Chapter 2 Woodland Ecology

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A basic knowledge of woodland ecology is essential for owners of even the smallest woodland parcel. Understanding and applying ecological principles is key to sound stewardship of your woodland property

Woodland ecology refers to the relationships among trees, other plants, and animals and their forest or woodland environment. Woodland ecosystems are complex: there are many parts, living and nonliving, that are interconnected and dependent on one another. Woodland ecosystems are also dynamic: they are changing constantly and at every level, from small gaps made by one dying tree to large disruptions such as wildfire or insect epidemics. In fact, change is the norm rather than the exception in woodland ecosystems.

Most aspects of ecosystem dynamics are cyclic. Cycles include the water cycle, the nutrient cycle, and the plant growth and decay cycle. None of these cycles exists by itself; outputs from one cycle are inputs for another. Thus, each cycle depends on the others to keep the system fully functioning.

Understanding how forests grow and develop is an important foundation for woodland mangement. Many projects you undertake in your woodland might be aimed at restoring or enhancing ecological functions of forest and streams, whether it's placing logs in a stream to improve stream habitat or planting or thinning trees to enhance tree and forest growth.

As you read and learn about watersheds, forests, and wildlife, you'll find that management activities are based on applied ecology concepts. Understanding ecological concepts, therefore, provides a blueprint for managing your woodland for timber, wildlife, recreation, water, and other amenities.

Forest ecosystems comprise plants, animals, and micoorganisms in a physical landscape. As scientists study forest ecosystems, they continue to find that "everything is connected to something else." Some connections or associations between two species—whether it be plant to plant, plant to insect, or animal to animal—are relatively straightforward and easily observed. Other associations are more subtle, and scientists believe many others are yet to be discovered.

It is hard to imagine all aspects of tree or plant growth and the effect of outside influences on a single organism's growth, health, and longevity.

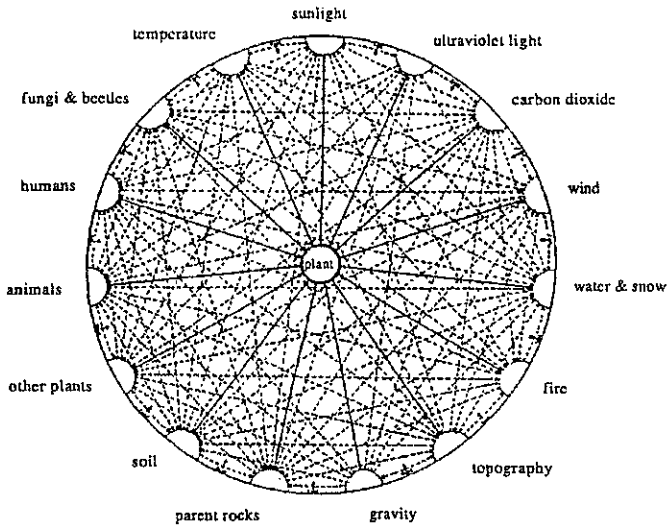


Figure 2.1—A plant and its environment.

However, consider for a moment one plant and its environment. Figure 2.1 shows some of the interconnecting factors that influence that plant. Now consider a forest ecosystem with thousands of plants and literally millions of microorganisms per acre—indeed a complex system.

How trees grow

Parts of a tree

A tree has essentially three growing regions or areas: roots, bole (trunk), and crown (Figure 2.2).

Roots Roots are important as an anchor to prevent trees from blowing over. More important, roots adsorb water and nutrients from the soil and transport them to the bole of the tree. Root tips have microscopic root hairs which greatly increase the surface area of roots so the tree can adsorb more water and nutrients. Beneficial fungi, called mycorrhizal fungi, reside in the root hairs and help the tree adsorb additional water and nutrients. Every year as the tree matures and increases in size, it produces new roots to supply enough water and nutrients to the crown. Roots also store food for the tree in dormant months (fall and winter).

Bole The bole, or trunk, links the roots with the crown. The bole comprises protective bark on the outside as well as cambium, sapwood, and heartwood on the inside (Figure 2.3).

Just under the bark is a thin layer of cells called the cambium. The outside portion of the cambium, nearest the bark, gives rise to a layer of cells called the phloem, sometimes referred to as the inner bark.

The phloem is a thin layer of cells through which food moves down the bole from the crown to the roots. It is this area that bark beetles bore into when they attack a tree because it is rich in nutrients. The inside portion of the cambium gives rise to new wood cells, which make up a ring of wood around the bole. Each ring represents one year's growth and makes up what is referred to as sapwood.

