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A Field Guide for Rapid Assessment of Post-Wildfire Recovery Potential in Sagebrush and Piñon-Juniper Ecosystems in the Great Basin

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

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Abstract

This field guide provides a framework for rapidly evaluating post-fire resilience to disturbance, or recovery potential, and resistance to invasive annual grasses, and for determining the need and suitability of the burned area for seeding. The framework identifies six primary components that largely determine resilience to disturbance, resistance to invasive grasses, and potential successional pathways following wildfire, as well as the information sources and tools needed to evaluate each component. The components are: (1) characteristics of the ecological site; (2) vegetation composition and structure prior to the wildfire; (3) fire severity; (4) post-wildfire weather; (5) post-wildfire management, especially grazing; and (6) monitoring and adaptive management. The tools provided are: (1) a conceptual model of the key components that largely determine resilience to disturbance and resistance to invasive annual grasses of the burn area, (2) a guide to evaluate post-wildfire severity, (3) indicators to estimate pre-wildfire plant composition and structure if not known, and (4) an evaluation score sheet to rate an area's potential post-wildfire resilience to disturbance, resistance to invasive annual grasses and, thus, the need for seeding and probability of success.

Keywords: restoration, post-fire rehabilitation, seeding, succession, invasive annual grasses, cheatgrass

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Introduction

Immediately following a wildfire, rapid response teams such as the Burned Area Emergency Response (BAER) and Emergency Stabilization and Recovery (ES&R) teams must quickly evaluate large and often heterogeneous areas for erosion and invasive species potential. To effectively allocate resources and apply the most appropriate treatments, these teams must be able to rapidly determine the resilience to disturbance (recovery potential) and resistance to invasive annual grasses of the burned area. Important questions for these teams to address are:

1. What is the resilience (recovery potential) of the ecological sites in the burned area?
2. How resistant are they to invasive annual grasses?
3. How susceptible is the burned area to erosion?
4. What areas within the burned area need seeding and are suitable for treatment?

These questions can be addressed by evaluating six primary components that largely drive plant successional pathways following wildfire. These components are: (1) characteristics of the ecological site; (2) composition and structure of vegetation present prior to the wildfire; (3) fire severity; (4) post-wildfire weather; (5) post-wildfire management, especially grazing; and (6) monitoring and adaptive management. Components (1) and (2) are the primary drivers of potential resilience, resistance to invasive annual grasses, and plant successional pathways for the various ecological sites present on the burned area. However, components (3) through (6) can modify the potential resilience and resistance following wildfire and thus plant succession.

Resilient ecosystems have the capacity to *regain* their fundamental structure, processes, and function following disturbance, stressors, and management treatments. The resilience of an ecosystem reflects its recovery potential and is determined by environmental characteristics and ecological conditions such as current vegetation at the time of the disturbance. **Resistant** ecosystems have the ability to *retain* their fundamental structure, processes, and function (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, water, forage, and wildlife habitat.

Purpose

The purpose of this field guide is to help managers effectively meet the management objectives of increasing or restoring resilience to disturbances and resistance to invasive annual grasses following wildfire in sagebrush and piñon and/or juniper ecosystems. This field guide provides a framework that will enhance the ability of rapid response teams to: (1) quickly evaluate post-wildfire resilience, resistance to invasive annual grasses, and potential successional pathways immediately following wildfire; and (2) assess the need and suitability of the area for seeding. This field guide can also be used as a training tool to increase the observational skills needed for assessing resilience to disturbance and resistance to invasive annual grasses for areas of concern across various ecological sites.

Approach

This field guide presents a framework for conceptualizing and synthesizing information gathered from observation, experience, ecological site descriptions, soils surveys, and other sources for the rapid evaluation of post-wildfire resilience and resistance to invasive annual grasses. A set of **Key Questions** related to the six primary components shown in fig. 1 are used to evaluate resilience, resistance to invasive annual grasses, and potential successional pathways, and to determine the need and suitability of areas within the burn for seeding. The guide also provides the following set of tools: (1) characteristics of the six primary components that influence resilience and resistance to invasive annual grasses, (2) ecological site indicators that help identify an area's resilience and resistance to invasive annual grasses, (3) criteria for evaluating post-wildfire severity, (4) state-and-transition models for five generalized ecological types of big sagebrush that describe potential successional pathways, and (5) an evaluation score sheet. The evaluation score sheet (Appendix 7) helps managers quickly rate potential post-wildfire resilience and resistance to invasive annual grasses and the need and suitability for seeding across a burned area. The quality of the rapid assessment depends on: (1) the assessment team's local expertise of soils, plants, and ecology; (2) familiarity with the burned area; and (3) amount of available information on the burned area.

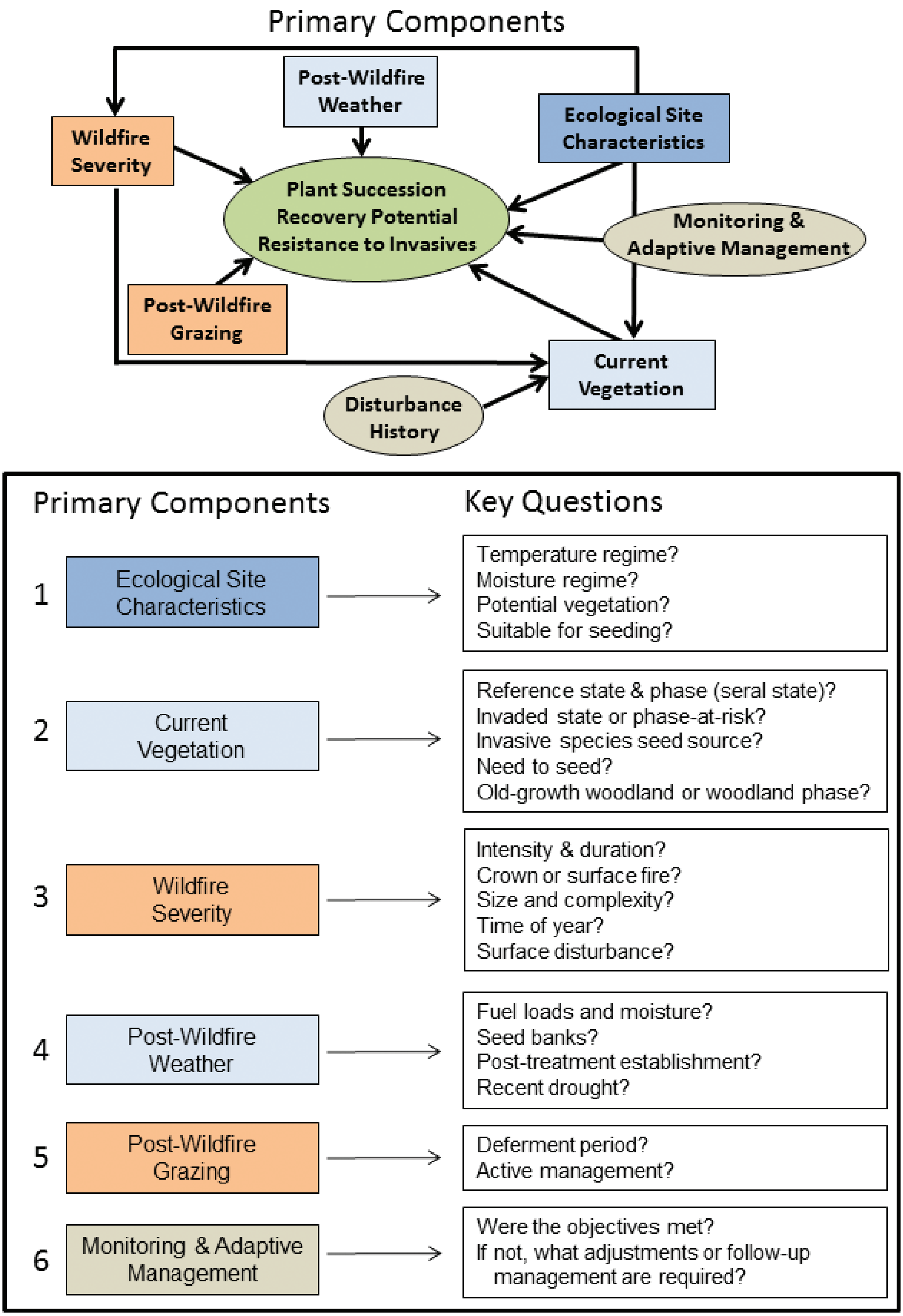


Figure 1. A simple conceptual model of the primary components that drive plant successional trajectories following wildfire. These components are the basis for a series of key questions to be addressed when evaluating resilience to fire and resistance to invasive annual grasses as well as predicting post-wildfire and seeding responses for an area of concern.

Area of Application

This field guide was developed for the northern Great Basin and Columbia River Plateau (fig. 2), which encompasses 11 Major Land Resource Areas (MLRAs) (table 1). MLRAs are geographically associated land resource units, usually encompassing millions of acres. They are characterized by particular patterns of soils, geology, climate, water resources, and land use. The MLRA in which the wildfire occurs provides important information for site evaluation, including:

1. The elevation, topographic position, and indicator species used to identify **soil temperature/moisture regimes** that are closely linked to resilience to disturbance and management treatments as well as resistance to invasive annual grasses (fig. 3, Appendixes 1 and 2).
2. **The relevant ecological site descriptions** (ESDs; see definitions in Appendix 8). ESDs are usually unique to each MLRA, but similar ESDs can occur across different MLRAs.
3. **The potential vegetation** (described in the ESD). Species composition may change across MRLAs, but the functional roles of plant groups (for example, deep-rooted and shallow-rooted perennial grasses, perennial forbs, and shrubs) are usually similar across MLRAs within the Great Basin and Columbia River Plateau regions.

   When extrapolating plant response across different wildfires within the region, comparing similarities among specific ecological ***site characteristics*** *(including soil temperature/moisture regimes and pre-fire composition of the plant groups, such as deep-rooted perennial grasses) is usually more important than differences in geographic locations within or across MLRAs.*

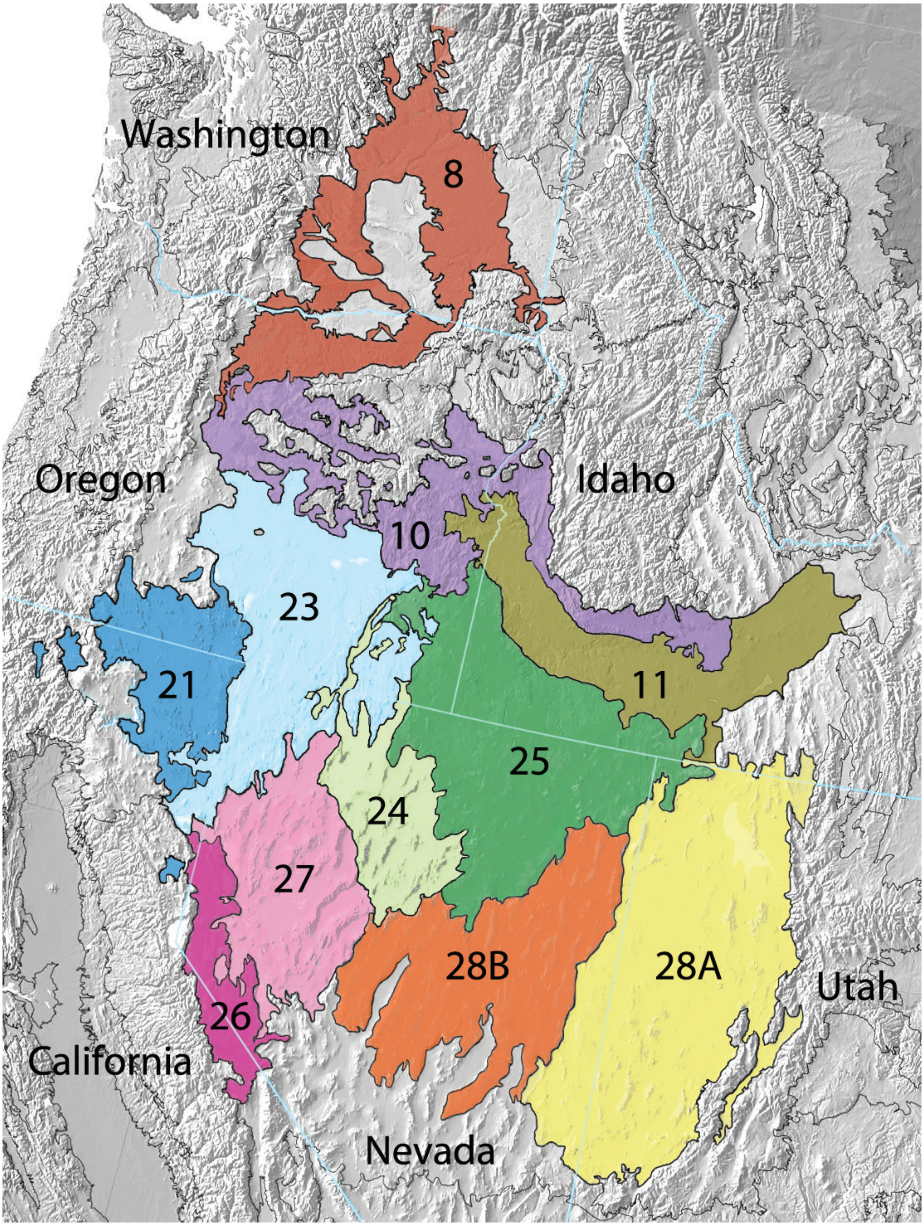


Figure 2. Major Land Resource Areas (MLRAs) located in the Great Basin and Columbia River Plateau Region: Columbia Plateau (8); Blue Mountain Foothills (10); Snake River Plain (11); Klamath Valleys (21); Malheur High Plateau (23); Humboldt Area (24); Owyhee High Plateau (25); Carson Basin and Mountains (26); Fallon-Lovelock (27); Great Salt Lake (28A); and Central Nevada Basin and Range (28B) (derived from USDA Natural Resources Conservation Service [2011] by Eugénie MontBlanc, University of Nevada, Reno).

Table 1. Major Land Resource Area (MLRA) names and identification numbers (see map in fig. 2) included in this field guide. For each MLRA, the size of land area, the states listed in descending order of proportion of area covered, most common elevation range (extreme), geology, common soil orders, range of average annual precipitation (extremes), and range in temperatures are described. The field guide only covers the sagebrush, salt-desert, and piñon pine and juniper ecological types within these MLRAs. MLRAs 8, 10, and 11 are located in the Northwestern Wheat and Range Region. The remaining MLRAs are located in the Western Range and Irrigated Region. Descriptions are derived from USDA Natural Resources Conservation Service (2011).

MLRA (id #)	Area (mi^2)	States	Elevation (ft)	Geology	Soils	Precipitation (in)	Temp (°F)
Columbia Plateau (8)	18,505	WA OR ID	1,300–3,600	basalt	Mollisols	10–16 (6–36)	48-54
Blue Mt Foothills (10)	17,515	OR ID	1,300–6,600	basalt alluvium sedimentary	Mollisols Aridisols	8–16 (41)	36–53
Snake River Plain (11)	16,475	ID OR	2,100–5,000	Idaho Batholith, basalts	Aridisols	7–12 (20)	41–55
Klamath Valleys (21)	11,495	CA OR	2,600–4,600 (>7,000)	basalt rhyolite andesite	Mollisols	12–30 (9-58)	39–52
Malheur High Plateau (23)	22,896	OR NV CA	3,900–6,900 (>9,000)	basalt & andesite	Aridisols Mollisols	6–12 (>50)	39–52
Humboldt Area (24)	12,680	NV OR	3,950–5,900 (>8,850)	alluvium (some andesite & basalt)	Entisols Inceptisols Mollisols	6–12 (40)	38–53
Owyhee High Plateau (25)	28,930	NV ID OR UT	3,000–7,550 (>9,800)	andesite basalt rhyolite	Aridisols Mollisols	7–16 (>50)	35–53
Carson Basin & Mts (26)	6,520	NV CA	3,900–6,550 (13,100)	granitic andesite basalt	Aridisols Mollisols	5–36	37–54
Fallon-Lovelock (27)	12,565	NV CA	3,300–5,900 (<7,800)	alluvium andesite basalt	Aridisols Entisols	5–10 (19)	43–54
Central NV Basin & Range (28B)	23,555	NV	3,950–6,560 basin 6,560–11,150 mts	playa lakebed deposits, old-sedimentary	Aridisols Entisols Mollisols	5–12 (49)	39–53
Great Salt Lake (28A)	36,775	UT NV ID	4,900–6,550 basin 6,550–11,900 mts	carbonate (north) andesite basalt (south) alluvium & lakebed deposits	Aridisols Entisols Mollisols	4–12 (basins) 8–36 (mountains)	34–52

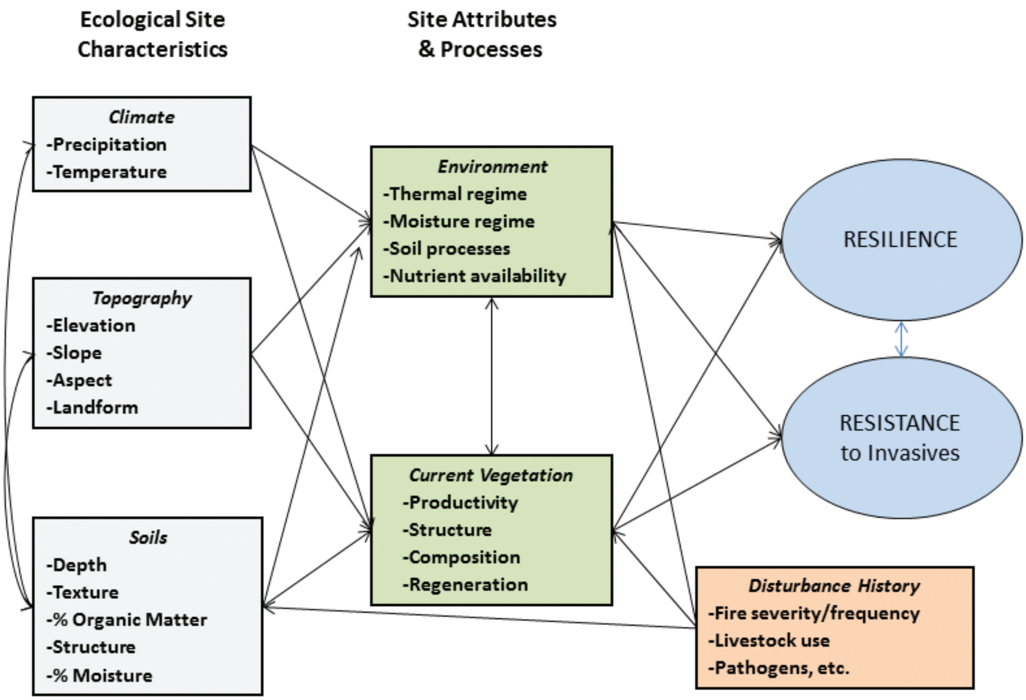


Figure 3. A conceptual model that illustrates the factors influencing resilience to treatment and resistance to invasive annual grasses. Ecological site characteristics or environmental factors are the primary factors that influence soil temperature/moisture regimes and potential vegetation. The regimes are identified in soil maps as mesic (warm), frigid (cool), cryic (cold), aridic (dry), and xeric (moist). Potential vegetation + disturbance history + time since disturbance or treatment = current vegetation. If all of the ecological site characteristics are favorable and the site attributes and processes are all functioning within the natural range of variability, then levels of resilience to wildfire and resistance to invasive species are near potential for that site. However, if the site is not at potential because one or more components are below potential or missing (for example, perennial grasses are severely depleted or invasive annual grasses are abundant), resilience to wildfire and/or resistance to invasive annual grasses will be lower than potential (adapted from Chambers and others 2014a).

