

Information and tools to conserve and restore Great Basin ecosystems

Putting Resilience and Resistance Concepts into Practice

Estimates of resilience and resistance provide information on how an area is likely to respond to disturbances and management. Relative resilience depends on the underlying characteristics of a site or landscape like climate, soils, and the type of vegetation. In the topographically diverse Great Basin, resilience has been shown to increase with elevation and to differ among vegetation types (Chambers et al. 2014 a, b). Higher precipitation and cooler temperatures, coupled with greater soil development and plant productivity, result in greater resources and more favorable environmental conditions for plant growth and reproduction at mid to high elevations (Figure 1).

In contrast, lower precipitation and higher temperatures result in lower available resources for plants at low elevations. Aspect, slope, and topographic position influence these rela-

Resilience and Resistance of Great Basin Ecosystems

Resilience is the capacity of an ecosystem to regain its fundamental structure, processes and functioning when altered by stresses and disturbances. Resilient ecosystems reorganize after stressors like drought and disturbances like wildfire without crossing a threshold to an alternative state with different structure and function.

Resistance is the capacity of an ecosystem to retain its fundamental structure, processes, and functioning (or remain largely unchanged) despite stressors, disturbances, or invasive species. Resistance to invasion is particularly important in Great Basin ecosystems and is a function of the attributes of ecosystems that limit invading species.

Applying resilience thinking as a land managers requires one to acknowledge that change is continually occurring and that ecosystems are adjusting to this change at scales ranging from the landscape to the site. Resilience and resistance concepts help managers understand key drivers of ecosystem change, identify relative risks of crossing thresholds to undesired states, and design appropriate management actions to promote desired ecosystem trajectories.

Purpose: Land managers are increasingly interested in improving resilience to disturbances, such as wildfire, and resistance to invasive species, such as cheatgrass and medusahead. This factsheet is designed to assist land managers in using resilience and resistance concepts to assess risks, prioritize management activities, and select appropriate treatments.

tionships because of their effects on solar radiation, effective precipitation, soil development, and vegetation composition and structure. Resilience can be decreased by disturbances that result in high mortality of native vegetation. These can include frequent or severe wildfires or long and severe droughts. They also can include inappropriate grazing by livestock or wild horses and burros.

Resistance to invasive annual grasses is particularly important in the Great Basin due to the widespread threat of altered fire regimes and risk of conversion to invasive annual grass dominance in low to mid elevation ecosystems. Invasive annual grasses increase the amount and continuity of fine fuels and, in many low to mid elevation areas, are resulting in

In Brief:

- Resilience and resistance concepts help managers understand key drivers of ecosystem change, identify relative risks of crossing thresholds to undesired states, and design appropriate management actions.
- An understanding of the relationships of environmental characteristics to vegetation types and their inherent resilience and resistance gives us the capacity to assess risks and prioritize management actions across large landscapes.
- Management tools such as Ecological Site Descriptions (ESDs) and state and transition models (STMs) give us the capacity to evaluate a sites' resilience and resistance when coupled with field surveys.

more frequent and larger wildfires. Resistance to an invasive species in general depends on (1) the climatic suitability of an area – whether or not it has the necessary soil temperature and moisture regimes for establishment, growth and reproduction of the invader, and (2) the composition and ecological condition of the native plant community – whether or not it has the capacity to effectively compete with and minimize the invader (Chambers et al. 2014a). Similar to resilience, resistance to invasive species is decreased by stressors and disturbances, especially those that decrease the ability of the native community to compete with the invader. These can include removal of sagebrush due to wildfire or insects like Aroga moth. They can also include grazing or frequent and repeated fires associated with invasive annual grasses that reduce the abundance of perennial grasses and forbs.

These species, especially deep-rooted perennial grasses such as bluebunch wheatgrass, are especially important as they typically recover after fire and are the best competitors with invasive annuals. The factors influencing resistance to invasive annual grasses are best understood for cheatgrass, the most widespread invasive annual grass in the Great Basin (Figure 1).

