USDA
United States Department of Agriculture

Rocky Mountain Research Station
Science You Can Use Bulletin

July / August 2019 | Issue 35

Getting Climate-Smart With Seeds: How a New Software Tool Helps Prepare Landscapes for Expected Future Conditions

PROTECTOR OF THE VULNERABLE

In Greek mythology, the goddess Artemis was known as the protector of the vulnerable. She earned this title when she was just a few minutes old, by helping with the birth of her twin brother, Apollo. Later on, after asking Zeus for all the mountains of the world as her home, she became associated with nature and wilderness, and for protecting defenseless animals. Today, Artemis might be considered an environmentalist.

In botany, the goddess' namesake is Artemisia, which is a genus that includes sagebrush, a dominant shrub species in western North America.

These days, there's a lot of vulnerability associated with

Weather data collected by a technician at a bluebunch wheatgrass experimental plot in Idaho is used by researchers to explore how different populations are adapted to different climates. (Photo by Francis Kilkenny, USDA Forest Service.)

SUMMARY

Sagebrush ecosystems are a major component of western U.S. landscapes and they provide vital habitat to a wide array of wildlife species, including greater sage-grouse and pygmy rabbits. However, in recent decades, sagebrush ecosystems have been reduced or degraded by a wide range of disturbances, including human development, overgrazing, severe fires, and encroachment by cheatgrass and pinyon-juniper woodlands. These factors are expected to continue or worsen with anticipated climate change.

To help restore and protect these ecosystems, scientists at the Rocky Mountain Research Station, Pacific Northwest Research Station and elsewhere have utilized research gardens and climate projections to help develop a software tool called the Climate-Smart Restoration Tool. The Tool, which launched in June, is helping land and resource managers to match seeds with geographic areas, or "seed zones," under current and projected environmental conditions. In other words, land managers can use the Tool to help guide ecosystem restoration efforts, with a higher likelihood that the restored ecosystems will thrive under expected climate conditions. The Tool features data on sagebrush, with plans to add data for bluebunch wheatgrass and other plants and trees.

this keystone species and its related ecosystems. Human development, overgrazing, severe fires, and encroachment by cheatgrass and pinyon-juniper woodlands have all reduced or degraded sagebrush ecosystems. It's been estimated that less than 10 percent of U.S. sagebrush habitat is unspoiled. Greater sage-grouse, pygmy rabbits, and hundreds of other sagebrush-dependent species are particularly vulnerable to current and expected habitat disruption, including projected climate change.

SEED ZONES AND COMMON GARDENS

One scientist whose research is helping to restore these ecosystems is Bryce Richardson, a research geneticist for the Rocky Mountain Research Station in Moscow, Idaho. Richardson's work involves identifying sagebrush "seed zones"—geographic areas in which seed can be relocated and remain adapted to environmental conditions. Richardson explains: "Big sagebrush appears to vary in tolerance to cold. Plants from continental climates

"We need to conserve and bank seeds from warm-adapted populations because those are the populations that are adapted to conditions that are expected 20 to 30 years from now in colder regions of the species range."

- Bryce Richardson, RMRS

To develop seed zone data for the Climate-Smart Restoration Tool software, mesh bags at a Utah common garden are used to develop seed yield data for various sagebrush subspecies. (Photo by Bryce Richardson, USDA Forest Service.)

SPOTLIGHT ON THE GSD PROGRAM: RESTORING GRASSLAND, SHRUBLAND, AND DESERT ECOSYSTEMS

With the Forest Service's role of administering more than 150 National Forests, it can be easy to overlook the fact that about 50 percent of those lands in the Interior West and Great Plains are grasslands, shrublands, and deserts. This includes 20 National Grasslands, most of which are located west of the Mississippi River and east of the Rocky Mountains. Through its Grassland, Shrubland, and Desert Ecosystems (GSD) Program, the Rocky Mountain Research Station is a leader in researching these ecosystems.

According to Deborah Finch, the GSD program manager and a supervisory biologist for the Rocky Mountain Research Station in Albuquerque, New Mexico, "The GSD program has 15 scientists and many science support staff whose research helps sustain, manage, and restore grasslands, shrublands, and associated riparian ecosystems—and most specifically plant species, plant communities, and habitats critical for wildlife—when they've been damaged by severe fire, invasive species, or drought-induced change."

