Why Plant Redwoods in the Pacific Northwest

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This paper is designed to highlight benefits to small landowners in the Pacific Northwest from planting redwoods. Redwoods consist of two species. **Coast redwoods** are the tallest tree species on the planet and **giants sequoias** the largest in volume. Coast redwoods occupy foggy forests in a narrow belt from dry shrubby land in southern California to rainforests in Del Norte County, even extending into southern Oregon. Giant sequoias in contrast, are a mountain-growing species divided into distinct groves in wet locations of the Sierra Nevada Mountains (**Figure 1**). **Although their natural range is mostly in California, redwoods thrive when planted in suitable locations in Oregon and Washington. The Pacific Northwest is ripe for planting these superlative trees where they are not yet common.**

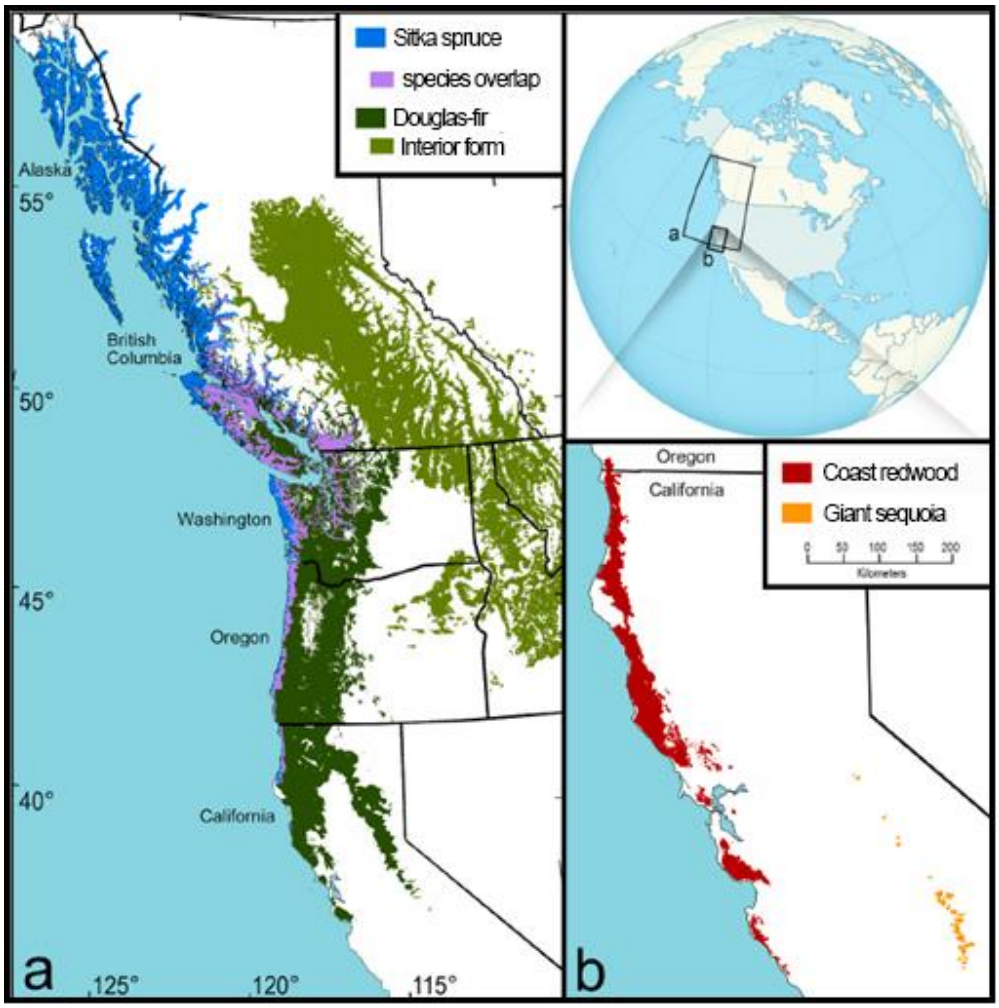

Figure 1. Ranges of the four tallest conifers on Earth. Sitka spruce and Douglas-fir are shown to the left (a), while coast redwood and giant sequoia are to the right (b). Suitable places for coast redwood likely extend into southern British Columbia along the lavender color in panel (a), while those suitable for giant sequoia are likely well into the dark green color excluding the most coastal locations and driest interior sites. Reprinted from Sillett et al. 2021[1], with permission from Elsevier.
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Importance of small landowners and their values

