

IMPROVING CLIMATE RESILIENCE OF PERSISTENT PINYON-JUNIPER WOODLANDS

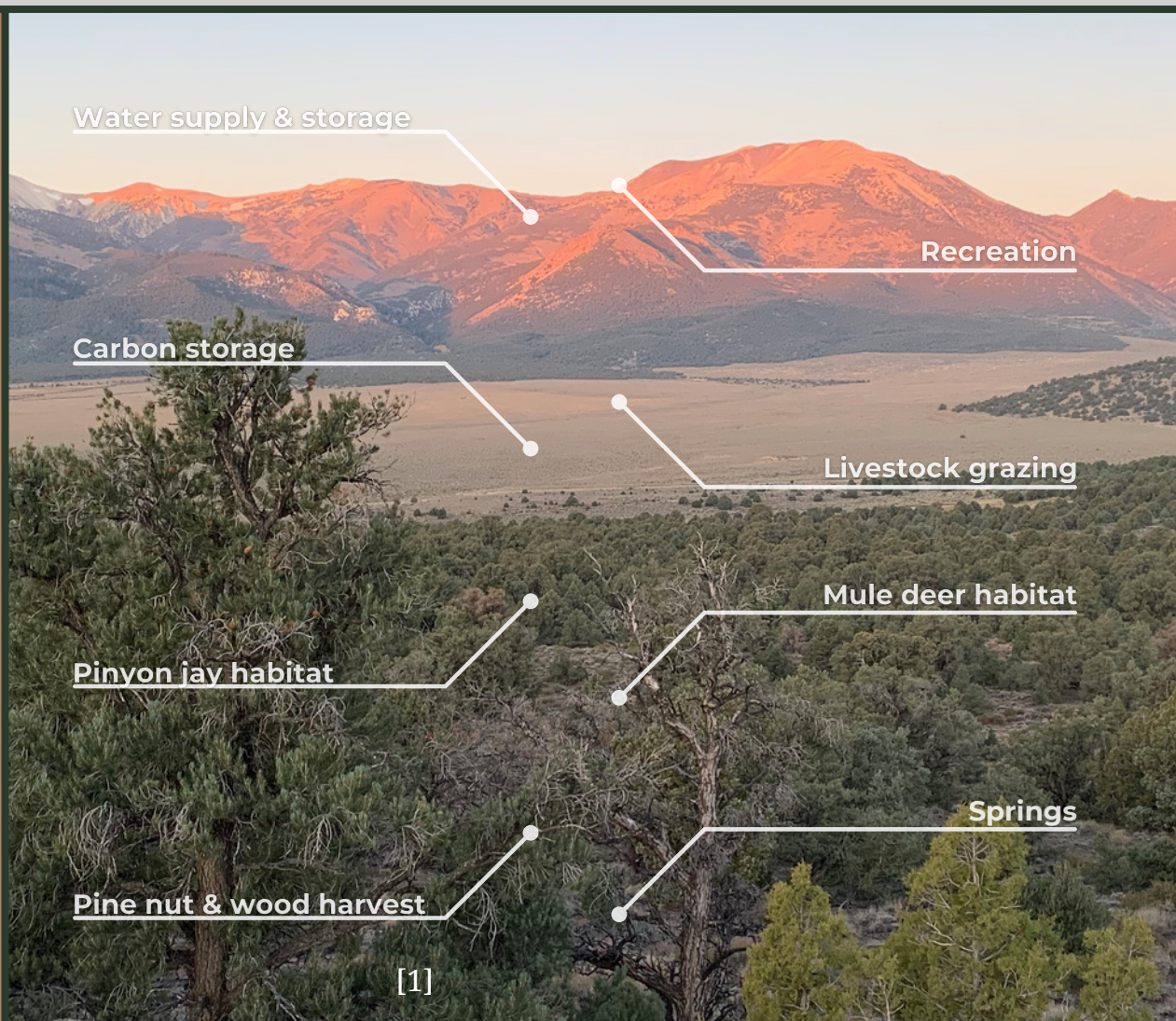
Pinyon-juniper woodlands, a hallmark of the West, provide for people and wildlife

