A CLIMATE RESILIENCE GUIDE FOR SMALL FOREST LANDOWNERS IN EASTERN WASHINGTON

Photo by David Hagen

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Recommended Citation:

Raymond, C., Peterson, D., Morgan, H., Halofsky, J. 2023. A Climate Resilience Guide for Small Forest Landowners in Eastern Washington. A Collaboration of the University of Washington Climate Impacts Group, the U.S. Forest Service, and the Northwest Climate Hub.

Acknowledgements

The authors thank Andy Perleberg, Dave W. Peterson, Becky Kerns, Karen Ripley, Melissa Fischer, Iral Ragenovich, Blakey Lockman, Darci Dickinson, Justina Dumont, Brennan Ferguson, Brigitte Ranne, Brandon Weinmann, and Beth Wilhite for valuable input during document writing and review.

Funding

Funding for development of this guide was provided by the U.S. Forest Service Pacific Northwest Research Station and the USDA Northwest Climate Hub.

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WHY ACT AND WHY NOW?

Forests in eastern Washington are being affected by changes in the climate. As the climate continues to warm, and extreme high temperatures and dry summers occur more often, forests will experience more impacts, with consequences for the values and benefits that small forest landowners derive from their lands.

Recent warming has contributed to extensive mortality of lodgepole pine and ponderosa pine in western North America due to outbreaks of mountain pine beetles. Large areas of forest and non-forest land in eastern Washington have burned severely in several hot and dry summers in the last decade. Some effects of extreme weather and climate on forests are well understood, and other effects will emerge over time, requiring landowners to be more flexible and adaptable in managing their land.

Climate change is challenging forest management, requiring emphasis on managing for resilience to climatic variation and extremes. As a landowner, you can take action now to ensure that your forest continues to be resilient and meets the goals you have for your land. Many of the practices you already use, especially keeping trees healthy, contribute to climate resilience. Although climate change is a complex, global-scale issue, many options are available for climate-smart management at the local scale.

Your forest can contribute to resilient ecosystems and thriving habitat for plants, fish, and wildlife, while storing carbon to help reduce greenhouse gas emissions.

Climate-smart actions appropriate for your forest depend on the setting of your property. For example, what is the management and harvest history of the landscape? Have recent wildfires or other disturbances affected the terrestrial and aquatic resources? Which stressors is your forest currently facing?

Actions also depend on your management goals over the next decade or more. Deciding which actions to implement depends on knowing how your goals might be affected by climate change.

This guide provides landowners in eastern Washington with information to:

1. Understand how your forest may be affected by climate change.

2. Identify actions that you can take to reduce adverse impacts, increase resilience, and contribute to thriving forest lands and habitat across the region.

WHO ARE SMALL FOREST LANDOWNERS?

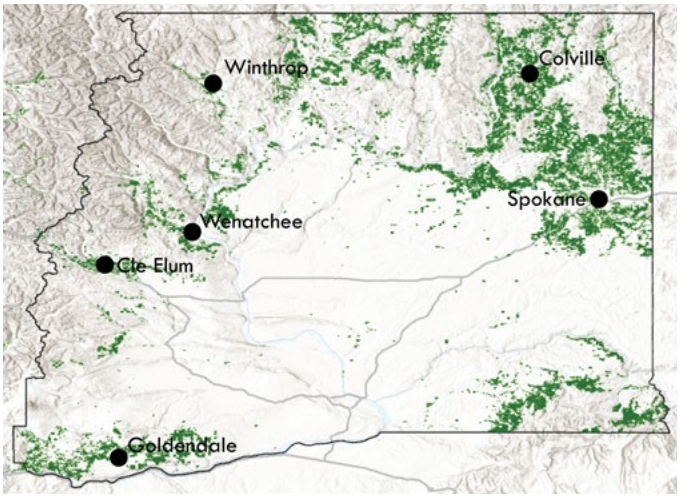
Small forest landowners collectively own about 15% of the forested land in Washington state and have a variety of objectives for their lands. If these objectives include management for climate resilience, as a forest landowner, you can collectively increase the overall climate resilience of forests in Washington.

In eastern Washington, you are considered a small forest landowner if you own at least 2 acres (1 acre of which is forested) and up to 9,900 acres that are private or tribal but not designated as industrial forest land. Although the total amount of land in small forest ownership is similar between eastern and western Washington, eastern Washington has fewer owners, and land is consolidated in fewer parcels, typically between 20 and 100 acres. Primary land uses as a percentage of forest area are designated as residential (9%), natural forest (74%), and agriculture (16%). The number of landowners has increased in the last five years, although the total acreage owned has decreased.[1]

As a small forest landowner in eastern Washington, you are a part of a group of landowners who are generally highly engaged in forest ownership and spend more time working and recreating on your own land compared to forest landowners in western Washington.[1] Fewer forest landowners in eastern Washington have income and investment as primary objectives. Most landowners have multiple objectives including enjoyment of nature, aesthetics, privacy, timber, non-timber products and resources, and providing a legacy for family members.

Regardless of why you value your land or what your objectives are, understanding the impacts of a changing climate on forests is important. Which actions you take to increase climate resilience will depend on how active you want to be in shaping your forest for the future. Taking action to increase the climate resilience of your forest now will enhance your forest's legacy for future generations.

The geographic location and current condition of your forest are important to consider when deciding which actions are most appropriate for your land. Many landowners have forests that have been harvested at least once with wildfire being excluded, resulting in high stem densities and accumulated surface fuels (dead branches, needles, etc.). Fire exclusion facilitates the growth of tree species that are vulnerable to fire when it does burn. Forests in this condition may need active management to ensure long-term sustainability, even in the absence of climate change, and the effects of climate change may further degrade forest health.



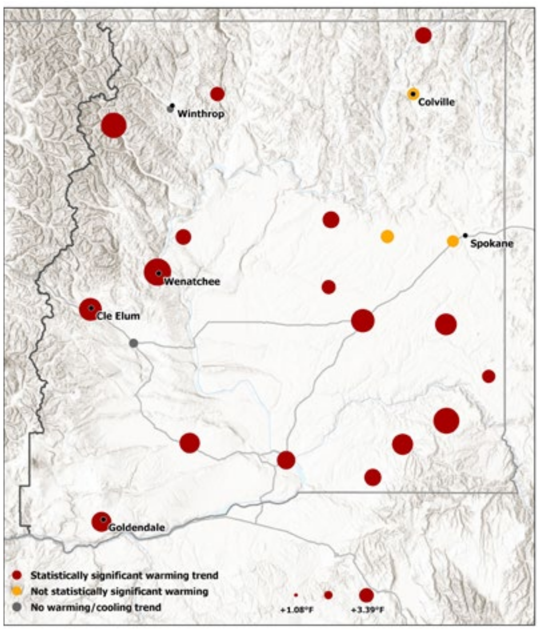
(Right) Area of small forest land ownership in eastern Washington as of 2020. Data Source: Comnick et al. (2021). Stevens, Spokane, and Okanogan counties contain the most small forest land. Digital Data. "The 2019 Washington State Forestland Database." Seattle, WA: University of Washington.

OBSERVED CHANGES IN CLIMATE

Temperature

The climate of eastern Washington has warmed over the last century[2], with consequences for forests. Since 1900, temperatures across eastern Wasington have risen by 1.8°F.

Temperature partially controls where different tree species can grow, and native trees in eastern Washington are adapted to cold winters and hot, dry summers. Higher temperatures will affect tree growth, regeneration, and ultimately the distribution and abundance of species across the region.

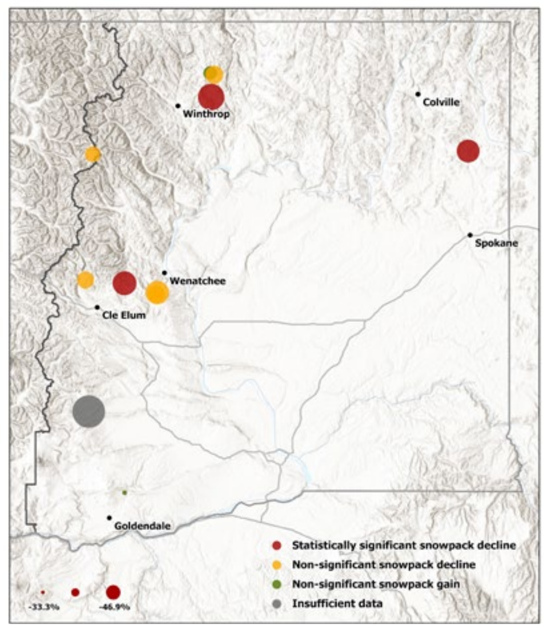


Since 1900, temperatures across eastern Washington have risen by 1.8°F. Circles depict observed temperature trends between 1900 and 2020 at weather stations. Larger circles indicate locations that have warmed more. Data source: OWSC Trend Analysis Tool

Snowpack

Warmer winters in eastern Washington cause less snow to accumulate. Spring snowpack fluctuates from year to year but decreased by 30% on average between 1955 and 2016[3].

Less snowpack means less snow melt in spring, reducing water in the soil for tree growth and water in streams for fish. Less snow also means less insulating snowpack that prevents trees at high elevation from being damaged by cold temperatures and frost.



Average snowpack has decreased throughout the mountains of eastern Washington over the last 80 years. Circles depict observed snowpack trends from 1940 to 2020 at weather stations. Larger circles indicate locations with larger declines. Data source: OWSC Trend Analysis Tool

Precipitation

In eastern Washington, precipitation varies greatly from year to year. Given this variability, there is no detectable long-term trend in precipitation over the past century. However, high temperatures contribute to dry conditions in summer, even without changes in precipitation. Eastern Washington has had several droughts in the last two decades, notably in 2001, 2005, 2015, and 2021. Trees are adapted to dry summers, but can become stressed, grow slowly, or die in abnormally dry conditions, often with impacts made worse by other stressors like insects.

