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Right Fuel Treatment, Right Place: Managing wildfire in sagebrush country

Sagebrush, the iconic gray-green shrub of the American West, occupies an area so vast it is often described as an ocean or sea. The Sagebrush Sea once stretched across nearly 175,000 square miles in western North America, but it has dwindled to nearly half that size since the arrival of European settlers in the 1800s. Today, the sagebrush biome, which encompasses parts of 11 western States in the Great Basin, is experiencing rapid transformations.

"Protecting sagebrush ecosystems has become more important because we are rapidly losing them," says Jeanne Chambers, research ecologist and emeritus senior scientist with the U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station (RMRS).

Initially, much of the loss was due to human population growth, agricultural conversion, and urban development. More recently, warmer and drier conditions, large fires, and invasive species are taking a toll.

New threats to a diverse biome

To early settlers, the expanses of gray-green sagebrush may have suggested uniformity. To the trained eye, the sagebrush biome tells a story of biological evolution and adaption to the dry, harsh conditions of the Great Basin.

"Sagebrush ecosystems are much more diverse than what people might usually think," Chambers says, "and these systems are really not recovering from fire like we would hope. We're facing a new series of issues including invasive annual grasses and forbs, in particular cheatgrass. When sagebrush systems burn, if the understory has been depleted, as it often is due to livestock grazing or other factors, we have conversion to cheatgrass."

Having spent her career focused on plant populations and landscapes in semi-arid shrublands and

Mechanical treatments and prescribed burning may help reduce wildfire risk and improve ecosystem integrity for some areas in sagebrush country. Left—Courtesy photo by Jeremy Roberts, Conservation Media. Center and right—Courtesy photos by Bruce Roundy, Bringham Young University.

woodlands, riparian areas, and alpine ecosystems, Chambers describes herself as a jack-of-all-trades restoration ecologist for the Intermountain West. She easily rattles off a list of ecological values within the complex sagebrush ecosystems that stretch from valley bottoms to mountain tops. These ecosystems support hundreds of native plant and animal species including the greater sage-grouse. Big sagebrush is deeply rooted and can improve soil water infiltration, and thus water availability downstream, which is important for people as well as species like the Federally threatened Lahontan cutthroat trout.

Along with invasive plants, the expansion of pinyon and juniper trees into shrublands, extreme fire weather, and more, human-caused fires threaten sagebrush ecosystems.

Summary

To reduce the risk of wildfire, it's important to understand where fuel treatments are most likely to succeed. Recent research by Rocky Mountain Research Station (RMRS) scientists and their collaborators provides insights for prioritizing fuel treatments in sagebrush country. The group first developed four spatial layers to characterize sagebrush and pinyon-juniper landscapes: (1) indicators of ecological resilience to disturbance and resistance to invasion, (2) sagebrush associations, (3) persistent pinyon-juniper woodlands, and (4) pinyon-juniper expansion phases. The new indicators of resilience and resistance are dynamic because they are based on climate and soil moisture availability and allow assessment of potential treatment effects in a rapidly changing environment.

The group combined the spatial data layers to identify areas where fuel treatments can reduce wildfire risk while maintaining or improving resilience and resistance across sagebrush landscapes. They found that prescribed fire is best suited to big sagebrush associations with moderate to high resilience and resistance. In contrast, mechanical treatments are best suited to big sagebrush associations with moderately low resilience or resistance as well as sagebrush associations with low productivity and moderately low or greater resilience and resistance. Persistent pinyon and juniper woodlands were considered high value resources and thus not suitable for treatments.

A publicly available data archive allows land managers and the public alike to access the new spatial information to assess the resilience and resistance of ecosystems and the likelihood of success of management actions for the different sagebrush associations. The treatment response groups enable managers to evaluate scenarios to reduce wildfire risk, protect communities, or conserve ecosystems, and to choose the most effective treatment options.

New tools for managing wildfire in sagebrush country

Land managers have a few treatment options to reduce woody fuels that contribute to wildfire risk in sagebrush landscapes. Yet it can be difficult to know how to determine the types and locations of fuel treatments that will result in the desired effects. One reason is the lack of spatial data. Chambers collaborated with a group of scientists and land managers from several organizations to develop new tools to bridge this gap.

