

# Landscape Conservation Forecasting™ for the Indian Peak Range, Pine Valley, and Mountain Home Range Project

Report to the Utah Division of Wildlife Resources in partial fulfillment of contract No. 191715  
and to the Bureau of Land Management, Cedar City Field Office in partial fulfillment of  
Cooperative Agreement No. L16AC00162



*Clockwise from top-left: Indian Peak seen from Pine Valley seeding; Juniper old growth in central Pine Valley; Wet Meadow in Indian Peak Wildlife Management Area; looking south on east slope of Indian Peak Range from Wildlife Management Area.*

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## Executive Summary

Project objectives were to: (a) complete mapping of ecological systems and current vegetation classes in the Greater Indian Peak Mapping Area, encompassing the Indian Peaks Wildlife Management Area (IP WMA), BLM land, and widely scattered state school trust lands (SITLA) and private inholdings; (b) append the newly mapped vegetation to the 2017 Pine Valley-Mountain Home vegetation map; and (c) forecast the effects of the same six combined management and climate scenarios using state-and-transition vegetation computer simulations as in the Pine Valley-Mountain Home project for CCFO, but updated to include the IP WMA, SITLA land, private land, and additional BLM CCFO land.

### Mapping the Greater Indian Peak Project Area

About 77,000 acres of newly mapped vegetation was added to the previously mapped 232,000-acre Pine Valley-Mountain Home project area. The added area's ownership was dominated in decreasing order by BLM, SITLA, IP WMA, and private lands. Updated map products that seamlessly stitched together the Greater Indian Peak Project and Pine Valley-Mountain Home Project areas were delivered to the UDWR and BLM in June 2020.

- A total area of 308,927 acres were mapped in the original 2017 and additional 2019 remote sensing effort.
- Land managed by the BLM, UT Department of Natural Resources (IP WMA), private landowners, and SITLA, respectively, represented 86%, 3%, 3%, and 9% of the land area of the entire landscape.
- Of the 27 ecological systems found in the entire project area – not counting other land cover types such as barren, roads, developed, and water – the most abundant on both BLM lands and the entire landscape are (in decreasing order) black sagebrush, Wyoming big sagebrush-upland, montane sagebrush steppe, pinyon-juniper woodland, and winterfat.
- The vegetation in the newly-mapped area was the same as in the Pine Valley-Mountain Home project area, except that dry wet meadows were prominent enough in the new geography to merit a new description and model. Dry wet meadows were found in the Pine Valley-Mountain Home area in small amounts, mostly as the outside concentric edge of wet meadows, but not as a stand-alone system. Other noteworthy observations were as follows:
  - A large area of potentially ancient pinyon-juniper woodland, dominated by Utah juniper and with healthy understory, was found on shallow slopes just west of the Pine Valley Road and south of Indian Creek. This exceptional large stand deserves a dendrochronological assessment.
  - Moist systems such as wet meadows, dry wet meadows, Utah serviceberry, aspen woodland, and aspen-mixed conifer were disproportionately more abundant on private lands. Montane riparian systems were disproportionately more abundant in the IP WMA, and secondly on private lands.

## Initial Conditions

### Ecological Systems

- Nineteen of 27 ecological systems (70%) were highly departed from desired future conditions based on Unified Ecological Departure in 2017 and 2019.
- Only juniper savanna and low sagebrush were lightly departed from desired future conditions.
- Systems moderately departed from desired future conditions were curl-leaf mountain mahogany, little-leaf mountain mahogany, mixed conifer, pinyon-juniper woodland, ponderosa pine and Stansbury cliffrose.
- The following thirteen focal systems were selected for management: aspen woodland, black sagebrush, calcareous grassland, dry wet meadow, montane riparian, montane sagebrush steppe, pinyon-juniper woodland, ponderosa pine, semi-desert grassland, Stansbury cliffrose, Utah serviceberry, wet meadow-montane, and Wyoming big sagebrush upland. While all thirteen focal systems were simulated, in this report we did not report on four of them: calcareous grassland, pinyon-juniper woodland, semi-desert grassland, and Stansbury cliffrose. Management actions for these four systems did not change from the previous report, because they: (1) were only or mostly found in the original Pine Valley-Mountain Home project area, and treatment rates did not change (calcareous grassland, semi-desert grassland); (2) had very small area (Stansbury cliffrose); or (3) involved low implementation rates to achieve a very specific goal (pinyon-juniper woodland).
- Among the focal management systems, three were moderately departed from desired future conditions (pinyon-juniper woodland, ponderosa pine and Stansbury cliffrose), while the remainder were highly departed from desired future conditions.

### Greater Sage-grouse

- The average habitat suitability index (HSI) for greater sage-grouse, calculated for the entire landscape where habitat could be present, was 29.96% based on the 2017 and 2019 interpreted imagery.
- The most widespread area of higher suitability was in the north-central part of the landscape, south of the northern-most expanses of winterfat and mixed salt desert scrub.
- Compared to HSI estimates in 2017 for the Pine Valley-Mountain Home project (Provencher et al. 2019), the additional land mapped in 2019 expanded the footprint of suitable habitat toward the west (i.e., toward the IP WMA), and improved habitat in the previously mapped project area due to the beneficial influence of distance effects.
- The IP WMA itself contained moderately suitable habitat, which extended to the south and south-east within a few miles north of the Jackson Wash Road.
- An interesting aspect of the patchwork of more to less suitable habitat is the potential of connecting the central Pine Valley to the IP WMA through two primary corridors of moderately suitable habitat, which could be restored to better condition. One corridor loosely follows the main east-west road into the IP WMA from the Pine Valley Road, and the other corridor parallels to the north the Cougar Spar Road from the western project boundary to the Pine Valley Road. Land managers are well aware that the west slope below the IP WMA could one day be a connectivity corridor for sage-grouse to the Hamlin Valley population (Provencher et al. 2018).

## Management Results

### Expenditures

- The total 60-year budgets of PREFERRED MANAGEMENT scenarios ranged from \$16 million to \$17.8 million among the three climates, with about \$12 million spent before year 2035 as specified by land managers. Total cost increased with lower fire activity, because conifers encroaching into shrublands that were not removed by fire required mechanical tree removal for restoration, which was the most expensive activity in shrublands. The least fire activity was in all ACCESS1 climate scenarios.
- The greatest cost after year 2035 was for actions to convert non-native annual species dominated classes to seedings of native species or mixed native and introduced species. The area dominated by non-native annual species was initially small in the landscape, but steadily increased with cumulative fires. The management scenarios incorporating the ACCESS1 climate produced the least area of the non-native annual species dominated class.
- Due to budget ceilings, many treatable areas were not treated. Doubling the BLM's budget, for example, resulted in its complete spending, i.e., no saturation of implementation rates. This effect was more pronounced on BLM lands and least pronounced in the IP WMA.
- Three systems accounted for 82% of total costs: black sagebrush for \$4 million to \$5.5 million, montane sagebrush steppe for about \$5.2 million, and Wyoming big sagebrush for \$4.4 million. By subtraction, nine other important systems with high wildlife value could be treated for \$3 million over 60 years.

### Ecological Systems

- Sixty years of simulations with additional active management (three PREFERRED MANAGEMENT scenarios) decreased the departure from reference conditions (lowered UED) in all ecological systems compared to simulations without additional management beyond the baseline (MINIMUM MANAGEMENT scenarios), except for montane sagebrush steppe and Wyoming big sagebrush.
- Management actions did not decrease the UED for montane sagebrush steppe and Wyoming big sagebrush from 100% departure, because extensive seedings of mixed native and introduced species, which are uncharacteristic vegetation classes used by greater sage-grouse as they mature, replaced other uncharacteristic classes, such as non-native annual species grassland and tree-encroached shrublands. As explained in Provencher et al. (2019), only the extensive use of pure native species mixtures in seedings can substantially lower UED as seedings mature.

### Greater Sage-grouse

- Without management actions (three MINIMUM MANAGEMENT scenarios), sage-grouse habitat degraded from 2017 to 2077 (Habitat Suitability Index decreased). Habitat degradation was least in the MINIMUM+ACCESS1 scenario because less fire was simulated, whereas the MINIMUM+HISTORIC and MINIMUM+CCSM4 scenarios achieved the same habitat conditions under greater fire activity.
- All PREFERRED MANAGEMENT scenarios significantly increased the Habitat Suitability Index of sage-grouse. Habitat improvements were significantly greater with the lesser fire activity of

the PREFERRED+ACCESS1 scenario, whereas the PREFERRED+HISTORIC and PREFERRED+CCSM4 scenarios were statistically similar.

- The most suitable areas for sage-grouse were (1) in the northern half of the landscape approximately extending from the IP WMA to the northeast, in a SW-NE oriented swath; and (2) in the southeastern part of the landscape, east of Pine Valley Road and south of Jockey Road.
- Many areas of habitat suitability in future years (i.e., after 2047) were matured seedings of mixed native and introduced species that generally had longer fire return intervals that escaped large fires or had time to undergo woody succession. Spatial differences among climates for PREFERRED MANAGEMENT scenarios generally resulted in more widespread and larger habitat improvements in these zones, although small habitat improvements were also observed in other areas farther away from the Pine Valley lek.
- Small changes in the absolute value of sage-grouse Habitat Suitability Index after implementation of management actions, such as from 26% to 29%, translated to marked spatial differences.

#### Unified Ecological Departure or Sage-grouse Habitat Suitability Index?

Unified Ecological Departure is non-spatial and is estimated per ecological system, whereas Habitat Suitability Index is spatial and estimated for whole landscapes. Managers may use both metrics to justify management actions, but with different results. The choice of management objectives needs to be explicit about prioritizing actions for ecological systems relative to benefits for special single species such as sage-grouse.

High UED values might encourage some managers to treat vegetation classes that contribute most to departure with the expectation that UED will decrease over time in treated areas. This expectation is not met at lower elevations because restoration often creates uncharacteristic vegetation classes where non-native annual grasslands and tree-encroached shrublands are replaced with mixed introduced and native species seedings. Higher-elevation systems and lower-elevation moist systems will be more likely to show UED reductions with treatments because they already contain reference classes, and pure native species mixtures can be seeded at higher elevations.

While UED was not consistently responsive to large amounts of restoration, Habitat Suitability Index responded to the effects of treatments and climate. Despite million-dollar investments in restoration, significant and easily spatially observable differences in the Habitat Suitability Index between MINIMUM and PREFERRED MANAGEMENT scenarios rarely exceeded 3% in absolute value (i.e., 29%-26%). This was expected because resource selection functions incorporate important physical characteristics of the landscape that do not change at all, such as distance to roads, leks, and moist summer vegetation for chick rearing. Therefore, absolute values of 2%-3% change in habitat suitability might represent a sizable improvement to sage-grouse demography.

#### Land Management and Climate Timing

Provencher et al. (2019) discussed that future climate might force the hand of managers by prioritizing early-future restoration over late-future restoration, because results showed that

seedings failed more often when increasingly frequent droughts coincided with seeding years. This was especially dire if the ACCESS1 climate was predicted as a likely future. In this report, the conclusion of erring towards early-future restoration did not change.

### Implementation Rates

Implementation rates that likely reflect a future climate were presented in Provencher et al. (2019) for the CCSM4 climate, as a compromise between the current (HISTORIC) climate and the worse-case (ACCESS1) climate. Results in that earlier report were restricted to BLM lands, so that report contained only one summary table of implementation rates and costs. However, four different land ownerships were simulated in this IP-PV-MH project, so four tables of rates and costs under the CCSM4 climate are presented in this report, at the end of Discussions & Conclusions section.

## Introduction

### Project Background

In 2015, The Nature Conservancy (TNC) completed conservation planning with the BLM Cedar City Field Office (CCFO) for 220,084 acres in Hamlin Valley and for 311,482 acres of the Black Mountains (Provencher et al. 2015; Provencher et al. 2018). These and subsequent projects all started with wall-to-wall remote sensing mapping of ecological systems and current vegetation classes using high-resolution satellite imagery. In 2017, TNC initiated conservation planning for the 377,000+ acres of the Pine Valley - Mountain Home project area situated immediately east of Hamlin Valley, using the same mapping methodology as before (Provencher et al. 2019).

Because of limited funding from the BLM CCFO, the Pine Valley-Mountain Home mapping could not include the State's Indian Peak Wildlife Management Area (hereafter, IP WMA), state school trust lands (SITLA), private inholdings, and a sizable area of BLM-managed land downslope of the IP WMA (all hereafter termed, Greater Indian Peak Area; Figure 1). The unmapped Greater Indian Peak Area represented a 77,000-acre gap in an otherwise continuous map from the Nevada border to the Wah Wah Range. Importantly, greater sage-grouse leks, scattered colonies of federally-listed Utah prairie dog, and mule deer inhabit this area. Sage-grouse in this part of Utah belong to the species' southern-most population. The geographic position of the entire proposed mapping area is significant for sage-grouse because of the proximity of the Mojave Desert and the western boundary of monsoonal rains and lightning activity, which could fluctuate to the east or west in future decades.

In 2019, the Utah Division of Wildlife Resources, within the Utah Department of Natural Resources, and The Nature Conservancy in Utah funded the mapping of the Greater Indian Peak Area to fill in the 77,000-acre gap mentioned above, including unmapped inholdings in the original Pine Valley-Mountain Home project area (see Figure 1). This entire gap-free area is known as the Indian Peak Range-Pine Valley-Mountain Home Range (hereafter, IP-PV-MH) landscape or project area.

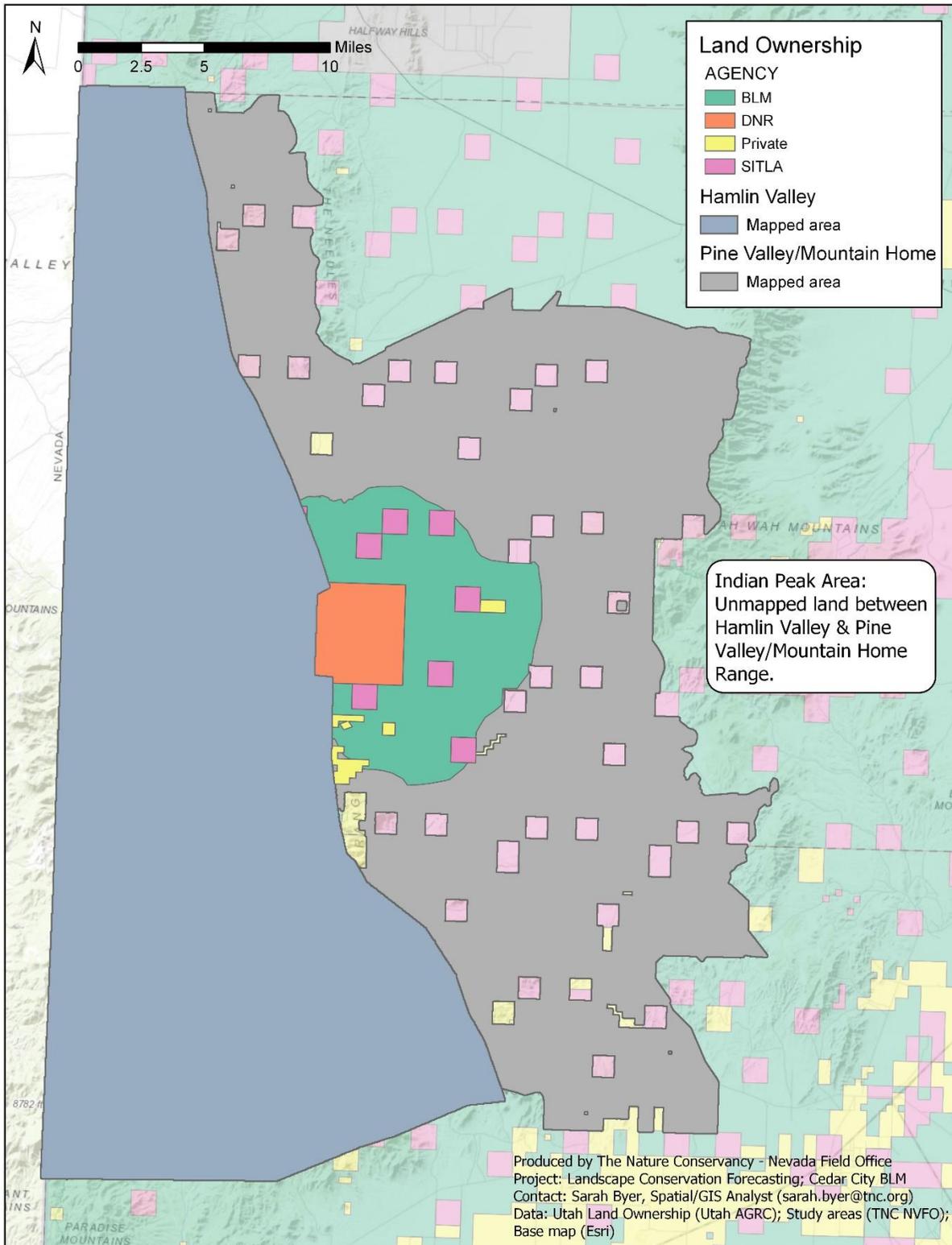
The intent of this combined IP-PV-MH project was to (a) complete mapping of ecological systems and current vegetation classes in the Greater Indian Peak Area, (b) append the newly mapped vegetation to the Pine Valley-Mountain Home vegetation map, and (c) forecast the effects of the same six combined management and climate scenarios using state-and-transition vegetation computer simulations as in the Pine Valley-Mountain Home project for CCFO, but updated to include the IP WMA, SITLA land, private land, and additional BLM CCFO land. The emphasis on 12 focal ecological systems and greater sage-grouse habitat suitability was maintained for BLM, SITLA, and private lands. Additional emphasis on mule deer habitat improvement and aspen regeneration was considered for the IP WMA.

### Report Content and Format

This IP-PV-MH report rides on the coattails of the Pine Valley-Mountain Home report (Provencher et al. 2019), as the methods here are nearly the same as those of that prior report. Any methods described here are limited to new items. Also, some results that apply only to systems unique to the prior Pine Valley-Mountain Home project area will not be repeated here,

such as the Calcareous Grasslands; and small systems with tiny levels of management action implementation were ignored, such as aspen-mixed conifer and low sagebrush.

Whereas the Pine Valley-Mountain Home project (Provencher et al. 2019) used three time reporting periods, this IP-PV-MH project uses four periods (see Table 7). This reflected the need to control funding more finely during the initial years of implementation. The first reporting period of the prior Pine Valley-Mountain Home project was split here into (a) years 2020 to 2024, and (b) years 2025 to 2034. The later reporting periods of the Pine Valley-Mountain Home project remain the same here: 2035 to 2044 and 2045 to 2077.



**Figure 1. The Greater Indian Peak Area, with Hamlin Valley to the west and Pine Valley - Mountain Home Project Area to the east, north, and south. All areas in gray (Pine Valley-Mountain Home) or blue-gray (Hamlin Valley) were previously mapped. The SITLA lands east of Pine Valley were not mapped.**

## Management Objectives

In Provencher et al. (2019), overarching management objectives were agreed upon by BLM CCFO and State of Utah staff and other stakeholders to guide the implementation of land management actions. The objectives were updated in this current IP-PV-MH report to account for the additional interests of the State for the IP WMA. The text box below shows the revised guiding management objectives, consistent with multiple-use management of public lands and regulations and goals for State of Utah lands.

### **Management Objectives for the LCF project for Indian Peak Range – Pine Valley – Mountain Home Range**

- Maintain or improve landscape-scale “health,” as measured by Unified Ecological Departure, of the major upland vegetation types (ecological systems) in the project area.
- Maintain or enhance the integrity of riparian corridors and wet meadows in the project area.
- Maintain or enhance the quality of wildlife habitat, with special attention to greater sage-grouse in the overall area, and mule deer in the Indian Peak Wildlife Management Area.
- Prevent expansion, and reduce the extent if possible, of undesirable vegetation classes in the project area – vegetation that is difficult or expensive to treat successfully, such as excessive spread of conifers or invasive annual grasses.
- Decrease fuel loads, maintain reduced fuel loads, or implement fuels management actions that decrease the likelihood of large high-severity wildfires, to reduce wildfire hazard to public-land resources and to human settlements and infrastructure in and around the project area.
- Develop and prioritize active management treatments — make treatment projects competitive for potential funding sources.
- Assess how types and amounts of active management treatments may need to be adjusted to achieve the above Objectives in a scenario of a warmer and drier future (climate variability forcing).

## Methods

Two components of the prior Pine Valley-Mountain Home project (Provencher et al. 2019) were different in this IP-PV-MH project: (1) details of imagery acquisition and remote sensing vegetation mapping challenges specific to the Greater Indian Peak Mapping Area, and (2) modeling updates reflecting restoration budgets and treatment priorities. We will cover only those two topics below, as the rest of this project’s methods are the same as those described in Provencher et al. (2019).

## Remote Sensing

Spatial Solutions, Inc. was contracted by TNC to conduct vegetation mapping via interpretation of satellite imagery of the Greater Indian Peak Area and all inholdings in the original Pine Valley-Mountain Home project area. Remote sensing was conducted with 1.5-m resolution Spot 6/7 multi-spectral satellite imagery captured on June 24, 2019 for the Greater Indian Peak Area, whereas 2017 Spot 6/7 imagery was used for inholdings in the original Pine Valley-Mountain Home area. During analysis, vegetation in unmapped areas was matched to the interpreted vegetation in the previously mapped areas, including Hamlin Valley to the west.

Spatial Solutions and TNC conducted field work for ground-truthing from July 3-11, 2019. The IP-PV-MH landscape was explored mostly on roads in a 4WD vehicle, but also by hiking and a drone for less-accessible locations. The goal of this field work was to visit all unique spectral class signatures (i.e., representing all systems and classes present) and document their vegetation and site features via rapid observations. During the 2019 summer field survey, 2,108 rapid observations and 1,502 photographs were documented.

Interpreted imagery was delivered by Spatial Solutions to TNC by mid-May 2020. The newly interpreted vegetation rasters from the 2019 mapping were appended to the 2017 interpreted vegetation rasters, thus creating a seamless product for the entire IP-PV-MH landscape. TNC delivered rasters of ecological systems and vegetation classes, shape files, a revised description of all ecological systems and vegetation classes that was used in the field, and georeferenced field photographs to the Utah Division of Wildlife Resources and BLM CCFO on June 9, 2020.

## Notes on Field Observations

Many of the challenges encountered in this project's mapping were the same as those encountered in 2017 (Provencher et al. 2019). A few differences are listed below:

1. Mapping of private inholdings, which was not required in 2017, was more difficult because we could not enter fenced or locked private lands flagged with "No-Trespassing" signs. In those cases where more observations would have been beneficial, walking or driving the land's outer perimeter was done if possible, and limited drone flights were performed to check specific spectral signatures. Because of these limitations, some private lands were not expected to be as accurately mapped as lands managed by the BLM or State of Utah.
2. A few remote SITLA inholdings in the Wah Wah Range and Mountain Home Range could not be reached by 4WD (no roads), did not allow line-of-sight navigation of a drone into the heart of the inholding, and were too far away over rough terrain for hiking given the crew's limited field time. While flying a drone higher than the preferred height to reach the edge of an inholding section was sometimes possible before losing line-of-sight, Spatial Solutions relied on extrapolation of spectral signatures from adjacent areas where observations were collected. These inholdings were also not expected to be as accurately mapped as more accessible lands.
3. Provencher et al. (2019) described the presence of juniper and pinyon woodlands that were dominated by older juniper trees with large-diameter lateral branches. Several of these stands were observed on shallow slopes that did not fit a common perception of pinyon-

juniper woodlands found on steep slopes with unproductive soils. More such impressive pinyon-juniper woodlands on shallow slopes were found in the Greater Indian Peak Area (see photograph on title page taken from a large woodland expanding in all directions from 38°16'18.55"N, 113°43'17.73"W). Moreover, the presence of sparse herbaceous and black sagebrush understories, instead of Wyoming big sagebrush, indicated that soils were unproductive. Thick volcanic ash deposits created by a super-volcano that left behind the Indian Peak Caldera after explosive eruption may be the source of badland-like soils formed of tuffaceous rocks (DeCourten and Biggar 2017). The expansive and potentially ancient woodland spanning several thousands of acres around the geographic coordinates listed above is worthy of special consideration and study to confirm the age of the trees.

4. State lands (WMA and SITLA) situated in the Greater Indian Peak Area were seeded with various introduced grass species. A common local practice from several decades ago appears to have been to chain tree-encroached sagebrush shrublands and then blade away the woody material and soil into long thin rows. These past operations remain clearly visible today on satellite imagery such as easily accessible Google Earth™ (Google L.L.C.) imagery. These areas were challenging to map to the correct sagebrush species, because the soil was modified by blading to various degrees such that even loamy soil appears brighter as if it were the same soil supporting black sagebrush. Using known observations, landform position (e.g., black sagebrush more likely on ridges), and assuming that darker soils either support mountain big sagebrush or Wyoming big sagebrush, whereas brighter soils support black sagebrush, Spatial Solutions classified the different sagebrush ecological systems.
5. For this IP-PV-MH project, we split the wet meadow system into dry wet meadow and wet wet meadow (hereafter, wet meadow), because we encountered more dry wet meadows than in previous projects. It was assumed that dry wet meadows whose herbaceous vegetation dries and senesces by early to mid-July would be somewhat less valuable for sage-grouse chick rearing than wet meadows that remain wet and green throughout the summer. Classifying dry wet meadows was sometimes tricky, as some were apparently true dry wet meadows even during the very wet 2019 hydrologic year, whereas others might have been the result of water diversions. For example, pipelines and venting pipes were found sometimes ½ to 1 mile away from a dry wet meadow with evidence of an old and faint trench leading back to the meadow. Because it was judged unlikely that water diversion would stop in the near or distant future and we could not confirm the historic status of these meadows, these human-caused dry wet meadows were labelled as dry wet meadow and not degraded wet meadow.

### Modeling Updates

Two major aspects of modeling were updated: The annual budget per land ownership was determined, and the list of land management actions was stated for IP WMA, SITLA, and private lands. These decisions were made during an online workshop with Utah Division of Wildlife Resources, BLM CCFO, and TNC staff during the afternoon of June 1-2, 2020. The annual budgets per land ownership are presented in Table 1.

**Table 1. Annual budgets by land ownership.**

Ownership	2020-2024	2025-2034	2035-2044	2045-2077
Indian Peak WMA	\$300,000	\$25,000	\$8,000	\$8,000
BLM CCFO	\$1,200,000	\$600,000	\$250,000	\$25,000
SITLA	\$106,000	\$55,000	\$22,145	\$2,215
Private	\$32,000	\$16,000	\$6,600	\$660

The BLM CCFO and IP WMA budgets were submitted by line officers during the workshop, whereas BLM offered that the annual budgets for SITLA and private lands were equal to the BLM’s annual budget multiplied by the proportion of each of these lands in the project area (Table 1). Implementation of actions on SITLA and private lands would be coordinated by BLM and Utah Division of Wildlife Resources staff, as is the current practice.

Actions used by the State, BLM, and private land managers were the same because land management contracts are negotiated by the Watershed Restoration Initiative for State agencies and BLM, and BLM extends restoration actions to private lands after a landowner has granted permission (Table 2).

**Table 2. Simulated actions used by different land management agencies and on private lands.**

Ecological System / Action	BLM	IP WMA	SITLA	Private
<b>Aspen Woodland</b>				
Chainsaw-Thinning	X	X	X	X
Fence	X			
RxFire	X			
<b>Aspen-Mixed Conifer</b>				
Chainsaw-Thinning		X		X
<b>Black Sagebrush</b>				
2xChaining+Seed	X		X	
Chaining+Native-Seed			X	
Chaining+Plateau+Seed	X			
Chainsaw-Thinning	X	X	X	X
Forb+Grass-Native-Seeding+Chaining	X			
Herbicide-Plateau+Seed	X			
Masticate+Seed	X	X	X	X
Small-Tree-Lopping		X	X	
<b>Calcareous Grassland</b>				
Thin+Herbicide+Native-Seed	X		X	
<b>Low Sagebrush</b>				
Small-Tree-Lopping		X		
<b>Montane Riparian</b>				
Chainsaw-Thinning		X		
Exotic-Control	X	X	X	X
Water-Table-Uplift	X	X	X	
Weed-Inventory+Treat	X	X		X

**Table 2. Simulated actions used by different land management agencies and on private lands.**

<b>Ecological System / Action</b>	<b>BLM</b>	<b>IP WMA</b>	<b>SITLA</b>	<b>Private</b>
<b>Montane Sagebrush Steppe</b>				
Chaining+Native-Seed	X		X	
Forb+Grass-Native-Seeding+Chaining	X			
Masticate+Seed	X	X	X	X
RxFire		X		
Small-Tree-Lopping	X	X	X	X
<b>Pinyon-Juniper Woodland</b>				
Chainsaw-Thinning	X			
Masticate+Native-Seed	X			
<b>Ponderosa Pine</b>				
Chainsaw-Thinning	X			
Masticate+PIPO-Planting	X		X	X
<b>Saline Meadow</b>				
Exotic-Control	X		X	
Weed-Inventory+Treat	X		X	
<b>Semi-Desert Grassland</b>				
Thin+Herbicide+Seed	X			
<b>Stansbury Cliffrose</b>				
Chainsaw-Thinning	X			
<b>Utah Serviceberry</b>				
Chainsaw-Thinning	X	X	X	X
Masticate+Seed		X		
RxFire		X		
<b>Wet Meadow-Montane</b>				
Exotic-Control	X	X	X	X
Fence	X			X
Small-Tree-Lopping		X	X	X
Water-Table-Uplift	X		X	X
Weed-Inventory+Treat	X	X	X	X
<b>Wyoming Big Sagebrush upland</b>				
Chaining+Native-Seed	X		X	
Chaining+Plateau+Seed	X		X	
Chaining+Seed	X		X	
Forb+Grass-Native-Seeding+Chaining	X			
Masticate+Herbicide+Seed	X		X	X
Small-Tree-Lopping	X		X	X

## Results

### Initial Conditions

#### VEGETATION

A total area of 308,927 acres were mapped in the original 2017 and additional 2019 remote sensing effort (Table 3). Lands managed by the BLM, UT Department of Natural Resources (IP WMA), private landowners, and SITLA represented 86%, 3%, 3%, and 9% respectively of this total area. Acreage values in Table 3 are based on the 1.5-m resolution Spot 6/7 map. Acreage values are different for the raster map resampled to 30-m resolution used for simulations. Only the focal systems in bold font received management actions. Empty cells indicate absence.

**Table 3. Area (acres) of ecological systems, barren coverage, anthropogenic features, and water for lands of the different ownership/management categories in the IP-PV-MH project area.**

<b>Ecological System</b>	<b>BLM</b>	<b>IP WMA</b>	<b>Private</b>	<b>SITLA</b>	<b>Total</b>
<b>Aspen Woodland</b>	76.7	2.9	15.6	3.0	98.2
Aspen-Mixed Conifer	93.8	8.1	120.8		222.8
Barren	1,567.6	17.5	56.1	44.0	1,685.2
Basin Wildrye	162.4	79.2	32.6	31.9	306.1
Big Sagebrush semi-desert				0.4	0.4
<b>Black Sagebrush</b>	89,352.5	1,200.5	900.3	10,019.1	101,472.4
<b>Calcareous Grassland</b>	905.6			259.1	1,164.7
Curl-leaf Mountain Mahogany	4,824.3	77.5	610.9	550.1	6,062.9
Desert Wash	114.2		0.7	29.0	143.9
Developed	0.6	0.0	14.5		15.1
<b>Dry Wet Meadow</b>	17.0	6.4	6.8	3.7	33.9
Four-Wing Saltbush	198.2			30.0	228.2
Greasewood-Basin Big Sagebrush	374.9			7.5	382.5
Juniper Savanna	399.7			11.2	410.9
Little-leaf Mountain Mahogany	2,331.9		6.2	58.0	2,396.1
Low Sagebrush	252.8	92.9	125.4	4.7	475.9
Mixed Conifer	37.2		67.9	14.6	119.7
Mixed Salt Desert	313.7			10.5	324.2
<b>Montane Riparian</b>	23.0	36.8	10.7	4.5	75.0
<b>Montane Sagebrush Steppe</b>	52,987.2	4,903.3	2,558.3	5,867.1	66,315.9
<b>Pinyon-Juniper Woodland</b>	25,348.9	1,852.3	704.7	1,867.1	29,772.9
<b>Ponderosa Pine</b>	3,720.2		93.3	145.2	3,958.8
Road	1,185.3	15.9	69.4	85.7	1,356.3
Saline Meadow	31.1	0.0	5.0		36.1
<b>Semi-Desert Grassland</b>	3,256.6			96.8	3,353.4
<b>Stansbury Cliffrose</b>	11.3			0.0	11.3
<b>Utah Serviceberry</b>	992.7	398.8	679.6	41.9	2,113.0
Water	3.7	2.1	1.6	0.7	8.1
<b>Wet Meadow-Montane</b>	74.4	27.6	49.7	8.5	160.3
Winterfat	17,457.1			2,521.6	19,978.6
<b>Wyoming Big Sagebrush upland</b>	58,582.4	0.5	2,014.6	5,647.3	66,244.7
<b>TOTAL</b>	264,697.1 (86%)	8,722.4 (3%)	8,144.8 (3%)	27,363.1 (9%)	308,927.3

Of the 27 ecological systems found in the entire IP-PV-MH project area – not counting other land cover types such as barren, roads, developed, and water – the most abundant are (in decreasing order) black sagebrush, montane sagebrush steppe, Wyoming big sagebrush-upland, pinyon-juniper woodland, and winterfat. On SITLA lands, the most abundant systems are (in decreasing order) black sagebrush, montane sagebrush steppe, Wyoming big sagebrush-upland, winterfat, and pinyon-juniper woodland. Given the higher elevations of the IP WMA, montane sagebrush steppe is the most widespread system followed by pinyon-juniper woodland, black sagebrush, and Utah serviceberry. On private lands, the most abundant systems (in decreasing order) are montane sagebrush steppe, Wyoming big sagebrush-upland, black sagebrush, pinyon-juniper woodland, Utah serviceberry, and curl-leaf mountain mahogany. While BLM lands had the largest areas of wet meadow and dry wet meadow, private lands showed the greatest proportion of these wetter systems relative to land ownership area.

Table 4 shows Unified Ecological Departure (UED) values for ecological systems of the IP-PV-MH project area, based on the new mapping of BLM, IP WMA, SITLA and private lands in 2019, and the original Pine Valley-Mountain Home map of 2017. Red, yellow, and green cell colors indicate, respectively, highly, moderately, and lightly departed UED from desired conditions based on the Natural Range of Variability (Provencher et al. 2019), allowable areas of seedings, and undesirability levels for uncharacteristic classes.

**Table 4. Unified ecological departure (UED, %) for ecological systems of the IP-PV-MH project area.**

Ecological System	UED (%)	Ecological System	UED (%)
<b>Aspen Woodland</b>	<b>100</b>	Mixed Conifer	<b>62</b>
Aspen-Mixed Conifer	<b>100</b>	Mixed Salt Desert	<b>100</b>
Basin Wildrye	<b>100</b>	<b>Montane Riparian</b>	<b>74</b>
Big Sagebrush semi-desert	<b>100</b>	<b>Montane Sagebrush Steppe</b>	<b>100</b>
<b>Black Sagebrush</b>	<b>88</b>	<b>Pinyon-Juniper Woodland</b>	<b>35</b>
<b>Calcareous Grassland</b>	<b>97</b>	<b>Ponderosa Pine</b>	<b>49</b>
Curl-leaf Mountain Mahogany	<b>48</b>	Saline Meadow	<b>100</b>
Desert Wash	<b>100</b>	<b>Semi-Desert Grassland</b>	<b>100</b>
<b>Dry Wet Meadow</b>	<b>100</b>	<b>Stansbury Cliffrose</b>	<b>36</b>
Four-Wing Saltbush	<b>100</b>	<b>Utah Serviceberry</b>	<b>85</b>
Greasewood-Basin Big Sagebrush	<b>100</b>	<b>Wet Meadow-Montane</b>	<b>79</b>
Juniper Savanna	<b>17</b>	Winterfat	<b>100</b>
Little-leaf Mountain Mahogany	<b>55</b>	<b>Wyoming Big Sagebrush upland</b>	<b>100</b>
Low Sagebrush	<b>31</b>		

Nineteen of the 27 ecological systems (70%) were highly departed (red cells) from desired future conditions based on Unified Ecological Departure in 2017 and 2019. Only juniper savanna and low sagebrush were lightly departed (green cells). Systems moderately departed from desired future conditions were curl-leaf mountain mahogany, little-leaf mountain mahogany, mixed conifer, pinyon-juniper woodland, ponderosa pine and Stansbury cliffrose. With regard to focal management systems (bold in Table 4), three were moderately departed

from desired future conditions (pinyon-juniper woodland, ponderosa pine and Stansbury cliffrose), while the remainder were highly departed from desired future conditions.

#### GREATER SAGE-GROUSE HABITAT SUITABILITY INDEX

The average habitat suitability index (HSI) for greater sage-grouse, calculated for the entire landscape where habitat could be present, was 29.96% for the combined 2017 and 2019 imageries. As shown on Figure 2, the most widespread area of higher suitability (greener colors) was in the north-central part of the landscape, south of the northern-most expanses of winterfat and mixed salt desert scrub. Compared to HSI estimates in 2017 (Provencher et al. 2019), the additional land mapped in 2019 expanded the footprint of suitable habitat toward the west (i.e., toward the IP WMA). The IP WMA itself contained moderately suitable habitat, which extended to the south and south-east within a few miles north of the Jackson Wash Road.

An interesting aspect of the patchwork of more to less suitable habitat is the potential of connecting the central Pine Valley to the IP WMA through two primary corridors of moderately suitable habitat, which could be restored to better condition. One corridor loosely follows the main east-west road into the IP WMA from the Pine Valley Road, and the other corridor parallels to the north the Cougar Spar Road from the western project boundary to the Pine Valley Road (Figure 2). Land managers are well aware that the west slope below the IP WMA could one day be a connectivity corridor for sage-grouse to the Hamlin Valley population (Provencher et al. 2018).

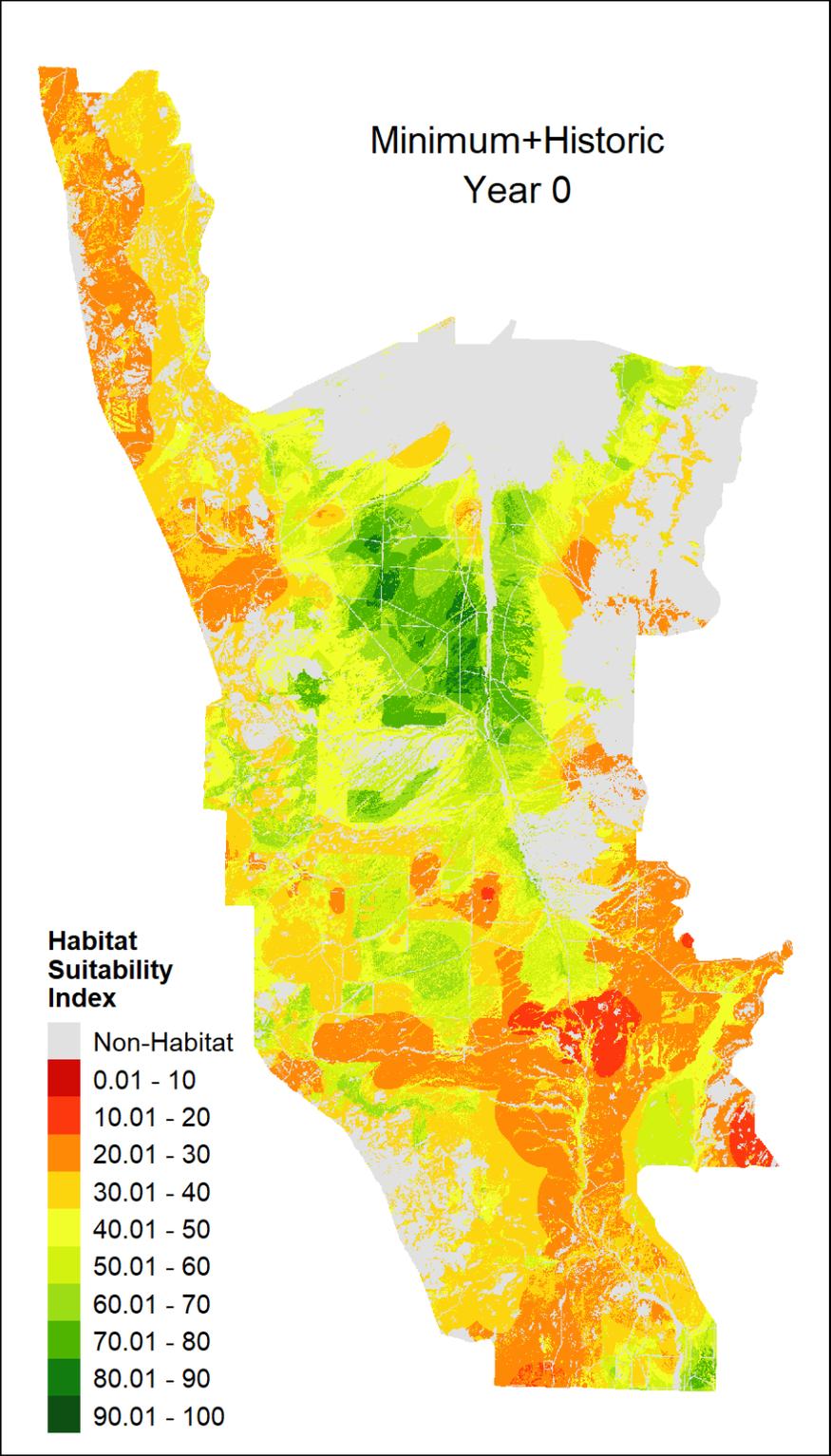


Figure 2. Habitat suitability index (HSI) for greater sage-grouse based on the new mapping of the IP WMA, SITLA and private inholdings in 2019, and the original Pine Valley-Mountain Home map of 2017. Increasing value of HSI (i.e., greener) indicates higher habitat suitability. Average HSI is 29.96% for the entire landscape.

