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Selecting Appropriate Vegetation Treatments in Shrubland and Pinyon-Juniper Ecosystems in a USDA Forest Service Wildfire Crisis Landscape: Evaluating Resilience to Disturbance and Resistance to Invasive Annual Grasses and Predicting Vegetation Response

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Abstract

This guide identifies seven primary components that largely determine the outcomes of vegetation treatments to reduce fuels and maintain or increase resilience to disturbance and resistance to invasive annual plants. The components are (1) characteristics of the ecological type, (2) current, pretreatment vegetation, (3) disturbance and management history, (4) fuel characteristics and appropriate treatments, (4) treatment severity and ecological response, (6) seeding considerations, and (7) posttreatment monitoring and management. Key questions and a set of tools are provided to assess the components. The guide provides information to (1) evaluate resilience and resistance for potential treatment areas, (2) determine likely effects of treatments on fuels, fire behavior, and ecological response, and (3) select appropriate treatments, including the need to seed. An evaluation score sheet is included for assessing relative resilience and resistance and seeding needs. The Pine Valley Ranger District of the Dixie National Forest, part of a USDA Forest Service “Wildfire Crisis Landscape,” is used as a case study. Maps and data summaries included for the district are dominant shrubland and pinyon-juniper ecological types, burn probabilities, cover of the invasive annual, cheatgrass, proxy soil temperature and moisture regimes, relative resilience and resistance, pinyon-juniper stand characteristics, and habit for mule deer and pinyon jay.

Keywords: resilience, resistance, shrublands, pinyon, juniper, fuels, fire behavior, prescribed fire, mechanical treatment, revegetation

Cover: Illustration of ongoing fuel treatments in the Pine Valley Ranger district near the town of Enterprise, Utah. Treatment objectives are reducing the risk of catastrophic wildfire, improving watershed ecological conditions, sustaining local communities, protecting recreational resources, and increasing resilience. USDA Forest Service photo by Mark Madsen.

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Photos of representative ecological types within the Pine Valley Ranger District. Top left—Old growth Juniper-Pinyon. Top right—Montane Chaparral. Middle left—Wyoming big sagebrush. Middle right—Black sagebrush. Lower left—Expansion Pinyon-Juniper. Lower right—Mountain shrub-Gambel oak. USDA Forest Service photos by: Jeanne Chambers, top left, and Mark Madsen, all other photos.

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INTRODUCTION

One of the most challenging roles of a resource manager is conducting vegetation treatments that meet the desired objectives for broad heterogeneous landscapes. In semi-arid landscapes with high fire risk, a common objective of vegetation treatments is to reduce woody species (shrubs and trees) to (1) reduce fuel loads and decrease the extent and severity of subsequent wildfires, (2) increase ecological resilience, or the ability of the site to recover, following wildfire and other disturbances, (3) increase resistance to invasive annuals and the longer term risk of conversion to invasives, or (4) maintain or improve ecosystem services. Key elements of effective vegetation treatments are the ability to determine a site's ecological type and its current ecological condition or state, and to evaluate the ecological type's resilience to disturbance or treatment and its resistance to invasive annual grasses. An understanding of the longer-term effects of treatments on fuels and fire behavior helps ensure that the treatments selected are durable over time. In combination, these key components provide managers with the information needed to evaluate the likely ecological responses of potential treatment areas to both management treatments and future wildfires, and to select the locations and treatments that will best meet the management objectives.

Purpose

This guide provides a framework for evaluating potential treatment areas within shrubland and pinyon pine (*Pinus edulis*, *Pinus monophylla*) and/or juniper (*Juniperus osteosperma*) (pinyon-juniper) landscapes that are being considered for vegetation management treatments. The framework helps managers evaluate the characteristics of potential treatment areas, select the proper treatment locations and types, and determine the appropriate posttreatment management, specifically:

- The ecological type and current ecological conditions or state;
- Ecological resilience and the likely recovery following vegetation treatments, such as prescribed fire, mechanical treatments, or their combination;
- Resistance to invasive annual grasses and the risk of increases in invasive annual grasses following vegetation treatments;
- The longer-term effects of vegetation treatments on fuels and fire behavior;
- Treatment severity and the likely ecological responses following vegetation treatments; and
- The most appropriate vegetation management treatments, including no treatment, based on the evaluation of the treatment area.

Although this guide is intended to assist in evaluating areas being considered for vegetation management treatments, the concepts, components, and questions are generally applicable to areas burned by wildfire or otherwise disturbed.

Approach

The guide's approach is based on developing an understanding of resilience to wildfire and other disturbances and resistance to invasive annual grasses (see Chambers et al. 2014a, b, 2019). *Resilient* ecosystems have the capacity to *regain* their fundamental structure, processes, and functioning following disturbance, stressors, and management treatments. The resilience of an ecological type is determined by its environmental characteristics and ecological conditions and reflects its recovery potential (fig. 1). *Resistant* ecosystems can *retain* their fundamental structure, processes, and functioning (or remain largely unchanged) despite disturbance and stressors. The resistance of an ecosystem to invasive annual grasses is a function of the environmental and ecological characteristics of an ecosystem that limit the population growth and expansion of the invasive species. Ecosystems that are both resilient and resistant provide valuable ecosystem services such as clean air and water, forage, and wildlife habitat.

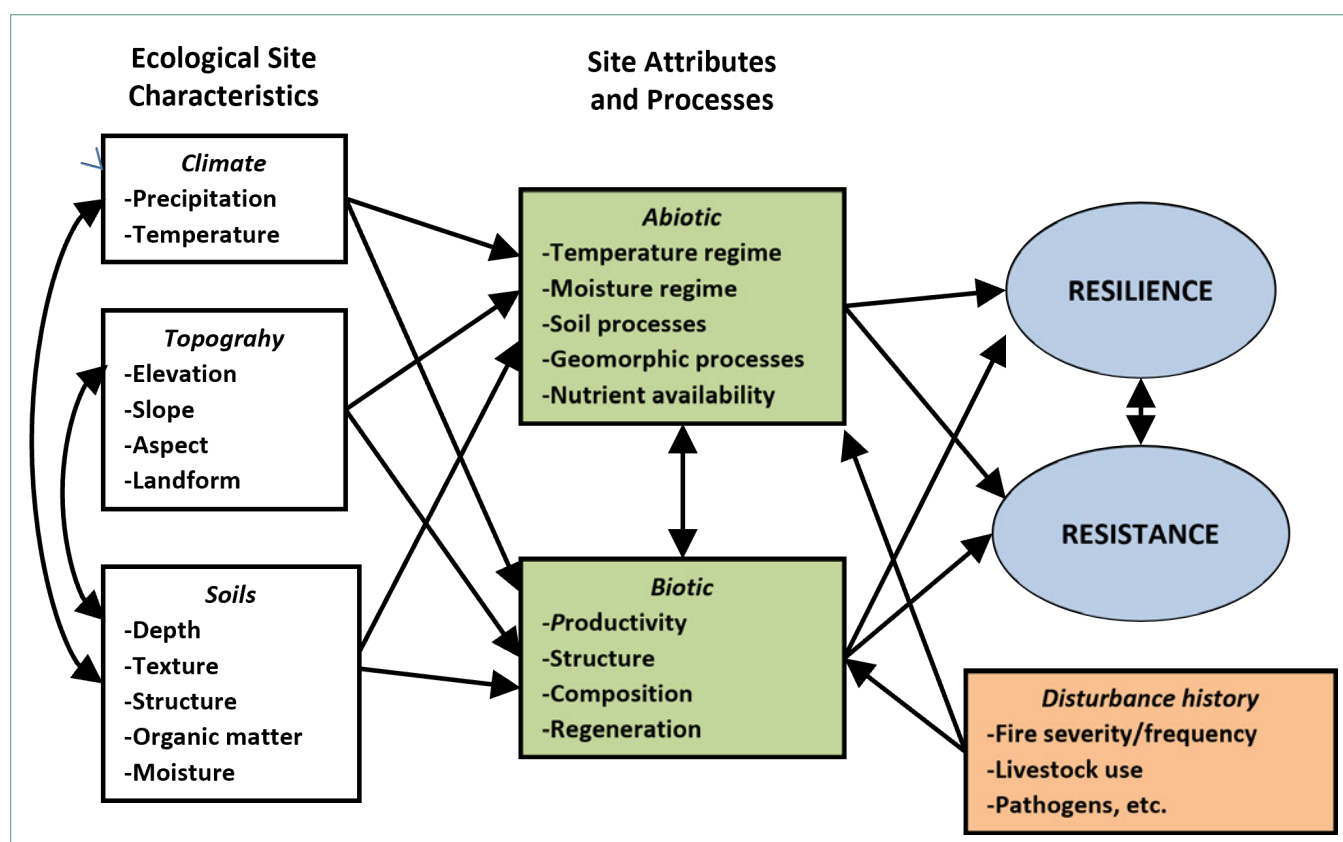


Figure 1—A conceptual model illustrating the factors that influence resilience to disturbance and treatment and resistance to invasive annual grasses. The climatic, topographic, and soil characteristics of ecological sites are the underlying factors influencing site attributes and processes and thus resilience and resistance. Disturbances and land uses, such as high severity or uncharacteristically frequent wildfire, excessive livestock grazing, and pathogens and disease, act on sites to influence abiotic factors like soil water and nutrient availability and biotic factors like vegetation structure and composition. These types of disturbances increase the management inputs required to return the site to a desired state with the required inputs increasing as resilience and resistance decrease. Figure adapted from Chambers et al. 2014a.

In shrubland and pinyon-juniper ecosystems, resilience and resistance change across climatic and topographic gradients (fig. 2). As illustrated for sagebrush (*Artemisia* spp.) shrublands, cooler and moister ecological types typically have greater resilience than warmer and drier types due to more favorable environmental conditions and higher productivity. Consequently, cooler and moister types experience less change and recover more quickly after disturbance. Resistance to invasive annual grasses depends on climatic suitability to the invader and competitive interactions with the native community. Resistance to the invasive annual cheatgrass (*Bromus tectorum*), the focus of this guide, increases with cold winter temperatures. Perennial grasses and forbs are essential for maintaining both resilience and resistance because they promote recovery following disturbance and are the primary competitors with invasive annual grasses.

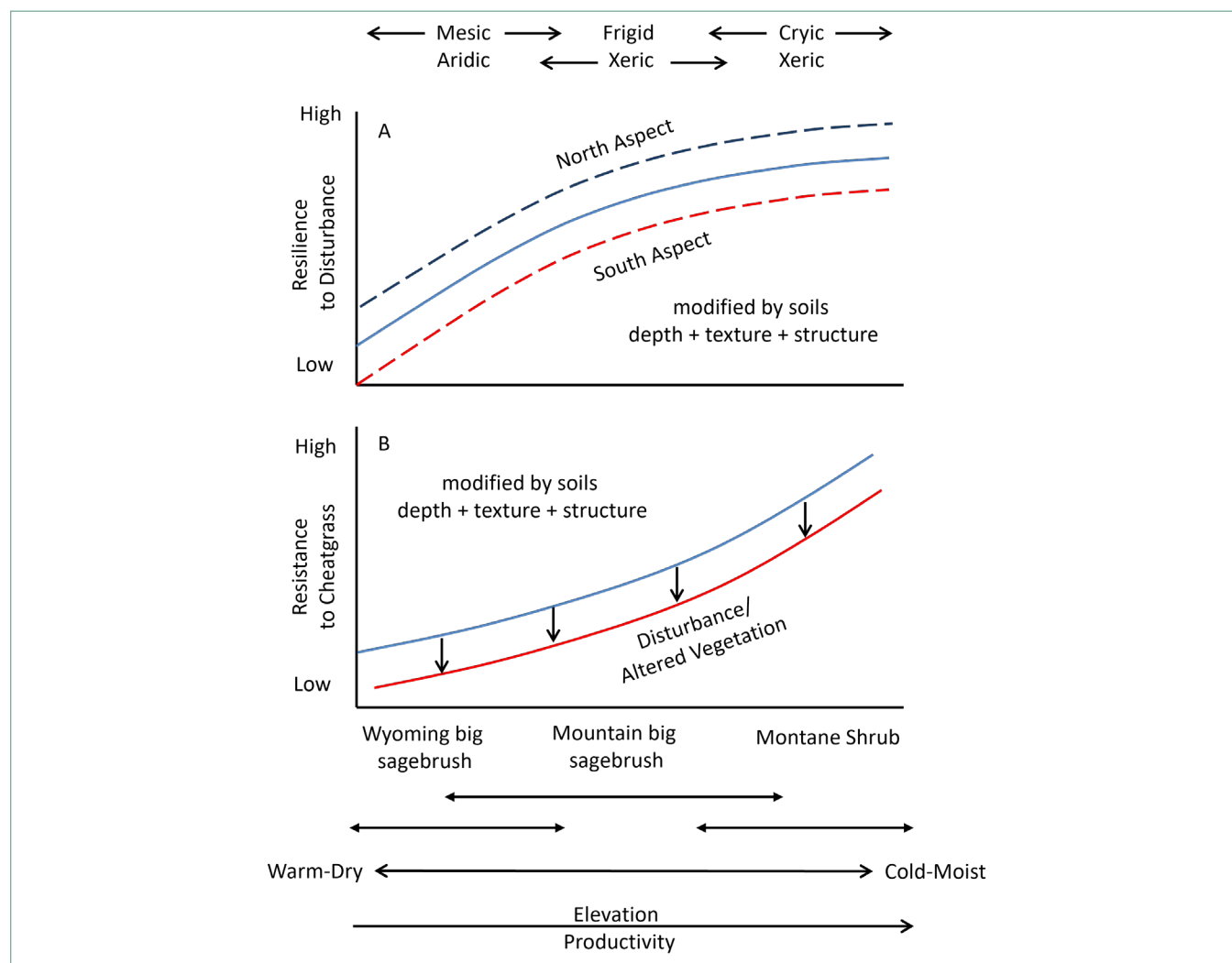


Figure 2—(A) Resilience to disturbance and management treatment and (B) resistance to invasive annual grasses for the Wyoming big sage, mountain big sagebrush, and montane shrub ecological types across an elevation/productivity gradient in which soil temperature/moisture regimes grade from warm/dry (mesic/aridic) to cold/moist (cryic/xeric). As illustrated for resilience, soil moisture availability along these gradients is modified by aspect and can influence relative resilience and resistance. As illustrated for resistance, changes in site attributes, like depletion of perennial grasses and forbs due to disturbance history or climate change, can reduce both resilience and resistance. Figure adapted from Chambers et al. 2014a.

In this guide, **Key Questions** related to **Seven Primary Components for Treatment Evaluation** (fig. 3) are used to evaluate resilience to disturbance or treatment, resistance to invasive annual grasses, and likely ecological responses of potential treatment areas. The answers to these questions are used to help determine those locations where treatments are most likely to meet management objectives, and to select effective management treatments. Terms commonly used in the guide are in the *Glossary*.

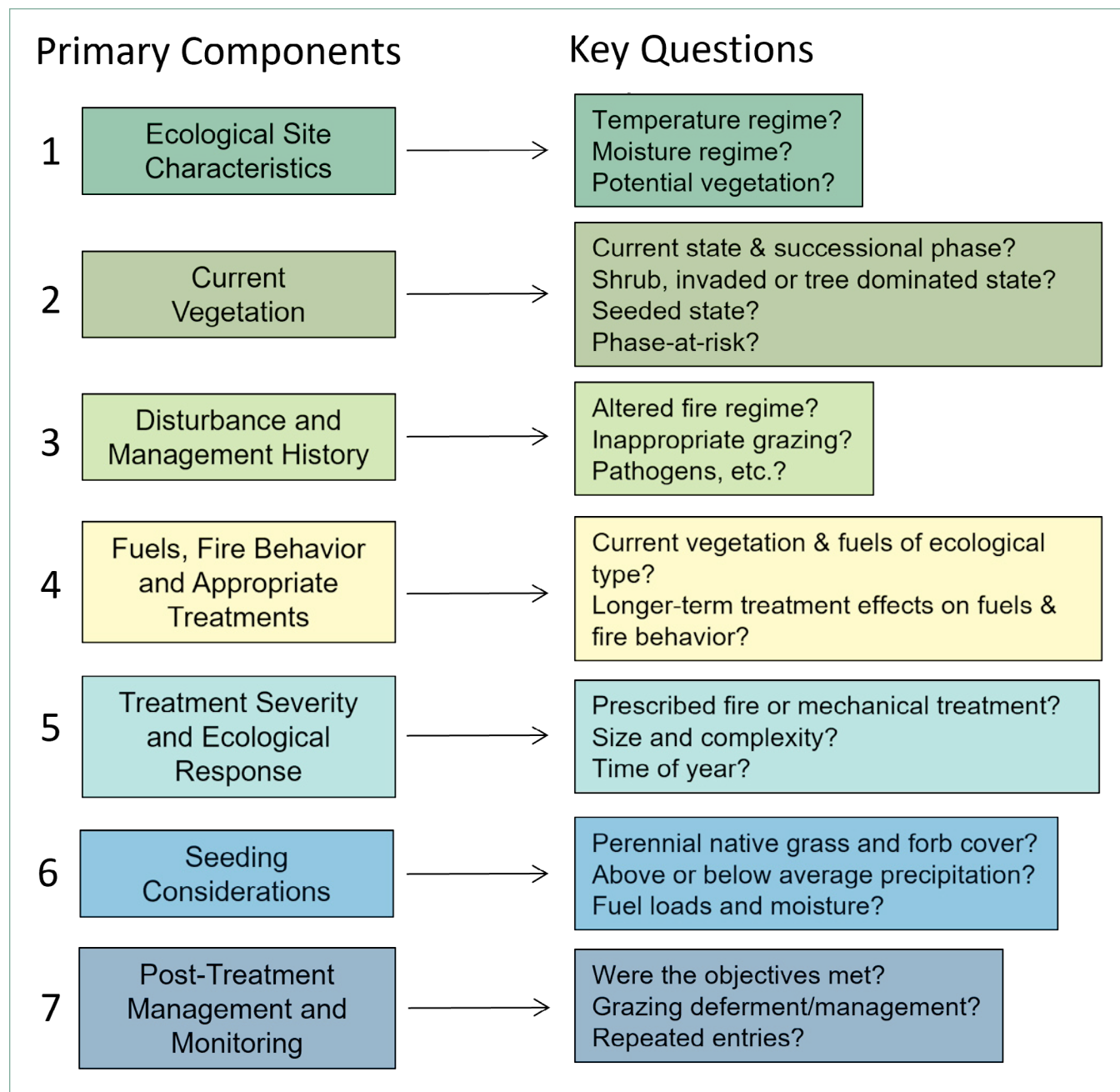


Figure 3—The seven primary components that are used to evaluate the relative resilience and resistance and likely ecological responses of potential treatment areas. These components are the basis for a series of key questions to help select effective management treatments and determine where treatments are most likely to meet management objectives. Figure adapted from Miller et al. 2014.

Area of Application

This guide builds on field guides developed for sagebrush and pinyon-juniper ecosystems in the Columbia Basin and Great Basin as defined by the Northern Basin and Range, Snake River Plain, and Central Basin and Range ecoregions (Miller et al. 2014, 2015). The previous field guides focused on Major Land Resource Areas (MLRAs) and used soil temperature and moisture regimes and ecological site descriptions (ESDs) to help identify the characteristics of potential treatment areas and current ecological conditions. Many National Forests lack publicly accessible completed soil surveys, accurate information on relative resilience and resistance, and ESDs. In this guide, proxy soil temperature and moisture regimes are used to develop (1) information on relative resilience and resistance, (2) ecological types (i.e., generalized ESDs), and (3) state-and-transition models (STMs). The Pine Valley Ranger District of the Dixie National Forest, part of a U.S. Department of Agriculture, Forest Service Wildfire Crisis Landscape, is used as a case study (fig. 4; USDA Forest Service 2023a).

The Pine Valley Ranger District supports numerous communities, high-value recreation areas, and important ecosystem services. Landscapes within the Pine Valley Ranger District are characterized by high annual burn probabilities, with much of the area at risk of increases in or conversion to cheatgrass following wildfire (fig. 5). The management strategy for the landscape is to treat National Forest System (NFS) lands with the objectives of reducing the risk of catastrophic wildfire, improving watershed ecological conditions, sustaining local communities, protecting recreational resources, and increasing resilience (USDA Forest Service 2023a).

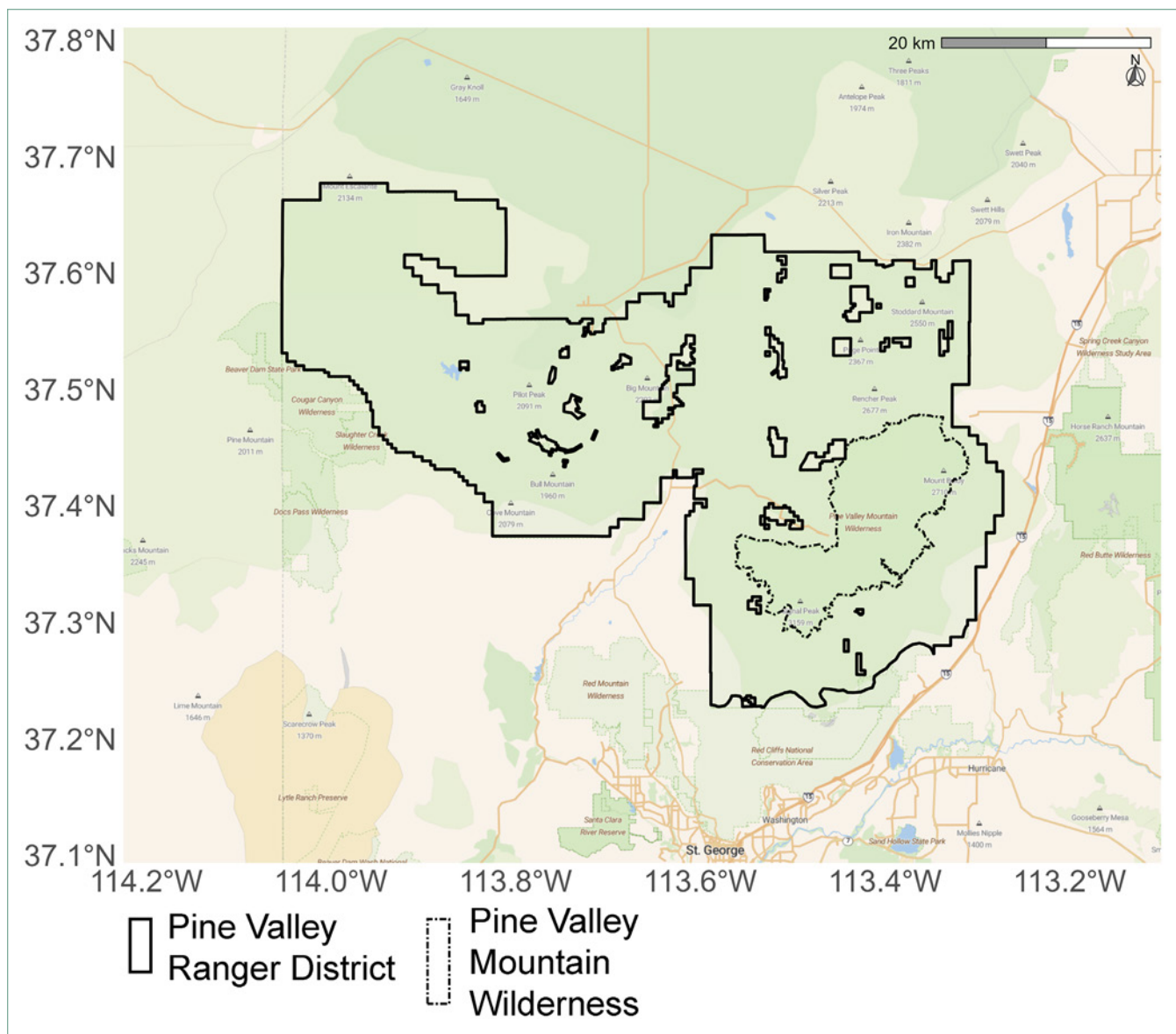


Figure 4—Map of the Pine Valley Ranger District of the Dixie National Forest, which is part of a USDA Forest Service “Wildfire Crisis Landscape.” The district lies at the intersection of three different ecoregions, namely, the Central Basin and Range, Colorado Plateaus, and Mojave Basin and Range and is characterized by a broad range of shrubland, pinyon-juniper, and forest ecological types. The Pine Valley Mountain Wilderness lies at the south-eastern part of the Ranger District.

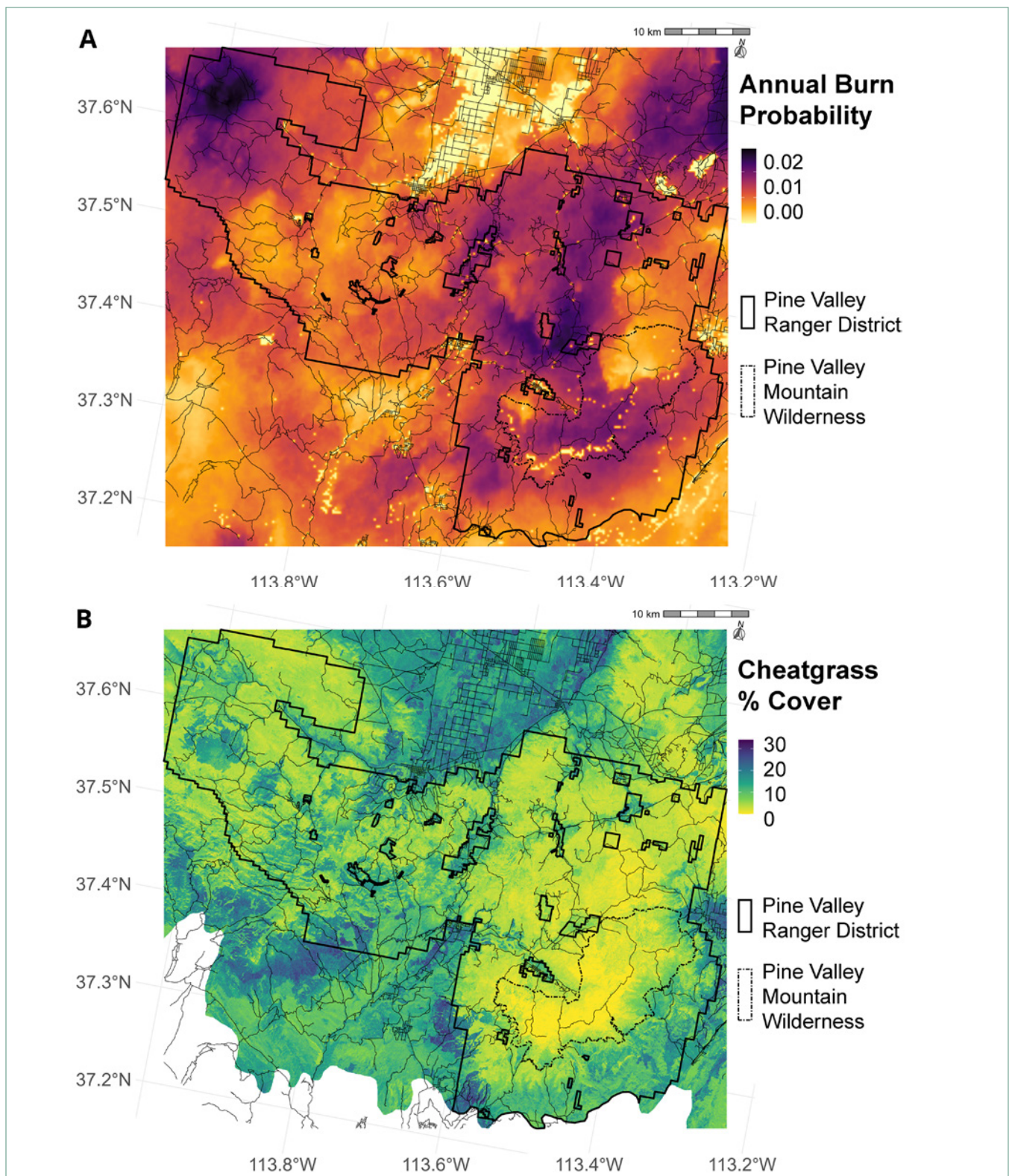


Figure 5—Maps of (A) annual burn probabilities (Dillon et al. 2023) and (B) cheatgrass cover for 2016-2022 (USGS Rangeland Exotic Plant Monitoring System, unpublished data) for the Pine Valley Ranger District and the Pine Valley Mountain Wilderness. The burn probabilities are among the highest observed in the Great Basin and Colorado Plateaus and the widespread presence of cheatgrass in the shrubland and pinyon-juniper ecological types results in high risk of invasive annual grass dominance following wildfire.

Supporting Information

This guide is based largely on syntheses of the state-of-our-knowledge for management of shrubland and pinyon-juniper ecosystems (Chambers et al. 2024; Hood et al. 2007; Miller et al. 2013, 2019). The ecological types and STMs align with LANDFIRE Biophysical Settings (BpS) compiled for the Pine Valley Ranger District by Tuhy et al. (2014). The STMs were modified from Stringham et al. (2015) and the ESDs available in the Ecosystem Dynamics Interpretive Tool (EDIT) for Major Land Resource Area 28A (USDA and New Mexico State University 2024). Proxy soil temperature and moisture regimes and precipitation zones (PZ) are from Daymet data (Thornton et al. 2022). The descriptions of the ecological types are primarily from Hood et al. (2007), Stringham et al. (2015), and Tuhy et al. (2014) and the Fire Effects Information System (USDA FEIS 2024). Plant nomenclature follows the PLANTS Database (USDA NRCS 2024). Coauthors, Mark Madsen, Dixie National Forest Botanist, Vaughn Thacker, Pine Valley Ranger District Soil Scientist, and Rhett Boswell, Pine Valley Ranger District Wildlife Biologist, provided information on species composition, soil characteristics, and management approaches.

This guide is not intended for evaluation of restoration/rehabilitation strategies following vegetation treatments. However, the components and questions in the guide can be used to evaluate the suitability of an area for seeding based on ecological type characteristics and the need for seeding based on current vegetation. Miller et al. (2015) specifically addresses how to evaluate the resilience and resistance of an area immediately following a wildfire, the area's suitability for seeding, and the need for seeding after wildfire in the Great Basin. Information on restoration/rehabilitation methods for sagebrush and associated pinyon-juniper ecosystems can be found in Monsen et al. (2004) and Pyke et al. (2015a, b).

THE SEVEN PRIMARY COMPONENTS FOR TREATMENT EVALUATION

Potential treatment areas are evaluated by addressing the key questions identified for each of the seven primary components (fig. 3). The answers to these questions are intended to provide the information needed to select appropriate treatment areas and treatment types.

1 Ecological Site Characteristics

Climate, topography, and soils affect temperature and moisture regimes, potential vegetation, and productivity, as well as resilience to disturbance and treatments and resistance to invasives (fig. 1). Differences in the underlying characteristics of ecological sites result in differences in resilience to treatment and resistance to annual invasive species. The Pine Valley Ranger District supports 11 shrubland or woodland generalized ecological types (table 1). These types represent groupings of ecological sites that span a range of soil temperature and moisture regimes (very warm and dry to cool and moist or hypermesic/aridic to frigid/xeric) (table 2) and that are characterized by shrublands and pinyon-juniper woodlands. To determine the relative resilience and resistance of an area prior to treatment, it is necessary to evaluate the soil temperature and moisture regimes, potential vegetation, and current vegetation.

Table 1—The relative resilience and resistance, descriptive characteristics, and ecological states/vegetation departure of the dominant shrubland and woodland ecological types in the Pine Valley Ranger District. Detailed descriptions of each type, including scientific names for indicator species, and the ecological states/degree of departure are in Appendix E. The cover values for the shrubs, perennial grasses and forbs, and pinyon and juniper are from the Rangeland Analysis Platform (means for 2018–2022; Allred et al. 2021). Cover values for invasive annuals are from the Rangeland Analysis Platform (2018–2022) and the USGS Rangeland Exotic Plant Monitoring System (2016–2022) (unpublished), respectively. Cover values for the seeded treatments are from 2009–2018 and for fuel treatments date from 2006–2023, and these values do not include the large, seeded areas that pre-dated the mid-2000s. (Condensed table available in Appendix F.)

Ecological type	Resilience and resistance	Descriptive characteristics	Ecological states/ Vegetation departure
Blackbrush Very warm/Moist	Resilience – Moderately low Resistance – Moderately low	Soil temperature/moisture regime: Hypermesic/xeric Precipitation: 12–16 in Indicator shrubs: blackbrush, Mojave golden bush, desert ceanothus, Yerba Santa Indicator grasses: James' galleta, Indian ricegrass, squirreltail, six weeks fescue	Shrubs: primary component (12.8%) Perennial grasses and forbs: minor (2.1%) Pinyon and juniper: widespread (23.4%), but low stand cover Seedlings: minor Invasive annuals: dominant in 2.9% to 10.0% of area. Present across entire area.
Mountain Shrub-Stanbury cliffrose Very warm to warm/Moist	Resilience— Moderately low to moderate Resistance— Moderately low	Soil temperature/moisture regime: Hypermesic to mesic/xeric Precipitation: 14–18 in Indicator shrubs: Stanbury cliffrose, green ephedra Indicator grasses: James' galletta, Indian ricegrass, needle and thread	Shrubs: major component (11.3%) Perennial grasses and forbs: severely depleted (3.9%) Pinyon and juniper: high presence (19.5% of area) Seedlings: minor component Invasive annuals: dominant in 11.5% to 10.7%. Present across entire area.
Montane chaparral Warm to very warm/Moist	Resilience— Moderate Resistance— Moderately low	Soil temperature/moisture regime: Mesic to hypermesic/xeric Precipitation: 16–20 in Indicator shrubs: Sonoran scrub oak, ashy silktassel, pointleaf manzanita, greenleaf manzanita, desert ceanothus, alderleaf mountain mahogany, Yerba Santa Indicator grasses: Indian ricegrass, blue grama, needle and thread, threewawn	Shrubs: dominant component (18.8%) Perennial grasses and forbs: depleted (5.7%) Pinyon and juniper: high presence (18.7%) Seedlings: minor component Invasive annuals: dominant in 5.0% to 10.0%. Present across entire area.
Wyoming big sagebrush Warm/Moist	Resilience— Moderate Resistance— Moderately low to moderate	Soil temperature/moisture regime: Mesic/xeric Precipitation: 16–20 in Indicator shrubs: Wyoming big sagebrush, bitterbrush, rabbitbrush, horsebrush Indicator grasses: muttongrass, blue grama, squirreltail, needle and thread, Indian ricegrass	Shrubs: major component (11.6%) Perennial grasses and forbs: severely depleted (4.4%) Pinyon and juniper: high presence (27.0%) Seedlings: minor component Pinyon-juniper treatments: 1575 acres Invasive annuals: dominant in 4.1% to 6.3%. Present across entire area.

Table 1 continued.

Ecological type	Resilience and resistance	Descriptive characteristics	Ecological states/ Vegetation departure
Mountain shrub-Utah serviceberry Warm/Moist	Resilience—Moderate Resistance—Moderately low to moderate	Soil temperature/moisture regime: Mesic/xeric Precipitation: 16–20 in Indicator shrubs: Utah serviceberry, alderleaf mountain mahogany, bitterbrush, skunkbush sumac Indicator grasses: grama grasses, needlegrasses, western wheatgrass, prairie Junegrass	Shrubs: dominant component (20.5%) Perennial grasses and forbs: depleted (6.6%) Pinyon and juniper: moderate presence (15.4%) Seedlings: minor component Pinyon-juniper treatments: 526 acres Invasive annuals: dominant in 7.2% to 6.3%. Present across entire area.
Juniper and pinyon Warm to very warm/Moist	Resilience—Moderately low Resistance—Low	Soil temperature/moisture regime: Mesic to Hypermesic/xeric Precipitation: 12–16 in Indicator shrubs: Wyoming big sagebrush, black sagebrush, bitterbrush Indicator grasses: muttongrass, Indian ricegrass, squirreltail, blue grama, Sandberg's bluegrass	Shrubs: moderate component (12.2%) Perennial grasses and forbs: severely depleted (2.3%) Pinyon and juniper: dominant component (30.3%) Seedlings: minor component Pinyon-juniper treatments: minor component Invasive annuals: dominant in 2.3% to 6.9%. Present across entire area
Black sagebrush Warm/Moist	Resilience—Moderate Resistance—Moderately low to moderate	Soil temperature/moisture regime: Mesic/xeric Precipitation: 16–20 in Indicator shrubs: black sagebrush Indicator grasses: muttongrass, Sandberg's bluegrass, Indian ricegrass, needle and thread, prairie Junegrass and Letterman's needlegrass on cooler and moister sites	Shrubs: dominant component (18.1%) Perennial grasses and forbs: moderate (13.3%) Pinyon and juniper: relatively minor component (6.2%) Seedlings: minor component Pinyon-juniper treatments: minor component Invasive annuals: dominant in 9.0% to 6.9%. Present across entire area.
Mountain big sagebrush Cool to warm/Moist	Resilience—Moderate to moderately high Resistance—Moderate to moderately high	Soil temperature/moisture regime: Frigid to mesic/xeric Precipitation: 18–22 in Indicator shrubs: mountain big sagebrush, snowberry, Utah serviceberry, bitterbrush, chokecherry Indicator grasses: muttongrass, blue grama, slender wheatgrass, Letterman's needlegrass	Shrubs: dominant component (18.0%) Perennial grasses and forbs: severely depleted (4.7%) Pinyon and juniper: high presence (23%) Seedlings: minor component Pinyon-juniper treatments: minor component Invasive annuals: minor component (2.5% to 3.0%)
Pinyon and Juniper Warm/Moist	Resilience—Moderate Resistance—Moderately low to moderate	Soil temperature/moisture regime: Mesic/xeric Precipitation: 16–20 in Indicator shrubs: mountain big sagebrush, bitterbrush, Utah serviceberry, chokecherry Indicator grasses: muttongrass, blue grama, squirreltail, needlegrasses	Shrubs: moderate component (12.0%) Perennial grasses and forbs: severely depleted (3.3%) Pinyon and juniper: dominant component (32.3%) Seedlings: minor component Pinyon-juniper treatments: minor component Invasive annuals: minor component (1.8% to 3.9%)

Table 1 continued.

Ecological type	Resilience and resistance	Descriptive characteristics	Ecological states/ Vegetation departure
Mountain shrub-Gambel oak Warm/Moist	Resilience—Moderate Resistance—Moderately low to moderate	Soil temperature/moisture regime: Mesic/xeric Precipitation: 16–22 in Indicator shrubs: Gambel oak, big sagebrush, bitterbrush, chokecherry, snowberry Indicator grasses: muttongrass, blue grama, squirreltail, needlegrasses	Shrubs: major component (34.1%) Perennial grasses and forbs: depleted (8.4%) Pinyon and juniper and other trees: moderate component (13.0%) Seedlings: minor component Pinyon-juniper treatments: minor component Invasive annuals: dominant in 4.6% to 4.8%. Present across much of area.
Curl-leaf mountain mahogany Cool/Moist	Resilience—Moderately high Resistance—Moderately high	Soil temperature/moisture regime: Frigid/xeric Precipitation: 18–24 in Indicator shrubs: mountain big sagebrush, black sagebrush, rabbitbrush on warmer and drier sites; mountain big sagebrush, Utah serviceberry, snowberry on cooler and moister sites Indicator grasses: blue grama, squirreltail, needle and thread, Indian ricegrass on warmer and drier sites; slender wheatgrass, prairie Junegrass, Letterman's needlegrass on cooler and moister sites	Shrubs: major component (26.2%) Perennial grasses and forbs: depleted (5.0%) Pinyon and juniper and other trees: major component 22.8%) Seedlings: minor component Pinyon-juniper treatments: minor component Invasive annuals: minor component (1.9% to 2.0%)

Table 2—Soil temperature and moisture regime names. See more detailed definitions in the *Glossary*.

Soil temperature regimes	
Hypermesic	Very warm
Mesic	Warm
Frigid	Cool
Cryic	Cold
Soil moisture regimes	
Aridic	Dry (< 12 inches)
Xeric	Moist (> 12 inches)

Soil Temperature and Moisture Regimes

Information on soil temperature and moisture regimes (table 2) can be obtained for areas with published soil surveys. In areas lacking published soil surveys, such as the Pine Valley Ranger District, proxy soil temperature and moisture regimes can be developed using climatic data from sources such as Daymet (Thornton et al. 2022). Proxy soil temperature and moisture regimes were developed for southern Utah (including the Pine Valley Ranger District) by equating Ecological Site Description (ESD) information in Bureau of Land Management, Assessment, Inventory and Monitoring plot data, with temperature, precipitation, and monsoonal index data for the same plots from Daymet (Chambers et al. in process; fig. 6). These proxy soil temperature and moisture regimes were refined by including the precipitation range, but effective moisture at a site may be less than indicated due to soil characteristics (e.g., shallow, rocky) or aspect (e.g., south-facing slope). Note that the monsoon index for the Pine Valley Ranger District ranges from 0.22 to 0.26 with a median of 0.24. This means that the Pine Valley Ranger District receives some summer precipitation and supports warm-season plant species, but it is not described as having a summer moist (ustic) soil moisture regime, which is characterized by a monsoonal index of about 0.30 or higher.

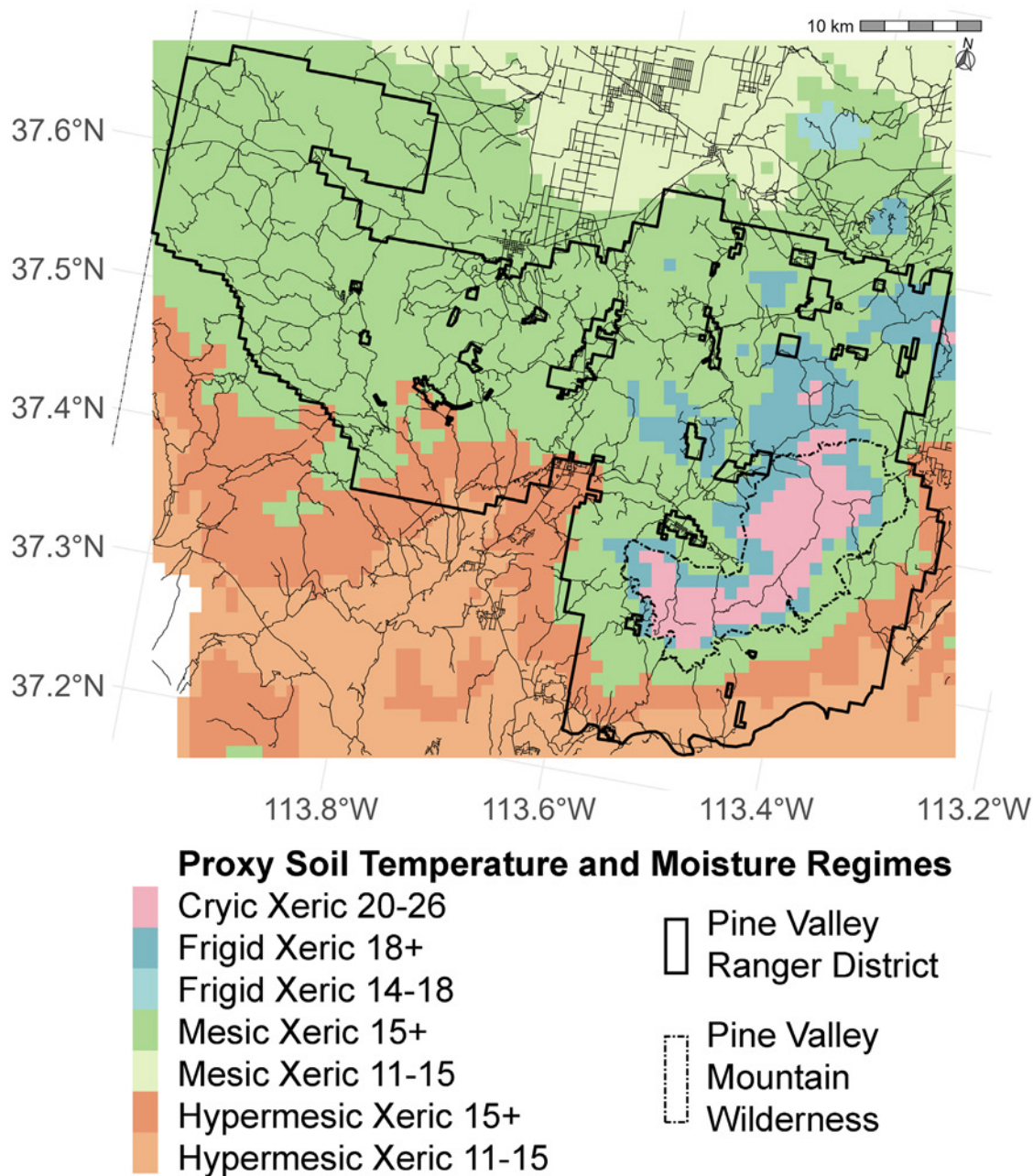


Figure 6—Proxy soil temperature and moisture regimes for the Pine Valley Ranger District and Pine Valley Mountain Wilderness. These regimes were developed for southern Utah (including the Pine Valley Ranger District) by equating Ecological Site Description (ESD) information in Bureau of Land Management, Assessment, Inventory and Monitoring plot data, with temperature, precipitation, and monsoonal index data for the same plots. These proxy soil temperature and moisture regimes were refined by including the precipitation range, but effective moisture at a site may be less than indicated due to soil characteristics (e.g., shallow, rocky, etc.). The Pine Valley Ranger District is characterized largely by a warm (mesic) temperature regime. Temperatures are cool to cold (frigid to cryic) in the Pine Valley Mountain Wilderness and surrounding area, and very warm (hypermecic) in the south. Precipitation is relatively high – generally > 12 inches (30 cm; xeric). The relatively warm and moist conditions in the shrublands and woodlands tend to result in relatively high fuel loads and low resistance to invasive annual grasses following wildfires or management treatments where the perennial grasses and forbs have been depleted. The data were from Daymet Annual and Monthly Climate Summaries at a scale of 1 km for the time period from 1980-2019 (<https://daymet.ornl.gov/>; Thornton et al. 2022).

Landscape information on soil temperature and moisture regimes is used for planning and selecting areas for more detailed assessments. Final site selection is informed by more detailed assessments of soil characteristics.

1. Are the soils very warm (hypermesic), warm (mesic), cool (frigid), or cold (cryic) as illustrated on soil maps and by the proxy climate regimes (fig. 6)?
 - a. Soil temperature regimes influence the ability of a species to establish and persist in a given area, and plant species composition can be used as an indicator of these regimes.
2. Do elevation and aspect place the ecological type on the upper or lower end of the soil temperature regime (for example, warm-mesic versus cool-mesic; fig. 2)?
 - a. Soil moisture and temperature regimes are gradients. Therefore, it helps to know if the ecological site is warm, mid, or cool relative to a specific soil temperature regime. This usually can be determined by the elevation and aspect of the ecological site. Indicator plant species also are helpful. North and south aspects with > 15% slope are usually adjusted 500 ft upwards or downwards, respectively.
3. Does the ecological type have a dry (aridic; 10–12 inch), moist (xeric; 12–16 inch), or very moist (xeric; > 16-inch) precipitation regime?
4. Is the soil depth very shallow (< 10 inch), shallow (10–20 inch), moderately deep (20–36 inch), or deep (> 36 inch)?
 - a. Soil depth influences the water storage capacity of the ecological site. Some very shallow soils (< 10 inch) may be mapped as dry or aridic due to limited water storage capacity even though annual precipitation is > 12 inch (moist or xeric).
 - b. A general estimate of soil depth can be determined from the shrub species or species or subspecies of sagebrush (table 3). However, digging small soil pits is the best method for determining soil depth in a proposed treatment area.
5. Is the soil texture clay, sandy, silt, loam, clay-loam, sandy-loam, or silt-loam? (See the soil texture triangle (fig. 25) in the *Glossary*.)
 - a. Texture is an important soil characteristic because it influences soil water capture and storage. Soils with loamy textures have the greatest capacity for capturing and storing water for plant use.