Small landowners collectively have a large impact on the nation's forests because they have a unique set of values compared to industrial or public landowners. Over 30% of forest land in the US is held in plots ranging from 1 to an average of ~50-70 acres. In Washington, Oregon, and California, small private forest land totals 1 to 4 million acres. Contrary to management on industrial or some public lands, economic return ranks relatively low as a reason to own forest land (**Figure 2**).
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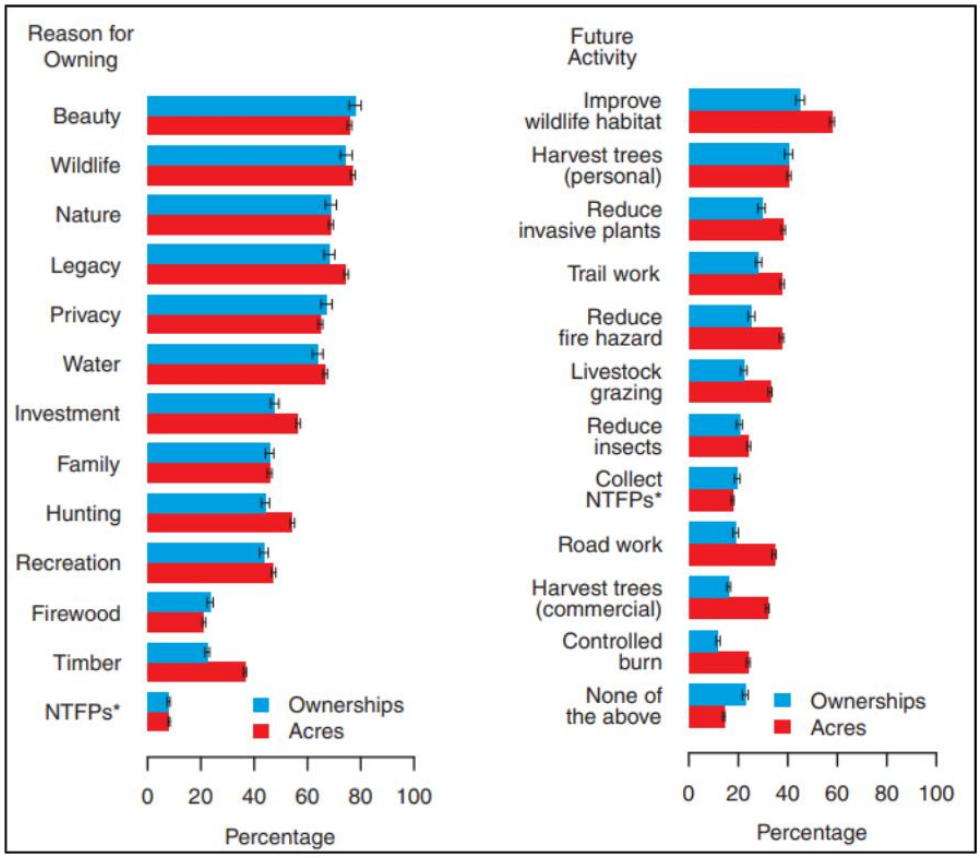

Figure 2. Nation-wide survey data from 2013 of small private landowners. The left shows percentage of ownerships that ranked each reason for owning highly, while the right shows future planned management activities. *NTFP = non-timber forest product such as mushrooms. Figures are reprinted from Butler et al. 2016[2], with permission from the Society of American Foresters.

Small landowners appreciate the aesthetic beauty and natural capacity of the forest to provide habitat, clean water, privacy, and a legacy to pass to the next generation. Increasingly on the minds of landowners, is the economic and social value of carbon sequestration. The value of carbon stored in trees can be sold on the carbon market to gain some economic return without cutting trees. Below we outline some of the advantages of planting redwoods for maintaining stable beautiful forests, wildlife habitat, and carbon sequestration.

Call in the redwoods!

Planting redwoods will enhance the beauty, health, and productivity of your forests because they have a suite of characteristics not shared by other Pacific Northwest species such as Douglas-fir, ponderosa pine, and western hemlock. These characteristics allow them persist for millennia, conserving your legacy for future generations (**Table 1**).