Sapwood is considered "living" wood because it transports nutrients and

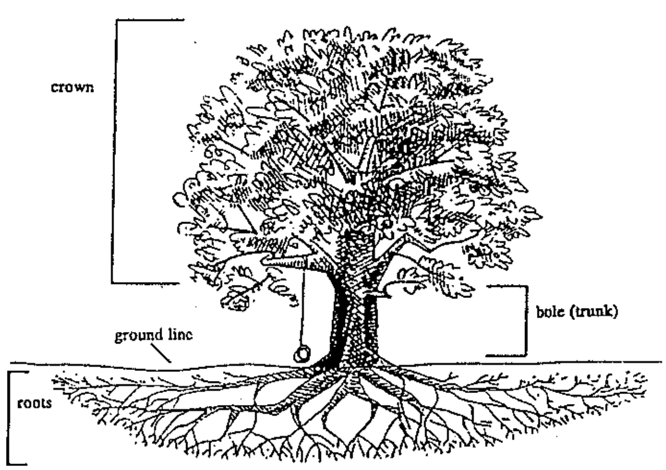


Figure 2.2—The growing regions of a tree.

water up the tree to the crown to be used in photosynthesis.

The innermost or central portion of the bole is called heartwood. It contains dead wood that often is a darker color than sapwood. Heartwood's primary function is structural support. Heartwood also contains protective chemicals which resist decay if the tree is injured.

Crown The crown is the green area containing the branches, buds, and leaves. The crown is the photosynthetic "factory" of the tree where all food is produced. Each year new needles, leaves, and buds are produced. In addition, reproductive structures such as cones and seeds are produced in the crown. Because reproduction is energy-intensive, some conifers and hardwoods produce heavy cone and seed crops only once every 3 to 15 years.

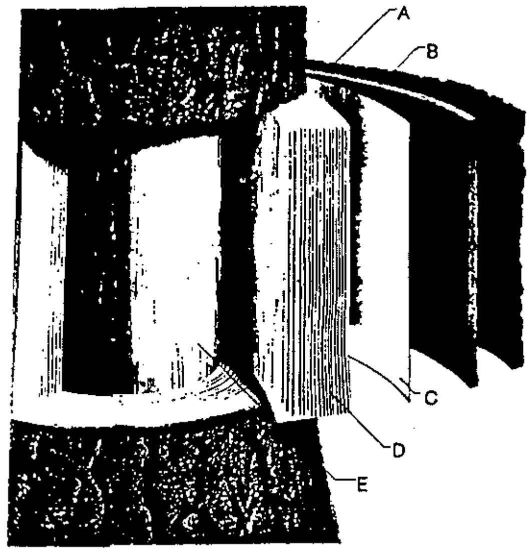


Figure 2.3—A cross-section of the tree bole: (A) outer bark; (B) phloem; (C) cambium; (D) sapwood; (E) heartwood.

Photosynthesis

Photosynthesis is probably the single most important biological process on earth. Photosynthesis is a process by which all green plants manufacture food (in the form of various sugars) for growth, reproduction, and maintenance.

Photosynthesis takes place in the leaves or needles—more specifically, in millions of microscopic green chloroplasts, which give leaves their green color. The basic building blocks for the tree's food are carbon dioxide from the air plus water and nutrients (such as nitrogen) from the soil.

Carbon dioxide moves into the leaves through microscopic openings or holes called stomates which can open and close. When stomates are open, carbon dioxide moves into the leaf from the atmosphere, and oxygen and water move out of the leaf. As water passes into the atmosphere, an evaporative pump is created. This pump, powered by the sun, essentially pulls water and nutrients up the tree from the roots to the leaves.

A tree can transpire hundreds of gallons of water into the atmosphere on a hot day, depending on tree size and species and the availability of water in the soil. When water is in short supply, the tree can close stomates to prevent drying out; however, photosynthesis then stops, also.

Energy is needed for photosynthetic processes. Chloroplasts trap energy from the sun; in the presence of other chemical activators, carbon dioxide, water, and various nutrients are converted into simple sugars. With the help of enzymes, these sugars can be converted to other compounds such as oils, starches, proteins, and fats.

The tree uses these compounds to produce new roots, wood, and buds as well as fruits, nuts, or seeds for reproduction. Some of these compounds are used to maintain and repair cells and to provide protection from insects, disease, and mechanical damage.

Determining site quality and resources

Trees and other plants require four basic resources in order live and compete with other plants: moisture, nutrients, light, and space.

Moisture Moisture is often in short supply to tree seedlings and even mature trees. In Oregon, 80 percent of the average year's moisture comes between November and June. During the growing season, rainfall is scant. Therefore, plants must obtain water stored in the soil. The soil, in many ways, acts as a sponge or reservoir which tree roots tap. Deep, fine-texture soils (loams) can store a considerable amount of water between soil particles. Shallow or sandy soils hold less because fewer pore spaces are available to store water.