Across the Intermountain West, low mountains and foothills are blanketed by pinyon-juniper woodlands. These ecosystems cover more than 100 million acres¹, support a diverse suite of plant and wildlife species, provide opportunities for recreation and solitude, and contribute to tribal and rural livelihoods (Box 1). Woodlands, alongside and intermixed with other grassland, shrubland, and forest ecosystems, are an important part of the mosaic of our Western landscapes (Box 2). In persistent woodlands, where pinyon pine and juniper trees have been growing for hundreds to thousands of years, changes occurring at local and regional scales may threaten the resilience and persistence of these woodlands in parts of the biome.

Although imperiled shrubland, grassland, and forest ecosystems in the region have justifiably received systematic conservation attention, relatively little focus has been on addressing the suite of interrelated changes facing persistent woodlands, such as increasing tree densities and localized pinyon pine population declines, in the context of changing climate. This report highlights recent science on primary threats to persistent woodlands, identifies the role of changing climate, and highlights new efforts and approaches to develop management strategies focusing on building pinyon-juniper woodland health and climate resilience.

¹Romme et al. 2009.

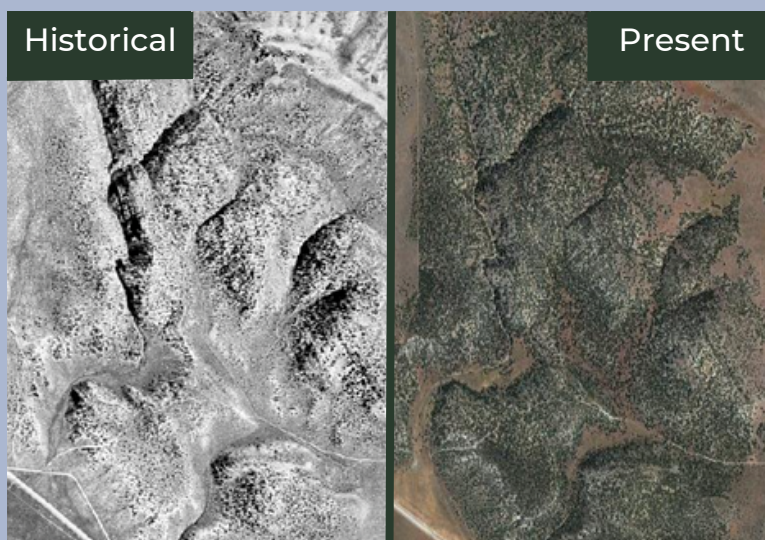
Box 1. Pinyon-juniper woodlands are part of a resilient mosaic of habitats across the West. Hikers take in iconic vistas, hunters seek out trophy mule deer, pinyon jays nest in their canopies, and Indigenous peoples collect their pine nuts for sustenance. Tribal identities are closely tied to these woodlands. Wildlife and livestock rely on them for forage and cover. Woodlands also provide many ecosystem services, from carbon storage to water supply.



Box 2. The landscape context for persistent pinyon-juniper woodland management

The cover and extent of pinyon-juniper woodlands is increasing at the biome scale, while at some local to regional scales, persistent woodlands are declining due to drought-induced mortality and wildfire.

At the biome scale, woodland cover is increasing as pinyon and juniper species expand into shrublands and grasslands where trees have not grown in recent history and infill existing woodlands². Despite a net increase in tree cover biome-wide, in some persistent woodlands, populations are declining as trees die of drought, wildfire, and insect and disease outbreaks³. High tree density, a result of infill, may in some cases exacerbate mortality⁴. When mortality is not balanced by recruitment of new trees, population declines occur (see Box 3).