Table 3—Site characteristics associated with different shrub species. Values reflect those typical of the southern Great Basin/southwest Utah (Hood et al. 2007; Tuhy et al. 2014; USDA FEIS 2024; Vaughn Thacker, coauthor).

Site Characteristics				Soil Characteristics		
Species	Precipitation (in)	Elevation (ft)	Depth (in)	Moisture regime	Temperature regime	Texture
Blackbrush	10–16	3,000–8,000	< 20	Dry-moist (Aridic-Xeric)	Very warm (Hypermesic)	Shallow, stony loams
Stansbury cliffrose	10–16	3,000–8,000	> 20	Dry-moist (Aridic-Xeric)	Very warm-warm (Hypermesic-Mesic)	Stony, clayey, loamy
Basin big sagebrush	10–16	2,000–4,000	> 36	Dry-moist (Aridic-Xeric)	Warm (Mesic)	Loamy, sandy
Wyoming big sagebrush	10–16	4,000–7,000	10–30	Moist-dry (Xeric-Aridic)	Warm (Mesic)	Loamy-skeletal or clayey skeletal soils
Sonoran scrub oak	10–16	4,000–7,500	> 20	Moist-dry (Xeric-Aridic)	Warm (Mesic)	Clayey or calcareous, stony loams
Black sagebrush	12–18	4,500–10,000	< 20	Moist-dry (Xeric-Aridic)	Warm-cool (Mesic-Frigid)	Shallow, calcareous or clayey, gravelly
Utah Serviceberry	12–18	5,000–9,500	> 20	Moist (Xeric)	Warm-cool (Mesic-Frigid)	Skeletal or clayey loams
Gambel oak	> 12	3,000–8,000	> 20	Moist (Xeric)	Cool (Frigid)	Clayey, stony loams
Mountain big sagebrush	> 12	6,000–10,000	18–36	Moist (Xeric)	Cool-cold (Frigid-Cryic)	Loam, sandy, clayey or gravelly loam
Snowberry	> 14	4,800–10,000	> 20	Moist (Xeric)	Cool-cold (Frigid-Cryic)	Loam, sandy, clayey or gravelly loams
Curl-leaf mountain mahogany	> 16	7,000–10,500	> 20	Moist (Xeric)	Cool-cold (Frigid-Cryic)	Shallow and stony to moderately deep loams

Soil family names include important information on related soil characteristics that influence resilience to treatment, resistance to invasives, and potential vegetation (Appendix A). This includes information related to organic matter content (e.g., Aridisols or Mollisols), soil depth (for example, mention of a restrictive layer), texture, and the soil temperature/moisture regime (hypermesic, mesic, frigid, or cryic, and aridic or xeric).

Resilience and Resistance

Indicators of resilience and resistance are closely related to temperature and moisture regimes and were recently developed for the sagebrush biome by using climate and soil water data (Chambers et al. 2023a). For southern Utah (including the Pine Valley Ranger District), the proxy soil temperature and moisture regimes were categorized according to their relative resilience and resistance based on literature review and expert knowledge of the responses of the dominant ecological types to disturbance and management actions and to invasion by cheatgrass (Chambers et al. in process). These indicators were used to assign resilience and resistance categories to the shrublands and pinyon-juniper woodlands of the Pine Valley Ranger District (fig. 7). The resilience and resistance categories provide important insights into the likely ecological responses of the different ecological types to disturbances like wildfire and management treatments. Site level assessments of the current vegetation, disturbance history, and pretreatment fuels and fire behavior are used to determine current levels of resilience and resistance as described below.

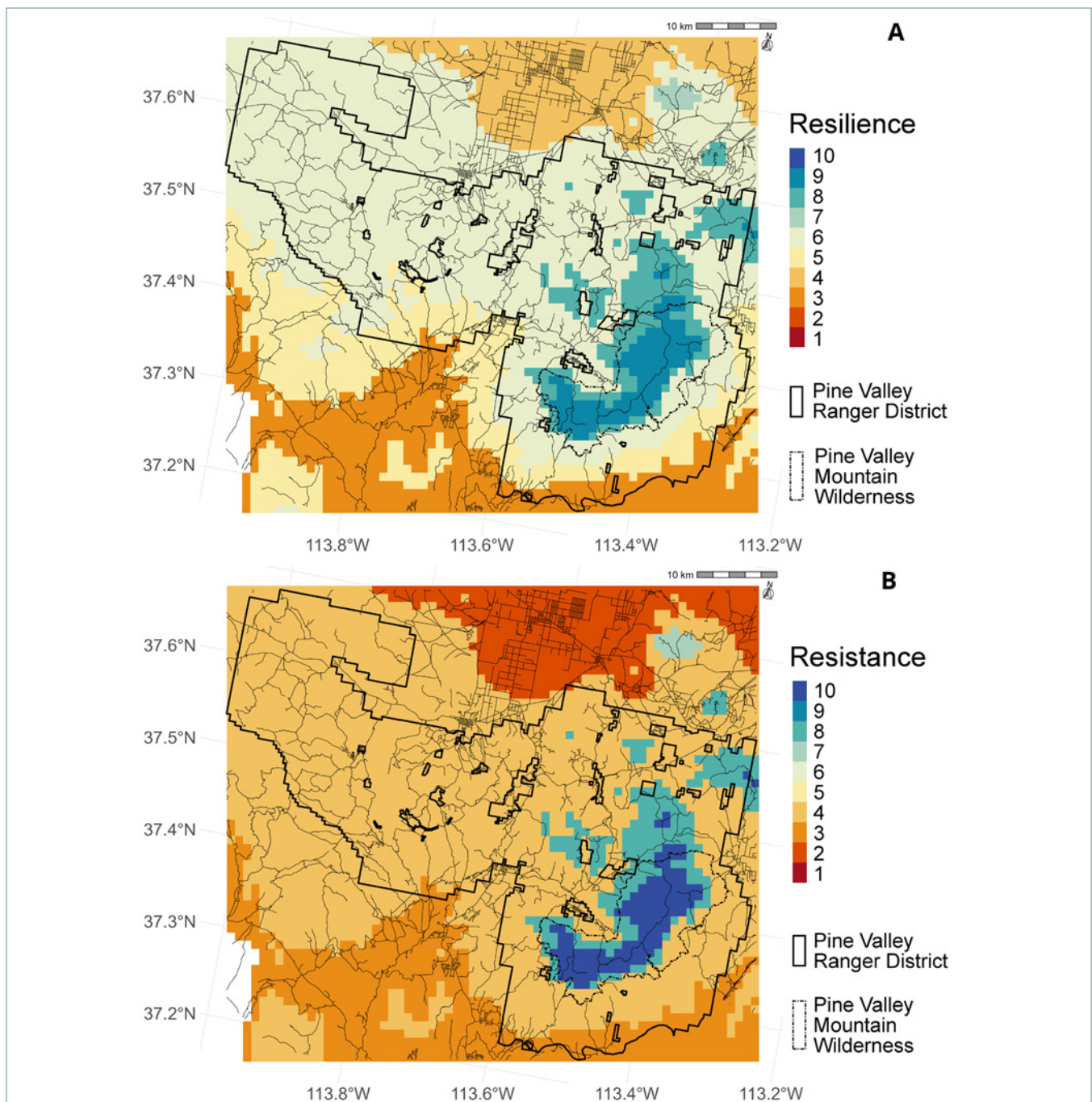


Figure 7— Maps of the indicators of (A) ecological resilience to disturbance and (B) resistance to invasion by cheatgrass for the Pine Valley Ranger District of the Dixie National Forest and Pine Valley Mountain Wilderness. The indicators were developed by categorizing the proxy soil temperature and moisture regimes (see fig. 6) according to their relative resilience and resistance based on literature review and expert knowledge of the responses of the dominant ecological types to disturbance, management actions, and invasion by cheatgrass (Chambers et al. in process). These indicators of resilience and resistance were used to categorize the shrubland and pinyon-juniper ecological types in the Pine Valley Ranger District. In general, the shrublands and woodlands of the Pine Valley Ranger District are characterized by moderate resilience and moderate to moderately low resistance. Resilience and resistance are higher in the Pine Valley Mountain Wilderness and surrounding area and lower and in the southern parts of the Pine Valley Ranger District. An understanding of the relative resilience and resistance of a proposed treatment area provides insights into the likely ecological responses to management treatments and disturbances like wildfire.

Potential Vegetation

The potential vegetation of an ecological type, as described in ESDs, is a function of ecological site characteristics (climate, topography, and soils), attributes and processes (soil moisture and temperature regime, soil processes, and vegetation dynamics), and disturbance history (fig. 1). The potential vegetation for the Pine Valley Ranger District was obtained from LANDFIRE Biophysical Settings (BpS) developed specifically for the Pine Valley Ranger District (Tuhy et al. 2014). These BpSs were used to identify the dominant shrubland and pinyon-juniper ecological types for the Pine Valley Ranger District (fig. 8). The temperature and moisture regimes and the relative resilience and resistance categories developed for the area were then determined for each ecological type. The characteristics of the ecological types in the Pine Valley Ranger District are summarized in table 1 and described in detail in Appendix E. Field assessments can ask the following questions to evaluate the potential vegetation and determine the ecological types.

1. What is the ecological type as indicated by the potential vegetation?
 - a. What are the dominant shrub species? The dominant shrub species are good indicators of both temperature and moisture regimes and soil characteristics (table 3) and can be used to determine the potential vegetation and ecological types.
 - In the Pine Valley Ranger District, blackbrush (*Coleogyne ramosissima*) and Stansbury cliffrose (*Purshia stansburiana*) characterize the warmest and driest types. Blackbrush occurs on shallow, rocky soils with a very warm (hypermesic) temperature regime and a dry (xeric to aridic) soil moisture regime. Stansbury cliffrose occurs on very warm (hypermesic) to warm (mesic) and moist to dry (xeric to aridic) soils that are moderately deep and rocky with loamy or clayey textures.
 - Sonoran scrub oak (*Quercus turbinella*), Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*), and Utah serviceberry (*Amelanchier utahensis*) occur on warm (mesic) and moist (xeric) soils with Sonoran scrub oak occurring on the warmest and driest sites. Sonoran scrub oak is characterized by relatively deep, loamy soils that are clayey or calcareous depending on geology, Utah serviceberry by moderately deep skeletal or clayey soils, and Wyoming big sagebrush by relatively shallow, clayey loam soils.
 - Black sagebrush (*A. nova*) and Gambel oak (*Q. gambelii*) occur on warm (cool mesic) and very moist (xeric) soils in the Pine Valley Ranger District. Black sagebrush is typically characterized by shallow, calcareous or gravelly soils, while Gambel oak is found on a variety of soils.
 - Species that occur at higher elevations with cool (frigid) and moist (xeric) temperature and moisture regimes and are characterized by moderately deep loams include mountain big sagebrush (*A.t.* ssp. *vaseyana*),

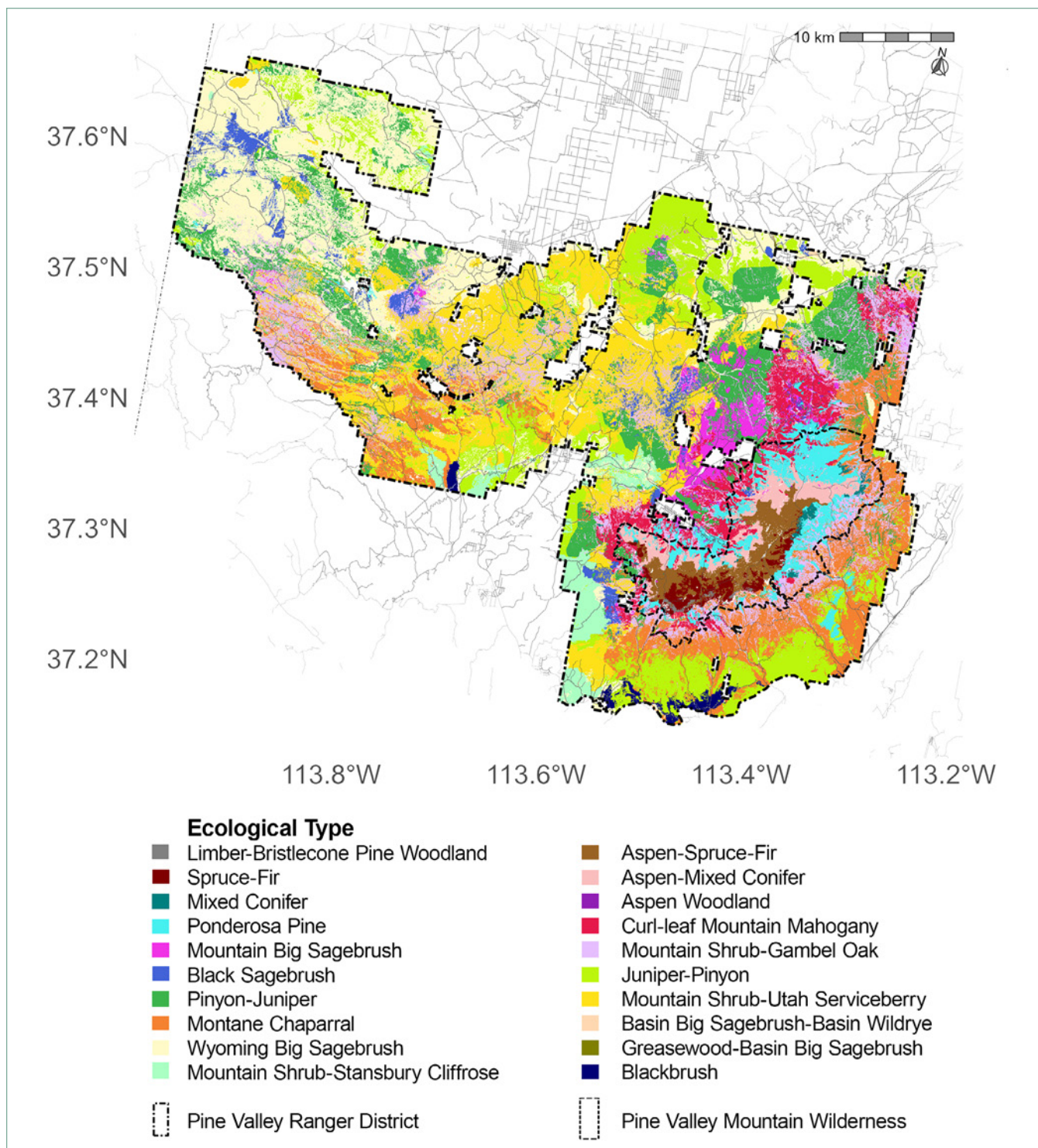


Figure 8—Map of the ecological types for the Pine Valley Ranger District of the Dixie National Forest and Pine Valley Mountain Wilderness. The ecological types reflect the potential vegetation and are based on the LANDFIRE Biophysical Settings (BpS) developed for the district (Tuhy et al. 2014).

snowberry (*Symphoricarpos* sp.), and curl-leaf mountain mahogany (*Cercocarpus ledifolius*).

b. What are the perennial grass species that characterize the potential vegetation of a site?

- The perennial grass species used to identify the potential vegetation are typically common or dominant in the reference and current potential states of the ecological type (Stringham et al. 2015; Appendix E). Like shrub species, perennial grasses are general indicators of temperature and moisture regimes (fig. 9) as well as soil depth and texture. For example, James' galleta (*Pleuraphis jamesii*) is an indicator of very warm (hypermesic to mesic) and generally dry (aridic) conditions, while slender wheatgrass (*Elymus trachycaulus*) is an indicator of cool to cold (frigid to cryic) and moist (xeric) conditions.
- Several grass species indicate excessive livestock grazing and likely decreases in other more palatable native grasses. These include low-growing bunch grasses, mat-forming grasses, and grasses with awned spikelets. Species that indicate excessive livestock grazing include blue grama (*Bouteloua gracilis*), sand dropseed (*Sporobolus cryptandrus*), and purple threeawn (*Aristida purpurea*) on warmer and dryer sites, mat muhly (*Muhlenbergia richardsonis*) and mountain muhly (*Muhlenbergia montana*) on cooler sites, and muttongrass (*Poa fendleriana*), needle and thread (*Heterostipa comata*), and squirreltail (*Elymus elymoides*) across a range of site conditions.

c. Are pinyon and juniper trees present on the site?

- Pinyon and juniper trees are often part of the species composition of shrublands that are climatically suitable for the trees. The trees can be listed in the reference and current potential states as well as other ecological states of shrubland ecological sites (Stringham et al. 2015; Appendix E). Old growth pinyon-juniper ecological site types are defined by the presence of trees that established prior to settlement and are > 150 years old. These types occur on specific kinds of ecological sites and are described by the dominant tree, shrub, and grass species that comprise the potential vegetation of the site. Examples of old growth pinyon-juniper ecological site types for Major Land Resource Area 28 are: Utah juniper/black sagebrush/Indian ricegrass-needle and thread (*Juniperus osteosperma*/*Artemisia nova*/*Achnatherum hymenoides*-*Heterostipa comata*), which occurs on relatively warm (mesic) and dry to moist (aridic to xeric) sites, and singleleaf pinyon/mountain big sagebrush/bluebunch wheatgrass-muttongrass (*Pinus monophylla*/*Artemisia tridentata* ssp. *vaseyana*/*Psuedoroegneria spicata*-*Poa fendleriana*), which occurs on relatively cool (cool mesic to frigid) and moist (xeric) sites (Stringham et al. 2015). The terms used to describe woodlands are in the *Glossary* and the types of woodlands are described in Section 2 below.

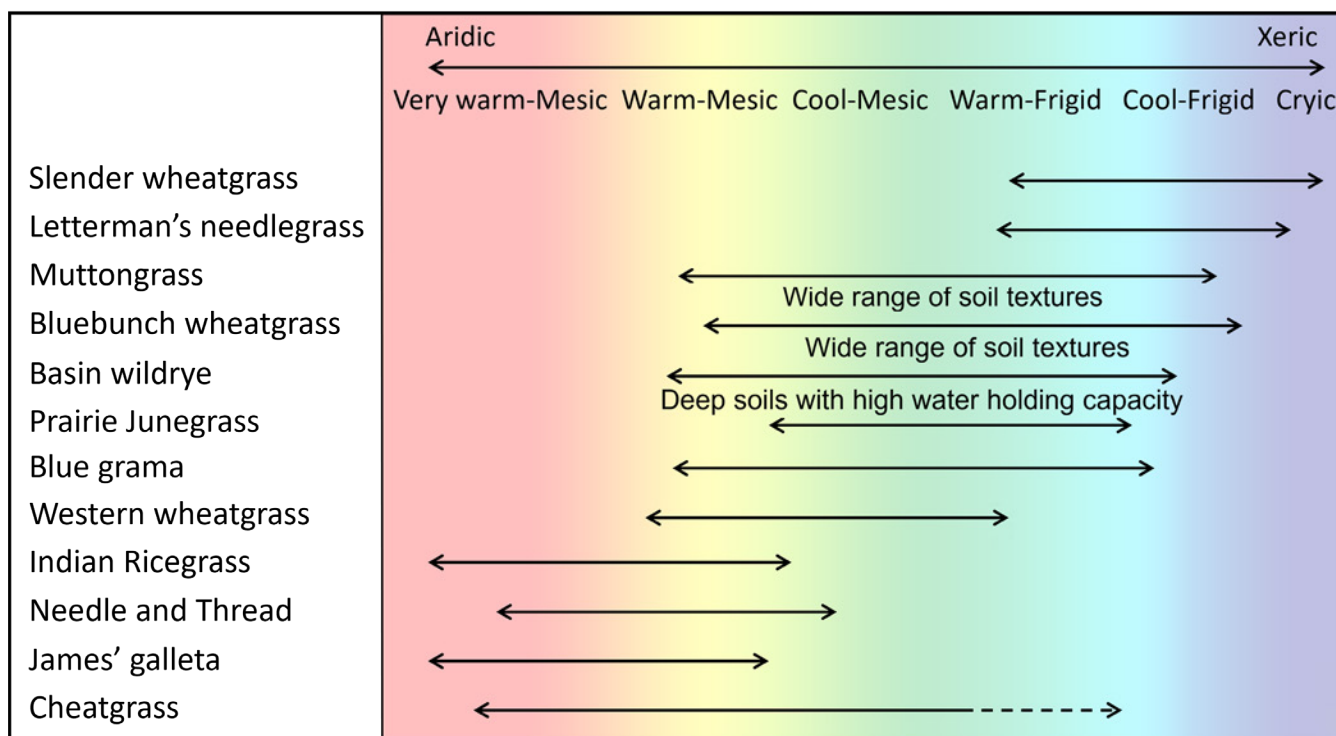


Figure 9—The general distribution of common native perennial grasses and cheatgrass across soil temperature and moisture gradients on the Pine Valley Ranger District of the Dixie National Forest.

2 Current Vegetation

Current vegetation plays a major role in the recovery of an ecological type following treatment or disturbance. The persistence and abundance of perennial vegetation immediately following treatment are primary drivers of resilience and resistance and therefore both short- and long-term site recovery (fig. 10). Posttreatment persistence and abundance of perennial vegetation are functions of pretreatment plant community composition and structure. The descriptions of vegetation departure and state-and-transition models in Appendix E provide information on the possible states and phases for the different ecological types in the Pine Valley Ranger District. The proportional cover of shrubs, perennial grasses and forbs, annual forbs and grasses, and trees for the shrubland and old growth pinyon-juniper ecological types can be obtained from landscape-scale spatial data, like the Rangeland Analysis Platform (Allred et al. 2021; table 1, fig. 11). However, field assessments are required to understand the current vegetation and the dominant ecological states of potential treatment areas.

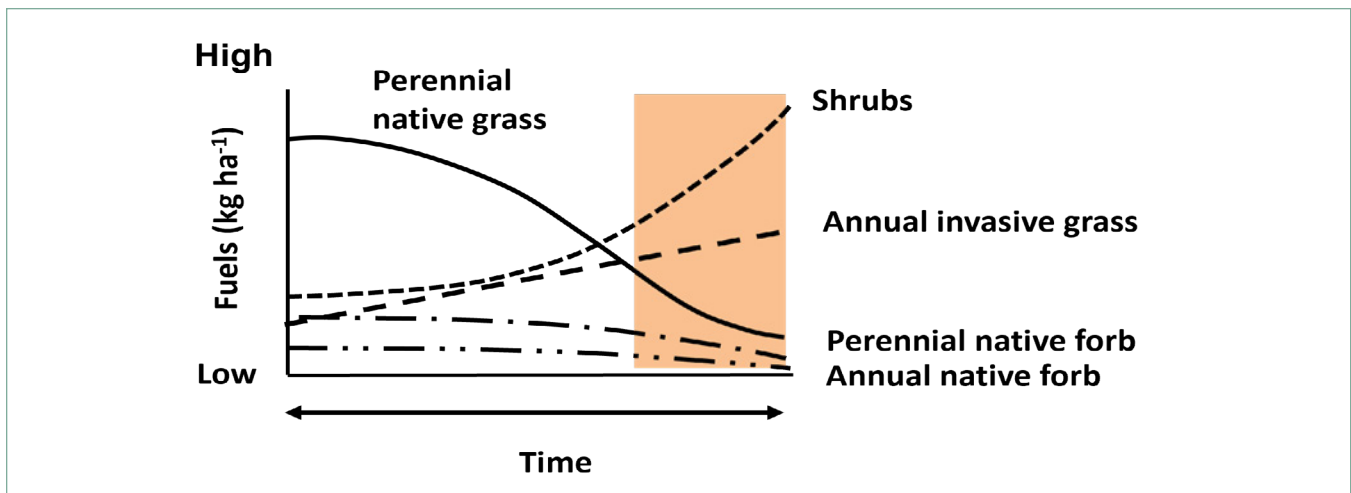


Figure 10—A conceptual model of the changes in fuel types over time in sagebrush dominated ecosystems that are not experiencing pinyon-juniper expansion. Increases in shrub fuels occur over time through a combination of succession, fire suppression, or livestock grazing and can result in decreases in native perennial grasses and native perennial and annual forbs. In warmer and drier ecosystems with relatively low resilience and resistance, native perennial grasses and forbs decrease while nonnative invasive annual grasses increase. Ecosystems with high levels of shrub and/or invasive annual grass fuels are at risk of transitioning to alternative states dominated by invasive annual grasses following wildfire or management treatments that remove shrubs (indicated by the shaded area). Figure from Chambers et al. 2024.

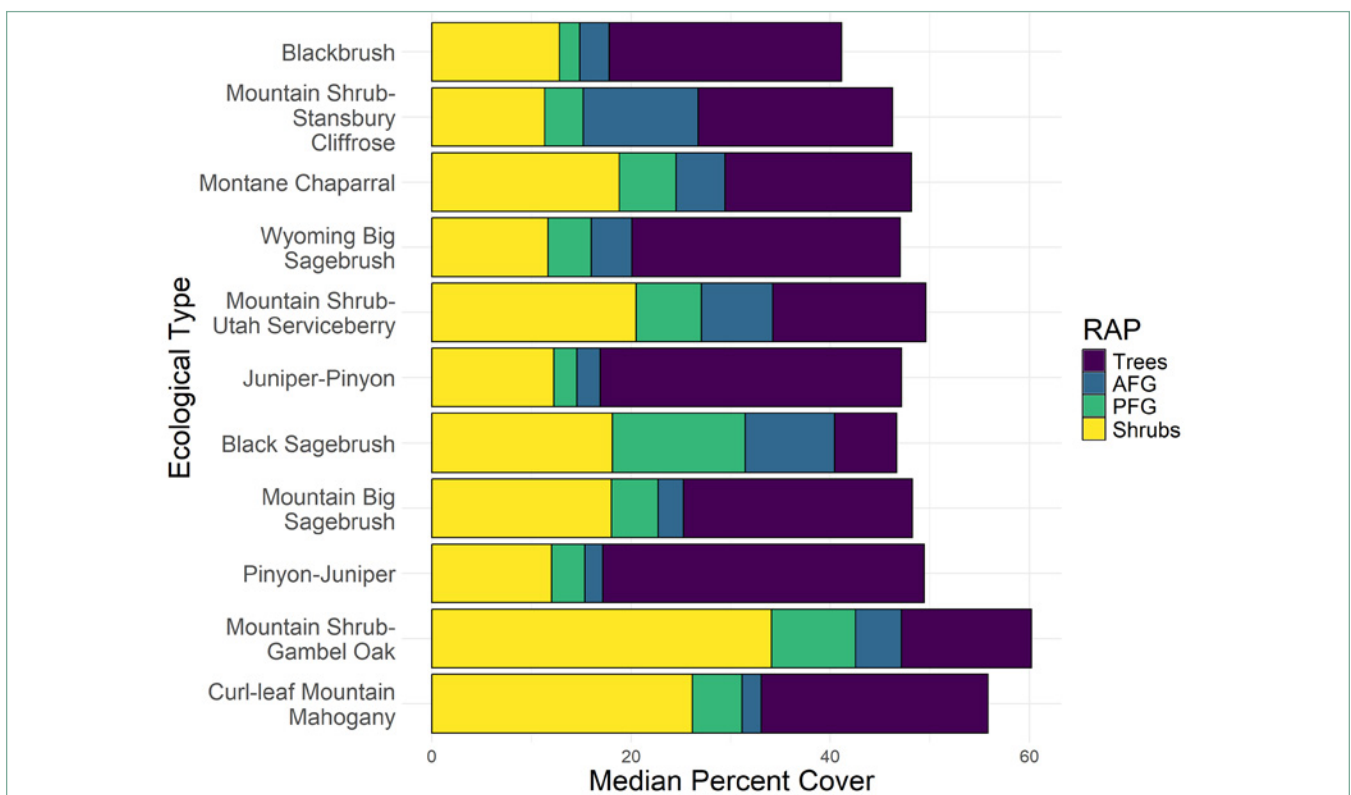


Figure 11— The shrub, perennial forb and grass, annual forb and grass, and tree cover for the dominant shrubland and pinyon-juniper ecological types in the Pine Valley Ranger District of the Dixie National Forest. The data are from the Rangeland Analysis Platform (RAP; Allred et al. 2021) which are derived from Landsat imagery at a scale of 30 m. Values represent averages for a 5-year period (2018-2022). These data are useful for understanding the dominant ecological states within an ecological type, but field assessments are needed to assess the potential of an area for treatment.

Shrubs

1. What is the composition and structure (cover and/or density) of the dominant shrubs?
 - a. Disproportionately high cover or overly dense shrubs with depleted perennial grasses and forbs in the understory can indicate excessive livestock grazing or overly long fire-return intervals and a decrease in resilience and resistance (fig. 10). Dominance by fire-tolerant species, like rabbitbrush (*Chrysothamnus* sp.) and broom snakeweed (*Gutierrezia sarothrae*), with few perennial grasses and forbs in the understory, can indicate the combination of excessive grazing and frequent fire.
 - b. A patchy distribution of indicator shrubs for the type with native perennial grasses and forbs in understory indicates a community that is near the reference state.

Perennial Grasses and Forbs

2. What is the composition and structure (cover and/or density) of perennial native grasses and forbs?
 - a. Severely depleted to depleted perennial native grasses and forbs can indicate excessive livestock grazing in combination with a lack of fire in shrub-dominated ecological types.
 - b. Perennial native grasses are *severely depleted* if: (1) perennial grasses are < 5% aerial cover for moist (xeric) conditions and < 3% aerial cover for dry (aridic) conditions; and (2) invasives are dominant or, if invasives are not dominant, woody species (shrubs or trees) are near maximum cover.
 - c. Perennial native grasses are *depleted* if: (1) perennial grasses are 5–10% aerial cover for moist (xeric) conditions and about 5% aerial cover for dry (aridic) conditions. Invasives may be codominant, or if invasives are not codominant, woody species (shrubs or trees) have high cover.
 - d. A patchy distribution of shrubs with native perennial grasses and forbs in the understory and few invasive annuals indicates a community that is near the reference state.

Invasive Annual Grass Potential

3. What is the potential for nonnative invasive annual grasses and forbs to increase based on site characteristics (figs. 1 and 2)?
 - a. Resistance to invasion depends on (1) suitability of the climate and soils of the site for establishment, growth, and reproduction of the invading species, and (2) competitive interactions among the invading species and the native species on the site (Chambers et al. 2014b, 2019).

- The presence and relative abundance of invasive species that are likely to increase following treatment strongly influences posttreatment recovery. Invasive species are adapted to different soil temperature and moisture regimes and thus different invaders are likely to occur on different ecological types (Appendix E). For example, red brome (*Bromus rubens*) occurs primarily on very warm (hypermesic) and dry to moist (aridic to xeric) sites. Cheatgrass (*Bromus tectorum*), the most widespread and problematic invader, occurs on very warm to warm cool (hypermesic to warm-frigid) and dry to moist (aridic to xeric) sites but is limited on cool to cold (cool frigid to cryic) sites.
 - Competition with invasive grasses and forbs increases as (1) temperature and moisture regimes become more favorable for plant growth and site productivity increases, and (2) the relative abundance of perennial grasses and forbs, the strongest competitors with annual invaders, increases. In general, very warm and warm (hypermesic and mesic) and dry to dry moist (aridic to dry-mesic) sites with lower productivity and less cover of perennial grasses and forbs have the least resistance to invasive grasses and forbs. Resistance increases as temperature and moisture regimes become cooler and moister, site productivity increases, and the cover of perennial grasses and forbs increases (fig. 2). Disturbances and management activities that decrease perennial grasses and forbs reduce relative resistance to invasive species regardless of temperature and moisture regime and ecological type.
- b. The densities, cover, and biomass of annual species are highly variable among years, and values obtained in a dry year often do not reflect those obtained in an average or wet year. This annual variability must be considered when evaluating the potential for an invasive species to increase following treatment. *On mesic-aridic ecological sites, annual grass and forb cover in one long-term study varied by > 10% among years after prescribed fire and mechanical treatments* (Chambers et al. 2014b).

Pinyon Pine and/or Juniper Expansion versus Old Growth?

4. If pinyon pine and/or juniper are present on the proposed treatment area, is the ecological type a shrubland with pinyon-juniper expansion or is it an old growth woodland?
 - a. Areas with pinyon pine and/or juniper present can be comprised of: (a) old growth trees located on specific types of soils, such as coarse or shallow, or topographic positions, such as ridges; (b) postsettlement trees expanding into shrublands where old growth trees are either absent or isolated to specific soils and topographic positions; (c) shrubland areas infilled with postsettlement trees that may have low densities of old trees.
 - Spatial data can be used to help differentiate old growth woodlands from pinyon-juniper expansion into shrublands at landscape scales. The

Forest's Vegetation Classification, Mapping, and Quantitative Inventory (VCMQ) provides spatial data on pinyon pine and juniper stand cover by tree diameter size class (USDA Forest Service 2016). The spatial data from the VCMQ on the characteristics of the woodlands can be mapped (fig. 12) and summarized by ecological type to help inform selection of treatment areas (fig. 13).

- To clearly differentiate areas of expansion into shrublands from old growth woodlands, it is always necessary to evaluate site characteristics, tree age, and tree morphology in the field (see woodland definitions in the *Glossary* and Appendices B1 and B2). Expansion areas are characterized by trees that are mostly young (< 150 years) and sites that have been predominantly shrublands historically. Fire-return intervals of less than 40–50 years in cooler, moister ecological types, can result in a tree dominated state where there is a pinyon pine and/or juniper seed source nearby (fig. 14).
 - The density, canopy cover, and age structure of the trees can be used to determine the phase of expansion (I, II, or III) into the shrublands (fig. 15; *Glossary*). The phase of expansion determines the tree cover and biomass, and thus the feasibility of conducting treatments and likely outcomes in terms of fuels, fire behavior, and the ecological response.
 - Old growth woodlands are characterized by trees that are mostly > 150 years old. Old growth trees have a characteristic morphology that can be used to determine approximate tree ages and differentiate old growth woodlands (Appendices B1 and B2). Old growth woodlands are often located on shallow (< 0.5-m deep), rocky soils and certain landscape positions, such as ridges (Burkhardt and Tisdale 1976), while younger trees and are typically associated with deeper, less rocky soils (Romme et al. 2009; Stringham et al. 2015).
 - To differentiate expansion from old growth, it is necessary to ask, what is the distribution of the old trees across the treatment area? Do they occur in small patches on shallow soils or particular landscape positions, or do they occur across most of the area?
 - Are there large stumps, burned snags, or logs indicating mortality of large trees during a past fire? If yes, would the projected tree cover (based on density of stumps, snags, and logs) have been relatively low (10–20%), which is characteristic of many old growth woodlands in the reference state?

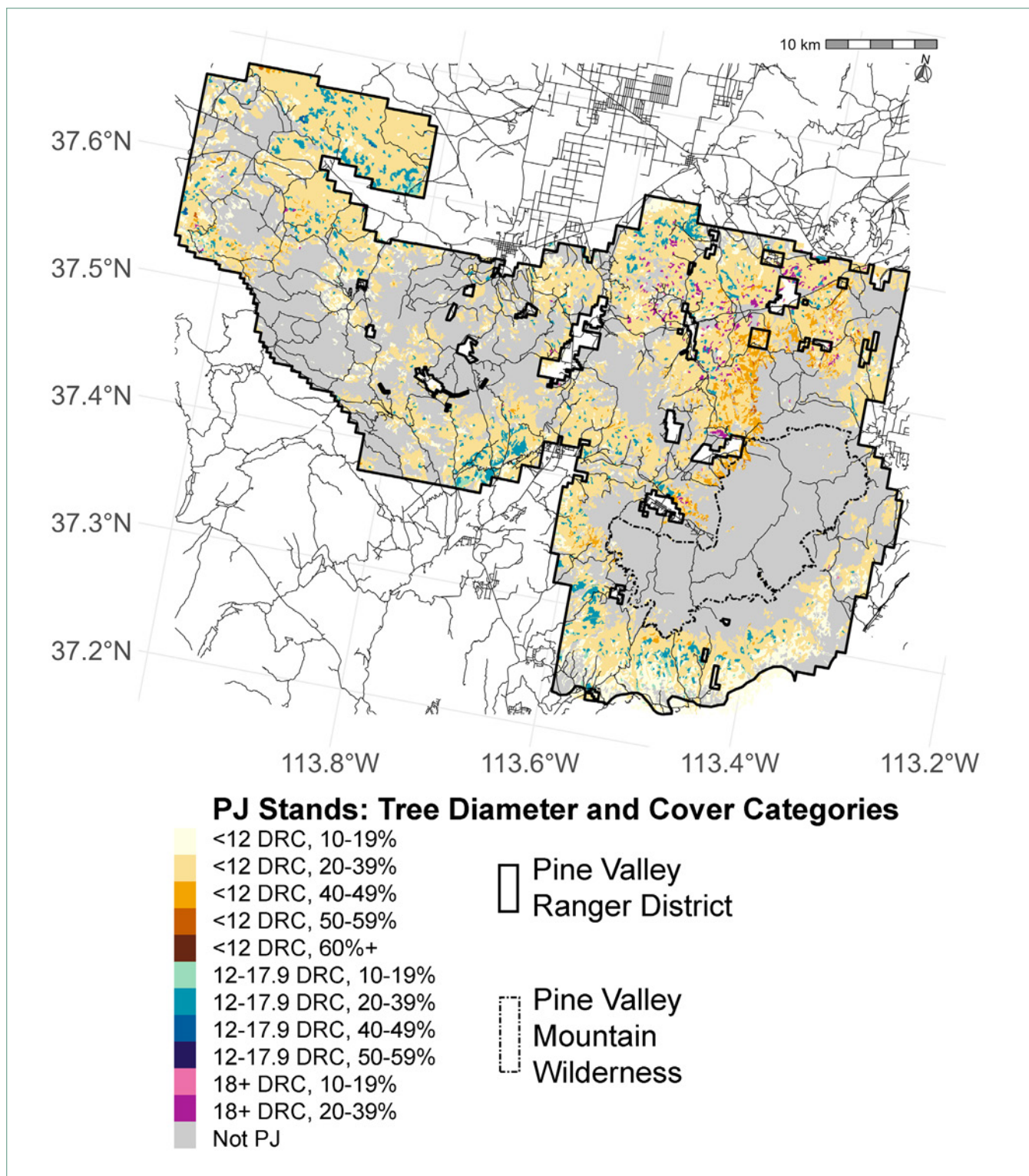


Figure 12—Map of pinyon-juniper stands categorized by percent aerial cover and tree diameter at the root collar (DRC) in inches for the Pine Valley Ranger District and the Pine Valley Mountain Wilderness. Diameter at the root collar is in inches, and cover is percent cover from above. Stand locations and attributes are from the Dixie National Forest's Vegetation Classification, Mapping, and Quantitative Inventory (VCMQ) Program Report for 2016 (USDA Forest Service 2016). These data provide information on the potential locations of expansion and old growth woodlands.

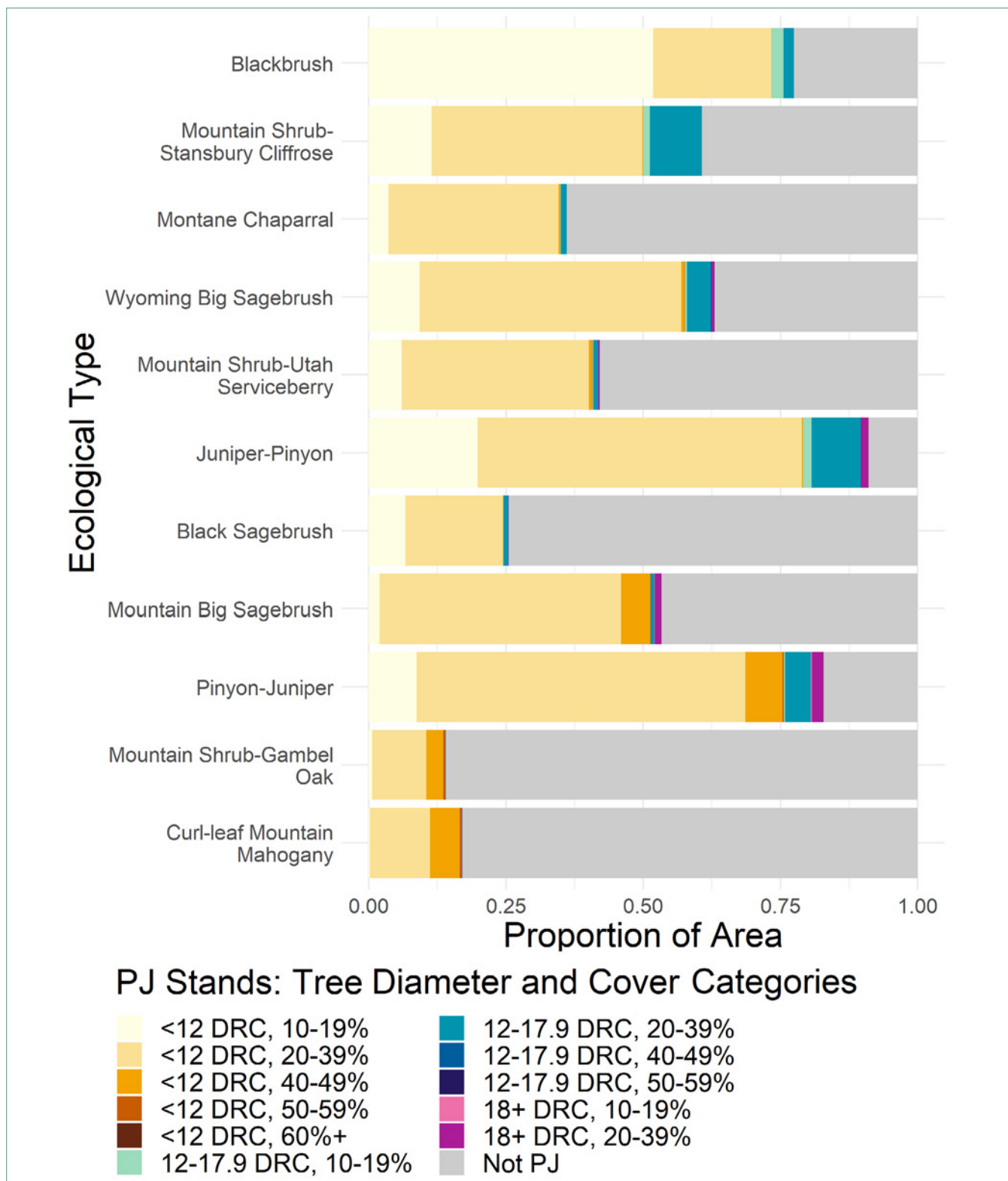


Figure 13—Proportion of area of the dominant shrubland and woodland ecological types occupied by pinyon juniper stands in the Pine Valley Ranger District. Stands are categorized by diameter at root collar (DRC; inches) and cover (% cover from above). Stand locations and attributes are from the 2016 Dixie National Forest's Vegetation Classification, Mapping, and Quantitative Inventory (VCMQ) Program Report (USDA Forest Service 2016).

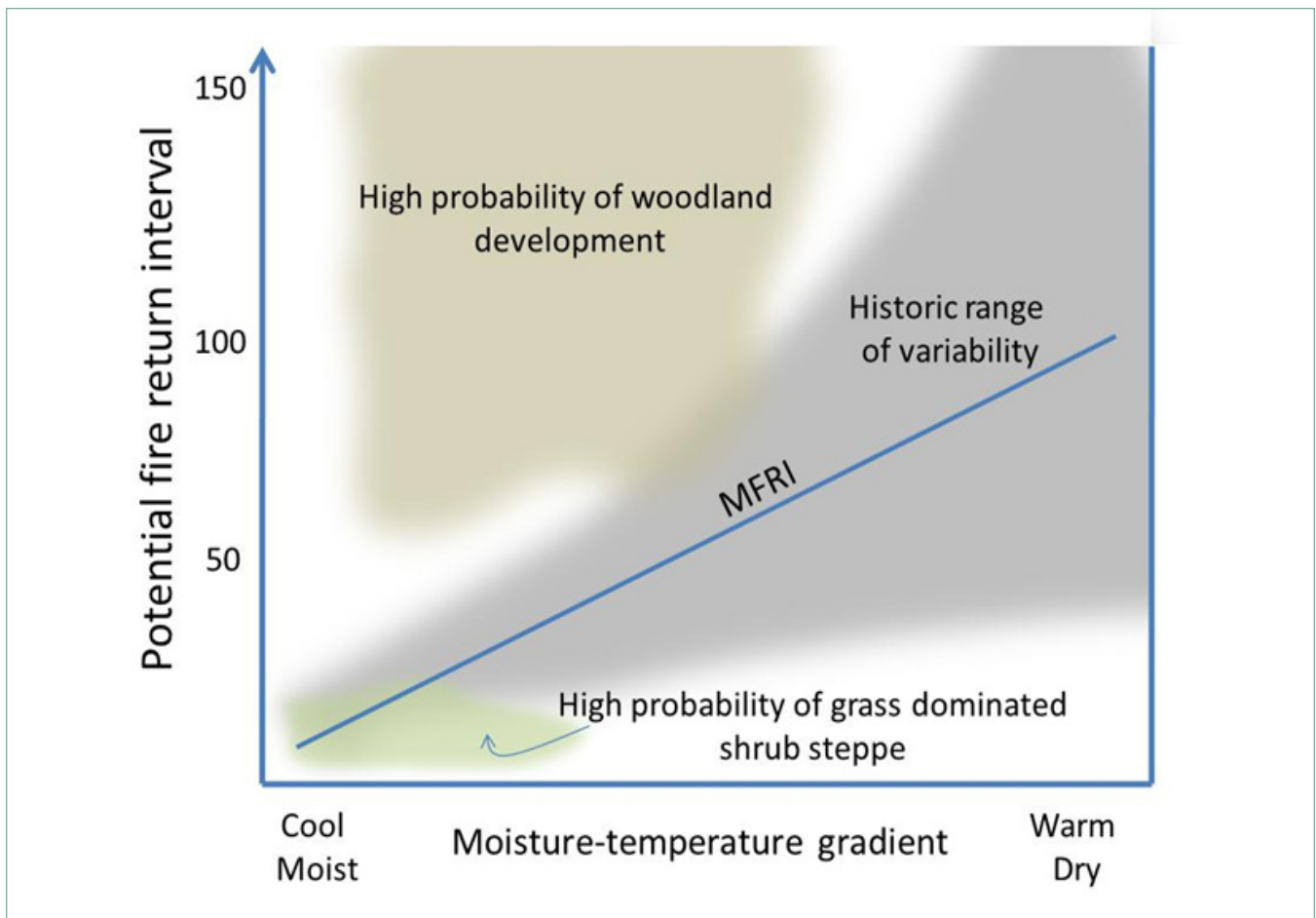


Figure 14—A conceptual model illustrating the range of potential historic mean fire-return intervals (MFRI, years between fires) for sagebrush ecosystems across the Great Basin. MFRI increases along a temperature and moisture gradient from cool-moist to warm-dry due to decreasing fuel abundance and continuity. The combination of temperature, water availability, and fire regime influences the potential natural vegetation that can persist as illustrated in this model: sagebrush ecosystems (gray); historic woodlands (brown); and grasslands (green). Persistent vegetation occupying the gray area likely represents a mix of shrubs and herbaceous species with the relative abundance of each dependent on time since fire and ecological site characteristics. Packrat-midden and pollen data indicate that the proportion of each plant community type across the Great Basin has been dynamic during the Holocene (last 10,500 years) due to shifting climate and fire regimes. From Miller et al. 2011.