"We put together new building blocks to look at treatment response groups that give us better information on how an area on the landscape is likely to respond to a particular fuel treatment, which hadn't been done before."

The information offers insights about where treatments are likely to be most effective.

The building blocks include four new spatial data layers: resilience and resistance categories, sagebrush associations, persistent pinyon-juniper woodlands, and pinyon-juniper expansion phases. This information was combined to develop fuel treatment response groups that describe the potential for fuel treatments to reduce fire risk while maintaining or improving resilience and resistance across large sagebrush landscapes. For managers, knowing how a particular location on the

Treatment response groups are sagebrush associations and pinyon-juniper woodlands that differ in resilience and resistance and therefore differ in their responses to woody fuel treatments (prescribed fire, mechanical thinning).

Phases of pinyon and juniper expansion. Phase I: trees are present, but shrubs and herbs dominate; Phase II: trees are codominant with shrubs and herbs; Phase III: trees are the dominant vegetation.

landscape is expected to respond to a fuel treatment can not only save time and money, but also maintain valuable resources.

Duncan Leao sees value in the new approach. He is the Program Manager/Priority Landscape Coordinator for the Humboldt-Toiyabe National Forest in Nevada and California. "We can modify fire behavior in sagebrush and pinyon-juniper ecosystems you know, given all sorts of tools, but is that effective and consistent with an ecological approach?" he says. "Treatment response groups provide an opportunity to not do the same thing over and over out of habit, but to apply best available science to adjust our treatments to be more effective."

New indicators of resilience and resistance

Indicators, or measures, of ecological resilience to disturbance and resistance to invasion can be used as tools to aid in conservation and restoration. Together, they provide useful information about the potential of ecosystems to recover from both wildfires and management actions. Historically, these indicators were based on static soil moisture and temperature regimes which did not allow for predictions of future conditions. In addition, mapping protocols for evaluating soil moisture and temperature varied across States.

To overcome these limitations, Chambers and her collaborators developed new indicators of resilience and resistance that are climate sensitive. The new indicators are based on the ecological site descriptions commonly used by managers and consider an array of climate and soil moisture availability variables, including mean temperature, temperature of the coldest month, climatic water deficit, summer precipitation, and precipitation of the driest month. Consistent patterns emerged in the analyses: low levels of resilience and resistance were associated with warm and dry conditions with limited water availability, and higher levels of resilience and resistance were characterized by

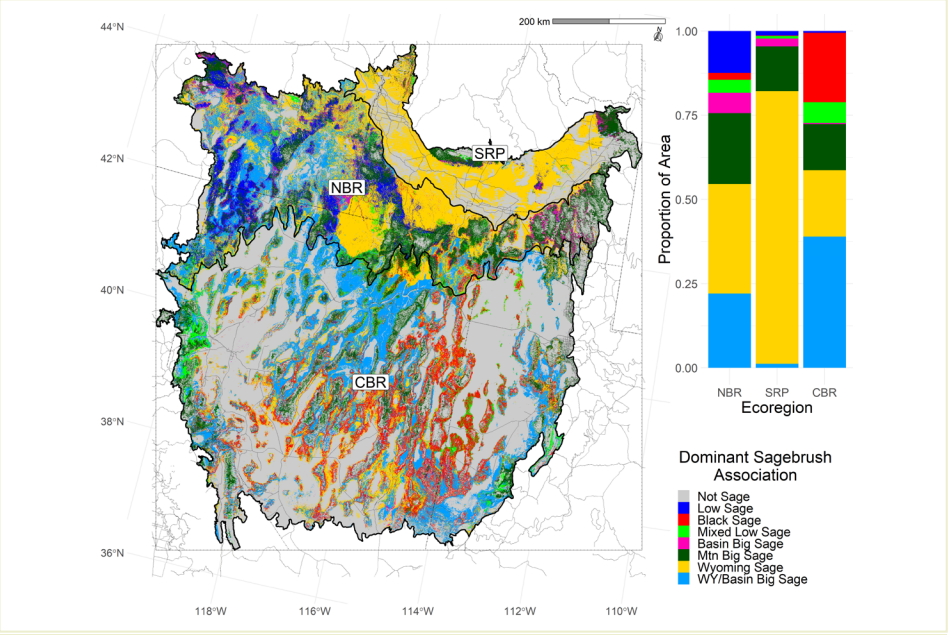
> "These systems are really not recovering from fire like we would hope. We're facing a new series of issues including invasive annual grasses and forbs, in particular cheatgrass."
>
> — Jeanne Chambers

cooler, moister conditions with greater water availability.

