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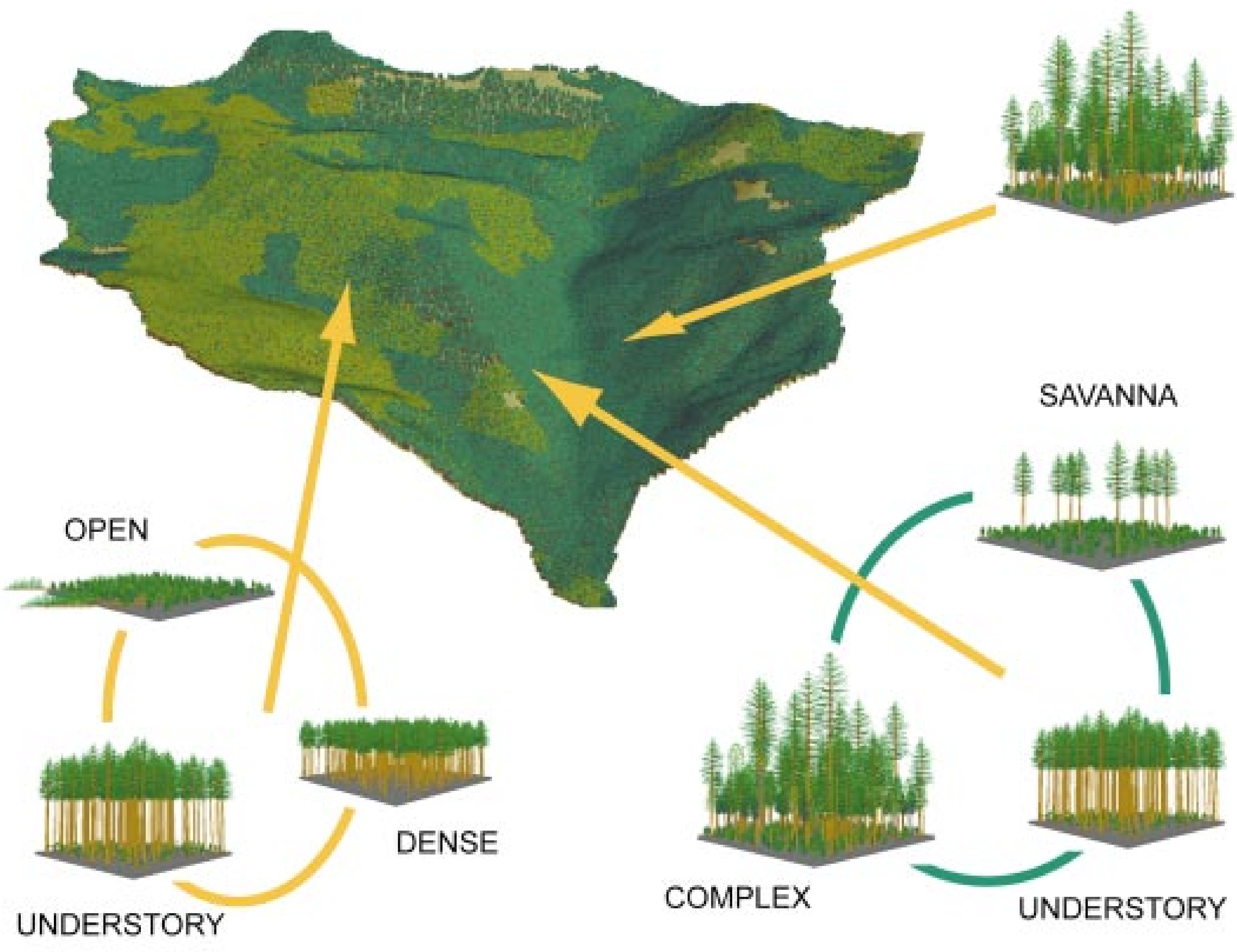
Forest Ecology in Washington



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Contents

Forest Ecology in Washington

Forest ecology is the foundation on which good forest management is built.

Introduction

A forest ecosystem is not just a collection of trees. Forests contain living, or *biotic* components, and nonliving, or *abiotic* components. Besides trees, the living portion of the forest includes herbs, shrubs, other plants, animals, and microorganisms like bacteria and fungi. Nonliving parts of the forest include snags, logs (also known as large organic debris or LOD), the underlying rocks from which soil is formed, and the soil itself, which provides water, nutrients, and support for the plants. The atmosphere and climate have an effect as well. Fires, frost, drought, windstorms, and other disturbances regularly influence forest growth and development.

Together, the living and nonliving pieces that make up the forests often are referred to as a forest ecosystem. Forest ecologists study how all the parts of a forest are related. The word ecology comes from the ancient Greek word "oikos" meaning "house" and the suffix "ology" meaning "study of." Just as members of a household influence each other, changes that happen in one part of a forest ecosystem influence other parts. Timber harvesting and natural disturbances also change the forest. It is important to learn to recognize the changes that occur and how they influence the total forest ecosystem.

Because forests are so complex, scientists do not completely understand how forest ecosystems work. As a field of study, forest ecology is very broad and theoretical, but also exciting and useful. From explaining how one population of soil bacteria relates to another, to describing why ponderosa pine will grow well on some sites and not on others, forest ecology deals with *virtually everything* relating to the forest as a whole. Foresters and landowners know different organisms in an ecosystem depend on each other and that changes to one organism can have an impact on others. This understanding has made people think about how they manage forested lands and realize that management practices must be based on sound principles of forest ecology.

Forest ecology is one of the most important courses forestry schools offer. It forms the basis of silviculture—the art and science of tending forests to achieve management goals. Forest ecology is complex. This publication presents key concepts as an aid to good forest management.

Structure, Function, and Change

Forest ecosystems have three major properties: structure, function, and change. Structure includes the underlying rock and soil, the living and dead tree and plant material, and the atmosphere. Function refers to the movement and exchange of matter and energy. This occurs between the physical environment and the living community and between living community components within and between ecosystems. For instance, the food chain or web represents the flow of energy from the producer level (green plants) through various consumer levels (plant-eating animals, carnivores, insects) and decomposer levels (bacteria, fungi) (Figure 1.) Many functions are described in terms of cycles—the energy cycle, the carbon cycle, the water cycle, and the nutrient cycle. Ecosystem structure and function also interact and change over time. This is why we say forests are dynamic.

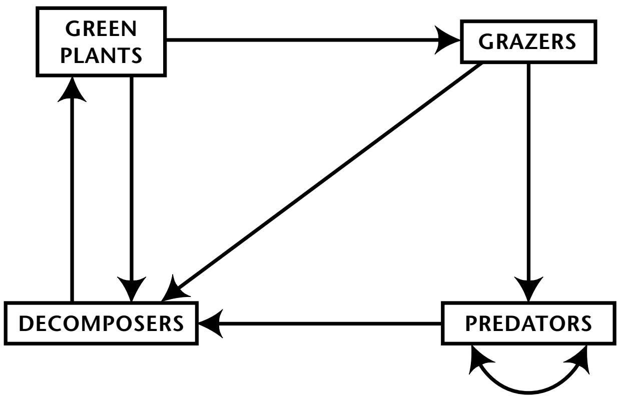


Figure 1—The Food chain. Green plants take up nutrients decomposers have returned to the soil. In turn, grazers, their predators, and other predators eat the plants. The bodies of grazers, predators, and green plants are decomposed and returned to the soil.

Scale

Scale is the frame of reference we use to define an ecosystem. The term "ecosystem" does not imply any particular size. Ecosystems range from quite tiny to very large. (Figure 2). The population of lichens on the bark of a Douglas-fir forms an ecosystem. All the plants and animals in a particular watershed also form an ecosystem. Both are ecosystems having a different scale. If we start by thinking about one scale, that of the individual tree, smaller scales would include a leaf on that tree, or even a single cell within that leaf. We can think about and observe larger scales: a recognizable unit of the forest, called a stand, or even an entire drainage or landscape made up of many interacting ecosystems.

Changes in structure and function may influence additional ecosystems. Effects become apparent at different scales. An event that occurs at one scale may not produce noticeable results at a greater scale, or may cause effects that magnify at increasingly larger scales. Interactions among lichen populations on the bark of an individual Douglas-fir may not be apparent at the scale of the forest stand. If insects defoliate a few needles, the effect will not be visible at the scale of the entire tree, which will survive and continue to grow. If insects eat many needles, they can seriously weaken or even kill the tree. While the death of an individual tree is usually not serious at the stand and landscape levels, the death of trees in an entire stand or landscape is serious because of the scale. Similarly, the effect on forest floor temperature and light will be different if many trees die or if only a few trees die. If a fire disturbs a small area, the effects on soil erosion and water quality will likely be less than if an entire drainage burns.

If a lightning bolt strikes a lodgepole pine in eastern Washington, the initial impact occurs at the scale of the cells and of the individual tree. Cells beneath the bark become so hot that many die. Cell death causes a stress reaction within the tree, since the tree cannot obtain adequate water or nutrients without these cells. One way a coniferous tree reacts to stress is by producing chemicals called terpenes. The chemicals attract insects such as bark beetles. The beetles colonize the stressed tree, eventually killing it. The effects of a single lightning-struck tree can spread to the stand level if other trees in the stand are sufficiently large and crowded. An outbreak of bark beetles may occur, originating at the lightning struck tree. If many trees in the stand are attacked, most will die. The buildup of dead trees in the stand can increase the amount of fuels. If lightning were to strike within this stand again, the result might be further magnified as a large fire that destroys many stands across the landscape. Disturbances such as this lightning strike example also might result in biodiversity changes that could be beneficial. As such, the increase in bark beetles attracts insect-eating birds, which in turn may increase cavity excavation in the dead and dying trees. Cavity increase may influence small mammal numbers, which may influence the number of predatory birds, such as owls.

In the past, forest ecology concentrated on studying interactions at the scale of individual stands. Now, landscape-scale interactions also are considered important. Think of a forest landscape as a mosaic or collage of many forest stands. Landscapes can be fairly homogenous—all stands can be similar in age and species composition. Heterogeneous, or mixed landscapes are made up of stands that differ from each other in age, composition, or both. Diverse landscapes usually result from past disturbances (fire, weather, insects, diseases) and topographic features.

Figure 2. Small ecosystems exist within larger ecosystems.

Landscapes

A landscape-scale ecosystem is made up of groups of smaller interacting ecosystems. Like all ecosystems, landscapes have the attributes of structure, function, and change. Landscape structure refers to the sizes, number, kinds, and configurations of ecosystems that make up the landscape. Landscape function refers to the flows of energy, materials, nutrients, and species among ecosystems. Landscape change refers to alterations in the structure and function of the mosaic of ecosystems over time.

Historically, landscape patterns were created and maintained by natural disturbance. In managed landscapes, political boundaries and management decisions affect these patterns and often the character of disturbances. Ecosystems and landscapes change over time as a result of vegetation development and disturbances.

In western Washington, large, infrequent fires created and maintained relatively homogeneous landscapes. Urban development and timber harvesting have fragmented this landscape, altering these ecosystems. Eastern Washington landscapes were historically patchy because frequent, low to moderately severe fires created a mosaic of different-aged forests across the landscape. During the past century, fire suppression has allowed dense fire-prone stands to establish and grow across the landscapes. This, coupled with poor selective logging or "high grade" logging practices earlier in this century, has created much more uniform landscapes than existed historically. These landscapes are more susceptible to outbreaks of insects, diseases, and catastrophic fires.

Energy Flows and Photosynthesis

Forest ecosystems are driven by solar energy through the process of photosynthesis (Figure 3). Trees and other green plants convert light energy from the sun into chemical energy. The leaves or needles capture solar energy (light) and convert carbon, hydrogen, and oxygen to simple sugars. These are then converted into more complex compounds such as cellulose, the main component of wood fiber. A mature forest produces many tons of sugars and other compounds per acre each year. Of these compounds, the leaves use approximately 70%; about 5% is converted to wood, branches, and fine roots, and 25% maintains tree functions. This maintenance is referred to as respiration. As forests age, more energy captured each year goes into respiration instead of into the production of wood, branches, roots, or leaves.

Photosynthesis Cycle

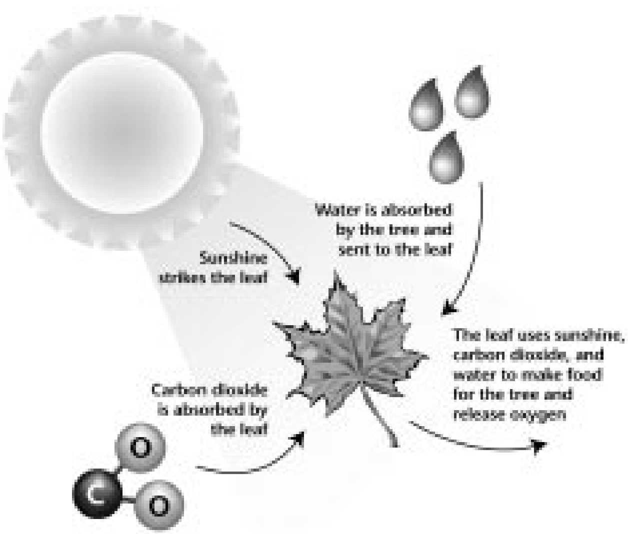


Figure 3. Trees and other green plants convert light energy from the sun into chemical energy through photosynthesis. The leaves or needles of trees capture solar energy (light) and convert it to complex sugars and starches made up of carbon, hydrogen, and oxygen.

Although a complete understanding of photosynthesis is beyond the scope of this publication, the faster and more efficiently a tree carries on photosynthesis, the faster it will grow and the less vulnerable it will be to insects and disease. This is primarily a function of the size of the live crown, actually the total leaf area (to capture light), and available soil nutrients and water. When a tree or parts of a tree die, it begins to decompose. The microbes and other organisms that decompose the twigs, leaves, and wood use some of the energy stored in the tree parts. Much of it remains in organic material that accumulates on the forest floor. Following a disturbance that removes most of the vegetation from an area, the increased light and temperature at the forest floor increase the rate of decomposition—that is, the rate at which the energy stored in the organic matter is released. Recovery of ecosystem structure and function following a disturbance is powered by solar energy stored in the forest floor.