Supporting Information

The framework for the field guide is based on a recent synthesis of the state-of-our knowledge titled, "A Review of Fire Effects on Vegetation and Soils in the Great Basin Region: Response and Ecological Site Characteristics," RMRS-GTR-308, by Miller and others (2013). Additional information required for evaluating post-wildfire areas includes soil surveys, ecological site descriptions, and potential and current vegetation (see http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm; http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/ecoscience/desc/).

This is not a field guide for restoration/rehabilitation methods following wildfire, but rather a guide to evaluate the need for restoration and seeding based on vegetation composition and structure present prior to the wildfire, resilience and resistance to invasive annual grasses, and suitability of the post-wildfire area for seeding based on ecological site characteristics. Once the suitability of a site and need for seeding have been determined, restoration/rehabilitation methods can be found in references such as *Field Guide for Restoration of Sagebrush-Steppe: Ecosystems with Special Emphasis on Greater Sage-Grouse Habitats*, by Pyke and others (in preparation), *Restoring Western Ranges and Wildlands*, by Monsen and others (2004), and the Great Basin Fire Science Exchange website references on post-fire management (http://www.gbfiresci.org).

Key Questions Addressing the Primary Components of Resilience and Resistance

Post-wildfire ecological function and plant successional pathways are closely related to and dependent on: (1) ecological site characteristics, (2) current vegetation (composition and structure) present prior to the wildfire, (3) wildfire severity, (4) post-wildfire weather, (5) post-wildfire grazing, and (6) monitoring and adaptive management.

The key questions identify specific characteristics of the six primary components that drive plant succession following wildfire and influence longer-term outcomes (fig. 1).

1—Ecological Site Characteristics

Climate, topography, and soils affect water availability, temperature regimes, potential vegetation, and productivity (fig. 3, Appendix 1). These, in turn, affect resilience to disturbance, resistance to invasive annual grasses, the need for vegetation treatments, and potential success of restoration treatments. Owing to underlying differences in characteristics of ecological sites, resilience after disturbance and resistance to invasive annual grasses following wildfire differ. Five ecological types for big sagebrush in the Great Basin and Columbia River Plateau regions are presented in table 2. They represent groupings of ecological sites that are occupied by Wyoming or mountain big sagebrush, span a range of soil temperature/moisture regimes (warm/dry to

In ecology, the term **mesic** is often used to mean moist or medium water supply for plant growth. However, in soil terminology and soil family names, mesic refers to warm soils, which in the Great Basin are often occupied by Wyoming big sagebrush and have relatively low resistance to invasive annual grasses (see Appendix 3, fig. 4).

Table 2. The five generalized ecological types for big sagebrush, their characteristics, and their resilience to wildfire and resistance to invasive annual grasses.

Ecological type	Site characteristics	Resilience and resistance
Warm and dry **Wyoming big sagebrush**	Soil temperature/moisture regime: Mesic/aridic Precipitation: 8–12 inches Indicator shrubs: *Artemisia tridentata* ssp. *wyomingensis* Indicator grasses: *Pseudoroegneria spicata, Achnatherum thurberianum* on cooler/moister sites; *A. hymenoides, A. comata, Elymus elymoides, Poa secunda* on drier/warmer sites	***Resilience*** **–** Low. Effective precipitation limits site productivity. Decreases in site productivity, herbaceous perennial species, and ecological conditions further decrease resilience. ***Resistance*** – Low. High climate suitability to cheatgrass and other invasive annual grasses. Resistance generally decreases as soil temperature increases, but establishment and growth are highly dependent on precipitation and vary among years.
Warm and moist **Big sagebrush** **Piñon and juniper potential**	Soil temperature/moisture regime: Cool mesic to warm frigid/xeric Precipitation:12–14 inches Indicator shrubs: *A. tridentata* ssp. *wyomingensis, A. tridentata* ssp. *vaseyana, Purshia tridentata* Indicator grasses: *Pseudoroegneria spicata*	***Resilience*** **–** Moderate. Precipitation and productivity are moderately high. Decreases in site productivity, herbaceous perennial species, and ecological conditions can decrease resilience. ***Resistance*** **–** Moderately low. Climate suitability to invasive annual grasses is moderately low but increases as soil temperatures increase.
Cool and moist **Mountain big sagebrush**	Soil temperature/moisture regime: Cool mesic to cool frigid/xeric Precipitation: 12–14 inches Indicator shrubs: *Artemisia tridentata* ssp. *vaseyana, Purshia tridentata* Indicator grasses: *Festuca idahoensis, Poa fendleriana*	***Resilience*** **–** Moderate. Precipitation and productivity are moderately high. Decreases in site productivity, herbaceous perennial species, and ecological conditions can decrease resilience. ***Resistance*** **–** Moderate. Climate suitability to invasive annual grasses is moderate but increases as soil temperatures increase.
Cool/cold and moist **Mountain big sagebrush** **Piñon and juniper potential**	Soil temperature/moisture regime: Cool frigid/xeric Precipitation: 12–14+ inches Indicator shrubs: *A. tridentata* ssp. *vaseyana, Amelanchier* ssp., *Symphoricarpos* ssp. Indicator grasses: *Festuca idahoensis, Koeleria macrantha, Melica bulbosa*	***Resilience*** **–** Moderately high. Precipitation and productivity are generally high. Decreases in site productivity, herbaceous perennial species, and ecological conditions can decrease resilience. ***Resistance*** **–** Moderately high. Low climate suitability to invasive annual grasses.
Cold and moist **Mountain big sagebrush**	Soil temperature/moisture regime: Cryic/xeric Precipitation: 14+ inches Indicator shrubs: *A. tridentata* ssp. *vaseyana, Amelanchier* ssp., *Symphoricarpos* ssp. Indicator grasses: *Festuca idahoensis, Koeleria macrantha, Melica bulbosa*	***Resilience*** **–** Moderately high. Precipitation and productivity are generally high. Short growing seasons can decrease resilience on coldest sites. ***Resistance*** **–** High. Low climate suitability to invasive annual grasses.

cold/moist), and characterize a large portion of the Great Basin and Columbia River Plateau regions. These can be useful when site-specific ESDs are not available or it is desirable or necessary to group ecological sites across a burn area. To determine the relative resilience and resistance of specific or generalized ecological sites(s) in the post-wildfire area, it is necessary to evaluate the soil temperature/moisture regimes, potential vegetation, and vegetation present and condition prior to the wildfire. If pre-wildfire vegetation composition, structure, and condition are unknown, assessment teams can make a best estimate based on a set of indicators listed in 2—Current Vegetation.

Soil Temperature Regime

1. Are the soils warm (mesic), cool (frigid), or cold (cryic) (fig. 4A and B)?

    a. This information can be attained from soil surveys, soil family names, and/or elevation based on criteria used in soils surveys in the appropriate MLRA (appendices 2 and 3). Potential vegetation for the ecological sites of concern can also be indicators of soil temperature regime (see "Potential Vegetation" in next section).

2. Do elevation and aspect place the ecological site on the upper or lower end of the soil temperature regime (for example, warm-mesic versus cool-mesic) (fig. 4)?

    a. In reality, soil temperature/moisture regimes are gradients. Thus, it helps to know if the ecological site is warm (lower one-half), or cool (upper one-half) relative to a specific soil temperature regime (fig. 4, Appendix 2). This can usually be determined by the elevation and aspect of the ecological site, which is adjusted for each MLRA. Indicator plant species can also be helpful. North and south aspects with >15 percent slope are usually adjusted by 500 ft. For example, in MLRA 23, the elevation boundary for mesic and frigid soils is 4,000 ft, but it is adjusted down to 3,500 ft on north aspects and up to 4,500 ft on south aspects.

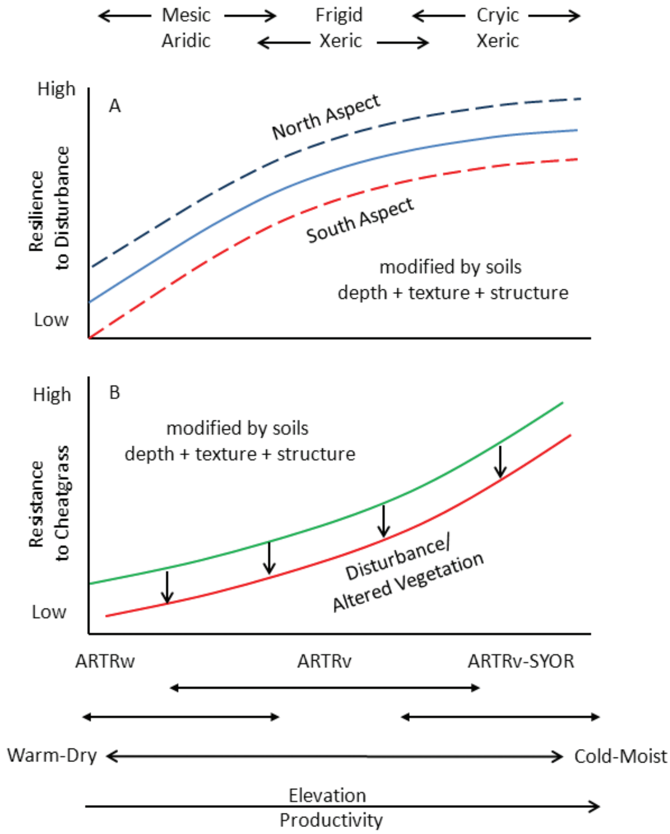


Figure 4. A conceptual model of (A) resilience to disturbance and (B) resistance to invasive annual grasses for Wyoming big sage (ARTRw), mountain big sagebrush (ARTRv), and mountain big sagebrush-snowberry (ARTRv-SYOR) along an elevation/ productivity gradient in which soil temperature/moisture regimes grade from warm/dry (mesic/aridic) to cold/ moist (cryic/xeric). Soil moisture availability along these gradients is modified by soil characteristics. The mountain big sagebrush-snowberry (ARTRv-SYOR) type is similar to mountain shrub in Nevada and Utah and often includes mountain big sagebrush, snowberry, serviceberry, bitterbrush, and curl-leaf mountain mahogany. Resilience and resistance are affected by topography; the dashed dark blue and red lines in the resilience graph illustrate the effects of aspect. Ecological site characteristics determine the potential resilience and resistance. However, potential resilience and resistance can be lowered if certain components such as perennial grass abundance are depleted as a result of disturbance history or extreme climate conditions. In the resistance graph, the solid green line represents potential resistance to annual invasives in the reference state, and the red line indicates decline in resistance as a result of being in the at-risk-phase. The relationship between soil temperature/moisture regimes and elevation changes across MLRAs (see Appendix 2). Soil temperature/ moisture regimes are not separated by distinct boundaries but represent a gradient (shown by the overlapping arrows). Changes in soil temperature and moisture can be gradual (a gradual increase in elevation) or abrupt (a shift from a south to an opposing north aspect). The shift from one sagebrush subspecies to another does not have a definite lower or upper elevation limit but will vary with other site attributes, including location (MLRA), soils, aspect, and microtopography. For example, an overlap of cool (frigid) mountain big sage (ARTRv) into warm (mesic) Wyoming big sagebrush (ARTRw) can occur and is often influenced by soil moisture availability. As environmental gradients move to the right, resilience and resistance increase. Productivity and, thus, fuel loads also increase, resulting in a greater potential for more frequent fires (from Chambers and others 2014a).

Soil Moisture Regime

1. Does the ecological site have a dry-aridic (<10 inches precipitation [ppt]), aridic (10 to 12 inches ppt), or xeric (>12 inches ppt) moisture regime (see table 3 and figs. 5 and 6 for indicator species)?
    a. This information can also be attained from soil surveys, soil family names, and/or elevation (based on criteria used in soils surveys in the appropriate MLRA) (appendices 2 and 3).
2. Is the soil depth very shallow (<10 inches), shallow (10 to 20 inches), moderately deep (20 to 36 inches), or deep (>36 inches)?
    a. Soil depth influences the water storage capacity of the ecological site. For example, a very shallow soil (<10 inches) in a xeric (>12 inches) precipitation regime may be mapped as aridic due to limited water storage capacity.
    b. A general estimate of soil depth can be determined by the species or subspecies of sagebrush that should occupy the area and their height (fig. 5 and table 3). However, digging small soil pits is the best technique to determine soil depth.
    c. Big sagebrush (*Artemisia tridentata*) are typically found on moderately deep to deep soils >20 inches depth.
3. Is the soil texture clay, sand, silt, loam, clay-loam, sandy-loam, or silt-loam (Appendix 3)?
    a. Texture is an important soil characteristic because it influences soil water capture and storage. Soils with loamy textures typically have the greatest capacity to both capture and store water for plant use.

> In ecology, the term **xeric** is often used to mean environments with little moisture. However, in soil terminology and soil family names, xeric refers to moist soils (as compared to dry or wet), which in the Great Basin are areas receiving typically >12 inch ppt (see Appendix 3, fig. 4).

What is in a soil family name?

A soil family name includes important information on related soil characteristics that influence ecological site resilience to disturbance, resistance to invasive annual grasses, and potential vegetation. This includes information related to relative organic matter content (Aridisols or Mollisols), soil depth (for example, mention of a restrictive layer), texture, and soil temperature/moisture regime (mesic, frigid, or cryic/aridic, or xeric) (see Appendix 3 for examples).

Table 3. Ecological site characteristics that commonly occur with different sagebrush and associated shrub species, although outliers occur. Lower elevation limits vary widely across Major Land Resource Areas. For example, the elevation where the transition of Wyoming to mountain big sagebrush occurs (modified by aspect) is commonly around 4,500 ft in the High Malheur Plateau (MLRA 23) and 6,500 to 7,500 ft in the Central Nevada Basin and Range (MLRA 28B) (from USDA-NRCS Plant Guide; Mahalovich and McArthur 2004).

			Soil			
Species	**PPT (in)**	**Elevation (ft)**	**Depth (in)**	**Moisture regime**	**Temperature regime**	**Texture and other characteristics**
Wyoming big sagebrush	8–12	2,600–7,200	10-30	aridic	mesic	loamy soils with high clay content
Basin big sagebrush	8–16	600–2,100	>36	aridic-xeric	mesic	loamy to sandy
Mountain big sagebrush	>12	2,600–10,000	18-36	xeric	frigid-cryic	loamy to gravely to clay loam
Xeric big sagebrush	12–16	2,600–4,900 (7,200)	>16	xeric	mesic	basalt or granitic
Low sagebrush		2,300–12,000	<20	aridic-xeric	frigid-cryic	rocky, shallow, clay soils
Black sagebrush	<12	2,000–10,000	<20	aridic	mesic-frigid	shallow, stony, calcareous
Snowbank big sagebrush	>12	6,800–10,000	>20	xeric	cryic	snow accumulation areas
Other Shrubs						
Snowberry	>14	4,800–10,000	>20	xeric	cool-frigid to cryic	sandy to clay loams
Serviceberry	>14	5,000–8,500	>20	xeric	cool-frigid to cryic	loam
Shadscale	4–8	4,000–7,000	>20	dry-aridic	mesic-frigid	Aridisols (uplands)
Spiny hopsage	<8	2,000–5,500	>20	dry-aridic	mesic	Aridisols
Mormon tea	<10	3,000–7,500	>20	dry-aridic	mesic	sandy, gravely, rocky Aridisols

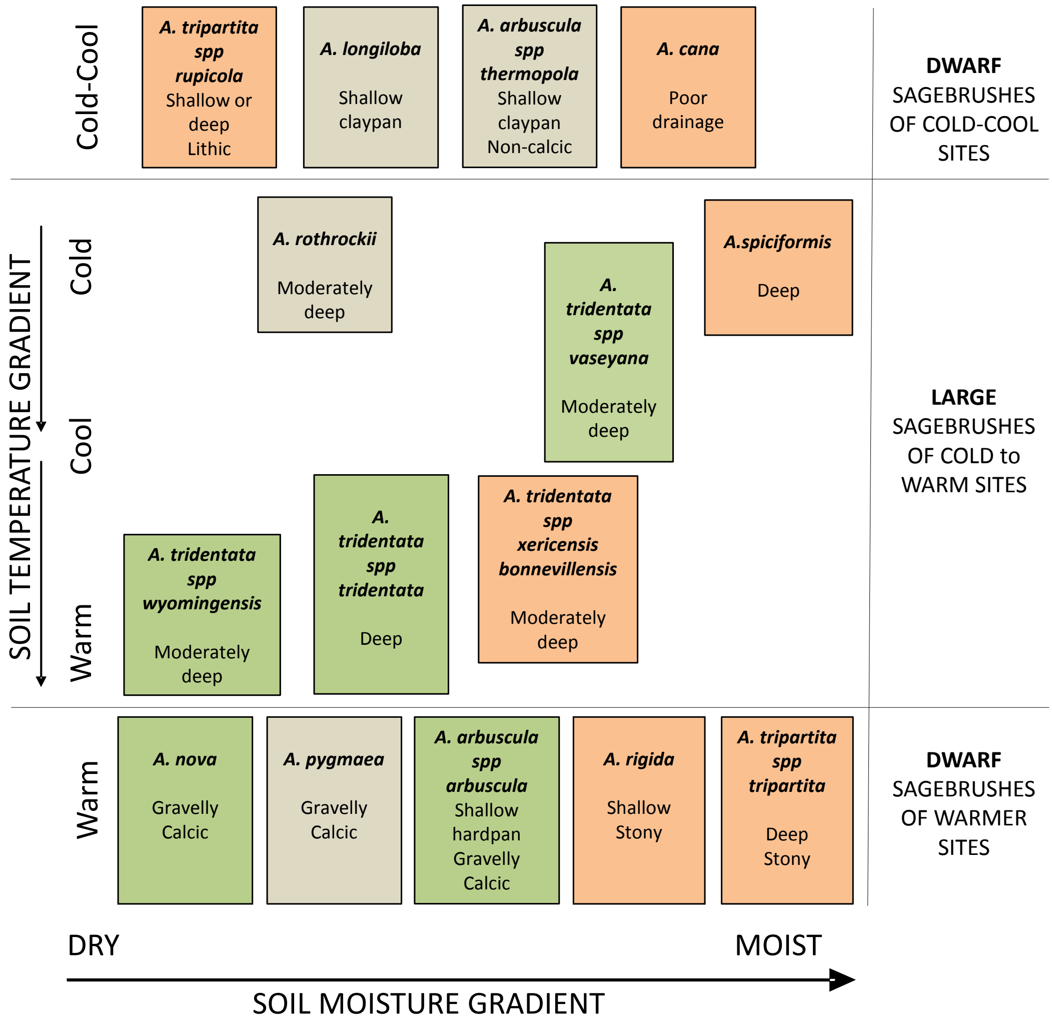


Figure 5. Major sagebrush taxa in the Great Basin and Columbia River Plateau positioned along gradients of soil temperature and soil moisture (adapted from Robertson and others 1966; McArthur 1983; West 1983; West and Young 2000; Rosentreter 2005; Schultz 2009, 2012). Key soil characteristics associated with each species are shown under the species name. Relative abundance of the sagebrush species and subspecies is color coded: grey = scarce, orange = common, and green = dominant.