## Future Conditions

### ASPEN WOODLAND

Current System Acres at 30-m resolution: 221 total

#### Condition: Unified Ecological Departure

In 2017:

100

In 2077 under MINIMUM MANAGEMENT & HISTORIC Climate:

66 ± 5

In 2077 under MINIMUM MANAGEMENT & CCSM4 LOCA:

64 ± 8

In 2077 under MINIMUM MANAGEMENT & ACCESS1 LOCA:

69 ± 2

#### Vegetation Classes

**Table 5. Vegetation classes of the aspen woodland ecological system at the current time (2017 and 2019), and after 60 years of MINIMUM MANAGEMENT (2077) under three climate scenarios.**

Vegetation Class	Ref NRV%	Undesir. Level	Allow. Thresh%	Current (2017)	MINIMUM MANAGEMENT (2077)		
				Class %	HISTORIC Class %	CCSM4 Class %	ACCESS1 Class %
A:All	8	0	—	0.2%	13%	14%	9%
B:Closed	25	0	—	23.5%	15%	15%	9%
C:Closed	39	0	—	2.8%	30%	33%	47%
D:Open	28	0	—	21.2%	34%	30%	26%
U-B:Depleted	0	1	0.0	0.5%	0%	0%	0%
U-C:Depleted	0	1	0.0	3.5%	0%	0%	0%
U-D:Depleted	0	1	0.0	48.3%	2%	2%	2%
ASP-U->MSS:All	0	1	0.0	0.0%	6%	6%	7%

**Table 6. Area (acres) of aspen woodland vegetation classes per ownership in 2017 and 2019. The value 0.0+ indicates trace amount smaller than one tenth of an acre.**

Vegetation Class	IP WMA	BLM	Private	SITLA
A:All	0.0	1.4	0.0	0.0
B:Closed	0.0	20.9	1.1	0.2
C:Closed	0.5	4.2	2.8	0.0
D:Open	1.8	9.2	4.5	0.7
U-B:Depleted	0.0	0.1	0.0	0.0
U-C:Depleted	0.0	6.0	1.2	0.5
U-D:Depleted	0.6	33.6	6.0	1.5
ASP-U->MSS:All	0.0	1.2	0.0	0.0+

## Problems or Concerns

2017: Throughout the project area, late-successional depleted aspen woodland (U-D:Depleted) accounted for 48% of the area of aspen woodland compared to the desired condition of 0% (Table 5). In addition, the early-successional class (A:All) was absent and the area of the late-successional closed class (C:Closed) was 3% compared to a desired condition of 39%. As a result, UED was 100% in 2017. The area of the U-D:Depleted uncharacteristic class needs to be reduced, as it can transition to the loss of aspen clones over time.

Aspen woodland was primarily found on BLM and private lands (Table 6) where the U-D:Depleted aspen clones are located. SITLA lands did not support much aspen woodland, but most of it was depleted and deserves attention.

After 60 years of MINIMUM MANAGEMENT: Sixty years with MINIMUM MANAGEMENT under any climate scenario reduced UED (i.e., improved ecological condition) in the range of 64% to 69% due primarily to fires burning more frequently into the depleted classes and eventually recruiting area into younger reference classes (Table 5). As shown in Provencher et al. (2019), lower fire activity in the ACCESS1 LOCA compared to other climates resulted in retention of older vegetation classes (C and D) to the expense of younger classes (A and B; Table 5). The U-D:Depleted class was reduced from 48% to 2% in all climate scenarios. The tradeoff for the improvement in UED was an increase in the area of lost clones (ASP-U→MSS:All) from 0% in 2017 to 6%-7% in 2077 (Table 5).

## Objective(s) for Management Actions

The objectives were to: (1) reduce the area of U-D:Depleted before clones were passively lost, (2) prevent the loss of aspen clones, and (3) increase the area of A:All and C:Closed classes. A serious challenge to reducing U-D:Depleted is that various actions such as prescribed fire and mechanical actions, with the exception of fencing, can partially cause the loss of clones during resprouting because depleted aspen is, by definition, distinguished by diminished root reserves in addition to open canopies and depleted understories caused primarily by chronic grazing.

## Treatment Rates and Costs

Only BLM, private and SITLA lands received treatments (Table 7). While aspen woodland on private and SITLA lands was only treated with chainsaw thinning, BLM used a combination of chainsaw thinning (Chainsaw-Thinning), prescribed fire (RxFire), and fencing (Fence). Less than \$200 was spent in each of private and SITLA lands. The larger spending and differences among climate scenarios were on BLM lands. Less fencing was used in the HISTORIC climate and the ACCESS1 scenarios than in the CCSM4 scenario. This resulted in about \$29,000 lower cost in the HISTORIC scenario and \$20,000 less in the ACCESS1 scenario than the CCSM4 scenario (Table 7).

**Table 7. Cumulative implementation rates and costs of actions in aspen woodland over periods of implementation.**

Scenario	Action	Cost/acre		Sum of Acres / Interval (Avg of 10 runs)				60-yr Total Cost
				2020-2024	2025-2034	2035-2044	2045-2077	
<b>BLM</b>								
Preferred +HISTORIC	Chainsaw-Thinning	\$112.50		6.2	0.0	0.0	0.0	
	Fence	\$10,000.00		43.5	0.0	0.0	0.0	
	RxFire	\$300.00		69.7	0.0	0.0	0.0	
			Cost→	\$457,065	\$0	\$0	\$0	\$457,065
Preferred +CCSM4	Chainsaw-Thinning	\$112.50		7.7	0.0	0.0	0.0	
	Fence	\$10,000.00		46.5	0.0	0.0	0.0	
	RxFire	\$300.00		69.3	0.0	0.0	0.0	
			Cost→	\$486,455	\$0	\$0	\$0	\$486,455
Preferred +ACCESS1	Chainsaw-Thinning	\$112.50		7.0	0.0	0.0	0.0	
	Fence	\$10,000.00		44.7	0.0	0.0	0.0	
	RxFire	\$300.00		71.7	0.0	0.0	0.0	
			Cost→	\$469,319	\$0	\$0	\$0	\$469,319
<b>Private</b>								
Preferred +HISTORIC	Chainsaw-Thinning	\$112.50		0.0	1.7	0.0	0.0	
			Cost→		\$188	\$	\$	\$188
Preferred +CCSM4	Chainsaw-Thinning	\$112.50		0.0	1.6	0.0	0.0	
			Cost→	\$0	\$175	\$0	\$0	\$175
Preferred +ACCESS1	Chainsaw-Thinning	\$112.50		0.0	1.7	0.0	0.0	
			Cost→	\$0	\$188	\$0	\$0	\$188
<b>SITLA</b>								
Preferred +HISTORIC	Chainsaw-Thinning	\$112.50		1.8	0.0	0.0	0.0	
			Cost→	\$198	\$0	\$0	\$0	\$198
Preferred +CCSM4	Chainsaw-Thinning	\$112.50		1.6	0.0	0.0	0.0	
			Cost→	\$180	\$0	\$0	\$0	\$180
Preferred +ACCESS1	Chainsaw-Thinning	\$112.50		1.7	0.0	0.0	0.0	
			Cost→	\$190	\$0	\$0	\$0	\$190

Management actions decreased UED compared to MINIMUM MANAGEMENT by 2077 (below). Reductions ranged from 17%, 16%, and 16% for HISTORIC, CCSM4, and ACCESS1 climates, respectively. Based on the 95% CI, differences were significant between MINIMUM and PREFERRED MANAGEMENT scenarios. Moreover, under PREFERRED MANAGEMENT a lack of significant difference was observed between the HISTORIC and CCSM4 LOCAs, whereas the ACCESS1 LOCA was borderline significantly different from both the HISTORIC climate and CCSM4 LOCA based on 95% CIs.

Unified Ecological Departure	MINIMUM MANAGEMENT	PREFERRED MANAGEMENT
In 2077 under HISTORIC Climate	66 ± 5	49 ± 5
In 2077 under CCSM4 LOCA	64 ± 8	48 ± 0
In 2077 under ACCESS1 LOCA	69 ± 2	53 ± 5

### Vegetation Classes

The U-D:Depleted class was the main target of restoration and, as a result, decreased in two phases (Figures 3-5). Prescribed fire and chainsaw thinning in the U-D:Depleted class resulted in a rapid increase of the A:All class from 2020 to 2025. After 10 years, these new acres of A:All transitioned to B:Closed with succession. The second change was the delayed effect of fencing and rest from herbivory for 5 years, after which the U-D:Depleted class transitioned to the D:Open class as specified in the model pathways (especially visible in Figure 3). Rest from herbivory also benefitted the MINIMUM MANAGEMENT scenarios because of the set-up of initial conditions, but not to the extent seen in the PREFERRED MANAGEMENT scenarios.

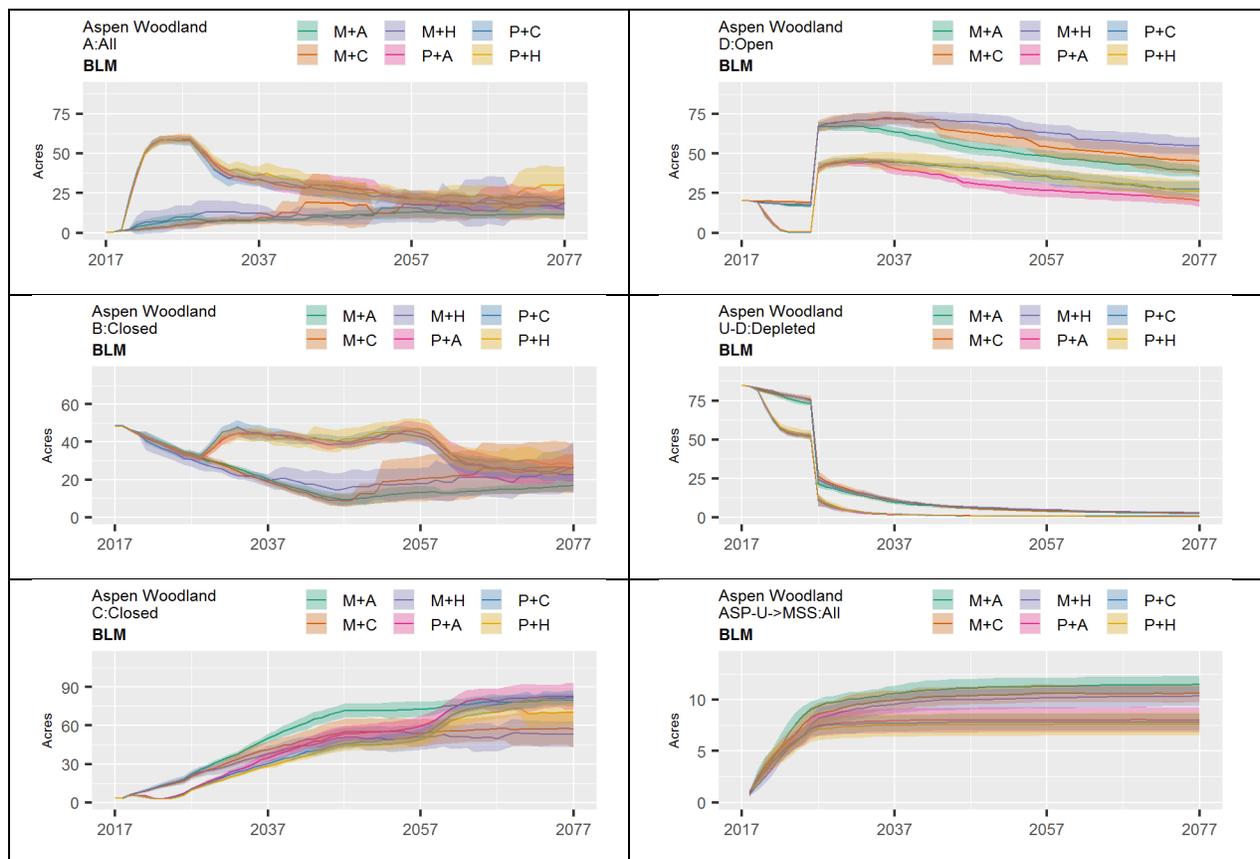


Figure 3 Area (acres) of focal vegetation classes over time in aspen woodland on BLM-managed lands. N = 10 iterations.

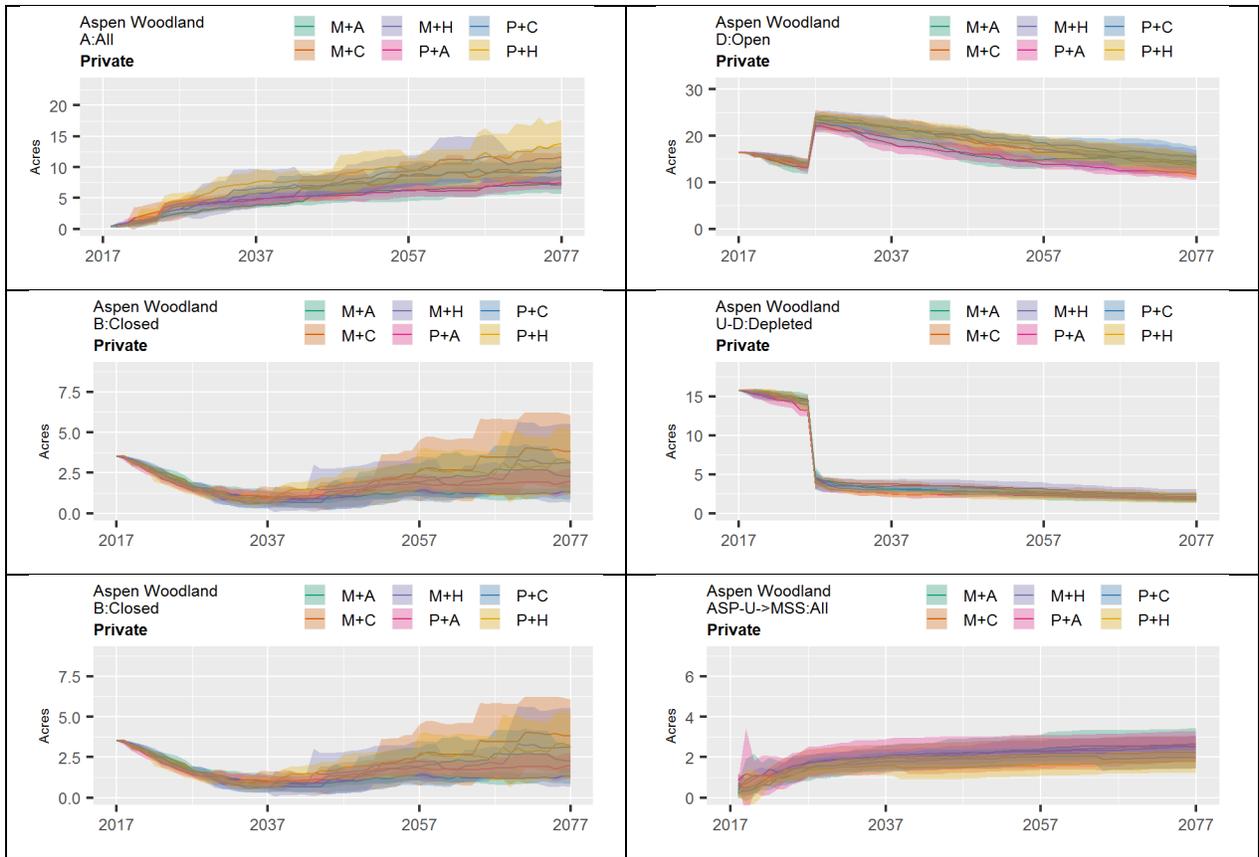


Figure 4. Area (acres) of focal vegetation classes over time in aspen woodland on private lands. N = 10 iterations.

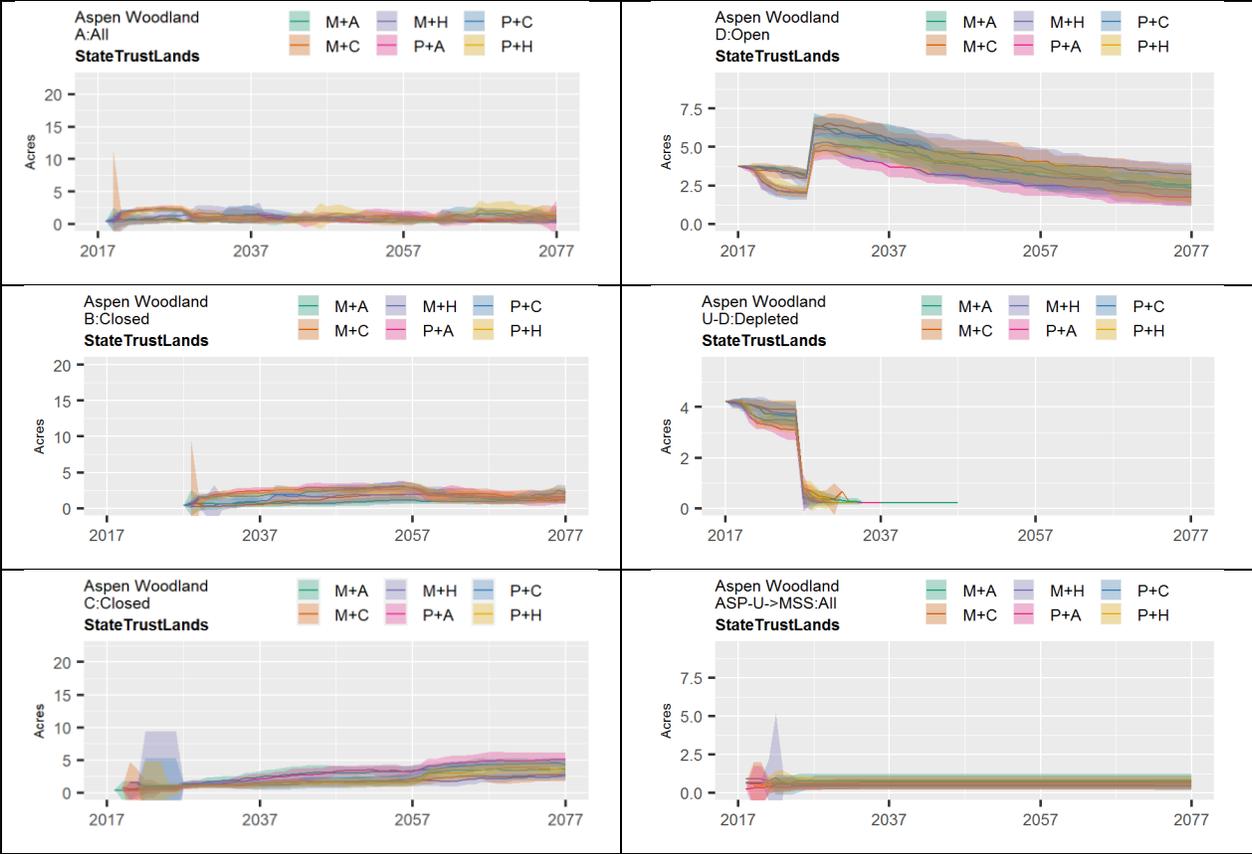


Figure 5. Area (acres) of focal vegetation classes over time in aspen woodland on SITLA-managed lands. N = 10 iterations.

BLACK SAGEBRUSH

Current System Acres at 30-m resolution: 101,472 total

Condition: Unified Ecological Departure

In 2017:

In 2077 under MINIMUM MANAGEMENT & HISTORIC Climate:

In 2077 under MINIMUM MANAGEMENT & CCSM4 LOCA:

In 2077 under MINIMUM MANAGEMENT & ACCESS1 LOCA:

88
98 ± 1
99 ± 1
100 ± 0

Vegetation Classes

**Table 8. Vegetation classes of the black sagebrush ecological system at the current time (2017 and 2019), and after 60 years of MINIMUM MANAGEMENT (2077) under three climate scenarios.**

Vegetation Class	Ref NRV%	Undesir. Level	Allow. Thresh%	Current (2017)	MINIMUM MANAGEMENT (2077)		
				Class %	HISTORIC	CCSM4	ACCESS1
					Class %	Class %	Class %
A:All	17	0	—	1.1%	5.0%	4.7%	1.6%
B:Open	51	0	—	6.4%	5.6%	5.2%	6.1%
C:Closed	19	0	—	4.1%	2.9%	3.1%	4.2%
D:Open	12	0	—	12.4%	4.0%	3.8%	2.3%
U-A:Annual Spp	0	1	0.0	0.4%	30.7%	28.8%	16.6%
U-A:Bare Ground	0	1	0.0	0.1%	0.2%	0.2%	0.2%
U-A:Early-Shrub	0	0	0.0	0.1%	4.1%	4.0%	5.3%
U-A:Exotic Forb	0	1	0.0	0.0%	0.1%	0.1%	0.1%
U-A:SAP	0	0	0.0	3.0%	0.5%	0.6%	0.5%
U-A:SAP+	0	1	0.0	0.0%	0.0%	0.0%	0.0%
U-A:Seeded Native	0	0	17.0	0.0%	0.0%	0.0%	0.0%
U-A:SI	0	0	9.6	3.0%	4.0%	3.5%	1.0%
U-A:SI+AS	0	0	0.0	0.9%	0.0%	0.0%	0.0%
U-B:SAP	0	0	0.0	2.8%	2.0%	1.8%	3.2%
U-B:SAP+	0	1	0.0	0.0%	0.1%	0.1%	0.4%
U-B:SI	0	0	30.0	8.3%	6.2%	6.1%	6.0%
U-B:SI+AS	0	0	0.0	0.5%	0.0%	0.0%	0.0%
U-C:Depleted	0	1	0.6	2.9%	0.8%	1.0%	1.9%
U-C:SA	0	1	0.0	0.7%	0.3%	0.3%	0.7%
U-C:SA+	0	1	0.0	0.0%	0.0%	0.0%	0.1%
U-C:SI	0	0	11.4	2.8%	3.5%	4.3%	6.8%
U-C:SI+AS	0	0	0.0	0.0%	0.0%	0.0%	0.0%
U-D:SI	0	0	0.0	1.6%	1.5%	1.7%	1.8%
U-D:SI+AS	0	0	0.0	0.1%	0.1%	0.1%	0.2%
U-D:TEA	0	1	0.0	48.6%	28.3%	30.5%	41.1%

**Table 9. Area (acres) of black sagebrush vegetation classes per ownership in 2017 and 2019.**

Vegetation Class	IP WMA	BLM	Private	SITLA
A:All	0.0	1031.9	2.9	0.4
B:Open	0.0	5304.6	16.5	594.5
C:Closed	0.2	3632.8	2.9	115.6
D:Open	103.0	10305.8	73.2	977.4
U-A:Annual Spp	0.0	391.9	0.0	4.7
U-A:Bare Ground	1.1	24.2	8.5	13.1
U-A:Early-Shrub	0.0	97.9	0.7	16.7
U-A:Exotic Forb	0.0	8.7	0.0	0.0
U-A:SAP	0.0	2643.8	3.3	136.8
U-A:SI	106.5	1740.5	5.8	899.1
U-A:SI+AS	1.6	369.2	2.7	499.3
U-B:SAP	0.0	2270.4	151.7	159.5
U-B:SI	426.8	5395.5	2.0	1825.2
U-B:SI+AS	94.3	79.8	0.0	275.5
U-C:Depleted	0.0	2111.0	2.0	586.7
U-C:SA	0.0	659.4	0.0	20.5
U-C:SI	426.8	5395.5	2.0	1825.2
U-D:SI	176.4	825.1	1.1	430.8
U-D:SI+AS	35.4	65.8	0.0	22.9
U-D:TEA	158.1	41970.1	554.2	2139.0

### Problems or Concerns

2017: The vegetation class that was most contributing to unified ecological departure of 88% from desired condition was the late-successional tree-encroached class (U-D:TEA), representing 49% of the area of black sagebrush (Table 8). Few other uncharacteristic classes reached levels of concern, with depleted sagebrush being the second highest at 2.9% (the U-A:SAP class at 3% was not a treated class). With the exception of the reference late-successional treed class (D:Open), the reference classes were greatly under-represented compared to desired future conditions.

Tree encroachment was unevenly distributed among land management ownerships (Table 9). BLM and SITLA lands showed similar patterns of departure described in the previous paragraph. Moreover, early tree encroachment in late-successional seeded classes (U-D:SI and U-D:SI+AS) was also obvious. BLM lands were the only ones with sizable area (392 acres) of non-native annual species (U-A:Annual Spp) and could be a source of new fire ignitions. Tree encroachment was the main problem on private lands, and the prevalence of sagebrush invaded by non-native annual species was also a visible problem. The IP WMA proportionally has the smallest area of tree-encroachment and more seedings due to past removal of trees in shrublands. Regardless, tree removal in the U-D:TEA and U-D:SI class was still possible to the area remaining.

After 60 years of MINIMUM MANAGEMENT: The most visible changes were (a) the large increase of the U-A:Annual Spp class matching the complementary reduction of the U-D:TEA class and (b) the decrease of the reference D:Open with area lost to the U-D:TEA class from drought as loss was greater in the drier and less fire-active ACCESS1 LOCA than the other climate scenarios (Table 8). Fire was the primary source of these changes, because proportionally less change was observed in scenarios with less fire activity, such as the ACCESS1 LOCA (Provencher et al. 2019).

Objective(s) for Management Actions

The primary objective was to reduce the area of the tree-encroached class (U-D:TEA). Also important was lopping of young conifers with loppers and chainsaw in late-successional seedings (U-D:SI and U-D:SI+AS) before the decades-old investment in seedings could be lost because trees will eventually suppress the sagebrush understory and render sage-grouse habitat unsuitable. A similar objective was the removal of young and older conifers, many that were Utah juniper, with heavier chainsaws in the reference late-successional treed class (D:Open). This and the previous action would cause, respectively, transitions to the mid-successional seeded classes (U-B:SI and U-B:SI+AS) and reference class (B:Open). Based on current values, thinning and seeding of 3,000 acres of depleted black sagebrush on BLM lands may be warranted. A future objective (requiring future fires) was the conversion of non-native annual species (U-A:Annual Spp) to seedings of mixed introduced and native species.

Treatment Rates and Costs

The main cause of funding differences among climate scenarios was the Masticate+Seed action. The ACCESS1 LOCA often had a greater availability of trees to remove with Masticate+Seed and 2xChaining+Seed because this climate scenario experienced less fire, which would have killed conifers. In the HISTORIC and CCSM4 climate scenarios, the burned treed areas were converted to the U-A:Annual Spp class, which was cheaper to convert to seedings than treed areas. However, more funding was spent in the CCSM4 scenario in the IP WMA because Masticate+Seed was used more, while 10 times less Chainsaw-Thinning was deployed only during the first period (2020-2024; Table 10). Total 60-year expense for BLM lands was at least \$3.3 million (\$4.9 million for the ACCESS1 LOCA), whereas expenses for IP WMA, private, and SITLA lands were, respectively, at least \$219,000, \$73,000, and \$301,000.

**Table 10. Cumulative implementation rates and costs of actions in black sagebrush over periods of implementation.**

Scenario	Action	Cost/ acre		Sum of Acres / Interval (Avg of 10 runs)				60-yr Total Cost
				2020-2024	2025-2034	2035-2044	2045-2077	
<b>IP WMA</b>								
Preferred +HISTORIC	Chainsaw-Thinning	\$112.50		19.5	0.0	0.0	0.0	
	Masticate+Seed	\$577.50		99.4	198.6	38.9	31.4	
	Small-Tree-Lopping	\$150.00		33.1	0.0	0.0	0.0	
			Cost →	\$64,584	\$114,716	\$22,437	\$18,148	

Scenario	Action	Cost/ acre		Sum of Acres / Interval (Avg of 10 runs)				60-yr Total Cost
				2020-2024	2025-2034	2035-2044	2045-2077	
Preferred +CCSM4	Chainsaw-Thinning	\$112.50		1.9	0.0	0.0	0.0	
	Masticate+Seed	\$577.50		119.8	192.4	45.3	74.1	
	Small-Tree-Lopping	\$150.00		33.8	0.0	0.0	0.0	
			Cost →	\$63,714	\$111,120	\$26,187	\$42,781	
Preferred +ACCESS1	Chainsaw-Thinning	\$112.50		19.3	0.0	0.0	0.0	
	Masticate+Seed	\$577.50		97.7	192.9	46.5	50.6	
	Small-Tree-Lopping	\$150.00		34.0	0.0	0.0	0.0	
			Cost →	\$63,700	\$111,428	\$26,855	\$29,231	
<b>BLM</b>								
Preferred +HISTORIC	2xChaining+Seed	\$202.50		3574.1	0.0	0.0	0.0	
	Chaining+Plateau+Seed	\$160.00		2067.2	0.0	0.0	0.0	
	Chainsaw-Thinning	\$112.50		1130.9	0.0	0.0	0.0	
	Forb+Grass-Native-Seeding+Chaining	\$160.00		247.5	0.0	0.0	0.0	
	Herbicide-Plateau+Seed	\$117.50		1249.5	0.0	0.0	0.0	
	Masticate+Seed	\$577.50		1756.2	1755.2	0.0	0.0	
			Cost →	\$2,382,342	\$1,013,618	\$0	\$0	
Preferred +CCSM4	2xChaining+Seed	\$202.50		3693.0	0.0	0.0	0.0	
	Chaining+Plateau+Seed	\$160.00		2170.6	0.0	0.0	0.0	
	Chainsaw-Thinning	\$112.50		1265.0	0.0	0.0	0.0	
	Forb+Grass-Native-Seeding+Chaining	\$160.00		249.8	0.0	0.0	0.0	
	Herbicide-Plateau+Seed	\$117.50		1249.9	0.0	0.0	0.0	
	Masticate+Seed	\$577.50		1761.8	1756.3	0.0	0.0	
			Cost →	\$2,441,694	\$1,014,285	\$0	\$0	
Preferred +ACCESS1	2xChaining+Seed	\$202.50		2145.0	0.0	0.0	0.0	
	Chaining+Plateau+Seed	\$160.00		1338.0	0.0	0.0	0.0	

Scenario	Action	Cost/ acre		Sum of Acres / Interval (Avg of 10 runs)				60-yr Total Cost
				2020-2024	2025-2034	2035-2044	2045-2077	
Preferred +ACCESS1	Chainsaw-Thinning	\$112.50		254.2	0.0	0.0	0.0	
	Forb+Grass-Native-Seeding+Chaining	\$160.00		1254.4	0.0	0.0	0.0	
	Herbicide-Plateau+Seed	\$117.50		1757.1	2993.7	0.0	0.0	
	Masticate+Seed	\$577.50		2145.0	0.0	0.0	0.0	
				Cost →	\$2,482,770	\$2,453,871	\$0	
<b>Private</b>								
Preferred +HISTORIC	Chainsaw-Thinning	\$112.50		3.2	0.0	0.0	0.0	
	Masticate+Seed	\$577.50		123.7	0.0	0.0	0.0	
				Cost →	\$73,361	\$0	\$0	
Preferred +CCSM4	Chainsaw-Thinning	\$112.50		5.4	0.0	0.0	0.0	
	Masticate+Seed	\$577.50		125.8	0.0	0.0	0.0	
				Cost →	\$73,265	\$0	\$0	
Preferred +ACCESS1	Chainsaw-Thinning	\$112.50		12.1	0.0	0.0	0.0	
	Masticate+Seed	\$577.50		126.2	0.0	0.0	0.0	
				Cost →	\$74,242	\$0	\$0	
<b>SITLA</b>								
Preferred +HISTORIC	2xChaining+Seed	\$202.50		199.0	0.0	0.0	0.0	
	Chaining+Native-Seed	\$205.00		0.0	0.0	297.7	0.0	
	Chainsaw-Thinning	\$112.50		227.9	0.0	0.0	0.0	
	Masticate+Seed	\$577.50		277.3	0.0	0.0	0.0	
	Small-Tree-Lopping	\$150.00		252.7	0.0	0.0	0.0	
				Cost →	\$263,963	\$0	\$61,028	
Preferred +CCSM4	2xChaining+Seed	\$202.50		142.0	0.0	0.0	0.0	
	Chaining+Native-Seed	\$205.00		326.0	0.0	280.7	0.0	
	Chainsaw-Thinning	\$112.50		280.1	0.0	0.0	0.0	
	Masticate+Seed	\$577.50		250.3	0.0	0.0	0.0	

Scenario	Action	Cost/ acre		Sum of Acres / Interval (Avg of 10 runs)				60-yr Total Cost
				2020-2024	2025-2034	2035-2044	2045-2077	
Preferred +CCSM4	Small-Tree-Lopping	\$150.00		142.0	0.0	0.0	0.0	
			Cost →	\$264,737	\$0	\$57,941	\$0	\$322,679
Preferred +ACCESS1	2xChaining+Seed	\$202.50		132.2	0.0	0.0	0.0	
	Chaining+Native-Seed	\$205.00		0.0	0.0	292.5	0.0	
	Chainsaw-Thinning	\$112.50		149.7	0.0	0.0	0.0	
	Masticate+Seed	\$577.50		278.1	0.0	0.0	0.0	
	Small-Tree-Lopping	\$150.00		249.5	0.0	0.0	0.0	
				Cost →	\$241,650	\$0	\$59,961	\$0

Compared to the MINIMUM MANAGEMENT scenarios, management actions reduced UED by about 12%, 13%, and 18%, respectively, for the HISTORIC, CCSM4 and ACCESS1 climates (below). Differences among all climate scenarios appeared significant only for the lower value of the ACCESS1 LOCA based on the 95% CI.

Unified Ecological Departure	MINIMUM MANAGEMENT	PREFERRED MANAGEMENT
In 2077 under HISTORIC Climate	98 ± 1	86 ± 2
In 2077 under CCSM4 LOCA	99 ± 1	86 ± 1
In 2077 under ACCESS1 LOCA	100 ± 0	82 ± 1

Vegetation Classes

The effects of management actions were not strong on IP WMA lands, except for tree removal in the U-D:TEA class that caused at least 150 acres of difference between the MINIMUM and PREFERRED MANAGEMENT scenarios (Figure 6). More subtle effects were observed for (i) tree removal in the reference late-successional D:Open class with PREFERRED MANAGEMENT scenarios showing lower areas of about 50 acres, and (ii) reduction of non-native annual grasslands especially for the HISTORIC and CCSM4 scenarios by year 2077 that also created the most area of U-A:Annual Spp class (Figure 6).

The benefits of these actions were observed as (i) a pulse of greater area (about 50 acres but highly variable) in the mid-successional open class (B:Open), and (ii) a 50-200 acre increase in the early-successional seeded class (U-A:SI), which followed a successional pathway to older classes (U-B:SI and U-C:SI) within decades.

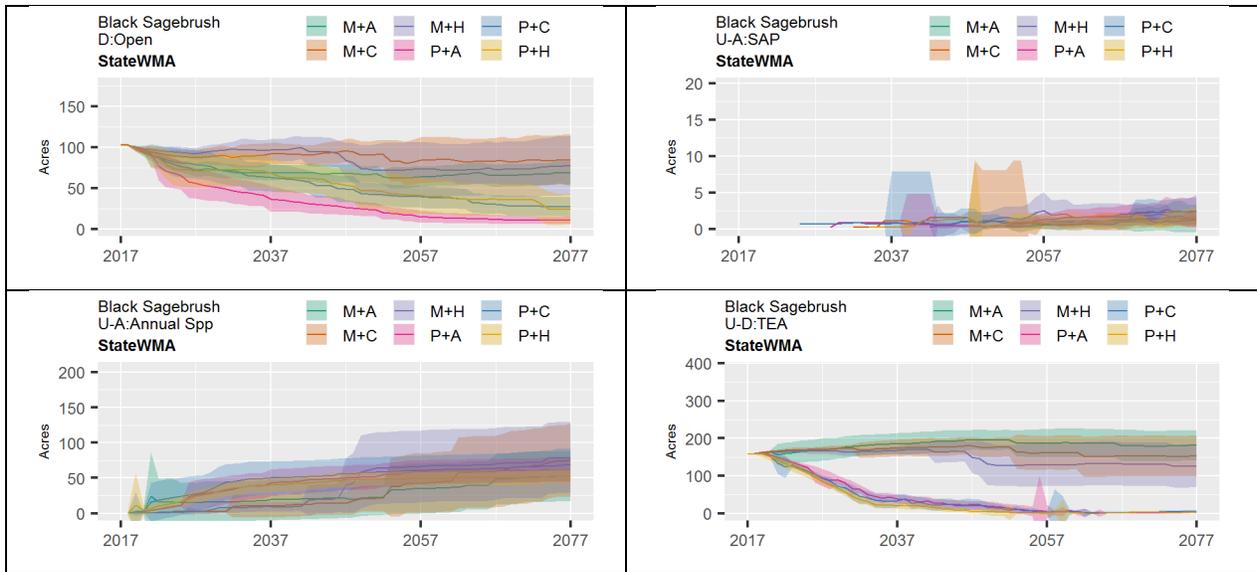


Figure 6. Area (acres) of treated vegetation classes over time in black sagebrush on IP WMA-managed lands. N = 10 iterations.

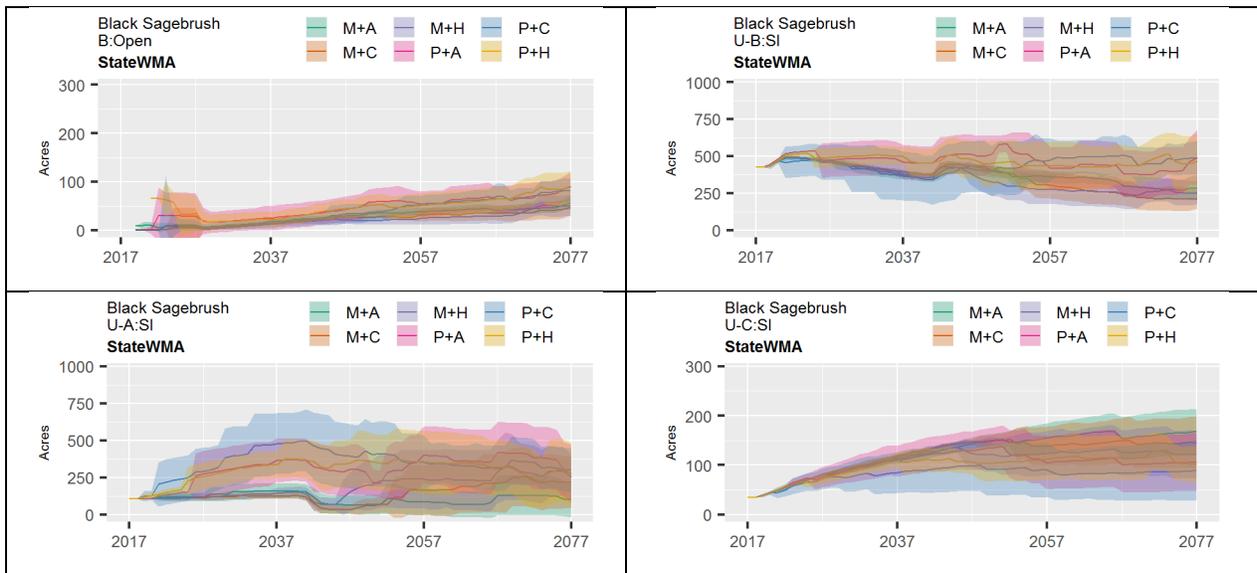


Figure 7. Area (acres) of recipient vegetation classes over time in black sagebrush on IP WMA-managed lands. N = 10 iterations.

Results for BLM lands are comparable to those seen in the IP WMA but differences among scenarios are clearer and the areas seen on BLM lands are orders of magnitude greater than on the IP WMA (Figure 8). Tree removal in the U-D:TEA class caused about 10,000 acres reduction compared to the MINIMUM MANAGEMENT scenarios (Figure 8). Also notable was the strong effect of climate scenarios. For example, the area of U-D:TEA for the PREFERRED+ACCESS1 MANAGEMENT scenario was greater than the area of MINIMUM+HISTORIC scenario decades into the simulation. Commensurate reduction of the U-A:Annual Spp class of 10,000 acres due to management actions was also observed, especially towards the end of the simulations (Figure 8). Smaller effects between 500 and 1,000 acres in reductions of D:Open and U-B:SAP classes within climate scenarios that reflected more modest investments in these classes were observed in the first 15 years of the simulations (Figure 8).

The intense restoration activities on BLM lands translated into 8,000 to 10,000 acres of new seedings of mixed introduced and native species (Figure 9). Because more money was spent for the ACCESS1 LOCA due to the greater area of treed sagebrush, this scenario was also the one with most seedings. Later as the dominance of cheatgrass in burned areas increased with decades (U-A:Annual Spp class; Figure 8), seedings became more abundant in the HISTORIC and CCSM4 LOCAs (Figure 9), which had the most fire. Finally, the increase of area in the reference mid-successional class (B:Open) due to chainsaw thinning in the D:Open class was modest, resulting in at most 500 acres difference compared to MINIMUM MANAGEMENT within each climate scenario (Figure 9).

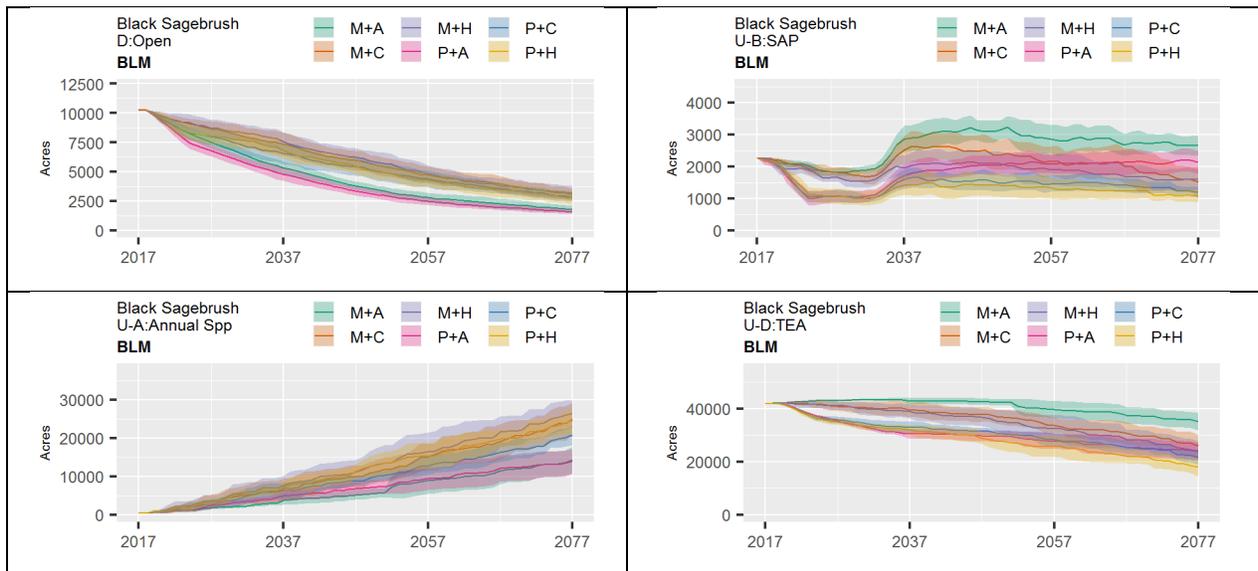


Figure 8. Area (acres) of treated vegetation classes over time in black sagebrush on BLM-managed lands. N = 10 iterations.

