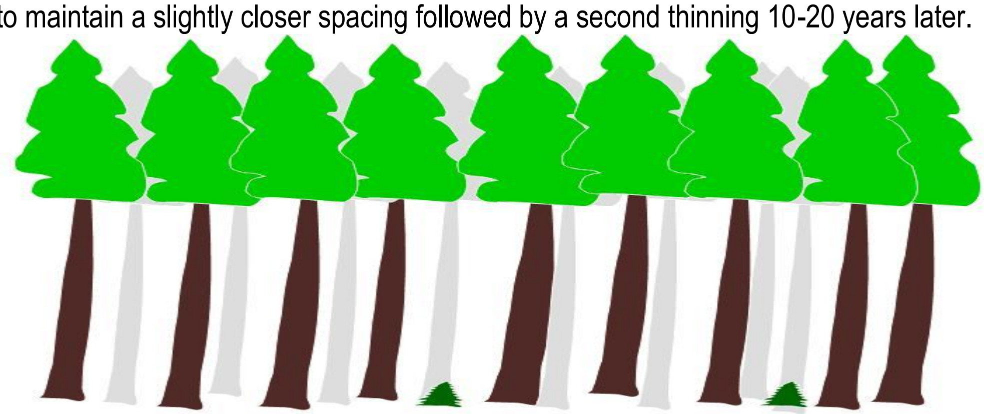
Thinning



The effectiveness of thinning trees depends a lot on the change in spacing of the trees and their growth potential (crown shape. Vigorously growing trees (pointy tops) tend to respond by growing larger more quickly. A common thinning rule is to space trees by adding their diameter plus 8 to develop the distance between residual trees. Thus a group of trees with an average diameter of 12" should be spaced (12 + 8) 20 feet apart.



It is better to maintain a slightly closer spacing followed by a second thinning 10-20 years later.



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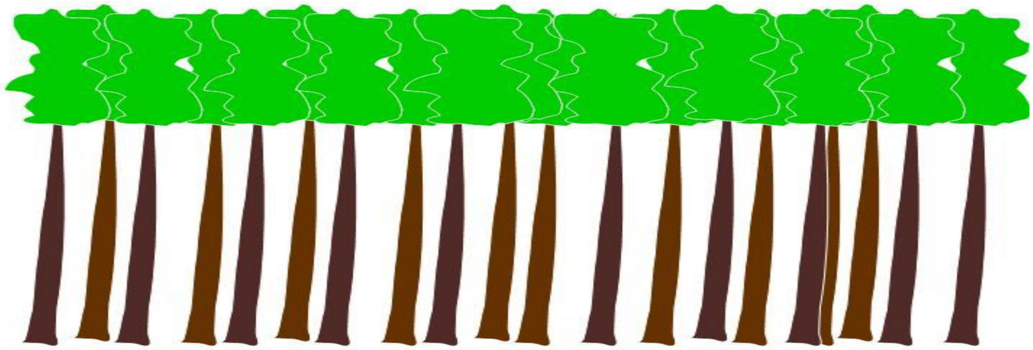
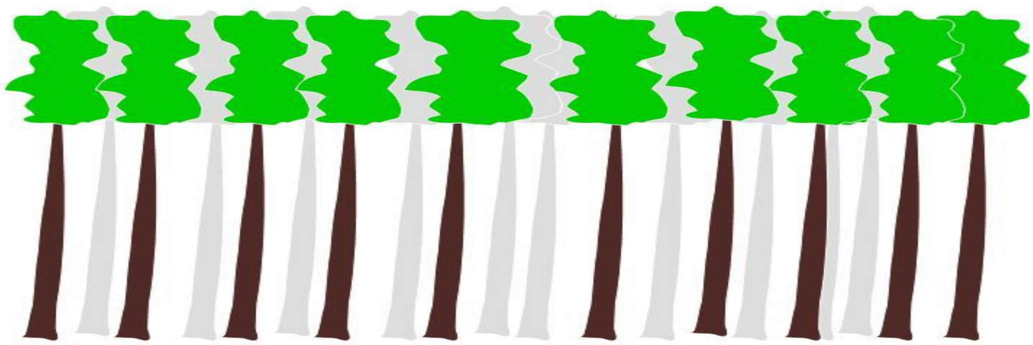
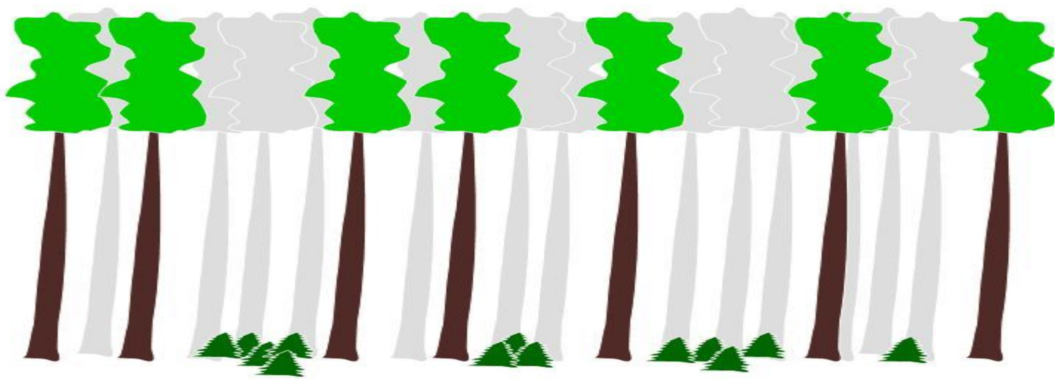
Poor crown scenario: Flat topped and small crowns indicate there is little potential for increasing total needle area and therefore growth potential.