Historical imagery shows how conifers have been expanding their footprint and infilling existing woodlands over time, like this example in Oneida County, Nevada. Historical images from USGS Single Frame Archive from the 1940s through the 1970s are compared to current satellite imagery. To view historical imagery in more areas, see the [Rangeland Analysis Platform Historical Imagery product](#).

Romme et al. (2009) define three general vegetation types in pinyon-juniper woodlands, demonstrating how climate, soils, and disturbance impact vegetation distribution and structure.

Persistent pinyon-juniper woodlands are dominant where soils, climate, and disturbance regimes are favorable for tree growth, allowing mixed-aged stands with old trees to develop. Persistent woodlands are common in areas with rugged, shallow, coarse-textured soils where fire is infrequent. Woodlands generally transition to forests where conditions favor more frost-tolerant conifer species.

Wooded shrublands are common where soils and climate can support both trees and shrubs. Tree- and shrub-dominated patches occur in a dynamic landscape mosaic driven by disturbance history. Trees generally expand their footprint during moist periods and when disturbance is low, and contract during droughts and after disturbance. Wooded shrublands may transition to shrublands or grasslands where conditions are consistently too dry to support pinyon and juniper trees.

Pinyon-juniper savannas are found where local soils and climate are suitable for both trees and grasses. Researchers believe that low-severity fires may have maintained low tree densities before fire suppression, but little information is available. Savannas may transition to grasslands where conditions are consistently too dry to support trees.

Please refer to [Romme et al. \(2009\)](#) for further details on each vegetation type.

Climate change and shifting stand structure threaten the resilience of some persistent pinyon-juniper woodlands

As the West becomes warmer and drier under a changing climate, increased wildfire, drought, and insect and disease outbreaks are predicted. These disturbances were important in driving stand and ecosystem dynamics historically⁵, but they shaped woodlands at relatively small spatial scales. Today, climate change is expected to exacerbate the scale, severity, and impacts of contemporary disturbances like drought and wildfire. As a result, woodlands at local to-regional scales in some parts of the West could look considerably different in the future if loss and population declines continue. High density of trees in today's woodlands may contribute to both higher mortality risk and degradation of wildlife habitat.

²Filippelli et al. 2020, Miller et al. 2019. See also the [Pinyon Juniper Encroachment Education Project](#). ³Meddens et al. 2014, Flake and Weisberg 2018, Campbell et al. 2020, Jaenicke et al. 2022, Kannenberg et al. 2021. ⁴Shriver et al. 2022, Flake and Weisberg 2018. ⁵Miller et al. 2019.

Persistent woodlands are already declining in some regions due to changing climate

Climate-driven woodland decline has already occurred in some areas (Box 3). As a result of climate-induced drought and insect and disease outbreaks, an estimated 350 million two-needle pinyons in the Colorado Plateau were killed in the early 2000s⁶. In the Great Basin, localized mortality of single-leaf pinyon in the last decade has been about eight times greater than what was previously estimated⁷. Juniper species—which are believed to be less susceptible to drought because of their deep roots and ability to maintain photosynthesis during water stress—are expected to increase in dominance as pinyon species decline. However, seemingly even more drought-tolerant juniper species have experienced recent localized mortality in parts of Utah and Arizona⁸.

In addition to drought, wildfire size, frequency, and total area burned is increasing in woodlands across the West, according to a synthesis by the Rocky Mountain Research Station⁹. The authors report that the largest increases are being seen in the northern Intermountain region, which includes much of the Great Basin. Greater burn areas are likely occurring as a result of climate change and invasive annual grasses, which may carry fire from adjacent shrublands or grasslands into woodlands. Substantial tree mortality has been documented in the southern Great Basin and Colorado Plateau regions, although total wildfire woodland loss across the biome has not been tallied.

⁶Meddens et al. 2014. ⁷Flake & Weisberg 2018. ⁸Campbell et al. 2020, Kannenberg et al. 2021, Jaenicke et al. 2022.

