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Managing Big Sagebrush in a Changing Climate

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This publication identifies areas where big sagebrush populations are most and least vulnerable to climate change and demonstrates where continued investment in sagebrush conservation and restoration could have the most impact.

Key Points:

- Many plant and animal species dependent on sagebrush ecosystems are declining and / or endangered.
- About 50% of the original distribution of sagebrush has been lost.
- Research suggests climate change will negatively impact big sagebrush in the hottest portions of its current range but that climate change will have weak or even positive effects in cooler regions.
- Concerns about climate change should not preclude investments in sagebrush conservation and restoration.
- In cooler areas, land management should focus on indirect threats to sagebrush habitat, such as cheatgrass and fire frequency.
- In hotter areas, land managers should focus on protecting sites with cooler or wetter microclimates where big sagebrush is more likely to thrive.

Sagebrush currently covers 120 million acres across 14 western states and three Canadian provinces, providing habitat for 357 vertebrate species and many more plants and invertebrates. (See Figure 1.)

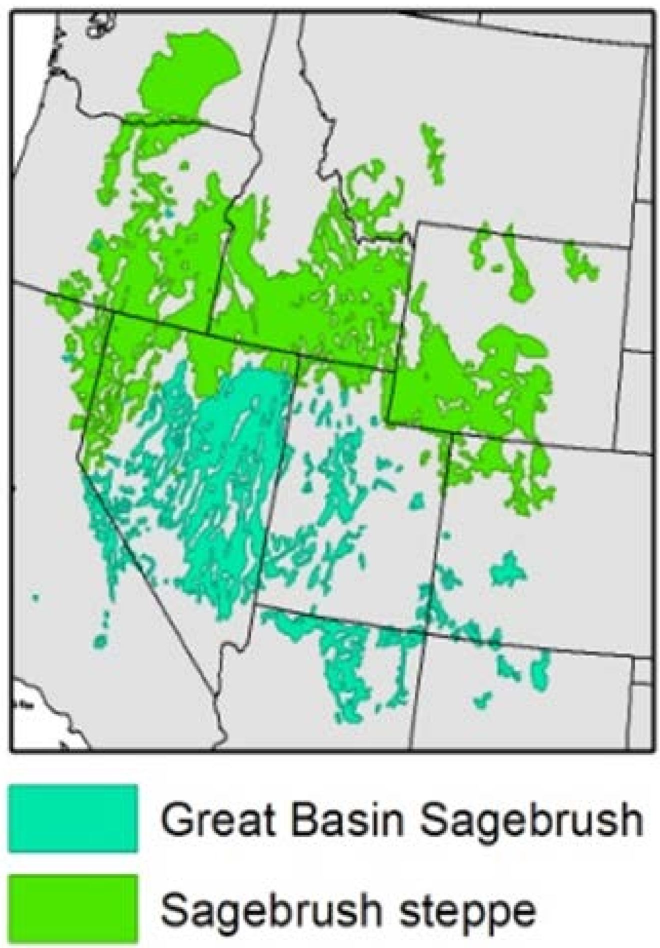

Figure 1. Distribution of sagebrush-dominated potential vegetation in the United States. Adapted from Kuchler, A. W. 1964. Potential Natural Vegetation of the Conterminous United States. American Geographical Society.

Wildlife species such as greater sage grouse *(Centrocercus urophasianus)* and Gunnison sage-grouse (*Centrocercus minimus)*, pygmy rabbits (*Brachylagus idahoensis*), sage-thrashers *Oreoscoptes montanus*), mule deer (*Odocoileus hemionus)* and pronghorn (*Antilocapra americana*) depend heavily on sagebrush habitats through parts or all of their life history.

Sagebrush ecosystems also provide opportunities for recreation, including hiking, hunting and fishing. Local economies depend quite heavily on the income that comes through these recreational services.

Sagebrush ecosystems have been used for livestock grazing, oil and gas development and mineral extraction. About 50% of the original distribution of sagebrush has been lost due to conversion to agricultural production or development, or has been degraded by invasive annual plants, altered fire regimes and other anthropogenic disturbances.

Populations of many sagebrush-dependent species are declining, triggering petitions to the U.S. Fish and Wildlife Service (USFWS) to list both species of sage-grouse and pygmy rabbits for protection under the Endangered Species Act (ESA) .Gunnison sage-grouse was listed as threatened under the ESA in 2010 (USFWS 2010. However, in 2015, the USFWS found the listing of the greater sage-grouse to be unwarranted (USFWS 2015), in large part because of an unprecedented, coordinated, $1 billion effort by private landowners and federal and state land management agencies to restore and conserve sage-grouse habitat. Because many other sagebrush-obligate species are identified as species of conservation concern in state Wildlife Action Plans, the emphasis of research and management has shifted from sagebrush eradication to restoration and conservation.

Climate Change Impacts

Climate change casts uncertainty over sagebrush conservation and restoration efforts and may also alter how historic land-use practices affect sagebrush communities. Given predicted changes, which species and subspecies of sagebrush will decline, persist or even thrive? Where are management efforts likely to achieve benefits over the long-term? Using “best available science” is a key principle of national efforts to prepare for the impacts of climate change, including policy specific to land management agencies (e.g., Executive Order 13653, DOI Climate Adaptation Plan, USFS National Roadmap for Responding to Climate Change).

Figure 2. Many wildlife species, including the greater sage grouse, have nearly complete reliance on sagebrush. These animals cannot survive in areas where sagebrush does not exist. Photo by Stephen Ting, Fish and Wildlife Service. Public domain.

Research to predict sagebrush responses to changing climate could resolve some of this uncertainty by identifying areas where climate change poses the greatest threat to sagebrush and the many species and ecosystem services that depend on it. This kind of climate change vulnerability analysis can also help decision makers prioritize areas for restoration, conservation and mitigation, and ensure efficient budget allocations.