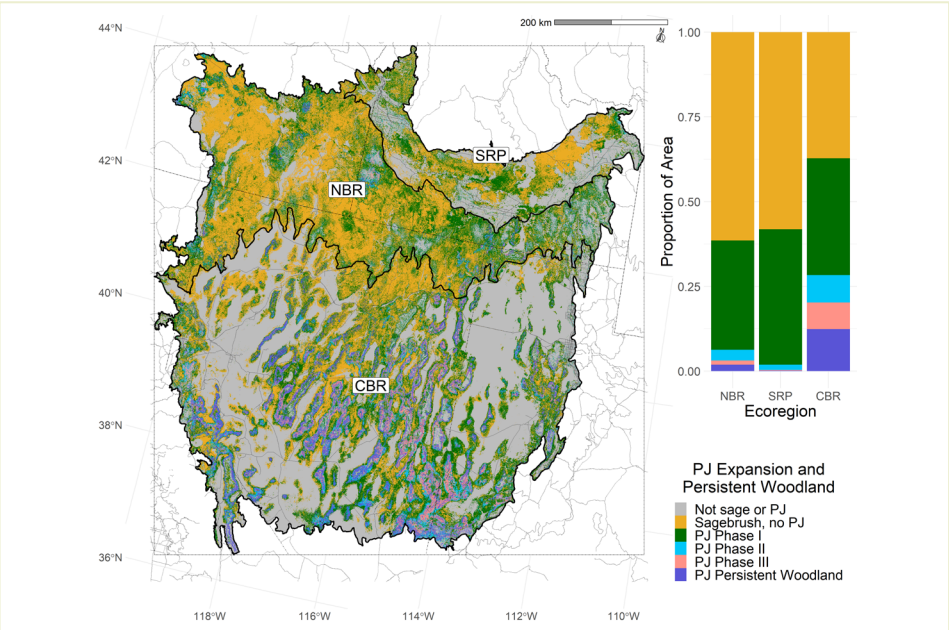
Mapping sagebrush and pinyon-juniper

Because responses to fuel treatments can vary across a landscape, mapping the dominant sagebrush associations in the region is important. Sagebrush within the study area covers 105,214 square miles. The largest portion is Wyoming big sagebrush (31.7 percent), followed by Wyoming/basin big sagebrush (29.1 percent), then mountain big sagebrush (14.7 percent), and black sagebrush (11.7 percent). Low sagebrush (5.5 percent), mixed low sagebrush (4.6 percent), and basin big sagebrush (2.8 percent) were also present. The associations differed across three ecoregions, with relatively more black sagebrush and Wyoming/basin big sagebrush in the Central Basin and Range, more low sagebrush and basin big sagebrush in the Northern Basin and Range, and more Wyoming big sagebrush in the Snake River Plain.

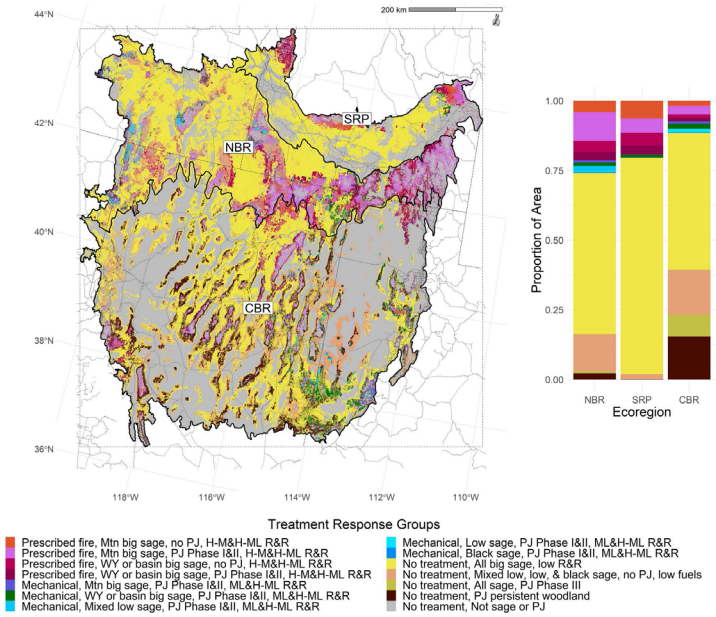
Mapping pinyon and juniper expansion is also important because expansion can deplete sagebrush understory and lead to soil erosion. Implementing woody fuel treatments becomes more difficult as expansion progresses. Infilling of pinyon and juniper woodlands can lead to higher severity fires that kill old-growth trees and convert woodlands to cheatgrass grasslands. On the other hand, persistent woodlands are considered high-value resources and were also mapped.



