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FOREST PROTECTION

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Abiotic Injury to Forest Trees in Oregon

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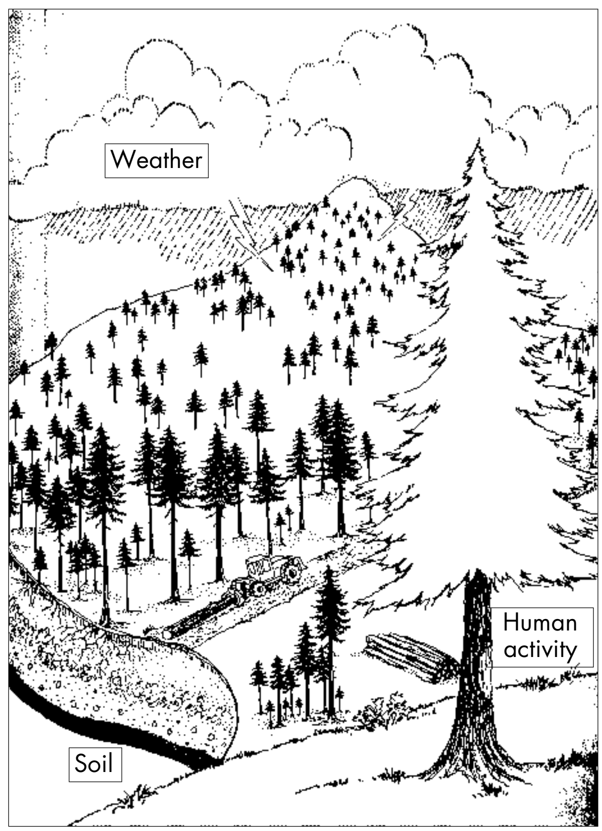
Contents

Three principal types of abiotic injury affect forests and woodlands in Oregon: injury related to weather, to soil, and to human activity. Abiotic injuries, also called *abiotic diseases*, can be found wherever forests exist. They are, for the most part, initiated by nonliving factors in the environment, such as temperature extremes, lightning, and wind. The exception to "nonliving" causes are disorders initiated, either directly or indirectly, by people.

Abiotic injuries by their very nature are not infectious. Trees damaged in that way cannot affect other trees with the same malady.



Abiotic injuries can cause poor forest health. Sound forest health is the ability to maintain vitality. A dynamic, fast-growing forest stand symbolizes robust health. An unhealthy forest, on the other hand, is one that does not have the resources to buffer extremes. For example, many trees in a dense (overcrowded) stand may be unable to survive a prolonged drought.

Causes of abiotic injuries usually are discussed individually, but they may work in concert. For example, not only is it sometimes difficult to isolate the effects of high temperature from those of moisture deficiency, high temperatures actually can aggravate low-soil-moisture conditions. Also, abiotic injury may influence and/or contribute to biotic (living) diseases and increase susceptibility to insect pests. (See OSU Extension publication Manual 9, *Forest Disease Ecology and Management*

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in Oregon, and Manual 10, *Forest Insect Ecology and Management in Oregon*, page 11.)

This publication won't make you an expert diagnostician, but it will help you basically understand abiotic injuries, identify some management (control) practices, and set the stage for further investigation.

Effects of abiotic injury

Effects of abiotic injury range from negligible (e.g., minor trunk damage to a single tree by a pickup truck) to considerable (e.g., "red belt," a wide band of trees, usually along elevational contours, that were killed by drying winds); from simple (e.g., windthrow) to complex (e.g., ozone damage); from obvious (e.g., lightning damage) to obscure (e.g., soil nutrient imbalance). Abiotic injury can reduce the economic value of individual trees, the productive potential of forest stands, and the beauty of woodland properties.

Abiotic injury can provide an entry for biotic pathogens and insects. For example, *mechanical damage* during tree felling or tractor yarding can lead to stem decays such as those caused by Indian paint fungus *(Echinodontium tinctorium)* and the red ring-rot fungus *(Phellinus pini).* Mechanical damage also can trigger an attack by wood-boring insects such as bark beetles.

Classification

Grouped by cause, abiotic injuries fall into three broad categories, each with subdivisions: *weather* (temperature, precipitation, wind, and lightning), *soil* (minerals and moisture), and *human activity* (air pollutants, herbicides, mechanical damage, and wildfire).

Common causes of abiotic injury in Oregon

Many kinds of abiotic injury are found throughout the forests and woodlands of the Pacific Northwest. Common and less common types are described briefly here.

