



Fuel treatments and fuel breaks considering invasive-fire-climate dynamics

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Fuel treatments in sagebrush ecosystems

A *fuel treatment* is intended to manipulate or reduce fuels to modify fire behavior and mitigate potential negative impacts of wildfire.

Vegetation is modified to reduce the amount, volatility, or structure of fuels, resulting in a decrease in wildfire intensity and/or rate of spread.

Fuel treatments and treatment systems for wildfire management in sagebrush rangelands

Mechanical

- Mowing
- Disking
- Conifer clearing (e.g., mastication, lop & scatter, pile burn)

Prescribed fire

- Rx fire in sagebrush
- Rx fire in woodlands
- Managed wildfire

Chemical

- Treat shrubs
- Treat annual herbaceous species (e.g., cheatgrass)

Biological

- Greenstrips
- Targeted grazing
- Soil pathogens

Fuel break systems

- Greenstrips
- Brownstrips
- Mowed
- Other (e.g., herbicide, grazing)

Changing contexts for fuels and fire management

Climate & global change

- Warming trends
- Variable precipitation
- Invasive species expansion
- Altered fire regimes
- Increased human population

Wildlife conservation

- Habitat fragmentation
- Habitat degradation
- Multiple species with different requirements
- Long-term data lacking

Socio-economic factors

- Local interests vs. public opinion (rural / urban)
- Public acceptance (trust) of management activities
- "Siloing" between programs and agencies

Information needs

- Standardized protocols for fuels assessments
- Stratification by eco-sites
- Periodic landscape- to regional-scale assessments

Fire modeling

- Accurate input data (e.g., fuelscapes)
- Scenarios that consider climate change
- Consideration of human population & distribution

- Control of annual herbaceous species (short- and long-term)
- Adaptation to warming & changing precipitation patterns

- Long-term monitoring
- Population dynamics
- Landscape change
- Evaluate management trade-offs (short- and long-term)

- Invest in participatory approaches
- Adaptive management (flexibility)
- Incentivize innovation in climate adaptation

- Fuel treatment monitoring (effectiveness & effects)
- Remote sensing of fuels (fuel loads, connectivity, moisture)

- Landscape modeling (to prioritize treatments)
- Evaluate fire effects
- Limit human ignitions
- Utilize novel remote sensing data/products

Research needs for forward-thinking fuels and fire management

Shinneman, D. J., E. K. Strand, M. Pellant, J. T. Abatzoglou, M. W. Brunson, N. F. Glenn, J. A. Heinrichs, M. Sadegh, and N. M. Vaillant. 2023. Future Direction of Fuels Management in Sagebrush Rangelands. *Rangeland Ecology & Management* 86:50–63.

Altered Fire Regimes: Invasive grass-fire cycle

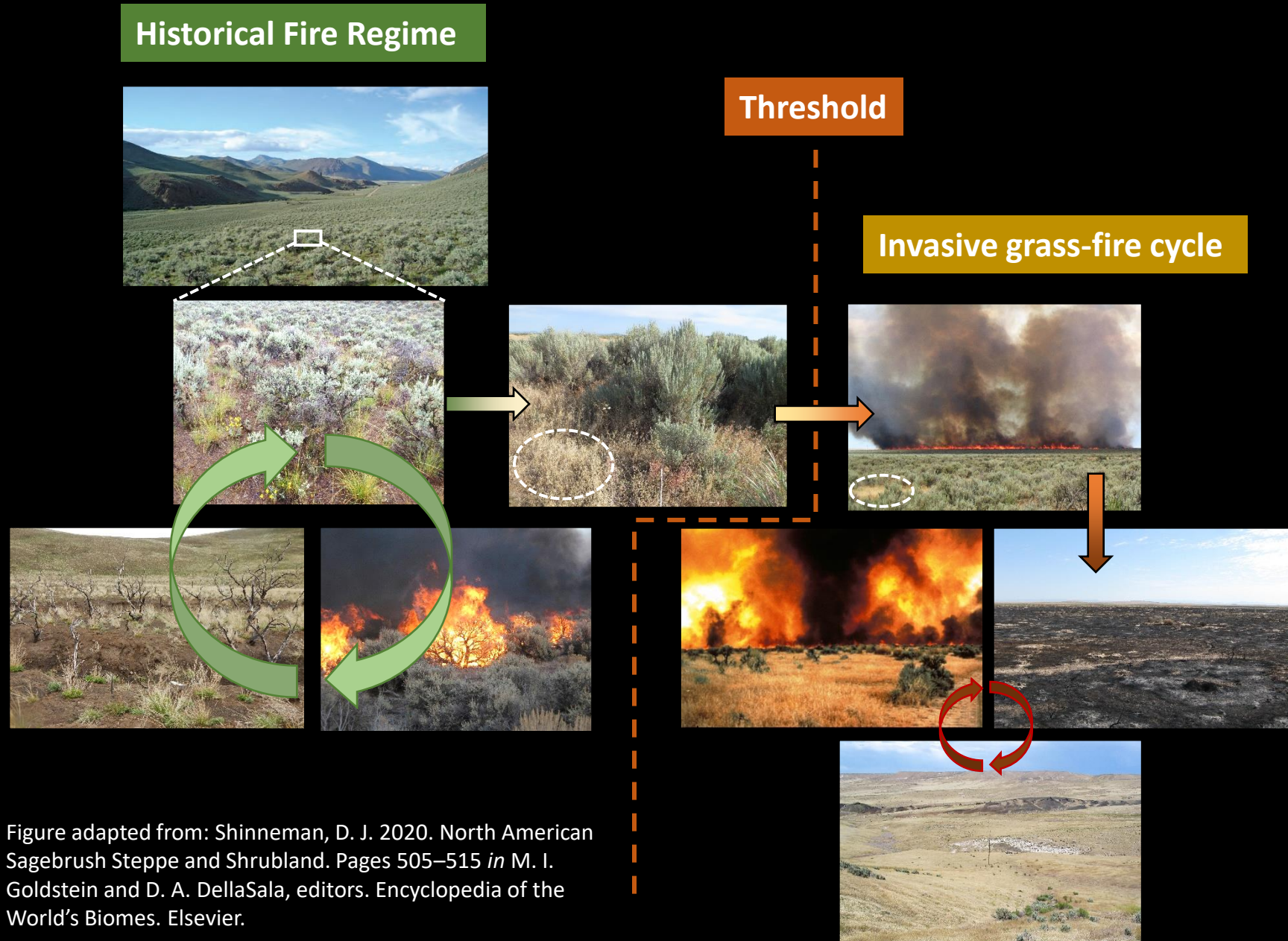


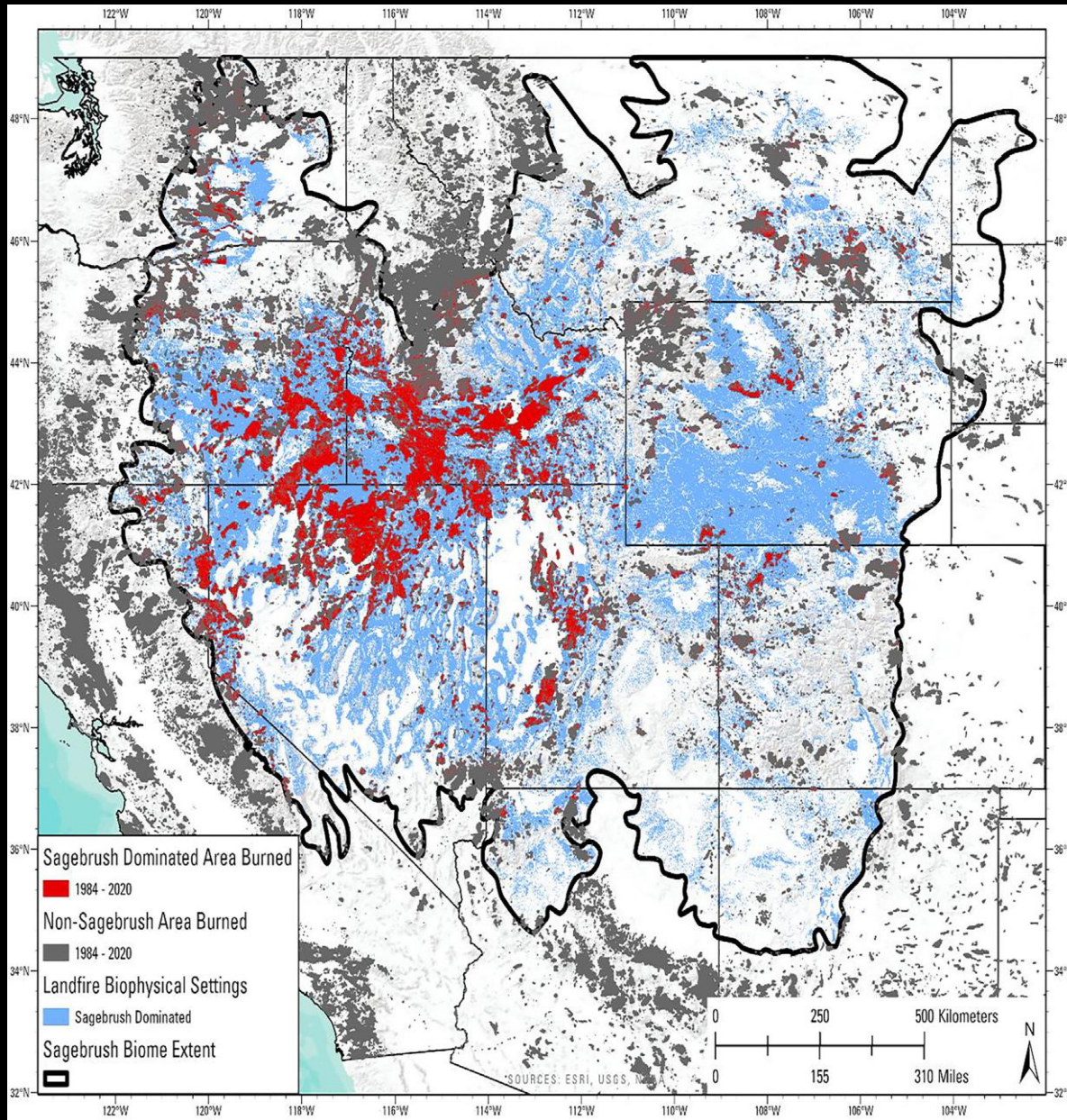
Figure adapted from: Shinneman, D. J. 2020. North American Sagebrush Steppe and Shrubland. Pages 505–515 in M. I. Goldstein and D. A. DellaSala, editors. *Encyclopedia of the World's Biomes*. Elsevier.

