

# Chapter 24: Sagebrush ecosystem resilience and resistance

## Authors:

Jeanne Chambers (Rocky Mountain Research Station, USDA Forest Service)

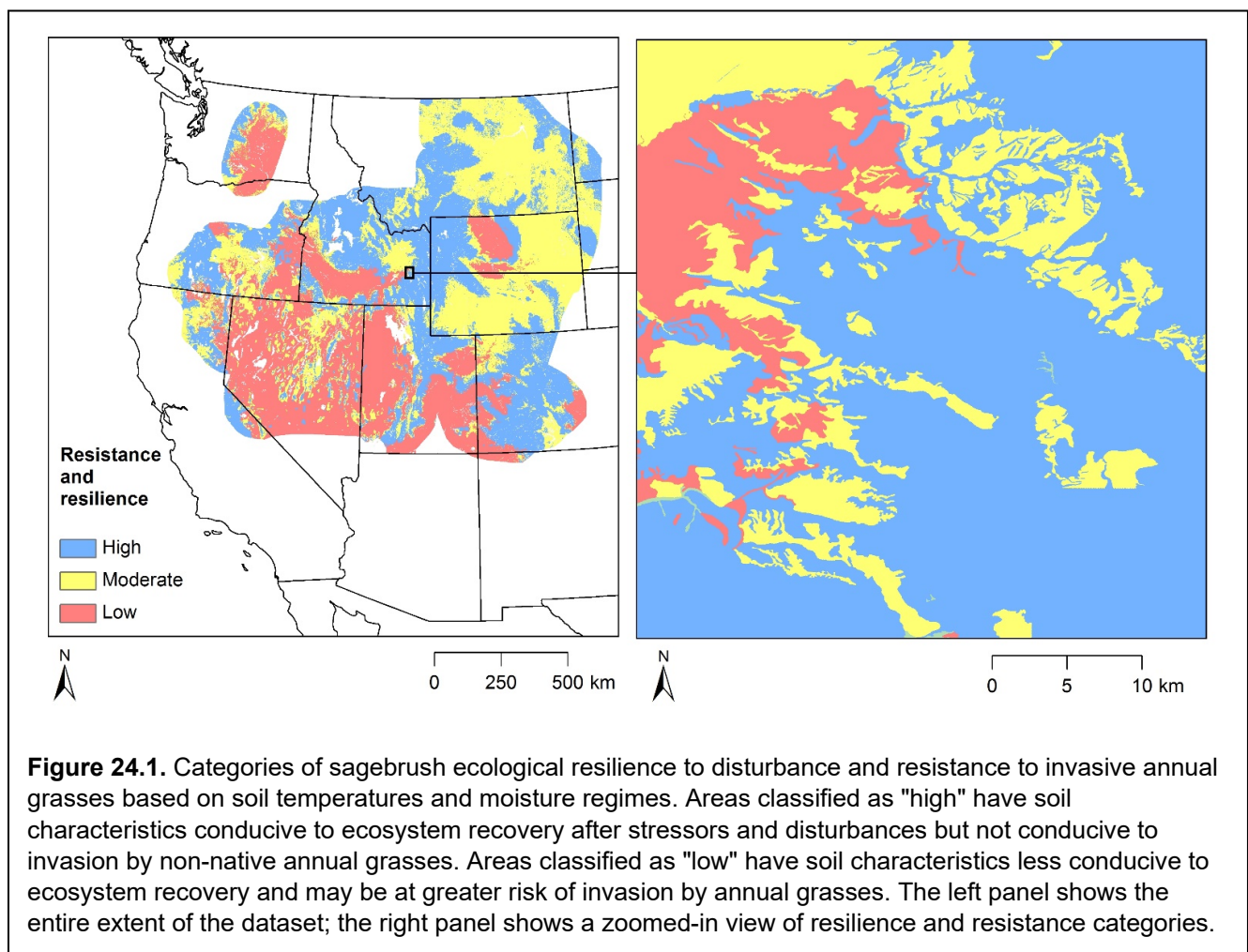
Steve Campbell (USDA Natural Resources Conservation Service)