Figure 3. Left to right: Giant sequoia trunks emerge from the understory, soft fibrous bark of coast redwood, leaves of both species. Left photo from Resilient Forestry, middle from depositphotos.com and right from Katherine A. Preston.

Table 1. Redwood characteristics that allow them to create long-lived forests with lasting value.

	Attribute	**Significance**
Both redwoods		
	thick fibrous bark (up to 9" in coast redwood and 16" in giant sequoia)[3]	beauty, protection from fire, nest sites
	rich heartwood	protection from decay
	extreme longevity (>1500 years)	old large trees are the most important for habitat and carbon storage
	unpalatable foliage	resistant to insects and disease
	unique fungal relationships	increases biodiversity
Coast redwood only		
	shade tolerant	can grow under other trees for privacy
	sprouts from stumps and branches	it can regenerate without replanting and recover quickly from fire damage to its crown
	roots commonly graft together	small trees in shade are nourished by older trees
	flooding tolerant	can grow in areas with high water tables
	six sets of each chromosome	more opportunity for genetic adaptation
Giant sequoia only		
	aerial seed bank in long lived cones	cones can live >20 years, releasing abundant seed after fire
	cold tolerant	Can be planted where coast redwood cannot

Resistant and resilient trees

Redwoods are able to resist effects of fire and insects with their bark and heartwood defenses and are resilient (i.e. rebound quickly) when these defenses are breached. Forests with resistant and resilient species provide a stable source of beauty, wildlife habitat, carbon capture, and other functions like water cleansing capabilities.

Insulating bark and a reproductive strategy adapted to fire allows them to thrive after even intense fires. Coast redwoods often respond to fire not by dying, but by sprouting new trees at the trunk base and new sprouts along the trunk and branches (**Figure 4a**). This video (https://youtu.be/ROLeLoNpFRQ) shows their response after the large fires near Santa Cruz, California. In contrast, giant sequoias have cones that can remain closed and living for more than 20 years[4]. The cones continually accumulate until a fire opens them and releases a rain of stored seeds. This tactic ensures abundant new seedlings to take advantage of exposed soil and increased sunlight (**Figure 4a, 4b**).

Large trees likely share their nutrients to fuel young tree growth through connected roots. For example, young redwoods in the shade grow faster than expected given their size, so are probably subsidized by their connections to larger redwood trees[5].

Did you know ??

Trees provide homes for bacteria and fungi in their leaves. These organisms are called endophytes.

In redwoods, endophytes produce secondary compounds that suppress disease and insect attack[6]. Some that are unique to redwoods, called sequoiatones, even suppress human tumor growth![7]

Endophytes help redwoods adapt to new stressors more rapidly than they could on their own.

Coast redwood in particular, is highly adaptable. The genus has existed for at least 150 million years and was once widespread in western North America, Europe, and Asia[8]. Even in its current distribution, it stretches from moist locations in otherwise dry scrubland to temperate rainforests. Coast redwood has six sets of chromosomes (humans and most other organisms have two). This increases redwood adaptability because there are 3 times more opportunities for beneficial mutations to give them a competitive edge.

Figure 4a. Coast redwoods recover quickly from fire by sprouting. Even if the tree dies, roots will send up new trees fed from well-developed root systems connected to other trees. Photos used with permission from Sonoma County Ag + Open Space.

Figure 4b. Giant sequoias regenerate prolifically from seeds after fire. Any dead trees provide habitat for cavity nesting animals, while the seedling replace the live tree. Photo is in the public domain from the National Park Service, Anthony Caprio.

Did you know ??

Trees do not die of old age. Plant tissues do not age the way animal tissues do. That is why you can take a cutting of an old tree and grow a new tree that is young and vigorous.

Instead, they die from factors such as fire, wind, insects, disease, and especially fungal decay.

One major influence on tree lifespan is its ability to resist decay by producing heartwood. This is core trunk wood that trees impregnate with chemicals give redwood its color.

Redwoods have some of the most decay-resistant heartwood of any conifers, which allows them to live more than 1500 years!

Biodiversity and wildlife

Biodiversity is a hedge against environmental uncertainty similarly to how a diversified stock portfolio protects against business uncertainty. Uncertainty for a landowner can come from slow environmental change, introduced pests with the ability to wipe out an entire species, and from sudden changes like fire.