Streamflow

Hotter summers and less mountain snowpack have shifted peak streamflow earlier in spring and decreased average streamflows in summer.[4] Lower summer streamflow also contributes to warmer water. These changes degrade habitat for salmon that depend on adequate cold water to migrate upstream to spawning grounds. In contrast, more rain instead of snow has increased streamflow in winter. High streamflows can scour salmon egg nests and flush young salmon downstream too early, increasing the risk of predation by larger fish.

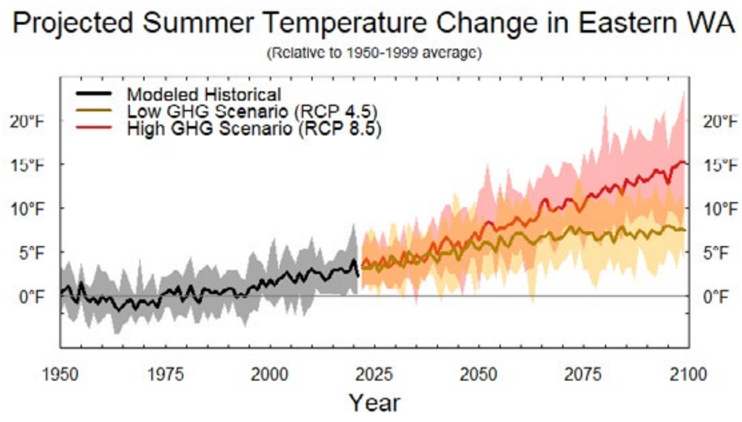
EXPECTED FUTURE CHANGES IN CLIMATE

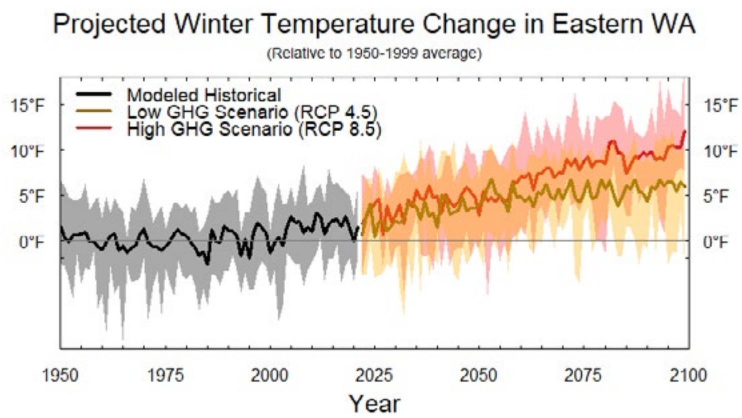
Summer Temperature

Warming is projected to be greatest during summer in eastern Washington.[5] Higher summer temperatures increase evaporation, dry soils, and can stress trees, even those that are tolerant of low soil moisture. Increasing summer temperatures also dry live and dead vegetation, increasing flammability potential in wildfires. By mid-century, average summer temperature across eastern Washington is expected to increase 5.9°F for a low greenhouse gas (GHG) emission scenario (RCP 4.5) and 7.8°F for a high scenario (RCP 8.5), relative to the 1950-1999 average. These trends are based on the average of many climate models; all models project warming. Learn more about observed and projected GHG scenarios in the box below.

Winter Temperature

Winters are also projected to warm across eastern Washington.[5] Cold temperatures in winter control dormancy (times when little to no growth occurs) and the formation of new buds for many conifer species, such as Douglas-fir. Warmer winters can harm trees that have adapted to colder winter temperatures of the past by causing buds to open too early. On the other hand, warmer winters can lengthen the growing season through earlier snowmelt at middle to high elevations, improving growth of some species. By mid-century, average winter temperature across eastern Washington is expected to increase 4.5°F for a low GHG emission scenario (RCP 4.5) and 5.5°F for a high scenario (RCP 4.5), relative to 1950–1999. All models project warming in winter. Not only will average winter temperatures increase, but the frequency of extremely warm winter days and the winter season (as occurred in 2015) will also increase.





Average summer and winter temperatures in eastern Washington are projected to increase throughout the 21st century. Summers are expected to warm more than other seasons. The graphs depict change in summer and winter temperature relative to the 1950-1999 average (horizontal line at zero). Solid lines are the climate model average; shaded areas are the range among models.
Data source: climate.northwestknowledge.net/MACA/.

OBSERVED AND PROJECTED GREENHOUSE GAS EMISSIONS

The Earth has already warmed as a result of human activity. Since the Industrial Revolution, atmospheric concentrations of carbon dioxide and global temperatures have increased significantly as a result of human activities. Atmospheric carbon dioxide increased from about 290 parts per million in 1880 to over 405 parts per million today. Over the same period, global temperatures increased approximately 1.8°F.

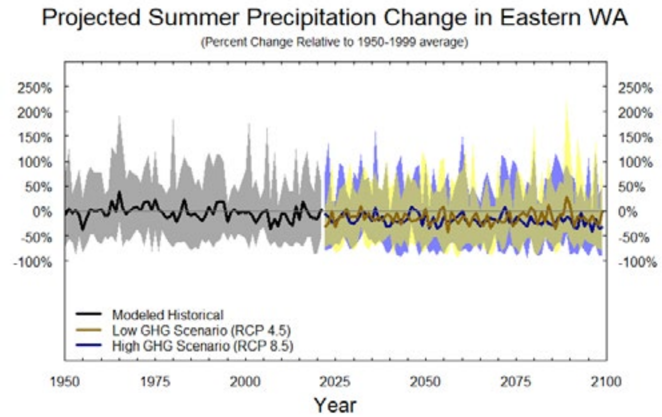
Human-caused warming resulting from greenhouse gas (GHG) emissions adds about 0.4°F to global average temperatures every decade. If this continues, global average warming is likely to reach 2.7°F between 2030 and 2052, which is within the lifetime of most people.

To make projections of future climate, scientists use "what if" scenarios of plausible future GHG emissions to drive computer model simulations of the Earth's climate. GHG emission scenarios affect how much and how fast the Earth warms. A "high" GHG scenario (RCP 8.5), which assumes continued increases in GHG until the end of the century, will cause faster and more warming than a "moderate" (A1B) or "low" (RCP 4.5) scenario. For each GHG scenario, there is a range of future climate based on different climate models that use unique assumptions to simulate the climate.

Precipitation

Expected changes in the total amount of precipitation (rain or snow) in an average year are small compared to expected high year-to-year variability. Summers in eastern Washington are typically dry, a limiting factor for tree growth and the distribution of tree species in many areas in the region. Summers are projected to be slightly drier by the end of the 21st century, but uncertainty in these projections is high.[5] Summer precipitation in eastern Washington typically comes in the form of convective storms, which are difficult to model.

Even without changes in summer precipitation, warmer temperatures are likely to stress tree species that are less tolerant of low soil moisture. This could reduce the area of suitable habitat for some tree species and convert forests to shrubland or grassland in some parts of eastern Washington.[6] Tree species more tolerant of low soil moisture may expand their ranges, although their growth could also be reduced in drought years.

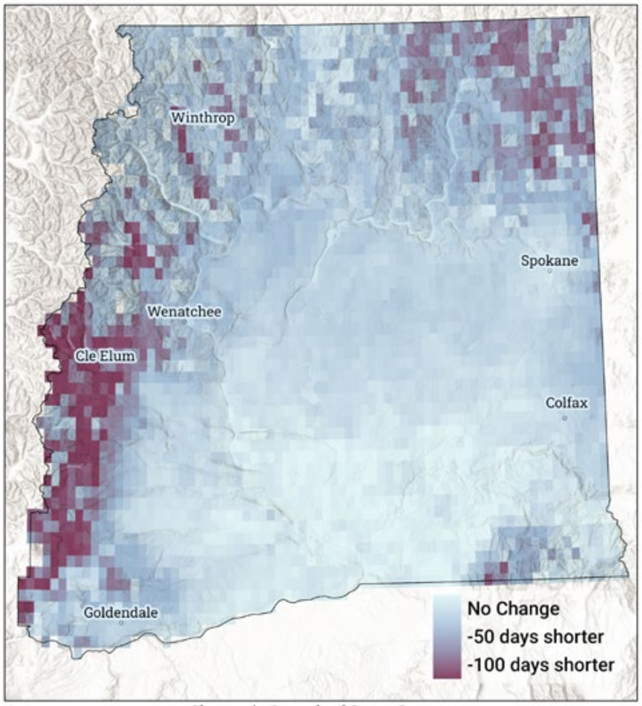


The long-term trend (dark blue and brown lines) is for summer precipitation to decrease in eastern Washington in the 21st century, but year-to-year variability will remain high. The graph depicts percent change in total summer precipitation relative to the 1950-1999 average (horizontal line at zero). Years with positive values show an increase, years with negative values show a decrease. Data source: https://climate.northwestknowledge.net/MACA/.

Snowpack

Despite little change in annual precipitation, snowpack is projected to further decrease in the Cascade Range as temperatures increase. Low- to mid-elevation foothills near the freezing line in winter are expected to see the greatest snowpack loss, whereas higher elevations and the northern Cascades will remain cold with significant snowpack.

Less snow cover will enable trees to grow in places that were too cold in the past, but it will also decrease protective insulation for some species. At lower elevations, less snow will reduce the amount of snow melt for soil moisture that contributes to tree growth in spring.



Change in Length of Snow Season

The duration of snowpack is projected to decrease in the mountains of eastern Washington, except at the highest elevations of the North Cascades. The map depicts projected change in length of the snow cover (difference between 1915-2006 and the 2040s) for a moderate GHG emission scenario (A1B). Purple shows the largest decrease; light blue shows no change. The duration of the snowpack is the number of days between the day with 10% of maximum snowpack and the day with 90% of the snowpack melt out. Data source: Hamlet et al. (2013).[7]

CHANGES IN CLIMATE WILL AFFECT FORESTS

This guide summarizes four key impacts of climate change on forests in eastern Washington. For each impact, actions are listed that you can take to reduce the negative consequences of climate change, increase forest health and resilience, and contribute to thriving forest lands and habitat across the region.