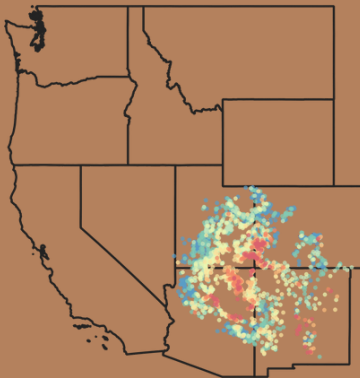
⁹Board et al. 2018.

Box 3. Within existing woodlands, populations of pinyon and juniper species are both increasing and decreasing in parts of their ranges

Population growth rates (λ) demonstrate population trends between 2000 and 2017 for five common pinyon and juniper species. Two-needle pinyon shows the most substantial demographic decline, with about 24% of populations decreasing. Juniper species tend to be stable or increasing in most of their ranges. Generally, declines are occurring in the warmest and driest portions of the species ranges, while populations are growing or stable in cooler and wetter areas. Tree loss due to fire was excluded from this analysis. See [Shriver et al. \(2022\)](#) for more information on data and trends.

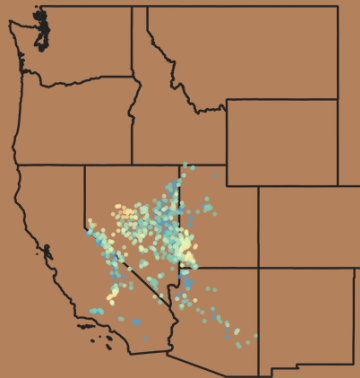
Two-needle pinyon (*Pinus edulis*)

Elevation: 4,500-7,500 feet
Precipitation: 10-22 inches, partially in summer



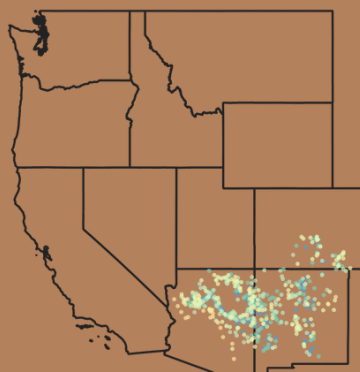
Single-leaf pinyon (*Pinus monophylla*)

Elevation: 3,300-9,000 feet
Precipitation: 10-16 inches, with varying seasonality



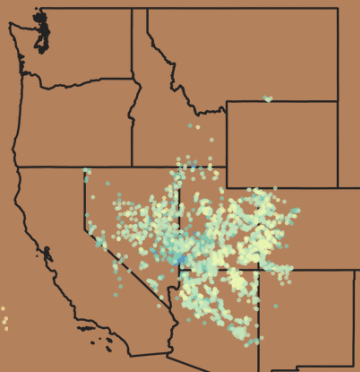
Oneseed juniper (*Juniperus monosperma*)

Elevation: 3,300-7,550 feet
Precipitation: 10-15 inches, partially in summer

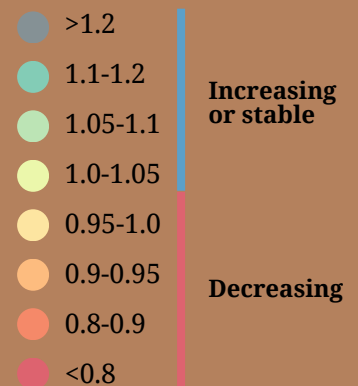


Utah juniper (*Juniperus osteosperma*)

Elevation: 4,500-8,500 feet
Precipitation: 12-18 inches, with varying seasonality

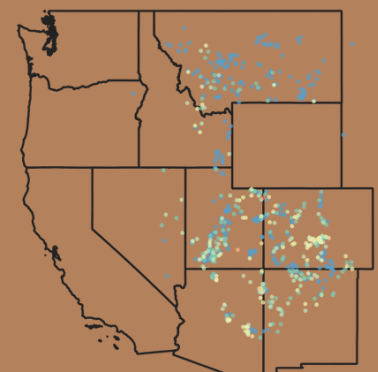


Population Growth Rate (λ)