Scientists identified the dominant sagebrush associations across three ecoregions of the Great Basin study area: Central Basin and Range (CBR), Northern Basin and Range (NBR) and Snake River Plain (SRP). The bar graph at the upper right shows the proportion of the area of each sagebrush association within each ecoregion. This data layer and others are available at project and regional scales (see the datasets provided in further reading below, available to download).



The extent of pinyon-juniper (PJ) expansion areas by phase of expansion, persistent woodlands, and sagebrush associations with no PJ cover across three ecoregions of the Great Basin study area. The bar graph at the upper right shows the proportion of the area of each category within each ecoregion.



The primary treatment response groups (TRGs) with assigned fuel treatments, including prescribed fire, mechanical tree removal, and no treatment, for the Northern Basin and Range (NBR), Snake River Plain (SRP), and Central Basin and Range (CBR).

> "Treatment response groups provide an opportunity to not do the same thing over and over out of habit, but to apply best available science to adjust our treatments to be more effective."
>
> — Duncan Leao

"By putting together these new building blocks," Chambers says, "we were able to identify areas on the landscape that are appropriate for different types of treatments. Knowing how an area on the landscape is likely to respond to a particular fuel treatment can tell us where treatments are going be most effective."

Additionally, a recent review of the effects of fuel treatments in sagebrush ecosystems and data on the long-term effects (10 years) of various fuel treatments on fuel levels and fire behavior offered valuable insights into where treatments should be located and the types of treatments that should be used.

Treatment response groups

The new building blocks of spatial information made it possible to identify treatment response groups––areas where prescribed fire, mechanical thinning, or no treatment are appropriate. These groups suggest extensive areas of sagebrush (just under 72,600 square miles, or 69 percent of the study area) where resistance and resilience are low, and therefore unsuitable for woody fuel treatments. Other types of treatments, such as fuel breaks, are typically most appropriate in areas that are not suitable for woody fuel treatments.

However, 18.4 percent (about 20,440 square miles) of the area may be suitable for woody fuel treatments. Most of these areas were considered suitable for prescribed fire or mechanical treatments (14.2 percent) and a smaller portion for mechanical treatments only (4.2 percent). Prescribed fire was considered to be appropriate in big sagebrush associations with moderate to high resilience and resistance due to the greater productivity, fuels, and recovery potential. Mechanical treatments were considered appropriate in big sagebrush associations with moderately low resilience, and in low, black, and mixed low sagebrush associations with low productivity in general. Persistent pinyon and juniper woodlands were considered high value resources and not appropriate for treatment.