Altered Fire Regimes

Cheatgrass dominated areas

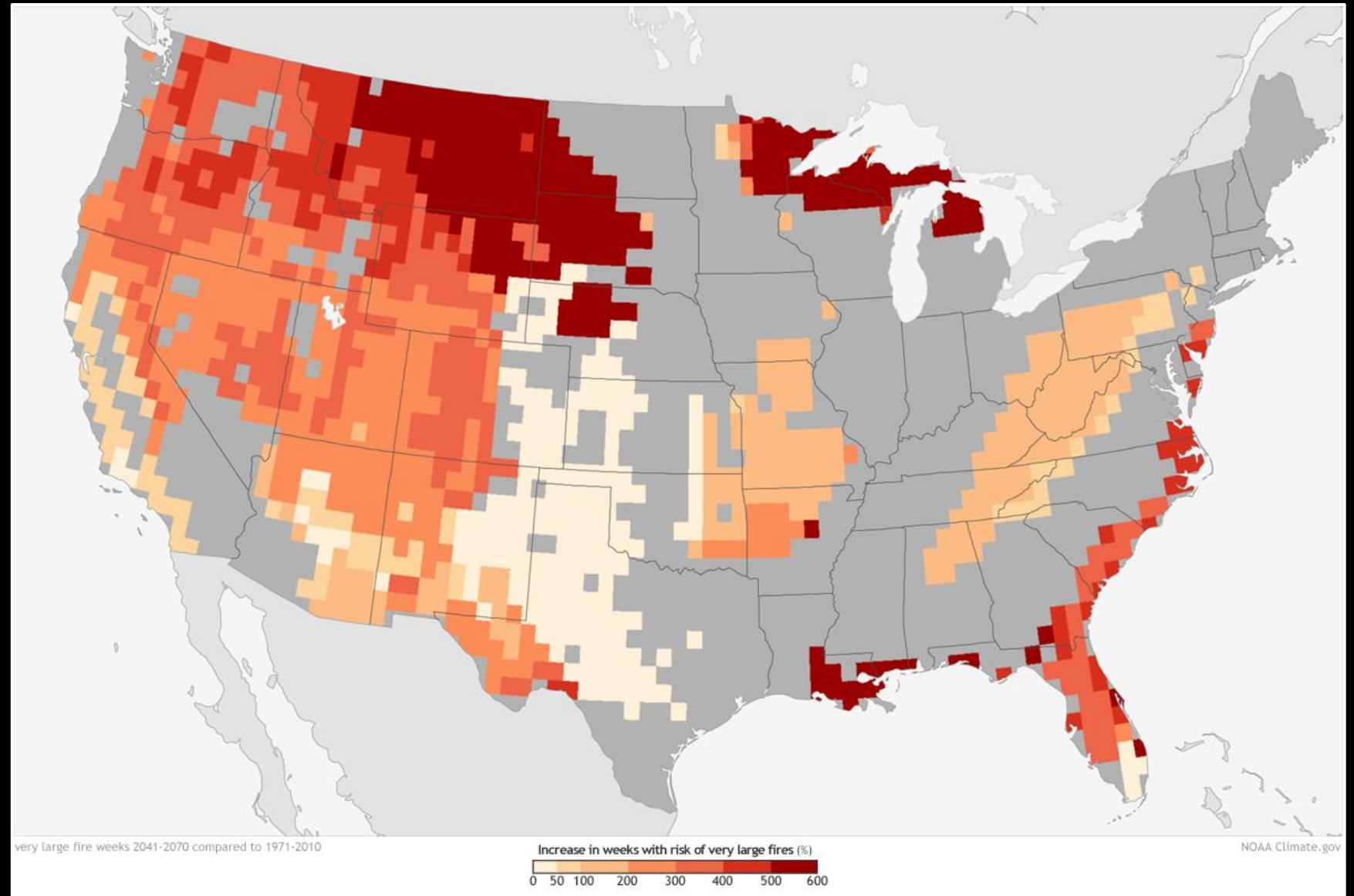
- more likely to burn (multiple times)
- have shorter fire return intervals
- support larger fires

e.g., Balch et al. 2013, Brooks et al. 2015, Bradley et al. 2018



From: Crist, et al. 2023. Trends, Impacts, and Cost of Catastrophic and Frequent Wildfires in the Sagebrush Biome. *Rangeland Ecology & Management* 89:3–19.

Future Fire Regimes under climate change



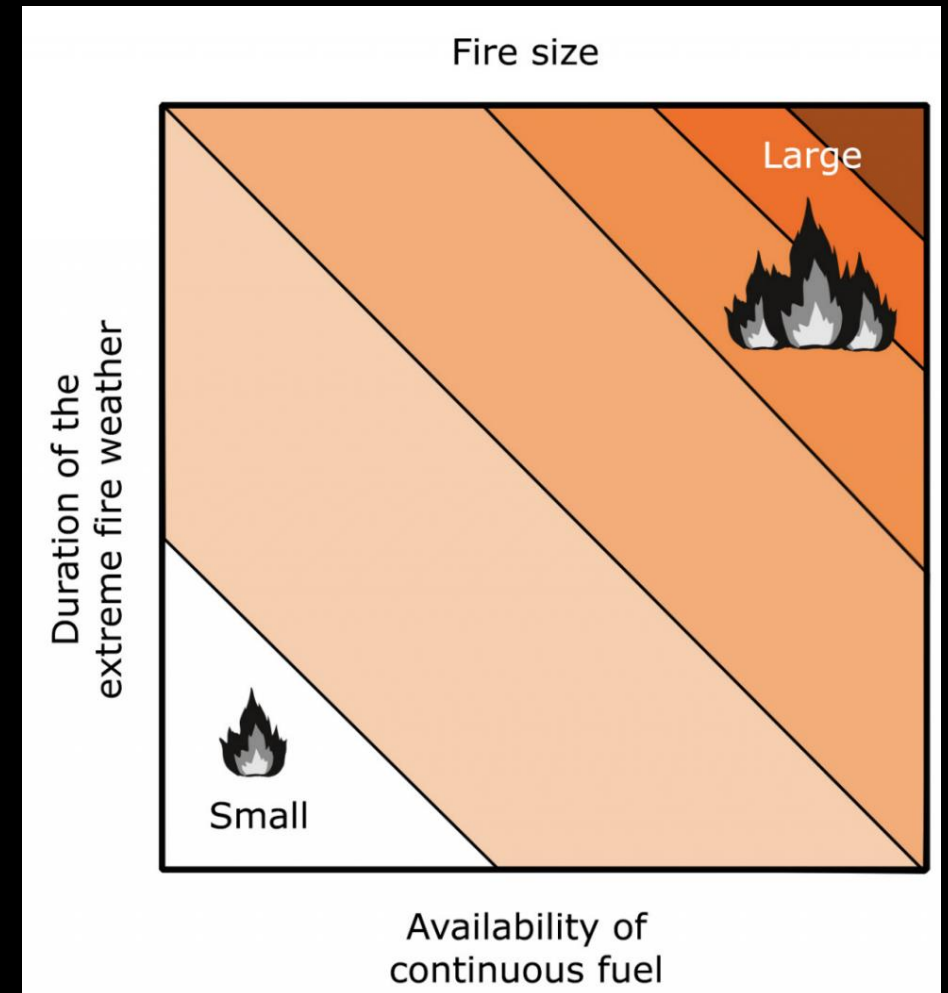
Very large fire weeks 2041-2070 compared to 1971-2010 <https://www.climate.gov/media/6401>

Barbero, R.; Abatzoglou, J.T.; Larkin, N.K.; Kolden, C.A.; Stocks, B. 2015. Climate change presents increased potential for very large fires in the contiguous United States. *International Journal of Wildland Fire*.