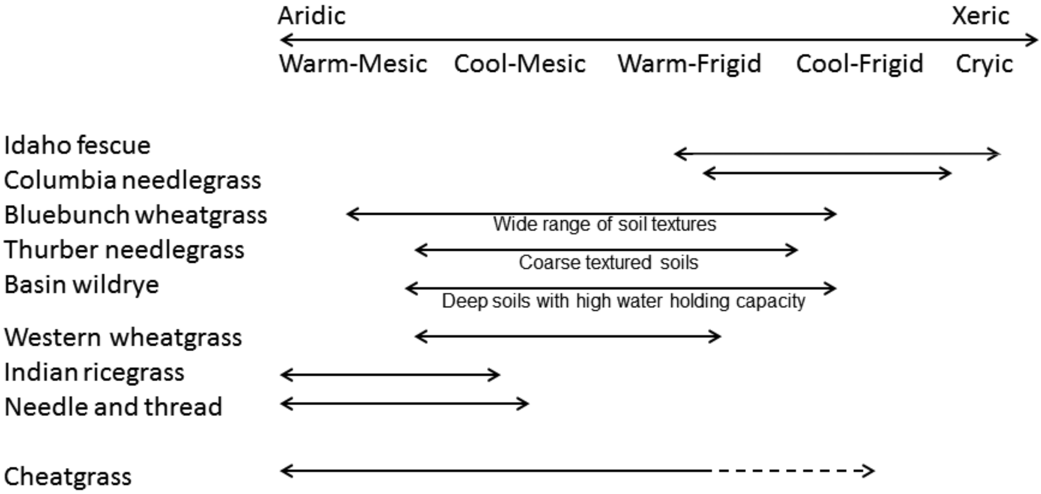


Figure 6. The general distribution of common, deep-rooted grasses and cheatgrass across a soil temperature/moisture gradient in the Great Basin and Columbia River Plateau.

Potential Vegetation

The potential vegetation of an ecological site, as described in an ESD, is a function of ecological site characteristics (climate, topography, and soils), attributes and processes (soil temperature/moisture regime, soil processes, and vegetation dynamics), and natural disturbance regimes (see fig. 3 and the reference state in ESD state and transition models (STMs) in Appendix 5). Most ESDs contain a detailed species list by life-form and the relative proportion of these species expected in the reference state (reference community phase). In the Great Basin and Columbia River Plateau regions, strong topographic gradients influence temperature and moisture, and are often reflected by changes in the dominant plant species and subspecies, such as sagebrush, which can be good indicators of soil temperature/moisture regimes (table 3).

1. What were the dominant shrub species or subspecies of sagebrush (fig. 5, table 3; see Shultz 2012)?
    a. Wyoming big sagebrush is most commonly found on moderately deep, mesic/aridic (warm/dry) soils but can occur on warm-frigid/aridic (cool/dry) soils (figs. 4 and 5).
    b. Mountain big sagebrush is most commonly found on moderately deep, frigid and cryic soils with xeric moisture regimes (cool/moist) (figs. 4 and 5).
    c. In zone where the big sagebrush subspecies come together, often near the threshold of mesic and frigid and/or aridic and xeric soil regimes, identification of subspecies can be difficult as a result of hybridization. Some

of these hybrid crosses have been separated out including Bonneville big sagebrush in Utah and xeric big sagebrush in Idaho, but in other areas they have not.

2. Some shrub species associated with sagebrush (usually present or co-dominant but not dominant) are also indictors of soil temperature/moisture regimes. For example, snowberry and serviceberry are common on cool-frigid and cryic (cool-cool and cold) soils with ≥14 inches ppt. In upland non-saline soils, shadscale and spiny hopsage often occur on mesic/dry-aridic (warm/dry) soils typically with <8 inches ppt (table 3).

3. What are the dominant perennial grass species on the ecological site?

   a. The perennial grass species that are potentially common or dominant in the reference state as described in the ESD (see Appendix 5 for examples and Appendix 8 for definition) for the ecological site are general indictors of moisture availability, temperature (fig. 6), and soil depth and texture.

   b. If Sandberg's bluegrass is the dominant grass, it can be an indicator of very shallow soils (< 10 inches) or, if on shallow to moderately deep soils (>10 inches), it can indicate improper grazing resulting in the loss of larger bunchgrasses. A high abundance of bottlebrush squirreltail is often an indicator of high severity and/or frequent disturbance. These two species increase resistance to invasive annual grasses on areas with shallow soils or where perennial native herbaceous species have been depleted.

2—Pre-Wildfire Vegetation

The composition and abundance of perennial vegetation that persists following wildfire is one of the primary drivers of both short- and long-term successional pathways. Post-wildfire vegetation is a function of pre-wildfire vegetation composition and structure, fire severity, post-wildfire herbivory, and weather.

Year-to-Year Invasive Annual Grass Variation

During a 20-year period on a mesic/aridic ecological site in Utah, annual grass cover varied from trace in dry years to 25 percent in wet years.

Pre-Wildfire Composition and Structure Known

1. What was the composition and structure (cover and/or density) of perennial native grasses and forbs, and invasive annual grasses just prior to the wildfire?

   a. Were the native perennials absent or severely depleted? In the severely depleted phase, perennial grasses were <2/m² (10 ft²) for xeric and <3/m² (10 ft²) for aridic sites; invasive annual grasses were dominant (in years with adequate winter/spring moisture), and/or woody species (shrubs or trees) were near maximum cover.

b. Were they co-dominant with invasive annual grasses? The area is at risk if perennial grass densities were <2/m^2 (10 ft^2) for xeric and <3/m^2 (10 ft^2) for aridic, and/or cover typically did not exceed 10 percent prior to the fire.

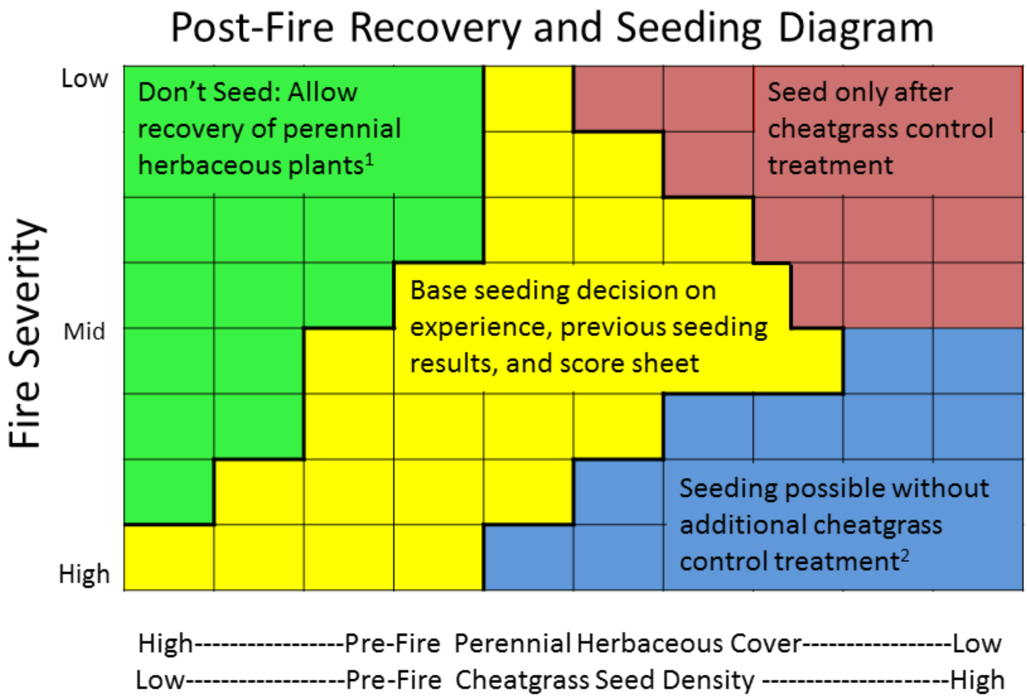
Perennial Grass Densities
A higher abundance of perennial grasses are required for recovery on sites with mesic/aridic regimes owing to low resilience and resistance.

c. Were perennial deep-rooted grasses and forbs dominant? If the area is not at risk, perennial deep-rooted grasses and forbs should be about >15 to 25 percent cover or greater, and invasive annual grasses should be <5 percent cover in years with adequate spring moisture.

d. What was the shrub canopy cover? Areas with >15 percent shrub canopy cover often burn hotter than areas with less cover or more open

Figure 7. Moderate to high severity fire (A) resulting in nearly 100% consumption of surface litter and seed. Low severity fire resulting in (B) residual litter and cheatgrass seed, and (C) intact medusahead litter.

canopies. Hotter fires typically consume the majority of invasive annual grass seed beneath the shrub canopies, which can substantially increase seeding success during favorable establishment years (figs. 7 and 8). Pre-fire sagebrush dominance can be estimated using readily available 1 m^2 aerial imagery (National Agricultural Imagery Program) with the assumption that the higher the density of sagebrush, the higher the fire severity.



[1] Reseeding with shrubs may be appropriate depending on rehabilitation objectives.

[2] It is assumed that high fire severity associated with increased sagebrush canopy cover (>15%) decreases cheatgrass seed density through consumption and mortality.

Figure 8. The relationships among pre-fire perennial herbaceous vegetation, wildfire severity and the post-fire cheatgrass seed bank, and seeding decisions. The red and green blocks represent two situations where a "don't seed' decision may be appropriate. The green blocks represent burned areas where sufficient perennial plants were present prior to the fire, fire severity was low to moderate, and pre-fire cheatgrass seed density was low or seeds were mostly consumed in the fire. In contrast, the red blocks represent areas where native perennials were severely depleted, cheatgrass was common to abundant, and cheatgrass seed mortality was limited as a result of low to moderate fire severity (sagebrush cover was less than 15%). The blue blocks represent areas where post-fire cheatgrass seed density is low as a result of high fire severity, and a 1-year window for seeding with minimal competition from cheatgrass typically occurs. The yellow blocks represent a less predictable vegetation response in the decision process that will require use of the score sheet to evaluate the areas resilience and resistance to annual invasives, information on past seeding results, and local experience.

Pre-Wildfire Composition and Structure Unknown

1. If the herbaceous composition prior to the wildfire is unknown, the following indicators can help approximate the abundance of perennial grasses and forbs prior to the wildfire.
    a. Based on the ecological site description, what perennial grasses would be present in the reference state?
    b. What is the potential for invasive annual grasses and other invaders to increase on the burned area based on ecological site characteristics (for example, soil temperature/moisture regime, elevation, and aspect), seed source (on or off site), and current and future disturbances, including livestock grazing? Is the potential for invasives low, moderate, or high? (If the ecological site is mesic to warm-frigid, resistance to invasive annual grasses will largely depend on the post-wildfire abundance of perennial grasses and forbs.)
    c. What is the density of germinable invasive annual grass seeds on the soil surface? Where shrub cover is relatively high (>15 percent) resulting in high fire intensity, the majority of cheatgrass seed under shrub canopies is usually consumed, decreasing cheatgrass competition and increasing seeding success given favorable first year conditions for establishment.
    d. What is the density of burned and unburned deep-rooted perennial grass crowns (see Appendix 4 for indicators of burn severity, which will influence mortality)?
    e. What is the density of shallow-rooted perennial grass crowns?
    f. Is the general disturbance and land use history known for the burned area (for example, local knowledge, utilization studies, and trend plots)?
        i. If not known, what would past grazing distribution and intensity likely have been based on topography, available water, and location of settlements (areas around towns and homesteads would have likely seen heavier grazing)?
            1. If historical grazing was likely improper and soil temperature/moisture regimes are mesic/dry-aridic, aridic, or xeric, native perennial grasses were likely severely depleted to absent, and annual grasses were likely dominant or co-dominant with native perennial grasses and forbs.
            2. If historical grazing was improper and the soil temperature/moisture regimes are frigid/xeric, native perennial grasses were likely depleted and invasive annual grasses were likely present but not dominant.

ii. What other types of disturbances or land uses have potentially impacted vegetation structure and composition (for example, off-highway vehicle use, and wild horse and burro use)?

g. If there are similar adjacent unburned areas or unburned islands within the fire perimeter, what is their plant composition? When comparing burned and unburned areas, it is necessary to ensure that the areas are the same or similar ecological sites. Be careful in extrapolating, as unburned areas may have contained different fuel loads as a result of differences in soils, disturbance history, and other factors.

2. What is the ability of plant species on the burned area to persist following wildfire?

a. How fire tolerant/persistent are the native species on the ecological site and how will this potentially influence post-wildfire composition?

i. Broadleaf grasses such as bluebunch wheatgrass are usually more fire tolerant than fine leaf grasses (e.g., Thurber needlegrass).

ii. Perennial grasses and forbs that are rhizomatous or have their crown buds below the soil surface are usually fire tolerant and quickly recover after fire.

b. What is the post-wildfire persistence of species of concern, and what is their potential for recovery?

i. The most common sagebrush species and subspecies are fire intolerant (*Artemisia tridentata* subspecies, *A. arbuscula,* and *A. nova*). Recovery depends on seedling establishment and is closely linked to ecological site characteristics, available seed source, pre-and post-wildfire weather, and subspecies of sagebrush.

> Fire persistence (tolerance or avoidance) of most herbaceous vegetation can often be determined from visible morphological traits (table 4). Persistence of shrubs depends on the ability to re-sprout (table 5), and new plant establishment depends on seed banks, external seed sources, and favorable years for germination and growth.

3. If piñon and/or juniper were present on the site, what was the woodland phase? Woodland phase affects understory composition in addition to fuel loads and structure, which affects fire severity.

a. Phase III woodlands can result in low perennial grass and forb cover unless soils are moderately deep to deep with minimal development of a restrictive layer (for example, argillic) that limits water infiltration through the soil profile.

b. Based on Appendix 4, what was the fire severity? Phase III woodlands usually burn at high severity resulting in high perennial grass and forb mortality.

Table 4. Examples of some common perennial forbs in the Great Basin and Columbia River Plateau Regions and their tolerance to fire as related to their growth form.

Tolerant (damage none to slight)	Intolerant (damage moderate to severe)
Buds below ground	**Buds above ground**
common yarrow (*Achillea millefolium*)	pussytoes (*Antennaria* spp)
mountain dandelion (*Agoseris* spp.)	sandwort (*Arenaria* spp.)
onion (*Allium* sp.)	matted buckwheat (*Eriogonum caespitosum*)
aster sp. (*Aster* sp.)	Douglas buckwheat (*Eriogonum douglasii*)
milkvetch sp. (*Astragalus* sp.)	parsnip buckwheat (*Eriogonum heracleoides*)
arrowleaf balsamroot (*Balsamorhiza* spp.)	slender buckwheat (*Eriogonum microthecum*)
mariposa lilly (*Calochortus* spp.)	rock buckwheat (*Eriogonum sphaerocephalum*)
hawksbeard (*Crepis* spp.)	sulfur-flower buckwheat (*Eriogonum umbellatum*)
fleabane (*Erigeron* spp.)	spiny phlox (*Phlox hoodii*)
sticky purple geranium (*Geranium viscosissimum*)	
old man's whiskers (*Geum triflorum*)	
biscutroot (*Lomatium* spp.)	
lupine sp. (*Lupinus* spp.)	
bluebells sp. (*Mertensia* spp.)	
woolly groundsel (*Pakera cana*)	
penstemon spp. (*Penstemon* spp.)	
longleaf phlox (*Phlox longifolia*)	
lambstongue ragwort (*Senecio integerrimus*)	
largehead clover (*Trifolium macrocarpum*)	
death camus spp. (*Zigadenus* spp.)	
mules ear (*Wyethia amplexicaulis*)	

Derived from Blaisdell 1953; Pechanec and others 1954; Mueggler and Blaisdell 1958; Lyon and Stickney 1976; Klebenow and Beall 1977; Wright and others 1979; Volland and Dell 1981; Bradley and others 1992; Pyle and Crawford 1996; Riegel and others 2006; USDA-Forest Service 2013.

3—Wildfire Severity

Fire severity is a function of fuel characteristics, weather, and topography.

Assessing Wildfire Severity

1. Was severity (Appendix 8) of the wildfire low, moderate, or high? Fire severity can be estimated after the wildfire by evaluating the percentage and types of aboveground organic matter consumed (Appendix 4) or using remote sensing models that portray burn severity across the entire burn (http://www.fs.fed.us/eng/rsac/baer/).
2. What is the size and distribution of unburned patches? What is the distribution of low, moderate, and high severity burned areas?

Table 5. Potential response of common shrubs to fire in the Great Basin and Columbia River Plateau Regions.