Weather

Of all the causes of abiotic injuries affecting Oregon's forests, weather is the most unpredictable and unmanageable. Weather extremes are certain to occur, and certainly they are uncontrollable.

Some management practices can create conditions that lead to weather-related injuries. For example, improperly thinning a ridgetop conifer stand might expose remaining trees to periodically intense winds. Tree breakage and windthrow in those settings can be extreme. Another example is frost pockets (areas of poor air drainage) created by clearcutting a high-elevation site. Frost pockets may prevent successful reforestation because of low-temperature damage to young seedlings.

Temperature

As a general rule, trees have particular temperature requirements, though there is some variation among tree species and among individuals within the same species. The extent of any injury hinges on a tree's ability to withstand temperature fluctuations. A tree's resilience to temperature extremes is affected by the magnitude, abruptness, and/or duration of the temperature shift that causes the damage.

Low temperatures All portions of a tree are vulnerable to the effects of low temperatures, even the roots (see "red belt" injury, below). *Frost* can damage or kill foliage, buds, and twigs. Frost injury may occur in late spring, when emerging foliage and shoots are still succulent and tender, or in the fall before the buds and shoot tips have "hardened off" to withstand the severe weather to come.

A type of abiotic damage to conifers called *winter killing* or *winter injury* occurs when below-freezing temperatures cause needles to become dehydrated, turn red, and die. In severe cases, buds and twigs of specific trees are killed. The severity of this type of damage varies among tree species and among trees within the same species.

Two types of winter injury occur when temperatures suddenly plunge after an unusually warm period. These are called *frost cracks* and *top kill*.

Frost cracks are caused by abnormal shrinkage of the sapwood. Normal shrinkage is primarily in the direction of the annual growth rings (tangential shrinkage). In the case of frost cracks, wood shrinkage is chiefly across the annual growth rings (radial shrinkage). The tree boles (trunks) may crack. Frost cracks can be as high as 20 feet above the ground.

The origin of frost cracks often can be traced to old trunk wounds. A frost crack fracture usually heals with a telltale ridge of callus tissue. In the case of grand fir *(Abies grandis)* and white fir *(Abies concolor),* a frost crack may provide the entrance point for Indian paint fungus, which can cause extensive decay in the host tree.

With *top kill*, the phloem (inner bark) freezes, and the top of the tree dies. Close examination may be required to identify this abiotic problem correctly. Insects (e.g., bark beetles), biotic diseases (e.g., dwarf mistletoe), and lightning also can produce "dead-top" trees.

In a reverse of the preceding scenario (a drop in temperature following an unseasonably warm spell), an abiotic injury called *parch blight* occurs when Chinook winds—dry winter winds from east of the Cascades—sweep over very cold soil. The cold soil reduces water absorption by tree roots while the winds accelerate transpiration from the foliage. Exposed foliage on the east side of individual trees or entire stands may become dehydrated and die.

Sun scorch or *winter drying* are an abiotic condition caused by the effect of the sun on clear, bright winter days when the soil is very cold or frozen. Foliage on the sunward side of the affected trees warms and subsequently loses moisture due to transpiration. Because the trees cannot replenish the lost moisture, needles become dehydrated and brown. This condition is irreversible and often affects trees over large areas.

"Red belt"—trees with red crowns within a well-defined elevational zone or belt—is an uncommon form of low-temperature injury. The red or desiccated needles are caused by alternating cold night temperatures and wind-driven, unseasonably warm daytime temperatures that occur along elevational contours over frozen soil. Once again, affected parts of the trees die because transpiration rates exceed the trees' ability to replenish lost moisture.

Figure 2.—A stand that has been partially cut in an improper way is at greater risk of windthrow damage to the remaining trees.

High temperatures The most extreme high temperature is fire. Consequences range from scorched bark to obliteration.

Solar heating is not in the same league as a forest fire, but it can injure trees and in some cases even kill them. Examples of high-temperature effects include *foliage* (leaf or needle) *scorch, shoot tip dieback,* and *bark scorch* (or *heat canker*).

Foliage scorch describes conifer needles or hardwood leaves that were damaged by a sudden increase in temperature after the leaves began developing in cool weather. Leaf margins look seared or scorched. Conifer needles change from healthy green to red.

Shoot tip dieback describes heat injury in two different situations. In the first, sudden temperature increases in late spring and early summer can impair delicate new shoots, causing them to become brown, dry, and easily broken. This condition can be mistaken easily for frost damage.

In the second situation, large trees suffer top-kill from sustained high temperatures during the summer and fall when soil moisture levels are low. Dead tops resulting from this temperature–moisture dilemma can be diagnosed incorrectly as bark beetle damage.