Nutrients Roots take up nutrients in water solution and use the nutrients for photosynthesis. Mycorrhizal fungi greatly aid the tree in nutrient uptake. The type of soil and parent material (underlying rock) on any particular site determine the amount of nutrients available to trees.

Plants use some nutrients, called macronutrients, in greater amounts. Nitrogen, calcium, and phosphorus are examples of macronutrients. Nutrients used in very small amounts are called micronutrients. Examples are boron and manganese. Although used in small amounts, micronutrients are no less important for tree growth.

Light Light from the sun provides the energy to fuel the process of photosynthesis. Young tree seedlings planted or naturally established in an opening after a fire or timber harvesting often can be overtopped by surrounding vegetation, shading the young seedlings and reducing growth. If seedlings remain in dense shade for long (2 to 4 years), they may eventually die; the other vegetation will continue to dominate the site. On the other hand, if seedlings are able to persist in this competitive environment and eventually dominate the site, then the surrounding vegetation becomes shaded and eventually dies out or is reduced. In either case, light is the limiting factor, impairing photosynthesis and resulting in growth-rate declines.

Space For plants to remain competitive in a plant community, they need space. Having enough space is critical in order for plants to develop to their full potential. Crowding reduces plant size and increases competition for moisture, light, and nutrients.

Quantifying site quality

Forest productivity can be determined by measuring various forest attributes including the following.

Forest attribute	Measure
Total biomass (leaves, branches, bole, roots)	tons per acre
Total usable wood	cubic feet per acre
Boards	board feet per acre
Basal area*	basal area per acre
Leaf area**	leaf area index

* Basal area is the cross-sectional area of a tree at 4.5 feet above ground level, measured in square feet.
** The square footage of leaves compared to a square foot of ground surface.

Mature, productive forests in western Oregon contain about 500 to 1,000 tons per acre of biomass above ground and 100 to 300 tons per acre under ground, in the roots. Dry-site forests of eastern Oregon support less biomass.

Table 2.1—Site indices for Douglas-fir.

Age (years)	Tree height (feet)													
20	21	24	26	29	31	34	37	39	42	44	47	49	52	54
30	37	41	46	50	55	60	64	69	74	78	83	88	92	96
40	48	54	60	66	72	78	84	90	96	102	108	114	120	126
50	56	63	70	77	84	91	98	105	112	119	125	132	139	146
60	63	70	78	86	93	101	109	117	124	132	140	148	156	163
70	68	77	85	94	102	110	119	127	135	144	152	161	170	178
80	73	82	91	100	109	118	127	136	145	154	163	172	181	190
90	77	86	96	105	115	125	134	144	153	163	172	182	192	201
100	80	90	100	110	120	130	140	150	160	170	180	190	200	210
Site index	80	90	100	110	120	130	140	150	160	170	180	190	200	210

Forest productivity can vary from site to site. For example, on more productive Douglas-fir sites, board foot growth may be two to three times higher than on the least productive Douglas-fir site. One method used to classify forest and site productivity is site index. This system describes the ability of trees of a particular species to grow to a specific height over a given period, which usually is 50 or 100 years (called base age-50 or -100). Table 2.1 presents site indices for Douglas-fir for a base age-100. Note that over a 100-year period, Douglas-fir on the most productive site can grow to 210 feet, but on the least productive site dominant trees grow only to 80 feet. This has a significant impact on wood production as well as on other ecosystem features.

From an ecosystem perspective, more productive sites can recover more quickly from disturbances such as fire or timber harvesting. In addition, productive sites generally are more diverse structurally, providing better habitat for wildlife and other organisms.

Factors affecting site productivity include tree genetics, tree species, aspect, slope, slope position (upper or lower), soil depth and texture, and climate.

Table 2.2—Comparison of Pacific Northwest tree species' tolerances to certain environmental stresses.