Some of this stored energy is lost through grazing and browsing by herbivores, such as squirrels, rabbits, grouse, deer, and elk. As these animals eat, they use the energy they consume to build tissue, such as muscle, fat, and bone. In turn, these herbivores become food for forest carnivores and the energy is transformed again, used in the development of body mass for these species. When an animal dies, the energy once again is transformed into food for decomposers and soil microbes. This transformation of energy from plant to animal tissues also contributes to the dynamic nature of the forest ecosystem. Through photosynthesis, forests accumulate biomass and stored energy, which cannot build up forever. Ultimately, this energy will be released through microorganisms, fire, or human activity.

Cycles

Ecosystem function—the exchange of energy and material within and between ecosystems—can be characterized as the interaction of several cycles, such as water and nutrient cycles. Cycle rates vary. Some cycles operate at regional or global scales and over long periods of time, so that material movement at smaller scales appears to go only in one direction. Soil movement is a good example. Soil moves down slope. It can move rapidly and in great quantities, as in a landslide, or gradually, as gravity moves particles slowly from ridge top to valley bottom. All cycles are powered by solar energy.

Water Cycle

The water cycle also is referred to as the hydrologic cycle. Rain or snow falling through the atmosphere first strikes the forest canopy (Figure 4). Some is intercepted by needles or leaves and may evaporate back into the atmosphere or be delayed before reaching the ground. Some water directly reaches the ground. In areas where vegetation is sparse and the soil is compacted, the soil cannot absorb much of the water, and the water

Hydrologic Cycle

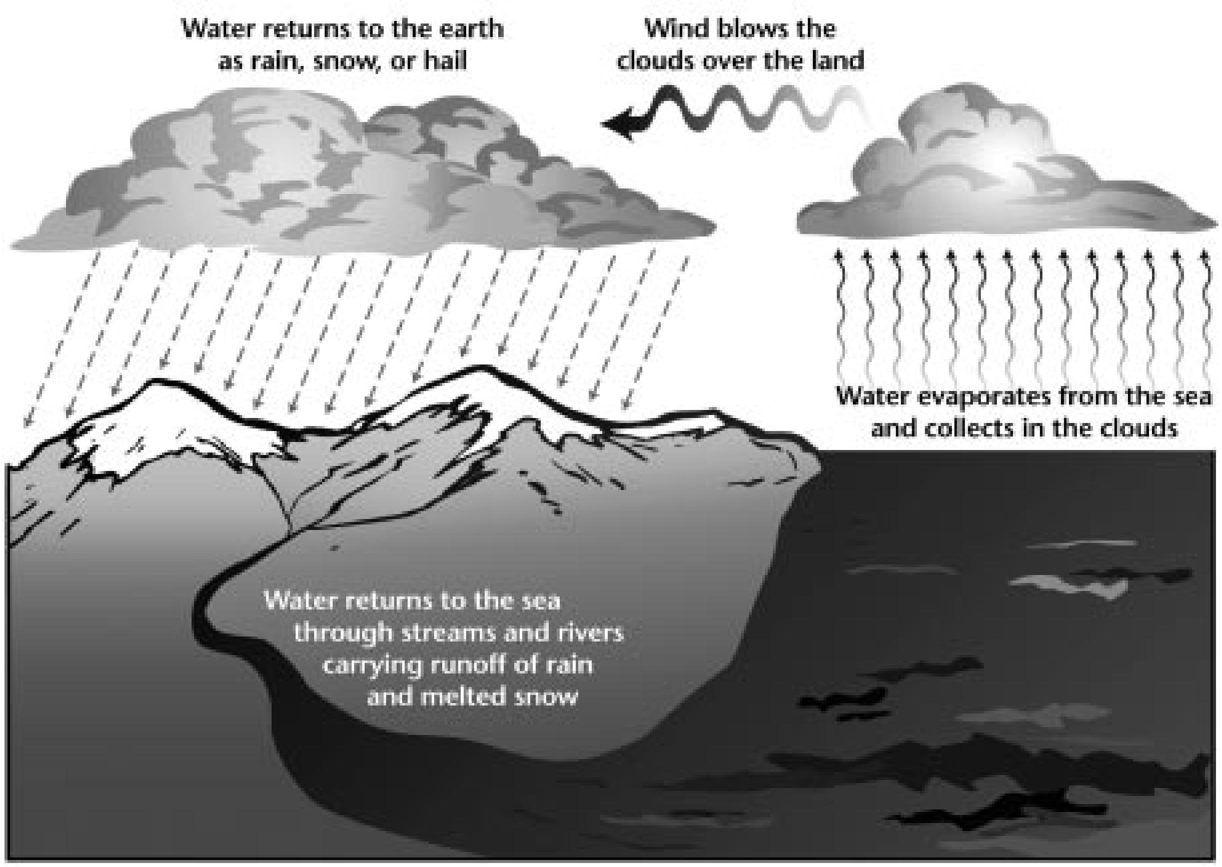


Figure 4. Water or hydrologic cycle.

flows over the soil surface, picking up soil particles. Eventually, this overland flow may reach a stream channel and transfer to another ecosystem, along with the soil particles and nutrients dissolved in it. If the forest floor is intact, most precipitation reaching the ground will move into the soil. The roots of trees and other vegetation usually take up water in the soil before the water reaches a stream channel. The trees will store some of this water, while some will return to the atmosphere through transpiration. Basically, transpiration is the process by which water is pulled first from the soil by tree roots, then pulled up the tree through xylem tissue and into the leaves or needles. The leaves contain small openings called stomata that continue the pull of moisture, allowing it to escape back into the atmosphere. [You can see the stomata as the thin white lines (termed stomatal bands) on the bottom of noble fir and subalpine fir needles.]

Nutrient Cycle

A properly functioning forest ecosystem is able to acquire, store, and recycle nutrients. (Figure 5).

Energy flows power the interconnected water and nutrient cycles. Through transpiration, the water cycle drives much of the circulation of nutrients within the ecosystem. Many dissolved nutrients are held within the soil water. These nutrients are lifted into the canopy by transpirational pull and eventually returned to the soil through needle fall and decomposition. Transpiration also controls photosynthesis. When not enough moisture is available in the soil for trees to transpire effectively, plants close their stomata to reduce transpiration. Photosynthesis also is reduced. This is why trees do not grow as fast when moisture is limiting.

A forest ecosystem, burned so severely that little organic matter remains in the soil, could lose much of its nutrient capital through erosion and streamflow. If no present vegetation is available to take up nutrients, and if few soil organisms are present to store the nutrients, they frequently are washed into streams and flow out of the area. In some cases, replacing these lost nutrients can take hundreds of years.

The woody parts of trees tie up only small amounts of nutrients. Traditional harvesting methods remove only minor amounts of a site's nutrient capital. Most nutrients occur in the needles, leaves, or fine roots of trees. Whenever possible, leave these tree parts on the ground after logging so the nutrients will be available to be cycled.

Ecosystem Productivity

The measurement of productivity provides us with an indication of the rate of photosynthesis and biomass accumulation in a community. Although all biological activity in plants ultimately depends on received solar radiation, solar radiation alone does not determine gross primary productivity. All plants require sunlight, carbon dioxide, water, and soil nutrients for photosynthesis. Photosynthesis also depends on temperature, moisture, and nutrient availability. Temperature (heat) controls the rate of plant metabolism, which in turn determines the amount of photosynthesis that can take place. Most biological metabolic activity takes place within the range 0°C to 50°C. There is little activity above or below this range. The optimal temperatures for productivity coincide with 15°C to 25°C (59°F–77°F) optimal range of photosynthesis. The graph in Figure 6 illustrates the relationship between the net primary productivity of forests and annual air temperature.

The general relationship between net primary productivity and precipitation for forests is shown in Figure 7. Water is a principal requirement for photosynthesis and the main

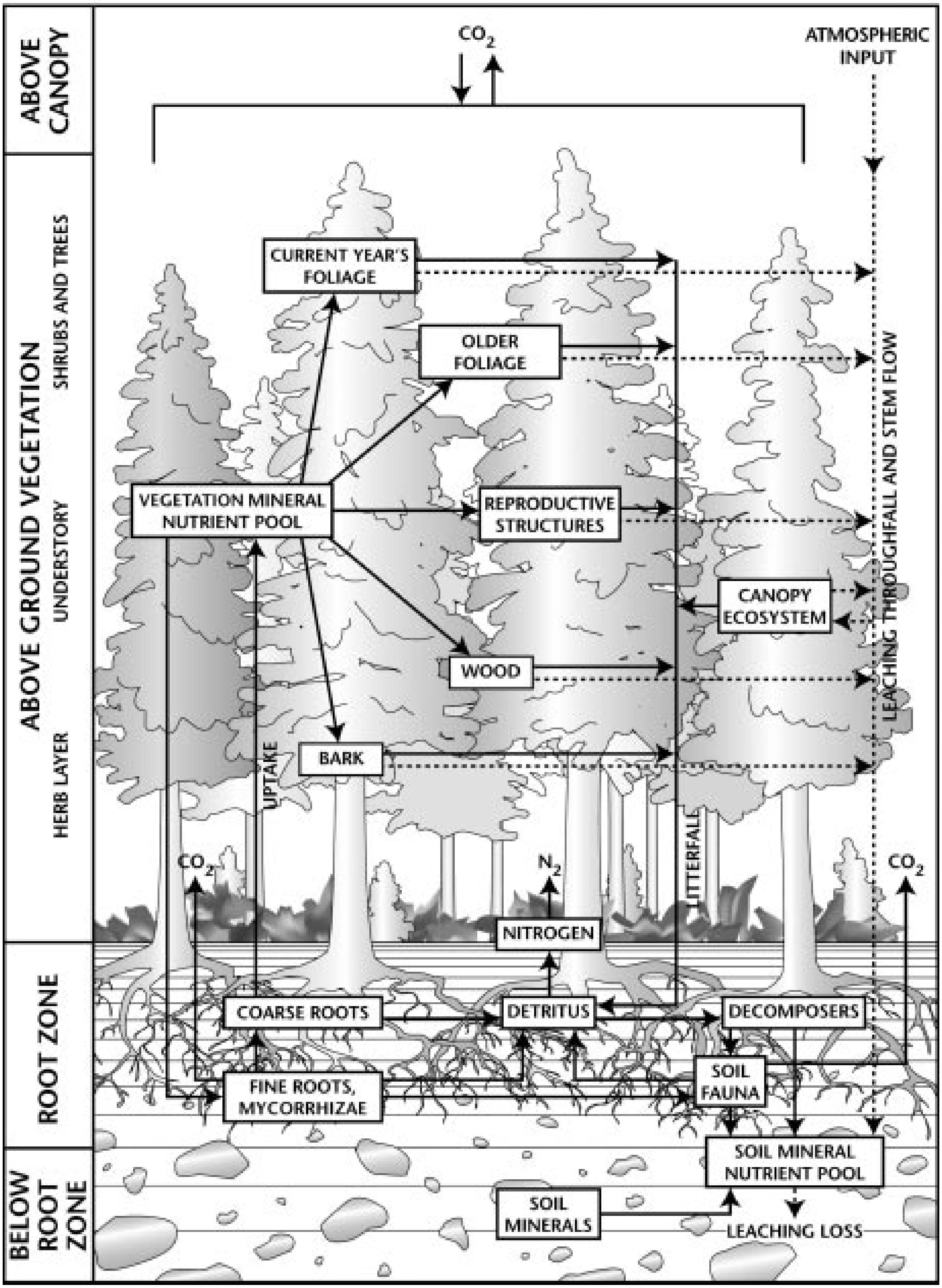


Figure 5. Nutrient cycle.

chemical component of most plant cells. In dry regions, there is a linear increase in net primary productivity with increased water availability. In the more humid forest climates of the world, plant productivity begins to level off at higher levels of precipitation. The productivity of plants, especially at the local scale, also can be controlled by the availability of nutrients. About 20 to 30 elements generally are considered essential for plant metabolism and growth. These essential nutrients are sometimes grouped into two categories: macronutrients and micronutrients. Plants use the macronutrients for the construction of structural molecules and for building a variety of organic molecules used in metabolic processes. Only two of the macronutrients used by plants normally occur in limiting concentration for plant uptake: nitrogen and phosphorus. When limiting, these two nutrients control the amount of plant productivity that can occur. Plants require micronutrients in extremely small quantities for the creation of less common organic molecules or as ions to catalyze specific metabolic reactions. In general, micronutrients are common in abundance and do not limit plant production.

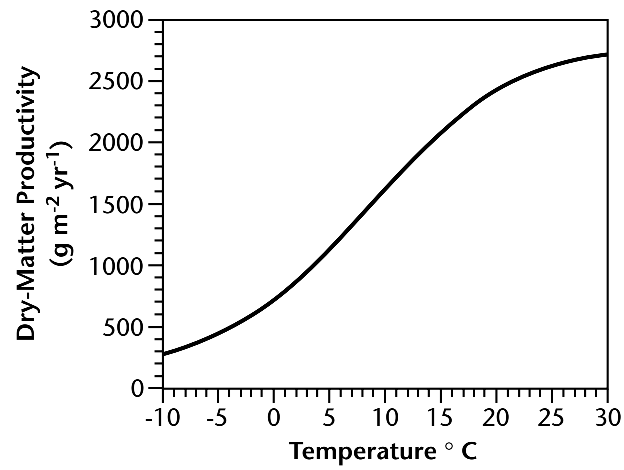


Figure 6. Relationship between forest net primary productivity and annual temperature. (Adapted from Lieth, H. 1973. Primary production: terrestrial ecosystems. Human Ecology 1: 303–332).

