USDA United States Department of Agriculture

Rocky Mountain Research Station

Science You Can Use Bulletin

JULY / AUGUST 2020 | Issue 41

"It's all up from here": Forest openings and seedling growth in western white pine restoration

Imagine you are a western white pine seedling growing in a forest opening. Your ability to grow into a mature tree depends on the visible sky above you in the opening and the light it provides. Seedlings of other species around you are also racing to grow upward and fill the same canopy space that you are striving to occupy. Your ability to maintain growth and outcompete the other seedlings is critical to your long-term survival.

"I often tell managers, 'The tree who gets there first captures the site and therefore has the competitive advantage to be there,'" said Terrie Jain, a research forester with the Rocky Mountain Research Station (RMRS). "And in mixed conifer forests, regeneration establishment is probably the most important part of any management strategy because it gives you the options for the future."

RMRS research forester Terrie Jain discussing the recent application of the free selection system with a colleague in Deception Creek Experimental Forest, Idaho (photo: J. Jerman, USDA Forest Service).

SUMMARY

For centuries, western white pine (*Pinus monticola*) dominated moist forests of the northern Rocky Mountains. The fast-growing species, which can reach heights of 150 feet, was once an economic driver in the region. However, not much of the former forest remains. A combination of blister rust, beetles, and logging severely reduced the range of white pine during the 20th century.

Managers have traditionally used large clearcuts followed by broadcast burning to grow western white pine and other early seral species. While this approach can be an effective and efficient way to get white pine on the landscape, clearcutting can come at the expense of other objectives, such as aesthetics, wildlife habitat, and water management.

Over a decade of research by Rocky Mountain Research Station scientists Terrie Jain and Russell Graham is now providing updated guidelines for regenerating and establishing white pine on the landscape by focusing on factors such as forest openings and visible sky.

Shade-intolerant species, such as western white pine, western larch, and ponderosa pine, require substantial sunlight to regenerate, become established, and grow at a fast-enough rate to elbow out other species like grand fir or western hemlock in the canopy. Forest managers typically use larger forest openings to manage for these species.

Jain and Russell Graham, also a research forester with the RMRS, have been conducting research for more than a decade designed to determine the optimum range of canopy openings needed to sustain early seral species and also meet other management objectives, such as promoting wildlife habitat and protecting watersheds.

Throughout much of the 20th century, managers used large clearcuts followed by broadcast burning to grow western white pine and other early seral species. While clearcutting is an effective and efficient way to get white pine on the landscape, its application can come at the expense of other objectives.

Beginning in the 1980s, the controversy surrounding the impact of logging on spotted owl habitats in forests on the West Coast brought the practice of clearcutting under scrutiny. Research showed that clearcutting, while effective at producing timber, was negatively affecting watersheds in the Pacific Northwest—particularly in the Columbia River basin—raising concerns about impacts on the headwaters important to anadromous fish (ones that migrate upriver from the sea to spawn), such as steelhead and salmon. In addition, concerns arose over impacts of clearcuts on the habitat of other wildlife species, such as goshawks and elk.

Graham said that these issues started to come to bear on the tried-and-true method of managing western white pine by clearcutting, broadcast burning, and planting in the inland northwest.

"We've been managing and understanding that species [western white pine] for a hundred years now, but we have different circumstances now, whether it's cumulative watershed effects or even people going out into the woods and looking at big clearcuts—the scenic values and sense of place," said Graham.

Jain said that without the availability of clearcuts, many managers began to believe they

A recently harvested stand (2019) in the Lone Cabin Stewardship sale area on the Idaho Panhandle National Forest. Underburning is planned for the spring of 2020, which will reduce hazardous slash fuels and prepare the site for planting of western white pine and western larch seedlings. The principles of the free selection system are being applied in this stewardship sale using relatively small openings and/or the retention of overstory larch, white pine, and Douglas-fir in larger openings in sufficient numbers to maintain diverse vertical structure while maintaining sufficient visible sky for the new crop of seedlings (photo: J. Jerman, USDA Forest Service).

