Tree Buffers along Streams on Western Oregon Farmland

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The listing of many Pacific Northwest anadromous fish stocks as threatened or endangered has heightened the need to protect or enhance the health of entire river systems. Salmon, steelhead, and other anadromous fish swim from the ocean to the headwaters of their home river, where they spawn. Their young hatch and live for a time in the streams and rivers before returning to the ocean. Stream conditions along the **entire migration route** are important to the success of anadromous fish populations.

This publication explores a variety of options, mindful of trade-offs between farmland production and fisheries and wildlife values.

Stream conditions depend in part on the vegetation in the riparian zone near the water. Trees shade the water, helping to keep summer stream temperatures in a range more favorable to fish. Leaves from trees and shrubs fall into the water and provide energy for the aquatic food chain that feeds insects and fish. Trees that fall into streams provide important structure that enhances spawning and rearing habitat for fish. Vegetation also protects the streambanks from excessive erosion during flooding.

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Basic concepts: Why establish a tree buffer?

In undisturbed river systems, native trees and shrubs growing in the riparian zone provide multiple physical and biological benefits (Figure 1b, page 4). The objective of riparian tree buffers is to restore many of these benefits in a relatively short time (Figure 2, page 4, and Figure 3b, page 5).

Physical benefits

Temperature moderation Energy in the form of light from the sun increases stream water temperature. Solar energy hits the water as both direct and diffuse light. Sun shining directly on the water is a strong energy input. Diffuse skylight comes in from the clear or cloudy sky overall; it is a relatively weak source of energy. Therefore, trees that block direct sunlight provide the most benefit; however, foliage that blocks diffuse light is also beneficial. Stream water also is warmed by direct contact with the warmer air and ground surrounding the stream. The shade of tree buffers helps keep the air and streambanks relatively cool, cutting *convective heat transfer* to stream water.

Streambank protection and in-stream habitat Trees, shrubs, and other vegetation protect against erosion from running water, especially during flooding. Riparian vegetation slows the stream's current and traps silt or sand suspended in floodwaters, thereby helping to filter the water and build streambank soil to support more vegetation. Tree trunks, roots, and debris jams provide important structure for aquatic habitat. Tree buffers tend to trap logs and woody debris carried by floods. Some of the trees grown in tree buffers may eventually die, fall into the stream, and provide valuable niches in aquatic habitat—traps for wood and leaf material used as food by aquatic insects and as critical cover by young salmonids hiding from fish predators such as great blue herons, kingfishers, and raccoons.

Biological benefits

Removing nutrients from groundwater and runoff Most nutrients are considered pollutants when they enter streams in high concentrations. Nitrogen and phosphorus used in fertilizers can contribute to *nonpoint-source pollution* of streams if they flow directly into the streams (Figure 1a). However, plants in a riparian zone will take up nutrients left over from fertilizers (Figure 1b, page 4) and use these nutrients for growth. Vigorously growing plants in tree buffers store nutrients in leaves and wood. Nutrients stored in wood that is removed from the site (e.g., via tree harvest) are effectively exported. Wood also is built from carbon dioxide removed from the atmosphere; therefore, tree buffers act to *sequester carbon* and reduce greenhouse gasses. Nutrients stored in leaves that fall on land will move into the soil when the leaves decompose. These nutrients can be taken up again by plants growing in the tree buffer. Organically rich soils typically develop beneath trees, and these soils hold more nutrients.

Decomposition of toxins Studies have shown that wood-decomposing organisms in tree buffers also enhance the detoxifying functions in the soil of tree buffers. After trees become established and grow, wood-decomposing organisms build up in the soil as branches and leaves fall to the ground. Toxins in some herbicides such as 2,4-D are broken down sooner by the organisms in a tree buffer than in a pasture or tilled field. Soils in tree buffers also enhance *denitrification* (nitrogen release) activity in the soil. Therefore, excess nitrogen from fertilized crops that enters the tree buffer is turned into a gas (denitrified) and released into the air where it is harmless. Thus, tree buffers can help detoxify herbicides and remove excess nitrogen used in managing farm crops.

Tree buffers or filter belts are plantations of trees and other vegetation established along streams or rivers to provide shade for streams, to provide riparian habitat, and to help filter excess nutrients and toxins from runoff or groundwater. Buffers benefit fish by providing better stream habitat and benefit wildlife by providing food and shelter; also, they are often aesthetically pleasing or are used for recreation. Although filter belts and tree buffers can differ in design and function, similar techniques are needed to establish trees for both types. We will use the term *buffer* throughout this publication.

This publication provides strategies and techniques for establishing these protective structures on agricultural lands in western Oregon. It is a guide for farm owners and managers who have little experience with this complex task. We will explore a variety of options, mindful of trade-offs between farmland production and fisheries and wildlife values. We will cover basic concepts, planning, site evaluation, species selection, site preparation, planting, vegetation management, and commercial harvest as well as long-term riparian forest schemes. Although the focus will be on trees, the concepts apply as well to shrubs, herbs, and grasses.

(text continues on page 6)