Tolerant	Moderately tolerant	Intolerant
	Sagebrush Steppe	
silver sagebrush (*Artemisia cana*) (s)	rubber rabbitbrush (*Ericameria nauseosus*) (s)	low sagebrush (*Artemisia cana*) (ns)
snowfield sagebrush (*Artemisia spiciformis*) (s)	three-tip sagebrush (*Artemisia tripartita*) (ws)	black sagebrush (*Artemisia nova*) (ns)
aspen (*Populus tremuloides*) (s)		big sagebrush (*Artemisia tridentata*) (ns)
green rabbitbrush (*Chrysothamnus viscidiflorus*) (s)		curl-leaf mountain mahogany (*Cercocarpus ledifolius*) (ws)
wax current (*Ribes cereum*) (s)		antelope bitterbrush (*Purshia tridentata* var. *tridentata*) (ws)
desert gooseberry (*Ribes velutinum*) (s)		Mexican cliffrose (*Purshia mexicana*) (ws)
Woods' rose (*Rosa woodsii*) (s)		broom snakeweed (*Guiterrezia sarothrae*) (ws)
mountain snowberry (*Symphoricarpos oreophilus*) (s)		
horsebrush sp (*Tetradymia* sp.) (s)		
serviceberry (*Amelanchier alnifolia*) (s)		
Stansbury cliffrose (*Purshia stansburiana*) (s)		
desert bitterbrush (*Purshia tridentata* var. *glandulosa*) (s)		
Nevada Mormon tea (*Ephedera nevadensis*) (s)		
	Desert shrub	
greasewood (*Sarcobatus velutinus*) (s)		spiny hopsage (Grayia spinosa) (ws)
Torrey's saltbush (*Atriplex torreyii*) (s)		bud sagebrush (*Picrothamnus desertorum*) (ns)
Gardner's saltbush (*Atriplex gardnerii*) (s)		shadscale (*Atriplex confertifolia*) (ns)
		fourwing saltbush (*Atriplex canescens*) (ws)
		winterfat (*Krascheninnikovia lanata*) (ws)

S = sprouter; ws = weak sprouter; ns = non-sprouter. Derived from Blaisdell 1953; Mueggler and Blaisdell 1958; Nord 1965; Wright 1972; Wright and others 1979; West 1994.

3. What were the weather conditions during the wildfire?
4. What were the fuel loads, if known?
   a. What was the general structure of the vegetation: grassland; open shrub-grassland; shrub-grassland; dense shrubland; or phase I, II, or III woodland?

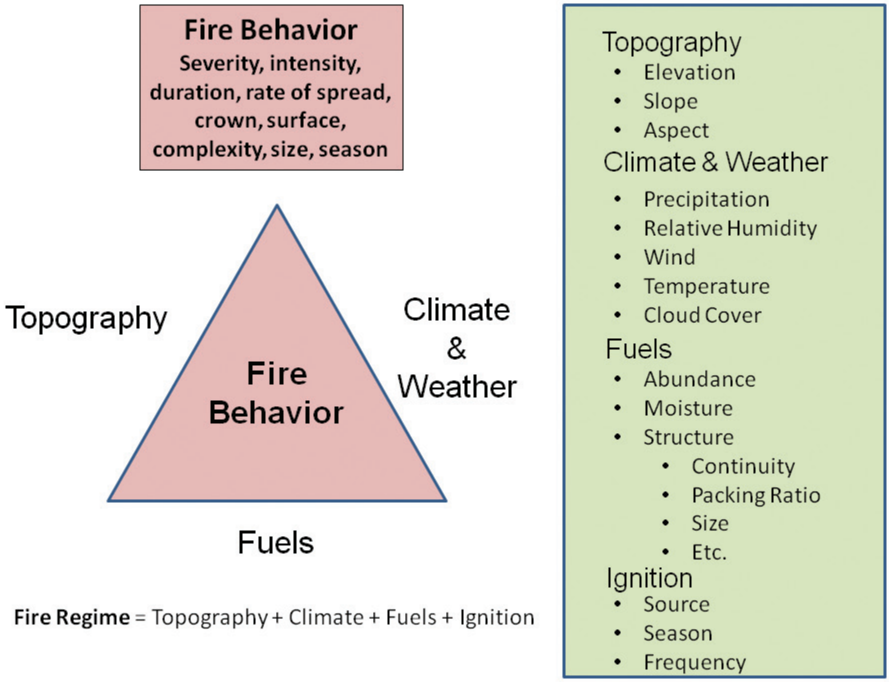


Figure 9. Fire behavior, including intensity, duration, and rate of spread, are determined by three components: topography, climate and weather, and fuels. The specific traits of each of these components influence fire behavior and are closely related to fire severity.

i. Wildfire severity in shrub grassland is most commonly low to moderate.

b. Were the surface fuels adequate to carry a wildfire across a shrubland community or woodland?

i. If shrub cover was relatively high (>15 percent), and invasive annual grasses were present, a large portion of the invasive annual grass seed bank is typically consumed, resulting in low abundance in the first post-wildfire year (see section 2. 1d).

As resilience to disturbance(s) and resistance to invasive annual grasses and other invasives decrease, fire severity becomes of greater concern because it can cause irreversible damage.

c. If juniper and/or piñon occupy the area, what is the woodland phase (I, II, or III)? Fuel structure in late phase II and especially phase III requires severe weather conditions (low humidity, high temperatures, and wind) to carry fire due to lack of horizontal fuel continuity resulting from limited surface fuels. The combination of extreme weather conditions and heavy fuels typically results in high severity fires.

i. High fire severity in phase III woodlands can result in >80 percent mortality of perennial grasses and forbs.

ii. Low to moderate fire severity usually results in <20 percent mortality of perennial grasses and forbs.

4—Post-Wildfire Weather

Post-wildfire weather conditions can influence future seed production, seedling establishment, and recovery of plants that survive the wildfire (both native and invasive species). Consequently, weather can influence the type of post-wildfire management actions, including length of deferment from grazing or closure of wildfire areas to off-road vehicles.

1. How will post-wildfire weather influence successional pathways, and will additional actions or multiple interventions potentially be needed (for example, invasive annual grass control, seeding or reseeding, or transplanting sagebrush)?
   a. Seed banks of perennial native species are often low, and seedling establishment usually only occurs during wet springs, especially on warm/dry ecological sites.
   b. Favorable weather conditions can increase establishment, productivity, and seed-crops of both desirable and undesirable plant species.
   c. Recovery of perennial herbaceous vegetation in the first 1 to 2 years is typically dependent on vegetation that survived the wildfire.
   d. Recovery of sagebrush is highly dependent upon nearby seed sources and seed in the post-fire seed bank. Successful establishment is dependent on favorable post-fire weather and limited competition from invasive annual grasses.
2. What is the potential for wind or water erosion in the first 1 to 2 years post wildfire?

Drought conditions may simply delay recovery or redirect successional pathways.

5—Post-Wildfire Grazing

1. Assuming proper livestock grazing management, how long should the burned area be deferred from grazing? The deferment period may vary across ecological sites in the area burned and, if so, the ecological site that is most sensitive to grazing impacts should dictate the deferment period. Vegetation present prior to the wildfire, wildfire severity, and if the burned area was reseeded also can influence length of the deferment period.
    a. Deferring grazing during the active growth period for the first 2 years is probably adequate only for ecological sites where:
        - Fire severity was low to moderate
        - Post-wildfire erosion is minimal
        - Resilience and resistance to invasive annual grasses is high
        - Pre-wildfire herbaceous vegetation was dominated by natives, and invasive annual grasses were only a minor component
        - Post-wildfire monitoring indicates adequate recovery of shrubs, perennial grasses, and forbs or that seeding objectives have been met

> The amount of time for post-wildfire grazing deferment that is necessary for recovery is largely determined by wildfire severity, ecological site characteristics, pre-wildfire plant composition and structure, and post-wildfire weather.

    b. Deferring grazing during the active growth period for the first 2 years is probably inadequate where any of following apply:
        - Wildfire severity was high, resulting in high mortality of deep-rooted perennial grasses
        - Resilience to wildfire and resistance to invasive annual grasses are moderate to low
        - Invasive annual grasses were co-dominant or dominant
        - Post-wildfire monitoring indicates low or slow recovery of perennial grasses and forbs or that seeding objectives have not been met

> The lack of adequate deferment or proper long-term grazing management can have a dramatic effect on the resilience and resistance of the burned area (fig. 10).

2. What is the post-wildfire level of control of grazing in terms of duration, stocking rates, distribution, and season of use? Appropriate grazing management after the post-fire livestock deferment period is necessary to maintain the recovered or seeded plant community.
3. What are the potential impacts of recreational use, wild horses and burros, and wildlife (for example, elk use in treated areas with increased grass abundance)?

Figure 10. Comparison of adjacent (**A**) exclosed and (**B**) grazed areas that were treated with prescribed fire 7 years before the photos were taken. The ecological site is a cool-mesic/aridic bordering on xeric Wyoming big sagebrush/Thurber's needlegrass type. The site is in Nevada at an elevation of 7,500 to 7,800 ft and was grazed prior to treatment. Fencing was installed after the fire. Inappropriate grazing resulted in loss and/or limited recovery of deep-rooted perennial grasses and the dominance of non-native invasives, as shown in photo B (photographs by Robin Tausch).

6—Monitoring and Adaptive Management

A monitoring plan should be implemented to direct adaptive management and provide information for future recovery plans or vegetation treatments.

1. Do the monitoring protocols measure the project objectives? See USGS publication "Monitoring Post-Fire Vegetation Rehabilitation Projects: A Common Approach for Non-Forested Ecosystems" (http://pubs.usgs.gov/sir/2006/5048/).
2. Are the monitoring methods consistent with those being used elsewhere?
3. Is a plan in place for data entry and analyses that is consistent across the agency(s) (for example, the Land Treatment Digital Library (http://ltdl.wr.usgs.gov/)?
4. Is there a mechanism for summarizing the results and incorporating the relevant information into the planning process?
5. Is there a mechanism to share monitoring results with others implementing similar treatments on similar sites? The Joint Fire Science Program's Great Basin Fire Science Exchange can assist with this effort (http://www.gbfiresci.org).

Monitoring provides essential information on post-wildfire outcomes that can be used to adjust future prescriptions and to determine if post-treatment actions are needed.

Post-Wildfire Vegetation Treatment Assessment

State and Transition Models

State and transition models (STMs) can be used to illustrate potential successional pathways that result from wildfire and follow-up vegetation treatment scenarios. Appendix 5 provides STMs that represent five generalized ecological types for big sagebrush in the Great Basin and Columbia River Plateau regions. For many areas, specific ESDs and STMs are available (see: http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/ecoscience/desc/).

Identification of the specific or generalized big sagebrush ecological sites and knowing (or estimating) the pre-wildfire vegetation composition and structure will help to determine the need and suitability of the area for seeding (Appendix 6) and the plant species that should be considered for the seed mix. ESDs also provide information related to relative resilience and resistance to invasive annual grasses and the associated STMs provide information on potential successional pathways.

Land Unit Evaluation Score Sheet

Appendix 7 provides a score sheet that can be used to quickly evaluate the level of ecological site resilience to disturbance and resistance to invasive annual grasses, and to determine the suitability of the area for seeding and the need for seeding. It is based on four components: (1) soil temperature regime, (2) soil moisture regime, (3) pre-wildfire plant composition, and (4) fire severity. Site characteristic scores, which evaluate soil temperature and moisture regimes, estimate the suitability of the area for seeding. Pre-wildfire vegetation and fire severity determine the need for seeding. Each major ecological site (or group of similar ecological sites) within the proposed burned area is evaluated with a separate score sheet. Scores are not absolute and should be used only 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 sites.

Seeding: Suitability and Need

Ecological criteria used to determine whether or not to seed are: (1) ecological site characteristics that strongly contribute to the degree of success (seeding success increases with resilience), (2) the ecological site's resistance to invasive annual grasses, (3) the composition and abundance of native perennial grasses and forbs that likely survived the wildfire, and (4) the pre-wildfire abundance of invasive annual grasses and post-fire seed bank survival.

Ecological Site Characteristics

The level and probability of successful seeding will vary across ecological sites. Success of seeding natives on ecological sites with mesic/aridic (warm/dry) (<10 inches ppt) soil temperature/moisture regimes is very low (accumulative soil temperature and moisture score ≤10) (fig. 11). Using introduced wheatgrasses or a half-shrub such as forage kochia (*Kochia scoparia*) may increase seeding success on these sites, but may not meet resource objectives. Seeding species such as crested wheatgrass and forage kochia can reduce the threat of fire and competition from invasive annual grasses. Seeding success on cool-mesic/aridic ecological sites (10 to 12 inches ppt) is usually mixed and is highly dependent on annual moisture in the first 2 to 3 post-fire years (cumulative soil temperature and moisture score = 12 to 15) (fig. 12) and the methods used to apply the seed (for example, drilling vs aerial or broadcast seeding). Seeding success on frigid/xeric (cool/moist) ecological sites (cumulative soil temperature and moisture score = 14 to 17) is typically high. Environmental factors such as precipitation timing and amount, *which cannot be controlled or predicted*, can affect seeding success even on cool-mesic/aridic and frigid/xeric ecological sites. Drill seeding is much more effective than aerial or broadcast seeding (without a follow-up coverage treatment), especially on mesic/aridic soil temperature/moisture regimes where establishment success is very low.

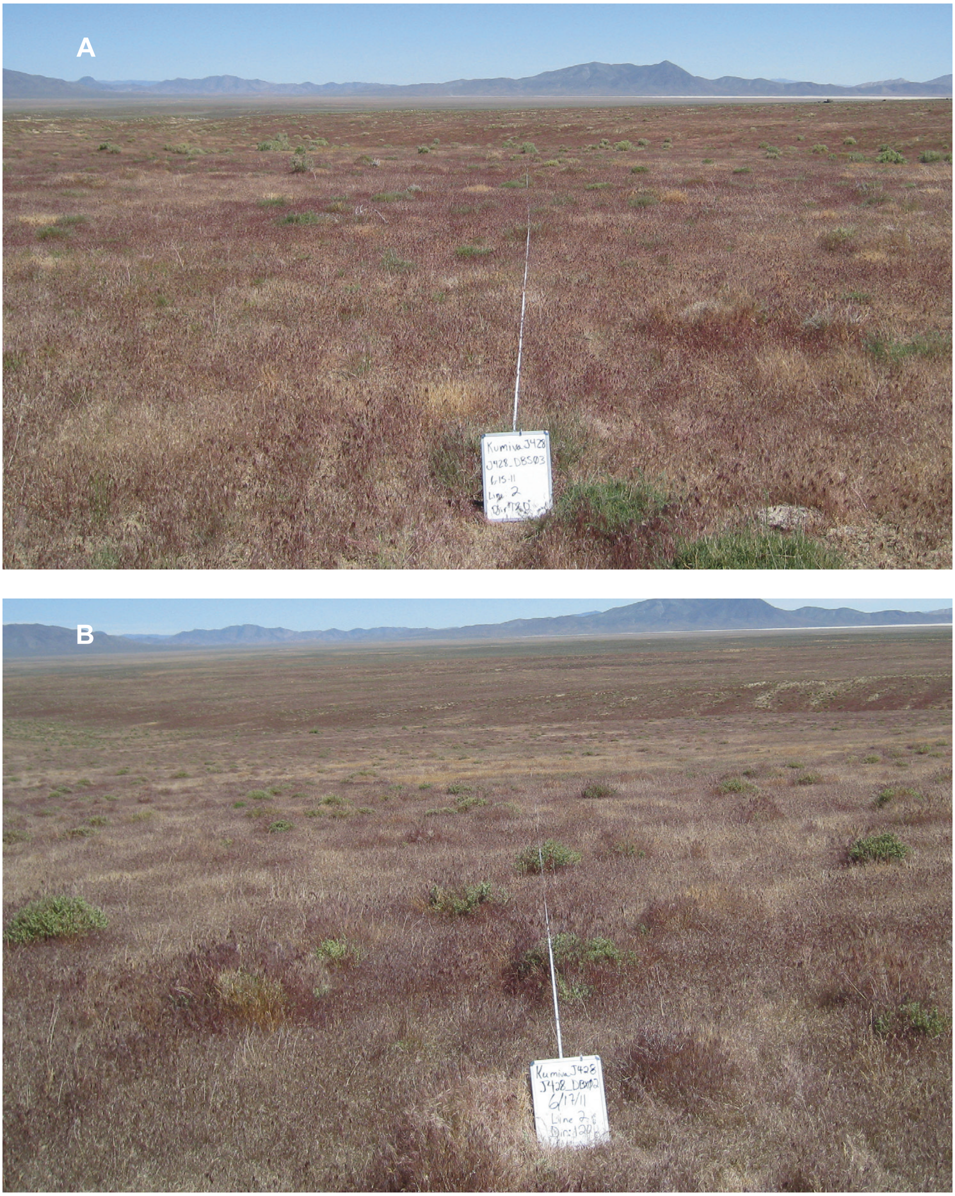


Figure 11. Post-wildfire response for adjacent (**A**) seeded and (**B**) unseeded areas that burned 9 years earlier in 2002. The ecological site is a warm-mesic/dry-aridic Wyoming big sagebrush/Indian ricegrass-Sandberg bluegrass type located at an elevation of 5,000 ft southeast of Gerlach, Nevada. Native herbaceous vegetation prior to the burn was probably severely depleted to absent and the presence of a sagebrush canopy was unknown. Based on the score card (Appendix 7), the soil temperature + moisture score is 9, and the total score is 9 to 12 depending on pre-fire vegetation. Limited moisture and warm temperature result in low suitability for seeding and resilience to disturbance. The treated area (A) was drill seeded in the fall following the fire to native grasses and (B) was not seeded. Cover in the seeded area (A) is 0% deep rooted perennial grasses, 89% cheatgrass, 6.7% native shrub, and 0% non-native shrub. Cover in the unseeded area (B) is 0% native deep-rooted perennial grasses, 61% cheatgrass, 3.3% native shrub, and 6% non-native shrub.