Species	Tolerance to[1] Shade	Drought	Flooding	Frost
Western hemlock	1	5	2	3
Western redcedar	2	4	1	3
Incense-cedar	4	2	3	3
Grand fir	2	4	2	3
Douglas-fir	3	3	5	3
Pacific silver fir	1	5	4	1
Noble fir	4	4	4	2
Lodgepole pine	5	2	1	1
Ponderosa pine	5	1	3	2
Sugar pine	4	2	3	3
White pine	3	2	2	1
Englemann spruce	4	4	2	1
Western larch	4	3	2	2
Red alder	5	4	3	4
Bigleaf maple	2	3	4	3
Oregon oak	5	1	2	2
Black oak	5	1	4	2
Oregon ash	3	3	1	3
Black cottonwood	5	5	1	3
Madrone	4	2	4	2
Bitter cherry	5	4	4	3
Chinkapin	2	3	4	2
Tanoak	1	3	4	4
Myrtle	2	3	2	4
Canyon live-oak	4	1	3	3

[1] 1 = high tolerance; 5 = low tolerance

Tree tolerance of environmental stresses

Over hundreds of thousands of years, trees have adapted to environmental stresses. These adaptations allow trees to compete successfully in a wide variety of climates and habitats. Adaptations to shade, extreme temperatures, and varying moisture regimes allow trees to seed in, colonize, and persist for long periods within a stand, a watershed, or a region.

Each tree species has its own set of adaptations to environmental stresses. We often rank tree species according to their ability to withstand these stresses. The ranking is relative and can change for a given species from one site or region to another. Stresses that most affect trees' survival include shade, fire, drought, frost, heat, flooding, wind, and low soil fertility (Table 2.2).

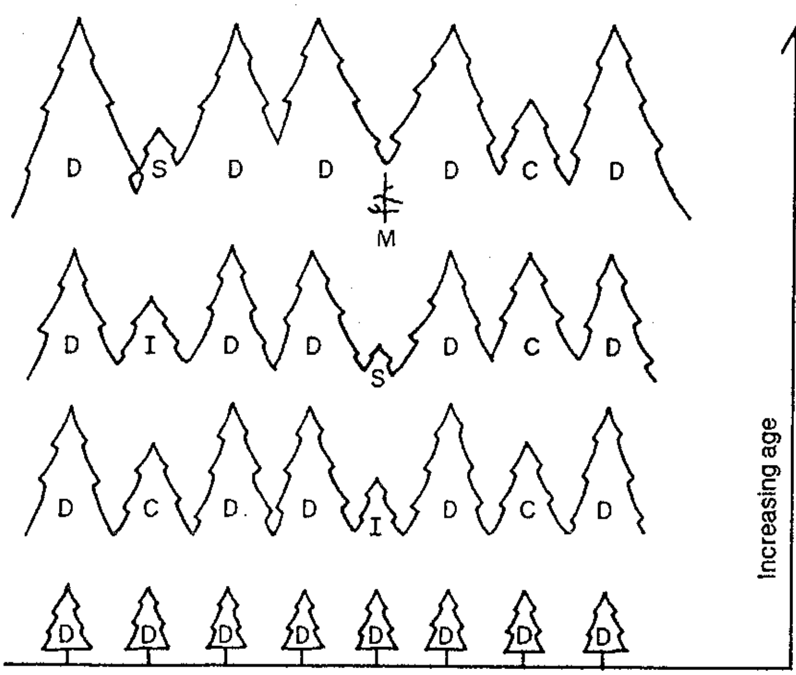


Figure 2.4—Stand development process. Trees differentiate into crown classes as stands age. Crown classes are: (D) dominant, (C) codominant, (I) intermediate, (S) suppressed, and (M) mortality.

A tree's ability to withstand stresses allows it to occupy a certain niche in the stand or landscape for long periods. For example, in riparian restoration planting on a western Oregon stream that typically floods, you would chose tree species that have a high tolerance for prolonged wet conditions. In this case, Oregon ash, black cottonwood, or western redcedar would be good candidates. Likewise, in reforesting a south-facing slope in southwestern Oregon, you would want a tree species adapted to hot, dry sites. An appropriate choice would be ponderosa pine.

Competition and stand development

Competition is the struggle to obtain limited site resources. When trees naturally seed in or are planted on a recently disturbed site, they must compete with an array of forbs, grasses, shrubs, and other trees. Competing vegetation often is better suited than tree seedlings to open, sunny conditions because the other vegetation can grow fast, reproduce profusely, and spread seed long distances. At this stage of development, competition for light, moisture, nutrients, and space is fierce.

If tree seedlings are able to establish quickly and begin to outgrow the surrounding vegetation, eventually they begin to dominate the site. As the trees grow into saplings, more and more site resources are channeled into the trees as their root systems spread. At this stage, competing vegetation is overtopped and becomes increasingly subordinate to the trees.

Eventually, tree crowns begin to touch, and competition begins among trees. At this stage, all trees are more or less the same size. However, as stand development continues, competition for light, moisture, nutrients, and space intensifies. As trees grow wider and taller, often some trees begin to slow in growth while others continue to grow as before and so become dominant. As competition increases (because trees' sizes increase), growth continues to decline on some trees; they become overtopped by neighbor trees and are suppressed. As surrounding trees continue to grow, suppressed trees eventually die; the resources the suppressed trees would have used are reallocated to adjacent trees. This process of competition and tree death in even-age stands is called self-thinning (Figure 2.4).