Rocky Mountain juniper (*Juniperus scopulorum*)

Elevation: 2,000-9,000 feet
Precipitation: 15-18 inches, with varying seasonality



Additional evidence suggests that in some places, pinyon-juniper mortality is not being offset by regeneration. New research led by Dr. Robert Shriver, plant ecologist and population biologist at the University of Nevada, Reno, documented localized population declines in parts of the ranges of four of the five most common pinyon and juniper species¹⁰. Shriver's team found that two-needle pinyon is likely the most susceptible to climate-related decline, with 50% of populations in the driest conditions declining between 2000 and 2017. Shriver's research provides evidence that regeneration, especially in the hottest and driest areas, may be limited for some species. In many other places, these same species' populations are increasing or stable, likely as a result of increasingly suitable climatic conditions and lack of disturbance in those locations.

“ Our research shows that pinyon and juniper species are threatened by changing climate, and climate-smart management actions are needed to mitigate some of these impacts.

DR. ROBERT SHRIVER
PLANT ECOLOGIST
UNIVERSITY OF NEVADA, RENO

Dense contemporary persistent woodlands are susceptible to the effects of climate change

Like many Western forest types, many of today's woodlands are much more dense than historic woodlands. This high tree density increases mortality risk when disturbance or stressors occur. Within existing woodlands, infill—or increasing tree density—has occurred throughout the 20th century, building up fuel loads and degrading wildlife habitat¹¹. Although increases in tree density appear to be widespread, they occur variably across the landscape and their causes are not well understood¹². Researchers believe increased density is largely a result of climate change, fire exclusion, recovery from historical management, and enhanced atmospheric carbon dioxide¹². These drivers likely vary in their importance across the landscape, and researchers caution against attributing local changes to any one driver without location-specific evidence.

Regardless of the causes of infill, for single-leaf pinyon, two-needle pinyon, oneseed juniper, and Rocky Mountain juniper, high tree densities have been shown to increase climate- and drought-related mortality¹³, making them more vulnerable to climate-driven disturbances. Further, high tree density is thought to decrease habitat quality for pinyon-juniper obligate species like the pinyon jay. In some places, it is thought that reductions in tree densities may help to reduce mortality risk and improve wildlife habitat.



Local-to-regional woodland mortality and population declines will increase management challenges

As the climate continues to warm and dry, climate-related woodland mortality is expected to continue¹⁴. Wildfire will grow its footprint¹⁵, as will invasive annual grasses¹⁶. Widespread loss of woodlands, especially if ecosystem state conversion to invasive annual grass monocultures occurs at large scales, could impact ecosystem services like water supply, carbon storage, and climate regulation¹⁷. Additionally, these changes will likely contribute to loss of recreational, cultural, and aesthetic values where they occur. For pinyon-juniper associated wildlife species like pinyon jays, woodland loss and degradation is expected to reduce available habitat¹⁸ and could contribute to species declines. Managers will have to contend with these changes and the uncertainty surrounding their causes and impacts as they balance ecosystem and human needs into the future.

¹⁰Shriver et al. 2022, ¹¹Filippelli et al. 2020, ¹²Miller et al. 2019, ¹³Romme et al. 2009, ¹⁴Shriver et al. 2022, ¹⁵Flake and Weisberg 2018, ¹⁶Miller et al. 2019, ¹⁷McDowell et al. 2016, ¹⁸Walsh et al. 2014, ¹⁹Abatzoglou et al. 2011, ²⁰McMahon et al. 2021, ²¹Guardiola-Claramonte et al. 2011, ²²Miller et al. 2019, ²³Boone et al. 2018, ²⁴Morano et al. 2018.