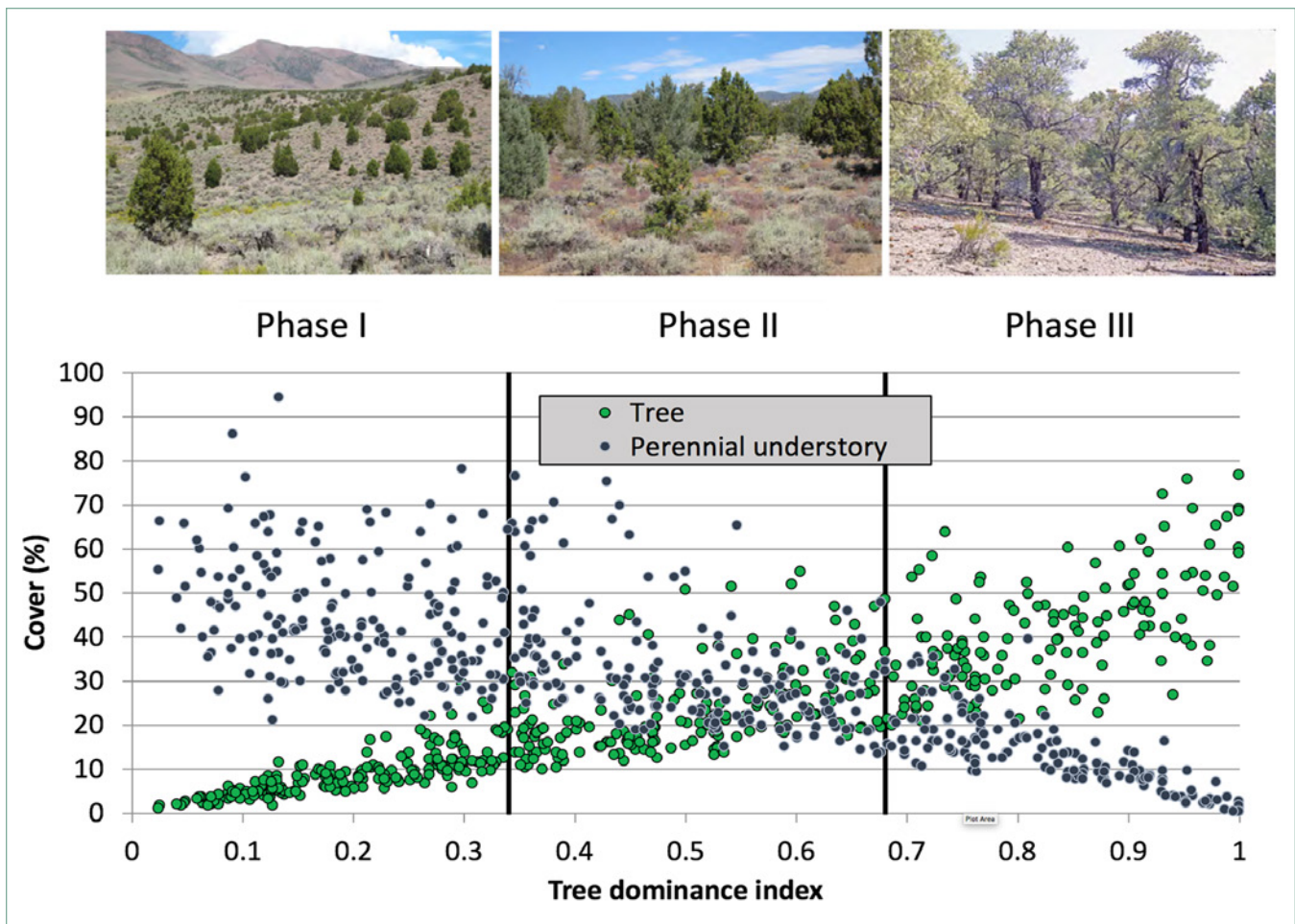


Figure 15—Changes in perennial understory cover and tree dominance index (tree cover/ [tree+shrub+tall perennial grass cover]) for 11 Great Basin sagebrush shrubland sites with woodland expansion ranging from phase I to phase III (see the *Glossary* for a complete description of phases and the tree dominance index). The wide variation is largely a result of differences in ecological site characteristics. Figure from Roundy et al. 2014.

3 Disturbance and Management History

Past disturbances and management influence the types of management activities needed to maintain resilience and resistance and to meet current objectives. The Pine Valley Ranger District has experienced large wildfires in recent decades (fig. 16) and has a long history of conducting management treatments (fig. 17).

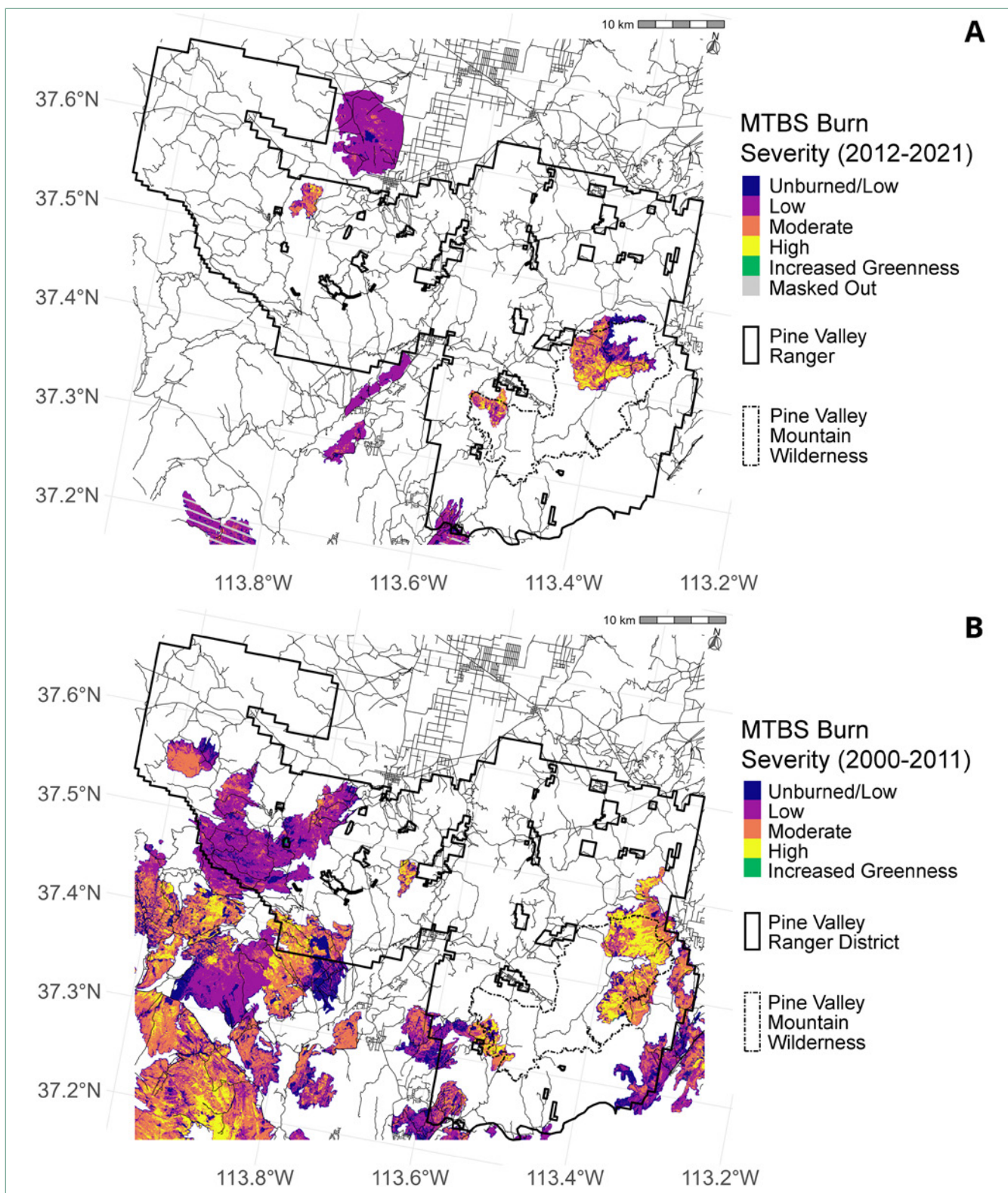


Figure 16—Maps of fire history for the Pine Valley Ranger District and the Pine Valley Mountain Wilderness. Colors within the fire perimeters show estimated burn severity from the Monitoring Trends in Burn Severity (MTBS) program (MTBS 2023). Fires from 2012 through 2021, specifically in 2012, 2016, 2018 and 2020, are shown in (A). Fires from 2000 through 2011, specifically in 2002, 2004, 2005, 2006, and 2009, are shown in (B). Colors within the fire perimeters show estimated burn severity from the Monitoring Trends in Burn Severity (MTBS) program (MTBS 2023).

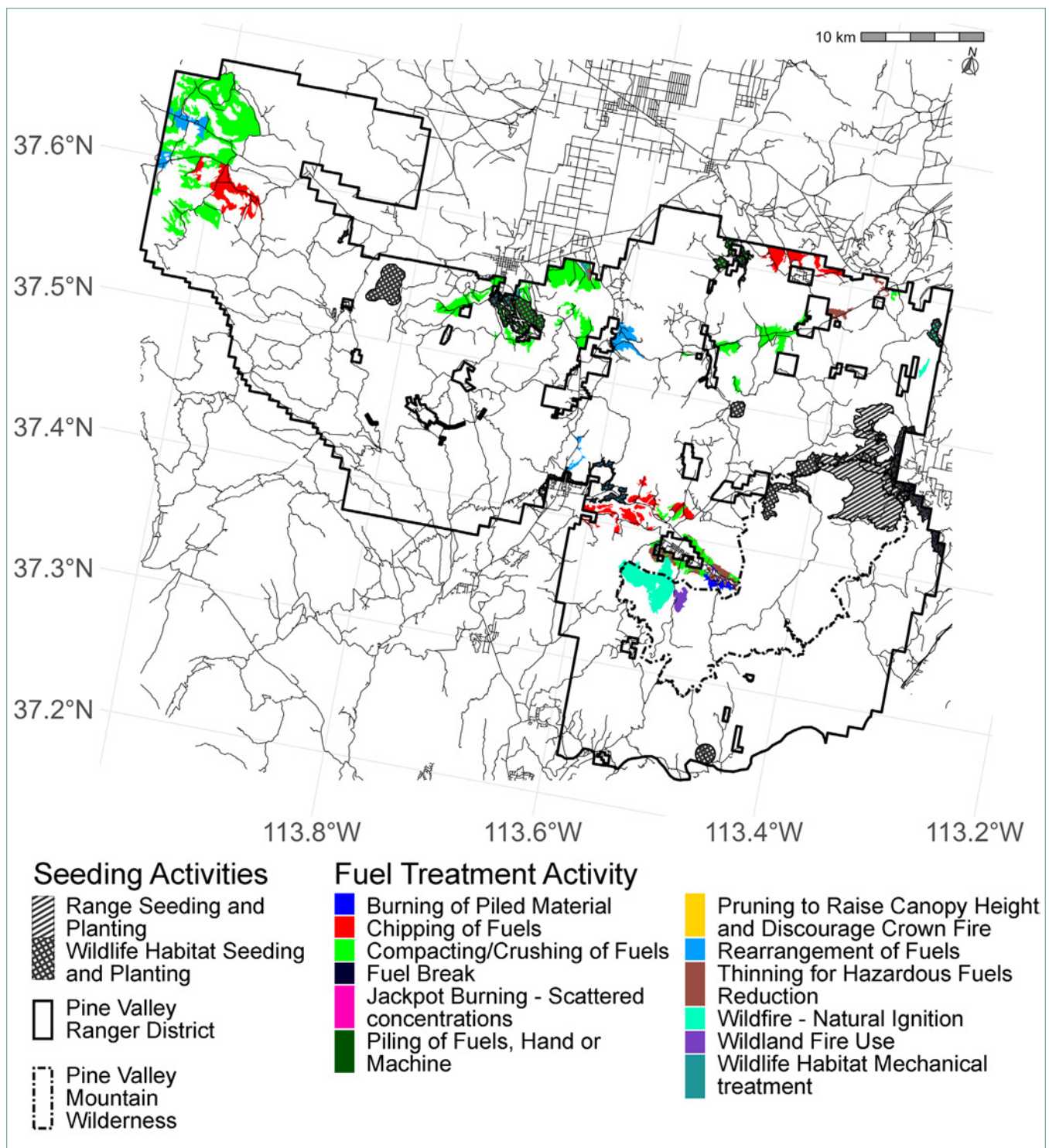


Figure 17—Map of past treatments for the Pine Valley Ranger District and the Pine Valley Mountain Wilderness. Records of restoration by seeding (hatched lines) date from 2009-2018, and fuel treatments (color coded) date from 2006-2023. The map does not include the extensive pinyon-juniper treatments and seeding that occurred prior to the mid-2000s.

1. How has disturbance history or past management affected current vegetation structure and composition?
 - a. How long has it been since the last wildfire and how does the current vegetation composition and structure affect treatment objectives? The length of time since the last wildfire influences the relative abundances of trees, shrubs, grasses, and forbs. Areas that burned relatively recently are less likely to require treatments to reduce woody fuels. However, if these areas experienced increases in invasive annual grasses, they may require changes in livestock management or other treatments to allow recovery of native perennial shrubs, grasses, and forbs.
 - b. How did postsettlement pinyon-juniper harvesting affect current shrubland and pinyon-juniper ecological types? Management objectives may differ if postsettlement harvesting was in expansion areas versus old growth woodlands.
2. Are past pinyon-juniper treatments in expansion areas experiencing infilling due to the growth of saplings and new seedlings, and is retreatment required? Treated areas with infilling are frequently retreated to remove young trees. Retreatment intervals depend on the site conditions with cooler and moister sites receiving more frequent treatments than warmer and drier sites.

4 Fuels, Fire Behavior, and Appropriate Treatments

The appropriate treatment for a given ecological type depends on the characteristics of the vegetation and fuels and the likely consequences for fire behavior if a wildfire occurs after treatment. Selection of the appropriate treatment also is influenced by the potential ecological effects of treatment (see *5-Treatment Severity and Ecological Response*).

Shrublands

Primary considerations for selecting treatments in shrublands are the type of shrubland, its temperature and moisture regime, relative resilience and resistance, and fuel characteristics (table 1).

1. Is this a warm and dry shrubland with low productivity and relatively low resilience and resistance, or is it a cool and moist shrubland with higher productivity and resilience and resistance?
2. Are the dominant shrub species fire/disturbance tolerant (table 4)?

Table 4—Fire adaptations of common shrubland species. Each species is rated on a scale of 0 to 4 for each area of adaptation where 0 indicates no adaptation and 4 indicates the species is highly adapted. Adapted from Kitchen and McArthur (2007) and USDA FEIS (2024).

Scientific name	Common name	Resprouting capability	Seed dispersal distance	Seed bank
<i>Amelanchier alnifolia</i>	Saskatoon serviceberry	4	3	1
<i>Amelanchier utahensis</i>	Utah serviceberry	4	3	1
<i>Arctostaphylos patula</i>	greenleaf manzanita	4	2	4
<i>Arctostaphylos pungens</i>	pointleaf manzanita	0	—	4
<i>Artemisia tridentata</i>	big sagebrush	0	1	1
<i>Ceanothus greggii</i>	desert ceanothus	0	1	4
<i>Cercocarpus montanus</i>	alderleaf mountain mahogany	3	3	1
<i>Chrysothamnus</i> spp.	rabbitbrush	4	4	0
<i>Coleogyne ramosissima</i>	blackbrush	0	1	1
<i>Ephedra nevadensis</i>	Nevada jointfir	3	1	2
<i>Gutierrezia</i>	snakeweed	4	4	0
<i>Purshia glandulosa</i>	desert bitterbrush	4	2	—
<i>Purshia mexicana</i>	Stansbury cliffrose	1	4	2
<i>Purshia tridentata</i>	antelope bitterbrush	2	2	2
<i>Quercus gambelli</i>	Gambel oak	4	2	1
<i>Quercus turbinella</i>	Sonoran scrub oak	4	2	1
<i>Rhus aromatica</i>	fragrant sumac	4	2	3
<i>Rhus trilobata</i>	skunkbush sumac	4	2	3
<i>Ribes cereum</i>	waxleaf current	2	3	3
<i>Symphoricarpus oreophilis</i>	mountain snowberry	3	1	1

— Indicates no data

3. What is the dominant ecological state of the shrubland (table 1, Appendix E)?

- a. The temperature and moisture regime, disturbance tolerance of the dominant shrubs, and current ecological state or degree of departure are considered together when selecting the appropriate treatments (see review in Chambers et al. 2024).
 - *Prescribed fire* is generally not appropriate for very warm (blackbrush) to warm (montane shrub-Stansbury cliffrose, montane chaparral) ecological types due to relatively slow recovery and high risk of increases in invasive annual grasses and forbs (fine, continuous fuels). Exceptions are small patchy burns to break up crown fuels in areas with decadent shrubs where sufficient perennial grasses and forbs exist to promote recovery, and the risk of increases in annuals is very low. Prescribed fire

can be used in cool-warm to cool (cool mesic to frigid) and moist (xeric) shrublands (Wyoming big sagebrush, mountain shrub-Utah serviceberry, mountain shrub-Gambel oak, mountain big sagebrush) to decrease woody fuel. However, sufficient perennial grasses and forbs to promote recovery and very low risk of increases in invasive annual fuels are still required. In sagebrush ecosystems, prescribed fire decreases fuel loads of all fuel types in years 1 and 2; subsequent increases vary by fuel type and depend on site conditions and pretreatment species composition (Ellsworth et al. 2022; Miller et al. 2013). Prescribed fire can decrease the rate of wildfire spread until herbaceous fuels increase. Longer-term reductions in flame length and fire intensity depend on the rate of shrub establishment and/or regrowth. Patchy burns conducted when the risk of high-severity fire is low (e.g., winter) will likely be most effective in restoring historic fire regimes, promoting recovery, and maintaining shrubland habitat (Miller and Rose 1999).

- *Mechanical treatments* to reduce woody fuels are generally inappropriate for very warm to warm shrublands due to the potential for surface disturbance and the high risk of increases in invasive annual grasses and forbs (see review in Chambers et al. 2024). Mechanical treatments may be appropriate in cooler and moister shrublands with sufficient perennial grasses and forbs to promote recovery and very low risk of increases in invasive annual fuels. In sagebrush ecosystems, mowing with a rotary cutter shifts woody fuel from shrub canopy to herbaceous, downed wood, and litter layers, and can result in reductions in rates of spread, flame lengths, and reaction intensity relative to controls (Ellsworth et al. 2022).

Pinyon Pine and/or Juniper Expansion Versus Old Growth?

Primary considerations for selecting treatments in shrublands experiencing pinyon-juniper expansion and pinyon-juniper woodlands are the ecological type, its temperature and moisture regime, and its relative resilience and resistance (table 5). An additional consideration is that different types of treatments vary in terms of residual fuels and these differences can have large effects on fire behavior and fire severity in a subsequent wildfire (figs. 18, 19).

Table 5—The vegetation/fuel structure, potential fuel treatments, fuels and fire behavior following treatment, and ecological responses to treatment for expansion and old growth woodlands. Potential treatments and subsequent fire behavior are based largely on Chambers et al. 2024. See Appendix E for additional management recommendations. R&R = resilience and resistance. (Condensed table available in Appendix F.)

Vegetation/fuel structure		Potential treatment(s)	Fire and fuels management	Ecological effects
Expansion woodlands Phase I and II	Warm and dry	Utah juniper dominant and pinyon subdominant	Following mechanical treatment, fine herbaceous fuel can increase causing greater fire spread and flame length in future wildfires	Tradeoffs exist between increasing perennial grasses and forbs, and thus R&R, and increasing fire spread in future wildfires
	Low to moderately low R&R	Phase I and II: < 20% tree cover	Seeding should be considered	
		Lower cover on less productive sites	Prescribed fire has high risk of invasive annuals and slow recovery without successful seeding	Pretreatment cover of trees and perennial grasses and forbs largely determines invasion risk
		High potential for invasive annuals (fine herbaceous fuel)	Lop and scatter increases woody surface fuels and risk of high severity fire	Retreatment is required within about 30–40 years
		Pinyon dominant and Utah juniper subdominant	Prescribed fire appropriate given enough perennial grasses and forbs to promote recovery and prevent invasion	Seeding natives preferred, but success may be low
Phase III	Cool and moist	Phase I and II: < 30% tree cover	All treatments eliminate risk of crown fire	Tradeoffs exist between increasing perennial grasses and forbs and fire spread in future wildfires
	Moderate to high R&R	Lower cover on less productive sites	Increases in fine herbaceous fuel	Invasion risk increases with depleted perennial herbs and on warmer aspects
		Lower potential for invasive annuals (fine herbaceous fuel)	Mechanical treatments, i.e., cut and pile burn, cut and broadcast burn, and mastication usually appropriate	Retreatment is required within about 15–30 years
	Warm and dry	Utah juniper dominant and pinyon subdominant	Complete removal not recommended due to high amounts of woody fuels	Thinning may increase stand health and improve habitat
	Low to moderately low R&R	Phase III: > 20% tree cover	Potential to use mechanical treatments to decrease crown fire risk next to communities and manage for high value resources	High risk of annual grass invasion and increases in fine herbaceous fuel
		Understories depleted and high potential for invasive annuals	Fine herbaceous fuels may increase posttreatment, elevating the potential for fire spread	Soil erosion may occur
		Potential for soil erosion	Selective thinning to reduce or modify woody fuel with cut and pile burn or mastication likely to be most successful	Seeding success of natives may be low; may convert the site to nonnative seeded species if introduced grasses and forbs are used
			Seeding will be required	

Vegetation/fuel structure		Potential treatment(s)	Fire and fuels management	Ecological effects
Phase III	Cool and moist Moderate to high R&R	Pinyon dominant and Utah juniper subdominant Phase III: > 30% tree cover Understories depleted with moderate potential for invasive annuals Potential for soil erosion	Complete removal not recommended due to high amounts or woody fuels Potential to use mechanical treatments to decrease crown fire risk next to communities and manage for high value resources Selective thinning to reduce or modify woody fuel using cut and pile burn or mastication will likely be most successful Seeding may be required	Thinning may increase stand health and improve habitat Ecological outcomes depend on soil erosion post treatment as well as choice of seeded species and seeding success
Old growth woodlands	Warm and dry Low to moderately low R&R	Utah juniper dominant and pinyon subdominant Cover values likely less than in Phase III woodlands High risk of invasive annuals if disturbed Potential for soil erosion if disturbed	No data exist on effects of fuel treatments in old growth on fuels or fire behavior Selective thinning of younger trees has the potential to decrease fire behavior Increases in herbaceous species following treatment may elevate risk of fire spread Seedling required where understories are depleted Fuel reduction treatments in adjacent areas to decrease risk of fire spreading into old growth Selective thinning of younger trees in areas with infilling to manage fire risk to communities and high value resources Cut and pile burning or masticating will likely be most successful in areas with infilling	Reducing risk of high severity fire in high value old growth woodlands can preserve unique ecosystems, cultural values, and habitat Ecological outcomes, i.e., restoration or conversion to the seeded state, will depend on choice of seeded species
	Cool and moist Moderate to high R&R	Pinyon dominant and Utah juniper subdominant Cover values likely less than Phase III woodlands Lower potential for fine, herbaceous invasive fuels Potential for soil erosion if disturbed	No data exist on effects of fuel treatments in old growth on fuels or fire behavior Selective thinning of younger trees has the potential to decrease fire behavior Higher levels of herbaceous fuels after treatment may increase fire spread Seedling likely required where understories are depleted	Reducing risk of high severity fire in high value old growth woodlands can preserve unique ecosystems, cultural values, and habitat Ecological outcomes, i.e., restoration or conversion to the seeded state, will depend on choice of seeded species

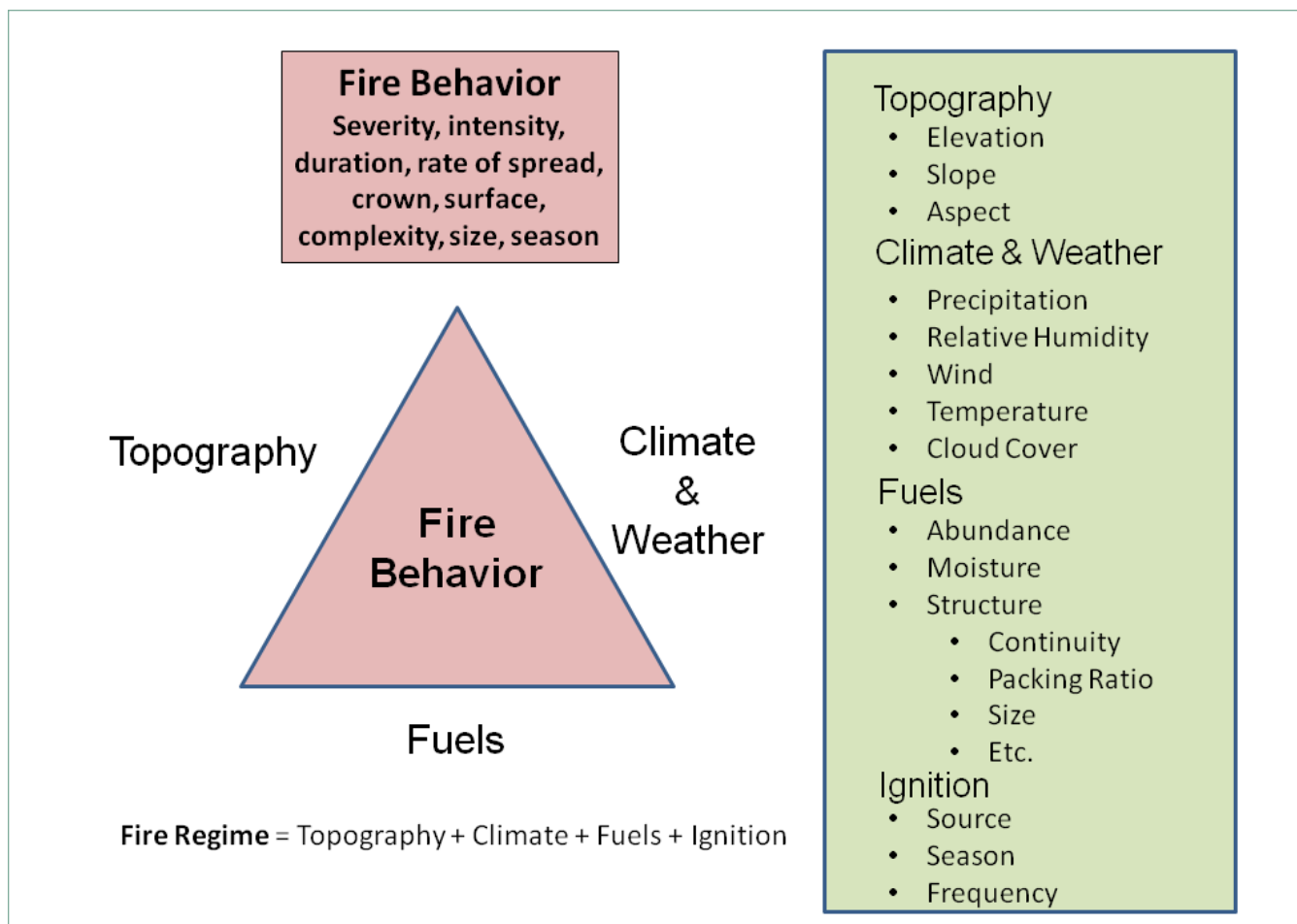


Figure 18—Fire behavior, including intensity, duration, rate of spread, etc. are determined by three components: topography, climate and weather, and fuels. Traits associated with each of these components influence fire behavior and fire severity.

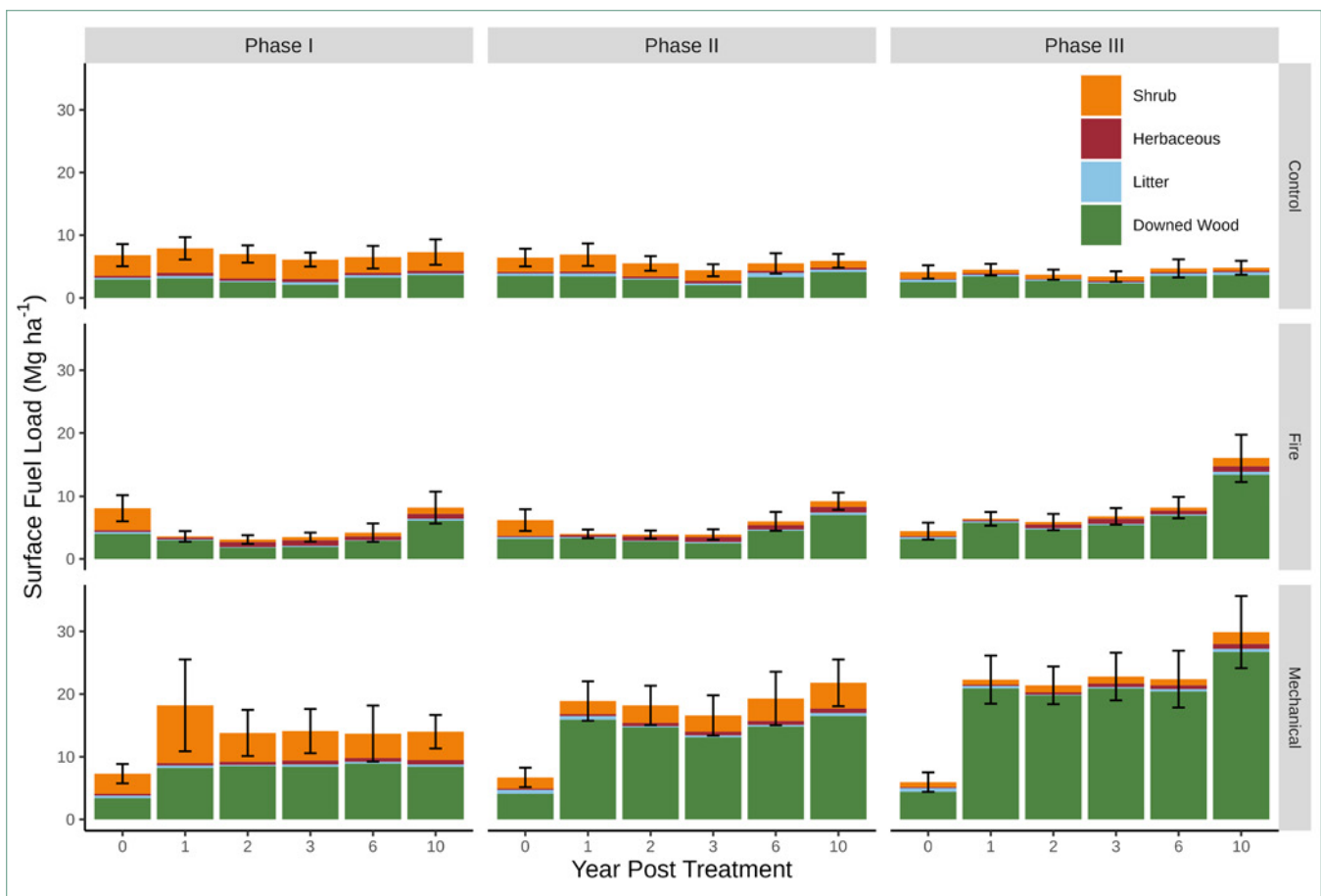


Figure 19—The response of surface fuels to prescribed fire and a mechanical cut and leave treatment averaged across 10 sites within the Sagebrush Treatment Evaluation Project (SageSTEP; www.sagestep.org) woodland network in Oregon, northern California, Nevada, and Utah. Shown are the mean shrub, herbaceous, litter, and downed woody fuel loads (Mg ha⁻¹) in control (top), prescribed fire (center), and mechanical treatment (bottom) plots for woodland phases I (left), II (center), and III (right) in years 0, 1, 2, 3, 6, and 10 after treatment. The error bars represent ± 1 standard error for the total fuel load at each time and phase. Total surface fuels averaged 6.23 Mg ha⁻¹ across all plots before treatments and had not changed by year 10 in control plots. In contrast, total surface fuels were 11.13 Mg ha⁻¹ across prescribed fire plots ($p < 0.01$) and 21.9 Mg ha⁻¹ across mechanical plots ($p < 0.01$) in year 10. Figure modified from Williams et al. 2023.

4. Is this a shrubland experiencing expansion of pinyon-juniper or is it an old growth woodland? If it is a shrubland experiencing woodland expansion, what is the ecological type (table 5) and the phase of expansion?
5. Is the shrubland warm and dry with low productivity, or is it cool and moist with higher productivity?
 - a. In shrublands experiencing woodland expansion, the phase of expansion and relative productivity of the ecological type are considered together when selecting the appropriate treatment (table 5; reviewed in Chambers et al. 2024). Relatively warm and dry shrublands with lower resilience and resistance typically receive mechanical tree reduction treatments to maximize the recovery potential and minimize the risk of invasive annuals following treatments. Cooler and moister shrublands with higher resilience

and resistance may be treated with either mechanical or prescribed fire treatments, although the risk of invasive annuals may still be relatively high following prescribed fire if the site is on the warm end of the temperature gradient or has insufficient perennial native grasses and forbs to promote recovery. As the phase of expansion and thus tree cover increases, both the difficulty of successfully implementing treatments and the ecological impacts increase due to the amount of woody fuel that is left on the soil surface following mechanical treatments (fig. 19), and the risk of high-intensity fire with severe ecological effects during prescribed fire (table 5, Appendix C). Cut and leave as well as cut, lop, and scatter in particular increase surface woody fuels and can greatly elevate fire intensity during subsequent wildfires if used to treat later phase II or phase III expansion areas.

- b. As the phase of expansion and thus tree cover increases, both the difficulty of successfully implementing treatments and the ecological impacts increase due to the amount of woody fuel that is left on the soil surface following mechanical treatments (fig. 19), and the risk of high-intensity fire with severe ecological effects during prescribed fire (table 5, Appendix C). Cut and leave as well as cut, lop, and scatter in particular increase surface woody fuels and can greatly elevate fire intensity during subsequent wildfires if used to treat later phase II or phase III expansion areas.
 - c. In phase III expansion areas, treatments may target objectives such as reducing continuity of crown fuels and reducing tree competition with understory species. The best option may be the use of mechanical thinning treatments, such as selective cutting and pile burning or mastication with a small masticator, followed by seeding (table 5). If the tree biomass is not too great, it may be possible to seed and then masticate (Bybee et al. 2016). Repeated entries may be required to achieve or maintain desired conditions. The effects of fuels and potential fire behavior during a subsequent wildfire are uncertain but undoubtedly depend on treatment configuration and proximity to other fuel types and time since treatment.
6. Is this an old growth woodland with presettlement trees > 150 years old and, if so, is it warm and dry with low productivity, or is it cool and moist with higher productivity?
- a. Mechanical thinning of younger trees may be used to maintain old growth woodlands in those areas with infilling of the old growth woodland. The effects of these thinning treatments on fuels and potential fire behavior during subsequent wildfire are untested but will depend on treatment configuration and proximity to other fuel types and time since treatments.

Prescribed Fire versus Mechanical Treatment

All treatments have tradeoffs in terms of the longer-term effects on fuels and fire behavior.

7. How do different treatments affect fuels and fire behavior in shrublands (reviewed in Chambers et al. 2024)?
 - a. Little information exists on treatment effects on fuels and fire behavior in most shrublands. However, in relatively warm and dry (mesic/aridic) sagebrush ecosystems with an initial understory of about 10% cover of perennial native grasses, prescribed fire was the most effective treatment at reducing total fuel load and thus the likelihood of severe wildfire effects for 10 years posttreatment (Ellsworth et al. 2022). Mowing with a rotary cutter to a height of 50 cm had shorter-term effects on total fuel loads and modeled fire behavior but reduced reaction intensity for the 10 years. Both treatments increased herbaceous fuels; these were dominated primarily by annual invasive fuels in relatively warm and dry Wyoming big sagebrush sites and by perennial native grass and forb fuels in cooler and moister mountain big sagebrush sites.
8. How do different treatments affect fuels and fire behavior in shrublands experiencing woodland expansion (reviewed in Chambers et al. 2024)?
 - a. All tree removal treatments are effective at reducing tree canopy cover and lowering the risk of high-intensity crown fire. Prescribed fire reduces surface fuel loads in phase I and II woodlands for up to 10 years (fig. 19) and can decrease modeled fire intensity in phase I for 10 years and in phase II for 3–6 years (Williams et al. 2023). Cut and broadcast burn may have similar effects depending on season of burn. A tradeoff for all treatments is that increases in shrub and especially herbaceous fuels following tree removal can elevate the rate of fire spread (Williams et al. 2023). The increase in herbaceous fuels is often largest in prescribed fire treatments.
 - b. Compared to other treatments, cut and leave, as well as cut, lop, and scatter, greatly increase surface fuels with progressively larger increases from phase I through phase III (fig. 19). The increase in woody surface fuels and, to a lesser degree, herbaceous fuels increase modeled fire intensity, flame length, and especially rate of spread in both treatments (Williams et al. 2023). The increase in fire behavior can increase fire severity.
 - c. Cut and pile burn treatments appear to be a better option than cut and leave or cut, lop, and scatter due to reduced canopy and woody surface fuels, except in the early phases of tree expansion where these latter treatments have less effect on surface fuels and fire behavior. In cut and pile burn treatments, increases in both shrub and herbaceous fuels occur over time and are associated with potential increases in surface fire intensity, flame length, and rate of spread relative to untreated controls (Chambers et al. 2024).
9. Mastication results in a high abundance of compacted 1-hour and 10-hour woody surface fuels, especially in mid-phase II through phase III. Canopy fires drop to the ground when encountering masticated fuels. This improves safety

for fire fighters who can then suppress the resulting ground fire. Masticated fuels appear to burn at lower intensity and at a slower rate, but prolonged smoldering may result in increased duff consumption, soil heating, and root injury (Kreye et al. 2014).

10. How do selective thinning treatments affect fuels and fire behavior in phase III and mature expansion woodlands?
 - a. Selective thinning of overstory trees that decreases canopy continuity may reduce the potential for crown fire spread, but little information exists on the effects of selective thinning on fuel distribution and fire behavior.

5 Treatment Severity and Ecological Response

The ecological site characteristics, current vegetation, and ecological state or degree of departure are as important as the characteristics of the fuels in determining treatment outcomes and the need for seeding. The ecological types in the Pine Valley Ranger District differ in both ecological states and degree of departure (table 1, Appendix E) and field evaluations of potential treatment areas are needed to determine likely responses to treatments.

Shrublands

In shrublands, a lack of fire and increased dominance of shrub species coupled with excessive livestock grazing can result in a decrease in native perennial grasses and forbs. Sites with low to moderately low resistance and depleted perennial grasses and forbs have a high likelihood of increases in invasive annuals following treatment.

1. What is the inherent resilience and resistance of the site as indicated by temperature and moisture regime and modified by aspect and soil characteristics such as soil depth and texture?
2. To what degree has the grass and forb cover been severely depleted (< 5% aerial cover) or moderately depleted (5–10% aerial cover)?
3. Is the site characterized largely by root-sprouting shrubs that will regrow following brush treatments or prescribed fire, or is it dominated by fire-intolerant shrubs like most sagebrush species (table 4)?
4. What is the potential for increases in invasive annuals?

Pinyon Pine and/or Juniper Expansion Versus Old Growth

As woodland expansion into shrublands progresses, the trees typically outcompete the native perennial understory and the potential for unassisted recovery without seeding decreases (fig. 20). Exceptions may be deeper soils or summer-dominated precipitation regimes where perennial herbaceous species can persist in the understory in the absence of excessive livestock grazing. The lower the inherent resistance of the site, and the more depleted the perennial grasses and forbs, the higher the likelihood of increases in invasive annuals after treatment.

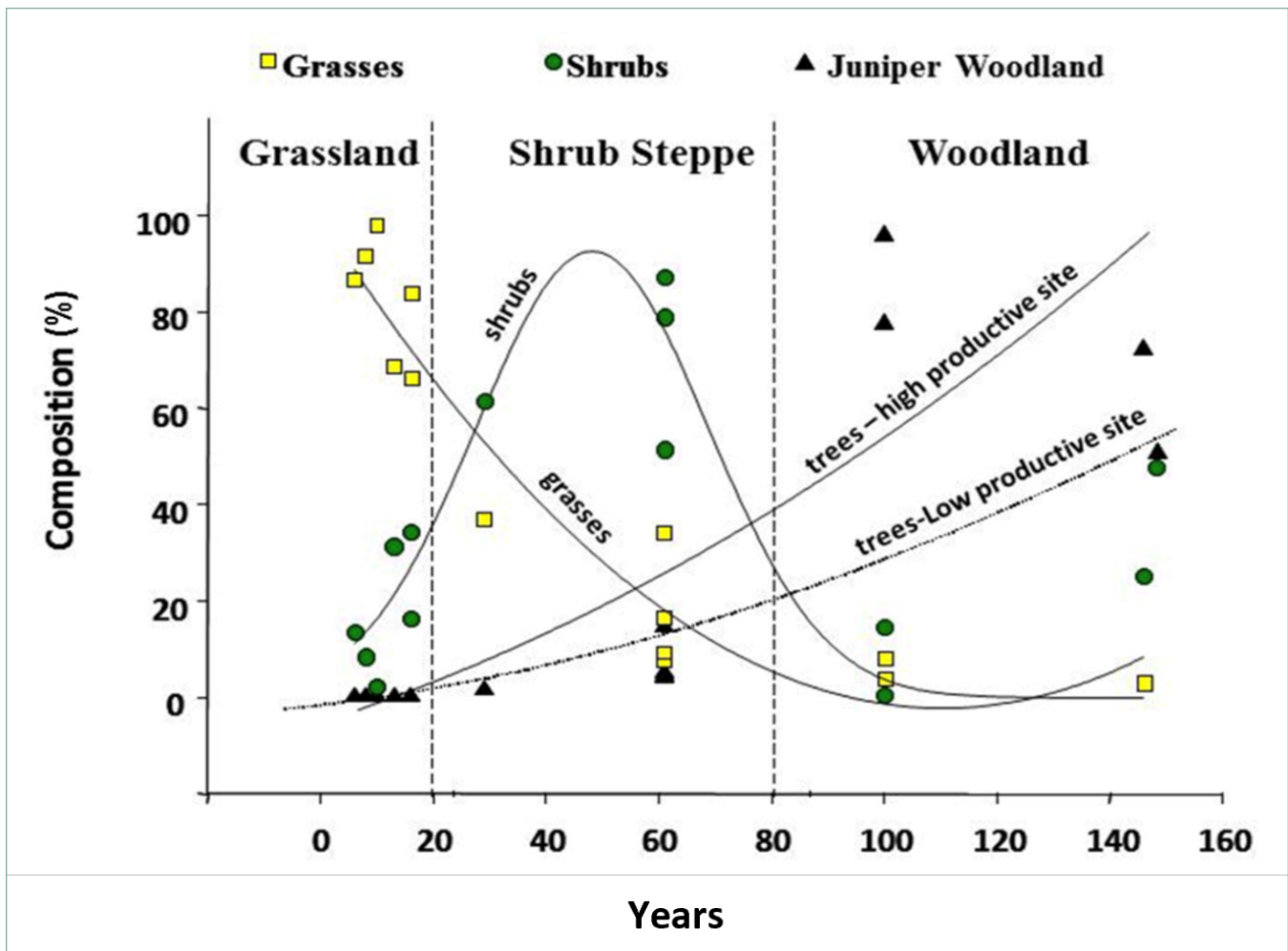


Figure 20— Model of changes in percent composition of grasses, shrubs, and junipers in cool/moist mountain big sagebrush in northeastern California over time after fire (Miller and Heyerdahl 2008). Successional trajectories follow this pattern across sagebrush ecosystems, but the time required to transition between stages varies by site. Figure from Johnson and Miller 2006.

5. What is the inherent resilience and resistance of the site as indicated by temperature and moisture regimes and modified by aspect and soil characteristics, such as soil depth and texture?
6. To what degree is the tree canopy influencing the understory composition and thus recovery potential? Is there high shrub mortality based on standing shrub skeletons or persistent shrub litter?
7. Is the grass and forb cover in the large interspaces between the shrubs and trees severely depleted (< 5% aerial cover) or moderately depleted (5–10% aerial cover)? Herbaceous cover is highly dependent upon soil characteristics and disturbance history.
8. Are there residual root-sprouting shrubs that will regrow following treatments like prescribed fire and serve as seed sources, or is the understory characterized by shrubs like sagebrush that are fire intolerant and damaged by mechanical treatments (table 4)?