Jeremy Maestas (USDA Natural Resources Conservation Service)

Jennifer Cartwright (U.S. Geological Survey)

## 1. Dataset overview

Emerging applications of ecological resilience and resistance concepts in sagebrush ecosystems allow managers to better predict and mitigate impacts of wildfire, invasive annual grasses, and other disturbances. Soil temperature and moisture strongly influence the kind and amount of vegetation and are closely related to sagebrush ecological resilience to disturbance and resistance to invasive annual grasses (Chambers *et al.* 2007, 2014a, 2014b). Consequently, soil taxonomic temperature and



moisture regimes can be used as indicators of resilience and resistance at landscape scales to depict environmental gradients in sagebrush ecosystems that range from cold/cool-moist sites with relatively high resilience and resistance to warm-dry **ecological types** with relatively low resilience and resistance (see chapter glossary for definitions of terms).

To facilitate broad-scale analyses of resilience and resistance across the range of sage-grouse, the dominant ecological types in the sagebrush range were identified and their **soil temperature and moisture regimes** determined. Then resilience and resistance categories were assigned to each ecological type based on available ecological site descriptions and expert knowledge (figure 24.1). Soil survey spatial and tabular data were aggregated according to soil temperature and moisture regime and moisture subclass (Maestas *et al.*, 2016). A simplified index of relative resilience and resistance was generated by assigning each soil temperature and moisture regime/moisture subclass to one of three categories (high, moderate, and low) based on the ecological site descriptions and expert input.

Soils data were derived from two primary sources available through the National Cooperative Soil Survey: (1) completed and interim soil surveys available through the Soil Survey Geographic Database (SSURGO) (Natural Resource Conservation Service, 2014a), and (2) the State Soils Geographic Database (STATSGO2) (Natural Resource Conservation Service, 2014b). The data product is a geodatabase with the dominant soil temperature regime, moisture regime, and moisture subclass of the soil map unit, and the corresponding resilience and resistance category across all sage-grouse Management Zones (Stiver *et al.*, 2006). The geodatabase also includes the dominant ecological type assigned to each soil map unit. Users are encouraged to consider the spatial scale of analyses when using the dataset and to field verify soils when planning onsite projects.

## Glossary

**Ecological resilience:** "the capacity of ecosystems to reorganize and regain their fundamental structure, processes, and functioning (i.e., to recover) when altered by stressors like drought and disturbances like inappropriate livestock grazing and altered fire regimes" (see dataset citation).

**Ecological type:** "a category of land with a distinctive (i.e., mappable) combination of landscape elements, including climate, geology, geomorphology, soils, and potential natural vegetation. Ecological types differ from each other in their ability to produce vegetation and respond to management and natural disturbances" (see dataset citation).

**Resistance to invasive annual grasses:** "the capacity of ecosystems to limit the establishment and population growth of the invader" (see dataset citation).

**Soil temperature and moisture regimes:** "soil temperature regimes are defined by the mean annual soil temperature at a depth of 20 inches, and seasonal fluctuations from the mean. Soil moisture regimes are defined by the length of time plant-available moisture is present during the growing season" (see dataset citation).

*For detailed information about these terms, please consult the dataset citation in section 2.*

## **2. Data access information**

### **Dataset citation:**

Maestas, D., S. Campbell, J. C. Chambers, M. Pellant, and R. Miller. 2016. Tapping soil survey information for rapid assessment of sagebrush ecosystem resilience and resistance. *Rangelands* 38: 120-128.

Chambers, J. C., J. D. Maestas, D. A. Pyke, C. S. Boyd, J. C. Chambers, J. D. Maestas, D. A. Pyke, C. S. Boyd, M. Pellant, and A. Wuenschel. 2017. Using resilience and resistance concepts to manage persistent threats to sagebrush ecosystems and greater sage-grouse. *Rangeland Ecology and Management* 70:149–164.