To implement climate-smart actions for your forest, you may also need to learn, plan, monitor, and collaborate on impacts and actions (pg. 22). This guide includes information on education and collaboration opportunities to help you implement recommended management actions.

Climate Impact	Impacts on Forests	Actions You Can Take
Drought stress	Although many tree species in eastern Washington are already adapted to dry summers, some forest types and species are expected to have reduced growth due to drier conditions in late spring and summer. This effect will be most pronounced at the edge of forests near grass and shrublands where water is already limited for trees.	• Improve forest resilience on sites with low soil moisture by planting or retaining tree species and genetic varieties more tolerant of low soil moisture. • In forests where fire has been excluded, reduce the number of trees and competing understory vegetation.
Wildfire	Hotter, drier summers are expected to increase the potential for large wildfires in eastern Washington. This change will interact with effects of a legacy of past fire exclusion and forest management that has made forests more likely to burn severely. Most low-elevation tree species in the region are adapted to, and even depend on, low-intensity fire, but large and severe fires can negatively affect ecosystems and local communities.	• Protect people, property, and high-value resources in your forest by following Firewise USA® guidelines. • Thin and remove enough small trees, understory vegetation, and small surface fuels to reduce fuel continuity. • If planting, selectively plant tree species that are resistant to wildfire.
Invasive species	Invasive plants are expected to spread more easily, reducing forest health by competing with trees and other native plants for water and, in some cases, facilitating wildfire. A warmer climate may directly favor some invasive species; others may establish and spread more easily after wildfires.	• Learn to identify common invasive species and monitor for their presence on your property. • Minimize the effects of invasive species by preventing introduction and detecting and controlling them as soon as possible.
Forest insects and diseases	Higher temperature may increase outbreaks of some insects that reduce tree vigor or kill trees; other insects may spread after wildfires or with declines in forest health due to other climate impacts. Some pathogens may be able to spread in drought-weakened forests, whereas others may be less vigorous in hotter, drier conditions.	• Learn to identify signs of common forest insects and diseases. • Improve tree vigor by removing weak trees that are susceptible to insects and disease. • Diversify the tree species in your forest to reduce widespread impacts of forest insects and disease.

CHANGES IN THE GEOGRAPHIC RANGES OF TREES

Temperature, precipitation, and snowpack patterns affect the geographic ranges of trees and understory plants. As the climate continues to change, your forest and the surrounding area are expected to become either more or less suitable for some plant species. Young trees are highly susceptible to stress from shifting climatic conditions, so the geographic distributions of species are expected to change gradually as it becomes more difficult for new generations of seedlings to establish or grow. Species ranges will change faster at the edges of their current distribution, where water availability and temperature are limiting factors. Over time, these effects may alter the distribution and abundance of species in eastern Washington forests.

Disturbance events, such as wildfire and insect outbreaks, will accelerate shifts in the distribution and ranges of species faster than the effects of climate alone. After a disturbance event, new trees of the same species or local population may have a harder time establishing because the climate of the area has changed compared to when the previous generation of trees established. Conversion from forest to non-forest vegetation, such as grasslands and shrublands, is also expected along the current forest edge and is more likely following major disturbances, such as high-severity fire.

DROUGHT STRESS

Climate Impacts

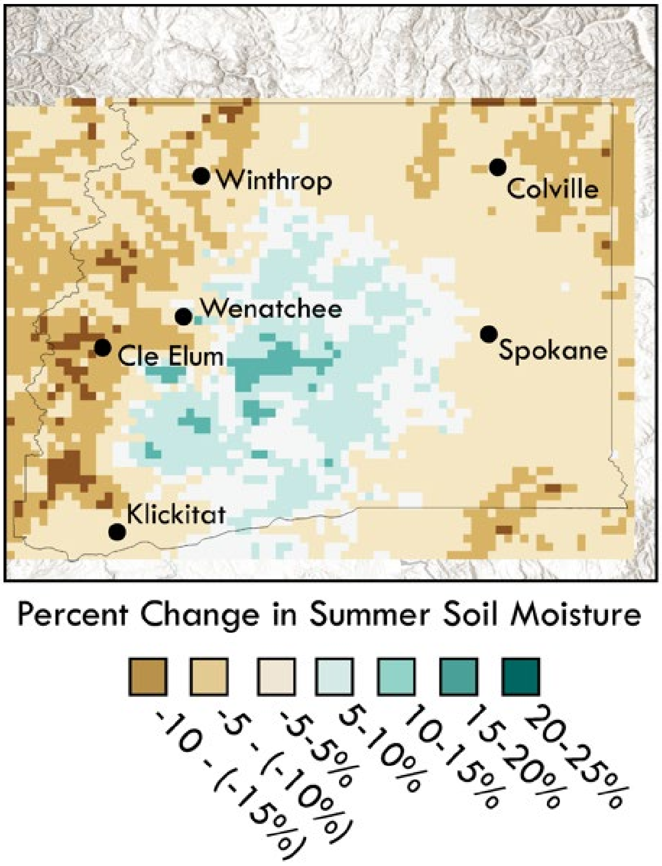
Most low-elevation native tree species in eastern Washington are tolerant of low soil moisture, given the region's normally dry summers (see Table of Tree Species, pg. 26). In the driest part of the year, many trees greatly reduce growth or stop growing but, in early summer, trees can still get sufficient water to grow by accessing moisture stored in the soil. Multiple climatic factors are expected to reduce water availability in the soil and increase drought stress for trees and other plants during the late spring and early summer.

Multiple climatic factors are expected to reduce water availability and increase drought stress for trees and other plants during the growing season.

A combination of less precipitation in early summer (June and July) and higher temperatures can cause exceptionally low soil moisture. Higher temperatures will evaporate more water from the land and increase transpiration from plants. At elevations where snow typically accumulates in winter, less snow and earlier melt are expected to decrease how much water enters the soil in spring and early summer, drying soils earlier in the season. Less snow and early melt also reduce the amount of water that replenishes groundwater and streams in spring.

Although some years will still be wetter than average because of natural climatic variability, summers are expected to be drier on average, so trees (especially seedlings) will still need to tolerate variable conditions from year to year.

Tree species have a range of tolerance to low soil moisture (see Table of Tree Species, pg. 26), and some are more sensitive than others to dry summers. For example, ponderosa pine forms a deep tap root that enables it to access water and tolerate low soil moisture.



Summer soil moisture is projected to decrease across the forested areas of eastern Washington due to a combination of warmer temperature, earlier snowmelt, and less summer precipitation. Dry summers, especially early in the season when trees are growing rapidly, can reduce tree growth and vigor. The map shows expected percentage change in summer (June, July, August) soil moisture for 2010-2039 (relative to 1971-2000) under a high scenario (RCP 8.5). Darker shades of brown depict more of a decrease; lighter shades depict little or no change in summer soil moisture. The dry, non-forested area of the Columbia Plateau where models project a slight increase in summer soil moisture (light greens) is difficult to model and should be interpreted with caution.
Data Source: Climate Toolbox

Management Options

Drought stress is expected to reduce tree growth and increase tree mortality in eastern Washington, and the effects will vary by location and forest type. In some locations—well-drained soils, south-facing slopes, at low elevation where forest transitions to non-forest vegetation—mortality rates may exceed what is acceptable for your forest objectives. However, several management actions may help increase resilience to low moisture conditions.

Although dead and dying trees may seem alarming, some dead trees are normal in forests, providing habitat for insects, birds, small mammals, and amphibians. If you manage your forest less actively, consider accepting a slightly higher number of dead trees, recognizing the benefits they provide for wildlife habitat.

- Learn about the topography and soils of your forest. Identify locations and soil types with low moisture retention, where trees are more likely to be affected by drought stress in the future.
- Eliminate non-native and invasive plant species that compete with native species for limited water.
- In dense forests, remove smaller trees and other species that are less tolerant of low soil moisture (see Table of Tree Species, pg. 26).

Forest regeneration—through natural seed germination and/or planting seedlings—after a harvest or other disturbance is a good time to manage for resilience to low soil moisture. Small seedlings are very sensitive to dry conditions compared to established mature trees. Managing regeneration to maximize seedling survival is critical.

- Consider seedling densities with respect to specific sites and management objectives. Seedlings on well-drained soils, south aspects, and steep slopes (i.e., low-moisture locations) may have higher mortality than in other locations.
- If you manage for timber production, relatively high planting densities will allow for thinnings to adjust densities in the future.
- If you manage for wildlife habitat or other non-timber objectives, lower tree densities, variable densities, and gaps will create a more variable forest structure, but perhaps with more competition from understory plants and invasive species.
- Consider the effects of soil moisture conditions on the survival of recently planted tree seedlings, and on the growth of residual trees following thinning.
- Review seasonal climate outlooks and long-lead weather forecasts; plant in a year or time of year that is not expected to be abnormally dry. Plant when soil moisture is high, typically following snowmelt if possible.
- Plant native understory and tree species that are tolerant of low soil moisture (see Table of Tree Species, pg. 26) in openings created by harvests or natural disturbances. Densities should be low enough to ensure minimal competition and low fuel continuity.
- Preserve existing species diversity by retaining hardwoods and rare and uncommon species during thinning and harvesting.
- Consider using assisted migration to increase genetic and species diversity of trees (see 'What is Assisted Migration?', pg. 10). Select species that are likely to remain appropriate for the site in a warmer climate because of their tolerance of low soil moisture (See Table of Tree Species, pg. 26).

WHAT IS ASSISTED MIGRATION?