9. Are there obvious signs of rill and sheet erosion that exceed the levels expected on the site (fig. 21)?

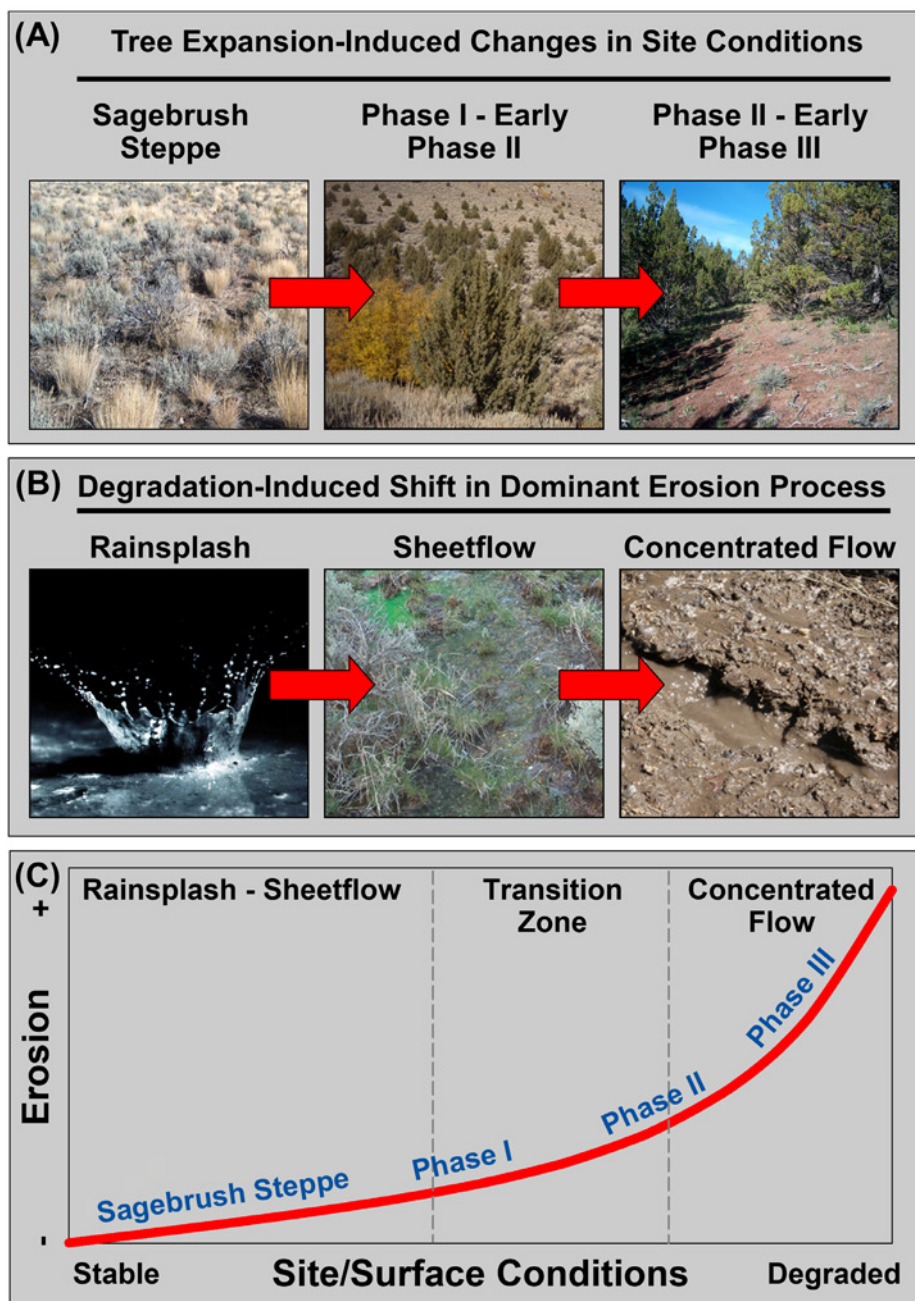


Figure 21—A) Changes in sagebrush shrublands with advancing pinyon-juniper expansion, (B) the associated degradation-induced shift in dominant erosion processes, and (C) a representative increase in erosion magnitude associated with changes in site/ground surface conditions. Erosion from stable sagebrush communities occurs primarily by rainsplash and sheetflow and is typically low. Erosion increases exponentially with site and ground surface degradation where bare soil increases beyond 50-60%. High rates of erosion typically occur where sagebrush communities transition to Phase II-III woodlands. The exponential increase in soil loss (C, red line) with site/ground surface degradation illustrates the effect of concentrated flow. Concentrated flow is the dominant erosion process at the transition from Phase II-III woodland encroachment and signals a transition from a stable to a degrading landscape. Concentrated flow has higher velocity than sheetflow and thereby exhibits greater sediment detachment and transport capacity than the combined effects of rainsplash and sheetflow. Figure modified from Williams et al. 2014.

10. If the woodland is in phase I or II (see *Glossary* for definitions), what is the expected rate of stand closure based on ecological site productivity (fig. 22)?

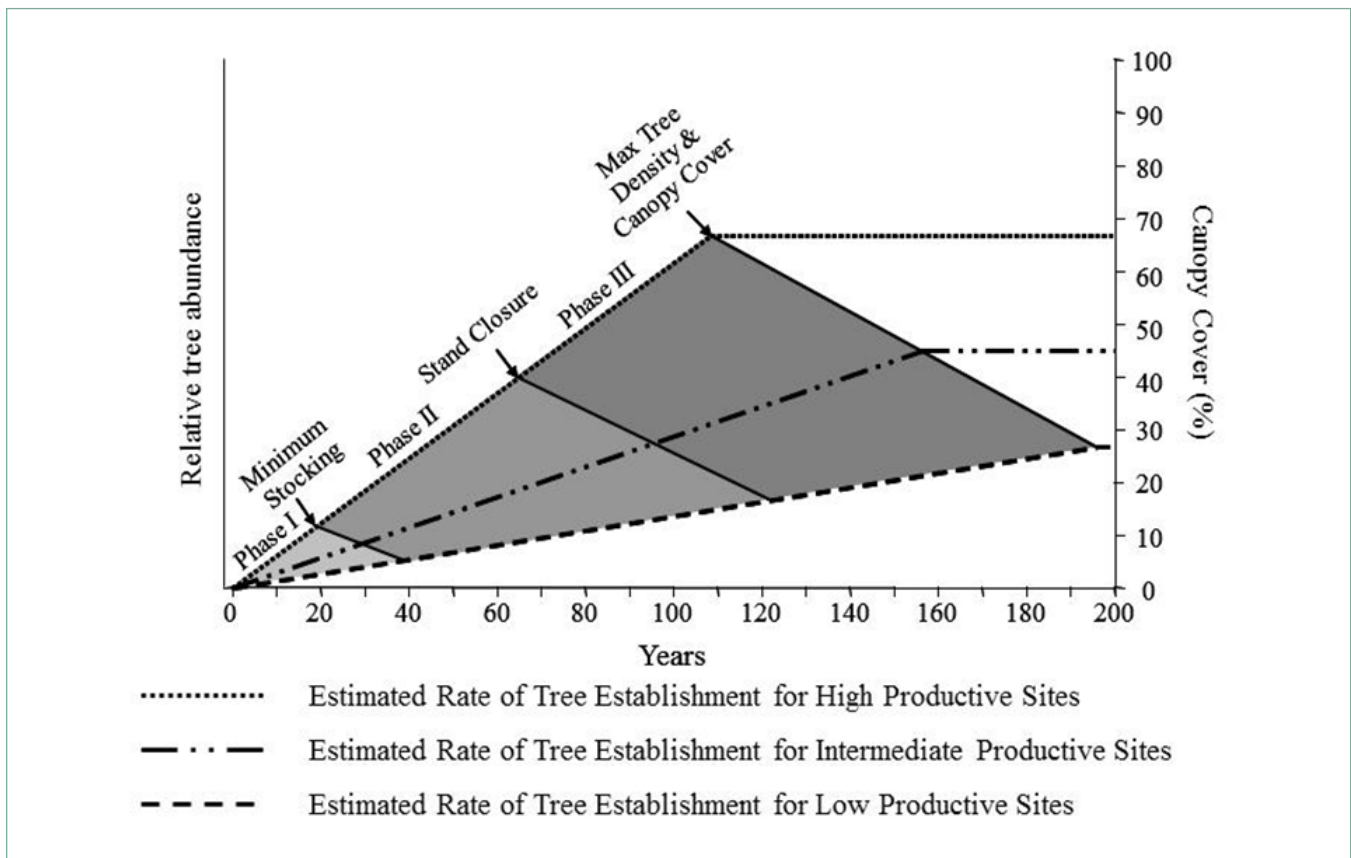


Figure 22—The hypothesized amount of time required from initial western juniper establishment (early Phase I) to a minimum stocking level adequate for Phase III, and the estimated maximum potential for tree density and cover for stands developing on varying elevations and aspects (from Johnson and Miller 2006). Projected rates of closure are similar for pinyon pine and Utah juniper (Tausch et al. 2007).

11. What is the distance to the nearest pinyon pine or juniper seed source? And, if the treatment area is large, what areas are most vulnerable to seed dispersal? Most bird and small mammal dispersed juniper seed is dispersed within 300 ft of the seed source (Miller et al. 2019). However, birds can disperse seeds up to 3 miles or more.

Prescribed Fire Versus Mechanical Treatment

All treatments have tradeoffs in terms of the longer-term effects on fuels and fire behavior (described above) as well as ecological response.

12. What are the ecological effects of different treatments in shrublands (reviewed in Chambers et al. 2024)?
 - a. In sagebrush shrublands with an initial understory cover of about 10% perennial native grasses, warm and dry sites with relatively low resilience and resistance were susceptible to invasion by annual grasses and forbs and tended to recover slowly, even with relatively high initial amounts

of competitive perennial grasses (Pyke et al. 2022). The invaders were most abundant after prescribed fire likely due to shrub mortality and an immediate release of water and nutrient resources. Regardless of treatment, cooler and moister sites with relatively high resilience and resistance had increases in perennial native herbaceous species and limited invasion, except in dense shrublands with depleted understories. The relative cover of sagebrush and perennial herbaceous species strongly influence recovery after treatments (see fig. 10) and should be a primary consideration in selecting treatment sites and posttreatment management strategies.

13. What are the effects of different treatments on wildlife habitat in shrublands (reviewed in Chambers et al. 2024)?
 - a. Loss of shrubs can decrease habitat quality in areas managed for shrubland obligate species. Fire is lethal to many species of sagebrush and high mortality can occur depending on how and when fire is applied. In areas with relatively high resilience, implementing patchy and incomplete burns that mimic historical fire patterns may prevent over-dense sagebrush stands and help maintain habitat. In relatively cool and moist sagebrush shrublands, mowing can affect habitat if sagebrush height is below the requirements for sagebrush obligates.
14. What are the ecological effects of different treatments in shrublands experiencing woodland expansion (table 5; reviewed in Chambers et al. 2024)?
 - a. Prescribed fire and cut and broadcast burn, especially in fall, are more severe treatments because of the loss of fire-intolerant shrubs, potential mortality of native grasses, and increases in invasive annuals. Treatment outcomes are generally most favorable (1) where resilience and resistance are categorized as moderate or higher, (2) in expansion phases I and II, (3) where sufficient perennial grasses and forbs exist to outcompete invasive annuals and promote recovery, and (4) where fire severity is relatively low.
 - b. Cut and leave, cut, lop, and scatter, cut and pile burn, and mastication are less severe treatments ecologically than prescribed fire and cut and broadcast burn because the understory shrubs and perennial herbaceous species are left intact. Recovery of the understory is still greatest in the early phases of woodland expansion and with adequate native perennial herbaceous species. In addition, treatment is possible in sites with moderately low as well as higher resilience and resistance because of the intact understory.
 - c. All mechanical treatments have tradeoffs. Cut and leave treatments in expansion phases II and III can decrease the longer-term ecological integrity of the site due to large increases in woody surface fuels and risk of high-severity fire, but these effects can be minimized by treating in phase I. Increases in invasive annuals may be promoted by cut and broadcast burn treatments as a result of broadcast burning of slash and by cut and pile

burn due to skid trails or pile burns requiring pretreatment assessment of relative resistance to invasive annuals and possibly posttreatment seeding. Mastication may result in smothering residual plants and reducing seedling establishment in shredded piles if chip depth is not managed. However, with evenly spread chips, shredded material may act like mulch increasing soil moisture availability into the growing season and promoting plant establishment. Like the other treatments, mastication can increase the potential for invasive plants due to competitive release and requires pretreatment assessment of site conditions and potentially seeding.

15. What are the ecological effects of different treatments on wildlife?
 - a. Tree removal treatments are typically prioritized for phase I and phase II pinyon-juniper expansion areas due to favorable vegetation responses. These removal treatments can increase suitable habitat for sagebrush-associated bird species, including greater sage-grouse (*Centrocercus urophasianus*), Brewer's sparrow (*Spizella breweri*), and sagebrush sparrow (*Artemisiospiza nevadensis*) (Zeller et al 2021). However, pinyon jay (*Gymnorhinus cyanocephalus*) habitat use is highly concentrated in areas with low tree cover at the woodland-shrubland ecotone (Boone et al. 2021), and treatments that reduce ecotone width or harden the woodland-shrubland edge may reduce habitat for pinyon jay (Zeller et al. 2021). Selective thinning treatments that leave both groups of trees and individual trees will be most conducive to wildlife species that use these ecotones.

6 Seeding Considerations

The primary factors used to determine if seeding is required are soil temperature and moisture regimes in combination with the composition and abundance of native perennial grasses and forbs and invasive annual grasses and forbs.

1. How are soil temperature and moisture regimes related to the probability of seeding success?
 - a. Success of seeding natives is very low on ecological sites with very warm to warm/dry (hypermesic to mesic/aridic) soil temperature and moisture regimes that receive < 10 inches of precipitation; success is usually variable and highly dependent on annual moisture in the first two to three postfire years on cool-warm/dry (cool-mesic/aridic) sites that receive 10–12 inches of precipitation; and success is typically high on cool/moist (frigid/xeric) sites that receive > 12 inches of precipitation.
 - b. Consider not treating areas where seeding success is unlikely or plan for repeated interventions.
2. How does the abundance of pretreatment native perennial grasses and forbs influence the need to seed?

- a. Seeding of herbaceous vegetation should not be considered where perennial grasses and forbs are sufficient to promote recovery following treatment. Seeding with introduced species or aggressive cultivars will retard or prevent recovery of the native community.
 - b. Seeding may not be necessary following low to moderate severity treatments where native herbaceous perennial grasses are depleted but cover is 5–10% on cool-moist (frigid/xeric) sites that receive > 12 inches of precipitation, or 10–15% on cooler warm/dry (cool-mesic/aridic) sites that receive 10–12 inches of precipitation. However, if invasive annual grasses have the potential to increase substantially on areas with cooler warm (cool mesic) soil temperatures that receive > 10 inches of precipitation, and native perennial grasses are depleted, seeding should be a strong consideration.
 - c. If native herbaceous perennial grasses are severely depleted (< 5% cover on cool/moist [frigid/xeric] and < 10% cover on cool-warm/dry [cool mesic/aridic] temperature and moisture regimes) and/or treatment severity was high, seeding should be considered.
 - d. If native perennial grasses are severely depleted (< 5% cover) or depleted (5–10% cover) and the site receives < 10 inches of precipitation, establishment success of native seed will likely be low regardless of the temperature regime. Seeding may still be a consideration in areas of conservation concern, but more than one intervention will likely be required.
3. How does the abundance of invasive annual grasses and forbs pretreatment influence the need to seed?
 - a. The potential for rapid reintroduction of invasive annual grasses on severely depleted treatment areas will depend on the ecological site's resistance to invasive annual grasses, seed source available following the wildfire, and posttreatment moisture availability.
 - b. Most invasive annual grass seed under shrub canopies is consumed by prescribed fire on areas with > 15% shrub cover, often resulting in low annual grass abundance in the first treatment growing season. However, increased soil resources following treatments result in high growth and reproduction of invasive annual grasses, leading to a large increase in abundance 2 or 3 years later. Thus, areas that are dominated by sagebrush with cheatgrass in the understory may have a 1- to 2-year window opportunity for seeding due to higher fire intensity under shrubs and the consumption of cheatgrass seed.
 4. How does posttreatment weather influence the probability of seeding success?
 - a. Environmental factors such as precipitation timing and amount, *which cannot be controlled or predicted without uncertainty*, can affect seeding success even on cooler and moister sites. Posttreatment monitoring

of seeding success provides the necessary information to determine if reseeding is needed.

5. How does the seeding method affect treatment outcomes?
 - a. Drill seeding is more effective than aerial or broadcast seeding, especially in relatively warm and dry temperature/moisture regimes where establishment success is low. Effectiveness of aerial seeding can increase with a follow-up treatment to cover the seeds.
6. How does the choice of native versus introduced species influence treatment outcomes?
 - a. The choice of seeding species determines the long-term ecological state of the site, and seeding introduced species often results in a largely irreversible site conversion to introduced species dominance.

7 Posttreatment Monitoring and Management

Monitoring and Adaptive Management

Monitoring provides essential information on treatment outcomes that can be used to adjust future management and determine if posttreatment actions are needed. A monitoring plan should be in place before the treatment is implemented and ideally pretreatment monitoring data are collected.

1. Do the monitoring methods measure the project objectives and are they consistent with those being used elsewhere?
2. Is a plan in place for data entry and analyses that is consistent across the agency(s)?
3. Is there a mechanism for summarizing the results, determining if follow-up treatments are needed, and incorporating the relevant information into future treatment plans?
4. Is there a mechanism to share monitoring results with others implementing similar treatments on similar sites?

Weather Conditions

Both pre- and posttreatment weather affect treatment outcomes. Weather conditions prior to treatment strongly influence treatment outcomes via effects on the abundance and continuity of fine fuel loads, percent dead fuels, plant vigor, and seed banks of both native and invasive species. Postfire weather conditions influence the recovery of plants that survive the treatment (both native and invasive species), future seed-crops, and seedling establishment. Consequently, weather can influence posttreatment management actions, including the need to seed and the length of deferment from livestock grazing or closure of treatment areas to off-road vehicles.

5. How has the vigor of perennial native species and potential seed banks (native and invasive species) been influenced by pretreatment weather?
6. How will posttreatment weather influence recovery and will additional actions or multiple interventions be needed (e.g., invasive species control, seeding of native species, or transplanting shrubs)?
 - a. Recovery in the first 1 to 2 years is typically dependent on persistent perennial vegetation that survived the treatment.
 - b. Seed banks of perennial native species are often low and seedling establishment usually occurs only during wet springs, especially on warm-dry ecological sites. However, wet late winters into early spring can also result in establishment of undesirable cool season annuals.
 - c. Favorable weather conditions can increase establishment, productivity, and seed-crops of both desirable and undesirable plant species.
7. What is the potential for wind or water erosion in the first 1 to 2 years posttreatment?

Livestock Grazing

The amount of time for posttreatment grazing deferment required for recovery is affected by the ecological site characteristics, pretreatment plant composition, treatment severity, and posttreatment weather. The lack of adequate deferment or proper long-term grazing management can significantly affect the recovery of the treatment area.

8. How long should livestock grazing be deferred for the treatment area? The deferment period may vary by ecological site and if so, the ecological site within the treatment area that is most sensitive to grazing impacts should dictate the deferment period. Evaluation of site conditions and posttreatment monitoring should be used to determine the appropriate deferment period.
 - a. Deferring grazing during the active growth period for the first 2 years is probably adequate only for sites where:
 - Treatment severity will be low to moderate;
 - Resilience and resistance are high;
 - Pretreatment herbaceous vegetation is dominated by natives and invasive annual grasses are a minor component; and
 - Posttreatment monitoring indicates adequate recovery of shrubs, perennial grasses, and forbs.

- b. Deferring grazing during the active growth period for the first 2 years is probably inadequate where any of following apply:
 - Treatment severity will likely be high;
 - Resilience to treatment and resistance to invasives are moderate to low;
 - Invasive annual grasses are co-dominant or dominant; and
 - Posttreatment monitoring indicates low or slow recovery of perennial grasses, and forbs.
9. What is the posttreatment level of control of grazing in terms of duration, stocking rates, distribution, and season of use?
10. What are the potential impacts of recreational use and wildlife?

SELECTING TREATMENT AREAS

What, where, and how much to treat is usually determined by priorities, potential outcomes, available resources, and funding availability. Questions to address when selecting areas to be treated include:

1. What are the chances of success based on the area's resilience to disturbance and resistance to invasive species, which are closely linked to ecological site characteristics and plant community composition and structure at the time of treatment?
2. Does the area provide important habitat for animal and/or plant species of concern?
 - a. The Pine Valley Ranger District provides habitat for a diversity of wildlife species, including mule deer and pinyon jay (fig. 23). It also supports several sensitive plants, including pinyon penstemon (*Penstemon pinorum*), guard milkvetch (*Astragalus zionis* var. *vigulus*), and Pine Valley goldenweed (*Haplopappus crispus*).

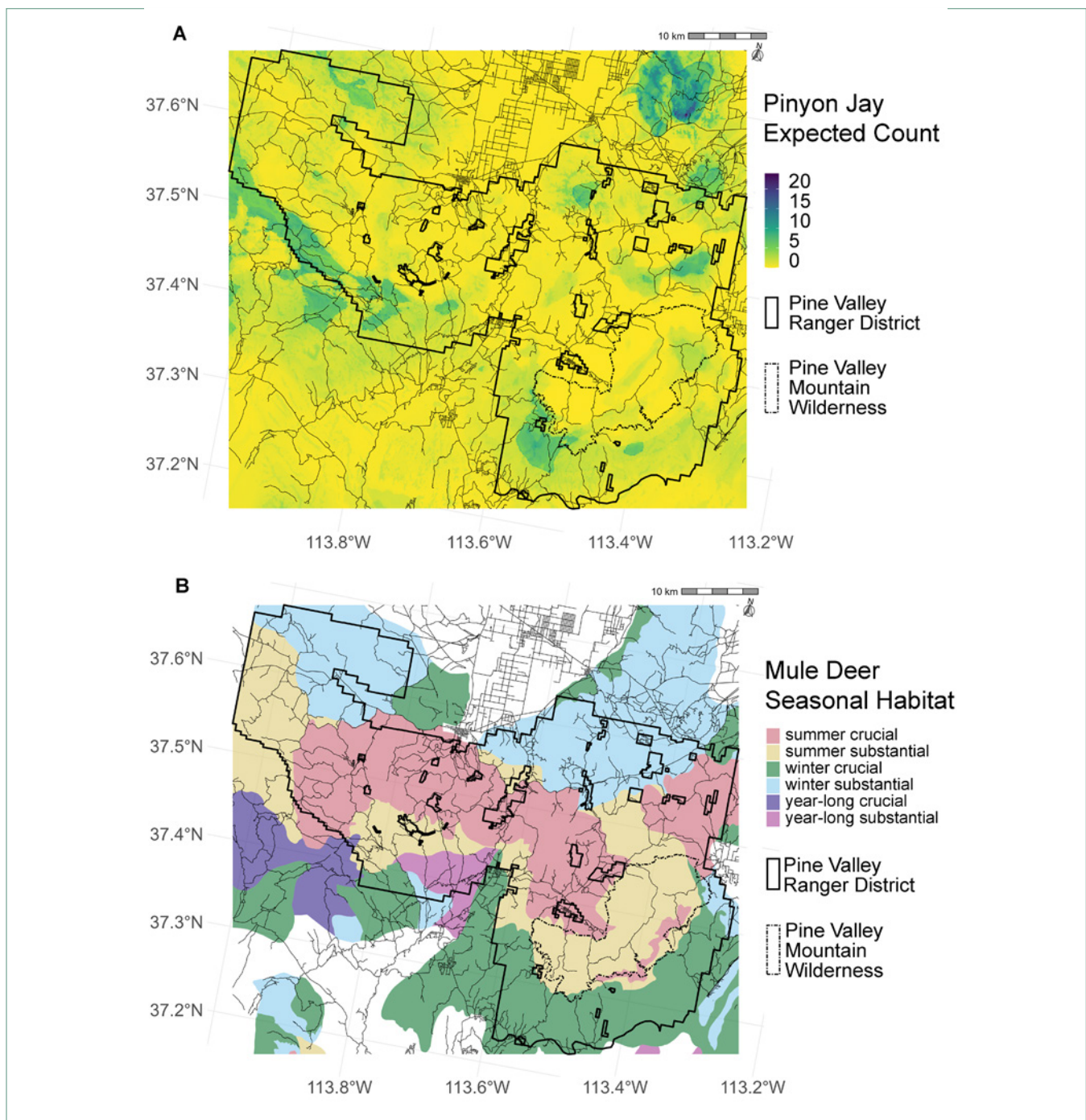


Figure 23—Maps of the distribution of two wildlife species of concern within the Pine Valley Ranger District. Pinyon jay (*Gymnorhinus cyanocephalus*) indices of abundance (A) were based on point count data from the U.S. Geological Survey's Breeding Bird Survey and modeled in relation to patterns of vegetation, topography, anthropogenic disturbance, fire history, and weather and climate (Tack et al. 2023). Darker colors indicate higher estimated counts of pinyon jays. Seasonal habitat of mule deer (*Odocoileus hemionus*) (B) was delineated based on regular surveys of their numbers and locations by the Utah Division of Wildlife Resources (Utah Division of Wildlife Resources 2023). Crucial value habitats are areas that the local population requires for survival because there are no alternative ranges or habitats available. Degradation or unavailability of crucial habitat leads to significant declines in carrying capacity and/or numbers of the wildlife species in question. Habitat with substantial value is used by a wildlife species but is not critical for population survival.

3. Can treatment increase the landscape connectivity for species of concern?
4. Is the proposed treatment area a major source of sediment to nearby streams or does it have high erosion potential?
5. What is the treatment cost?
6. Is retreatment likely to be needed and if so, is it an option?
 - a. See table 5 for likely retreatment intervals following mechanical treatments in pinyon-juniper expansion areas.
7. Can posttreatment management be modified to promote attainment of project objectives? For example, can livestock grazing be deferred long enough for the site to recover, and can appropriate grazing be implemented to maintain the treatment objectives once the decision to graze has been made?
8. How is climate change likely to affect treatment longevity?
 - a. Iron County, Utah, which encompasses much of the Pine Valley Ranger District, experienced significant warming since 2000 (fig. 24). This trend is projected to continue into the future with increasing variability in precipitation (U.S. Global Change Research Program 2023). This indicates that current treatments and seed mixes should be adjusted to accommodate warmer and more variable temperature and moisture regimes in the future.

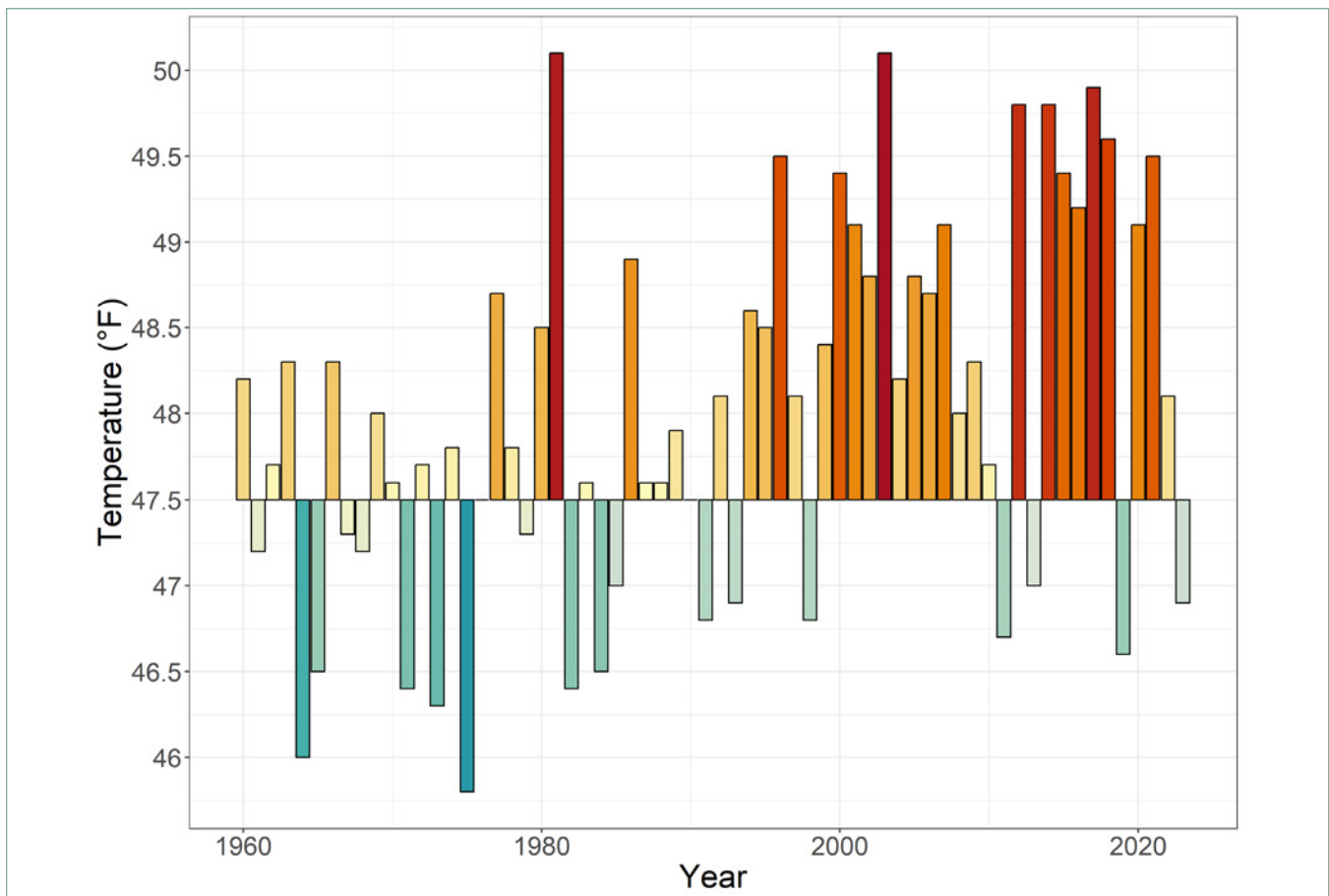


Figure 24— Annual mean temperature since 1960 in Iron County, UT, USA (Western Regional Climate Center 2024), which contains most of the Pine Valley Ranger District. Annual climate values are shown as estimated areal averages in relation to the mean value from 1961-1990 (47.5 °F). This graph shows that the district has experienced significant warming since the turn of the century. This warming trend is projected to continue throughout the remainder of the century (U.S. Global Change Research Program 2023). Precipitation during the same time period has been more variable, but the warmer temperatures indicate greater rates of evapotranspiration and less available soil moisture (U.S. Global Change Research Program 2023). The progressive warming indicates that current treatments and seed mixes should be adjusted now to accommodate warmer and more variable temperature and moisture regimes in the future.

SELECTING THE MOST APPROPRIATE TREATMENT

Ecological Types and State-and-Transition Models

Descriptions of 11 ecological types (groups of similar ecological sites) representing the dominant shrublands and old growth woodlands within the Pine Valley Ranger District are in Appendix E. Identifying the specific site characteristics and current condition of the ecological types located within the proposed treatment area helps to determine which treatments are most appropriate and if treatments are likely to have desired outcomes. The ecological type descriptions provide information on (1) resilience to both wildfire and management treatments, (2) resistance to invasive annual species, (3) potential ecological response following treatment, and (4) the most effective treatments (mechanical treatments, prescribed fire, and/or seeding) and outcomes. Each ecological type is associated with a state-and-transition model (STM) that illustrates the potential

successional pathways (shifts between phases and states) that result from both disturbance and management treatments for the different ecological types.

Field Assessment and the Land Unit Evaluation Score Sheet

A score sheet to help evaluate the level of ecological resilience and resistance to invasive annual forbs and grasses and determine the most appropriate treatment is in Appendix D1. Information on using the score sheet is in Appendices D2 and D3. Each major ecological type (or groups of similar ecological sites) within the proposed treatment area is evaluated with a separate score sheet. Scores are not absolute and should be used as guidelines. The score sheet values can be modified when quantitative data and/or scientific studies provide better information or when the results of monitoring of similar treatments become available for the same ecological types.

1. Mechanical treatments with minimal surface disturbance should be considered when:
 - a. Resilience and resistance scores from the score sheet for rating resilience and resistance in Appendix D1 are at least 10–15 and sufficient perennial herbaceous species occur to promote recovery. It is desirable to retain the shrub layer and the shrub species are impacted more by fire than mechanical treatment due to low fire tolerance.
 - b. It is desirable to retain the shrub layer and the shrub species are impacted more by fire than mechanical treatment due to low fire tolerance.
 - c. Sufficient resources exist for seeding in areas where perennial grasses and forbs are relatively low in cover and the risk of invasive annual grasses and forbs is relatively high.
2. Prescribed fire can be considered when:
 - a. Resilience and resistance scores are > 20 ; these are typically cool-moist ecological sites occupied by mountain big sagebrush and other shrubs.
 - b. The risk of increases in invasive annual forbs and grasses is low.
 - c. Larger areas need to be treated.
 - d. Funds are limited.
3. The ecological response of areas being considered for treatment with scores between 15 and 20 is often difficult to predict.
 - a. If the area being evaluated is cool xeric (> 12 inches precipitation), then either low to moderate severity prescribed fires or mechanical treatments can be considered when sufficient perennial herbaceous species exist to promote recovery.
 - b. If the area being evaluated is dry (aridic) (< 10 inches precipitation), the use of prescribed fire should not be considered.

- c. If the area is aridic (10–12 inches precipitation) and perennial herbaceous vegetation is depleted, the use of prescribed fire should be discouraged unless reseeding follows immediately after the fire and the soil moisture + temperature score is > 12.
 - d. Depending on the extent of the prescribed fire area, reseeding or transplanting fire-intolerant shrubs, like sagebrush, should be considered in high resource value areas.
4. When predicted ecological responses do not meet the objectives of increasing or restoring resilience and resistance following treatment, a logical decision is “not to treat.” Exceptions include:
- a. Critical habitat where sufficient funds exist for repeated interventions, and/or integrated strategies can be used such as mechanical treatments followed by control of invasive annual grasses and revegetation.
 - b. Wildland urban interface (WUI) areas where fuels treatments are needed to decrease fire risk.
 - c. Critical portions of a watershed where treatment is necessary to prevent postfire sediment delivery or the introduction of an invasive seed source.

Seeding Considerations

The decision to seed should be based on (1) site characteristics that influence the likelihood of success and (2) current composition and structure of native and invasive species.

- a. Seeding success on cooler (cool mesic) and relatively dry (aridic; 10–12 in precipitation) sites is usually mixed and is highly dependent on annual moisture in the first 2–3 years following treatment (score = 12–15). Seeding success on cool/moist (frigid/xeric) ecological sites (score = 15–20) is typically high. Environmental factors such as precipitation timing and amount cannot be controlled or predicted without uncertainty but can affect seeding success even on cool mesic/aridic and frigid/xeric sites.
- b. Treatment areas where perennial herbaceous species are absent or severely depleted will need to be seeded posttreatment (or pretreatment for mastication) if the site characteristics are suitable for success (cumulative soil moisture and temperature scores usually > 10). However, for areas with scores > 10–15 that have sufficient perennial herbaceous species to recover following prescribed fire or mechanical treatments, seeding with introduced species or aggressive cultivars will likely retard or prevent recovery of the native community.

CONCLUSIONS

Concern over increasing extents and severity of wildfires has placed increased emphasis on implementing fuel treatments that will both reduce fire risk and increase or maintain the ecological resilience of shrubland and pinyon-juniper ecosystems. Key elements of effective fuel treatments are the ability to determine a site's ecological type and its current ecological condition or state, and to evaluate the ecological type's resilience to disturbance or treatment and its resistance to invasive annual grasses. An understanding of the longer-term effects of treatments on fuels and fire behavior helps ensure that the treatments selected are durable over time. In combination, these key components provide the information needed to evaluate the likely responses of potential treatment areas to both management treatments and future wildfires, and to select the locations and treatments that will best meet the management objectives.

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GLOSSARY

At-risk phase—community phase that is most vulnerable to transition to an alternative state (for example, least resilient). See definition of phase below.

Biophysical Setting (BpS)—represents the vegetation system that may have been dominant on the landscape prior to Euro-American settlement and is based on both the current biophysical environment and an approximation of the historical disturbance regime. LANDFIRE uses BpS to depict reference conditions of vegetation across landscapes. See <https://www.landfire.gov/bps.php>

Ecological resilience—capacity of ecosystems to reorganize and regain fundamental structure, processes, and functioning (i.e., recover) when altered by stresses and disturbances, such as wildfire, drought, insects, etc. (Holling 1973; Scheffer 2009).

Ecological Site (ES)—a conceptual division of the landscape that is defined as a distinctive kind of land based on recurring soil, landform, geology, and climatic characteristics and that differs from other kinds of land in its ability to produce distinctive kinds and amounts of vegetation and to respond similarly to management actions and natural disturbances. Similar to ecological type used by the USDA Forest Service.

Ecological Site Description (ESD)—a description of the characteristics of an ecological site that includes the biotic and abiotic characteristics that differentiate the site (i.e., climate, physiographic, soil characteristics, plant communities), and the ecological dynamics of the site that describe how changes in disturbance processes and management may affect the site. An ESD also provides interpretations about the land uses and ecosystem services that a particular ecological site can support and the management alternatives.

Ecological type—a group of ecological sites with similar biotic and abiotic characteristics that respond similarly to disturbances and management treatments. Ecological types represent a category of land with a distinctive (i.e., mappable) combination of landscape elements, including climate, geology, geomorphology, soils, and potential natural vegetation. Ecological types differ from each other in their ability to produce vegetation and respond to management and natural disturbances.

Fire behavior—the manner in which a fire reacts to the influences of fuel, weather, and topography (USDA FEIS 2024). Fire behavior variables:

- Flame length—the length of flames in a fire front measured along the slant of the flame from the midpoint of its base to its tip (USDA FEIS 2024).
- Fire intensity—the heat energy released during phases of a fire as determined by the amount and rate of fuel consumption (USDA FEIS 2024).
- Fire spread—the rate at which a fire moves across the landscape as influenced by factors such as the amount and arrangement of fine surface fuels, fuel moisture, wind, and slope (USDA FEIS 2024).

- **Reaction intensity**—the rate of heat release per unit area of the flaming front; typically used in fire behavior models and expressed as kilowatts per square meter per minute (Keeley 2009).

Fire severity— the impacts of fire on ecological processes, soil, flora, and fauna; degree to which an ecosystem has been altered or disrupted by fire (USDA FEIS 2024).

Major Land Resource Area/MLRA—geographic area, usually several thousand acres in extent, that is characterized by a particular pattern of soils, climate, water resources, land uses, and type of farming.

Phase (community)—a characteristic composition of plant species, functional and structural groups, soil functions, and range of variability resulting from interactions of the plant community with the environment, disturbance, and management activities. Phases may not progress directly to the most resilient community phase without passing through an intermediate phase.

Potential vegetation—potential vegetation of an ecological site or type, as described by ESDs and LANDFIRE Biophysical Systems, is a function of ecological site characteristics (climate, topography, and soils), attributes and processes (soil temperature and moisture regime, soil processes, and vegetation dynamics), and disturbance history.

Reference state—historic or potential plant community including seral (successional) stages; based on conditions believed to be present before widespread alterations after settlement.

Resistance to invasion—abiotic and biotic attributes and ecological processes of an ecosystem that limit the population growth of an invading species (Thomsen and D'Antonio 2007).

Restoration pathways—descriptions of the environmental conditions and management practices that are required to recover a state that has undergone a transition, usually to an undesirable state.

Soils, climate regimes—soil temperature and moisture regimes are used in soil taxonomy to classify soils and assigned to soil map unit components as part of the National Cooperative Soil Survey program. Abbreviated definitions of predominant soil temperature and moisture regime classes are listed below. Complete descriptions can be found in the 13th edition of the Keys to Soil Taxonomy (Soil Survey Staff 2022; <https://www.nrcs.usda.gov/sites/default/files/2022-09/Keys-to-Soil-Taxonomy.pdf>)

Soil temperature regimes—

- *Cryic (cold)*—Soils that have a mean annual soil temperature between 0 and 8 °C and do not have permafrost at a depth of 50 cm below the surface or at a restrictive feature, whichever is shallower.
- *Frigid (cool)*—Soils that have a mean annual soil temperature between 0 and 8 °C and the difference between mean summer and mean winter soil temperatures is

greater than 6 °C at a depth of 50 cm below the surface or at a restrictive feature, whichever is shallower.

- *Mesic (warm)*—Soils that have a mean annual soil temperature of 8–15 °C and the difference between mean summer and mean winter soil temperatures is greater than 6 °C at a depth of 50 cm below the surface or at a restrictive feature, whichever is shallower.

Soil moisture regimes—

- *Udic (moist)*—Characteristic of high elevation areas with winter snowfall and/or summer precipitation. The soil is dry for less than 90 consecutive days in normal years.
- *Ustic (summer moist)*—Generally there is some plant-available moisture during the growing season, although significant periods of drought may occur. Summer precipitation allows presence of warm-season plant species. The soil is dry for 90 or more cumulative days in normal years.
- *Xeric (winter moist; generally mapped at > 12 inches mean annual precipitation)*—Characteristic of areas where winters are moist and cool and summers are warm and dry. The soil is dry for 45 or more consecutive days in the 4 months following the summer solstice but moist in some part for 90 or more consecutive days during the growing season.
- *Aridic (dry; generally mapped at < 12 inches mean annual precipitation)*—Characteristic of arid regions. The soil is dry for at least half the growing season and moist for less than 90 consecutive days.
- *Hypermesic (warm/hot)*—Soils that have a mean annual soil temperature that is intermediate between mesic and thermic soils at a depth of 50 cm below the surface or at a restrictive layer, whichever is shallower. Thermic soils have a mean temperature of 15–22 °C. Term was developed to more accurately describe the temperature regimes in the southwest drylands.

Soils, depths—classified as very shallow < 10 in; shallow 10–20 in; moderately deep 20–30 in; deep > 36 in. Soil depth affects soil water availability and rooting depth and, therefore, plant species composition.

Soils, textures—relative content of particles of various sizes, such as sand, silt, and clay in the soil (fig. 25). Soil texture affects the behavior of soils, such as water-holding capacity, nutrient retention and supply, drainage, and nutrient leaching. Sandy soils have the largest particle size and tend to have low water and nutrient-holding capacity. Silty soils have medium-sized particles, moderate water-holding capacity, and drainage characteristics. Clay soils have a lot of small fine particles with many inner layers creating a lot of surface areas that hold water and nutrients tightly. They have higher water and nutrient-holding capacity but lower drainage, resulting in slower water

movement and potential waterlogging. Also, they have lower plant-available water capacity than silty soils because clays hold water tightly as they dry.

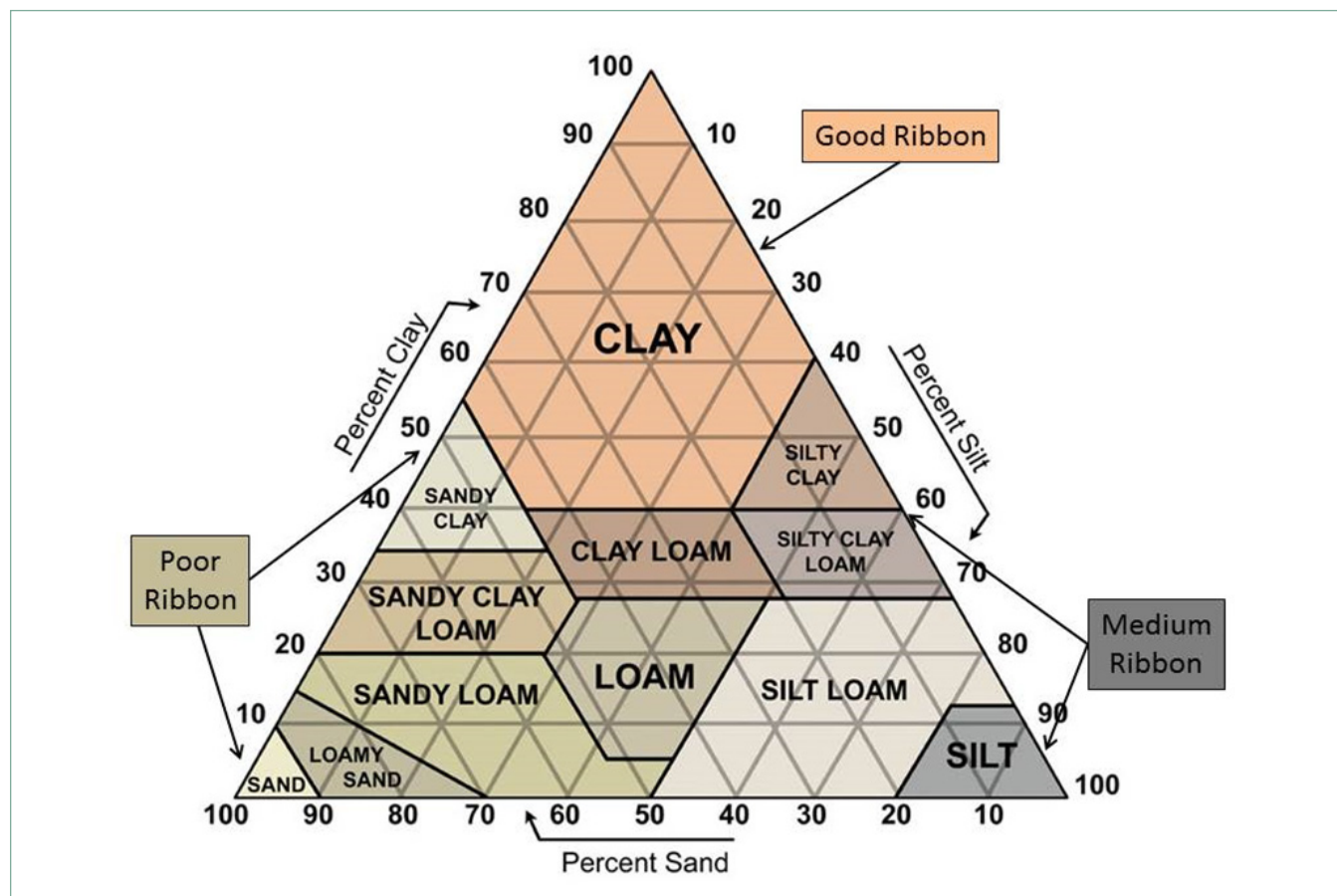


Figure 25— Soil texture triangle.

State—a suite of plant community successional phases occurring within an ecological site or type that interact with the environment to produce resistant functional and structural attributes with a characteristic range of variability that are maintained through autogenic repair mechanisms.

Treatment area—an area being considered for some form of vegetation manipulation (prescribed fire or mechanical treatment) to reduce fuels or increase resilience and/or resistance or that has experienced a wildfire. The treatment area is often composed of different ecological sites that may have different resilience to disturbance and resistance to invasives (a result of varying elevation, topography, soils, and disturbance history). It is helpful to place these sites into general groups based on soil temperature and moisture regime and current vegetation.

Treatments, fuels—vegetation management treatments implemented to reduce or redistribute burnable material and decrease fire spread rates, intensity, and/or severity (Hood et al. 2022; Reinhardt et al. 2008). In sagebrush and other shrubland ecosystems, fuel treatment objectives typically include (1) decrease woody or fine fuels in a manner that has reliable and durable effects on fire behavior and (2) improve ecological

resilience and resistance to nonnative invasive plants (Brooks et al. 2007; Hood et al. 2007; Kitchen et al. 2007; Miller et al. 2013, 2019). Types of treatments:

- *Chaining*—pulling large woody plants, such as pinyon and juniper trees, out of the ground by dragging a ship anchor chain, 200–500 feet long, between two bulldozers and then leaving the downed trees on the site (Miller et al. 2019).
- *Cut and leave*—felling pinyon and juniper trees and leaving the downed trees and slash on the site (Miller et al. 2019).
- *Cut, lop, and scatter*—felling pinyon and juniper trees and distributing the slash across the site (Miller et al. 2019).
- *Cut and broadcast burn*—felling pinyon and juniper trees and then reducing the amount of downed wood fuels remaining on the soil surface by broadcast burning the entire area (Miller et al. 2019).
- *Cut and pile burn*—felling pinyon and juniper trees and then reducing the amount of downed woody fuels remaining on the soil surface by piling and burning the downed trees and slash (Miller et al. 2019).
- *Mastication*—mechanical treatment implemented to convert vertical canopy material from pinyon and juniper trees to chipped or shredded woody surface fuel distributed across the treated area using a rotary head or horizontal drum masticator (Kreye et al. 2014).
- *Pre-emergent herbicides to control invasive annuals*—applying an herbicide, typically Imazapic® or Indaziflam® (Rejuvra®), to decrease emergence and establishment of nonnative invasive annual grasses and prevent development of annual grass fire cycles (Davies et al. 2019; Pyke et al. 2022; Terry et al. 2021).
- *Prescribed fire*—intentionally igniting a fire in accordance with applicable laws, policies, and regulations to reduce woody fuels and/or improve ecological resilience and resistance to nonnative invasive plants (Miller et al. 2013, 2019).