Active management is needed to increase woodland resilience to changing climate

Focusing on persistent woodland climate resilience is critical as climate change impacts increase Renewed effort is needed to improve woodland climate resilience, or the ability for woodlands to experience climate-related stressors—like wildfire, drought, and insect and disease outbreaks—without conversion to an alternative ecosystem state, such as an invasive annual grass monoculture. Despite local-to-regional concerns about mortality and declining woodland health, persistent pinyon-juniper woodlands have not seen the same conservation focus as forests in the West. In other forest types, billions of dollars are spent each year on forest restoration, fuels reduction, and fire mitigation¹⁹. Although past and ongoing efforts have focused on fuels reduction in pinyon-juniper woodlands, additional investment is needed to promote climate resilience, woodland health, and wildlife habitat goals in addition to fuels reduction goals. Collaborative, science-driven efforts are needed for woodlands and their inhabitants, such as the pinyon jay.

Partnership between researchers and land managers is needed to implement climate resilience-focused management and monitor outcomes

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As we implement projects that aim to increase woodland resilience to drought and wildfire and provide wildlife habitat, we're working with researchers to learn from the outcomes of our efforts. Our goal is to always be improving.

IAN BARRET
FUELS PROGRAM LEAD
BUREAU OF LAND MANAGEMENT
COLORADO STATE OFFICE

As the decline of the pinyon jay and woodland die-off sounds the alarm for this vulnerable ecosystem, scientists and managers are recognizing that new approaches are needed at landscape levels to conserve pinyon-juniper woodlands and their inhabitants. Although experts agree action is needed, there is much to be learned about managing woodlands for climate resilience, wildlife habitat, and other goals. Yet, the conservation community can't wait to start implementing proactive woodland management treatments. Researchers and managers are increasingly working together to build knowledge on these topics and develop guidance for managers (Boxes 4 & 5).

Landscape-scale prioritization can help to achieve meaningful benefits for people and wildlife

To balance the needs of people and wildlife, landscape-scale prioritization is needed to put the right treatments in the right place based on ecological and social considerations. Working with partners—including Tribal Nations, land managers, researchers, and special interest groups—across scales and fence lines can achieve a mosaic of connected, diverse habitats with multiple benefits. A new collaborative doing this in the eastern Sierra Nevada is highlighted in Box 5. Additional similar efforts are needed across the Intermountain West in order to make meaningful gains in the climate resilience of woodlands and other habitats.

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If we work together at appropriate scales to set clear objectives, we can maintain diverse, resilient landscapes and meet the needs of many stakeholders, from pinyon jays and sage-grouse to Tribal Nations and recreationists.

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RESEARCH ECOLOGIST
U.S. FOREST SERVICE
ROCKY MOUNTAIN RESEARCH STATION

¹⁹[Crist 2023](#).



Box 4. In Colorado, the Bureau of Land Management partners with researchers to implement and learn from climate-smart management of pinyon-juniper woodlands

Project Partners

- Bureau of Land Management Tres Rios Field Office, Southwest District Fire Management Unit, and Colorado State Office
- University of California, Berkeley
- U.S. Forest Service Rocky Mountain Research Station
- Colorado State University, Fort Collins
- University of Nevada, Reno
- U.S. Geological Survey Southwest Biological Science Center
- Bird Conservancy of the Rockies

Project Description

In the Colorado Plateau, widespread woodland die-off has occurred as a result of wildfire, drought, and insect attacks, yet research is needed to understand what managers can do to promote climate-resilient woodlands. In Southwest Colorado, fuels specialists and researchers have come together to experimentally assess the efficacy of different silvicultural treatments in enhancing pinyon-juniper ecosystem health and reducing fire risk on Bureau of Land Management (BLM) lands.