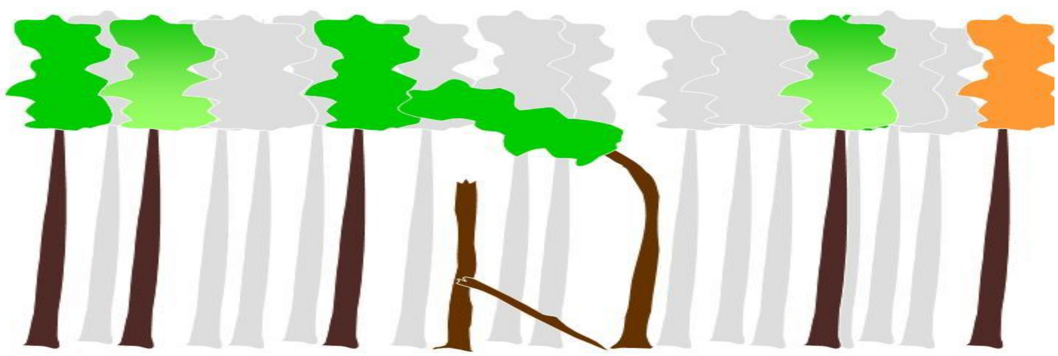


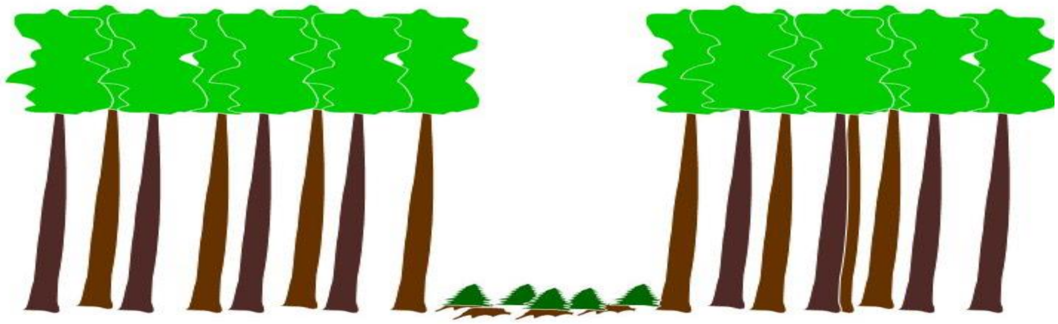


A very mild thinning can result in increased vigor for pest protection.   A modified rule of diameter plus 4 might work better in this scenario.

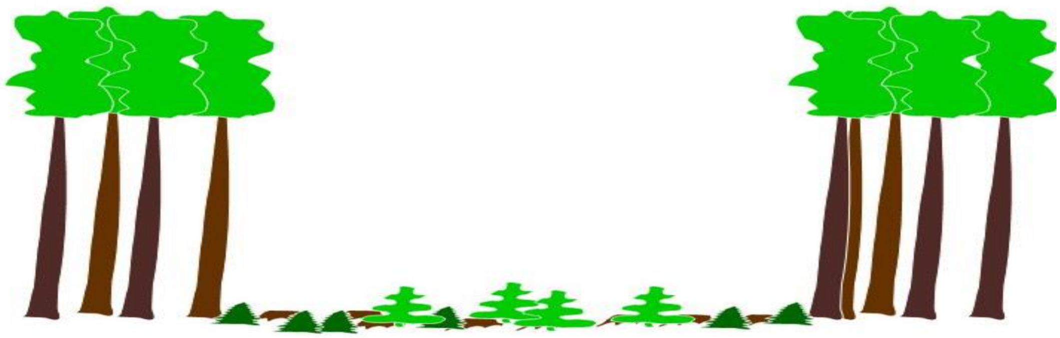


Too wide a spacing in older and less vigorous groups of trees can lead to increased stress from wind, snow and high temperatures.



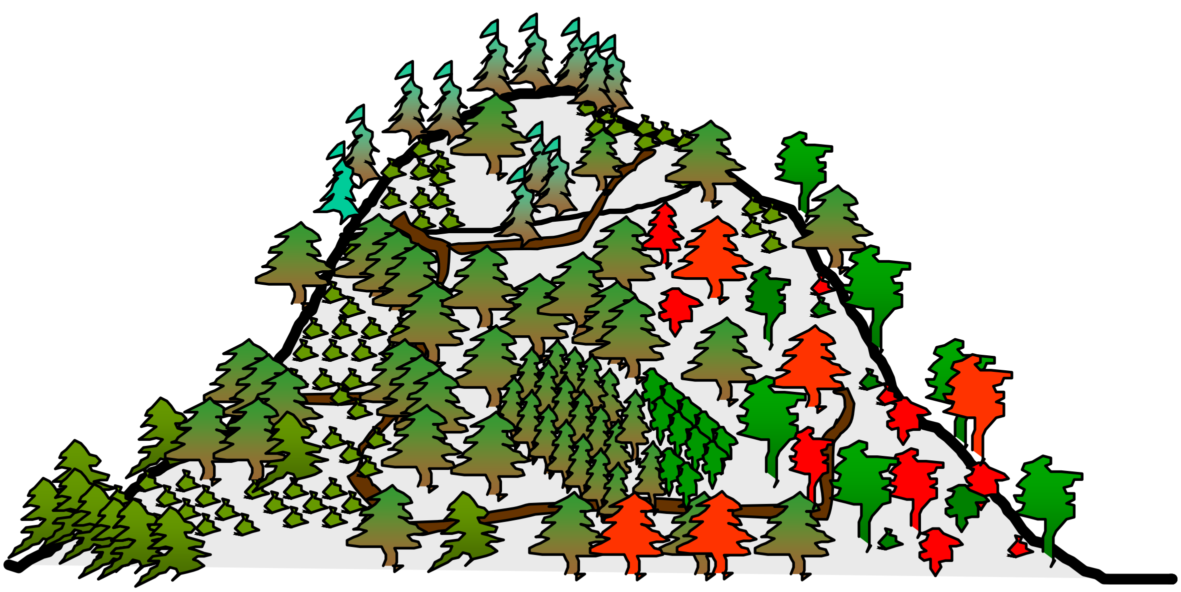


Group selections might be more appropriate. The size of the opening may determine if shade tolerant or pioneer tree species will regenerate. The rule of thumb is to create an opening as wide as the adjacent trees are tall.