Fuel treatments across a Great Basin watershed

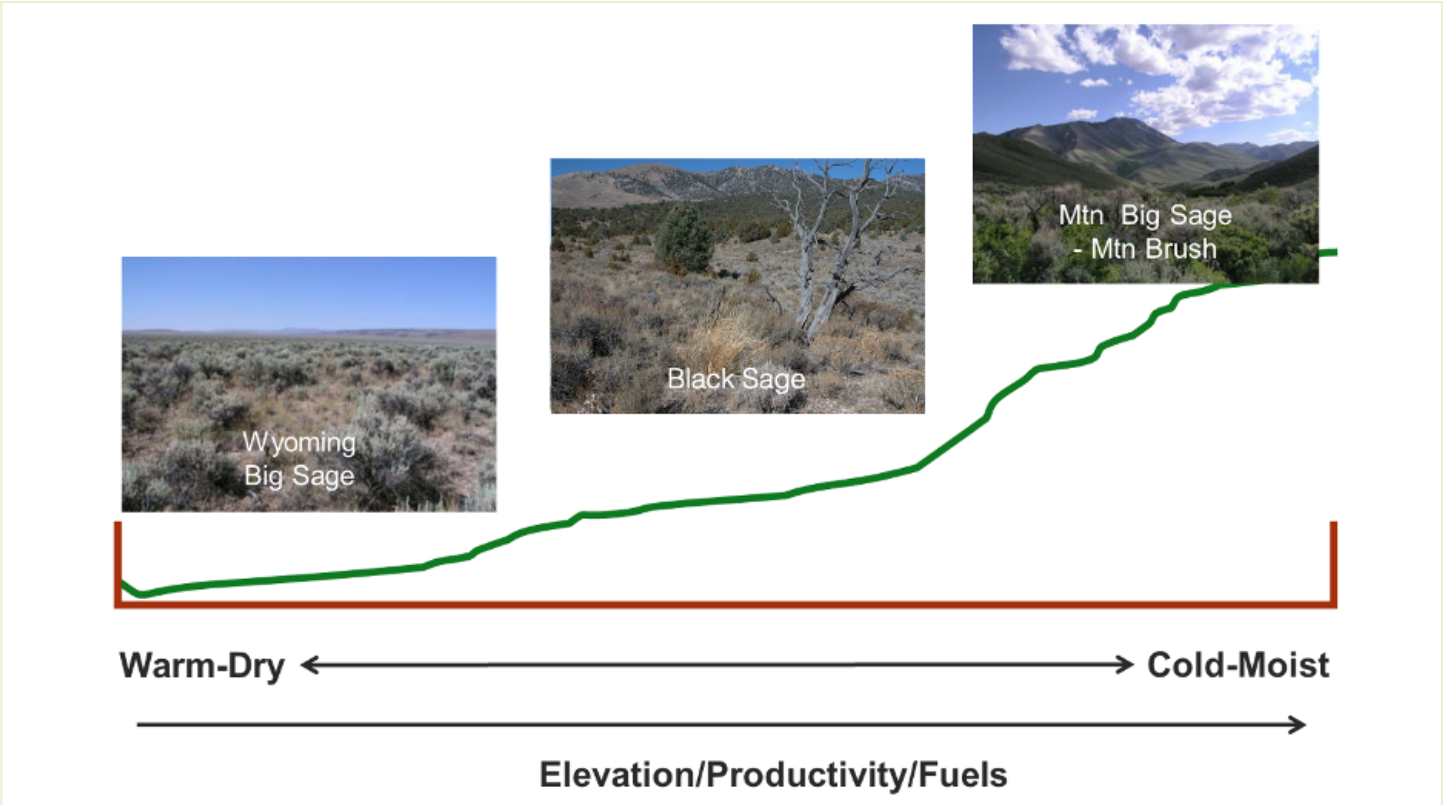
Treatment response groups can be combined with spatial information about threats such as pinyon-juniper expansion or invasive annual grasses, as well as valuable resources like wildlife habitat to help determine where to place fuel treatments. To illustrate this at a watershed scale, consider a drive up a single watershed in the Great Basin from low to high elevation. Along your journey you would encounter an array of sagebrush associations that reflect a gradient of environmental conditions and relative resilience and resistance.

At warmer, drier, low elevations, Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*), which tends to have lower resilience and lower resistance to invaders, would dominate. These systems, which have lower productivity and longer fire return intervals (50 to 100 years), would be considered unsuitable for woody fuel treatments.

As you drive higher and encounter an alluvial fan with coarser or shallower soils, a less productive black sagebrush (*A. nova*) association takes over. These systems take a long time to recover from disturbances like wildfire and fire return intervals would be longer. However, if pinyon and juniper expansion is occurring, mechanical removal treatments might be appropriate.

Farther up in elevation where precipitation increases, mountain big sagebrush (*A. tridentata* ssp. *vaseyana*) becomes predominant. This more productive system supports more understory species and has relatively high resilience and resistance. Historically, these systems may have burned as frequently as every 25 years. Prescribed fire here may effectively reduce woody fuels and fire risk while maintaining ecological function.