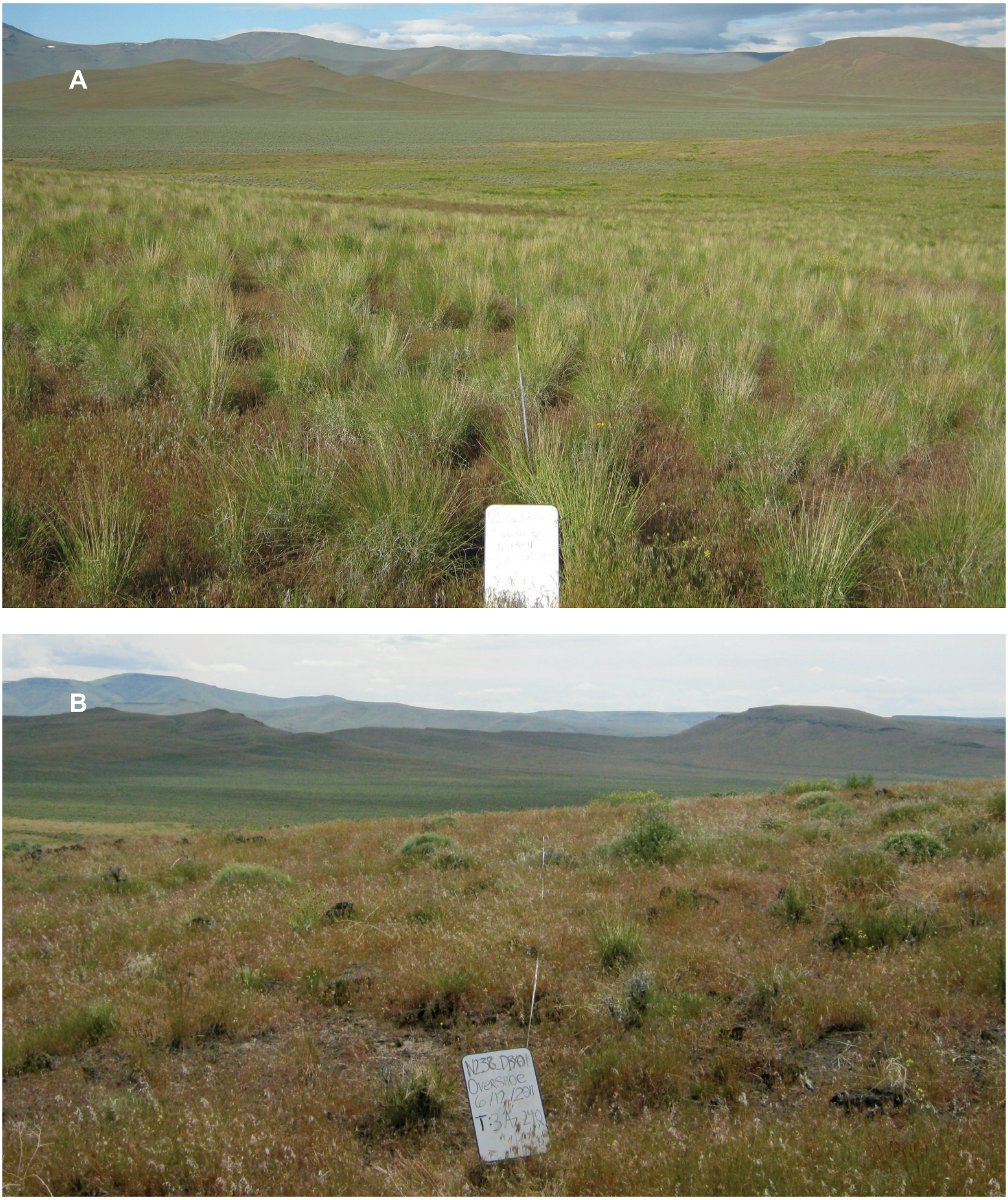


Figure 12. Post-wildfire response for adjacent (**A**) seeded and (**B**) unseeded areas that burned 9 years earlier. The ecological site is a cool-mesic/aridic Wyoming big sagebrush/bluebunch (10 to 12 inch PZ) type located south of Rome, Oregon, at an elevation of 5,000 ft. Native herbaceous vegetation prior to the burn was probably severely depleted to absent, and the presence of a sagebrush canopy was unknown. Based on the score card (Appendix 7), the soil temperature + moisture score is 12, and the total score is 12 to 15 depending on pre-fire vegetation. The treated area (A) was drill seeded in the fall following the fire to native grasses. Cover in the seeded area (A) is 23% native deep-rooted perennial species and 65% cheatgrass; cover in the unseeded area (B) is 7% native deep-rooted perennial and 69% cheatgrass.

Need

Seeding should be considered on burned areas where perennial herbaceous species were severely depleted to absent; cheatgrass seed bank is low; or fire severity was high, resulting in high mortality of perennial herbaceous species, and where ecological site characteristics are suitable for success (cumulative soil temperature and moisture usually scores $\geq$10). However, for areas with scores between 10 and 15 that have sufficient perennial herbaceous species to recover following wildfire, seeding with introduced species or aggressive cultivars will likely retard or prevent recovery of the native community. Considerations for evaluating the need to seed (fig. 8) are:

1. Seeding of herbaceous vegetation should not be considered for areas in the burn where perennial grasses and forbs were common in the area prior to the wildfire and fire severity was low to moderate. Recovery may occur in high severity burn areas but the degree of recovery is lower than in the moderate to low categories.
2. Seeding may not be necessary on low to moderate severity burned areas where native herbaceous perennial grasses are depleted but are likely $>2/m^2$ (10 ft^2) on frigid-xeric and $>3/m^2$ (10 ft^2) on mid to cool mesic/aridic (10 to 12 inches ppt). However, if invasive annual grasses have the potential to substantially increase on areas with mid- to cool-mesic soil temperatures and >10 inches ppt, and native perennial grasses are depleted ($<3/m^2$ [10 ft^2]), seeding should be a strong consideration.
3. If native herbaceous perennial grasses are severely depleted, ($<2/m^2$ [10 ft^2] on frigid/xeric and $<3/m^2$ (10 ft^2) on mid to cool-mesic/aridic temperature/moisture regimes) and/or fire severity was high, seeding should be considered.
4. If native perennial grasses are severely depleted ($<3/m^2$ [10 ft^2]) on warm- to mid-mesic/aridic or mesic/xeric (<10 inches ppt) regimes, establishment success of native seed will likely be low. Seeding may still be a consideration in areas of conservation concern, but more than one intervention may be required.
    a. The potential for rapid reintroduction of invasive annual grasses on severely depleted burned areas will depend on the ecological site's resistance to invasive annual grasses, seed source available following the wildfire, and post-wildfire moisture availability.
    b. Most invasive annual grass seed under shrub canopies is consumed by wildfire on areas with >15 percent shrub cover, often resulting in low plant abundance in the first post-wildfire growing season. However, increased soil resources result in high growth and reproduction of invasive

annual grasses, leading to a large increase in abundance the second or third year after wildfire.

   c. Areas that are dominated by sagebrush with cheatgrass in the understory often provide a 1-year window opportunity to seed due to the higher intensity fires resulting in the consumption of cheatgrass seed.

5. Seeding big sagebrush?

   a. Seeding Wyoming big sagebrush on areas with mid- to cool-mesic soils and >10 inches ppt should also be a consideration. However, seeding success is often very low when seed is broadcast or applied with a rangeland drill. Seeding methods that result in a firm seedbed, such as a Truax Roughrider® drill with cultipacker wheels, can result in increased establishment of sagebrush. Planting seedlings or distributing straw mulch over the sagebrush seed is costly but may be a consideration in areas of conservation concern.

   b. Sagebrush cover in burned areas previously occupied by mountain big sagebrush usually recovers to pre-wildfire conditions within 25 to 35 years in the absence of seeding. Seeding or transplanting mountain big sagebrush may be a consideration to increase the rate of recovery or connectivity in areas of conservation concern.

   c. Post-fire establishment of basin big sagebrush is usually faster than Wyoming big sagebrush but slower than mountain big sagebrush. Seeding decisions should be based on local experience.

6. Recovery of low sagebrush (*Artemisia arbuscula*) on shallow claypan soils, where Sandberg's bluegrass is the potential dominant herbaceous species is typically very slow.

7. Recovery of black sagebrush, which typically grows on shallow mesic/aridic soils, is usually very slow.

8. Success of seeding native shrubs and herbaceous species on warm- to mid-mesic soils with <10 inches of precipitation is low.

Recovery of big sagebrush is largely determined by ecological site characteristics, subspecies, competition from invasive annual grasses, post-wildfire weather conditions, and size and complexity of the wildfire, which effects distance to seed source and seed pools present immediately after the wildfire.

When seeding is not likely to meet the objectives of increasing or restoring resilience to disturbance and resistance to invasive annual grasses following treatment, a logical decision is “not to treat.” Exceptions may include:

1. Critical habitat where sufficient funds exist for repeated interventions and integrated strategies can be used such as prescribed-fire treatments followed by control of invasive annual grasses and revegetation.
2. Critical portions of a watershed where treatment is necessary to prevent erosion or introduction of an invasive annual grass seed-source. Also, areas where integrated strategies can be used such as prescribed-fire treatments followed by control of invasive annual grasses and revegetation.

Selecting Areas Within the Burn for Seeding

What, where, and how much area to seed across a burn area is usually determined by priorities, need, potential for success, and available resources, including funding and availability of seed adapted to the area. Questions to address when selecting areas to be treated include:

1. What are the chances of seeding success based on the area's resilience to disturbance and resistance to invasive annual grasses, which are closely linked to ecological site characteristics?
2. What is the need for seeding based on plant community composition and structure prior to the wildfire and fire severity?
3. Does the area provide important habitat for animal and/or plant species of concern?
4. Can reseeding increase the landscape connectivity for species of concern?
5. Are portions of the burn major sources of sediment to nearby streams, or do they have high erosion potential?
6. What is the treatment cost?
7. What seeding methods can be used based on steepness of slope, rockiness, etc.
8. Is retreatment likely to be needed and, if so, is it an option?
9. Can post-treatment management be modified to attain 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 resume grazing has been made?

Key References

Chambers, J.C.; Bradley, B.A.; Brown, C.S.; D'Antonio, C.; Germino, M.J.; Grace, J.B.; Hardegree, S.P.; Miller, R.F.; Pyke, D.A. 2014a. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. Ecosystems. 17: 360–376.

Miller, R.F.; Bates, J.D.; Svejcar, T.J.; Pierson, F.B.; Eddleman, L.E. 2005. Biology, ecology, and management of western juniper (*Juniperus occidentalis*). Tech. Bull. 152. Corvallis, OR: Oregon State University Agricultural Experiment Station. 77 p.

Miller, R.F.; Bates, J.D.; Svejcar, T.J.; Pierson, F.B.; Eddleman, L.E. 2007. Western juniper field guide: asking the right questions to select appropriate management actions. Circular 1321. Reston, VA: U.S. Department of the Interior, Geological Survey. 59 p.

Miller, R.F.; Knick, S.T.; Pyke, D.A.; Meinke, C.W.; Hanser, S.E.; Wisdom, M.J.; Hild, A.L. 2011. Characteristics of sagebrush habitats and limitations to long-term conservation. In: Knick, S.T.; Connelly, J.W., eds. Greater sage-grouse: ecology and conservation of a landscape species and its habitats. Studies in Avian Biology. Berkley, CA: University California Press: 38: 146–184.

Parson, A.; Robichaud, P.R.; Lewis, S.A.; Napper, C.; Clark, J.T. 2010. Field guide for mapping post-fire soil burn severity. Gen. Tech. Rep. RMRS-GTR-243. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 49 p.

Pyke, D.A. 2011. Restoring and rehabilitating sagebrush habitats. In: Knick, S.T.; Connelly, J.W., eds. Greater sage-grouse: ecology and conservation of a landscape species and its habitats. Studies in Avian Biology. Berkeley, CA: University of California Press. 38: 531–548.

Shultz, L.M. 2012. Pocket guide to sagebrush. Petaluma, CA: Point Blue Conservation Science. 85 p.

Tausch, R.J.; Miller, R.F.; Roundy, B.A.; Chambers, J.C. 2009. Piñon and juniper field guide: asking the right questions to select appropriate management actions. Circular 1335. Reston, VA: US. Department of the Interior, U.S. Geological Survey. http://pubs.usgs.gov/circ/1335/. (April 13, 2015).

Literature Cited

Blaisdell, J.P. 1953. Ecological effects of planned burning of sagebrush-grass range on the upper Snake River Plains. Tech. Bull. 1075. Washington, DC: U.S. Department of Agriculture. 39 p.

Bradley, A.F.; Noste, N.V.; Fischer, W.C. 1992. Fire ecology of forests and woodlands in Utah. Gen. Tech. Rep. INT-GTR-287. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 128 p.

Chambers, J.C.; Bradley, B.A.; Brown, C.S.; D'Antonio, C.; Germino, M.J.; Grace, J.B.; Hardegree, S.P.; Miller, R.F.; Pyke, D.A. 2014a. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of Western North America. Ecosystems. 17: 360–376.

Chambers, J.C.; Miller, R.F.; Board, D.I.; Grace, J.B.; Pyke, D.A.; Roundy, B.A.; Schupp, E.W.; Tausch, R.J. 2014b. Resilience and resistance of sagebrush ecosystems: implications for state and transition models and management treatments. Rangeland Ecology and Management. 67(5): 440–454.

Klebenow, D.A.; Beall, R.C. 1977. Fire impacts on birds and mammals on Great Basin rangelands. In: Proceedings of the 1977 Rangeland Management and Fire Symposium. Missoula, MT: University of Montana Press: 59–62.

Lyon, L.F.; Stickney, P.F. 1976. Early vegetal succession following large northern Rocky Mountain wildfires. In: Proceedings, Tall Timbers Fire Ecology Conference No. 14. Tallahassee, FL: Tall Timbers Research Station: 355–375.

Mahalovich, M.F.; McArthur, D.E. 2004. Sagebrush (*Artemisia* spp.): seed and plant transfer guidelines. Native Plants. Fall: 141–148.

McArthur, E.D. 1983. Taxonomy, origin, and distribution of big sagebrush (*Artemisia tridentata*) and allies (subgenus Tridentatae). In: Johnson, R.L., ed. First Utah Shrub Ecology workshop. Logan, UT: Utah State University, College of Natural Resources: 3–11.

Miller, R.F.; Chambers, J.C.; Pyke, D.A.; Pierson, F.B.; Williams, C.J. 2013. A review of fire effects on vegetation and soils in the Great Basin Region: response and ecological site characteristics. Gen. Tech. Rep. RMRS-GTR 308. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 169 p.

Monsen, S.; Stevens, R.; Shaw, N. 2004. Restoring western ranges and wildlands. Vols. I, II, III. RMRS-GTR-136. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 884 p. + appendices and index.

Mueggler, W.F.; Blaisdell, J.P. 1958. Effects on associate species of burning, rotobeating, spraying, and railing sagebrush. Journal of Range Management. 11: 61–66.

Nord, E.C. 1965. Autecology of bitterbrush in California. Ecological Monographs. 35: 307–334.

Parson, A.; Robichaud, P.R.; Lewis, S.A.; Napper, C.; Clark, J.T. 2010. Field guide for mapping post-fire soil burn severity. RMRS-GTR-243. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 49 p.

Pechanec, J.F.; Stewart, G. 1954. Sagebrush burning good and bad. Farmers' Bulletin 1948. Washington, DC: U.S. Department of Agriculture. 32 p.

Pyke, D.A.; and others. [In preparation]. Field guide for restoration of sagebrush-steppe ecosystems with special emphasis on greater sage-grouse habitats. Reston, VA: U.S. Geological Survey.

Pyle, W.H.; Crawford, J.A. 1996. Availability of foods of sage grouse chicks following prescribed fire in sagebrush-bitterbrush. Journal of Range Management. 49: 320–324.

Riegel, G.M.; Miller, R.F.; Smith, S.E.; Skinner, C. 2006. The history and ecology of fire in northeastern Plateaus bioregion. In: Sugihara, N.G.; Borchert, M.; van Wagtendonk, J.W.; Shaffer, K.E.; Fites-Kaufmann, J.; Thode, A.E., eds. Fire in California ecosystems. Berkeley, CA: University California Press: 225–263.

Robertson, D.R.; Nielsen, J.L.; Bare, N.H. 1966. Vegetation and soils of alkali sagebrush and adjacent big sagebrush ranges in North Park, Colorado. Journal of Range Management. 19: 17–20.

Rosentreter, R. 2005. Sagebrush identification, ecology, and palatability relative to sage-grouse. In: Shaw, N.L.; Pellant, M.; Monsen, S.B., comps. Sage-grouse habitat restoration symposium. Proc RMRS-P-38. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 3–15.

Shultz, L.M. 2009. Monograph of *Artemisia* subgenus *tridentata* (Asteraceae-Anthemideae). Systematic Botany Monographs. 89: 131.

Shultz, L.M. 2012. Pocket guide to sagebrush. Petaluma, CA: Point Blue Conservation Science. 85 p.

Stringham, T.K.; Novak-Echenique, P.; Blackburn, P.W.; Coombs, C.; Synder, D.; Wartgow, A. 2015. USDA ecological site description state-and transition models major land resource area 28A and 28B Nevada. Final Report Agreement No. 58-5370-211. 1524 p.

U.S. Department of Agriculture, Forest Service [USDA FS]. 2013. Fire effects information system. http://www.fs.fed.us/database/feis/plants/index.html. (April 13, 2015).

U.S. Department of Agriculture, Natural Resources Conservation Service [USDA-NRCS]. 1999. Soil taxonomy: a basic system of soil classification for making and interpreting soil surveys. Agric. Handb. 436. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_051232.pdf. (April 13, 2015).

U.S. Department of Agriculture, Natural Resources Conservation Service [USDA-NRCS]. 2011. Major land resource regions custom report. Agric. Handb. 296 p. http://apps.cei.psu.edu/mlra/. (April 13, 2015).

U.S. Department of Agriculture, Natural Resources Conservation Service [USDA-NRCS]. Big sagebrush: plant guide. Plant Fact Sheet/Guide: 1–12. https://plants.usda.gov/plantguide/pdf/pg_artr2.pdf. (April 13, 2015).

Volland, L.A.; Dell, J.D. 1981. Fire effects on Pacific Northwest forest and range vegetation. Range Management and Aviation and Fire Report 6. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 23 p.

West, N.E. 1983. Western Intermountain sagebrush steppe. In: West, N.E., ed. Temperate deserts and semi-deserts. Amsterdam, the Netherlands: Elsevier Publishing Company: 351–374.

West, N.E. 1994. Effects of fire on salt-desert shrub rangelands. In: Monsen, S.B.; Kitchen, S.G., eds. Proceedings—Ecology and management of annual rangelands. INT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 71–74.

West, N.E.; Young, J.A. 2000. Intermountain valleys and lower mountain slopes. In: Barbour, M.G.; Billings, W.D., eds. North American terrestrial vegetation. Second edition. Cambridge, UK: Cambridge University Press: 255–284.