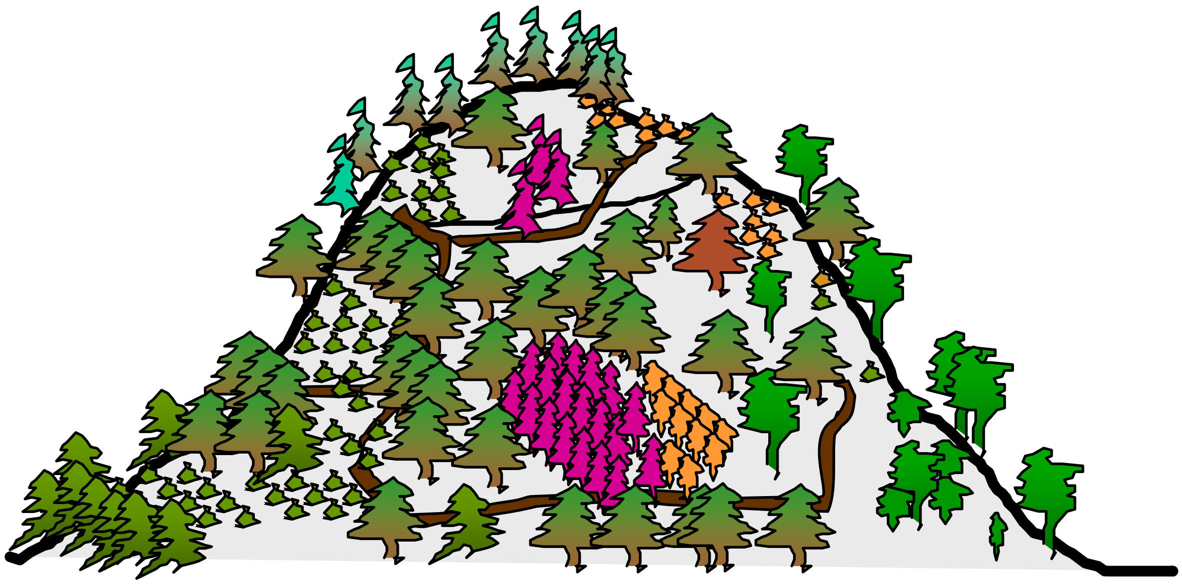
The landscape picture

To keep forests across the northern and central Rocky Mountains functional, forest management must be matched to the ecological potential and historic disturbance processes. This allows forest management practices to help mitigate catastrophic events that could degrade forest ecosystems



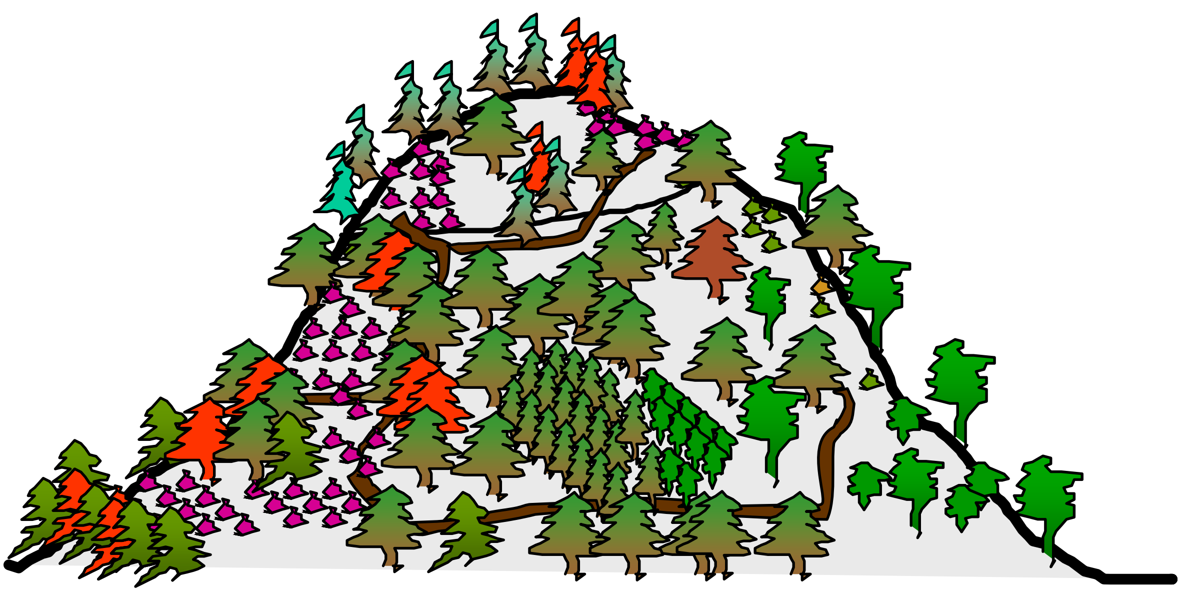
Dry forests- *Multi-aged trees mixed individually and in small groups simulating frequent surface fires.*

and all of the values and services they provide ranging from wildlife habitat and clean water sources to sources of wood fiber for human use. Dry forests historically experienced frequent wildfires that kept forests thinned and prevented overcrowding by tree regeneration and subsequent drought related stresses. Individual tree thinning and small group selections are most appropriate for these forests. Openings that are too large in these forest types may require decades or even centuries to reforest due to the effects of intense sunlight and high soil surface temperatures.