The third kind of high-temperature injury is *bark scorch* (also called *heat canker* or *sunscald*). It can develop when bark and cambial tissues are exposed suddenly to solar heating. Forest managers risk this disease when they thin a dense conifer stand during summer. This is especially true if the trees have thin bark (Figure 3). Discolored, indented, and even fractured bark indicate this slow-to-heal malady.

Precipitation

Precipitation, in the form of rain or snow, is in itself of little consequence in causing abiotic disease. Water is used in dynamic but fairly innocuous life-sustaining processes. It collects on and slides off vegetation. It infiltrates the soil mantle where it combines with various chemical elements. Nutrients, made available by water, are taken up by tree root systems and used for survival, growth, and reproduction.

On the other hand, fierce rain accompanied by strong winds can damage tender foliage. Hail can injure trees, and, under the influence of wind, hail damage can be severe. Injury from hail is to the windward side of trees and is restricted to the upper surface of the branches.

Also devastating are freezing rain or ice storms. Under unusual conditions, these events can significantly injure and deform conifers and hardwoods. Consequences of both hail and ice storm injury are broken tops, cracked tree limbs, and bark fractures through which destructive insects and fungi can gain entrance.

Sometimes snow can be a problem in particular forest settings. For example, heavy snow can overwhelm young conifers, causing extreme bending and even breakage. Damage also can occur to pole-size conifers when snow or ice accumulates on witches' brooms caused by mistletoe or rust.