Chambers, J.C., J.L. Beck, J.B. Bradford, J. Bybee, S. Campbell, J. Carlson, T.J. Christiansen, K.J. Clause, G. Collins, M.R. Crist, J.B. Dinkins, K.E. Doherty, F. Edwards, S. Espinosa, K.A. Griffin, P. Griffin, J.R. Haas, S.E. Hanser, D.W. Havlina, K.F. Henke, J.D. Hennig, L.A. Joyce, F.M. Kilkenny, S.M. Kulpa, L.L. Kurth, J.D. Maestas, M. Manning, K.E. Mayer, B.A. Meador, C. McCarthy, M. Pellant, M.A. Perea, K.L. Prentice, D.A. Pyke, L.A. Wiechman, and A. Wuenschel. 2017. Science framework for conservation and restoration of the sagebrush biome: Linking the Department of the Interior's Integrated Rangeland Fire Management Strategy to long-term strategic conservation actions. Gen. Tech. Rep. RMRS-GTR-360. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 213 p.

### **Dataset documentation links:**

<https://doi.org/10.1016/j.rala.2016.02.002>

(open access)

<https://doi.org/10.1016/j.rama.2016.08.005>

(subscription or fee required)

<https://www.treeseearch.fs.fed.us/pubs/53983>

(open access)

### **Data access:**

The dataset can be downloaded from:

<https://www.sciencebase.gov/catalog/item/55229c34e4b027f0aee3cfa5>

The dataset can be viewed online at:

[https://map.sagegrouseinitiative.com/ecosystem/collapse?ll=43.4799,-110.7624&overlay=mesc\\_average&opacity=0.80&z=6&basemap=roadmap](https://map.sagegrouseinitiative.com/ecosystem/collapse?ll=43.4799,-110.7624&overlay=mesc_average&opacity=0.80&z=6&basemap=roadmap)

**Metadata access:**

Metadata are available from:

<https://www.sciencebase.gov/catalog/item/55229c34e4b027f0aee3cfa5?community=LC+MAP+-+Landscape+Conservation+Management+and+Analysis+Portal>

**Dataset corresponding authors:**

Steve Campbell  
USDA National Resources Conservation Service  
[Steve.Campbell@por.usda.gov](mailto:Steve.Campbell@por.usda.gov)

Jeanne Chambers  
USDA Forest Service  
[jchambers@fs.fed.us](mailto:jchambers@fs.fed.us)

Jeremy Maestas  
USDA Natural Resources Conservation Service  
[Jeremy.Maestas@por.usda.gov](mailto:Jeremy.Maestas@por.usda.gov)

**3. Conceptual information****Data type category (as defined in the Introduction to this guidebook):**

Topoedaphic

**Species or ecosystems represented:**

This dataset represents sagebrush ecosystems and greater sage-grouse management zones (Stiver *et al.* 2006).

**Units of mapped values:**

categorical

**Range of mapped values:**

**Ecological resilience** and **resistance to invasive annual grass** values are classified as "high", "moderate", or "low".

**4. Spatial information**

**Spatial data type:** a raster dataset (grid)

**Data file format(s):** Esri file

**Spatial resolution:** 10 m

**Geographic coordinate system:**

North American Datum of 1983

**Projected coordinate system:**

North American Datum of 1983 USA Contiguous Albers Equal Area Conic

**Spatial extent:**

Regional

**Dataset truncation:**

The dataset is truncated along the border between the United States and Canada and the greater sage-grouse management zones for the United States (Stiver *et al.* 2006).

## **5. Temporal information**

**Time period represented:** Static (relatively unchanging over time)

## **6. Methods information**

**Methods overview:**

The data product is a geodatabase with the dominant soil temperature regime, moisture regime, and moisture subclass of the soil map unit (Campbell, 2016), and the corresponding resilience and resistance category, across all sage-grouse management zones (Stiver *et al.*, 2006). The geodatabase also includes the dominant ecological type assigned to each soil map unit. Data on soil temperature and moisture regimes were derived from two sources: (1) completed and interim soil surveys available through the Soil Survey Geographic Database (SSURGO), and (2) the State Soils Geographic Database (STATSGO2) to fill gaps where SSURGO data were not available.