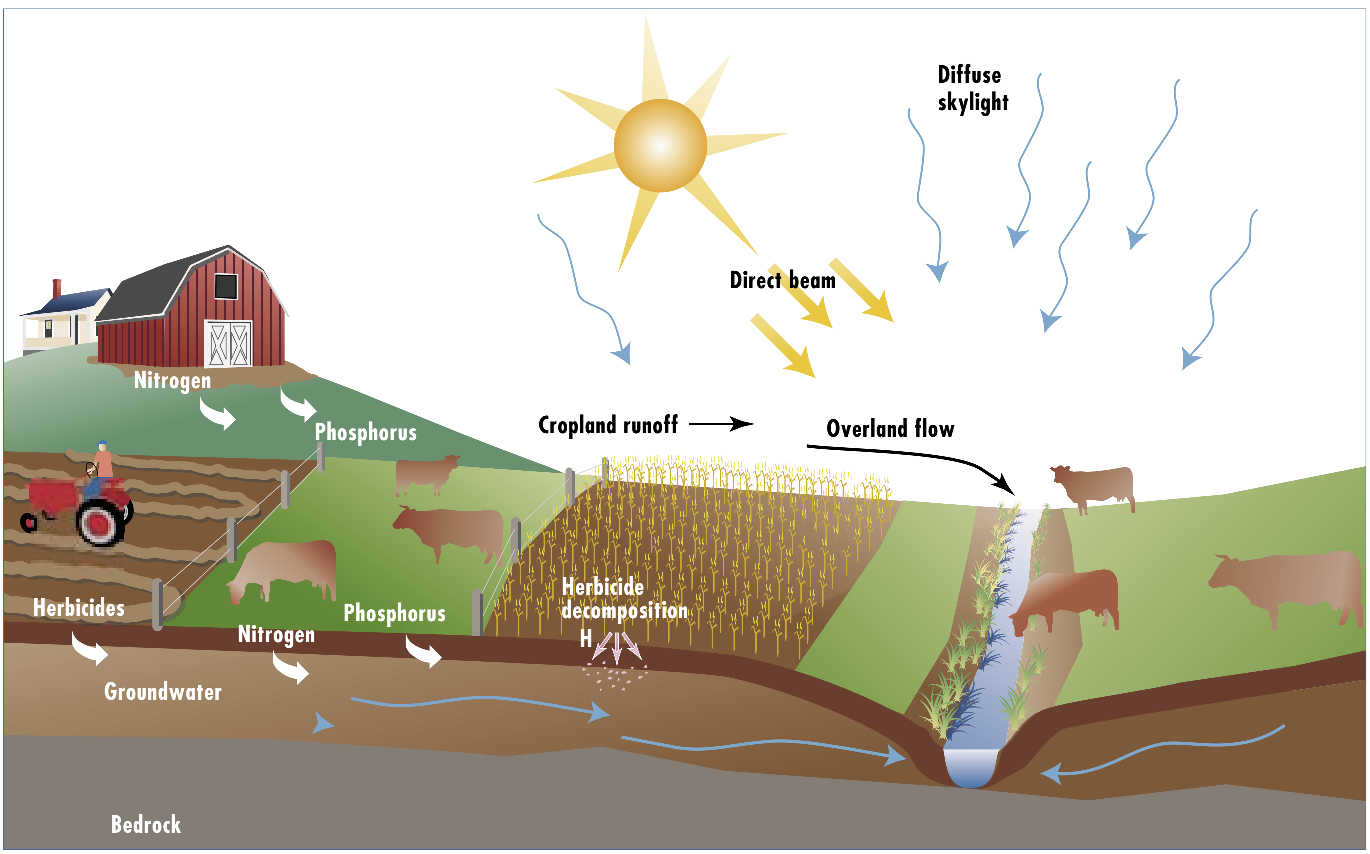


Figure 1a. Intensive farming often pushes farming to the streambank and removes native trees and shrubs. Unshaded streams are heated by direct sunlight or diffuse skylight. Erosional sediments, nutrients from fertilizers, or herbicide residues may be carried into waterways by overland flow or groundwater.

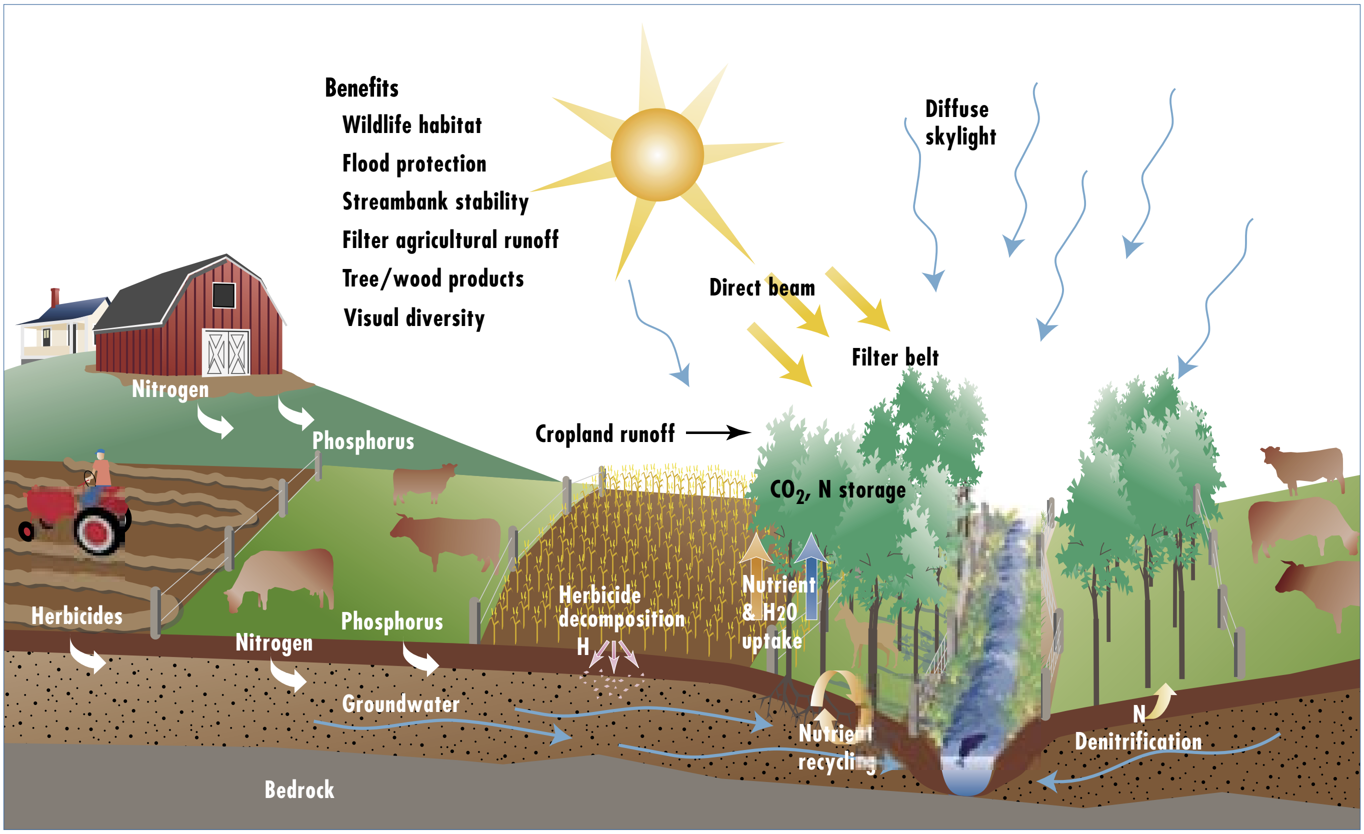


Figure 1b. Tree buffers provide an ecological filter between farmland and streams, rivers, and lakes. Buffers also can provide shade, reduce erosion during high water, and improve both in-stream and riparian habitat for fish and wildlife. Beneficial functions also include absorbing excess nutrients before they enter the stream, enhancing denitrification of nitrogen and sequestering carbon dioxide (see "Biological benefits," page 2). Many streams of the Pacific Northwest have very low flow rates in summer, so shading that helps reduce stream temperature is a primary benefit for juvenile salmonids and other fish.

Figure 2. Intensive pasturing of cattle (far bank) has denuded the streambank, which is now subject to erosion during high winter flow. Lack of tree cover means that the stream heats up during summer's low flows, and filtering action is reduced. Note the heavy grass cover on the near bank, which grew because fencing excluded the cattle.

Figure 3a (at top). A stream reach in a pasture in the Oregon Coast Range just after a tree buffer was installed. Note erosion and lack of tree or vegetative cover on the streambanks.

Figure 3b. The same site, 5 years after fencing to exclude livestock and planting a red alder tree buffer. The tree buffer is well established; trees 20 to 25 feet tall are shading the stream, providing leaf material to feed the aquatic food chain and providing habitat for wildlife. Devices were used to protect the trees from beaver cutting.

Figure 4. The streambank on the left has recovered considerably in the 3 years since it was fenced and a red alder tree buffer was established. The alder are beginning to provide shade, and the vigorously growing grass is protecting the streambank. The right streambank was not protected by fencing, and cattle have been grazing it.

Tree buffers of fast-growing trees such as red alder *(Alnus rubra)* or hybrid cottonwood *(Populus* spp.) can provide substantial benefits within a few years of planting and, in some cases, a cash crop in 8 to 12 years. They are particularly valuable for producing shade and for filtering along streams where intensive agriculture or grazing extends to the water's edge and native trees and shrubs have been removed (Figure 1a, page 3, and Figure 2, page 4).