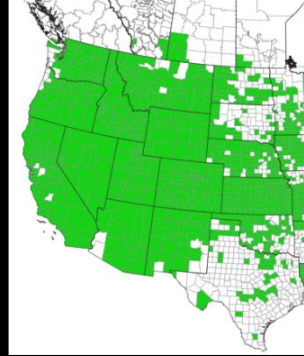
Future fire-fuel-climate feedbacks

How might changing fuels affect future fire regimes under more extreme climate?

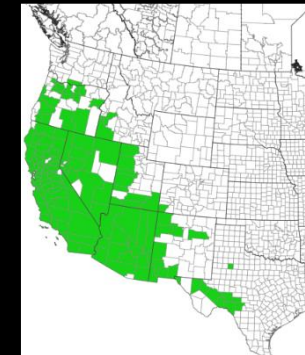
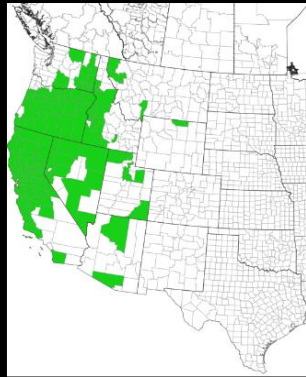
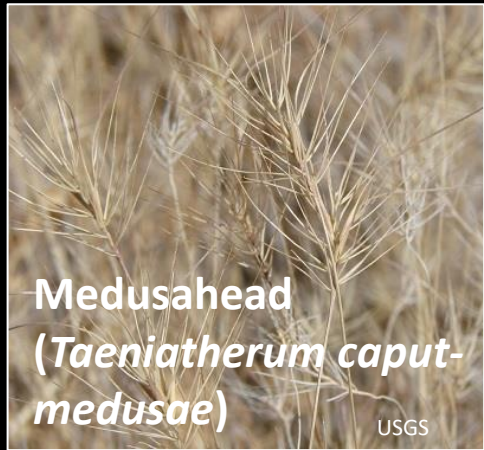
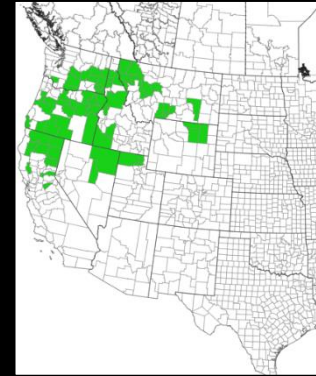
- Complex, long-term future interactions between climate, fire, and vegetation
- Positive feedback loops



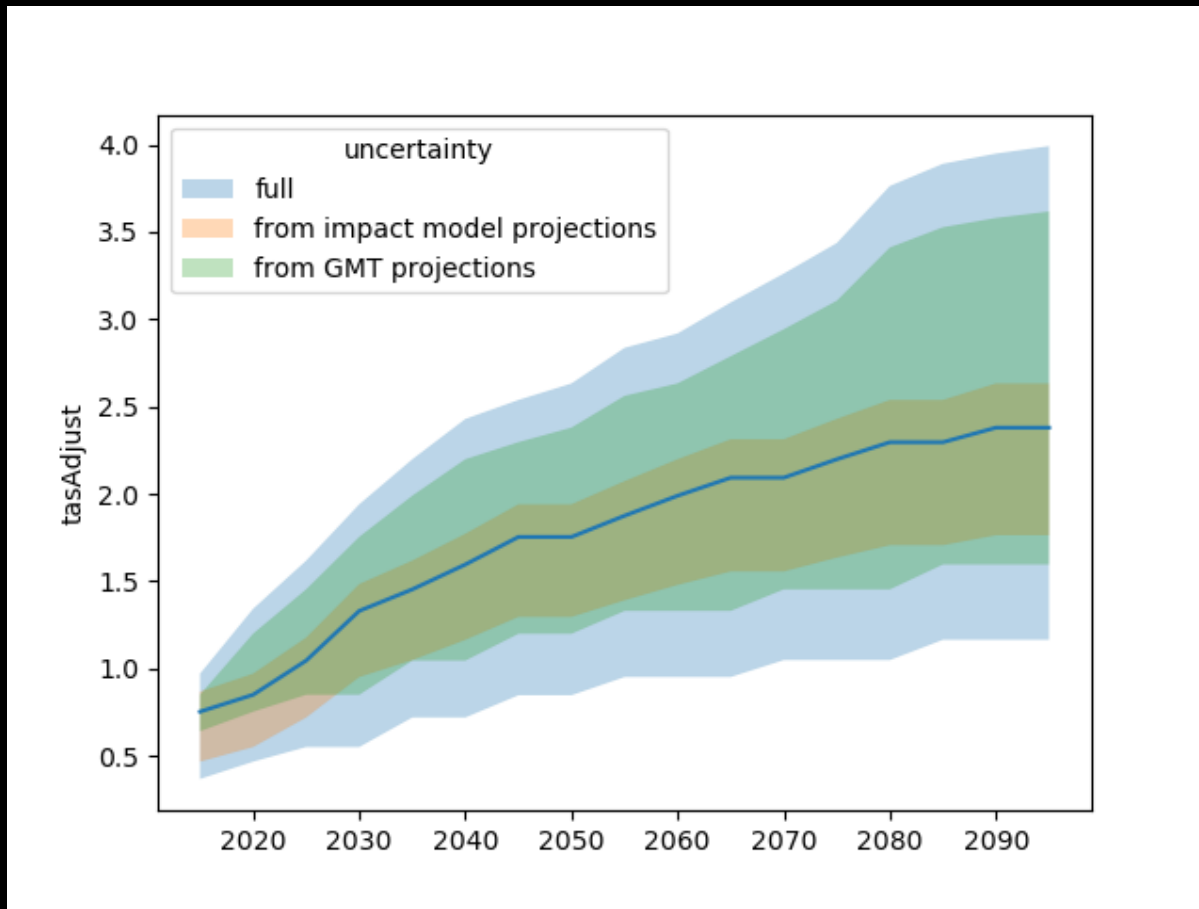
Pausas and Keeley. 2021. *Frontiers in Ecology and the Environment* 19:387–395.



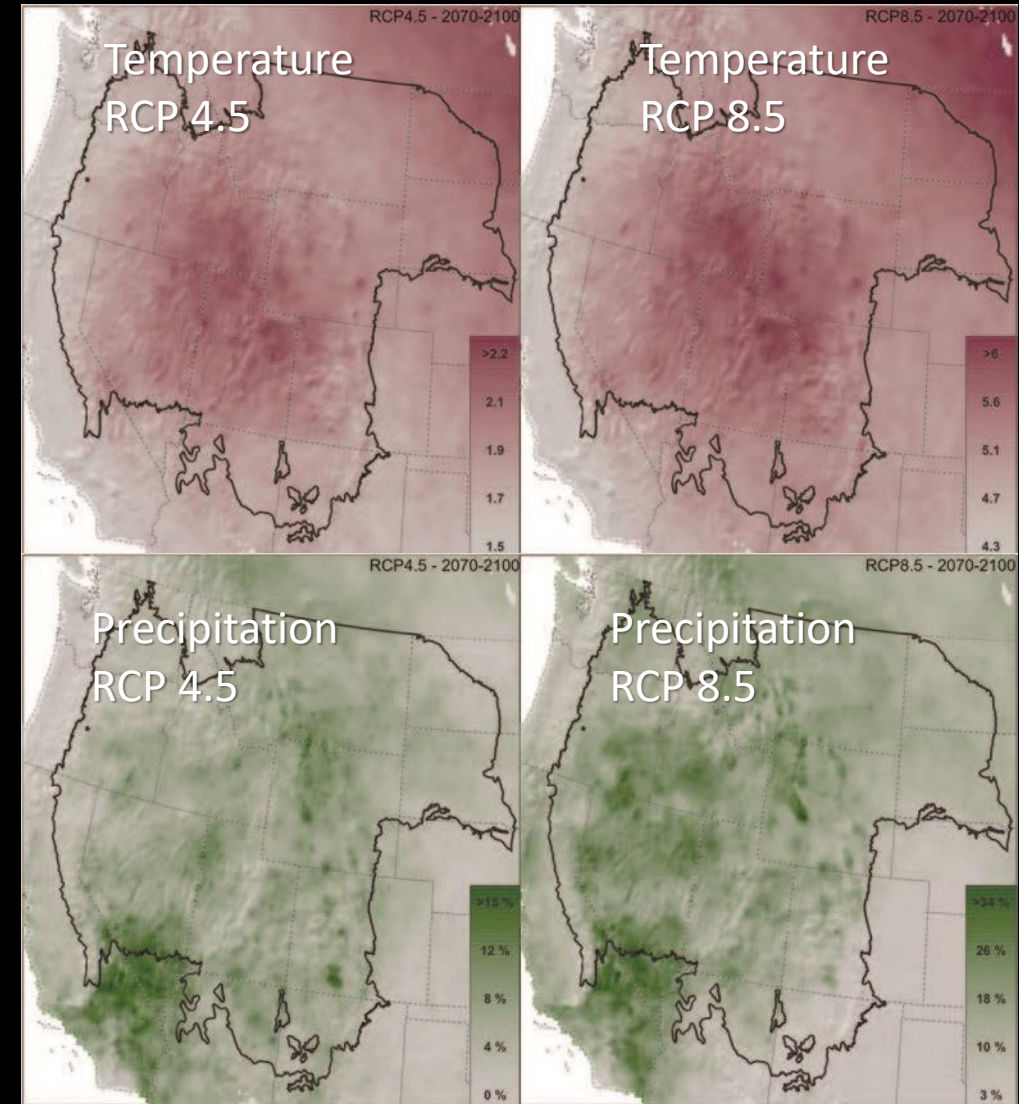
Future climate will affect the distribution and productivity of exotic species that alter fuel conditions and fire regimes