Scientists in the GSD program, including Bryce Richardson and Francis Kilkenny, conduct research in five main areas: disturbance ecology, invasive species, restoration, climate change, and ecosystem sustainability and management. Finch explains: "It's an important area of study right now because there are so many threats to these ecosystems, from the interactions of fire and invasive plants in the Great Basin and the Southwest to frequent drought and habitat fragmentation and loss in the Great Plains. Along with the other agencies that are doing work in this area, the Rocky Mountain Research Station is providing products and tools that are particularly important for Federal and State agencies and tribes that are managing habitats for species such as greater sage-grouse, riparian and grassland birds, pollinators, and many rare and endangered plants."

More information on the GSD program can be found by visiting https://www.fs.fed.us/rmrs/science-program-areas/grassland-shrubland-and-desert-ecosystems.

Sagebrush and bluebunch wheatgrass historically dominated many western range areas, including Shasta Valley in Siskiyou County, California. (Photographer: Dwight K., USDA Soil Conservation Service, 1969.)

"We're not just focusing on traditional concerns like cheatgrass control, erosion control, and forage needs—we're now trying to support biodiversity and achieve higher restoration success while considering projected climate change."

- Francis Kilkenny, RMRS

exhibit greater cold hardiness, resulting in higher survival in colder environments. Such information is used to develop seed zones. If seed is moved outside of seed zones—for example, from a warmer to a colder climate—these plants would be maladapted and would likely die due to cold injury. Seed zones incorporate maladaptation concerns, cold tolerance, and other traits to ensure that seed or seedlings are suited for the planting location."

The key to this data lies in specially monitored test planting zones called "common gardens." Common-garden studies involve planting different populations of the same species in a single location, generally to see which ones thrive. In this case, scientists are monitoring common gardens in multiple ecosystems and then comparing the results, using a methodology known as "reciprocal transplants." Scientists collect data on plant characteristics such as survival, growth, leaf form, fertility, and the timing of biological events such as leafing and flowering.

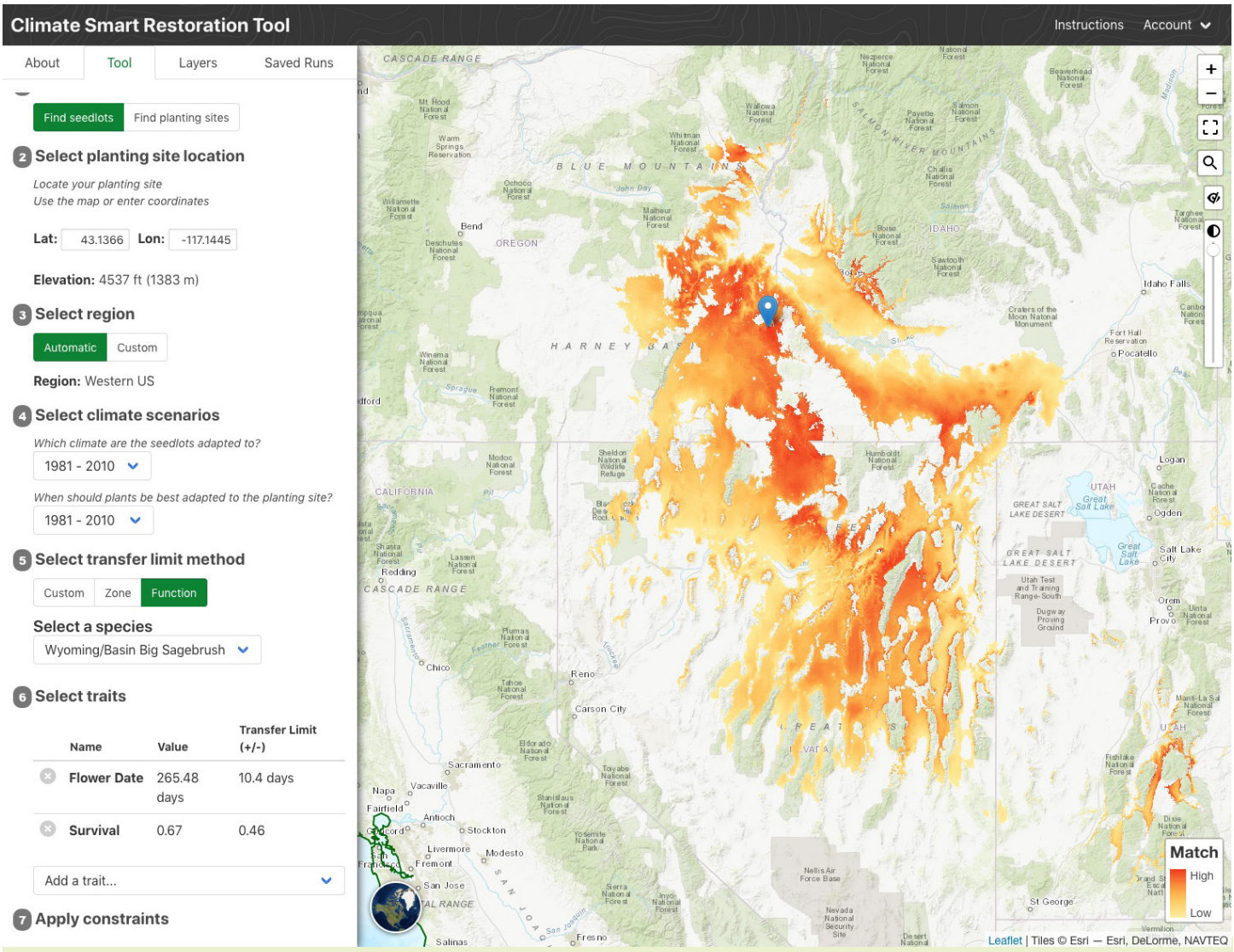
This research is particularly important in light of expected climate variability. "We're seeing climate changes now and we need to adapt to further expected changes," Richardson says, adding, "We need to conserve and bank seeds from warm-adapted populations because these populations are adapted to conditions that will likely be more widespread 20 to 30 years from now in colder regions of the species range."