How can Resilience and Resistance be used to prioritize management actions at large scales?

An understanding of the relationships of environmental characteristics to vegetation types and their inherent resilience and resistance gives us the capacity to assess risks and prioritize management actions across large landscapes. We can use these relationships to evaluate how likely an area is to recover following disturbances or management treatments, and how likely it is to be invaded by annual grasses. Because resilience to disturbance and resistance to invasive annual grasses are highly correlated with soil temperature and moisture regimes, we can use these regimes to evaluate how resilience and resistance vary across landscapes and within planning areas (Chambers et al. 2014c).

For example, evaluating these regimes in relation to potential conifer removal projects

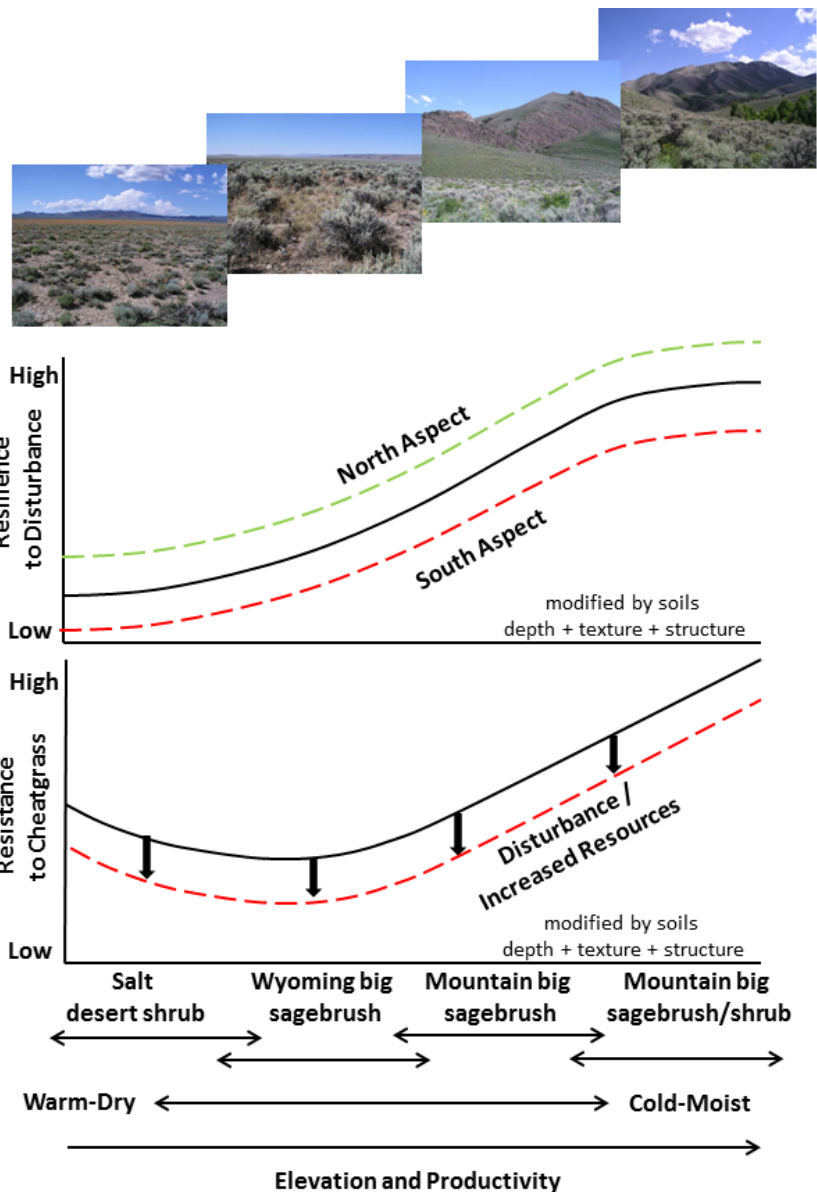


Figure 1. Resilience and resistance of the dominant vegetation types in the Great Basin. Resilience to disturbance is lowest in salt desert shrub types with warm (mesic) and dry (aridic) soils and highest in mountain big sagebrush/mountain brush types with cool (frigid) to moist (xeric) bordering on cold (cryic) soils. Resilience is often lower for soils with shallow depths or coarse textures which reduce available moisture. Low and black sagebrush are typical on these soils and are slower to recover following disturbance than neighboring sagebrush species on deeper or finer textured soils.

Resilience also tends to be lower on warmer and drier south-facing slopes. Resistance to invasive annual grass follows a pattern similar to resilience, but is lowest in Wyoming big sagebrush types with warm and dry soils and highest in mountain big sagebrush/mountain brush types with cold soils. The annual invasive grass, cheatgrass, is climatically limited in low elevation salt desert types by frequent, low precipitation years, and at high elevations by low soil temperatures, but has near optimal conditions at mid elevations with relatively moderate soil temperature and soil moisture. Disturbances that remove perennial native species, like fire or inappropriate grazing, can increase available water and nutrient resources providing cheatgrass with a competitive advantage. Adapted from Chambers et al. 2014 a, b.