Uncertainty under future climate change





<https://climate-impact-explorer.climateanalytics.org/methodology/#three-visualization>










Projected changes in mean annual precipitation and mean annual temperature for 2070–2100 over the distribution of big sagebrush ecosystems. Maps show median climate value from a set of 11 climate models (Adapted from: Chambers et al. 2017. USFS RMRS-GTR-360)

Map 8
Fuel Breaks Alternative D
Potential Treatment Areas

-  Fuel Breaks PEIS project area
-  Potential treatment area (1,088,000 total acres)^{1 2}

Vegetation States

-  Perennial grasses and forbs
-  Shrubs with perennial grasses and forbs
-  Shrubs with depleted understory
-  Invasive annual grassland
-  Perennial grasses and forbs with invasive annual grasses
-  Invasive annual grasses with shrubs
-  Shrubs and perennial grasses and forbs with invasive annual grasses

Pinyon-Juniper Phase

-  Phase I
-  Phase II
-  Phase III

¹ Treatment areas consist of pinyon-juniper woodland and sagebrush habitat along a 500 ft corridor of existing interstates, federal highways, state highways, BLM-administered roads, BLM-administered ROWs, and BLM-administered primitive roads.
² Treatment areas exclude specially designated areas, riparian conservation areas, lynx habitat, and wolverine habitat.

BLM. 2020. Programmatic EIS for Fuel Breaks in the Great Basin

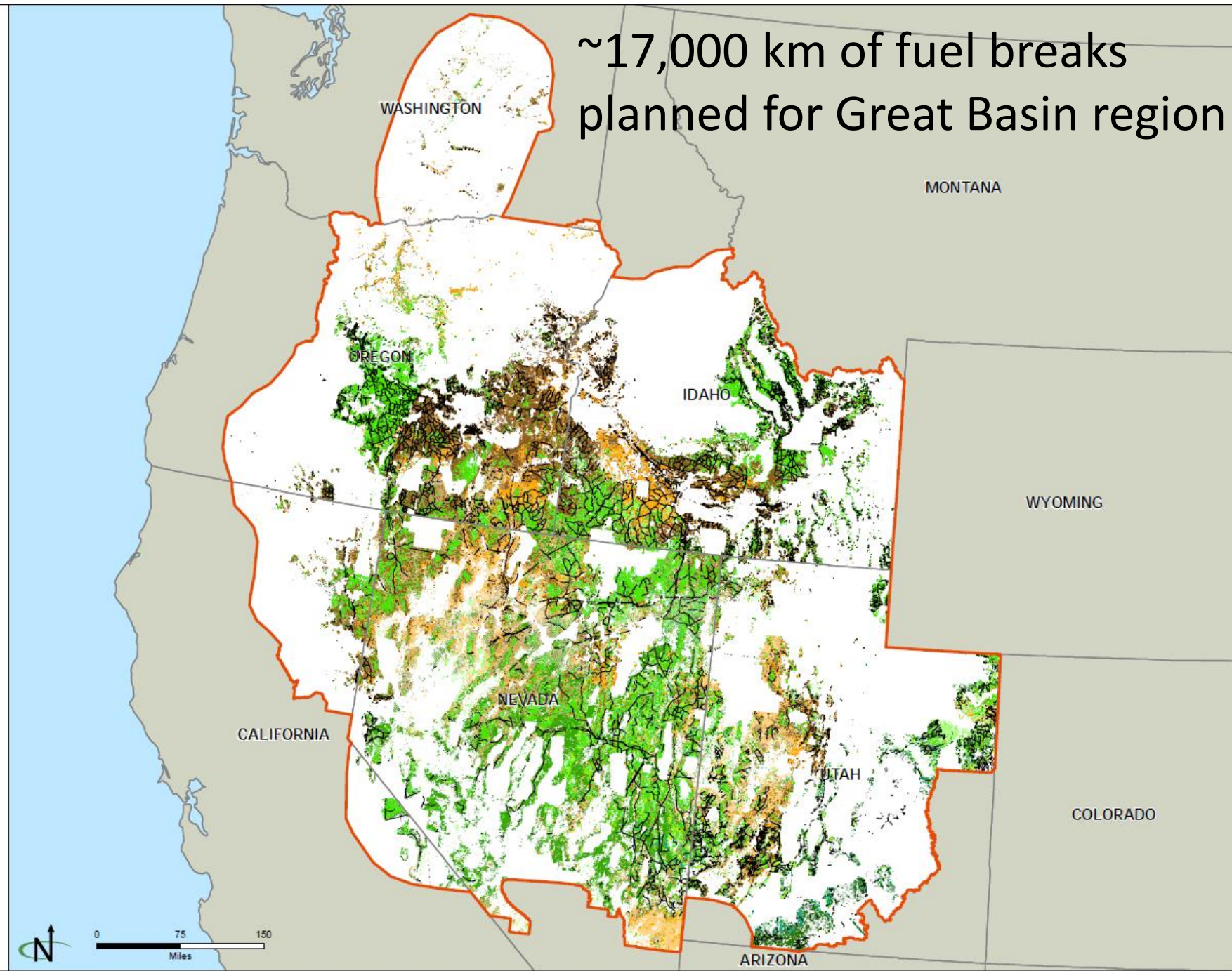


Department of the Interior
 Bureau of Land Management

Source: BLM GIS 2018
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Coordinate System and Map Projection:
 NAD 1983 (2011) Contiguous USA Albers

~17,000 km of fuel breaks
 planned for Great Basin region



Three main types of linear fuel breaks

Mowed



Brown Strips



Green Strips



Fuel Break Effects

1. Changes within fuel breaks
2. Edge effects
3. Species movements
4. Habitat fragmentation
5. Benefits to intact sagebrush

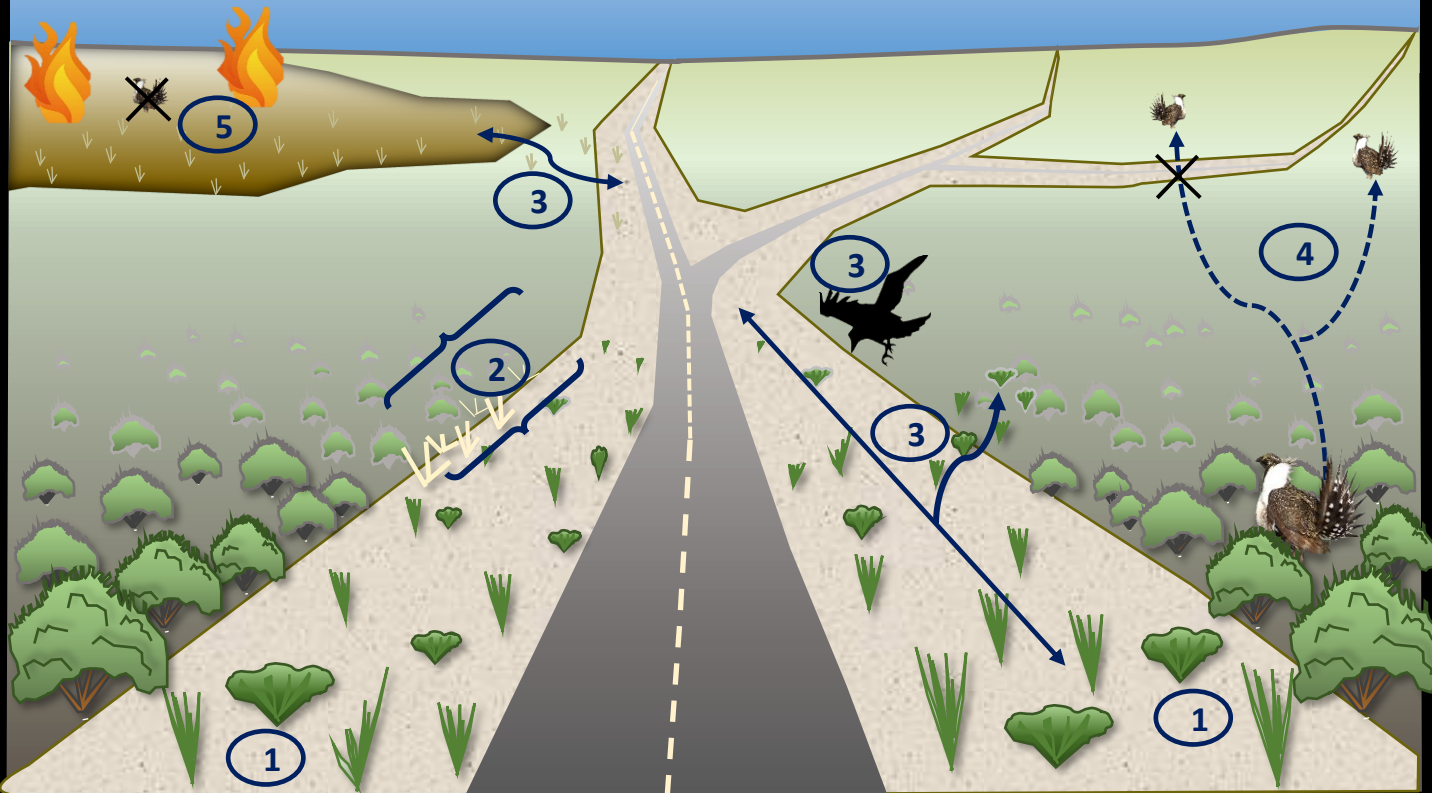


Figure adapted from: Shinneman, et al. 2019. The ecological uncertainty of wildfire fuel breaks: examples from the sagebrush steppe. *Frontiers in Ecology and the Environment* 17:279–288.