In stand development, trees differentiate by size or dominance. After 60 years of competition, a stand of Douglas-fir might look like the one in Figure 2.5. This stands contains dominant, codominant, intermediate, and suppressed trees as well as trees that died from competition. Dominant trees are the largest in the stand and typically receive light on all sides of their crowns. Dominant trees are vigorous, display good diameter growth, and have large crowns.

Codominant trees are shorter and thinner; they receive light at the tops of their crowns and some light on the sides. They are less vigorous than dominant trees and have smaller crowns.

Intermediate trees are smaller than codominant trees and intercept light only at the tops of their crowns. Intermediate trees have small crowns, and as a result tree growth is poor. Intermediate trees eventually become suppressed.

Suppressed trees usually occupy the understory and display very poor diameter and height growth. Little light falls on their small crowns. Suppressed trees soon die and fall to the forest floor.

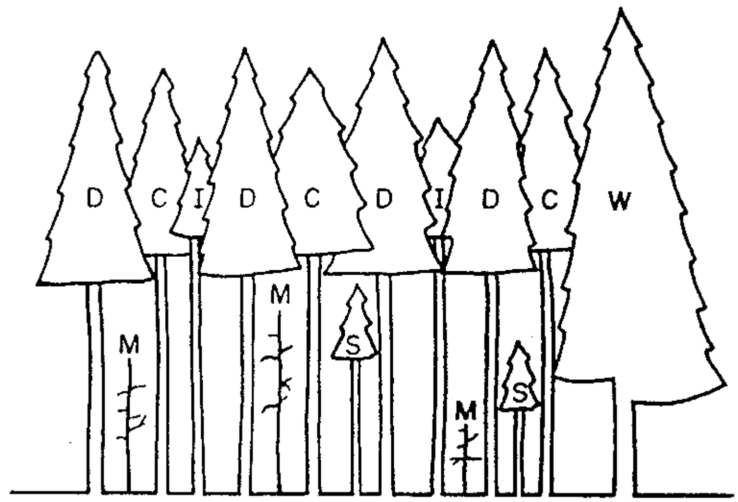


Figure 2.5—Crown classes in an even-age stand of Douglas-fir. The crown ratio is calculated by dividing the height of the live crown by the height of the entire tree. Here, the dominants have a 50 percent crown ratio, while the wolf tree (W) on the edge of the stand has an 80 percent ratio.

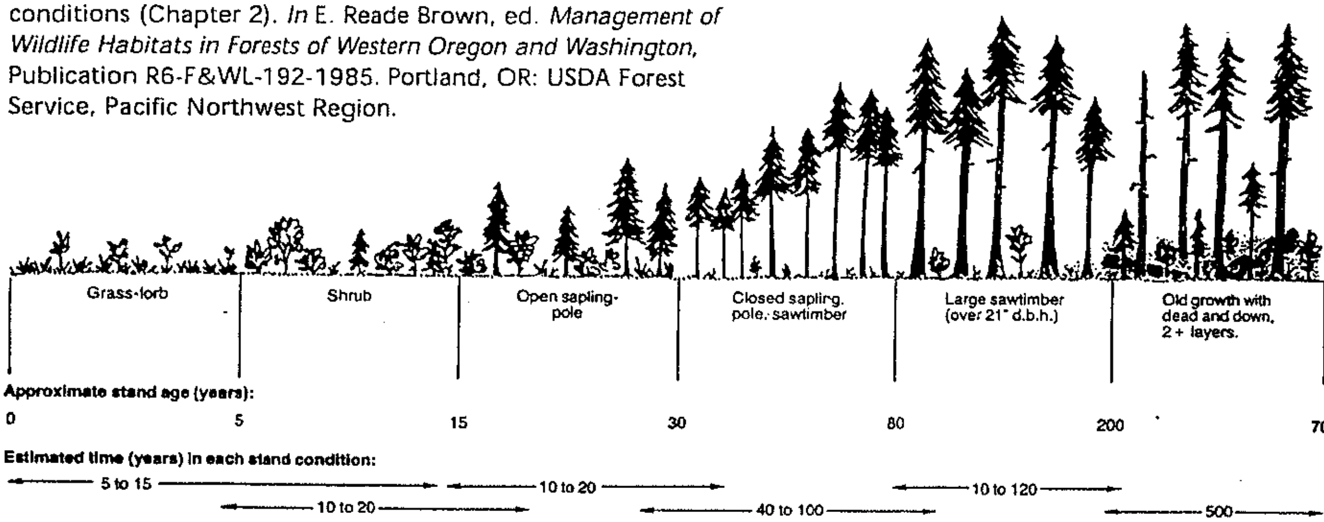
Forest structure

Simply stated, forest structure refers to "pieces" of the ecosystem, such as trees and shrubs, and how they are arranged in spacial relationships. Structural attributes useful to ecologists and wildlife managers include:

- Number of large and small trees per acre
- Number of canopy layers
- Amount of downed wood and snags per acre
- Tree species or composition
- Percent cover and composition of grasses forbs and shrubs
- Size of stand or patch

Why is forest structure important? Individual wildlife species or groups of species depend on certain structural features of forests for habitat (Figure 2.6, page 18). For example, some species of wildlife require snags and

Figure 2.6—Stages of forest development (succession). From Frederic Hall et al. 1985. Plant communities and stand conditions (Chapter 2). *In* E. Reade Brown, ed. *Management of Wildlife Habitats in Forests of Western Oregon and Washington*, Publication R6-F&WL-192-1985. Portland, OR: USDA Forest Service, Pacific Northwest Region.



downed logs. Maintaining or creating this "dead wood" structure in stands is essential in order to maintain populations of woodpeckers, songbirds, bats, ants, and termites. Snags are important for woodpeckers which excavate cavities for nesting. These holes are used later by squirrels, songbirds, owls, and other wildlife.

Many species of songbirds and woodpeckers prey on insects that kill or defoliate trees. Snags and downed wood are home to ants, which are the main prey for several species of woodpeckers. So without a component of dead wood in the forest ecosystem, the system becomes simplified, and wildlife diversity is lowered.

We can create forest structure that either prevents or promotes the buildup of certain kinds of insects and diseases. For example, the western spruce budworm, which defoliated several million acres of mixed-conifer forest in central and eastern Oregon, prefers multistoried stands dominated by fir species. Managing existing stands or creating new stands (and landscapes) that are single-canopy and contain a lower proportion of fir species is one way to manage forest structure to reduce budworm habitat and reduce the potential for future large-scale outbreaks.

Forest structure varies across the landscape due to changes in topographic position, site productivity, and disturbance history.

Disturbances and forest succession

Disturbance to forest ecosystems affects forest succession and alters forest structure and habitat for wildlife. A major disturbance such as a fire or windstorm can speed up or reverse the process of succession depending on which plant species remain on or colonize a site after the disturbance.

Natural and human-caused disturbances

For thousands of years forest ecosystems have been shaped and changed by natural and human-caused disturbances, including Native Americans' burning. Only in the past few hundred years, however, have human-caused disturbances begun to significantly alter the natural disturbance pattern in forest ecosystems.

Probably the most significant natural disturbances of forest ecosystems in the Pacific Northwest have been fire, insects, and wind. In other parts of North America, windstorms and hurricanes are more prominent.

Human-caused disturbances have greatly affected natural disturbance regimes in forest ecosystems and, therefore, have changed the makeup or structure of the forests over large areas.

Timber harvesting, for example, has created a forest landscape that is dominated by younger forests. Older forests make up a smaller percentage of the forest; thus, some populations of wildlife species dependant on old forest conditions have declined.

On the other hand, younger forests have provided beneficial habitat to other species such as elk and deer, and their populations have increased. However, studies also show that in northwest Oregon, for example, the forest was not a continuous "sea" of old growth as once believed. In fact, before Euro-American settlement began in the 1840s, as much as 60 percent of the forest consisted of stands younger than 200 years. This was due to large, stand-replacement fires every 125 to 250 years.

Natural and human-caused disturbances common to the Pacific Northwest include:

Natural	**Human-caused**
Fire	Fire
Insects	Timber harvesting
Disease	Grazing
Wind	Exotic weeds
Floods	
Landslides	
Wildlife browsing	
Volcanic eruptions	

Effect of intensity, frequency, and size of disturbances

The intensity, frequency, and size of natural and human-caused disturbances profoundly affect forest development and, consequently, forest and landscape structure (habitat).