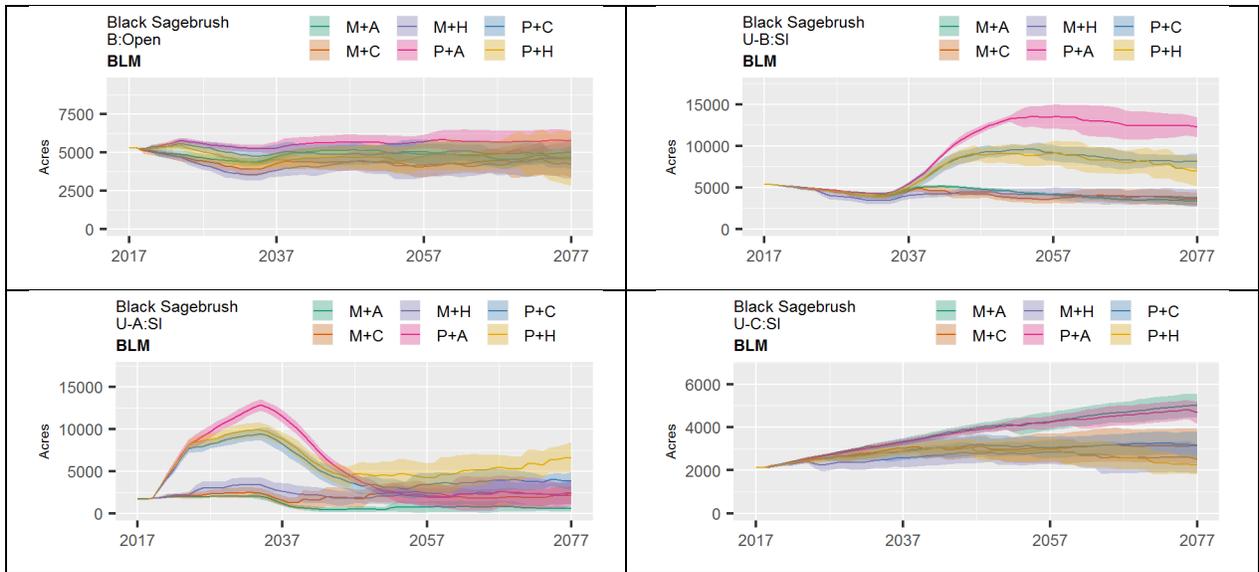


Figure 9. Area (acres) of recipient vegetation classes over time in black sagebrush on BLM-managed lands. N = 10 iterations.

On private lands, the most noticeable change due to actions was an approximate 100-acre decrease in the area of the U-D:TEA class (Figure 10). Other actions yielded small decreases compared to MINIMUM MANAGEMENT that are difficult to see with overlapping error bars. The most noticeable recipient of actions was an about 100-acre increase of new seedings (U-A:SI; Figure 11). As vegetation matured, the early-successional seeding decreased in area and the mid-successional seeding (U-B:SI) increased in area (Figure 11).

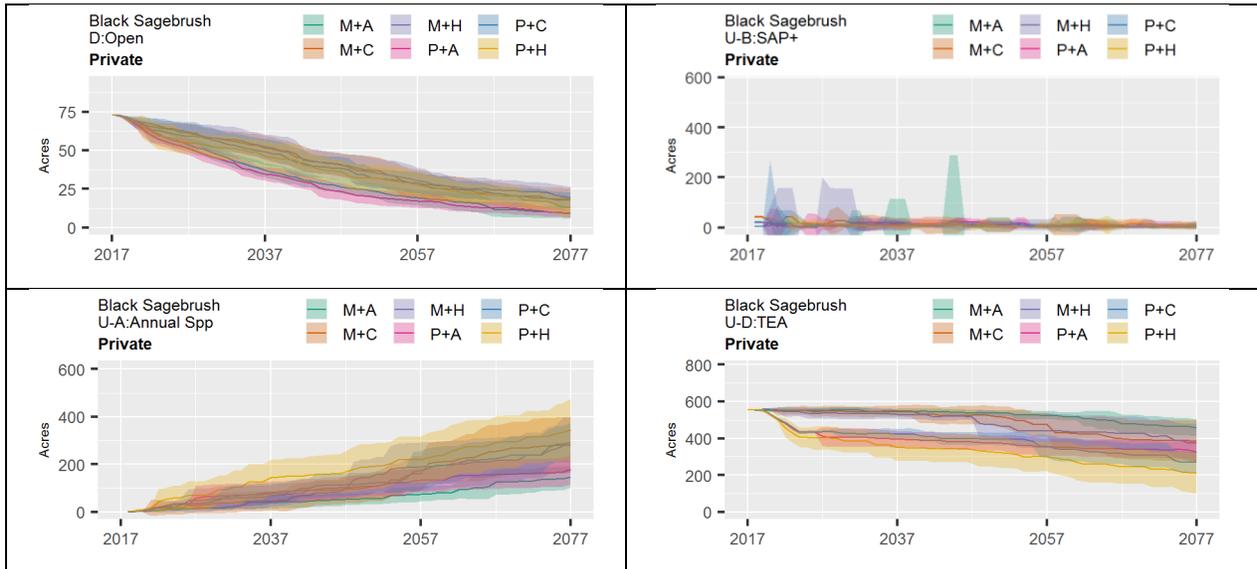


Figure 10. Area (acres) of treated vegetation classes over time in black sagebrush on private lands. N = 10 iterations.

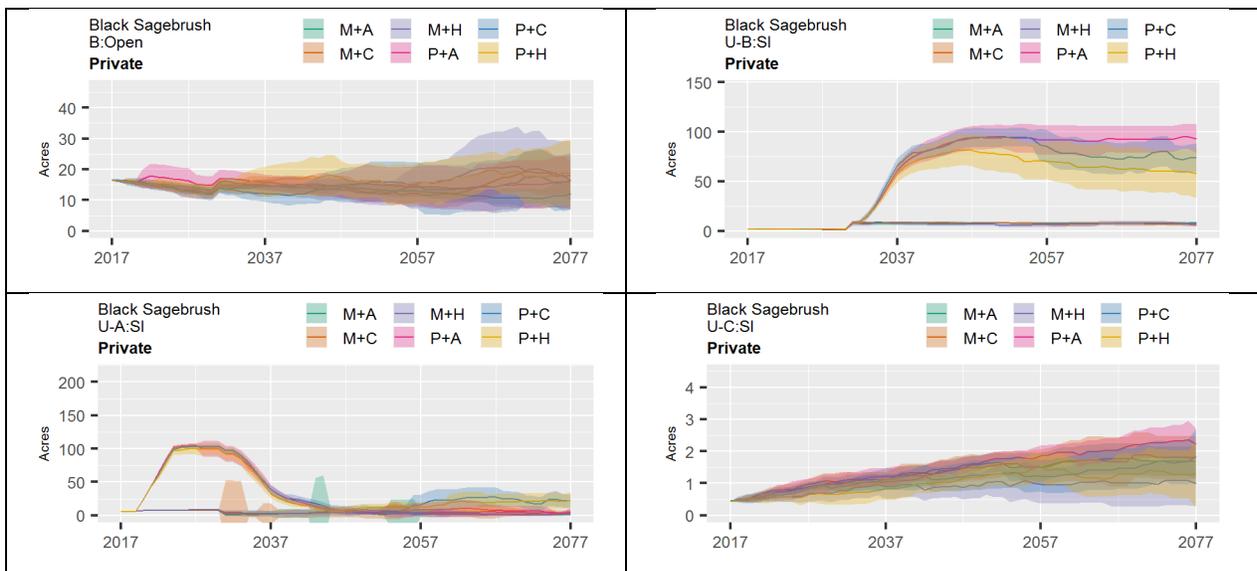


Figure 11. Area (acres) of recipient vegetation classes over time in black sagebrush on private lands. N = 10 iterations.

The results for SITLA lands follow the qualitative pattern as seen for private lands, with the exceptions that more area of each class was found on SITLA lands, the effect of restoration was more visible for the non-native annual species class (U-A:Annual Spp), and all seeded classes (U-A:SI U-B:SI, and U-C:SI) were already present in 2017 (Figures 12 and 13). Both tree removal in the U-D:TEA class and reduction of the U-A:Annual Spp class totaled a change of 500 to 800 acres in two intervals: About 500 acres of new seedings (U-A:SI) were detected from 2020 to 2034 due to tree removal, and about 100-200 acres due to cheatgrass conversion to seedings can be seen from 2045 to 2077. It also appears that climate effects were important in all results, as MINIMUM and PREFERRED MANAGEMENT differences from the same climate scenario do not overlap with those of other climates.

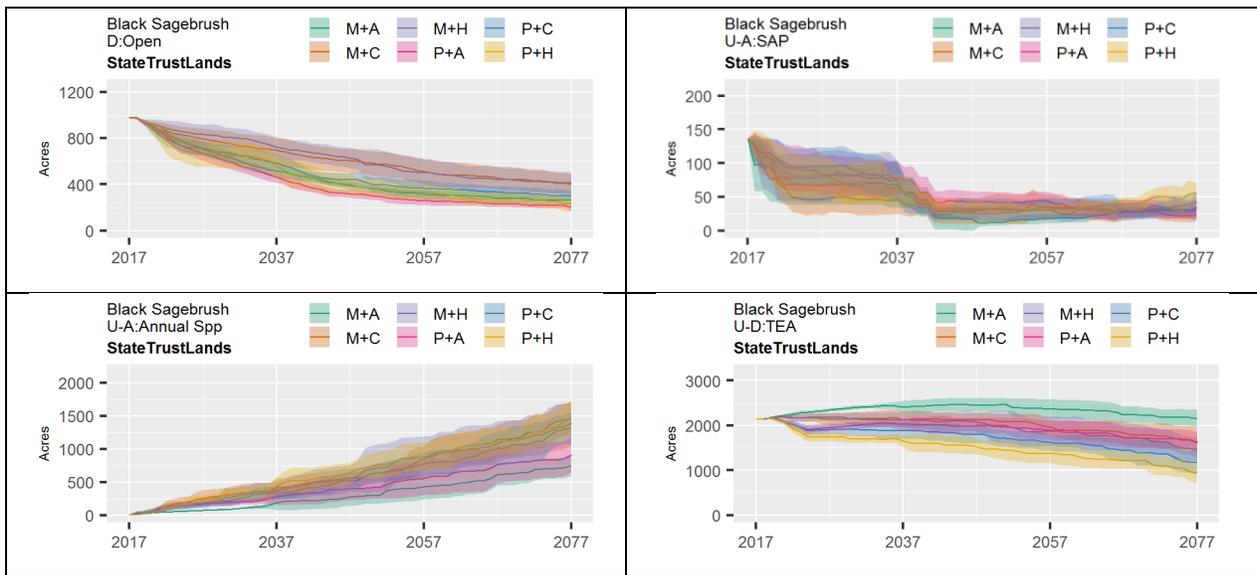


Figure 12. Area (acres) of treated vegetation classes over time in black sagebrush on SITLA-managed lands. N = 10 iterations.

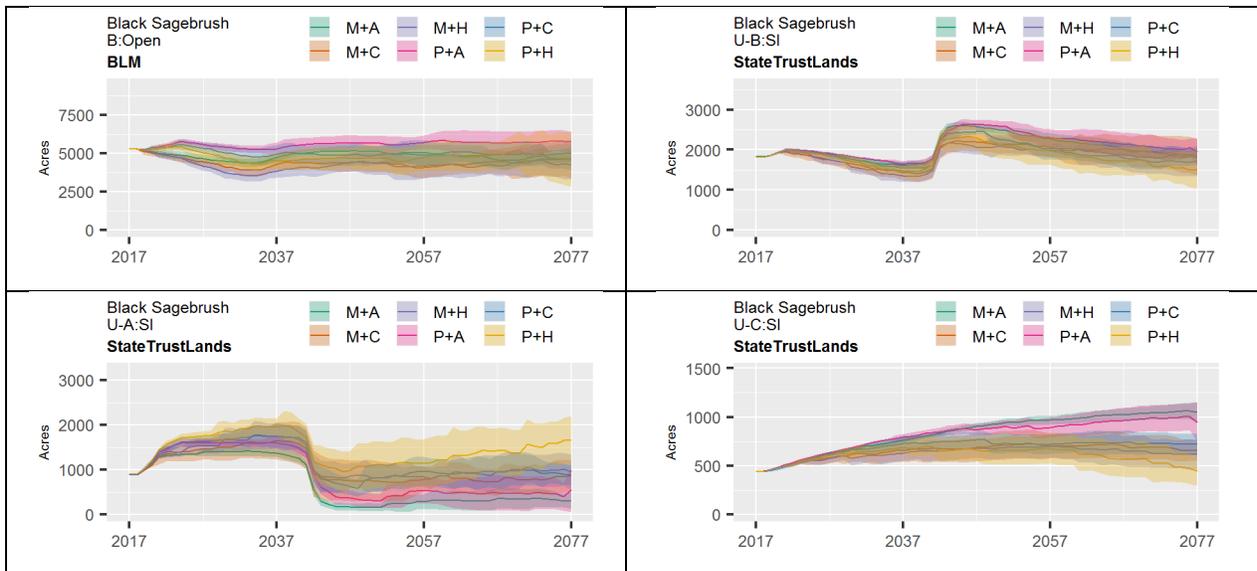


Figure 13. Area (acres) of recipient vegetation classes over time in black sagebrush on SITLA-managed lands. N = 10 iterations.

DRY WET MEADOW

Current System Acres at 30-m resolution: 90 total

Condition: Unified Ecological Departure

In 2017:

In 2077 under MINIMUM MANAGEMENT & HISTORIC Climate:

In 2077 under MINIMUM MANAGEMENT & CCSM4 LOCA:

In 2077 under MINIMUM MANAGEMENT & ACCESS1 LOCA:

100
83 ± 6
87 ± 5
94 ± 4

Vegetation Classes

**Table 11. Vegetation classes of the dry wet meadow ecological system at the current time (2017 and 2019), and after 60 years of MINIMUM MANAGEMENT (2077) under three climate scenarios.**

Vegetation Class	Ref NRV%	Undesir. Level	Allow. Thresh%	Current (2017)	MINIMUM MANAGEMENT (2077)		
				Class %	HISTORIC Class %	CCSM4 Class %	ACCESS1 Class %
A:All	12	0	—	3.0%	5.3%	3.2%	2.1%
B:Closed	84	0	—	14.8%	23.6%	21.3%	14.3%
C:Open	4	0	—	0.0%	2.6%	3.9%	9.7%
U-A:Annual Spp	0	1	0.0	0.0%	0.8%	1.1%	0.9%
U-A:Bare Ground	0	1	0.0	0.0%	0.0%	0.5%	0.4%
U-A:Early-Shrub	0	1	0.0	0.0%	0.0%	0.0%	0.0%
U-A:Exotic Forb	0	2	0.0	0.0%	2.3%	2.7%	1.4%
U-A:SAP	0	1	0.0	12.8%	0.0%	0.5%	0.7%
U-A:SI	0	0	0.0	43.8%	43.1%	43.7%	43.7%
U-A:SI+AS	0	0	0.0	0.0%	0.8%	0.4%	0.4%
U-B:SAP	0	1	0.0	11.8%	17.7%	18.9%	13.4%
U-C:SA	0	1	0.0	0.0%	0.0%	0.2%	0.1%
U-C:SAP	0	1	0.0	13.8%	3.3%	3.4%	12.7%
U-C:Shrb-Frb Encr	0	0	0.0	0.0%	0.0%	0.0%	0.1%
U-C:TEA	0	1	0.0	0.0%	0.0%	0.0%	0.0%

**Table 12. Area (acres) of dry wet meadow vegetation classes per ownership in 2017 and 2019.**

Vegetation Class	IP WMA	BLM	Private	SITLA
A:All	0.0	0.9	0.0	1.8
B:Closed	6.7	6.7	0.0	0.0
C:Open	0.0	0.0	0.0	0.0
U-A:Annual Spp	0.0	0.0	0.0	0.0
U-A:Bare Ground	0.0	0.0	0.0	0.0
U-A:SAP	0.4	9.3	0.0	1.8
U-A:SI	4.0	14.2	14.2	7.1
U-A:SI+AS	0.0	0.0	0.0	0.0
U-B:SAP	2.9	5.8	0.0	2.0
U-C:SA	3.3	8.0	0.0	1.1
U-C:SAP	0.0	0.9	0.0	1.8

Problems or Concerns

2017: The dry wet meadow system was highly departed from reference conditions because of introduced species seedings, and non-native annual species in all successional phases (Table 11). A secondary concern was woody vegetation in the late-successional shrub with annual and perennial graminoids (U-C:SAP) class. The majority of dry wet meadows were on BLM lands. Private lands had the next greatest amount, with least on IP WMA and SITLA lands (Table 12). All dry wet meadows on private lands were seeded; therefore, they were not further managed.

After 60 years of MINIMUM MANAGEMENT: The greatest future concern was the presence of exotic forbs, which was least observed in the MINIMUM+ACCESS1 scenario by year 2077. Secondary concerns in the MINIMUM+ACCESS1 scenario were the increase of woody vegetation in the C:Open reference class beyond the 4% of the reference condition (Table 11), and abundance of the uncharacteristic late-successional shrub with annual and perennial graminoids class (U-C:SAP). Woody vegetation classes increased most in climate scenarios with the least fire activity, such that the MINIMUM+ACCESS1 scenario had more woody vegetation, and the MINIMUM+HISTORIC scenario showed the smallest area.

Objective(s) for Management Actions

Limited objectives were to thin (i.e., mow) woody vegetation classes, and control exotic forbs.

Treatment Rates and Costs

Two actions used in all ownerships were thinning shrubs with a mower, and weed inventory with spot spraying of small exotic forb occurrences (Table 13). In addition, exotic forb control was implemented only in the PREFERRED+HISTORIC scenario on BLM lands.

Differences of cost were greatest among land ownerships and small among climate scenarios. The BLM incurred the largest costs (>\$75,000) because it harbored most dry wet meadows and used herbicides for exotic control. About half the money was spent in the IP WMA and a third on SITLA lands.

**Table 13. Cumulative implementation rates and costs of actions in dry wet meadow over periods of implementation.**

Scenario	Action	Cost/acre		Sum of Acres /Interval (Avg of 10 runs)				60-yr Total Cost
				2020-2024	2025-2034	2035-2044	2045-2077	
IP WMA								
Preferred +HISTORIC	Thin	\$150.00		0.0	0.0	1.0	0.0	
	Weed-Inventory+Treat	\$253.00		15.5	30.1	31.8	98.3	
			Cost →	\$3,910	\$7,607	\$8,191	\$24,858	
Preferred +CCSM4	Thin	\$150.00		0.0	0.0	1.4	0.0	
	Weed-Inventory+Treat	\$253.00		18.9	31.4	31.1	102.3	
			Cost →	\$4,771	\$7,939	\$8,077	\$25,877	

Scenario	Action	Cost/acre		Sum of Acres /Interval (Avg of 10 runs)				60-yr Total Cost
				2020-2024	2025-2034	2035-2044	2045-2077	
Preferred +ACCESS1	Thin	\$150.00		0.0	0.0	3.8	0.0	
	Weed-Inventory+Treat	\$253.00		18.5	28.5	28.9	99.8	
			Cost →	\$4,687	\$7,219	\$7,891	\$25,258	
<b>BLM</b>	<b>Thin</b>							
Preferred +HISTORIC	Exotic-Control	\$360.00		0.0	0.0	0.3	1.5	
	Thin	\$150.00		0.0	0.0	4.8	0.0	
	Weed-Inventory+Treat	\$253.00		28.8	50.8	52.0	172.9	
			Cost →	\$7,298	\$12,857	\$13,991	\$44,281	
Preferred +CCSM4	Exotic-Control	\$360.00		0.0	0.1	0.3	1.9	
	Thin	\$150.00		0.0	0.0	4.5	0.0	
	Weed-Inventory+Treat	\$253.00		25.6	50.7	47.9	167.6	
			Cost →	\$6,471	\$12,858	\$12,915	\$43,082	
Preferred +ACCESS1	Exotic-Control	\$360.00		0.0	0.0	0.2	1.4	
	Thin	\$150.00		0.0	0.0	5.9	0.0	
	Weed-Inventory+Treat	\$253.00		24.4	55.6	54.0	185.3	
			Cost →	\$6,178	\$14,069	\$14,622	\$47,396	
<b>SITLA</b>								
Preferred +HISTORIC	Thin	\$150.00		0.0	0.0	1.1	0.0	
	Weed-Inventory+Treat	\$253.00		11.0	18.7	19.5	62.3	
			Cost →	\$2,785	\$4,721	\$5,116	\$15,760	
Preferred +CCSM4	Thin	\$150.00		0.0	0.0	1.5	0.0	
	Weed-Inventory+Treat	\$253.00		12.5	19.1	18.6	61.8	
			Cost →	\$3,151	\$4,839	\$4,933	\$15,625	
Preferred +ACCESS1	Thin	\$150.00		0.0	0.0	1.6	0.0	
	Weed-Inventory+Treat	\$253.00		11.9	19.5	20.1	63.2	
			Cost →	\$3,021	\$4,946	\$5,332	\$15,979	

Compared to the MINIMUM MANAGEMENT scenarios, management actions decreased UED, although not significantly for the ACCESS1 LOCA (below). Woody vegetation was largest and more persistent under the ACCESS1 LOCA, and climate effects seemed to have been stronger than the effects of the small implementation rates (Figures 14-16).

Unified Ecological Departure	MINIMUM MANAGEMENT	PREFERRED MANAGEMENT
In 2077 under HISTORIC Climate	83 ± 6	73 ± 6
In 2077 under CCSM4 LOCA	87 ± 5	81 ± 6
In 2077 under ACCESS1 LOCA	94 ± 4	93 ± 3

### Vegetation Classes

It was difficult to distinguish among scenarios due to the small area values and small implementation rates involved. The effects of management actions were most visible from the thinning of woody vegetation in the C:Open class and commensurate increase of the B:Closed class, which is more suitable to sage-grouse (Figures 14-16). Differences between PREFERRED and MINIMUM MANAGEMENT scenarios increased with years of simulation.

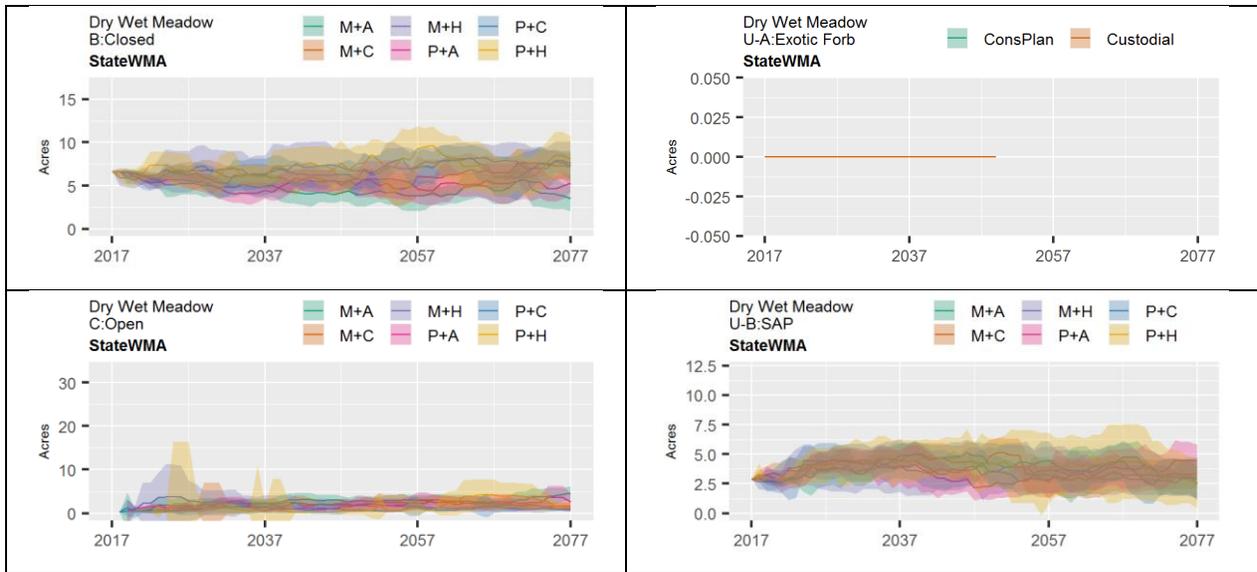


Figure 14. Area (acres) of focal vegetation classes over time in dry wet meadow on IP WMA-managed lands. N = 10 iterations.

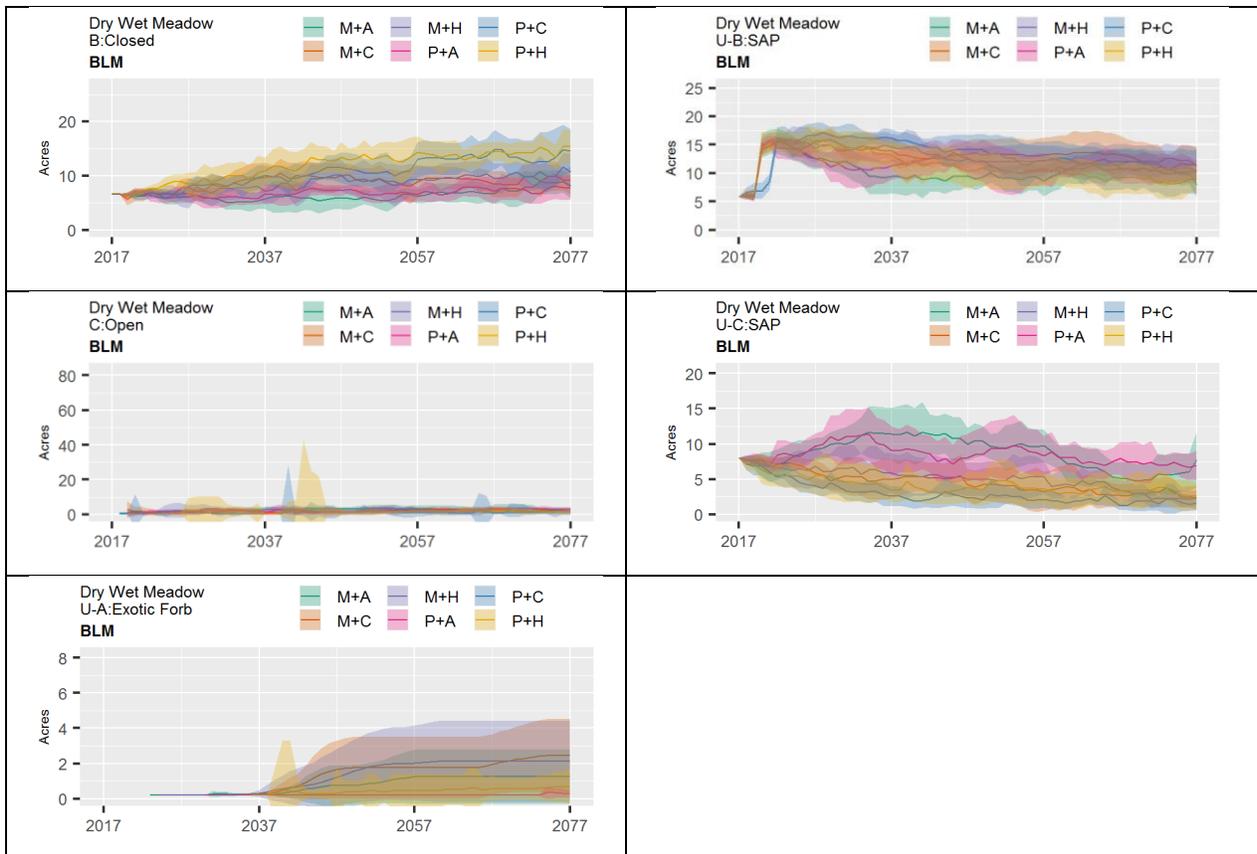


Figure 15. Area (acres) of focal vegetation classes over time in dry wet meadow on BLM-managed lands. N = 10 iterations.

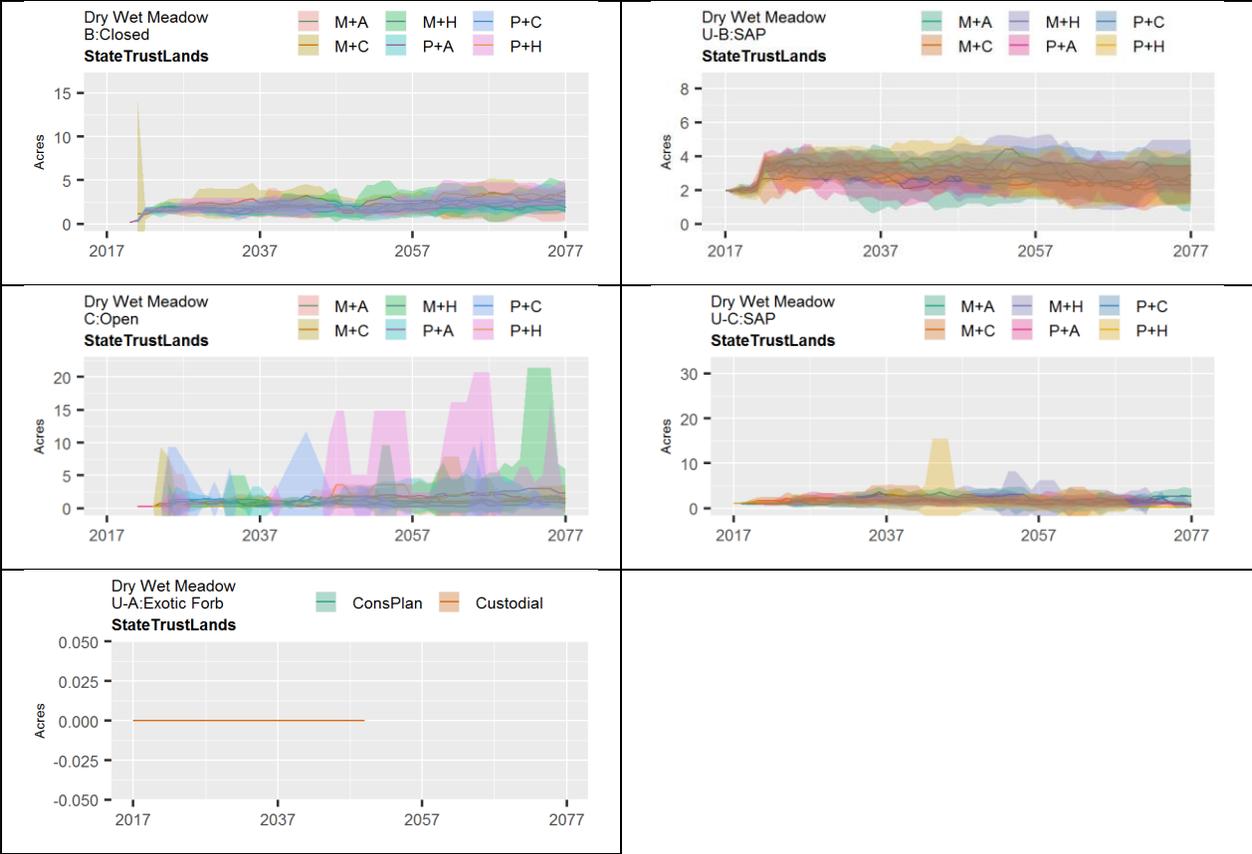


Figure 16. Area (acres) of focal vegetation classes over time in dry wet meadow on SITLA-managed lands. N = 10 iterations.

MONTANE RIPARIAN

Current System Acres at 30-m resolution: 235 total

Condition: Unified Ecological Departure

In 2017:

In 2077 under MINIMUM MANAGEMENT & HISTORIC Climate:

In 2077 under MINIMUM MANAGEMENT & CCSM4 LOCA:

In 2077 under MINIMUM MANAGEMENT & ACCESS1 LOCA:

74
71 ± 5
71 ± 3
71 ± 2

Vegetation Classes

**Table 14. Vegetation classes of the montane riparian ecological system at the current time (2017 and 2019), and after 60 years of MINIMUM MANAGEMENT (2077) under three climate scenarios.**

Vegetation Class	Ref NRV%	Undesir. Level	Allow. Thresh%	Current (2017)	MINIMUM MANAGEMENT (2077)		
				Class %	HISTORIC Class %	CCSM4 Class %	ACCESS1 Class %
A-Willow:All	3	0	—	0.0%	5.2%	2.7%	1.0%
B-Willow:Closed	92	0	—	27.4%	28.4%	26.2%	27.3%
C-Cottonwood:Closed	5	0	—	18.0%	9.0%	15.1%	15.7%
U-A:Agriculture	0	1	0.0	0.0%	0.0%	0.0%	0.0%
U-A:Annual Spp	0	1	0.0	0.0%	0.0%	0.0%	0.0%
U-A:Bare Ground	0	1	0.0	0.0%	0.0%	0.0%	0.0%
U-A:Early-Shrub	0	0	0.0	0.0%	0.6%	0.3%	0.2%
U-A:EFT	0	2	0.0	2.6%	6.3%	3.5%	3.8%
U-A:Hummocked	0	1	0.0	0.0%	0.1%	0.0%	0.1%
U-A:Incised-EFT	0	2	0.0	0.0%	0.0%	0.0%	0.0%
U-A:Inset	0	0	0.0	1.6%	8.4%	7.7%	7.8%
U-A:Inset-EFT	0	2	0.0	0.0%	0.0%	0.0%	0.1%
U-A:Inset-HU	0	1	0.0	0.0%	0.1%	0.0%	0.0%
U-A:Inset-SFE	0	1	0.0	0.0%	0.1%	0.1%	0.1%
U-A:Seeded Native	0	0	0.0	0.0%	0.0%	0.0%	0.0%
U-A:SI+AS	0	1	0.0	0.0%	0.0%	0.0%	0.0%
U-C:Desertified	0	1	0.0	7.6%	0.5%	0.6%	0.8%
U-C:SAP	0	1	0.0	0.0%	0.0%	0.0%	0.0%
U-C:Shrb-Frb Encr	0	0	0.0	42.8%	41.2%	43.5%	43.0%
U-C:TEA	0	1	0.0	0.0%	0.0%	0.0%	0.0%

Table 15. Area (acres) of montane riparian vegetation classes per ownership in 2017 and 2019.

Vegetation Class	IP WMA	BLM	Private	SITLA
A-Willow:All	0.0	0.0	0.0	0.0
B-Willow:Closed	30.5	10.9	9.3	13.8
C-Cottonwood:Closed	11.1	27.6	2.7	0.9
U-A:Agriculture	0.0	0.0	0.0	0.0
U-A:Annual Spp	0.0	0.0	0.0	0.0
U-A:Bare Ground	0.0	0.0	0.0	0.0
U-A:Early-Shrub	0.0	0.0	0.0	0.0
U-A:EFT	0.0	0.0	6.2	0.0
U-A:Hummocked	0.0	0.0	0.0	0.0
U-A:Incised-EFT	0.0	0.0	0.0	0.0
U-A:Inset	3.8	0.0	0.0	0.0
U-A:Inset-EFT	0.0	0.0	0.0	0.0
U-A:Inset-HU	0.0	0.0	0.0	0.0
U-A:Inset-SFE	0.0	0.0	0.0	0.0
U-A:Seeded Native	0.0	0.0	0.0	0.0
U-A:SI+AS	0.0	0.0	0.0	0.0
U-C:Desertified	0.2	14.2	0.0	3.3
U-C:SAP	0.0	0.0	0.0	0.0
U-C:Shrb-Frb Encr	66.9	32.5	0.2	1.1
U-C:TEA	0.0	0.0	0.0	0.0

### Problems or Concerns

2017: The greatest concern was the presence of exotic forb and trees (U-A:EFT; Table 14), which in 2017 and 2019 were only found on private lands (Table 15). Stream incision (U-C:Desertified) was the second problem and was mapped in all land ownerships except private lands. At 14.2 acres, BLM lands have the largest area followed by SITLA lands (3.3 acres), and the IP WMA (0.2 acres; Table 15). The third concern was the inset floodplain in the IP WMA that implied a past drop of the water table where former floodplains became uplands. The large area of late-successional shrub and forb encroached floodplain (U-C:Shrb-Frb Encr) indicated a past history of grazing leaving behind mostly unpalatable species. However, this native cover is considered acceptable. This problem is more prevalent in the IP WMA and half as widespread on BLM lands.

After 60 years of MINIMUM MANAGEMENT: Problems found in initial conditions persisted until 2077 (Table 14). Only the areas of exotic forbs and trees (U-A:EFT) and inset floodplain (U-A:Inset) increased noticeably. The inset floodplain area increased because the 33-year flood events widened the stream width in the desertified class (U-C:Desertified) and formed a new, lower-elevation floodplain made of fine sediment (Table 14). In fact, the area of the U-C:Desertified class decreased by the same amount as the U-A:Inset increased (Table 14).

### Objective(s) for Management Actions

Control of exotic forbs and trees should be a general maintenance objective in the montane riparian system. In the initial case of private lands, the species of concern was *Tamarix* spp. Two actions that should be implemented are periodic weed surveys with spot treatment of small noxious weed occurrences, and more extensive exotic species treatment of larger patches.

Incised streams can be restored with low-technology, inexpensive, and often temporary barriers to flow (“Water-Table-Uplift” treatment; Table 16) that both elevate the stream and below-ground water levels and trap sediment (Clothier and Zeedyk 2014). While flow barriers may generally help with incisions, the restoration of inset floodplains using the same technology is hard to justify because a native, often functional floodplain has formed in an incised stream over decades and elevating the water table would probably flood the lower riparian area. Restoration may be even trickier because incised and inset floodplains often occupy the same streams. It is possible to slowly elevate the water levels of inset floodplains with aggressive sediment trapping without killing the new floodplain, but one would want to mitigate for the underlying causes of incisions before going through a major and controversial riparian improvement effort.

For the IP WMA only, managers stated the need to thin young pinyon and juniper trees encroaching in the montane riparian system (Chainsaw-Thinning). Precedent for this action exists in the form of proposal for it by BLM in the Hamlin Valley and Black Mountains project (Provencher et al. 2015).

#### Treatment Rates and Costs

Four, three, two, and two management actions, respectively, were used in the IP WMA and BLM, private, and SITLA lands (Table 16). With the exception of an implementation rate error under HISTORIC climate (an erroneous rate of 510 acres per year was used instead of 5 for weed inventory and spot spraying for herbicide!), the total cost of riparian actions was about three to four times larger on BLM lands (\$72,000 to \$74,000) than in the IP WMA (\$21,000 to \$22,000). Private and SITLA lands required less funding (disregarding the erroneous high rate in the PREFERRED+HISTORIC scenario).

Variability among climate scenarios per ownership was large because of the larger use of Exotic-Control and Weed-Inventory+Treat in the PREFERRED+HISTORIC scenario compared to the other two scenarios (Table 16). For private and SITLA lands, the expenses were, respectively, two and 1.25 times higher for the HISTORIC climate than other climate scenarios. Also, funding for exotic control increased from 2017 to 2077.

Small areas of chainsaw thinning (Chainsaw-Thinning) and flow barriers (Water-Table-Uplift) were used only on the IP WMA and BLM lands.

**Table 16. Cumulative implementation rates and costs of actions in montane riparian over periods of implementation.**

Scenario	Action	Cost/ acre		Sum of Acres /Interval (Avg of 10 runs)				60-yr Total Cost
				2020-2024	2025-2034	2035-2044	2045-2077	
<b>IP WMA</b>								
Preferred +HISTORIC	Chainsaw-Thinning	\$1500.00		0.0	7.3	0.0	0.0	
	Exotic-Control	\$360.00		0.0	0.0	0.0	0.1	
	Water-Table-Uplift	\$500.00		0.2	0.0	0.0	0.0	
	Weed-Inventory+Treat	\$253.00		5.0	15.1	376.7	42.4	
			Cost →	\$1,380	\$4,929	\$95,314	\$10,756	
Preferred +CCSM4	Chainsaw-Thinning	\$1500.00		0.0	7.2	0.0	0.0	
	Exotic-Control	\$360.00		0.0	0.0	0.0	1.8	
	Water-Table-Uplift	\$500.00		0.2	0.0	0.0	0.0	
	Weed-Inventory+Treat	\$253.00		5.0	13.9	14.2	43.8	
			Cost →	\$1,377	\$4,602	\$3,596	\$11,746	
Preferred +ACCESS1	Chainsaw-Thinning	\$1500.00		0.0	7.5	0.0	0.0	
	Water-Table-Uplift	\$500.00		0.2	0.0	0.0	0.0	
	Weed-Inventory+Treat	\$253.00		9.0	14.2	11.7	47.3	
			Cost →	\$2,400	\$4,731	\$2,952	\$11,995	
<b>BLM</b>								
Preferred +HISTORIC	Exotic-Control	\$360.00		0.00	0.02	0.00	0.04	
	Water-Table-Uplift	\$500.00		0.0	8.6	0.4	0.0	
	Weed-Inventory+Treat	\$253.00		26.0	43.2	302.1	152.9	
			Cost →	\$6,566	\$15,233	\$76,654	\$38,699	
Preferred +CCSM4	Exotic-Control	\$360.00		0.0	0.0	0.2	2.3	
	Water-Table-Uplift	\$500.00		0.0	9.0	0.4	0.0	
	Weed-Inventory+Treat	\$253.00		24.7	43.7	44.5	150.6	
			Cost →	\$6,246	\$15,549	\$11,533	\$38,909	

Scenario	Action	Cost/ acre		Sum of Acres /Interval (Avg of 10 runs)				60-yr Total Cost
				2020-2024	2025-2034	2035-2044	2045-2077	
Preferred +ACCESS1	Exotic-Control	\$360.00		0.0	0.0	0.0	0.2	
	Water-Table-Uplift	\$500.00		0.0	9.2	0.3	0.0	
	Weed-Inventory+Treat	\$253.00		20.1	46.3	46.3	158.5	
			Cost →	\$5,075	\$16,318	\$11,878	\$40,169	
<b>Private</b>								
Preferred +HISTORIC	Exotic-Control	\$360.00		2.6	3.0	5.8	13.5	
	Weed-Inventory+Treat	\$253.00		0.9	2.5	2.3	8.1	
			Cost →	\$1,210	\$1,569	\$13,088	\$7,999	
Preferred +CCSM4	Exotic-Control	\$360.00		3.0	3.5	7.3	18.3	
	Weed-Inventory+Treat	\$253.00		0.8	2.2	2.5	6.4	
			Cost →	\$1,283	\$1,806	\$3,283	\$8,194	
Preferred +ACCESS1	Exotic-Control	\$360.00		3.2	1.1	0.1	0.0	
	Weed-Inventory+Treat	\$253.00		1.1	2.0	3.8	6.6	
			Cost →	\$1,164	\$1,722	\$2,672	\$6,881	
<b>SITLA</b>								
Preferred +HISTORIC	Exotic-Control	\$360.00		0.0	0.0	0.0	0.9	
	Water-Table-Uplift	\$500.00		0.0	2.4	0.0	0.0	
			Cost →	\$0	\$1,179	\$0	\$320	
Preferred +CCSM4	Exotic-Control	\$360.00		0.0	0.0	0.1	2.3	
	Water-Table-Uplift	\$500.00		0.0	2.8	0.0	0.0	
			Cost →	\$0	\$1,401	\$32	\$825	
Preferred +ACCESS1	Water-Table-Uplift	\$500.00		0.0	2.6	0.0	0.0	
			Cost →	\$0	\$1,287	\$0	\$16	

As was the case with the MINIMUM MANAGEMENT scenarios, no differences were observed among climate scenarios under PREFERRED MANAGEMENT, as confidence intervals overlapped (see below).