The ecological uncertainty of wildfire fuel breaks: examples from the sagebrush steppe

Douglas J Shinneman^{1*}, Matthew J Germino¹, David S Pilliod², Cameron L Aldridge³, Nicole M Vaillant⁴, and Peter S Coates⁴

Fuel breaks are increasingly being implemented at broad scales (100s to 10,000s of square kilometers) in fire-prone landscapes globally, yet there is little scientific information available regarding their ecological effects (eg habitat fragmentation). Fuel breaks are designed to reduce flammable vegetation (ie fuels), increase the safety and effectiveness of fire-suppression operations, and ultimately decrease the extent of wildfire spread. In sagebrush (*Aristida* spp) ecosystems of the western US, installation of extensive linear fuel breaks is also intended to protect habitat, especially for the greater sage-grouse (*Centrocercus urophasianus*), a species that is sensitive to habitat fragmentation. We examine this apparent contradiction in the Great Basin region, where invasive annual grasses have increased wildfire activity and threaten sagebrush ecosystems. Given uncertain outcomes, we examine how implementation of fuel breaks might (1) directly alter ecosystems, (2) create edges and edge effects, (3) serve as vectors for wildlife movement and plant invasions, (4) fragment otherwise contiguous sagebrush landscapes, and (5) benefit from scientific investigation intended to disentangle their ecological costs and benefits.

Front Ecol Environ 2019; doi:10.1002/fee.2045

Wildfire is an important natural process that can initiate plant community succession, contribute to vegetation mosaics and a diversity of wildlife habitats, and expedite biogeochemical cycles (DeBano *et al.* 1998). Yet wildfire can also threaten natural resources, human safety, and development

and, under certain conditions, has the potential to irrevocably degrade native ecosystems (Brooks *et al.* 2004). In fire-prone landscapes around the world, from forests to grasslands, “fuel breaks” are often used to minimize the negative impacts of wildfire (Figure 1; Wilson 1988; Agee *et al.* 2000; Oliveira *et al.* 2016). A fuel break can be defined as “a natural or man-

In a nutshell:

- Linear fuel breaks may help reduce wildfire spread, and at the same time improve fire suppression effectiveness, but their ecological impacts include habitat loss and fragmentation, as well as faunal movement (eg that of invasive plants).
- There is very little peer-reviewed scientific information available for land managers about the ecological effects of fuel breaks.
- As such, land managers may face trade-offs: either substantially alter habitats to potentially minimize wildfire impacts, or accept habitat loss and degradation from wildfire.
- The Great Basin region of the western US offers an opportunity to better understand the relative costs and benefits of fuel breaks, and to identify key knowledge gaps.

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Prepared in cooperation with the U.S. Forest Service

A Conservation Paradox in the Great Basin—Altering Sagebrush Landscapes with Fuel Breaks to Reduce Habitat Loss from Wildfire



Open-File Report 2018-1034

U.S. Department of the Interior
U.S. Geological Survey

Challenges of fuels management given uncertainties in climate / environmental response

Where are the best places to put fuel treatments?

How sustainable will they be over time?

Will they be effective under more extreme fire conditions?

What are their benefits and risks?



Photos: BLM

Resources and tools for planning fuel treatments



United States
Department of
Agriculture
Forest Service
Rocky Mountain
Research Station
General Technical
Report GTR-219
November 2014

A Field Guide for Selecting the Most Appropriate Treatment in Sagebrush and Piñon-Juniper Ecosystems in the Great Basin

Evaluating Resilience to Disturbance and Resistance to Invasive Annual Grasses, and Predicting Vegetation Response

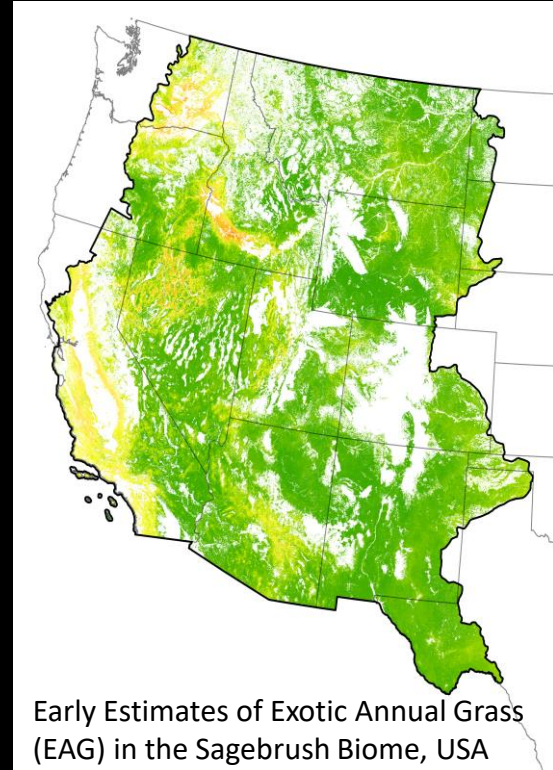
Richard F. Miller, Jeanne C. Chambers, and Mike Pellant



Warm and dry Wyoming big sagebrush—Invaded State



Cool and dry mountain big sagebrush—Reference State

Early Estimates of Exotic Annual Grass (EAG) in the Sagebrush Biome, USA

Dahal et al. 2024. USGS data release, <https://doi.org/10.5066/P1Y5TZBM>.

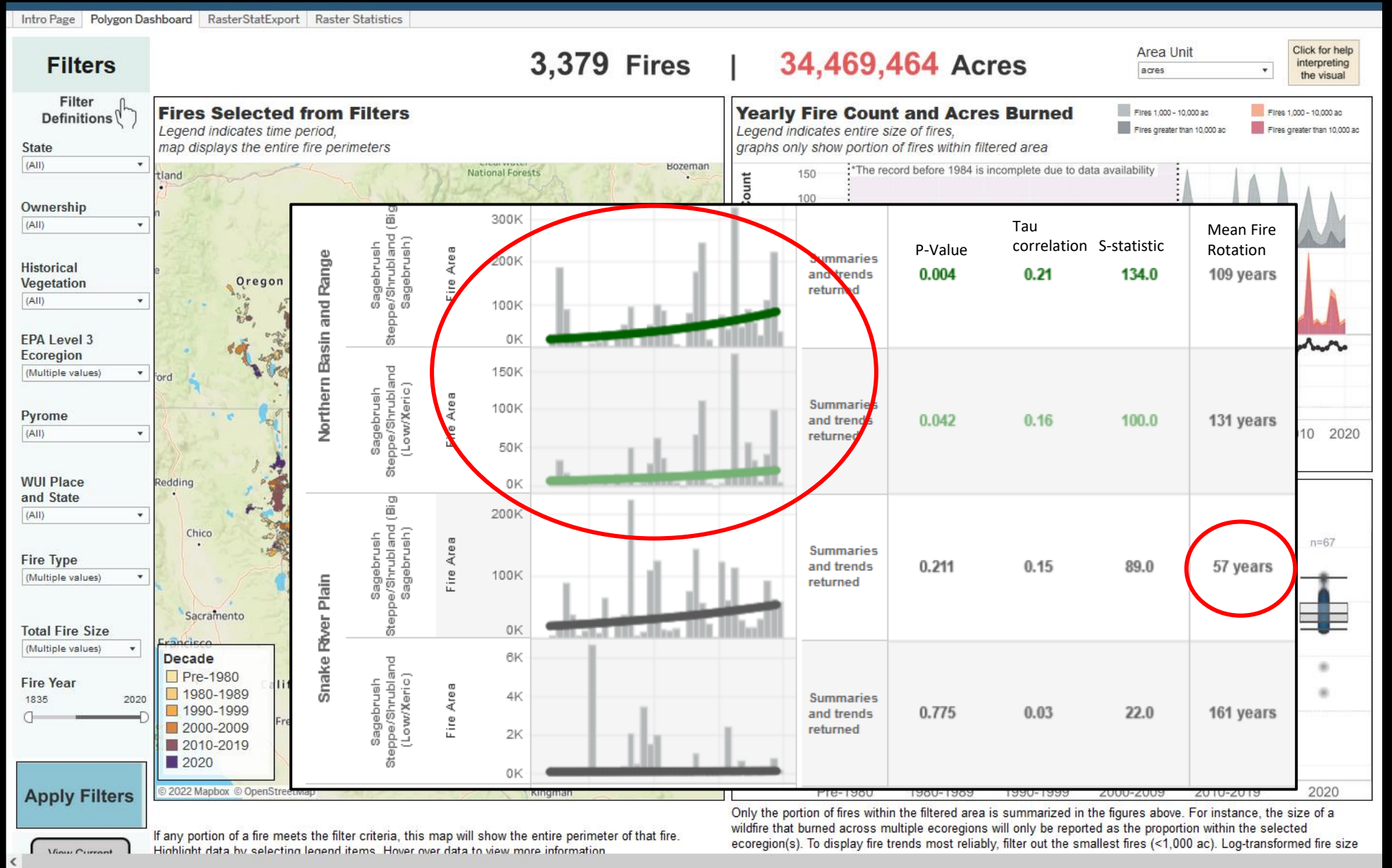
<https://www.usgs.gov/apps/land-treatment-exploration-tool/>