The dataset was produced by first identifying the dominant ecological types in the sagebrush range and then determining their soil temperature and moisture regime from the corresponding SSURGO and STATSGO2 soil map unit component data. In the western portion of the range (Columbia Plateau, Snake River Plain, Northern Basin and Range, Central Basin and Range), 12 ecological types were identified, and their soil temperature and moisture subclasses determined based on available ecological site descriptions, expert knowledge, and data from the USDA, Natural Resources and Conservation Service, National Soils Information System (NASIS; Maestas *et al.*, 2016). In the eastern portion of the range (Northwestern Glaciated

Plains, Northwestern Great Plains, Wyoming Basin, Colorado Plateau, Southern Rockies) representative ecological site descriptions were organized by soil temperature and moisture subclasses and used to identify the dominant ecological types. Twenty ecological types were identified, and their soil temperature and moisture regime subclasses determined based on the ecological site descriptions, data from NASIS, and expert input (Chambers *et al.*, 2017a). For both portions of the range, the ecological types and soil temperature and moisture regime subclasses were categorized according to their relative ecological resilience and resistance to invasive annual grasses based on recent research (Chambers *et al.*, 2007, 2014a, 2014b) and expert knowledge.

To facilitate broad-scale analyses of resilience and resistance across the range of greater sage-grouse, simplified categories of relative resilience and resistance (high, moderate, and low) were assigned to each ecological type and their associated soil temperature and moisture regime. Data for soil map unit components were aggregated to identify the dominant soil temperature regime, moisture regime, and moisture subclass for each soil map unit. The soil map units were then assigned one of the three resilience and resistance categories. For regional analyses that consider the ecological types, a specific set of soil temperature and moisture regimes can be used (see table 6 in Chambers *et al.*, 2017a). Soils with high water tables, wetlands, frequent ponding, or uncommon regimes that would not typically support sagebrush can be excluded from the dataset.

#### **Major input data sources for this dataset included:**

Soil characteristics

Specific input data sources were:

Soil Survey Geographic Data (SSURGO) (Natural Resource Conservation Service, 2014a)  
State Soils Geographic Data (STATSGO2) (Natural Resource Conservation Service, 2014b)  
Published Ecological Site Descriptions from the Ecological Site Information System (Natural Resources Conservation Service, 2012)

Unpublished Ecological Site Descriptions for the State of Nevada (Patti Novak, NRCS, personal communication)

#### **7. Guidelines for interpretation**

##### **The mapped values of the dataset may be interpreted as follows:**

Areas classified as "high resilience and resistance" in this dataset are considered to have soil characteristics (e.g., cool to cold and wet to moist soil conditions) that are conducive to ecosystem recovery after stressors and disturbances, but not conducive to invasion and population growth of invasive annual grasses. Stressors and disturbances include persistent ecosystem threats, such as nonnative plant invasions, altered fire regimes, conifer expansion, and climate change, and land use and development threats, such as energy development, conversion to cropland, livestock grazing, mining, and urban, suburban, and exurban development. Areas classified as "low resilience and resistance" are considered to have soil characteristics (e.g., warm and moist to dry) that are less conducive to ecosystem recovery after

stressors and disturbances and may be at greater risk of conversion to alternative states (e.g., conversion of sagebrush-perennial grass systems to invasive annual grass systems).

### **Representations of key concepts in climate-change ecology:**

This dataset uses soil temperature and moisture regimes as foundational layers for defining categories of ecological resilience to disturbance and resistance to invasion. Because soil temperature and moisture regimes are integrative indicators of long-term climatic conditions, they are increasingly used to assess ecological vulnerability and adaptive capacity. A process-based, ecosystem water-balance model was recently used to characterize current and future patterns in soil temperature and moisture conditions in dryland ecosystems across the western United States (Bradford *et al.*, 2019). Results indicate soil temperature increases in the 21<sup>st</sup> century that are substantial, relatively uniform geographically, and robust across climate models. Higher temperatures will expand the areas of warm and hot soil temperature regimes while decreasing the area of cold and cool temperature conditions. Despite large geographic variability in precipitation projections, and variation among climate models, future soil moisture conditions are relatively consistent across climate models. Many areas dominated by big sagebrush, particularly the Central and Northern Basin and Range and the Wyoming Basin ecoregions, have projections of increasing soil moisture. Also, many areas dominated by big sagebrush are expected to experience pronounced shifts toward cool season moisture, and thus more area with winter moist and less area with summer moist conditions. These results imply widespread geographic shifts in the distribution of resilience and resistance categories and provide a quantitative framework for assessing climate-change impacts on the responses of these ecosystems to stress and disturbance and the likelihood of invasion.

