PRELIMINARY REPORT:
Wildfire Prevention, Preparedness, and Expenditure Review

LEGISLATIVE AUDITOR'S CONCLUSION:

DNR's long-term approach to wildfire prevention and preparedness is supported by science and best practices. The approach requires coordination with other entities and can reduce fire severity, which may impact costs to suppress fires.

*December 2020*

Executive Summary

In 2019, the Joint Legislative Audit and Review Committee (JLARC) directed its staff to review the Department of Natural Resources' (DNR) wildfire prevention and preparedness activities and related expenditures. The study directive also required a review of research to identify whether there is evidence to show how effectively the activities reduce the negative impacts and costs of wildfire.

DNR has a strategic, science-based approach to prevention and preparedness

DNR developed long-term wildfire and forest health plans that provide a strategic approach to prevention and preparedness. The approach is grounded in science and the planned activities (e.g. thinning, chipping, prescribed fire) are consistent with science and best practices. Plans address:

- **Prevention** - activities that are aimed at reducing the number of human caused fires.

- **Preparedness** - activities that are intended to improve forest health and help communities adapt to wildfire. For this report, preparedness does not include suppression-related activities to control or extinguish fires (e.g., training, placing staff and equipment near anticipated fires).

Since the plans were developed in 2017 and 2018 and have 10-20 year timelines, DNR is still in the early stages of implementation. To date, DNR has identified 33 initial priority areas in eastern Washington (yellow areas on map) to focus forest health efforts, and activities have begun in these areas.

Forest health priority areas
DNR land
Other state and federal land
Private and other land
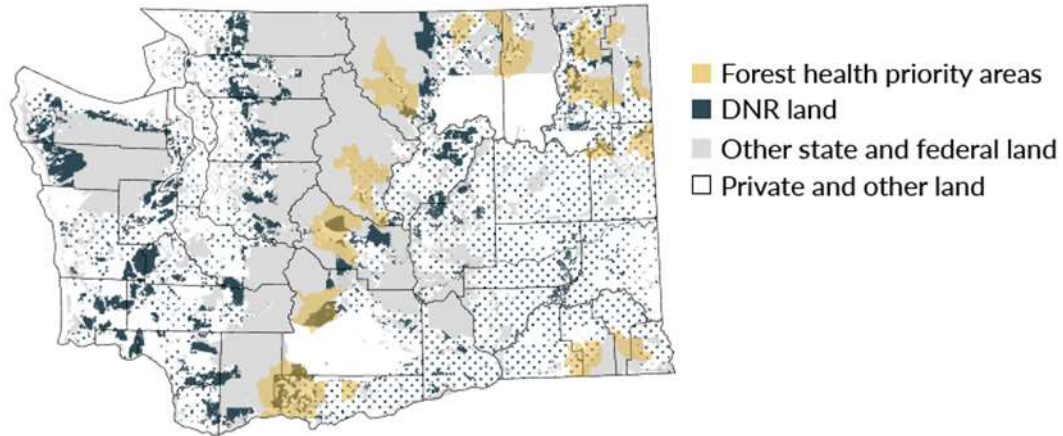
Source: JLARC staff analysis of DNR data.

DNR spent a total of $70 million on preparedness and prevention in fiscal years 2018-2020. More detail is available in Appendix B.

DNR is one of many partners that must work together to achieve prevention and preparedness goals

Statute requires DNR to assess and treat one million acres of forest land in eastern Washington by 2033. DNR manages only 500,000 acres within its priority areas, so meeting this goal will require working with other federal, state, private, and tribal entities.

Landscape preparedness activities are coordinated through formal agreements and collaboratives. DNR also provides financial and technical assistance to small forest landowners.

Community preparedness and prevention activities (e.g. Firewise USA®[1], Community Wildfire Protection Plans) involve conservation districts, community groups, fire agencies, and local governments. Research suggests that community preparedness can increase firefighter safety and reduce loss to private property.

Currently, DNR cannot systematically show how much it has spent on forest health treatments in a specific area. However, DNR is developing a new system that could provide this information.

DNR currently uses multiple systems to track prevention and preparedness information needed to meet statutory reporting requirements. These systems are unable to connect activity location and cost, so DNR cannot easily show how much it has spent on preparedness activities in the

---

[1]A program that encourages residents of wildfire-prone areas to take voluntary actions to reduce wildfire risks to their homes and neighborhoods.
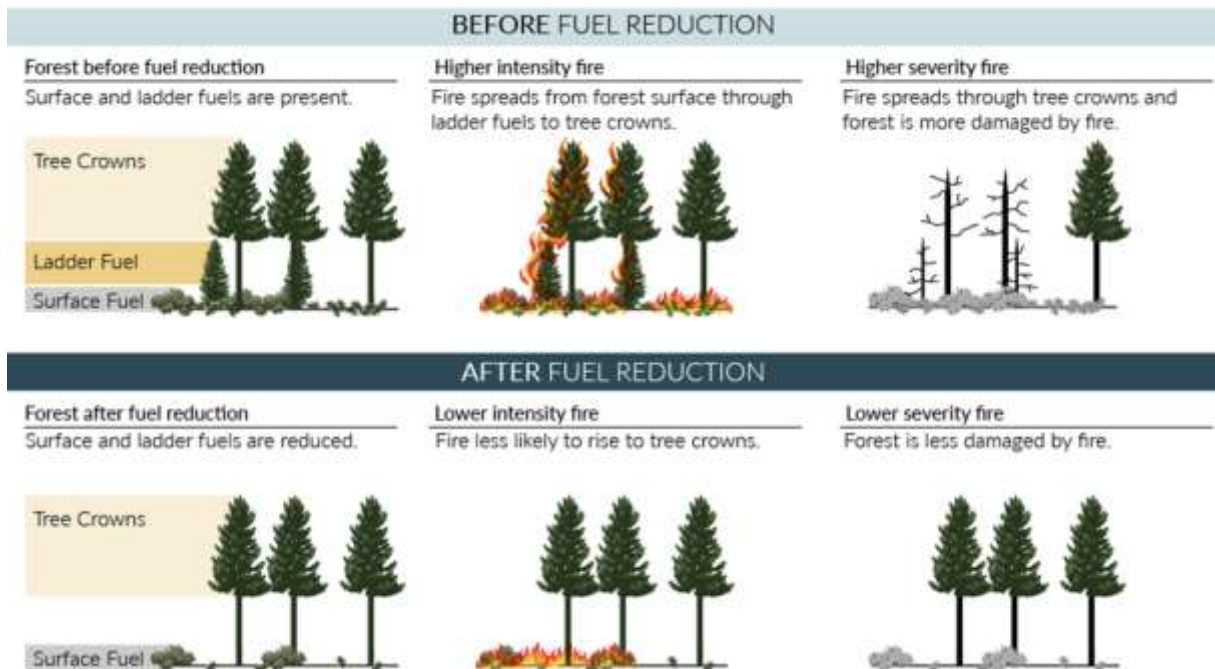
specific priority areas. This makes it difficult to know if the agency's spending is consistent with its plans and goals.

However, as required by law, DNR is developing a monitoring strategy to track forest health accomplishments. One component of the broader monitoring strategy is a forest health tracking system. The system will include maps, activity type, and project level information, such as location, funding, and costs. DNR plans to provide public access to the tracking system in 2021.

Research indicates that preparedness activities can reduce fire intensity and severity, and may decrease suppression costs for individual fires

JLARC staff worked with consultants to review more than 300 peer reviewed articles, guidance documents, and published reports about fire ecology and management (see Appendix A for bibliography). Research, which is generally applicable to eastern Washington forests, suggests that fuel reduction projects that combine thinning and prescribed fire effectively reduce fire intensity, fire severity, and have other ecological, public safety, and economic benefits. DNR is taking steps to increase its use of prescribed fire.

- **Fire intensity** measures a fire's energy, usually in terms of temperature or flame length.

- **Fire severity** refers to the effects of fire on forest material, such as percent of trees that burned or died.

BEFORE FUEL REDUCTION

Forest before fuel reduction
Surface and ladder fuels are present.

Higher intensity fire
Fire spreads from forest surface through ladder fuels to tree crowns.

Higher severity fire
Fire spreads through tree crowns and forest is more damaged by fire.

Tree Crowns
Ladder Fuel
Surface Fuel

AFTER FUEL REDUCTION

Forest after fuel reduction
Surface and ladder fuels are reduced.

Lower intensity fire
Fire less likely to rise to tree crowns.

Lower severity fire
Forest is less damaged by fire.

Tree Crowns
Surface Fuel

Source: JLARC staff depiction based on diagrams created by the U.S. Forest Service.

There are many factors that influence overall fire suppression costs, and the relationship between prevention, preparedness, and suppression spending is too complex for a simple equation (e.g. a dollar spent in one area equates to reducing suppression costs by $X). However, research models predict that preparedness activities may reduce suppression costs for individual fires.

REPORT DETAILS
1. DNR has a strategic, science-based approach

DNR's wildfire and forest health plans provide a strategic approach to fire prevention and preparedness. The approach is grounded in science and the planned activities are consistent with best practices.

In 2019 and 2020, the Legislature considered bills that would create a new funding source for the Department of Natural Resources' (DNR) wildfire suppression, prevention, and preparedness activities. DNR stated that the proposal would reduce "wildfire damage and cost by investing in proven wildfire prevention and preparedness strategies."

The bills did not pass and the Joint Legislative Audit and Review Committee (JLARC) directed its staff to:

- Review the Department of Natural Resources' wildfire prevention and preparedness activities and related expenditures.

- Identify whether there is evidence to show how effectively the activities reduce the impacts and costs of wildfire.

Terms used in this report

For purposes of this report, we use the following terms to describe DNR's activities:

- **Prevention** activities are aimed at reducing the number of human caused fires.
- **Preparedness** activities are intended to improve forest health and help communities adapt to wildfire. Preparedness does not include suppression-related activities that extinguish or control the spread of fire (e.g., training, placing staff and equipment near anticipated fires).

DNR developed long-term wildfire and forest health plans

While there are many factors that contribute to wildfire, there is broad agreement among many scientists and land managers that historic forest management practices and fire suppression

policies at the federal and state level have led to an unnatural buildup of fuels[2] on the landscape. Dense, unhealthy forests create fuels that make fires harder to control and more expensive to suppress.

DNR developed long-term forest health plans, as required by state and federal law. It also developed a 10-year plan to address wildfire. The plans set forth strategies to achieve healthy forests, resilient landscapes, fire adapted communities, and safe wildfire response. Since the plans were written in 2017 and 2018 and have 10-20 year implementation timelines, DNR is still in the early stages of implementation.

Exhibit 1.1: DNR's plans provide a strategic approach to achieve prevention and preparedness goals

Forest Health Strategic Plan and Implementation Strategy			
	20-Year Forest Health Strategic Plan: Eastern Washington (2017) Overarching framework for addressing forest health needs on all forest lands in eastern Washington, regardless of ownership.		*Strategy to Restore Forest Health on State Lands in Eastern Washington (2017)* Implements the 20-Year Forest Health Strategic Plan on DNR-owned lands.

---

[2]These include grasses, shrubs, woody debris, and small trees.

Wildfire Strategic Plan and Forest Action Plan			
	Washington State Wildland Fire Protection 10-Year Strategic Plan (2018) Strategy and implementation plan to address wildland fire issues across the state. Aligns with the National Cohesive Wildland Fire Strategy.		*Forest Action Plan (2017)* Strategy for using DNR's forestry programs to address threats to forest resources and advance federal goals. DNR published an update in the fall of 2020, after the field work for this study was complete.

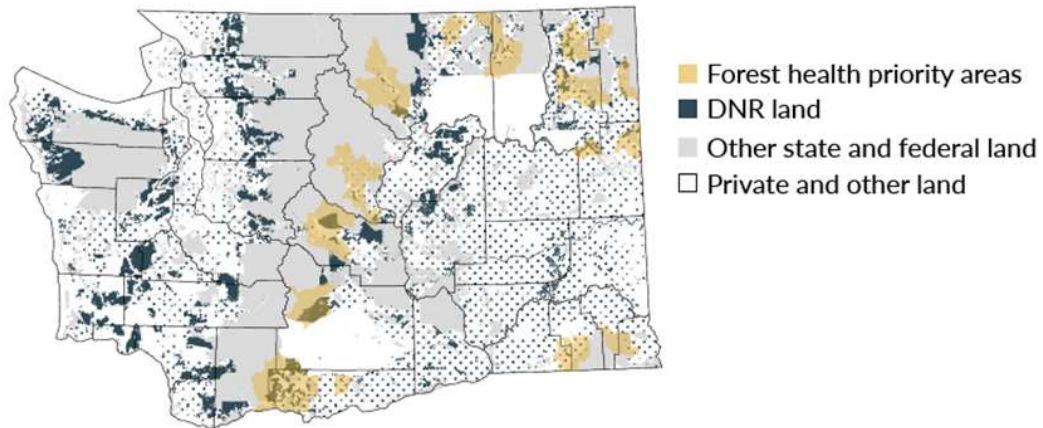Source: JLARC staff analysis of DNR planning documents.