Wright, H.A. 1972. Shrub response to fire. In: McKell, C.M.; Blaisdell, J.P.; Goodin, J.R., eds. Wildland shrubs—their biology and utilization. INT-GTR-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 204–217.

Wright, H.A.; Neunshwander, L.F.; Britton, C.M. 1979. The role and use of fire in sagebrush and pinyon-juniper communities. Gen. Tech. Rep. INT-GTR-58. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 48 p.

Appendix 1: Primary Components and Attributes That Influence Resilience to Disturbance, Resistance to Invasive Annual Grasses, and Successional Trajectories.

Component	Characteristics
Ecological site (figs.1, 2, and 3)	Regional location (MLRA) Climate Topography Elevation, aspect, slope, landform, and landscape position (*consider how topography affects water movement and storage, and heat loads*) Soils Soil temperature/moisture regimes Depth, texture, percentage of organic matter, and structure (*consider factors that influence water storage and availability*) Potential vegetation within the reference state Species composition and structure (biomass, cover, density, etc.) Potential production in favorable, average, and unfavorable years
Current vegetation	Vegetation productivity (annual production) Species composition and structure relative to the ecological site description Fire-tolerant and non-tolerant species (morphology) Native and invasive species Residual perennial herbaceous species are often more important for recovery than seed banks and seed sources Potential for invasive species Environmental characteristics of the site (mesic to warm frigid; south-facing slopes, etc.) Relative abundance of perennial herbaceous species On site and adjacent invasive seed banks and potential seed rain Fuel load and structure Woodland phase (*fire severity increases with increased tree biomass*) Fine surface fuels and structure (biomass, continuity, and packing ratios) Woodland age structure (pre- and post-settlement tree densities) Amount and distribution of bare ground and gap size between perennial plants Amount and distribution of biological soil crusts At-risk-phase?

Disturbance history (figs. 1 and 3; pre- and post)	Severity and frequency
	Time since last event
	Type
	  Fire
	  Mechanical
	  Drought
	  Herbivory, including livestock, native and introduced herbivores
	  Disease, snow-mold, fungus, etc.
	  Insects

Fire severity (fig. 7)	Fuels Topography Fire weather Season (*linked with fire weather and plant phenology*) Current vegetation (*fuel abundance, continuity, and structure*) Fire type Ground, surface, crown, head fire, backfire, and backing fire

Pre-wildfire weather (previous 1 to 3 years)	Timing and amount of precipitation
	Temperatures (primarily extremes)
	Consider how it has influenced:
	  Fuels
	  Seed banks
	  Pre-treatment species composition and vigor

Appendix 2: Examples of Elevation Breaks and Plant Indicators for Soil Temperature Regimes in Two MLRAs

Soil temperature regime		Elevation (ft)[a]		PPT (in)	Moisture regime	Indicator plants[b]	Ecological zones
		MLRA 23	MLRA 28B				
Mesic	Warm	<3000	4,000–6,000	4–8	Typic aridic	Arsp, Atco, Krla, Heco, Achy	Desert basins
	Cool	3,000–4,000	5,500–6,500	8–12	Aridic bordering xeric	Arno, Artrw, (few Juos or Juoc), Acth	Sagebrush semi-desert
Frigid	Warm	4,000–5,000	6,000–8,000	12–14	Xeric bordering aridic	Arno, Arar, Artrv, Artrw, Juos or Juoc, Pimo, Acth	Upland sagebrush, juniper, piñon
	Cool	5,000–6,000	7,500–8,200	14+	Typic xeric	Artrv, Symph, Amal, Pimo, Juos or Juoc, Feid, Acne, snow pocket Potr	Upland mountain sagebrush, piñon, juniper
Cryic	Warm	6,000–7,500 (8,000)	8,200–9,600	16+	Typic xeric	Artrv, Arsp8, Arar, Symph, Amal,Cele, Abco, Potr	Mountain brush
	Cool	8,000–9,000	9,300–10,600	18+	Typic xeric	Pien, Piar, Pifl	High mountain
	Cold	>9,000	10,600–13,061	20+	Xeric bordering aridic	Alpine plants	Subalpine and alpine

[a] Elevation is usually adjusted 500 ft for north (-) or south (+) aspects, and elevation breaks change from the north to south ends of the MLRA. Elevation and indicator species should be fine-tuned for a specific management area. It is also important to consider that changes along elevation gradients or from north to south locations within an MLRA are usually gradual and are not defined by distinct boundaries.

[b] Plant codes: Abco = *Abies concolor*, Achy = *Achnatherum hymenoides*, Acne = *Acnatherum nevadense*, Acth = *Achnatherum thurberianum*, Amal = *Amelachier alnifolia*, Arar = *Artemisia arbuscula*, Arno = *Artemisia nova*, Arsp = *Artemisia spinescens*, Arsp8 = *Artemisia spiciformis*, Artrv = *Artemisia tridentata* spp. *vaseyana*, Artrw = *Artemisia tridenatata* spp. *wyomingensis*, Atco = *Atriplex confertifolia*, Cele = *Cercocarpus ledifolius*, Feid = *Festuca idahoensis*, Heco = *Hesperostipa comata*, Juoc = *Juniperus occidentalis*, Juos = *Juniperus osteosperma*, Krla = *Krascheninnikovia lanata*, Piar = *Pinus aristata*, Pifl = *Pinus flexilis*, Pimo = *Pinus monophylla*, Symph = *Symphoricarpos* sp., Potr = *Populus tremuloides*.

Appendix 3: What is the Meaning of a Soil Family Name?

Soil Family Names

In general, soil family names ending in "olls" are Mollisols indicating that they have a minimum of 1 percent organic matter. Soils ending in "ids" are Aridisols. They contain <1 percent 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 Course 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

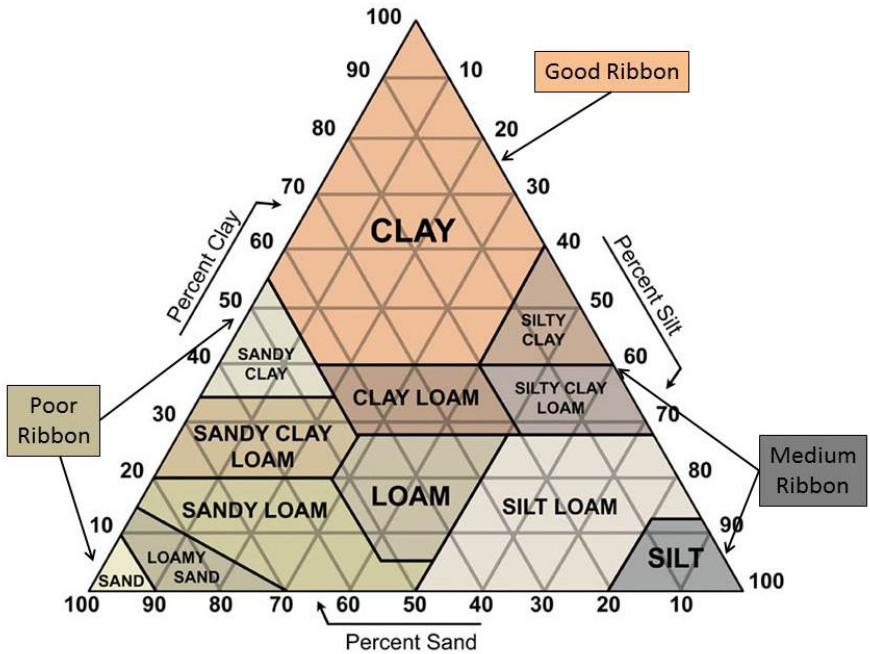
Soil texture / temperature / moisture

Soil 1: Warm (mesic), dry (aridic) soil with an aridic moisture regime that is approaching xeric (xer for xeric) or 12 inches of annual ppt. 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 (xeric), shallow (lithic) soil with accumulation of clay in the B horizon (argi for argillic layer) and ≥12 inches of annual ppt. 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 for shallow) and <1 percent organic matter content.

Soil 3: A cold (cry for cryic)/moist (xeric, ≥12 inches of annual ppt) soil with accumulation of clay (argi) in the B horizon. 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 (xeric), 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.



Soil Terms

Arigillic—Typically defined by percent increase in alluvial clay content (usually the B horizon) relative to the overlying soil layer (usually the A horizon). The increase in clay and abrupt change in texture can substantially reduce infiltration rates.

Duripan—A subsurface horizon that is cemented by alluvial (water transported) silica to the degree that fragments from the air-dry horizon do not slake (take in water or crumble) during prolonged soaking.

Lithic—Shallow soils over a paralithic (soft bedrock) contact or duripan (subsurface horizon cemented by bedrock).

Skeletal—Soils with ≥35 percent particle sizes >2 mm by volume.

Soil depth—Very shallow is <10 inches; shallow is 10-20 inches; moderately deep is 20-36 inches; and deep is >36 inches.

Soil moisture regime—An important soil property that, in combination with growing season soil temperature, influences plant growth and biological soil processes. The moisture regime is based on the amount of soil moisture available during the growing season in areas with cool/moist winters and hot/dry summers. Xeric (moist or >12 inches annual ppt) and aridic (dry or <12 inches of annual ppt) soils are characteristic of arid regions where soil is dry for at least half the growing season and moist for less than 90 days. Although mapped as distinct breaks in precipitation (<12 inches or >12 inches), soil moisture regimes, in reality, are continuous gradients that change with location and elevation. Thus, it is important to consider where the site fits along the gradient. For example, a site with an aridic moisture regime that receives 11.5 inches of ppt will often be more resilient to disturbance than an aridic site receiving 9 inches of ppt. For a detailed definition and description of each soil moisture regime, see USDA-NRCS (1999). For this field guide, we define the following soil moisture regimes:

Dry-aridic: <10 inches annual ppt

Aridic: 10-12 inches annual ppt

Xeric: 12-14 inches annual ppt

Moist-xeric: >14 inches annual ppt

Soil temperature regime—An important property of a soil that, along with soil moisture, influences plant growth and biological soil processes. Soil temperature is usually measured at a depth of 20 inches (50 cm) (or depth at the lithic or paralithic contact), which is considered deep enough to reflect seasonal temperatures and not daily cycles. Since measurements of seasonal soil temperatures are spatially limited across the Great Basin, soil temperature regimes are estimated based on seasonal air temperatures, which are largely influenced by location, elevation, and aspect. When soils are mapped, temperature regimes are most commonly based on elevation and aspect, which are adjusted for each sub-region (MLRA). For a detailed definition and description of each soil regime, see USDA-NRCS (1999).

Mesic (warm)—indicator species are Wyoming big sagebrush and black sagebrush. Mesic soils have low relative resistance to invasives compared to frigid and cryic soils. They also are considered to have lower resilience.

Frigid (cool)—indicator species are mountain big sagebrush, piñon pine, and low sagebrush on shallow soil, but black sagebrush and, occasionally, Wyoming big sagebrush may occur on the warmer end of this soil regime or where soil moisture is limiting. Resilience to disturbance and resistance to invasive species are higher than on mesic soils.

Cryic (cold)—indicator species are curl-leaf mountain mahogany, white and grand fir, limber pine, lodgepole, and white bark pine, which typically intermingle with mountain big and low sagebrush. Resilience is high on the warm end of this regime but declines as temperatures become colder due to limitations on plant growth. Resistance to invasive species is higher than for mesic and likely frigid soils (although data are limited). Cryic soils are cooler in summer than frigid soils.

Soil Temperature and Moisture Regimes

The soil terms and the precipitation ranges used in the text refer to the specific soil terms shown in the following table (personal communication with Steve Campbell, NRCS). For a detailed definition and description of each soil regime, see USDA-NRCS (1999).

Term or value used in text	Soil term
- Soil temperature -	
hot-mesic	mesic bordering on thermic
warm-mesic	mesic-typic
cool-mesic	mesic bordering frigid
warm-frigid	frigid bordering mesic
cool-frigid	frigid bordering on cryic
warm-cryic	cryic bordering on frigid
cool-cryic	cryic-typic
- Soil moisture -	
dry-aridic ***or*** <10 inches ppt	aridic-typic
aridic ***or*** 10-12 inches ppt	aridic bordering on xeric
xeric ***or*** 12-14 inches ppt	xeric bordering on aridic
moist-xeric ***or*** >14 inches ppt	xeric-typic

Appendix 4: Post-Wildfire Indicators of Fire Severity

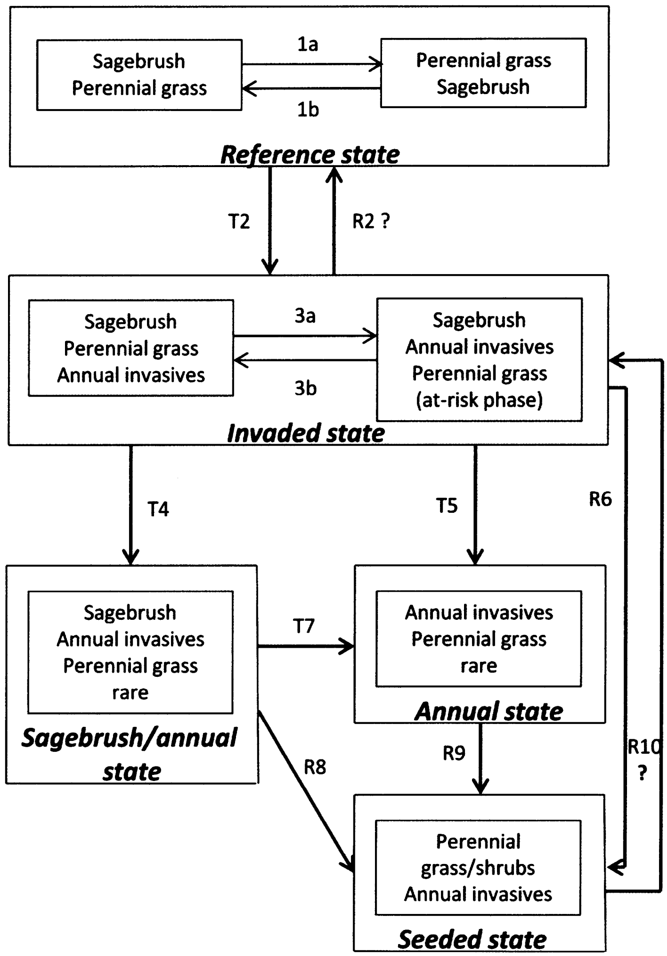
Low severity	Moderate severity	High severity
>75% burned sagebrush skeletons remaining	15 to 75% burned sagebrush skeletons remaining	Sagebrush basal stumps remain or burned below the soil surface
<25% tree foliage dead, <15% foliage consumption	25 to 75% tree foliage dead, 15 to 50% foliage consumed	>75% tree foliage dead, >50% consumed
Tree duff blackened but little consumed	Majority of tree duff consumed, surface blackened	White ash layer beneath tree canopy
>2 inches blackened stubble remains on burned grasses	0.25 to 1 inch blackened stubble remains on burned grasses	Grass crowns consumed to or below the surface
Unburned patches >50%	Unburned patches 15 to 50%	Unburned patches <15%
Interspace litter consumption <50%	Interspace litter consumption 50 to 80%	Interspace litter consumption >80%, white ash deposition
Shrub canopy litter consumption <50%	Shrub canopy litter consumption 50 to 80%	Shrub canopy litter consumption >80%, white ash deposition
Minimal ash, ground fuels blackened and 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	Surface structure slightly to not altered	Aggregated stability reduced or destroyed, surface loose and/or powdery
Cheatgrass seeds common with minimal signs of consumption outside of pre-fire shrub canopies	Cheatgrass seeds few to moderately abundant outside of pre-fire shrub canopies, seed consumption variable	Cheatgrass seeds sparse both inside and outside of pre-fire shrub canopies, seed consumption nearly complete

Soil and litter indicators are derived from Parson and others (2010).

Appendix 5: State and Transition Models (STMs) for Five Generalized Ecological Types for Big Sagebrush (from Chambers and others 2014b)

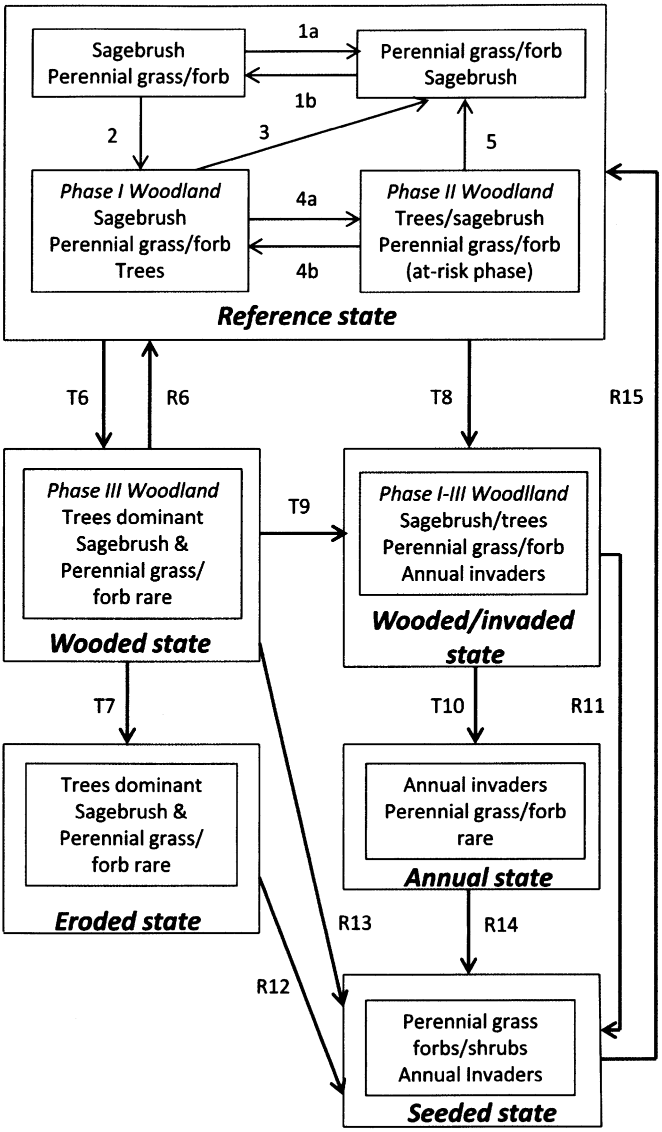
These STMs represent groupings of ecological types that are occupied by Wyoming or mountain big sagebrush, span a range of soil temperature/moisture regimes (warm-dry to cold-moist), and characterize a large portion of the Great Basin and Columbia River Plateau regions: (A) Mesic/aridic Wyoming big sagebrush (8 to 12 inch precipitation zone [PZ]); (B) Cool-mesic to warm-frigid/xeric big sagebrush with piñon pine and juniper potential (12 to 14 inch PZ), (C) Cool-mesic to cool-frigid/xeric mountain big sagebrush (12 to 14 inch PZ); (D) Cool frigid/xeric mountain big sagebrush with piñon and juniper potential (12 to 14+ inch PZ); and (E) Cryic/xeric mountain big sagebrush/mountain brush (14+ inch PZ). Large boxes illustrate states that are comprised of community phases (smaller boxes). Transitions among states are shown with arrows starting with T; restoration pathways are shown with arrows starting with R. The "at risk" community phase is most vulnerable to transition to an alternative state.