***Mid-elevation forests -** Different age class patches simulating mixed severity fires.*

Mid-elevation forests cycle through climatic periods of abundant moisture from rain and snow to periods of drought. Typically these forests would grow well during periods of moisture and experience moderate patch sized failures during drought from wildfires and insect and disease outbreaks. Openings will vary with small opening on south and west facing aspects and larger openings on north and east aspects. Patch size will vary depending on the landscape and location. Forest thinning, group selections and smaller irregular shaped clear-cuts come closest to emulation natural disturbances on these forests.



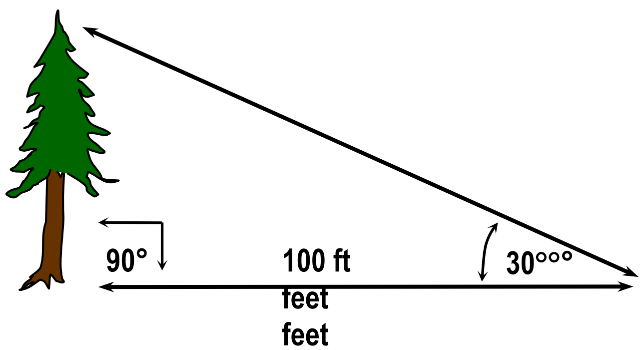
***Wet and high elevation forests -** Simulation of larger stand replacing fires that created irregular large patches.*

High elevation and wetter forest types across the northern Rockies would experience longer periods (decades to centuries) without major disturbances and often progress to forests comprised of shade tolerant tree species. Large landscape catastrophic wildfires were more common here, though the same practices as on mid-elevation forests also are applicable.

Measuring Site Index

Site index is a means of measuring how fast a tree will grow on a given site. It is a useful tool for comparing growth rates among different sites and species site preferences. For economic reasons, site index can be used to determine where to grow what species for the best fiber productivity. Similarly it can be used to predict how long it takes to grow a merchantable tree. To make comparisons meaningful, a "base age" is used, usually 50 years in Montana. Site index is, therefore, a height estimate for when a tree is 50 years old. Trees that are older than 50 years are extrapolated back in time and younger trees are extrapolated forwards using the charts provided at the end of this chapter.

To measure age, an increment core is taken at 4.5 feet above the ground (diameter breast height or DBH for short) and the growth rings are counted from the center pith to where the bark starts. Usually 5 years are added to that number to account for the time it took the seedling to reach 4.5 feet. Some foresters will core the base of the tree as well and compare ages to get a better estimate of total age. The height of the tree is then measured using a tape measure and level. For example, if the angle of a tree height measured from a horizontal distance of 100 ft is 30 degrees, using trigonometry, the height would be (100 feet) x (Tan30degrees) = 57.7 feet. Foresters usually use levels that are precalibrated to specific horizontal distances (called clinometers) for instant height measurements.



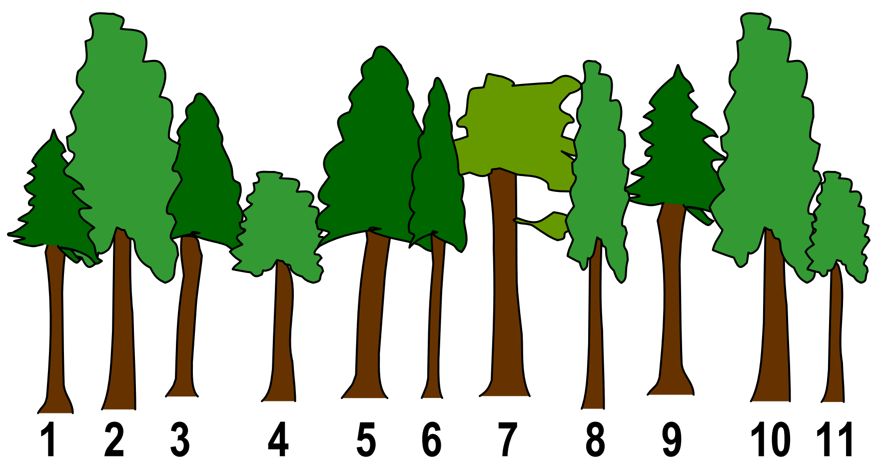
The taller a tree at 50 years, the more productive the site may be for tree growth. Several ecological factors need to be taken into account, however, to use "site index" appropriately. Furthermore, faster tree growth is not an indicator of tree "health". Some trees will devote most of their energy to growth and little to defense, making them more susceptible to pests and pathogens. Trees that are stimulated to grow tall fast due to competition for light and space may be especially at risk to pests and pathogens. Slower growing trees on a poorer site be nutritionally unattractive to bugs and fungus, similar to sour grapes from the shade versus sweet ones from the sun. The current philosophy based upon research indicates that fast growing trees that are suddenly stressed from too much competition for light, water and nutrients are the most susceptible to pests and pathogens.