DNR used a scientific approach to identify 33 initial priority areas for preparedness activities in eastern Washington

Statute[3] defines healthy forests as sound in ecological function, sustainable, resilient to insects, diseases, fire, and other disturbances, and able to meet landowner objectives. DNR's Forest Health Plan identifies priority areas to focus forest health treatments, as state law requires (see Exhibit 1.2).

- DNR identified 33 initial priority areas in eastern Washington based on data that includes fire risk, wildland urban interface, drinking water, wildlife habitat, climate change, timber volume, and aquatic resources. DNR's methodology is included in the Plan. DNR plans to identify additional priority areas each biennium.

- After identifying priority areas, DNR conducted landscape evaluations to assess forest health conditions and determine treatment needs. The evaluations summarize vegetation changes compared to historical conditions, current fire and drought risk, and wildlife habitat needs. This information is used to identify specific actions needed to move the landscape into a more ecologically resilient condition and reduce fire risk.

[3]RCW 76.06.020

Exhibit 1.2: The 33 priority areas in eastern Washington cross multiple ownership boundaries

Legend:
- Forest health priority areas
- DNR land
- Other state and federal land
- Private and other land

Source: JLARC staff analysis of DNR data.

DNR compiled agency and partner data about forest health treatments into a database. The database includes information from 2017 through 2019 and shows that treatments took place on state, federal, and private land in the 33 priority areas. Treatments include fuel reduction projects such as thinning, chipping, piling and burning vegetation.

DNR is developing a tracking system to monitor forest health accomplishments, as described in Section 3.

Activities identified in DNR's plans align with federal guidance and best practices

DNR's plans and activities are consistent with national guidance. For example, the National Cohesive Wildland Fire Management Strategy[4] has three goals: restore and maintain resilient landscapes, create fire adapted communities, and respond to wildfires safely and effectively. DNR's Wildfire Strategy adopts the same goals and identifies similar activities such as fuel reduction treatments, prescribed fire, reduction of human-caused ignitions, and community action. DNR's Forest Health Plan provides an approach for creating healthy, resilient landscapes in eastern Washington.

The activities in DNR's plans also are consistent with best practices identified in scientific literature. For example, research shows that activities such as thinning, chipping, and prescribed fire reduce the fuels that allow fires to grow and spread. More information is in Section 4.

---

[4]Federally mandated strategy that sets national-level direction for fire preparedness and management across all lands.

Exhibit 1.3: DNR's plans identify a variety of prevention and preparedness activities for itself and its partners
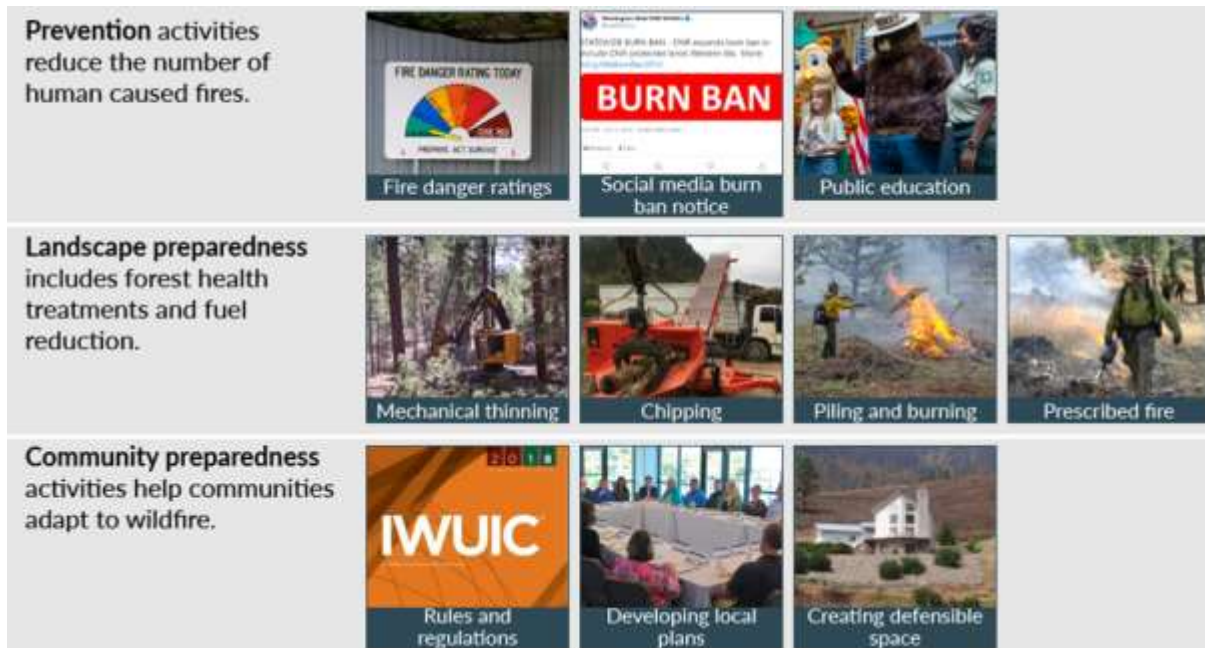
Source: JLARC staff analysis.

DNR spends more on preparedness activities than prevention

DNR spent a total of $70 million on preparedness and prevention in fiscal years 2018, 2019, and 2020. Of this, $63 million was spent on landscape preparedness activities such as forest health and fuel reduction.

Sources include state, federal, and non-appropriated funds. State budget provisos and federal grants have directed more funding to preparedness (e.g., forest health, hazard reduction) than to prevention (e.g., public education).

DNR uses unique accounting codes to differentiate prevention and preparedness spending from other DNR activities including wildfire suppression. The codes also provide details about its spending, such as the type of activity (e.g., forest health, prevention education), specific projects, and the region where funds were spent.

Additional detail for fiscal year 2020 is in Appendix B.

DNR is one of many partners that must work together to achieve prevention and preparedness goals

There are 22 million acres of forest land in Washington. Landowners include the Department of Natural Resources (DNR), the U.S. Forest Service (USFS), the U.S. Fish and Wildlife Service (USFWS), Washington Department of Fish and Wildlife (WDFW), State Parks, Tribes, and private forest landowners.
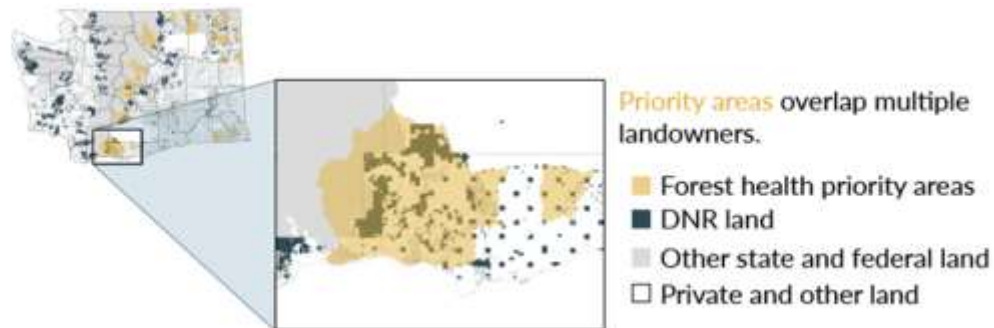
Federal, tribal, and private landowners collectively own more Washington forest land than DNR, which owns about three million acres. Landowners may have objectives prioritized differently for their land, such as emphasizing timber revenue or recreation opportunities.

State law directs DNR to treat one million acres and coordinate with others

Statute sets requirements for DNR's forest health treatments and interagency collaboration. For example:

- DNR must aim to complete forest health treatments on one million acres in eastern Washington by 2033 (RCW 76.06.200). DNR identified 33 initial priority areas to focus treatments. It plans to identify additional areas each biennium (see Section 1). Because DNR owns or manages only 500,000 acres within these areas, it will need to work with others to accomplish the Legislature's goal.

- DNR must coordinate with other parties to monitor forest health and provide education or technical assistance (RCW 76.06.030). Additional stakeholders include city and county governments, non-forest landowners, other residents, community groups, and businesses.

Exhibit 2.1: There are multiple landowners and other stakeholders in each of the 33 priority areas[5]

Priority areas overlap multiple landowners.
- ◼ Forest health priority areas
- ◼ DNR land
- ◻ Other state and federal land
- ☐ Private and other land

Source: JLARC staff analysis of DNR data.

Landscape preparedness is coordinated through formal agreements, collaboratives, and assistance programs

As described below, DNR and federal agencies use the Good Neighbor Authority (GNA), a Shared Stewardship agreement, and forest collaboratives to coordinate landscape preparedness across state and federal land.

- The GNA is an agreement signed in 2017 that allows DNR to plan and implement forest health treatments on land managed by the U.S. Forest Service (USFS) and Bureau of Land Management. The federal agencies reimburse DNR. There are 46 GNA projects completed or underway in Washington.

- The Shared Stewardship agreement, signed in 2019, encourages larger, more targeted restoration efforts based on the state's Forest Action Plan (see Section 1). The USFS and Washington Department of Fish and Wildlife participate. There are currently no projects completed or in progress.

- Forest health collaboratives help DNR, federal agencies, Tribes, conservation groups, and others reach non-binding agreements about forest management on federal forest land. Two of the nine Washington forest collaboratives also address other public and private land.

---

[5]Those with less than 5,000 acres.

Financial and technical assistance is available to small private forest landowners

DNR provides free forest stewardship consultations to private forest landowners across the state. In eastern Washington, DNR offers a landowner assistance program to help small forest landowners[6] improve forest health and resilience to wildfire. Through the program, DNR and the landowner share the cost of approved forest health treatments (e.g., thinning, chipping, pruning). DNR aims to have 80% of landowner assistance projects located within the priority areas.

Other agencies also support the work of small forest landowners. For example, conservation districts provide technical assistance and can help connect DNR with interested landowners. A 2019 agreement between DNR, USFS, conservation districts, Washington State University Extension, and other partners clarifies responsibilities for information sharing, technical assistance, funding, and administration.

Community preparedness and prevention activities involve conservation districts, community groups, fire agencies, and local governments

Many communities in the wildland urban interface (WUI)[7] take steps to prepare for wildfire. The WUI is the area where homes are built near or among lands prone to wildland fire. Research suggests that fire in the WUI is a key driver of suppression costs. Research also suggests that community preparedness can increase firefighter safety and reduce loss of private property (see Appendix A for bibliography).

Residents, government agencies, and private organizations share responsibility for prevention and preparedness in the WUI. For example:

- **Prevention:** DNR and fire agencies offer wildfire prevention education. They also establish and communicate burn restrictions.

- **Defensible space and home hardening:** Residents can create defensible space[8] and use fire-resistant materials on homes. Conservation districts, fire agencies, and DNR provide information through print materials, web sites and social media, and public meetings.

---

[6]Those with less than 5,000 acres.

[7]Pronounced as "woo-ee."

[8]Area in which vegetation and debris has been cleared or reduced to slow the spread of fire.

Many fire agencies[9] and conservation districts conduct home assessments and provide assistance. DNR and conservation districts also help communities receive formal recognition through Firewise USA®[10].

- **Regulations:** Local governments adopt and enforce building codes, including those specific to the WUI.

- **Information sharing:** Groups called fire adapted community learning networks and coalitions connect stakeholders so that they can share best practices, resources, and lessons learned. Members include fire agencies, conservation districts, DNR, residents, and others.

- **Planning:** Local governments may develop a Community Wildfire Protection Plan (CWPP) to identify and prioritize local needs for hazard mitigation, community preparedness, and structure protection. Participants have included conservation districts, federal agencies, emergency management, forest collaboratives, businesses, residents, and nonprofit conservation groups. DNR, local fire agencies, and local governments must agree to the CWPP. There are 62 plans in Washington reflecting the needs of counties, cities, towns, and other communities.

REPORT DETAILS
3. Treatment costs for specific areas not currently available

Currently, DNR cannot systematically show how much it has spent on forest health treatments in a specific area. However, it is developing a tracking system that could provide this information.