5A - Mesic/aridic
Wyoming big sagebrush (8 to 12 inch PZ)
Low to moderate resilience and low resistance



(1a) Perennial grass increases due to disturbances that decrease sagebrush such as wildfire, insects, disease, and pathogens.
(1b) Sagebrush increases with time.
(T2) An invasive seed source and/or improper grazing trigger an invaded state.
(R2) Proper grazing, fire, herbicides, and/or mechanical treatments are unlikely to result in return to the reference state on all but the coolest and wettest sites.
(3a) Perennial grass decreases and both sagebrush and invasives increase with improper grazing resulting in an at-risk phase. Decreases in sagebrush due to insects, disease, or pathogens can further increase invasives.
(3b) Proper grazing and herbicides or mechanical treatments that reduce sagebrush may restore perennial grass and decrease invaders on wetter sites (10-12 inches). Outcomes are less certain on drier sites (8-10 inches) and/or with low perennial grass.
(T4) Improper grazing triggers a largely irreversible threshold to a sagebrush/annual state.
(T 5 and T7) Fire or other disturbances that remove sagebrush result in an annual state. Perennial grass is rare and recovery potential is low due to low precipitation, mesic soil temperatures, and competition from annual invasives. Repeated fire can cause further degradation.
(R6, R8, and R9) Seeding following fire and/or invasive species control results in a seeded state. Sagebrush may recolonize depending on patch size, but annual invasives are still present.
(R10) Seeding effectiveness and return to the invaded state are related to site conditions, seeding mix, and post-treatment weather.

5B - Cool mesic to warm frigid/xeric
Big sagebrush (12 to 14 inch PZ)
Piñon pine and/or juniper potential
Moderate resilience and moderately low resistance



(1a) Disturbances such as wildfire, insects, disease, and pathogens result in less sagebrush and more perennial grass/forb.

(1b) Sagebrush increases with time.

(2) Time combined with seed sources for piñon and/or juniper trigger a Phase I Woodland.

(3 and 5) Fire and or fire surrogates (herbicides and/or mechanical treatments) that remove trees may restore perennial grass/forb and sagebrush dominance on cooler/wetter sites. On warmer/drier sites with low perennial grass/forb abundance, resistance to invasion is moderately low.

(4a) Increasing tree abundance results in a Phase II woodland with depleted perennial grass/forb and shrubs and an at-risk phase.

(4b) Fire surrogates (herbicides and/or mechanical treatments) that remove trees may restore sagebrush and perennial grass/forb dominance.

(T6) Infilling of trees and improper grazing can result in a biotic threshold crossing to a wooded state with increased risk of high severity crown fires.

(R6) Fire, herbicides, and/or mechanical treatments that remove trees may restore perennial grass/forb and sagebrush dominance on cooler/wetter sites.

(T7) An irreversible abiotic threshold crossing to an eroded state can occur depending on soils, slope, and understory species.

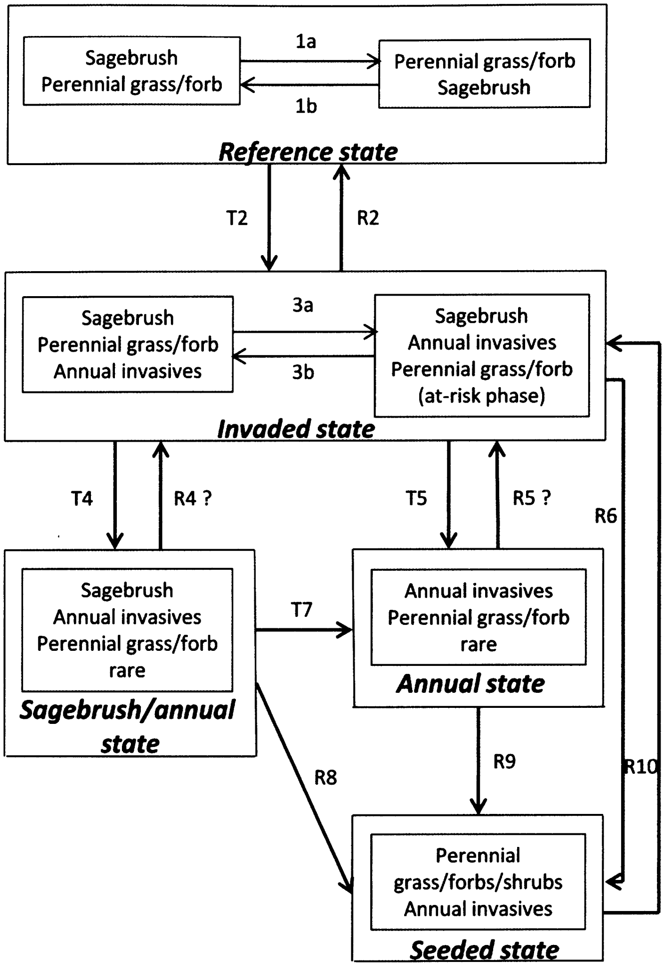
(T8 and T9) An invasive seed source and/or improper grazing can trigger a wooded/invaded state.

(T10) Fire or other disturbances that remove trees and sagebrush can result in a biotic threshold crossing to annual dominance on warmer/drier sites with low resilience.

(R11, R12, R13, and R14) Seeding after fire and/or invasive species control increases perennial grass/forb. Sagebrush may recolonize depending on seed sources, but annual invaders are still present. Seeded eroded states may have lower productivity.

(R15) Depending on seed mix , grazing, and level of erosion, return to the reference state may occur on cooler and wetter sites if an irreversible threshold has not been crossed.

5C - Cool mesic to cool frigid/xeric
Mountain big sagebrush (12 to 14 inch PZ)
Moderate resilience and resistance



(1a) Perennial grass/forb increases due to disturbances that decrease sagebrush such as wildfire, insects, disease, and pathogens.

(1b) Sagebrush increases with time .

(T2) An invasive seed source and/or improper grazing trigger an invaded state.

(R2) Proper grazing, fire, herbicides, and/or mechanical treatments may restore perennial grass/forb and sagebrush dominance with few invasives.

(3a) Perennial grass/forb decreases and sagebrush and invasives increase with improper grazing by livestock resulting in an at-risk phase. Decreases in sagebrush due to insects, disease, or pathogens can further increase invasives.

(3b) Proper grazing, herbicides, or mechanical treatments that reduce sagebrush may increase perennial grass/forb and decrease invasives.

(T4) Improper grazing results in a sagebrush/annual state.

(R4) Proper grazing may facilitate return to the invaded state on cooler/wetter sites if sufficient grass/forb remains .

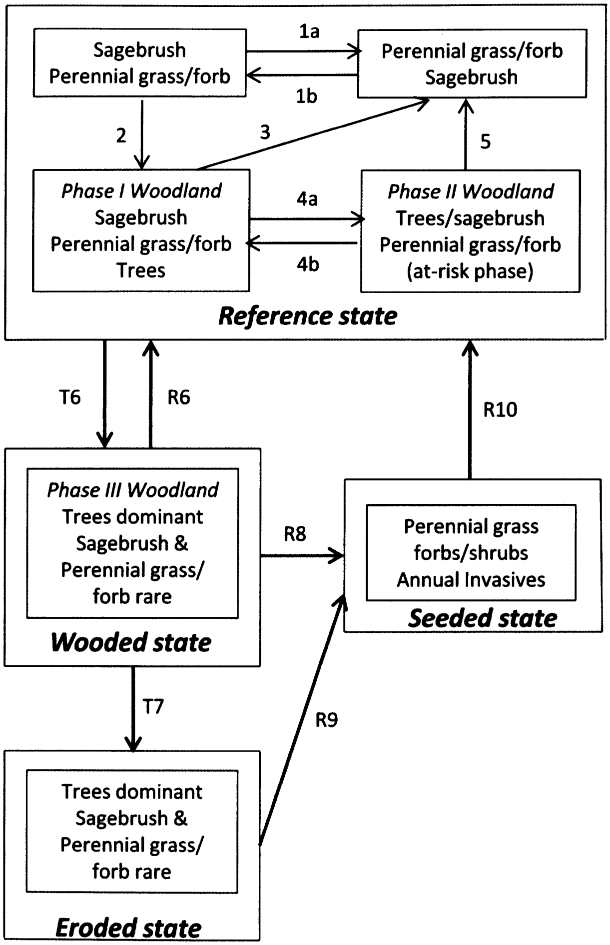
(T5 and T7) Fire or other disturbances that remove sagebrush result in an annual state. Perennial grass/forb are rare and recovery potential is reduced. Repeated fire can result in a biotic threshold crossing to annual dominance on warmer/drier sites, and root-sprouting shrubs may increase.

(R5) Cooler and wetter sites may return to the invaded or reference state with lack of fire, proper grazing, and favorable weather.

(R6, R8, and R9) Seeding following fire and/or invasive species control results in a seeded state. Sagebrush may recolonize depending on patch size, but annual invaders are still present.

(R10) Cooler and wetter sites may return to the invaded or possibly reference state depending on seeding mix, grazing, and weather.

5D - Cool frigid/xeric
Mountain big sagebrush (12 to 14+ inch PZ)
Piñon pine and/or juniper potential
Moderately high resilience and resistance



(1a) Disturbances such as wildfire, insects, disease, and pathogens result in less sagebrush and more perennial grass/forb.

(1b) Sagebrush increases with time.

(2) Time combined with seed sources for piñon and/or juniper trigger a Phase I Woodland.

(3 and 5) Fire and or fire surrogates (herbicides and/or mechanical treatments) that remove trees may restore perennial grass/forb and sagebrush dominance.

(4a) Increasing tree abundance results in a Phase II woodland with depleted perennial grass/forb and shrubs and an at-risk phase.

(4b) Fire surrogates (herbicides and/or mechanical treatments) that remove trees may restore perennial grass/forb and sagebrush dominance.

(T6) Infilling of trees and/or improper grazing can result in a biotic threshold crossing to a wooded state with increased risk of high severity crown fires.

(R6) Fire, herbicides, and/or mechanical treatments that remove trees may restore perennial grass/forb and sagebrush dominance.

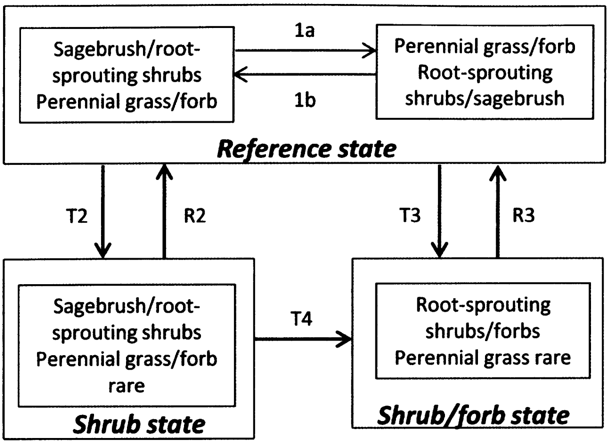
(T7) An irreversible abiotic threshold crossing to an eroded state can occur depending on soils, slope, and understory species.

(R8 and R9) Seeding after fire may be required on sites with depleted perennial grass/forb, but seeding with aggressive introduced species can decrease native perennial grass/forb. Annual invasives are typically rare. Seeded eroded states may have lower productivity.

(R10) Depending on seed mix and grazing, return to the reference state may be possible if an irreversible threshold has not been crossed.

5E - Cryic/xeric mountain big sagebrush/
Mountain brush (14+ inch PZ)

Moderately high resilience and high resistance



(1a) Perennial grass/forb increases due to disturbances that decrease sagebrush such as wildfire, insects, disease, and pathogens.

(1b) Sagebrush and other shrubs increase with time.

(T2) Improper grazing triggers a shrub-dominated state.

(R2) Proper grazing results in a return to the reference state.

(T3 and T4) Fire or other disturbances that remove sagebrush result in dominance by root-sprouting shrubs and an increase in native forbs such as lupines.

(R3) Proper grazing and time result in return to the reference state.

Note: Resilience is lower on cold cryic sites due to short growing seasons.

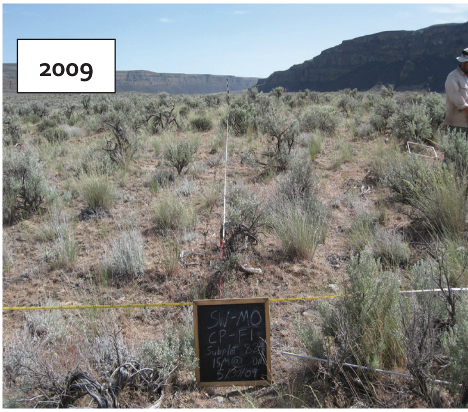
Appendix 6: Examples of States, Phases, and Transitions Following Prescribed Fire Treatment for Three General Ecological Types in Different Phases and Precipitation Zones (PZ)

Photos are from SageSTEP plots (http://www.sagestep.org). For interpretation of resilience and resistance scores, see Appendix 7.

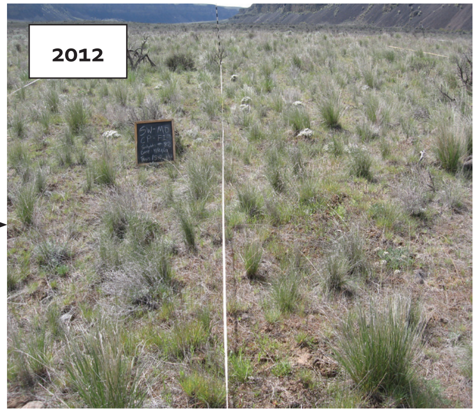
6A—Warm-mesic/aridic

Wyoming big sagebrush/bluebunch wheatgrass-Sandberg bluegrass (8 to 12 inch PZ)

Reference State



Fire

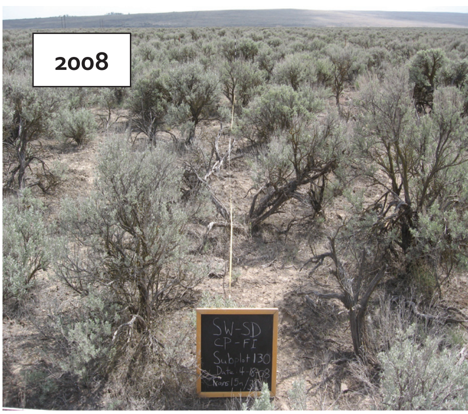


Fire resistant bluebunch wheatgrass is abundant, Sandberg bluegrass fills the interspaces, and cheatgrass is only a trace. Although warm-mesic/aridic, the area has a high probability of a successful recovery following a wildfire of low to moderate severity. Resilience and Resistance score = 17.

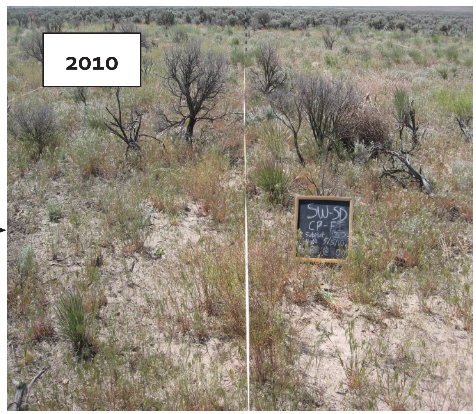
6B—Warm-mesic/aridic

Wyoming big sagebrush/bluebunch wheatgrass-Indian ricegrass (8 to 12 inch PZ)

Invaded State



Fire



6C—Cool mesic/aridic

Basin and Wyoming big sagebrush/bluebunch wheatgrass (10 to 12 inch PZ)

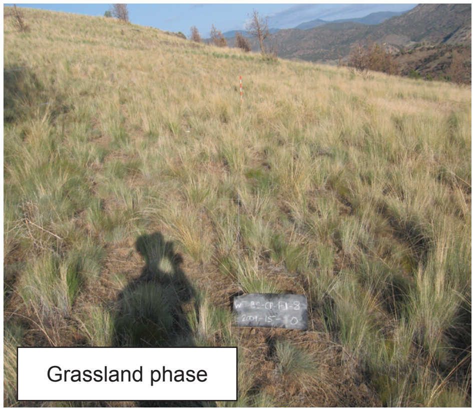
Juniper potential

Reference State

Phase I woodland/sagebrush/perennial grass/forb

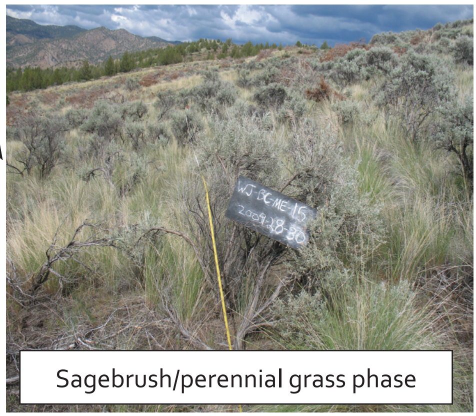
This site is near the reference state. Bluebunch wheatgrass is abundant and cheatgrass is only a trace. The area has a high probability for recovery following wildfire or prescribed fire without seeding. Resilience and Resistance score = 20.

Fire



Grassland phase

Mechanical



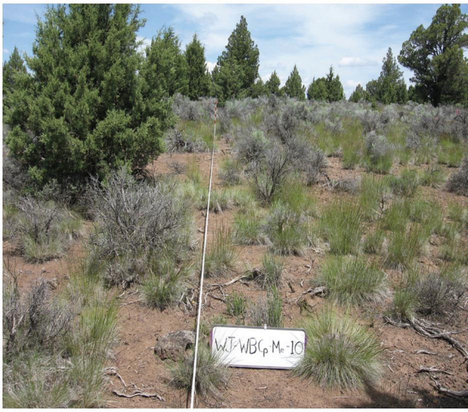
Sagebrush/perennial grass phase

6D—Cool frigid/xeric

Mountain big sagebrush/Idaho fescue (12 to 14 inch PZ)

Juniper potential

Reference State



Fire

The presence of Idaho fescue indicates that this is a cool-frigid soil temperature regime. The herbaceous layer is dominated by native grasses and forbs. There is only a trace of invasive annuals. An Aroga moth infestation caused nearly 100% sagebrush mortality prior to a prescribed fire. The combination of good herbaceous plant cover and soil moisture/temperature regimes resulted in high resilience and resistance. Due to adequate cover of native grasses and forbs and relatively high resistance, seeding is not required on this site after fire. Resilience and Resistance score = 25.