provides information on the risk of annual invasives for different treatments (prescribed fire or mechanical) and whether additional weed control or seeding will be needed post-treatment (Figure 2). Soil temperature and moisture data are fundamentally important in classifying and mapping soils, are available for most areas, and can be used as the first filter for evaluating the resilience and resistance and how they vary across project areas (Maestas and Campbell 2014).

Recently, resilience and resistance to annual invasive grasses have been linked to sage-grouse habitat requirements in a decision support matrix for prioritizing management strategies to minimize persistent habitat threats such as wildfire and invasive annual grasses (Figure 3; Chambers et al. 2014c). The matrix is a tool that allows land managers to evaluate risks and decide where to focus specific activities in order to promote desired ecosystem trajectories. The overall management goal is to improve the ecological conditions of a site and increase the contiguous amount of land supporting sagebrush (a primary requirement for sage-grouse). Potential management activities include fire operations, fuels management, post-fire rehabilitation, and habitat restoration among others. These scenarios illustrate how the matrix can be used to inform decisions on various sites:

- *High to moderate resilience and resistance, high sagebrush landscape cover:* May not require intervention at the time of assessment, but should be monitored regularly to inform and adapt management.
- *High to moderate resilience and resistance, moderate to low sagebrush landscape cover:* May recover favorably following wildfire given sufficient native grasses and forbs. Management activities in these areas may focus on increasing habitat connectivity by removing conifers, or accelerating the rate of recovery after disturbance by seeding or transplanting sagebrush.
- *Low resilience and resistance, moderate to high sagebrush landscape cover:* May require active and focused protection to minimize stress and disturbance. If these areas lack adequate perennial grasses and forbs, and are at risk of conversion to invasive annual grasses, preventative activities like creation of fuel breaks and pre-positioning of firefighting resources may be needed to reduce fire size and frequency. These areas would likely require seeding after disturbances.
- *Low resilience and resistance, low sagebrush landscape cover:* May no longer have the capacity to support the desired species or may be so altered that they are lower priori-