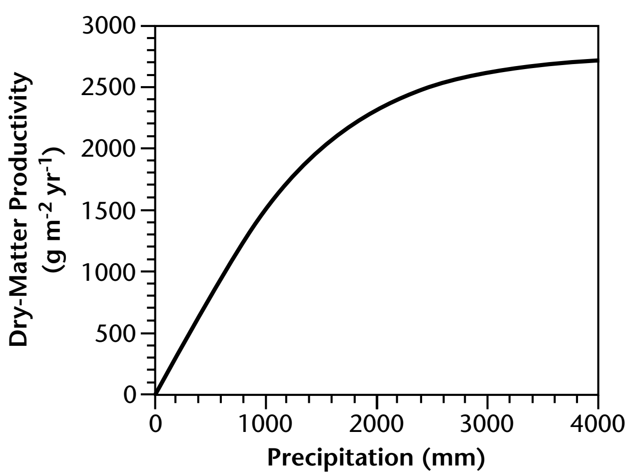


Figure 7. Relationship between forest net primary productivity and annual precipitation. (Adapted from Lieth, H. 1973. Primary production: terrestrial ecosystems. Human Ecology 1: 303–332).

Site Quality

Foresters refer to the sum of all the natural factors that influence forest vigor, health, and growth as the site. Additionally, foresters frequently talk about site index, or refer to relative productivity of sites. What they really are talking about is the combination of environmental influences such as climate, soil texture, soil nutrients, slope, aspect, and elevation. These factors affect where tree species grow, how rapidly they grow, how healthy they are, and their form at maturity.

Slope, aspect, and elevation combine with local climate conditions to determine the microclimate of a site. For example, gently sloped, northeast-facing slopes tend to be cool and moist, while steep, southwest slopes, which face the sun in the afternoon, tend to be warm and dry. High elevation sites are colder and more exposed to wind than sites deep within a valley. However, frost pockets may exist in low-lying areas where air drainage is restricted. The orientation of a valley determines its exposure to prevailing winds.

Just by knowing the aspect, elevation, and slope of a site (and whether it is east or west of the Cascades Mountains), one can make some predictions about its potential productivity and which species will grow well there. For example, in western Washington on northeast slopes below 1000 feet elevation, Douglas-fir—western hemlock forests dominate. Northern aspects often result in Douglas-fir—western hemlock—western white pine forests. In eastern Washington, ponderosa pine forests usually grow at lower elevations that have hot and dry southern aspects. Slope position is also important. On wet or poorly drained riparian areas, western redcedar, red alder, Oregon ash, or black cottonwood may dominate on the west side. On the east side, western redcedar, black cottonwood, Engelmann spruce, or subalpine fir may dominate.

One of the most important things to know about a site is the nature and condition of the soil. Forest soils are made up of four main ingredients: mineral particles, organic matter, water, and air. The minerals it contains largely determine soil fertility. Soils derived from basalt or volcanic ash tend to be more fertile than those derived from granite or sandstone, because basalt has a greater concentration of nutrient-bearing minerals than either granite or sandstone.

The physical properties of a soil—whether it is fine or coarse—depend on the type of minerals present and on the size of the soil particles. The three basic soil particle sizes are sand, silt, and clay. Sand is the coarsest size; clay is the finest. Sand is very porous and normally does not contain many nutrients. Clay is very nutrient-rich but drains poorly and is easily compacted. Soil texture refers to the proportions of sand, silt, and clay particles in a particular soil. Soils that contain a large proportion of clay and silt have a fine texture. Finer soils are usually more productive than coarse soils, but fine soils do not drain as quickly, are very susceptible to damage from compaction, and are more easily eroded than coarse soils. A soil made up of roughly equal amounts of sand, silt, and clay is referred to as a loam. Loams tend to be fertile and hold water, without becoming overly wet.

Organic matter—rotting debris such as needles, leaves, and twigs—strongly influences the physical and chemical properties of a soil. Soils having large amounts of organic matter have better structure and greater fertility. Organic matter also helps forest soils hold water. However, too much organic matter, such as in a poorly drained bog, can tie up nutrients, making them unavailable to living vegetation, including trees. Thick layers of organic matter on the forest floor can hinder seed germination for some tree species, such as ponderosa pine, Douglas-fir, and western larch.

More than half the volume in the upper layers of an undisturbed forest soil can be made up of air and water. The proportion of air and water is both affected and determined by the physical properties of the soil. Since roots need air to respire and water to supply the rest of the tree, the air and water components of a soil are very important. More than half the "feeder" roots in a forest occur in the top 6 inches of soil. Soil compaction reduces the amount of space available for air and water, and lowers site productivity. This is why it is so important for rubber-tired skidders to stay on established trails, especially on sites having wet or fine-textured soils that tend to compact easily.

Soils contain living matter too. Fungi, bacteria, insects, and a host of tiny creatures live on organic matter produced by trees and shrubs. Even though we cannot see most of them without a microscope, these organisms are absolutely essential to the growth and development of forests. Although some occasionally cause disease in trees, most soil organisms feed on fallen leaves and woody debris. Their main role is to recycle nutrients like phosphorous, potassium, and calcium tied up in dead vegetation and animals. During the process of decomposition, nutrients locked up in dead vegetation and animal carcasses are ingested by soil microorganisms and returned to the soil upon the death of these decomposers. Without them, the forest floor would be littered with debris accumulated over thousands of years, and trees would be starved for the nutrients locked up in this material.

A group of soil organisms known as mycorrhizae-forming fungi actually colonize the roots of some trees and greatly improve their ability to take up water and nutrients. The tree and the fungus depend on each other; the tree provides food to the fungus while the fungus transfers water and nutrients to the tree and provides protection against harmful soil organisms. Mycorrhizal fungi are highly susceptible to changes in environmental conditions, especially those caused by soil compaction. Forestry operations must take into consideration these unseen, but very important components of forest ecosystems.

Characterizing Site Quality

Site quality refers to the productive capacity of a forest stand. Site quality knowledge is useful for predicting potential growth and determining management priorities. Site quality is affected by factors such as soil depth, soil texture and composition, slope, elevation, and aspect. Forests on the east side of the Cascades, on gentle slopes, north or northeast aspects, and cool, moist areas are usually the most productive. In west side forests, the best sites are those having deep nonglaciated soils at lower elevations. Erosion or soil compaction can degrade site quality.

Site quality can be measured by many methods. Foresters often estimate site quality by the approximation called site index. Site index is based on dominant tree height, the aspect of tree growth least affected by competition from surrounding trees. Dominant tree height is compared with an expected tree height (from a site index table) to estimate relative productivity (Figure 8). For example, a site index of 120 for ponderosa pine means the site is capable of producing trees 120 feet tall when the stand is 100 years old—an average for a good site in east side forests. A site index of 80 for the same species is a less productive site. Because growth is more rapid west of the Cascades, tables generally use 50 years as the index age. Excellent Douglas-fir sites in western Washington range from 140 to 180 feet with a 50-year base. Sometimes site index is described in relative terms, on a scale of I to V (Roman numerals) with site I being the best and site V the poorest.

If a stand site index is known and if good yield tables exist for the species in the region, the volume of wood a stand will produce over time can be predicted with reasonable accuracy. However, site index is rarely used to predict yield; rather, it is commonly used to determine the *relative* productivity of stands on a tract of forest land.

Many foresters learn how to visually estimate site index and will do measurements occasionally as a check. How do they do this? Through experience, the same way a seasoned logger can "sight cruise" a stand of timber and arrive at a remarkably accurate estimate of volume. Experience is aided by visual clues from the stand. Size and form of trees, the height and condition of their crowns, bark characteristics, and the presence or absence of certain indicator plants all factor into the equation. Stem taper, bark appearance, and species composition of the stand are three good indicators of site quality. Although straight stems with tall, full crowns may be inherent genetic characteristics of a species, they are more apt to be a full expression of the capabilities of the tree on a favorable site. The same tree on a poor site will be shorter and have a sparse crown and tapered bole.

Use the following four steps to determine site index:

1. Select six to eight trees to measure. They should be trees that have been dominant throughout their lives, relatively free of disease or injury, sound enough to determine age, and without visible crown damage or height growth interruption.
2. Measure the height of the selected trees and calculate their average height.
3. Determine the age of these trees. Increment borings are generally taken at diameter at breast height (DBH) (4-1/2') above the ground. Average the ages of the selected trees.
4. Determine site index using site index tables or curves for the species and region.

Forest Health

Forest health has been defined as the condition of a forest when it is

- resilient to change, it can recover from a disturbance.
- biologically diverse over a large area (landscape diversity), and
- able to provide a sustained habitat for vegetation, fish, wildlife, and humans.

A healthy forest is made up of trees and other organisms all dependent on each other. The presence of single or a small group of unhealthy trees does not necessarily indicate an unhealthy forest. For example, bark beetles can actually promote forest structural diver-

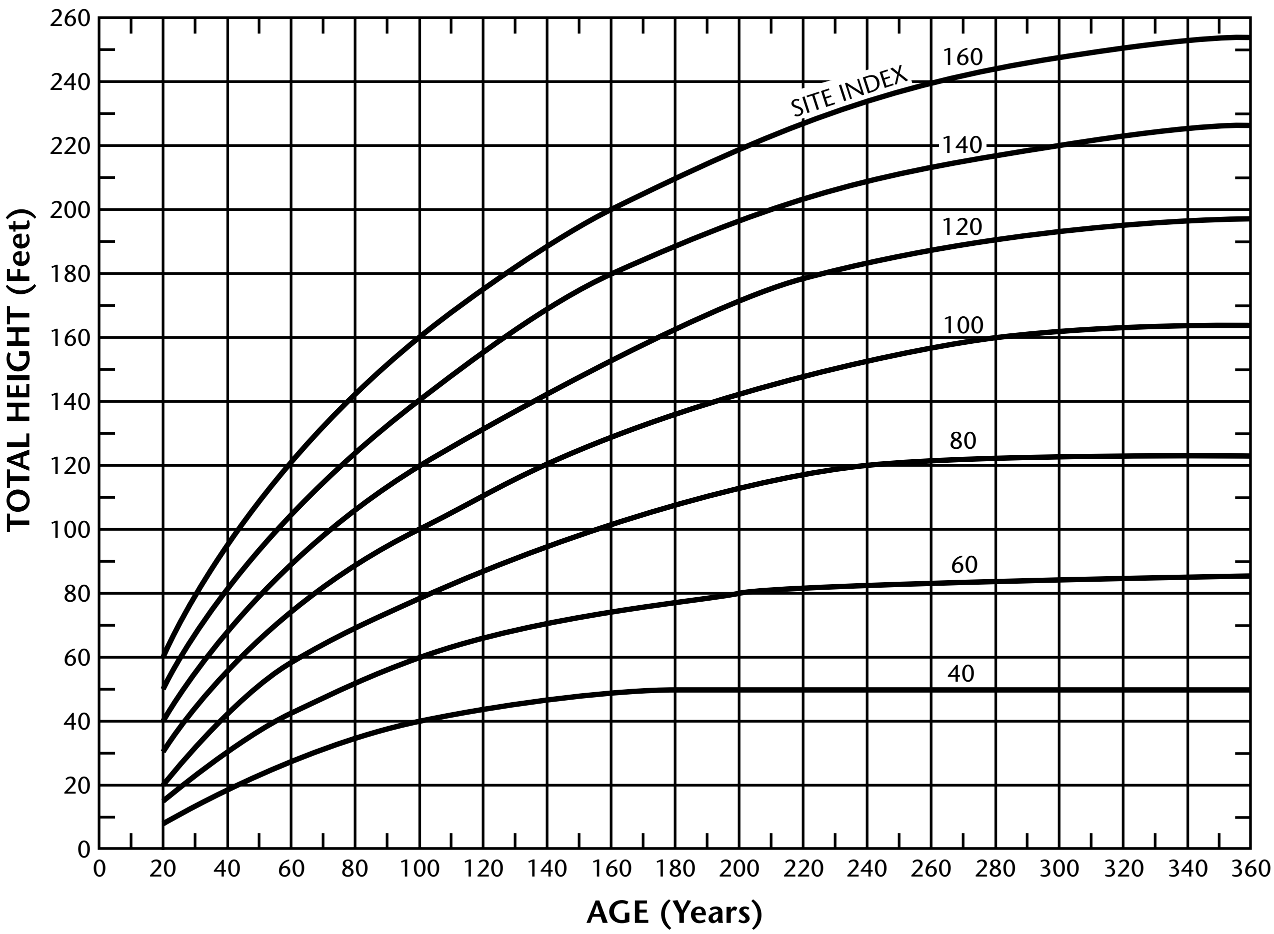


Figure 8. Site Index Table for Ponderosa Pine, 100-year Basis.

sity. A professional forester can help you determine the severity of a forest health concern.

Just as humans need a certain combination of food, water, and exercise to maintain physical health, forests and the trees require certain inputs to maintain their health and growth. If one or more of these inputs is missing or insufficient, trees experience stress. Forest managers can influence these inputs through silvicultural practices.

One of the major health concerns in Washington forests is stress caused by having too many trees per acre, or overstocking. Overstocking causes tree stress because it forces trees to compete with surrounding trees for limited light, water, and nutrients. Many silvicultural practices are effective because they reduce the number of trees per acre and, thus, the competition for these essential elements. Other stress factors may include air pollution, soil compaction, and climate changes.

The first requirement for healthy tree growth is light. Through photosynthesis, plants manufacture their own food by using the sun's energy to convert carbon dioxide and water to a usable food source. Heavy shade, found underneath the closed canopy of a forest, provides insufficient energy for the smaller, less dominant trees to grow. Shade-intolerant species have great difficulty growing under these circumstances. These include pines and larches. Other species, such as Douglas-fir, Engelmann spruce, and most hardwoods, are considered moderately shade tolerant. They can grow in partial shade. The tolerant species—grand fir, hemlock, and western redcedar—can grow under conditions of heavy shade, although not very fast. A thinning operation can release slow-growing (suppressed) trees by providing them more light and space in which to grow.

The second requirement for healthy tree growth is water. Tree species vary considerably in their water needs and drought tolerance. Shade-intolerant species commonly grow in hot, sunny areas and are more drought resistant. Shade-tolerant species grow naturally in the cool, moist forest. When drought occurs, which happens frequently in all western states, these shade-tolerant species are more stressed than the shade-intolerant species. Thinning reduces the total number of trees competing for water and can relieve drought stress. However, overthinning (the removal of too many trees) may increase the amount of sunlight reaching the ground and dry out the area more rapidly. This is especially true on steep terrain.