Unified Ecological Departure	MINIMUM MANAGEMENT	PREFERRED MANAGEMENT
In 2077 under HISTORIC Climate	71 ± 5	65 ± 2
In 2077 under CCSM4 LOCA	71 ± 3	64 ± 3
In 2077 under ACCESS1 LOCA	71 ± 2	63 ± 2

### Vegetation Classes

On BLM (Figure 18) and SITLA lands (Figure 20) where incised riparian areas (U-C:Desertified) were more prevalent, the Water-Table-Uplift treatment eliminated this class. This treatment resulted in a transition to the shrub and forb encroached class (U-C:Shrb-Frb Encr), which was clearly observed (Figures 18 and 20).

Reduction of the area of the exotic forb and tree class (U-A:EFT) had mixed results. For the CCSM4 and ACCESS1 climates in all ownerships, exotic species invasion was low and exotic control was able to maintain invaded areas at low values (Figures 17-20). On private lands, the 6 acres of U-A:EFT remained stable until 2077 in the MINIMUM MANAGEMENT scenarios. Exotic species control actions in PREFERRED MANAGEMENT scenarios reduced to about 2.5 acres the area of invasion until 2024 (Figure 19) because the planned implementation rate was too low for full control (0.1 acre per year for Exotic-Control and 0.5 acres per year for Weed-Inventory+Treat). After year 2024, the area invaded only increased in the HISTORIC climate as the variability of invasion rates driven by wetter climate time series than those of the CCSM4 and ACCESS1 scenarios exceeded the exotic control effort. However, invaded area did not flare up in the MINIMUM MANAGEMENT scenario, except on SITLA lands (Figure 20). We believe this spurious result was due to the very high application of Weed-Inventory+Treat action that effectively inhibits exotic control through the Time-Since-Disturbance function. Exotic control was not inhibited before the high rate of Weed-Inventory+Treat was implemented later in the simulation.

The beneficiary of exotic control was the reference mid-successional closed class (B-Willow:Closed), which increased in response to exotic forb and tree control (Figures 17-20). The only PREFERRED MANAGEMENT scenario for which B-Willow:Closed did not increase was for the HISTORIC climate on BLM lands, presumably because the increase in the area of the exotic forb and tree class was at the expense of the reference classes.

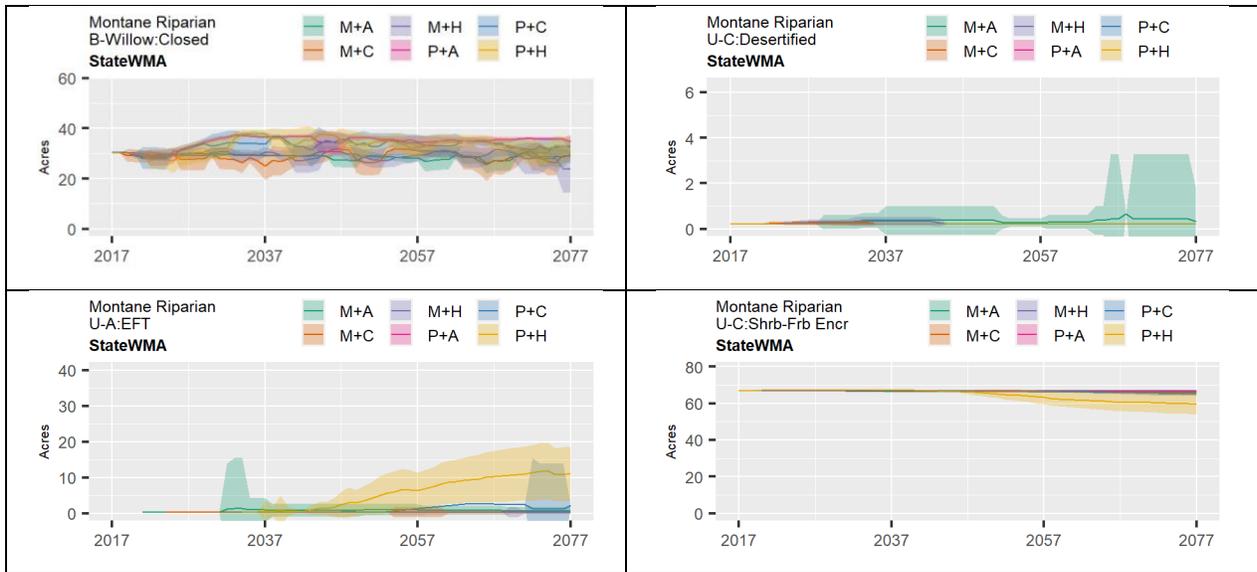


Figure 17. Area (acres) of focal vegetation classes over time in montane riparian on IP WMA-managed lands. N = 10 iterations.

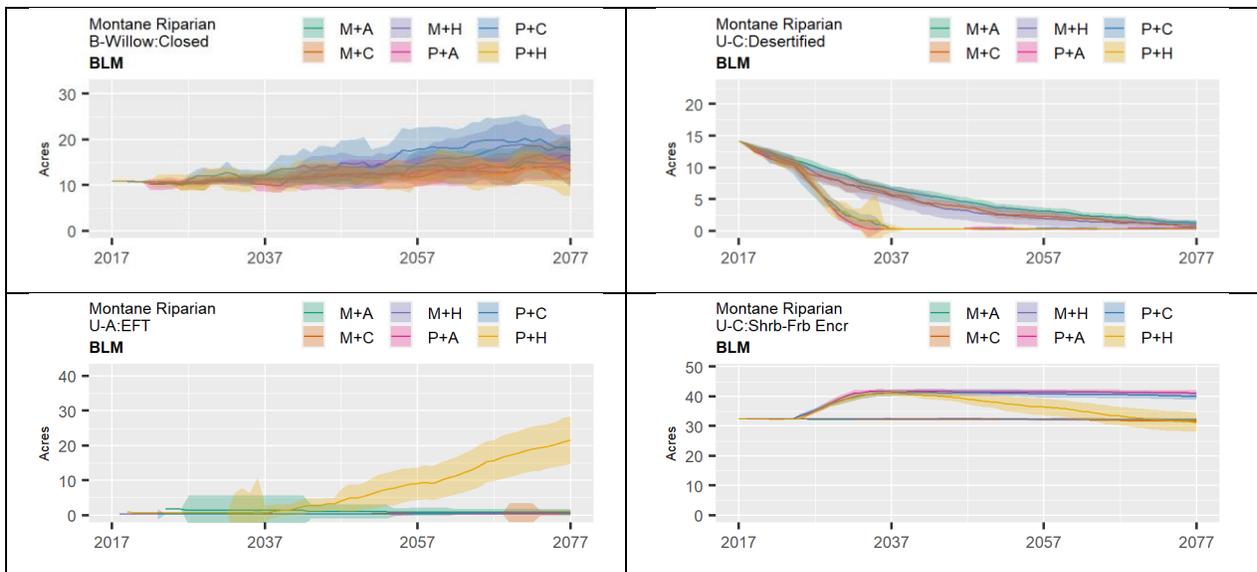


Figure 18. Area (acres) of focal vegetation classes over time in montane riparian on BLM-managed lands. N = 10 iterations.

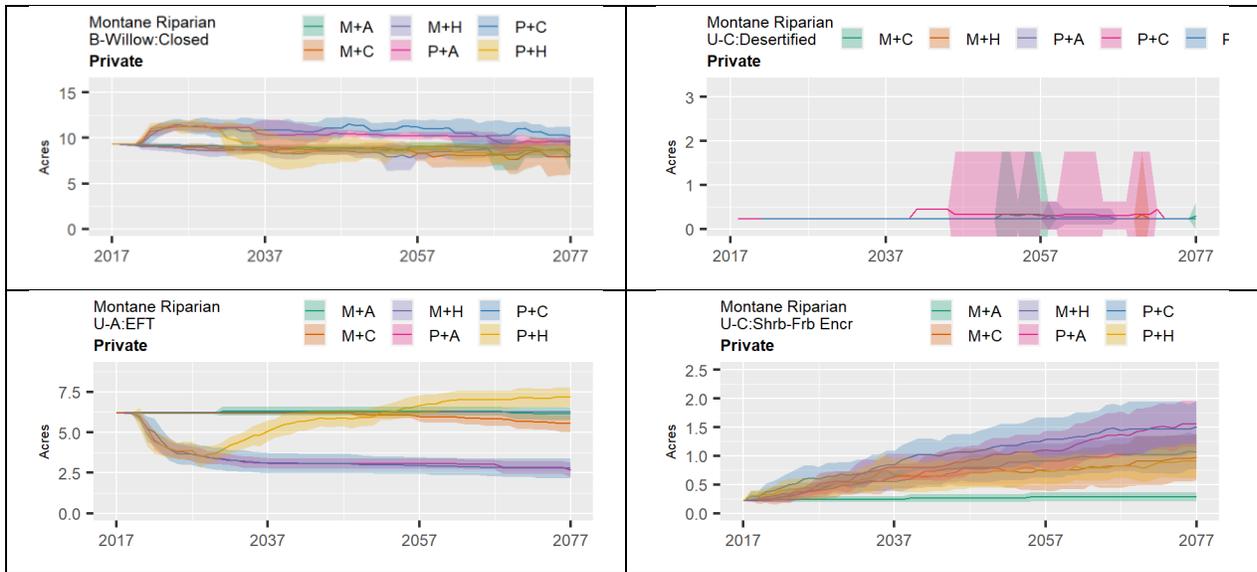


Figure 19. Area (acres) of focal vegetation classes over time in montane riparian on private lands. N = 10 iterations.

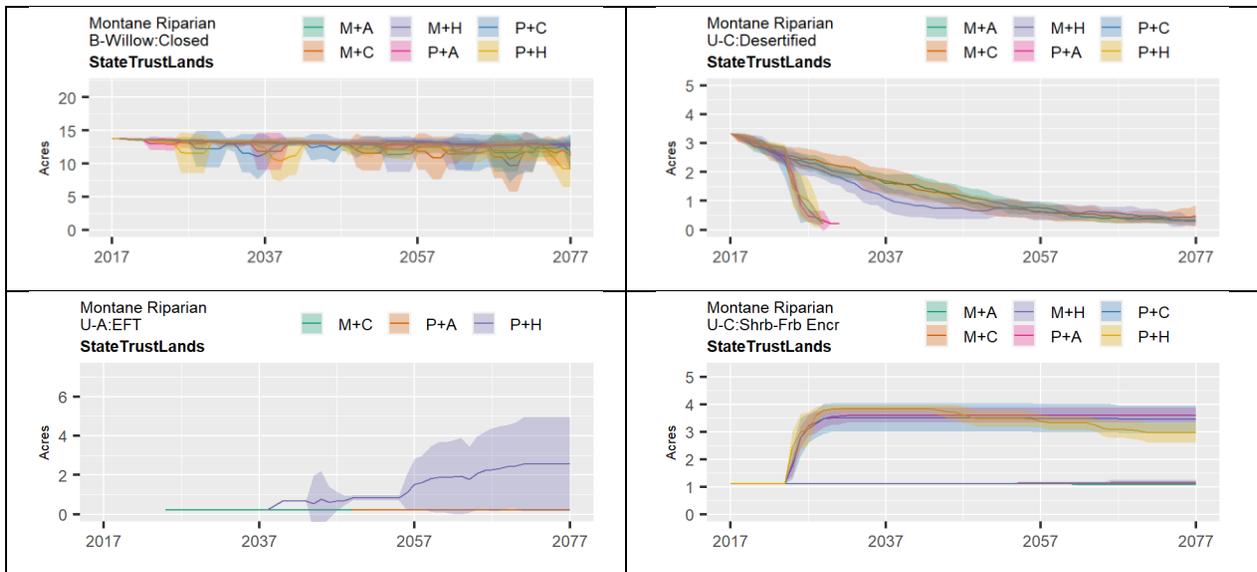


Figure 20. Area (acres) of focal vegetation classes over time in montane riparian on SITLA-managed lands. N = 10 iterations.

MONTANE SAGEBRUSH STEPPE

Current System Acres at 30-m resolution: 61,251 total

Condition: Unified Ecological Departure

In 2017:

In 2077 under MINIMUM MANAGEMENT & HISTORIC Climate:

In 2077 under MINIMUM MANAGEMENT & CCSM4 LOCA:

In 2077 under MINIMUM MANAGEMENT & ACCESS1 LOCA:

100
100 ± 0
100 ± 0
100 ± 0

Vegetation Classes

**Table 17. Vegetation classes of the montane sagebrush steppe ecological system at the current time (2017 and 2019), and after 60 years of MINIMUM MANAGEMENT (2077) under three climate scenarios.**

Vegetation Class	Ref NRV%	Undesir. Level	Allow. Thresh%	Current (2017)	MINIMUM MANAGEMENT (2077)		
				Class %	HISTORIC	CCSM4	ACCESS1
					Class %	Class %	Class %
A:All	21	0	0.0	0.1%	1.1%	1.2%	0.5%
B:Open	34	0	0.0	0.5%	1.0%	0.7%	0.7%
C:Closed	39	0	0.0	0.3%	1.7%	2.1%	2.7%
D:Open	3	0	0.0	2.9%	0.3%	0.4%	0.7%
E:Closed	2	0	0.0	1.7%	2.4%	2.5%	2.3%
U-A:Annual Spp	0	1	0.0	0.2%	30.5%	27.8%	20.1%
U-A:Bare Ground	0	1	0.0	0.1%	0.1%	0.1%	0.1%
U-A:Early-Shrub	0	0	0.0	0.1%	3.0%	2.8%	2.3%
U-A:Exotic Forb	0	2	0.0	0.0%	0.0%	0.0%	0.0%
U-A:SAP	0	0	0.0	0.7%	0.0%	0.0%	0.0%
U-A:SAP+	0	1	0.0	0.0%	0.0%	0.0%	0.0%
U-A:Seeded Native	0	0	22.0	0.0%	0.0%	0.0%	0.0%
U-A:SI	0	0	13.0	2.0%	6.6%	5.4%	2.2%
U-A:SI+AS	0	0	0.0	2.9%	0.6%	0.6%	0.4%
U-B:SAP	0	0	0.0	0.9%	0.5%	0.5%	0.8%
U-B:SAP+	0	1	0.0	0.0%	0.0%	0.0%	0.1%
U-B:SI	0	0	20.0	4.9%	4.0%	3.2%	2.6%
U-B:SI+AS	0	0	0.0	4.0%	0.4%	0.4%	0.4%
U-C:Depleted	0	1	0.0	11.2%	2.4%	2.8%	5.1%
U-C:SA	0	1	0.0	1.8%	0.9%	0.9%	1.6%
U-C:SA+	0	1	0.0	0.0%	0.0%	0.0%	0.0%
U-C:SI	0	0	24.0	2.5%	4.8%	5.8%	8.7%
U-C:SI+AS	0	0	0.0	2.1%	0.6%	0.8%	1.6%
U-D:SI	0	0	2.0	1.0%	0.8%	1.2%	1.4%
U-D:SI+AS	0	0	0.0	1.4%	0.2%	0.4%	0.5%
U-E:TEA	0	1	0.0	58.6%	38.1%	40.4%	45.3%

**Table 18. Area (acres) of montane sagebrush steppe vegetation classes per ownership in 2017 and 2019.**

Vegetation Class	IP WMA	BLM	Private	SITLA
A:All	0.2	20.2	0.7	13.3
B:Open	4.2	111.2	190.8	11.3
C:Closed	2.9	90.1	82.5	3.8
D:Open	200.8	1201.6	170.1	197.7
E:Closed	274.2	618.5	0.9	173.2
U-A:Annual Spp	1.1	90.7	0.2	9.3
U-A:Bare Ground	2.4	38.7	17.8	9.6
U-A:Early-Shrub	0.0	41.8	7.8	1.3
U-A:Exotic Forb	0.0	0.0	0.0	0.0
U-A:SAP	0.0	377.2	0.0	55.2
U-A:SI	375.8	540.0	4.9	324.5
U-A:SI+AS	72.5	1227.2	6.9	445.5
U-B:SAP	42.0	451.7	10.5	30.2
U-B:SAP+	0.0	0.0	0.0	0.0
U-B:SI	0.0	0.0	0.0	0.0
U-B:SI+AS	656.1	1613.9	95.0	652.3
U-C:Depleted	458.1	1426.4	25.4	552.9
U-C:SA	37.8	6069.8	337.4	431.2
U-C:SA+	0.0	0.0	0.0	0.0
U-C:SI	95.0	1189.1	23.8	224.0
U-C:SI+AS	58.0	1108.0	40.7	106.1
U-D:SI	163.0	398.8	0.2	73.6
U-D:SI+AS	106.5	641.4	7.1	85.6
U-E:TEA	1703.8	31400.5	717.2	2090.3

### Problems or Concerns

2017: Tree-encroached montane sagebrush steppe occupied 58% of the area (Table 17). About 31,000 acres were on BLM lands, whereas SITLA, IP WMA, and private lands, respectively, held 2,090, 1,704, and 717 acres (Table 18). The second most extensive uncharacteristic class at 11.2% of the area was depleted sagebrush (U-C:Depleted; Table 17). This class was present in all ownerships, with most on BLM lands (1,426 acres) and least on private lands (25.4 acres; Table 18). While there was a scattering of other uncharacteristic classes with low acreage values, one glaring problem was the shortage of all reference classes with the exception of the late-successional treed class (E:Closed; Table 17). With expectation of the E:Closed class increasing with succession from the D:Open class, the E:Closed class was disproportionately represented in the IP WMA. This made sense as most of the montane sagebrush steppe system was tree-encroached, depleted or already in seedings. A sizable proportion of seeded areas were invaded by non-native annual species (U-A:SI+AS, U-B:SI+AS; U-C:SI+AS, and U-D:SI+AS; Table 17). Moreover, the late-successional seedings (U-D:SI and U-D:SI+AS) are, by definition, being encroached by young trees that are easier and cheaper to lop now than cut decades later (Tables 17 and 18).

After 60 years of MINIMUM MANAGEMENT: The most obvious change was the large reduction of the area of the tree-encroached class (U-E:TEA) and concomitant increase of the non-native annual species class (U-A:Annual Spp; Table 17). Fire was the main cause of this transition because the climate scenario with the least (ACCESS1) and most (HISTORIC) fire produced the least and most of the U-A:Annual Spp class. The depleted sagebrush class (U-C:Depleted) also decreased in area with acres transitioning to the early shrub class (U-A:Early-Shrub; Table 17).

#### Objective(s) for Management Actions

The primary objective was to reduce the large areas of tree encroachment (U-E:TEA ) in favor of native or mixed introduced and native seedings. Completing this objective will be expensive using a masticator. A secondary objective would be to thin and seed in the depleted sagebrush class (U-C:Depleted) before it permanently transitions to rabbitbrush, snakeweed, or even non-native annual species. Under current conditions, third and fourth objectives, respectively, would be to lop young trees in the seeded (U-D:SI and U-D:SI+AS) and late-successional open (D:Open) classes, and to reduce the area of the reference late successional class (E:Closed), especially in the IP WMA. A fifth objective carrying over from Provencher et al. (2019) was to seed native forb and grass species in older seedings to benefit sage-grouse chick nutrition on BLM lands only.

In anticipation of future increases in non-native annual species dominance (Table 17), a sixth objective would be to control the area of the U-A:Annual Spp class by seeding it.

#### Treatment Rates and Costs

The greatest expenses were experienced on BLM lands due to the greater ownership footprint and areas to treat (Table 19). About three times more expenses were incurred on BLM lands (\$3.8+ million) than the IP WMA (about \$1.1 million) over a 60-year period. Both private and SITLA lands ranged around \$100,000. Differences among climates were small.

The largest expense was the Masticate+Seed action in all ownerships because the unit cost was high and there were many treed areas to treat (Table 19). Variation in the use of Masticate+Seed generally explained the variation in cost among ownerships and among climate scenarios. Variation in the restoration of the non-native annual species class (U-A:Annual Spp) and depleted sagebrush (U-C:Depleted) using chaining to incorporate native seed into the soil (Chaining+Native-Seed) was the second largest factor in total expenditures that was increasingly more important with time after 2025.

**Table 19. Cumulative implementation rates and costs of actions in montane sagebrush steppe over periods of implementation.**

Scenario	Action	Cost/ acre		Sum of Acres /Interval (Avg of 10 runs)				60-yr Total Cost
				2020-2024	2025-2034	2035-2044	2045-2077	
<b>IP WMA</b>								
Preferred +HISTORIC	Masticate+ Seed	\$577.50		1763.1	13.3	16.0	28.1	
	RxFire	\$100.00		251.6	0.0	0.0	0.0	
	Small-Tree-Lopping	\$150.00		197.2	0.0	0.0	0.0	
			Cost →	\$1,072,937	\$7,667	\$9,247	\$16,208	\$1,106,059
Preferred +CCSM4	Masticate+ Seed	\$577.50		1774.1	21.4	20.3	40.7	
	RxFire	\$100.00		251.6	0.0	0.0	0.0	
	Small-Tree-Lopping	\$150.00		196.8	0.0	0.0	0.0	
			Cost →	\$1,079,224	\$12,368	\$11,726	\$23,516	\$1,126,835
Preferred +ACCESS1	Masticate+ Seed	\$577.50		1789.5	38.8	23.5	34.8	
	RxFire	\$100.00		250.1	0.0	0.0	0.0	
	Small-Tree-Lopping	\$150.00		202.0	0.0	0.0	0.0	
			Cost →	\$1,088,719	\$22,386	\$13,550	\$20,125	\$1,144,779
<b>BLM</b>								
Preferred +HISTORIC	Chaining+ Native-Seed	\$205.00		0.0	1699.4	1744.6	0.0	
	Forb+Grass-Native-Seeding+ Chaining	\$160.00		0.0	2007.7	999.8	0.0	
	Masticate+ Seed	\$577.50		0.0	1500.1	2244.9	0.0	
	Small-Tree-Lopping	\$150.00		0.0	1700.4	1568.5	362.6	
			Cost →	\$0	\$1,790,937	\$2,049,306	\$54,389	\$3,894,632
Preferred +CCSM4	Chaining+ Native-Seed	\$205.00		0.0	1634.7	1635.0	0.0	
	Forb+Grass-Native-Seeding+ Chaining	\$160.00		0.0	1995.2	994.7	0.0	
	Masticate+ Seed	\$577.50		0.0	1489.8	2258.0	0.0	
	Small-Tree-Lopping	\$150.00		0.0	1693.6	1640.4	345.5	
			Cost →	\$0	\$1,768,778	\$2,044,398	\$51,820	\$3,864,996
Preferred +ACCESS1	Chaining+ Native-Seed	\$205.00		0.0	1642.5	1704.6	0.0	

Scenario	Action	Cost/ acre		Sum of Acres /Interval (Avg of 10 runs)				60-yr Total Cost
				2020-2024	2025-2034	2035-2044	2045-2077	
Preferred +ACCESS1	Forb+Grass-Native-Seeding+Chaining	\$160.00		0.0	2001.0	1004.7	0.0	
	Masticate+Seed	\$577.50		0.0	1499.1	2247.8	0.0	
	Small-Tree-Lopping	\$150.00		0.0	1696.8	1584.8	313.2	
			Cost →	\$0	\$1,777,122	\$2,046,013	\$46,986	\$3,870,121
<b>Private</b>								
Preferred +HISTORIC	Masticate+Seed	\$577.50		0.0	102.5	0.0	0.0	
	Small-Tree-Lopping	\$150.00		0.0	128.2	57.3	13.3	
			Cost →	\$0	\$78,436	\$8,593	\$2,002	\$89,031
Preferred +CCSM4	Masticate+Seed	\$577.50		0.0	100.0	0.0	0.0	
	Small-Tree-Lopping	\$150.00		0.0	145.5	71.1	16.4	
			Cost →	\$0	\$79,574	\$10,658	\$2,462	\$92,694
Preferred +ACCESS1	Masticate+Seed	\$577.50		0.0	0.0	101.8	0.0	
	Small-Tree-Lopping	\$150.00		0.0	0.0	132.8	90.6	
			Cost →	\$0	\$78,693	\$13,591	\$2,662	\$94,946
<b>SITLA</b>								
Preferred +HISTORIC	Chaining+Native-Seed	\$205.00		0.0	0.0	138.5	0.0	
	Masticate+Seed	\$577.50		0.0	0.0	48.4	0.0	
	Small-Tree-Lopping	\$150.00		0.0	314.3	11.4	0.0	
			Cost →	\$0	\$47,143	\$58,049	\$0	\$105,192
Preferred +CCSM4	Chaining+Native-Seed	\$205.00		0.0	0.0	137.4	0.0	
	Masticate+Seed	\$577.50		0.0	0.0	50.1	0.0	
	Small-Tree-Lopping	\$150.00		0.0	310.7	14.5	0.0	
			Cost →	\$0	\$46,603	\$59,260	\$0	\$105,863
Preferred +ACCESS1	Chaining+Native-Seed	\$205.00		0.0	0.0	156.1	0.0	
	Masticate+Seed	\$577.50		0.0	0.0	47.1	0.0	
	Small-Tree-Lopping	\$150.00		0.0	326.8	9.5	0.0	
			Cost →	\$0	\$49,021	\$60,668	\$0	\$109,690

Effects of management actions on Unified Ecological Departure were minimal because few actions caused transitions to reference classes, which were highly under-represented even in the future (below). For example, seedings of mixed introduced and native species do not transition to reference classes, whereas the action Chaining+Native-Seed can lead to mid- and late-successional classes but with a delay due to vegetation maturation. Therefore, we did not expect major change in UED due to management. The role of climate variability would similarly be to reshuffle areas among uncharacteristic classes, but not recruit into reference classes that would reduce UED.

Unified Ecological Departure	MINIMUM MANAGEMENT	PREFERRED MANAGEMENT
In 2077 under HISTORIC Climate	100 ± 0	98 ± 1
In 2077 under CCSM4 LOCA	100 ± 0	99 ± 1
In 2077 under ACCESS1 LOCA	100 ± 0	98 ± 0

### Vegetation Classes

Removal of trees followed by seeding effectively reduced U-E:TEA levels to near zero from about 1,500 acres starting in 2020 in the IP WMA (Figure 21). After 2025, U-E:TEA was reduced by about 4,000 acres, 200 acres, and 500 acres, respectively, on BLM (Figure 23), private (Figure 25), and SITLA (Figure 27) lands. However, complete elimination of the U-E:TEA class was not accomplished due to limited funding. For instance, about 20,000 acres remained on BLM lands, many on slopes too steep for mechanical equipment as modeled.

The area of new early-successional seeding of introduced and native species (U-A:SI) created by Masticate+Seed accordingly responded at 1,500 (Figure 22), 2,000-3,000 (Figure 24), 100 (Figure 26), and 500 acres (Figure 28), respectively, on IP WMA, BLM, private, and SITLA lands. With successional time, the U-A:SI class predictably transitioned to the mid-successional seeded class (U-B:SI; Figures 22, 24, 26, and 28). As a result of treatment failure, the areas of the early-shrub class (U-A:Early-Shrub; Figures 22, 24, 26, and 28) and non-native annual species class (U-A:Annual Spp; Figures 21,23,25, and 27) also increased.

The use of chaining and seeding native species (Chaining+Native-Seed) was applied to three classes of concern restricted to BLM and SITLA lands: depleted sagebrush (U-C:Depleted), non-native annual species (U-A:Annual Spp), and reference late-successional treed (E:Closed). Compared to the MINIMUM MANAGEMENT scenario within climate scenarios, the Chaining+Native-Seed action decreased the area of depleted sagebrush (U-C:Depleted) by about 1,000 acres and 200 acres, respectively, for depleted sagebrush on BLM (Figure 23) and SITLA (Figure 27) lands. The area of the U-A:Annual Spp class was decreased by 5,000-10,000 acres and 200-500 acres, respectively, on BLM (Figure 23) and SITLA (Figure 27) lands. The third class, E:Closed, decreased by 200-1,000 acres and about 100 acres due to Chaining+Native-Seed on BLM (Figure 23) and SITLA (Figure 27) lands.

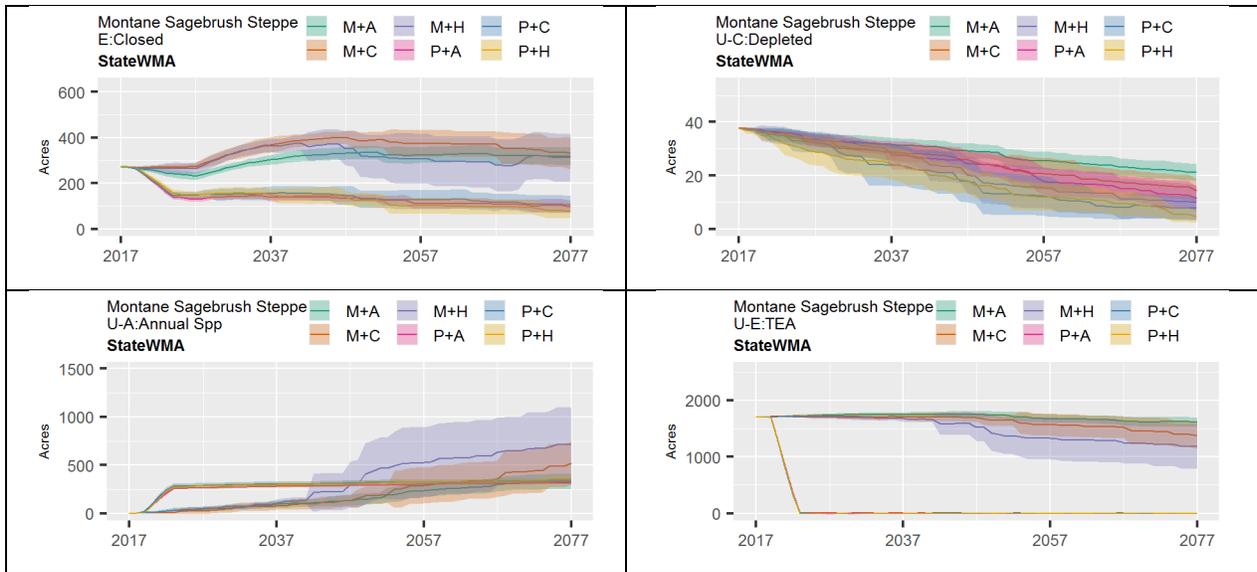


Figure 21. Area (acres) of treated vegetation classes over time in montane sagebrush steppe on IP WMA-managed lands. N = 10 iterations.

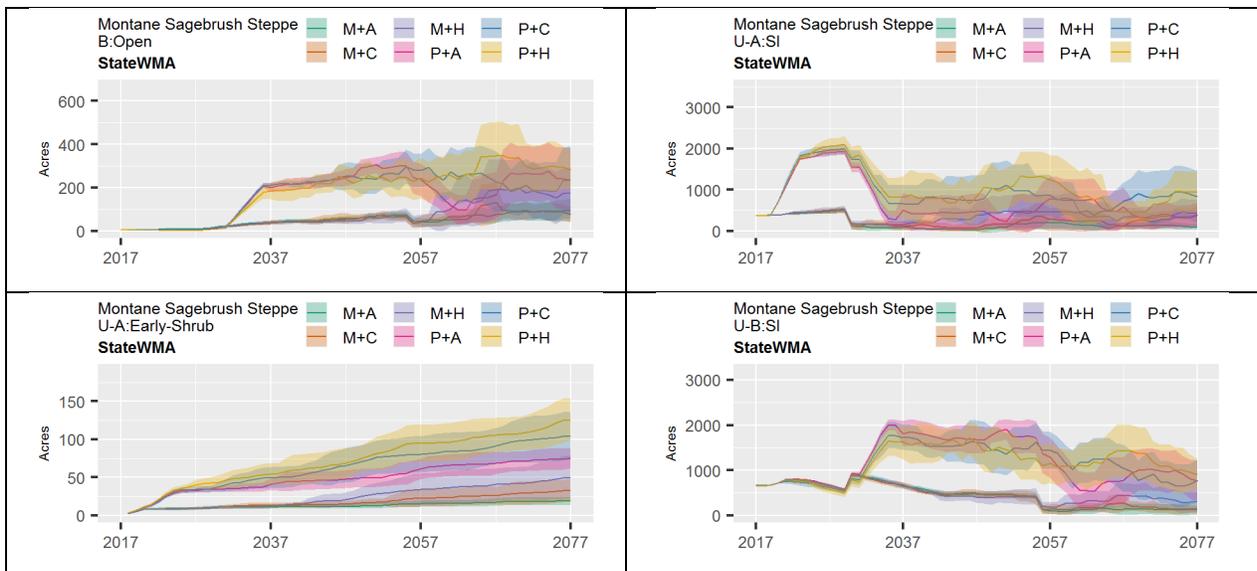


Figure 22. Area (acres) of recipient vegetation classes over time in montane sagebrush steppe on IP WMA-managed lands. N = 10 iterations.

In response to chaining followed by native species seeding, the area of the native seeded class (U-A: Seeded-Native) increased by 1,500 acres and 60 acres at its highest values for BLM (Figure 24) and SITLA (Fig, 28) lands, respectively. While native seedings transitioned to reference classes within decades, as seen in the reference mid-successional class (B:Open; Figures 23 and 27), new seedings were added in simulated out-years as non-native annual species dominance increased in burned areas.

Prescribed fire (RxFire) was only applied in the IP WMA before 2025 (Table 19) to reduce the reference late-successional treed class (E:Closed). In addition, the late-successional open class (D:Open) with young trees would be burned as this treatment was modeled in both classes. The reduction of the E:Closed class of 100-200 acres was observed in all climate scenarios compared to the MINIMUM MANAGEMENT scenarios (Figure 21). It is also noticeable that recruitment into the E:Closed class from the D:Open class was occurring as the area trajectory was initially increasing in the MINIMUM MANAGEMENT scenarios (Figure 21). A couple of decades after prescribed fire, the successional process caused the increase to the B:Open class (Figure 21).

Lopping young trees was used in all ownerships, but the only class plotted that would show its effect was the reference E:Closed class because cutting young trees in the D:Open class would reduce recruitment (small tree lopping was also applied to late-successional seedings and three other classes, which were not plotted). For private lands, where this treatment was not confounded with the use of the Chaining+Native-Seed action, the small-tree lopping appeared to have reduced the area of the E:Closed class by 20-40 acres, although it is hard to see (Figure 25).

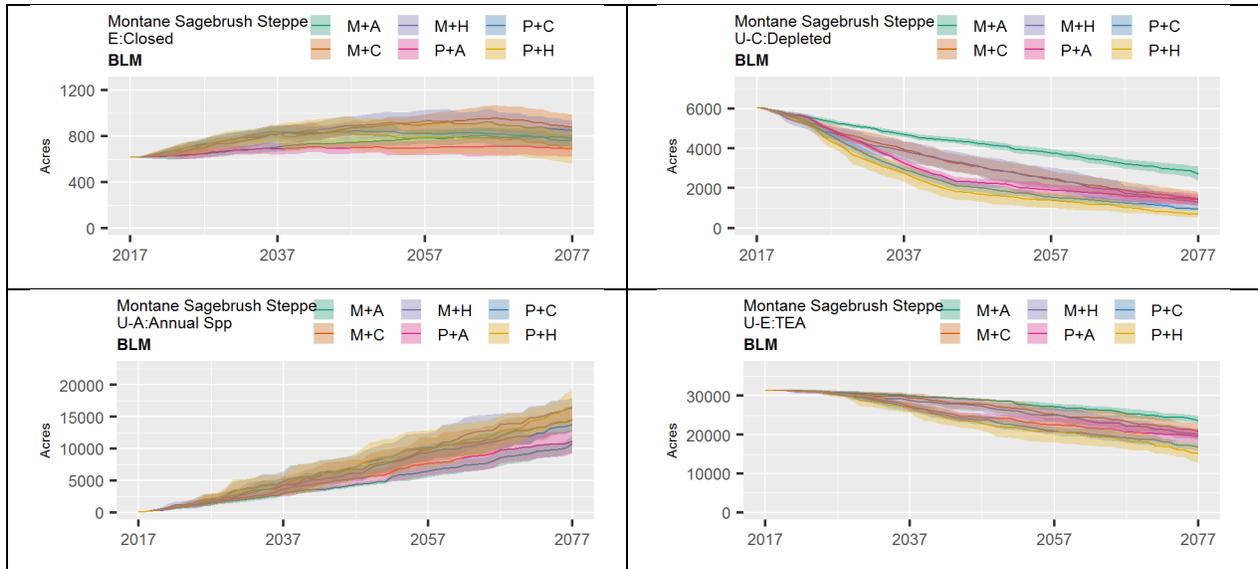


Figure 23. Area (acres) of treated vegetation classes over time in montane sagebrush steppe on BLM-managed lands. N = 10 iterations.

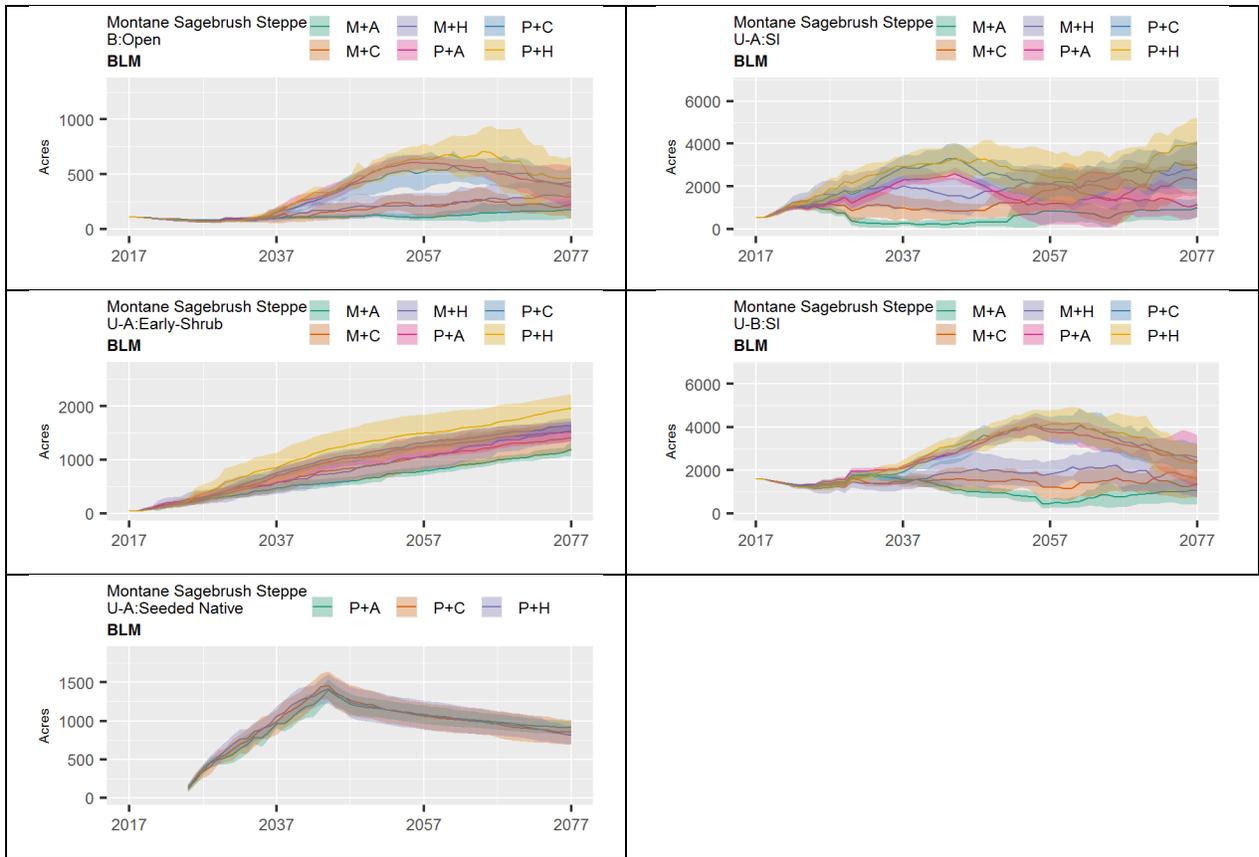


Figure 24. Area (acres) of recipient vegetation classes over time in montane sagebrush steppe on BLM-managed lands. N = 10 iterations.

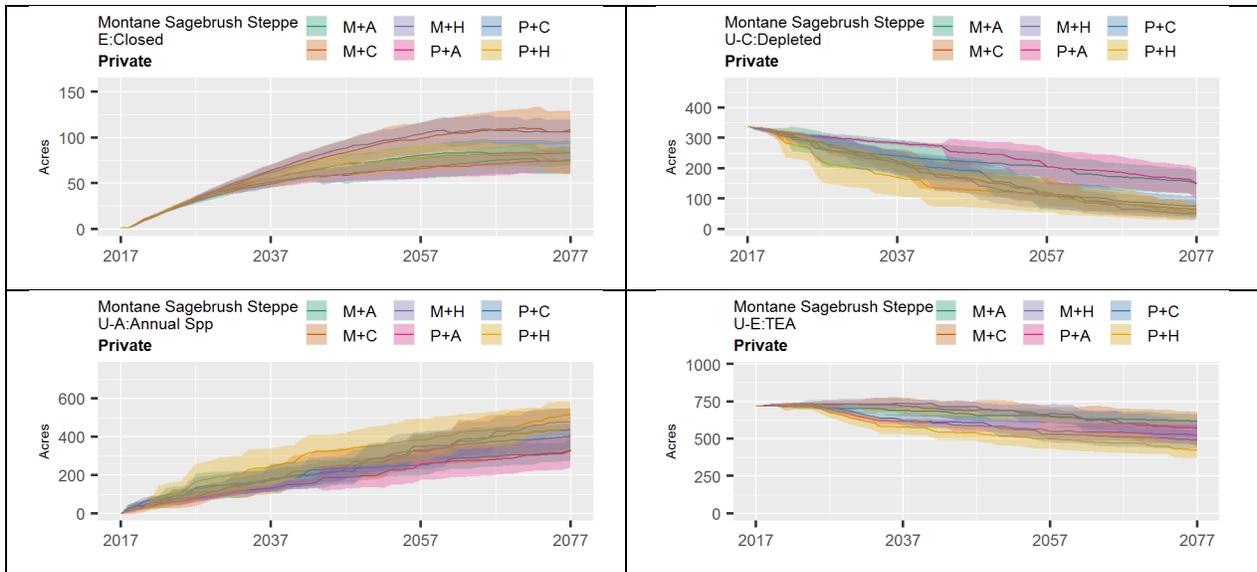


Figure 25. Area (acres) of treated vegetation classes over time in montane sagebrush steppe on private lands. N = 10 iterations.