### **8. Uncertainties**

#### **This dataset involves the following assumptions, simplifications, and caveats:**

This dataset represents soil conditions based on information from the SSURGO and STATSGO databases (Maestas *et al.*, 2016). Although soil temperature and moisture regimes are closely aligned with the relative resilience and resistance of ecological types, other factors that may influence resilience and resistance, such as vegetation condition or presence of invasive plant species, are not represented.

These data are intended to be used at regional/landscape scales and other data and assessments are available for evaluating resilience and resistance at project and site scales. As with most large-scale mapping products, there are limitations in using Soil Survey information, including incongruities in soil regime classifications, especially along mapping boundaries, and variation in the level of survey detail available. Until improved products emerge, the Soil Survey still provides the most complete dataset to advance understanding of resilience and resistance.

## **Quantification of uncertainty:**

This dataset does not include any quantification of uncertainty relating to the mapped values.

## **Field verification:**

The dataset serves as one of the map layers for a Fire and Invasives Assessment Tool (FIAT), viewable at <https://landscape.blm.gov/geoportal/catalog/FIAT/FIAT.page>. FIAT was used successfully by the Bureau of Land Management (BLM) in the Snake River Plain, Northern Great Basin, and Central Great Basin to evaluate relative resilience and resistance as indicated by soil temperature and moisture regimes, habitat suitability for greater sage-grouse as indicated by land cover of sagebrush, and the primary threats (invasive annual grasses or conifer expansion depending on the area). The resilience-and-resistance layer was key to understanding potential for areas on the landscape to recover from wildfires and management treatments and prioritizing areas for conservation and restoration actions.

The dataset was also field tested in a series of field workshops sponsored by the Sage-Grouse Initiative and the Joint Fire Sciences Program, Fire Science Exchange. The map layers on relative resilience and resistance as indicated by soil temperature and moisture regimes helped to accurately identify the locations of different sagebrush ecological types. The map layers were also indicative of the capacity to resist invasive annual grasses and recover following wildfires.

## **9. Peer review**

The National Cooperative Soil Survey has policy in place in the National Soil Survey Handbook (National Resources Conservation Service, 2019) for providing quality control and quality assurance for soil survey data products. See Part 609 of the National Soil Survey Handbook at the link below:

<https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=41523.wba>

All publications that describe the use of the dataset have received external peer review (at least three anonymous reviewers from different institutions).

## **10. Conservation applications**

### **Potential conservation applications of this dataset could include the following:**

Geospatial data on the resilience and resistance of ecosystems enables managers to: (1) evaluate differences in ecosystem responses to disturbance and their recovery potentials across landscapes; (2) identify locations where systems may exhibit critical transitions to alternative states in response to altered climate or other drivers; and (3) determine where conservation and restoration investments will have the greatest benefits. These data can be used in a risk-based framework along with data on high-value resources, such as greater sage-



grouse populations (Doherty *et al.*, 2016), and ecosystem threats, such as the probability of large wildfires (Short *et al.*, 2016), to inform strategic management investments at regional scales and determine appropriate management strategies at local scales (Chambers *et al.*, 2017a, 2019 a and b; Crist *et al.*, 2019). For example, landscapes with relatively low resilience and resistance and high wildfire risk that support large populations of greater sage-grouse may be priorities for fuels reduction and fire suppression because these areas recover more slowly following disturbance and are less resistant to invasive annual grasses.