Vegetation departure—used in LANDFIRE to indicate how different current vegetation on a landscape is from estimated historical conditions. Vegetation Departure is based on changes to vegetation composition, structural stage, and canopy closure. See <https://www.landfire.gov/vdep.php>.

Woodland, expansion—areas where pinyon and juniper trees are expanding into shrubland and other ecological types. Three phases of expansion have been defined: phase I, II, and III (Miller et al. 2019) (table 6). In phase I, trees are present but shrubs and herbs are the dominant vegetation influencing ecological processes on the site; in phase II trees are codominant with shrubs and herbs and all three vegetation layers influence ecological processes; and in phase III trees are the dominant vegetation on the site and the primary plant layer influencing ecological processes on the site (from Miller et al. 2005). Most trees in stands are less than 150 years old. Phases can be calculated using percent cover (from Roundy et al. 2014).

Phase I = total tree / total tree + shrub + perennial grass = < 0.33
(relative tree cover < 1/3)

Phase II = total tree / total tree + shrub + perennial grass = 0.34–0.65
(relative tree cover 1/3 to 2/3)

Phase III = total tree / total tree + shrub + perennial grass = > 0.66
(relative tree cover > 2/3)

Table 6—Characteristics of old growth pinyon-juniper defined in USDA Forest Service, FS-1215a (USDA Forest Service 2023b) for the northwest (NW) and southeast (SE) parts of Region 4, and for low and high productivity areas. To clearly differentiate old growth woodlands, it is necessary to evaluate old growth characteristics based on tree morphology (see Appendix B).

Characteristics	Phase I (early)	Phase II (mid)	Phase III (late)
Tree canopy (% of maximum potential cover)	Open, actively expanding < 1/3 max potential	Open, actively expanding 1/3 to 2/3 max potential	Expansion nearly stabilized > 2/3 max potential
Leader growth (dominant trees, cm/yr)	Terminal > 10 Lateral > 10	Terminal > 10 Lateral 5 to > 10	Terminal > 10 Lateral < 5
Crown lift (dominant trees)	Absent	Absent	Lower limbs dying or dead where tree canopy > 40%
Tree recruitment	Active	Active	Limited to absent
Leader growth (understory trees, cm/yr)	Terminal > 10 Lateral > 8	Terminal 5 to > 10 Lateral 2 to > 8	Terminal < 5 Lateral < 2
Shrub layer	Intact	Nearly intact to significant thinning	> 75% dead

Woodland, mature—the stage of woodland development immediately before old growth in which the woodlands exhibit structural characteristics that are lacking in earlier stages of development and may contain some but not all the structural attributes in old growth (USDA Forest Service 2023b). The mature stage of pinyon-juniper stand development generally begins when a stand starts to exhibit old growth characteristics and can occur in ecological sites characterized as either phase III expansion or old growth woodlands. In the mature stage of stand development, some trees may have established prior to settlement and be more than 150 years old (Miller et al. 2019). The mid-1800s is typically used to separate presettlement and postsettlement.

Woodland, old growth—later stages of woodland development that typically differ from earlier stages in a variety of characteristics, including tree size, accumulations of large dead woody material, species composition, and ecosystem function (table 7) (Hamilton 1993; USDA Forest Service 2023b). In pinyon-juniper old growth woodlands, most trees are old (> 150 years) and exhibit old growth characteristics (see Appendix B). The trees established prior to settlement and the understory is composed of large dead wood including snags, logs, and weathered stumps. Characteristics of individual old growth pinyon and juniper trees compared to younger mature trees are differences in tree canopy shape, distinct bark characteristics, and branch structure, which may include large basal branches, and dead branches sometimes covered with lichen. Old

growth woodlands are typically characterized by shallow (< 0.5-m deep), coarse or rocky soils, while expansion woodlands are usually associated with deeper, less coarse, or rocky soils (Romme et al. 2009; Stringham et al. 2015). In addition, old growth is typically associated with certain landscape positions, such as ridges and steep slopes (Burkhardt and Tisdale 1976). Potential understory vegetation is variable depending on climate, soils, tree canopy characteristics, and past disturbance.

Table 7—Characteristics of old growth pinyon-juniper defined in USDA Forest Service, FS-1215a (USDA Forest Service 2023b) for the northwest (NW) and southeast (SE) parts of Region 4, and for low and high productivity areas. To clearly differentiate old growth woodlands, it is necessary to evaluate old growth characteristics based on tree morphology (see Appendix B).

Old growth type	Minimum large tree age (years)	Minimum large tree diameter (in)	Minimum large trees per acre
Pinyon-juniper-NW Low	200	12	12
Pinyon-juniper-NW High	250	18	30
Pinyon-juniper-SE Low	150	9	12
Pinyon-juniper-SE High	200	12	30

Appendix A—Understanding soil family names.

Soil Family Names

In general, soil family names ending in “olls” are Mollisols indicating that they have a minimum of 1% organic matter. Soils ending in “ids” are Aridisols. They contain <1% organic matter, usually occur in aridic precipitation zones, and are less productive than Mollisols. Both soil orders are common in the Great Basin. Examples of naming protocols for Mollisols and Aridisols follow.

1 Coarse sandy loam mixed mesic aridic Typic Haploxerolls

2 Clayey smectic frigid lithic xeric Haplargids

3 Fine loamy mixed super active xeric Argicryolls

4 Loamy skeletal mixed frigid Pachic Haploxerolls

Soil texture / temperature / moisture

Soil 1: Warm (mesic) dry (aridic) soil with an aridic moisture regime that is approaching xeric (xer for xeric) or 12 inches precipitation. This soil has the lowest potential resilience to disturbance and resistance to invasives due to its mesic-aridic soil temperature-moisture regime.

Soil 2: A cool (frigid), moist (xer), shallow (lithic) soil with an accumulation of clay in the B horizon (argi for argillic layer) and >12 inches precipitation. This soil has the lowest potential infiltration rates due to the presence of an argillic layer and the lowest storage potential due to a shallow soil depth (lithic = shallow) and <1% organic matter content.

Soil 3: A cold (cry for cryic), moist (xeric, >12 inches precipitation) soil with an accumulation of clay in the B horizon (argi). This soil has the highest potential resistance to invasive species due to the cold temperature regime. Potential resilience will usually decline along a gradient from warm-cryic to cold-cryic as a result of a shortened growing season.

Soil 4: A moist (xer), cool (frigid), rocky (skeletal) soil. This soil has relatively high resilience and moderate resistant to invasives. It has the highest water capture potential of the four soils due to the loamy soil texture and lack of an argillic layer.

See the *Glossary* for additional soil terms.

Appendix B1—Woodland characteristics and tree growth forms that differentiate post- and pre-settlement woodlands (modified from Miller et al. 2014).

Common types of woodlands are characterized by a) old growth trees that established pre-settlement; b) a low density of old growth trees scattered across the area and infilled with post-settlement trees; or c) post-settlement trees where old growth is either absent (including old stumps and logs) or located on specific soils or topographic positions (e.g., shallow soils and ridges).

Characteristic	Post-settlement	Pre-settlement
Juniper crown shape	Conical with pointed tip	Flattened, rounded, or uneven tops
Pinyon crown shape	Conical with pointed to slightly rounded tip	Flattened, rounded, or uneven top
Juniper branch structure	Branches get progressively smaller from bottom to top of tree	In open stands, large branches near the base
Pinyon branch structure	Branches become smaller from bottom to top of tree, general orientation is vertical	In open stands, branches large near base and remain relatively large well into the crown, more randomly oriented
Juniper bark	Flaky, relatively thin with limited or shallow vertical furrows	Thick, fibrous with well-developed vertical furrows
Pinyon bark	Relatively thin, flaky, with weak vertical furrows	Thicker, more plate-like structure than furrowed
Juniper leader growth	Terminal leader growth in the upper 1/4 of the tree usually > 2 in. In open stands, leader growth > 2 in from bottom to top	Leader growth in the upper 1/4 of the tree usually <1 in
Pinyon leader growth	Leader growth in pinyon similar to juniper but not directly visible. Must look for bud scale scars to determine length	Leader growth in upper 1/4 of the tree usually <2 in
Tree canopy lichen	Little or no foliose lichen on juniper	Juniper often covered by bright green foliose lichen
Large wood across the site	Large diameter logs and stumps absent	Large diameter logs and stumps, often charred, scattered across the site
Dead wood in standing tree	Little dead wood in bole, few to no dead trees, logs, or large stumps	Dead branches, bark missing, black stain and/or black lichen

Appendix B2—Photographs showing examples of old and young trees and the characteristics that differentiate them.



Figure B2.1—Utah junipers have multiple old-growth characteristics including black lichen and black stain, which is often mistaken for charred wood. Dead wood may occur as part of the trunk and there is very limited leader growth at the branch tips. Courtesy photos by Rick Miller, Oregon State University.



Figure B2.2—Bark on Utah juniper is typically flaky and thin on trees <130-150 years old. Bark on trees around 150-180 years old is thicker and beginning to develop vertical furrows. On trees >200-250 years old deep furrows continue to develop with the bark becoming very fibrous. Courtesy photos by Robin Tausch, Emeritus scientist, Rocky Mountain Research Station.

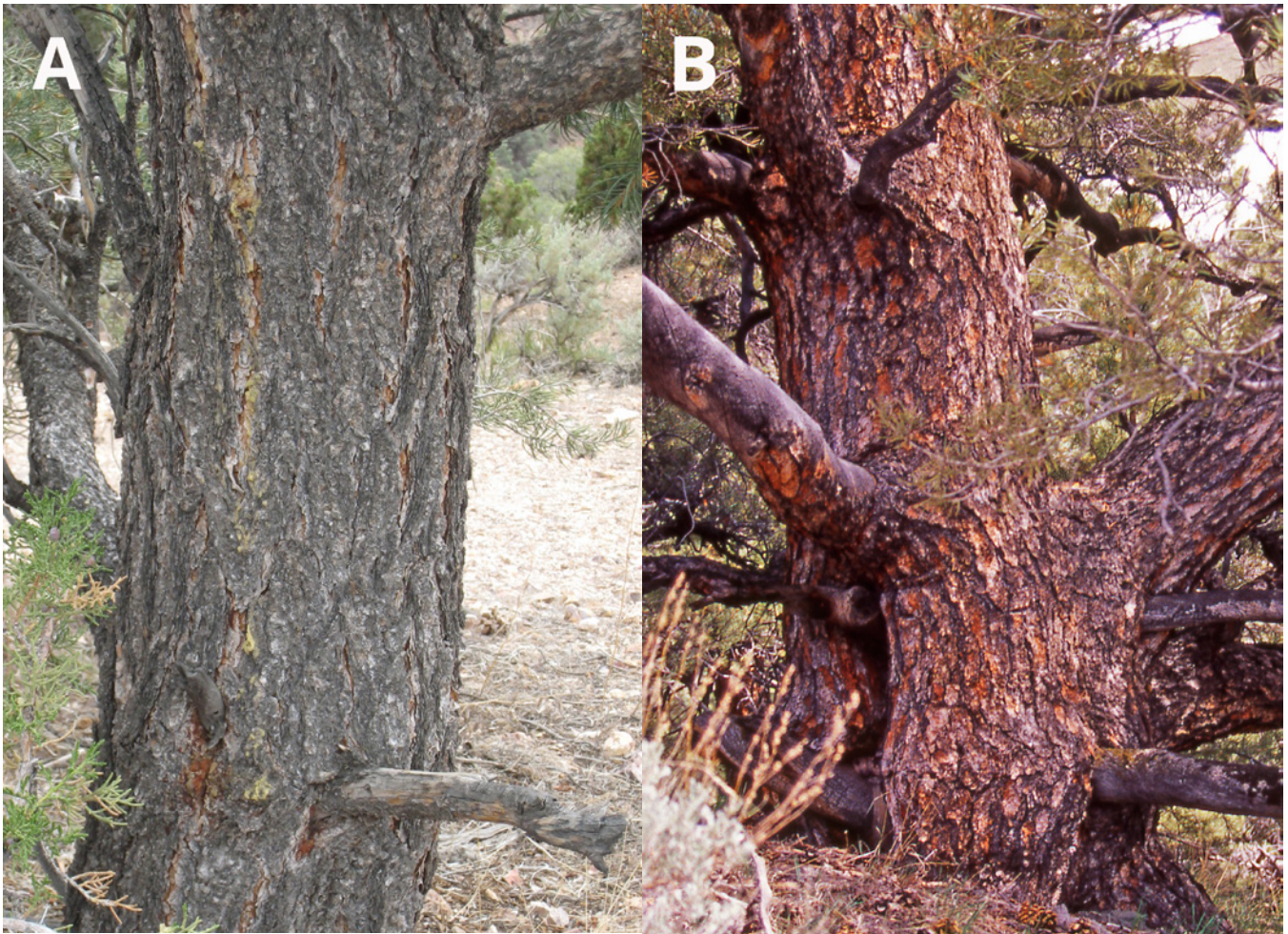


Figure B2.3—Bark on singleneedle pinyon pine is relatively thin and flaky with weak vertical furrows on trees < 130 years old (A). Trees >300 years old (B) have thicker bark that is more plate-like than furrowed. Courtesy photos by Robin Tausch, Emeritus scientist, Rocky Mountain Research Station.



Figure B2.4—Old growth Utah juniper (A) exhibits flattened or rounded crowns that may have dead tops, as well as twisted trunks, very limited terminal and lateral growth on the branch tips, and bark that is thick, furrowed and fibrous. Old growth singleneedle pinyon pine (B) exhibits dead branches, thick platy bark, and flattened round crowns. Courtesy photos A and B1 by Robin Tausch, Emeritus scientist, Rocky Mountain Research Station. Courtesy photo B2 by Rick Miller, Oregon State University.

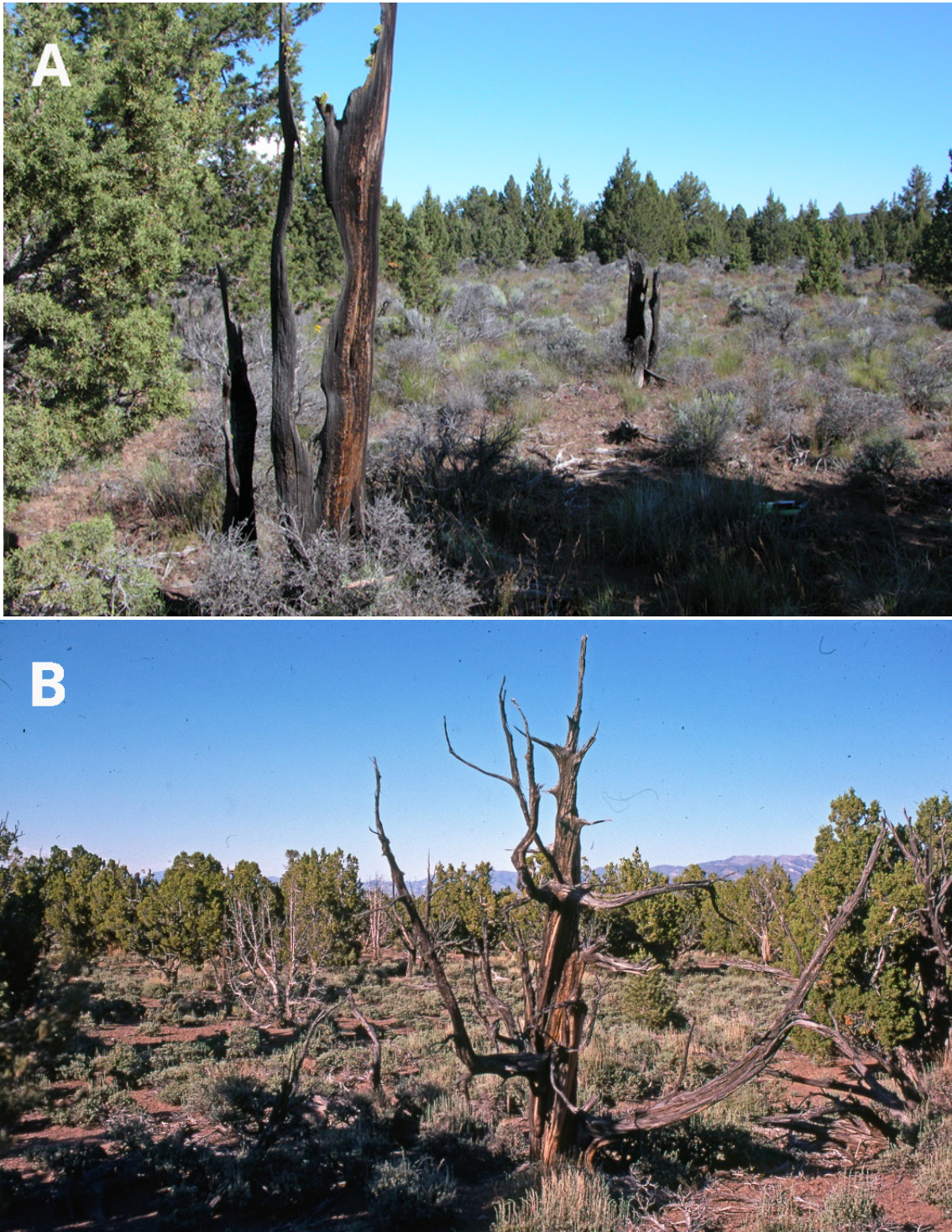


Figure B2.5—Low density of old trees killed by fire that would have had an understory of (A) mountain big sagebrush-bitterbrush/Idaho fescue and (B) Wyoming big sagebrush/needlegrass. Both communities have greater than a 10-fold increase in young trees compared to pre-burn densities. Size and density of snags, stumps, and logs can help project stand structure prior to the fire. (A) Fire occurred around 1900; (B) time since fire in unknown. Courtesy photos by A, Rick Miller, Oregon State University; B, Robin Tausch, Emeritus scientist, Rocky Mountain Research Station.

Appendix C—Indicators of fire severity after a prescribed fire or wildfire.

The fire severity influences plant survival and soil water and nutrient availability post-fire. Soil and litter indicators are derived from Parson et al. (2010).

Low Severity	Moderate Severity	High Severity
> 75% burned sagebrush skeletons remaining	15-75% burned sagebrush skeletons remaining	Sagebrush basal stumps remain or burned below the soil surface
< 25% tree foliage dead, < 15% foliage consumed	25-75% tree foliage dead, 15-50% foliage consumed	> 75% tree foliage dead, > 50% consumed
Tree duff blackened but little consumed	Majority of tree duff consumed, surface blackened	White ash layer beneath tree canopies
> 2 in blackened stubble remains on burned grasses	0.25-1 in blackened stubble remains on burned grasses	Grass crowns consumed to or below the surface
Unburned patches > 50%	Unburned patches 15-50%	Unburned patches < 15%
Interspace litter consumption < 50%	Interspace litter consumption 50-80%	Interspace litter consumption > 80%, white ash deposition
Shrub canopy litter consumption < 50%	Shrub canopy litter consumption 50-80%	Shrub canopy litter consumption > 80%, white ash deposition
No ash, ground fuels blackened & recognizable	Thin layer of black to gray ash, some litter recognizable	Layer of powdery gray or white ash, > 90% surface organics consumed
No fire induced water repellency	Weak to medium water repellency at or just below the surface	Strong water repellency at or below the surface
Surface soil structure unchanged	Soil surface structure slightly to not altered	Aggregated stability reduced or destroyed, soil surface loose and/or powdery

Appendix D1—Assessment of resilience to management treatments and resistance to cheatgrass within a proposed treatment area.

The evaluation sheet is intended for use where increasing or maintaining resilience and resistance are an objective of woody fuel reduction and other vegetation management treatments. The evaluation is based on temperature and moisture regimes, soil characteristics, and current plant composition and can be used to help select the appropriate treatment and to determine site suitability for seeding following treatment.

Score Sheet for Rating Resilience to Disturbance and Resistance to Annual Invasives									
Ecological Site or Type Name _____ %Area _____ UTMs: _____ <i>(Use ecological site descriptions as guidelines for the MLRA with field assessment to complete score sheet.)</i>						Stand (plot)† <i>(Sample two to five plots per ecological site depending on size and variability of area)</i>			
SITE CHARACTERISTICS		SCORE FOR VARIABLE		1	2	3	4	5	
Temperature									
Soil temperature regime	1=hot mesic, 2=warm mesic, 3=cool mesic, 4=warm frigid, 5=cool frigid, 6=warm cryic								
Sagebrush subspecies and other shrubs	1=blackbrush, Stansbury cliffrose; 2=Wyoming, black, Gambel oak, scrub oak, manzanita, serviceberry; 3=mountain, curl-leaf mahogany								
A. Total Temperature Score =									
Moisture									
Precipitation (inches)	1=<10, 2=10-12, 3=12-14, 4=>14								
Soil texture	1=clay, sand, or silt; 2=silty, sandy, or clay loams; 3=loam								
Soil depth (inches)	0=very shallow (<10), 1=shallow (10-20), 3=moderately deep to deep (>20)								
Aspect	0=S facing, 1=E or W facing, 2=N facing								
B. Total Moisture Score =									
Total Temperature + Moisture Score (determines likelihood of seeding success; if score is <10 seeding success will be low)									
Pre-Treatment Vegetation (PTV) (Plant groups modified by soil depth)									
Plant Groups: Deep-rooted perennial grasses (DRPG) Rhizomatous perennial grasses (RHPG) Perennial forbs (PF) Invasive annual forbs and grasses (IAFG)	0 = DRPG and/or RHPG scarce to severely depleted (<5% foliar cover). IAFG may be present and may dominate. 3 = Soils >10 in deep and DRPG and/or RHPG scarce (about 5% foliar cover). IAFG may be present and may be abundant. 6 = Soils >10 in deep and DRPG and/or RHPG depleted (5-10% foliar cover); or on soils <10 in deep DRPG and/or RHPG have >10% foliar cover. IAFG may be present and relatively abundant. 9 = Soils >10 in deep and DRPG and/or RHPG and PF dominant; or on soils <10 in deep DRPG and/or RHPG codominant with PF. IAFG scarce.								
Pre-Treatment Vegetation PTV Adjusted for Treatment Severity (Estimated)									
C. Adjusted Pre-Treatment Vegetation <i>(Estimate fire severity by plot based on fuels and burn prescription; estimate mechanical treatment severity by plot based on woody species biomass)</i>		<i>Low severity mechanical treatment (cut, lop, and scatter) or prescribed fire = PTV x 95%</i> <i>Moderate severity mechanical treatment (mastication or cut and pile burn) or prescribed fire = PTV x 80%</i> <i>High severity prescribed fire = PTV x 20%</i>							
Total Resilience & Resistance Score = Temperature (A) + Moisture (B) + Adjusted PTV (C)									
Mean Resilience and Resistance Rating: Very low = <10, Low = 10-15, Moderate = 16-25, High = >25									

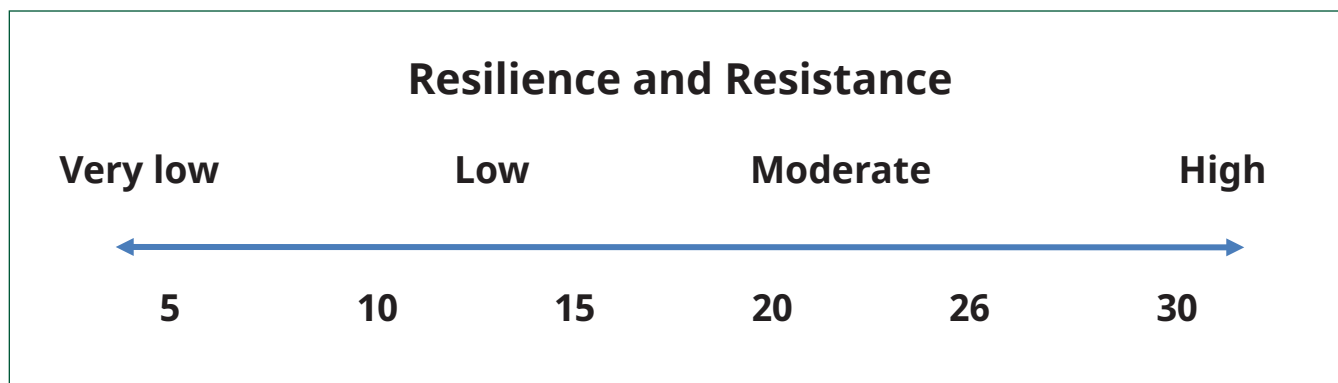
†The plot should represent a plant community and fit within one ecological type. It can vary in size but must be small enough to easily observe vegetation composition and structure by standing at one point or walking a short distance (approximately 100 ft).

Appendix D2—Explanation of the variables in the score sheet.

Begins on next page.

Explanations of Variables Used in the Score Sheet for Rating Resilience and Resistance				
Site	Variable	Explanation	Score	
Characteristics			min	max
Temperature				
Soil temperature regime	1 = Hot mesic (hypermesic) 2 = Warm mesic 3 = Cool mesic 4 = Warm frigid 5 = Cool frigid 6 = Warm cryic	Derived from soil descriptions or ecological type descriptions (tables 1, 2, Appendix A). It is necessary to adjust for aspect and to consider if you are in the lower (warm) or upper (cool) part of the temperature regime.	1	6
Sagebrush and other shrub	1 = blackbrush, Stansbury cliffrose 2 = Wyoming sage, black sage, Gambel oak, scrub oak, manzanita, serviceberry 3 = mountain sage, curl-leaf mahogany	Sagebrush and other shrubs correspond to soil temperature and moisture regimes, and soil depth and texture differ across elevation gradients (tables 2, 3).	1	3
Temperature (A)		Sum of soil temperature + sagebrush subspecies	2	9
Moisture				
Precipitation	1 = <10 in 2 = 10-12 in 3 = 12-14 in 4 = >14 in	Precipitation corresponds to the soil moisture regime: dry-aridic <10 in, aridic 10-12 in, xeric 12-14 in, and xeric >14 in.	1	4
Soil texture	1 = clay, sandy, or silty 2 = silty, sandy, or clay loams 3 = loam	Derived from a soil pit for soils within the surface 20 in or above any type of restrictive layer. Estimated by hand: gritty (sandy), silky (silty) or plastic/sticky (clay). Loams have good water availability; clay, sandy or silty soils do not.	1	3
Soil depth	0 = very shallow (<10 in) 1 = shallow (10-20 in) 3 =mod deep to deep (>20 in)	Derived from a soil pit and measures the depth to a restrictive layer if any. Soil depth is a major determinant of water storage and rooting depth.	0	3
Aspect	0 = South facing 1 = East or West facing 2 = North facing	Based on the general aspect of the site and derived from a compass reading. Aspect influences heat load and water availability.	0	2
Total Moisture		Sum of precipitation + soil texture + soil depth	2	10
Temperature (A) + Moisture (B)		Sum of total temperature and moisture scores.	4	19
Pre-treatment Vegetation (PTV) (Plant groups modified by soil depth)				
Plant Groups Deep-rooted perennial grasses (DRPG) Rhizomatous perennial grasses (RHPG) Perennial forbs (PF) Invasive annual forbs and grasses (IAFG)	0 = DRPG and/or RHPG scarce to severely depleted (< 5% foliar cover). IAFG present and may dominate. 3 = Soils >10 in deep and DRPG and/or RHPG scarce (about 5% foliar cover). IAFG present and may be abundant. 6 = Soils >10 in deep and DRPG and/or RHPG depleted (5 to 10% foliar cover); or on soils <10 in deep DRPG and/or RHPG have >10% foliar cover. IAFG may be present and relatively abundant. 9 = Soils >10 in deep and DRPG and/or RHPG and PF dominant; or on soils <10 in deep DRPG and/or RHPG codominant with PF. IAFG scarce.	0 = DRPG and/or RHPG <5% cover; invasives dominate the understory or, if invasives are not dominant, woody species (shrubs or trees) are near maximum cover. 3 = DRPG and/or RHPG are scarce and limit resilience and resistance. Relative abundance of invasives depends on temperature and moisture regime and cover of woody species. 6 = DRPG and/or RHPG are sufficient to promote recovery following treatment. Relative abundance of invasives depends on temperature and moisture regime and cover of woody species. 9 = Native herbaceous species are dominant. If the area is seeded to nonnative grasses, return to reference state is unlikely, but IAFG resistance may be high.	0	9
Pre-treatment Vegetation (PTV) Adjusted for Treatment Severity (Estimated)				
PTV adjusted for treatment severity	<i>Low severity mechanical treatment or prescribed fire</i> = PTV x 95% <i>Moderate severity mechanical treatment or prescribed fire</i> = PTV x 80% <i>High severity mechanical treatment or prescribed fire</i> = PTV x 20%	<i>Low treatment severity</i> results in little mortality of perennial grasses and forbs. <i>Moderate treatment severity</i> can occur in phase I and II expansion and high biomass shrublands. <i>High treatment severity</i> can occur in phase III expansion areas.	0	8.6
Total Resilience & Resistance Score: Very low = <10, Low = 10-15, Moderate = 16-25, High = >25		Temperature (A) + Moisture (B) + Adjusted PTV (C) = resilience & resistance score.	5	29.6

Interpretation of Resilience and Resistance Ratings from Score Sheet



The resilience and resistance rating from the Score Sheet is intended to provide information on the likely recovery potential of a treatment area and its susceptibility to invasive annual forbs and grasses. Lower ratings indicate that either the abiotic characteristics (precipitation regime, soils) and/or biotic characteristics (relative abundance of perennial grasses and invasive annual forbs and grasses) are limiting the recovery potential and increasing susceptibility to invasion. Higher ratings indicate that the abiotic and biotic characteristics are less limiting and that the site should exhibit less change and recover more quickly following either wildfire or treatment.

Appendix D3—Example of the use of the score sheet.

The ecological type is: Wyoming big sagebrush – Mesic/Xeric 16-20 in PZ. The potential treatment areas is in variable condition and the planned treatment is mastication. See Appendix E for the description of the ecological type and the STM.

Score Sheet for Rating Resilience to Disturbance and Resistance to Annual Invasives								
Ecological Site or Type Name: <u>Wyoming big sagebrush – Mesic/Xeric 16-20 in PZ</u> %Area <u>60%</u> UTMs: <u>Your site</u> <i>(Use ecological site descriptions as guidelines for the MLRA with field assessment to complete score sheet.)</i>					Stand (plot)† (can sample up to five per ecological type)			
SITE CHARACTERISTICS		SCORE FOR VARIABLE		1	2	3	4	5
Temperature								
Soil temperature regime	1=hot mesic, 2=warm mesic, 3=cool mesic, 4=warm frigid, 5=cool frigid, 6=warm cryic	2	3	2	2	3		
Sagebrush subspecies and other shrubs	1=blackbrush, Stansbury cliffrose; 2=Wyoming, black, gambel oak, scrub oak, manzanita, serviceberry; 3=mountain, curl-leaf mahogany	2	2	2	2	2		
A. Total Temperature Score =		4	5	4	4	5		
Moisture								
Precipitation (inches)	1=<10, 2=10-12, 3=12-14, 4=>14	4	4	4	4	4		
Soil texture	1=clay, sand, or silt; 2=silty, sandy, or clay loams; 3=loam	2	2	2	2	2		
Soil depth (inches)	0=very shallow (<10), 1=shallow (10-20), 3=moderately deep to deep (>20)	3	3	3	3	3		
Aspect	0=S facing, 1=E or W facing, 2=N facing	0	1	1	0	2		
B. Total Moisture Score =		9	10	10	9	11		
Total Temperature + Moisture Score (determines likelihood of seeding success; if score is <10 seeding success will be low)		13	15	13	12	15		
Pre-Treatment Vegetation (PTV) (Plant groups modified by soil depth)								
Plant Groups: Deep-rooted perennial grasses (DRPG) Rhizomatous perennial grasses (RHPG) Perennial forbs (PF) Invasive annual forbs and grasses (IAFG)	0 = DRPG and/or RHPG scarce to severely depleted (<5% foliar cover). IAFG may be present and may dominate. 3 = Soils >10 in deep and DRPG and/or RHPG scarce (about 5% foliar cover). IAFG may be present and may be abundant. 6 =Soils >10 in deep and DRPG and/or RHPG depleted (5-10% foliar cover); or on soils <10 in deep DRPG and/or RHPG have > 10% foliar cover. IAFG may be present and relatively abundant. 9 = Soils >10 in deep and DRPG and/or RHPG and PF dominant; or on soils <10 in deep DRPG and/or RHPG codominant with PF. IAFG scarce.	0			0			6
Pre-Treatment Vegetation PTV Adjusted for Treatment Severity (Estimated)								
C. Adjusted Pre-Treatment Vegetation <i>(Estimate fire severity by plot based on fuels and burn prescription; estimate mechanical treatment severity by plot based on woody species biomass)</i>	<i>Low severity mechanical treatment (cut, lop, and scatter) or prescribed fire = PTV x 95%</i> <i>Moderate severity mechanical treatment (mastication or cut and pile burn) or prescribed fire = PTV x 80%</i> <i>High severity prescribed fire = PTV x 20%</i>	0	2.4	2.4	0	4.8		
Total Resilience & Resistance Scores = Temperature (A) + Moisture (B) + Adjusted PTV(C)		13	17	15	12	20		
Mean Resilience and Resistance Rating: Very low = <10, Low = 10-15, Moderate = 16-25, High = >25								

†The plot should represent a plant community and fit within one ecological type. It can vary in size but must be small enough to easily observe vegetation composition and structure by standing at one point or walking a short distance (approximately 100 ft).

Appendix E—Descriptions, vegetation departure and ecological states, state-and-transition models (STMs), and management recommendations for the shrubland and pinyon-juniper ecological types within the Pine Valley Ranger District of the Dixie National Forest.

This appendix provides the information needed to identify the dominant shrubland and pinyon-juniper ecological types, evaluate vegetation departure and current ecological states, and determine appropriate management strategies. The ecological types and STMs align with the Biophysical Settings (BpS) compiled for the Pine Valley Ranger District by Tuhy et al. (2014). Proxy soil temperature and moisture regimes and precipitation zones (PZ) are from Daymet (Thornton et al. 2022). The descriptions of the ecological types and vegetation departure are primarily from USDA FEIS (2024), Hood et al. (2007), Stringham et al. (2015), and Tuhy et al. (2014). The STMs were modified from Stringham et al. (2015) and the ESDs available in the Ecosystem Dynamics Interpretive Tool (EDIT) for Major Land Resource Area 28A. Plant nomenclature follows the PLANTS Database (USDA NRCS 2024). Mark Madsen, Forest Botanist; Vaughn Thacker, Pine Valley Ranger District Soil Scientist; and Rhett Boswell, Pine Valley Ranger District Wildlife Biologist, provided information on species composition, soil characteristics, and management approaches.

List of Ecological Types

1. Blackbrush - Hypermescic/Xeric 12–16 in PZ; moderately low resilience and moderately low resistance
2. Mountain shrub - Stansbury cliffrose - Hypermescic to Mesic/Xeric 14–18 in PZ; moderately low to moderate resilience and moderately low resistance
3. Montane chaparral - Mesic to Hypermescic/Xeric 16–20 in PZ; moderate resilience and moderately low resistance
4. Wyoming big sagebrush - Mesic/Xeric 16–20 in PZ; moderate resilience and moderately low to moderate resistance
5. Mountain shrub - Utah serviceberry - Mesic/Xeric 16–20 in PZ; moderate resilience and moderately low to moderate resistance
6. Black sagebrush - Mesic/Xeric 16–20 in PZ; moderate resilience and moderately low to moderate resistance
7. Mountain big sagebrush - Frigid to Mesic/Xeric 18–22 in PZ; moderate to moderately high resilience and moderate to moderately high resistance
8. Old growth juniper-pinyon - Mesic to Hypermescic/Xeric 12–16 in PZ; moderately low resilience and low resistance

9. Old growth pinyon-juniper - Mesic/Xeric 16–20 in PZ; moderate resilience and moderately low to moderate resistance
10. Mountain shrub - Gambel oak - Mesic/Xeric 16–22 in PZ; moderate resilience and moderately low to moderate resistance
11. Curl-leaf mountain mahogany - Frigid/Xeric 18–24 PZ; moderately high resilience and moderately high resistance

1. Blackbrush - Hypermestic/Xeric 12–16 in PZ; moderately low resilience and moderately low resistance

The blackbrush type occurs at the Mojave Desert - Colorado Plateau ecotone in the southern portion of the Pine Valley Ranger District and comprises 4,209 ac (1,703 ha). Precipitation ranges from 12 to 16 in (305 to 406 mm) based on Daymet data, but effective moisture may be lower depending on soils and aspect. Soil temperature of this type is hypermesic (very warm). The blackbrush type typically occurs at elevations ranging from 4,000 to 4,985 ft (1,220 to 1,520 m) and is found on low hills, mountains, and broad alluvial fans. Soils are predominantly shallow to a root-restrictive layer on basalt fans and have a high level of rock fragments within the profile. The type typically occurs above the creosotebush zone and below the montane chaparral or big sagebrush/pinyon-juniper zones. Wyoming big sagebrush and Utah juniper are often associated with blackbrush at higher elevations. The blackbrush type is characterized by relatively high cover (30% to 50%) of low stature (20 in [50 cm] tall), woody evergreen shrubs.

The dominant shrub is blackbrush (*Coleogyne ramosissima*). Codominant shrub species may include Mohave goldenbush (*Haplopappus linearifolius*), desert ceanothus (*Ceanothus greggii* var. *vestitus*), Yerba Santa (*Eriodictyon angustifolium*), green ephedra (*Ephedra viridis*), buck-horn cholla (*Opuntia whipplei*), and banana yucca (*Yucca baccata*). Grasses may include squirreltail (*Elymus elymoides*), Indian ricegrass (*Achnatherum hymenoides*), James' galleta (*Pleuraphis jamesii*), bulbous bluegrass (*Poa bulbosa*), and sixweeks fescue (*Festuca octoflora*). Dominant nonnative species include annuals like red brome (*Bromus rubens*), cheatgrass (*Bromus tectorum*), and red-stemmed filaree (*Erodium cicutarium*). Commonly encountered native forbs may include Arizona popcorn flower (*Plagiobothrys arizonicus*), woolly plantain (*Plantago patagonica*), winding mariposa lily (*Calochortus flexuosus*), woolly easterbonnets (*Eriophyllum wallacei*), desert fraseria (*Swertia albomarginata*), Fremont's phacelia (*Phacelia fremontii*), Ives' phacelia (*Phacelia ivesiana*), Lindley's silverpuffs (*Microseris lindleyi*), wingnut cryptantha (*Cryptantha pterocarya*), narrowstem cryptantha (*Cryptantha gracilis*), moth combseed (*Pectocarya setosa*), and wedgeleaf draba (*Draba cuneifolia*).

The historical fuel complex in late seral blackbrush stands was probably similar to that observed in relatively undisturbed sites today (reviewed in Brooks et al. 2007). Shrub cover was likely comprised primarily of blackbrush at 30% to 50% total cover, and interspaces were probably mostly bare, even during years of high rainfall, due to

root competition from blackbrush. Other species, such as perennial grasses and early seral shrubs, probably occurred sporadically depending on time since disturbance. Low amounts of fine fuels in interspaces probably limited fire spread to only extreme fire weather conditions during which high winds, low relative humidity, and low fuel moisture resulted in high intensity stand-replacing crown fires. Natural fire return intervals may have been on the order of centuries. Long fire-free intervals are necessary for the recovery of late seral blackbrush stands.

Currently, blackbrush shrublands are one of the more flammable vegetation types due to the high proportion of fine fuels and optimal fuel bulk density (Brooks et al. 2007). Nonnative annual grasses (herbaceous fine fuels) now occur in most blackbrush stands, although their dominance varies substantially among sites. Blackbrush fires usually kill most plants and are usually stand-replacing. Individual fires can kill upwards of 80% of the seeds of all species in the soil seed bank. However, when only a portion of a blackbrush plant is consumed, it may survive and resprout from the root crown after fire. Blackbrush stands can recover within 50 to 75 years of a fire under favorable conditions. It seems probable that the ability of blackbrush to resprout after burning varies across its wide geographic range and is likely highest in more mesic areas at the edges of its geographic range.

Land cover data from the Rangeland Analysis Platform (Allred et al. 2021) for 2018–2022 indicated that shrubs were a primary component (12.8%), perennial grasses and forbs were minor (2.1%), and pinyon-juniper was widespread (23.4%). Cover of invasive annuals from the Rangeland Analysis Platform was 2.9% and from the USGS Rangeland Exotic Plant Monitoring System (unpublished) was 10.0% for 2016–2022. An early analysis indicated invasive annual grasses were widespread across this type (Tuhy et al. 2014).

Ecological States and Vegetation Departure (Brooks et al. 2007)

Not departed—reference states or current ecological states not at risk of transitioning to an undesirable state.

Mature blackbrush stands are typically late seral with occasional early seral patches created by infrequent stand-replacing fires. The fire regime is active crown fire carried primarily by blackbrush and perennial grasses, including Indian ricegrass and James' galleta on deeper soils. Burns are complete and stand-replacing, fire intensity is high, and fire return intervals are much longer than 100 years. Long fire return intervals allow for the typically slow process of blackbrush reestablishment.

Moderately departed—current potential states at risk or shrub state at risk.

These states are characterized by blackbrush stands with late seral unburned patches and early seral burned patches. These states also include blackbrush stands with patches that have been degraded by overgrazing, prescribed burning in the mid-1900s, or other forms of surface disturbance. These disturbances reduce cover of blackbrush and increase cover of early seral and root-sprouting shrubs such as rabbitbrush (*Chrysothamnus* spp.), early seral herbaceous perennials, and nonnative annual plants.

Burned stands without livestock overgrazing that are situated on deep, silty soils can also have a large perennial grass component (Indian ricegrass and James' galleta). Fires in late seral patches are crown fires carried by blackbrush, perennial grasses, and nonnative annual grasses and forbs. Burns are complete and fire intensity is high. Fires within early seral patches are passive crown fires or surface fires carried by perennial grasses and nonnative annual grasses between the sparse cover of early seral shrubs. Burns are patchy and fire intensity is low to moderate. Fire return intervals in moderately departed stands are approximately 50 to 100 years. This shorter fire return interval, and overgrazing pressure from livestock, helps to maintain dominance by early seral species and may prevent reestablishment of blackbrush.

Highly departed (uncharacteristic)—annual states.

These states are characterized by vegetation and fire regime attributes that have been significantly altered from their natural range. The risk of losing key ecosystem components, such as high blackbrush cover and its associated protection from soil erosion, is high. Blackbrush stands that burned during the 1900s, and have reburned at least once, are in these states. These stands are typically dominated by nonnative annuals and early seral perennials. Recurrently burned stands without livestock overgrazing can also have a large perennial grass component. The fire regime for this condition class is typically surface fire fueled primarily by nonnative annual plants. Burns are patchy, fire intensity is low, and fire return intervals are < 50 years. Reestablishment by blackbrush is highly unlikely under this fire regime.

Recommended Treatments (Brooks et al. 2007)

Not departed—reference states or current ecological states not at risk. Manage to maintain ecological resilience and resistance to invasives.

- Manage livestock grazing at a stocking rate, season of use, and duration that maintains or increases perennial grasses and forbs.
- Suppress human-caused fires that can result in extensive, high severity burns.
- Prescribed fires should not be conducted except for small research burns designed to evaluate fire behavior, fire effects, and fire management techniques and treatments.
- Only apply fuels management treatments at the wildland urban interface to reduce fire hazard, or in wildland areas where fuel breaks are deemed necessary to achieve management goals.
- Realize that regular maintenance may be required to maintain managed fuel zones because fuel treatments that involve replacement of late seral woody fuels with early seral fine fuels will reduce fire intensity but may increase susceptibility to ignition and rates of fire spread.

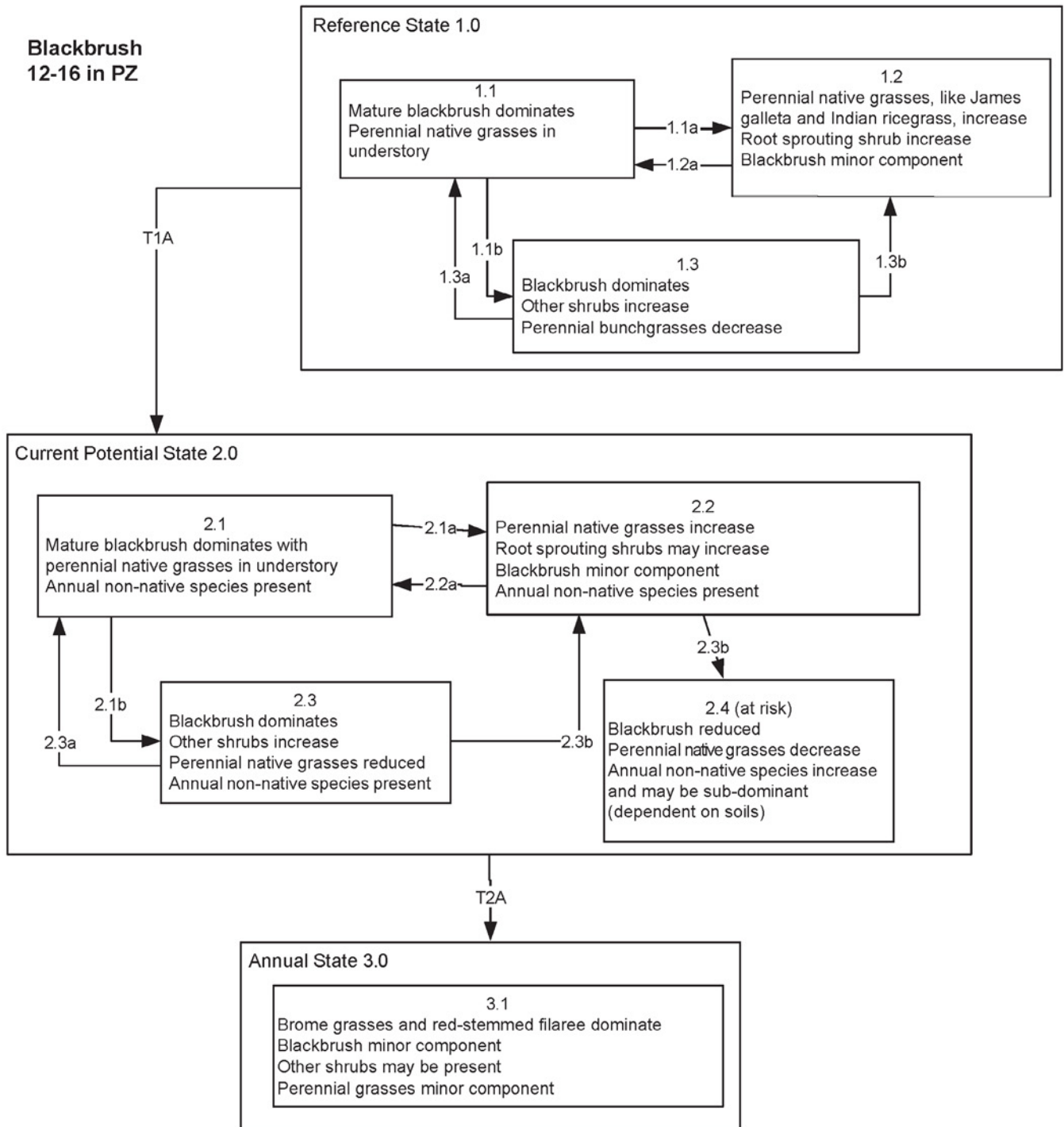
Moderately departed—current potential states at risk or shrub state at risk. Manage to increase ecological resilience and resistance to invasives.