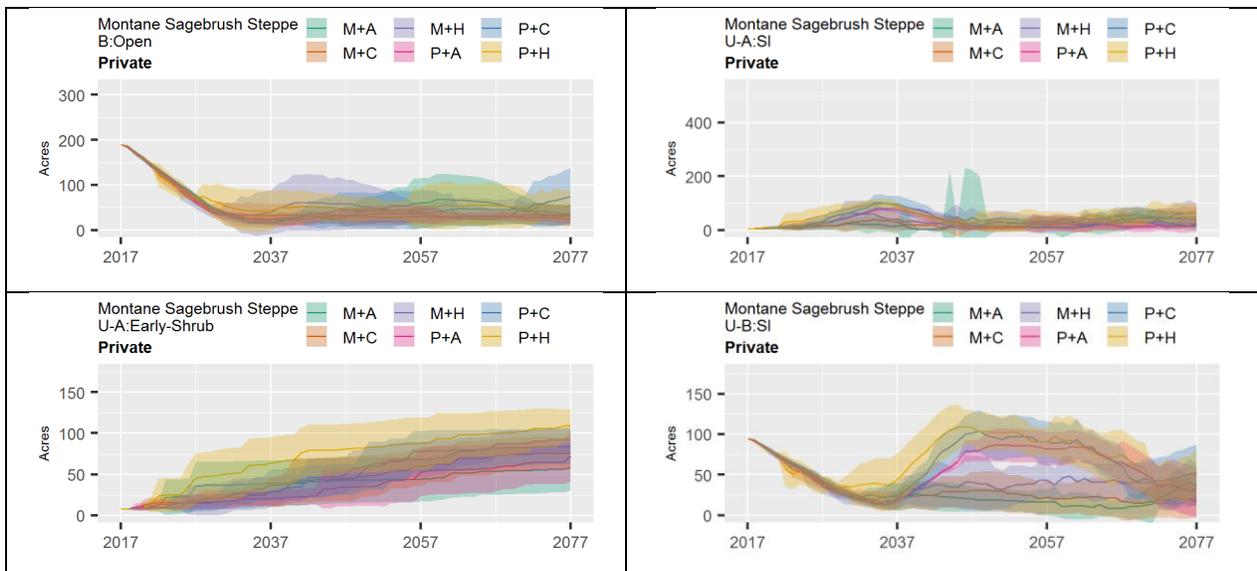


Figure 26. Area (acres) of recipient vegetation classes over time in montane sagebrush steppe on private lands. N = 10 iterations.

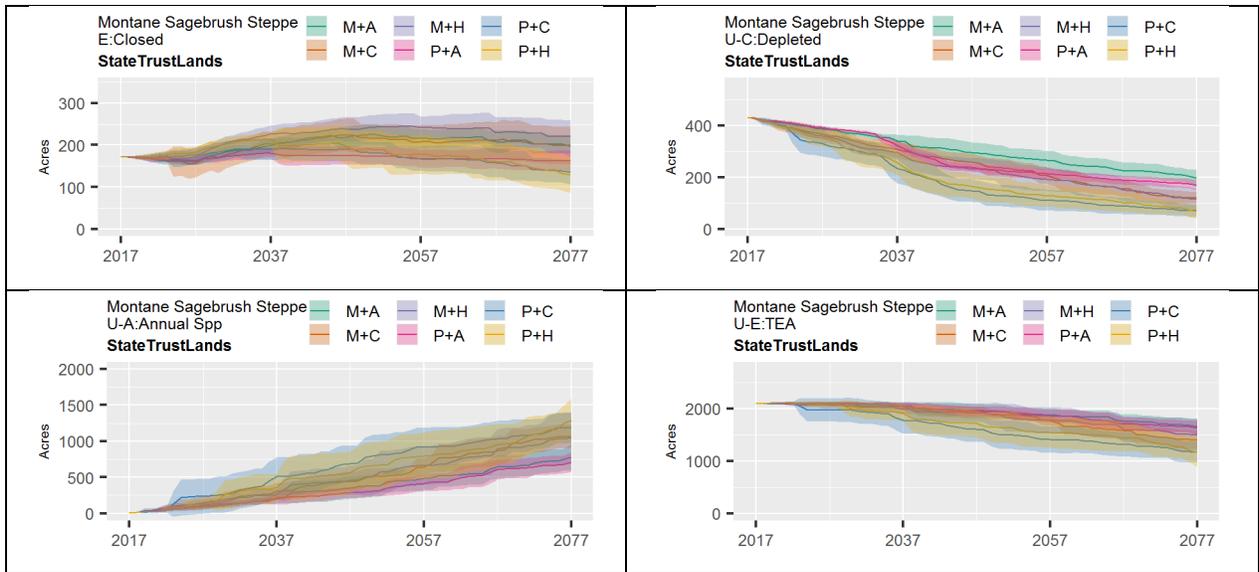


Figure 27. Area (acres) of treated vegetation classes over time in montane sagebrush steppe on SITLA-managed lands. N = 10 iterations.

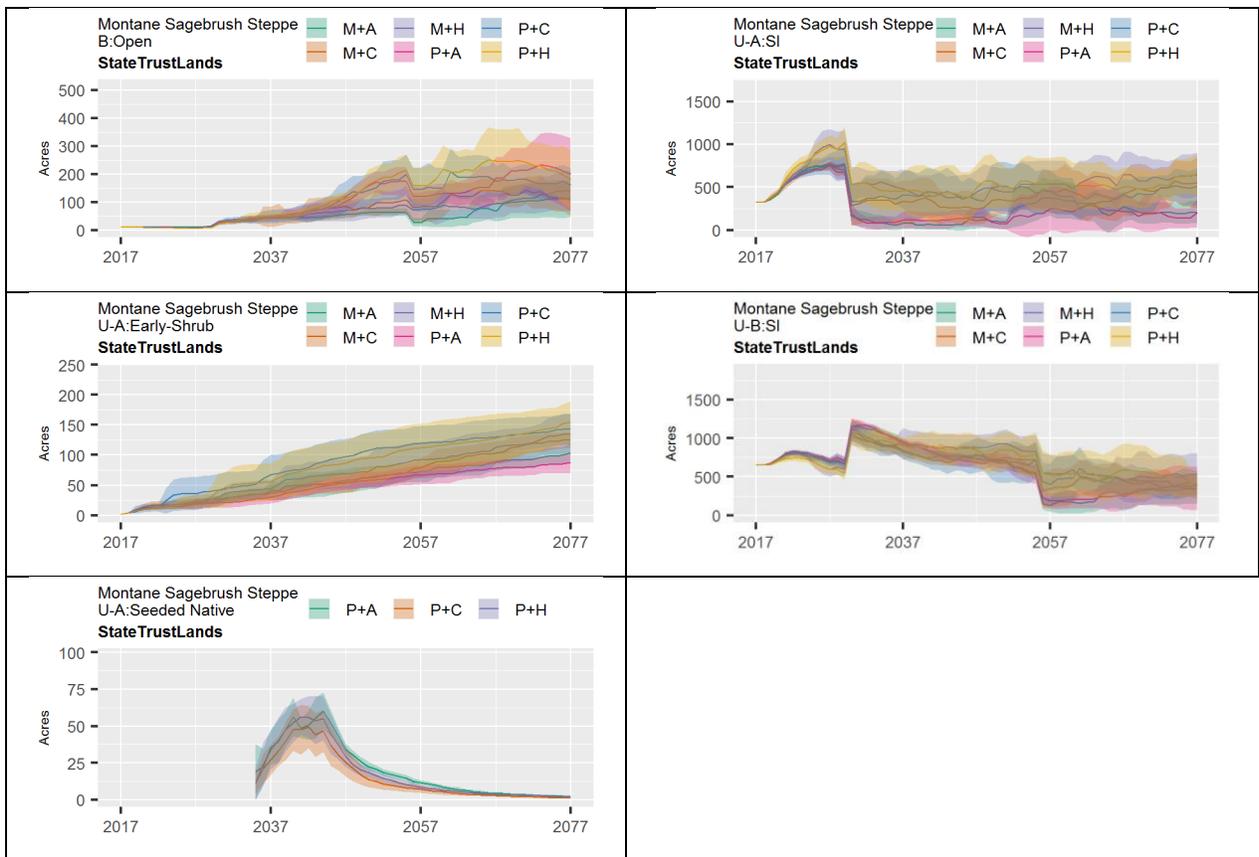


Figure 28. Area (acres) of recipient vegetation classes over time in montane sagebrush steppe on SITLA-managed lands. N = 10 iterations.

PONDEROSA PINE

Current System Acres at 30-m resolution: 4,748 total

Condition: Unified Ecological Departure

In 2017:

In 2077 under MINIMUM MANAGEMENT & HISTORIC Climate:

In 2077 under MINIMUM MANAGEMENT & CCSM4 LOCA:

In 2077 under MINIMUM MANAGEMENT & ACCESS1 LOCA:

49
50 ± 4
51 ± 4
53 ± 2

Vegetation Classes

**Table 20. Vegetation classes of the ponderosa pine ecological system at the current time (2017 and 2019), and after 60 years of MINIMUM MANAGEMENT (2077) under three climate scenarios.**

Vegetation Class	Ref NRV%	Undesir. Level	Allow. Thresh%	Current (2017)	MINIMUM MANAGEMENT (2077)		
				Class %	HISTORIC Class %	CCSM4 Class %	ACCESS1 Class %
A:All	10	0	0.0	2.3%	3.8%	3.4%	2.2%
B:Closed	11	0	0.0	0.4%	16.9%	16.5%	17.6%
B:Open	32	0	0.0	43.5%	18.6%	19.3%	20.5%
C:Closed	3	0	0.0	0.3%	11.6%	12.3%	12.2%
C:Open	44	0	0.0	21.3%	17.2%	16.8%	15.4%
U-A:Annual Spp	0	1	0.0	0.0%	0.7%	0.4%	0.3%
U-A:Bare Ground	0	1	0.0	0.0%	0.0%	0.0%	0.0%
U-A:FIC-All	0	0	0.0	0.0%	7.2%	5.7%	1.6%
U-A:SAP	0	0	0.0	0.0%	0.1%	0.1%	0.0%
U-A:SI	0	0	0.0	0.0%	0.0%	0.0%	0.0%
U-A:SI+AS	0	1	0.0	0.3%	0.0%	0.0%	0.0%
U-B:FIC-Closed	0	0	0.0	10.4%	4.1%	4.5%	6.1%
U-B:FIC-Open	0	0	0.0	19.9%	8.1%	9.0%	12.2%
U-C:FIC-Closed	0	1	0.0	0.7%	3.1%	3.2%	3.2%
U-C:FIC-Open	0	0	0.0	0.9%	5.8%	6.0%	5.8%
U-C:TEA	10	0	0.0	0.0%	3.0%	2.8%	2.8%

**Table 21. Area (acres) of ponderosa pine vegetation classes per ownership in 2017 and 2019.**

Vegetation Class	IP WMA	BLM	Private	SITLA
A:All	0.0	100.3	0.2	10.5
B:Closed	0.0	18.0	0.0	0.0
B:Open	0.0	1954.6	11.3	100.3
C:Closed	0.0	9.1	0.0	6.4
C:Open	0.0	872.7	67.6	72.3
U-A:Annual Spp	0.0	0.0	0.0	0.0
U-A:Bare Ground	0.0	0.0	0.0	0.0
U-A:FIC-All	0.0	0.0	0.0	0.0
U-A:SAP	0.0	0.0	0.0	0.0

Vegetation Class	IP WMA	BLM	Private	SITLA
U-A:SI	0.0	0.0	0.0	0.0
U-A:SI+AS	0.0	15.1	0.0	0.0
U-B:FIC-Closed	0.0	468.8	24.0	0.4
U-B:FIC-Open	0.0	878.7	38.0	26.2
U-C:FIC-Closed	0.0	31.4	0.0	0.0
U-C:FIC-Open	0.0	41.6	0.9	0.0
U-C:TEA	0.0	0.0	0.0	0.0

### Problems or Concerns

2017: Ponderosa pine was not found in the IP WMA. Elsewhere, the main problem was that about 30% of ponderosa pine was in the fire-intolerant conifer classes (Table 20), which represent ponderosa pine that was historically logged and replaced by pinyon, juniper, and/or curl-leaf mountain mahogany. Most of this area of concern was on BLM lands, and one order of magnitude more abundant than on private and SITLA lands (Table 21).

After 60 years of MINIMUM MANAGEMENT: The percentage of reference mid- and late-successional closed-canopied classes (B:Closed and C:Closed) increased from <1% to >28% in all climate scenarios and beyond the natural range of variability (Table 20). The increase of these classes matched the loss of reference mid- and late-successional open-canopied classes (B:Open and C:Open) below their natural range of variability. Also, the area of fire-intolerant classes was redistributed among themselves but persisted.

### Objective(s) for Management Actions

The current primary objective was to masticate fire-intolerant conifers and curl-leaf mountain mahogany, and plant containerized ponderosa pine seedlings. A second future objective was chainsaw thinning of younger trees that build up as fuel ladders during periods with insufficient surface and mixed severity fire activity.

### Treatment Rates and Costs

Ponderosa pine was only treated after 2024 on BLM, private, and SITLA lands (Table 22). Mastication of the fire-intolerant conifer classes followed by ponderosa pine seedling planting was only conducted during the 2025-2034 period, and accounted for most of the cost (Table 22). Expenditures were about one order of magnitude higher on BLM lands than on private or SITLA lands. Differences among climate scenarios were small. However, there was about a \$6,000 to \$7,000 difference between the ACCESS1 (highest cost) and, respectively, CCSM4 and HISTORIC (lowest cost) climates on BLM lands that was entirely due to the slightly greater rate of the Masticate+PIPO-Planting action (Table 22).

**Table 22. Cumulative implementation rates and costs of actions in ponderosa pine over periods of implementation.**

Scenario	Action	Cost/ acre		Sum of Acres /Interval (Avg of 10 runs)				60-yr Total Cost
				2020-2024	2025-2034	2035-2044	2045-2077	
<b>BLM</b>								
Preferred +HISTORIC	Chainsaw-Thinning	\$250.00		0.0	37.5	37.5	102.7	
	Masticate+ PIPO-Planting	\$1,100.00		0.0	401.1	0.0	0.0	
			Cost →	\$0	\$450,596	\$9,379	\$25,675	\$485,651
Preferred +CCSM4	Chainsaw-Thinning	\$250.00		0.0	0.0	42.3	39.9	
	Masticate+ PIPO-Planting	\$1,100.00		0.0	0.0	401.2	0.0	
			Cost →	\$0	\$451,908	\$9,974	\$25,064	\$486,946
Preferred +ACCESS1	Chainsaw-Thinning	\$250.00		0.0	40.3	45.0	115.8	
	Masticate+ PIPO-Planting	\$1,100.00		0.0	402.3	0.0	0.0	
			Cost →	\$0	\$452,653	\$11,253	\$28,945	\$492,851
<b>Private</b>								
Preferred +HISTORIC	Masticate+ PIPO-Planting	\$1,100.00		0.0	49.0	0.0	0.0	
			Cost →	\$0	\$53,942	\$0	\$0	\$53,942
Preferred +CCSM4	Masticate+ PIPO-Planting	\$1,100.00		0.0	47.6	0.0	0.0	
			Cost →	\$0	\$52,401	\$0	\$0	\$52,401
Preferred +ACCESS1	Masticate+ PIPO-Planting	\$1,100.00		0.0	50.5	0.0	0.0	
			Cost →	\$0	\$55,581	\$0	\$0	\$55,581
<b>SITLA</b>								
Preferred +HISTORIC	Masticate+ PIPO-Planting	\$1,100.00		0.0	26.3	0.0	0.0	
			Cost →	\$0	\$28,916	\$0	\$0	\$28,916
Preferred +CCSM4	Masticate+ PIPO-Planting	\$1,100.00		0.0	26.6	0.0	0.0	
			Cost →	\$0	\$29,258	\$0	\$0	\$29,258
Preferred +ACCESS1	Masticate+ PIPO-Planting	\$1,100.00		0.0	26.1	0.0	0.0	
			Cost →	\$0	\$28,720	\$0	\$0	\$28,720

UED decreased with management actions (below). Overlap of 95% C.I.s for MINIMUM and PREFERRED MANAGEMENT under the HISTORIC climate indicate that the effect of chainsaw thinning and/or mastication followed by ponderosa pine seedlings may have been just barely significant. However, the MINIMUM – PREFERRED difference was clearly significant for the ACCESS1 and CCSM4 climates. Also, climate differences were not significant within MINIMUM and PREFERRED MANAGEMENT scenarios.

Unified Ecological Departure	MINIMUM MANAGEMENT	PREFERRED MANAGEMENT
In 2077 under HISTORIC Climate	50 ± 4	44 ± 3
In 2077 under CCSM4 LOCA	51 ± 4	42 ± 5
In 2077 under ACCESS1 LOCA	53 ± 2	43 ± 3

### Vegetation Classes

The Mastication+PIPO-Planting action reduced the area of the mid- and late-successional fire-intolerant conifer closed and open classes. U-B:FIC-Closed, U-B:FIC-Open, U-C:FIC-Closed, and U-C:FIC-Open, respectively, were reduced by about 250, 250, 50, and 25 acres on BLM lands (Figure 29). Effects were highly visible. The effects of chainsaw thinning on the areas of reference closed-canopied classes (B: Closed and C:Closed) were more subtle, but nonetheless around 100 acres (Figure 29).

In response to mastication and planting, about 450 acres of the reference early-successional class (A:All) increased compared to MINIMUM MANAGEMENT scenarios on BLM lands (Figure 30). Chainsaw thinning of reference closed-canopied classes, B:Closed and C:Closed, respectively, caused the reference open-canopied classes B: Open and C:Open to increase by 200 and 100 acres.

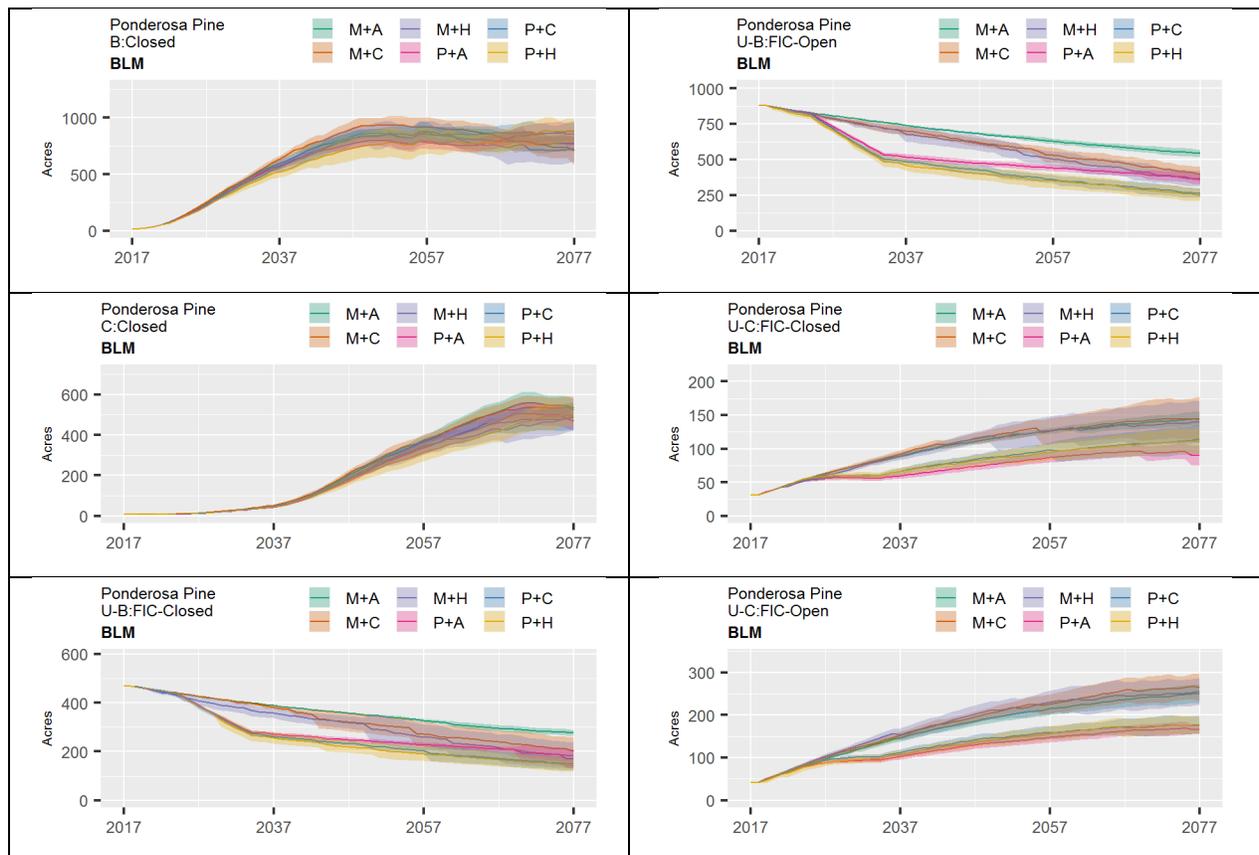


Figure 29. Area (acres) of treated vegetation classes over time in ponderosa pine on BLM-managed lands. N = 10 iterations.

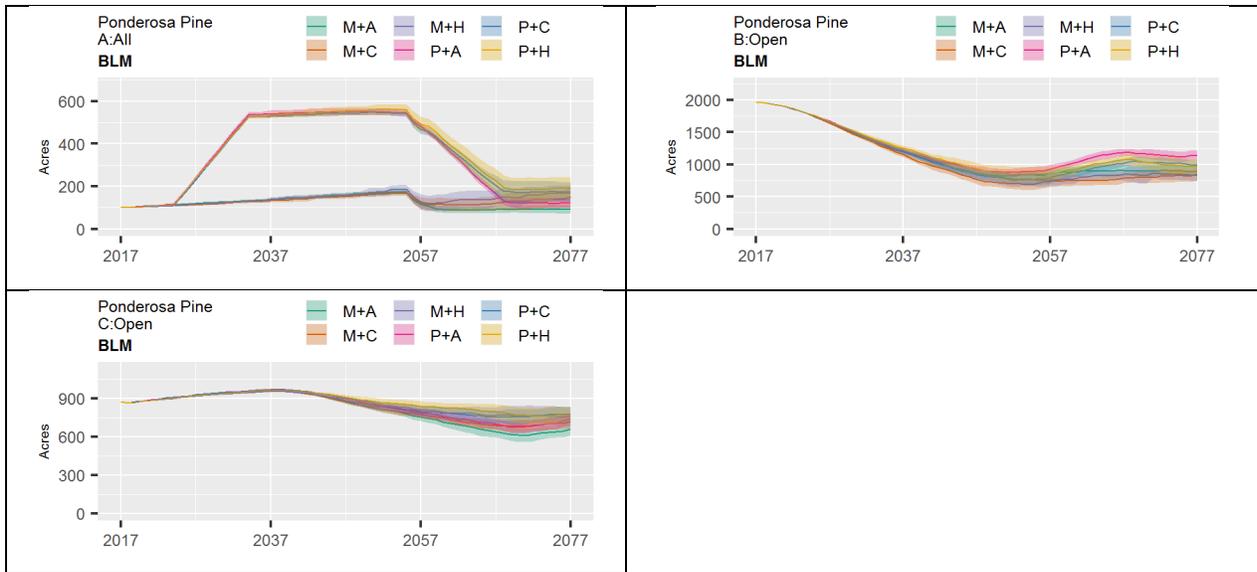


Figure 30. Area (acres) of recipient vegetation classes over time in ponderosa pine on BLM-managed lands. N = 10 iterations.

About 45 and 30 acres total of the fire-intolerant conifer classes were masticated and planted, respectively, on private (Figure 31) and SITLA (Figure 33) lands. 20 and 5 acres total reductions, respectively, were caused by chainsaw thinning in the B:Closed and C:Closed compared to MINIMUM MANAGEMENT scenarios (Figure 31). Chainsaw thinning was not used on SITLA lands (Table 19). These treatment effects were clearly reflected in the increased area of the reference A:All class and both open-canopied reference classes (B:Open and C:Open; Figure 32).

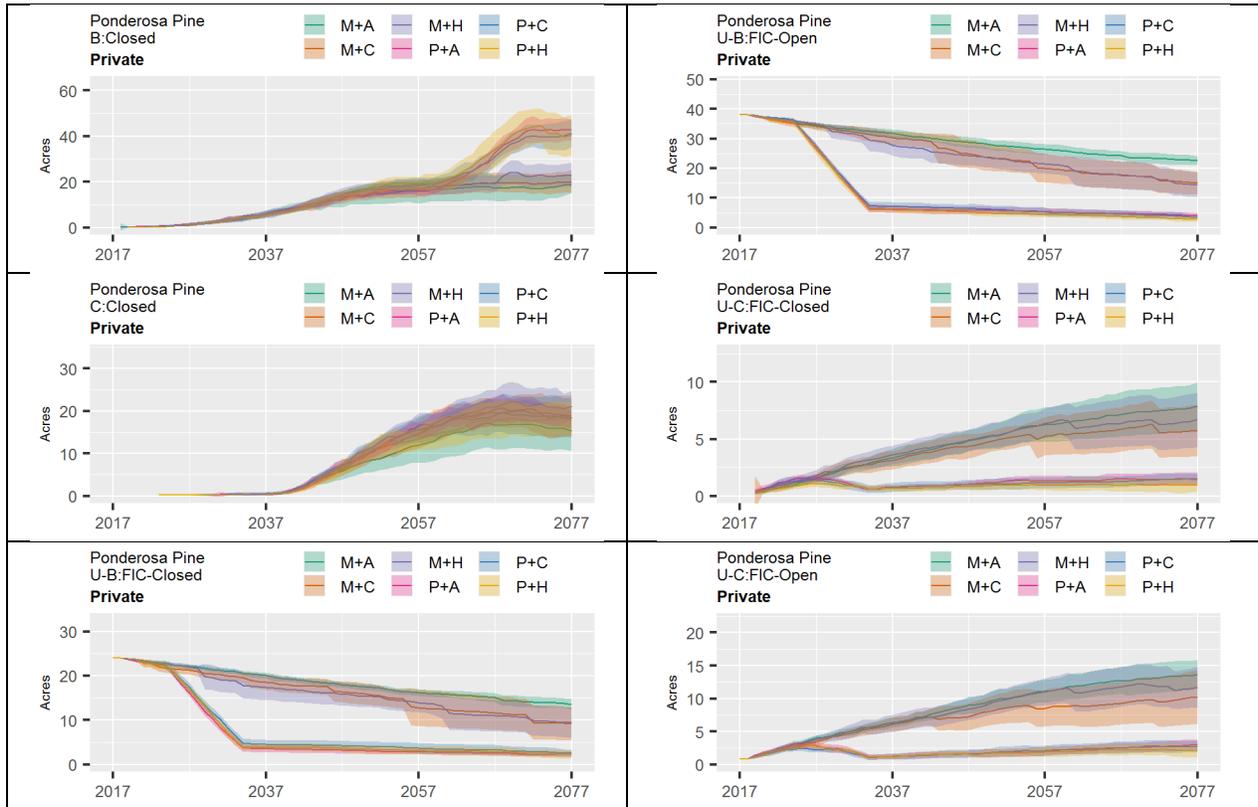


Figure 31. Area (acres) of treated vegetation classes over time in ponderosa pine on private lands. N = 10 iterations.

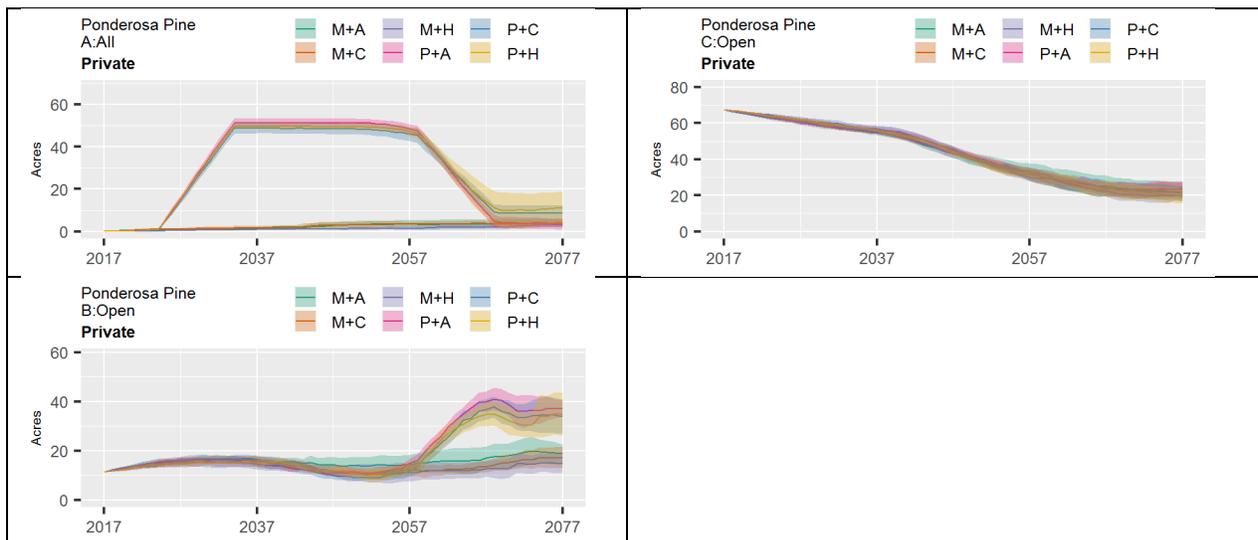


Figure 32. Area (acres) of recipient vegetation classes over time in ponderosa pine on private lands. N = 10.

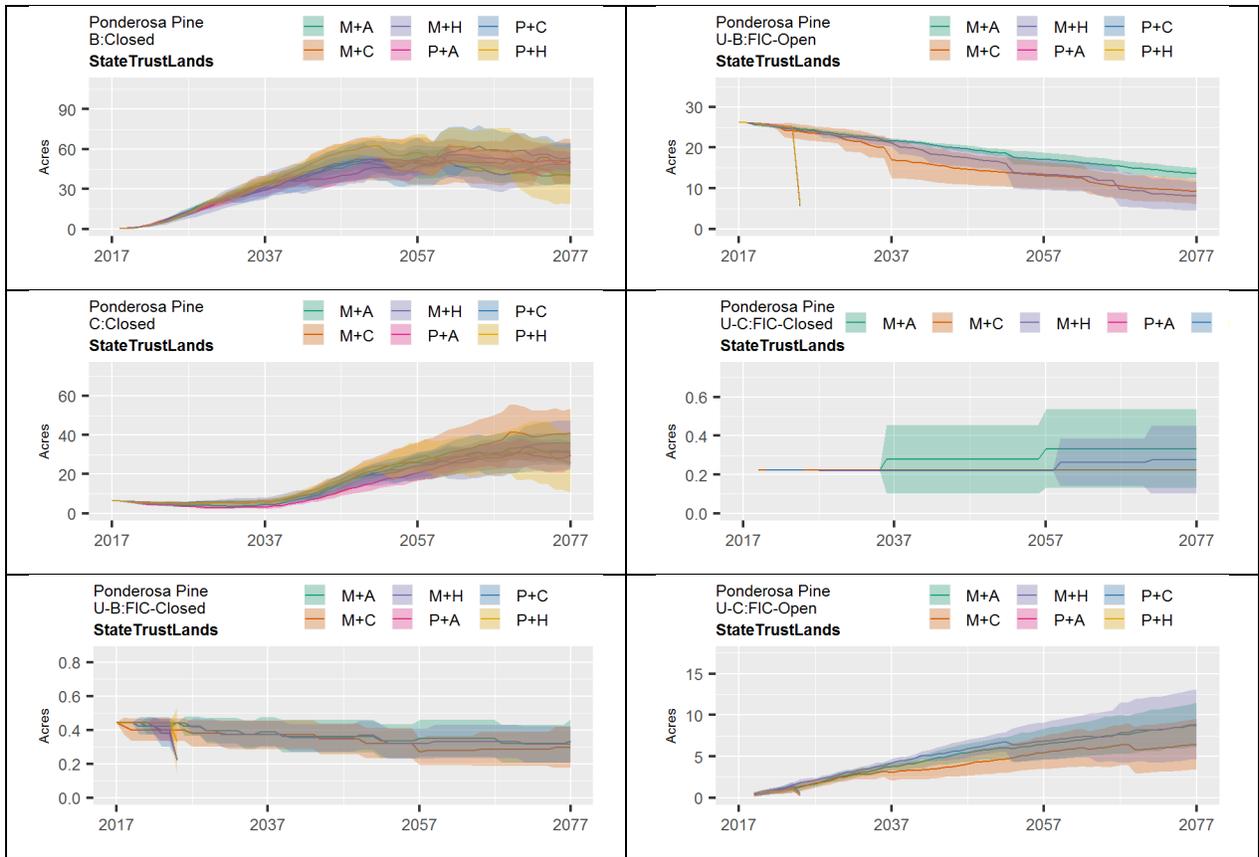


Figure 33. Area (acres) of treated vegetation classes over time in ponderosa pine on SITLA-managed lands. N = 10 iterations.

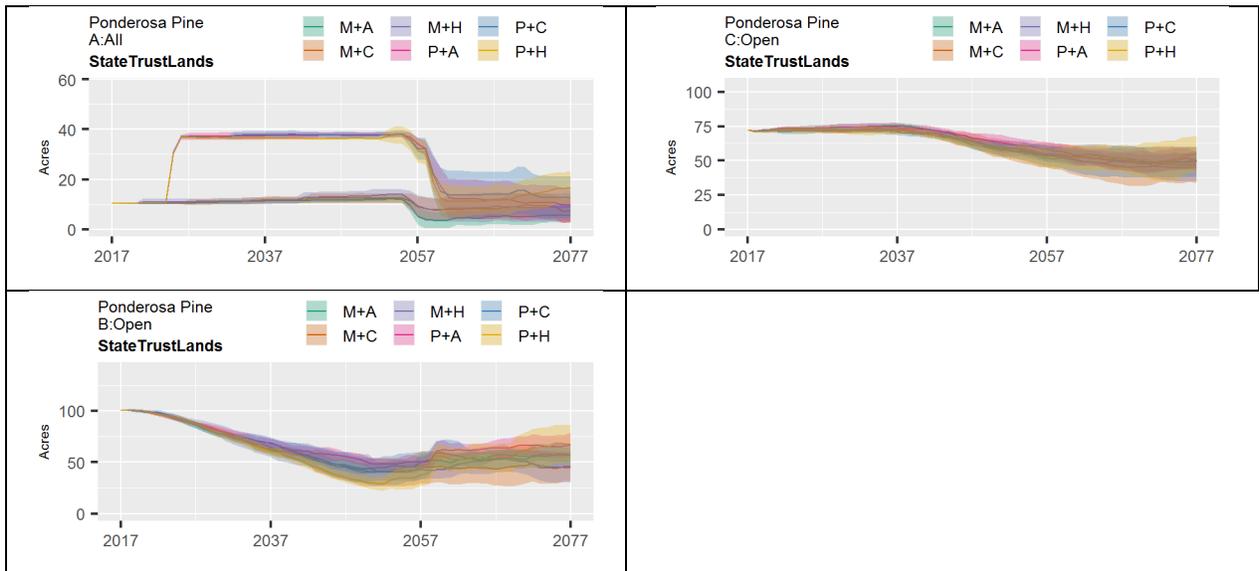


Figure 34. Area (acres) of recipient vegetation classes over time in ponderosa pine on SITLA-managed lands. N = 10 iterations.

Current System Acres: 3,771.6 total

Condition: Unified Ecological Departure

In 2017:

In 2077 under MINIMUM MANAGEMENT & HISTORIC Climate:

In 2077 under MINIMUM MANAGEMENT & CCSM4 LOCA:

In 2077 under MINIMUM MANAGEMENT & ACCESS1 LOCA:

85
83 ± 9
88 ± 5
95 ± 3

Vegetation Classes

**Table 23. Vegetation classes of the Utah serviceberry ecological system at the current time (2017 and 2019), and after 60 years of MINIMUM MANAGEMENT (2077) under three climate scenarios.**

Vegetation Class	Ref NRV%	Undesir. Level	Allow. Thresh%	Current (2017)	MINIMUM MANAGEMENT (2077)		
				Class %	HISTORIC	CCSM4	ACCESS1
					Class %	Class %	Class %
A:All	9	0	0.0	0.0%	3.1%	2.5%	0.7%
B:Closed	29	0	0.0	12.6%	7.4%	5.8%	3.1%
C:Closed	60	0	0.0	0.7%	21.1%	21.3%	21.8%
D:Open	3	0	0.0	79.1%	24.3%	20.7%	8.4%
U-A:Annual Spp	0	1	0.0	0.0%	6.4%	5.8%	5.8%
U-A:Bare Ground	0	1	0.0	0.0%	0.0%	0.0%	0.0%
U-A:Early-Shrub	0	0	0.0	0.0%	1.2%	1.3%	4.6%
U-A:SI	0	0	5.4	0.0%	0.1%	0.1%	0.0%
U-A:SI+AS	0	0	0.0	0.0%	0.0%	0.0%	2.1%
U-B:SAP	0	0	0.0	0.3%	1.6%	1.2%	0.3%
U-B:SAP+	0	1	0.0	0.0%	0.3%	0.3%	0.1%
U-B:SI	0	0	16.8	1.3%	0.1%	0.1%	0.0%
U-B:SI+AS	0	0	0.0	0.0%	0.0%	0.0%	0.1%
U-C:Depleted	0	1	0.0	0.1%	0.1%	0.1%	5.7%
U-C:SAP	0	0	0.0	0.1%	3.3%	3.2%	0.7%
U-C:SI	0	0	36.0	0.0%	0.7%	0.7%	0.0%
U-C:SI+AS	0	0	0.0	0.0%	0.0%	0.0%	0.7%
U-D:SI	0	0	1.2	5.8%	0.0%	0.0%	0.0%
U-D:SI+AS	0	0	0.0	0.0%	0.0%	0.0%	0.0%
U-D:TEA	0	1	0.0	12.6%	30.4%	34.0%	46.5%

**Table 24. Area (acres) of Utah serviceberry vegetation classes per ownership in 2017 and 2019.**

Vegetation Class	IP WMA	BLM	Private	SITLA
A:All	0.2	0.0	1.3	0.0
B:Closed	78.3	109.6	278.9	9.1
C:Closed	1.6	6.0	15.8	3.1
D:Open	550.2	1,563.0	819.7	49.8
U-A:Annual Spp	0.0	0.0	0.0	0.0

Vegetation Class	IP WMA	BLM	Private	SITLA
U-A:Bare Ground	0.0	0.0	0.0	0.0
U-A:Early-Shrub	0.0	0.0	0.0	0.0
U-A:SI	0.0	0.0	0.0	0.0
U-A:SI+AS	0.0	0.0	0.0	0.0
U-B:SAP	2.4	0.0	0.0	8.5
U-B:SAP+	0.0	0.0	0.0	0.0
U-B:SI	50.7	0.0	0.0	0.0
U-B:SI+AS	0.0	0.0	0.0	0.0
U-C:Depleted	0.0	0.0	1.6	0.4
U-C:SAP	0.0	2.2	0.0	0.0
U-C:SI	0.0	0.0	0.0	0.0
U-C:SI+AS	0.0	0.0	0.0	0.0
U-D:SI	0.0	0.0	0.0	0.0
U-D:SI+AS	0.0	0.0	0.0	0.0
U-D:TEA	0.0	185.7	0.0	33.4

### Problems or Concerns

2017: Too many trees dominated the Utah serviceberry ecological system. The reference late-successional treed class (D:Open) and the late-successional tree-encroached class (U-D:TEA), respectively, accounted for 79% and 13% of the system (Table 20). Unified ecological departure was 85%, indicating high departure from desired future conditions (above). Most acres of U-D:TEA were found on BLM lands (185.7) with SITLA lands also contributing 33.4 acres (Table 21). The over-represented reference late-successional D:Open class covered 1563, 820, 550, and 50 acres, respectively, on BLM, private, IP WMA, and SITLA lands (Table 24).

After 60 years of MINIMUM MANAGEMENT: The main concern was a more than doubling of the U-D:TEA class at the expense of reference classes (Table 23). As fire activity successively decreased from HISTORIC to CCSM4 to ACCESS1 climates, the area of the U-D:TEA class increased from 30.4% to 34.0% to 46.5% (Table 23). The D:Open class decreased because some of the area transitioned to the U-D:TEA, whereas a smaller proportion of the remaining area burned and started succession, which populated younger reference classes. Only the 95% CI of unified ecological departure for the ACCESS1 LOCA of 95% in 2077 did not overlap with the 85% departure of Utah serviceberry in 2017.

### Objective(s) for Management Actions

Removal of trees was the primary objective. The reference class (D:Open) only required chainsaw thinning or prescribed fire and no seeding. The uncharacteristic treed class (U-D:TEA) required heavy tree removal, such as mastication or intense chainsaw thinning, preferably followed by seeding if the serviceberry and understory were strongly suppressed. Utah serviceberry usually resprouts after cutting, burning, or release from very intense competitive pressure. Because Utah serviceberry is excellent mule deer browse preferred in younger successional stages, and can be used by greater sage-grouse for nesting, there are strong

incentives to rejuvenate older treed stands to younger stages of greater nutritional value and to remove trees for sage-grouse nesting and foraging.

### Treatment Rates and Costs

Chainsaw thinning was the only action used on BLM, private, and SITLA lands (Table 25). The IP WMA also used (1) mastication followed by seeding of mixed introduced and native species, and (2) prescribed fire; most of the funding was spent in the IP WMA. Spending was least on SITLA Lands (about \$1,300), six times higher on private lands (about \$7,533) and ranged from \$26,873 to \$27,401 on BLM lands (Table 25). Differences among climate scenarios were minimal for BLM, private and SITLA lands (Table 25). Twice as much funding was spent on the IP WMA as on BLM lands for the ACCESS1 scenario (\$55,542). Less funding was needed as fire activity increased (Provencher et al. 2019) from the ACCESS1 climate to the CCSM4 climate (\$49,055) to the HISTORIC climate (\$44,640). The differences of cost among climates on the IP WMA was entirely due to the greater area masticated and seeded (Table 25).