<https://rangelands.app/>

Resources and tools - Wildland Fire Trends Tool (WFTT)

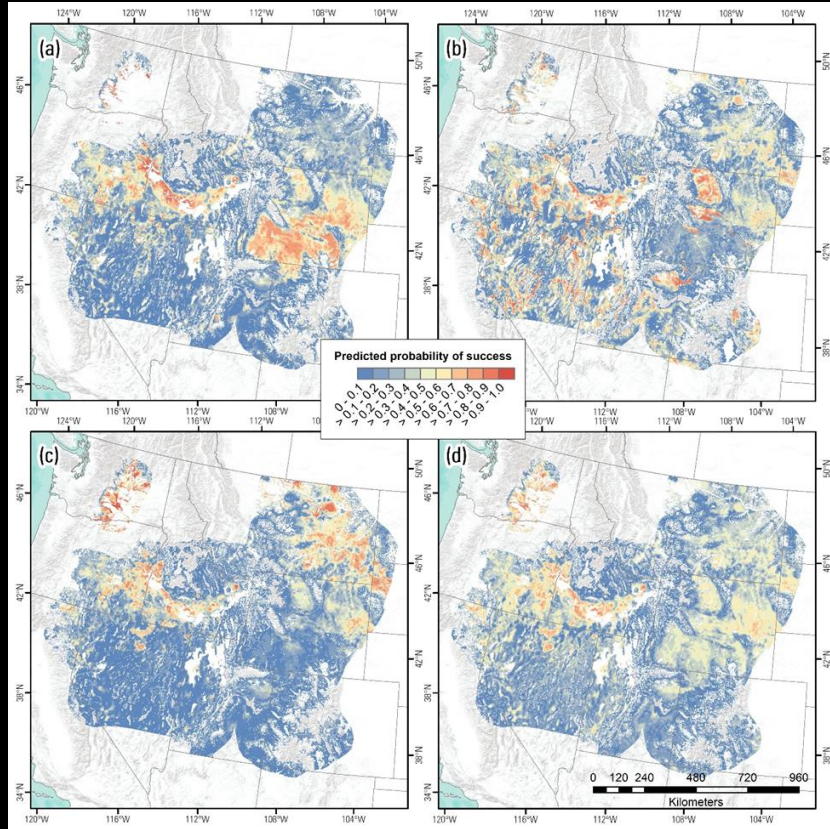
Jeffries, M., D. Shinneman, J. Welty, and D. Pilliod. 2021. Wildland Fire Trends Tool: A data visualization and analysis tool to meet land management needs and facilitate scientific inquiry.

<https://geonarrative.usgs.gov/wftt/>



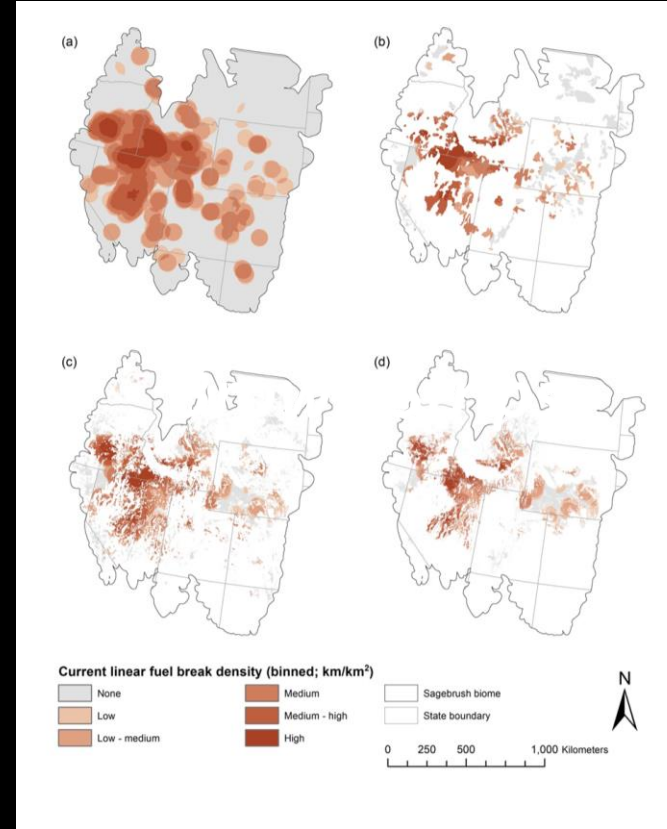
Fuel break effects and effectiveness – spatial analysis

Retrospective assessments of success



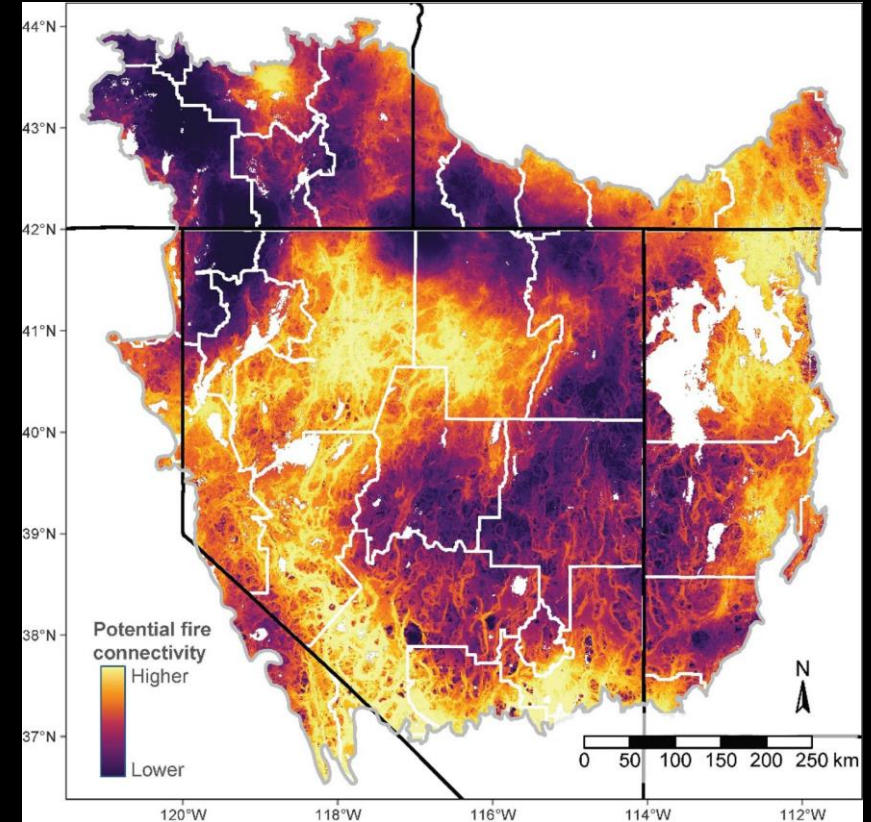
Weise, C. L., B. E. Brussee, P. S. Coates, D. J. Shinneman, M. R. Crist, C. L. Aldridge, J. A. Heinrichs, and M. A. Ricca. 2023. A retrospective assessment of fuel break effectiveness for containing rangeland wildfires in the sagebrush biome. *Journal of Environmental Management* 341:117903.