State law and federal grants require DNR to report forest health treatments, including acres and costs

Each biennium, the Department of Natural Resources (DNR) must submit two reports to the Legislature. They both must identify areas prioritized for forest health treatments, report progress on completing the treatments, and estimate the work and costs for the next biennium.

---

[9]Fire agencies are responsible for structure protection in the WUI.

[10]A program that encourages residents of wildfire-prone areas to take voluntary actions to reduce wildfire risks to their homes and neighborhoods.

The Legislature passed these requirements in 2017 and the next reports are due in December 2020.

1. One report focuses on state lands (RCW 79.10.530).

2. The other addresses the 20-Year Forest Health Strategic Plan (see Section 1). In addition to the requirements above, DNR must report on the treatments completed in the preceding biennium, the costs, and treatment outcomes (RCW 76.06.200).

Federal grant agreements also require DNR to submit annual progress reports on the acres treated and associated costs.

DNR collects financial and spatial data

DNR collects the information it needs to fulfill its reporting requirements and make management decisions about where to direct its spending on landscape preparedness.

- DNR maintains financial data in the state accounting system and in spreadsheets that track landowner assistance projects. The data includes information such as amount spent, fund source, and project. The data allows DNR to report the amount spent from federal grants or state appropriations, as well as overall costs (see Section 1 and Appendix B).

- DNR stores spatial data in a separate database. The spatial data includes the specific location and information about the types of forest health treatments completed. This data can be mapped with the other spatial information to show whether the treatment took place within a priority area. DNR began collecting this data for treatments conducted in 2017 through 2019. Currently, it allows DNR to show the treatments at specific locations and whether those locations overlap with priority areas.

DNR's systems currently do not link financial and spatial data, so it is unclear how much has been spent on treatments in specific priority areas

The financial and spatial data systems do not currently share a set of common unique identifiers that could be used to link treatment location and costs. Further, data quality issues in the spreadsheets and database (e.g., null fields, inconsistent name and date conventions) hinder efforts to create the link manually. As a result, DNR cannot systematically show the cost of treatments at specific locations or know whether its spending is consistent with its plans and goals.

DNR reports that it is working to correct this problem with proposed data standards, beginning with landowner assistance projects. DNR intends to complete this work by June 2021 for projects completed since 2017.

Exhibit 3.1: DNR has proposed data standards to link financial and spatial data by June 2021
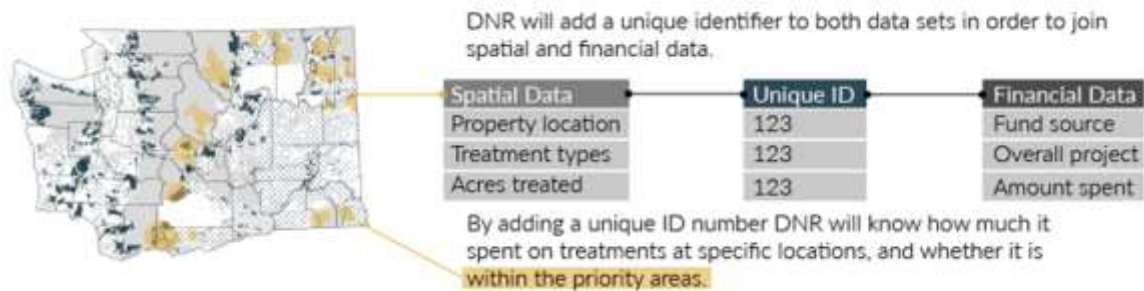
Source: JLARC staff analysis.

DNR is developing a forest health tracking system to monitor forest health accomplishments from multiple entities. DNR plans to include treatments and costs.

As required by state law[11], DNR is developing a monitoring strategy to track forest health treatments, outcomes (e.g., changes to forest condition), and effectiveness over time.

One component of this is a forest health treatment tracking system. The system includes information from the spatial database described above, as well as data from other state, federal and private landowners. The tracking system will include information about where treatments are located and basic information about each treatment, such as treatment type, objectives, and completion date. The system is intended to provide a multiparty view of forest health treatment activities that does not currently exist.

DNR began developing the tracking system in September 2018. It plans to make the data and maps viewable on its web site in 2021. At that time, the tracking system will:

- Include a map of project locations.
- Filter projects by completion stage and type.

---

[11] RCW 76.06.030

- Provide available project-level information such as project name and number, project description, start and completion dates, location, organization and contacts, funding and cost, grants and agreements, and photos.

Subject to funding, the tracking system will eventually replace the spreadsheets and include data for forest health treatments statewide and ongoing monitoring.

REPORT DETAILS
4. Preparedness can reduce fire intensity, severity

Research indicates that preparedness activities can reduce fire intensity and severity, and may decrease suppression costs for individual fires

JLARC directed its staff to evaluate whether research identifies certain types of activities that affect the negative impacts and costs of wildfire. Staff worked with expert consultants to review more than 300 peer reviewed articles, guidance documents, and published reports about fire ecology and management (see bibliography in Appendix A).

Research suggests that removing fuels from the landscape has reduced the intensity and severity of individual fires

Landscape preparedness activities such as thinning, chipping, and prescribed fire can reduce or alter the fuels on the ground (surface fuels[12]), increase gaps[13] between trees, and increase distance from the forest floor to its canopy. The goal of these activities is not to stop all fires, but to make it more difficult for a fire to move from the ground into the canopy and then spread from canopy to canopy. This has been shown to decrease the fire's intensity and severity.

- **Fire intensity** measures the fire's energy, usually in terms of temperature or flame length. For example, a high intensity fire is hotter than a low intensity fire.

- **Fire severity** refers to the effects of fire. It reflects the loss or change in forest material, such as the percent of trees that burned or died.

---

[12]These include grasses, brush, and wood debris.

[13]Referred to as the canopy distance.

Exhibit 4.1: Preparedness activities reduce fuels on the landscape

BEFORE FUEL REDUCTION

Forest before fuel reduction
Surface and ladder fuels are present.

Higher intensity fire
Fire spreads from forest surface through ladder fuels to tree crowns.

Higher severity fire
Fire spreads through tree crowns and forest is more damaged by fire.

Tree Crowns
Ladder Fuel
Surface Fuel

AFTER FUEL REDUCTION

Forest after fuel reduction
Surface and ladder fuels are reduced.

Lower intensity fire
Fire less likely to rise to tree crowns.

Lower severity fire
Forest is less damaged by fire.

Tree Crowns
Surface Fuel

Source: JLARC staff depiction based on diagrams created by the U.S. Forest Service.

Prescribed fire is a best practice for removing surface fuels

Fuel reduction projects are most effective when they combine thinning and the removal of surface fuels. When appropriate, prescribed fire[14] is one way to reduce surface fuels, and is generally less labor intensive and costly than other methods.

Research that is generally applicable to forests in eastern Washington shows that fires are less severe in areas that have been treated with thinning and prescribed fire compared to similar areas without these activities.

- Researchers studied areas burned during the 2014 Carlton Complex fire in north-central Washington. They found that areas with fuel reduction treatments that included thinning and prescribed fire burned with less severity even when there was high wind and temperatures.

- Computer models that simulate the effect of fuel reduction activities confirm the effectiveness of thinning combined with prescribed fire for reducing fire intensity and severity in forests like those in eastern Washington.

---

[14]The controlled application of low to moderate intensity fire under specific weather conditions to meet management objectives.

The Department of Natural Resources (DNR) is taking steps to increase the use of prescribed fire in Washington. For example, DNR's planning documents provide goals and strategies for the use of prescribed fire. At the Legislature's direction, DNR conducted a prescribed fire pilot project (2016 HB 2928) and is developing a certification program for prescribed fire (2018 HB 2733).

Exhibit 4.2: Thinning and prescribed fire reduced fuels and fire impacts
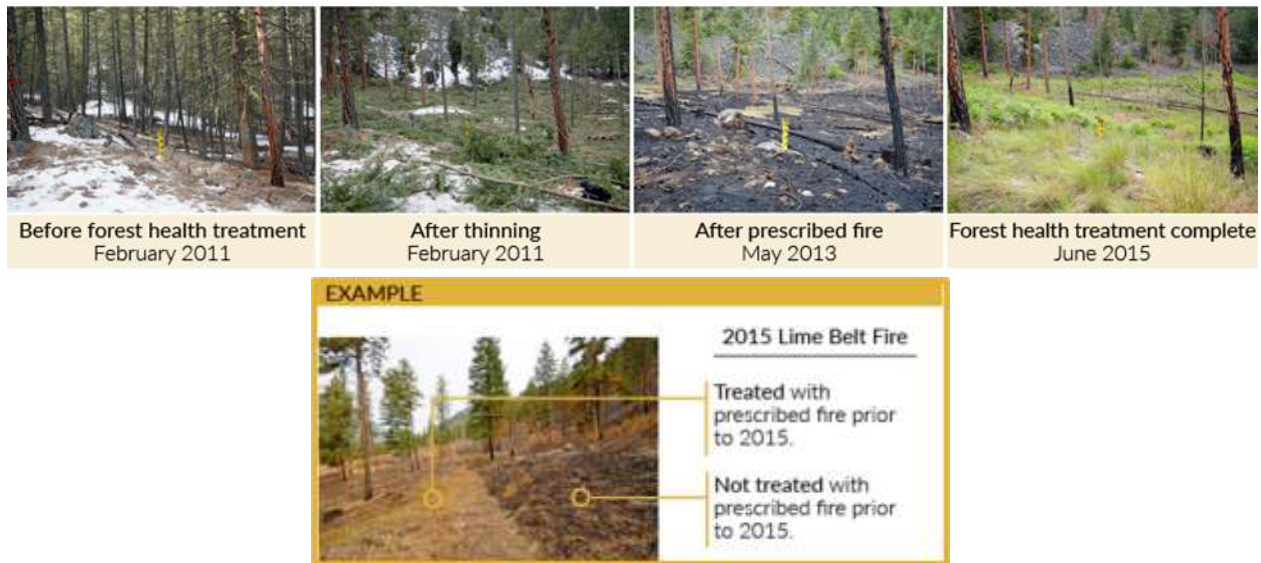
Source: JLARC staff analysis. Photographs taken by Justin Haug, Washington Department of Fish and Wildlife (WDFW).

Research indicates landscape preparedness may have ecological, public safety, and economic benefits

By reducing fire intensity and severity, fuel reduction activities can provide ecological benefits and improve public safety. The activities can also provide economic opportunities. The research cautions that these types of benefits are often site-specific and the experiences from one location may not directly apply to another.

Ecological: Research has found that fuel reduction can improve habitat for some species (e.g. deer, elk) and preserve water sources that could be affected by high severity fire.

Public safety: Fuel reduction activities may modify a fire's behavior, allowing firefighters safer access and improved suppression opportunities. Less intense and severe fires produce less harmful air quality impacts and smoke emissions than more severe fires.

Economic: Landowners and management agencies often hire contractors to perform fuel reduction activities such as thinning and chipping. This may provide jobs in rural economies and marketable timber products.

Models predict that preparedness activities may reduce suppression costs for individual fires

The relationship between prevention, preparedness, and suppression spending is complex. Without extensive and detailed information on costs and benefits, it cannot be simplified to an equation (e.g. a dollar spent on preparedness equates to reducing suppression costs by $X). This cost and benefit information is often unavailable or unknown.

Instead, researchers use two key methods to evaluate the effect of fuel reduction activities on fire suppression costs: case studies and computer simulations.

- **Case studies** compare actual suppression costs in areas with and without fuel reduction activities. This approach is uncommon and some researchers show reduced suppression costs in areas with past fuel reduction activities, while others find no significant relationship.

- **Computer simulations** assess the effect of fuels on fire growth, behavior, and size, and the subsequent effect on suppression response and costs. The simulations suggest that preparedness activities that reduce fuels may lower suppression costs for individual fires when they occur in a treated area.

DNR's ability to relate prevention, preparedness, and suppression spending is further complicated by the agency's data systems (see Section 3 and below).

DNR's systems cannot yet identify costs for individual fires

JLARC directed its staff to evaluate DNR's progress in implementing the recommendations from the 2018 JLARC report *Wildfire Suppression Funding and Costs*. The three recommendations instructed DNR to:

- Refine its collection of key data elements.

- Improve the accuracy and reliability of the key data elements.

- Develop a systematic and verifiable way to identify the costs of individual fires.

DNR concurred with each recommendation and has taken some steps towards implementation. However, it did not meet the implementation deadlines, and as of August 2020, DNR reports that implementation is "in progress."