Assisted migration (also called managed relocation) is the practice of people facilitating the movement of tree species across the landscape in response to a changing climate. Assisted migration includes planting seedlings in new locations (1) within the current range of a species, (2) just outside the current range, or (3) far outside the current range. The primary reason to do this is to increase genetic or species diversity in new forest stands in order to improve resilience to heat and to water limitations, because trees will not be able to move around the landscape fast enough to track a changing climate. Consider the benefits and challenges of assisted migration before implementing it in your forest.[8] This practice is still in the early stages of application as a response to climate change, so consult with local forestry experts if you consider applying assisted migration on your land.

BENEFITS

- Can help maintain productive forests as the climate changes by moving species to a suitable climate that may be beyond their recent historical range.
- Relatively inexpensive, especially for readily available species and seed sources.
- Can help species move across human-made barriers, such as developed areas, that may prevent species from shifting ranges in response to climate change.
- Can help maintain wildlife habitat by maintaining resilient forests.

CHALLENGES

- Introduced species may hybridize with native species, become invasive, or compete with native species. However, most tree species in the western U.S. have low potential to become invasive.
- Outside their native range, tree species may be more susceptible to insects and diseases that are not in the native range of the trees.
- The seedling stage is the most susceptible to climatic variability. Introduced species or genetic varieties must survive the current climate during the seedling stage, which may be difficult if moved too far from their original range.
- It may be difficult to obtain seedlings of alternative seed sources for planting.

RECOMMENDATIONS

- Use detailed, location-specific information on soils and topography to decide where to plant the species or seed sources that are best suited for your forest.
- Plant tree seedlings from multiple seed zones for a given species to increase genetic diversity and enhance long-term survival.
- Do not move tree species or seed sources too far from their current ranges to avoid risk of seedling mortality and greater susceptibility to insects and diseases.
- Protect seedlings from non-climate stressors such as browsing by deer.

RESOURCES TO HELP WITH ASSISTED MIGRATION

To identify alternative seed sources that are adapted to the climate expected for your location in the future, explore the Seedlot Selection Tool. This tool identifies potential source areas for some Washington tree species under climate change scenarios. The Table of Tree Species (pg 26) indicates potential species for assisted migration depending on the conditions in your forest. The USDA Climate HUB provides more information on assisted migration.

FOREST INSECTS AND DISEASES

Climate Impacts

Trees in eastern Washington can be affected by several insects and diseases that reduce growth or even kill trees. Higher temperatures and altered precipitation patterns may affect the range and abundance of some insects and disease-causing pathogens directly by creating more favorable conditions for reproduction and survival.[9] However, the effects of climate change on many insects and diseases are poorly known.

In some cases, a warmer climate and altered precipitation may increase the spread of insects and diseases indirectly by stressing host trees and reducing tree vigor.[10] Forest insects are often attracted to stressed or weakened trees. In addition, when low soil moisture compromises tree vigor, host trees are less capable of resisting or surviving infections by pathogens.

A combination of drought plus beetles is often enough to kill trees, but "secondary" beetle species and other insects sometimes infest host trees following an initial attack, causing high levels of tree mortality. Multiple insect species attacking stressed trees may become more common in a warmer climate. Damaging insect species that appear to be moving northward (e.g., flatheaded fir borer, California five-spined Ips, eastern five-spined engraver) may spread throughout eastern Washington in a warmer climate.

Fresh slash created by timber harvest or naturally injured pines can attract Ips beetles, promoting higher beetle populations that can lead to outbreaks. Beetle outbreaks have killed millions of conifers in eastern Washington during the prevailing warm, dry climate of the past 30 years, and frequent outbreaks are likely in the future if drought frequency and duration increase.

Pine Bark Beetles: (host: lodgepole pine, ponderosa pine, western white pine, whitebark pine). Several pine bark beetle species are a concern for conifers in a warmer climate, including western pine beetle, mountain pine beetle, and Ips beetles. These species can cause outbreaks in drought-stressed trees, and in some cases infest adjacent healthy trees. Warm, dry summers facilitate larger beetle populations.

Other Forest Insects: The fir engraver attacks grand fir in eastern Washington, especially in stands that have high stem densities or are weakened by drought, defoliation, fire injuries, root disease, or soil compaction. After prolonged drought, many trees may die simultaneously due to beetle activity and latent root diseases. At high elevation, the non-native balsam woolly adelgid can reduce the vigor of subalpine fir, often causing mortality. Defoliators such as western spruce budworm may be a concern for Douglas-fir, grand fir, Engelmann spruce, and subalpine fir in a warmer climate. Sawfly outbreaks can occur following drought.


Mountain pine beetle galleries


Fir engraver

White Pine Blister Rust (host: western white pine, whitebark pine): White pine blister rust, which has already caused extensive damage to western white pine and whitebark pine throughout the western United States, could be even more of a problem in the future, especially in whitebark pine populations that are also affected by bark beetles. The rust is caused by a non-native fungal pathogen that is associated with a cool, moist climate and appears to be restricted by extreme temperatures (hot and cold). More precipitation in spring and winter could favor the rust in some areas, but higher temperatures and summer drought may create less favorable conditions in other areas.

Foliar Diseases (host: multiple species): Foliar diseases are currently a relatively minor concern in eastern Washington. However, they have flourished in ponderosa pine during recent warm, wet springs and could become more prevalent in the future. Elytroderma needle blight appears to be increasing and could be stimulated by warm, wet weather. Other foliar pathogens, especially Swiss needle cast, are increasing in other locations and could become more prominent in a warmer climate.

Sooty Bark Disease (host: maple): Sooty bark disease, an emerging pathogen in the Northwest, is spreading rapidly in maples in some locations and could become a significant problem in the future.

Root Diseases (host: multiple conifer species): Fungal pathogens, especially root diseases, are nearly always present in eastern Washington forests. They can become a problem in forests where trees have been weakened by stress from various causes, including drought stress. As a result, laminated root rot, armillaria root disease, and Heterobasidion root disease could become more widespread in a warmer climate. In addition, trees that are weakened by root diseases can facilitate outbreaks of bark beetles.

Dwarf Mistletoe (host: Douglas-fir, western larch, ponderosa pine): Dwarf mistletoes, which are a widespread but sporadic concern in eastern Washington, could become more damaging in a warmer climate, compounding the effects of drought stress in Douglas-fir and western larch.


Armillaria root disease


White pine blister rust


Dwarf mistletoe

Management Options

Although tree damage or mortality caused by insects and diseases may seem alarming, many tree species are resilient, especially if the insects and diseases are endemic to the area. Low levels of forest insects and diseases are a natural part of forest ecosystems. Tree damage and mortality can create openings and structural diversity that allow different plant species to establish and improve habitat for some animal species. When mortality is widespread or caused by non-native insects or diseases, actively managing your forest for resilience can reduce negative outcomes and help meet your management objectives.

Management options to increase resilience to forest insects and diseases are consistent with practices to increase overall forest health because a healthy forest is better able to resist attacks by insects that are favored in a changing climate.

- Learn to identify common forest insects and diseases and regularly monitor for their presence and effects on trees.
- Use management practices that prevent introducing non-native insects and diseases to your forest.

Forest insects and diseases typically depend on one or a few host tree species, so management actions that maintain or increase tree species diversity can decrease the potential for insects and disease to spread across large areas.

- When harvesting or thinning, leave trees of different species, including both conifers and hardwoods where appropriate.
- Recognize the early signs of insects and diseases with the potential to cause outbreaks if unchecked. Remove these trees early to prevent spread.
- Plant tree species that are native to eastern Washington (see Table of Tree Species, pg. 26), and consider increasing genetic and species diversity through assisted migration.
- If a specific insect or disease is already present in your forest, reduce the density of its host species by planting other species that are less susceptible to that insect or disease. For example, if laminated root rot has killed Douglas-fir in a stand, replant with ponderosa pine if the site is appropriate.
- If planting western white pine, use rust-resistant nursery stock.

Use openings caused by tree mortality from insects or diseases as opportunities to diversify your forest.

- Openings can be left unplanted to allow natural regeneration of understory plants from adjacent portions of the stand.
- If forest openings do not meet your forest objectives, use the openings as an opportunity to plant tree species that increase diversity and resilience to climate change (see Table of Tree Species, pg. 26).

RESOURCES FOR MANAGING INSECTS AND DISEASE

USDA Forest Service Forest Insect & Disease Leaflets provide information on forest insects and diseases, including those of concern in eastern Washington.

Washington State University Extension Forestry provides resources on most forest insects and diseases in eastern Washington, including those described in this guide that are expected to increase with climate change.

Goheen, E.M. and E.A. Willhite. 2021. Field guide to the common diseases and insect pests of Oregon and Washington conifers. R6-FHP-RO-2021-01. U.S. Forest Service, Pacific Northwest Region, Portland, OR.