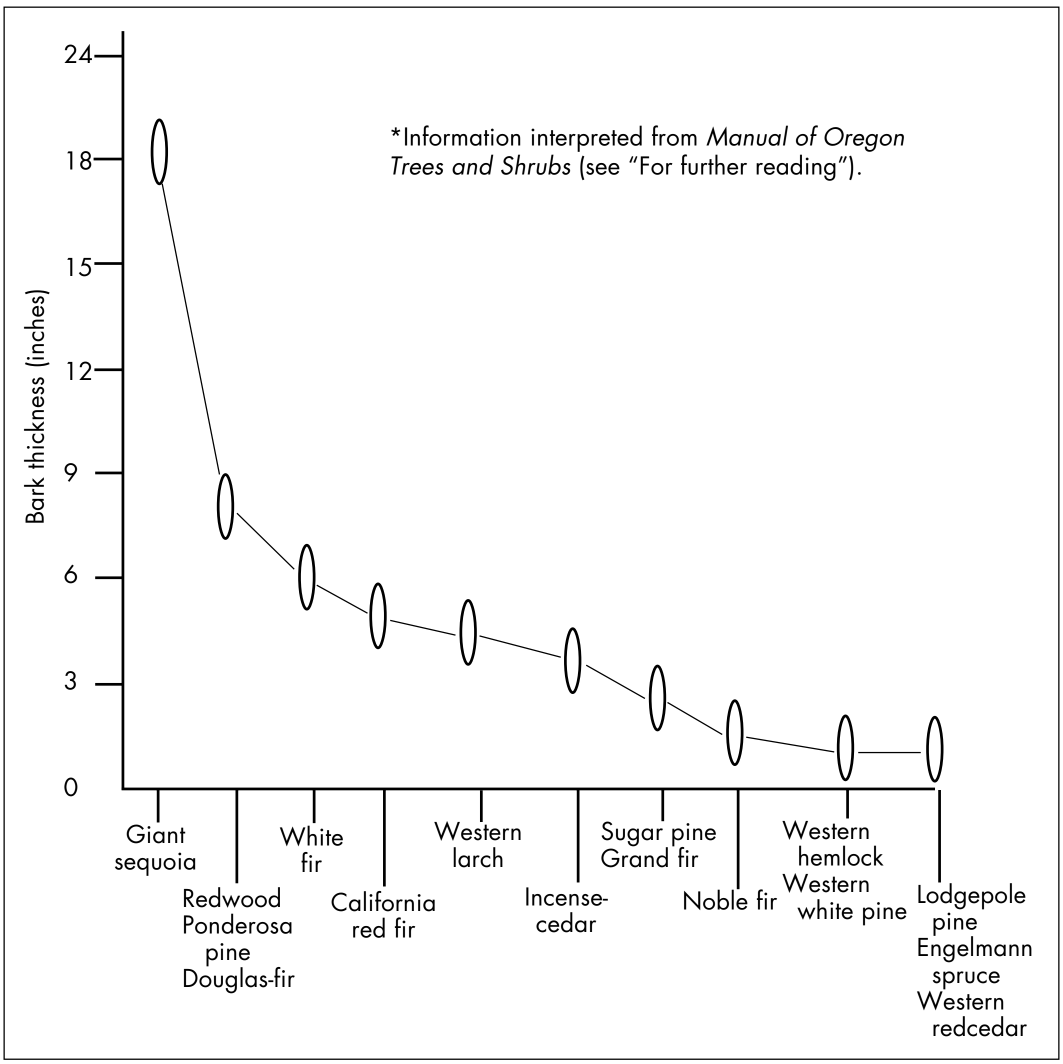

Figure 3.—Relative bark thickness of selected conifers found in Oregon.* (Note contrast with California's giant sequoia.)

Wind

Structural damage from wind is usually obvious and straightforward. Trees are broken and/or uprooted, also called windthrown (Figure 2, page 3). Injury typically is over broad areas but also can be on relatively small sites, such as those that have been improperly partially cut.

With some conifer species, such as white fir *(Abies concolor)*, harsh winds can distress the tree's wood cylinder, resulting in wood fiber separation along the annual growth rings. This injury, called *wind shake*, means a scaling deduction when the logs are sold.

Wind also can amplify other weather factors, such as temperature and precipitation, resulting in further impairment of tree survival, growth, and reproduction.

Trees that break bud prematurely might not go unscathed when spring temperatures plummet and winds blow. For example, wind at 20 knots (17.4 mph) when the air is 10°F has a wind chill effect of -28°F (Table 1, page 6).

Warm summer winds blowing over moisture-depleted soils also can cause physiological distress in trees by increased respiration and excessive transpiration, increasing the probability of foliage desiccation and even tree death.

"Red belt" injury and hail damage illustrate how wind can increase injury in other situations.

Lightning

Contrary to common belief, lightning doesn't target snags particularly. Dry wood isn't a good conductor of electricity. Unless a nearby snag is drenched with rain, a tall green tree is more attractive to lightning. The moist cambium layer under the bark of a live tree completes the electrical circuit by providing a direct route to the ground.

A lightning strike can destroy the entire tree or simply can skin off a strip of bark from the top of the tree to the ground in a straight line or a spiral. In some situations, only the tree top is killed.

Sometimes, lightning injury isn't visible externally. The only evidence may be the so-called "lightning rings" (abnormal cell development) formed along the annual growth rings.

Conifers struck by lightning are more susceptible to bark beetle attack (Figure 4, page 6).

Soil

Soils are separated into various layers or horizons, such as the litter layer, the humus layer, the A and B horizons, and parent material. Soil classification systems have been developed that organize soils into various Orders, Suborders, Great Groups, Subgroups, Families, and Series.

Woodland managers need a basic understanding of soil taxonomy and the variations among and within soil classifications. Differences in mineral content and in moisture-holding (and moisture-releasing) capacity are especially important. Abiotic injury normally identified with a particular soil condition may be misinterpreted if essential facts about that soil are unknown (see "Surviving abiotic injury," item 7, page 11.)

Minerals

The primary soil nutrients for tree survival and growth are nitrogen, potassium, phosphorus, calcium, magnesium, and sulfur. In forest soils, naturally occurring mineral (nutrient) deficiencies or excesses that prevent tree growth or cause injury are the exception rather than the rule. Table 2 (page 7) identifies common nutrient deficiency symptoms.

Forests on serpentine soils in the Siskiyou Mountains of southwest Oregon show nutrient deficiency symptoms. Characteristic symptoms include sparse vegetation with stunted growth. Serpentines are of volcanic origin, usually are shallow, and typically are low in molybdenum, nitrogen, phosphorus, potassium, and exchangeable calcium. They normally are high in magnesium, chromium, and nickel. Among Oregon's conifers, only Jeffrey pine *(Pinus jeffreyi)* is well adapted to serpentine sites.

Some tracts of Oregon's coastal forests display another distinctive type of nutrient imbalance. If the water table has a high salt content, conifers often have shortened, yellow needles with bronze tips.

Landowners who plant native trees on nonforest soils (afforestation), such as agricultural lands, may need to adjust existing soil nutrients to achieve acceptable tree development. For example, some farm lands tend to be alkaline (a soil pH above 7), whereas forest lands generally have acid soils (pH less than 7). Nutrients in equal amounts in farm and forest soils can differ in their availability to trees because of different pH levels.

Nutrient inaccessibility may be perceived as nutrient deficiency, especially in areas where soil compaction masks soil fertility. A soil test before tree planting can help to identify a nutrient imbalance that, left

Figure 4.—Conifers struck by lightning show increased susceptibility to bark beetle attack.

uncorrected, might result in poor seedling performance or even death.