Preparedness activities are among many factors that may influence overall suppression costs

Rising suppression costs have led researchers to study the factors driving suppression costs. It is important to note that a small percentage of fires each year typically account for a large percentage of suppression costs.

Some of the many factors that affect suppression costs include:

- **Fire size and behavior:** costs increase with fire intensity and severity and the area burned is often correlated with annual suppression costs.

- **Development in the wildland urban interface (WUI):** there is wide recognition among fire managers and researchers that increased development in the WUI has led to higher suppression costs.

- **Climate and weather:** long term climatic patterns that increase temperature, produce drought, and lengthen the annual fire season increase fire suppression costs. Specific weather patterns that produce high winds and low relative humidity can also increase fire severity and suppression costs.

- **Fuels:** the widespread buildup of forest fuels on the landscape makes fires more intense, severe, and costly to suppress.

- **Fire management decisions**: resource allocation and suppression strategies can affect costs.

Some of these factors may be influenced by DNR's and other entities' preparedness activities (e.g. fuel reduction, community preparedness), while others, such as suppression management decisions and weather patterns, are not.

REPORT DETAILS
Appendix A: Literature review methodology

Staff and consultants reviewed more than 300 sources

JLARC staff worked with two consultants to review fire ecology and management literature. Collectively, we reviewed more than 300 documents and worked with subject matter experts to reach the conclusions in Section 4. A list of sources is available in the table below.

Jump to Appendix B.

Sources include peer reviewed articles, guidance documents, and published reports

Author	Year	Title
Abrams, J., Huber-Stearns, H., Gosnell, H., Santo, A., Duffey, S. and Moseley, C.	2020	Tracking a governance transition: identifying and measuring indicators of social forestry on the Willamette National Forest
Abrams, J., Nielsen-Pincus, M. Paveglio, T. and Moseley, C.	2016	Community wildfire protection planning in the American West: homogeneity within diversity?
Absher, J.D., Vaske, J.J. and Shelby, L.B.	2009	Residents' responses to wildland fire programs: a review of cognitive and behavioral studies
Abt, K.L., Butry, D.T., Prestemon, J.P. and Scranton, S.	2015	Effect of fire prevention programs on accidental and incendiary wildfires on tribal lands in the United States
Agee, J.K. and Huff, M.H.	1986	Structure and process goals for vegetation in wilderness areas
Agee, J.K. and Skinner, C.N.	2005	Basic principles of forest fuel reduction treatments
Agee, J.K., Wright, C.S., Williamson, N. and Huff, M.H.	2002	Foliar moisture content of Pacific Northwest vegetation and its relation to wildland fire behavior
Agee, J.K., Bahro, B., Finney, M.A., Omi, P.N., Sapsis, D.B., Skinner, C.N., Van Wagtendonk, J.W. and Weatherspoon, C.P.	2000	The use of shaded fuelbreaks in landscape fire management
Agee, J.K.	1998	The landscape ecology of western forest fire regimes
Agee, James K	1993	Fire ecology of Pacific Northwest forests
Ager, A.A., Finney, M.A., Kerns, B.K. and Maffei, H.	2007	Modeling wildfire risk to northern spotted owl (Strix occidentalis caurina) habitat in Central Oregon
Ager, A.A., Vaillant, N.M. and Finney, M.A.	2010	A comparison of landscape fuel treatment strategies to mitigate wildland fire risk in the urban interface and preserve old forest structure

Author	Year	Title
Ager, A.A., Vaillant, N.M. and Finney, M.A.	2011	Integrating fire behavior models and geospatial analysis for wildland fire risk assessment and fuel management planning
Alexander, M.E. and Cruz, M.G.	2013	Are the applications of wildland fire behaviour models getting ahead of their evaluation again?
Alexander, M.E. and Yancik, R.F.	1977	The effect of precommercial thinning on fire potential in a lodgepole pine stand
Alexander, M.E.	1988	Help with making crown fire hazard assessments
Alexandre, P.M., Stewart, S.I., Keuler, N.S., Clayton, M.K., Mockrin, M.H., Bar-Massada, A., Syphard, A.D. and Radeloff, V.C.	2016	Factors related to building loss due to wildfires in the conterminous United States
Allen, C.D., Savage, M., Falk, D.A., Suckling, K.F., Swetnam, T.W., Schulke, T., Stacey, P.B., Morgan, P., Hoffman, M. and Klingel, J.T.	2002	Ecological restoration of southwestern ponderosa pine ecosystems: a broad perspective
Andrews, P.L., Loftsgaarden, D.O. and Bradshaw, L.S.	2003	Evaluation of fire danger rating indexes using logistic regression and percentile analysis
Andrews, P.L.	1982	Charts for interpreting wildland fire behavior characteristics (Vol
Andrews, P.L.	2018	The Rothermel surface fire spread model and associated developments: A comprehensive explanation
Arkle, R.S., Pilliod, D.S. and Welty, J.L.	2012	Pattern and process of prescribed fires influence effectiveness at reducing wildfire severity in dry coniferous forests
Arno, S.F. and Brown, J.K.	1991	Overcoming the paradox in managing wildland fire
Bagdon, B. and Huang, C.	2016	Review of Economic Benefits from Fuel Reduction Treatments in the Fire Prone Forests of the Southwestern United States
Baker, W.L.	1994	Restoration of landscape structure altered by fire suppression

Author	Year	Title
Barnett, K., Parks, S.A., Miller, C. and Naughton, H.T.	2016	Beyond fuel treatment effectiveness: Characterizing Interactions between fire and treatments in the US Forests
Barnwell J.	2015	Congress: Land swaps, new wilderness, but no wildfire funding bill
Bayham, J., Belval, E.J., Thompson, M.P., Dunn, C., Stonesifer, C.S. and Calkin, D.E.	2020	Weather, Risk, and Resource Orders on Large Wildland Fires in the Western US Forests
Berry, A.H. and Hesseln, H.	2004	The effect of the wildland-urban interface on prescribed burning costs in the Pacific Northwestern United States
Black, A.E. and Sutherland, E.K.	2004	Wildland fire use: The other treatment option
Boerner, R.E., Huang, J. and Hart, S.C.	2009	Impacts of Fire and Fire Surrogate treatments on forest soil properties: a meta-analytical approach
Bolding, M.C., Kellogg, L.D. and Davis, C.T.	2006	A productivity and cost comparison of two non-commercial forest fuel reduction machines
Bradley, T., Gibson, J. and Bunn, W.	2006	Fire severity and intensity during spring burning in natural and masticated mixed shrub woodlands
Bremer, L.L., Auerbach, D.A., Goldstein, J.H., Vogl, A.L., Shemie, D., Kroeger, T., Nelson, J.L., Benítez, S.P.,Calvache, A., Guimarães, J. and Herron, C.	2016	One size does not fit all: Natural infrastructure investments within the Latin American Water Funds Partnership
Brenkert-Smith, H., Champ, P.A. and Flores, N.	2012	Trying not to get burned: understanding homeowners' wildfire risk–mitigation behaviors
Brillinger, D.R., Preisler, H.K. and Benoit, J.W.	2006	Probabilistic risk assessment for wildfires
Brown, J.K. and Arno, S.F.	1991	The paradox of wildland fire
Brown, R.T., Agee, J.K. and Franklin, J.F.	2004	Forest restoration and fire: principles in the context of place

Author	Year	Title
Buckley, M., N. Beck, P. Bowden, M. E. Miller, B. Hill, C. Luce, W. J. Elliot, N. Enstice, K. Podolak, E. Winford, S. L. Smith, M. Bokach, M. Reichert, D. Edelson, and J. Gaither	2014	Mokelumne watershed avoided cost analysis: Why Sierra fuel treatments make economic sense
Byram, G.M.	1959	Combustion of forest fuels
Byram, G.M.	1966	Scaling laws for modeling mass fires
Calkin, D.E., Cohen, J.D., Finney, M.A. and Thompson, M.P.	2014	How risk management can prevent future wildfire disasters in the wildland-urban interface
Calkin, D.E., Gebert, K.M., Jones, J.G. and Neilson, R.P.	2005	Forest Service large fire area burned and suppression expenditure trends
Campbell, J.L. and Ager, A.A.	2013	Forest wildfire, fuel reduction treatments, and landscape carbon stocks: A sensitivity analysis
Campbell, J.L., Harmon, M.E. and Mitchell, S.R.	2012	Can fuel-reduction treatments really increase forest carbon storage in the western US by reducing future fire emissions?
Campbell, R.M. and Anderson, N.M.	2019	Comprehensive comparative economic evaluation of woody biomass energy from silvicultural fuel treatments
Caprio, A.C. and Swetnam, T.W.	1995	Historic fire regimes along an elevational gradient on the west slope of the Sierra Nevada
Carey, H. and Schumann, M.	2003	Modifying wildfire behavior-The effectiveness of fuel treatments
Carter, M.C. and Foster, C.D.	2004	Prescribed burning and productivity in southern pine forests: a review
Catchpole, E.A., Catchpole, W.R. and Rothermel, R.C.	1993	Fire behavior experiments in mixed fuel complexes
Champ, J.G., Brooks, J.J. and Williams, D.R.	2012	Stakeholder understandings of wildfire mitigation: A case of shared and contested meanings
Champion, H.G.	1950	Forest Terminology

Author	Year	Title
Charnley, S., Kelly, E.C. and Fischer, A.P.	2020	Fostering collective action to reduce wildfire risk across property boundaries in the American West
Chazdon, R.L.	2008	Beyond deforestation: restoring forests and ecosystem services on degraded lands
Christiansen, J.R.	1969	Forest-Fire Prevention Knowledge and Attitudes of Residents of Utah County, Utah, With Comparisons to Butte County California
Churchill, D., Larson, D., Dahlgreen, M., Franklin, J., Hessburg, P., and Lutz, J.	2013	Restoring forest resilience: From reference spatial patterns to silvicultural prescriptions and monitoring
Clark, A.M., Rashford, B.S., McLeod, D.M., Lieske, S.N., Coupal, R.H. and Albeke, S.E.	2016	The impact of residential development pattern on wildland fire suppression expenditures
Cleaves, D.A., Haines, T.K. and Martinez, J.	2000	Influences on prescribed burning activity in the National Forest System
Cleaves, D.A., Schuster, E.G. and Bell, E.F.	1996	Fire management expenditures by the USDA Forest Service: trends and recommendations for controlling costs
Cochrane, M.A., Moran, C.J., Wimberly, M.C., Baer, A.D., Finney, M.A., Beckendorf, K.L., Eidenshink, J. and Zhu, Z.	2012	Estimation of wildfire size and risk changes due to fuels treatments
Cohen, J.D.	2004	Relating flame radiation to home ignition using modeling and experimental crown fires
Collins, B.M., Everett, R.G. and Stephens, S.L.	2011	Impacts of fire exclusion and recent managed fire on forest structure in old growth Sierra Nevada mixed-conifer forests
Collins, B.M., Kramer, H.A., Menning, K., Dillingham, C., Saah, D., Stine, P.A. and Stephens, S.L.	2013	Modeling hazardous fire potential within a completed fuel treatment network in the northern Sierra Nevada
Collins, B.M., Stephens, S.L., Roller, G.B. and Battles, J.J.	2011	Simulating fire and forest dynamics for a landscape fuel treatment project in the Sierra Nevada

Author	Year	Title
Collins, B.M., Stephens, S.L., Moghaddas, J.J. and Battles, J.	2010	Challenges and approaches in planning fuel treatments across fire-excluded forested landscapes
Combrink, T., Cothran, C., Fox, W., Peterson, J. and Snider, G.B.	2013	Issues in Forest Restoration: Full Cost Accounting of the 2010 Schultz Fire
Cooper, C.F.	1961	Controlled burning and watershed condition in the White Mountains of Arizona
Cooper, H.M., Hedges, L.V. and Valentine, J.C.	2019	Handbook of research synthesis and meta-analysis
Covington, W.W. and Moore, M.M.	1994	Southwestern ponderosa forest structure: changes since Euro-American settlement
Cram, D.S., Baker, T.T. and Boren, J.C.	2006	Wildland fire effects in silviculturally treated vs untreated stands of New Mexico and Arizona
Cram, D.S., Baker, T.T., Fernald, A.G.,Cibils, A.F. and VanLeeuwen, D.M.	2015	Fuel and vegetation trends after wildfire in treated versus untreated forests
Cron, R.H.	1969	Thinning as an aid to fire control
Cruz, M.G. and Alexander, M.E.	2010	Assessing crown fire potential in coniferous forests of western North America: a critique of current approaches and recent simulation studies
Debano, L.F., Neary, D.G., Folliott, P.F.	1998	Fire's Effect on Ecosystems
Deeming, J.E.	1972	National fire-danger rating system
Dellasala, D.A., Williams, J.E., Williams, C.D. and Franklin, J.F.	2004	Beyond smoke and mirrors: a synthesis of fire policy and science
Demchik, M.C., Abbas, D., Current, D.,Arnosti, D., Theimer, M. and Johnson, P.	2009	Combining biomass harvest and forest fuel reduction in the Superior National Forest, Minnesota
Dickinson, M.B.	2001	Fire effects on trees