WILDFIRE

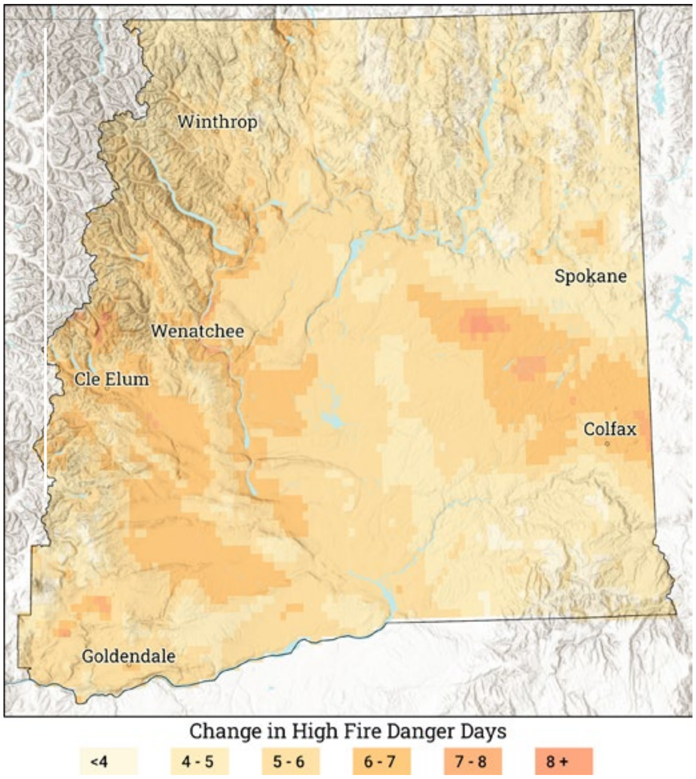
Climate Impacts
Wildfires in eastern Washington forests have both ecological benefits and costs for people, property, and communities. Wildfires reduce tree density and favor species that are tolerant of wildfire, creating forests that will be more resilient to drought and future wildfires. Wildfires also create openings that are used by wildlife such as elk and deer for browse and easy travel. These openings provide places where shade-intolerant tree species and plants can grow, thus increasing species diversity and food for wildlife.

Warmer, drier summers are expected to increase fire danger, lengthen the fire season, and decrease fuel moisture, making it easier for fires to burn over larger areas.

However, many fires threaten communities, homes, and human safety in the wildland-urban interface (WUI) and, in the short term, reduce the value of scenery, recreation opportunities, and timber resources. In recent years, especially 2015 and 2020, large wildfires burned in eastern Washington coinciding with drought across the region. Much of the area burned severely, and some communities sustained heavy socioeconomic and health impacts.

(Right) High fire danger days are projected to increase across eastern Washington. Days with high fire danger have fuel moisture below the 20th percentile, or the driest 73 days of the year on average. Darker shades of orange indicate a larger increase in the number of high fire danger days. Under a high scenario (RCP 8.5), the region is projected to have up to 10 more, or 83, days of high fire danger per year on average for 2010-2039 relative to 1971-2000. Data Source: Climate Toolbox

The increase in wildfire potential due to climate change[11] comes with a legacy of decades of fire exclusion and timber harvest that have also increased fire potential. In many forests in eastern Washington, fire suppression has eliminated low-intensity fires that would have reduced small and fire-intolerant trees, causing fuels to accumulate. Timber harvests removed large trees and species that are more tolerant of wildfire, such as ponderosa pine and Douglas-fir. At the same time, more people now live in the WUI, putting more people at risk.



RESOURCES TO HELP MANAGE WILDFIRE RISK

The Washington Department of Natural Resources Wildland Urban Interface map defines the extent of the WUI in Washington. The WUI is where wildlands and structures mix. If your property is in the WUI, taking action can reduce wildfire risk to valued structures and resources.

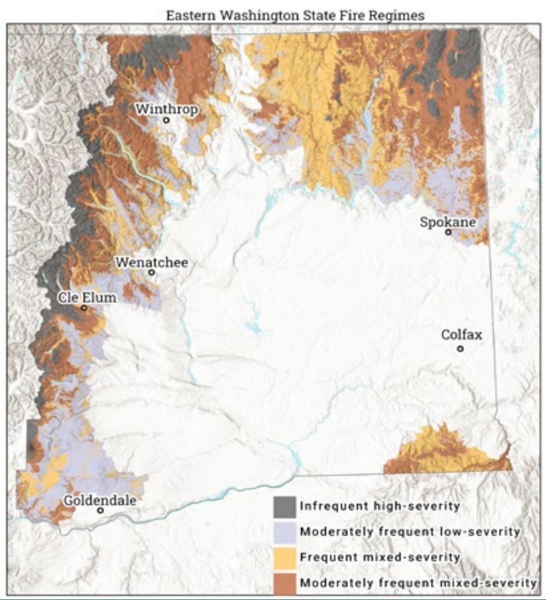
Washington State University Extension Forestry, local natural resource departments, and conservation districts provide resources that help private landowners reduce wildfire risk. Cascadia Conservation District provides resources for wildfire preparedness in Chelan and Douglas counties.

The Fire Adapted Communities Learning Network offers resources, tools, and connections to help individual communities collectively reduce wildfire risk, while also engaging with similar communities in the state.

EASTERN WASHINGTON WILDFIRE

The context for fire in your forest is important when considering management options to reduce the negative impacts of wildfire on property and resources, especially as wildfire increases with climate change. In some forests, more wildfire can improve forest health and wildlife habitat.

The frequency, size, and severity (proportion of trees killed) of wildfires vary across forests of eastern Washington. Historically, wildfires were ignited by lightning and Native American burning and were rarely suppressed. Low-elevation dry forests burned frequently but typically at low intensity, killing mostly small trees and species not adapted to fire. At high elevations, fires were less frequent and burned with higher severity, killing more trees. Many fires burned with mixed severity (a combination of low, moderate, and high severity).



General fire regimes of eastern Washington. A fire regime is the characteristic frequency, size, and severity of fire. Most forests in eastern Washington have a frequent-fire regime, except for forests at the highest elevations. Data Source: Adapted from Reilly et al. (2021).[12]

Management Options

Dry, low-elevation forest ecosystems of eastern Washington are adapted to frequent moderate and low-severity fire. However, an absence of fire in recent decades has allowed more live and dead vegetation—or fuels—to accumulate, causing recent wildfires to spread faster and burn severely. Climate change contributes to conditions for large and uncharacteristically severe wildfires by making vegetation drier for more of the year.

If your forest land contains your home or other valued structures, take action to reduce the risk of wildfire to those structures and increase the likelihood that your property can be protected during a fire.

Wildfire risk reduction

- Prevent human-caused ignitions by using caution in activities that could start fires on your land, especially when fire danger is high.
- Reduce invasive species that can facilitate the spread of fires, especially along roadways and in forest openings.
- Implement Firewise USA® landscaping and vegetation management practices around homes and other structures to reduce potential damage.
- Ensure firefighter access and increase accessibility to your property by clearing vegetation along roads, which will facilitate protection in the event of a fire.

Managing forest fuels can reduce the likelihood of high-severity fires in forests with frequent fire regimes, especially if implemented over large areas and if treated areas are maintained regularly.

Forest health and fuel treatments

- Favor large trees and tree species with some resistance to fire (e.g., ponderosa pine, Douglas-fir; see Table of Tree Species, pg 26). Plant these species in existing forest openings and after harvest or fire. Retain large trees and fire-resistant species when harvesting or thinning.
- Thin dense forests and manage fuels by thinning small trees and ladder fuels (fuels that connect the forest floor to the tree canopy) to reduce fire spread and severity in forests with frequent and moderately frequent fire regimes.
- In your forest management plan, include post-fire objectives and responses for when your forest does burn, such as whether to plant trees and which trees and seed sources to plant.
- Participate in a forest health collaborative or other group (e.g., Washington Farm Forestry Association) that can support restoration and other forest management activities on your land.
- Collaborate with neighbors to treat larger contiguous blocks of land to increase the effectiveness of thinning and fuel reduction.
- Seek opportunities for funding to support fuels management and fire preparedness (e.g., NRCS Environmental Quality Incentives Program [EQIP] and DNR financial assistance programs).

INVASIVE SPECIES

Climate Impacts

Invasive plants—species that are not native to a particular ecosystem—are well-established in eastern Washington. Many invasive plants have highly negative impacts on local ecosystems, plants, agriculture, human health, and wildlife. "Noxious weed" is a term for invasive plants often used for official designations and regulation by local governments with different levels of required control based on designations.

Invasive plants spread or have the potential to spread pervasively, compete with native species, and change the local environment. In eastern Washington, many common invasive species are more tolerant of dry soil than are native species. Invasive plants often propagate easily and grow fast, allowing them to take advantage of openings along roads or after forest disturbances.

Invasive species can negatively affect forest health in ways that worsen the direct effects of climate change on forests, competing with native plants for water, and increasing moisture stress for natives.

As a result of these characteristics, some invasive plants in central and eastern Washington may become more abundant in a climate with more wildfire, insect, and disease disturbances that create openings in the forest and opportunities for establishment.[13] Many species invade cropland and rangeland, but openings in harvested areas and along roadsides in forests are also susceptible to invasive species. In dry forests, non-native invasive species compete with native species for limited water and can affect the regeneration of native trees and other plant species.

Invasive Grasses: Cheatgrass is a widespread invasive annual grass in low-elevation dry forests (and grasslands and shrublands), displacing native perennial grasses and herbaceous species. It reduces biological diversity, degrades pollinator habitat, and reduces forage quality for native animals and livestock. The grass dies in early summer, creating an abundance of dry fuels that enhance fire spread. If sites reburn at short intervals, cheatgrass can reduce the survival of tree seedlings and saplings.

Ventenata is a widespread, invasive annual grass with similar ecological effects as cheatgrass, and it tolerates soils that are marginal for other species. It grows in different habitats than cheatgrass and can spread into forest openings, including at higher elevations.

Increasing wildfire frequency will create conditions that are ideal for the continued persistence and spread of cheatgrass and ventenata, making it difficult for other species to establish. Medusahead, smooth brome, and bulbous bluegrass (also non-native annual grasses) have a more limited distribution but could become more dominant in forested landscapes in the future.

Invasive Forbs: Several species of forbs are a potential concern, including knapweeds, thistles, hawkweeds, common mullein, Dalmatian toadflax, whitetop, St. John's wort, and common houndstongue. Although they are currently a transient problem in some forests, if they become more persistent in a warmer climate, they can outcompete native herbaceous and forb species, especially if fire frequency increases. This can greatly alter biodiversity and pollinator interactions.