The third requirement is a good nutrient supply. Trees take up minerals through their roots and incorporate them into developing cells. One of the basic determinants of potential tree growth is the level of nutrients available in the soil. Nutrient-poor soils will never produce large trees, and even rich soils cannot produce large trees if they are overstocked. A forest manager may thin a stand to reduce competition for nutrients. Although it is not always cost effective, using a fertilizer on forest soils can provide needed tree nutrients.

Vegetation Patterns

Northwest ecosystems contain many different vegetation patterns, ranging from brush fields to old growth forests, and including every successional stage in between. Collectively, the types, amounts, and distribution of vegetation patterns define water quantity and quality, timber resources, wildlife habitat, and many other important ecosystem characteristics. Vegetation patterns also impact forest processes such as streamflow, erosion, and succession.

Northwest forest landscapes are created and maintained through a balance of disturbance and recovery processes. Disturbance alters a portion of the current forest stand. A new forest grows, declines, and is again replaced. Ultimately, all living biomass is recycled. Disturbance and restoration processes create a sustainable cycle that conserves both biological capacity and options for future forests. Disturbance requirements within ecosystems vary greatly in intensity and frequency. The most common forms of disturbance that have influenced Northwest forest ecosystems in the past are fire, wind, ice, insects, and disease. We have altered historical forest ecosystems by creating unnatural disturbances, such as excessive logging, urbanization, and overgrazing, while suppressing fire. Consequently, these forests have different fire, insect, disease, and hydrologic disturbance cycles and processes. Fires in some areas are larger and more severe than in the past. Insect attacks last longer and spread wider. Sites favorable for tree disease are expanding. Vegetation cover in riparian areas has been diminished and stream structure has grown less complex, reducing fisheries habitat.

Human-caused disturbances can be used in management to proactively mimic natural disturbances (anthropogenic or human disturbances such as fires set by Native Americans have been a part of many landscapes for centuries) and to help with restoration activities.

Vegetation Development

Vegetation development refers to the processes of change that occur in forest stands and landscapes over time. In the absence of past disturbances, changes in the species composition of a forest are slow but continuous. The process of continual change is referred to as succession. Forest management is based on the fact that the *direction* of forest succession is both predictable and controllable. "Direction" refers to the gradual order of species replacement from intolerant to tolerant—or the scaling back of succession as a result of natural disturbances or silvicultural manipulation. If forest succession progresses to a more-or-less stable vegetative state over time, we define this vegetative association as a Habitat Type. Thus, Habitat Types reflect the climax vegetation in a location. Habitat Types often are defined by the dominant overstory tree species and the understory for forest floor complex. One common Habitat Type in eastern Washington is the Douglas-fir/ninebark Habitat Type.

The rate at which succession proceeds can be increased or decreased by altering the species composition and density of species in the forest. Disturbances influence rate and direction of succession, while forestry practices mimic natural disturbances. Thinning small trees in the understory mimics ground fires or natural mortality in a stand. Harvesting the dominant and co-dominant trees in a stand can have results similar to those following a windstorm that removes the overstory. (Figure 9).

A key concept to understanding why succession occurs is tolerance. Though tolerance is really the degree to which a species can successfully compete for site resources (light, moisture, and nutrients), it is most often used with respect to light and, thus, is referred to as shade tolerance (Table 1). Pioneer or early successional species such as red alder, western larch, and ponderosa pine are often extremely intolerant of shade. They are not able to grow or reproduce in shaded conditions. Mid-tolerant or intermediate species can grow in partial shade, and late-successional species are able to grow and reproduce in heavy shade. As a result, unless interrupted by disturbances that remove all or part of the canopy, forest succession usually proceeds toward more shade-tolerant species.

For example, in western Washington, Douglas-fir, western hemlock, and western redcedar occur together in many forest stands. Of the three, Douglas-fir is the least tolerant of shade and will almost always be found only in the overstory. Western hemlock and western redcedar, both very tolerant of shade, can exist in either the overstory or in the understory. As overstory trees die, cedars and hemlocks in the understory will grow into the overstory. If many centuries pass without fires or logging, the stand will increasingly be composed of western redcedar and western hemlock. In eastern Washington, western larch is a very shade-intolerant species that grows rapidly and may quickly dominate

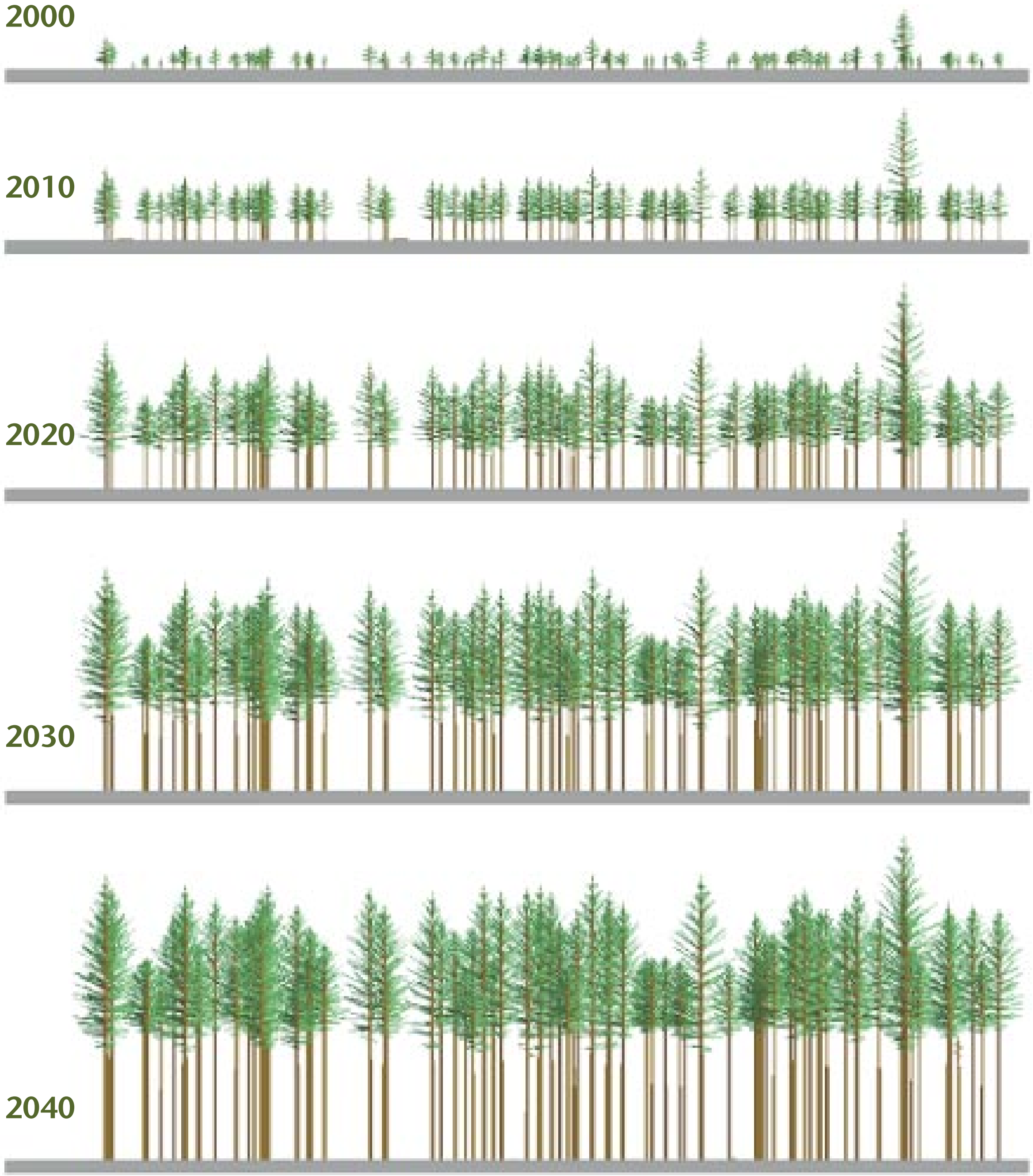


Figure 9. Forest Succession is the Gradual Change in the Species of a Forest Stand over Time.

Table 1. Shade Tolerance of Commercially Important Conifers in Washington

Extremely Tolerant	Tolerant	Intermediate Tolerance	Intolerant	Extremely Intolerant
Western Hemlock Western Redcedar Pacific Silver Fir Alaska Yellow Cedar Mountain Hemlock	Grand Fir Subalpine Fir Engelmann Spruce	Inland Douglas-fir Western White Pine	Coastal Douglas-fir Noble Fir Ponderosa Pine Sitka Spruce	Lodgepole Pine Western Larch

some forest stands following fires. More shade-tolerant species such as grand fir or subalpine fir are able to grow beneath the larch; however, because of its intolerance for shade, larch only appears in the overstory.

Two additional concepts provide a framework for understanding vegetation development patterns. These concepts are growing space and disturbance. Growing space refers to the availability of all the requirements a plant needs to grow. The most important requirements—or growth factors—are light (for photosynthesis), water, and nutrients. Each tree in a forest uses these growth factors until one or more becomes unavailable. When that occurs, the growing space is essentially filled. No new plants can establish, and the ones already there must compete with each other to gain more growing space. Plants that compete the best get more growing space and continue to grow. The losers often die. This competition ultimately causes forest succession.

The amount of growing space varies in time and in space. Light is most generally abundant for trees in the upper canopy but may be extremely limited at the forest floor. Sometimes light reduction at the forest floor can be as much as 97% of that in open conditions! Some species are able to tolerate growing conditions (such as low light levels) that are not adequate for other species. Differences among species are not great, but can give some species a competitive advantage on a particular site. For instance, ponderosa pine needs more light to grow than does Douglas-fir. In the understory, Douglas-fir seedlings have a competitive advantage over ponderosa pine. Growing space also can change over time. In much of the Pacific Northwest, moisture is limited during the dry summer months but seldom during the fall, winter, and spring. As a young stand matures, some nutrients may become tied up within the vegetation, limiting further growth, especially on coarse-textured soils.

Each tree species has a unique collection of silvical characteristics, or how the individual tree interacts with the environment. These characteristics are summarized for young trees growing in both eastern and western Washington in Tables 2 and 3.

Role of Disturbance

Disturbances play an important role in determining forest structure and species composition. Natural disturbances are quite common in all regions of the world. Every area has characteristic types of disturbances that occur at relatively predictable frequencies. Coastal Washington is subject to periodic windstorms or “blows” that knock down overstory trees, allowing seedlings in the understory to grow. On the western slopes of the Cascades, large, infrequent fires have provided conditions favorable for Douglas-fir to germinate and grow. East of the crest, many areas had historic fire regimes consisting of frequent, low intensity ground fires that killed competing seedlings, but spared, or only scarred, thick-

Table 2. Eastern Washington Species Characterization—A Summary for Young Trees*

	Western Larch	Western White Pine	Douglas-fir	Grand Fir	Western Hemlock	Western Redcedar	Engelmann Spruce	Lodgepole Pine	Black Cottonwood	Subalpine Fir	Ponderosa Pine
Where is Species Found?											
Hot—Dry Environment	No	No	Maybe	No	No	No	No	No	No	No	Yes
Cool—Wet Environment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	No
Cold—Wet Environment	Yes	Maybe	No	Maybe	Maybe	Yes	Yes	Yes	No	Yes	No
Cold—Dry Environment	No	No	No	No	No	No	No	Yes	No	Yes	No
What species to Plant?											
Ponderosa Pine Habitats	No	No	No	No	No	No	No	No	No	No	Yes
Douglas-fir Habitats	Yes	No	Yes	No	No	No	No	Maybe	Maybe	No	Yes
Grand Fir Habitats	Yes	Yes	Yes	Maybe	No	No	Maybe	Yes	Maybe	No	Yes
Western Redcedar Habitats	Yes	Yes	Yes	Yes	Maybe	Yes	Yes	Yes	Yes	No	Yes
Western Hemlock Habitats	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	No	No
High Elevation Habitats	Yes	Maybe	No	No	No	No	Yes	Yes	No	Yes	No
Frost Pocket Habitats	Yes	Yes	No	No	No	No	Yes	Yes	No	Yes	No
Riparian Habitats	Maybe	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Maybe	Maybe
Time of Year to Plant	Spring or Fall	Spring	Spring	Spring or Fall	?	Spring	Spring or Fall	Spring or Fall	Spring	Fall	Spring
What is Expected?											
Early Survival	Fair	Excellent	Good	Fair	Fair	Good	Good	Excellent	Good	Good	Good
Early Growth	Excellent	Excellent	Fair	Fair	Fair	Poor	Fair	Excellent	Excellent	Fair	Good
Is Genetically Improved Stock Available?	?	Yes	Yes	Yes	?	?	?	No	Yes**	No	Yes
Species Characteristics											
Shade Tolerance	Very Low	Medium	Medium	High	Very High	High	High	Low	Low	High	Low
Wet Ground Tolerance	Fair	Fair	Poor	Fair	Medium	High	Fair	Medium	Very High	Low	Poor
Tolerates Rocky or Sandy Soils	Poor	Poor	Medium	Medium	Medium	Poor	Medium	High	Low	High	High
Rebounds from Physical Damage	Poor	Poor	Medium	Medium	Poor	High	Medium	High	Poor	Poor	High
Vulnerable to											
Weed Competition	Maybe	Maybe	Yes	Yes	Yes	Yes	Maybe	Maybe	Maybe	Medium	Yes
Snow Breakage	No	No	Maybe	Maybe	No	No	Maybe	No	Yes	No	Maybe
Drought	No	Yes	Maybe	Maybe	Yes	Yes	Yes	No	Yes	Maybe	No
Heat	No	Maybe	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No
Late Spring Frost	Maybe	Maybe	Yes	Yes	Maybe	No	No	No	Yes	No	No
Animal Damage	Yes	Yes	Yes	Yes	Maybe	Low	Low	Yes	Yes	No	Yes
Grazing (eaten)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	No	Maybe
Root Diseases	Yes	Yes	Maybe	Yes	Yes	No	Maybe	No	Immune	Yes	No
Stem Diseases	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Insects	Yes	No	Yes	Yes	Yes	No	Maybe	Maybe	Yes	Yes	Maybe
Yearly Frequency of Good Seed Crops	4–8	5+	3–6	3–6	3–6	2–4	4–8	3–5	1	3–6	4–8

* Adapted by Don Hanley from numerous sources and personal experience. Use as a general guide only.