This interdisciplinary team is working together to implement replicated silvicultural treatments that vary in spatial complexity and amount of thinning across an elevational gradient, spanning from mid-elevation (~6,900 ft) to high elevation (~7400 ft) pinyon-juniper woodlands. A major goal of this effort is to understand how these resulting changes in woodland structure influence tree health, including tree mortality, pine nut production, and growth rates, understory vegetation, and bird populations. Through fuels sampling and spatially-explicit wildfire behavior modeling, this project will also assess how these treatments influence fire behavior under varying weather conditions to help aid future silvicultural treatment design and placement. Using an adaptive management framework to monitor and further refine silvicultural approaches, this project aims to provide tools needed to promote drought resilience and restore ecological integrity to pinyon-juniper ecosystems in the region. The team will also develop a landscape prioritization framework to be used by managers to identify which treatments will be most effective at accomplishing management goals across different areas.

Funding for this project was made possible by the [Bipartisan Infrastructure Law \(BIL\)](#).

To learn more about this effort, contact Ian Barrett (Fuels Program Lead, BLM Colorado State Office; ipbarret@blm.gov) or Miranda Redmond (Assistant Professor in Forest Science and Climate Change, University of California Berkeley; mir@berkeley.edu).



Box 5. In California's eastern Sierra Nevada, diverse partners work across the landscape towards social and ecological resilience

Project Partners

- U.S. Forest Service Rocky Mountain Research Station
- Humboldt-Toiyabe National Forest
- Bridgeport Indian Colony
- Washoe Tribe of Nevada and California
- Great Basin Bird Observatory
- University of Nevada, Reno
- University of California, Berkeley
- Stanford University

Project Description

In California's eastern Sierra Nevada, a group of agency managers, Tribal Nations, and researchers are working together to design a landscape-scale management project to increase woodland resilience to drought and fire while protecting cultural values for

Indigenous peoples and improving overall ecosystem health. A core component of the project is the co-leadership of Tribal Nations, recognizing the importance of pinyon-juniper ecosystems for the cultural identities, ceremonies, and traditional practices of Indigenous peoples. Through the principles of shared stewardship, the project will produce a management plan for 18,000 acres of lands on the Bridgeport District of the Humboldt-Toiyabe National Forest. The group formed in 2021 to address shared concerns about pinyon-juniper woodland vulnerability to climate change, and this demonstration management project aims to provide a transferable framework that can be adapted to meet the needs of land managers in other areas. The project was recently awarded a three-year planning grant from the Sierra Nevada Conservancy's Wildfire Recovery and Forest Resilience grant program.

Currently, the group is working to develop management objectives and alternative treatment designs, drawing on Indigenous Traditional Ecological Knowledge (ITEK) and supported by the best available science to design silvicultural approaches for promoting woodland resilience in the context of climate change. The group is also developing a set of guiding principles for prioritizing management objectives in heterogeneous landscapes, such as balancing areas that are managed to maintain resilient woodland ecosystems with areas managed to support sagebrush-obligate wildlife. These guiding principles will be tiered to ecological data collected from the planning area so as to delineate specific treatment units managed for various objectives. The project will also produce a scalable monitoring toolkit for measuring vegetation and wildlife indicators of woodland ecosystem health, which will eventually be used to assess the impacts of woodland silvicultural treatments.

To learn more about this effort, contact Alexandra Urza (Research Ecologist, U.S. Forest Service, Rocky Mountain Research Station; alexandra.urza@usda.gov).



What can managers do to improve the climate resilience of pinyon-juniper woodlands?

Despite large gaps in our knowledge, the urgency of climate change may necessitate that land managers begin to take action with the best available information. The following considerations may help manage for climate resilient persistent pinyon-juniper woodlands in the Intermountain West:

1 Consider managing with explicit woodland climate resilience goals. Active management, such as silvicultural treatments to reduce woodland density, post-fire restoration, and invasive annual grass treatments, may be needed in some places. Ongoing research investigates appropriate treatments for climate resilience goals (see Boxes 4 & 5, [Floyd and Romme 2012](#)). When available, use local information, Traditional Ecological Knowledge, and relevant research to inform objectives. Ecological site descriptions, in conjunction with information on current and future climate, historical fire and disturbance regimes, and past human disturbance and management efforts are a good starting point. Local information documenting trends in infill, expansion, and fire history is needed to understand how these factors have impacted an area of interest, as substantial spatial variation exists and regional patterns may not always apply locally. Habitat reference conditions are needed to guide management actions. Guidelines specifying woodland structure, stand size and distribution, and plant associations may not yet exist and will need to be developed for priority areas.