Cheatgrass

Ventenata

Dalmatian toadflax

Management Options

- Learn to identify common invasive species, even those that are currently rare but could increase as the climate changes.
- Monitor regularly for invasive species, especially in openings associated with roads, timber harvest, and tree mortality.
- Avoid introducing potential invasive species through landscaping.
- Prevent the introduction of invasive species during timber harvest or other forest management activities by using cleaned equipment, vehicles, and personal gear.
- Work with your county noxious weed control board to remove invasive species with biological controls, mechanical treatments, and chemical treatments.
- Remove invasive species as early as possible after detection to prevent further spread—this is known as "early detection and rapid response."
- If livestock use your land, reduce overgrazing, which can encourage the establishment of invasive species, and manage grazing to reduce biomass and decrease fuel (such as cheatgrass) in early spring.
- Report invasive species on the Washington Invasive Species Council website.

RESOURCES TO IDENTIFY AND MANAGE INVASIVE SPECIES

The Washington State Noxious Weed Control Board uses a database of 140 invasive species to help identify invasive plants.

Washington State University Extension provides information about the most problematic species in the state.

County Weed Boards and local Weed Districts provide educational and technical assistance. Some Boards help identify invasive plants, suggest control strategies, and provide grant or voucher programs to help control invasives and/or purchase non-invasive replacement plants.

FOREST CO-BENEFITS

Co-benefits for Other Forest Resources

Managing your forest for climate resilience can benefit natural resources and ecosystem services other than trees and timber. These non-timber resources and ecosystem services are also likely to be affected by climate change. You can manage your forest to improve habitat for wildlife and fish, and to increase water availability for people, plants, and animals.

Wildlife Habitat

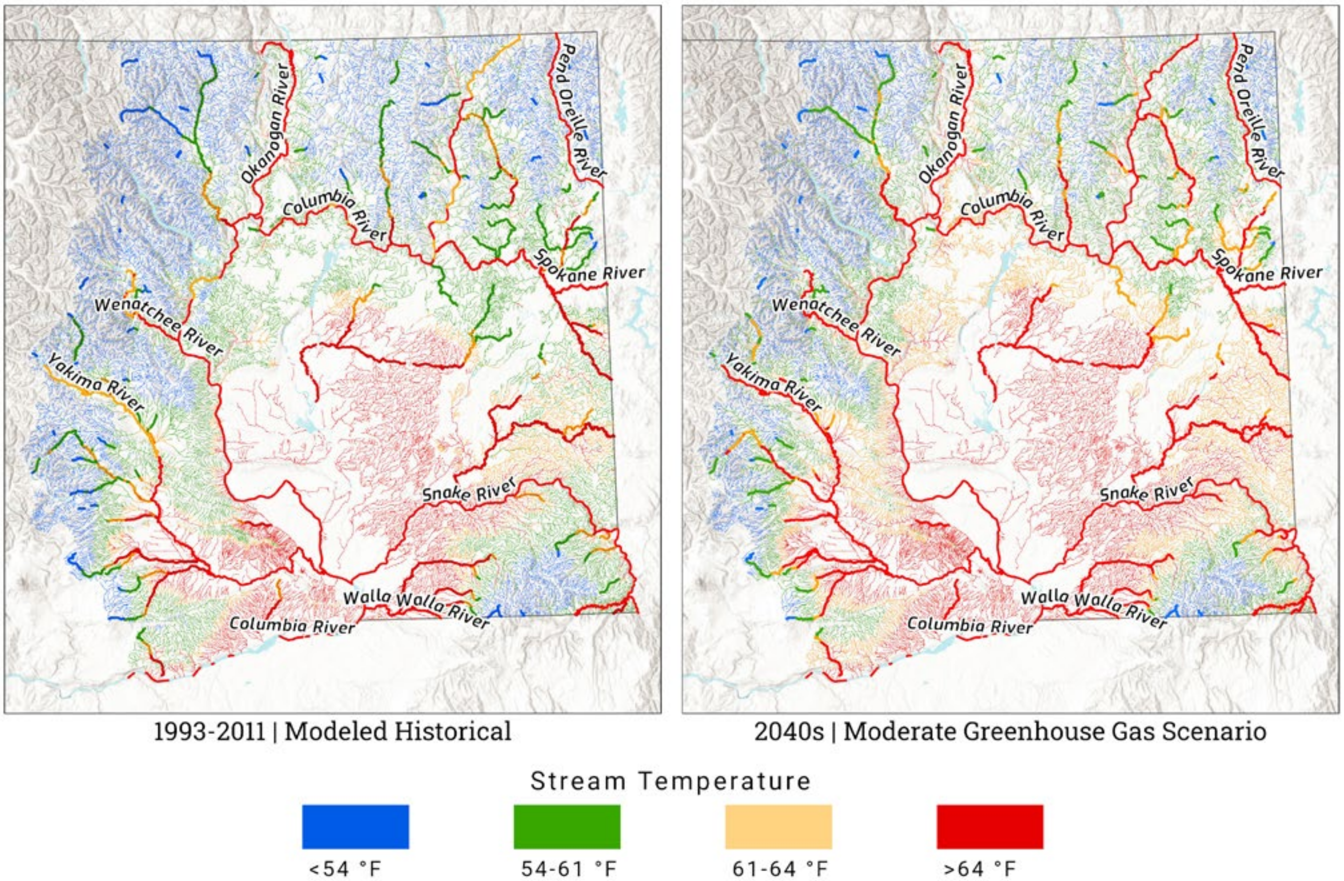
In a warmer climate, some animal species may move to areas with more suitable climate and habitat. Improving the quantity, quality, and connectivity of forest and riparian habitats can help wildlife populations persist and potentially migrate to other locations. Forest structure, including tree density and stand age, influences habitat suitability for many animal species. Managing forest structure to improve food availability (e.g., small trees such as chokecherry) and cover (e.g., high tree crowns) can improve habitat quality. Vegetation that produces fleshy fruits is particularly important for birds and small mammals. Structural features (e.g., downed and standing dead trees) provide wildlife with nesting locations, protection from weather exposure, and protection from predators.

Fish and Aquatic Habitat

Managing your forest for climate resilience can contribute to high-quality habitat for fish and other aquatic species, some of which are expected to be stressed in a warmer climate. Trees and other vegetation along streams offer high-quality habitat for salmon and trout by shading streams and keeping water temperatures cool. Vegetation along riverbanks reduces sediment erosion into the water, thus maintaining good water quality and preventing the smothering of salmon eggs. Fallen trees in streams can slow water flow, creating pools where fish can rest and avoid predation. Maintaining and restoring riparian vegetation helps to keep stream temperatures from exceeding tolerance levels for salmon and trout.

Water Resources

In forested watersheds, many processes influence streamflow and water quality. Forests and vegetation cover influence the retention and movement of water across watersheds. For example, tree canopies intercept rainfall which reduces the amount of water that reaches the ground. Trees also encourage precipitation infiltration by slowing runoff. Healthy, well-managed forests can improve water quality and water storage, increase streamflows in summer, reduce high flows in winter, and contribute to recharge of groundwater.



Stream temperatures are projected to increase by mid-century in some areas of eastern Washington. These maps show modeled historical (1993-2011) and projected August stream temperatures for the 2040s (2030-2059) under a moderate GHG emission scenario (A1B). The coolest streams are shown in blue and green, and the warmest streams are shown in orange and red. Most change is expected along the lower elevations of the Cascade Range. Red and orange areas in the Columbia Basin include streams that are already too warm for some fish or are ephemeral streams. Source: NorWeST Stream Temperature.

Management Options | Wildlife Habitat

- Increase the diversity of native tree species, especially those that are tolerant of low soil moisture. This can include both conifer and hardwood species.
- Protect and create key forest structures (e.g., standing dead trees, downed logs, old trees) that are important habitat features for multiple animal species, especially cavity-nesting species (e.g., owls) and amphibians.
- Thin dense forests to create openings that facilitate understory plant establishment and increase food sources for wildlife, especially deer and elk.

Management Options | Aquatic Habitat

- Plant vegetation adjacent to streams to provide shade and keep the water cool. Trees also help reduce erosion into streams.
- Keep livestock away from riparian areas.

Management Options | Water Resources

- Accommodate or tolerate American beaver activity on your property.
- Protect riparian forest to reduce runoff and soil erosion, which can reduce water quality.