At larger, regional landscape scales, treatment response groups can be



New spatial data make it possible to identify treatment response groups (areas where prescribed fire, mechanical thinning, or no treatment are appropriate) across an environmental gradient. Figure and courtesy photos by Jeanne Chambers.

Better together: Linking threat-based conservation strategies with resilience and resistance

In the sagebrush biome, major ecosystem threats may stem from (1) human activities (urban development, land conversion to agriculture, and oil and gas development), (2) wildfires that give rise to invasion of nonnative annual grasses, or (3) expansion of pinyon and juniper trees into shrublands.

A threat-based approach to conservation considers the integrity of an ecosystem––how much of an area is intact versus degraded––in order to make management decisions to reduce or remove the threats. Whether a system is likely to recover following management actions or removal of threats depends in large part on its ecological resilience and resistance to invasion.

A new index of sagebrush ecological integrity provides information about areas of intact sagebrush and areas experiencing threats. Indicators of resilience and resistance for these same areas provide information about their recovery potential and ability to resist plant invasions. Together they offer a tool to better support management decisions.

For example, sagebrush areas of high ecological integrity (low threats) may require protective management across varying levels of resilience and resistance to conserve sagebrush ecosystems. Areas with intermediate ecological integrity offer opportunities to maintain or improve ecological conditions through proactive management.

Areas of low ecological integrity (high threats) tend to be warmer, drier, less resilient, and are more vulnerable to warming conditions. Looking at how resilience and resistance might change with warming temperatures can guide management at all levels of ecological integrity.

“The new sagebrush index of ecological integrity along with new resilience and resistance indicators work well together,” says RMRS scientist Jeanne Chambers. “Assessing both together helps us understand the environmental factors that influence the success of conservation and restoration efforts.”

used to evaluate scenarios to reduce wildfire risk, protect communities, or conserve ecosystems and to choose the most effective treatment options.

Informed decision making

Leao and his colleagues are using the treatment response groups to see where they can get the biggest bang for the buck. “We’re looking at where treatments can be most effective without causing future problems,” he says.

Before having this information, he says, planners relied primarily on experience. “Having data to go along with allocating treatments on the landscape instead of us

Management Implications

- Understanding where and how ecosystems recover from disturbance and resist invasion helps to design management treatments that reduce fire risk and maintain resilient ecosystems.
- Treatment response groups, along with maps of threats (such as invasive grasses and areas with high burn probabilities) and valuable resources (intact sagebrush ecosystems), help land managers to prioritize treatments where they will have the greatest benefits and to determine the most effective management strategies.
- Prescribed fire to reduce woody fuels is more likely to be successful in big sagebrush associations with moderate to high resilience and resistance. For areas with lower resilience and resistance, or lower productivity, mechanical treatments are more appropriate.
- Treatment response groups help managers plan, design, and prioritize fuel treatments to reduce wildfire risk at landscape scales. Mapping sagebrush ecological integrity with resilience and resistance values enables land managers to prioritize conservation and restoration actions.

Field trip participants consider a treatment response group map as they discuss follow-up options for a cut and leave treatment applied to Wyoming big sagebrush with pinyon and juniper expansion in the Ruby Mountains of the Humboldt-Toiyabe National Forest in Nevada. USDA Forest Service photo by Duncan Leao.

just looking at a map and relying on what we know from prior experience complements and validates that experience and helps identify areas where we might have missed a detail."

In the summer of 2024, Leao helped host a field trip for a group to look at how recent woody fuel treatments aligned with treatment response group data for an area in the south end of the Ruby Mountains of the Humboldt-Toiyabe National Forest. The group included Chambers and colleagues from RMRS and Oregon State University as well from the Nevada Department of Wildlife, the Bureau of Land Management, Elko County and others. In light of the fuel treatment response groups data, they discussed potential treatments with the goal of balancing ecological goals with vegetation and fuel management and improving habitat, watershed, and forest health.

One area the group considered was a large swath of a cut-and-leave treatment in a phase two pinyon-juniper setting. They looked at the treatment response group map and the data for the specific polygon where the treatment took place. "It was cool because that directed where to apply follow-up treatments if we want to go back in to reduce the sheer amount of fuel that we put on the ground," Leao says. The maps showed where mastication would be appropriate or where prescribed burning would be effective to implement.