**Table 25. Cumulative implementation rates and costs of actions in Utah serviceberry over periods of implementation.**

Scenario	Action	Cost/ acre		Sum of Acres /Interval (Avg of 10 runs)				60-yr Total Cost
				2020-2024	2025-2034	2035-2044	2045-2077	
<b>IP WMA</b>								
Preferred +HISTORIC	Chainsaw-Thinning	\$112.50		36.0	0.0	0.0	0.0	
	Masticate+Seed	\$577.50		27.2	0.0	0.0	0.0	
	RxFire	\$100.00		248.6	0.0	0.0	0.0	
			Cost →	\$44,640	\$0	\$0	\$0	
Preferred +CCSM4	Chainsaw-Thinning	\$112.50		38.9	0.0	0.0	0.0	
	Masticate+Seed	\$577.50		32.7	0.0	0.0	0.0	
	RxFire	\$100.00		249.5	0.0	0.0	0.0	
			Cost →	\$48,209	\$0	\$0	\$0	
Preferred +ACCESS1	Chainsaw-Thinning	\$112.50		40.6	0.0	0.0	0.0	
	Masticate+Seed	\$577.50		44.9	0.0	0.0	0.0	
	RxFire	\$100.00		250.5	0.0	0.0	0.0	
			Cost →	\$55,542	\$0	\$0	\$0	
<b>BLM</b>								
Preferred +HISTORIC	Chainsaw-Thinning	\$112.50		0.0	246.2	0.0	0.0	
			Cost →	\$0	\$26,873	\$0	\$0	
Preferred +CCSM4	Chainsaw-Thinning	\$112.50		0.0	244.7	0.0	0.0	
			Cost →	\$0	\$27,534	\$0	\$0	
Preferred +ACCESS1	Chainsaw-Thinning	\$112.50		0.0	243.6	0.0	0.0	
			Cost →	\$0	\$27,401	\$0	\$0	

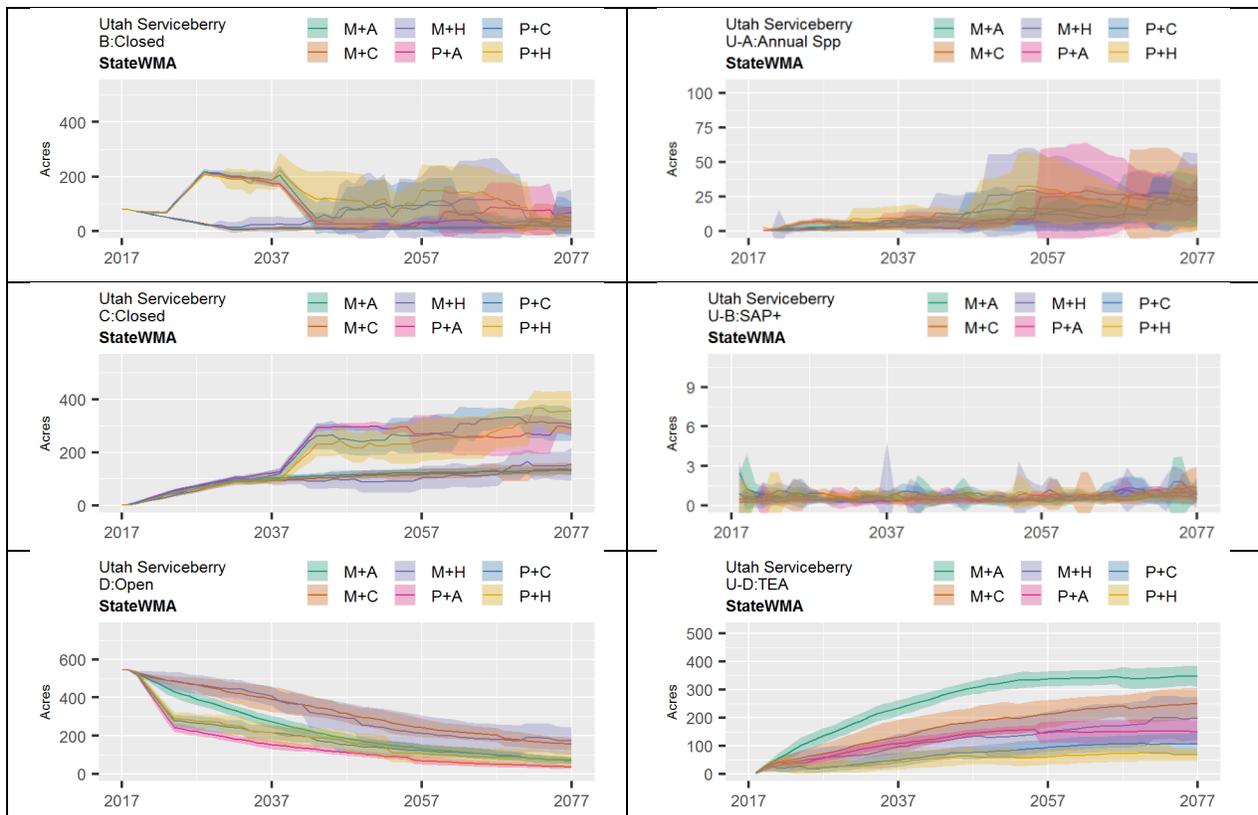
Scenario	Action	Cost/ acre		Sum of Acres /Interval (Avg of 10 runs)				60-yr Total Cost
				2020-2024	2025-2034	2035-2044	2045-2077	
<b>Private</b>								
Preferred +HISTORIC	Chainsaw-Thinning	\$112.50		0.0	65.0	0.0	0.0	
			Cost →	\$0	\$7,313	\$0	\$0	\$7,313
Preferred +CCSM4	Chainsaw-Thinning	\$112.50		0.0	66.2	0.0	0.0	
			Cost →	\$0	\$7,443	\$0	\$0	\$7,443
Preferred +ACCESS1	Chainsaw-Thinning	\$112.50		0.0	66.6	0.0	0.0	
			Cost →	\$0	\$7,543	\$0	\$0	\$7,543
<b>SITLA</b>								
Preferred +HISTORIC	Chainsaw-Thinning	\$112.50		0.0	11.1	0.0	0.0	
			Cost →	\$0	\$1,248	\$0	\$0	\$1,248
Preferred +CCSM4	Chainsaw-Thinning	\$112.50		0.0	12.0	0.0	0.0	
			Cost →	\$0	\$1,351	\$0	\$0	\$1,351
Preferred +ACCESS1	Chainsaw-Thinning	\$112.50		0.0	11.8	0.0	0.0	
			Cost →	\$0	\$1,331	\$0	\$0	\$1,331

Management actions significantly reduced UED between PREFERRED and MINIMUM MANAGEMENT scenarios for all climate scenarios (below). Average reduction of UED (in absolute value) was 13%, 16%, and 11%, respectively, for the HISTORIC climate, and CCSM4 and ACCESS1 LOCAS.

Unified Ecological Departure	MINIMUM MANAGEMENT	PREFERRED MANAGEMENT
In 2077 under HISTORIC Climate	83 ± 9	70 ± 6
In 2077 under CCSM4 LOCA	88 ± 5	71 ± 4
In 2077 under ACCESS1 LOCA	95 ± 3	84 ± 4

### Vegetation Classes

In the IP WMA, about 200 acres of the reference late-successional class (D:Open) transitioned to the reference mid-successional class (B:Closed) due to chainsaw thinning or prescribed fire for the HISTORIC and CCSM4 climates, whereas the reduction was closer to 150 acres for the ACCESS1 climate scenario (Figure 35). Succession moved the new area of the B:Closed class to the next successional phase (C:Closed) after 2037.



**Figure 35.** Area (acres) of treated and recipient vegetation classes over time in Utah serviceberry on IP WMA-managed lands. N = 10 iterations.

Management actions caused at most a 50-acre drop of the tree-encroached class (U-D:TEA) for the ACCESS1 LOCA before 2025, whereas reductions were closer to 25 acres for the HISTORIC and CCSM4 climates (Figure 35). The principal pathways of transition from U-D:TEA due to management actions were to the mid-successional shrub with annual and perennial grass species (U-B:SAP), representing success; and to the non-native annual species class (U-A:Annual Spp), representing failure. The U-B:SAP and U-A:Annual Spp classes increased by 15 and 2-3 acres, respectively (Figure 35). The area of the U-D:TEA class was absent in 2019.

Chainsaw thinning was the only action implemented in ownerships other than the IP WMA, and then only during the 2025-2034 period. On BLM lands, reduction of the U-D:TEA class varied among climates, with about 90 acres fewer in the ACCESS1 climate and 70 acres fewer in both the HISTORIC and CCSM4 climates, compared to MINIMUM MANAGEMENT (Figure 36). As a result, the U-B:SAP class (success) and U-A:Annual Spp class (failure) increased, respectively, by 50 acres (CCSM4 and HISTORIC climates) to 70 acres (ACCESS1 climate), and about 20 acres (Figure 36). Chainsaw thinning resulted in a reduction of the reference D:Closed class by about 100 acres for the CCSM4 and HISTORIC climates, and somewhat less at 50 acres in the ACCESS1 climate (Figure 36). The reference B:Closed class increased by the same area as a result of a transition from D:Open.

This general pattern of reduction of U-D:TEA and D:Open classes, and increase of U-B:SAP and B:Closed classes, was repeated, but with less area, on private (Figure 37) and SITLA (Figure 38) lands.

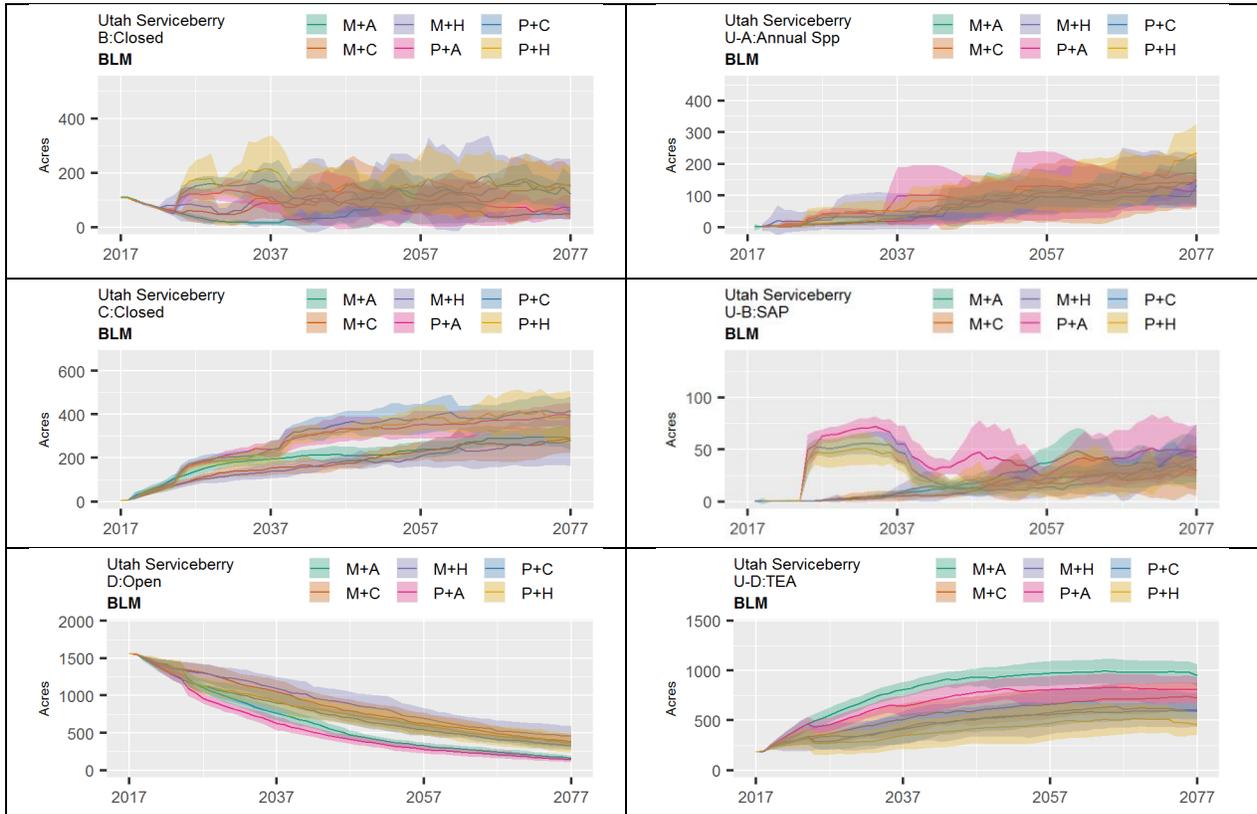


Figure 36. Area (acres) of treated vegetation and recipient classes over time in Utah serviceberry on BLM-managed lands. N = 10 iterations.

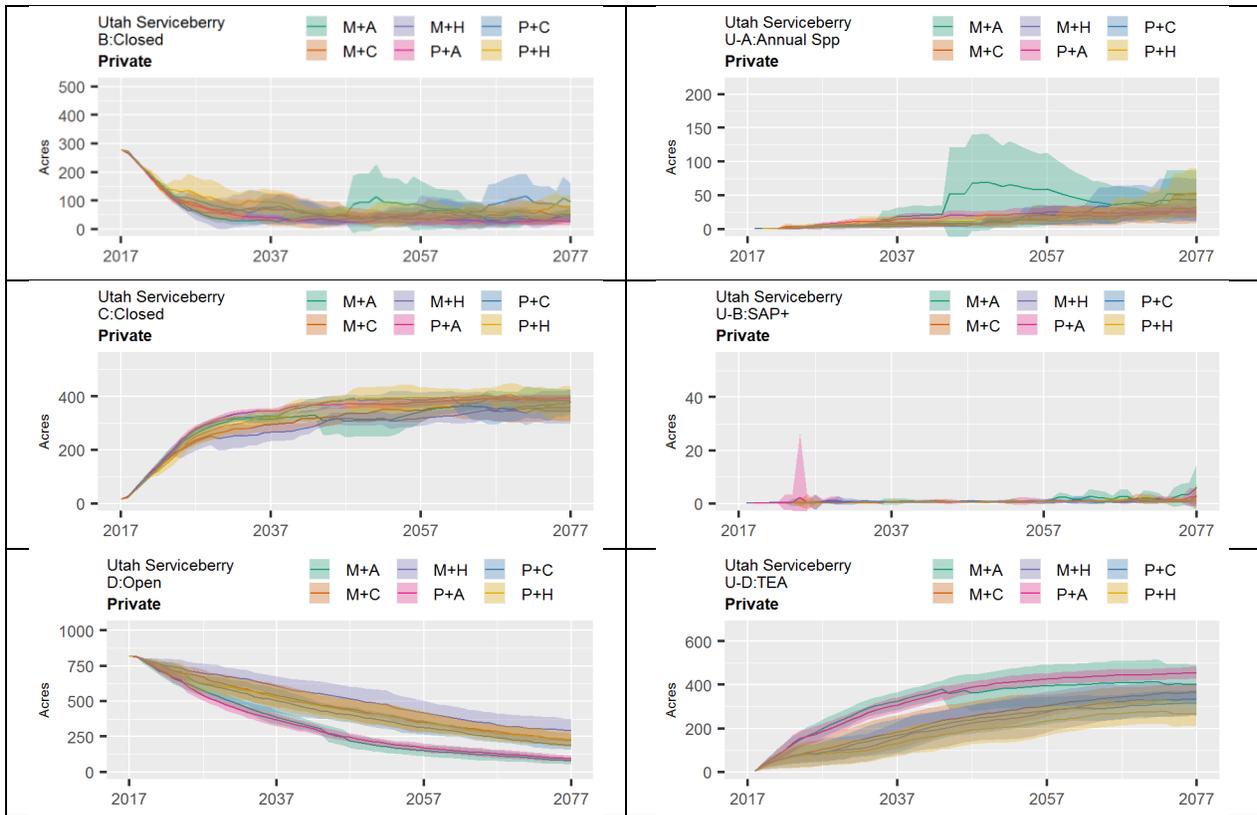


Figure 37. Area (acres) of treated and recipient vegetation classes over time in Utah serviceberry on private lands. N = 10 iterations.

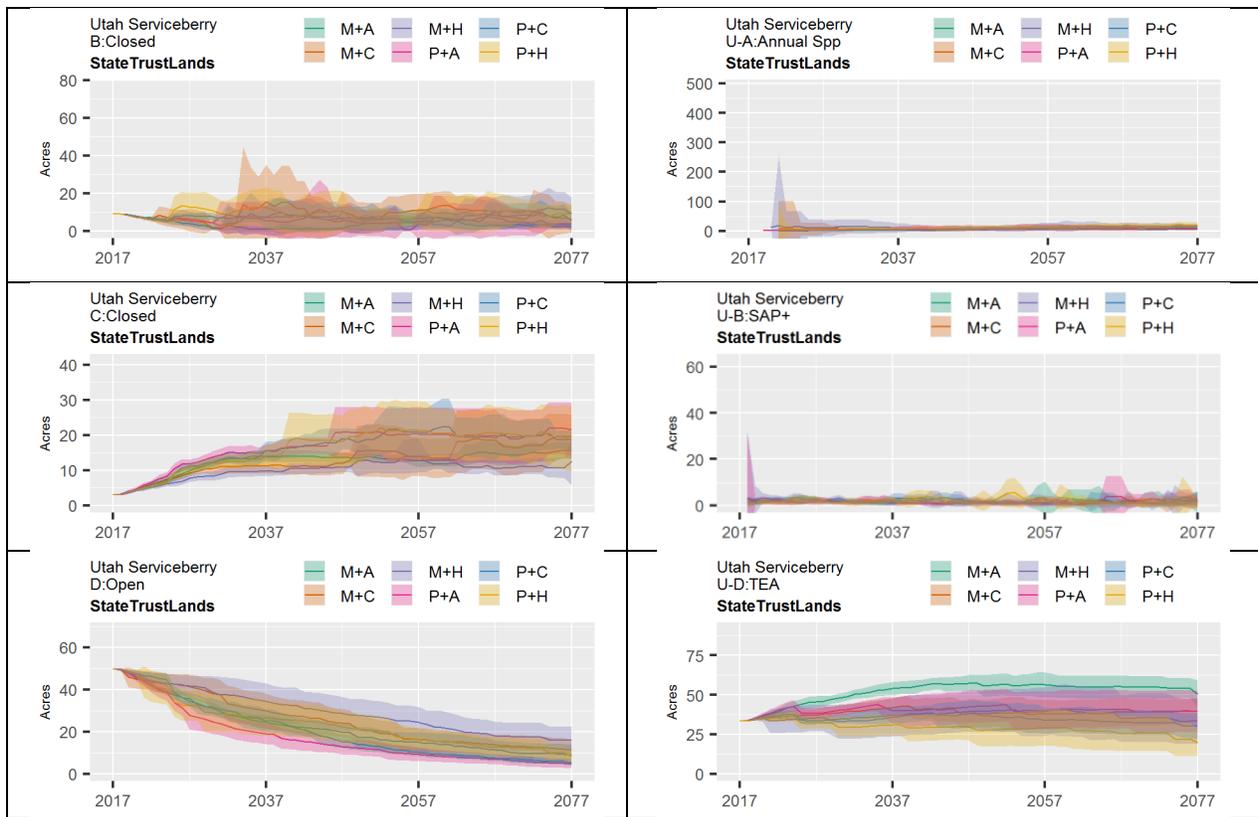


Figure 38. Area (acres) of treated and recipient vegetation classes over time in Utah serviceberry on SITLA-managed lands. N = 10 iterations.

WET MEADOW

Current System Acres at 30-m resolution: 364 total

Condition: Unified Ecological Departure

In 2017:	79
In 2077 under MINIMUM MANAGEMENT & HISTORIC Climate:	89 ± 4
In 2077 under MINIMUM MANAGEMENT & CCSM4 LOCA:	87 ± 3
In 2077 under MINIMUM MANAGEMENT & ACCESS1 LOCA:	92 ± 3

Vegetation Classes

**Table 26. Vegetation classes of the wet meadow ecological system at the current time (2017 and 2019), and after 60 years of MINIMUM MANAGEMENT (2077) under three climate scenarios.**

Vegetation Class	Ref NRV%	Undesir. Level	Allow. Thresh%	Current (2017)	MINIMUM MANAGEMENT (2077)		
				Class %	HISTORIC	CCSM4	ACCESS1
					Class %	Class %	Class %
A:All	5	0	0.0	3.2%	1.1%	1.1%	0.6%
B:Closed	90	0	0.0	23.7%	25.4%	24.2%	18.3%
C:Open	5	0	0.0	4.5%	5.6%	7.6%	13.8%
U-A:Annual Spp	0	1	0.0	1.1%	3.0%	2.4%	1.9%
U-A:Bare Ground	0	1	0.0	0.7%	0.6%	0.6%	0.6%
U-A:Early-Shrub	0	1	0.0	0.8%	0.6%	0.7%	0.9%
U-A:Exotic Forb	0	2	0.0	4.5%	9.4%	8.9%	8.8%
U-A:Hummocked	0	1	0.0	2.1%	2.3%	1.4%	1.3%
U-A:Inset	0	1	0.0	2.7%	2.5%	1.9%	0.7%
U-A:Inset-EF	0	2	0.0	0.0%	3.2%	2.9%	2.7%
U-A:Inset-HU	0	1	0.0	0.0%	0.1%	0.0%	0.0%
U-A:SAP	0	1	0.0	0.0%	0.1%	0.1%	0.1%
U-A:SI	0	1	0.0	32.7%	30.2%	31.9%	32.8%
U-B:SAP	0	1	0.0	0.7%	0.4%	0.4%	0.4%
U-C:Desertified	0	1	0.0	1.2%	1.8%	1.8%	2.0%
U-C:SA	0	1	0.0	0.0%	0.1%	0.0%	0.1%
U-C:Shrb-Frb Encr	0	0	0.0	19.0%	12.1%	12.0%	12.6%
U-C:TEA	0	1	0.0	3.0%	1.5%	2.1%	2.3%

**Table 27. Area (acres) of wet meadow vegetation classes per ownership in 2017 and 2019.**

Vegetation Class	IP WMA	BLM	Private	SITLA
A:All	6.7	0.0	0.0	10.0
B:Closed	47.1	46.7	15.8	14.5
C:Open	16.5	3.1	0.7	3.6
U-A:Annual Spp	5.8	0.0	0.0	0.0
U-A:Bare Ground	0.2	3.3	0.0	0.0
U-A:Early-Shrub	2.2	1.8	0.0	0.0
U-A:Exotic Forb	9.6	14.2	0.0	0.0
U-A:Hummocked	2.4	6.0	2.4	0.0
U-A:Inset	12.7	1.3	0.0	0.0

Vegetation Class	IP WMA	BLM	Private	SITLA
U-A:Inset-EF	0.0	0.0	0.0	0.0
U-A:Inset-HU	0.0	0.0	0.0	0.0
U-A:SAP	0.2	0.0	0.0	0.0
U-A:SI	39.8	5.6	6.7	119.2
U-B:SAP	3.6	0.0	0.0	0.0
U-C:Desertified	5.3	1.1	0.0	0.0
U-C:SA	0.0	0.0	0.0	0.0
U-C:Shrb-Frb Encr	54.0	23.1	10.9	11.3
U-C:TEA	12.2	1.6	1.6	0.4

### Problems or Concerns

2017: The wet meadow ecological system was highly departed from desired future conditions in 2017 and 2019. An important source of departure was that >32% of the wet meadow area was seeded with introduced species (e.g., intermediate wheatgrass; U-A:SI), which was predominantly found on the IP WMA and SITLA lands (Tables 26 and 27). The presence of exotic forbs or trees (U-A:Exotic-Forb at 4.5% of the area) on the IP WMA and BLM lands also added to departure because the class has the highest undesirability level that elevated departure (Table 26). At the intermediate level of undesirability of 1, several classes each represented by small areas contributed incrementally to departure and belonged to either vegetation classes perched on incised floodplains, incision itself, or hummocked zones (Table 26). Many of these classes were mostly found on the IP WMA or BLM lands (Table 27). A common (19% of wet meadow area) uncharacteristic class found on all ownerships was the shrub or forb encroached class (U-A:Shr-Frb Encr; Tables 26 and 27). While this class is native vegetation, most commonly Woods' rose, with no elevated undesirability level (0) other than being uncharacteristic, it nonetheless added substantially to unified ecological departure.

After 60 years of MINIMUM MANAGEMENT: Three major changes occurred in the intervening 60 years (Table 26): (1) The shrub and forb encroached class (U-C:Shrb-Frb Encr) decreased in all scenarios; (2) the reference late-open class (C:Open) increased in the ACCESS1 climate and did not decrease for other climate scenarios; and (3) the exotic forb class (U-A:Exotic Forbs) doubled in area. All other classes remained constant, although the reference mid-successional class (B:Closed), which is important to sage-grouse, decreased from 23.7% to 18.3% in the ACCESS1 climate (Table 26).

### Objective(s) for Management Actions

Control of exotic forbs and trees as a maintenance activity was a no-regret objective for all ownerships. Where incisions were present in meadow streams, lifting the water table to rehydrate the floodplain with a low technology permeable barrier to flow that also traps sediments (water-table-uplift) was proposed on BLM, private, and SITLA lands. Healing hummocked meadow sections by temporarily restricting livestock and horse hoof action using fences was proposed for BLM and private lands. Removing conifers established in wet meadows, especially Rocky mountain juniper, was recommended for the IP WMA and private lands.

## Treatment Rates and Costs

The cost of management actions varied by one order magnitude between the BLM budget (\$459,745 to \$478,597) and all other ownerships (\$11,675 to \$152,547; Table 28). The least amount of funding was spent in the IP WMA, somewhat more funding was used on SITLA lands, and about three times less funding was spent on private lands than on BLM lands. Cost to BLM and private landowners was higher because fences were deployed (Table 28). Implementation of actions was minimal in the IP WMA. More of the Water-Table-Uplift action (low technology flow barriers) was implemented than anticipated, although permeable flow barriers could only be implemented once per 15 years per pixel.

Twice as much money was spent in the PREFERRED+HISTORIC scenario due to a greater implementation rate of exotic forb control than under other climates in the IP WMA (Table 28). Differences in spending were smaller among climate scenarios in other ownerships (Table 28). On BLM, Private, and SITLA lands slightly more was spent under the HISTORIC climate than under the CCSM4 and ACCESS1 climates (Table 28).

**Table 28. Cumulative implementation rates and costs of actions in wet meadow over periods of implementation.**

Scenario	Action	Cost/ acre		Sum of Acres /Interval (Avg of 10 runs)				60-yr Total Cost
				2020-2024	2025-2034	2035-2044	2045-2077	
<b>IP WMA</b>								
Preferred +HISTORIC	Small-Tree-Lopping	\$112.50		0.4	0.0	0.0	0.0	
	Weed-Inventory+Treat	\$253.00		0.0	9.1	65.5	30.9	
			Cost →	\$56	\$2,307	\$16,565	\$7,821	
Preferred +CCSM4	Exotic-Control	\$360.00		0.0	0.0	0.0	0.1	
	Small-Tree-Lopping	\$500.00		0.4	0.0	0.0	0.0	
	Weed-Inventory+Treat	\$253.00		0.0	11.0	9.2	30.6	
			Cost →	\$50	\$2,774	\$2,318	\$7,774	
Preferred +ACCESS1	Small-Tree-Lopping	\$360.00		0.4	0.0	0.0	0.0	
	Weed-Inventory+Treat	\$253.00		0.0	9.2	6.2	30.6	
			Cost →	\$50	\$2,318	\$1,570	\$7,737	
<b>BLM</b>								
Preferred +HISTORIC	Exotic-Control	\$360.00		8.6	4.3	20.7	90.3	
	Fence	\$2,200.00		40.4	25.6	0.0	0.0	
	Water-Table-Uplift	\$500.00		0.0	30.4	0.0	11.6	

Scenario	Action	Cost/ acre		Sum of Acres /Interval (Avg of 10 runs)				60-yr Total Cost
				2020-2024	2025-2034	2035-2044	2045-2077	
Preferred +HISTORIC	Weed-Inventory+Treat	\$253.00		72.2	136.3	205.4	572.9	
			Cost →	\$110,254	\$107,647	\$59,427	\$183,267	\$460,595
Preferred +CCSM4	Exotic-Control	\$360.00		8.6	4.4	20.7	103.0	
	Fence	\$2,200.00		40.9	26.2	0.0	0.0	
	Water-Table-Uplift	\$500.00		80.7	149.8	148.4	570.0	
	Weed-Inventory+Treat	\$253.00		8.6	4.4	20.7	103.0	
				Cost →	\$113,388	\$114,030	\$44,984	\$187,343
Preferred +ACCESS1	Exotic-Control	\$360.00		7.5	4.4	22.3	110.4	
	Fence	\$2,200.00		42.4	29.4	0.0	0.0	
	Water-Table-Uplift	\$500.00		0.0	29.0	0.0	12.2	
	Weed-Inventory+Treat	\$253.00		77.9	139.3	153.8	609.0	
				Cost →	\$115,698	\$116,041	\$46,932	\$199,925
<b>Private</b>								
Preferred +HISTORIC	Exotic-Control	\$360.00		10.2	13.8	26.3	120.5	
	Fence	\$2,200.00		0.0	11.3	9.7	0.0	
	Small-Tree-Lopping	\$112.50		0.2	0.0	0.0	0.0	
	Water-Table-Uplift	\$500.00		0.0	7.5	9.3	0.0	
	Weed-Inventory+Treat	\$253.00		6.0	16.9	53.5	68.3	
				Cost →	\$5,225	\$37,722	\$48,957	\$60,643
Preferred +CCSM4	Exotic-Control	\$360.00		10.3	11.6	33.9	121.7	
	Fence	\$2,200.00		0.0	10.7	9.5	0.0	
	Small-Tree-Lopping	\$112.50		0.2	0.0	0.0	0.0	
	Water-Table-Uplift	\$500.00		10.8	11.1	15.8	59.0	
	Weed-Inventory+Treat	\$253.00		10.0	10.2	15.4	68.3	
				Cost →	\$6,471	\$33,880	\$41,893	\$58,753
Preferred +ACCESS1	Exotic-Control	\$360.00		10.5	12.4	33.9	131.1	
	Fence	\$2,200.00		0.0	7.6	9.9	0.0	

Scenario	Action	Cost/ acre		Sum of Acres /Interval (Avg of 10 runs)				60-yr Total Cost
				2020-2024	2025-2034	2035-2044	2045-2077	
Preferred +ACCESS1	Small-Tree-Lopping	\$112.50		0.2	0.0	0.0	0.0	
	Water-Table-Uplift	\$500.00		0.0	8.3	8.8	0.0	
	Weed-Inventory+Treat	\$253.00		10.1	13.6	21.1	68.3	
			Cost →	\$6,363	\$28,732	\$43,600	\$64,465	\$143,160
<b>SITLA</b>								
Preferred +HISTORIC	Exotic-Control	\$360.00		0.0	0.0	0.1	3.5	
	Water-Table-Uplift	\$500.00		0.0	6.9	2.7	0.0	
	Weed-Inventory+Treat	\$253.00		7.6	9.0	16.6	33.2	
			Cost →	\$1,930	\$5,743	\$5,569	\$9,646	\$22,888
Preferred +CCSM4	Water-Table-Uplift	\$500.00		0.0	0.0	0.2	1.8	
	Weed-Inventory+Treat	\$253.00		3.2	6.8	6.9	28.6	
			Cost →	\$818	\$4,832	\$3,284	\$7,889	\$16,824
Preferred +ACCESS1	Water-Table-Uplift	\$500.00		0.0	7.0	2.7	0.0	
	Weed-Inventory+Treat	\$253.00		4.0	9.3	6.8	32.1	
			Cost →	\$1,024	\$5,855	\$3,101	\$8,130	\$18,110

Management actions significantly decreased UED (improved condition; below). The greater improvement was for the HISTORIC climate.

Unified Ecological Departure	MINIMUM MANAGEMENT	PREFERRED MANAGEMENT
In 2077 under HISTORIC Climate	89 ± 4	65 ± 2
In 2077 under CCSM4 LOCA	87 ± 3	67 ± 3
In 2077 under ACCESS1 LOCA	92 ± 3	74 ± 4

### Vegetation Classes

On the IP WMA, the primary focus was the control of the Exotic-Forb class (Figure 39). The Exotic-Forb class area barely exceed zero. Low levels of cattle grazing and no wild horse use in this section of the landscape allowed the natural recovery of the shrub and forb encroached class (U-C:Shrb-Frb Encr) that caused the increase of the reference mid-successional class (B:Closed; Figure 39). With succession, the B:Closed class transitioned to the reference late-successional class (C:Open; Figure 39).

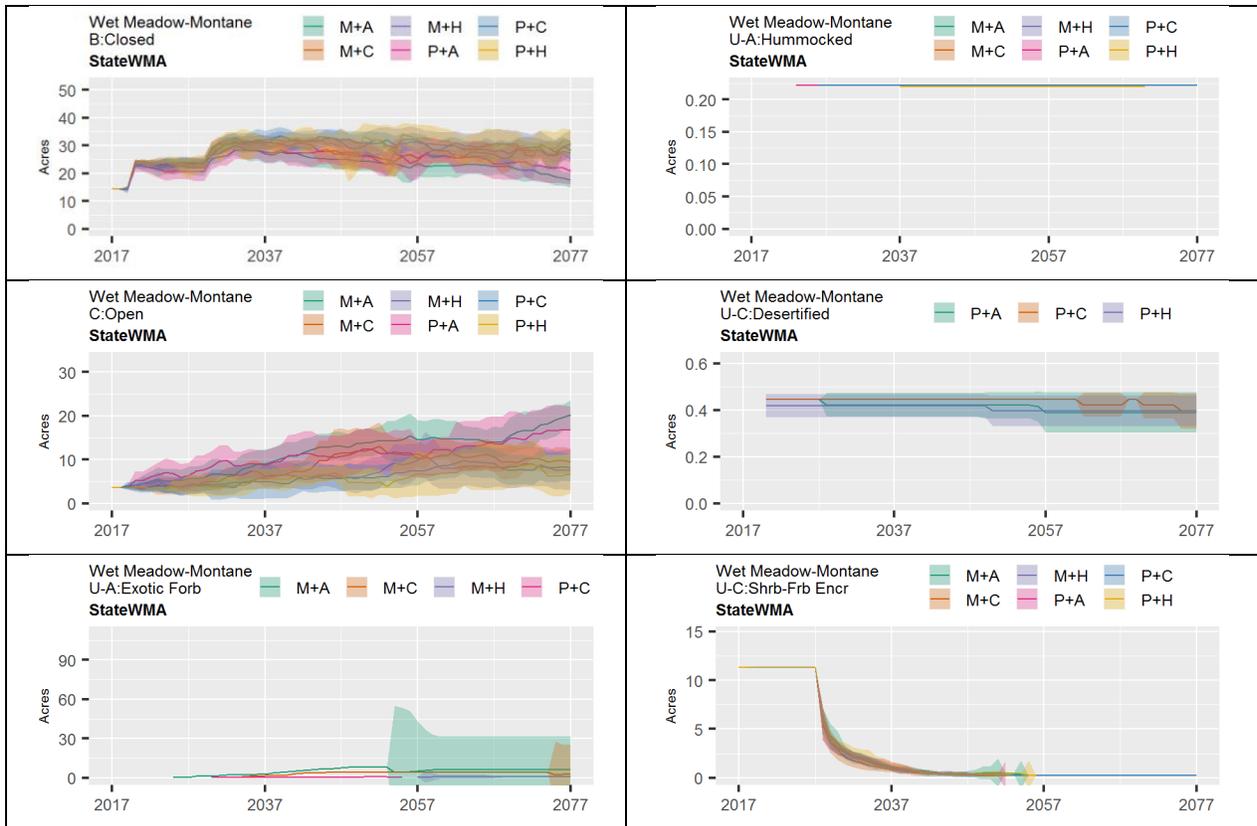


Figure 39. Area (acres) of focal vegetation classes over time in wet meadow on IP WMA-managed lands. N = 10 iterations.

On BLM (Figure 40), private (Figure 41), and SITLA (Figure 42) lands, a combination of fencing, permeable barriers to flow (Water-Table-Uplift), and, only for BLM, small amounts of tree lopping were used, with several results: Exotic forbs decreased or were kept in check, except in the PREFERRED+HISTORIC scenario on BLM Lands where wetter conditions favored exotic invasion and control levels were too small. Fencing or permeable flow barriers contributed to the reduction of the primary incised class (U-C:Desertified), hummocked class (U-A:Hummocked), and shrub and forb encroached class (U-C:Shrb-Frb Encr). Reference classes (B:Closed and C:Open) all increased as they did in the IP WMA.

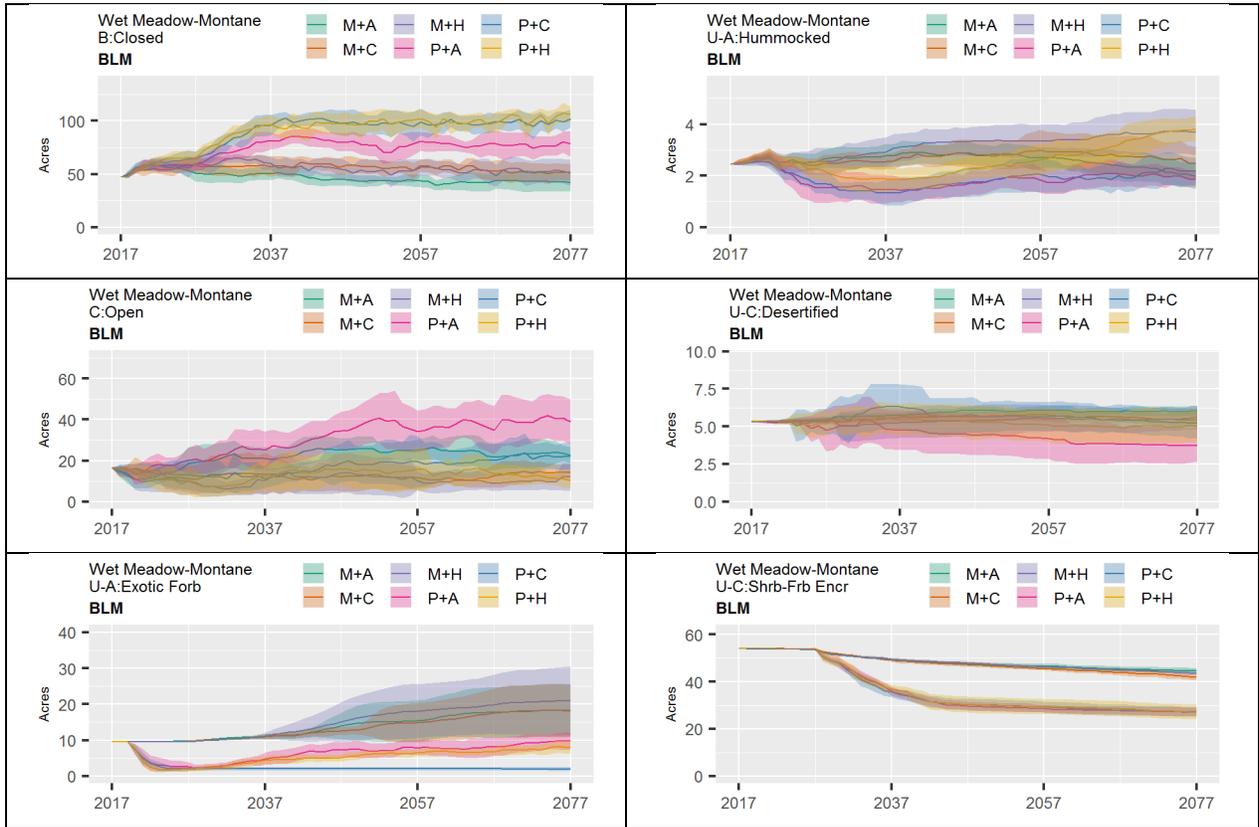


Figure 40. Area (acres) of focal vegetation classes over time in wet meadow on BLM-managed lands. N = 10 iterations.

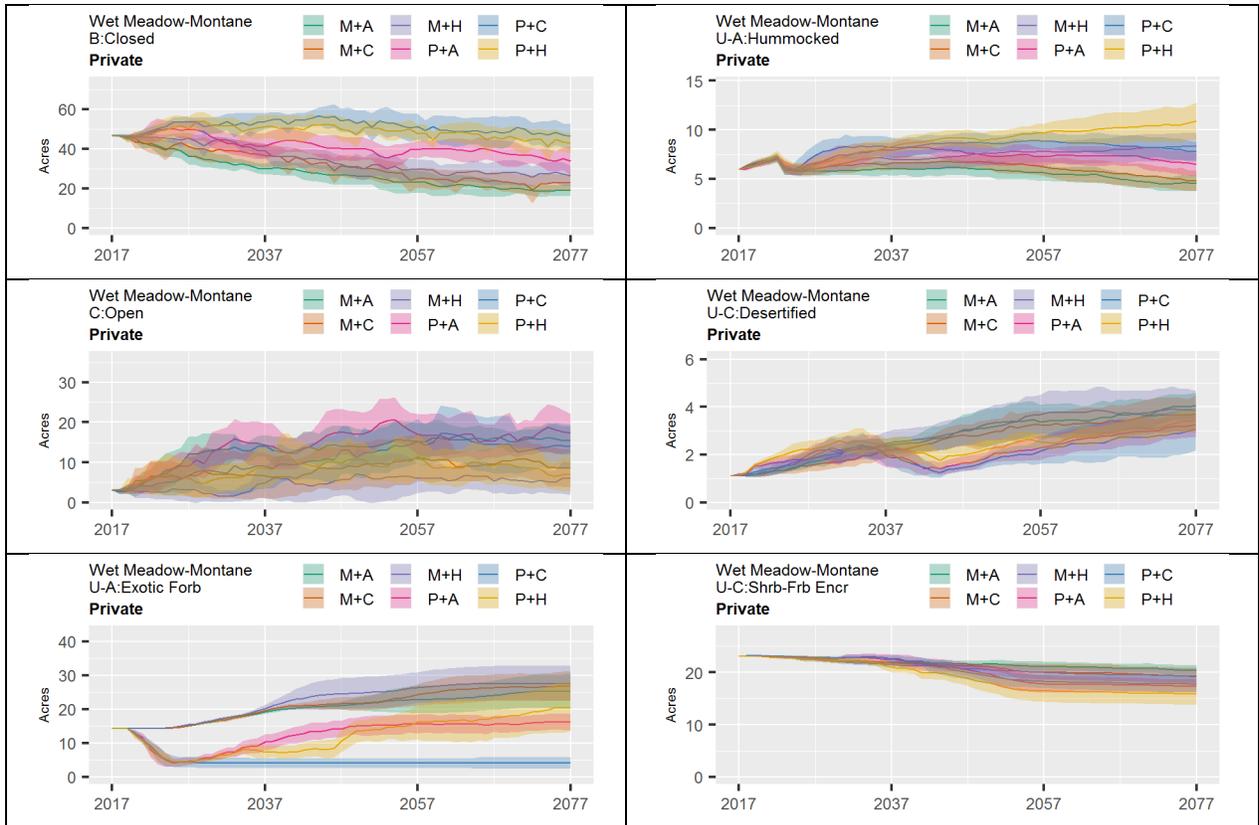


Figure 41. Area (acres) of focal vegetation classes over time in wet meadow on private lands. N = 10 iterations.