White Pine Blister Rust

By the time white pine blister rust (WPBR) was first found in western North America in 1921, it had already established in populations of western white pine and spread rapidly through its range. The introduction of WPBR completely transformed one of the most productive and resilient ecosystems in North America, and the population size of western white pine is now estimated to be 5 percent of what it was at the turn of the 20th century.

Research started in the 1950s to develop WPBR-resistant seed stocks for western white pine, and these became available for large-scale application in the 1980s. However, without substantial openings, shade intolerant pine seedlings will quickly be outcompeted by larger numbers of shade-tolerant fir and hemlock. Therefore, even without the impacts of WPBR, low numbers of scattered western white pine may not be sustainable in these forests over the long term.

Orange-yellow spores of Cronartium ribicola*, the cause of white pine blister rust on white pine (photo D. Burton, USDA Forest Service).*

couldn't manage effectively for western white pine.

"There was a theory or philosophy that western white pine could grow nowhere else but in a clearcut and therefore people were no longer managing it because they thought they couldn't put any more clearcuts in," said Jain. "But early research [1940s] showed that white pine can actually grow and regenerate under a wide range of different canopy openings and therefore you don't need a clearcut to manage western white pine."

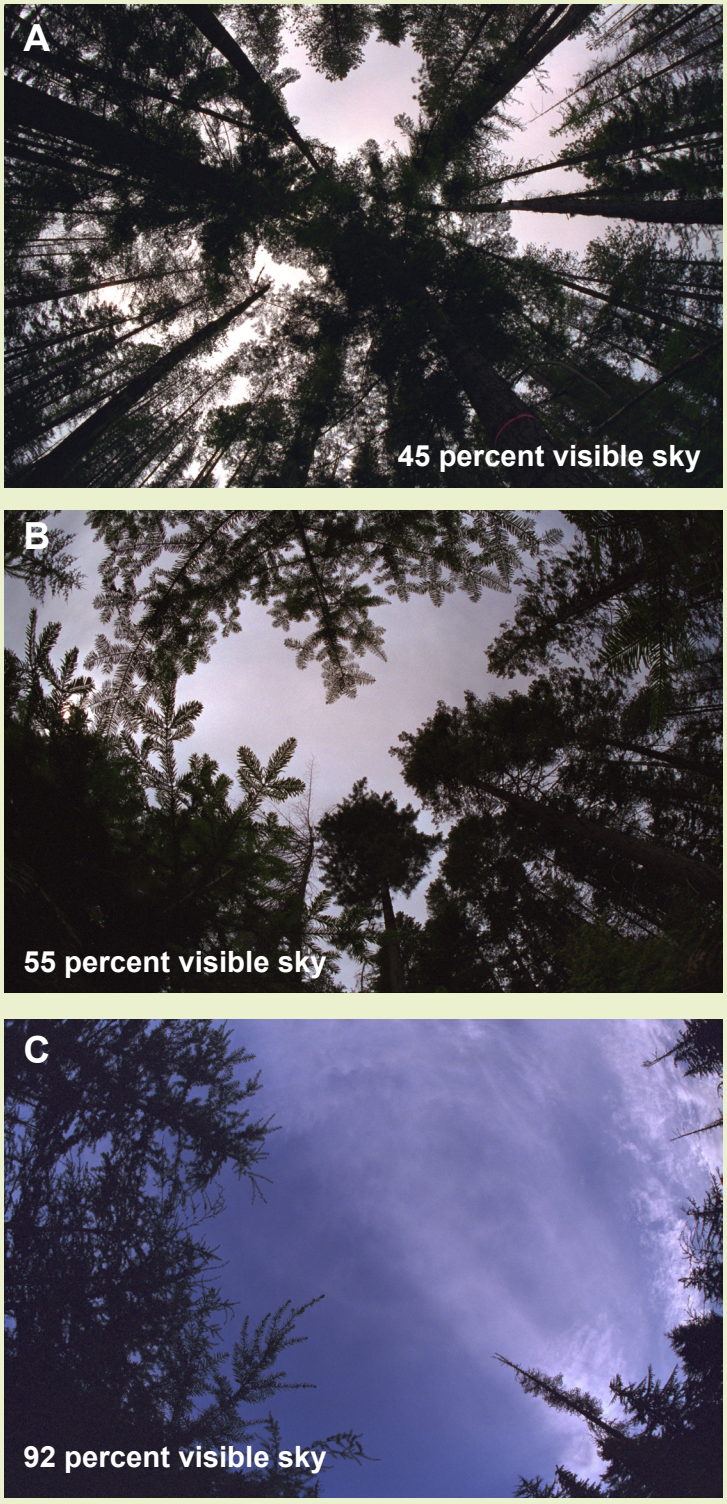
The research findings provide a landscape silvicultural perspective for managers that allows them to maintain flexibility and strategic options in how they manage the species, depending on management objectives and where they are on the landscape.