Author	Year	Title
Dombeck, M.P., Williams, J.E. and Wood, C.A.	2004	Wildfire policy and public lands: integrating scientific understanding with social concerns across landscapes
Donovan, G.H., Prestemon, J.P. and Gebert, K.	2011	The effect of newspaper coverage and political pressure on wildfire suppression costs
Duclos, P., Sanderson, L.M. and Lipsett, M.	1990	The 1987 forest fire disaster in California: assessment of emergency room visits
Dunn, C.J., Thompson, M.P. and Calkin, D.E.	2017	A framework for developing safe and effective large-fire response in a new fire management paradigm
Ecological Restoration Institute	2013	Efficacy of hazardous fuel treatments: A rapid assessment of the economic and ecologic consequences of alternative hazardous fuel treatments: A summary document for policy makers
Edmonds, R.L. and Marra, J.L.	1999	Decomposition of woody material: nutrient dynamics invertebrate/fungi relationships and management in Northwest forests
Eidenshink, J., Schwind, B., Brewer, K., Zhu, Z.L., Quayle, B. and Howard, S.	2007	A project for monitoring trends in burn severity
Ellefson, P.V. and Miles, P.D.	1985	Protecting water quality in the Midwest: Impact on timber harvesting costs
Elliot, William, and Pete Robichaud.	2005	Fuels planning: science synthesis and integration
Ellison, A., Coughlan, M.R., Kooistra, C. and Schultz, C.A.	2018	Accomplishing collaborative, landscape-scale restoration on forests without CFLRP or Joint Chiefs' projects
Ellison, A., Moseley, C. and Bixler, R.P.	2015	Drivers of Wildfire Suppression Costs
Engebretson, J., Hall, T., Blades, J., Olsen, C., Toman, E., and Prederick, St	2016	Characterizing Public Tolerance of Smoke from Wildland Fires in Communities across the United States
Englin, J., Boxall, P.C., Chakraborty, K. and Watson, D.O.	1996	Valuing the impacts of forest fires on backcountry forest recreation

Author	Year	Title
Evans, A., Auerbach, S., Miller, L.W., Wood, R., Nystrom, K., Loevner, J., Aragon, A., Piccarello, M. and Krasilovsky, E.	2015	Evaluating the effectiveness of wildfire mitigation activities in the wildland-urban interface
Fernandes, P.M. and Botelho, H.S.	2003	A review of prescribed burning effectiveness in fire hazard reduction
Fight, Roger D. and Barbour, R. James	2006	Financial analysis of fuel treatments on national forests in the Western United States
Finney, M.A., McHugh, C.W. and Grenfell, I.C.	2005	Stand-and landscape-level effects of prescribed burning on two Arizona wildfires
Finney, M.A., Bartlette, R., Bradshaw, L., Close, K., Collins, B.M., Gleason, P., Hao, W.M., Langowski, P., McGinely, J., McHugh, C.W. and Martinson, E.	2003	Fire behavior, fuel treatments, and fire suppression on the Hayman Fire
Finney, M.A., Seli, R.C., McHugh, C.W., Ager, A.A., Bahro, B. and Agee, J.K.	2008	Simulation of long-term landscape-level fuel treatment effects on large wildfires
Finney, M.A.	2001	Design of regular landscape fuel treatment patterns for modifying fire growth and behavior
Fischer, A.P. and Charnley, S.	2012	Risk and cooperation: managing hazardous fuel in mixed ownership landscapes
Fischer, A.P., Klooster, A. and Cirhigiri, L.	2019	Cross-boundary cooperation for landscape management: Collective action and social exchange among individual private forest landowners
Fitch, R.A., Kim, Y.S., Waltz, A.E. and Crouse, J.E.	2018	Changes in potential wildland fire suppression costs due to restoration treatments in Northern Arizona Ponderosa pine forests
Fites, J.A., Campbell, M., Reiner, A. and Decker, T.	2007	Fire Behavior and Effects Relating to Suppression, Fuel Treatments, and Protected Areas on the Antelope Complex: Wheeler Fire
Fontaine, J.B. and Kennedy, P.L.	2012	Meta-analysis of avian and small-mammal response to fire severity and fire surrogate treatments in US fire-prone forests

Author	Year	Title
Fontaine, J.B., Donato, D.C., Robinson, W.D., Law, B.E. and Kauffman, J.B.	2009	Bird communities following high-severity fire: response to single and repeat fires in a mixed-evergreen forest
Foxx, T.S.	1996	Vegetation succession after the La Mesa fire at Bandelier National Monument
Fulé, P.Z., Crouse, J.E., Roccaforte, J.P. and Kalies, E.L.	2012	Do thinning and/or burning treatments in western USA ponderosa or Jeffrey pine-dominated forests help restore natural fire behavior?
Fulé, P.Z., McHugh, C., Heinlein, T.A. and Covington, W.W.	2000	Potential fire behavior is reduced following forest restoration treatments
Gannon, B.M., Wei, Y., MacDonald, L.H., Kampf, S.K., Jones, K.W., Cannon, J.B., Wolk, B.H., Cheng, A.S., Addington, R.N. and Thompson, M.P.	2019	Prioritizing fuels reduction for water supply protection
Gebert, K.M. and Black, A.E.	2012	Effect of suppression strategies on federal wildland fire expenditures
Gebert, K.M., Calkin, D.E. and Yoder, J.	2007	Estimating suppression expenditures for individual large wildland fires
Glitzenstein, J.S., Streng, D.R.,Achtemeier, G.L., Naeher, L.P. and Wade, D.D.	2006	Fuels and fire behavior in chipped and unchipped plots: implications for land management near the wildland/urban interface
Goldman-Benner, R.L., Benitez, S., Boucher, T., Calvache, A., Daily, G.,Kareiva, P., Kroeger, T. and Ramos, A.	2012	Water funds and payments for ecosystem services: practice learns from theory and theory can learn from practice
González-Cabán, A., Loomis, J., Sánchez, J.J., Rideout, D. and Reich, R.	2019	Do fuel treatment costs affect wildfire suppression costs and property damages? An analysis of costs, damages avoided and return on investment
González-Cabán, A.	1997	Managerial and institutional factors affect prescribed burning costs
Gorte, R. and Economics, H.	2013	The rising cost of wildfire protection

Author	Year	Title
Government Accounting Office	2006	Update on federal agency efforts to develop a cohesive strategy to address wildland fire threats
Graham, R.T., Jain, T.B. and Loseke, M.	2009	Fuel treatments, fire suppression, and their interaction with wildfire and its impacts: The Warm Lake experience during the Cascade Complex of wildfires in central Idaho
Graham, R.T., McCaffrey, S. and Jain, T.B.	2004	Science basis for changing forest structure to modify wildfire behavior and severity
Graham, R.T.	1999	The effects of thinning and similar stand treatments on fire behavior in western forests (Vol
Graham, R.T.	2003	Hayman Fire Case Study: Summary
Gude, P.H., Jones, K., Rasker, R. and Greenwood, M.C.	2013	Evidence for the effect of homes on wildfire suppression costs
Gude, P.R., Rasker, M., Essen, M.D. and Lawson, M.	2014	An empirical investigation of the Effect of the Firewise Program on Wildfire Suppression Costs
Halbrook, Jeff, Han-Sup Han, Russell T. Graham, Theresa B. Jain, and Robert Denner.	2006	Mastication: a fuel reduction and site preparation alternative
Hall, S.A. and Burke, I.C.	2006	Considerations for characterizing fuels as inputs for fire behavior models
Halofky, J., Peterson, D., and Harvey, B	2020	Changing wildfire, changing forests: the effects of climate change on fire regimes and vegetation in the Pacific Northwest, USA
Hamins, A., Averill, J., Bryner, N., Butry, D., Gann, R., Davis, R., Madrzykowski, D., Maranghides, A., Yang, J., Bundy, M., Manzello, S, Gilman, J., Amon, F., and Mell, W	2013	Plenary – Reducing the Risk of Fire in Buildings and Communities
Han, H.S., Halbrook, J., Pan, F. and Salazar, L.	2010	Economic evaluation of a roll-off trucking system removing forest biomass resulting from shaded fuelbreak treatments
Han, H.S., Lee, H.W. and Johnson, L.R.	2004	Economic feasibility of an integrated harvesting system for small-diameter trees in southwest Idaho

Author	Year	Title
Han, S.K., Han, H.S., Elliot, W.J. and Bilek, E.M.	2017	ThinTool: A spreadsheet model to evaluate fuel reduction thinning cost, net energy output, and nutrient impacts
Harbert, S., Hudak, A., Mayer, L., Rich, T. and Robertson, S.	2007	An assessment of fuel treatments on three large 2007 Pacific Northwest fires
Hardy, C.C. and Hardy, C.E.	2007	Fire danger rating in the United States of America: an evolution since 1916
Harold H.. Biswell, Harry R.. Kallander, Komarek, R., Richard J.. Vogl and Weaver, H.	1973	Ponderosa fire management: A task force evaluation of controlled burning in ponderosa pine forests of central Arizona
Harrod, R.J., Ohlson, P.L., Flatten, L.B., Peterson, D.W. and Ottmar, R.D.	2009	A user's guide to thinning with mastication equipment
Hartsough, B.	2003	Economics of harvesting to maintain high structural diversity and resulting damage to residual trees
Hartsough, B.R., Abrams, S., Barbour, R.J., Drews, E.S., McIver, J.D.,Moghaddas, J.J., Schwilk, D.W. and Stephens, S.L.	2008	The economics of alternative fuel reduction treatments in western United States dry forests: financial and policy implications from the National Fire and Fire Surrogate Study
Hawbaker, T.J., Radeloff, V.C., Stewart, S.I., Hammer, R.B., Keuler, N.S. and Clayton, M.K.	2013	Human and biophysical influences on fire occurrence in the United States
Headwaters Economics	2014	The Firewise Program: Perspectives of Incident Commanders
Hessburg, Paul F., Russel G. Mitchell, and Gregory M. Filip.	1994	Historical and current roles of insects and pathogens in eastern Oregon and Washington forested landscapes
Hesseln, H.	2018	Wildland fire prevention: a review
Hood, S. and Wu, R.	2006	Estimating fuel bed loadings in masticated areas
Houtman, R.M., Montgomery, C.A., Gagnon,	2013	Allowing a wildfire to burn: estimating the effect on future fire suppression costs

Author	Year	Title
A.R., Calkin, D.E., Dietterich, T.G., McGregor, S. and Crowley, M.		
Huang, C.H., Finkral, A., Sorensen, C. and Kolb, T.	2013	Toward full economic valuation of forest fuels-reduction treatments
Hudak, A.T., Rickert, I., Morgan, P., Strand, E., Lewis, S.A., Robichaud, P., Hoffman, C. and Holden, Z.A.	2011	Review of fuel treatment effectiveness in forests and rangelands and a case study from the 2007 megafires in central Idaho USA
Huff, M.H. and Everett, R.L.	1995	Historical and Current Forest Landscapes of Eastern Oregon and Washington: Part II: Linking Vegetation Characteristics to Potential Fire Behavior and Related Smoke Production
Hurteau, M. and North, M.	2009	Fuel treatment effects on tree-based forest carbon storage and emissions under modeled wildfire scenarios
Hurteau, M.D., Koch, G.W. and Hungate, B.A.	2008	Carbon protection and fire risk reduction: toward a full accounting of forest carbon offsets
Hutto, R.L.	2008	The ecological importance of severe wildfires: some like it hot
Ice, G.G., Neary, D.G. and Adams, P.W.	2004	Effects of wildfire on soils and watershed processes
Jain, T.B. and Graham, R.T.	2007	The relation between tree burn severity and forest structure in the Rocky Mountains
Jain, T.B., Battaglia, M.A., Han, H.S., Graham, R.T., Keyes, C.R., Fried, J.S. and Sandquist, J.E.	2012	A comprehensive guide to fuel management practices for dry mixed conifer forests in the northwestern United States
Jain, Theresa Benavidez, and Russell T. Graham.	2004	Is forest structure related to fire severity? Yes, no, and maybe: methods and insights in quantifying the answer
Johnson, E.A. and Gutsell, S.L.	1994	Fire frequency models, methods and interpretations
Johnson, M., Peterson, D., and Raymond, C	2007	Managing Forest Structure and Fire Hazard – A Tool for Planners