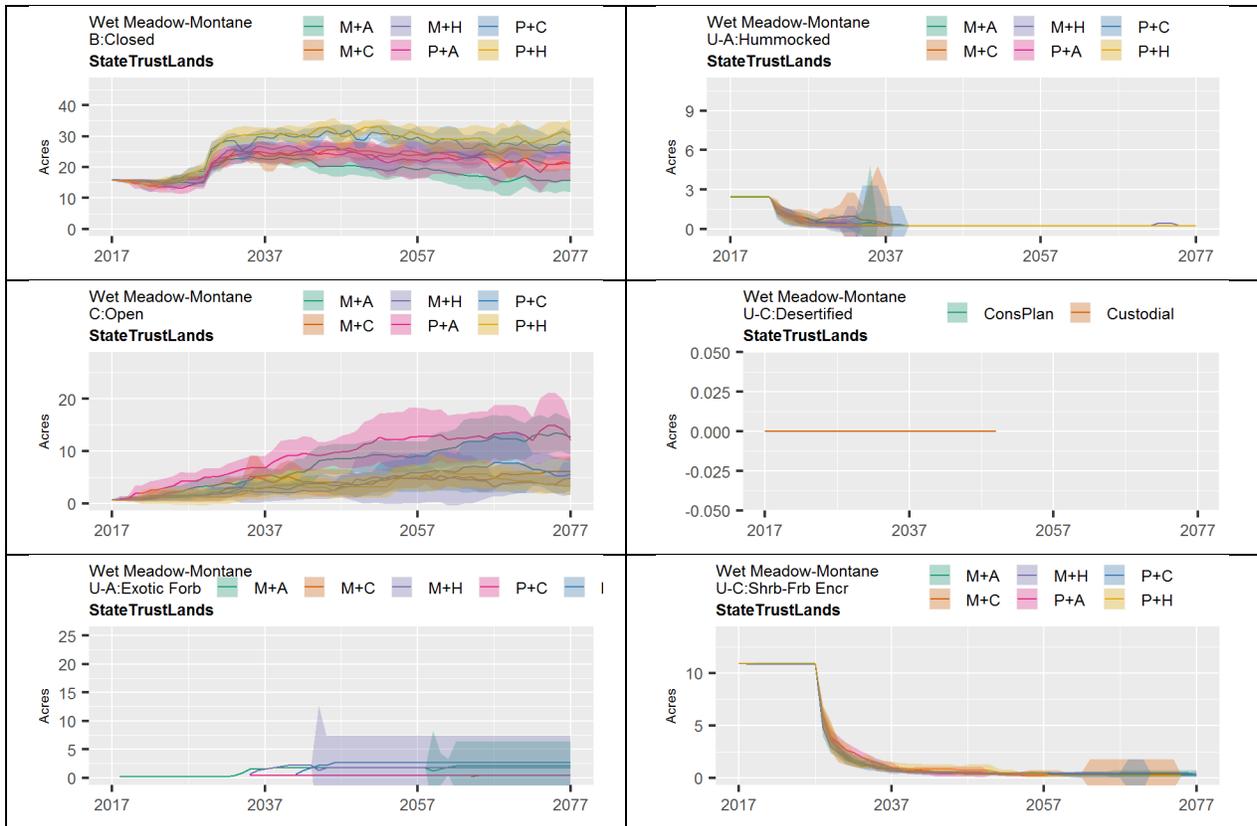


Figure 42. Area (acres) of focal vegetation classes over time in wet meadow on SITLA-managed lands. N = 10 iterations.

Current System Acres at 30-m resolution: 61,395 total

Condition: Unified Ecological Departure

In 2017:

In 2077 under MINIMUM MANAGEMENT & HISTORIC Climate:

In 2077 under MINIMUM MANAGEMENT & CCSM4 LOCA:

In 2077 under MINIMUM MANAGEMENT & ACCESS1 LOCA:

100
100 ± 0
100 ± 0
100 ± 0

Vegetation Classes

**Table 29. Vegetation classes of the Wyoming big sagebrush ecological system at the current time (2017 and 2019), and after 60 years of MINIMUM MANAGEMENT (2077) under three climate scenarios.**

Vegetation Class	Ref NRV%	Undesir. Level	Allow. Thresh%	Current (2017)	MINIMUM MANAGEMENT (2077)		
				Class %	HISTORIC Class %	CCSM4 Class %	ACCESS1 Class %
A:All	16	0	0.0	0.0%	0.7%	1.0%	0.3%
B:Open	28	0	0.0	1.8%	0.7%	0.6%	0.5%
C:Closed	42	0	0.0	0.8%	1.3%	1.4%	2.0%
D:Open	6	0	0.0	2.2%	0.4%	0.4%	0.5%
E:Closed	8	0	0.0	0.0%	1.4%	1.3%	1.1%
U-A:Annual Spp	0	1	0.0	0.6%	38.0%	35.2%	21.4%
U-A:Bare Ground	0	1	0.0	0.0%	0.1%	0.1%	0.1%
U-A:Early-Shrub	0	0	0.0	3.8%	9.6%	9.3%	7.7%
U-A:Exotic Forb	0	2	0.0	0.0%	0.0%	0.0%	0.0%
U-A:SAP	0	0	0.0	0.4%	0.9%	1.4%	0.9%
U-A:Seeded Native	0	0	16.0	0.0%	0.0%	0.0%	0.0%
U-A:SI	0	0	9.6	1.8%	2.7%	3.0%	0.8%
U-A:SI+AG	0	0	0.0	4.9%	0.3%	0.4%	0.1%
U-B:SAP	0	0	0.0	18.5%	2.9%	3.3%	7.3%
U-B:SAP+	0	1	0.0	0.0%	0.1%	0.3%	0.6%
U-B:SI	0	0	16.8	5.6%	2.8%	2.0%	1.2%
U-B:SI+AG	0	0	0.0	2.9%	0.3%	0.2%	0.3%
U-C:Depleted	0	1	0.0	23.3%	6.5%	6.7%	13.2%
U-C:SA	0	1	0.0	12.1%	4.8%	5.5%	10.6%
U-C:SA+	0	1	0.0	0.0%	0.2%	0.4%	0.7%
U-C:SI	0	0	27.0	0.0%	5.7%	6.2%	9.4%
U-C:SI+AG	0	0	0.0	1.8%	0.9%	1.0%	1.6%
U-D:SI	0	0	5.4	0.3%	1.0%	1.0%	1.1%
U-D:SI+AG	0	0	0.0	0.5%	0.4%	0.5%	0.5%
U-E:TEA	0	1	0.0	18.6%	18.5%	18.9%	18.1%

**Table 30. Area (acres) of Wyoming big sagebrush vegetation classes per ownership in 2017 and 2019.**

Vegetation Class	IP WMA	BLM	Private	SITLA
A:All	0.0	0.9	0.0	0.0
B:Open	0.0	1,049.0	4.7	22.2
C:Closed	0.0	470.6	0.2	0.7
D:Open	0.0	1,288.1	4.2	74.5
E:Closed	0.0	8.9	0.0	0.0
U-A:Annual Spp	0.0	103.9	232.0	35.8
U-A:Bare Ground	0.0	15.3	6.2	3.6
U-A:Early-Shrub	0.0	2,247.1	20.5	74.9
U-A:Exotic Forb	0.0	23.1	0.0	2.9
U-A:SAP	0.0	160.8	35.6	66.3
U-A:SI	0.7	927.4	45.6	141.2
U-A:SI+AS	0.0	2,500.6	30.0	487.0
U-B:SAP	0.0	10,721.6	146.3	488.6
U-B:SAP+	0.0	0.0	0.0	0.0
U-B:SI	0.0	2,410.1	379.4	640.9
U-B:SI+AS	0.0	781.0	62.3	923.2
U-C:Depleted	0.0	12,702.5	464.4	1128.0
U-C:SA	0.0	6,803.9	122.8	487.7
U-C:SA+	0.0	0.0	0.0	0.0
U-C:SI	0.0	0.0	0.0	0.0
U-C:SI+AS	0.0	1,027.0	20.0	49.8
U-D:SI	0.0	169.2	8.0	18.9
U-D:SI+AS	0.0	234.6	23.8	59.6
U-E:TEA	0.0	10,702.1	191.7	542.6

### Problems or Concerns

2017: Several uncharacteristic classes dominate the area of Wyoming big sagebrush (Table 29). Not surprisingly, Wyoming big sagebrush was 100% departed from reference conditions (see above). Very little of the system's area was in reference classes (Table 29) and most of the system was on BLM lands (Table 30). About equal areas of the following classes required attention (Table 29): 23.3% in the depleted sagebrush class (U-C:Depleted), 18.6% in the tree-encroached class (U-E:TEA), 18.5% in the mid-successional shrub with annual and perennial grasses class (U-B:SAP), and 12.1% in the late-successional shrub with annual grass class (U-C:SA). The BLM harbored disproportionately more of the U-C:Depleted, U-E:TEA, U-B:SAP, and U-C:SA classes than private and SITLA lands (Table 30).

After 60 years of MINIMUM MANAGEMENT: The area of the tree-encroached class (U-E:TEA) did not appreciably change, but the classes of depleted sagebrush (U-C:Depleted), shrub with annual grass (U-C:SA), and shrubs with annual and perennial grasses (U-B:SAP) evenly decreased, although more in the CCSM4 and ACCEES1 climates (Table 29). The loss of area of these decreasing classes corresponded with the large increase of the non-native annual species class

(U-A:Annual Spp). The smallest increase of this class was for the ACCESS1 climate, which had the least fire.

Objective(s) for Management Actions

Under current conditions, reduction of the more abundant uncharacteristic classes formed a set of objectives. These included larger tree removal in heavily treed areas followed by seeding and lopping trees in the late successional open classes (i.e., younger trees), and mechanical thinning of degraded shrublands followed by seeding with or without herbicide to control annual species. Removal of tree-encroachment in shrublands is the most important objective for sage-grouse management. Treating the U-B:SAP class is not recommended because it contributes fully to sage-grouse habitat suitability for nesting and foraging. Also, a worthy objective would be to increase the percentage of reference classes perhaps by implementing native species seedings.

In the future as fire causes transitions to non-native annual grasslands (U-A:Annual Spp), seeding perennial species into this class becomes important for future sage-grouse nesting success and general fuels management.

Treatment Rates and Costs

No actions were used in the IP WMA as Wyoming big sagebrush was nearly absent. Spending was two orders of magnitude higher on BLM lands than on private lands and one order of magnitude higher than on SITLA lands due to the difference in area and disproportional representation of treed areas, which were more expensive to treat with a masticator (Table 31). Expenses for BLM ranged from \$4,091,804 to \$4,180,732 ,with little difference among climate scenarios (Table 31). Private and SITLA lands investments, respectively, varied from \$47,253 to \$51,436 and from \$271,114 to \$283,890, again with minor climate differences (Table 31). Differences in cost among climates, while small, were caused by the greater use of Chaining+Native-Seed and Masticate+Herbicide+Seed that are the more expensive actions in the PREFERRED+HISTORIC scenario (Table 31).

**Table 31. Cumulative implementation rates and costs of actions in Wyoming big sagebrush over periods of implementation.**

Scenario	Action	Cost/ acre	Sum of Acres /Interval (Avg of 10 runs)				60-yr Total Cost
			2020-2024	2025-2034	2035-2044	2045-2077	
<b>BLM</b>							
Preferred +HISTORIC	Chaining+ Native-Seed	\$205.00	584.5	0.0	0.0	0.0	
	Chaining+ Plateau+ Seed	\$192.50	1581.9	0.0	0.0	0.0	
	Chaining+ Seed	\$165.00	2058.4	0.0	0.0	0.0	
	Forb+ Grass- Native- Seeding+ Chaining	\$160.00	2505.3	0.0	0.0	0.0	

Scenario	Action	Cost/ acre		Sum of Acres /Interval (Avg of 10 runs)				60-yr Total Cost
				2020-2024	2025-2034	2035-2044	2045-2077	
	Masticate+ Herbicide+ Seed	\$605.00		2494.8	1643.4	0.0	0.0	
Preferred +HISTORIC	Small-Tree- Lopping	\$150.00		2504.3	1004.1	1006.0	1892.6	
			Cost →	\$2,861,974	\$1,069,571	\$75,447	\$141,943	\$4,148,934
Preferred +CCSM4	Chaining+ Native-Seed	\$205.00		558.4	0.0	0.0	0.0	
	Chaining+ Plateau+ Seed	\$192.50		1674.7	0.0	0.0	0.0	
	Chaining+ Seed	\$165.00		1980.3	0.0	0.0	0.0	
	Forb+ Grass- Native- Seeding+ Chaining	\$160.00		2488.9	0.0	0.0	0.0	
	Masticate+ Herbicide+ Seed	\$605.00		2496.2	1698.0	0.0	0.0	
	Small-Tree- Lopping	\$150.00		2506.5	1003.7	1001.3	1907.3	
				Cost →	\$2,860,004	\$1,102,583	\$75,097	\$143,049
Preferred +ACCESS1	Chaining+ Native-Seed	\$205.00		590.8	0.0	0.0	0.0	
	Chaining+ Plateau+ Seed	\$192.50		1582.8	0.0	0.0	0.0	
	Chaining+ Seed	\$165.00		2070.6	0.0	0.0	0.0	
	Forb+ Grass- Native- Seeding+ Chaining	\$160.00		2504.2	0.0	0.0	0.0	
	Masticate+ Herbicide+ Seed	\$605.00		2505.5	1532.7	0.0	0.0	
	Small-Tree- Lopping	\$150.00		2495.3	999.7	1005.1	1907.7	
				Cost →	\$2,871,054	\$1,002,288	\$75,382	\$143,081
<b>Private</b>								
Preferred +HISTORIC	Masticate+ Herbicide+ Seed	\$605.00		50.1	0.0	0.0	0.0	
	Small-Tree- Lopping	\$150.00		23.7	0.0	101.5	101.1	
			Cost →	\$32,063	\$0	\$7,611	\$7,579	\$47,253
Preferred +CCSM4	Masticate+ Herbicide+ Seed	\$605.00		57.2	0.0	0.0	0.0	

Scenario	Action	Cost/ acre		Sum of Acres /Interval (Avg of 10 runs)				60-yr Total Cost
				2020-2024	2025-2034	2035-2044	2045-2077	
	Small-Tree-Lopping	\$150.00		24.5	0.0	99.5	100.0	
			Cost →	\$36,468	\$0	\$7,466	\$7,502	\$51,436
Preferred +ACCESS1	Masticate+ Herbicide+ Seed	\$605.00		55.7	0.0	0.0	0.0	
	Small-Tree-Lopping	\$150.00		23.8	0.0	99.4	101.4	
			Cost →	\$35,503	\$0	\$7,457	\$7,606	\$50,566
<b>SITLA</b>								
Preferred +HISTORIC	Chaining+ Native-Seed	\$205.00		205.2	0.0	0.0	0.0	
	Chaining+ Plateau+ Seed	\$192.50		65.2	0.0	0.0	0.0	
	Chaining+ Seed	\$165.00		16.9	0.0	0.0	0.0	
	Masticate+ Herbicide+ Seed	\$605.00		184.7	0.0	0.0	0.0	
	Small-Tree-Lopping	\$150.00		248.7	301.3	151.5	662.5	
				Cost →	\$187,843	\$22,598	\$11,360	\$49,690
Preferred +CCSM4	Chaining+ Native-Seed	\$205.00		228.2	0.0	0.0	0.0	
	Chaining+ Plateau+ Seed	\$192.50		87.2	0.0	0.0	0.0	
	Chaining+ Seed	\$165.00		24.9	0.0	0.0	0.0	
	Masticate+ Herbicide+ Seed	\$605.00		0.0	0.0	0.0	0.0	
	Small-Tree-Lopping	\$150.00		188.3	0.0	0.0	0.0	
				Cost →	\$200,625	\$22,606	\$11,339	\$49,320
Preferred +ACCESS1	Chaining+ Native-Seed	\$205.00		181.9	0.0	0.0	0.0	
	Chaining+ Plateau+ Seed	\$192.50		105.8	0.0	0.0	0.0	
	Chaining+ Seed	\$165.00		27.5	0.0	0.0	0.0	
	Masticate+ Herbicide+ Seed	\$605.00		177.4	0.0	0.0	0.0	
	Small-Tree-Lopping	\$150.00		250.7	297.2	150.4	656.3	
				Cost →	\$188,323	\$22,287	\$11,284	\$49,220

Management actions had no to little effect on UED because uncharacteristic classes were largely, but not entirely, replaced with large areas of mixed introduced and native species seedings that are also uncharacteristic classes. Because so much area was seeded, the allowed threshold percentages of seedings (Table 29) were easily exceeded.

Unified Ecological Departure	MINIMUM MANAGEMENT	PREFERRED MANAGEMENT
In 2077 under HISTORIC Climate	100 ± 0	100 ± 0
In 2077 under CCSM4 LOCA	100 ± 0	100 ± 0
In 2077 under ACCESS1 LOCA	100 ± 0	99 ± 1

### Vegetation Classes

On BLM lands, tree removal combined with seeding reduced the tree-encroached class (U-D:TEA) by about 4,000 to 5,000 acres compared to MINIMUM MANAGEMENT scenarios, with the greatest reduction found under HISTORIC climate (Figure 43). The shrub with annual species class (U-C:SA) was reduced by 700 acres under HISTORIC climate, and up to 1,000 acres under other climates (Figure 43). Treatment effects on depleted sagebrush (U-C:Depleted) were difficult to observe graphically. However, a 700-acre reduction due to treatments was detected in the HISTORIC and CCSM4 climates, but practically no change was detected in the ACCESS1 climate. The climate effect was strong as 2,000-3,000 acres more of depleted sagebrush were found in the ACCESS1 climate than both the HISTORIC and CCSM4 climates (Figure 43). Treatment of the non-native annual species class (U-Annual Spp) achieved, respectively, about 2,000, 3,000 and 2,000-acre reductions of this class under the HISTORIC, CCSM4, and ACCESS1 climates; this reflects the order of fire activity in these climates (Figure 43; Provencher et al. 2019). Strong climate effects were also found with 10,000 fewer acres in the MINIMUM+ACCESS1 scenario compared to the MINIMUM+HISTORIC scenario by 2077. At most 50 acres of young tree reduction by small tree lopping was achieved in both the reference late-successional open class (D:Open) and late-successional open seeded class (U-D:SI) for the ACCESS1 climate. Effects were even smaller in the other climates, where fire presumably also removed more trees than in the less fire-active ACCESS1 climate.

Both native species seedings (U-A:Seeded-Native) and mixed introduced and native species seedings (U-A:SI) increased in response to tree removal and shrubland restoration in non-native annual species grasslands (U-A:Annual Spp; Figure 44). As much as 4,000 acres of new U-A:SI seedings were created in one year, although large areas of new seeding creation persisted for decades as long as non-native annual species were controlled. Succession from U-A:SI to the older classes (U-B:SI and then U-C:SI) was also evident (Figure 44). Finally, recruitment of area in the reference mid-successional open class (B:Open) from long-term tree removal in both of the reference late-successional classes (D:Open and E:Closed) was modest at 200-300 acres, and mostly observed in the PREFERRED+HISTORIC scenario (Figure 44).

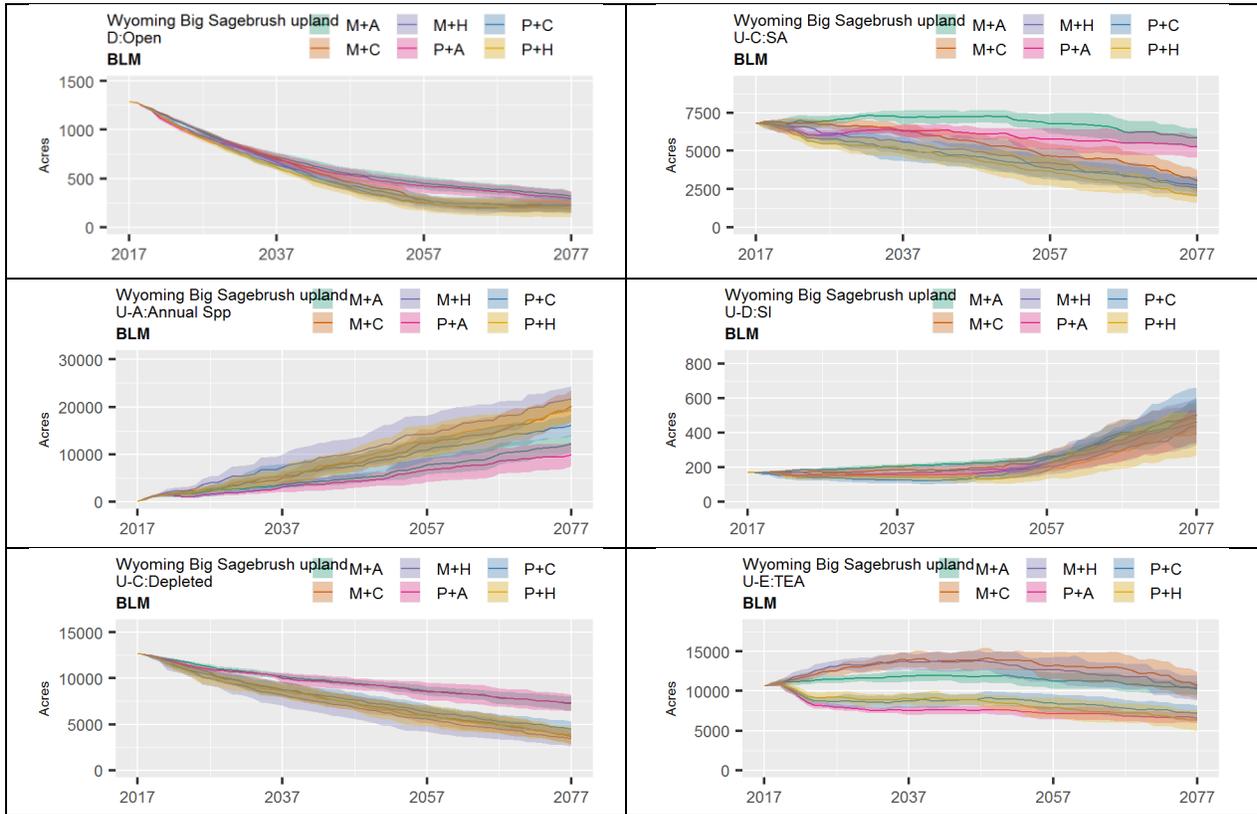


Figure 43. Area (acres) of treated vegetation classes over time in Wyoming big sagebrush on BLM-managed lands. N = 10 iterations.

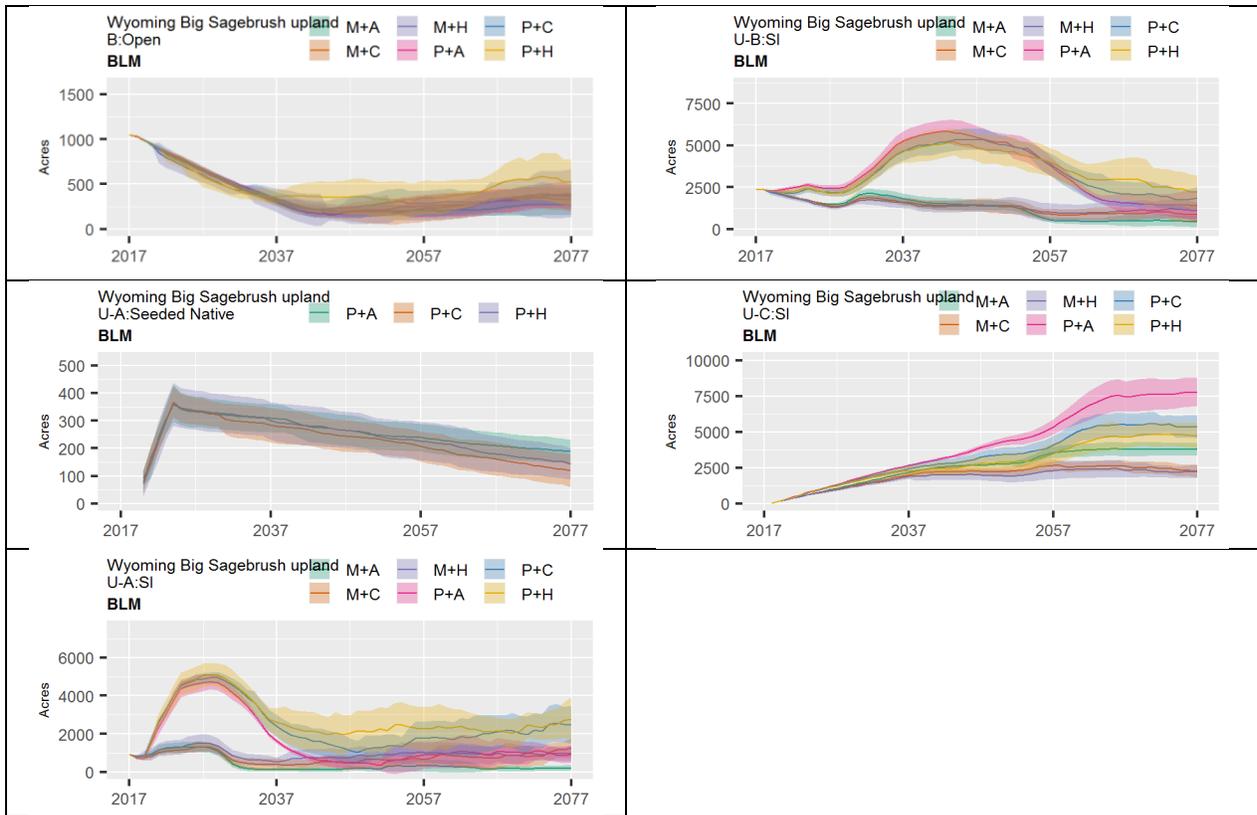


Figure 44. Area (acres) of recipient vegetation classes over time in Wyoming big sagebrush on BLM-managed lands. N = 10 iterations.

The patterns seen on BLM lands were reproduced on private lands (Figures 45-46) and SITLA lands (Figures 47-48), but with smaller areas, sometimes with less marked treatment effects for tree removal and native species seedings (U-A:Seeded-Native) for private lands. Also, while the transitions from U-X:SI+AS to U-X:SI (where X is A, B, C, or D) still increased seeded classes in the MINIMUM+ACCESS1 scenario, the effect was less important in the early-successional seeded class (U-A:SI), which suggested that seeded classes are generally older on private and SITLA lands as observed (Figures 46 and 48). A difference between BLM and SITLA lands was the proportionally greater response after tree removal and resulting increase of the reference of mid-successional class (B:Open) in SITLA lands.

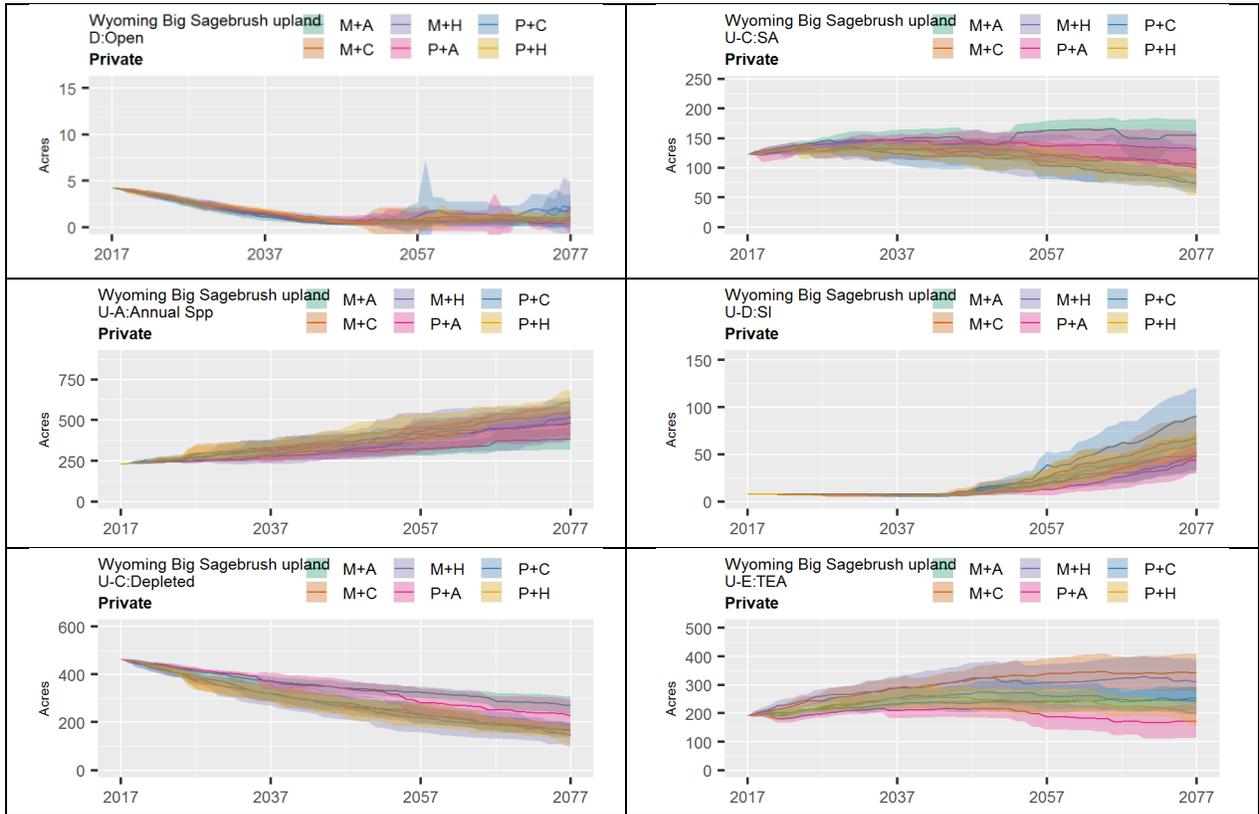


Figure 45. Area (acres) of treated vegetation classes over time in Wyoming big sagebrush on private lands. N = 10 iterations.

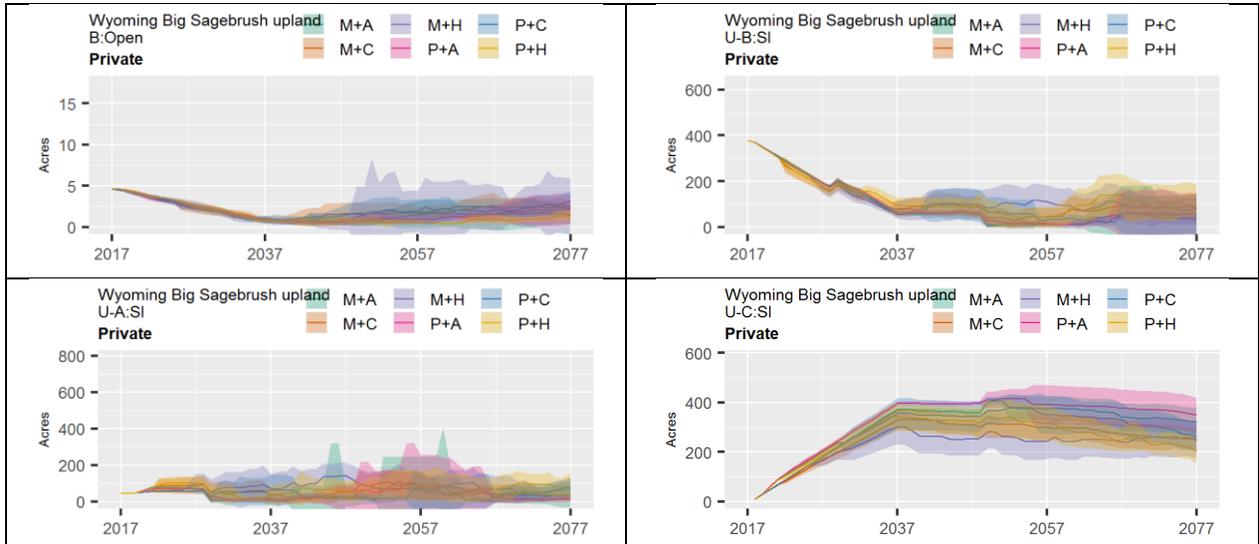


Figure 46. Area (acres) of recipient vegetation classes over time in Wyoming big sagebrush on private lands. N = 10 iterations.

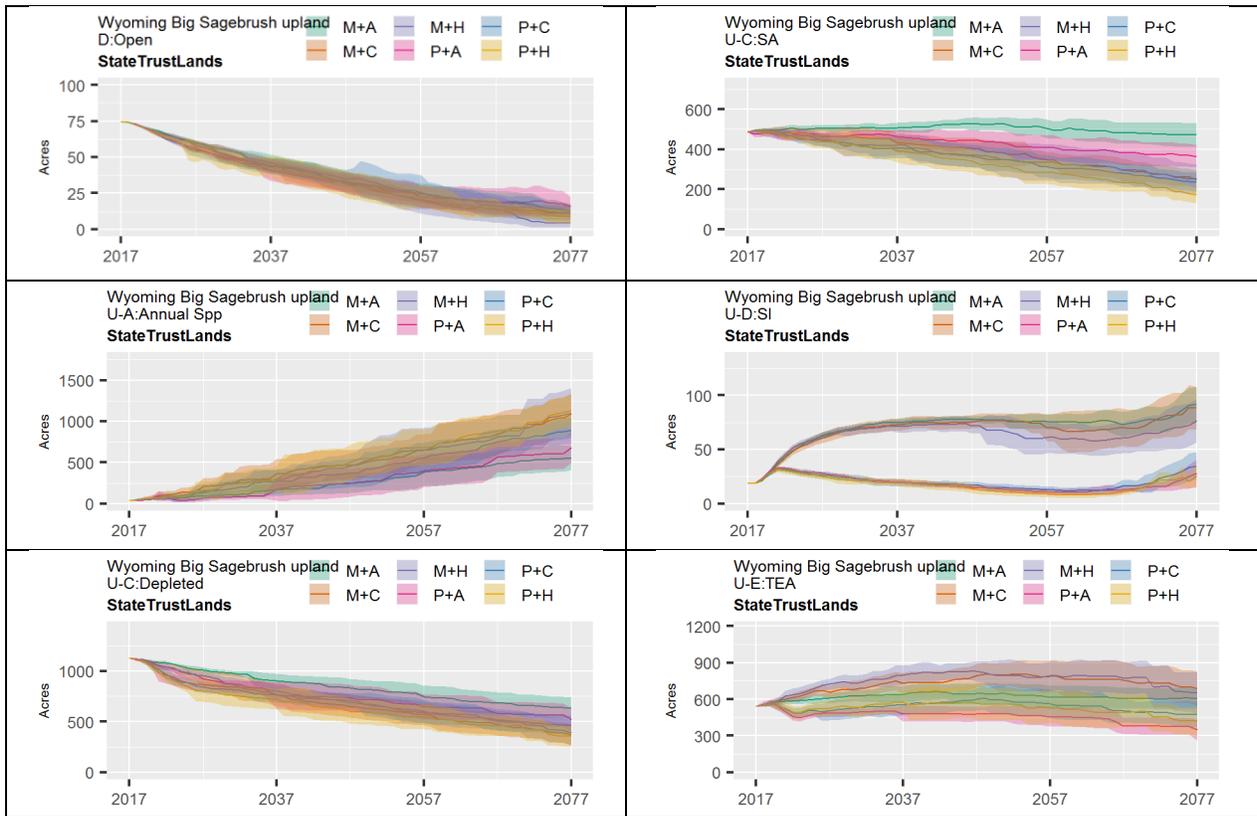


Figure 47. Area (acres) of treated vegetation classes over time in Wyoming big sagebrush on SITLA-managed lands. N = 10 iterations.

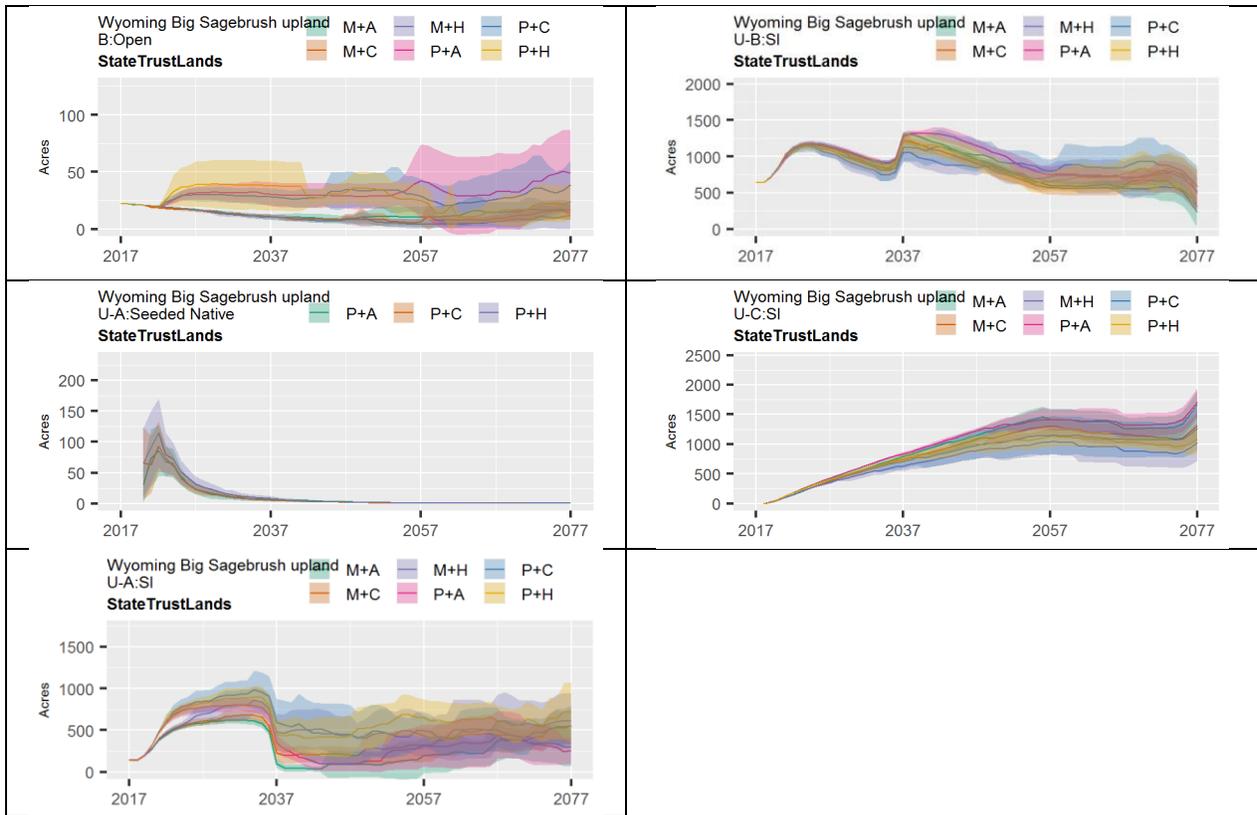


Figure 48. Area (acres) of recipient vegetation classes over time in Wyoming big sagebrush on SITLA-managed lands. N = 10 iterations.

## GREATER SAGE-GROUSE HABITAT SUITABILITY INDEX

Overall, habitat suitability indices were slightly smaller in 2047 than in 2017 for all scenarios. After 30 years (2047) under MINIMUM MANAGEMENT, the habitat suitability index was significantly higher for the ACCESS1 climate than the HISTORIC or CCSM4 climates. However, the difference was <1% in absolute value, and may have been caused by the loss of suitability east of the IP WMA, which is an important area for sage-grouse (Table 32; Figure 49). The lower fire activity of the ACCESS1 LOCA compared to other climates protected sagebrush shrublands and may have allowed recovery of shrublands in the north-central and northeastern part of the landscape, despite general loss of suitability (darker blues for gain in suitability, Figure 49). Within PREFERRED MANAGEMENT scenarios, habitat suitability significantly increased with lower fire activity from HISTORIC or CCSM4 climates to the ACCESS1 climate (Table 28; Figure 50). The improvement areas for the ACCESS1 climate were obvious in the north-central part of the landscape, the IP WMA, and in spots in the southeastern corner (Figure 50).

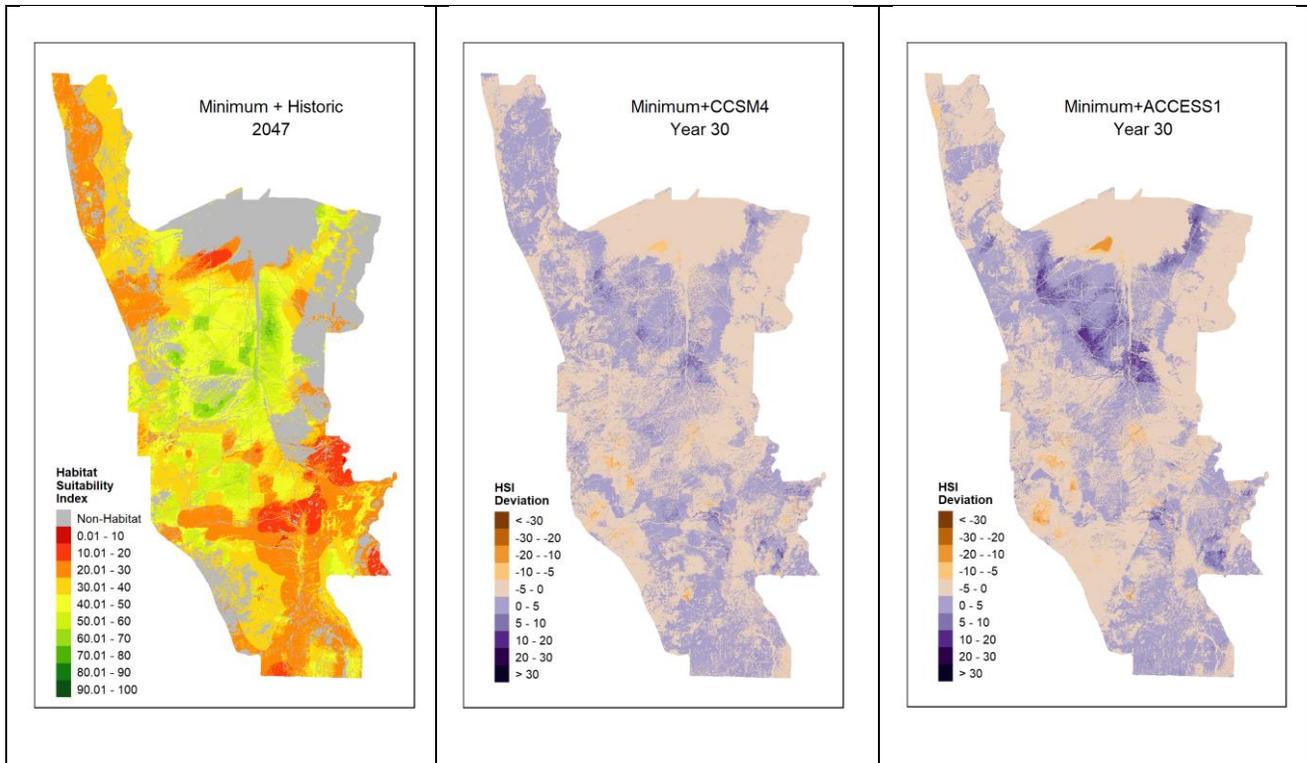
**Table 32. Average greater sage-grouse habitat suitability index (percent and  $\pm 1$  95% C.I.). Different lower-case letters (a, b, c, d) indicate significantly different ( $P \leq 0.05$ ) means.**

Scenario		2017	2047	2077
M+H	MINIMUM+HISTORIC	29.96	26.56 $\pm$ 0.19 a	26.26 $\pm$ 0.24 a
M+C	MINIMUM+CCSM4	29.96	26.64 $\pm$ 0.13 a	26.12 $\pm$ 0.10 a
M+A	MINIMUM+ACCESS1	29.96	26.88 $\pm$ 0.12 b	26.26 $\pm$ 0.14 b
P+H	PREFERRED+HISTORIC	29.96	28.69 $\pm$ 0.17 c	28.14 $\pm$ 0.25 c
P+C	PREFERRED+CCSM4	29.96	28.63 $\pm$ 0.23 c	28.08 $\pm$ 0.20 c
P+A	PREFERRED+ACCESS1	29.96	29.37 $\pm$ 0.15 d	28.73 $\pm$ 0.16 d

Box-Cox transformation for HSI in 2077 was  $(HSI_{2077}^{4.999997} - 1) / 4.999997$ . No transformation was required in 2047.