Jain and Graham first set out to survey natural regeneration of western white pine in the Coeur d'Alene Mountains to get a sense of what type of openings were needed to manage for the species. They identified different canopy openings and randomly assigned plots to look at the regeneration establishment and the growth response of the white pine under different opening sizes. They then worked with the Idaho Geological Survey to come up with different biophysical setting characteristics for the sites using landform, topography, geologic features, and soil weathering.

Looking at forests under low (45 inches of annual precipitation), medium (50 inches), and high moisture (55 inches) regimes, they found that white pine could establish and grow in a wide range of openings, from very small to 40 acres to large clearcuts. They also found that the response of white pine under those different canopy openings varied depending on whether there was a local source of water. On large slopes with many streams dissecting them, white pine did better across the opening sizes versus slopes that were not dissected by streams and creeks.

Jain said the research findings provide a landscape silvicultural perspective for managers that allows them to maintain flexibility and strategic options in how they manage the species, depending on management objectives and where they are on the landscape.

"Maybe we are looking at a landscape and want to restore riparian areas and get western white pine in there," said Jain. "We could have very good success in terms of regeneration



Fisheye photos are used to measure the amount of tree canopy and visible sky from the perspective of a seedling. The photos above show the amount of visible sky estimated for (A) regeneration establishment (45 percent), (B) competitive advantage (55 percent), and (C) free-to-grow (92 percent) (photos: T. Jain, USDA Forest Service).

and growth under much smaller openings than we would, say, mid-slope on a steep hill with a 60 percent slope where we would need a bigger opening to get the same growth response."

Canopy Opening Thresholds

For western white pine, there is a lot of mortality in the first 6 years of establishment, but after 6 years, the trees that are still there have a good chance of remaining. After 6 years, if western white pine is established, it "captures the site," outcompeting grand fir and hemlock to become the dominant canopy species.

"If you can't establish the trees you want, the species you want, it doesn't do you any good and you haven't achieved your management objectives," said Jain.

Stand percent canopy opening is the percentage of visible sky available for seedlings on the ground and is an important measure of light availability. Jain and Russell identified that a canopy opening of 25 percent (basal area of 100–120 ft^2/acre) (meaning an image of the sky taken from the perspective of a seedling would be filled with 75 percent tree canopy) provided a 55 percent probability of regeneration establishment for western white pine seedlings. And a 45 percent canopy opening (basal area of 80-100 ft^2/acre) created an 85 percent probability

of regeneration establishment of western white pine. Below the 25 percent threshold, the more shade-tolerant grand fir and western hemlock have the advantage in establishing in a plot.

For each opening threshold, there is a range of basal areas, stand density indices, trees per acre, and opening sizes. These are practical estimates.

Land managers can use these [canopy opening] thresholds when designing management treatments, particularly when integrated with other management objectives, such as wildlife habitat.