- Suppress all wildfires.
- Prescribed fires should not be conducted except for small research burns.
- Minimize livestock grazing and other surface disturbances on early seral stands, or where early seral and late seral stands are intermixed.
- Do not apply fuels management treatments to late seral stands, except possibly at the wildland urban interface to reduce fire hazards or in wildland areas where fuel breaks are deemed necessary to achieve management goals. Regular maintenance may be required to maintain these managed fuel zones. Fuel treatments that involve replacement of late seral woody fuels with early seral fine fuels will reduce fire intensity, but may increase susceptibility to ignition, fire spread rates, and fire frequency.
- Fuels treatments in early seral stands dominated by nonnative annual plants may include the use of grass-specific herbicides.
- Carefully managed livestock grazing may reduce fine fuel loads temporarily but may hinder the reestablishment of blackbrush and other late seral species and thus, may be counterproductive in the long-term.

Highly departed (uncharacteristic)—annual states. Manage to increase ecological resilience and resistance to invasives.

- Suppress wildfires where possible.
- Prescribed fires should not be conducted except for small research burns.
- Extreme measures may be required in these stands. Revegetation with blackbrush and other late seral shrubs and perennial grasses, and exclusion of livestock grazing and other surface disturbances, may be necessary. Due to the harsh climate, repeated intervention may be required.
- Control of nonnative annual grasses using herbicides or early season prescribed fire implemented immediately before revegetation treatments may increase initial establishment rates of revegetated plants.

**Blackbrush
12-16 in PZ**



2. Mountain shrub-Stansbury cliffrose - Hypermescic to Mesic/Xeric 14–18 in PZ; moderately low to moderate resilience and moderately low resistance

This ecological type comprises 11,362 ac (4,598 ha). Precipitation ranges from 14 to 18 in (356 to 457 mm) based on Daymet data, but effective precipitation may be lower depending on soils and aspect. The elevation range of this type is 915 to 2,438 m (3,000 to 8,000 ft). The type occurs in the southern part of the Pine Valley Ranger District soil, and the temperature regime is very warm (hypermescic) to warm (mesic). The type is found in small patches on benches, mountain foothills, and lower slopes with deep and moderately deep soils formed in residuum from basalt flows, but also occurs on sedimentary substrates. Soils have a loamy or clayey texture with high rock fragments and are typically extremely cobbly. The Stansbury cliffrose (*Purshia stansburiana*) form of mountain shrub is usually at lower elevations and adjacent to or imbedded in the montane portion of mesic blackbrush (*Coleogyne ramosissima*) and pinyon-juniper woodlands. On warmer and drier sites associated species may include the shrub green ephedra (*Ephedra viridis*) and the grasses James' galleta (*Pleuraphis jamesii*), Indian ricegrass (*Achnatherum hymenoides*), and needle-and-thread (*Heterostipa comata*). On cooler and moister sites, the shrub black sagebrush (*Artemisia nova*), and the grasses blue grama (*Bouteloua gracilis*) and Sandberg's bluegrass (*Poa secunda*) may co-occur.

Land cover data from the Rangeland Analysis Platform (Allred et al. 2021) for 2018–2022 indicated that shrubs were a primary component (11.3%), perennial grasses and forbs were depleted (3.9%), and pinyon-juniper was widespread (19.5%). Cover of invasive annuals from the Rangeland Analysis Platform was 11.5%, and from the USGS Rangeland Exotic Plant Monitoring System (unpublished) was 10.7% for 2016–2022. An early analysis indicated invasive annual grasses were a major component across 30% of the type (Tuhy et al. 2014). In addition, seeded areas occur where annual grasses were present.

This type is specific to the Pine Valley Pine Valley Ranger District and information on its historical fire regime and response to fire is limited. Information provided here is from Howard (1995) and Tuhy et al. (2014). Historically, it is likely that fire return intervals were similar to montane chaparral, ranging from about 80 to 130 years (Tuhy et al. 2014). Cover of Stansbury cliffrose in late seral reference communities was < 30% and herbaceous cover was also < 30%; this probably reflects presettlement conditions. Fires were likely moderate to high severity resulting from transmission from other types during years of high fuel productivity and extreme fire weather conditions. Recovery of the site was likely relatively slow. Stansbury cliffrose is usually killed by fire, but some sources indicate a variable or weak ability to resprout after fire (Howard 1995). Stansbury cliffrose can produce large numbers of seeds during favorable years, which promotes establishment from wind dispersed seeds across disturbed areas. Seed caching by rodents also may promote recovery on some sites.

Following fire, root-sprouting shrubs like snakeweed (*Gutierrezia* spp.) and rabbitbrush (*Chrysothamnus* spp.) may increase and in some cases replace Stansbury cliffrose, especially where annual grasses are abundant. Currently, a significant portion of the

site is experiencing tree expansion and associated annual grass invasion. The greatest risk to this system is conversion to annual grass dominance following high severity wildfires.

Ecological States and Vegetation Departure (Howard 1995; Tuhy et al. 2014)

Not departed—reference states or current ecological states not at risk of transitioning to an undesirable state.

These stands are typically late seral with occasional early seral patches created by infrequent stand-replacing fires. The fire regime is active crown fire carried primarily by Stansbury cliffrose. Burns are complete and stand-replacing, fire intensity is high, and fire return intervals are between 80 and 130 years. Long fire return intervals allow for the reestablishment of species present in the seed bank and the development of the fuel loads and spatial continuity necessary for fire to occur. Not departed sites may have pinyon-juniper present.

Moderately departed—current potential states at risk or shrub state at risk.

These states are characterized by vegetation and fire regime attributes that have been moderately altered from their natural range. The risk of losing key ecosystem components, such as cover for wildlife, is moderate. There are two types of moderately departed sites: (1) where the fire return intervals are greater than the natural range of variation (> 100 years) and expansion of Utah juniper and pinyon has occurred; and (2) sites where fire return intervals, or other landscape-scale disturbances, are within or slightly less than the natural range of variation (80 to 130 years) and the postdisturbance community contains a significant intermix of late seral unburned patches and early seral burned patches dominated by nonnative grasses.

Highly departed (uncharacteristic)—annual, seeded, and tree dominated states.

These states are characterized by vegetation and fire regime attributes that have been significantly altered from their natural range. Shrub sites that have burned repeatedly, lost most of the shrub cover and shrub seed bank, and have significant amounts of *Bromus* spp. or other nonnative grasses fall into this category. Nonnative annuals and early seral perennials typically dominate these stands. The fire regime is typically surface fire carried primarily by nonnative annual plants. Burns are patchy, fire intensity is low, and fire return intervals can be < 20 years. Reestablishment by Stansbury cliffrose is diminished under this fire regime and becomes less likely as native seed banks disappear. In areas with woodland expansion, trees may have reached densities sufficient to fully occupy the site. Shrubs and perennial herbs are minor components and scattered in tree openings. Extensive bare soil may be exposed and eroding between the trees. Total conversion to tree dominance (phase III) may occur in about 50 years on moderately productive sites. Weed invasion frequently occurs synchronously with woodland expansion and the risk of conversion to annual invasives following wildfire is high.

Management Recommendations (Chambers et al. 2024; Kitchen and McArthur 2007; Miller et al. 2013, 2019).

Not departed—reference states or current ecological states not at risk of transitioning to an undesirable state. Manage to maintain ecological resilience and resistance to invasives.

- Manage livestock grazing at a stocking rate, season of use, and duration that maintains or increases perennial grasses and forbs.
- Suppress human-caused fires that can result in extensive, high severity burns.
- Do not conduct prescribed fires except for small-scale research burns.
- Allow natural recovery following wildfires where sufficient perennial native grasses exist for recovery and risk of invasive grass is low; do not seed with introduced species.
- To maintain multiple seral stages, consider allowing spot fires to burn in areas with moderate resilience where there is no risk to human communities, sufficient perennial native grasses exist for recovery, and annual grasses are rare or absent.
- Establish fuel breaks or green strips adjacent to annual grass dominated areas to prevent fire transmission into these high value ecosystems. Recognize that fuel breaks require regular maintenance.
- Consider fuel reduction treatments at the wildland urban interface to reduce fire hazard where necessary to achieve management goals.

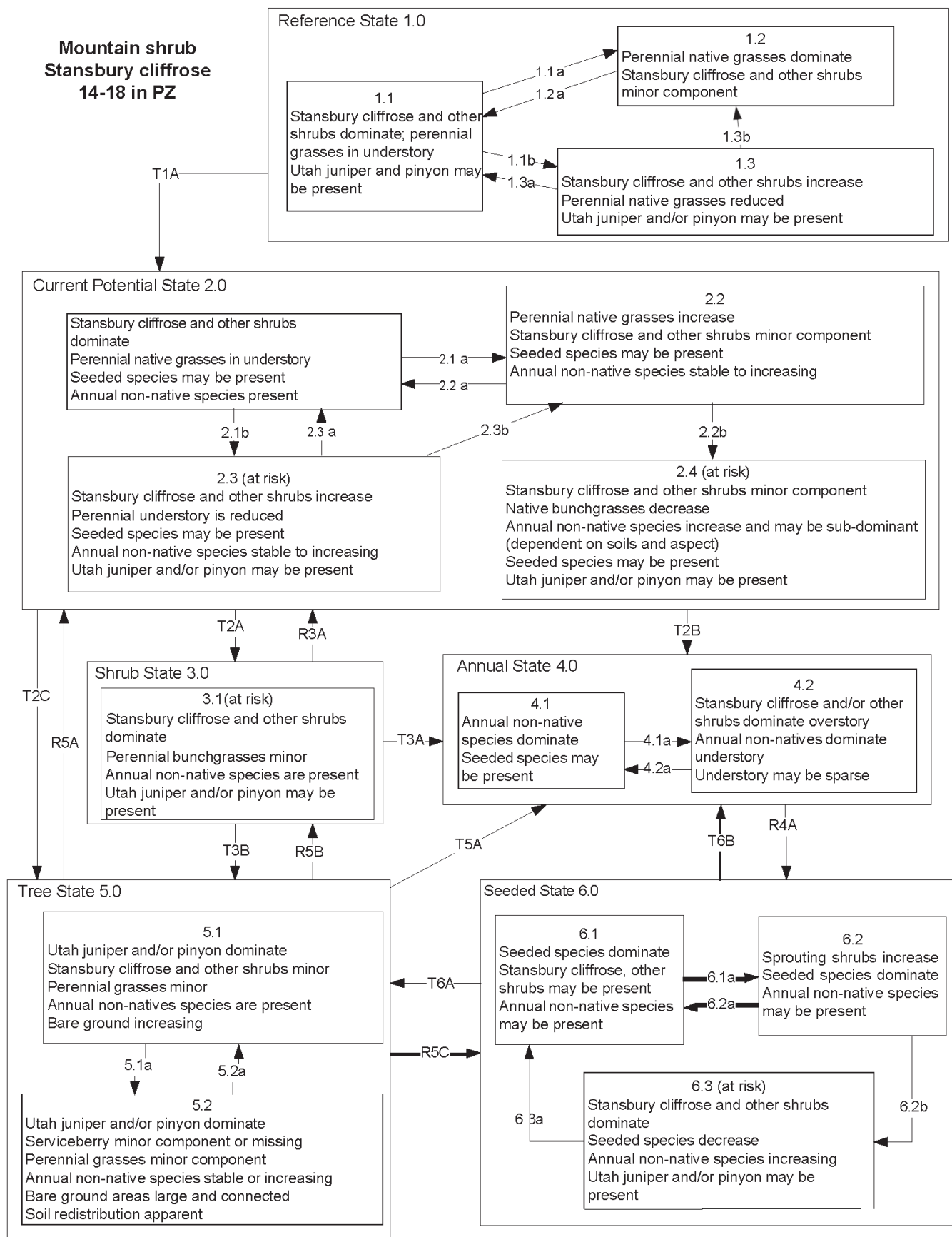
Moderately departed – current potential states at risk or shrub state at risk. Manage to increase ecological resilience and resistance to invasives.

- Manage departed states similarly to not departed states, paying particular attention to areas at risk of transitioning to pinyon-juniper dominance and converting to nonnative annual grasses following wildfire and other disturbances.
- Consider tree removal in phase I and phase II expansion. The vegetation/fuel structure of the different phases of expansion, potential fuel treatments for each phase, likely consequences of treatments for subsequent fire behavior, and ecological responses to treatment are in table 5. Prescribed fire should not be used in these relatively warm and dry sites. Cut and pile burn and mastication can be considered where resilience and resistance are moderately low or higher. These treatments will be most successful if sufficient perennial grasses are present to promote recovery and prevent increases in invasive plants. Cut, lop, and scatter can be considered in phase I and early phase II. In late phase II and phase III, cut, lop, and scatter increases woody surface fuels and the risk of high severity fire.

- Species selected for seeding areas at risk of invasion following management treatments and wildfires determine longer-term outcomes. If native perennial grasses and forbs comprise 10–15% or more cover, seeding may not be needed. If perennial grasses and forbs are depleted, seeding will likely be needed. Seeding native species will increase the likelihood of site restoration. Introduced grasses and forbs as well as shrubs like forage kochia can outcompete residual natives and result in a highly departed state dominated by the introduced seeded species.
- The herbicide Imazapic® suppresses annual grasses but can also decrease establishment of native grasses and forbs. Indaziflam® is a nonselective herbicide that reduces native seed banks and seedling establishment of natives, particularly in warmer and drier areas.

Highly departed (uncharacteristic)—annual, tree, and seeded states. Manage to increase ecological resilience and resistance to invasives.

- Manage highly departed states similarly to not departed states, paying particular attention to areas that are transitioning to pinyon-juniper dominance and converting to nonnative annual grasses following wildfire and other disturbances.
- Consider tree removal in phase I and phase II pinyon-juniper expansion areas as described for moderately departed sites.
- Consider seeding and evaluate species selection as described for moderately departed sites.
- In phase III pinyon-juniper expansion areas that occur on Stansbury cliffrose sites, consider thinning treatments adjacent to human communities and/or to enhance resource and cultural values. The vegetation/fuel structure of the different phases of expansion, potential fuel treatments for each phase, likely consequences of treatments for subsequent fire behavior, and ecological responses to treatment are in table 5. Little data exist on treatment effects on fuels or fire behavior, but implementing cut and pile burning or mastication treatments to thin the trees will decrease crown fire risk. Thinning effects on fuels and fire behavior will depend on treatment extent, configuration, and proximity to other fuel types. Treatments that leave both groups of trees and individual trees will be most conducive to wildlife use. Seeding will be required on sites with severely depleted understory species.



3. Montane chaparral - Mesic to Hypermесic/Xeric 16–20 in PZ; moderate resilience and moderately low resistance

The montane chaparral ecological type is representative of interior chaparral type of the Colorado Plateau (reviewed in Brooks et al. 2007), occurs primarily in the southern portion of the Pine Valley Ranger District, and comprises 46,783 ac (18,933 ha). Precipitation ranges from 16 to 20 in (406 to 508 mm) depending on slope and aspect, and the soil temperature regime is mesic (warm) to hypermesic (very warm). The type typically occurs at elevations of 4,500 to 7,000 ft (1,219 to 3,124 m) on side slopes. Soils are usually deep, are derived from a mixture of igneous and sedimentary sources, and generally have 35 to 60% rock fragments throughout the profile. On the Pine Valley Ranger District, these types intergrade with low-elevation desert landscapes into Stansbury cliffrose mountain shrublands on warmer and drier sites or Wyoming big sagebrush and Utah serviceberry montane shrubland types on cooler and moister sites. Montane chaparral is typically characterized by moderate cover, ranging from 40% on dry sites to 80% on wetter sites. Vegetation is predominantly moderately tall (3.3 to 8.2 ft [1 to 2.5 m]), woody evergreen shrubs with dense crowns. Characteristic species include Sonoran scrub oak (*Quercus turbinella*), ashy silktassel (*Garrya flavescens*), pointleaf manzanita (*Arctostaphylos pungens*), greenleaf manzanita (*Arctostaphylos patula*), desert ceanothus (*Ceanothus greggii*), Yerba Santa (*Eriodictyon angustifolium*), alderleaf mountain mahogany (*Cercocarpus montanus*), littleleaf mountain mahogany (*Cercocarpus intricatus*), Eastern Mojave buckwheat (*Eriogonum fasciculatum*), Mexican cliffrose (*Purshia mexicana*), and fragrant sumac (*Rhus aromatica*). Diagnostic species are Sonoran scrub oak, ashy silktassel, or pointleaf manzanita. Grasses include Indian ricegrass (*Achnatherum hymenoides*), blue grama (*Bouteloua gracilis*), needle-and-thread (*Hesperostipa comata*), and three awn (*Aristida* spp.). In the absence of stand-replacing fires, Utah juniper and pinyon pine can expand into these sites.

Most montane chaparral species are adapted to a fire-prone system (reviewed in Brooks et al. 2007). Sonoran scrub oak is well adapted to survive fire and typically resprouts vigorously from the root crown and rhizomes following fire or other disturbance, while buckbrush and pointleaf manzanita regenerate from long-lived seeds that accumulate in the soil and germinate prolifically following fire. Yerba Santa (*Eriodictyon angustifolium*) is a rapid postfire increaser that usually comes in first following wildfire in the Pine Valley Ranger District's montane chaparral systems. Areas dominated by nonsprouting chaparral species, including pointleaf manzanita, may develop a persistent cover of herbaceous species following fire, especially where *Bromus* spp. are present. Interior chaparral dominated by Sonoran scrub oak have estimated fire return intervals of 74 to 100 years. At least 20 years may be required before sites without invasive annual fuels have sufficient woody fuels to reburn.

Chaparral communities are fire dependent, and exclusion of fire can lead to expansion of woodland and forest species into these communities. Nonnative annual grasses can increase fire frequency to the point where even the fire-adapted interior chaparral cannot recover. Thus, montane chaparral requires fire, but not too much fire.

Conventional wisdom in the fire suppression community is that chaparral either does not burn, or when it does burn, it burns very intensely. Due to threats to humans and



Figure E3.1—L A view looking southeast over the montane chaparral ecological type in the current potential state. The site is on the east slope of the Pine Valley Mountains north of Oak Grove Campground. USDA Forest Service photo by Mark Madsen.

their property, as well as to other high value resources, full suppression remains the primary response to wildfires that occur under the hot, dry conditions of summer in the southwest.

Land cover data from the Rangeland Analysis Platform (Allred et al. 2021) for 2018–2022 indicated that shrubs were a primary component (18.8%), perennial grasses and forbs were moderately depleted (5.7%), and pinyon-juniper was widespread (18.7%). Cover of invasive annuals from the Rangeland Analysis Platform was 5.0%, and from the USGS Rangeland Exotic Plant Monitoring System (unpublished) was 10.0% for 2016–2022. A separate analysis estimated that about 25% of this type was characterized by relatively closed stands and 60% had annual grasses in the understory (Tuhy et al. 2014). Very little area had been seeded.

Ecological States and Vegetation Departure (Brooks et al. 2007)

Not departed—reference states or current ecological states not at risk of transitioning to an undesirable state.

These states are characterized by vegetation and fire regime attributes within the natural range of variation. These stands are typically late seral with occasional early seral patches created by infrequent stand-replacing fires. The fire regime is active crown fire carried primarily by Sonoran scrub oak, buckbrush, and manzanita species. Burns are complete and fire intensity is high, and fire return intervals are between 50 and 100 years. Long fire return intervals allow for reestablishment of seed banks and development of the fuel loads and spatial continuity necessary for fire to occur.

Moderately departed—current potential states at risk or shrub state at risk.

These states are characterized by vegetation and fire regime attributes that have been moderately altered from their natural range. There are two types of moderately departed chaparral sites: (1) where the fire return intervals are greater than historical fire return interval (> 100 years) and expansion of pinyon-juniper into montane chaparral by conifer woodlands is occurring; and (2) sites where fire return intervals, or other landscape-scale disturbances, are within or slightly less than the natural range of variation (< 50 to 100 years) and the postdisturbance community contains a significant intermix of late seral unburned patches and early seral burned patches dominated by nonnative grasses. These sites typically retain significant amounts of area with late seral montane chaparral characteristics, but the trend is toward highly departed.

Highly departed (uncharacteristic)—annual, tree dominated, and seeded states.

These states are characterized by vegetation and fire regime attributes that have been significantly altered from their natural range. Chaparral stands that have burned repeatedly have lost most of their shrub cover and seed bank and have significant amounts of *Bromus* spp. or other nonnative grasses are in this category. Nonnative annuals and early seral perennials typically dominate. The fire regime for this category is typically surface fire carried primarily by nonnative annual plants. Fire intensity is low, and fire return intervals are < 20 years. Reestablishment by native chaparral shrub species is diminished and becomes less likely under this fire regime as native chaparral seed banks disappear.

Management Recommendations (Brooks et al. 2007)

Not departed—reference states or current ecological states not at risk.

- Manage livestock grazing at a stocking rate, season of use, and duration that maintains or increases perennial grasses and forbs.
- Suppress human-caused fires that can result in extensive, high severity burns.
- Allow natural recovery after wildfires where sufficient perennial native grasses exist for recovery and risk of invasive grass is low; do not seed with introduced species.

- Consider allowing lightning-caused spot fires to burn unless there is a risk of increases in invasive annuals, the stands are comprised of non-sprouting chaparral species, or there are other reasons for suppression.
- Consider countering the effects of fire suppression in these fire-dependent ecosystems by implementing prescribed burn treatments where there is no risk to human communities, sufficient perennial native grasses exist for recovery, and annual grasses are not present or present in trace amounts. The goal of these treatments would be to replicate normal patch size/mosaic patterns to provide diversity and potentially reduce the size of wildfires. Treatment frequency should not exceed one fire in 20 years at any site. Treatments on sites dominated by seed propagators (e.g., pointleaf manzanita) may need to be seeded with these species.
- Establish fuel breaks or green strips adjacent to annual grass dominated areas to prevent fire transmission into these high value ecosystems. Recognize that fuel breaks require regular maintenance.
- Consider fuel reduction treatments at the wildland urban interface to reduce fire hazard where necessary to achieve management goals.

Moderately departed—current potential states at risk or shrub state at risk. Manage to increase ecological resilience and resistance to invasives.

- Manage moderately departed states similarly to not departed states, paying particular attention to areas at risk of transitioning to pinyon-juniper dominance and converting to nonnative annual grasses following wildfire and other disturbances.
- Consider tree removal in phase I and phase II expansion areas. The vegetation/fuel structure of the different phases of expansion, potential fuel treatments for each phase, likely consequences of treatments for subsequent fire behavior, and ecological responses to treatment are in table 5. Prescribed fire should not be used except where both resilience and resistance are moderate or higher, i.e., on relatively cool and moist sites with sufficient perennial grass cover to promote recovery and prevent increases in annual grasses. Cut and pile burn and mastication can be considered where resilience and resistance are moderately low or higher and will be most successful if sufficient perennial grasses are present to promote recovery and prevent increases in invasive plants. Cut, lop, and scatter can be considered in phase I and early phase II. In late phase II and phase III, cut, lop, and scatter increases woody surface fuels and the risk of high severity fire.
- Species selected for seeding areas at risk of invasion following management treatments and wildfires determine longer-term outcomes. If native perennial grasses and forbs comprise 10–15% or more cover, seeding may not be needed. If perennial grasses and forbs are depleted, seeding will likely be needed. Seeding native species will increase the likelihood of site restoration. Introduced grasses

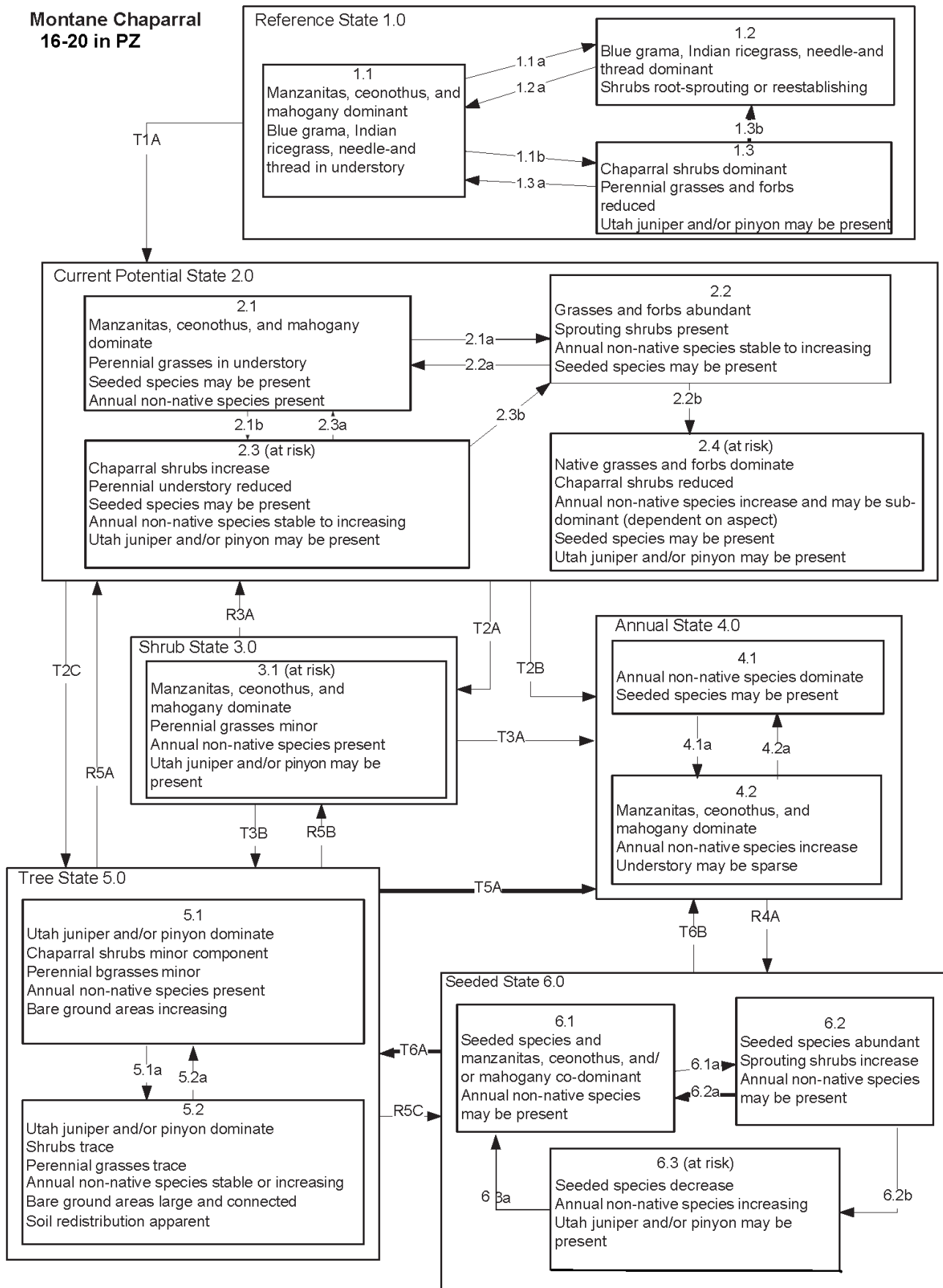
and forbs as well as shrubs like forage kochia can outcompete residual natives and result in a highly departed state dominated by the introduced seeded species.

- The herbicide Imazapic® suppresses annual grasses but can also decrease establishment of native grasses and forbs. Indaziflam® is a nonselective herbicide that decreases native seed banks and reduces seedling establishment of natives, particularly in warmer and drier areas.

Highly departed (uncharacteristic)—annual, tree, and seeded states. Manage to increase ecological resilience and resistance to invasives.

- Manage highly departed states similarly to not departed states, paying particular attention to areas that are transitioning to pinyon-juniper dominance and converting to nonnative annual grasses following wildfire and other disturbances.
- Consider tree removal in phase I and phase II pinyon-juniper expansion areas as described for moderately departed sites, paying particular attention to the risk of conversion to nonnative invasive annuals.
- Consider seeding and evaluate species selection as described for moderately departed sites.
- In Phase III pinyon-juniper expansion areas that occur on montane chaparral sites, consider thinning treatments adjacent to human communities and/or to enhance resource and cultural values. The vegetation/fuel structure of the different phases of expansion, potential fuel treatments for each phase, likely consequences of treatments for subsequent fire behavior, and ecological responses to treatment are in table 5. Little data exist on treatment effects on fuels or fire behavior, but implementing cut and pile burning or mastication treatments to thin the trees will decrease crown fire risk. Thinning effects on fuels and fire behavior will depend on treatment extent, configuration, and proximity to other fuel types. Treatments that leave both groups of trees and individual trees will be most conducive to wildlife use. Seeding will be required on sites with severely depleted understory species.

**Montane Chaparral
16-20 in PZ**



4. Wyoming big sagebrush - Mesic/Xeric 16–20 in PZ; moderate resilience and moderately low to moderate resistance

This widespread ecological type comprises 84,554 ac (34,219 ha) and ranges in precipitation from 16 to 20 in (406 to 508 mm) based on Daymet data. Effective precipitation may be lower depending on soils and aspect. The soil temperature regime is generally warm (mesic) and the elevation range of this type is 4,000 to 8,000 ft (1,219 to 2,134 m). This type is located on hillslopes and benches with loamy-skeletal or clayey skeletal soils derived primarily from rhyolite, basalt, and other volcanic parent materials. Soils are generally shallow to moderately deep mollisols with argillic horizons at a core elevation range of 5,200 to 6,800 ft (1,585 to 2,073 m).

The potential native plant community for these sites varies depending on precipitation, elevation, and landform. Sites within this ecological type are characterized by Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) and are often transitional between salt desert types at lower elevations and mountain big sagebrush at higher elevations. Basin big sagebrush (*Artemisia tridentata* ssp. *tridentata*) may occur on concave sites with finer soils. Associated shrubs include ephedra (*Ephedra* spp.), rabbitbrush (*Chrysothamnus* spp.), snakeweed (*Gutierrezia* spp.), horsebrush (*Tetradymia* spp.), and on cooler and moister sites antelope bitterbrush (*Purshia tridentata*). On warmer and drier sites, common perennial grasses are squirreltail (*Elymus elymoides*), Indian ricegrass (*Achnatherum hymenoides*), needle-and-thread (*Heterostipa comata*), and blue grama (*Bouteloua gracilis*), and on cooler and moister sites, muttongrass (*Poa fendleriana*), bluebunch wheatgrass (*Pseudoroegneria spicata*), and western wheatgrass (*Pascopyron smithii*). Utah juniper (*Juniperus osteosperma*), singleleaf pinyon (*Pinus monophylla*), two-needle pinyon (*Pinus edulis*) or a hybrid of the two pinyon species may occur on these sites with Utah juniper dominating on warmer and drier sites. Shrub canopy cover generally ranges from 5 to 25% but can exceed 30% at the upper elevation and precipitation zones. Perennial forb cover is usually < 10% with perennial grass cover reaching 20 to 25% on more productive sites.

Land cover data from the Rangeland Analysis Platform (Allred et al. 2021) for 2018–2022 indicated that shrubs were a primary component (11.6%), perennial grasses and forbs were depleted (4.4%), and pinyon-juniper was widespread (27.0%). Cover of invasive annuals from the Rangeland Analysis Platform was 4.1%, and from the USGS Rangeland Exotic Plant Monitoring System (unpublished) was 6.3% for 2016–2022. An earlier analysis indicated that invasive annuals were widespread across this type (Tuhy et al. 2014). Pinyon-juniper removal treatments were common in this type and an earlier analysis indicated that about 24% of the type had been seeded and that annual grasses were typically present within the seedings (Tuhy et al. 2014).

Ecological States and Vegetation Departure (Kitchen and McArthur 2007; Tuhy et al. 2014)

Not departed—reference states or current ecological states not at risk of transitioning to an undesirable state.

Following decreases in sagebrush cover due to low severity wildfires or infestations of aroga moths (*Aroga websteri*), perennial native grasses promote recovery of the site. Perennial grasses and forbs are the strongest competitors with annual grasses and so these sites have relatively high resistance to exotic grass and forb invasion. Fire return intervals range between 60 and 100 years. For Wyoming big sagebrush dominated communities in this category, sagebrush cover typically ranges from 15 to 35%. Fires are generally patchy and mature sagebrush stands are generally multi-aged. At the landscape scale, multiple seral stages are represented in an ever-shifting mosaic reflecting periodic occurrence of fire or other disturbance. If present, cheatgrass is scattered and forms an insignificant portion of the herbaceous biomass. At mid to lower elevations, cryptobiotic crusts may be present on bare inter-shrub openings. Pinyon and juniper trees are widely scattered if present. If grazed by livestock, light to moderate stocking rates and periodic rest during the growing season are needed to maintain the perennial herbaceous component.

Moderately departed—current potential states at risk or shrub state at risk.

The herbaceous perennial component in this category is moderately depleted in abundance or diversity. A shift in species composition reflecting palatability to livestock is often noticeable. Sagebrush cover often exceeds that of the not departed condition due to competitive release by a weakened herbaceous understory. On drier sites, cheatgrass is generally present (some soil types excepted) but does not dominate except in scattered patches. Current fire-free intervals are often longer than estimated historic intervals. The Wyoming big sagebrush type is at risk of both annual grass and forb invasion and woodland conversion. The probability of conversion (transition) from a shrub-grass community to weed-dominated grassland is moderately high. In moderately departed sites, trees may have reached 25 to 50% of their potential cover for the type, and native perennial herbaceous cover has been reduced up to 75%.



Figure E4.1—The Wyoming big sagebrush ecological type in (A) the shrub state with a depleted understory and (B) the annual state with an understory dominated by annual grasses. A is in Paradise Flat northwest of Rencher Peak and B is in Colie Flat southwest of Enterprise Reservoir. USDA Forest Service photos by Mark Madsen.

Highly departed (uncharacteristic)—annual, tree, and seeded states.

Perennial grasses and forbs are usually severely depleted in highly departed Wyoming big sagebrush communities. Weedy annuals, especially cheatgrass, may dominate the understory. Shrub cover may be variable, but Wyoming big sagebrush plants tend to be old aged with little new recruitment. The current fire-free interval may be much longer than estimated historic intervals. There is a high probability that a single fire event will result in conversion to an annual-dominated community with corresponding short fire-free intervals and large fire size. Where susceptible to woodland expansion, trees may have reached densities sufficient to fully occupy the site. Shrubs and perennial grasses and forbs are a minor component and are scattered in tree openings. Litter accumulates under trees and extensive bare soil may be exposed and eroded between the trees. Total conversion to tree dominance (phase III) may occur in about 40 to 50 years on moderately productive sites. Because cheatgrass invasion frequently occurs synchronously with woodland expansion, the risk of cheatgrass expansion with fire counters that of conversion to woodland (loss of shrubs and herbs) in the absence of fire.



Figure E4.2—The Wyoming big sagebrush ecological type in the tree state characterized by woodland expansion in Fish Hollow with the North Hills in the background. USDA Forest Service photo by Mark Madsen.

Management Recommendations (Chambers et al. 2024; Kitchen and McArthur 2007; Miller et al. 2013, 2019)

Not departed—reference states or current ecological states not at risk of transitioning to an undesirable state. Manage to maintain ecological resilience and resistance to invasives.

- Manage livestock grazing at a stocking rate, season of use, and duration that maintains or increases perennial grasses and forbs.
- Suppress human-caused fires that can result in extensive, high severity burns.
- Do not conduct prescribed fires except for small-scale research burns.
- Allow natural recovery after wildfires where sufficient perennial native grasses exist for recovery and risk of invasive grass is low; do not seed with introduced species.
- To maintain multiple seral stages, consider allowing spot fires to burn in areas with moderate resilience where there is no risk to human communities, sufficient perennial native grasses exist for recovery, and annual grasses are rare or absent.
- Establish fuel breaks or green strips adjacent to annual grass dominated areas to prevent fire transmission into these high value ecosystems. Recognize that fuel breaks require regular maintenance.
- Consider fuel reduction treatments at the wildland urban interface to reduce fire hazard where necessary to achieve management goals.

Moderately departed—current potential states at risk or shrub state at risk. Manage to increase ecological resilience and resistance to invasives.

- Manage departed states similarly to not departed states, paying particular attention to areas at risk of transitioning to pinyon-juniper dominance and converting to nonnative annual grasses following wildfire and other disturbances.
- Sagebrush reduction treatments (mowing, herbicides) are seldom used in Wyoming big sagebrush types due to the risk of increasing annual grasses. However, in cooler and moister sites with perennial grasses and forbs and moderate or higher resilience and resistance, mowing of decadent sagebrush may increase the abundance of the perennial grasses and forbs.
- Consider tree removal in phase I and phase II expansion areas. The vegetation/fuel structure of the different phases of expansion, potential fuel treatments for each phase, likely consequences of treatments for subsequent fire behavior, and ecological responses to treatment are in table 5. Prescribed fire should not be used except where both resilience and resistance are moderate or higher, i.e., on relatively cool and moist sites with sufficient perennial grass cover to both promote recovery and prevent increases in annual grasses. Cut and pile burn and

mastication can be considered where resilience and resistance are moderately low or higher and will be most successful if sufficient perennial grasses are present to promote recovery and prevent increases in invasive plants. Cut, lop, and scatter can be considered in phase I and early phase II. In late phase II and phase III, cut, lop, and scatter significantly increases woody surface fuels and the risk of high severity fire.

- Species selected for seeding areas at risk of invasion by nonnative annuals following management treatments and wildfires determine longer-term outcomes. If native perennial grasses and forbs comprise 10–15% or more cover, seeding probably is not needed. If perennial grasses and forbs are depleted, seeding is likely needed. Seeding native species will increase the likelihood of site restoration. Introduced grasses and forbs as well as shrubs like forage kochia can outcompete residual natives and result in a highly departed state dominated by the introduced seeded species.
- The herbicide Imazapic® suppresses annual grasses but can also decrease establishment of native grasses and forbs. Indaziflam® is a nonselective herbicide that decreases native seed banks and reduces seedling establishment of natives, particularly in warmer and drier areas.

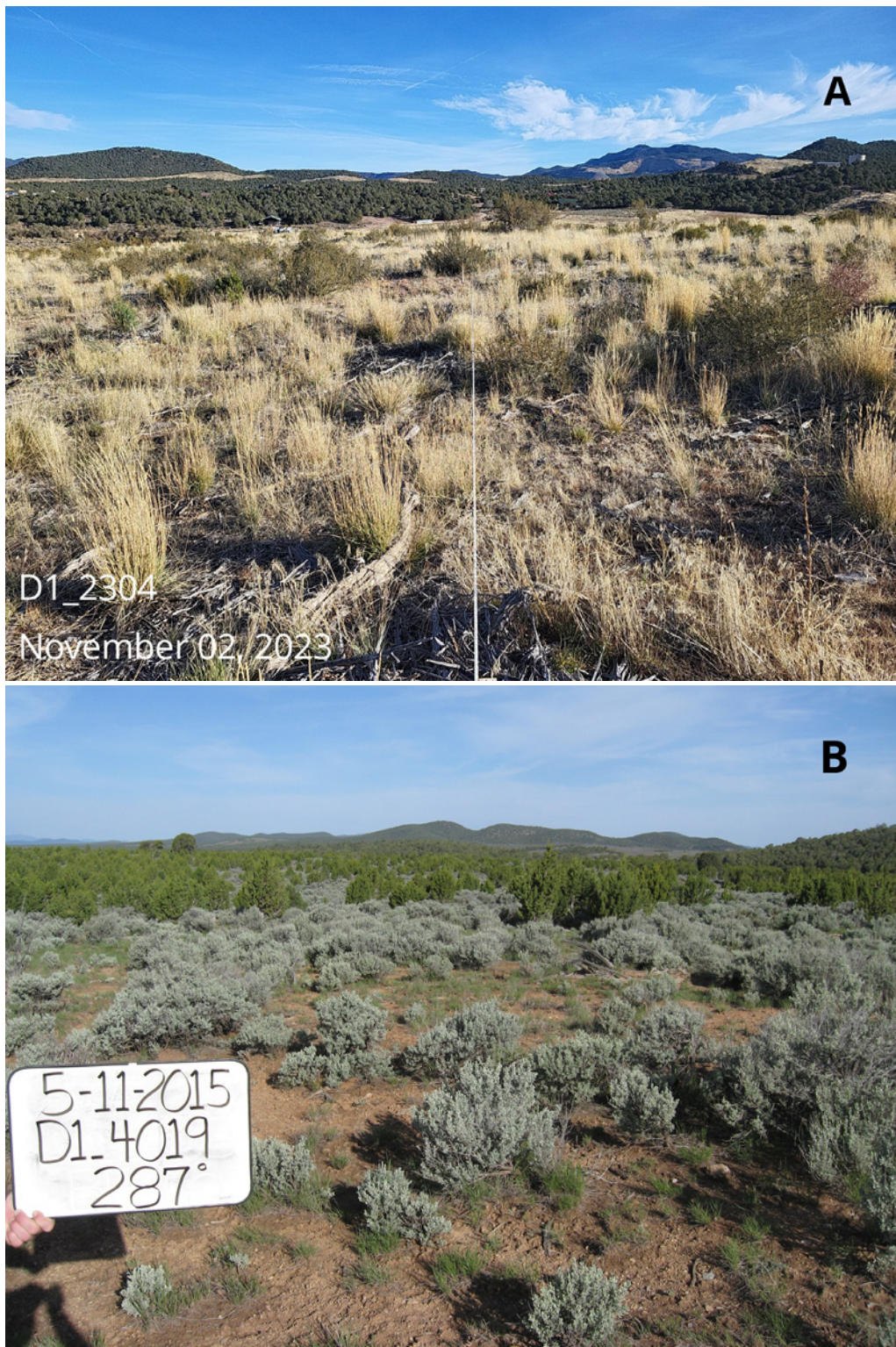
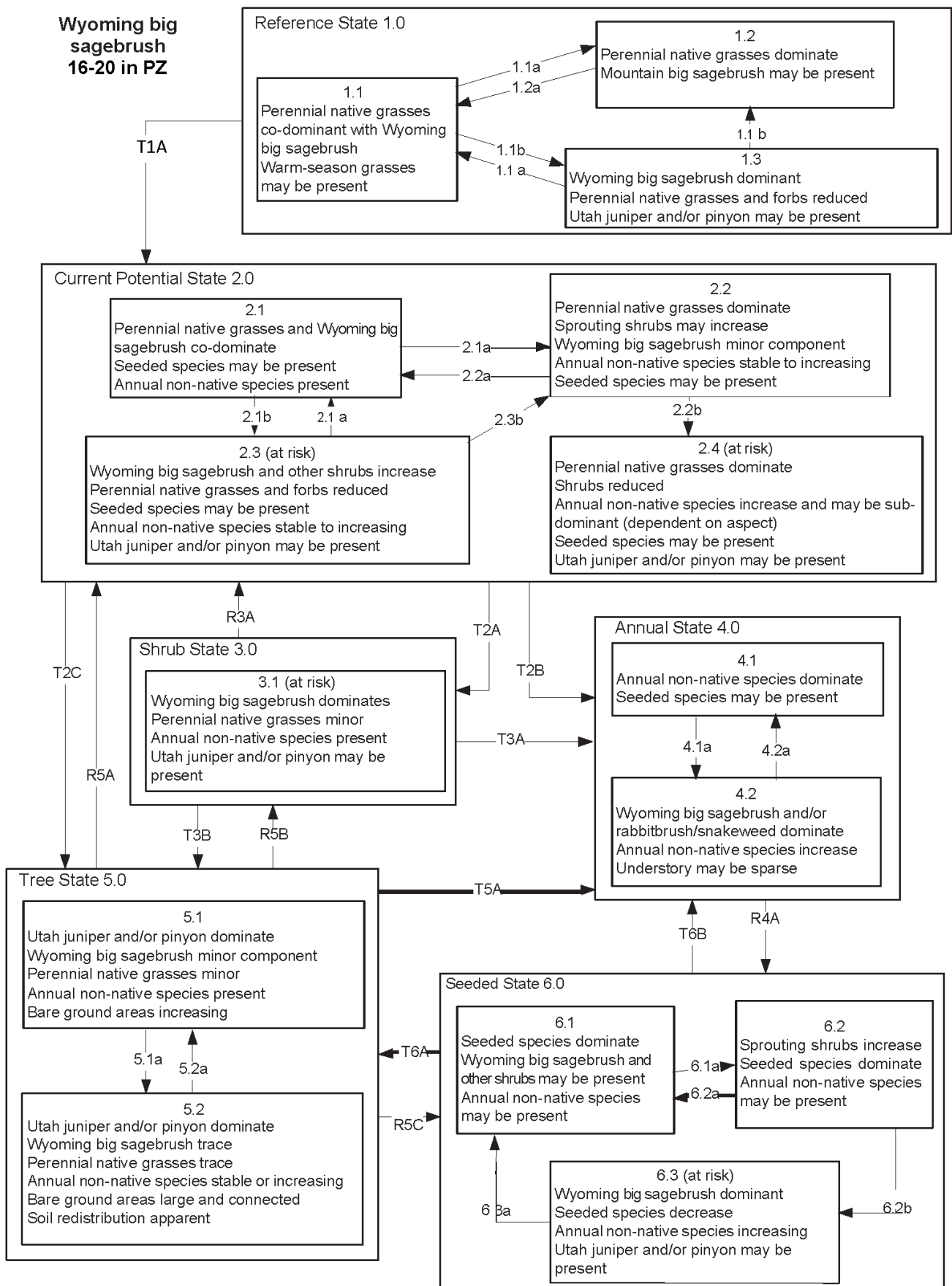


Figure E4.3—The Wyoming big sagebrush ecological type in the seeded state. Photo A is a phase III to mature pinyon-juniper site that was masticated and seeded in 2020 with crested wheatgrass, western wheatgrass, big bluegrass, and squirrel tail. The relative frequency of invasive annuals is 30 to 40%. Photo B is a site experiencing regrowth of pinyon and juniper following a mechanical roller chopper treatment and seeding with crested wheatgrass and intermediate wheatgrass in 1991. Site A is east of wheatgrass reservoir and site B is south-southwest of Irontown. USDA Forest Service photos by Mark Madsen.

Highly departed (uncharacteristic)—annual, tree, and seeded states. Manage to increase ecological resilience and resistance to invasives.

- Manage highly departed states similarly to not departed states, paying particular attention to areas that are transitioning to pinyon-juniper dominance and converting to nonnative annual grasses following wildfire and other disturbances.
- Consider tree removal in phase I and phase II pinyon-juniper expansion areas as described for moderately departed sites, paying particular attention to the risk of conversion to nonnative invasive annuals.
- Consider seeding and evaluate species selection as described for moderately departed sites.
- In phase III pinyon-juniper expansion areas that occur on Wyoming big sagebrush sites, consider thinning treatments adjacent to human communities and/or to enhance resource and cultural values. The vegetation/fuel structure of the different phases of expansion, potential fuel treatments for each phase, likely consequences of treatments for subsequent fire behavior, and ecological responses to treatment are in table 5. Little data exist on treatment effects on fuels or fire behavior, but implementing cut and pile burning or mastication treatments to thin the trees will decrease crown fire risk. Thinning effects on fuels and fire behavior will depend on treatment extent, configuration, and proximity to other fuel types. Treatments that leave both groups of trees and individual trees will be most conducive to wildlife use. Seeding will be required on sites with severely depleted understory species.