Also consider planting seedlings inoculated with mycorrhizae (fungus–root symbionts) which increase root branching and growth. Mycorrhizae increase the tree's phosphorus uptake and facilitate transfer of organic nitrogen to seedlings from amino acids that were converted from mineral (soil) nitrogen.

Moisture

Soil moisture deficiency is the principal cause of abiotic injury to conifer and hardwood trees in Oregon. An exceptionally low level of precipitation or below-normal snow pack in the mountains may herald drought for whole forest stands. In addition, distinctive types of soil and varieties of vegetation in the natural landscape influence the availability of moisture for potential crop trees.

Symptoms of inadequate soil moisture include chlorotic and/or withered foliage, decreased growth rate, premature shedding of leaves or needles, and dead branches. Insufficient internal moisture usually is evidenced from the top of the tree down and from the outside of the crown to the inside.

Excessive water also can cause problems for developing trees. High water around ponds, lakes, and reservoirs can reduce air space in the soil, decreasing oxygen needed for root growth. Trees that suffer from too much water tend to die from the bottom up and from the inside of the crown to the outside.

Floods are not a common threat to forests in Oregon. Nevertheless, floods can seriously damage individual trees and forest stands. Fast-moving, turbulent waters can kill trees outright by uprooting them. Or, extensive erosion can strip soil from tree roots, diminishing the tree's ability to extract water and nutrients from the soil.

Though trees can be stressed by either too little or too much water, the most important consequence of the stress is that it predisposes trees to injury by insects and fungi. Stressed trees are less vigorous and less able to produce defensive chemicals to ward off attacks by many pests.

Table 1. Wind chill.*

Wind (knots)		Temperature (°F)										
	[miles/hour]	40	35	30	25	20	15	10	5	0	-5	-10
5	*[4.3]*	36	30	25	19	14	8	3	-2	-8	-13	-19
10	*[8.7]*	26	20	13	7	1	-6	-12	-18	-25	-31	-37
15	*[13.0]*	20	13	6	-1	-7	-14	-21	-28	-35	-42	-49
20	*[17.4]*	16	9	2	-6	-13	-20	-28	-35	-42	-50	-57
25	*[21.7]*	13	6	-2	-9	-17	-25	-32	-40	-47	-55	-63
30	*[26.1]*	11	4	-4	-12	-20	-28	-35	-43	-51	-59	-66
35	*[30.4]*	10	2	-6	-14	-22	-30	-37	-45	-53	-61	-69
40	*[34.8]*	3	1	-7	-15	-23	-31	-39	-47	-55	-63	-71

*Information is from the Oregon Climate Service, the archive agency for Oregon weather and climate data, serving Oregon and the Pacific Northwest. OCS is affiliated with the College of Oceanic and Atmospheric Sciences at Oregon State University, Corvallis.

Bark beetles, for example, attack conifers that are drought stressed. Damage and/or mortality caused by bark beetles increases dramatically during and for a few years following drought.

Human activity

Are we part of our environment, or are we simply "onlookers"? Most of us agree that we are or should be stewards of the natural resources in our environment. Caring for and wisely using forest resources certainly conforms to this understanding.

Sometimes, forest resource managers and users find themselves *mis*managers and *mis*users. For one reason or another they bungle the job. On the other hand, people not associated with managing forest resources also contribute to forest survival and growth dilemmas.

Human activity is a cause of abiotic injury. People can, voluntarily or not, harm forest resources. An arson fire, for example, is a deliberate human action that damages a forest. Voluntary injury also comes from not considering the possible consequences of an activity or operation. Herbicide damage from overspraying target vegetation on a windy day is an example of negligence.

Involuntary or unintentional damage, on the other hand, may happen when people are truly unaware of the possible outcome of their activities. One example would be a prescribed fire that escapes from established boundaries even after the woodland manager observes all the required precautions and regulations.

Here are three cases in which human activities contribute to abiotic injury.

Table 2. Nutrient deficiency symptoms in trees.*

Nutrient	Function	Symptoms
Nitrogen	Key component of proteins	Discolored foliage (yellow). Premature death of buds and foliage. Poorly developed root structure. Stunted tree growth.
Potassium	Significant in cell division and in formation of proteins	Inhibited foliage development and root growth. Discolored foliage (yellow to "scorched"). Death of needle tips/leaf edges.
Phosphorus	Component of cell nucleus; important in cell division	Discolored foliage (bronze to purple). Deteriorated older foliage and buds. Restricted root growth.
Calcium	Important part of substance bonding cells together	Stunted tree growth. Discolored foliage (brown). Death of leader tip and branch shoots. Death of root structure.
Magnesium	Component of chlorophyll molecule	Discolored foliage (yellow). Premature loss of foliage.
Sulfur	Component of proteins; important in respiration	Symptoms similar to nitrogen deficiency.