** Do not use hybrids in native ecosystems.

Table 3. Western Washington Species Characterization—A Summary for Young Trees*

	Western White Pine	Douglas-fir	Grand Fir	Western Hemlock	Western Redcedar	Sitka Spruce	Red Alder	Noble Fir
Where is Species Found?								
Hot—Dry Environment	Maybe	Yes	No	No	No	No	No	No
Cool—Wet Environment	Yes	Maybe	Yes	Yes	Yes	Yes	Yes	Yes
Cold—Wet Environment	Maybe	No	No	Yes	Yes	No	No	Yes
What species to Plant?								
Douglas-fir Habitats	Yes	Yes	Yes	Yes	Yes	No	Yes	Maybe
Grand Fir Habitats	Yes	No	Yes	Yes	No	No	Yes	Yes
Western Redcedar Habitats	No	Yes	Maybe	Yes	Yes	Maybe	Yes	No
Western Hemlock Habitats	No	No	No	Yes	Yes	Maybe	Yes	No
High Elevation Habitats	Maybe	No	No	No	No	No	No	Yes
Coastal Habitats	Maybe	No	No	Yes	Yes	Yes	Yes	No
Time of Year to Plant	Fall or Winter	Fall or Winter	Fall or Winter	Fall or Winter	Fall or Winter	Fall or Winter	Fall or Winter	Fall or Winter
What is Expected?								
Early Survival	Excellent	Excellent	Fair	Fair	Fair	Fair	Good	Fair
Early Growth	Excellent	Excellent	Fair	Fair	Fair	Good	Good	Fair
Is Genetically Improved Stock Available?	Yes	Yes	?	?	?	?	No	?
Species Characteristics								
Shade Tolerance	Medium	Low	High	Very High	High	Low	Very Low	Low
Wet Ground Tolerance	Fair-Low	Poor	Fair	Medium	High	High	High	Medium
Tolerates Rocky or Sandy Soils	Medium	Medium	Medium	Poor	Poor	Poor	Poor	Medium
Rebounds from Physical Damage	Poor	Poor	Poor	Poor	High	Medium	Poor	Poor
Vulnerable to								
Weed Competition	Maybe	Yes	Yes	Yes	Yes	Maybe	Low	Yes
Snow Breakage	No	Maybe	Maybe	No	No	Maybe	High	No
Drought	Maybe	Yes	Maybe	Yes	Yes	Yes	High	Yes
Heat	Maybe	Maybe	Yes	Yes	Yes	Yes	High	Yes
Animal Damage	Yes	Maybe	Yes	Maybe	No	No	High	Yes
Grazing (eaten)	No	Yes	Yes	Yes	Yes	No	Low	Yes
Root Diseases	Yes	Yes	Yes	Yes	No	Maybe	Immune	Yes
Stem Diseases	Yes	Maybe	Yes	Yes	Yes	Yes	Yes	Yes
Insects	No	Yes	No	No	No	Yes	Low	No
Yearly Frequency of Good Seed Crops	5+	5–7	3–6	3–6	2–4	4–8	1	4–8

* Adapted by Don Hanley from numerous sources and personal experience. Use as a general guide only.

barked mature ponderosa pine or western larch. Lodgepole pine stands often had a life cycle featuring outbreaks of mountain pine beetles followed by catastrophic fires that perpetuated the species. Insects and diseases killed some trees, creating snags and logs that provided important habitat for wildlife. The type of wildlife using these structures depended on the disturbance that created them. For instance, stem decay fungi often produced soft snags useful for cavity nesting birds and animals. Douglas-fir mistletoe creates large witches-brooms used as nesting and hiding sites for some birds. But the brooms also can allow wildfires to move from the ground into the crowns of infested trees.

To create sustainable forest ecosystems, conserving disturbance processes is as important as conserving individual species. Timber harvests and prescribed fires can mimic many effects of wildfire and other disturbances. However, we need to balance such natural disturbances with needs for wildlife, aquatic resources, and sustainable commodity production. Ultimately, these goals may depend on sustaining the broader ecosystem through managed disturbance.

Disturbances change the availability of growing space. Disturbances that remove the overstory—for example windstorms or timber harvesting—change the amount of light that reaches the forest floor. Disturbances that remove organic matter and soil—some fires, landslides, and site preparation techniques—reduce the amount of nutrients and, thus, the total amount of growing space on a particular site. Disturbances that remove most of the vegetation on a site increase the amount of light, moisture, and nutrients available for new plants to utilize.

Following a disturbance, surviving plants and new ones expand into the now-available new growing space. The plants that grow the fastest and capture the most growing space can dominate the stand for decades; such is the role of red alder on the west side of the Cascades. Trees in the open grow more quickly than those in the understory. In managed stands, thinning and harvesting can control the amount of light available to trees. Removing part of the stand allows more available light for the remaining trees. In a young stand, it may be only a matter of a few years before the crowns of residual trees grow into the spaces left by those removed.

Dynamic Processes and Stand Development

Forests are dynamic. Changing vegetation patterns caused by disturbance or succession alter forest benefits and values. Ecosystem management anticipates and plans for change rather than simply responding to undesirable events.

Understanding succession is an important criterion when actively managing forests to create desired future conditions. Nature will continue to provide disturbances. Insight into potential vegetation patterns across adjoining land should help landowners, managers, and other ecosystem management cooperators plan how to better interact for their own needs.

Not all disturbances are stand replacing. Vegetation responses can be described by categorizing disturbances according to low, moderate, or high severity. Forest ecologists define high severity disturbances as those killing 70% or more of the trees in a stand. Moderate severity disturbances kill between 20% and 70% of the stand, and low severity disturbances kill less than 20%.

Succession depends on both the severity and type of disturbance. After a high severity fire, pioneer species such as grasses, forbs, brush, and tree species such as western larch and lodgepole pine, are usually favored. After a high severity windstorm, shade-tolerant advanced regeneration, such as western hemlock or western redcedar, is more likely to be favored.

Moderate severity disturbances favor disturbance-tolerant species. For example, in eastern Washington, moderate severity fires in stands containing a mixture of lodgepole pine, western larch, and grand fir will favor thick-barked, fire-tolerant western larch. The other two species have thin bark and usually are killed by moderately severe fires. The result of moderate severity disturbances often is a stand in which two or three age classes (cohorts) are represented. The oldest trees were able to survive the disturbances. Trees killed by the disturbances freed resources for the surviving trees and allowed new trees to establish.

Low severity disturbances kill individual trees or small groups of trees. Ground fires, small pockets of root rot, and small-scale insect attacks are examples of low severity disturbances. A classic example of the effects of periodic low severity disturbances are ponderosa pine forests subject to frequent, low severity fires, and small-scale outbreaks of western bark beetles. These low severity disturbances maintain open, parklike stands of pine.

Forest Development Phases

Following stand-replacing or catastrophic disturbances, forest development can be defined by four phases:[1] 1) Stand initiation or "*open*," 2) Stem exclusion or "*dense*," 3) Understory reinitiation or "*understory*," and (4) Old-growth or "*complex*." Each phase is characterized by different structures, providing different wildlife habitats and forest products (Figure 10).

While these four phases are useful to understand stand development over time, there are no absolute boundaries between them. Residual trees and shrubs are not often completely killed, resulting in "islands" of an older successional stage. "Legacy areas" act as "refugia" for later successional dependent plants and animals. As the new forest matures, these plants and animals are able to colonize that new forest area. These legacies often provide significant biological diversity to the forest site over time and provide wildlife habitats that differ from the adjacent areas by providing more vertical structural diversity. This can be very important to wildlife, especially birds. It was once thought that all forests developed from seral stages to stable old-growth stages in a predictable fashion. We now know that site conditions change over time, influencing the rate and direction of forest development.

[1] Defined by Professor C.D. Oliver, Yale University.

Stand Initiation or "Open" Phase

Death or removal of most trees from a site, whether by wind, fire, logging, or some other disturbance, greatly changes the environment at the forest floor. More sunlight reaches the ground, so temperature increases. Grasses, forbs, and shrubs are the dominant vegetation. Decomposition increases the availability of many nutrients that were bound up in living vegetation. Available water also may increase since trees are no longer taking it up from the soil and transpiring it through the leaves.

The soil and forest floor are very important. Energy and nutrients stored in the forest floor are released as the ecosystem adjusts from the disturbance. New plants grow, capturing and cycling the nutrients. The stand initiation phase ends when trees, shrubs, and other plants capture all the available growing space on a site. The many species of plants that grow on the site during the stand initiation phase include not only trees but shrubs, grasses, and other herbaceous plants. The diversity of plant life encourages a great diversity of animal species. The many flowering and fruiting plants near the ground provide habitats for a wide range of animals—from butterflies to bears. Shrubs and herbaceous plants provide browse for deer, elk, and rabbits. These animals provide food for cougars and bears. Seed-eating and insect-eating birds forage in these open areas. Some of the plant and animal species found in this phase are generalists; that is, species adapted to a wide range of conditions. Others, such as butterflies, are specialists and cannot survive in other conditions.

The coastal Douglas-fir forests owe their existence, in part, to severe fires that infrequently burned west of the Cascades. The large size of some of these fires would have made it difficult for the seed of trees and shrubs in adjacent stands to rapidly colonize the interiors of the burned areas. The stand initiation phase probably lasted for many decades before trees filled all the available growing space. An exception to this generalization occurs when red alder seed is available. Red alder has the ability to disperse seed great distances and colonize disturbed sites rapidly. Stand development following the eruption of Mount St. Helens is a good example of red alder's colonization ability.

Stem Exclusion or "Dense" Phase

When the trees on a site have captured most of the available growing space, their crowns touch. This point, called crown closure, marks the end of rapid and successful establishment of new shade-intolerant trees in the stand. Trees must compete with other trees for limited sunlight, water, and nutrients to survive, so they must grow larger than their neighbors. Larger trees or those having a competitive advantage are able to grow into the space occupied by less competitive individuals and reduce their growth rate or even kill them. The process by which dominant trees maintain their dominance is by out-competing their neighbors for site resources. This process results in crown differentiation. The trees that compete most successfully develop large crowns above the general level of the canopy. These trees are the dominants. Trees a little smaller, but still having large crowns, are the codominants. Intermediate trees have crowns quite crowded on all sides, and suppressed trees have crowns that fall below the general level of the canopy.

During the stem exclusion phase, the stand begins to accumulate both living and dead matter. The trees in the stand have captured the available growing space, so nutrients are not readily washed out of the ecosystem. Smaller, weaker trees continue to die during

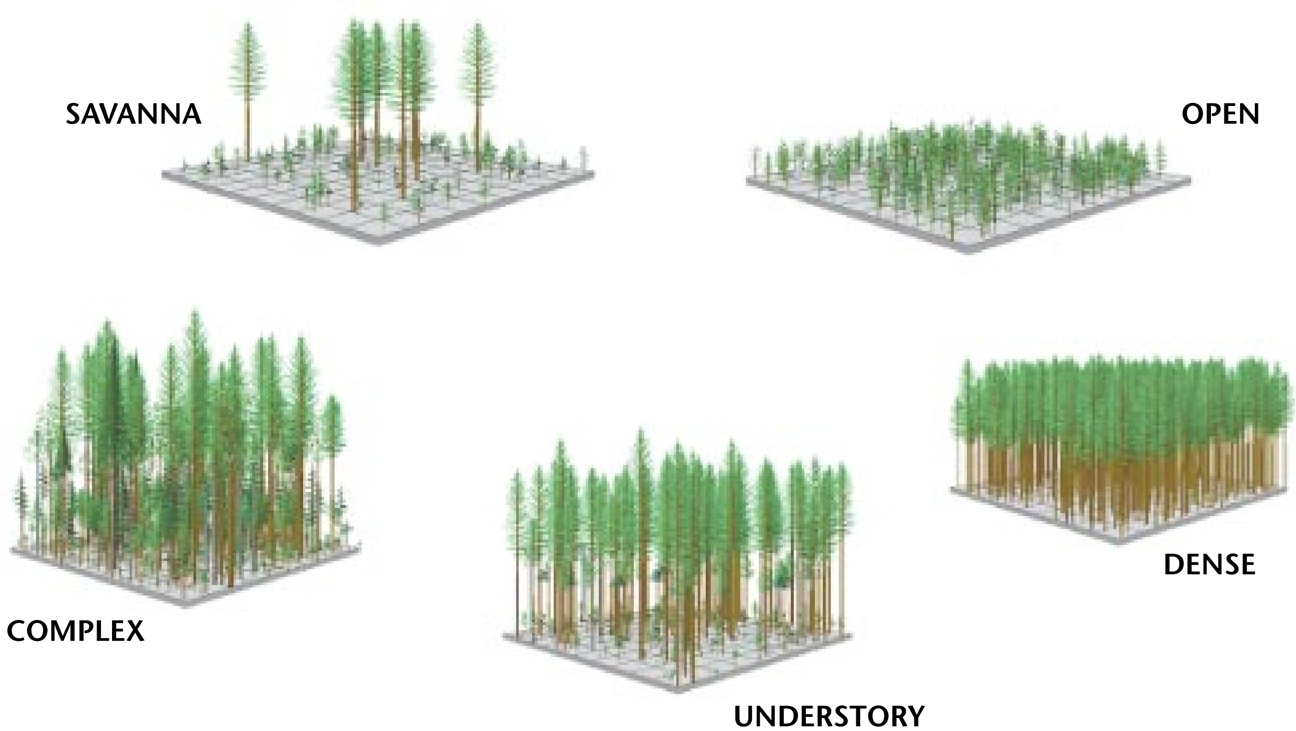


Figure 10. Stand Development Phases as Defined by C.D. Oliver are Useful to Describe Stand Development.

this phase, while surviving trees grow taller and increase in diameter. In western Washington, the overstory casts a deep shade on the forest floor, and little or no vegetation may grow there. In parts of eastern Washington, moisture is more limiting than light. Stands may appear open, but beneath the surface, roots utilize all available growing space. During this phase, intense competition between trees often reduces the amount of shrubs and other plants in the ecosystem. Plant and animal diversity is frequently quite low. However, snowshoe hares and lynx frequently use dense, pole-sized stands of lodgepole pine and subalpine fir for hiding and to avoid intense heat and cold, while eating plants and prey in nearby stand initiation areas. Many managed forests are harvested sometime during the stem exclusion phase and, consequently, the last two phases of vegetation development are rarely achieved in traditional management of forests.