Author	Year	Title
Jolly, W.M., Cochrane, M.A., Freeborn, P.H., Holden, Z.A., Brown, T.J., Williamson, G.J. and Bowman, D.M.	2015	Climate-induced variations in global wildfire danger from 1979 to 2013
Jones, K.W., Cannon, J.B., Saavedra, F.A., Kampf, S.K., Addington, R.N., Cheng, A.S., MacDonald, L.H., Wilson, C. and Wolk, B.	2017	Return on investment from fuel treatments to reduce severe wildfire and erosion in a watershed investment program in Colorado
Kalies, E.L. and Kent, L.L.Y.	2016	Tamm Review: Are fuel treatments effective at achieving ecological and social objectives? A systematic review
Kalies, E.L., Chambers, C.L. and Covington, W.W.	2010	Wildlife responses to thinning and burning treatments in southwestern conifer forests: a meta-analysis
Kane, J.M., Varner, J.M. and Knapp, E.E.	2009	Novel fuelbed characteristics associated with mechanical mastication treatments in northern California and south-western Oregon
Keane, R.E.	2002	Cascading effects of fire exclusion in Rocky Mountain ecosystems: a literature review (Vol
Keeley, J.E. and McGinnis, T.W.	2007	Impact of prescribed fire and other factors on cheatgrass persistence in a Sierra Nevada ponderosa pine forest
Keeley, J.E.	2009	Fire intensity, fire severity and burn severity: a brief review and suggested usage
Keenan, R.J. and Kimmins, J.P.	1993	The ecological effects of clear-cutting
Kennedy, M., Johnson, M., and Harrison, S	2019	Fuel Treatments Change Forest Structure and Spatial Patterns of Fire Severity
Kennedy, M., Johnson, M.M Fallon, K., and Mayer, D	2019	How big is enough? Vegetation structure impacts effective fuel treatment width and forest resiliency
Kennedy, M.C. and Johnson, M.C.	2014	Fuel treatment prescriptions alter spatial patterns of fire severity around the wildland–urban interface during the Wallow Fire
Kennedy, P.L. and Fontaine, J.B.	2009	Synthesis of knowledge on the effects of fire and fire surrogates on wildlife in US dry forests

Author	Year	Title
Kent, L.L.Y., Shive, K.L., Strom, B.A.,Sieg, C.H., Hunter, M.E., Stevens-Rumann, C.S. and Fulé, P.Z.	2015	Interactions of fuel treatments, wildfire severity, and carbon dynamics in dry conifer forests
Kim, M.K. and Jakus, P.M.	2019	Wildfire, national park visitation, and changes in regional economic activity
Kim, Y.S.	2010	Ecological restoration as economic stimulus: A regional analysis
Kline, J.D.	2004	Issues in evaluating the costs and benefits of fuel treatments to reduce wildfire in the Nation's forests
Knapp, E.E., Varner, J.M., Busse, M.D., Skinner, C.N. and Shestak, C.J.	2012	Behaviour and effects of prescribed fire in masticated fuelbeds
Kobziar, L.N., McBride, J.R. and Stephens, S.L.	2009	The efficacy of fire and fuels reduction treatments in a Sierra Nevada pine plantation
Kolb, P.F., Adams, D.L. and McDonald, G.I.	1998	Impacts of fire exclusion on forest dynamics and processes in central Idaho
Koontz, T.M., Jager, N.W. and Newig, J.	2020	Assessing collaborative conservation: A case survey of output, outcome, and impact measures used in the empirical literature
Kopper, K.E., McKenzie, D. and Peterson, D.L.	2009	The evaluation of meta-analysis techniques for quantifying prescribed fire effects on fuel loadings
Kreitler, J., Thompson, M.P., Vaillant, N.M. and Hawbaker, T.J.	2020	Cost-effective fuel treatment planning: a theoretical justification and case study
Kreye, J.K., Brewer, N.W., Morgan, P., Varner, J.M., Smith, A.M., Hoffman, C.M. and Ottmar, R.D.	2014	Fire behavior in masticated fuels: a review
Kreye, J.K., Varner, J.M. and Knapp, E.E.	2011	Effects of particle fracturing and moisture content on fire behaviour in masticated fuelbeds burned in a laboratory
La Puma, I.P.	2012	Fire in the pines: A landscape perspective of human-induced ecological change in the pinelands of New Jersey (Doctoral dissertation

Author	Year	Title
Liang, J., Calkin, D.E., Gebert, K.M., Venn, T.J. and Silverstein, R.P.	2008	Factors influencing large wildland fire suppression expenditures
Lickwar, P., Hickman, C. and Cubbage, F.W.	1992	Costs of protecting water quality during harvesting on private forestlands in the southeast
Lolley, M.R. and Bloomfield, B.,	undated	Tieton Forest Collaborative - Using Conservation Action Planning for Collaborative Fire and Restoration and Planning
Loomis, J., Gonzalez-Caban, A. and Englin, J.	2001	Testing for differential effects of forest fires on hiking and mountain biking demand and benefits
Loomis, J.B., Hung L.T and González-Cabán, A.	2009	Willingness to pay function for two fuel treatments to reduce wildfire acreage burned: a scope test and comparison of White and Hispanic households
Loreno, S., Fried, J., and Yost, A	2016	Applying management modeling to assess the feasibility of accelerating landscape restoration on federal forests in eastern Oregon
Low, G	2003	Developing strategies, taking action and measuring success. Landscape - scale conservation. A practitioner's guide
Lynch, D.L.	2001	Financial results of ponderosa pine forest restoration in southwestern Colorado
Macie, E.A. and Hermansen, L.A. eds.	2002	Human influences on forest ecosystems: the southern wildland-urban interface assessment
Malmsheimer, R.W., Bowyer, J.L., Fried, J.S., Gee, E., Izlar, R., Miner, R.A., Munn, I.A., Oneil, E. and Stewart, W.C.	2011	Managing forests because carbon matters: integrating energy, products, and land management policy
Maranghides, A., McNamara, D., Mell, W., Trook, J. and Toman, B.	2013	A case study of a community affected by the Witch and Guejito Fires: Report# 2: Evaluating the effects of hazard mitigation actions on structure ignitions
Martinson, E.J. and Omi, P.N.	2003	Performance of fuel treatments subjected to wildfires
Martinson, E.J. and Omi, P.N.	2013	Fuel treatments and fire severity: a meta-analysis

Author	Year	Title
Mason, C., Lippke, B., Zobrist, K., Bloxton, T., Cedar, K., Comnick, J., McCarter, J., and Rogers, H	2006	Investments in Fuel Removals to Avoid Forest Fires Result in Substantial Benefits
McCaffrey, Sarah M. and Christine S. Olsen	2012	"Research perspectives on the public and fire management: a synthesis of current social science on eight essential questions
McCandliss, D.S.	2002	Prescribed burning in the Kings River ecosystems project area: lessons learned
McIver, J., Stephens, S., Agee, J., Barbour, J., Boerner, R., Edminster, C., Erickson, K., Farris, K., Fettig, C., Fiedler, C., Haase, S, Hart, S., Keeley, J., Knapp, E., Lehmkuhl, J., Moghaddas, J., Otrosina, W., Outcalt, K., Schwilk, D., W., Skinner, C., Waldrop, ThomaT., Weatherspoon, C.., Yaussy, D., Youngblood, A., and Zack, S	2013	Ecological effects of alternative fuel-reduction treatments: highlights of the National Fire and Fire Surrogate study (FFS)
McIver, J.D., Adams, P.W., Doyal, J.A., Drews, E.S., Hartsough, B.R., Kellogg, L.D., Niwa, C.G., Ottmar, R., Peck, R.,Taratoot, M. and Torgersen, T.	2003	Environmental effects and economics of mechanized logging for fuel reduction in northeastern Oregon mixed-conifer stands
Mercer, D.E. and Zipperer, W.	2012	Fire in the wildland–urban interface
Meyer, G.A., Pierce, J.L., Wood, S.H. and Jull, A.T.	2001	Fire, storms, and erosional events in the Idaho batholith
Mhawej, M., Faour, G. and Adjizian-Gerard, J.	2015	Wildfire likelihood's elements: A literature review
Miller, C. and Ager, A.A.	2013	A review of recent advances in risk analysis for wildfire management
Miller, C. and Urban, D.L.	2000	Modeling the effects of fire management alternatives on Sierra Nevada mixed-conifer forests

Author	Year	Title
Minshall, G.W., Brock, J.T. and Varley, J.D.	1989	Wildfires and Yellowstone's stream ecosystems
Moghaddas, J.J. and Craggs, L.	2008	A fuel treatment reduces fire severity and increases suppression efficiency in a mixed conifer forest
Moghaddas, J.J., Collins, B.M.,Menning, K., Moghaddas, E.E. and Stephens, S.L.	2010	Fuel treatment effects on modeled landscape-level fire behavior in the northern Sierra Nevada
Moore, M.M., Wallace Covington, W. and Fulé, P.Z.	1999	Reference conditions and ecological restoration: a southwestern ponderosa pine perspective
Moreno, J.M. and Oechel, W.C.	1989	A simple method for estimating fire intensity after a burn in California chaparral
Mutch, R.W. and Quigley, T.M.	1993	Forest health in the Blue Mountains: a management strategy for fire-adapted ecosystems
Mutch, R.W.	1994	Fighting fire with prescribed fire: a return to ecosystem health
Naeher, L.P., Brauer, M., Lipsett, M.,Zelikoff, J.T., Simpson, C.D., Koenig, J.Q. and Smith, K.R.	2007	Woodsmoke health effects: a review
Nagy, R., Fusco, E., Bradley, B.,Abatzoglou, J.T. and Balch, J.	2018	Human-related ignitions increase the number of large wildfires across US ecoregions
Narayan, C., Fernandes, P.M., van Brusselen, J. and Schuck, A.	2007	Potential for CO2 emissions mitigation in Europe through prescribed burning in the context of the Kyoto Protocol
National Research Council	2000	Environmental Issues in Pacific Northwest forest management
National Wildfire Coordinating Group (NWCG)	1998	Wildfire prevention strategies
National Wildfire Coordinating Group (NWCG)	2006	Glossary of Wildland Fire Terminology
National Wildfire Coordinating Group	2014	Fire behavior field reference guide

Author	Year	Title
Neary, D.G., Klopatek, C.C., DeBano, L.F. and Folliott, P.F.	1999	Fire effects on below ground sustainability: a review and synthesis
Nelson Jr, R.M. and Adkins, C.W.	1986	Flame characteristics of wind-driven surface fires
North, M., Brough, A., Long, J., Collins, B., Bowden, P., Yasuda, D., Miller, J. and Sugihara, N.	2015	Constraints on mechanized treatment significantly limit mechanical fuels reduction extent in the Sierra Nevada
North, M., Collins, B.M. and Stephens, S.	2012	Using fire to increase the scale, benefits, and future maintenance of fuels treatments
North, M.P. and Hurteau, M.D.	2011	High-severity wildfire effects on carbon stocks and emissions in fuels treated and untreated forest
Noss, R.F.	1999	A citizen's guide to ecosystem management (No
O'Connor, C.D. and Calkin, D.E.	2019	Engaging the fire before it starts: a case study from the 2017 Pinal Fire (Arizona)
Omi, P.N., Martinson, E.J. and Chong, G.W.	2006	Effectiveness of pre-fire fuel treatments
Omi, P.N.	2015	Theory and practice of wildland fuels management
Parisien, M.A., Snetsinger, S., Greenberg, J.A., Nelson, C.R., Schoennagel, T., Dobrowski, S.Z. and Moritz, M.A.	2012	Spatial variability in wildfire probability across the western United States
Parkinson, T.M., Force, J.E. and Smith, J.K.	2003	Hands-on learning: its effectiveness in teaching the public about wildland fire
Parks, S.A., Holsinger, L.M., Miller, C. and Nelson, C.R.	2015	Wildland fire as a self-regulating mechanism: the role of previous burns and weather in limiting fire progression
Parks, S.A., Miller, C., Nelson, C.R. and Holden, Z.A.	2014	Previous fires moderate burn severity of subsequent wildland fires in two large western US wilderness areas