Tree growth is dependant on four major factors: light, temperature, water, and nutrients. Light will vary according to aspect, slope and competition from other plants (trees). When estimating site potential, any tree that has had approximately 30% or more of its crown shaded, particularly the top of the crown, will exhibit a reduced growth rate. Some trees may have been shaded when they were younger which can be seen in zones of very closely spaced growth rings on an increment core. Some shade may actually stimulate a tree to expend more energy into height growth (a mechanism for increasing competitive status in a crowded stand of trees). The best indicators of site index are trees that are slightly taller than the majority of other trees in the forest canopy and that have been growing at a uniform rate, which would be reflected by evenly spaced growth rings. Several trees may need to be cored to find those that will adequately reflect site potential.

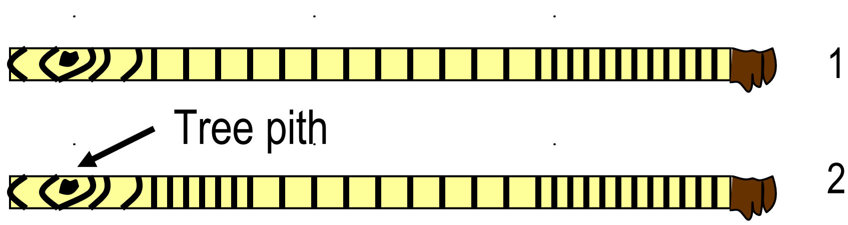
For best estimates, measure the ages and heights of several trees per site. Then using the charts provided, estimate site index for each tree and average the values. For example, three ponderosa pines may be measured as follows: Tree 1, 90 ft tall, 90 years old, on page I – 6 locate 90 years on the X – axis and follow the line up until it intersects with the line corresponding to 90 feet on the Y – axis. Where the two lines intersect falls approximately 2/3's of the way between the "90" and "100" curve. The site index would be estimated near "96". Tree 2, 74 ft tall, 70 years old, following the same procedure gives a site index near "91". Tree 3, 85 ft tall and 75 years old should be equivalent to a site index near "100". The average site index for ponderosa pine is therefore (96 + 91 + 100)/ 3 = "95.7".

Practice questions:

1. Which of the trees in the diagram below would be best suited as indicators for site index?



2. Which of the two increment cores shown below would be best as an indicator tree?



Estimating wood volume in standing trees

Landowners wishing to sell logs from their property to a local mill may find the process similar to negotiating a sale in some foreign country. To the uninitiated, price reports such as "$450 per thousand for mill delivered yellow pine and $200 per thousand stumpage" may sound a bit obscure.

Traditional timber sales take into account a tree's value based upon the wood fiber characteristics unique to each species and the usable wood product that can be manufactured from each stem. The actual wood of a tree is comprised of elongated cells that conduct water from the roots to the needles or leaves of a tree. Each species has different cell lengths, cell wall thickness, cell wall composition, etc. that gives a species wood different abilities to bend, carry weight, hold nails, accept paint, resist decay and so on. Ponderosa pine, for example, can be cut to make fairly light yet strong boards. However, if cut to smaller dimensions such as construction 2x4's, it tends to warp when drying which is why it has a higher value as a board than a stud. Lodgepole pine on the other hand makes great studs but is often too small in diameter or too knotty to make good boards. Similarly such differences can occur between fast and slow growing trees of the same species. Each mill has its preferences for tree species to make a specific product, and the price they are willing to pay reflects those preferences.

Useable wood product per log for the lumber market is calculated in the west using what is called the Scribner Decimal C Rule. In 1846, J. M. Scribner created a simple mathematical formula that estimates the number of boards that can be cut from an average log. The standard unit back then and still used today was the board-foot, which is simply a piece of wood or board 12 inches long, 12 inches wide and 1 inch thick. Scribner's assumptions were that the minimum board dimensions cut from a log would be 1" thick by 4" wide and that each cut made by the sawmill would result in a ¼ inch wide loss to sawdust (called saw kerf). Furthermore, each standard log was a cylinder with a diameter the size of the small end of the log. Obviously a log with a lot of taper would (ie. 20" diameter at one end and 10" diameter at the other end) only be calculated to produce boards from a cylinder based on the small end. The inherent flaw of the Scribner rule is to underestimate the actual number of boards cut from a log (called overrun) if any kind of taper is present. The actual formula is: Volume (bd. ft.)= $(0.79d^2 - 2d - 4)L/16$ where "d" is equal to small end diameter in inches and "L" is equal to the log length in feet. A log 16 feet long and with a 10" diameter small end would therefore have 55 board feet of lumber end product in it. To make volume estimating easier, numerical tables have been developed for standard log dimensions.

To match the volume of lumber needed to make a practical value, board-feet are usually represented by the thousands of board feet, hence the expression "per thousand". Wood volume is calculated and sold in the thousands of board feet and expressed as "MBF". For example, NIPF lands provided logs totaling 624,667 MBF (thousand board-feet) in Montana in 1997. To make estimating lumber volume easier, since it is calculated in the thousands, the Decimal C Scribner rule was adopted where the volume is estimated to the nearest tens of board-feet. Hence in our previous example, 55 bdft. would be rounded to 6 Decimal C bdft.

With all of that in mind, a mill paying *$350 per thousand delivered* is actually paying $350 for each estimated one thousand board-feet delivered to the mill. Stumpage refers to the same volume estimating procedure, but the landowner is paid for the standing trees prior to any kind of logging or hauling cost. "Stumpage" sales always include the value of the trees minus logging and delivery costs.