If trees are able to establish in a stand reproduced over a period of many decades, they will vary in size and ability to compete for growing space. If little difference exists in tree size and age, there may not be clear winners and losers in the competition for growing space. As a result, the stand may stagnate, with all trees developing small crowns. The size of the tree crowns will greatly influence the amount of energy produced in photosynthesis. Trees first allocate their energy to growing taller. If taller trees grow larger crowns, they capture more sunlight energy and grow large in diameter. In a stagnated stand, many trees continue to grow uniformly taller, so their crowns become small. Consequently, they grow slowly in diameter. Eventually, the trees become so tall and thin that they fall over. This occasionally happens in natural stands of lodgepole pine and also has occurred in managed plantations—especially during wind or snow storms. When trees are tall and thin, they also are vulnerable to insect attacks, and so become infested, die, and create fire hazards.

Understory Reinitiation Phase

This phase marks the *beginning of the end* for the original trees that established following a major disturbance. Weather related disturbances such as wind and ice storms often start the reinitiation phase by killing or breaking up less dominant overstory trees, allowing some light to reach the forest floor. Shade-tolerant plants, including shrubs and trees, are able to establish, survive, and grow in the partial sunlight reaching the understory. Given little sunlight, these trees do not grow very tall. When a tree in the overstory dies and falls, it often leaves a large opening having more sunlight. A new age class of trees often establishes in the opening, and these trees grow more rapidly upward. During this phase, plant and animal diversity again increases with the addition of new age classes and structures, such as multiple canopy layers, snags, logs, and trees with forked or broken tops. Birds and animals that use large snags or broken-topped trees for nesting often thrive in the understory reinitiation and old growth phases of stand development. Several species of woodpeckers, including the pileated; Vaux's swifts, northern goshawks, spotted owls, marbled murrelets, flying squirrels, pine martens, lynx, fisher, and wolverines choose these stages. Many beneficial insects such as carpenter ants need snags and down logs also. Deer and elk find winter shelter in these multi-canopied forests. In the extreme northeastern part of Washington, woodland caribou are associated with stands in the understory reinitiation phase. Many of the birds and animals are habitat specialists that prefer older forests where overstory trees are beginning to die and multiple canopy layers are starting to form. Unlike generalist species that can adapt to a wide range of conditions, these specialists require specific forest structures or compositions. For instance, Vaux's swifts use snags hollow at the top since they enter these snags from above. Marbled murrelets build their nests in living old trees whose gnarled broken tops provide suitable nesting platforms.

Many forests, such as Douglas-fir and western larch, on the west and east sides of the Cascades, respectively, are referred to as old-growth. However, they are actually in the understory reinitiation phase, since the Douglas-fir trees established following fire still make up a large proportion of the overstory. Stands in the stem exclusion phase can be manipulated silviculturally to bring about the understory reinitiation phase sooner than in unmanaged stands. (Figure 10).

Old-Growth or "Complex" Phase

In many forests, some sort of disturbance generally resets the biological clock before the old-growth phase of forest development is achieved. In a true old-growth forest, the multi-aged stand is composed of trees that established beneath the original overstory and eventually replaced it. Many plants and animals found in these forests are specialists. An interesting question is "how old does a forest have to be before it functions as old-growth"? Scientists are interested in finding if plants and animals believed to require old forest habitat can successfully live and reproduce in younger stands if they have some of the structures and compositions usually occurring only in older forests. These old growth complexes are also commonly known as habitat types.

Natural and Human-Caused Disturbances Alter Development Phases

The stand development theory described above is under further study by ecologists and silviculturists, who now think, given periodic disturbances (fire, wind, floods, insect infestations, clearcut or partial cut logging), stand structures are much more dynamic as described in Figures 11 and 12. Both natural and human-caused disturbances create a mosaic of diversity across the landscape as described below.

Forests and Trees in Washington

Washington has diverse forest types, from coastal forests where western redcedar, Douglas-fir, western hemlock, and Sitka spruce dominate, to inland forests of ponderosa, lodgepole and western white pine, Douglas-fir, and western larch. Descriptions of some of the major forest types occurring within the state follow:

West Side Forest Types

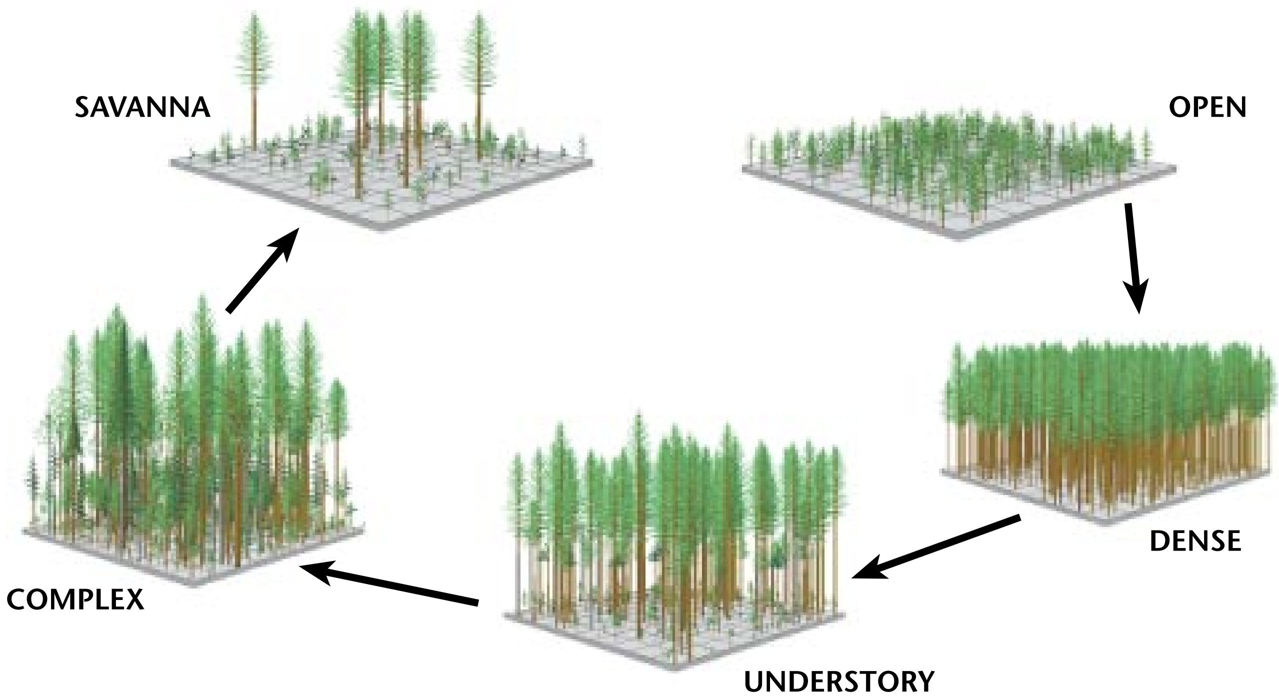
Coastal Douglas-fir

Coastal Douglas-fir forests are among the most productive forests in the world. These stands are composed of at least 80% Douglas-fir and lesser amounts of other species, including western hemlock, grand fir, Pacific silver fir, noble fir, western redcedar, Sitka spruce, red alder, bigleaf maple, and Pacific madrone. Forests of this type are widespread west of the Cascade Range at elevations from sea level to approximately 1,500 feet. Douglas-fir forests regenerate naturally following fire with seed provided by scattered surviving trees. Planting following harvest also regenerates Douglas-fir forests. Mature stands may remain healthy for decades. When death of some of these trees creates gaps in the canopy, shade-tolerant species such as western hemlock, western redcedar, and grand fir become established. Unless another disturbance renews the cycle, these shade-tolerant species will eventually take over the site. Most coastal Douglas-fir forests are essentially even-aged; not until many centuries pass and shade-tolerant species become established do these forests become more diverse in age class structure.

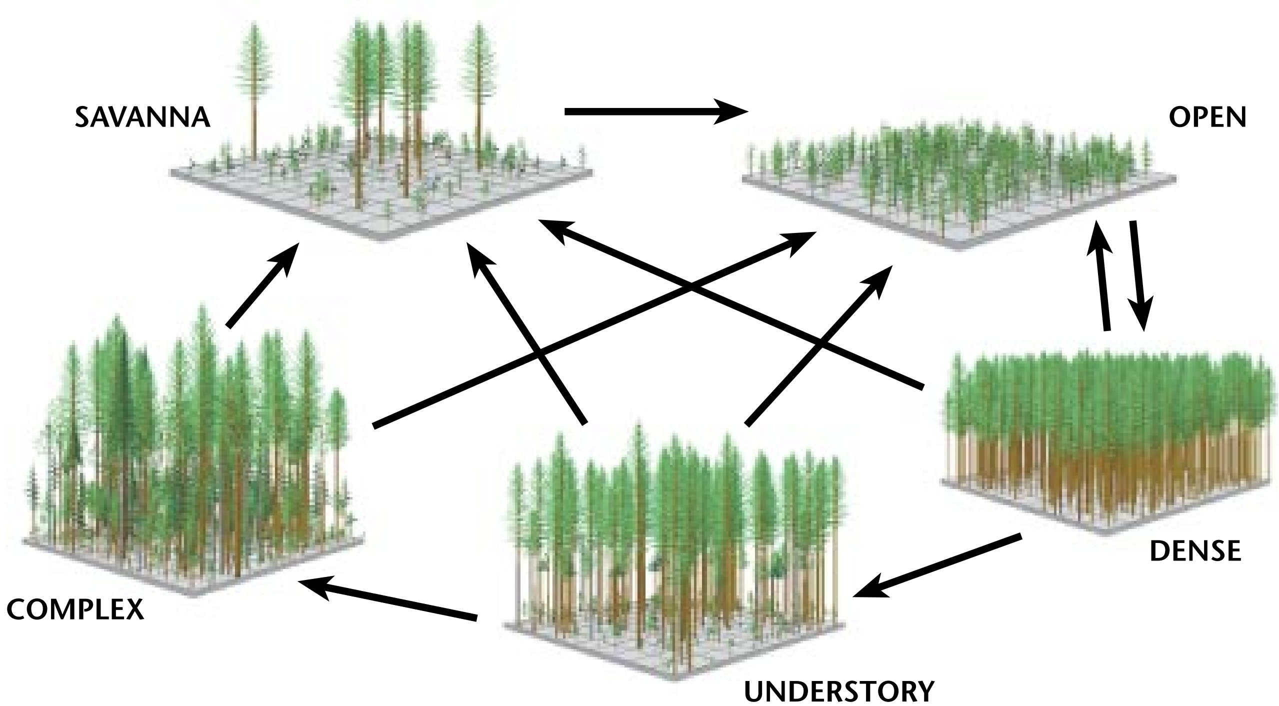
Douglas-fir/Western Hemlock

These forests are similar to coastal Douglas-fir forests except that together, Douglas-fir and western hemlock make up 80% of the

Traditional Stand Development Theory:
Forests grow into stable “old-growth” over time



Modern Stand Development Theory:
Forests are dynamic and change by growth and disturbance resulting in many structures.



Figures 11 & 12. Both natural and human-caused disturbances create a mosaic of diversity across the landscape.

species. These are mixed species stands. Douglas-fir is usually the most common species but on less fertile or very moist sites, hemlock may dominate. The most common associated species is western redcedar. Other associated species include grand fir and western white pine. At low elevations, Sitka spruce is often present. Noble fir may be present at higher elevations in the Cascades. This forest type thrives in mild, humid climates. Following fire, these mixed stands may convert to nearly pure stands of red alder. Hemlock often seeds in, recreating the mixed species type. Sometimes hemlock forms a substantial portion of the main canopy. When stressed by high temperatures or low soil moisture, hemlock remains in the understory as other species grow over the hemlock to form the overstory.

Red Alder

These forests occur west of the Cascades, usually as pure stands. Stands of red alder typically grow below 1500-foot elevation, in riparian areas, in moist coves, or in early stages of succession following soil disturbance. Elsewhere in western Washington, red alder grows mixed with other short-lived hardwoods such as bigleaf maple, black cottonwood, and Pacific willow; or with conifers, including Douglas-fir, Sitka spruce, western hemlock, western redcedar, and grand fir. Forests dominated by red alder are always even-aged. Because red alder is very shade intolerant, only dominant or codominant trees survive. Starting at an early age, red alder produces abundant annual seed. This gives it a competitive advantage over most conifers. Since red alder has no serious insect or disease problems, it will grow readily on many sites infected by conifer root-rots. Red alder improves soil fertility through nitrogen fixing and produces large quantities of litter that decompose rapidly, adding nutrients and organic matter to forest soils. Shrubs are generally an important component of red alder forests. Common shrubs associated with red alder include Pacific red elder, blueberry elder, salmonberry, thimbleberry, and devils club.

Sitka Spruce

Sitka spruce occurs primarily along the Pacific Coast. It is a shade-intolerant species unlike other spruce species found in the west. It often forms pure stands within 3 to 4 miles of salt water. The white pine weevil (*Pissodes strobi*), a native insect, often limits Sitka spruce range. On better sites Sitka spruce often grows with western redcedar and western hemlock. Red alder occurs where light reaches the forest floor.