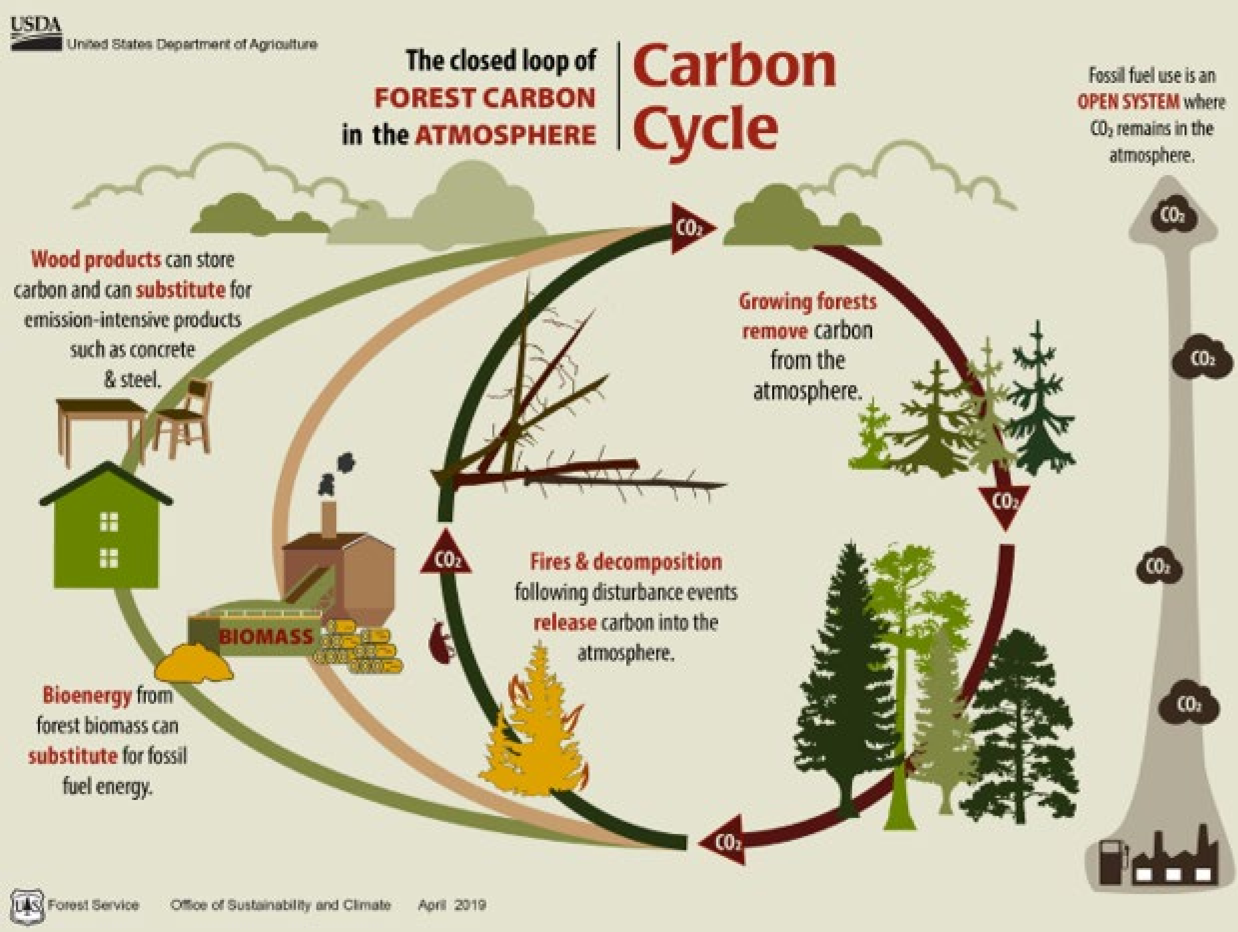
THE FOREST CARBON CYCLE

Carbon dioxide is one of the most abundant greenhouse gases in the atmosphere and is a major contributor to climate change.

Carbon dioxide (CO_2) is emitted by the combustion of fossil fuels. It is also both emitted by and stored in forests. Forest management can increase the amount of carbon that is released from the forest or contribute to carbon storage. In addition to increasing the resilience of your forest to climate change with the actions in this guide, you can implement practices that remove CO_2 from the atmosphere and store it as organic carbon. Your forest can help reduce emissions of CO_2 that cause climate change.

The ongoing storage and release of carbon in forests is a natural cycle. Trees and other forest vegetation store carbon. As plants die, carbon is also stored in the forest floor and soil. Carbon is released from the forest when plant material decomposes or when trees and other organic material burn.

Carbon can also be released when timber is removed, although the amount and timing of that release depend on the life cycle of timber products. Some is released immediately through the process of converting trees to other materials. Some is stored in forest products such as wood used to build houses. When wood products are substituted for more carbon-intensive building materials such as steel and concrete, they further reduce the release of CO_2.



Management Options

Some forest management actions can increase the carbon stored by your forest.

- Keep forest land covered by forests. This is the most effective way to store carbon over the long term. Minimize converting land to agriculture or clearing land for development.
- Maintain healthy forests to store more carbon over time. Some actions that increase resilience to a changing climate, such as thinning, may require removing carbon in the short term. However, in the long term, a healthy forest ecosystem will store more carbon than one suffering from stress due to low soil moisture or impacts from insects and diseases.
- Plant trees to increase carbon storage. Fast-growing young trees have a high rate of CO_2 uptake from the atmosphere.

When planting, tree species and density should reflect other considerations in this guide for maintaining forests that are resilient to climate change (see Table of Tree Species, pg. 26). Avoid planting trees that are not well suited to the future climate, or at densities higher than can be supported by available soil moisture; this will result in only short-term carbon storage.

Managing for carbon storage requires consideration of many aspects of forest management. Planting, thinning, harvesting, and other activities may be implemented to accomplish other objectives such as improving wildlife habitat and reducing fire risk. Each activity has different carbon gains and losses at different time scales, so tradeoffs need to be considered when managing for multiple objectives.

LEARN, PLAN, MONITOR, COLLABORATE

The management actions described in the sections above increase forest resilience to climate change by taking action "on the ground." Additional actions involve education, monitoring and record keeping, planning, and collaboration with neighboring landowners and public agencies. These actions also increase your ability to improve forest resilience in a changing climate.

Learn

Getting to know your forest in detail provides a foundation for successful forest management. Not all actions are right for all forests, and the better you know your forest, the more you will be able to select appropriate actions to increase climate resilience. Here are some important learning objectives:

- Learn to identify common trees and other plant species in your forest.
- Learn to identify soil characteristics and understand the geographic setting of your forest.
- Learn to identify common insects and forest diseases and their effects on trees and other vegetation.
- Learn to identify common invasive species that can have negative consequences for native species.
- Maintain awareness of changing fire season conditions. The Wildland Fire Potential Outlook for Eastern Washington provides information on wildfire risk in a particular year. Elevated fire potential may lead to burn bans and a shorter season for forest management activities, such as prescribed burning and using chainsaws.

Monitor and Keep Records

- A forest inventory of your land will provide a starting point from which to monitor natural resource conditions and prepare for climate impacts as they emerge.
- Monitor for tree damage and mortality to identify emerging stressors such as the presence of new insects or diseases.
- Maintain a list of non-native and invasive plant and aquatic species on your property.

Plan

- Develop a forest stewardship plan that describes management objectives for your forest, including many of the actions listed in this guide. Consider how climate change may affect those objectives. How far into the future are you planning? Are you planning for multiple generations?
- Include in your planning some actions you would consider after a wildfire or other major disturbance. Will you plant trees? If so, which species and seed sources, and where would you get seedlings?

Collaborate

- Connect with Washington State University Extension Forestry staff, conservation districts, private consulting foresters, and others to identify nurseries and find sources of seeds and seedlings from alternative seed zones that can be used for assisted migration.
- Reach out to Washington Department of Natural Resources service foresters (including the Small Forest Landowner Office) who can help you achieve your management goals and sustainably manage your forest.
- Collaborate with your neighbors on fire risk reduction and response planning.
- Determine if there is a Fire Adapted Community in your area. Fire Adapted Community networks offer support for coordination with your neighbors on fire risk reduction and response planning.
- Engage in partnerships with organizations that can help identify current and potential carbon storage in your forest.
- Coordinate with adjacent landowners and agencies to maintain and restore beaver habitat and populations.

DEFINITION OF KEY TERMS

Adaptation	The process of adjusting to actual or projected climate and its associated effects, including with human intervention to facilitate the adjustment.
Carbon sequestration	The process of capturing atmospheric carbon dioxide and storing the carbon in solid (e.g., plants) or liquid (e.g., oceans) form.
Climate	Average weather conditions over multiple years.
Climate change	Change of climate that is linked directly or indirectly to human activity that alters the atmosphere and is in addition to natural climatic variability.
Ecosystem services	Ecological processes or functions that provide benefits or values to individuals or services to society (e.g., flood reduction, wildlife habitat, carbon storage).
Forest fuels	Combustible biomass, including leaves, branches, downed trees, and live trees and other plants.
Greenhouse gas	Gases (e.g., carbon dioxide, water vapor, methane) that absorb heat in the atmosphere near the Earth's surface and prevent heat from escaping into space. If the atmospheric concentrations of these gasses increase, the average temperature of the lower atmosphere will gradually increase, a phenomenon known as the greenhouse effect.
Mitigation	A human intervention to reduce greenhouse gas emissions or enhance the storage of greenhouse gases (e.g., carbon dioxide).
Natural climatic variability	Fluctuation in temperature, precipitation, and other factors over long periods of time (years to centuries) caused by non-human forces (e.g., variation in the Earth's orbit around the sun, interactions between the atmosphere and ocean).
Representative Concentration Pathways	Scenarios of future greenhouse gas concentration trajectories used by the international climate science community in computer models to simulate change in the climate and its effects. The scenarios describe different climate futures, all of which are considered possible depending on near-term greenhouse gas emissions.
Resilience	The capacity of an environmental or human system to cope with and recover from a disturbance or extreme event to provide essential functions and structure.
Tree Vigor	The health and productivity of a tree, including its resilience to stressors.
Weather	Short-term atmospheric conditions that are measured for minutes, hours, or days.
Wildland-Urban Interface	Areas where wildlands and human development (typically built structures) meet or intermingle. The wildland-urban interface does not imply fire risk, simply where the two land types are adjacent or intermixed.

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The management options for climate resilience described in this guide are documented in several U.S. Forest Service publications and the scientific literature. Sources and references for specific management actions can be found in the Climate Change Adaptation Library for the Western United States.