2 Work with partners on coordination, prioritization, and evaluation at the landscape scale. Work with a broad partnership to identify appropriate places to improve woodland climate resilience. Where appropriate, aim to create a mosaic of heterogeneous habitats that balance multiple conservation objectives, including climate resilience, wildlife habitat, fuels management, and human use. Work with researchers to evaluate the impacts of management actions at the landscape scale. See Boxes 4 & 5 for examples.

3 For projects with a fuels management component, assess if fuels reduction can also improve woodland climate resilience. If possible, integrate ecological and wildlife objectives into fuels management efforts. Ecological site descriptions and local information on wildfire probability, historical wildfire regimes (for example, local fire history studies), future climate and fire regimes, and likelihood of

invasive annual grass invasion will be important to assess if fuels reduction treatments will meet ecological and wildlife objectives. For an overview of historical fire regimes in pinyon-juniper woodlands, see [Romme et al. \(2009\)](#) and [Baker and Shinneman \(2004\)](#). To find local fire history studies, use the [Paleo Data Search Tool](#).

4 Expect invasive annual grasses after disturbance. After natural or management-related disturbance occurs, invasive annual grasses may increase, especially where native vegetation cannot readily recover due to lack of seed sources or germination microsites, unfavorable weather or climate, or substantial presence of invasive annual grasses prior to disturbance. Addressing invasive annual grasses should be a top priority of all management efforts to avoid both conversion to invasive annual monocultures and increases in fine fuels that contribute to more frequent and larger wildfires.

5 Consider the addition of management goals focused on improving wildlife habitat. Persistent pinyon-juniper woodlands provide habitat for multiple species of conservation concern. Species-specific guidelines exist for some species; see the [WAFWA Mule Deer Habitat Guidelines by Ecoregion](#) and the [Pinyon Jay Working Group Conservation Strategy](#). Where species-specific management guidelines exist, they should be used whenever possible.

Management of woodlands for pinyon jays is poorly understood. To help address this gap, the [Pinyon Jay Working Group](#) is developing a predictive occurrence model and rangewide standardized survey protocols and coordinating research and monitoring efforts. For more information, reach out to Scott Somershoe (Land Bird Coordinator, U.S. Fish and Wildlife Service Region 6; scott_somershoe@fws.gov).

To provide timely information to managers, BLM is developing guidance for pinyon jays based on the Pinyon Jay Working Group Conservation Strategy. For more information, reach out to Elroy Masters (BLM National Wildlife Program Lead; emasters@blm.gov) or Renee Chi (BLM National Migratory Bird Person of Contact; rchi@blm.gov).



INTERMOUNTAIN WEST JOINT VENTURE

Want to learn more? Seeking support or collaborators on a project?

This report was produced by the [Intermountain West Joint Venture](#) in collaboration with the Bureau of Land Management and the U.S. Fish and Wildlife Service. Please reach out for more information.

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Photos courtesy of: [Kaibab National Forest](#) (Bert Fire, pg. 1), [Paul Burow](#) (Humboldt-Toiyabe National Forest pinyon-juniper landscape, pg. 1), U.S. Forest Service Southwest Region (dead pinyon trees, pg. 4), [Mike Lewinski](#) (pinyon jays, pg. 5), Ian Barrett (both photos, pg. 6), Alexandra Urza (both photos, pg. 7), [Oregon and Washington BLM / Bob Wick](#) (pg. 8), [Oregon and Washington BLM / Bob Wick](#) (pg. 9). Some photos were cropped from their original size.