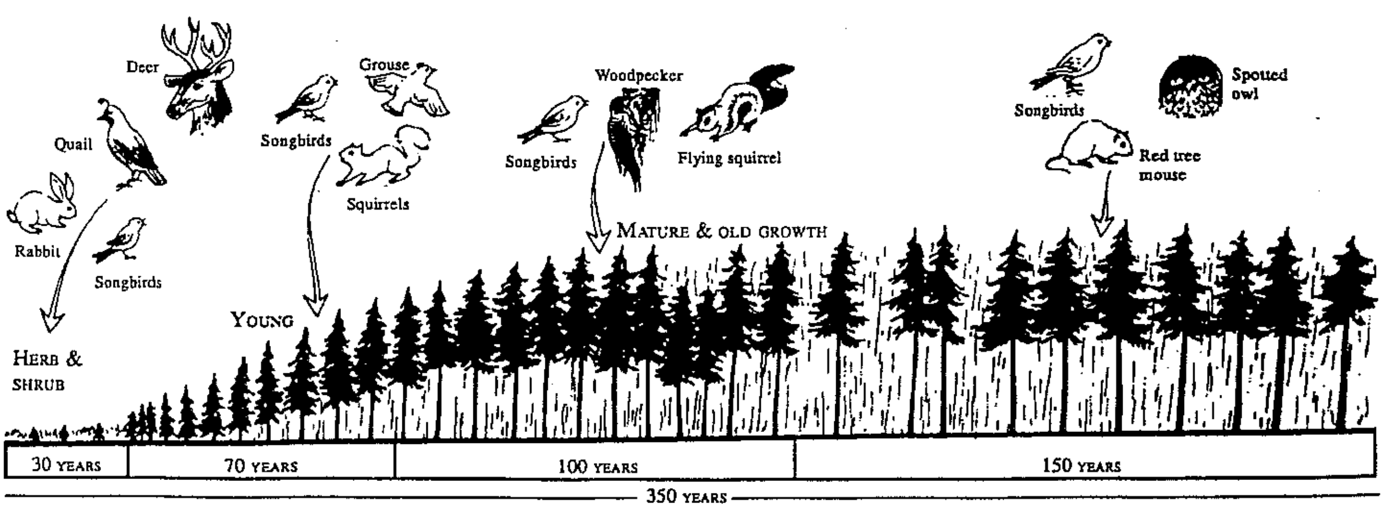


Figure 2.7—Forest succession showing changes in forest structure and wildlife habitat.

Intensity refers to the severity of the disturbance. This can be measured by how much of the original plant community remains after the disturbance, the amount of mineral soil exposed, and site resources available for exploitation or colonization by other species.

An example of a severe disturbance would be a large, stand-replacement fire in a second-growth or old-growth Douglas-fir forest. An event like this would kill many trees and expose a large area of mineral soil to colonization by trees and other plants. The new plant community might or might not progress to another old-growth forest.

The *frequency* of disturbances in forest ecosystems also affects succession and thus forest structure (including species composition). In frequently disturbed systems, trees and other plants develop ways to survive. For example, in the ponderosa pine ecosystem, cool surface fires often average every 5 to 20 years. As a result, ponderosa pine has developed thick bark and other features for protection. Other plants, such as certain shrubs and hardwoods, have developed sprouting capabilities in order to persist in fire-dominated ecosystems.

The *size* of the disturbance affects landscape structure and diversity. In most forest systems, disturbances can be large or small, frequent or infrequent. As a result, disturbances create patches on the landscape, each with its own distinct structure. This mosaic of patch sizes and structures creates a landscape with a high level of species and structural diversity.

Succession

Succession is the gradual replacement of one set of plants or plant community with another. As the plant community changes, so does forest structure. Thus, wildlife species also are replaced as habitat becomes more suited to another group of wildlife species. At each stage of succession, species dominance changes.

Primary succession

Primary succession is the development of a plant community from virtually bare rock. It occurs in areas having no plant community or in which all traces of a plant community have been wiped out (such as after landslides and volcanic eruptions). Primary succession is an extremely slow process.

A good example of primary succession is when lichens colonize rock and produce acids that help rock break down into soil. Frost action can assist the process by fracturing rock into progressively smaller fragments. Wind may speed the process a bit by depositing soil particles in cracks and small depressions in the rock.

All these actions help in soil formation, which is the primary resource needed for plant colonization. Because nitrogen—a critically important plant nutrient—is in such short supply on these sites, many of the first plants to colonize have the ability to extract nitrogen from the air and use it for plant growth. As these plants die and decay, the organic matter produced helps enrich the soil which in turn allows other plant species to colonize the site.

An aquatic example of primary succession is the conversion of a pond to a bog, the bog to a wet meadow, and finally the meadow to wetland-forest.