Appendix 7a: Score Sheet for Rating Resilience, Resistance to Annual Invasive Grasses, and the Need and Suitability for Seeding of an Ecological Site or Type Following Wildfire

Applicability—This score sheet is a tool for a rapid assessment of resilience and resistance to invasive annuals for an area-of-concern that is based largely on three key attributes; soil temperature, available moisture, and pre-fire vegetation. These three attributes are primary drivers of resilience to disturbance or vegetation management, and resistance to invasives and are a function of climate, topography, and soils. Stringham and others (2015) state that: "Many ecological sites are similar in their plant composition and other important physical attributes such as soils but may differ in total production or landscape setting. Thus, often these similar ecological sites will respond to the same disturbance in a similar manner. The rate of response to disturbance may be different but the endpoint of the change will be very similar." Because the score sheet is based on the physical attributes and vegetation composition that determine resilience and resistance to invasive annuals, it has widespread applicability.

Adaptation—It may be possible to further adapt the score sheet to a specific MLRA or ecological site as additional information becomes available. Attributes specific to the MLRA and/or ecological site, such as timing of moisture, can modify the response to disturbance or vegetation management. For example in the Intermountain West, the densest and most extensive stands of *B. tectorum* in unburned sagebrush occur in locations with hot dry summers and relatively warm, wet winters (Lavin and others, in review). These conditions minimize plant growth in mid-summer and promote plant growth in the winter and are characteristic of the Lahontan Basin (MLRA 27 & 24), Columbia Plateau (MLRA 8), lower Snake River Plain (western half of MLRA 11), and west central Utah (small central portion of MLRA 28A).

How to use this score sheet—Scores are based on soil temperature and moisture indicators, pre-fire plant composition, and estimated fire severity. Large wildfires frequently burn across several ecological sites or types. The % Area on the score sheet is the estimated proportion of the ecological site type within the treatment area. Explanations of the variables used in the score sheet are found in appendix 7b. If pre-wildfire vegetation is not known, see "Pre-Wildfire Composition and Structure Unknown" in the text. To estimate fire severity following a wildfire, see Appendix 4.

Score Sheet for Rating Resilience to Disturbance and Resistance to Invasive Annual Grasses

Ecological Site or Type Name: ____

____

%Area: _____________ **UTMs:** ____

(Use ecological site descriptions or guidelines for the MLRA with field assessment to complete score sheet.)

PLOT SCORE†
(Sample two to five plots per ecological site depending on size and variability of area.)

SITE CHARACTERISTICS	SCORE FOR VARIABLE	1	2	3	4	5
Temperature (Soil temperature regime + Species or subspecies of sagebrush)						
Soil temperature regime	**1** = hot-mesic, **2** = warm-mesic, **3** = cool-mesic, or cool-cryic (resilience is low but resistance is high), **4** = warm-frigid, **5** = cool-frigid, **6** = warm-cryic					
Species or subspecies of sagebrush	**1** = Wyoming, low, black, or Lahontan; **2** = basin, Bonneville, or xeric; **3** = mountain					
A. Temperature Score =						
Moisture (Precipitation + Soil texture + Soil depth)						
Precipitation in inches (in)	**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 in inches (in)	**0** = very shallow (<10), **1** = shallow (10-20), **3** = moderately deep to deep (>20)					
B. Moisture Score =						
Temperature Score (A) + Moisture Score (B)						
Pre-Fire Vegetation (PFV) (Plant groups modified by soil depth)						
Plant Groups: Deep-rooted perennial grasses (DRPG) (potentially dominant in shallow to deep soils >10 in) Sandberg bluegrass (POSE) (potentially dominant in very shallow soils <10 in) Perennial forbs (PF) Invasive annual grasses (IAG)	**0 =** DRPG and POSE scarce to severely depleted (DRPG <2-3/m^2 and/or less than 5% foliar cover) **3 =** DRPG on soils >10 in deep scarce, but POSE or PF are >50% foliar cover (resistance may be relatively high, but resilience is low) **6 =** DRPG on soils >10 in deep depleted (2-3/m^2or about 5-10% foliar cover), or co-dominant with IAG; ***or*** on soils <10 in deep, POSE and PF 5-15% foliar cover and co-dominant with IAG **9 =** DRPG and PF dominant on soils >10 in deep; or POSE and PF dominant on soils <10 in deep.					
Pre-Fire Vegetation (PFV) Adjusted for Fire Severity (Estimated)						
C. Adjusted Pre-Fire Vegetation ***(Estimate from fire severity indicators in Appendix 4.)***	*Low severity wildfire* = PFV x 95% *Moderate severity wildfire* = PFV x 80% *High severity wildfire* = PFV x 20%					
Total Resilience & Resistance Score=Temperature (A) + Moisture (B) + Adjusted PFV(C)						
Resilience & Resistance Rating: Very low = <10, Low = 10-14, Moderate = 15-20, High = >20						

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

Appendix 7b: Explanation of Variables Used in the Resilience and Resistance Score Sheet

Explanation of Variables Used in the Score Sheet for Rating Resilience and Resistance				
Site Characteristics	**Variable**	**Explanation**	**Score**	
			min	**max**
Temperature (Soil temperature regime + Species or subspecies of sagebrush)				
Soil temperature regime	**1** = hot-mesic **2** = warm-mesic **3** = cool-mesic **3** = cool-cryic **4** = warm-frigid **5** = cool-frigid **6** = warm-cryic	Estimated from soil survey data, ESDs, or from elevation within each MLRA (see Appendix 2). 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
Species or subspecies of sagebrush	**1** = Wyoming, low, black, and Lahontan **2** = basin, Bonneville, and xeric **3** = mountain	Sagebrush species and subspecies correspond to soil temperature/moisture regimes as well as soil depth and texture, and differ over elevation gradients, as described in ESDs, Table 3, and Appendix 2. Species identities are confirmed through on-site surveys.	1	3
Temperature (A)		Sum of soil temperature + sagebrush subspecies	2	9
Moisture (Precipitation + Soil texture + Soil depth)				
Precipitation in inches (in)	**1** = <10 in **2** = 10 to 12 in **3** = 12 to 14 in **4** = >14 in	Estimated from soil surveys, ESDs, or climate models, and confirmed on-site. Soil moisture regimes are: < 10 in = dry-aridic; 10 to 12 in = aridic; 12 to 14 in = xeric; >14 in = moist-xeric.	1	4
Soil texture	**1** = clay, sand, or silt **2** = silty, sandy, or clay loams **3** = loam	Dominant soil texture in upper 20 in of soil profile from soil descriptions and on-site soil pits. Loams often show balance between infiltration and water storage capacity; clay, sand, or silt soils are more variable.	1	3
Soil depth in inches (in)	**0** = very shallow (<10) **1** = shallow (10 to 20) **3** = mod deep to deep (>20)	Depth to restrictive layer from soil descriptions and on-site soil pits. Soil depth largely determines water storage capacity and rooting depth.	0	3
Moisture (B)		Sum of precipitation + soil texture + soil depth	2	10
Total Temperature (A) + Moisture (B)		Sum of temperature and moisture scores	4	19
Pre-Fire Vegetation (PFV) (Plant groups modified by soil depth)				
Plant Groups Deep-rooted perennial grasses (DRPG) Sandberg bluegrass (POSE) Perennial Forbs (PF) Invasive annual grasses (IAG)	**0** = DRPG scarce to severely depleted (<2-3/m^2); ***or*** POSE and PF are <5% foliar cover on very shallow soils **3** = Soils >10 in deep; DRPG scarce; but POSE, PF, and/or crusts >50% cover **6** = Soils >10 in deep; DRPG depleted (2-3/m^2, 5-10% cover); ***or*** where soils <10 in deep, POSE and PF 5-15% cover and/or co-dominant with IAG **9** = Soils >10 in deep and DRPG dominant; ***or*** soils <10 in deep and POSE or PF dominant	**0** = DRPG are <2/m^2 for xeric and <3/m^2 for aridic; invasives are dominant ***or***, if invasives are not dominant, woody species (shrubs or trees) are near maximum cover. **3** = Cover of POSE, PF, and/or crusts is high. Establishment of DRPG is often limited, thus resilience may be low, but resistance can still be high. **6** = Abundance of DRPG, POSE, and PF is near or equal to IAG (IAG abundance is highly variable depending on moisture). IAG have low abundance (<5% cover), and DRPG are depleted, but >2/m^2 for xeric and >3/m^2 for aridic; ***or*** soils are very shallow and POSE and PF are 5 to 15% cover. **9** = Native grasses and forbs are dominant. If the area is seeded to non-native grasses, return to the reference state is unlikely, but resistance to annual grasses can be high.	0	9
Pre-Fire Vegetation (PFV) Adjusted for Fire Severity (Estimated)				
PFV adjusted for fire severity based on indicators in Appendix 4.	*Low severity fire* = PFV x 95% *Moderate severity fire* = PFV x 80% *High severity fire* = PFV x 20%	*Low severity fire* can occur on low productivity sites and results in little mortality of perennial grasses and forbs. *Moderate severity fire* can occur in Phase I and II woodlands and high density shrublands. *High severity fire* usually occurs in Phase III woodlands.	0	8.6
Total Resilience and Resistance Score Rating: Very low = <10, Low = 10-14, Moderate = 15-20, High = >20		Temperature (A) + Moisture (B) + Adjusted PFV(C) = Resilience & Resistance Score	**4**	**27.6**

Appendix 7c. Example of Rating Resilience and Resistance to Invasive Annual Grasses

Example of rating resilience and resistance to invasive annual grasses for the mesic/aridic Wyoming big sagebrush (8 to 12 inch PZ) ecological type, where the pre-treatment vegetation varies in ecological condition and fuel characteristics. See the STM for this ecological type in Appendix 5A to determine the potential states and community phases.

Score Sheet for Rating Resilience to Disturbance and Resistance to Invasive Annual Grasses

Ecological Site or Type Name: Mesic/aridic Wyoming big sagebrush/Thurber needlegrass (8 to 12 inch PZ)

%Area: _60%___________ **UTMs:** _(your site)_________________________________

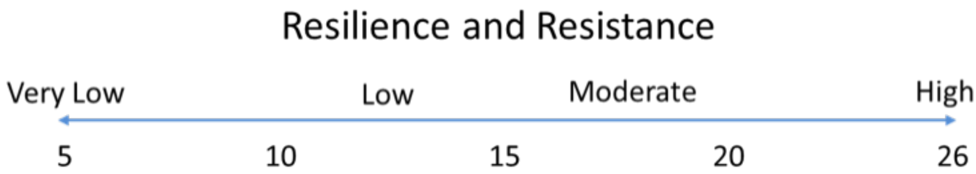
(Use ecological site descriptions or guidelines for the MLRA with field assessment to complete score sheet.)

PLOT SCORE† (***Sample two to five plots per ecological site depending on size and variability of area.***)

SITE CHARACTERISTICS	**SCORE FOR VARIABLE**	**1**	**2**	**3**	**4**	**5**
Temperature (Soil temperature regime + Species or subspecies of sagebrush)						
Soil temperature regime	**1** = hot-mesic, **2** = warm-mesic, **3** = cool-mesic, or cool-cryic (resilience is low but resistance is high), **4** = warm-frigid, **5** = cool-frigid, **6** = warm-cryic	2	3	2	2	3
Species or subspecies of sagebrush	**1** = Wyoming, low, black, or Lahontan; **2** = basin, Bonneville, or xeric; **3** = mountain	1	1	1	1	1
A. Temperature Score =		3	4	3	3	4
Moisture (Precipitation + Soil texture + Soil depth)						
Precipitation in inches (in)	**1** = <10, **2** = -12, **3** = 12-14, **4** = >14	2	2	2	2	2
Soil texture	**1** = clay, sand, or silt; **2** = silty, sandy, or clay loams; **3** = loam	2	2	2	2	2
Soil depth in inches (in)	**0** = very shallow (<10), **1** = shallow (10-20), **3** = moderately deep to deep (>20)	3	3	3	3	3
B. Moisture Score =		7	7	7	7	7
Temperature Score (A)+ Moisture Score (B)		10	11	10	10	11
Pre-Fire Vegetation (PFV) (Plant groups modified by soil depth)						
Plant Groups: Deep-rooted perennial grasses (DRPG) (potentially dominant in shallow to deep soils >10 in) Sandberg bluegrass (POSE) (potentially dominant in very shallow soils <10 in) Perennial forbs (PF) Invasive annual grasses (IAG)	**0 =** DRPG and POSE scarce to severely depleted (DRPG <2-3/m^2 and/or less than 5% foliar cover) **3 =** DRPG on soils >10 in deep scarce, but POSE or PF are >50% foliar cover (resistance may be relatively high but resilience is low) **6 =** DRPG on soils >10 in deep depleted (2-3/m^{2}or about 5-10% foliar cover), or co-dominant with IAG; ***or*** on soils <10 in deep POSE and PF 5-15% foliar cover and co-dominant with IAG **9 =** DRPG and PF dominant on soils >10 in deep; or POSE and PF dominant on soils <10 in deep.	0	3	0	3	6
Pre-Fire Vegetation (PFV) Adjusted for Fire Severity (Estimated)						
C. Adjusted Pre-Fire Vegetation ***(Estimate from fire severity indicators in Appendix 4.)***	*Low severity wildfire* = PFV x 95% *Moderate severity wildfire* = PFV x 80% *High severity wildfire* = PFV x 20%	0	2.9	0	2.9	4.8
Total Resilience & Resistance Score=Temperature (A) + Moisture (B) + Adjusted PFV(C)		**10**	**14**	**10**	**13**	**16**
Resilience & Resistance Rating: Very low = <10, Low = 10-14, Moderate = 15-20, High = >20						

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

Explanation of Resilience and Resistance Rating from Example Score Sheet.



Potential vegetation on this ecological site is Wyoming big sagebrush and Thurber needlegrass. Soil temperatures vary from warm-mesic to cool-mesic depending on elevation and aspect. Mean annual precipitation is 10 to 12 inches. Soils are moderately deep clay loams. Current vegetation ranges from severely depleted on approximately 65% of the area to native perennial grasses and forbs dominating the understory on about 15% of the area. Fire severity varies from low to moderate. Resilience on the majority of the area (75%) is very low to low. The only area where resilience is moderate to approaching high is where native perennial herbaceous vegetation is dominant.

Appendix 8: Definitions of Terms Used in This Field Guide

(For soil terms, see Appendix 3)

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

Ecological site—A conceptual division of the landscape that is defined as a distinctive kind of land based on recurring soil, landform, geological, and climate characteristics; that differs from other kinds of land in its ability to produce distinctive kinds and amounts of vegetation and in its ability to respond similarly to management actions and natural disturbances. Similar to "ecological type" used by the USDA Forest Service and "Range Site Description" used by the NRCS.

Ecological Site Descriptions (ESD) —The documentation of the characteristics of an ecological site. The documentation includes data used to define the distinctive properties and characteristics of the ecological site; the biotic and abiotic characteristics that differentiate the site (i.e., climate, topography, soil characteristics, and plant communities); and the ecological dynamics of the site that describe how changes in disturbance processes and management can affect the site. An ESD also provides interpretations about the land uses and ecosystem services that a particular ecological site can support and management alternatives for achieving land management. Similar to "ecological type" used by the USDA Forest Service and "Range Site Description" used by the NRCS.

Ecological type—A category of land with a distinctive combination of landscape elements—specifically, climate, geology, geomorphology, soils, and potential natural vegetation. Ecological types differ from one other in their ability to produce vegetation and respond to management and natural disturbances.

Fire intensity—A general term relating to the heat energy released in a fire; the amount and rate of surface fuel consumption.

Fire severity—The effects of fire on ecological processes, soil, flora, and fauna; the degree to which a site has been altered or disrupted by fire.

Major Land Resource Areas/MLRAs—Geographic area that is usually several thousand acres in extent and characterized by a particular pattern of soils, climate, water resources, and land use.

Phase (community) **—**Community phases interact with the environment to produce a characteristic composition of plant species, functional and structural groups, soil functions, and range of variability. Phases may not progress directly to the most resilient community phase without passing through an intermediate phase.

Potential vegetation—As described in an ESD, is a function of ecological site characteristics (climate, topography, and soils), attributes and processes (soil temperature/moisture regime, soil processes, and vegetation dynamics), and disturbance history.

Reference state—Historical or potential plant community, including seral (successional) stages; based on conditions believed to be present before widespread alterations by Euro-Americans.

Resilience—Capacity of an ecosystem to regain its fundamental structure, processes, and functioning when altered by stresses such as increased CO_2, nitrogen deposition, and drought and by disturbances such as land development and fire.

Resistance—Capacity of an ecosystem to retain its fundamental structure, processes, and functioning (or remain largely unchanged) despite stresses, disturbances, or invasive species.

Resistance to invasion—Abiotic and biotic attributes and ecological processes of an ecosystem that limit the population growth of an invading species.

Restoration pathways—These describe the environmental conditions and management practices that are required to recover a state that has undergone a transition.

State—A suite of plant community successional phases occurring on similar soils 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 that is being considered for some form of vegetation manipulation (prescribed fire or mechanical treatments) to 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 moisture/temperature regime and current vegetation.

Woodland phase I, II, III—*Phase I* trees are present but shrubs and herbs are the dominant vegetation influencing ecological processes on the site; *phase II* trees are co-dominant with shrubs and herbs, and all three vegetation layers influence ecological processes; *phase III* trees are the dominant vegetation on the site and the primary plant layer influencing ecological processes on the site (from Miller and others 2005). Phases can be calculated using % cover (from Roundy and others 2014).

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

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

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

Phases of Woodland Succession			
Characteristics (post-settlement stands)	**Phase I (early)**	**Phase II (mid)**	**Phase III (late)**
Tree canopy percentage 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
Potential berry production	Low	Moderate to high	Low to near 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

*Crown lift is the mortality of lower tree limbs usually associated with shading of neighboring trees as tree density and size increases in relatively dense stands.

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