* Information excerpted from:

1. Gessel, S.P., K.J. Turnbull, and F.T. Tremblay, *How to Fertilize Trees and Measure Response,* Natural Plant Food Institute (Washington, DC, 1960).
2. Wilde, S.A., *Forest Soils,* The Ronald Press Company (New York, 1958).

Air pollutants

Air pollution has begun to cause concern for human health in Oregon communities. Although air quality has not yet become a significant forest health problem in Oregon, sophisticated monitoring methods using state-of-the-art technologies (ground-based studies, aerial surveys, satellite imagery) are assessing Oregon forests for damage caused by airborne chemical pollutants.

Ozone is on the increase. It is the product of a photochemical reaction of nitrogen dioxide and hydrocarbons (given off by gasoline-powered motor vehicles and some industrial operations) and sunlight. Ozone damage to forests generally is not a problem in Oregon. There is, however, growing apprehension because of the increase in the number of people in and near forest lands (area residents and recreationists) and the consequent rise in fossil fuel use.

General symptoms of ozone injury include mottled older foliage, premature loss of older leaves or needles, reduced tree growth (tree tops tend to flatten out), and dead branches.

Herbicides

Chemical herbicides are used in farm, forest, park, and residential settings. Used wisely, herbicides cause little or no damage to nontarget vegetation. On the other hand, careless or inappropriate use can result in significant, very costly damage. Woodland managers who use chemical herbicides need to be alert to the danger of injury to nontarget forest vegetation.

Chemical herbicide container labels list the target plants and give instructions for proper application and safety. Table 3 lists damage symptoms caused by herbicides commonly used in forests. A sublethal dose of glyphosate, for example, may cause new foliage to be twisted, curled, or otherwise malformed.

Detailed information about herbicide application and safety requirements is available from distributors and manufacturers of chemical herbicides, from the Oregon Department of Forestry, and from the OSU Extension Service office that serves your county.

Mechanical damage

Crawler tractors, rubber-tire skidders, and four-wheel-drive vehicles can injure trees. So can livestock. The common element in these kinds of damage is human negligence. People can, either directly or indirectly, cause mechanical damage that affects tree survival and growth.

The most obvious type of injury to standing trees is structural damage. Trees of all ages can sustain wounds. Examples include trunk injuries *(cat faces)* from bulldozer blades and tree breakage during the felling and yarding stages of a logging operation. Such damage, if excessive, can decrease the growth and reduce the value of the landowner's timber resource. Thin-bark trees of course are more vulnerable to damage by heavy equipment during logging. Figure 3 (page 4) shows relative bark thickness of certain mature conifers.

It also is important to recognize that minor tree wounds (not serious enough to restrict tree growth) might provide entrance points for biotic diseases and/or destructive insects. Disease and insect damage may prove worse than the physical damage caused by heavy equipment. For example, dormant infections of the stem-decaying Indian paint fungus are triggered by mechanical injuries. Indian paint fungus is the major cause of stem decay in old-growth grand and white fir in eastern and southern Oregon. For details, see Manual 9, *Forest Disease Ecology and Management in Oregon* (page 11).

A more subtle type of mechanical damage to forest trees is from site disturbance and soil compaction. Logging or road-building equipment and unmanaged herds of domestic livestock can easily damage trees' root systems.

Ninety percent of a tree's fine roots grow in the top 2 feet of soil. Most of the tree's water-absorbing roots grow in the uppermost layers of the soil, many within a few inches of the surface. Soil compaction can reduce water penetration in the root zone and impede gas exchange in roots. Consequences include increased mortality of fragile, nutrient-absorbing roots, restricted root growth, and less potential for nutrient and water uptake. Trees growing on compacted soils may have many of the symptoms of moisture deficiency (water stress).

Wildfire

Lightning can cause a wildfire, but lightning isn't the only cause. People cause wildfires, too. Whether by arson or carelessness—that is, improperly maintaining or using equipment—the consequences are the same. Wildfire injury can lead to growth impairment, loss of wood quality, and death.

Tree wounding is a direct effect of wildfire (Figure 5, page 11). Wounding and stress caused by wildfire commonly predispose both hardwood and coniferous trees to biotic attack. For example, as in the case of trees stressed from drought, bark beetles often damage and kill trees injured by wildfire, attacking the same year as the fire and for a few years after.