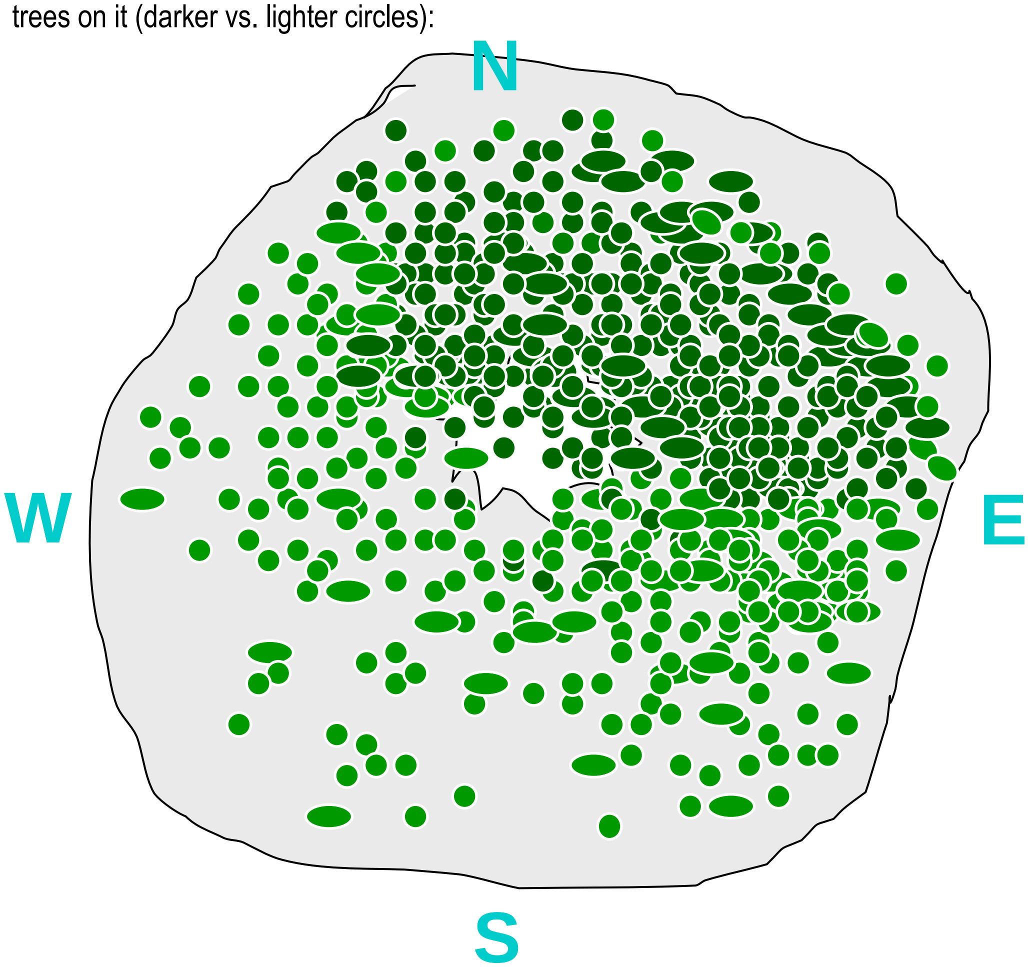
How to estimate wood volume

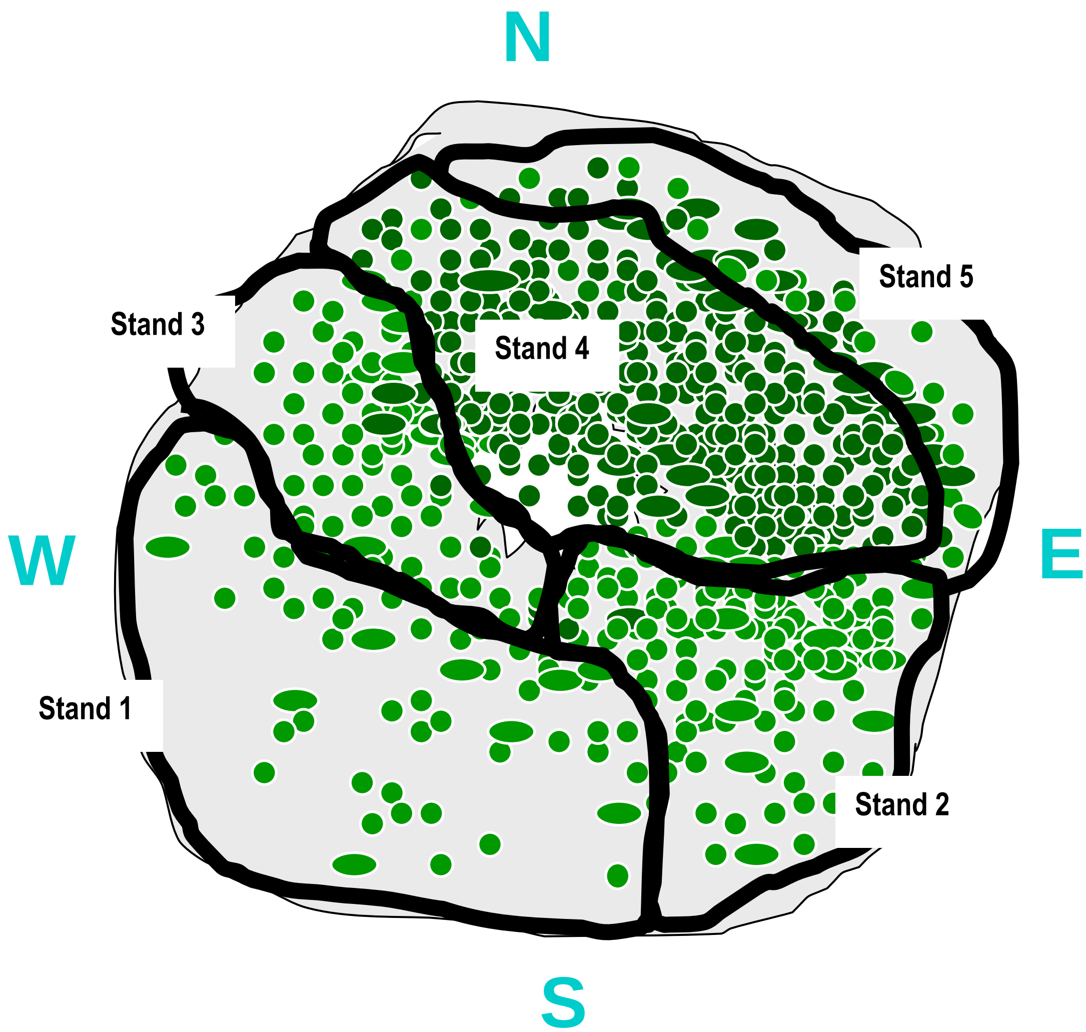
To get a rough estimate of the wood volume and its value for any group a trees, a certain number of trees need to be measured. Foresters refer to this procedure as a "timber cruise". The number of trees measured in a cruise depends on the number of acres involved and the uniformity of the trees on that acreage. For example, a forest can be compared to a spilled bag of M&M's. In this example, each color of M&M would represent a tree with different characteristics (size, age, defect, species, etc.). Likewise, when the bag is spilled, the M&M's do not scatter in a perfectly spaced pattern, some end up in groups and others end up individually scattered. If someone asked you how many green M&M's had spilled, you would simply count the number of green ones. However, if you had a million M&M's on 100 square feet of floor, and were faced with the same question, you might count the number of green M&M's on 1 square foot of floor and multiply the result by 100 to get an estimate. The more uniform the distribution of M&M's the better your estimate would be. The less uniform the distribution of M&M's, the less accurate your estimate would be, unless you sampled more square feet and perhaps divided the spilled M&M's in groups based on how clumped or scattered they fell on the floor.