East Side Forest Types

Inland Douglas-fir

In some parts of eastern Washington, inland Douglas-fir forests consist of pure or nearly pure stands of Douglas-fir, but this species occurs primarily in various combinations with grand fir, subalpine fir, western larch, lodgepole pine, ponderosa pine, and western white pine. Douglas-fir generally occurs as an overstory species on moist sites with more shade-tolerant grand fir and western hemlock in the understory in northeastern Washington. On drier sites, ponderosa pine may dominate, relegating Douglas-fir to an understory position, especially in younger stands. Several insects and pathogens can seriously affect inland Douglas-fir forests. Dwarf mistletoes affect nearly all species growing in inland Douglas-fir forest types and can reduce growth and kill severely infested trees. The “witches brooms” caused by mistletoe infestations are highly flammable and may cause ground fires to climb into the crowns of infested trees. Outbreaks of bark beetles, triggered by wind, ice, or other physical damage, or sometimes root diseases, kill mature and old individuals. Defoliation by western spruce budworm and Douglas-fir tussock moth may retard growth, damage tree form, reduce seed production, and even kill trees. These two insects preferentially feed on shade-tolerant species, such as grand fir, and are especially damaging in stands with more than one canopy layer.

Grand Fir/Western Hemlock

Forests in which grand fir makes up a significant portion of the stands, occur as the Douglas-fir forests age and grand fir replaces the Douglas-fir. Grand fir associates primarily with ponderosa pine, inland Douglas-fir, western hemlock, western redcedar, western white pine, lodgepole pine, and western larch. Grand fir forests are common in northeastern Washington, in the Blue Mountains of southeastern Washington, and on the eastern slopes of the Cascades. Decades of fire suppression and poorly done "selective logging" have allowed grand fir forests to occupy areas previously dominated by ponderosa pine and western larch. Grand fir is extremely susceptible to root and stem rots, especially following logging damage or other injury. Indian paint fungus (*Echinodontium tinctorium*) is the most common stem and root disease in grand fir. *Annosus* root and butt rot, caused by the fungus *Heterobasidion annosum* (formerly *Fomes annosus*), commonly enters through freshly cut stumps, wounds, fire scars, and dead or broken tops. The fungus can spread from one tree to another by root contact. Grand fir is also highly susceptible to *armillaria* root disease caused by the *Armillaria ostoyae* fungus. Grand fir is a preferred food of several defoliating insects including the western spruce budworm. Because of its vulnerability to these diseases and insects, harvest grand fir whenever possible in selective logging.

Western Larch

Western larch forests rarely occur as pure stands in Washington. Larch, a deciduous conifer, usually occurs in various combinations with Douglas-fir, grand fir, ponderosa pine, lodgepole pine, western white pine, and subalpine fir. Western larches most frequently occur in northeastern Washington with Douglas-fir as the most common associate. Western larch also grows in the eastern Cascades and in the Okanogan Highlands, where it associates with grand fir and lodgepole pine. Western larch is the most shade-intolerant conifer in the inland northwest. Historically, its presence on the landscape was maintained by stand replacement wildfires. In the absence of intense fires or logging, more shade-tolerant conifers replace western larch: Douglas-fir on drier sites, grand fir on warm, moist sites, and subalpine fir on cool, moist sites. Infestations of dwarf mistletoe (*Arceuthobium laricis*) and the larch casebearer (*Coleophora laricella*) can seriously reduce western larch growth. Western larch is very fire resistant due to its thick bark.

Lodgepole Pine

Lodgepole pine forests frequently occur as pure stands in Washington State. Lodgepole pine has one of the broadest ranges of temperature and moisture tolerances of any conifer. Most natural stands of lodgepole pine develop after catastrophic fires or reseed on frost-prone locations after a killing frost or clear-cut logging. Repeated fires aid perpetuation of this forest type. In the absence of disturbances, lodgepole pine forests may convert to interior Douglas-fir on warm dry sites, or to grand fir, western redcedar, or western hemlock on warm, moist sites. At higher elevations, subalpine fir and Engelmann spruce replace lodgepole pine. Lodgepole pine older than 100 years becomes increasingly susceptible to outbreaks of mountain pine beetle (*Dendroctonus ponderosae*), which can hasten forest conversion to more shade-tolerant conifer species. Historically, mortality from beetle outbreaks created fuel loads that predisposed these stands to catastrophic fires.

Ponderosa Pine

This forest type covers extensive areas of the West. This type may consist of pure stands or mixed species stands that also include some combination of Douglas-fir, grand fir, lodgepole pine, or western larch. As a result of fire suppression, some formerly pure stands of ponderosa pine are developing understories of Douglas-fir and grand fir. The mountain pine beetle threatens unthinned stands of pole-size trees, especially on poor sites. Western pine beetle plays a lesser role because many of the large, old trees that are the primary target have been felled. Dwarf mistletoe can become a problem, especially when two or more canopy layers exist.

Forest Ecology Glossary[2]

Abiotic
Nonliving components of the environment such as air, rocks, soil particles, and plant litter.

Adaptive management
A process for ecosystem management that allows for continual change as more information becomes available on resource conditions and the effects of management actions on resources.

Age class
All trees in a stand within a given age interval, usually 10 or 20 years.

Age structure
The number and ratio of age classes within a stand.

Anadromous
Migratory behavior of fish, such as salmon, that mature in the sea but return to fresh water to spawn.

Annual growth
The yearly increase in wood volume, usually expressed in terms of board feet or cubic feet per acre.

Annual ring
Bands, which show tree growth for one year, as viewed on the cross section of a stem, branch, or root, or on a trunk core sample. Can be counted to determine a tree's age. Variation in width of rings records how the tree responded to growing conditions in different years.

Aquatic ecosystem
A water-based system of living organisms interacting with their environment.

[2]Adapted from *Terminology for Forest Landowners*, WSU Cooperative Extension, EB1353.

Aquifer
A stratum of earth or permeable rock that stores significant quantities of water. A confined aquifer is sealed above and underlain below by impermeable material.

Aspect
The compass direction that a slope faces.

Autecology
Ecology dealing with biological relations between a species or individual organism and its environment.

Bacteria
One-celled (or single-celled) organisms that live in soil and water.

Basal area
A key descriptive measure of trees and stands. For a tree, it is the cross-sectional area of the trunk at breast height (4.5 feet above ground). The basal area of a tree 14 inches in diameter at breast height (DBH) is approximately 1 square foot. Basal area per acre is the sum of basal areas of the individual trees on an acre. A stand of 100 14-inch DBH trees would contain about 100 square feet of basal area per acre.

Biological control
Controlling plants, diseases, and animal pests by the use of natural enemies; or inhibiting the reproduction of pests by methods that result in the laying of infertile eggs.

Biological diversity
Richness and abundance of species and variety of natural communities in a forest environment. Both the number of species and the number of individuals of each species are important in considering the extent of biological diversity in an area. Also referred to as biodiversity.

Biological properties
In soils, this refers to the living organisms in the soils that assist with decomposition and nutrient cycling (bacteria, insects, and fungi).

Biomass
The total quantity (weight) of biological matter in a unit area, including all living organisms above and below ground; or the total quantity of one or more species in a unit area. Tree biomass components include wood, bark, foliage, and roots, of a single tree or of all the trees in a specified area.

Biota
The plants and animals of a given region or period, considered collectively.

Biotic
Having to do with the living components of an ecosystem.

Bole
The main tree trunk.

Breast height
Four and one-half (4.5) feet above the ground on the uphill side. Diameter is usually measured and basal area calculated at this point on the tree.

Brush
Commonly refers to undesirable shrubs and small trees.

Buffer
A protective strip of land or timber adjacent to an area requiring attention or protection. For example, a protective strip of unharvested timber along a stream.

Cambium
The growing layer of cells beneath the bark of a tree.

Candidate species
Plants and animals being considered for listing as federally endangered or threatened species in the United States.

Canopy
The uppermost layer in a forest, formed collectively by tree crowns.

Canopy layers
Forests with varying age classes may have several height classes. For example, an overstory canopy layer of trees may overtop a lower canopy of other trees or shrubs.

Climax community
A relatively stable plant community that has evolved through stages and has a dominant plant population suited to the environment.

Codominant trees
Trees whose crowns form the general level of the stand, receiving full light from above but comparatively little from the sides. *See also* Crown class.

Community
A natural assemblage of different organisms living and functioning together in a particular area. Usually named for the dominant plants, animals, or major physical components of the area.

Conifer
A cone-bearing tree with needles, such as pine, spruce, fir, and larch.

Connectivity
Condition of ecosystem integrity allowing natural processes to work across a landscape without discontinuity. *See also* Corridors; Fragmentation.

Conservation
The protection, improvement, and wise use of the natural environment (such as the forests, soils, and water systems) to prevent destruction and exploitation while still producing goods and services for the human population.

Conservation biology
The science of diversity, scarcity, and survival of species. Deals with active management to protect and maintain genetic variety within species. Deals also with the concept of sustainability and relationships between biotic and abiotic resources. *See also* Sustainability.

Corridors
Generally, linear strips of habitat linking isolated patches of natural habitat in the landscape. Establishment and maintenance may be actively promoted at the state and regional levels. *See also* Connectivity; Fragmentation.

Cover
Vegetation or other natural shelter serving to conceal wildlife from predators. Also refers to the protective shade vegetation provides to wildlife, fish, and the forest floor.

Critical habitat
Specific areas within the geographic range occupied by a species listed by the federal government as endangered or threatened. The physical and biological features considered necessary for the survival and recovery of the species.

Crown
The branches and foliage of a tree.

Crown class
A relative designation of tree crowns. *Dominant trees* are those whose crowns grow above the general level of the canopy. *Codominant trees* are those having crowns forming the general level of the canopy. *Intermediate trees* have crowns growing below the general level of the canopy. *Suppressed trees* are much shorter than trees in the general level of the canopy.

Crown closure
The point when, in a young stand, the crowns of the trees begin to touch each other.

Crown differentiation
The process whereby some trees grow faster and develop large, full crowns, while others fall behind in height and have smaller, sparser crowns.

Crown ratio
A measure of the length of a tree's crown relative to total tree height.

DBH
The tree diameter at breast height (4.5 feet above the ground on the uphill side).

Deciduous tree
A tree that loses its leaves or needles during the fall and winter.

Decomposition
The breaking down of dead matter by decay organisms.

Defect
That portion of a tree or log that makes it unusable for the intended product. Defects include rot, crookedness, cavities, and cracks. Severe defects cause the log to be classified as a cull.

Defoliators
Insects that feed on foliage.

Dendrology
The study of tree identification.

Desertification
The process of desert expansion caused by loss of soil and vegetative cover through climate change, overgrazing, or other influences.

Diameter tape
A measuring tape used to directly determine tree diameter when stretched around the circumference of the tree stem.

Dieback
Any condition where portions of a tree's crown die due to conditions other than shading.

Disturbance
A natural or human-caused event, such as a forest fire, disruptive wind storm, or insect infestation that alters the structure and composition of an ecosystem.

Disturbance management
Managing disturbance events and effects, such as insects and fire, to approximate natural conditions.

Dominant trees
See Crown class.

Dormancy
A biological process in which a plant ceases most growth activities and simply maintains existing tissue.

Drainage
An area of land above a given point on a waterway that contributes runoff water.

Duff
Various stages of decaying organic matter found on the soil surface.

Dysgenic selection
Removing the best trees in the stand while permitting the worst trees to occupy the site and reseed the new stand. Over time, the stand becomes filled with individuals of undesirable species or poor form.

Early-successional
The first species to occupy an area after a major disturbance, often known as "pioneers." Typically, an association of plants and animals capable of surviving and reproducing under harsh environmental conditions.

Ecological approach
A type of natural resource management that in developing management strategies considers the relationships among all organisms, including humans, and their environment.

Ecology
The science that studies the interaction of plants and animals with their environment.

Ecosystem
Ecological system. An interacting system of living organisms and their environment. The dynamic relationships of living (biotic) and nonliving (abiotic) components of a region, as well as the forces, such as weather and wildfire, that affect them.

Ecosystem health
A measure of the overall capacity of an ecosystem to maintain biological diversity, normal productivity, sustainability, and resilience to disturbance.

Ecosystem management
A long-term approach to managing a forest, using ecological principles and considering biological, physical, economic, and societal needs, while sustaining or restoring ecosystem integrity. *See also* Adaptive management.

Ecosystem structure
The horizontal and vertical distribution of living and dead vegetation.

Ecosystem sustainability
See Sustainability.

Ecotone
A transitional area between two forest or rangeland communities containing the characteristic species of each as well as characteristics of its own. A point of abrupt change, such as a prairie-forest junction or a land-water interface.

Edaphic
Of the soil or influenced by the soil rather than by climatic factors, especially pertaining to living organisms.

Edge effect
The tendency toward greater species variety and greater density of animal and plant life in the margin where two ecological communities meet. *See also* Ecotone.

Elements
Those basic substances such as carbon, calcium, nitrogen, hydrogen, and phosphorus required for tree growth. Some come from the weathering of bedrock, while others such as nitrogen come from the air. An element is the same as a nutrient.

Endangered species
A plant or animal vulnerable to extinction in all or a significant portion of its range. Identified by the Secretary of the Interior in accordance with the Endangered Species Act (1973).

Endemic population level
A normal (insect) population level.

Entomology
The study of insects and their environments. *See also* Forest entomology.

Environment
The external conditions, both physical and biological in which an organism lives. Includes climate, soil, topography, food supply, and all other influences affecting development.

Ephemeral stream
A stream that flows only sporadically, such as after storms.

Epidemic
Widespread insect or disease incidence beyond normal proportions.

Exotic species
A nonnative plant or animal species introduced by humans, either deliberately or accidentally.

Extinct
Said of a species or other taxonomic group having no living members.

Feeder roots
Fine roots of trees and other vegetation used to absorb water and nutrients from the soil.

Forest
A plant community dominated by trees and other woody plants.

Forest entomology
The science that deals with insects in forest trees or products.

Forest ecology
The study of life in areas where the dominant vegetation is trees. This includes both the biology of organisms and how they interact with each other and their environment.

Forester
A professional who has been educated in forestry at a college or university.

Forest management
The application of scientific, economic, and social principles to managing a forest property for specific objectives.

Forest pathology
The science that deals with diseases of forest trees.

Forest Plan
A document that guides all natural resource management activity and establishes management standards and guidelines for a National Forest, embodying the provisions of the National Forest Management Act (1976).

Forest Practices Act
Washington State legislation designed to protect public resources such as water and wildlife from effects of indiscriminate management practices. All forest operations on private lands must comply with regulations administered by state forestry personnel.