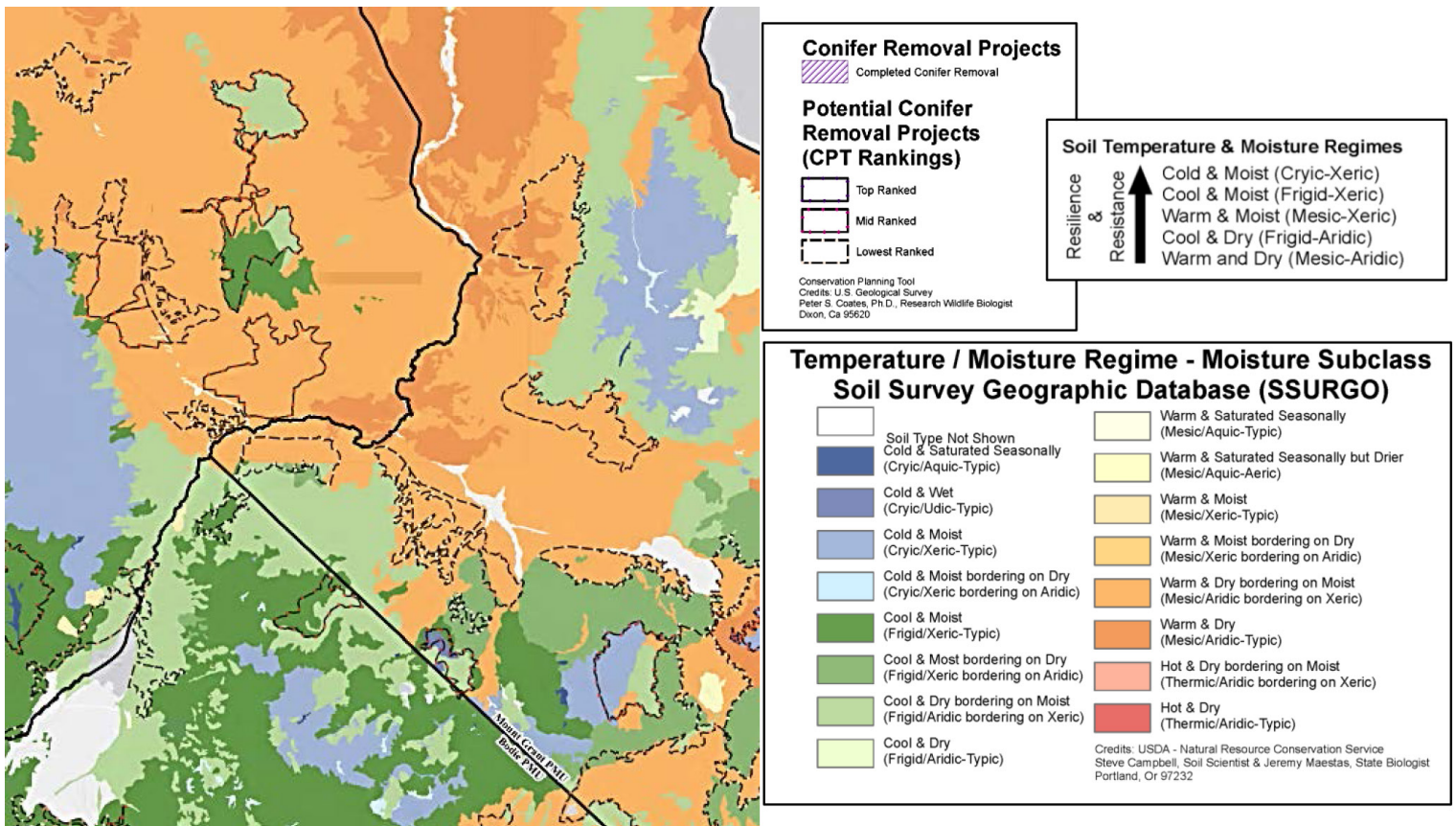


Figure 2. Soil temperature and moisture regimes and proposed conifer removal projects for the Pine Nuts Land Health Project within the planning area for the bi-state population of sage-grouse. Warm and dry areas (mesic-aridic) with low resilience and resistance recover more slowly and may require follow-up treatments to control weeds and restore native perennial species; cool and moist areas (frigid-xeric) with relatively higher resilience and resistance recover more quickly and may not require follow-up actions. All areas will require monitoring to determine management needs after treatment.