Most forests in the Pacific Northwest are dominated by only two species, Douglas-fir and western hemlock. If circumstances were to decrease their survival, the fundamental character and functions of these forests would change dramatically. Incorporating vigorous and dominant conifer species, such as redwoods, which have vastly different survival strategies, will further ensure your forest can provide the values you desire.

Because redwoods can recover well after injury and grow to be so old, they can become some of the most important habitat trees. A small handful of old trees with large crowns provide the most above-ground habitat. They have recovered from many injuries that created cracks, decay pockets, platforms, and hollows. Cracks provide homes for insects, bats, and salamanders, decay pockets hold water used by canopy-living plants and animals, large limbs and crotches support canopy soils, and hollows are nesting sites for owls, birds, and even bears!

Redwoods associate with a community of fungi distinct from those of Douglas-fir and western hemlock. All trees rely on fungal relationships with their roots to help them absorb nutrients and communicate about threats to their neighbors. Planting redwoods can diversify the fungal community and thus nutrient absorption, food chains, and tree-to-tree communication.

Wood growth and carbon sequestration

Coast redwood has distinct advantages for growing wood in the Pacific Northwest. The first is that few pathogens attack it, therefore fewer resources need be to spent managing for pests. The second is that redwood can reproduce without seed[9]. Root-sprouting after cutting or fire nearly eliminates the need to replant and spray herbicides to re-establish trees. Additionally, coast redwood is tolerant of shade, meaning young trees can grow in the shade of older trees (unlike Douglas-fir). This allows landowners to leave more trees behind following harvest. Such partial harvests allow landowners to conserve other values such as beauty and wildlife habitat. Last, coast redwood lumber is often more expensive than other woods. Landowners producing redwood will have more options than those who are not.

Both coast redwood and giant sequoia offer outsized benefits for carbon sequestration. Native redwood forests can store 36 to 107% more carbon than other large conifers in the Pacific Northwest (**Figure 5)**. Their carbon dominance comes from their longevity and decay-resistant heartwood (central red core of wood in their trunks). More than 75% of new growth is converted to heartwood so is protected from decay in addition to being protected from fire by thick bark[5]. Redwood carbon capture rates are similar to slightly less than other species during their first few centuries, but they dwarf other three species in later years (**Figure 6**). As other trees age, disease and decay reduce energy that would otherwise grow wood. In contrast, redwoods continue to produce wood at high rates through old age[10].

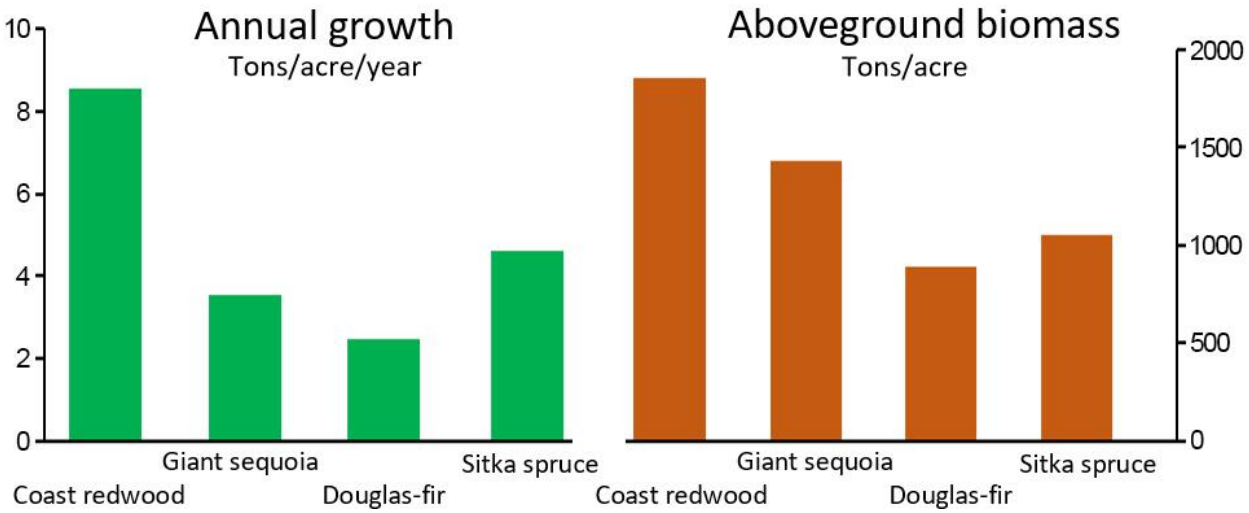

Figure 5. Annual biomass change and total aboveground biomass in world-record holding forests of each of the tallest four conifers in the Pacific Northwest. These numbers represent biomass as if all wood, bark, and leaves were first dried in an oven. Wet biomass is at least double these figures. Carbon weight is approximately 50% of dry biomass. Figure created from data in Sillett et al. 2020[5], Table 7 within. https://www.sciencedirect.com/science/article/pii/S0378112720314572