Threshold name	Threshold value (visible sky)	Basal area (ft^2/acre)	Stand density index	Trees/ acre	Opening size (acres)
55% regeneration establishment	25%	100 to 120	425	80 to 100	0.1
80% regeneration establishment	45%	80 to 100	350	60 to 80	0.25
Competitive advantage	55%	40 to 80	300	20 to 60	0.3
Free to grow	92%	≤ 40	≤ 120	≤ 20	1

Western white pine in the Deschutes National Forest, Oregon (photo: R. Mutch).

At 55 percent canopy opening, western white pine has competitive advantage, growing faster than western hemlock. At 92 percent opening, western white pine is free to grow, meaning it will likely become the dominant tree in the canopy.

Land managers can use these thresholds when designing management treatments, particularly when integrated with other management objectives, such as wildlife habitat. For example, spotted owl habitat may limit opening sizes or require a minimum canopy cover. In

KEY FINDINGS

- The response of white pine under different canopy openings varied depending on whether there was a local source of water. On large slopes with lots of streams dissecting it, white pine did better across the opening sizes versus slopes that were not dissected by streams and creeks.
- For western white pine, there is a lot of mortality in the first 6 years of establishment, but after 6 years the trees that are still there have a good chance of remaining. After 6 years, if western white pine is established, it "captures the site," outcompeting grand fir and hemlock to become the dominant canopy species.
- At 55 percent canopy opening, western white pine has competitive advantage, growing faster than western hemlock. At 92 percent opening, western white pine is free to grow, meaning it will likely become the dominant tree in the canopy.
- A sunfleck is a short period of direct sunlight. The number of sunflecks that affect a seedling has a negative relationship with growth. Jain and Graham found it is best to leave overstory trees in clumps rather than evenly spaced. This decreases the number of sunflecks and increases the period of direct sunlight reaching the established trees.

these situations, a manager can still manage for important disturbance resistant tree species and meet these management objectives.

Jain said managers can use this information to apply a "free selection silvicultural system," a hybrid between uneven aged and even-aged management, where the management objective is to create spatial diversity within a site or on a landscape.

"Say you want to create an opening that is 40 acres in size but want to leave trees in groups and create diversity of different sized trees," said Jain. "Yet you still want to regenerate western white pine and western larch. You can use the free-to-grow threshold to create a diversity of canopy openings in a larger area and still regenerate and grow western white pine and other tree species while leaving some overstory there for other purposes, whether it's snag recruitment, wildlife habitat, snow water management, or a variety of other reasons that you might want to leave some canopy. So, free to grow provides another tool for managers to use because it provides guidance on what kind of residual overstory you can leave and still get western white pine."

Jason Jerman, a forester and silviculturist for the Idaho Panhandle National Forest, said that the Forest's management plan is committed to white pine restoration while trying to increase other shade intolerant conifers such as western larch and ponderosa pine. Jerman said the Forest works closely with local collaborative groups who are very engaged with forest management and who don't want to see big clearcuts devoid of all mature trees on the Forest. These groups were attracted to the parts of Jain's and Graham's research that says it's possible to regenerate white pine in small openings.

"What they were talking about was what we would call in silviculture a traditional group selection approach," said Jerman. "Very small opening, 2 to 3 acres or less. Terrie's and Russ' research indicates that you can establish trees in openings that small. But, they're not free to grow. And most of them cannot reach optimal growth or achieve competitive advantage."

He said many of the stakeholder groups did not initially understand that in the smaller openings—even ones where white pine seedlings are free to grow or have competitive advantage—the available light will decrease as you move from the center of an opening toward the edge where there is more influence from the overstory.

But he said the research helped start a dialogue with these groups to explain how a seedling on the ground experiences available light.

"The research helps people actually put themselves in place—as weird as it may seem—to think like a seedling and imagine the influence exerted on a seedling by its surroundings," said Jerman. "Those small opening sizes are only going to actually facilitate growth for a small amount of white pine in a much smaller core area within the opening."