Proportion of Landscape Dominated by Sagebrush




		Low = < 25%	Medium = 25-65%	High = > 65%
Resilience & Resistance of Sagebrush Community	 <p>High</p>	<p>RESTORATION/RECOVERY POTENTIAL HIGH <i>Native grasses and forbs sufficient for recovery</i> <i>Annual invasive risk low</i></p>		
		Requires longer timeframe, enhance connectivity.	Little intervention needed, enhance connectivity.	Little-to-no intervention needed.
	 <p>Moderate</p>	<p>RESTORATION/RECOVERY POTENTIAL INTERMEDIATE <i>Native grasses and forbs usually adequate for recovery</i> <i>Annual invasive risk moderate</i> <i>Treatment success depends on site characteristics</i></p>		
	Requires longer timeframe and intervention.	Enhance connectivity, minimize risk of invasives.	Little intervention needed, minimize risk of invasives.	
 <p>Low</p>	<p>RESTORATION/RECOVERY POTENTIAL LOW <i>Native grasses and forbs inadequate for recovery</i> <i>Annual invasive risk is high</i> <i>May require multiple management interventions</i></p>			
	Recovery unlikely.	Long timeframe for recovery, high amount of intervention.	Moderate timeframe for recovery, moderate-high amount of intervention.	

Figure 3. Matrix designed to link resilience and resistance with habitat for sage-grouse. The rows provide information on the restoration/recovery potential of ecological types with relatively high, moderate, and low resilience and resistance and are illustrated here by mountain big sagebrush/mountain brush, mountain big sagebrush, and Wyoming big sagebrush, respectively. The columns provide information on the amount of time and types of intervention required to increase sagebrush cover. Sagebrush landscape cover is one of the primary indicators of sage-grouse habitat. The probability of maintaining active sage-grouse leks or breeding areas is one of our best indicators of population viability and is closely related to sagebrush landscape cover; the probability of sage-grouse persistence varies with land cover of sagebrush (low = < 25%, intermediate = 25-65%, and high = > 65%). The management objective is to move from left to right within each resilience and resistance category and increase contiguous land cover of sagebrush (adapted from Chambers et al. 2014c).

ty for allocation of limited management resources. Managers may need to restore critical habitat in these types of areas, but must recognize that substantial investment and repeated interventions may be required to achieve habitat objectives.

How can Resilience and Resistance be used to select the best management practices at site scales?

The relative resilience and resistance of a site can be used to determine if a potential project area is appropriate for specific land treatments, such as conifer removal, post-fire seeding, etc. Assessing the resilience and resistance of an area begins with determining the ecological site types, and locating the relevant ecological site descriptions (ESDs). ESDs provide much of the baseline information necessary to evaluate

changes in soil characteristics, such as temperature and moisture regimes, and vegetation attributes, like the composition and relative abundance of plant species, to evaluate the current resilience and resistance of a site. They are part of a land classification system that describes the potential of a set of climate, topographic, and soil characteristics and natural disturbances to support a dynamic set of plant communities. State-and-transition models (STMs) are a central component of ecological site descriptions that illustrate changes in plant communities and associated soil properties, causes of change, and effects of management interventions.

These models use state (a relatively stable set of plant communities that are resilient to disturbance) and transi-

tion (the drivers of change among alternative states) to describe the range in composition and function of plant communities within ESDs (Briske et al. 2008). STMs illustrate changes or transitions among states that are characterized by thresholds that may persist over time without active intervention. They also show restoration pathways that are used to identify the environmental conditions and management actions required for return to a previous state. Detailed STMs are not yet available for the entire Great Basin, but a generalized set of models has been developed that incorporate resilience and resistance and that are widely applicable to Great Basin ecosystems (Chambers et al. 2014b, c, Miller et al. 2014, 2015).