Impacts on wildlife habitat



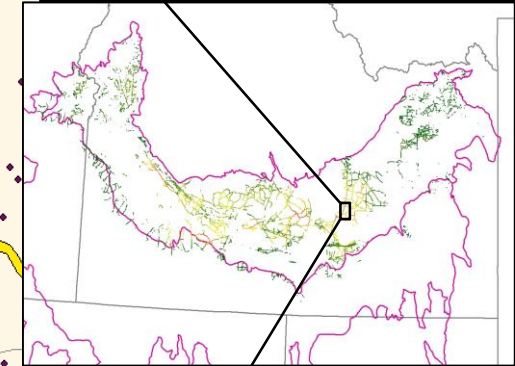
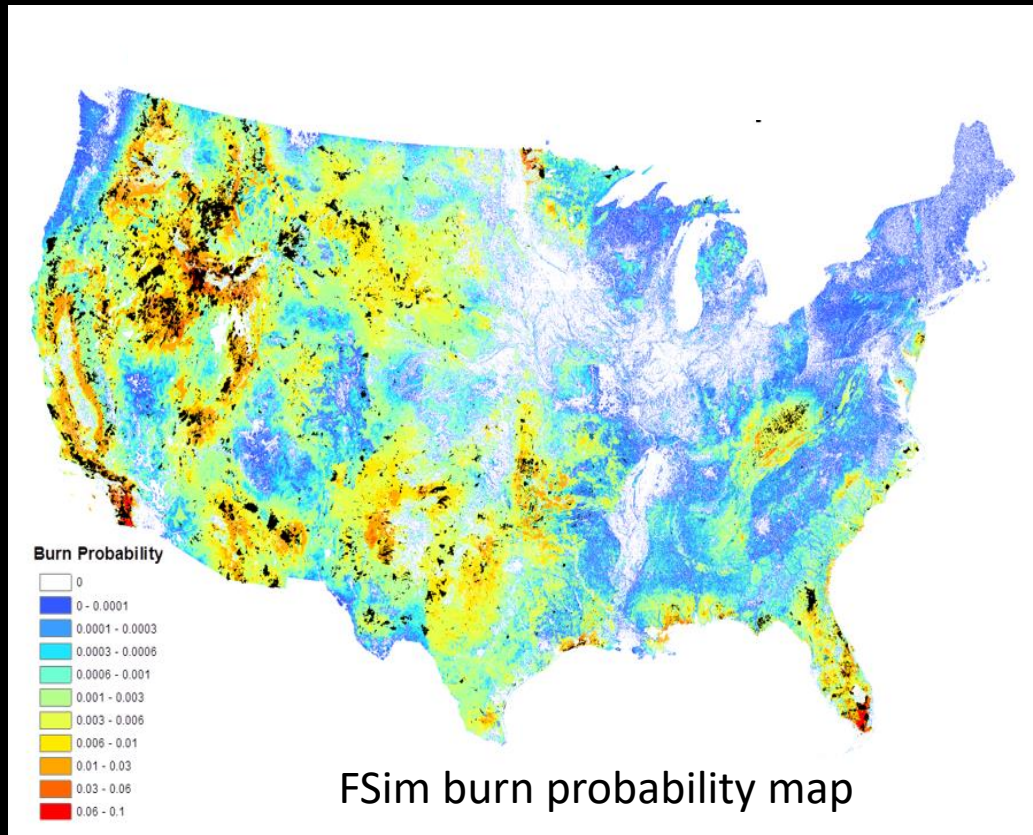
Roche, M.; Saher, D.J.; Buchholtz, E.; Crist, M.; Shinneman, D.; Aldridge, C.; Brussee, B.; Coates, P.; Weise, C.; Heinrichs, J. (In review). Ecological trade-offs associated with fuel breaks in the sagebrush ecosystem. *Fire Ecology*.

Relationship to fire connectivity



Buchholtz, E. K., J. Kreitler, D. J. Shinneman, M. Crist, and J. Heinrichs. 2023. Assessing large landscape patterns of potential fire connectivity using circuit methods. *Landscape Ecology* 38:1663–1676.

Fuel Break planning: Optimization of network design



Input for ForSys
Scenario
planning model
for multi-
objective fuel
management
planning

Total fire area "avoided" summed for each fuel break segment (Shinneman, et al. in prep.)

Climate change and fuel treatment monitoring

Determining treatment success at reducing fuels and impacting fire behavior

Assessing adequacy of retreatment frequency

Detecting increase in fire-prone exotics

Identifying changes in wildlife use



Forage kochia planting invaded by cheatgrass



USGS



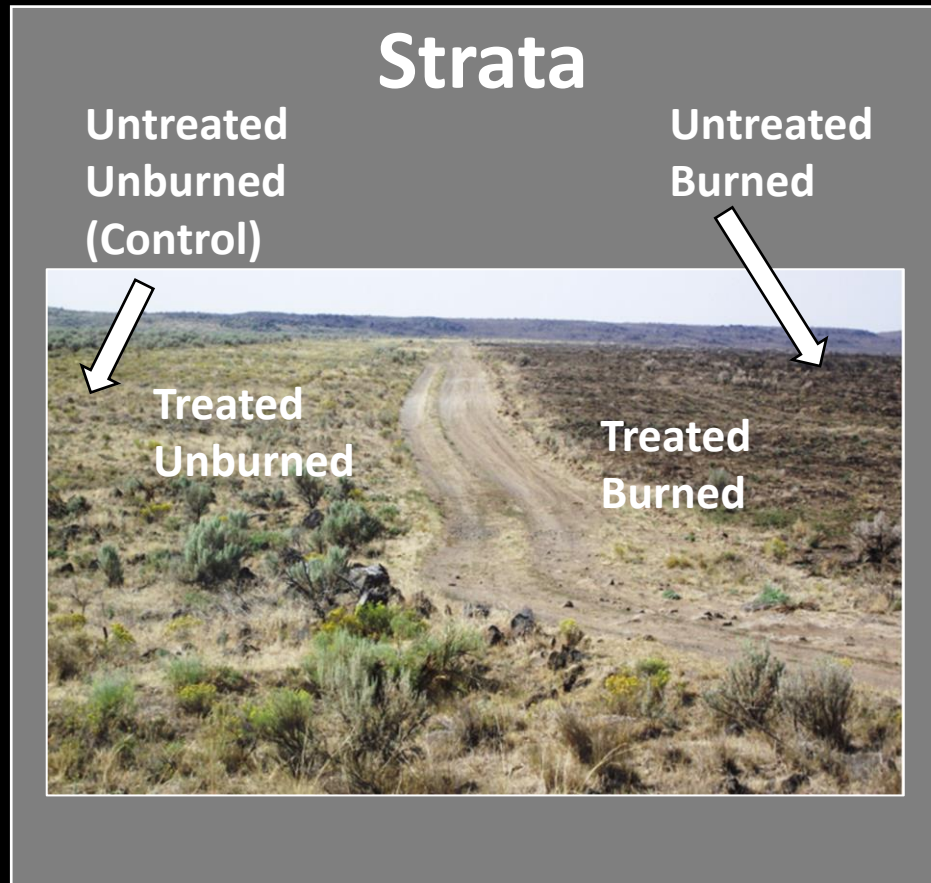
BLM

Adaptive Management



BLM

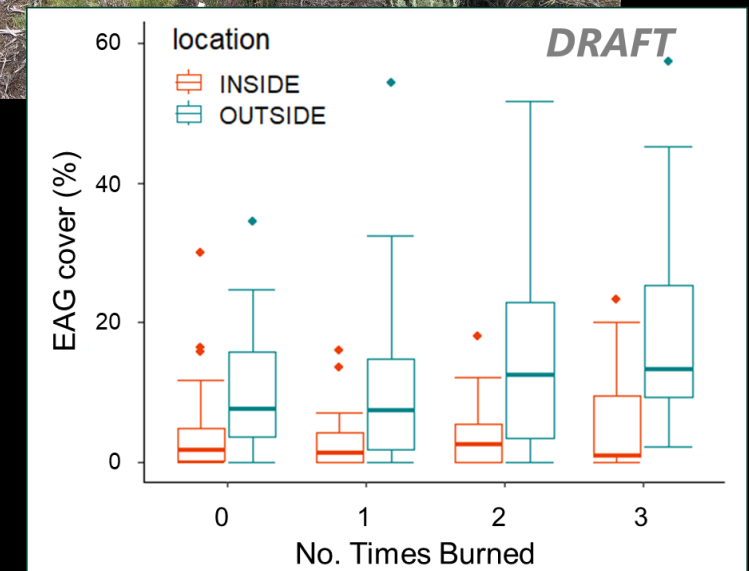
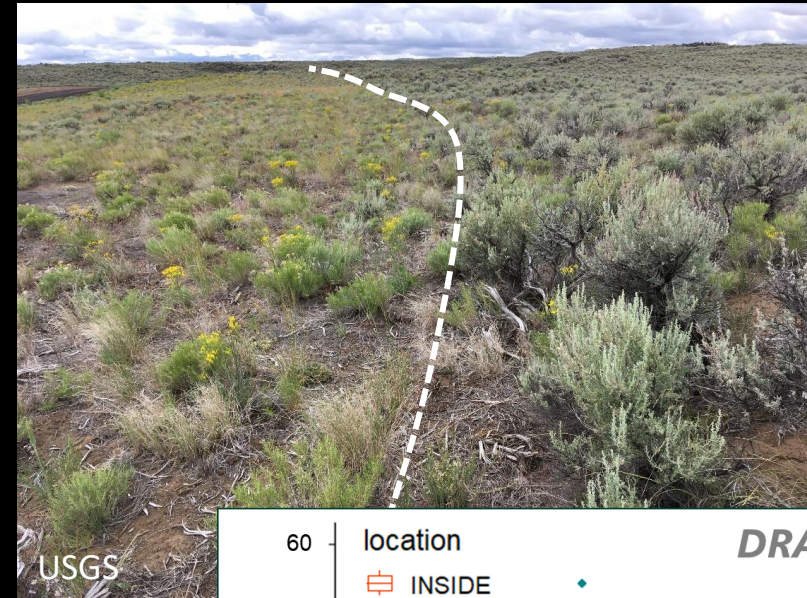
Monitoring fuel break treatment effects



Adapted from: Shinneman, D. J., S. K. McIlroy, and M.-A. de Graaff. 2021. Disentangling the effects of multiple fires on spatially interspersed sagebrush (*Artemisia* spp.) communities. *Journal of Vegetation Science* 32:e12937.