GUIDANCE FOR GRASSES

Similar research is being conducted on bluebunch wheatgrass, which is considered one of the most important forage grass species on the western rangelands. It's also widely used for revegetation of degraded habitat, especially after fires. For these reasons, bluebunch wheatgrass seeds are in high demand.

Francis Kilkenny, Brad St. Clair, and Holly Prendeville are scientists developing and evaluating seed transfer guidelines for bluebunch

Site maintenance at the Quinn River bluebunch wheatgrass reciprocal transplant site helped improve the quality of seed zone data used in Climate-Smart Restoration Tool software. (Photo by Jessica Irwin, USDA Forest Service.)



The web-based Climate-Smart Restoration Tool helps improve the seed selection process, which is a key part of ecosystem restoration efforts and preparing ecosystems for climate change. Seed transfer limits are mapped based on user-designated geographic locations. (Image source: www.fs.fed.us/rmrs/tools/climate-smart-restoration-tool.)

wheatgrass. According to Kilkenny, a research biologist with the Rocky Mountain Research Station in Boise, Idaho, "Bluebunch wheatgrass is important because it's a common species and because it often forms codominant plant communities with sagebrush. It also competes well with cheatgrass. But when you're doing restoration you want to make sure you're using the bluebunch wheatgrass seeds that have the highest likelihood of success for projected climate conditions—particularly factors such as the winter and summer temperature differential and aridity."

A CLIMATE-SMART RESTORATION TOOL

In August 2019, these seed zone insights will be made available to natural resource managers who access an interactive, Web-based application called the Climate-Smart Restoration Tool, accessible at https://climaterestorationtool.org. According to Deborah Finch,

Following severe fire, land managers can use Climate-Smart Restoration Tool seed zone recommendations to determine the sagebrush species most likely to thrive as habitat disruptions continue and climate conditions change. (Image source: Scott Shaff, USGS.)

Commonly found throughout the western United States, bluebunch wheatgrass is easily outcompeted by noxious weeds. (Image source: Dave Powell, USDA Forest Service [retired], Bugwood.org.)

who leads the Rocky Mountain Research Station's Grassland, Shrubland, and Desert Ecosystems program, "The Climate-Smart Restoration Tool matches the climate adaptability of seeds with climate zones and conditions of restoration sites. I think it's going to be really useful in making sure that plants will survive under future climates."