Jerman said the research helped him develop a dialogue with the groups that opened them to the idea that bigger openings were needed to establish white pine over a significant extent on the landscape.

Jerman said the research has been an important communication tool, helping nonspecialists build a mental image of how tree physiology, specifically seedling and sapling growth, connect to canopy opening sizes, visible sky, and competition with other species. That dialogue with stakeholder groups paid off when they began applying the concepts in white pine restoration treatments done in collaboration with the Panhandle Forest Collaborative.

The Panhandle Forest Collaborative restoration project involves multiple entries, creating relatively small openings to begin with for planting, and then

coming back about 8 years later to harvest some of the surrounding timber to expand the original openings.

"The idea is to get enough light in the openings to get the seedlings established, then establish more seedlings in the second entry, but make sure the original seedlings achieve free-to-grow status," said Jerman. "They can actually gain competitive advantage and free-to-grow status because we've expanded the opening and increased the amount of visible sky to the seedlings."

Openings that are only a few acres would have few retained trees in them. Where initial openings need to be larger, more trees can be retained without sacrificing as much visible sky because the edge of the opening is farther from the center. So larger openings will tend to have more retained overstory within them, particularly larch, white pine, ponderosa pine, and Douglas fir, when they are available. Jason Jerman said his vision for the restoration treatments is that in 30 years the stands will look like a landscape that has experienced a relatively natural disturbance.

"I hope the disturbance will lie on the landscape and follow natural lines more than what historic harvests have done," Jerman said. "It will have fingers and harvested and unharvested parts. There will be mature live trees

Pre-commercial thinning

Shelagh Fox, the Northern Region's regional silviculturalist, has been incorporating the forest openings research into her work in several ways, including designing treatments for implementing pre-commercial thinnings. Says Fox:

"We wanted to take even-aged saplings, small pole-sized stands, and move them into uneven-aged management to create spatial heterogeneity across time while developing these into uneven-aged, mature stands. The research helped me develop the prescriptions for implementing the spatial pattern and opening sizes during pre-commercial thinning and subsequent harvest treatments.

"The goal was to gradually and incrementally move the evenly spaced, even-aged, single-storied conifer stands toward having openings to regenerate early seral species and create multiple age classes. The research was incorporated into the initial pre-commercial thinning prescriptions and recommendations on opening sizes to regenerate early seral species, as well as prescription development for subsequent vegetation treatments.

"In the prescriptions, we varied the size of openings and the spacing variance between trees designated to be left after the thinning. In the initial pre-commercial thinning treatment, we could not open stands to some of the recommended opening sizes. The modeling showed that over time and multiple treatments, the stands move towards the desired structure through variable spacing during thinning, starting at the pre-commercial thinning stage.

"From an ecological perspective, the many even-aged ponderosa pine plantations in Region 1 should be managed as uneven-aged. Modeling of the proposed prescriptions showed success in moving these even-aged, single-storied ponderosa pine stands to uneven-aged, multistory stands over time and again through multiple treatments, both noncommercial and commercial. On the ground, we're in the early stages of implementation of these prescriptions. The modeling has provided a trajectory of how to, over time, move these stands to larger diameter, multistory, three age class, pine stands to facilitate habitat for pileated woodpeckers and flammulated owls."

Multiple treatments of even-aged ponderosa pine plantations to move them to larger diameter, multistory, three age class pine stands can enhance habitat for pileated woodpeckers and flammulated owls (photos: pileated woodpecker, J. McFarland; flammulated owl, J. Mulero).

A harvest unit in Deception Creek Experimental Forest in northern Idaho, where the free selection system was applied and slash disposal was recently completed. Note the live residual overstory and mosaic of burned and unburned fire effects (photo: J. Jerman, USDA Forest Service).

intermixed with young trees as you would see perhaps where a fire burned through with a low-to-moderate intensity."