Forestry
The science, art, and practice of managing and protecting tree and forest resources for human benefit.

Forest type
A group of tree species that, because of their environmental requirements, commonly grow together. Examples of forest types are the Douglas-fir/hemlock type or the spruce/fir type. In addition, a descriptive term used to group stands with similar composition and development characteristics.

Form class
A measure of bole taper derived by dividing diameter inside bark at a given height (usually 17.3 or 33.6 feet) by DBH, times 100. These values often are entered when using tree-volume tables.

Fragmentation
The breaking up of a large forest area into patches either by natural processes or through management or conversion to other land uses. Natural habitats may become separated into isolated segments or "islands." *See also* Connectivity.

Free-grown tree
A tree that has always grown in the open with no competition from adjacent trees.

Fungi
Any group of organisms that live in the soil and decompose dead organic matter.

Growing space
The availability of all the requirements a plant needs in order to grow, including soil, light, water, nutrients, CO_2.

Growing stock
All the trees growing in a stand, generally expressed in terms of number, basal area, or volume.

Habitat
The local environment in which a plant or animal naturally lives and develops.

Habitat type
Classification of a land area according to dominant plant forms (usually trees and shrubs) and physical characteristics. Can help to indicate the biological potential of a site.

Hardwood
A term describing broadleaf trees, usually deciduous, such as oaks, maples, cottonwood, ashes, and elms.

Harvest
Removing trees on an area to obtain an income or usable product.

Herbicide
Any chemical used to kills plants.

Increment
See Annual growth.

Increment borer
A hollow, augerlike instrument used to bore into the tree trunk to remove a cylindrical cross section (core sample) of wood. It is used to expose annual growth rings.

Indicator species
A plant or animal species whose presence in an area indicates that certain specific habitat conditions prevail throughout the area.

Insecticide
Any chemical used to kill insects. The term often is used interchangeably with pesticide.

Integrated pest management (IPM)
A method that evaluates alternatives for managing forest pest populations on the basis of pest-host relationships.

Integrated resource management
A term used to indicate the simultaneous consideration of ecological, physical, economic, and social aspects of lands, waters, and resources in developing and carrying out multiple-use, sustained-yield management.

Intermediate trees
See Crown class.

Intolerant species
Tree species that are incapable of establishing or growing in the shade of other trees.

Landscape
A large land area composed of interacting groups of ecosystems, including all the physical and biological aspects of such an area, regardless of ownership.

Landscape configuration
The pattern of forest stands, meadows, lakes, and other features within a large area.

Landscape connectivity
See Connectivity.

Landscape ecology
The study of biological interactions across a large land area, or watershed.

Litter
The uppermost layer of the soil, made up of freshly fallen or slightly decomposed organic materials. *See* Duff.

Live crown ratio
The percentage of the length of a tree stem supporting living branches.

Low fires
Fires with a low flame height and low temperature that burn duff, seedlings, saplings, and trees that are not fire-resistant. Mature fire-resistant trees are scorched but generally not killed by low fires.

Macroclimate
The climate of a large region as a whole, considered apart from modifying irregularities of land and vegetation. *See also* Microclimate.

Management plan
A written plan for the organized handling and operation of a forest property. It usually includes data and practices designed to provide optimum use of forest resources according to the landowner's objectives.

Mature forest
A term generally applied in an economic sense to indicate a forest that has attained harvest age.

Mature tree
A tree in a managed forest that has reached the size or age for its intended use.

MBF
Abbreviation for thousand board feet.

Mean annual increment (MAI)
The annual increase in size (volume) of a tree. Or the increase in size (volume) of a stand at a certain age, divided by that age in years.

Mensuration
That phase of forestry dealing with the measurement of volume, growth, and development of individual trees and stands.

Microclimate
The climate of a small, specific area reflecting such local differences as soil surfaces, vegetation, and atmospheric characteristics.

Microsite
An environmental feature that is small in scale but unique in character. Microsites often have a significant impact on natural regeneration.

Mid-successional
An association of plant and animal species that replaces early successional species, but is eventually replaced by climax species in the absence of disturbance.

Mixed conifers
Timber stands characterized by a mixture of conifer species, including ponderosa pine, lodgepole pine, Douglas-fir, grand fir, western white pine, and western larch. A mixture of forest types.

Mixed-species stand
Forest stands made up of more than one type of tree.

MMBF
Abbreviation for million board feet.

Montane forests
Forests that are mid-elevation and generally moister than foothill forests, but not as cold as subalpine forests.

Mortality
Death of forest trees as a result of competition, disease, insect damage, drought, wind, fire, and other factors.

Multiple use
Forest land management for more than one purpose, such as wood production, water, wildlife, recreation, forage, and aesthetics.

Multi-storied
Forest stands containing trees of different heights.

Mycorrhizal fungi
Fungi, which form a symbiotic relationship with the roots of certain trees, enabling those trees to extract more water and nutrients from the soil.

Nutrients
Chemical substances necessary for plant and tree growth.

Nutrient cycling
The biological, geological, and chemical circulation of inorganic elements such as nitrogen, phosphorus, and potassium through the soil, living organisms, water, and air, thus providing nutrients to animals and vegetation in the process.

Obligate species
A species restricted to a particular environment or a particular mode of life, such as a plant or animal found only in a narrowly defined habitat, e.g., a tree cavity.

Old growth
A forest ecosystem containing old trees, usually over 125 years old, and associated plants and wildlife.

Organic matter
Material produced by plants and animals, such as leaves, branches, bark, wood, hair, fur, and bones.

Overmature
A stand of trees that is older than normal rotation age for the forest type.

Overstocked
A stand or forest condition, indicating more trees than desired.

Overstory
That portion of the trees in a stand forming the upper crown cover.

Overstory retention
Leaving some of the bigger trees in the stand to serve as seed trees or shelterwoods for instance.

Pathology
The science that deals with diseases of forest trees, forest stands, and products.

Photosynthesis
The process in trees and other plants changing air and water into food using the sun's energy.

Pioneers
Shade-intolerant species that are the first trees to invade freshly disturbed sites.

Plant association
A vegetation community, in which the dominant species forms the highest level in the hierarchy of plant species. *See also* Climax community.

Plantation
A reforested area established by planting trees.

Planting stock
Seedling trees ready for planting.

Population
Organisms (trees, shrubs, herbs, animals, insects) of common ancestry that occupy a particular forest area.

Prescription
A management action to cause orderly change in a forest.

Preservation
As applied to wood—Treating wood products with chemicals to prevent damage by insects or decay. *In reference to land and resources*—Maintaining a natural environment undisturbed by human influence.

Productivity
Growth per unit time.

Provenance
The geographical source or place of origin of tree seed.

Pure stand
A stand of trees of all one species.

Reforestation
Reestablishing a forest on an area where forest vegetation has been removed.

Regeneration
The natural or artificial renewal of trees in a stand.

Reproduction
Young trees. The process of forest replacement or renewal that may be introduced artificially by planting or naturally by sprouting or self-seeding.

Residual
Trees left in a stand, after cutting, to grow until the next harvest.

Resilience
The ability of a forest ecosystem to recover from a disturbance.

Riparian
Pertaining to the area along the banks of a river, stream, or lake.

Riparian ecosystem
An ecosystem that is transitional between land and water ecosystems. The soils, plants, animals, and other organisms found in such an area.

Rotation
The number of years required to establish and grow trees to a specified size, product, or condition of maturity.

Second growth
Young forests that originated naturally or were planted on the site of a previous stand that was removed by cutting, fire, or other cause.

Seed year
A year in which a given species produces a large seed crop. Used in reference to trees that produce seed irregularly or infrequently.

Seed zone
Areas that have similar climate and elevation conditions. Used to specify where tree seed was collected and where trees from such seed will probably grow successfully.

Seral stage
A phase of ecological development toward a more mature or climax community. *See* Climax community; Successional stage.

Serotinous cones
Cones that remain closed after maturity. Lodgepole pine cones open after being exposed to intense heat. This mechanism ensures seed production following a fire.

Shade intolerant
A term applied to tree species that grow better in direct sunlight than in the shade of other trees. The opposite of shade tolerant. Examples include coastal Douglas-fir, western larch, lodgepole pine, and red alder.

Shade tolerance
A tree's capacity to develop and grow in the shade of, and in competition with, other trees. Examples of highly shade-tolerant species are western hemlock, western redcedar, and Pacific yew.

Shade tolerant
A term applied to tree species that grow better in the shade. The opposite of shade intolerant. Examples include western hemlock, western redcedar, and pacific yew.

Shrub
A low growing perennial plant with a woody stem and low branching habit.

Single-layered canopy
When the codominant trees in the stand are all about the same height (an even-aged stand), the forest has a more or less continuous single-layered

canopy. Trees in the understory usually are not numerous enough to make additional layers of canopy.

Site
An area evaluated for its capacity to produce forest products. Evaluation is based on combined biological, climatic, and soil factors.

Site class
A grouping of similar sites that indicates relative productivity. The common system for the Douglas-fir region includes five site classes, in which Site I is the most productive and Site V is the least productive.

Site index
An expression of forest site quality based on the height of the dominant and codominant trees in the stand at a specified age, usually 50 or 100 years.

Site productivity
Growth per unit time on a given site, determined by geologic and climatic conditions.

Slope
The incline of the terrain usually expressed as the amount of incline in feet over a hundred feet of horizontal distance.

Socioeconomic
Combining social and economic considerations.

Soil texture
Proportion of clay, silt, and sand in soil.

Specialists
Plants or animals that require specific conditions to grow and reproduce.

Species
A group of organisms (plants or animals) very similar in appearance, which can interbreed freely with each other but not with other groups.

Species composition
The mixture of tree species in a stand within a forest.

Stand
A recognizable area of the forest that is relatively homogeneous and can be managed as a single unit. Stands are the basic management units of the forest. Stand types include:

All-aged
A stand that supports trees of all ages and usually all sizes. This stand type is rare. Contrast it with an even-aged stand.

Even-aged
A stand in which trees are essentially the same age (within 10 to 20 years).

Fully stocked
A stand where trees effectively occupy all growing space, yet ample room exists for developing crop trees.

Mixed
A stand that has more than one species in the main tree canopy.

Overstocked
A stand that is overcrowded, thus reducing tree vigor.

Pole
A stand in which most trees are 5 to 9 inches in diameter.

Pure
A stand in which at least 80% of the trees belong to a single species.

Residual
The stand that remains after cutting.

Sawtimber
Most trees in the stand are large enough in diameter (usually 10 to 12 inches DBH or larger) to be sawn into lumber.

Understocked
A stand in which crop trees do not effectively occupy the growing space.

Uneven-aged
A stand that supports trees of several age classes (technically, more than two age classes).

Stand condition
A silvicultural classification used to describe the present overall health of the stand, particularly in relation to its need for treatment.

Stand density
A quantitative measure of stand stocking, or the number of trees for a given area.

Stand initiation phase
Following a disturbance, plants regenerate the disturbed site.

Stand-replacement fire
A large fire that burns duff, seedlings, saplings, and mature trees, leaving the site unoccupied by vegetation and at the start of a successional cycle.

Stand structure
Stages in the natural development of a forest stand, which often include distinct phases such as stand initiation, stem exclusion, understory reinitiation, and old growth.

Stand table
A table by diameter classes of volume, basal area, or trees per acre existing in a stand or expected to exist at a certain time.

Stem exclusion phase
After several years, new individuals are not able to regenerate within the stand. Some of the existing trees die. Survivors grow larger and express differences in height and diameter.

Succession
The replacement of one plant community by another until ecological stability is achieved. *See* Climax community; Plant association.

Successional development
Where a stand lies in the successional cycle between pioneer and climax conditions.

Successional stage
A phase in the natural development of forest communities. Over time, favorable conditions are reached for the establishment of the next stage. *See* Stand structure.

Suppressed trees
Trees much shorter than the general level of the canopy. These trees exhibit reduced growth rate and vigor.

Suppression
When a larger tree overtops a smaller tree, permitting little or no sunshine to reach the crown of the smaller tree and retarding its growth.

Sustainability
Forest development that incorporates the means to maintain biological diversity, resilience to stress, and ecosystem health and integrity, in the context of the ability to meet future as well as present human needs.

Sustained yield
Management of forest land to produce a relatively continuous flow of timber or revenue.

Terrestrial ecosystem
A land-based ecosystem.

Timber stand improvement (TSI)
Applying cultural practices to a young forest stand to improve the growth and form of trees and to achieve the desired stocking and species composition.

Tolerance
The ability of a tree to grow satisfactorily in the shade of or in competition with other trees. Trees classified as tolerant can survive and grow under continuous shade.

Transpiration
Water loss from leaves during growth and respiration.

Transplant
A very young tree or seedling lifted from a nursery seedbed and replanted at the nursery.

Treatment
Any action in forest stands controlled by a silvicultural prescription.

Tree
A woody plant having a well-defined stem, usually standing over 30 feet high at maturity.

Tree farm
A privately owned woodland in which producing timber is a major management goal. It may be recognized as a "Certified Tree Farm" by the American Tree Farm System.

Understory
That portion of the trees or other vegetation below the canopy in a forest stand.

Understory reinitiation phase
A later stage in stand development when forest floor trees and shrubs again regenerate and survive in the understory.

Uneven-aged management
Managing a forest by periodically harvesting trees of all ages to maintain a broad age (or size) class distribution. The forester maintains a greater number of trees in each smaller age class than in the next older or larger class, up to some maximum age. This type of management is not common in the West. *See* Selection harvest.

View shed
The landscape seen from a particular viewpoint or along a transportation corridor.

Virgin forest
A forest essentially uninfluenced by human activity.

Watershed
An area of land that collects and discharges water into a single stream or other outlet. Also called a catchment or drainage basin.

Watershed analysis
The study of how a particular drainage network functions. An aspect of ecosystem management planning.

Wetlands
Marshes, swamps, and other water-saturated soils. These areas offer important habitat for wildlife, significant support of nutrient cycling in ecosystems, and protection against the severity of storms and floods. Wetlands are among the lands most vulnerable to destruction and conversion to other uses.

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