The Tool relies on present and projected climate data from a climate-mapping software program called ClimateNA, which uses climate prediction data from the Intergovernmental Panel on Climate Change. It's designed to easily adjust for different climate change scenarios and time periods. Natural resource managers can choose the appropriate seed sources for their restoration sites for current and projected climates. These managers can also view geographic information system maps of current and future

"The Climate-Smart Restoration Tool matches the climate adaptability of seeds with climate zones and conditions of restoration sites."

- Deborah Finch, RMRS

climates. Plus, they can see seed zones and ecoregions while adjusting for climate change assumptions, risk tolerance, and management practices such as controlled burns.

The Tool has roots in similar software. According to Brad St. Clair, a research geneticist with the Pacific Northwest Research Station and a bluebunch wheatgrass collaborator with Francis Kilkenny, "The initial tool, called the Seedlot Selection Tool, had an interface that was focused on forest trees, but at some point we decided that it would be useful to have a tool aimed specifically at sagebrush restoration managers and knowledge of genetic variation in restoration species. Bryce Richardson has worked to expand the Climate-Smart Restoration Tool significantly, particularly with respect to his research on sagebrush."

St. Clair believes that the Climate-Smart Restoration Tool will be highly useful, given expected warming. "Although the climate has changed in the last decades, it's still within the amount of change that may be tolerable for many species, particularly given the large amount of genetic variation within species. But by mid-century the amount of change is expected to be large enough for many species' populations to show evidence of maladaptation."

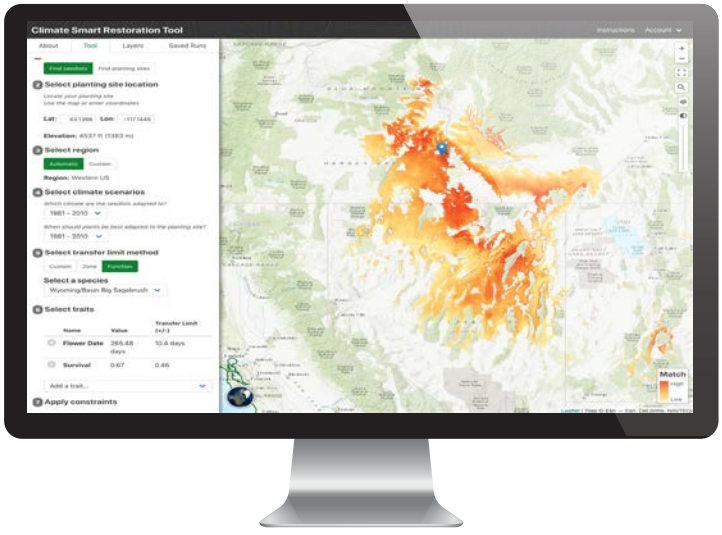
MANAGEMENT IMPLICATIONS

- Newly developed software that combines seed zone recommendations with anticipated climate change data can help land managers plan for the future while addressing reduced or degraded sagebrush ecosystems and diminished wildlife habitat.
- The Climate-Smart Restoration Tool, which launched in June 2019, provides climate-informed seed zone recommendations for sagebrush, with other species such as bluebunch wheatgrass set to follow.
- Scientists believe that the Tool will help land and resource managers plan ahead for projected climate change by identifying the appropriate seeds for current and expected environmental conditions in specific locations. This is expected to improve restoration outcomes and reduce costs.
- The Tool can be found at www.fs.fed.us/rmrs/tools/climate-smart-restoration-tool.

The Tool currently features only sagebrush species, but the addition of bluebunch wheatgrass is planned as well. Richardson adds, "We hope to add some other tree, shrub, and grass species—anything that the Forest Service or others have common gardens for."

CREATING THE SOFTWARE

A key partner in the software development effort has been the Conservation Biology Institute, a nonprofit organization based in Corvallis, Oregon. Known as CBI, this organization works with Federal and State agencies and other organizations to support conservation and biological diversity through applied research, education, planning, and community service. CBI's work includes ecological modeling, in which the organization develops services and tools based on factors that include wildfire, climate change impacts, wildlife connectivity, and species



"This is a tool that can be used in the real world ... it addresses not just how the climate is going to change but how we're going to prepare for it."