Tree buffers only a few feet wide can provide many benefits while removing a minimum of land from agricultural production (Figure 1b, page 4).

Types of tree buffers

Tree buffers can be designed for many different situations and objectives, from a simple line of trees to a large plantation or complex forest. The ideas presented here are on a gradient from small to large and from simple to complex. Different types may be mixed along stream reaches. The buffer type selected will make a big difference in the benefits and when they are achieved. A larger buffer close to the stream will provide more benefits at an earlier time than a small buffer farther away.

Individual trees and irregular clusters

"Every little bit helps." Streams often wind, and farming is not possible close to the entire length of the streambank. Planting small clumps of trees in places that are not easy to farm is a good way to provide some filtering and stream protection (Figure 5a). Because some trees might not grow well and small trees require only a small space, it is a good idea to plant several trees together, even if there is growing space for only one large tree. It is easy to remove one or more trees when they have grown past the early stage, when risk of mortality is high. The rule of thumb is "If one tree will be enough, plant three in the rough."

The advantage of this approach is that little, if any, ground is taken out of farm production. The disadvantage is that tree cover may not be continuous along the stream, and individual, scattered trees will not provide a significant amount of protection until they grow large, in 5 to 20 years. Also, you must provide

Figure 5a. Individual trees and irregular clusters.

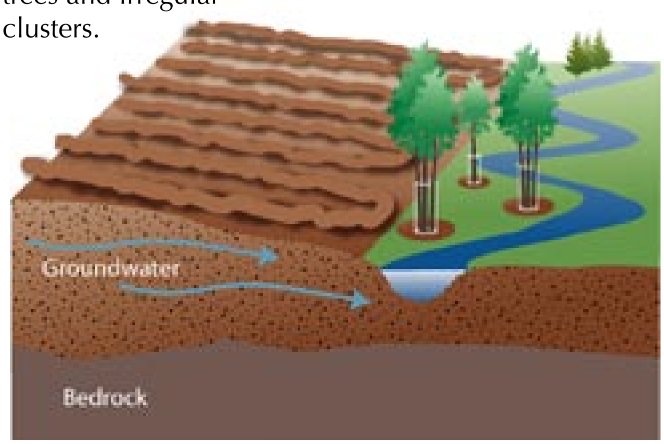
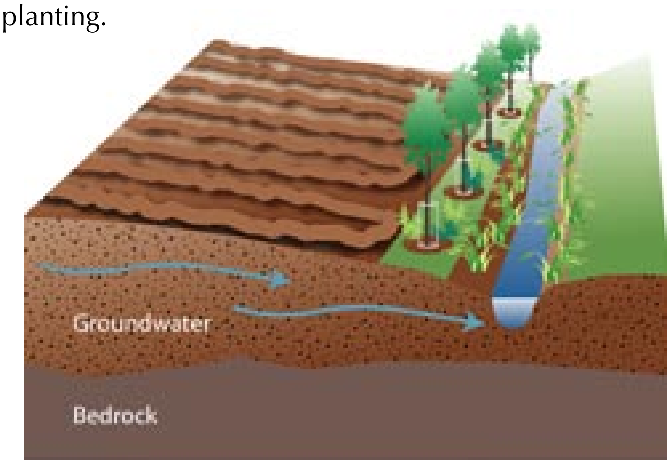


Figure 5b. Single-row planting.



protection from farm animals or wildlife for individual trees or clumps.

Single-row planting

"A good compromise solution." Where space is limited and minimal tree cover is the primary goal, simply planting and protecting a single row of trees along the streambank is a good option, and it eventually can provide considerable shade as trees grow larger (Figure 5b). A disadvantage is that a few small trees do not provide much shade, so early filtering or buffering effects are minimal. Significant beneficial effects come over time after trees grow tall and have large crowns. A single row of trees could be protected by individual tree protectors or by fencing. The advantage of this approach is that it removes a minimal amount of land from agricultural production while providing long-term benefits.

Multiple-row planting

"A few rows add a lot more benefits." Where more space is available, a tree buffer of several rows of trees provides considerably more benefit (Figure 5c). Because the trees will form a canopy, the shading benefits are greater and come sooner. There will be more organic debris and more wildlife habitat. The amount of wood produced is not great, but wood could be harvested on a small scale (e.g., for firewood) as trees grow larger and need to be thinned.

Large commercial plantation

"Wood production and value can help pay the bills." If commercial wood production is an objective, you can plant a larger area (Figure 5d). How large an area you need for a commercial enterprise depends on many factors including local market conditions,

Figure 5c. Multiple-row planting.

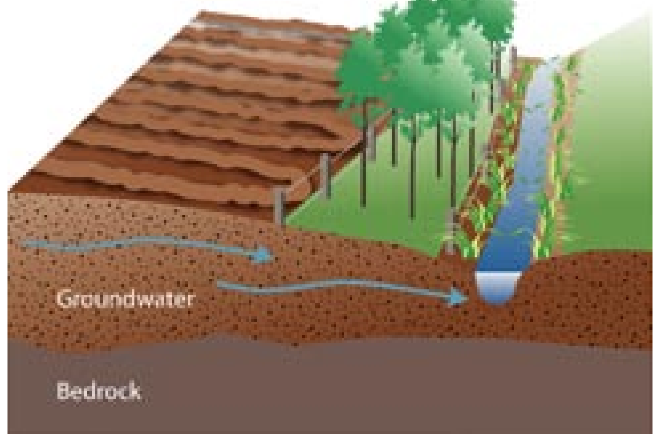
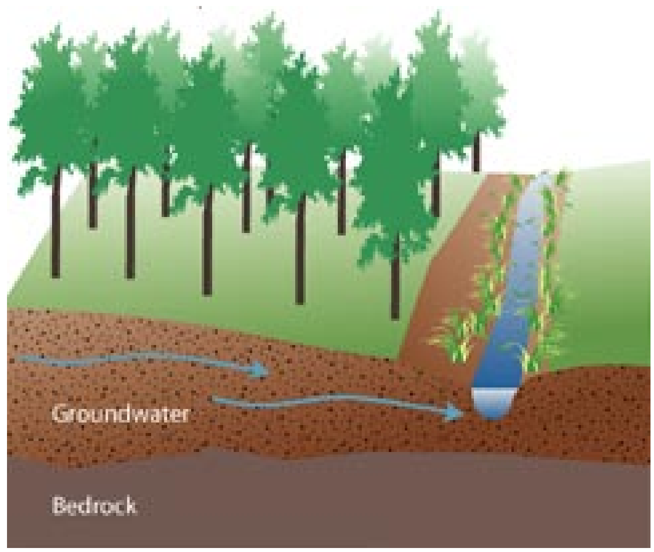


Figure 5d. Large, commercial plantation.