Surviving abiotic injury

Although abiotic injury can't be averted completely, damage can be prevented or minimized through planning, good silviculture, and stewardship. People are the key to coping with abiotic injury through each of these forestry practices. Techniques to foster stand establishment, development, productivity, and vigor include:

1. Reduce **mechanical injury** to trees during harvesting by methods such as directional felling to avoid injury to remaining trees. Careful yarding with cables and heavy equipment minimizes wounding of standing trees.

Table 3. Symptoms of damage caused by herbicides commonly used in forestry, listed according to effect on plant.[a]

Herbicide mode of action Common name	Trade name(s)	Damage symptoms
1. Photosynthesis inhibitor		Marginal leaf chlorosis (yellowing); death of leaf inward from margins or tip; crinkling of leaf margin.
atrazine*	AAtrex, Atrazine, Atra-Pril, Cheat Stop	
simazine	Princep, Simazine	
hexazinone	Velpar, Velpar L, Velpar ULW, Pronone	
linuron	Lorox, Linex	
2. Amino acid and protein synthesis inhibitor		Mottled foliage, chlorosis; growing points often killed; young leaves show severe necrosis *(necrosis = death of living tissue)*; mature leaves develop random necrotic spots that enlarge over time; stem dieback; plant death. Sublethal dose may cause new foliage to be twisted, curled, or otherwise malformed.
glyphosate	Roundup, Roundup L & G, Rodeo, Kleenup, Accord, Honcho, Roundup RT, Expedite Grass & Weed, E-Z-Ject, Jury, Mirage, Pondmaster, Protocol, Rattler, Ruler, Silhouette, Roundup Quik Stik, Roundup Drypak	
sulfometuron	Oust	
3. Enzyme inhibitor (enzyme used in amino acid synthesis)		Abrupt termination of growth in some species; shortening of internodes; chlorosis and necrosis.
imazapyr	Arsenal, Chopper, Contain, Arsenal Applicator Concentrate	
metsulfuron	Escort, Ally	
4. Natural plant hormone imitator		Abnormal plant growth including needle twisting or leaf curling; dieback, wilted and/or brittle leaves; severe stunting; malformation of roots and shoots.
2,4-D	*Numerous trade names*	
triclopyr	Garlon 3A, Garlon 4 Herbicide, Turflon D, Redeem, Remedy	
picloram*	Tordon 22K	

* Restricted-use herbicide

[a] Information excerpted from:
1. *Pacific Northwest Weed Management Handbook*
2. *Herbicide Families and Injury Symptoms*, Florida Agricultural Information Retrieval System. http://hammock.ifas.ufl.edu/txt/fairs/18078

2. **Soil compaction and disturbance** can be controlled by properly planning, building, and using designated skid trails and by using yarding equipment suited to the task at hand.

3. Damage from **wildfire**, whether caused by lightning, arson, or negligence, does not have to be catastrophic. Prudent woodland managers prepare for fire by building road systems and fire breaks beforehand. Managers also eliminate concentrations of woody debris and ladder fuels to minimize potential for a crown fire.

4. Injury to forested properties from human-generated **air pollutants** and **chemical herbicides** is, of course, the responsibility of individuals, industries, and government. Research, education, and in some cases legislation are fundamentally important in using chemical herbicides wisely and in managing chemical byproducts. In the end, effective problem solving can emerge only from individual, community, and corporate acceptance of responsibility.

An example of the public's accepting responsibility for chemical use is Oregon Revised Statutes (ORS), Chapter 634. This section requires that *all pesticides produced, distributed, sold or offered for sale in Oregon be registered with the Oregon Department of Agriculture*. This is in addition to federal registration required by the 1947 Federal Insecticide, Fungicide and Rodenticide Act as amended in 1972, 1975, 1978, and 1988.