- Nikolas Stevenson-Molnar, CBI

population modeling. This focus and expertise enabled CBI to create the software behind the Seedlot Selection Tool and the Climate-Smart Restoration Tool, as well as for other seed-related projects for other agencies.

"There are two things about this project that excited me," CBI software engineer Nikolas Stevenson-Molnar says. "The first was that this is a tool that can be used in the real world. The second is that it addresses not just how the climate is going to change but how we're going to prepare for it. And based on how the Seedlot Selection Tool has been used and the recommendations we've implemented, I'm confident that the Climate-Smart Restoration Tool will be just as successful."

"GAME-CHANGING RESEARCH"

While the Tool is expected to be used by natural resource managers across the western states, the Bureau of Land Management is one of the agencies that's expected to benefit. According to Fred

Sagebrush wildfires have become more frequent and intense, partly due to the spread of non-native annual grasses. (Image source: Winnemucca BLM District Office.)

Edwards, the BLM's Great Basin ecoregional coordinator: "The BLM's Great Basin Native Plant Project, which has supported this research financially, has the goal of increasing and improving the plant and seed resources available to resource managers. Part of this is making the seed selection process more efficient and cost-effective. The Climate-Smart Restoration Tool is game-changing research from a land management perspective, as it allows us to choose more cost-effective seed resources."

SIMILAR SOFTWARE IN DEVELOPMENT

With the Seedlot Selection Tool already in use and the Climate-Smart Restoration Tool nearly ready to launch, it's important to know that more tools to address related needs will be developed, as long as funding is available. According to Glenn Howe, an associate professor in Oregon State University's College of Forestry and the originator of the Seedlot Selection Tool concept: "When we first came up with this idea, we envisioned four tools that could be used together. The Seedlot Selection Tool and the Climate-Smart Restoration Tool are basically the same tool but for different species and with some different functions. The second tool we envisioned is the Species Potential Habitat Tool, which is in the early development stages. The other two tools that I'd like to see developed are the Forest

The Great Basin Native Plant Project

The Great Basin Native Plant Project (GBNPP) is a multistate collaborative research project led by RMRS scientists in Utah and Idaho and the BLM Plant Conservation Program. GBNPP's goal is to improve the availability of native plant materials-especially seeds-and to provide the knowledge and technology required for their use in restoring diverse native pant communities across the Great Basin.

In addition to collecting native seed, GBNPP supports researchers and land managers in developing sound management and successful restoration practices in the face of threats from invasive species, shifting fire regimens, and climate change. One project focuses on increasing the seed production of native species, so that less time and resources are spent on collecting these seeds for the restoration seed mixes.

GBNPP has a library of technical information for practitioners about plant selection, weed control, irrigation, pollination, and plant propagation-much of which is derived from RMRS work/studies. This project gives managers the tools they need to complete rangeland restoration projects in accordance with the best available restoration science.

For more information, visit http://www.greatbasinnpp.org/.

The study of plant materials and cultural practices produces native seedlings ready for out planting. (Photo is courtesy of BLM Idaho.)

Further Reading

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Growth Modeling Tool and the Forest Vulnerability Tool."

With this suite in place, Howe hopes to provide clarity in an uncertain situation. He says: "Everyone I work with is concerned with climate change in one form or another, but they don't have sufficient site-specific information to proceed with management changes. They're all grappling with uncertainty, so there can be a reluctance to make changes. On the other hand, if you assume the future is going to be like it is today, you're almost certain to be off. With these tools, resource managers can begin to adapt land management for climate change—and at a local scale that wasn't possible before."

FUNDING

Funding for the ClimateSmart Restoration Tool was provided by the GBNPP and Conservation Biology Institute.

Bluebunch common gardens were funded by the GBNPP, National Fire Plan, BLM Plant Conservation Program, and USFWS.

Sagebrush Common gardens were funded by the GBNPP, National Fire Plan and BLM Plant Conservation Program.

Funding for the Seedlot Selection Tool was provided by US Forest Service Washington Office, USFS Pacific Northwest Research Station, Oregon State University, Conservation Biology Institute, the USDA Northwest Climate Hub, USFS Northern Institute of Applied Climate Science, USFS International Programs and Natural Resources Canada.