Leao says that validating past experience with treatment response group data provides a better feel for future decision making or adaptive management. "It increases our confidence," he says. "It allows us to fall back on not just experience alone or theory alone, but also on data and modeling. It's informed decision making."

Looking to the past to guide the future

Changing climatic conditions add to the complexity of decisions about where to place fuel treatments in sagebrush country. Chambers and

her collaborators are examining climatic variables and vegetation shifts in the recent past to help identify and prioritize vegetation treatments to help ecosystems thrive in the long term.

"We are looking at the climate over the last 40 years and associated shifts in plant functional group composition, resilience and resistance, and fire risk," Chambers says. The idea is that combining knowledge about ecological types with information about the type and amount of change, can help land managers figure out which vegetation and fuel treatments might work best, and which areas need them most. The findings are expected to help managers direct ecosystems to conditions that will be more sustainable into the future.

Key Research Findings

- New indicators of ecological resilience to disturbance and resistance to invasive annual grasses help predict ecosystem responses to both wildfires and vegetation management. These indicators rely on climate and water availability data, so they can also show how changing climatic conditions might affect these responses.
- Sites with low resilience and resistance tend to be warm and dry and have limited water availability; sites with high resilience and resistance tend to have cooler, moister conditions and greater water availability.
- New spatial data make it possible to identify treatment response groups–– sagebrush associations and pinyon-juniper woodlands—that differ in resilience and resistance and thus responses to woody fuel treatments such as prescribed fire and mechanical thinning.
- About 20,440 square miles (18 percent) of the sagebrush associations are suitable for woody fuel treatments. However, extensive areas of sagebrush (just under 72,600 square miles, or 69 percent) have low resistance and resilience and are unsuitable for woody fuel treatments. These areas may benefit from other treatments, like fuel breaks.
- Complementary research on the longer-term effects of treatments on fuels and fire behavior provide important insights into the potential characteristics of future wildfires in treated sagebrush and pinyon-juniper areas.

Further Reading

Chambers, J.C.; Strand, E.K.; Ellsworth, L.M.; [et al.]. 2024. Review of fuel treatment effects on fuels, fire behavior and ecological resilience in sagebrush (Artemisia spp.) ecosystems in the Western U.S. Fire Ecology. 20:32.

Chambers, J.C.; Brown, J.L.; Bradford, J.B.; [et al.]. 2023a. New indicators of ecological resilience and invasion resistance to support prioritization and management in the sagebrush biome, United States. Frontiers in Ecology and Evolution.

Chambers, J.; Brown, J.L.; Reeves, M.; [et al.]. 2023b. Fuel treatment response groups for fire-prone sagebrush sandscapes. Fire Ecology. 19: 70.

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Ellsworth, L.M.; Newingham, B.A.; Shaff, S.E.; [et al.]. 2022. Fuel reduction treatments reduce modeled fire intensity in the sagebrush steppe. Ecosphere. 13: e4064.

Miller, Richard F.; Chambers, Jeanne C.; Evers, Louisa; [et al.] 2019. The ecology, history, ecohydrology, and management of pinyon and juniper woodlands in the Great Basin and Northern Colorado Plateau of the western United States. Gen. Tech. Rep. RMRS-GTR-403. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 284 p.

Williams, C.L.; Ellsworth, L.M.; Strand, E.K.; [et al.]. 2023. Fuel treatments in shrublands experiencing pinyon and juniper expansion result in trade-offs between desired vegetation and increased fire behavior. Fire Ecology. 19: 46.

Diving into the details: Where to find and how to use new sagebrush spatial data

The Forest Service Research Data Archive is a publicly available resource that allows land managers to access the new spatial information to assess the resilience and resistance of ecosystems and the likelihood of success of management actions at landscape scales. The data archive includes the treatment response groups and all of the spatial data that make up the treatment response groups, including the sagebrush associations, resilience and resistance indicators, and pinyon-juniper expansion phases and persistent woodlands.

A U.S. Geological Survey data release is available for those interested in the indicators of sagebrush ecological integrity for the sagebrush biome, specifically, the core habitat and growth areas estimated from a threat-based approach.