5. Mountain shrub-Utah serviceberry - Mesic/Xeric 16–20 in PZ; moderate resilience and moderately low to moderate resistance

Utah serviceberry (*Amelanchier utahensis*) is the diagnostic shrub in the absence of Gambel oak in the mountain shrub-Utah serviceberry type. This ecological type comprises 73,997 ac (29,947 ha) and ranges in precipitation from 16 to 20 in (406 to 508 mm) based on Daymet data. Effective precipitation may be lower depending on soils and aspect. Soil temperatures are mesic (warm). These shrublands occur from 4,921 to 9,515 ft (1,500 to 2,900 m) elevation and are usually located on hillslopes and benches comprised of rhyolite and basalt with greater than 35% rock fragments. Soils are typically skeletal or clay loams and moderately deep, although the type also occurs on some shallow areas. The type occupies the same elevation band as pinyon-juniper woodlands and big sagebrush. Scattered trees or inclusions of grassland patches or sagebrush shrublands may be present. The vegetation is typically dominated by a variety of shrubs including Utah serviceberry (*Amelanchier utahensis*), alderleaf mountain mahogany (*Cercocarpus montanus*), bitterbrush (*Purshia tridentata*), skunkbush sumac (*Rhus trilobata*), waxleaf current (*Ribes cereum*), or snowberry (*Symphoricarpos oreophilus*). Alderleaf mountain mahogany is a resprouting shrub that sometimes dominates this ecological type. Mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) and oceanspray (*Holodiscus* spp.) may occur on moist sites. Grasses are represented by species of grama grasses (*Bouteloua* spp.) and needle grasses (*Heterostipa* spp.) and by western wheatgrass (*Elymus smithii*) and prairie junegrass (*Koeleria macrantha*). Expansion of Utah juniper (*Juniperus osteosperma*), singleleaf pinyon (*Pinus monophylla*), two-needle pinyon (*Pinus edulis*), or a hybrid of the two pinyon species into these types is common.

The mountain shrub-Utah serviceberry type comprises about 16% of the Pine Valley Ranger District and is important for supporting mule deer and other wildlife. Fire plays an important role in this type, and historic fire return intervals are estimated at 20 to 80 years (Tuhy et al. 2014). The dominant shrubs are characterized by strong to weak resprouting capabilities (table 4) and can reoccupy postfire sites relatively quickly. Livestock grazing likely influences the rate of postfire shrub recovery by reducing the cover of understory native perennial grasses and forbs and thus competition with the shrubs. Reduction of the native herbaceous species, which are the primary competitors with annual grasses, may also result in an increase in the invasive annuals. Fire suppression may have allowed expansion of Utah juniper and pinyon into some of these shrublands. The widespread occurrence of annual grasses in this type is a concern for future wildfires.

Land cover data from the Rangeland Analysis Platform (Allred et al. 2021) 2018–2022 indicated that shrubs were the major component (20.5%), perennial grasses and forbs were moderately depleted (6.6%), and pinyon-juniper had moderate presence (15.4%). Cover of invasive annuals from the Rangeland Analysis Platform was 7.2%, and from the USGS Rangeland Exotic Plant Monitoring System (unpublished) was 6.3% for 2016–2022. An earlier analysis indicated that invasive annuals occurred in about 74% of the type (Tuhy et al. 2014). Pinyon-juniper removal treatments were occurring in this type and some of the area has been seeded.

Ecological States and Vegetation Departure (Kitchen and McArthur 2007; Tuhy et al. 2014)

Not departed—reference states or current ecological states not at risk of transitioning to an undesirable state.

The mountain shrub-Utah serviceberry type has a diverse assemblage of perennial grasses and forbs. Following low to moderate severity wildfires, perennial native grasses increase in cover and promote recovery of the site. These perennial grasses and forbs are the strongest competitors with annual grasses, and not departed sites have relatively high resistance to weed invasion. The shrubs on these sites resprout and/or establish from seed. Depending on disturbance history and site conditions, percent cover of shrubs can range from 10 to 30% at 5 to 20 years postfire and from 30 to 50% at 20 to 80 years postfire (Tuhy et al. 2014). Fires are generally patchy and mountain shrub-Utah serviceberry stands are generally multi-aged. At the landscape scale, multiple seral stages are represented in an ever-shifting mosaic reflecting periodic occurrence of fire or other disturbance. If present, cheatgrass is scattered and forms an insignificant portion of the herbaceous biomass. Woodland species are widely scattered, if present. If grazed by livestock, light to moderate stocking rates and periodic rest during the growing season are needed to maintain the herbaceous component.

Moderately departed—current potential states at risk or shrub state at risk.

The herbaceous perennial component is moderately depleted in abundance or diversity. A shift in species composition of the perennial grasses and forbs reflecting palatability to livestock is often noticeable. Total shrub cover is often higher and can exceed that of not departed sites due to decreases in the herbaceous understory and competitive release of the shrubs. On warmer sites, cheatgrass may be present (some soil types excepted) but it does not dominate except in scattered patches. The probability of conversion (transition) from a shrub-grass community to weed-dominated grassland is highly dependent upon having sufficient perennial native grasses to promote recovery. In moderately departed sites, trees may have reached 25 to 50% of their potential cover for the type, and herbaceous cover has been reduced by up to 75%.

Highly departed (uncharacteristic)—annual, tree, or seeded states.

Perennial herbs are usually severely depleted in highly departed areas. Utah serviceberry and other shrubs tend to be old aged with little new recruitment. There is a high probability that a high severity fire event results in conversion to annual dominance with cheatgrass dominating the understory on the warmest sites. The root-sprouting shrubs may increase and dominate in some areas. The current fire-free interval may be much longer than estimated historic intervals. Where susceptible to woodland expansion, trees may have reached densities sufficient to fully occupy the site. Shrubs and perennial herbs are minor components and scattered in tree openings. Litter accumulates under trees and extensive bare soil may be exposed and eroded between the trees. Total conversion to tree dominance (phase III) can occur in about 40 to 50 years on moderately productive sites. Because weed invasion frequently occurs

synchronously with woodland expansion, the risk of weed invasion with fire counters that of conversion to woodland (loss of shrubs and herbs) in the absence of fire.

Management Recommendations (Chambers et al. 2024; Kitchen and McArthur 2007; Miller et al. 2013, 2019)

Not departed—reference states or current ecological states not at risk of transitioning to an undesirable state. Manage to maintain ecological resilience and resistance to invasives.

- Manage livestock grazing at a stocking rate, season of use, and duration that maintains or increases perennial grasses and forbs.
- Suppress human-caused fires that can result in extensive, high severity burns.
- Do not conduct prescribed fires except for small-scale research burns.
- Allow natural recovery after wildfires where sufficient perennial native grasses exist for recovery and risk of invasive grass is low; do not seed with introduced species.
- To maintain multiple seral stages, consider allowing spot fires to burn in areas with moderate resilience where there is no risk to human communities, sufficient perennial native grasses exist for recovery, and annual grasses are rare or absent.
- Establish fuel breaks or green strips adjacent to annual grass dominated areas to prevent fire transmission into these high value ecosystems. Recognize that fuel breaks require regular maintenance.
- Consider fuel reduction treatments at the wildland urban interface to reduce fire hazard where necessary to achieve management goals.

Moderately departed—current potential states at risk or shrub state at risk. Manage to increase ecological resilience and resistance to invasives.

- Manage departed states similarly to not departed states, paying particular attention to areas at risk of transitioning to pinyon-juniper dominance and converting to nonnative annual grasses following wildfire and other disturbances.
- Consider tree removal in phase I and phase II expansion areas. The vegetation/fuel structure of the different phases of expansion, potential fuel treatments for each phase, likely consequences of treatments for subsequent fire behavior, and ecological responses to treatment are in table 5. Prescribed fire should not be used except where both resilience and resistance are moderate or higher, i.e., on relatively cool and moist sites with sufficient perennial grass cover to both promote recovery and prevent increases in annual grasses. Cut and pile burn and mastication can be considered where resilience and resistance are moderately low or higher and will be most successful if sufficient perennial grasses are present to promote recovery and prevent increases in invasive plants. Cut, lop,

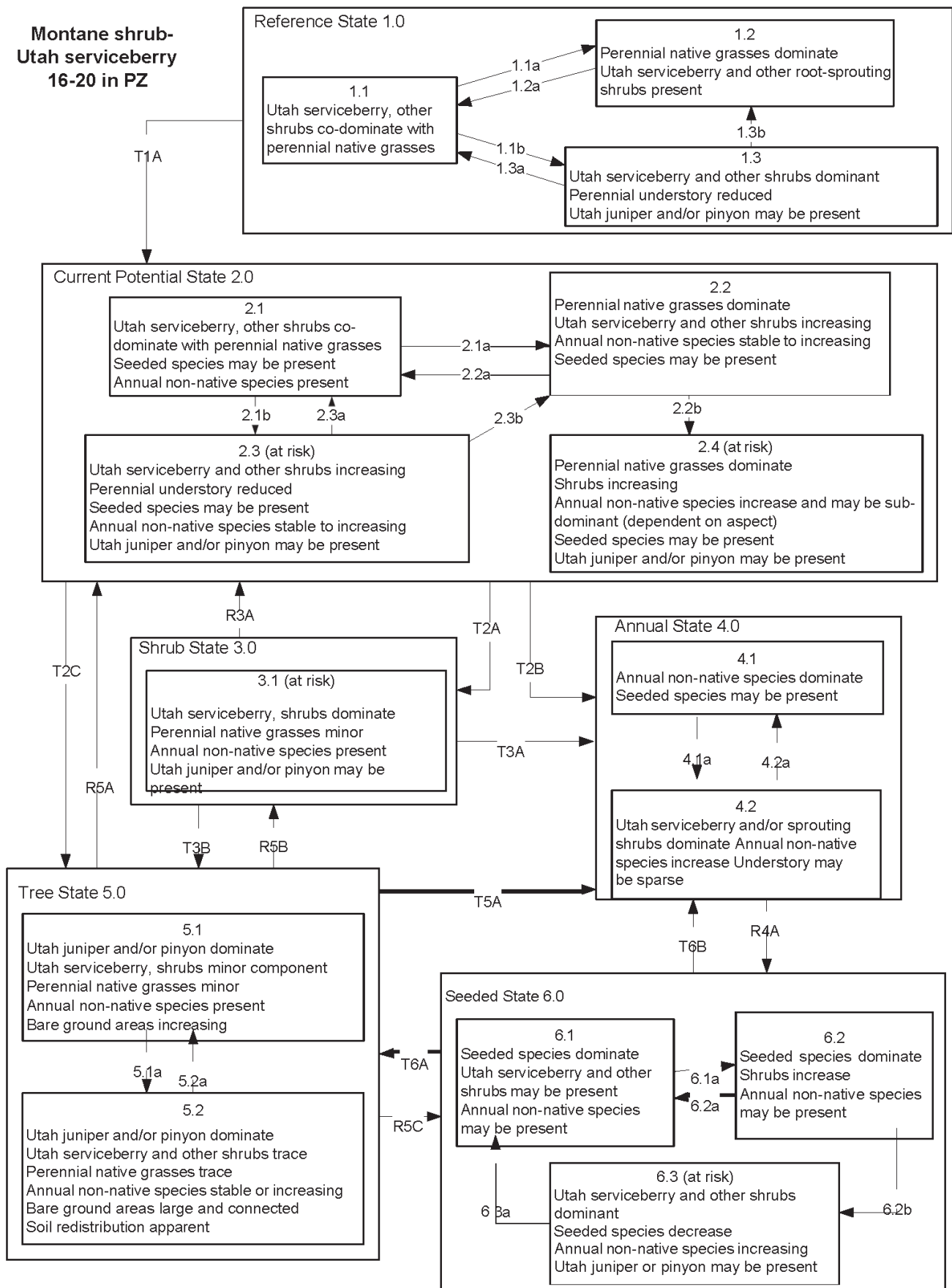
and scatter can be considered in phase I and early phase II. In late phase II and phase III, cut, lop, and scatter significantly increases woody surface fuels and the risk of high severity fire.

- Species selected for seeding areas at risk of invasion by nonnative annuals following management treatments and wildfires determine longer-term outcomes. If native perennial grasses and forbs comprise about 10–15%, seeding probably is not needed. If perennial grasses and forbs are depleted, seeding is likely needed. Seeding native species will increase the likelihood of site restoration. Introduced grasses and forbs as well as shrubs like forage kochia can outcompete residual natives and result in a highly departed state dominated by the introduced seeded species.
- The herbicide Imazapic® suppresses annual grasses but can also decrease establishment of native grasses and forbs. Indaziflam® is a nonselective herbicide that decreases native seed banks and reduces seedling establishment of natives, particularly in warmer and drier areas.

Highly departed (uncharacteristic)—annual, tree, and seeded states. Manage to increase ecological resilience and resistance to invasives.

- Manage highly departed states similarly to not departed states, paying particular attention to areas that are transitioning to pinyon-juniper dominance and converting to nonnative annual grasses following wildfire and other disturbances.
- Consider tree removal in phase I and phase II pinyon-juniper expansion areas as described for moderately departed sites, paying particular attention to the risk of conversion to nonnative invasive annuals.
- Consider seeding and evaluate species selection as described for moderately departed sites.
- In phase III pinyon-juniper expansion areas that occur on Utah serviceberry sites, consider thinning treatments adjacent to human communities and/or to enhance resource and cultural values. The vegetation/fuel structure of the different phases of expansion, potential fuel treatments for each phase, likely consequences of treatments for subsequent fire behavior, and ecological responses to treatment are in table 5. Little data exist on treatment effects on fuels or fire behavior, but implementing cut and pile burning or mastication treatments to thin the trees will decrease crown fire risk. Thinning effects on fuels and fire behavior will depend on treatment extent, configuration, and proximity to other fuel types. Treatments that leave both groups of trees and individual trees may be most conducive to wildlife use. Seeding will be required on sites with severely depleted understory species.

**Montane shrub-
Utah serviceberry
16-20 in PZ**



6. Black sagebrush - Mesic/Xeric 16–20 in PZ; moderate resilience and moderately low to moderate resistance

The black sagebrush (*Artemisia nova*) ecological type comprises 9,535 ac (3,859 ha) and is broadly distributed on the Pine Valley Ranger District. Precipitation ranges from 16 to 20 in (406 to 508 mm) based on Daymet data, but effective precipitation may be lower depending on soils and aspect. Elevations range from 4,920 ft (1,500 m) to as high as 9,000 ft (2,743 m), and the soil temperature regime is generally warm (mesic). These sites are often found on calcareous influenced soils derived from igneous parent material (typically basalt and rhyolite). The soils also may be sedimentary in origin and/or shallow with an impervious argillic layer near the surface. The soil surface is often gravelly or may support biological soil crusts. Wyoming big sagebrush and basin big sagebrush may occur with black sagebrush on small patches of moderately deep to deep soils that are well-drained. The type mostly occurs on alluvial fans, piedmonts, bajadas, rolling hills, and mountain slopes, but also may be found on flats and plains. The black sagebrush type generally has relatively low fuel loads with low-growing cushion forbs and scattered bunchgrasses including Sandberg's bluegrass (*Poa secunda*), Indian ricegrass (*Achnatherum hymenoides*), and needle-and-thread (*Heterostipa comata*) on warmer and drier sites, and muttongrass (*Poa fendleriana*), prairie Junegrass (*Koeleria macrantha*), and Letterman's needlegrass (*Achnatherum lettermanii*) on cooler and moister sites. Forbs often include buckwheats (*Eriogonum* spp.), fleabanes (*Erigeron* spp.), phloxes (*Phlox* spp.), paintbrushes (*Castilleja* spp.), globemallows (*Sphaeralcea* spp.), and lupines (*Lupinus* spp.). Expansion of Utah juniper (*Juniperus osteosperma*), singleleaf pinyon (*Pinus monophylla*), and two-needle pinyon (*Pinus edulis*), or a hybrid of the two pinyon species, is common on these sites with Utah juniper dominating the warmer and drier sites.

Land cover data from the Rangeland Analysis Platform (Allred et al. 2021) for 2018–2022 indicated that shrubs were the major component (18.1%), perennial grasses and forbs were moderately high (13.3%), and pinyon-juniper had low presence (6.2%). Cover of invasive annuals from the Rangeland Analysis Platform was 9.0%, and from the USGS Rangeland Exotic Plant Monitoring System (unpublished) was 6.9% for 2016–2022. Pinyon-juniper removal treatments and seedings since the mid-2000s are minor components.

Historically, the fuel complex in late seral blackbrush stands was probably like that observed in relatively undisturbed sites today, except for the relatively high presence of annual grasses (Fryer 2009). Shrub cover in black sagebrush communities typically averages < 30% and varies from very open to moderately dense depending on site conditions. In general, diversity and relative cover decrease with increasing aridity. Potential fire spread depends on stand structure; black sagebrush communities with low productivity and fuels may function as fuel breaks, while highly productive sites have the potential to carry fire.

There are no records of historic fire frequencies or fire regimes for the black sagebrush type. Because these types tend to occupy unproductive sites that have little fuel buildup, fire was probably rare historically with return intervals estimated at > 100 years

(Fryer 2009). Annual grass invasion can result in an increase in fine herbaceous fuels that extends the fire season and may result in stand replacing fires following years with favorable spring moisture. Black sagebrush has moderate palatability to both wildlife and sheep, but long-term overgrazing of stable black sagebrush communities by domestic sheep can result in conversion to highly departed states characterized by nearly solid stands of rabbitbrush (*Chrysothamnus* spp.) or broom snakeweed (*Gutierrezia sarothrae*) (MacArthur 2005). Past brush management and seeding with crested wheatgrasses and forage kochia has converted large portions of this type to introduced species. Expansion of pinyon pine and juniper into black sagebrush is common, and trees may fully occupy the site within 75 years or less depending on site conditions and last disturbance.

Ecological States and Vegetation Departure (Fryer 2009; Kitchen and McArthur 2007)

Not departed—reference states or current ecological states not at risk of transitioning to an undesirable state.

Following disturbances like wildfire that decrease the abundance of black sagebrush, perennial native grasses and forbs promote recovery of the site. Perennial grasses and forbs are strong competitors with annual grasses and these sites have relatively high resistance to weed invasion. Black sagebrush reestablishes from seed on these sites. Time required for black sagebrush reestablishment and recovery to prefire cover depends on the seed bank, the presence of residual seed plants, and the environmental characteristics of the site. Mature stands are generally multi-aged. If present, cheatgrass is scattered and forms an insignificant portion of the herbaceous biomass. Woodland species are widely scattered if present. If grazed by livestock, light to moderate stocking rates and periodic rest during the growing season are needed to maintain the perennial herbaceous component.



Figure E6.1—The black sagebrush ecological type in the current ecological state intermixed with Utah serviceberry and Gambel Oak. The site is in Horse Valley with Harrison Peak in the background. USDA Forest Service photo by Mark Madsen.

Moderately departed—current potential states at risk or shrub state at risk.

The herbaceous perennial component in this category is moderately depleted in abundance or diversity. A shift in the species composition of grasses and forbs from inappropriate livestock grazing in the past and/or present often reflects palatability to livestock. The cover of black sagebrush often exceeds that of the not-departed condition due to decreases in perennial grasses and forbs and competitive release of the shrubs. On warmer sites, cheatgrass is generally present (some soil types excepted) but it does not dominate except in scattered patches. The probability of conversion (transition) from at-risk states to weed-dominated grassland is highly dependent on the relative abundance of competitive perennial grasses and forbs. In moderately departed sites, trees may have reached 25 to 50% of their potential cover for the type, and herbaceous cover has been reduced by up to 75%.

Highly departed (uncharacteristic)—annual, tree, and seeded states.

Perennial native grasses and forbs are usually severely depleted in highly departed black sagebrush communities. Highly departed states may be characterized by nearly solid stands of rabbitbrush (*Chrysothamnus* ssp.) or broom snakeweed (*Gutierrezia sarothrae*). Weedy annuals, especially cheatgrass, may dominate the herbaceous understory. Shrub cover may vary, but black sagebrush plants tend to be old aged with little new recruitment. On sites with high shrub cover and annual grasses in shrub interspaces, there is a risk that a single fire event will result in conversion to an annual-dominated community supporting short fire-free intervals and large fire sizes. Where susceptible to woodland expansion, trees may have reached densities sufficient to fully occupy the site. Shrubs and perennial herbs are minor components scattered in tree openings. Litter accumulates under trees and extensive bare soil may be exposed and eroded between the trees. Total conversion to tree dominance (phase III) can occur in about 75 years on black sagebrush sites. Because cheatgrass invasion frequently occurs synchronously with woodland expansion, fire risks are compounded. Sites seeded with introduced grasses after brush management or wildfire also are highly departed, although they may still support some perennial native grasses and shrubs may increase over time. Seeded sites are characterized by fine herbaceous vegetation and can be highly flammable when the fuel moisture content is low and fire weather is extreme.



Figure E6.2—The black sagebrush ecological type in the tree state (A) with phase I in the foreground and phase III in the background. The two types are separated by a change in slope and soils. Scattered basin wildrye and ground cover indicates moderately deep to deep soils. Photo B is the same ecological type showing late phase III to mature single-leaf pinyon. Photo A is from Spruce Mountain in northeastern Nevada. Courtesy photo by Rick Miller, Oregon State University. Photo B is from the Egan Range in southeastern Nevada. USDA Forest Service photo by Mark Madsen.

Management Recommendations (Chambers et al. 2024; Kitchen and McArthur 2007; Miller et al. 2013, 2019)

Not departed—reference states or current ecological states not at risk of transitioning to an undesirable state. Manage to maintain ecological resilience and resistance to invasives.

- Manage livestock grazing at a stocking rate, season of use, and duration that maintains or increases perennial grasses and forbs.
- Suppress human-caused fires that can result in extensive, high severity burns.
- Do not conduct prescribed fires except for small-scale research burns.
- Allow natural recovery after wildfires where sufficient perennial native grasses exist for recovery and risk of invasive grass is low; do not seed with introduced species.
- To maintain multiple seral stages, consider allowing spot fires to burn in areas with moderate resilience where there is no risk to human communities, sufficient perennial native grasses exist for recovery, and annual grasses are rare or absent.
- Establish fuel breaks or green strips adjacent to annual grass dominated areas to prevent fire transmission into these high value ecosystems. Recognize that fuel breaks require regular maintenance.
- Consider fuel reduction treatments at the wildland urban interface to reduce fire hazard where necessary to achieve management goals.

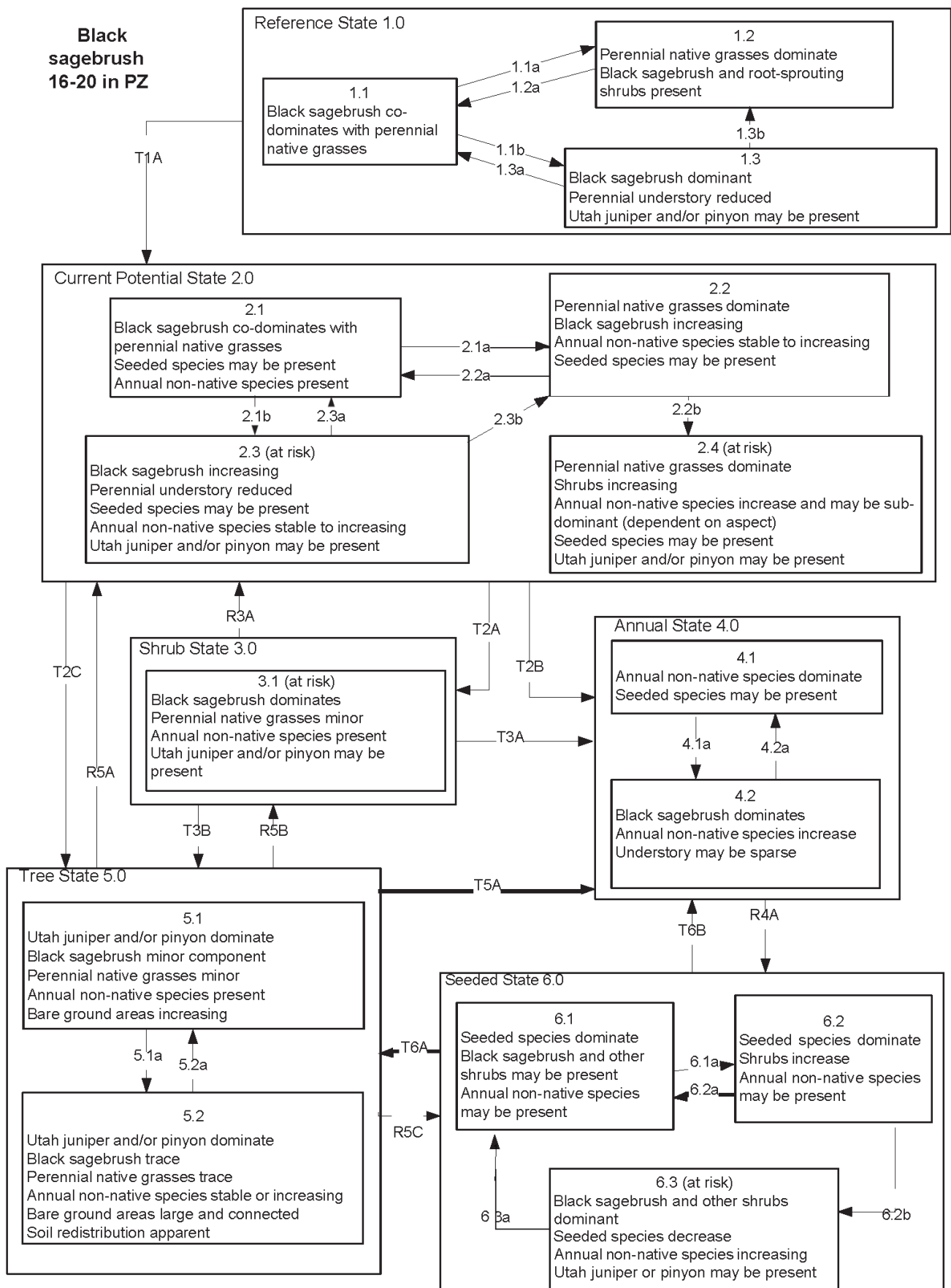
Moderately departed—current potential states at risk or shrub state at risk. Manage to increase ecological resilience and resistance to invasives.

- Manage departed states similarly to not departed states, paying particular attention to areas at risk of transitioning to pinyon-juniper dominance and converting to nonnative annual grasses following wildfire and other disturbances.
- Consider tree removal in phase I and phase II expansion areas. The vegetation/fuel structure of the different phases of expansion, potential fuel treatments for each phase, likely consequences of treatments for subsequent fire behavior, and ecological responses to treatment are in table 5. In general, prescribed fire should not be used in black sagebrush communities due to shallow soils and low productivity. Cut and pile burn or mastication can be considered where resilience and resistance are moderately low or higher and will be most successful if sufficient perennial grasses are present to promote recovery and prevent increases in invasive plants. Cut, lop, and scatter can be considered in phase I and early phase II. In late phase II and phase III, cut, lop, and scatter significantly increases woody surface fuels and the risk of high severity fire.

- Species selected for seeding areas at risk of invasion by nonnative annuals following management treatments and wildfires determine longer-term outcomes. If native perennial grasses and forbs comprise about 10% cover, seeding probably is not needed. If perennial grasses and forbs are depleted, seeding is likely needed. Seeding native species will increase the likelihood of site restoration. Introduced grasses and forbs as well as shrubs like forage kochia can outcompete residual natives and result in a highly departed state dominated by the introduced seeded species.
- The herbicide Imazapic® suppresses annual grasses but can also decrease establishment of native grasses and forbs. Indaziflam® is a nonselective herbicide that decreases native seed banks and reduces seedling establishment of natives, particularly in warmer and drier areas.

Highly departed (uncharacteristic)—annual, tree, and seeded states. Manage to increase ecological resilience and resistance to invasives.

- Manage highly departed states similarly to not departed states, paying particular attention to areas that are transitioning to pinyon-juniper dominance and converting to nonnative annual grasses following wildfire and other disturbances.
- Consider tree removal in phase I and phase II pinyon-juniper expansion areas as described for moderately departed sites, paying particular attention to the risk of conversion to nonnative invasive annuals.
- Consider seeding and evaluate species selection as described for moderately departed sites.
- In phase III pinyon-juniper expansion areas that occur on black sagebrush sites, consider thinning treatments adjacent to human communities and/or to enhance resource and cultural values. The vegetation/fuel structure of the different phases of expansion, potential fuel treatments for each phase, likely consequences of treatments for subsequent fire behavior, and ecological responses to treatment are in table 5. Little data exist on treatment effects on fuels or fire behavior, but implementing cut and pile burning or mastication treatments to thin the trees will decrease crown fire risk. Thinning effects on fuels and fire behavior will depend on treatment extent, configuration, and proximity to other fuel types. Treatments that leave both groups of trees and individual trees will be most conducive to wildlife use. Seeding will be required on sites with severely depleted understory species.



7. Mountain big sagebrush - Frigid to Mesic/Xeric 18–22 in PZ; moderate to moderately high resilience and moderate to moderately high resistance

This ecological type comprises 10,543 ac (4,267 ha) and ranges in precipitation from 18 to 22 in (457 to 559 mm) based on Daymet data. Effective precipitation may be lower depending on soils and aspect. The soil temperature regime is cool (frigid) to warm (mesic). Elevation is generally above 8,000 ft (2,438 m) in the Mojave Desert and above 6,500 ft (1,981 m) in the southern Great Basin. Soils are generally moderately deep to deep, well-drained, and textural classes are loam, sandy loam, clay loam, or gravelly loam. Soils may have a substantial volume of coarse fragments and are derived from a variety of parent materials. This type occurs on stony flats, ridges, nearly flat ridge tops, and mountain slopes. The mountain big sagebrush type (*Artemisia tridentata* spp. *vaseyana*) is found above and intergrades with the Wyoming big sagebrush (*Artemisia tridentata* spp. *wyomingensis*) type. A variety of shrubs occur within this type, including Utah serviceberry (*Amelanchier utahensis*), chokecherry (*Prunus virginiana*), bitterbrush (*Purshia tridentata*), and elderberry (*Sambucus racemosa*). Grasses include Sandberg's bluegrass (*Poa secunda*), muttongrass (*Poa fendleriana*) blue grama, (*Bouteloua gracilis*), Ross' sedge (*Carex rossii*), slender wheatgrass (*Elymus trachycaulus*), and Letterman's needlegrass (*Achnatherum lettermanii*).

Land cover data from the Rangeland Analysis Platform (Allred et al. 2021) for 2018–2022 indicated that shrubs were a major component (18.0%), perennial grasses and forbs were depleted (4.7%), and pinyon-juniper had high overall cover (23.0%). Cover of invasive annuals from the Rangeland Analysis Platform was 2.5%, and from the USGS Rangeland Exotic Plant Monitoring System (unpublished) was 3.0% for 2016–2022. An earlier analysis estimated annual grasses occurred in about 40% of the native community (Tuhy et al. 2014). Seeded areas with annual grasses were almost 24% of the type, and tree expansion was occurring in > 40% of the type (Tuhy et al. 2014).

Ecological States and Vegetation Departure (Kitchen and McArthur 2007; Tuhy et al. 2014)

Not departed—reference states or current ecological states not at risk of transitioning to an undesirable state.

Relatively cool and moist stands of mountain big sagebrush have a diverse assemblage of perennial grasses and forbs. Following low severity wildfires or infestations of aroga moths, perennial native grasses promote recovery of the site as sagebrush plants are not fire tolerant. Perennial grasses and forbs are the strongest competitors with annual grasses and these sites have relatively high resistance to annual grass invasion. Sagebrush reestablishes from seed on these sites, and depending on disturbance history and site conditions, percent cover of mountain big sagebrush cover can vary from < 5% at 1 to 20 years after fire to 20 to 40% at 30 to 70 years after fire. Fires are generally patchy and mature sagebrush stands are generally multi-aged. At the landscape scale, multiple seral stages are represented in an ever-shifting mosaic reflecting periodic occurrence of fire or other disturbance. If present, cheatgrass is scattered and forms an

insignificant portion of the herbaceous biomass. Woodland species are widely scattered if present. If grazed by livestock, light to moderate stocking rates and periodic rest during the growing season are needed to maintain the herbaceous component.

Moderately departed—current potential states at risk or shrub state at risk.

The herbaceous perennial component is moderately depleted in abundance or diversity. A shift in species composition of the perennial grasses and forbs reflecting palatability by livestock is often noticeable. Sagebrush cover often increases and can exceed that of not departed sites due to competitive release of sagebrush facilitated by decreases in the herbaceous understory. On warmer sites, cheatgrass may be present (some soil types excepted) but it dominates only scattered patches. The probability of conversion (transition) from a shrub-grass community to weed-dominated grassland is highly dependent on retaining sufficient perennial native grasses to promote recovery. In moderately departed sites, trees may have reached 25 to 50% of their potential cover for the type, and herbaceous cover has been reduced by up to 75%.



Figure E7.1—The mountain big sagebrush ecological type in the tree state with late phase I singleleaf pinyon and Utah juniper expansion. The site is comprised of a mixture of shrubs, forbs, and deep-rooted perennial grasses such as blue bunch wheatgrass and June grass. The site is located near Cave Lake south of Ely, NV and is represented of the Pine Valley ecological type. Courtesy photo by Rick Miller, Oregon State University.

Highly departed (uncharacteristic)—annual, tree, and seeded states.

Perennial herbs are usually severely depleted in highly departed mountain big sagebrush communities. The current fire-free interval may be much longer than estimated historic intervals. Mountain big sagebrush plants tend to be old aged with little new recruitment. Shrub cover may be variable. There is a high probability that a high severity fire event will result in conversion to an annual-dominated community with cheatgrass dominating the warmest sites and other cold-tolerant weedy species dominating the colder sites. Root-sprouting shrubs may dominate the site after fire in some areas. Where susceptible to woodland expansion, trees may have reached densities sufficient to fully occupy the site. Shrubs and perennial herbs are minor components restricted to tree openings. Litter accumulates under trees and extensive bare soil may be exposed and eroded between the trees. Total conversion to tree dominance (phase III) may occur in about 40 to 50 years after the last disturbance on moderately productive sites. Because weed invasion frequently co-occurs with woodland expansion, the risk of weed invasion with fire counters that of conversion to woodland (loss of native shrubs and herbs) without fire.

Management Recommendations (Chambers et al. 2024; Kitchen and McArthur 2007; Miller et al. 2013, 2019)

Not departed—reference states or current ecological states not at risk of transitioning to an undesirable state. Manage to maintain ecological resilience and resistance to invasives.

- Manage livestock grazing at a stocking rate, season of use, and duration that maintains or increases perennial grasses and forbs.
- Suppress human-caused fires that can result in extensive, high severity burns.
- Do not conduct prescribed fires except for small-scale research burns.
- Allow natural recovery after wildfires where sufficient perennial native grasses exist for recovery and risk of invasive grass is low; do not seed with introduced species.
- To maintain multiple seral stages, consider allowing spot fires to burn in areas with moderate resilience where there is no risk to human communities, sufficient perennial native grasses exist for recovery, and annual grasses are rare or absent.
- Establish fuel breaks or green strips adjacent to annual grass dominated areas to prevent fire transmission into these high value ecosystems. Recognize that fuel breaks require regular maintenance.
- Consider fuel reduction treatments at the wildland urban interface to reduce fire hazard where necessary to achieve management goals.

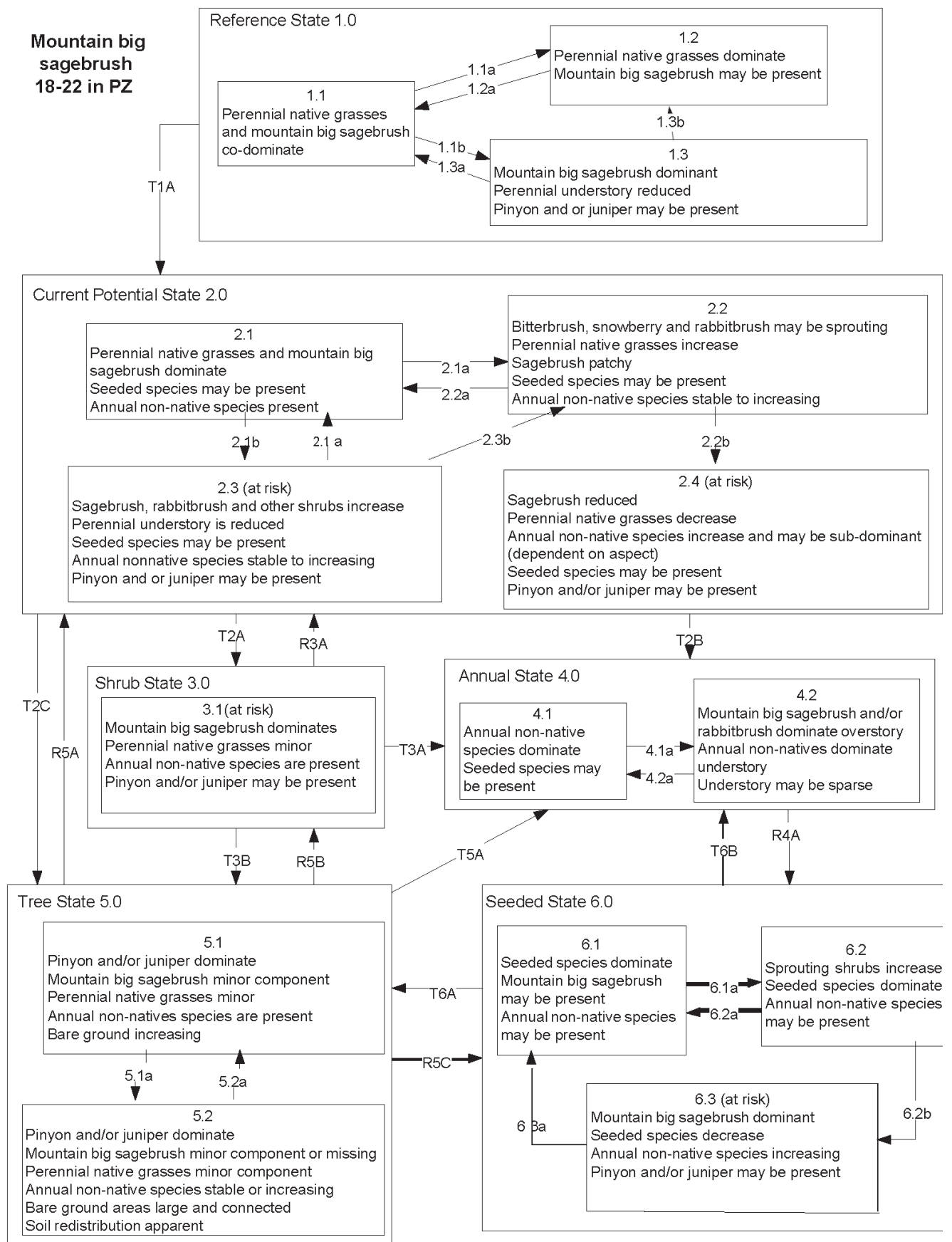
Moderately departed —current potential states at risk or shrub state at risk. Manage to increase ecological resilience and resistance to invasives.

- Manage departed states similarly to not departed states, paying particular attention to areas at risk of transitioning to pinyon-juniper dominance and converting to nonnative annual grasses following wildfire and other disturbances.
- Consider tree removal in phase I and phase II expansion areas. The vegetation/fuel structure of the different phases of expansion, potential fuel treatments for each phase, likely consequences of treatments for subsequent fire behavior, and ecological responses to treatment are in table 5. Prescribed fire should not be used except on relatively cool and moist sites where resilience and resistance are moderate or higher and perennial grasses are sufficient to promote recovery and prevent increases in annual grasses. Cut and pile burn and mastication can be considered where resilience and resistance are moderately low or higher and will be most successful if sufficient perennial grasses are present to promote recovery and prevent increases in invasive plants. Cut, lop, and scatter can be considered in phase I and early phase II. In late phase II and phase III, cut, lop, and scatter significantly increases woody surface fuels and the risk of high severity fire.
- Species selected for seeding areas at risk of invasion by nonnative annuals following management treatments and wildfires determine longer-term outcomes. If native perennial grasses and forbs comprise about 5-10% cover, seeding probably is not needed. If perennial grasses and forbs are depleted, seeding is likely needed. Seeding native species will increase the likelihood of site restoration. Introduced grasses and forbs as well as shrubs like forage kochia can outcompete residual natives and result in a highly departed state dominated by the introduced seeded species.
- The herbicide Imazapic® suppresses annual grasses but can also decrease establishment of native grasses and forbs. Indaziflam® is a nonselective herbicide that decreases native seed banks and reduces seedling establishment of natives, particularly in warmer and drier areas.

Highly departed (uncharacteristic)—annual, tree, and seeded states. Manage to increase ecological resilience and resistance to invasives.

- Manage highly departed states similarly to not departed states, paying particular attention to areas that are transitioning to pinyon-juniper dominance and converting to nonnative annual grasses following wildfire and other disturbances.
- Consider tree removal in phase I and phase II pinyon-juniper expansion areas as described for moderately departed sites, paying particular attention to the risk of conversion to nonnative invasive annuals.
- Consider seeding and evaluate species selection as described for moderately departed sites.

- In phase III pinyon-juniper expansion areas that occur on mountain big sagebrush sites, consider thinning treatments adjacent to human communities and/or to enhance resource and cultural values. The vegetation/fuel structure of the different phases of expansion, potential fuel treatments for each phase, likely consequences of treatments for subsequent fire behavior, and ecological responses to treatment are in table 5. Little data exist on treatment effects on fuels or fire behavior, but implementing cut and pile burning or mastication treatments to thin the trees will decrease crown fire risk. Thinning effects on fuels and fire behavior will depend on treatment extent, configuration, and proximity to other fuel types. Treatments that leave both groups of trees and individual trees will be most conducive to wildlife use. Seeding may be required on sites with severely depleted understory species.



Old Growth Pinyon-Juniper

A recent analysis of LANDFIRE biophysical settings (BpS) for the Pine Valley Ranger District classified pinyon-juniper woodlands into one general type (Tuhy et al. 2014). However, these woodlands are typically characterized according to their environmental characteristics and the potential shrub and grass species for the ecological site (Miller et al. 2014, 2019; Stringham et al. 2015). Here, the broad class of pinyon-juniper woodlands identified for the Pine Valley Ranger District is split into two types to recognize likely differences in responses to wildfire and management treatments: (1) a warm (mesic) to very warm (hypermecic) and moist (xeric) old growth juniper and pinyon type with low productivity and moderately low resilience and low resistance; and (2) a cool to warm (cool mesic) and moist (xeric) old growth pinyon-juniper type with moderate to moderately high resilience and resistance. The type descriptions are based on Tuhy et al. (2014) and personal communications with Mark Madson, Dixie National Forest Botanist, and Vaughn Thacker, Pine Valley Ranger District soil scientist. The woodlands identified by Tuhy et al. (2014) may include expansion in addition to old growth and persistent woodlands (see definitions in *Glossary*). The expansion woodlands are likely phase III with trees that established postsettlement and are < 150-170 years old. Old-growth woodlands are typically characterized by trees the established presettlement and are > 150-170 years old, but some old growth and persistent woodlands may have much older trees. In all cases, the trees are usually the dominant vegetation on the site and the primary plant layer influencing ecological processes. State-and-transition models are provided for old growth woodlands that are adapted from STMs for MLRA 28A (Stringham et al. 2015). Field assessments of these sites will be required to determine tree ages, associated shrubland ecological types, relative resilience and resistance, and appropriate treatments if any.

Historic tree densities, as determined from tree cores in old growth and persistent stands, indicate that presettlement tree canopy cover was relatively open throughout pinyon-juniper woodlands in the Great Basin and Colorado Plateau (Miller et al. 2019). Several factors likely contributed to maintaining relatively open stands: (1) reoccurring low-intensity surface fire in some areas and infrequent fires with occasional patchy high-severity events in others; (2) competition from herbaceous vegetation that limited or slowed establishment of tree seedlings and thus infilling; (3) tree thinning resulting from droughts and pests; and (4) Native American management that included periodic fire. In general, fire return intervals were relatively long in these open stands and typically increased during extended wet periods and declined during extended dry periods (as evidenced by charcoal abundance and size).

The recent analysis of BpS for the Pine Valley Ranger District indicates the pinyon-juniper type comprised 106,230 ac (42,995 ha), and on average, 80% of the area classified as pinyon-juniper had 20–60% cover of pinyon and/or juniper < 5–9 m in height, 10–40% shrub cover, and > 5% cheatgrass cover (Tuhy et al. 2014). Tree establishment increased across the Great Basin and Colorado Plateau postsettlement likely because of favorable climate at the beginning of the 20th century, excessive livestock grazing and decreases in competitive grasses and forbs, increases in shrubs which served as nurse plants for tree establishment, fire suppression, and elimination

of Native American burning practices (see Miller et al. 2019). The STMs presented for the two pinyon-juniper types illustrate that depending on site conditions (soils and climate) and the type and extent of disturbances (fire, pests, excessive grazing, and/or browsing) an infilled tree state may develop in old growth woodlands (Stringham et al. 2015). This infilled state is characterized by increases in tree density and canopy cover, a decrease in understory perennial vegetation, and an increase in tree litter. Biomass is shifted from surface fuels to canopy fuels that have the potential to significantly impact fire behavior. Decreases in the understory woody and herbaceous fuels required to carry surface fires and increases in pinyon-juniper canopy fuels reduce the likelihood that the woodlands will burn under moderate conditions and increase the likelihood of infrequent high intensity fires (see review in Miller et al. 2019). As understory vegetation cover decreases so does the soil seed bank of the understory species. An increase in bare ground and decrease in competition from perennial native species allows for invasion by nonnative annual species such as cheatgrass, and the potential for conversion to nonnative annual invaders increases following wildfire. In recent decades, more extreme fire weather is resulting in a higher incidence of high intensity wildfires with more severe effects.

A map of pinyon juniper (PJ) stands categorized by cover and tree diameter at the root collar from the Dixie National Forest's Vegetation Classification, Mapping, and Quantitative Inventory (VCMQ) Program (fig. 12) and information on identifying old growth trees (Appendix B1 and B2) are available for Pine Valley Ranger District and can be used to determine where these types occur on the landscape. In addition, information on selecting appropriate treatments based on the type of woodland, its productivity, and its relative resilience and resistance is in table 5.

8. Old growth juniper and pinyon - Mesic to Hypermestic/Xeric 12–16 in PZ; moderately low resilience and low resistance

This juniper and pinyon type receives 12–16 in (304 to 406 mm) of precipitation based on Daymet data and is associated with most of the other BpS identified for the Pine Valley Ranger District within this precipitation zone. Soil temperatures are warm (mesic) to very warm (hypermestic), and these sites generally occur at the lower range of elevations for pinyon-juniper (5,500 to 8,000 ft [1,675 to 2,440 m]). Utah juniper (*Juniperus osteosperma*), singleleaf pinyon (*Pinus monophylla*), two-needle pinyon (*Pinus edulis*), or a hybrid of the two pinyon species, may occur on these sites. The sites have relatively low productivity and Utah juniper is typically dominant and pinyon subdominant. The soils are typically shallow to moderately deep and available water holding capacity is often low. These soils usually have high amounts of rock fragments at the soil surface that occupy plant growing space but help to reduce evaporation and conserve soil moisture. Shrub species reflect those of the associated ecological types, but include black sagebrush (*Artemisia nova*), Wyoming big sagebrush (*Artemisia tridentata* spp. *wyomingensis*), and bitterbrush (*Purshia tridentata*). Perennial grass species likely include Indian ricegrass (*Achnatherum hymenoides*), squirreltail (*Elymus elymoides*), Sandberg's bluegrass (*Poa secunda*), blue grama (*Bouteloua gracilis*), and muttongrass (*Poa fendleriana*).