Cruising timber is much like estimating the number and color of spilled M&M's except instead of color we measure tree species, diameter, height, and potentially age and log quality. If an acreage is small enough, every tree can be measured. However, considering that there are often over 400 trees per acre in an average forest, it does not take many acres to get overwhelmed, which requires some sort of sampling design. Usually a 1/10th acre plot is established for every 5 to 10 acres of forest. The first step is to identify groups of trees that have similar characteristics (called a "stand" by foresters). The most common delineation of stands is by species density and composition, and general height (or age which typically is similar to height).

Past disturbance patterns (such as fire for example), or microclimate because of the different aspect and elevation, tree distributions and characteristics vary tremendously across the landscape. If only several acres were sampled to represent the entire forest, the estimate would be quite inaccurate because of the tremendous variability of tree density and characteristics. To increase the accuracy of a sample timber inventory, this forest could be divided into separate stands. A stand should be delineated so that all of the tree characteristics are as similar as possible within the boundary. In the following example stands were delineated based upon density and species (or age). Sometimes stands can have similar characteristics but be geographically separated such as stands 3 and 4. If the acreage was small enough these could be lumped into one stand or if this was a large property treated as separate stands. The size of each stand is something the landowner must decide based on their management objectives. For example a stand could be 1000 acres in size or ¼ acre in size.

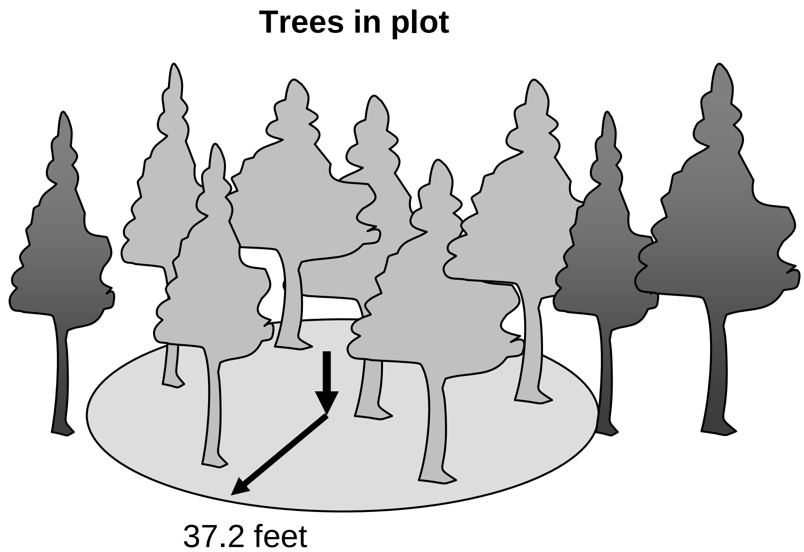
Consider the following diagram which represents an aerial view of a hill with two species or sizes of trees on it (darker vs. lighter circles):