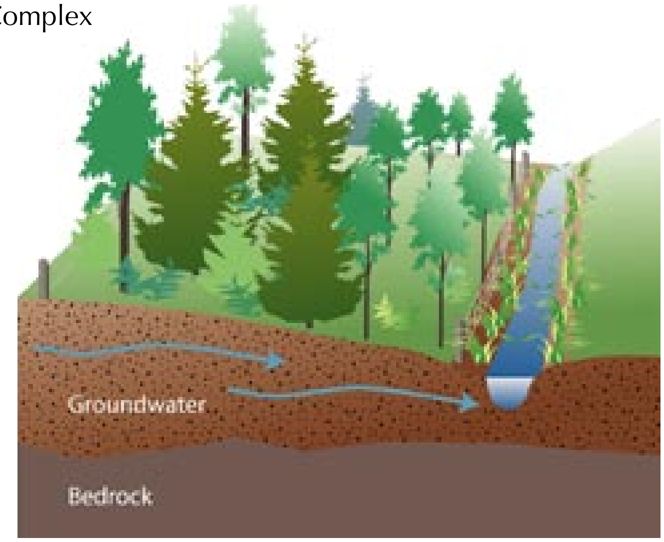


Figure 5e. Complex forest.

distance to market, and availability of harvest equipment. Be sure to check local markets to see which species is in demand. Hybrid cottonwood can produce a crop in less than 12 years and is considered an agricultural activity so that harvest restrictions placed on forestland do not apply. Most other species will take 2 to 4 decades to produce commercial-size trees. Thinning is a good way to keep residual trees healthy while providing useful wood products. During thinning operations, leave enough trees to continue providing tree buffer functions. See *Thinning: An*

Table 1. Types of tree buffers and area required.

	Area required*		
Type of tree buffer	Square feet	Acres	Percentage of 20 acres
Clumps and individual trees	Little or none	0	0
Single row with individual tree protecters (166 spray circles, each 4 ft in diameter)	2,086	0.05	less than 0.3
Single row fenced (6-ft spacing, 6 ft wide)	6,000	0.14	0.7
Three rows (6-ft spacing, 18 ft wide)	18,000	0.42	2.1
Six rows (10-ft spacing, 50 ft wide)	56,000	1.28	6.4
Plantation (100 ft wide)	100,000	2.29	11.4
Complex forest (100 ft wide)	100,000	2.29	11.4

* Calculations are based on 1,000 ft of stream reach with buffer on one side.

Important Timber Management Tool, PNW 184 (page 23) for information about thinning.

Complex forest

"The high end produces multiple values." When objectives include long-term stream protection, wildlife habitat and diversity, recreation, and even wood production, the strategy can be to establish a more complex forest with several tree species, shrubs, and other vegetation (Figure 5e). This type of tree buffer is considerably more difficult to establish, but the additional values generated may be worth the extra effort. Leaves from a mixed stand of conifer and hardwood species will support a more complex food chain of aquatic life than a single-species buffer. A more diverse plant community will support more species of wildlife. Recreational features such as picnic sites can be added.

Be forewarned that this approach requires extra effort and more skill to carry out. For example, different trees with different growth rates will require planting at different spacings. Clumps of conifers should be planted no closer than 15 feet to fast-growing hardwoods. Fast-growing hardwoods can be planted close to the stream to provide shade in only a few years, while slow-growing conifers are placed away from the stream since they eventually grow taller than the hardwoods. Desirable shrubs or grasses may be added to replace blackberries or other invasive species. If recreation sites are to be included, buffers should be designed to fit the type of recreation planned. For example, if fishing is an objective, keeping the streambanks open and accessible is important.

The buffer type selected will make a big difference in the benefits and when they

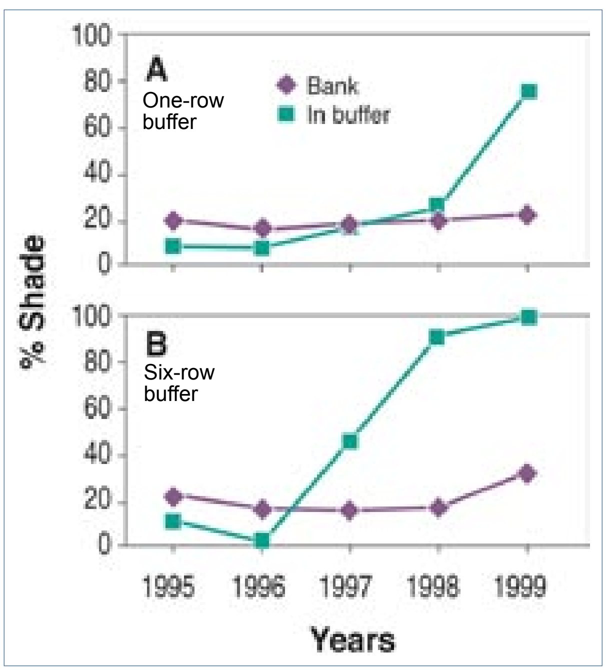


Figure 6. The percentage of a sunny summer day that a riparian area in the Oregon Coast Range is shaded. Shade-time percentages are related to the location and age of the buffer trees in (A) a one-row buffer and (B) a six-row buffer. Shade provided near the stream (purple line) for the first 2 years (for the one-row buffer) to 4 years (for the six-row buffer) was provided by the tall grass that grew after livestock were fenced out. Shade under the buffer trees (green line) rose to over 80 percent in the fourth year after planting (B). In the fifth year, the six-row buffer began to shade the stream as the trees grew tall enough to cast shade some 10 to 15 feet from the edge of the buffer rows. Establishing buffers closer to the stream would provide more shade to the stream in a shorter time. Note the six-row belt provided more shade earlier than the one-row buffer.

occur. A larger buffer that is close to the water will provide more benefits earlier than a small buffer farther from the water (Figure 6).

Establishing tree buffers

Evaluating site characteristics

The exact location, tree species, and type of tree buffer selected depend not only on your objectives but also on many characteristics of the site including soils, location, and surrounding land uses. Get the answers to questions such as:

- What tree species will do well on this site?
- How can you get the most benefit to the stream without using a lot of farmable land?
- What problems are likely with weeds, tree predators, and floods?

Site factors Site factors include slope, aspect, elevation, and position with respect to the stream. These factors determine basic growing conditions for the trees and other plants that will become established in tree buffer. Elevation determines rainfall; aspect and soil characteristics determine moisture conditions during the growing season.

Soils Soil factors include soil texture and depth, rock content, and overall water- and nutrient-holding capacity. Riparian sites sometimes have heavy clay soils. In general, soils in a given riparian area are notoriously variable because of the ways in which streams meander, causing periodic soil deposition or erosion. Because rock content can vary widely, moisture-holding capacity also varies. The depth and seasonal differences in the water table are important in determining which tree species will survive and thrive on a particular site. Some trees—for example, Douglas-fir—will die if flooded for a week or more, even in winter. Others, such as Oregon ash, can survive both winter flooding and summer drought. Many agricultural sites provide good growing conditions, suitable for fast-growing trees such as cottonwood, red alder, and willow.

Stream factors Streams and rivers interact with the land in many complex ways. Some streams meander through deep soils while others are constrained, confined, or channeled through bedrock. Some locations flood annually while others rarely flood. Some riparian zones have uniform soils while seasonal overflow or flood channels dissect others.

Management factors Management factors include equipment access and present vegetation. Most likely, the site has been plowed recently or is in pasture. In either case, assume that trees, like most crop plants, need help in getting established, especially during the long summer drought in the Pacific Northwest. Where soil conditions are suitable and farming equipment is available, the site can be prepared by plowing. Early control of competing vegetation also may be possible with farming equipment. Otherwise, manual labor or herbicides will be necessary to control competing vegetation.