Monitoring Fuel Breaks – Effects on species abundance

- Interactions between number of times burned and treatment - beneficial reduction exotic annual grasses (EAG) in fuel breaks
- Increase in exotic annual grass cover near the outer fuel break edges
- Increasing density of resprouting shrubs in fuel breaks



This information is preliminary and is subject to revision. It is being provided to meet the need for timely best science. The information is provided on the condition that neither the U.S. Geological Survey nor the U.S. Government may be held liable for any damages resulting from the authorized or unauthorized use of the information.

Monitoring Fuel Breaks – effects on fire behavior

- Factors influencing fire behavior
 - Year since treatment X treatment type (Ellsworth et al. 2022)
 - Fire weather conditions X EAG or sagebrush cover (Price and Germino 2023)
- Risks of treatment (trade-offs)
 - Increased herbaceous surface fuels following treatments increased rate of surface fire spread & flame length (Williams et al. 2023)

Received: 23 June 2021 | Revised: 27 December 2021 | Accepted: 7 January 2022
DOI: 10.1002/eos.4664

ARTICLE
Special Feature: Sagebrush Steppe Treatment Evaluation Project

Fuel reduction treatments reduce modeled fire intensity in the sagebrush steppe

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Abstract
Increased fire size and frequency coupled with annual grass invasion pose major challenges to sagebrush (*Artemisia* spp.) ecosystem conservation, which

Journal of Environmental Management 353 (2024) 120154

Contents lists available at ScienceDirect
Journal of Environmental Management
journal homepage: www.elsevier.com/locate/jenvman

Research article
Variability in weather and site properties affect fuel and fire behavior following fuel treatments in semiarid sagebrush-steppe

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ARTICLE INFO
Keywords:
Fire modeling
Fuel treatments
Sagebrush
Soil
Climate

ABSTRACT
Fuel-treatments targeting shrubs and fire-prone exotic annual grasses (EAGs) are increasingly used to mitigate increased wildfire risks in arid and semiarid environments, and understanding their response to natural factors is needed for effective landscape management. Using field-data collected over four years from fuel-break treatments in semiarid sagebrush-steppe, we asked 1) how the occurrence of EAG and sagebrush fuel treatments varied with site biophysical properties, climate, and weather, and 2) how predictions of fire behavior using the Fuel Characteristic Classification System fire model related to land-management objectives of maintaining fire

Williams, et al. Fire Ecology (2023) 19:46
https://doi.org/10.1186/s42408-023-00201-7

Fire Ecology

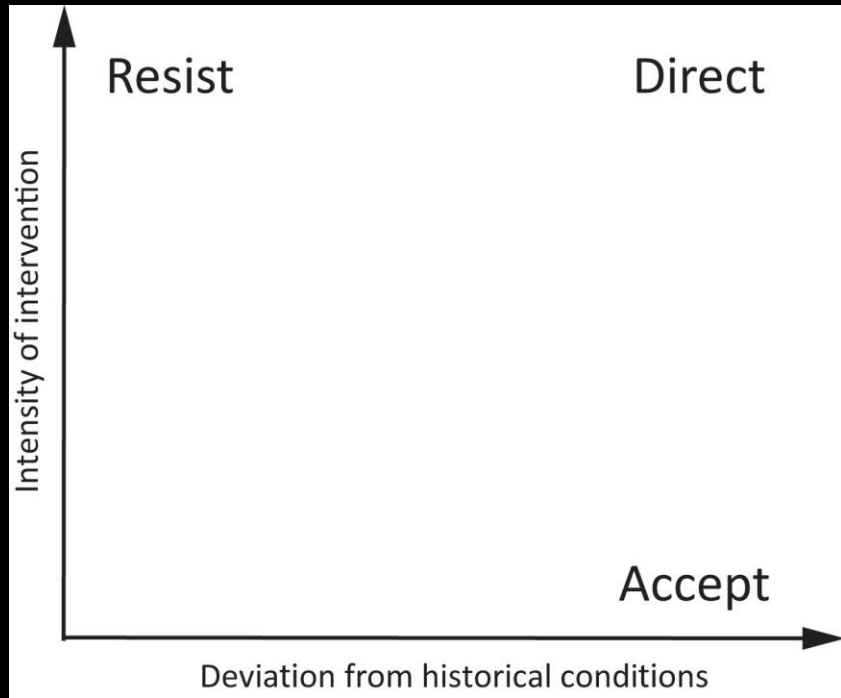
ORIGINAL RESEARCH Open Access

Fuel treatments in shrublands experiencing pinyon and juniper expansion result in trade-offs between desired vegetation and increased fire behavior

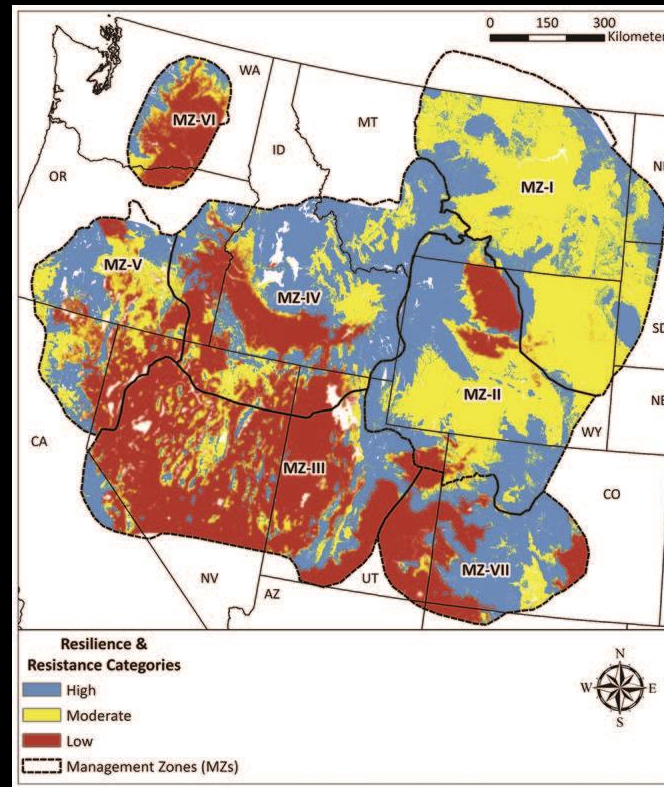
Claire L. Williams¹ | Lisa M. Ellsworth¹ | Eva K. Strand² | Matt C. Reeves³ | Scott E. Shafl⁴ | Karen C. Short⁵ | Jeanne C. Chambers⁶ | Beth A. Newingham⁷ and Claire Tortorelli⁸

Abstract
Background Native pinyon (*Pinus* spp.) and juniper (*Juniperus* spp.) trees are expanding into shrubland communities across the Western United States. These trees often outcompete with native sagebrush (*Artemisia* spp.) associated species, resulting in increased canopy fuels and reduced surface fuels. Woodland expansion often results in longer fire return intervals with potential for high severity crown fire. Fuel treatments are commonly used to prevent continued tree infilling and growth and reduce fire risk, increase ecological resilience, improve forage quality and quantity, and/or improve wildlife habitat. Treatments may present a trade-off; they restore shrub and herbaceous cover and decrease risk of canopy fire but may increase surface fuel load and surface fire potential. We measured the accumulation of surface and canopy fuels over 10 years from ten sites across the Intermountain West in the Sagebrush Steppe Treatment Evaluation Project woodland network (www.SageSTEP.org), which received prescribed fire or mechanical (cut and drop) tree reduction treatments. We used the field data and the Fuel Characteristic Classification System (FCCS) in the Fuel and Fire Tools (FFT) application to estimate surface and canopy fire behavior in treated and control plots in tree expansion phases I, II, and III.

Considering fuel treatments within the RAD Framework



Schurmann *et al.* 2022. *BioScience*, 72: 16–29.
<https://doi.org/10.1093/biosci/biab067>



Chambers, *et al.* 2017. Gen. Tech. Rep. RMRS-GTR-360. Fort Collins, CO: USDA Forest Service

USGS
 science for a changing world

Prepared in cooperation with the Western Association of Fish and Wildlife Agencies and the U.S. Fish and Wildlife Service

A Sagebrush Conservation Design to Proactively Restore America's Sagebrush Biome

Core Sagebrush Areas 2020

Open-File Report 2022–1081

U.S. Department of the Interior
 U.S. Geological Survey

Doherty *et al.* 2022. A sagebrush conservation design to proactively restore America's sagebrush biome: U.S. Geological Survey Open-File Report 2022–1081, <https://doi.org/10.3133/ofr20221081>.

Resist



Accept



Direct



Thanks!