Author	Year	Title
Parks, S.A., Parisien, M.A. and Miller, C.	2011	Multi-scale evaluation of the environmental controls on burn probability in a southern Sierra Nevada landscape
Parrish, J.D., Braun, D.P. and Unnasch, R.S.	2003	Are we conserving what we say we are? Measuring ecological integrity within protected areas
Perry, D.A., Hessburg, P.F., Skinner, C.N., Spies, T.A., Stephens, S.L., Taylor, A.H., Franklin, J.F., McComb, B. and Riegel, G.	2011	The ecology of mixed severity fire regimes in Washington, Oregon, and Northern California
Peterson, D.L.	2005	Forest structure and fire hazard in dry forests of the western United States
Peterson, J., Lahm, P., Fitch, M., George, M., Haddow, D., Melvin, M., Hyde, J. and Eberhardt, E.	2018	NWCG smoke management guide for prescribed fire
Prestemon, J.P., Butry, D.T., Abt, K.L. and Sutphen, R.	2010	Net benefits of wildfire prevention education efforts
Prestemon, J.P., Abt, K.L. and Barbour, R.J.	2012	Quantifying the net economic benefits of mechanical wildfire hazard treatments on timberlands of the western United States
Prichard, S., Povak, N., Kennedy, M., and Peterson, D	2020	Fuel treatment effectiveness in the context of landform, vegetation, and large
Prichard, S.J. and Kennedy, M.C.	2012	Fuel treatment effects on tree mortality following wildfire in dry mixed conifer forests, Washington State, USA
Prichard, S.J., Peterson, D.L. and Jacobson, K.	2010	Fuel treatments reduce the severity of wildfire effects in dry mixed conifer forest, Washington, USA
Quigley, T.M. and Arbelbide, S.J.	1997	An assessment of ecosystem components in the interior Columbia basin and portions of the Klamath and Great Basins (Vol
Quigley, T.M., Starr, L., Daterman, G.E., Hayes, J.L. and Brown, S.	2001	A framework for addressing forest health and productivity in Eastern Oregon and Washington

Author	Year	Title
Raymond, C.L. and Peterson, D.L.	2005	Fuel treatments alter the effects of wildfire in a mixed-evergreen forest, Oregon, USA
Reiner, A.L., Vaillant, N.M., Fites-Kaufman, J. and Dailey, S.N.	2009	Mastication and prescribed fire impacts on fuels in a 25-year old ponderosa pine plantation, southern Sierra Nevada
Reinhardt, E., Lutes, D. and Scott, J.	2006	FuelCalc: A method for estimating fuel characteristics
Reinhardt, E.D., Keane, R.E., Calkin, D.E. and Cohen, J.D.	2008	Objectives and considerations for wildland fuel treatment in forested ecosystems of the interior western United States
Reynolds, Richard T., Graham, Russell T., Reiser, M. Hildegard	1992	Management recommendations for the northern goshawk in the southwestern United States
Rhodes, J.J. and Baker, W.L.	2008	Fire probability, fuel treatment effectiveness and ecological tradeoffs in western US public forests
Rideout, D.B., Loomis, J.B. and Omi, P.N.	1999	Incorporating non-market values in fire management planning
Rideout, D.B., Wei, Y., Kirsch, A. and Botti, S.J.	2008	Toward a unified economic theory of fire program analysis with strategies for empirical modeling
Rieman, B. and Clayton, J.	1997	Wildfire and native fish: issues of forest health and conservation of sensitive species
Ritchie, M.W., Skinner, C.N. and Hamilton, T.A.	2007	Probability of tree survival after wildfire in an interior pine forest of northern California: effects of thinning and prescribed fire
Roberts, R.M., Jones, K.W., Duke, E.,Shinbrot, X., Harper, E.E., Fons, E., Cheng, A.S. and Wolk, B.H.	2019	Stakeholder perceptions and scientific evidence linking wildfire mitigation treatments to societal outcomes
Rocca, M.E., Brown, P.M., MacDonald, L.H. and Carrico, C.M.	2014	Climate change impacts on fire regimes and key ecosystem services in Rocky Mountain forests
Roussopoulos, P.J.	1975	Help in making fuel management decisions
Rummer, B.	2008	Assessing the cost of fuel reduction treatments: A critical review

Author	Year	Title
Rummer, B.	2010	Tools for fuel management
Rummer, R.B.	2005	A strategic assessment of forest biomass and fuel reduction treatments in western states
Safford, H.D., Schmidt, D.A. and Carlson, C.H.	2009	Effects of fuel treatments on fire severity in an area of wildland–urban interface, Angora Fire, Lake Tahoe Basin, California
Sasser, E	2019	Smoke Ready Communities: Preparing for Smoke Events
Schmidt, D.A., Taylor, A.H. and Skinner, C.N.	2008	The influence of fuels treatment and landscape arrangement on simulated fire behavior, Southern Cascade range, California
Schoennagel, T., Veblen, T.T. and Romme, W.H.	2004	The interaction of fire, fuels, and climate across Rocky Mountain forests
Schroder, S.A.K., Tóth, S.F., Deal, R.L. and Ettl, G.J.	2016	Multi-objective optimization to evaluate tradeoffs among forest ecosystem services following fire hazard reduction in the Deschutes National Forest
Schultz, C., Santo, A., Huber-Stearns, H. and McCaffrey, S	2020	Strategies for Increasing Prescribed Fire Application on Federal Lands: Lessons from Case Studies in the U
Schultz, C.A. and Moseley, C.	2019	Collaborations and capacities to transform fire management
Schultz, C.A., Coelho, D.L. and Beam, R.D.	2014	Design and governance of multiparty monitoring under the USDA Forest Service's Collaborative Forest Landscape Restoration Program
Schultz, C.A., McIntyre, K.B., Cyphers, L., Kooistra, C., Ellison, A. and Moseley, C.	2018	Policy design to support forest restoration: the value of focused investment and collaboration
Selig, M., D. Vosick, and J. Seidenberg.	2010	Four forest restoration initiative landscape strategy: Economics and utilization analysis
Shaffer, R.M., Haney, H.L., Worrell, E.G. and Aust, W.M.	1998	Forestry BMP implementation costs for Virginia
Smith, D.M., Larson, B.C., M.J., and Ashton, P.M.S	1997	The Practice of silviculture: applied forest ecology

Author	Year	Title
Snider, G., Daugherty, P.J. and Wood, D.	2006	The irrationality of continued fire suppression: an avoided cost analysis of fire hazard reduction treatments versus no treatment
Spyratos, V., Bourgeron, P.S. and Ghil, M.	2007	Development at the wildland–urban interface and the mitigation of forest-fire risk
Stephens, S.L. and Moghaddas, J.J.	2005	Experimental fuel treatment impacts on forest structure, potential fire behavior, and predicted tree mortality in a California mixed conifer forest
Stephens, S.L. and Ruth, L.W.	2005	Federal forest-fire policy in the United States
Stephens, S.L., Burrows, N.,Buyantuyev, A., Gray, R.W., Keane, R.E., Kubian, R., Liu, S., Seijo, F., Shu, L., Tolhurst, K.G. and Van Wagtendonk, J.W.	2014	Temperate and boreal forest mega-fires: characteristics and challenges
Stephens, S.L., McIver, J.D., Boerner, R.E., Fettig, C.J., Fontaine, J.B.,Hartsough, B.R., Kennedy, P.L. and Schwilk, D.W.	2012	The effects of forest fuel-reduction treatments in the United States
Stephens, S.L., Moghaddas, J.J.,Edminster, C., Fiedler, C.E., Haase, S., Harrington, M., Keeley, J.E., Knapp, E.E., McIver, J.D., Metlen, K. and Skinner, C.N.	2009	Fire treatment effects on vegetation structure, fuels, and potential fire severity in western US forests
Stratton, R.D.	2009	Guidebook on LANDFIRE fuels data acquisition, critique, modification, maintenance
Stronach, N.R. and McNaughton, S.J.	1989	Grassland fire dynamics in the Serengeti ecosystem, and a potential method of retrospectively estimating fire energy
Sun, N., Wigmosta, M., Zhou, T., Lundquist, J., Dickerson-Lange, S. and Cristea, N.	2018	Evaluating the functionality and streamflow impacts of explicitly modelling forest–snow interactions and canopy gaps in a distributed hydrologic model
Swetnam, T.W. and Baisan, C.H.	1994	Historical fire regime patterns in the southwestern United States since AD 1700

Author	Year	Title
Symons, J.N., Fairbanks, D.H. and Skinner, C.N.	2008	Influences of stand structure and fuel treatments on wildfire severity at Blacks Mountain Experimental Forest, northeastern California
Syphard, A.D., Radeloff, V.C., Keeley, J.E., Hawbaker, T.J., Clayton, M.K., Stewart, S.I. and Hammer, R.B.	2007	Human influence on California fire regimes
Syphard, A.D., Scheller, R.M., Ward, B.C., Spencer, W.D. and Strittholt, J.R.	2011	Simulating landscape-scale effects of fuels treatments in the Sierra Nevada, California
Taylor, A.H. and Skinner, C.N.	2003	Spatial patterns and controls on historical fire regimes and forest structure in the Klamath Mountains
Taylor, M.H., Sanchez Meador, A.J., Kim, Y.S., Rollins, K. and Will, H.	2015	The economics of ecological restoration and hazardous fuel reduction treatments in the ponderosa pine forest ecosystem
Tedim, F., Leone, V., Amraoui, M., Bouillon, C., Coughlan, M.R., Delogu, G.M., Fernandes, P.M., Ferreira, C., McCaffrey, S., McGee, T.K. and Parente, J.	2018	Defining extreme wildfire events: difficulties, challenges, and impacts
Thomas, C.W. and Koontz, T.M.	2011	Research designs for evaluating the impact of community-based management on natural resource conservation
Thomas, D., Butry, D., Gilbert, S., Webb, D. and Fung, J.	2017	The costs and losses of wildfires
Thomas, D.S. and Butry, D.T.	2014	Areas of the US wildland–urban interface threatened by wildfire during the 2001–2010 decade
Thompson, M. and Anderson, N.	2015	Modeling fuel treatment impacts on fire suppression cost savings: A review
Thompson, M.P. and Calkin, D.E.	2011	Uncertainty and risk in wildland fire management: a review
Thompson, M.P., Bowden, P., Brough, A., Scott, J.H.,	2016	Application of wildfire risk assessment results to wildfire response planning in the southern Sierra Nevada, California, USA

Author	Year	Title
Gilbertson-Day, J., Taylor, A., Anderson, J. and Haas, J.R.		
Thompson, M.P., Liu, Z., Wei, Y. and Caggiano, M.D.	2018	Analyzing wildfire suppression difficulty in relation to protection demand
Thompson, M.P., Riley, K.L., Loeffler, D. and Haas, J.R.	2017	Modeling fuel treatment leverage: encounter rates, risk reduction, and suppression cost impacts
Thompson, M.P., Vaillant, N.M., Haas, J.R., Gebert, K.M. and Stockmann, K.D.	2013	Quantifying the potential impacts of fuel treatments on wildfire suppression costs
Thomspon, M., MacGregor, D., and Calkin, D	2016	Risk Management: Core Principles and Pracrices, and their Relevance to Wildland Fire
Tolhurst, K.G.	1995	Fire from a flora, fauna and soil perspective: sensible heat measurement
Tubbesing, C.L., Fry, D.L., Roller, G.B., Collins, B.M., Fedorova, V.A., Stephens, S.L. and Battles, J.J.	2019	Strategically placed landscape fuel treatments decrease fire severity and promote recovery in the northern Sierra Nevada
Turner, M.G., Hargrove, W.W., Gardner, R.H. and Romme, W.H.	1994	Effects of fire on landscape heterogeneity in Yellowstone National Park, Wyoming
United States Government Accountability Office (GAO)	2012	Key Considerations for Implementing Interagency Collaborative Mechanisms
United States Government Accountability Office (GAO)	2015	Wildland fire management: agencies have made several key changes but could benefit from more information about effectiveness
USDA Forest Service, Rocky Mountain Research Station	2004	Fuels planning: science synthesis and integration
USDA Forest Service	2004	Fuels Planning: Science Synthesis and Integration: Economic Uses Fact Sheet
USDA Forest Service	2015	Collaborative Forest Landscape Restoration Program 5-Year Report, FY 2010–2014
USDA	2012	Forest to Faucets