KEY FINDINGS

- Researchers have used common gardens in the western United States to identify differences in sagebrush subspecies characteristics, including cold tolerance, fertility, and the timing of biological events such as leafing and flowering. Other plant species exhibit similar variations.
- By identifying "seed zones," land and resource managers can improve restoration outcomes by matching seed with appropriate geographic locations and environmental conditions.

FURTHER READING

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SCIENTIST PROFILES

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

BRYCE RICHARDSON is a research geneticist with the Rocky Mountain Research Station in Moscow, Idaho. His research focuses on molecular and quantitative genetics of shrub and tree species, including sagebrush, blackbrush, and aspen. His research is frequently used for ecological restoration and to mitigate projected impacts of climate change. Bryce received a bachelor's degree in biology from the College of Idaho, a master's degree in forest resources from the University of Idaho, and a Ph.D. in plant pathology from Washington State University. Learn more about Bryce's work at https://www.fs.fed.us/rmrs/people/brichardson02.

FRANCIS KILKENNY is a research biologist with the Rocky Mountain Research Station in Boise, Idaho. He is the technical lead of the Great Basin Native Plant Project. His research focuses on the adaptation of plants such as bluebunch wheatgrass to local climates. This research is used to develop seed transfer guidelines and model the impacts of changing climates. Francis received a bachelor's degree in environmental studies from the University of California at Santa Cruz, a certificate of study in geographical information systems and remote sensing from Humboldt State University, and a Ph.D. in biology from the University of Virginia. Additional details on Francis's work can be found at https://www.fs.fed.us/rmrs/people/ffkilkenny.

BRAD ST. CLAIR is a research geneticist with the Pacific Northwest Research Station in Corvallis, Oregon. His research, which has included genetic studies on Douglas-fir and bluebunch wheatgrass, is related to describing and understanding geographic variation in how plants are adapted to their environments and the implications for management including reforestation, restoration, tree improvement, gene conservation, and responses to climate change. Brad received a bachelor's degree in forestry from U.C. Berkeley, a master's degree in forest genetics from the University of Wisconsin, and a Ph.D. in forest genetics from Oregon State University. Brad's work is further described at https://www.fs.usda.gov/pnw/people/st-clair-brad.

DEBORAH FINCH is a program manager and supervisory biologist for the Forest Service in Albuquerque, New Mexico. As the program manager for the Rocky Mountain Research Station's Grasslands, Shrubland, and Desert Ecosystems, she supports work that meets the mission of the program, including related plant genetics research. Her research interests include riparian and rangeland environments, bird migratory patterns, species vulnerability to climate change, and urban ecosystem services related to open spaces. Deborah received a bachelor's degree in wildlife management from Humboldt State University, a master's degree in zoology from Arizona State University, and a Ph.D. in zoology and physiology from the University of Wyoming. Learn more about Deborah's work at https://www.fs.fed.us/rmrs/people/dfinch.

HOLLY R. PRENDEVILLE is the Coordinator for the USDA Northwest Climate Hub based out of the Pacific Northwest Research Station in Portland, Oregon. As the coordinator, Holly serves Alaska, Idaho, Oregon, and Washington by working with partners to develop and deliver science-based, region-specific technologies and practical information that will assist with climate-informed decision making. Holly started in the Forest Service as a research geneticist, working with Brad and Francis as the project lead of the bluebunch wheatgrass study evaluating the efficacy of its seed zones in the Intermountain West. Learn more about the USDA Northwest Climate Hub by visiting this website: https://www.climatehubs.oce.usda.gov/hubs/northwest and Holly's research here: https://www.fs.usda.gov/pnw/people/prendeville-holly-r

WRITER'S PROFILE

BRIAN COOKE is a science writer for the Rocky Mountain Research Station in Fort Collins, Colorado. His work has included writing assignments for several Forest Service divisions, the National Park Service, and several environmental services companies and federal contractors. Brian's science and environmental writing is frequently colored by his National Park Service interpretive training and experience as a volunteer docent for Alcatraz Island, San Francisco Maritime National Historical Park and Deadman fire lookout tower in Arapaho Roosevelt National Forest. He received a bachelor's degree in journalism-science writing from Lehigh University.

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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).

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