#### **Applicable scales for detailed spatial assessments:**

For conservation applications requiring detailed assessment of spatial variation of the dataset within a geographic boundary (such as a protected area), the following geographic scales may be most appropriate (see appendix 3 for more information).

The categorized dataset is intended for use at the scale of large landscapes, such as one or more Level III U.S. Environmental Protection Agency (EPA) ecoregions or Sage-grouse Management Zones (there are seven Management Zones across the western United States, each spanning the boundaries of two or more states). The dataset can also be used at the scale of a single state (Washington, Oregon, or Idaho) or at a regional scale (multiple states in the Pacific Northwest or in western North America). The entire dataset of soil temperature and moisture regimes provides greater detail, can be related to specific sets of ecological types, and can be used at smaller project scales (hundreds to thousands of hectares).

#### **Use of the dataset in conservation applications may be limited by the following considerations:**

This dataset represents resilience and resistance to invasive annual grasses based primarily on soil indicators and does not represent other potential factors influencing resilience and resistance, which could include disturbance history, vegetation cover and type, and projected changes in climate conditions. Thus, use of this dataset in conservation applications can be supplemented with additional datasets representing these other considerations.

#### **Past or current conservation applications:**

### **Conservation case study**

U.S. Federal land management and natural resource agencies including the BLM and the USDA Forest Service are using the dataset in a risk-based framework for prioritizing sage-grouse conservation resources at national and regional scales and for developing more ecologically effective wildland fire operations, postfire rehabilitation, fuels management, and habitat restoration strategies (Chambers *et al.*, 2017b). Recently, the risk-based framework has been used by the BLM to develop a multi-year program of work for conservation and restoration actions in the Great Basin (part or all of the Snake River Plain, Northern Great Basin, Central Great Basin).

The data have been used by the USDA Forest Service to develop their own risk assessment that evaluates key threats to all greater sage-grouse habitat in Forest Service Region 4, on lands managed by the Forest Service and for the region as a whole. The Forest Service is using this risk assessment to inform management decisions related to sagebrush ecosystems.

*For more information on this conservation case study, please contact the corresponding author listed in section 2.*

## **References cited**

- Bradford, J.A., Shlaepfer, D.R., Lauenroth, W.K., Palmquist, K.A., Chambers, J.C., Maestas, J.D., Campbell, S.B. 2019. Climate-driven shifts in soil temperature and moisture regimes suggest opportunities to enhance assessments of dryland resilience and resistance. *Frontiers in Ecology and Evolution*. <https://doi.org/10.3389/fevo.2019.00358>.
- Campbell, S. 2016. Soil temperature and moisture regimes across sage-grouse range. <https://www.sciencebase.gov/catalog/item/538e5aa9e4b09202b547e56c>. USDA Natural Resources Conservation Service, Portland, OR
- Chambers, J.C, Allen, C.R., Cushman, S.A. 2019a. Operationalizing ecological resilience concepts for managing species and ecosystems at risk. *Frontiers in Ecology and Evolution*. 7:241.doi: 10.3389/fevo.2019.00241
- Chambers, J.C., Brooks, M.L., Germino, M.J., Maestas, J.D., Board, D.I., Jones, M.O., Allred, B.W. 2019b. Operationalizing resilience and resistance concepts to address invasive grass-fire cycles. *Frontiers in Ecology and Evolution*. 7:185. Online: doi: 10.3389/fevo.2019.00185.
- Chambers, J.C., J.L. Beck, J.B. Bradford, J. Bybee, S. Campbell, J. Carlson, T.J. Christiansen, K.J. Clause, G. Collins, M.R. Crist, J.B. Dinkins, K.E. Doherty, F. Edwards, S. Espinosa, K.A. Griffin, P. Griffin, J.R. Haas, S.E. Hanser, D.W. Havlina, K.F. Henke, J.D. Hennig, L.A. Joyce, F.M. Kilkenny, S.M. Kulpa, L.L. Kurth, J.D. Maestas, M. Manning, K.E. Mayer, B.A. Meador, C. McCarthy, M. Pellant, M.A. Perea, K.L. Prentice, D.A. Pyke, L.A. Wiechman, and A. Wuenschel. 2017a. Science framework for conservation and restoration of the sagebrush biome: Linking the Department of the Interior's Integrated Rangeland Fire Management Strategy to long-term strategic conservation actions. Gen. Tech. Rep. RMRS-GTR-360. Fort Collins, CO: U.S Department of Agriculture, Forest Service, Rocky Mountain Research Station. 213 p.
- Chambers, J. C., J. D. Maestas, D. A. Pyke, C. S. Boyd, J. C. Chambers, J. D. Maestas, D. A. Pyke, C. S. Boyd, M. Pellant, and A. Wuenschel. 2017b. Using resilience and resistance concepts to manage persistent threats to sagebrush ecosystems and Greater Sage-grouse. *Rangeland Ecology and Management* 70:149–164.
- Chambers, J. C., B. A. Bradley, C. S. Brown, C. D. Antonio, M. J. Germino, J. B. Grace, S. P. Hardegree, R. F. Miller, and D. A. Pyke. 2014a. Resilience to stress and disturbance, and resistance to *Bromus tectorum* L. invasion in cold desert shrublands of western North America. *Ecosystems* 17:360–375.
- Chambers, J. C., R. F. Miller, D. I. Board, D. A. Pyke, B. A. Roundy, J. B. Grace, E. W. Schupp, and R. J. Tausch. 2014b. Resilience and resistance of sagebrush ecosystems: implications for state and transition models and management treatments. *Rangeland Ecology and Management* 67:440–454.
- Chambers, J., B. Roundy, R. Blank, S. Meyer, and A. Whittaker. 2007. What makes Great Basin sagebrush ecosystems invulnerable by *Bromus Tectorum*? *Ecological Monographs* 77:117–145.