Author	Year	Title
Vasilakos, C., Kalabokidis, K.,Hatzopoulos, J., Kallos, G. and Matsinos, Y.	2007	Integrating new methods and tools in fire danger rating
Veblen, T.T., Kitzberger, T. and Donnegan, J.	2000	Climatic and human influences on fire regimes in ponderosa pine forests in the Colorado Front Range
Venn, T.J. and Calkin, D.E.	2011	Accommodating non-market values in evaluation of wildfire management in the United States: challenges and opportunities
Wade, D.D.	1989	A guide for prescribed fire in southern forests
Wagner, C.V.	1973	Height of crown scorch in forest fires
Waldrop, T., and Goodrick, S.	2012	Introduction to prescribed fires in Southern ecosystems
Warziniack, T. and Thompson, M.	2013	Wildfire risk and optimal investments in watershed protection
Weatherspoon, C.P. and Skinner, C.N.	1996	Fire-silviculture relationships in Sierra forests
Weaver, H.	1943	Fire as an ecological and silvicultural factor in the ponderosa-pine region of the pacific slope
Wells, C.G.	1979	Effects of fire on soil: a state-of-knowledge review (No
Westerling, A.L., Hidalgo, H.G., Cayan, D.R. and Swetnam, T.W.	2006	Warming and earlier spring increase western US forest wildfire activity
Wiedinmyer, C. and Hurteau, M.D.	2010	Prescribed fire as a means of reducing forest carbon emissions in the western United States
Willis, J., Roberts, S., and Harrington, C.	2018	Variable density thinning promotes variable structural responses 14 years after treatment in the Pacific Northwest
Wimberly, M.C., Cochrane, M.A., Baer, A.D. and Pabst, K.	2009	Assessing fuel treatment effectiveness using satellite imagery and spatial statistics

| Author	Year	Title
Winkel, G.	2014	Sustainable forest management on federal lands in the US Pacific Northwest-making sense of science, conflict, and collaboration
Wolk, BH, Stevens-Rumann, CS, Battaglia, MA, Wennogle, C, Dennis, C, Feinstein, JA, Garrison, K, and Edwards, G.	2020	Mulching: A knowledge summary and guidelines for best practices on Colorado's Front Range
Wondzell, S.M. and King, J.G.	2003	Postfire erosional processes in the Pacific Northwest and Rocky Mountain regions
Wotton, B.M.	2009	Interpreting and using outputs from the Canadian Forest Fire Danger Rating System in research applications
Wright, C.S. and Agee, J.K.	2004	Fire and vegetation history in the eastern Cascade Mountains, Washington
Wurtzebach, Z. and Schultz, C.	2016	Measuring ecological integrity: history, practical applications, and research opportunities
Yager, L.Y., HEISE, C.D., EPPERSON, D.M. and HINDERLITER, M.G.	2007	Gopher tortoise response to habitat management by prescribed burning
Yoder, J. and Gebert, K.	2012	An econometric model for ex ante prediction of wildfire suppression costs
Youngblood, A., Grace, J.B. and McIver, J.D.	2009	Delayed conifer mortality after fuel reduction treatments: interactive effects of fuel, fire intensity, and bark beetles
Youngblood, A.	2010	Thinning and burning in dry coniferous forests of the western United States: effectiveness in altering diameter distributions

REPORT DETAILS
Appendix B: Fiscal year 2020 expenditure detail

Interactive dashboard of DNR's spending in FY 20

The Department of Natural Resources (DNR) uses budget codes to track expenditure data. The tool below provides additional information about DNR's spending in fiscal year 2020.
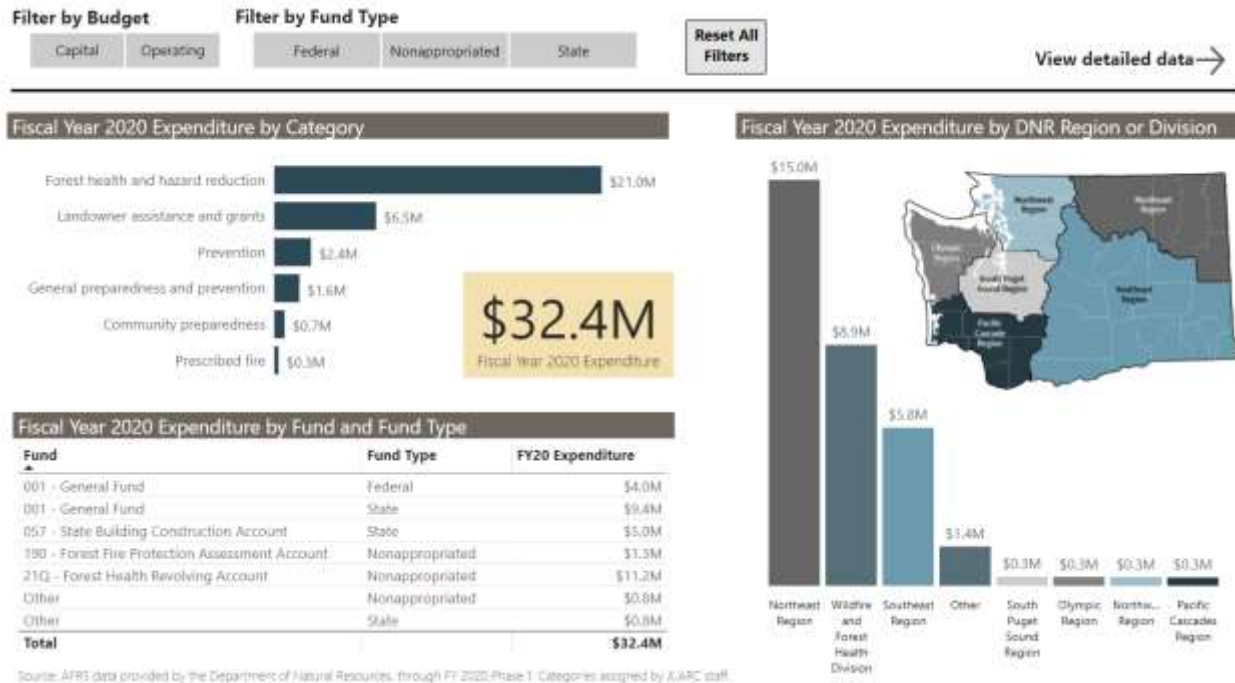
Source: AFRS data provided by DNR and summarized for presentation by JLARC staff. Data is accurate as of Phase 1 fiscal year close.

RECOMMENDATIONS & RESPONSES
No Legislative Auditor Recommendations

The Legislative Auditor did not issue recommendations for this study

Agency responses to the report will be included in the Proposed Final Report.

RECOMMENDATIONS & RESPONSES
Agency Response

Agency response(s) will be included in the proposed final report, planned for January, 2021.

MORE ABOUT THIS REVIEW
Audit Authority

The Joint Legislative Audit and Review Committee (JLARC) works to make state government operations more efficient and effective. The Committee is comprised of an equal number of House members and Senators, Democrats and Republicans.

JLARC's non-partisan staff auditors, under the direction of the Legislative Auditor, conduct performance audits, program evaluations, sunset reviews, and other analyses assigned by the Legislature and the Committee.

The statutory authority for JLARC, established in Chapter 44.28 RCW, requires the Legislative Auditor to ensure that JLARC studies are conducted in accordance with Generally Accepted Government Auditing Standards, as applicable to the scope of the audit. This study was conducted in accordance with those applicable standards. Those standards require auditors to plan and perform audits to obtain sufficient, appropriate evidence to provide a reasonable basis for findings and conclusions based on the audit objectives. The evidence obtained for this JLARC report provides a reasonable basis for the enclosed findings and conclusions, and any exceptions to the application of audit standards have been explicitly disclosed in the body of this report.

Washington **JLARC**

PROPOSED STUDY QUESTIONS
Wildfire Prevention, Preparedness, and Expenditure Review

State of Washington Joint Legislative Audit and Review Committee   April 2020

JLARC directed a study of DNR's wildfire prevention and preparedness activities and expenditures

The Department of Natural Resources (DNR) includes wildfire prevention and preparedness activities in many of its planning documents. The intent of these activities is to reduce the risk of wildfire. Examples include public education, landowner assistance, forest health assessments and treatment, fuel mitigation, good neighbor agreements, and fire adapted communities. DNR may work with other agencies and landowners to implement the plans.

In 2019, the Joint Legislative Audit and Review Committee directed its staff to review DNR's wildfire prevention and preparedness activities and related expenditures, and to identify if evidence exists about how effectively they reduce the risk of wildfire.

JLARC also directed its staff to evaluate DNR's progress in implementing recommendations from the 2018 JLARC report *Wildfire Suppression Funding and Costs*. The recommendations are focused on refining DNR's data collection and reporting efforts and improving its ability to identify the costs of individual fires.

Study will address DNR's activities, costs, and potential results

1. What fire prevention and preparedness activities is DNR planning and/or performing? How does DNR work with other agencies and landowners?
2. How does DNR track information about its activities and related spending? How does it use and report this information?
3. Does research identify certain types of activities that affect the number, size, and cost of wildland fires? How do the activities DNR is planning or performing align with those identified in the research?
4. What actions has DNR taken to fulfill the recommendations in JLARC's 2018 *Wildfire Suppression Funding and Costs* report to improve fire data collection and reporting?

Fire suppression and pre-suppression activities (e.g., staging resources) are not part this study.

Study Timeframe
Preliminary Report: December 2020   Proposed Final Report: January 2021

Study Team
Team Lead	Casey Radostitz	(360) 786-5176	casey.radostitz@leg.wa.gov
Research Analyst	Rebecca Connolly	(360) 786-5175	rebecca.connolly@leg.wa.gov
Research Analyst	Suzanna Pratt	(360) 786-5106	suzanna.pratt@leg.wa.gov
Research Analyst	Jennifer Sulcer	(360) 786-5181	jennifer.sulcer@leg.wa.gov
Project Coordinator	Valerie Whitener	(360) 786-5191	valerie.whitener@leg.wa.gov
Legislative Auditor	Keenan Konopaski	(360) 786-5187	keenan.konopaski@leg.wa.gov

JLARC Study Process

Study Mandate	Proposed Study Questions	Legislative Auditor's Preliminary Report	Legislative Auditor's Proposed Final Report	Final Report
Budget, legislation, committee direction			Agency response included	Option to append committee comment

○ Committee votes to distribute completed audit

JOINT LEGISLATIVE AUDIT & REVIEW COMMITTEE
106 11th Ave SW, Olympia, WA 98501 | Email: JLARC@leg.wa.gov | Website: www.jlarc.leg.wa.gov
Twitter: @WALegAuditor | Phone: (360) 786-5171 | Fax: (360) 786-5180

MORE ABOUT THIS REVIEW
Methodology

The methodology JLARC staff use when conducting analyses is tailored to the scope of each study, but generally includes the following:

- **Interviews** with stakeholders, agency representatives, and other relevant organizations or individuals.

- **Site visits** to entities that are under review.

- **Document reviews**, including applicable laws and regulations, agency policies and procedures pertaining to study objectives, and published reports, audits or studies on relevant topics.

- **Data analysis**, which may include data collected by agencies and/or data compiled by JLARC staff. Data collection sometimes involves surveys or focus groups.

- **Consultation with experts** when warranted. JLARC staff consult with technical experts when necessary to plan our work, to obtain specialized analysis from experts in the field, and to verify results.

The methods used in this study were conducted in accordance with Generally Accepted Government Auditing Standards.

More details about specific methods related to individual study objectives are described in the body of the report under the report details tab or in technical appendices.

CONTACT
JLARC Authors

Casey Radostitz, **Research Analyst,** 360-786-5176

Rebecca Connolly, **Research Analyst,** 360-786-5175

Suzanna Pratt, **Research Analyst,** 360-786-5106

Jennifer Sulcer, **Research Analyst,** 360-786-5181

Valerie Whitener, Audit Coordinator

Keenan Konopaski, Legislative Auditor

Senators

Bob Hasegawa

Mark Mullet, Chair

Rebecca Saldaña

Shelly Short

Dean Takko

Lynda Wilson, Secretary

Keith Wagoner

Representatives

Jake Fey

Noel Frame

Larry Hoff

Christine Kilduff

Vicki Kraft

Ed Orcutt, Vice Chair

Gerry Pollet, Assistant Secretary

Drew Stokesbary

**Washington Joint Legislative
Audit and Review Committee**
106 11th Avenue SW, Suite 2500
PO Box 40910
Olympia, WA 98504-0910
Phone: 360-786-5171
Email: JLARC@leg.wa.gov