Table 4: Tolerance to drought, frost, flooding, and shade: a comparison of selected Oregon tree species.*

Species	Tolerance to:[a] Drought	Flood	Frost	Shade
Conifers				
Douglas-fir *(Pseudotsuga menziesii)*	3	5	3	3
Engelmann spruce *(Picea engelmanni)*	4	2	1	4
grand fir *(Abies grandis)*	4	2	3	2
incense-cedar *(Calocedrus decurrens)*	2	3	3	4
lodgepole pine *(Pinus contorta)*	2	1	1	5
noble fir *(Abies procera)*	4	4	2	4
Pacific silver fir *(Abies amabilis)*	5	4	1	1
ponderosa pine *(Pinus ponderosa)*	1	3	2	5
sugar pine *(Pinus lambertiana)*	2	3	3	4
western hemlock *(Tsuga heterophylla)*	5	2	3	1
western larch *(Larix occidentalis)*	3	2	2	4
western redcedar *(Thuja plicata)*	4	1	3	2
western white pine *(Pinus monticola)*	2	2	1	3
Hardwoods				
bigleaf maple *(Acer macrophyllum)*	3	4	3	2
bitter cherry *(Prunus emarginata)*	4	4	3	5
black cottonwood *(Populus trichocarpa)*	5	1	3	5
California black oak *(Quercus kelloggii)*	1	4	2	5
California-laurel *(Umbellularia californica)*	3	2	4	2
canyon live oak *(Quercus chrysolepis)*	1	3	3	4
golden chinkapin *(Castinopsis chrysophylla)*	3	4	2	2
Oregon ash *(Fraxinus latifolia)*	3	1	3	3
Oregon white oak *(Quercus garryana)*	1	2	2	5
Pacific madrone *(Arbutus menziesii)*	2	4	2	4
red alder *(Alnus rubra)*	4	3	4	5
tanoak *(Lithocarpus densiflorus)*	3	4	4	1

[a] Tolerance: 1 = high; 5 = low

* Information developed by William Emmingham, Extension silviculturist emeritus, Oregon State University.

5. Planting stock selected to reforest cut-over areas should fit seed-zone and elevation guidelines. Inappropriate, out-of-zone seedlings will not meet tolerance requirements for drought, flooding, frost, and shade (Table 4). The seedlings—and, if they should survive, young saplings—are at greater risk for **weather injury** and premature mortality.

Tolerance is a tree species' ability to survive (*to tolerate*) specific environmental conditions (Table 4). Western hemlock, for example, can survive and grow under deep shade (tolerance level 1) but has difficulty in a droughty situation (tolerance level 5). Oregon white oak grows quite well on droughty sites (tolerance level 1) but poorly if at all in deep shade (tolerance level 5).

6. Prudent precommercial thinning of stands in windy areas (e.g., dense ridgetop stands) can preclude **wind damage**. In addition, careful attention to tree spacing while thinning

dense stands of thin-bark trees can avert **bark scorch**.

7. In reforestation or afforestation, first evaluate the site's **soil minerals** (nutrients). Extension foresters can give information on soil testing, interpreting test results, and properly using chemical fertilizers to improve forest trees' growth. Contact the OSU Extension office that serves your county.

In addition, soil survey information and maps are available from the USDA Natural Resources Conservation Service (NRCS), formerly known as the Soil Conservation Service (SCS).

8. On woodland properties with inadequate **soil moisture**, pay close attention to nonessential vegetation and tree spacing. Controlling unnecessary vegetation means more of the site's water is available for desired tree species and other flora.

Properly timing precommercial and commercial thinning eases moisture stress. Also, appropriate sanitation and salvage logging can be helpful in forest stands where low soil moisture causes problems.

Conclusion

Landowners and managers are responsible for preventing abiotic damage and managing stands with abiotic damage. Silvicultural practices that guide forest establishment, composition, and growth provide solutions to various abiotic dilemmas. Woodland managers working to alleviate abiotic injury and its effects should seek help from forestry professionals, partnerships with other woodland owners, and constructive communication with neighbors. Sources of help include:

Oregon Department of Forestry
2600 State Street
Salem, OR 97310
503-945-7376

Forest Sciences Laboratory
College of Forestry
Oregon State University
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Figure 5.—Wildfire damage is evident in the blackened trunks of these conifers.

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For further reading

OSU Extension publications

Filip, G.M., A. Kanaskie, and A. Campbell 3rd, *Forest Disease Ecology and Management in Oregon*, Manual 9. 1995. 68 pp.

Filip, G.M., D. Overhulser, and P.T. Oester, *Forest Insect Ecology and Management in Oregon*, Manual 10. 1998. 60 pp.

Pacific Northwest Weed Management Handbook. Revised annually; 2003 edition has 422 pp.

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Other publications

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The Woodland Workbook is a collection of publications prepared by the Oregon State University Extension Service specifically for owners and managers of private, nonindustrial woodlands. Publications contain information of long-range and day-to-day value for anyone interested in wise management, conservation, and use of woodland properties. Publications are available in a three-ring binder with tabbed dividers for each section. For information about how to order, and for a current list of titles and prices, inquire at the OSU Extension Service office that serves your county.

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