Pest management factors Tree predators are a primary cause of tree buffer failure, so it is essential to know what types of wildlife or livestock have access to the site. You may not have serious tree predators (e.g., deer or beavers) until the trees are planted and the animals come in to use the new food source. In pastures, livestock will be a problem unless young trees are protected adequately, with fencing or tree protectors. Elk and deer will seriously damage planted trees. Most streams in Oregon support beavers, and in western Oregon nutria are common; both cut down trees and eat the bark of standing trees.

In the great majority of tree buffer projects, some form of tree protector or fencing must be installed to prevent serious predation on young trees. Individual tree protectors or fencing must be installed to keep domestic and wild animals from approaching from both the upslope and streamside directions. As trees grow, eventually the terminal growing tip and leaves will be out of reach of most species. Beavers, however, can fell even large trees, so if beaver visit, even rarely, protectors are necessary indefinitely.

Tree buffer design

A tree buffer is a dynamic structure that requires management as it changes over time. You need both a short-term plan (for establishment) and a long-term plan (for maintenance). For example, as trees grow together in a stand, each tree needs an increasing amount of space. At some point, you might need to thin some trees out of the tree buffer to maintain the health and vigor of the remaining trees.

Location Placing the tree buffer strategically can increase the buffer's beneficial effects greatly while minimizing loss of farm ground.

Tree buffers' primary function is to reduce farming's effects on streams and rivers by providing as much shade as possible and by filtering ground and surface waters. Therefore, establishing trees on both sides of the stream is best. If keeping the stream cool is important and farming is not intense (e.g., adjoining land is in pasture rather than row crops), placing the tree buffer on the south to southwest side when possible may provide substantial shading benefit. Tree buffers on the south to southwest side are good because they provide shade during the hottest part of the day (10 a.m. to 6 p.m.). Figure 7 shows how tree buffers in different directions from the stream provide different amounts of shade to the stream. Two things should be apparent, however: first, any tree buffer near a stream will shade the stream part of the day; and, second, tree buffers on both sides of the stream are

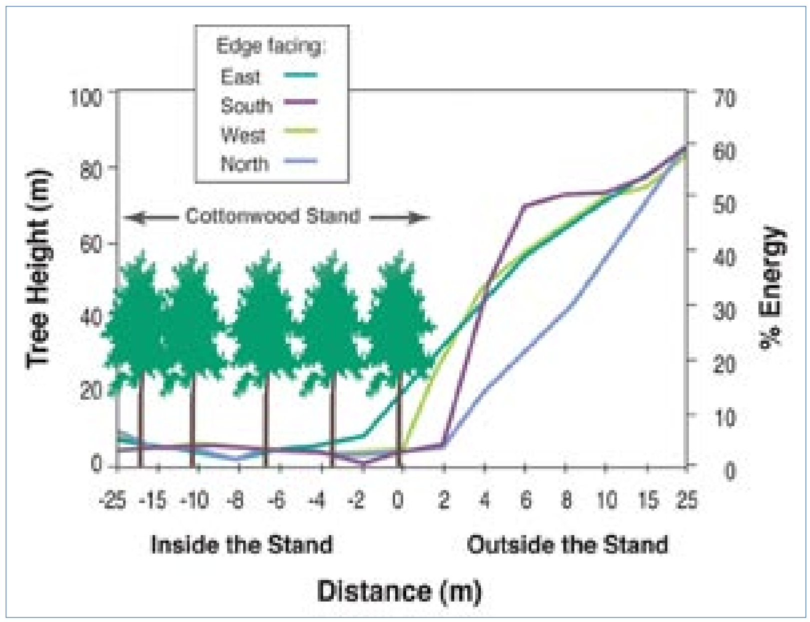


Figure 7. How much energy reaches different locations along a line that extends from within the stand out into the stream? That depends on the distance from the stream to the edge of the tree buffer stand, the height of the stand, and the stand's position relative to the stream. Tree buffers on the south side of the stream face north (blue line) and will provide more shade during the midday hours, when direct-beam radiant energy from the sun is most intense, than trees on the north side (purple line), which face south.

Table 2. Characteristics of trees commonly used in riparian buffers.

Tree	Growth rate	Height in 5 years (feet)	Palatability[1]	Predators[2]	Benefits[3]	Flood tolerance	Site needs	Commercial rotation (years)
Hardwoods								
Alder, red	Fast	20–35	High	All	ES, LT, WV	High	Good	25–35
Alder, white	Moderate	10–25	No data	No data	ES, LT	High	Willamette and Siskiyou valleys	No data
Ash, Oregon	Slow	5–15	Moderate	No data	DIV, WV, LT	High	Clay bottomland	No data
Cottonwood, black	Fast	30–40	High	All	ES, ST, WV	High	Good	8–15[4]
Cottonwood, hybrid	Fastest	35–50	High	All	ES, ST, WV	High	Good	7–12[4]
Maple, bigleaf	Moderate	15–25	High	BG, LS	DIV, WV	High	Medium to good	No data
Oak, Oregon white	Very slow	3–10	Moderate	LS	DIV, WV	High	Moist to dry	No data
Willow[5]	Moderate	10–20	High	All	DIV	High	Wet, streamside	None
Conifers[6]								
Dougas-fir	Slow	10–15	Moderate	All	DIV, LT, WV	None	Plant only well above winter flood levels	35–50
Fir, grand	Slow	4–10	Low	BG, MV	DIV	Low	Plant above flood line; can tolerate heavy clay soil	40–70
Hemlock, western	Moderate	10–15	Low	BG	DIV, LT, WV	Moderate	Moist Coast Range	30–50
Pine, KMX	Moderate	8–12	Low	All	DIV	Moderate	Dry sites with high winter moisture	
Pine, ponderosa – Willamette Valley source	Slow	5–12	Low	All	DIV, LT, WV	High	Willamette Valley sandy or heavy soils	45–80
Redcedar, western	Slow	5–13	High	All	DIV, LT, WV	High	Coast Range	50– 60
Spruce, Sitka	Moderate	10–20	Low	BG	DIV, WV, LT	High	Coastal fog belt	30–50

[1] Palatability: The degree to which wildlife and livestock seek out the species for browsing.
[2] Predators: All = All of the following; B = Beavers and nutria; BG = Big game; LS = Livestock; MV = Mice and voles
[3] Benefits: DIV = Provides biological diversity; ES = Provides substantial shading within 5–10 years; LT = Shading benefits are good in the long term but limited in the short term; ST = Shading benefits are good in the short term but may be limited in the long term; WV = Can provide economic value if managed for marketable wood.
[4] Cottonwood grown on short rotations is considered an agricultural crop.
[5] There are many species of willow with a wide variety of sizes, growth rates, and adaptations.
[6] All conifer species grow slowly for 1–5 years, compared to most hardwood species.

more beneficial than a buffer on only one side. Also, remember that a tree buffer on either side of the stream will block indirect light and thereby help keep the stream cool.

Species selection

The objectives you set, the site characteristics, and the type of tree buffer you wish to develop will determine the types of plants (herbs, shrubs, and/or trees) and the species that are compatible with your site. We will focus on tree species. See Table 2 for a rating of tree characteristics for tree buffers.