- Crist, M.R, Chambers, J.C., Phillips, S.L., Prentice, K.L., Wiechman, L.A., eds. 2019. Science framework for conservation and restoration of the sagebrush biome: Linking the Department of the Interior's Integrated Rangeland Fire Management Strategy to long-term strategic conservation actions. Part 2. Management applications. Gen. Tech. Rep. RMRS-GTR-389. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 237 p.
- Doherty, K. E., J. S. Evans, P. S. Coates, L. M. Juliusson, and B. C. Fedy. 2016. Importance of regional variation in conservation planning: a rangewide example of the Greater Sage-Grouse. *Ecosphere* 7:e01462.
- Maestas, B. J. D., S. B. Campbell, J. C. Chambers, M. Pellant, and R. F. Miller. 2016. Tapping soil survey information for rapid assessment of sagebrush ecosystem resilience and resistance. *Rangelands* 38:120–128.
- Natural Resources Conservation Service. 2012. Ecological Site Information System (ESIS). <https://esis.sc.egov.usda.gov/About.aspx>
- Natural Resource Conservation Service. 2014a. Soil Survey Geographic (SSURGO) Database. <http://sdmdataaccess.nrcs.usda.gov/>
- Natural Resource Conservation Service. 2014b. U.S. General Soil Map (STATSGO2) Database. <http://sdmdataaccess.nrcs.usda.gov/>
- Natural Resources Conservation Service. 2019. National Soil Survey Handbook, Title 430-VI. [http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/ref/?cid=nrcs142p2\\_054242](http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/ref/?cid=nrcs142p2_054242)
- Short, K. C., M. A. Finney, J. H. Scott, *et al.* 2016. Spatial dataset of probabilistic wildfire risk components for the conterminous United States. U.S. Department of Agriculture, USDA Forest Service Research Data Archive, Fort Collins, CO. <https://doi.org/10.2737/RDS-2016-0034>.
- Stiver, S., A. Apa, J. Bohne, S. Bunnell, P. Deibert, S. Gardner, M. Hilliard, C. McCarthy, and M. Schroeder. 2006. Greater Sage-grouse comprehensive conservation strategy. Western Association of Fish and Wildlife Agencies, Cheyenne, WY.