Land cover data for 2018–2022 from the Rangeland Analysis Platform (Allred et al. 2021) indicated that shrubs were a moderate component (12.2%), perennial grasses and forbs were highly depleted (2.3%), and pinyon-juniper had high overall cover (30.3%). Cover of invasive annuals from the Rangeland Analysis Platform was 2.3%, and from the USGS Rangeland Exotic Plant Monitoring System (unpublished) was 6.0% for 2016–2022. An earlier analysis indicated invasive annuals were widespread in this type (Tuhy et al. 2014).

Ecological States and Vegetation Departure (Miller et al. 2019; Stringham et al. 2015; Tausch and Hood 2007).

Not departed—reference states or current ecological states not at risk of transitioning to an undesirable state.

Late seral sites are characterized by widely dispersed old growth Utah juniper and pinyon trees with a sagebrush and perennial bunchgrass understory. Tree cover varies from 10 to 20% on sites with low productivity to 20 to 35% on more productive sites (Stringham et al. 2015). Trees have reached maximal or near maximal heights for the site and many tree crowns may be flat- or round-topped. Understory shrubs and forbs are usually sparse. Fire return intervals are typically long, and fires are likely small and patchy due to low and discontinuous fuel loads. Under these conditions an ever-shifting mosaic of multiple seral stages are likely represented due to periodic occurrences disturbance or fire. High intensity fires typically require extreme fire weather and can eliminate or reduce trees and shrub. These high intensity fires result in a successional sequence where grass and forb dominance is followed by establishment and growth of shrubs and then trees. If present, cheatgrass is patchy and forms an insignificant portion of the herbaceous biomass. If grazed by livestock, light to moderate stocking rates and periodic rest during the growing season are needed to maintain the herbaceous component.



Figure E8.1—The old growth juniper and pinyon ecological type on low productivity sites with shallow, rocky soils in the Petrified Forest State Park, Utah. USDA Forest Service photo by Jeanne Chambers.

Moderately departed—current potential states at risk or shrub state at risk.

These sites are similar to not departed sites with four general community phases depending on time since disturbance: a grass and forb dominated phase, a grass-shrub phase with young trees, an immature woodland phase with multiple age classes, and an old growth woodland phase. Excessive livestock grazing and browsing may result in shifts in understory composition and increases in shrub and/or tree cover. Cheatgrass is generally present but does not dominate the understory except in scattered patches. Current fire-free intervals are often longer than estimated historic intervals. A lack of protective soil cover may have resulted in some surface soil erosion depending on the type of soil and topography.

Highly departed (uncharacteristic)—annual, tree, and seeded states.

Time and a lack of disturbance allow trees to dominate the site. Inappropriate grazing management and high levels of browsing may favor tree dominance. Pinyon and Utah juniper canopy cover depends on soils and aspect but is typically greater than 30%. Little understory vegetation remains due to competition with trees for site resources. Transition to an annual dominated state may occur if high intensity crown fire results in the loss of the trees and residual shrubs on the site. Annual dominance may also occur if cheatgrass and other native annuals dominate the site prior to a high

intensity fire. Transition to a tree dominated (infilled) state with cover greater than 30% can occur if understory vegetation is largely eliminated due to increasing shade and competition from trees. Bare ground areas are large and interconnected. Soil redistribution may be extensive. Seeding with introduced grasses following wildfire can result in a highly departed state dominated by the introduced seeded species.

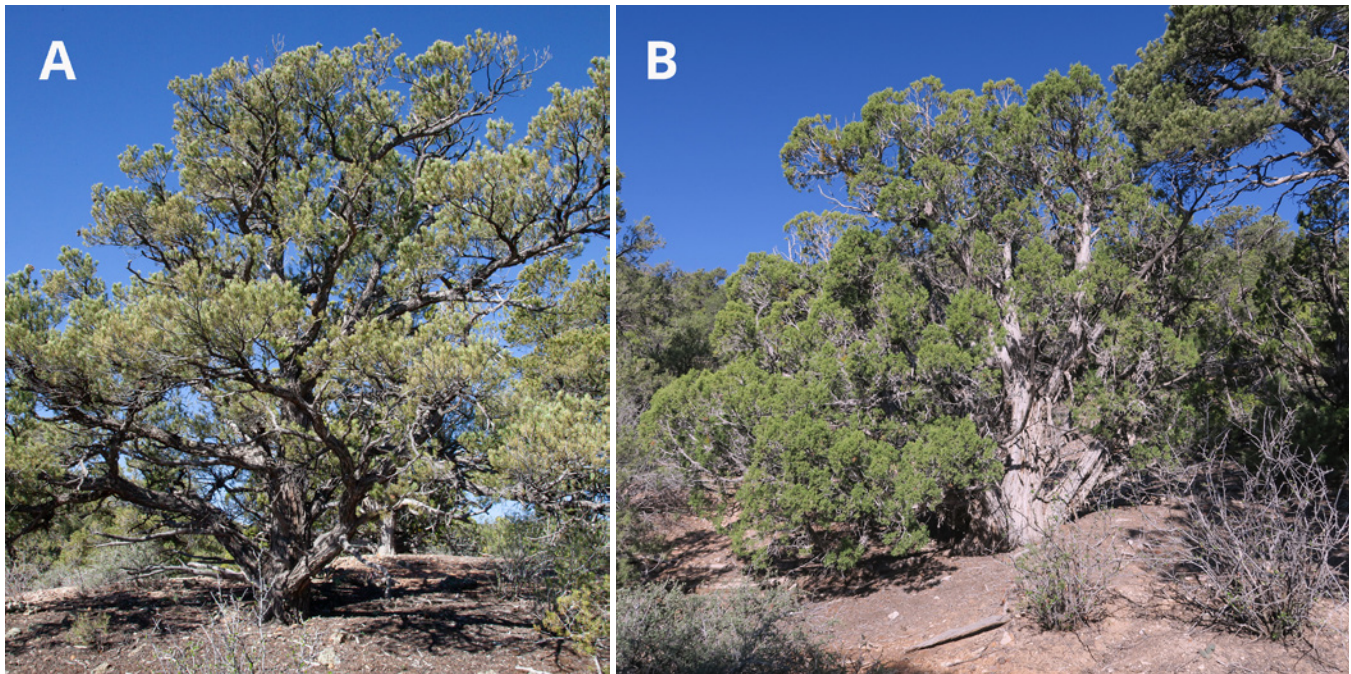


Figure E8.2—Old growth singleleaf pinyon (A) and Utah juniper (B) trees in the juniper and pinyon ecological type in Pine Valley near the Pinto Road. The understory is characterized by species typical of the mountain shrub – Utah serviceberry ecological type. USDA Forest Service photos by Jeanne Chambers.

Management Recommendations (Chambers et al. 2024; Kitchen and McArthur 2007; Miller et al. 2013, 2019)

Many of the management recommendations for the old growth juniper and pinyon ecological type are similar to those for the other ecological types. However, those for tree thinning are unique to old growth woodlands (see table 5).

Not departed—reference states or current ecological states not at risk of transitioning to an undesirable state. Manage to maintain ecological resilience and resistance to invasives.

- Manage livestock grazing at a stocking rate, season of use, and duration that maintains or increases perennial grasses and forbs.
- Suppress human-caused fires that can result in extensive, high severity burns.
- Do not conduct prescribed fires except for small-scale research burns.
- Allow natural recovery after wildfires where sufficient perennial native grasses exist for recovery and risk of invasive grass is low; do not seed with introduced species.

- To maintain multiple seral stages, consider allowing spot fires to burn in areas with moderate resilience where there is no risk to human communities, sufficient perennial native grasses exist for recovery, and annual grasses are rare or absent.
- Consider treatments to decrease transmission of fire into high value old growth woodlands in the reference or current ecological state, such as fuel treatments or fuel breaks in adjacent areas.

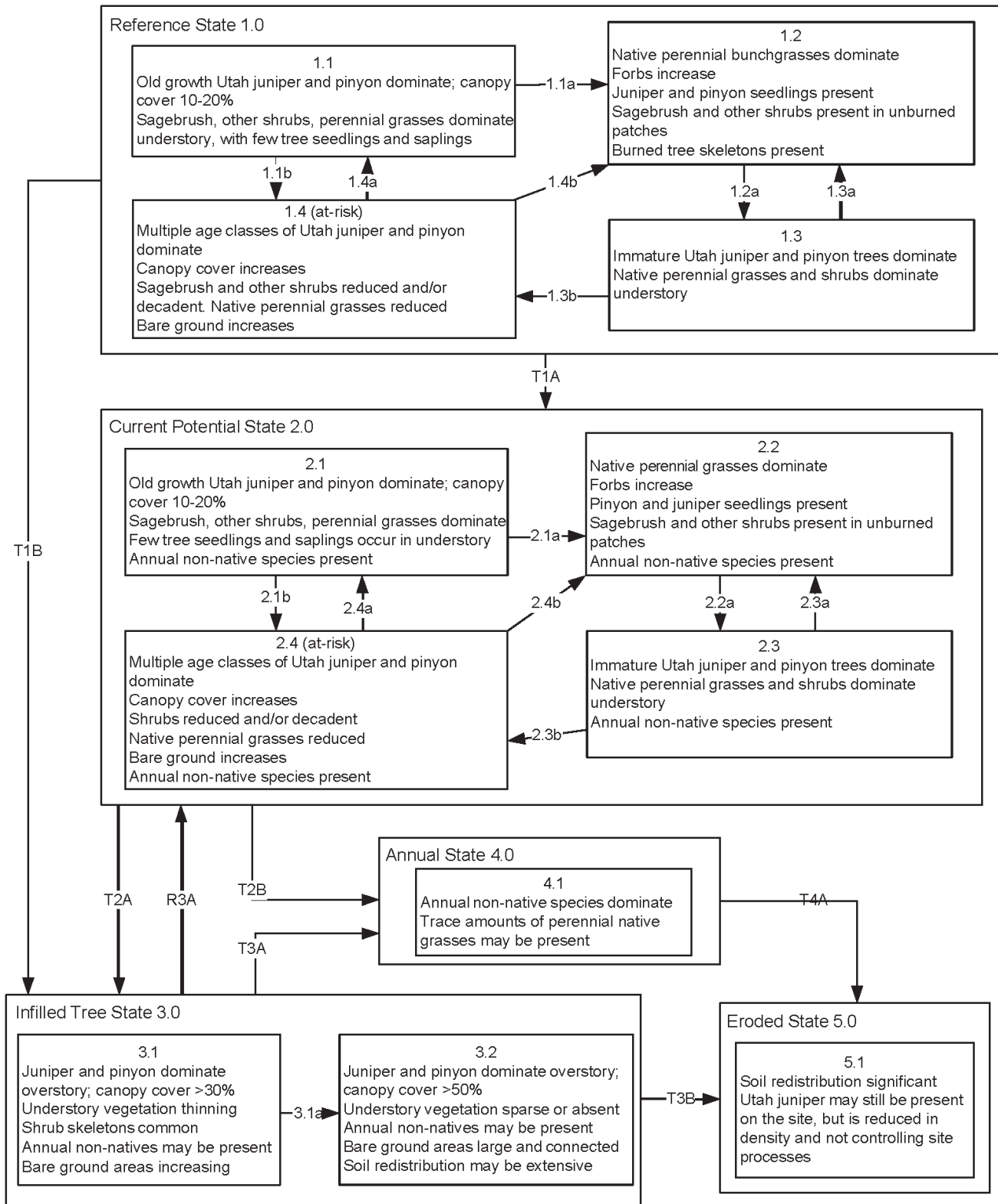
Moderately departed—current potential states at risk or shrub state at risk. Manage to increase ecological resilience and resistance to invasives.

- Manage moderately departed states similarly to not departed states, paying particular attention to areas where infilling of young trees is occurring, and the site is at risk of converting to nonnative annual grasses following wildfire and other disturbances.
- Consider mechanical thinning of younger trees where infilling of young trees is occurring in old growth woodlands. Cut and pile burn or mastication using a small masticator can be considered where resilience and resistance are moderately low or higher. Seeding will be required if insufficient perennial grasses are present to promote recovery and prevent increases in invasive plants.
- Species selected for seeding areas at risk of invasion by nonnative annuals following management treatments and wildfires determine longer-term outcomes. If native perennial grasses and forbs comprise 10–15% cover, seeding probably is not needed. If perennial grasses and forbs are depleted, seeding is likely needed. Seeding native species will increase the likelihood of site restoration. Introduced grasses and forbs as well as shrubs like forage kochia can outcompete residual natives and result in a highly departed state dominated by the introduced seeded species.
- The herbicide Imazapic® suppresses annual grasses but can also decrease establishment of native grasses and forbs. Indaziflam® is a nonselective herbicide that decreases native seed banks and reduces seedling establishment of natives, particularly in warmer and drier areas.

Highly departed (uncharacteristic)—annual, tree, and seeded states. Manage to increase ecological resilience and resistance to invasives.

- Manage highly departed states similarly to not departed states, paying particular attention to areas that are experiencing infilling by young trees and converting to nonnative annual grasses following wildfire and other disturbances.
- Consider mechanical thinning of younger trees where infilling of young trees is occurring in old growth woodlands as described for moderately departed sites. Seeding will likely be required in these highly departed sites.
- Consider seeding and evaluate species selection as described for moderately departed sites.

Juniper and Pinyon
12-16 in PZ



9. Old growth pinyon-juniper - Mesic/Xeric 16–20 in PZ; moderate to moderately high resilience and moderate to moderately high resistance

The pinyon-juniper type receives 16 to 20 in (406 to 508 mm) of precipitation based on Daymet data and is associated with most of the other BpS identified for the Pine Valley Ranger District within this precipitation zone. Soil temperatures are cool warm (cool mesic), and these sites generally occur at the upper range of elevations for pinyon and juniper trees (5,500 to 8,000 ft [1,675 to 2,440 m]). Utah juniper (*Juniperus osteosperma*), singleleaf pinyon (*Pinus monophylla*), two-needle pinyon (*Pinus edulis*), or a hybrid of the two pinyon species, occur on these sites. These are sites with higher productivity relative to the juniper and pinyon type and pinyon is dominant while Utah juniper subdominant. The soils are typically shallow to moderately deep and available water holding capacity is typically low. These soils are often coarse and have high amounts of rock fragments. Shrub species reflect those of the associated ecological types and include mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*), bitterbrush (*Purshia tridentata*), Utah serviceberry (*Amelanchier utahensis*), chokecherry (*Prunus virginiana*), and elderberry (*Sambucus racemosa*). Grasses include blue grama, (*Bouteloua gracilis*), Ross' sedge (*Carex rossii*), slender wheatgrass (*Elymus trachycaulus*), Sandberg's bluegrass (*Poa secunda*), and Letterman's needlegrass (*Achnatherum lettermannii*). Ecological states and departure are similar to the juniper and pinyon type.

Land cover data from the Rangeland Analysis Platform (Allred et al. 2021) for 2018–2022 indicated that shrubs were a moderate component (12.0%), perennial grasses and forbs were highly depleted (3.3%), and pinyon-juniper had high overall cover (32.3%). Cover of invasive annuals from the Rangeland Analysis Platform was 1.8%, and from the USGS Rangeland Exotic Plant Monitoring System (unpublished) was 3.9% for 2016–2022.

Ecological States and Vegetation Departure (Miller et al. 2019; Stringham et al. 2015; Tausch and Hood 2007).

Not departed—reference states or current ecological states not at risk of transitioning to an undesirable state.

Late seral sites are characterized by widely dispersed old growth pinyon and juniper trees with a mountain big sagebrush, mountain shrub, and perennial grass understory. Tree cover varies from 10 to 20% on sites with low productivity to 20 to 35% on more productive sites. Trees have reached maximal or near maximal heights for the site and many tree crowns may be flat- or round-topped. The understory shrubs and herbaceous species are relatively sparse. Fire return intervals are relatively long, and fires are likely small and patchy due to low and discontinuous surface fuels. Under these conditions an ever-shifting mosaic of multiple seral stages are likely represented due to periodic occurrence of fire or other disturbance. High intensity fires typically occur (or require) during extreme fire weather, eliminating or reducing the trees and shrubs and resulting in a successional sequence where grass, forb, and re-sprouting shrubs dominate followed by establishment and growth of fire-intolerant shrubs and

then trees. Cheatgrass and other invasive plants are rare on these moderately to highly resistant sites. If grazed by livestock, light to moderate stocking rates and periodic rest during the growing season are needed to maintain the herbaceous component.

Moderately departed—current potential states at risk or shrub state at risk.

These sites are like the not departed sites with four general community phases depending on time since disturbance: a grass and forb dominated phase, a grass-shrub phase with young trees, an immature woodland phase with multiple age classes, and an old growth woodland phase. Excessive livestock grazing and browsing may result in shifts in understory composition and increases in tree cover. Cheatgrass or other weedy species may be present on warmer and drier sites but only dominate the understory in scattered patches. Current fire-free intervals are often longer than estimated historic intervals. A lack of protective soil cover may have resulted in some surface soil erosion depending on the type of soil and topography.

Highly departed (uncharacteristic)—annual, tree, and seeded states.

Time and a lack of disturbance allow trees to dominate the resources on the site. Inappropriate grazing management and high levels of browsing may favor tree dominance. Pinyon and Utah juniper canopy cover depends on soils and aspect but is typically greater than 30%. Little understory vegetation remains due to competition with trees for site resources. Transition to an annual or weed dominated state may occur if high intensity crown fire results in the loss of the trees and residual shrubs on the site. On these cooler sites, weedy species may include prickly lettuce (*Lactuca serriola*), curvseed butterwort (*Ceratocephala testiculata*), and flatspine stickseed (*Lappula occidentali*). Transition to a tree dominated state with cover greater than 30% can occur if understory vegetation is largely eliminated due to increasing shade and competition from trees. Bare ground areas are large and interconnected. Soil redistribution may be extensive. Seeding with introduced grasses following wildfire can result in a highly departed state dominated by the introduced seeded grasses.

Management Recommendations (Chambers et al. 2024; Kitchen and McArthur 2007; Miller et al. 2013, 2019)

Many of the management recommendations for the old growth juniper and pinyon ecological type are similar to those for the other ecological types. However, those for tree thinning are unique to old growth woodlands (see table 5).

Not departed—reference states or current ecological states not at risk of transitioning to an undesirable state. Manage to maintain ecological resilience and resistance to invasives.

- Manage livestock grazing at a stocking rate, season of use, and duration that maintains or increases perennial grasses and forbs.
- Suppress human-caused fires that can result in extensive, high severity burns.
- Do not conduct prescribed fires except for small-scale research burns.

- Allow natural recovery after wildfires where sufficient perennial native grasses exist for recovery and risk of invasive grass is low; do not seed with introduced species.
- To maintain multiple seral stages, consider allowing spot fires to burn in areas with moderate resilience where there is no risk to human communities, sufficient perennial native grasses exist for recovery, and annual grasses are rare or absent.
- Consider treatments to decrease transmission of fire into high value old growth woodlands in the reference or current ecological states, such as fuel treatments or fuel breaks in adjacent areas.

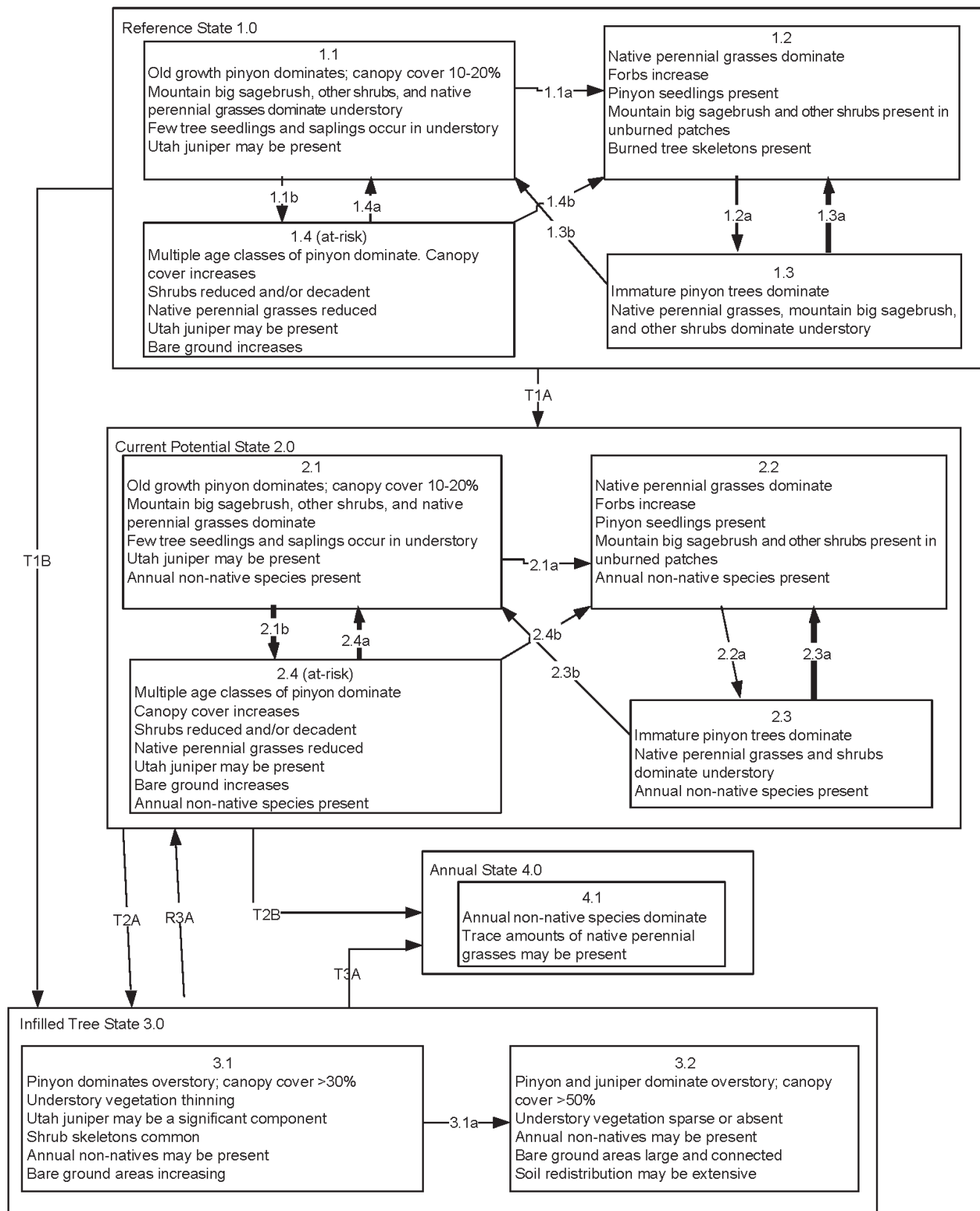
***Moderately departed—current potential states at risk or shrub state at risk.
Manage to increase ecological resilience and resistance to invasives.***

- Manage departed states similarly to not departed states, paying particular attention to areas where infilling of young trees is occurring, and the site is at risk of converting to nonnative annual grasses following wildfire and other disturbances.
- Consider mechanical thinning of younger trees where infilling of young trees is clearly occurring in old growth woodlands. Cut and pile burn or mastication using a small masticator can be considered where resilience and resistance are moderately low or higher. Seeding will be required if insufficient perennial grasses are present to promote recovery and prevent increases in invasive plants.
- Species selected for seeding areas at risk of invasion by nonnative annuals following management treatments and wildfires determine longer-term outcomes. If native perennial grasses and forbs comprise 5-10% cover, seeding may not be needed. If perennial grasses and forbs are depleted, seeding is likely needed. Seeding native species will increase the likelihood of site restoration. Introduced grasses and forbs as well as shrubs like forage kochia can outcompete residual natives and result in a highly departed state dominated by the introduced seeded species.
- The herbicide Imazapic® suppresses annual grasses but can also decrease establishment of native grasses and forbs. Indaziflam® is a nonselective herbicide that decreases native seed banks and reduces seedling establishment of natives, particularly in warmer and drier areas.

Highly departed (uncharacteristic)—annual, tree, and seeded states. Manage to increase ecological resilience and resistance to invasives.

- Manage highly departed states similarly to not departed states, paying particular attention to areas that are experiencing infilling by young trees and converting to nonnative annual grasses following wildfire and other disturbances.
- Consider mechanical thinning of younger trees where infilling of young trees is occurring in old growth woodlands as described for moderately departed sites. Seeding will likely be required in these highly departed sites.
- Consider seeding and evaluate species selection as described for moderately departed sites.

Pinyon and Juniper
16-20 in PZ



10. Mountain shrub - Gambel oak - Mesic/Xeric 16–22 in PZ; moderate resilience and moderately low to moderate resistance

The mountain shrub-Gambel oak (*Quercus gambelii*) type comprises 51,457 ac (20,825 ha) and ranges in precipitation from 16 to 20 in (406 to 508 mm) based on Daymet data, but effective precipitation depends on soils and aspect. The temperature regime is warm (mesic). Elevations range from 3,000 to 8,000 ft (915 to 2,438 m) and the type typically occurs on mountain foothills and lower slopes on gentle to steep slopes and all aspects. On less productive south or west-facing slopes and at lower elevations, the vegetation structure of this type is characterized by patchy Gambel oak clones that cover $\leq 60\%$ of the area. These sites have soils that are shallow to moderately deep, occur on rhyolite and basalt benches, mesas, canyon side slopes and hillslopes, and typically have a clayey skeletal texture and rock fragments greater than 35%. On more productive sites at higher elevations and on northern and eastern slopes cover of Gambel oak ($> 60\%$) is more continuous. These sites have soils that are deep to very deep and occur on rhyolite and basalt side slopes, benches, and narrow valleys with fine-loamy textures and rock fragments $< 35\%$. There are small areas with rock fragments $> 35\%$ and some soils are derived from sandstone and shale.

Gambel oak can occur as shrubs of moderate height (3–8 ft; 0.3–2.4 m) with high stem densities and as trees with stem diameters of 10–16 in (254–406 mm) and heights greater than 20 ft (6.1 m) in open woodland like stands (Kaufman et al. 2016). Gambel oak is associated with a variety of shrubs on these sites, including Utah serviceberry (*Amelanchier utahensis*), mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*), chokecherry (*Prunus virginiana*), bitterbrush (*Purshia tridentata*), wild rose (*Rosa woodsii*), squawapple (*Peraphyllum ramosissimum*), and snowberry (*Symphoricarpos oreophilus*). Commonly encountered grasses may include muttongrass (*Poa fendleriana*), Kentucky bluegrass (*Poa pratensis*), bulbous bluegrass (*Poa bulbosa*), squirreltail (*Elymus elymoides*), slender wheatgrass (*Elymus trachycaulus*), needle and thread (*Hesperostipa comata*), and Letterman's needlegrass (*Achnatherum lettermanii*). Forbs may include common yarrow (*Achillea millefolium*), pale agoseris (*Agoseris glauca*), limestone hawkbeard (*Crepis intermedia*), twolobe larkspur (*Delphinium nuttallianum*), redroot buckwheat (*Eriogonum racemosum*), silvery lupine (*Lupinus argenteus*), Great Basin Indian potato (*Orogenia linearifolia*), longleaf phlox (*Phlox longifolia*), mountain phlox (*Phlox austromontana*), elkweed (*Frasera speciosa*), King's clover (*Trifolium macilentum*), and American vetch (*Vicia americana*). Two-needle pinyon (*Pinus edulis*), Rocky Mountain juniper (*Juniperus scopulorum*), and ponderosa pine (*Pinus ponderosa*) may be associated with Gambel oak sites.

Land cover data from the Rangeland Analysis Platform (Allred et al. 2021) for 2018–2022 indicated that shrubs were the major component (34.1%), perennial grasses and forbs were moderate (8.4%), and pinyon-juniper had moderate overall cover (13.0%). Cover of invasive annuals from the Rangeland Analysis Platform was 4.6%, and from the USGS Rangeland Exotic Plant Monitoring System (unpublished) was 4.8% for 2016–2022. An earlier analysis estimated that this type ranged from mid-seral open to mid-seral closed (Tuhy et al. 2014). Sites seeded with introduced grasses also occurred within the Gambel oak-montane shrub type (Tuhy et al. 2014). Several exotic plants occur within the site,

including cheatgrass (*Bromus tectorum*), Sierra tansymustard (*Descurainia californica*), ribseed sandmat (*Chamaesyce glyptosperma*), prickly lettuce (*Lactuca serriola*), curvseed butterwort (*Ceratocephala testiculata*), common mullein (*Verbascum thapsus*), and crossflower (*Chorispora tenella*).

Gambel oak is an ecologically important species providing food and shelter for many wildlife species. The foliage has moderate to high palatability to a variety of species, including livestock, and it produces mast crops of acorns (Simonin 2000).

Fire frequency within the Gambel oak-montane shrub type likely varies with plant associates but has been reported to range from 40 to 80 years (Johanson 2011; Simonin 2000). The relatively frequent fire return intervals likely prevented the sites from becoming occupied by pinyon, juniper, and/or ponderosa pine. When associated with ponderosa pine forests, Gambel oak typically occupies an early seral, postfire successional stage. Density of Gambel oak stems within a stand is significantly related to stand height, with stem density decreasing with age. Gambel oak understories may serve as ladder fuels that carry fire to overstory tree crowns, increasing the fire risk to associated tree species. Gambel oak is a fire-adapted species that resprouts vigorously after fire. Several of the other shrub species associated with this type are also root-sprouters including Utah serviceberry, chokecherry, wild rose, and snowberry. The introduction of invasive annual grasses and forbs with livestock grazing likely increased fine fuel production resulting in more rapid fire spread in high precipitation years.

Ecological States and Vegetation Departure (Johanson 2011; Simonin 2000)

Not departed—reference states or current ecological states not at risk of transitioning to an undesirable state.

Relatively cool and moist stands of Gambel oak have a diverse assemblage of perennial grasses and forbs. Relatively short fire return intervals (about 35 to 100 yrs) rejuvenate the grass and forb understory. Fire return intervals are sufficiently long to allow Gambel oak and root-sprouting shrubs to regenerate. Tree species may be present but occur in relatively low abundance. If grazed by livestock, light to moderate stocking rates and periodic rest during the growing season is necessary to maintain the herbaceous component.

Moderately departed—current potential states at risk or shrub state at risk.

The herbaceous perennial component is moderately depleted in abundance and/or diversity. A shift in species composition of the perennial grasses and forbs reflecting palatability by livestock is often noticeable. Gambel oak and other shrubs may have reached maximum cover for the site. On warmer and less productive sites, cheatgrass and other weedy species may be present but they only dominate scattered patches. In moderately departed sites, trees may have reached 25–50% of their potential cover for the type, and herbaceous cover reduced by up to 75%.



Figure E10.1—The mountain shrub - Gambel oak ecological type on Stoddard Mountain. The site is in the shrub state and is transitioning to a tree state dominated by pinyon pine and Utah Juniper. USDA Forest Service photo by Mark Madsen.

Highly departed (uncharacteristic)—annual, tree dominated, and seeded states.

Understory grasses and forbs are typically severely depleted in highly departed sites. The current fire-free interval may be much longer than estimated historic intervals, and Gambel oak and other shrubs tend to be old-aged with little new recruitment. There is a relatively high probability of a high intensity fire burning through the site. Repeated fires at short return intervals may cause a decrease in the shrub species and an increase in nonnative invasive annuals. Seeding with introduced grasses may convert the site largely to introduced species with scattered shrubs. Pinyon, Rocky Mountain juniper, and/or ponderosa pine may dominate the site and Gambel oak and other understory species may be reduced.

Management Recommendations (Chambers et al. 2024; Kitchen and McArthur 2007; Miller et al. 2013, 2019)

Not departed—reference states or current ecological states not at risk of transitioning to an undesirable state. Manage to maintain ecological resilience and resistance to invasives.

- Manage livestock grazing at a stocking rate, season of use, and duration that maintains or increases perennial grasses and forbs.
- Suppress human-caused fires that can result in extensive, high severity burns.
- Do not conduct prescribed fires except for small-scale research burns.
- Allow natural recovery after wildfires where sufficient perennial native grasses exist for recovery and risk of invasive grass is low; do not seed with introduced species.
- To maintain multiple seral stages, consider allowing spot fires to burn and/or conducting patchy prescribed fires in areas with moderate resilience and resistance where there is no risk to human communities, sufficient perennial native grasses exist for recovery, and annual grasses are rare or absent.
- Establish fuel breaks or green strips adjacent to annual grass dominated areas to prevent fire transmission into these high value ecosystems. Recognize that fuel breaks require regular maintenance.
- Consider fuel reduction treatments at the wildland urban interface to reduce fire hazard where necessary to achieve management goals.

Moderately departed—current potential states at risk or shrub state at risk. Manage to increase ecological resilience and resistance to invasives.

- Manage moderately departed states similarly to not departed states, paying particular attention to areas transitioning to pinyon, juniper, or ponderosa pine dominance and converting to nonnative annual grasses following wildfire and other disturbances.
- Consider tree removal in phase I and phase II expansion areas where managing for oak is desired. Prescribed fire should not be used except on relatively cool and moist sites where resilience and resistance are moderate or higher and perennial grass abundance will promote recovery and prevent increases in annual grasses. Cut and pile burn or mastication can be considered where resilience and resistance are moderately low or higher and will be most successful if sufficient perennial grasses are present to promote recovery and prevent increases in invasive plants. Cut, lop, and scatter can be considered in phase I and early phase II. In late phase II and phase III, cut, lop, and scatter significantly increases woody surface fuels and the risk of high severity fire.

- Species selected for seeding areas at risk of invasion by nonnative annuals following management treatments and wildfires determine longer-term outcomes. If native perennial grasses and forbs comprise 5-10% cover, seeding may not be needed. If perennial grasses and forbs are depleted, seeding is likely needed. Seeding native species will increase the likelihood of site restoration. Introduced grasses and forbs as well as shrubs can outcompete residual natives and result in a highly departed state dominated by the introduced seeded species.
- The herbicide Imazapic® suppresses annual grasses but can also decrease establishment of native grasses and forbs. Indaziflam® is a nonselective herbicide that decreases native seed banks and reduces seedling establishment of natives, particularly in warmer and drier areas.

Highly departed (uncharacteristic)—annual, tree dominated, and seeded states. Manage to increase ecological resilience and resistance to invasives.

- Manage highly departed states similarly to not departed states, paying particular attention to areas that are transitioning to pinyon, juniper, or ponderosa pine dominance and converting to nonnative annual grasses following wildfire and other disturbances.
- Consider tree removal as described for moderately departed sites, paying particular attention to the risk of conversion to nonnative invasive annuals.
- Consider seeding and evaluate species selection as described for moderately departed sites.
- In the later stages of tree expansion, consider thinning treatments adjacent to human communities and/or to enhance resource and cultural values. Little data exist on treatment effects on fuels or fire behavior, but implementing cut and pile burning or mastication treatments to thin the trees can decrease crown fire risk. However, increases in Gambel oak following have the potential to increase fire spread. Thinning effects on fuels and fire behavior will depend on treatment extent, configuration, and proximity to other fuel types. Treatments that leave both groups of trees and individual trees will be most conducive to wildlife use. Seeding may be required on sites with severely depleted understory species.



11. Curl-leaf mountain mahogany - Frigid/Xeric 18–24 PZ; moderately high resilience and moderately high resistance

The curl-leaf mountain mahogany (*Cercocarpus ledifolius*) type comprises 18,258 ac (7,389 ha), receives between 18 to 24 in (457 to 610 mm) of precipitation, and is usually found on upper slopes and ridges between 2,133 to 3,200 m (7,000 to 10,500 ft) elevation (Tuhy et al. 2014). Soil temperatures are cool (frigid). Most stands occur on rocky shallow soils and outcrops. The type is present in two distinct forms due to soil differences: (1) savannas of old and well-dispersed trees in open and often grassy woodlands (mature stand cover between 10–55%) with a diverse understory on soils that have a large proportion of boulders above and below ground; and (2) dense thickets of old shrubs (56–100% cover) with thick litter and little understory cover formed on soils without boulders. On warmer and drier sites, Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*), black sagebrush (*Artemisia nova*), and rabbitbrush (*Chrysothamnus* ssp.) may occur along with blue grama (*Bouteloua gracilis*), squirreltail (*Elymus elymoides*), needle and thread (*Hesperostipa comata*), and Indian ricegrass (*Achnatherum hymenoides*). On cooler and moister sites, mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*) co-occurs with curl-leaf mountain mahogany, but other shrubs such as Utah serviceberry (*Amelanchier utahensis*) and snowberry (*Symphoricarpos oreophilus*) are typically present. Grasses may include muttongrass (*Poa fendleriana*), slender wheatgrass (*Elymus trachycaulus*), prairie Junegrass (*Koeleria macrantha*), and Letterman's needlegrass (*Achnatherum lettermanii*). Invasive species may include cheatgrass (*Bromus tectorum*) on warmer sites, as well as prickly lettuce (*Lactuca serriola*), curvseed butterwort (*Ceratocephala testiculata*), and flatspine stickseed (*Lappula occidentalis*). Two-needle pinyon (*Pinus edulis*), Rocky Mountain juniper (*Juniperus scopulorum*), and ponderosa pine (*Pinus ponderosa*) may be associated with these sites.

The historic fire return interval of curl-leaf mountain mahogany is not well documented, but likely reflected that of the surrounding vegetation (Stringham et al. 2015). Curl-leaf mahogany plants are long-lived, and stands may reach > 1,000 years old in the absence of fire. Fire return intervals were likely longest on fire-protected, rocky sites. Curl-leaf mountain mahogany is considered a weak root-sprouter after fire and it is usually moderately to severely damaged by high intensity fire. Seed production is irregular, but seed crops can be large, and the wind-dispersed seeds can establish on exposed soils following fire or other disturbances. Depending on fire severity, rabbitbrush, mountain snowberry, and Utah serviceberry may increase after fire. The recovery time of curl-leaf mountain mahogany on these sites is not known; some studies show that stands lack recruitment for up to 30 years after fire. Expansion of pinyon, juniper, or ponderosa pine into these sites can result in depletion of understory grasses and forbs and may increase fire return intervals depending on site productivity and the characteristics of the surrounding vegetation.

Land cover data from the Rangeland Analysis Platform (Allred et al. 2021) for 2018–2022 indicated that shrubs were the major component (26.2%), perennial grasses and forbs were depleted (5.0%), and pinyon, juniper, and other trees were a major component (22.8.0%). Cover of invasive annuals from the Rangeland Analysis Platform was 1.9%,

and from the USGS Rangeland Exotic Plant Monitoring System (unpublished), was 2.0% for 2016–2022.

Ecological States and Departure (Stringham et al. 2015).

Not departed—reference states or current ecological states not at risk of transitioning to an undesirable state.

Low fuel loads on the site result in infrequent low severity fires and, consequently, a mosaic characterized by patches of curl-leaf mountain mahogany and other shrubs and patches of grasses and forbs. Snow loading or insect damage also may decrease the overstory allowing for herbaceous plants in the understory to increase. High severity fires are rare. Invasive annual grasses are rare on these moderately to highly resistant sites. If grazed by livestock, light to moderate stocking rates and periodic rest during the growing season are needed to maintain the herbaceous component.

Moderately departed—current potential states at risk or shrub state at risk.

On these sites curl-leaf mountain mahogany has increased in dominance while mountain big sagebrush, mountain snowberry, and rabbitbrush have decreased. Excessive livestock grazing may have caused a decrease in perennial herbaceous species and increases in bare ground. The curl-leaf mahogany may have a “hedged” or tree-like appearance from browsing by mule deer. Annual grasses are increasing on warmer and less productive sites, and annual nonnative plants adapted to the colder conditions are increasing on cooler and moister sites. Trees may be present on the site and increasing in cover.

Highly departed (uncharacteristic)—annual and tree states.

On these sites overgrazing in the presence of nonnative invasive species has caused a decrease in native perennial grasses and an increase in the invaders. Spring and/or fall moisture may result in an increase in the invaders (fine fuels) and provide the necessary conditions for fires to burn through these sites. Loss of mahogany overstory, mountain big sagebrush, and native perennial grasses may result in conversion to root-sprouting shrubs and nonnative invaders. Alternatively, progressive infilling of the tree species may provide the necessary conditions for high-intensity, stand-replacing fire that significantly reduces or eliminates curl-leaf mountain mahogany and sagebrush. Perennial native grasses may be damaged by the fire and further reduced or eliminated with inappropriate postfire grazing management. The site may be converted largely to nonnative invaders.

Management Recommendations (Stringham et al. 2015)

Not departed—reference states or current ecological states not at risk of transitioning to an undesirable state. Manage to maintain ecological resilience and resistance to invasives.

- Manage livestock grazing at a stocking rate, season of use, and duration that maintains or increases perennial grasses and forbs.

- Suppress human-caused fires that can result in extensive, high severity burns.
- Allow natural recovery after wildfires where sufficient perennial native grasses exist for recovery and risk of invasive grass is low; do not seed with introduced species.
- To maintain multiple seral stages, consider allowing spot fires to burn in areas with moderate resilience where there is no risk to human communities, sufficient perennial native grasses exist for recovery, and annual grasses are rare or absent.
- Establish fuel breaks or green strips adjacent to annual grass dominated areas to prevent fire transmission into these high value ecosystems. Recognize that fuel breaks require regular maintenance.
- Consider fuel reduction treatments at the wildland urban interface to reduce fire hazard where necessary to achieve management goals.

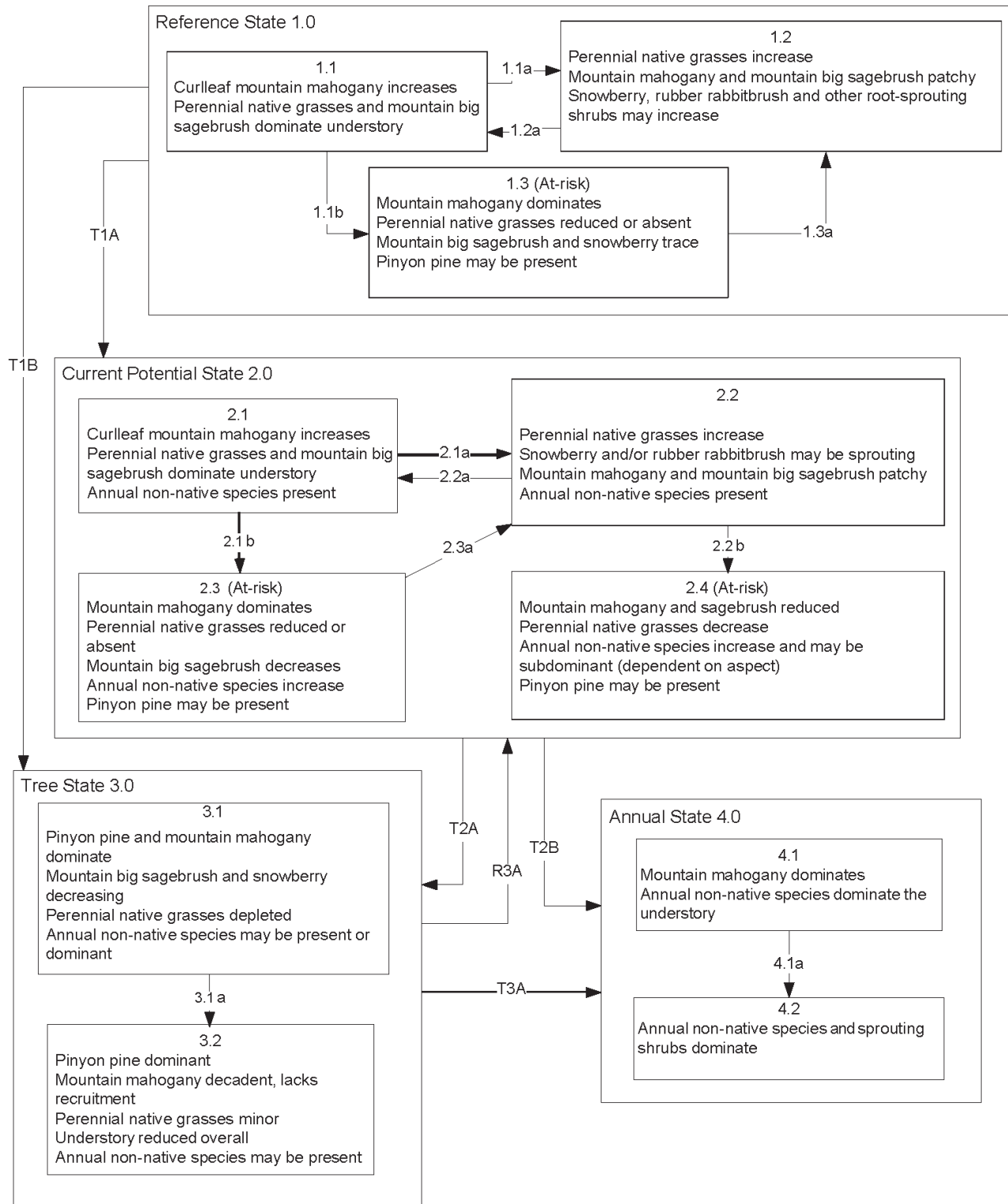
***Moderately departed—current potential states at risk or shrub state at risk.
Manage to increase ecological resilience and resistance to invasives.***

- Manage moderately departed states similarly to not departed states, paying particular attention to areas at risk of transitioning to tree dominance and converting to nonnative annual grasses following wildfire and other disturbances.
- Where it is desirable to maintain the curl-leaf mountain mahogany type, consider removal or thinning of pinyon, juniper, and other trees that are expanding into the site. Cut and pile burn and mastication are treatment options where resilience and resistance are moderately low or higher. Little data exist on treatment effects on fuels or fire behavior, but treatment extent, configuration, and proximity to other fuel types will determine outcomes. These treatments will likely be most successful in the early phases of tree expansion and where sufficient perennial shrubs and grasses are present to promote recovery and prevent increases in invasive plants.
- Species selected for seeding areas at risk of invasion by nonnative annuals following management treatments and wildfires determine longer-term outcomes. If native perennial grasses and forbs comprise 5-10% cover, seeding may not be needed. If perennial grasses and forbs are depleted, seeding is likely needed. Seeding native species will increase the likelihood of site restoration. Introduced grasses and forbs as well as shrubs can outcompete residual natives and result in a highly departed state dominated by the introduced seeded species.
- The herbicide Imazapic® suppresses annual grasses but can also decrease establishment of native grasses and forbs. Indaziflam® is a nonselective herbicide that decreases native seed banks and reduces seedling establishment of natives, particularly in warmer and drier areas.

Highly departed (uncharacteristic)—annual and tree states. Manage to increase ecological resilience and resistance to invasives.

- Manage highly departed states similarly to not departed states, paying particular attention to areas that are transitioning to tree dominance and converting to nonnative annual grasses following wildfire and other disturbances.
- Consider tree removal as described for moderately departed sites.
- Consider seeding and evaluate species selection as described for moderately departed sites.

**Curl-leaf mountain
mahogany
18-24 in PZ**



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