Many tree species, both hardwoods and conifers, can provide the benefits of a tree buffer, but the degree and timing of the benefits after planting will vary. Since tree buffers are used primarily in areas without tree cover, a few tree species stand out as good candidates to provide maximum benefits in the shortest possible time. For example, black cottonwood, hybrid cottonwood, and red alder are fast-growing trees that also have commercial value within 8 to 30 years. They are good choices where early shading is important. Although conifers grow much more slowly during the first 10 years, they can live longer, which extends filtering and shading benefits. Also, conifers traditionally have had higher timber value at age 25 to 50 years. Conifers also grow large, and some have wood that is more resistant to decomposition (e.g., redcedar and Douglas-fir), so in the very long run they may provide more stable stream structure. Planting a number of species in a series of patches can develop a more diverse tree buffer. Although mixtures of species are harder to manage, they provide more diversity and long-term benefits.

Black cottonwood and hybrid cottonwood Because the cottonwoods have the highest juvenile growth rates, they may provide the greatest shading benefit in the shortest time. Cottonwood can grow 6 to 10 feet per year during the first decade (with adequate vegetation control), far exceeding most other species suitable for tree buffers in this region. When moisture is adequate, cottonwood can be established simply by poking foot-long cuttings of 1-year-old branches into the soil during the winter.

Note: Successful establishment requires removing nearly all competing vegetation during the first 2 to 4 years. Use any of a variety of methods; see "Vegetation management," page 17. In some areas, cottonwood is marketable for short-rotation pulpwood, and commercial harvest is possible in 8 to 12 years. In other areas, cottonwood might be valued as saw logs on a rotation of 15 to 20 years for lumber or veneer. Marketing cottonwood has been problematic in the past, so check out your local markets before you design your buffer.

Black cottonwood *(Populus trichocarpa)* is a native tree species found along most rivers in the Pacific Northwest. As with any wild population of trees, considerable genetic variation is found in any given location. Genetic variation can be expressed in how well the tree grows, the tree form, and its resistance to insects and disease. Hybrid cottonwood *(Populus* spp.) is a cross between the native black cottonwood and some other cottonwood species. Hybrids are carefully selected for rapid growth, good form, and some degree of resistance to insects and disease. Buy planting stock from a knowledgeable and reliable source. Check to make sure that the planting stock is suited to your local area and that it is properly stored before you take possession. For more information, see "Selecting and Buying Quality Seedlings," EC 1196 (page 23).

Alder Red alder *(Alnus rubra)* is another fast-growing Pacific Northwest species common in western Oregon and Washington. It grows well in coastal and Cascade Range valleys on good soils. Although it cannot grow as fast as cottonwood, it easily outgrows any of the conifer species with 4 to 7 feet of height growth per year (Figure 8), and its wood is more valuable than cottonwood. It has the potential for commercial saw log production in 25 to 30 years, but it also is used for pulpwood on shorter rotations. Alder is available from nurseries as bareroot planting stock. White alder, a closely related species, grows in the Willamette Valley and is best on heavy clay soils. Again, **careful site preparation and weed control are necessary for success with the alders.**

Figure 8. Red alder trees planted in a buffer on a pasture near the Oregon Coast have grown to more than 10 meters (yellow pole) in height in five growing seasons.

Willow Many useful species of willow *(Salix* spp.) grow naturally in riparian areas; however, not all willows achieve treelike form and size. Like cottonwood, willow can be propagated by inserting cuttings from juvenile (1-year-old) branches into the soil during the dormant season. Willow can withstand frequent flooding. It has not been a commercial species, and there is little experience with establishing plantations. Willow may be most useful as a tree or shrub that can establish on the streambank near the water line. Beavers are fond of eating willow.

Oregon ash Ash *(Fraxinus latifolia)* often grows in riparian areas of larger rivers in western Oregon and Washington. It has the special ability to survive in areas with heavy clay soils, winter flooding, and summer drought. It is, however, a slow-growing tree that takes 15 to 20 years to grow 20 to 30 feet tall. It is a good species to plant on very poorly drained sites and may have use in mixtures with other fast-growing trees because it can tolerate shade.

Bigleaf maple Maple *(Acer macrophyllum)* is common in riparian forests throughout the Coast Range of Oregon.

It attains greater size and longevity than red alder, and its bark and branches support a rich array of mosses and lichens. It grows well right to the water's edge, and its roots provide bank stability. It is highly palatable to deer, elk, and livestock and so needs tree shelters to protect it from browsing. Its growth rate is moderate to fast.

Oregon white oak White oak *(Quercus garryana)* is common in riparian forests in the Willamette Valley. It is a notoriously slow starter and may take decades to grow into a tree form. Therefore, it can be included for diversity but won't provide shade in the short term.

Conifers Various conifers are candidates for riparian planting, depending on location. Compared to fast-growing cottonwood and red alder, conifers are very slow starters. Alder and cottonwood often grow 20 to 30 feet tall in 5 years; conifers are likely to reach only 10 to 15 feet in the same period. Also, the pointed conifer crown does not provide as much summer shade as a hardwood tree of the same height. On the other hand, conifers contribute leaf material that lasts longer than hardwood leaves in the aquatic food chain.

Sitka spruce *(Picea sitchensis)* is well adapted to riparian conditions close to the Oregon coast. It tolerates salt spray, so it survives near the beach, where other conifers would be killed by salt spray. It also is tolerant of high water tables, spreading its roots out near the surface. Inland, however, spruce is susceptible to the *Pissodes* tip weevil, and it develops multiple tops and poor form following repeated weevil attacks.

Western redcedar *(Thuja plicata)* is a good candidate for many Coast Range and Cascade Mountain locations because it withstands flooding and considerable summer drought. Unfortunately, it is also a favorite browse of deer and elk, so extra protection is required until it is 5 to 8 feet tall.

The **Willamette Valley ponderosa pine** *(Pinus ponderosa)* is a good choice for sandy soils in low-lying areas along streams and rivers of westside interior valleys. Be sure to find a nursery that has the Willamette Valley variety (as opposed to an eastern Oregon variety) of ponderosa. For more information, see "Establishing and Managing Ponderosa Pine in the Willamette Valley," EM 8805 (page 23).

Grand fir *(Abies grandis)* is often in riparian locations and may be used in mixed-species plantings where it is common. It is, however, notorious as a slow starter. It compensates by being tolerant of shade and can live in the understory of many faster growing trees. It also can survive and grow on moist, heavy clay soils.

Douglas-fir *(Pseudotsuga menziesii)* is not a good choice anywhere that floods, even at long intervals. **Even short periods of flooding will kill Douglas-fir.** However, it could be part of any tree buffer that has slopes well above the high flood mark. It is long lived and grows tall.

KMX pine is a hybrid of knobcone pine *(Pinus attenuata)* and Monterey pine *(Pinus radiata)*. It may be used for riparian plantings on dry sites in the Siskiyou Mountains and the valleys of southwestern Oregon. It is quite drought tolerant and survives well compared to other conifers, such as Douglas-fir and grand fir, when planted on dry sites. It also grows well during the first 10 years after establishment. Like ponderosa pine, it can withstand winter flooding and dry summer conditions.