Common Name	Scientific Name
Alaska yellow cedar	*Callitropsis nootkatensis*
Armillaria root disease	*Armillaria* spp.
Balsam woolly adelgid	*Adelges piceae*
Bigleaf maple	*Acer macrophyllum*
Bitter cherry	*Prunus emarginata*
Black cottonwood	*Populus trichocarpa*
Bulbous bluegrass	*Poa bulbosa*
California five-spined Ips	*Ips paraconfusus*
Cascara	*Rhamnus purshiana*
Cheatgrass	*Bromus tectorum*
Chokecherry	*Prunus virginiana*
Common houndstongue	*Cynoglossum officinale*
Common mullein	*Verbascum thapsus*
Dalmatian toadflax	*Linaria dalmatica*
Douglas-fir	*Pseudotsuga menziesii* var. *menziesii*
Douglas-fir beetle	*Dendroctonus pseudotsugae*
Dwarf mistletoe	*Arceuthobium* spp.
Eastern five-spined engraver	*Ips grandicollis*
Elytroderma needle blight	*Elytroderma deformans*
Engelmann spruce	*Picea engelmannii*
Fir engraver	*Scolytus ventralis*
Flatheaded fir borer	*Phaenops drummondi*
Grand fir	*Abies grandis*
Hawkweed	*Hieracium* spp.
Heterobasidion root disease	*Heterobasidion irregulare* & *H. occidentale*
Incense cedar	*Calocedrus decurrens*
Ips beetle	*Ips.* spp.
Knapweed	*Centaurea* spp.
Laminated root rot	*Phellinus weirii*
Lodgepole pine	*Pinus contorta* var. *latifolia*
Lymantria dispar (previously gypsy moth)	*Lymantria dispar*
Medusahead	*Taeniatherum caput-medusae*
Mountain pine beetle	*Dendroctonus ponderosae*
Oregon white oak	*Quercus garryana*
Pacific yew	*Taxus brevifolia*
Paper birch	*Betula papyrifera*
Ponderosa pine	*Pinus ponderosa*
Quaking aspen	*Populus tremuloides*
Rocky Mountain maple	*Acer glabrum*
Sawfly	Order Hymenoptera, Suborder Symphata
Smooth brome	*Bromus inermis*
Sooty bark disease	*Cryptostroma corticale*
Spotted knapweed	*Centaurea stoebe*
Spruce beetle	*Dendroctonus rufipennis*
St. John's wort	*Hypericum perforatum*
Subalpine fir	*Abies lasiocarpa*
Sugar pine	*Pinus lambertiana*
Swiss needle cast	*Phaeocryptopus gaeumannii*
Tent caterpillar	*Malacosoma* spp
Thinleaf alder	*Alnus incana* ssp. *tenuifolia*
Ventenata	*Ventenata dubia*
Vine maple	*Acer circinatum*
Western hemlock	*Tsuga heterophylla*
Western juniper	*Juniperus occidentalis*
Western larch	*Larix occidentalis*
Western mountain-ash	*Sorbus sitchensis*
Western pine beetle	*Dendroctonus brevicomis*
Western redcedar	*Thuja plicata*
Western spruce budworm	*Choristoneura freemani)*
Western white pine	*Pinus monticola*
White pine blister rust	*Cronartium ribicola*
Whitetop	*Lepidium draba*
Willow (Pacific)	*Salix lucida* var. *lasiandra*
Willow (Scouler's)	*Salix scouleriana*
Willow (Sitka)	*Salix sitchensis*

TABLE OF TREE SPECIES

This table describes tree species that you may either now have in your forest or wish to plant; included is their relative tolerance for low soil moisture and for shade (i.e., whether they grow in openings or closed forests). The management considerations can help determine which species are compatible with your current forest species and climate, as well as which species may be good candidates for assisted migration (see pg. 10). Consult with local forestry experts if you consider applying assisted migration on your land.

Species	Tolerance of low soil moisture	Shade tolerance	Management considerations
Low-elevation conifers			
Douglas-fir	Moderate-high; forms a deep taproot in coarse-textured soils	Moderate (in managed stands)	A resilient tree in a warmer climate, although not as drought tolerant as ponderosa pine. Plant only if plenty of light is available. Fire resistant. Laminated root rot is a problem in some areas and may be a bigger problem in a warmer climate. Susceptibility to insects may increase in a warmer climate.
Grand fir	Moderate	High	Commonly found in the understory of ponderosa pine and Douglas-fir, this tree diversifies the structure of conifer forests. Low resistance to fire. Fir engraver (in dense stands) may be a problem in some areas. Susceptible to armillaria root disease and laminated root rot. Grand fir-white fir hybrids, currently found in Oregon, could spread to or be planted in eastern Washington.
Incense cedar	High	High	Commonly found in mixed conifer stands, rarely the dominant species and often in the understory. Currently found in northern Oregon, it could spread to or be planted in eastern Washington. Can be planted with more dominant conifer species to provide diversity.
Oregon white oak	High, but will tolerate poorly-drained soils during the wet season	Low	Currently found in western Washington and the southwest portion of eastern Washington, often in open stands, sometimes mixed with conifers. Sprouts vigorously after fire. Plant only if plenty of light is available. It could spread to or be planted more extensively in eastern Washington.
Pacific yew	Moderate	High	Can be underplanted in existing stands to provide a multi-storied canopy. Not fire resistant. Plant in moist soils, drainages, and north aspects.

Ponderosa pine	High; a deep taproot in older trees makes it both drought tolerant and wind tolerant	Low	A resilient tree in a warmer climate. Plant only if plenty of light is available and stand density will be managed. Very fire resistant. Will be more susceptible to bark beetles and other insects in a warmer climate. It may also be more susceptible to fungal pathogens and dwarf mistletoe.
Sugar pine	Moderate	Low-moderate	Commonly grows in mixed conifer stands. Moderately fire resistant. Currently found in northern Oregon, it could spread to or be planted in eastern Washington. Can be planted with other conifer species to provide diversity.
Western hemlock	Low	High	Often germinates in the understory where it can grow slowly for decades. Not a resilient species in a warmer climate but can perhaps be planted on north aspects and in drainages to provide species diversity and a multi-storied canopy. Susceptible to several pathogens, some of which could be more of a problem in a warmer climate.
Western juniper	Very high	Low	A small to medium-sized tree or shrub sparsely distributed in eastern Washington but more common in Oregon. Found in dry soils and exposed landscapes across a range of elevations, the sole species or mixed with other drought-tolerant conifers and shrubs. Not fire resistant.
Western larch	Moderate	Low	A tall deciduous conifer found at mid elevations mixed with other conifer species. Very fire resistant and cold tolerant. Plant only if plenty of light is available, preferably in soils that retain some moisture during summer (drainages, north and east aspects).
Western redcedar	Low-moderate	High	Not expected to be resilient in a warmer climate but can be planted in drainages, north aspects, and soils that retain moisture (but do not have standing water). Can be underplanted in existing conifer and hardwood stands. Resistant to most insects and pathogens. Susceptible to browsing by deer and elk.
Western white pine	Moderate	Low-moderate	A good tree for diversifying some forests. Plant only if plenty of light is available. White pine blister rust is a serious concern for this species, so it should be planted only in areas where no currants (*Ribes*) are present; use rust-resistant nursery stock if possible.

Species	Tolerance of low soil moisture	Shade tolerance	Management considerations
Mid-high elevation conifers			
Engelmann spruce	Moderate	High	Mid- to high-elevation tree, often associated with subalpine fir. Plant where soil moisture is adequate (e.g., in drainages, near streams). Susceptible to spruce beetles, especially in older, dense stands.
Lodgepole pine	Moderate; tolerant of shallow or rocky soils	Low	Mid- to high-elevation tree. Plant only if plenty of light is available. Tolerant of cold drainages. Susceptible to mountain pine beetles during drought periods when trees are stressed.
Subalpine fir	Moderate	High	High-elevation tree, especially in high-snow areas, and in drainages at mid elevation. Often associated with lodgepole pine and Engelmann spruce. Low branches can root where they touch the ground. Susceptible to balsam woolly adelgid in some places.
Hardwoods			
Bigleaf maple	Moderate	Moderate-high	Long-lived tree that occupies a variety of sites; a good choice for drainages and riparian areas. Fast juvenile growth. Susceptible to the newly emerging sooty bark disease. Recent dieback in some areas appears to be related to hot, dry summers.
Bitter cherry	Low	Low-moderate	Short-lived tree in young stands, often growing vigorously after timber harvest. Produces lots of fruit for wildlife.
Black cottonwood	Low; tolerates wet soil, flooding, and sediment deposition	Low	Generally grows only in wet soils and riparian areas. Mature trees are tall with large crowns, often outcompeting other hardwoods.
Cascara	Moderate	High	Small to medium-sized, often multi-stemmed tree typically found in the understory of conifer forests. Can be underplanted in existing stands to provide a multi-storied canopy and berries for wildlife.
Chokecherry	Moderate	Low-moderate	Small tree or large shrub found along forest edges and in open areas. Sprouts vigorously when damaged. Produces lots of fruit. Susceptible to tent caterpillars, other butterfly/moth larvae, and some fungal pathogens.
Paper birch	Moderate	Moderate	Northern Washington is the southern extent of this medium-sized tree. It is typically short-lived and susceptible to several insects. Planting south of its current distribution is not advised.

Species	Tolerance of low soil moisture	Shade tolerance	Management considerations
Quaking aspen	Low but can grow in drier soils if near a water source	Low	Tall, fast-growing tree that is distributed primarily in the northern part of eastern Washington. Small stands of pure aspen can provide diversity adjacent to conifer stands. Susceptible to several insects and pathogens. Planting south of its current distribution is not advised.
Rocky Mountain maple	Moderate	Moderate	A small tree that can be planted with other conifers or hardwoods to provide diversity and a multi-storied canopy.
Thinleaf alder	Moderate; grows in a variety of soils	Moderate	Small tree or shrub commonly found in riparian areas, often mixed with conifers. Tolerant of short periods of flooding. Fixes nitrogen. Sprouts after fire.
Vine maple	Low-moderate	High	Small, sprawling understory tree, often found in riparian areas and wetlands. Can be planted in the understory of conifer forest to provide a multi-storied canopy.
Western mountain-ash	Moderate	Moderate	Small tree or shrub found in open forests, clearings, streambanks, and avalanche slopes at mid to high elevation. Sprouts after fire. Provides fruit for wildlife, especially in fall and winter.
Willow (Pacific, Scouler's, Sitka)	Low-moderate; tolerates wet soils	Low-moderate	Small to medium-sized trees typically found in riparian areas and wetlands. Good tree for providing rapid shade in riparian restoration. Scouler's willow tolerates dry sites better than the other willow species.