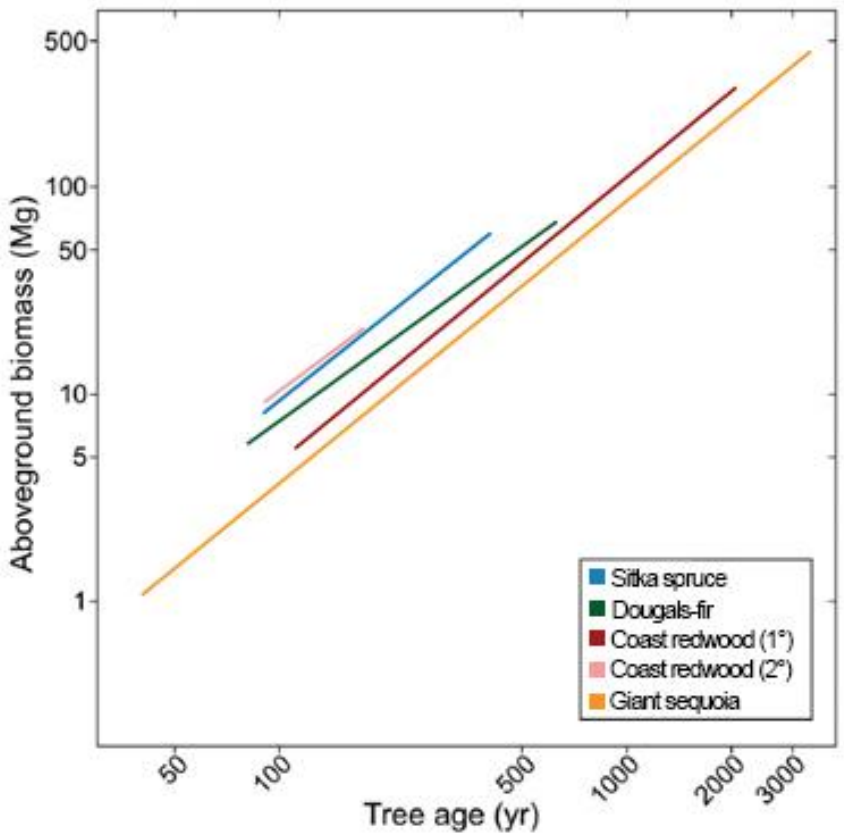

Figure 6. Biomass of redwoods, Douglas-fir, and Sitka spruce trees of different ages. In coast redwood, 1° and 2° labels refer to old-growth forest and second-growth forests. Note that redwoods may grow less initially, but accumulate vastly more biomass than other species. Axes are on a logarithmic scale. Figure simplified and reprinted from Sillett et al. 2021[1], with permission from Elsevier.
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The legacy of planting redwoods will last at least centuries and possibly millennia because they outlive other Pacific Northwest Conifers (**Table 2**). Additionally, in redwoods, a higher and higher proportion of growth is converted to decay-resistant heartwood as they age, effectively locking in carbon gains for long periods. So even if a redwood dies, the subsequent log will continue to store carbon for at least as long as it took the tree to grow!

Table 2. Maximum characteristics of the four tallest Pacific Northwest conifer species based on the largest and oldest known individuals. Biomass and growth rate are expressed as oven-dry-weight per tree. Western hemlock and red cedar are not included and have substantially less biomass. Table modified from Sillett et al. 2021[1], Table 2 and Figure 9.

Species	Lifespan (years)	Height (ft)	Aboveground biomass (tons)	Growth rate (lbs/year)
Coast redwood	>2000	>380	~430	~1320
Giant sequoia	>3000	>315	~620	~1430
Douglas-fir	<1000	>320	~170	~550
Sitka spruce	<500	>317	~130	~700

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