Western hemlock *(Tsuga heterophylla)* is not a good choice except for cool north-facing valleys or high-rainfall areas. It does not tolerate summer drought and is sensitive to hot weather during planting. Also, it is somewhat sensitive to flooding.

Figure 9. Survival of red alder during the first growing season was good when the site was clean and well prepared, and young seedlings were protected from cattle grazing and beavers. Seedlings shown here were surviving well but were soon attacked by beavers. The weed control on this site was provided by glyphosate applied with a backpack sprayer before planting. The cattle in the background could not cross the intervening stream channel.

Preparation, planting, and pest and weed management

Successful establishment and management of a tree buffer is a complex process with many critically important, linked steps. Like any chain, one broken link is enough to make the chain fail. Those with little interest or time to manage a tree buffer should hire a professional to do the job.

The most common mistake novice managers make is to underestimate the effect of competing vegetation.

Many projects have failed, or have produced only modest benefits, because competing vegetation was ignored. Most sites either are fully occupied with vegetation even when they appear otherwise (for example, when they are grassy and open) or will acquire competitive vegetation quickly once farming stops. Both site preparation before planting and vegetation management after planting are necessary for successful tree buffer establishment!

The second most common mistake is to underestimate the effects of tree predators (deer, elk, livestock, mice, voles, rabbits, beavers, nutria, etc.). The interval between first damage and total failure can be short.

Securing planting material

Before you think about site preparation or planting, be sure to order high-quality planting stock. Order your material 6 months to a year before your winter or early-spring planting date. Ask your local Farm Services Agency Conservation Reserve Enhancement Program representative, OSU Forestry Extension agent, or Oregon Department of Forestry stewardship forester about reliable sources of planting stock. For details, see "Selecting and Buying Quality Seedlings," EC 1196 (page 23).

How many trees to order? To figure how many trees to order, you need to know the size of the area to be planted and the average spacing between trees.

If you plant your trees on a 10- by 10-foot spacing, each tree will take 100 square feet of space. If you plant 1 acre at that spacing, you'll need about 440 trees (43,560 square feet per acre ÷ 100 square feet per tree). If you are planting three rows of trees at a 10-foot spacing along 500 feet of stream on one side, you'll need 150 trees (500 feet ÷ 10-foot spacing = 50/row; 50 x 3 = 150).

Site preparation

Site preparation is most often a critical step in getting new plants established. Site preparation options include plowing and herbicides (Figure 9); both can be effective. It is important to remove most of the competing vegetation from the site before planting and to remove it in such a way that it does not recover during the first growing season. In pastures, a herbicide treatment before planting often is sufficient. The residual effect of some herbicides can help keep weeds down during the first growing season. Rapid weed invasion after plowing is common, so be prepared to follow up with appropriate weed control.

Planting

Planting always involves some hard work but is much easier if site preparation has been thorough. Choose a tool that fits the type of tree you are planting. A good shovel can be used to plant most bareroot stock. Only a small shovel is needed to plant stock raised in plugs. When planting cottonwood or willow cuttings, it is best to have a dibble about the same diameter as the average cutting stock. Using a dibble to create a hole for the cutting saves lots of energy and prevents bending and breaking the cut stock. Remember to handle planting stock (including cuttings) with care: keep them cool and moist until they are planted in moist soil. Be sure to press soil firmly around the roots or stems. Fresh, warm air is **not** what roots need. Don't plant on warm, dry days. For detailed information on planting trees, see "The Care and Planting of Tree Seedlings on Your Woodland," EC 1504, and "Seedling Care and Handling," EC 1095 (see page 23).

Vegetation management

You must control competing vegetation until the desired tree buffer plants almost completely monopolize the site's growing resources. An advantage of fast-growing species is that vegetation management is needed for only 2 to 4 years after planting. In some cases, hybrid cottonwood can be established effectively in 1 year if it is planted at high density. Conifers commonly need several more years of weed control before they occupy the site fully enough.

Whether you use mechanical or chemical methods, you must remove more than 90 percent of competing vegetation within 6 feet of planted trees for 2 to 5 years. In a large planting, farm machinery can do the job. Mechanically removing vegetation by hand, with hoes or shovels, is rarely effective. Skilled use of herbicides is generally the most cost

Figures 10a–d. In most agricultural settings, protecting trees is critical to their survival. A standard three-strand barbed wire fence (A, top left) is good for keeping livestock out and must be installed before planting if livestock are already in the field. The tree shelter (B, top right), a solid plastic tube, is good for keeping beavers, voles, and mice away for 2 to 5 years, but the tube must have a sturdy support and may need annual maintenance. The 2-foot-tall beaver cage (C, bottom left) is good for keeping beavers and nutria away from trees for a decade or more. The 3- to 4-foot plastic mesh tube (D, bottom right) can prevent some deer browsing of the terminal shoot for a year or two, but mesh tubes proved ineffective in protecting trees from beavers.

effective. For small-scale plantings or on rough terrain, the versatile backpack sprayer can be very effective.

Noxious weeds A second reason to control vegetation is to avoid or retard invasion of noxious weeds. It is important to control weeds on ground opened up for planting so that they do not spread to adjacent farm fields or downstream to a neighbor's land. After trees are well established, a shade-tolerant grass that uses relatively little water (e.g., a turf-type fescue) may be seeded beneath the trees to help keep out noxious weeds.

Mouse and vole management A third reason to control vegetation is that grass and weeds give cover to mice and voles which can girdle and kill young trees. These rodents commonly attack young trees and shrubs by gnawing away the bark at the base of the stem during the winter. This occurs, however, only when grasses and herbs surround the tree. Controlling competing vegetation is the most effective way to eliminate this problem. Another way is to install protective devices around the base of each tree (Figures 10a–d).

Fencing for protection

Protecting trees from animal damage is also absolutely critical for establishing successful tree buffers. Fencing is a primary means of protecting tree buffer plantings from livestock, beavers, and nutria. Different types of fencing are required for each animal. Besides protecting trees, fencing protects streambanks in pastures and provides an opportunity for grasses, herbs, and shrubs to become established.

Livestock (cows, sheep, horses, llamas, etc.) Most domestic livestock will eat both hardwood and conifer seedlings at some time during the year. Cottonwood leaves and small stems are highly palatable to livestock, and cows have been seen walking down cottonwood trees over 15 feet tall to get at the foliage. With few exceptions, standard livestock fencing (either electric or wire) is the best approach to permanently protect tree buffers. A possible exception is where smaller cages can be used to protect isolated clumps or single trees; however, individual protectors must be stout enough to withstand livestock rubbing or pressure.

Big game (deer and elk) Big game animals can jump over livestock fencing, so additional protection is required. Most damage is in spring and early summer when new shoots are young and tender. It is important to protect the main stem of the tree until it grows above the height that deer (3.5 feet) and elk (4.5 to 6 feet) commonly browse. If damage is light, big-game repellents can be sprayed on the trees at about 2-week intervals during the critical spring period. If browsing is heavy, individual tree protectors may be necessary even inside fences! Also, in the fall bucks and bulls may rub their antlers against sapling-size trees. Here again, individual tree protectors may be necessary.

Beavers and nutria Special fencing is required to keep these two rodents from eating many plants in the riparian zone. Both will travel several hundred feet from the stream to clip trees and shrubs. They tend to travel straight from the stream to the food source. In most cases, an 18-inch-high chickenwire fence between the stream and the plantings will keep them away. Otherwise, individual tree protectors are required.