The Forest Service Research Data Archive also includes updated fuel and terrain (fuelscape) information generated for wildfire hazard risk assessment for the sagebrush biome. The data are based on fuel conditions from around 2020 and reflect expected fire behavior in sagebrush ecosystems, including influences from nonnative annual grass (e.g., cheatgrass) invasion and pinyon and juniper expansion. These data sets are available for downloading:

New indicators of ecological resilience and invasion resistance in the sagebrush biome
Chambers, J.C.; Brown, J.L.; Bradford, J.B.; [et al.]. 2023. New indicators of ecological resilience and invasion resistance to support prioritization and management in the sagebrush biome, United States [Dataset]. Dryad. https://doi.org/10.5061/dryad.h18931zpb

Fuel treatment response groups for the Great Basin Level III ecoregions
Chambers, Jeanne C.; Brown, Jessi L.; Reeves, Matthew C.; [et al.]. 2024. Treatment Response Groups (TRGs) for use in landscape-scale assessments of fuel treatment types and locations in the Snake River Plain, Northern Basin and Range, and Central Basin and Range level III ecoregions in the western United States. Fort Collins, CO: U.S. Department of Agriculture, Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2024-0008

Dominant sagebrush associations for the Great Basin Level III ecoregions
Chambers, Jeanne C.; Brown, Jessi L.; Reeves, Matthew C.; [et al.]. 2024. Dominant sagebrush associations of the Snake River Plain, Northwestern Basin and Range, and Central Basin and Range level III ecoregions in the western United States. Fort Collins, CO: U.S. Department of Agriculture, Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2024-0008

Pinyon and juniper expansion areas and persistent woodlands for the Great Basin Level III ecoregions (combined data sets)
Chambers, Jeanne C.; Brown, Jessi L.; Reeves, Matthew C.; [et al.] 2024. Pinyon and juniper expansion areas and persistent woodlands in the Snake River Plain, Northern Basin and Range, and Central Basin and Range level III ecoregions in the western United States. Fort Collins, CO: Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2024-0007

Indicators of sagebrush ecological integrity for the sagebrush biome
Doherty, K.; Theobald, D.M.; Holdrege, M.C.; [et al.]. 2022. Biome-wide sagebrush core habitat and growth areas estimated from a threat-based conservation design: U.S. Geological Survey data release. https://doi.org/10.5066/P94Y5CDV

Spatial datasets of probabilistic wildfire risk components for the sagebrush biome.
Short, Karen C.; Dillon, Gregory K.; Scott, Joe H.; [et al.]. 2023]. Spatial datasets of probabilistic wildfire risk components for the sagebrush biome (270m). Fort Collins, CO: Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2023-0050

Fuelscape datasets for wildfire risk assessment in the sagebrush biome
Short, Karen C.; Scott, Joe. H.; Gilbertson-Day, J.W. [et al.]. 2024. Fuelscape datasets for wildfire risk assessment in the sagebrush biome (270m). Fort Collins, CO: Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2024-0004

For assistance with interpreting the spatial data in the archive, contact Jessi Brown, jessilbrown@gmail.com.

For assistance with interpreting Treatment Response Groups, contact Dr. Jeanne Chambers, jeanne.chambers@usda.gov.

For help interpreting the wildfire risk datasets, contact Dr. Karen Short, karen.c.short@usda.gov.

Contributor Profiles

Jeanne Chambers is an Emeritus Senior Scientist with the Rocky Mountain Research Station located in Reno, Nevada. Her research continues to focus on developing an understanding of the factors that determine ecological resistance to invasive species and that affect ecological resilience to disturbances like wildfire and using that information to develop effective management and restoration approaches. Study systems include alpine ecosystems and arid and semi-arid shrublands, woodlands, and riparian ecosystems.

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Duncan Leao is the Program Manager/ Priority Landscape Coordinator for the Humboldt-Toiyabe National Forest in Nevada and California. He provides interpretation, guidance, and program leadership for planning efforts in the Sierra and Elko Fronts Landscape. He also works with Tribal governments, States, and other partners to address challenges and explore opportunities to improve forest health and resiliency across management jurisdictions.

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About the

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