Because Great Basin ecosystems occur over a broad range of environmental conditions, and have differing land use histories and species composition, careful assessment of the project area will always be necessary to determine the appropriate management action. Factors that are used to develop STMs and to assess a site's relative resilience and resistance include various soil characteristics, current or potential vegetation, and wildfire severity or treatment impacts.

These same factors can be used to "score" a site's relative resilience and resistance and determine appropriate management actions (see Table 1; Miller et al. 2014, 2015). Generally, sites with high scores are those that are relatively cool and moist, have deep and/or fine textured soils, a high percentage of deep-rooted perennial native grasses and forbs, and little to no invasive plant species. These types of sites typically recover well after

Table 1. Factors that can be used to "score" a site's relative resilience to disturbance and resistance to invasive annual grasses and to determine appropriate management actions (adapted from Miller et al. 2014, 2015).

Site Characteristic	Explanation
Temperature	
Soil temperature regime	Estimated from soil survey data, Ecological Site Descriptions (ESDs), or elevation within each Major Land Resource Area. 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.
Species or subspecies of sagebrush	Derived from ESDs or site descriptions, but should be confirmed from site surveys. Sagebrush species and subspecies differ over elevation gradients, correspond to soil temperature and moisture regimes, and are influenced by soil depth and texture.
Effective Moisture	
Precipitation	Estimated from soil survey data, ESDs, or climate models but should be confirmed from site evaluation. Soil moisture regime can be used as an indicator of precipitation; moisture subclass level data is most appropriate at site scales.
Soil texture	Derived from soil descriptions or ESDs but should be confirmed through on-site soil pits. Loams often have a good balance between infiltration and water storage capacity; clay, sandy, or silt soils are more variable.
Soil depth	Depth to restrictive layer estimated from soil descriptions but should be confirmed through on-site soil pits. Soil depth is one of the major variables in determining water storage capacity and rooting depth.
Pre-treatment or Wildfire Vegetation (Plant Functional Groups)	
Deep-rooted perennial grasses	Derived from site surveys. The relative abundance of different plant functional groups determines site response to fire and management treatments. Resilience and resistance are highest if native grasses and forbs dominate the site. Resilience and resistance are lowest if deep-rooted perennial grasses are <2/m ² for relatively cool and moist sites and <3/m ² for relatively warm and dry sites, invasives are dominant or , woody species (shrubs or trees) are near maximum cover.
Sandberg bluegrass	
Perennial forbs	
Invasive annual grasses	
Treatment or Fire Severity	
Treatment or fire severity adjustment	Derived from site surveys. <i>Low severity treatment or fire</i> results in little mortality of perennial grasses and forbs. <i>Moderate severity treatment or fire</i> can occur in Phase I and II woodlands and high density shrublands. <i>High severity treatment or fire</i> usually occurs in Phase III woodlands.

treatment or disturbance and often do not require seeding. Sites with low scores are those with some combination of relatively warm and dry conditions, shallow soils and/or coarse textured soils, few deep-rooted perennial native grasses and forbs, and/or an abundance of invasive plant species. These sites are often slow to recover after management treatment or disturbance, and are at risk of conversion to invasive annuals.

Management treatments require careful monitoring to determine if follow-up actions such as weed control and/or seeding are needed. Post-fire rehabilitation success on these sites will be weather dependent and may require repeated interventions and substantial investment to ensure success.

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Websites

Aggregated SSURGO and STATSGO Soil Temperature and Moisture Regime data: <https://www.sciencebase.gov/catalog/folder/538e5aa9e4b09202b547e56c>

Ecological site descriptions: <http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/ecoscience/desc/>

Web soil survey: <http://websoilsurvey.sc.egov.usda.gov/>

Great Basin Factsheets are developed and produced collaboratively by the groups below. Jeanne Chambers edited the factsheets, Lael Gilbert created the design and was responsible for layout, and Nolan Preece shot the photo for the masthead, which is of Monitor Valley in central Nevada.