Mice and voles See "Mouse and Vole Management" (page 19).

Other pests (mountain beavers, rabbits, gophers) These pests are less common in riparian plants, but they may cause problems in some areas, and livestock or beaver fencing will not provide adequate protection. In most cases, individual tree protectors used to prevent big game or beaver damage will prevent damage from these animals. Check with your local Extension agents if these pests become a problem.

Tending tree buffers

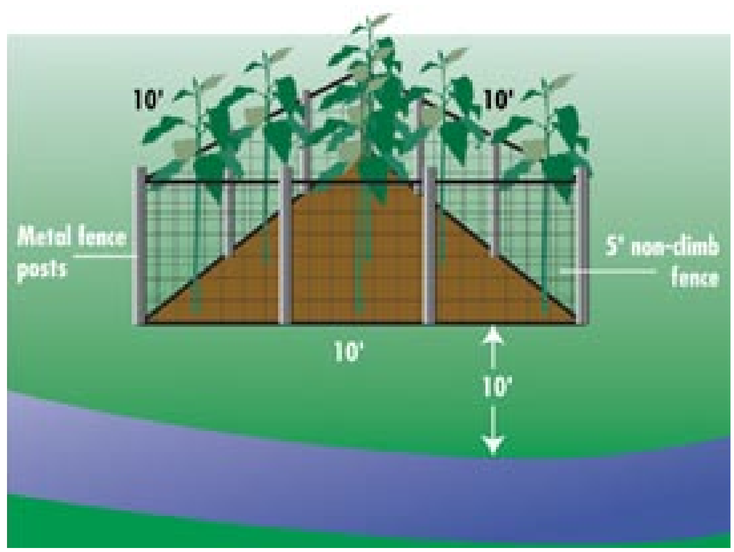
Don't walk away from your tree buffer after the first year or two, assuming you've been successful. A tree buffer is a dynamic structure that will require management as it changes over time.

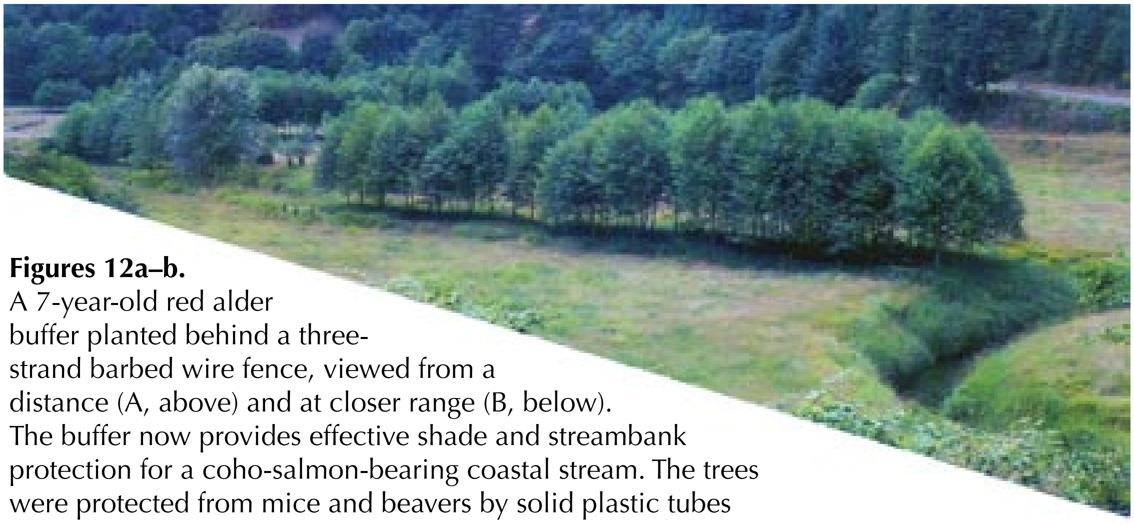
Continued vegetation management and tree protection

You must continue to manage competing vegetation and otherwise protect the trees until they are well established and beyond damage by most pests. Even after the second year, vegetation management will keep trees growing at a faster rate so they will provide more shade and stream protection sooner. Fencing and tree protectors are important until trees are strong enough to withstand rubbing and pushing by livestock (Figures 11a–b). And, protection against beaver or nutria is required continuously as long as they use the area.

(text continues on page 22)

Figures 11a–b. The 4- to 5-foot-tall pigwire cage (A, above) proved effective in protecting a small group of trees from livestock and beavers. However, a tree shelter or vegetation control around the bases of the trees was necessary to prevent mice and voles from girdling the trees. A diagram (B, at right) shows how the cage was constructed.





Figures 12a–b.
A 7-year-old red alder buffer planted behind a three-strand barbed wire fence, viewed from a distance (A, above) and at closer range (B, below). The buffer now provides effective shade and streambank protection for a coho-salmon-bearing coastal stream. The trees were protected from mice and beavers by solid plastic tubes and chickenwire cages.

Thinning As trees grow, each tree needs an increasing amount of space. Thinning your tree buffer may be required to maintain trees' health and vigor. To successfully manage red alder or mixed-species stands for a high-value commercial crop usually requires thinning. Commercial cottonwood plantations are planted at a spacing (often 10 by 7 feet) that allows for harvest in 7 to 10 years for pulpwood market without thinning. Managing a complex multispecies tree buffer will likely require selective thinning to maintain a balance of species; see "Thinning: An Important Timber Management Tool," PNW 184 (page 23).

Pruning If you want the tree buffer to produce sawtimber eventually, you can prune the lower tree limbs so the tree produces knot-free (clear) wood. Considerably more clear wood can result from pruning red alder, cottonwood, or conifers than if they are left unpruned. Some tree spacing and thinning practices, however, could accomplish almost the same level of wood quality as pruning. Pruning is costly in time and energy (or wages) and in general should not be done in stands that are not going to be thinned or otherwise managed intensively for wood production. However, pruning can be used to remove lower branches for aesthetic purposes and to allow access to young stands if dead limbs present a barrier. For more information about pruning, see "Pruning to Enhance Tree and Stand Value," EC 1457 (page 23).

Summary

Tree buffers are an effective means of filtering runoff or subsurface water and protecting streambanks. Buffers' shade can enhance streams and rivers for fish, especially those with marginally high water temperatures and poor stream structure. Within a few years, fast-growing trees such as black cottonwood or red alder can grow to 20 to 30 feet and begin providing significant amounts of nutrient filtering, shade, and improved stream habitat. Conifers take longer to begin producing the same level of benefits, but they are longer lived and thus the benefit period is extended.

For more information

OSU Extension publications

Pruning to Enhance Tree and Stand Value, EC 1457

Establishing and Managing Ponderosa Pine in the Willamette Valley, EM 8805

Thinning: An Important Timber Management Tool, PNW 184

The Care and Planting of Tree Seedlings on Your Woodland, EC 1504

Selecting and Buying Quality Seedlings, EC 1196

Seedling Care and Handling, EC 1095

The above publications are available in print as well as online; this publication (EM 8895-E) is available only online. To view online publications, go to http://extension.oregonstate.edu and then select 'Publications.' Prices of printed publications are listed in the online catalog on the Extension publications website.

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Other resources

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