To investigate the question of how big sagebrush (*Artemisia tridentata*) populations will respond to changes in temperature and precipitation within the species’ current range, researchers compared predictions from four independent climate models. Three of these models considered the direct effect of changes in precipitation and temperature on big sagebrush; the fourth included the potential for indirect effects such as competition with other plant species or changes in the fire regime. (See more details about the models on last page.)

Modeling Results

Despite considerable variation in predicted changes among models and climate projections, consistent patterns in the predictions emerged. Ignoring potential changes in fire and invasive species, all four models predicted that big sagebrush would respond positively to climate change at the coldest locations in the region but was more likely to respond negatively at the warmest sites.

These negative responses were confined to fairly small geographic areas, primarily hot deserts to the south and sites receiving very little summer precipitation east of the Sierra Nevada (Fig. 3). Across much of the range of sagebrush, the models consistently projected negligible or positive responses to climate change. Agreement among the four models was relatively high; the models achieved consensus on the direction of change for 83 percent of sites.

Almost all of the sites where the models predicted a negative or uncertain response to climate change were located in areas where big sagebrush has low resistance and resilience to invasion and fire. The models projected positive effects of climate change on big sagebrush performance at the overwhelming majority of sites where big sagebrush showed moderate or high resistance and resilience.

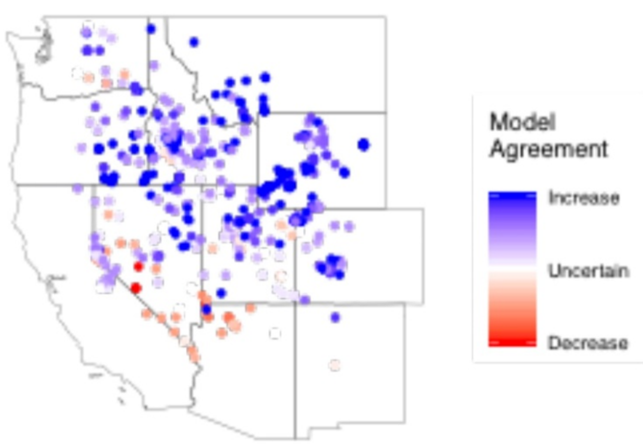

Figure 3. Map of predicted vulnerability to climate change. Red indicates high confidence that performance will decrease, blue indicates high confidence that performance will increase.

Management Implications

Across much of the current range of big sagebrush, the model comparison suggested that climate change will have negligible to positive impacts on sagebrush communities. Particularly in cooler portions of the study region, climate change appeared unlikely to harm big sagebrush directly, meaning that concerns about climate change impacts should not preclude investments in big sagebrush conservation and restoration. Within these areas, land management should continue to focus on other threats to sagebrush habitat, some of which could be exacerbated by warming climates.

In the hotter areas, where the models predicted negative impacts of climate change on sagebrush—some of which have low resistance and resilience to invasions and fire—management should focus on protecting sites with cooler and wetter micro-climates where big sagebrush is more likely to persist. Efforts to promote big sagebrush seedling establishment and stand resiliency to disturbances may become increasingly difficult under climate change.

Research Parameters

The study only evaluated climate change impacts on big sagebrush within its current range; not the expansion of big sagebrush into new areas, such as montane forests or prairies.

Additionally, the study only focused on a single species—big sagebrush—not the three *A. tridentata* sub-species, nor understory species such as forbs.

Lastly, the study did not evaluate how climate change could impact cheatgrass or the probability of fire within sagebrush communities. Both could offset or overwhelm the generally positive impacts of climate change that the models predict.

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About the Models Used for This Research

Predicting climate change impacts on sagebrush ecosystems requires the use of models that typically rely on spatial, temporal or mechanistic information.

Spatial correlations capture landscape or regional-scale relationships between average climate and an ecological response, such as the presence or abundance of a focal species. Advantages of a spatial correlation approach include coverage of a broad spatial scale, readily available spatial data for many species, and the fact that both abiotic and biotic processes are implicit in the statistical relationships. Disadvantages include the assumption that average climate conditions are the primary driver of the species distribution and abundance, failure to consider indirect effects of changes in biotic interactions or disturbance regimes, and a lack of dynamic processes, which means that projections have no associated time scale.

Temporal correlations capture relationships between short-term natural or experimental variation in weather and an ecological response. This approach is most commonly used in population models fit to data from just one site, but it is possible to use long-term data sets from multiple sites. While temporal correlations have the advantage of focusing on the dynamic processes that drive change, they assume responses to short-term weather fluctuations can be extrapolated over longer time scales, ignoring the potential for adaption, and, like spatial correlations, may not consider biotic interactions or altered disturbance regimes.

Finally, mechanistic models use detailed mathematical descriptions of known physical relationships and biological processes to predict an ecological response. An advantage of mechanistic models is that predictions for novel environmental conditions do not depend on statistical extrapolation. A disadvantage is that mechanistic models may ignore poorly understood processes, such as nutrient uptake, and they typically require information on many parameters, increasing uncertainty in overall predictions.

Without a formal validation of model predictions, which is extremely difficult in the context of climate change, we cannot determine which of these approaches makes the most accurate and precise predictions. However, we can take advantage of their complementary strengths. The stronger the agreement among individual models based on distinct and independent sources of information, the greater confidence we can have in predictions of the effects of climate change on sagebrush ecosystems. Conversely, low model agreement reveals uncertainty.

A focus on model comparison and agreement will not only help researchers identify key uncertainties and paths to improved predictions, but will be extremely valuable to the decision-makers responsible for long-term conservation and restoration planning.

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