Follow the Sun

James Pass, a silviculturist for the Colville National Forest in Kettle Falls, Washington, has been using Jain's and Graham's research to design white pine restoration treatments.

"The beauty of the Colville is that we're treating thousands and thousands of acres every year," said Pass. "So we have room for trying different things, and I've seen the whole gamut of openings. We're not doing clearcuts anymore. We're not in that era. But in terms of variable retention harvests or free selection harvests, irregular shelterwood-type systems, yeah, we're getting those, a variability of opening sizes on the landscape."

Pass said that Jain's and Graham's research on sunflecks and the distribution of the overstory, particularly the finding that the number of sunflecks that affect a seedling has a negative relationship with growth, influenced how he has approached white pine restoration treatments.

A sunfleck is a short period of direct sunlight. Overstory trees determine the length of a sunfleck by blocking direct sunlight from reaching understory trees. Jain and Graham found it is best to leave overstory trees in clumps rather than evenly spaced. This decreases the number of sunflecks and increases the

period of direct sunlight reaching the established trees.

"You can leave some given basal area, let's say 40 square feet of basal area in the overstory, and leave the trees as dispersed or aggregated," said Pass. "If you distribute the trees in a dispersed pattern where you have a tree every 40 feet, that's not a good light environment for western white pine or larch. What you want to do is create aggregations and some clumps so there are fewer sunflecks hitting the ground and lasting only for a short period. If you have a clumped up aggregated retention, then you'll have longer periods of sunlight hitting the seedling and it will grow better."

"When they give you specific thresholds or parameters, it makes it so the silviculturist can plan an actual on-the-ground silvicultural prescription to implement. A lot of research doesn't provide these metrics or parameters, and it's hard to step down to implement in the field."

–Shelagh Fox, Northern Region regional silviculturist

Applying Research on the Ground: The View That Matters

Basic science is driving Jain's and Graham's research, but from the beginning they have remained committed to helping forest managers use the research to create more resilient forests. Jain said the fundamental question of how white pine grew as canopy openings increased initially inspired the project. Over the past decade they have made important contributions in quantifying how subtle shifts in overstory trees influence seedling establishment and growth in the understory. In addition, the project has increased understanding of the relationship between sunfleck abundance and tree growth.

"Well that sounds fine and dandy, but what do you do with it when you're trying to manage for white pine? So, we went that extra step and developed these management thresholds," Jain said.

Shelagh Fox, the Northern Region's regional silviculturist, said she appreciates the effort Jain and Graham have made on the application side of the research.

MANAGEMENT IMPLICATIONS

To restore western white pine to portions of its historical range, the following guidelines are provided:

- Create more opportunities (and improved rust-resistant materials) for artificial regeneration while continuing to create opportunities for expanding the genetic base for WPBR-resistant stock.
- Maintain as much as possible of the surviving western white pine in current forests and provide openings for its regeneration in subsequent second-generation stands.
- Develop a broader understanding of alternate host ecology and potential resistance. This may lead to a better understanding of the current WPBR pathogen potential for adapting to changing environments or developing new races.
- Emphasize coordinated, aggressive management with strong integrated pest management.
- In nonforested areas, more aggressive planting and the use of WWP would at least help maintain an extended genetic base for possible future use. Source: Harvey, Alan E.; Byler, James W.; McDonald, Geral I.; Neuenschwander, Leon F.; Tonn, Jonalea R. 2008. Death of an ecosystem: perspectives on western white pine ecosystems of North America at the end of the 20th century. Gen. Tech. Rep. RMRS-GTR-208. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 10 p.

"When they give you specific thresholds or parameters, it makes it so the silviculturist can plan an actual on-the-ground silvicultural prescription to implement," she said. "A lot of research doesn't provide these metrics or parameters, and it's hard to step down to implement in the field."

James Pass said that the research has helped him look at the relationship between forest openings and seedling growth from a new perspective.