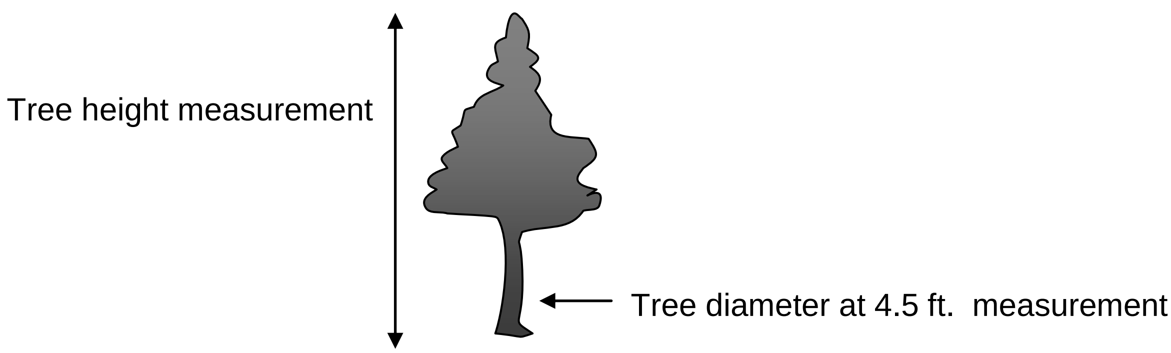


Once the area to be sampled has been determined, individual plots should be established. A general rule is to establish one plot per ten acres if the stand is fairly uniform or 1 plot per 5 acres if the stand has a lot of variability (trees of different sizes, species, shape, etc.). A minimum of 3 plots per stand should be measured with 5 - 10 plots closer to optimal. The more plots established the better the accuracy of your timber cruise. Sample plots are located by a variety of means. The easiest is to estimate where the center of your stand is and pace 100 ft in the cardinal directions. Where your last pace ends will then become your plot center.

A measurement plot can be as small or large as you want it to be. Again the dimensions will depend on the density for trees. It is usually good to try and get approximately 10 trees in each plot. The easiest plot to establish is called a "fixed radius plot". Often a 1/10th acre plot is used. Once plot center has been determined, a tape or string 37.2 ft in length is stretched out and a circle is walked 37.2 ft in radius. Every tree that falls within this circle is considered "in" the plot and will be measured. Obviously to determine the extent of the plot will require walking around numerous trees!



Once a plot has been established, individual trees must be measured. Typically, this is done by starting with one tree (often for reference it is easiest to start with the tree closest to North on your compass) and working in a clockwise direction. Each tree is numbered, species determined, measured for diameter and measured for total height. Diameter is measured at 4.5 ft above the ground to get the best estimate of log diameter without bias from root flair or swelling at the base of the tree. These measurements are recorded on a tally sheet. After all trees have been measured, a new tally sheet is prepared for the next plot.



Once a tree's height and diameter are known, an estimate of volume can be obtained using a volume table. Diameter at breast height (DBH - 4.5 ft) are located along the left margin and total tree height is located along the top of the table. For example, a ponderosa pine 100 ft tall and with an 18 inch DBH will contain 339 board feet.

To finish the estimate of volume on a per acre basis, all of the trees measured in the plots are converted to board-feet and totaled. Next all of the volumes per plot are summed and an average volume per plot is calculated. Since in this example, 1/10th acre plots were used, the average volume per plot is multiplied by 10 to gain a volume per acre estimate. This can be further expanded by multiplying the number of acres in the stand times the volume per acre to estimate the total stand volume present.

Annual Increase in Board Foot Volume

Board foot (or feet) of volume in a log refers to how much lumber can be cut from a log. A board foot is equivalent to a piece of wood 1 inch thick, 12 inches long and 12 inches wide or a 1 foot length of a 12 x 1" board. This has traditionally been the standard measure of volume for the timber industry. Cubic feet (a piece of wood 12 x 12 x 12 inches) is gaining in popularity, especially with small diameter logs because it can be converted to a measure of weight (tons) with more accuracy and simplifies the scaling procedure at the processing mill. The measure of board feet in a log in the Northwestern United States is calculated using the Scribner log rule. This rule is essentially based on a diagram table of how many 1-inch boards separated by a ¼ inch sawkerf can be cut from a wood cylinder with a diameter equal to the small end of the log.

The annual increase in board feet of a tree stem is based upon the existing diameter of the stem and the annual growth rate. Since the formula for calculating the volume of a cylinder is "volume = $\pi r^2 h$" or (3.14) x (cylinder radius)^2 x cylinder height, increases in diameter geometrically increases volume. Hence, the larger the diameter, the smaller a growth ring needs to be for the same increase in volume that a small diameter tree will gain with a large annual growth ring.

To help estimate how much volume a tree is producing, the tables at the back of this chapter can be used based upon a tree diameter measurement and an increment core. For example, a tree with a DBH (diameter breast height, 4.5 ft) of 18 inches, 32 feet of merchantable height, and a growth rate of 10 rings per inch of diameter will be gaining 5.67 board feet per year. In general, only the last inch of the increment core (measured from the bark inwards) needs to be measured because that represents how the tree is currently growing. Trees grow from the cambial layer (the layer between the bark and the wood) inwards, usually one ring per year. Merchantable height, or number of 16 foot logs varies based upon the minimum log diameter a mill will accept, usually 4 or 6 inches. Therefore, the height to a 4 or 6 inch top needs to estimated, and the number of 16-foot increments that will fit into that height calculated to use the tables. If your good at mathematics partial log increments can be extrapolated by using the values above and below the number of logs. For example, an 18 inch DBH tree with 40 feet to the minimum merchantable diameter and 10 rings to the inch growth will gain between 5.67 (2 logs) and 8.23 (3 logs) board-feet per year. The difference is 8.23 – 5.67 = 2.56 bdft/yr. Half of 2.56 is added to 5.67 which results in an estimate of 6.95 bdft/yr growth.

The next step will be to calculate how tree growth rate is equivalent to the interest rate invested money will earn. The growth of a tree can be equated to the increase in value of that tree based upon the prices mills are willing to pay for logs. It is quite simple to calculate when a tree is growing at a rate faster or slower than the value of that tree would earn you if you invested that amount in a bank account for example.

Answers to Site Index Questions:

1) Trees 2, 5, 10, maybe 3, 6 and 8
2) #1 because it has been consistently growing without stress as indicated by irregular growth rings on #2.