Secondary succession

In secondary succession, disturbance removes the aboveground parts of a plant community, but the soil, seeds, roots, and soil organisms remain intact. Secondary succession proceeds faster

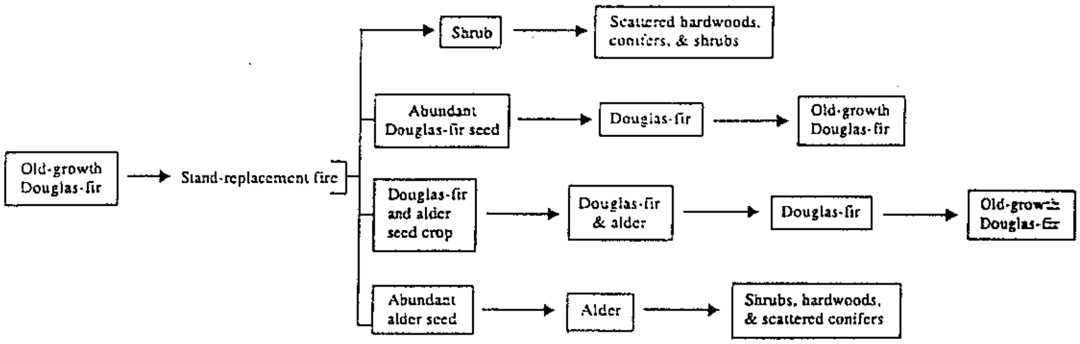


Figure 2.8—Possible successional pathways after an intense fire in a coastal Douglas-fir stand.

than primary succession because soil is already present, and the site can be colonized by plant species that prefer open, sunny conditions. Colonization can be from seeds or other propagules (roots, sprouts, spores) already on the site or from seed carried in from long distances by wind, wildlife, or humans.

Plant species that colonize sites soon after a disturbance are called pioneer species. Pioneer species include forbs, grasses, and shrubs. Some trees species seed in and grow well after disturbances and are considered pioneer species as well. Examples include red alder and Douglas-fir in western Oregon and lodgepole pine in eastern Oregon.

Successional pathways

Succession in forest ecosystems can take many paths (Figure 2.7). The successional pathway on a particular site after disturbance depends on the type of disturbance (for example, fire, insects, or landslide) and its intensity, size, and frequency as well as site productivity. Chance also is a factor in, for example, the availability of seed. Trees do not produce abundant seed crops every year. Thus, succession in a Douglas-fir stand after an intense stand-replacement fire may take different paths depending on the availability of seed from surrounding stands or surviving trees or from buried seed on site.

Climax forest conditions

A climax forest is the final stage of forest succession, in which tree species have been replaced with other tree species that can reproduce, establish, and grow under shade (i.e., are shade tolerant) or can develop in small gaps created when overstory trees die and fall. At this stage of forest succession, the forest is thought to be in a steady state and will remain at this stage until another disturbance.

An example of this process is an old-growth Douglas-fir stand that is being replaced with the more shade-tolerant western hemlock. Without another disturbance, western hemlock will come to dominate the site and will be the climax species. Because disturbances are the norm rather than the exception in forest ecosystems, however, few forests ever reach this "final," or climax, stage of succession.

Forest landscape development

Disturbances on many different scales—from the death of a single tree creating a gap in the forest canopy to large, stand-replacement fires—and at different intervals create landscapes that comprise many different stages of succession. These landscapes have a complex forest structure, containing diverse niches (patches or mosaics) that provide habitat to a variety of plant and wildlife species.

In landscapes where natural disturbance patterns are allowed, patches (stand conditions) do change from one place to another, but the relative amounts of each successional stage across the broad landscape remain the same over a long period.

However, over the past 150 years or so, human activities have altered natural disturbance regimes in the Pacific Northwest. Those activities include land settlement and urban development, timber harvesting, livestock grazing, fire suppression, and introduction of exotic weeds.

These activities have changed forest landscapes dramatically. Today, landscapes are dominated by younger forests across a much broader area; other conditions, such as old-growth forest, make up a smaller proportion. These changes in landscape dynamics have created some forests that are more vulnerable to insects, disease, and stand-replacement fires.

A structurally diverse forest landscape benefits not only a wide variety of wildlife species; it also may be essential to have forests that can withstand natural and human-caused calamities and sustain themselves in the long run.

The concept applicable here, and the main driving force behind ecosystem management, follows the old saying "Don't put all your eggs in one basket." In many areas, you, the landowner, will be designing and carrying out projects aimed creating more "baskets"—restoring or enhancing certain aspects of ecosystem structure and diversity.

Other resources

Publications

Forest Ecosystem Stewardship, EM 8676. Richard Fletcher and Robert Logan. 1997. Corvallis: Oregon State University Extension Service, 52 pp. $9.00

Managing Woodlands in the Coastal Fog Belt, EC 1131. William Emmingham and Michael Bondi. 1993. Corvallis: Oregon State University Extension Service, 6 pp. $1.00

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Organizations

Learn more about Oregon's forests at the World Forestry Center, 4033 SW Canyon Road, Portland, OR 97221. Or, visit the center's Web site
http://www.worldforestry.org