Photo: R. Mutch


Photo: R. Mutch

SCIENTIST AND MANAGER PROFILES

The following individuals were instrumental in the creation of this Bulletin:

THERESA JAIN is a Research Forester with the U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station in Moscow, Idaho. Her research focus is integrating silviculture research and management applications. Jain can be contacted at https://www.fs.usda.gov/rmrs/people/tjain.

RUSSELL GRAHAM is a Research Forester with the U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station in Moscow, Idaho. His research involves understanding long-term forest productivity and landscape processes. Graham can be contacted at https://www.fs.usda.gov/rmrs/people/rtgraham.

WRITER'S PROFILE

JOSH MCDANIEL is a science writer living in Grand Junction, Colorado. He can be reached at jmmcdaniel24@gmail.com.

FURTHER READING

Jain, Theresa B.; Graham, Russell T.; Morgan, Penelope. 2002. Western white pine development in relation to biophysical characteristics across different spatial scales in the Coeur d'Alene River basin in northern Idaho, U.S.A. Canadian Journal of Forest Research. 32(7): 1109-1125. https://www.fs.usda.gov/rmrs/publications/western-white-pine-development-relation-biophysical-characteristics-across-different

Jain, Theresa B.; Graham, Russell T.; Morgan, Penelope. 2004. Western white pine growth relative to forest openings. Canadian Journal of Forest Research. 34(11): 2187-2198. https://www.fs.usda.gov/rmrs/publications/western-white-pine-growth-relative-forest-openings

Jain, Theresa B.; Graham, Russell T.; Sandquist, Jonathan; Butler, Matthew; Brockus, Karen; Frigard, Daniel; Cobb, David; Sup-Han, Han; Halbrook, Jeff; Denner, Robert; Evans, Jeffrey S. 2008. Restoration of northern Rocky Mountain moist forests: Integrating fuel treatments from the site to the landscape. In: Deal, R. L., ed. Integrated restoration of forested ecosystems to achieve multi-resource benefits: Proceedings of the 2007 national silviculture workshop; 2007 May 7-10; Ketchikan, AK. Gen. Tech. Rep. PNW-GTR-733. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. P. 147-172. https://www.fs.usda.gov/rmrs/publications/restoration-northern-rocky-mountain-moist-forests-integrating-fuel-treatments-site

SYCU

SCIENCE YOU CAN USE BULLETIN

U.S. Department of Agriculture
Forest Service
Rocky Mountain Research Station
240 W. Prospect Rd.
Fort Collins, CO 80526

POSTAGE

The purpose of the Science You Can Use Bulletin: To provide scientific information to people who make and influence decisions about managing land.

The U.S. Forest Service RMRS Science You Can Use Bulletin is published regularly by: Rocky Mountain Research Station (RMRS).

Nehalem Clark
Bulletin Editor / Science Delivery Specialist
nehalem.clark@usda.gov

Jessica Brewen
Bulletin Editor / Science Delivery Specialist
jessica.brewen@usda.gov

To subscribe online to future Bulletins via email, use this link: tinyurl.com/RMRSsciencebulletin. Previously published Bulletins are posted on our website at: https://www.fs.usda.gov/rmrs/science-you-can-use.

Rocky Mountain Research Station researchers work at the forefront of science to improve the health and use of our Nation's forests and grasslands.

RMRS is one of 7 Forest Service Research & Development Stations located throughout the U.S. Within the 12 state RMRS footprint, we maintain 12 research locations, conduct long-term ecological research on 14 experimental forests, ranges and watersheds and work in hundreds of research natural areas.

You may also be interested in regular science delivery bulletins similar to Science You Can Use, produced by the Pacific Northwest and Southern Research Stations: PNW Science Findings and SRS CompassLive.

More information about the Rocky Mountain Research Station can be found here www.fs.usda.gov/rmrs/ and you can learn more about Forest Service Research at www.fs.fed.us/research.

USDA

"USDA is an equal opportunity provider, employer, and lender."