All PREFERRED MANAGEMENT scenarios significantly improved habitat suitability compared to MINIMUM MANAGEMENT scenarios (Table 32). The greatest increase in habitat suitability was significantly achieved by the PREFERRED+ACCESS1 scenario compared to the PREFERRED+CCSM4 and PREFERRED+HISTORIC scenarios (Table 32). These last two scenarios were not different from each other for both MINIMUM and PREFERRED Management.

PREFERRED MANAGEMENT scenarios improved sage-grouse habitat primarily in the north-central part of the project area to the west of Pine Valley Road toward and including the IP WMA, and northeast of Pine Valley Road flanking areas of winterfat and mixed salt desert scrub systems (Figure 50). Less extensive but still strong habitat improvement was observed in the southeast, approximately south of Jockey Road (Figure 50). These areas of improvement overlap with existing or future simulated seedings of mixed native and introduced species. The same patterns existed among all three climates, except habitat improvement was stronger and more widespread under the ACCESS1 LOCA. A noteworthy observation was the existence of a pinch point of lower habitat suitability between the IP WMA (suitable) and land to the east and northeast toward the Pine Valley road (suitable; Figure 50).



**Figure 49. Greater sage-grouse habitat suitability index after 30 years of simulation for the MINIMUM+HISTORIC scenario, and the MINIMUM+CCSM4 and MINIMUM+ACCESS1 scenarios expressed as deviation from the HISTORIC climate.**

After 60 years (2077), habitat suitability slightly decreased for all MINIMUM MANAGEMENT scenarios compared to 2047 (30 years; Table 32). Again, suitability was significantly more for the ACCESS1 climate than both the HISTORIC and CCSM4 climates, although the absolute change was higher for the ACCESS1 climate between 2047 and 2077. The layout of habitat suitability was more clearly defined in 2077 than previously, as the strength of climates increased (Figure 51). The areas of higher habitat suitability (green) were less so in 2077 than 2047 for HISTORIC climate. The CCSM4 climate showed nearly no area of habitat improvement in 2077, whereas the same clear zones of improvement described above were observed in the north-central and southeast portions of the landscape with the ACCESS1 climate (Figure 51).

The PREFERRED+ACCESS1 scenario achieved the highest habitat suitability, followed by a significantly smaller value for the PREFERRED+CCSM4 AND PREFERRED+HISTORIC scenarios (Table 32). The areas of improvement in the northern part of the landscape seen in 2047 were more widespread in 2077, whereas zones of deterioration overlapped with fires that were more abundant in the PREFERRED+HISTORIC scenario (Figure 52). In the southern part of the landscape, zones of improvement were more faded in 2077 compared to 2047. New fires after 2035 were not treated in the simulations due to the limited future budgets.

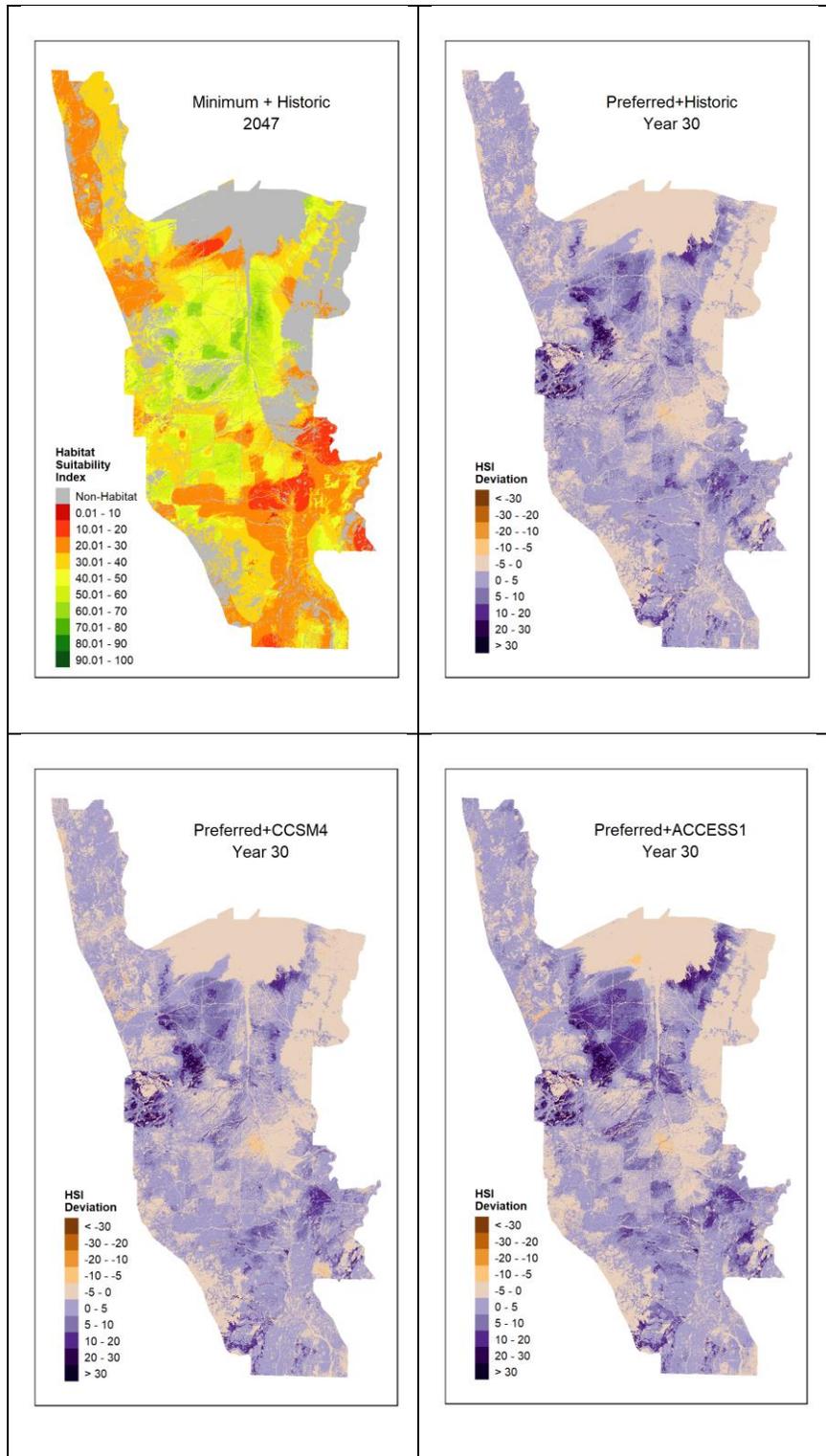


Figure 50. Greater sage-grouse habitat suitability index after 30 years of simulation for the MINIMUM+HISTORIC scenario; and the PREFERRED+HISTORIC, PREFERRED+CCSM4 and PREFERRED+ACCESS1 scenarios expressed as deviation from the MINIMUM+HISTORIC scenario.

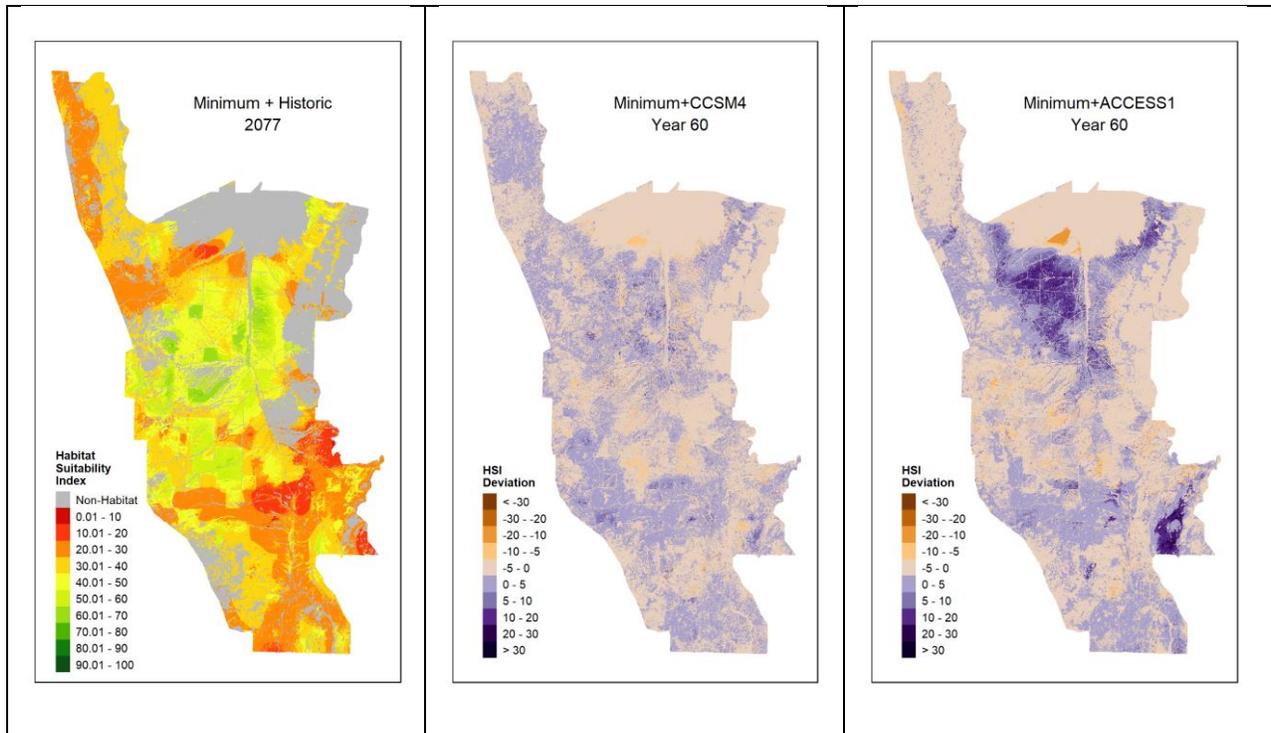


Figure 51. Greater sage-grouse habitat suitability index after 60 years of simulation for the MINIMUM+HISTORIC scenario, and the MINIMUM+CCSM4 and MINIMUM+ACCESS1 scenarios expressed as deviation from the HISTORIC climate.

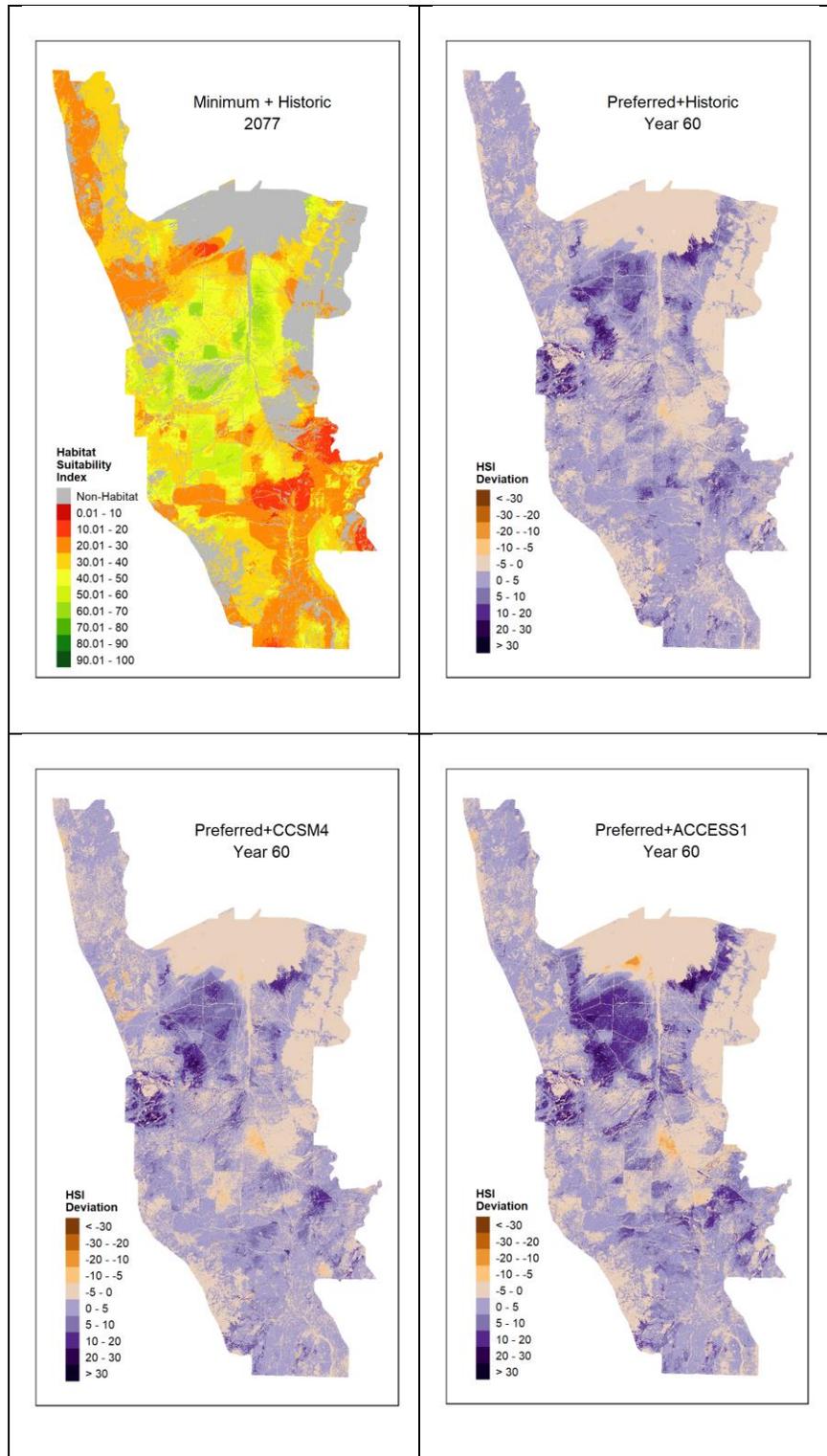


Figure 52. Greater sage-grouse habitat suitability index after 60 years of simulation for the MINIMUM+HISTORIC scenario; and the PREFERRED+HISTORIC, PREFERRED+CCSM4 and PREFERRED+ACCESS1 scenarios expressed as deviation from the MINIMUM+HISTORIC scenario.

## Frequency of Fire and Management Actions

Maps showing the simulated occurrence of fires (Figure 53) and management actions (Figures 54-69) were displayed as frequencies. Frequency is the number of times a pixel experienced a fire or management occurrence out of a total of 600 possible occurrences (600 = 60 Years x 10 model-run replicates). While the goal here was not to explain locations of implementation, the treated ecological systems and vegetation classes were noted for the benefit of managers. Managers will receive in digital format the geospatial products for these actions.

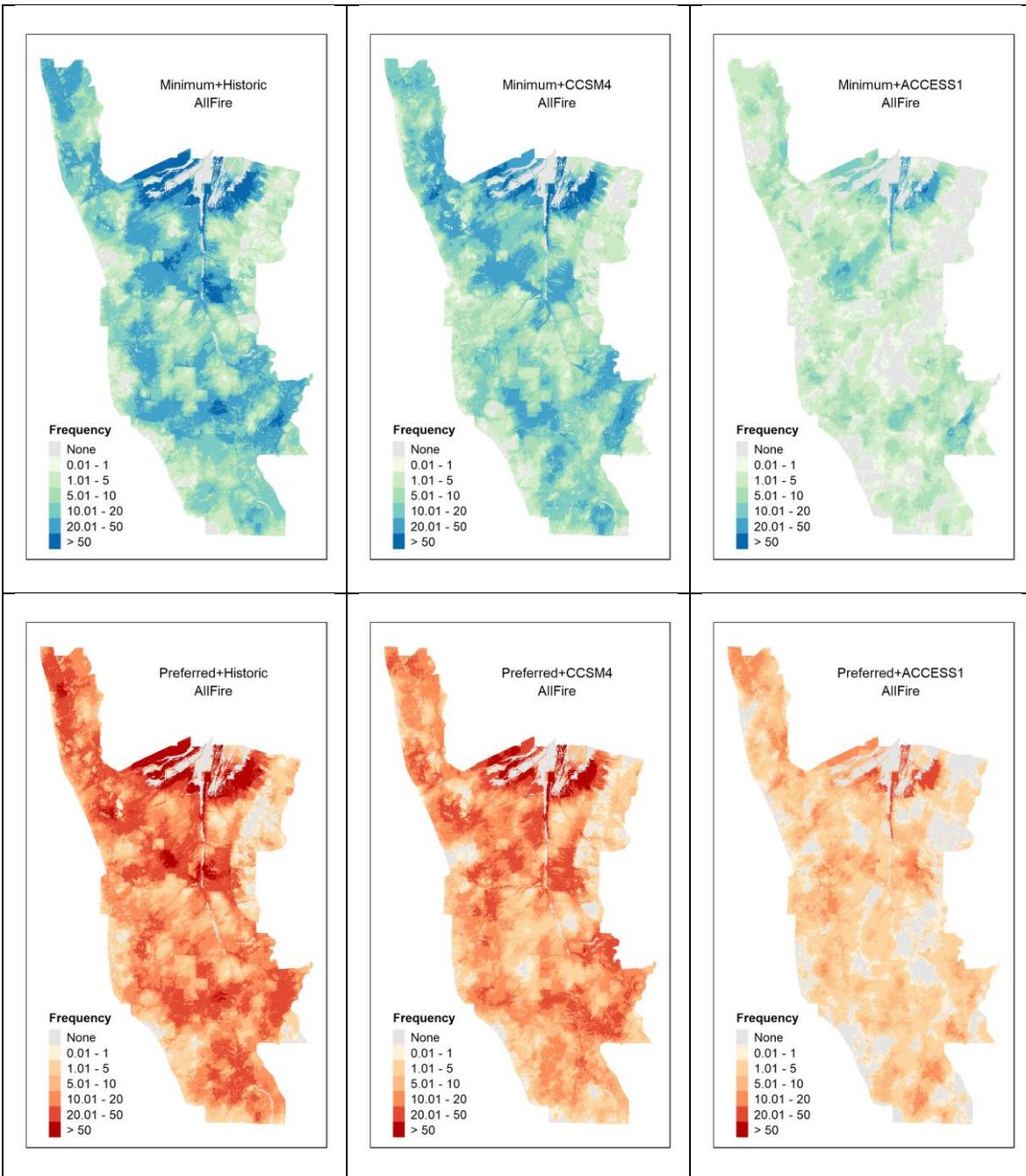


Figure 53. Fire frequency in the Indian Peak-Pine Valley-Mountain Home landscape.

The more consequential disturbance was fire, as it affected all systems and sage-grouse habitat (Figure 53, different color ramps, but same scale, for MINIMUM and PREFERRED MANAGEMENT scenarios). Most fires burned in the northern section of the landscape for both MINIMUM and PREFERRED MANAGEMENT scenarios. Most areas experienced at least one fire, except for substantial areas under the ACCESS1 climate. The other striking result was the much lower fire frequencies in the ACCESS1 climate versus the other climates. The HISTORIC and CCSM4 climates shared spatial features and levels of fire frequency, although fire appeared more frequent in the HISTORIC climate scenarios than the CCSM4 scenarios.

Frequency maps of management actions appear in Figures 54-69 below.

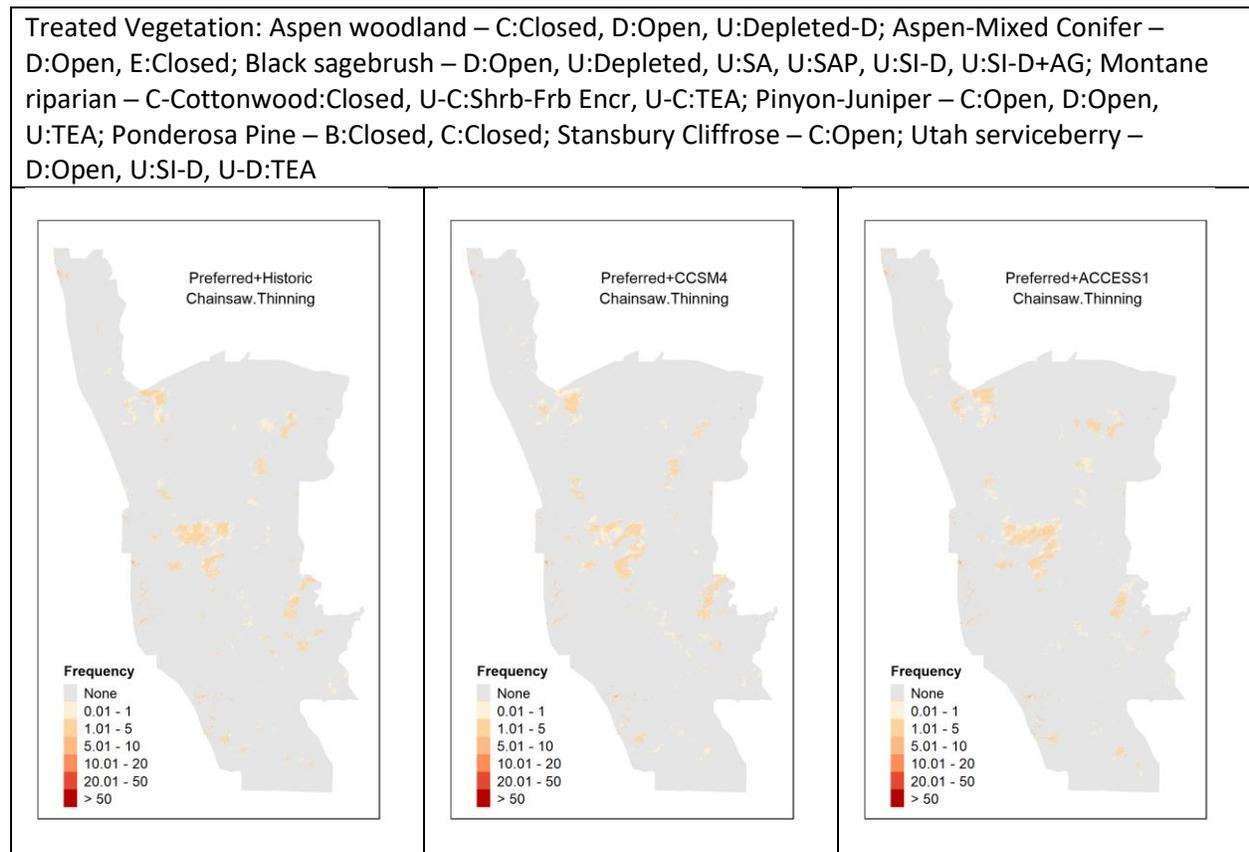


Figure 54. Chainsaw thinning in the Indian Peak-Pine Valley-Mountain Home landscape.

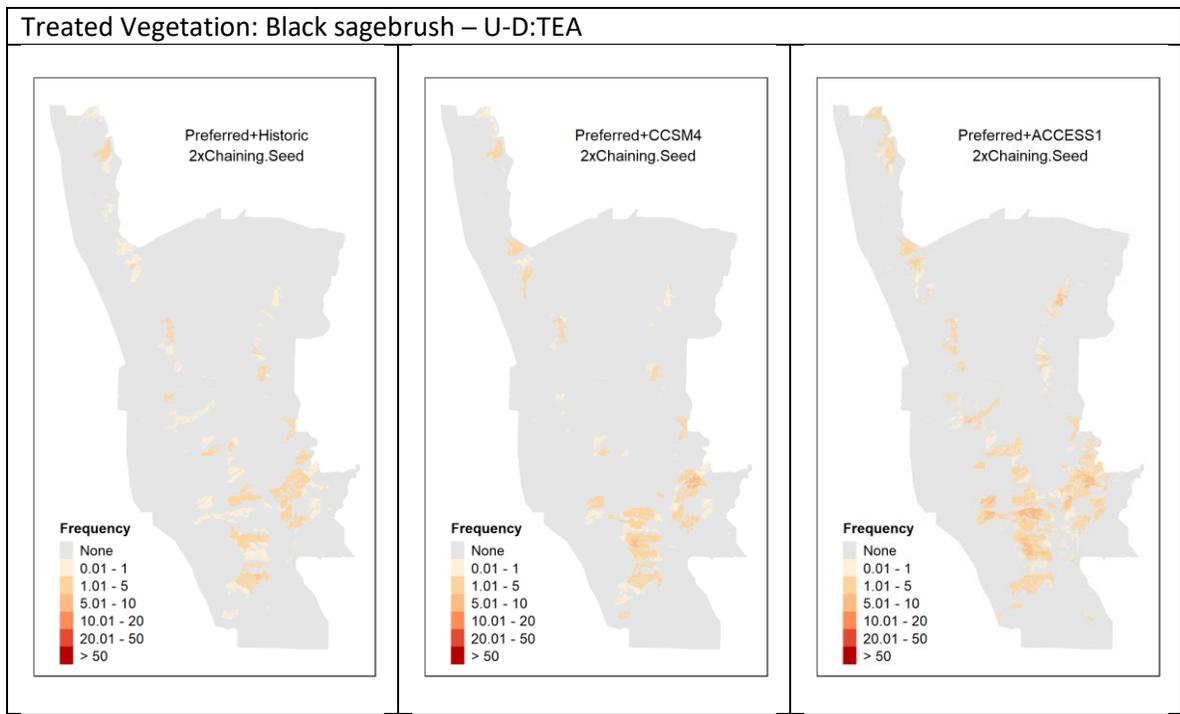


Figure 55. 2xChaining+Seed in the Indian Peak-Pine Valley-Mountain Home landscape.

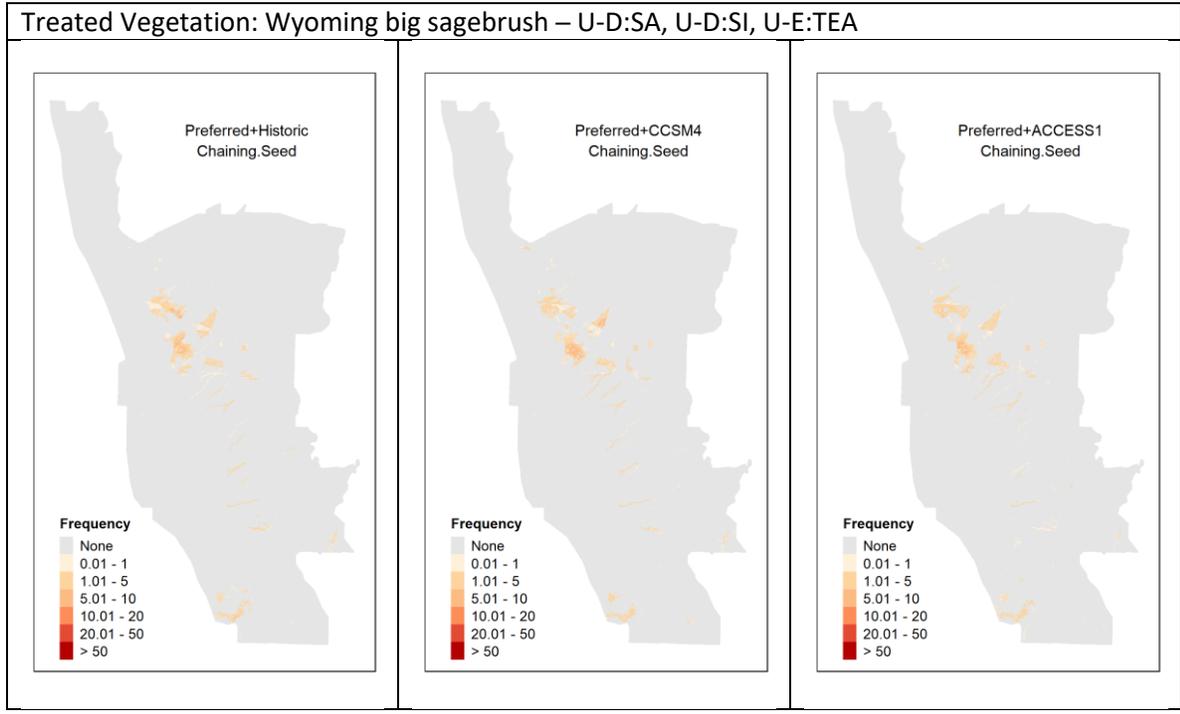


Figure 56. Chaining+Seed in the Indian Peak-Pine Valley-Mountain Home landscape.

Treated Vegetation: Black sagebrush – D:Open, U-A:Annual Spp, U-C:Depleted; Monatne sagebrush steppe – E:Closed, U-A:Annual Spp, U-C:Depleted; Wyoming big sagebrush – E:Closed, U-A:Annual Spp, U-C:Depleted



Figure 57. Chaining+Native-Seed in the Indian Peak-Pine Valley-Mountain Home landscape.

Treated Vegetation: Black sagebrush – U-A:Annual Spp, U-A:SAP, U-B:SAP, u-C:SA, U-C:SA+; Wyoming big sagebrush – U-A:Annual Spp

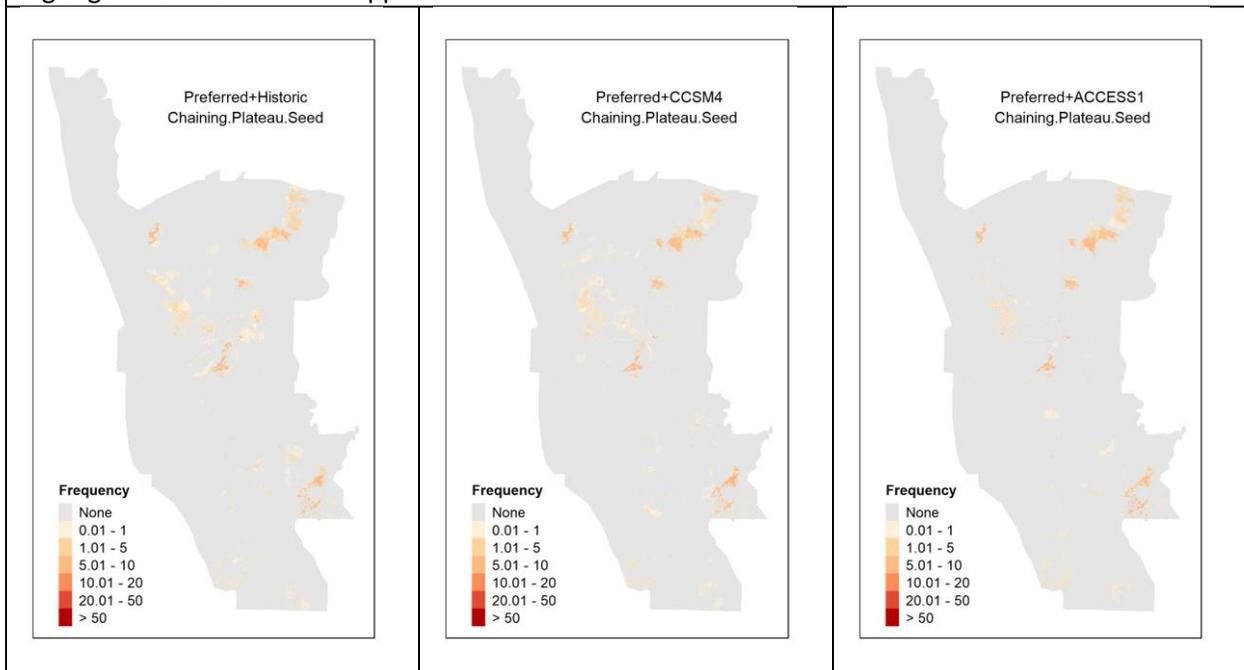


Figure 58. Chaining+Plateau+Seed in the Indian Peak-Pine Valley-Mountain Home landscape.

Treated Vegetation: Dry wet meadow – U-A:Exotic Forb; Montane riparian – U-A:Exotic Forb, U-A:Incised-EFT, U-A:Inset-EFT; Saline meadow – U-A:Exotic Forb; Wet meadow – U-A:Exotic Forb

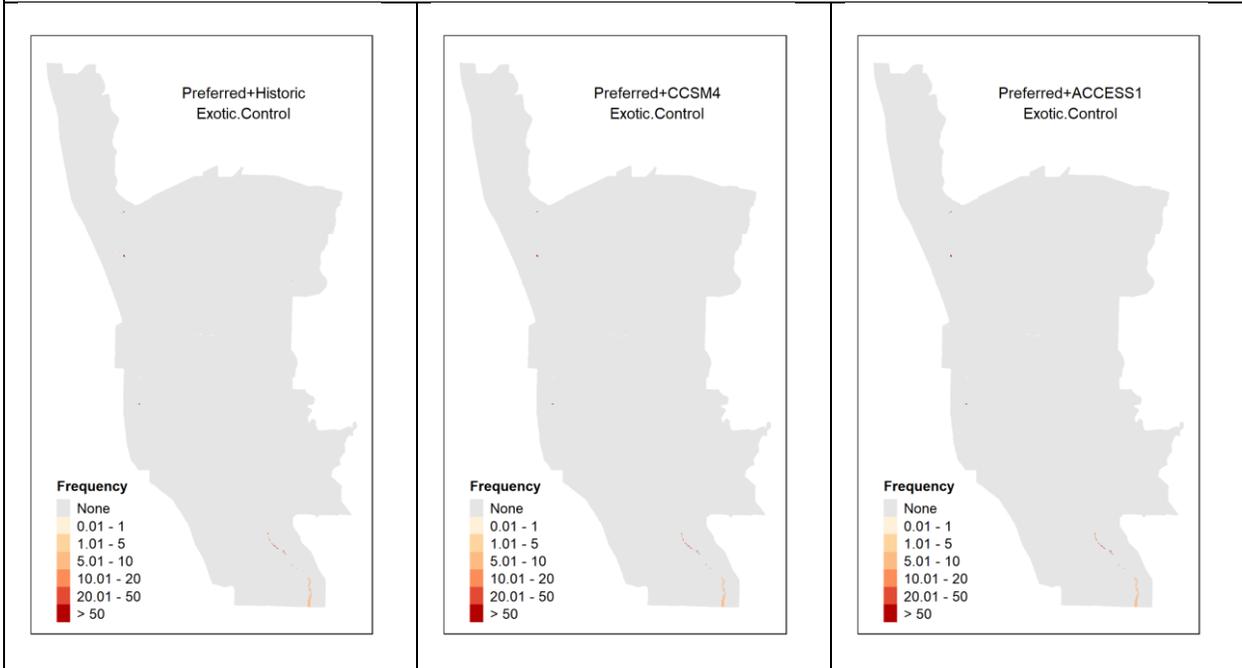


Figure 59. Exotic control in the Indian Peak-Pine Valley-Mountain Home landscape.

Treated vegetation: Black sagebrush, Montane sagebrush Steppe, Wyoming big sagebrush – U:SI-A, U:SI-A+AS, U:SI-B, U:SI-B+AS, U:SI-C, U:SI-C+AS

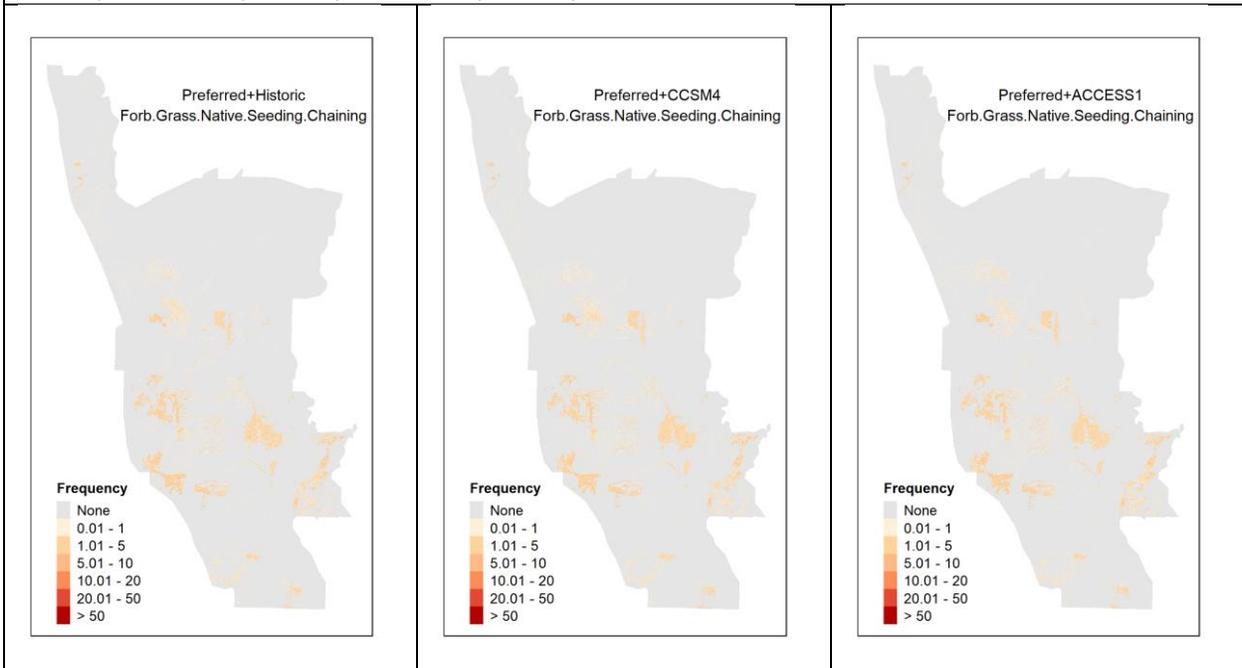


Figure 60. Forb-Grass-Native-Seeding-Chaining in the Indian Peak-Pine Valley-Mountain Home landscape.

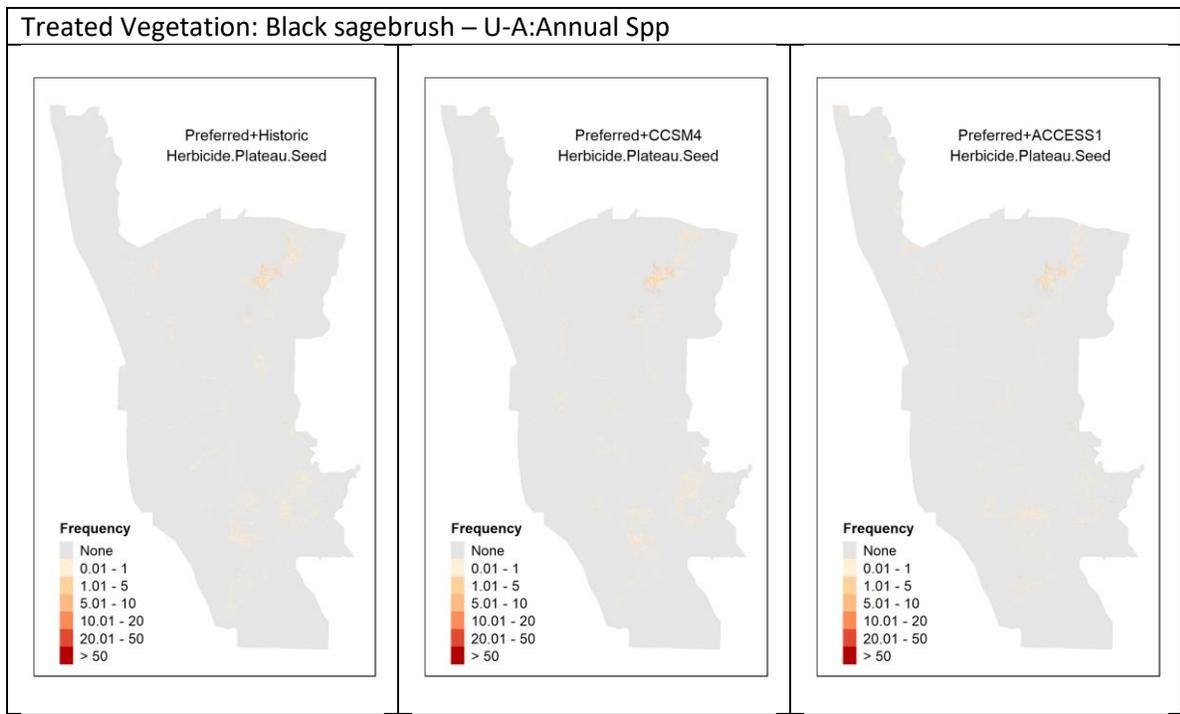


Figure 61. Herbicide+Plateau+Seed in the Indian Peak-Pine Valley-Mountain Home landscape.

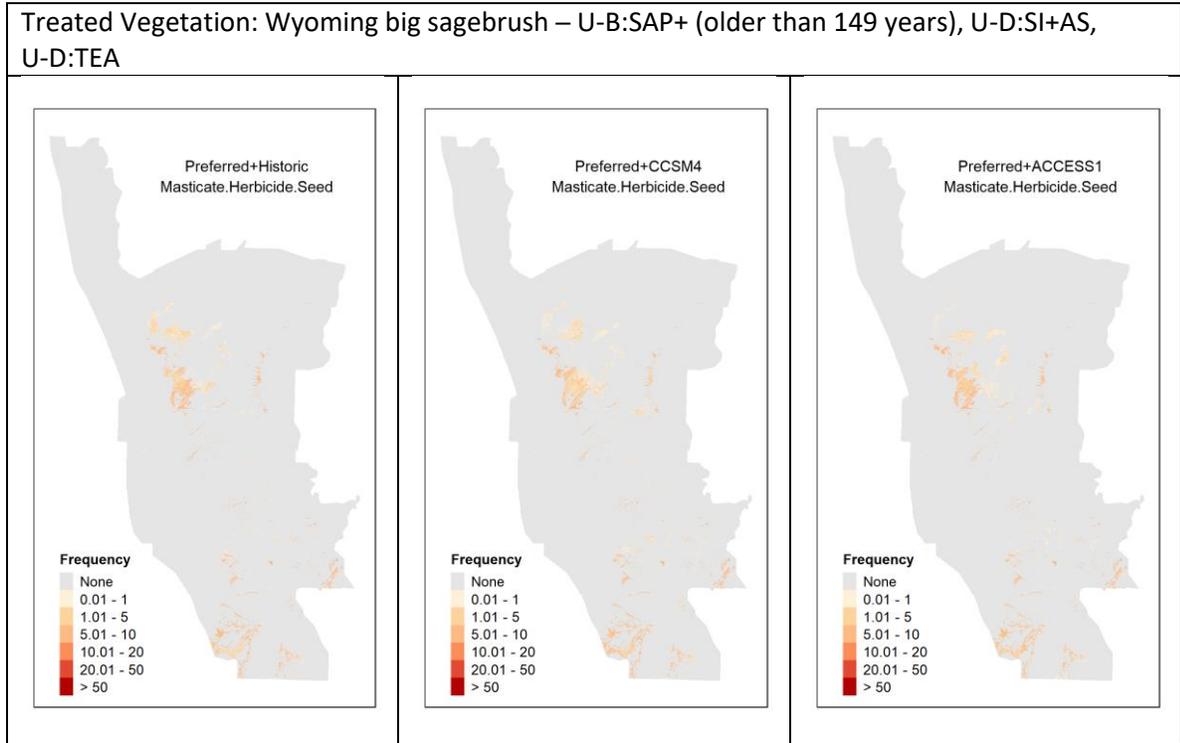


Figure 62. Masticate+Herbicide+Seed in the Indian Peak-Pine Valley-Mountain Home landscape.

Treated Vegetation: Ponderosa pine – U-B:FIC-Closed, U-B:FIC-Open, U-c:FIC-Closed, U-C:FIC-Open

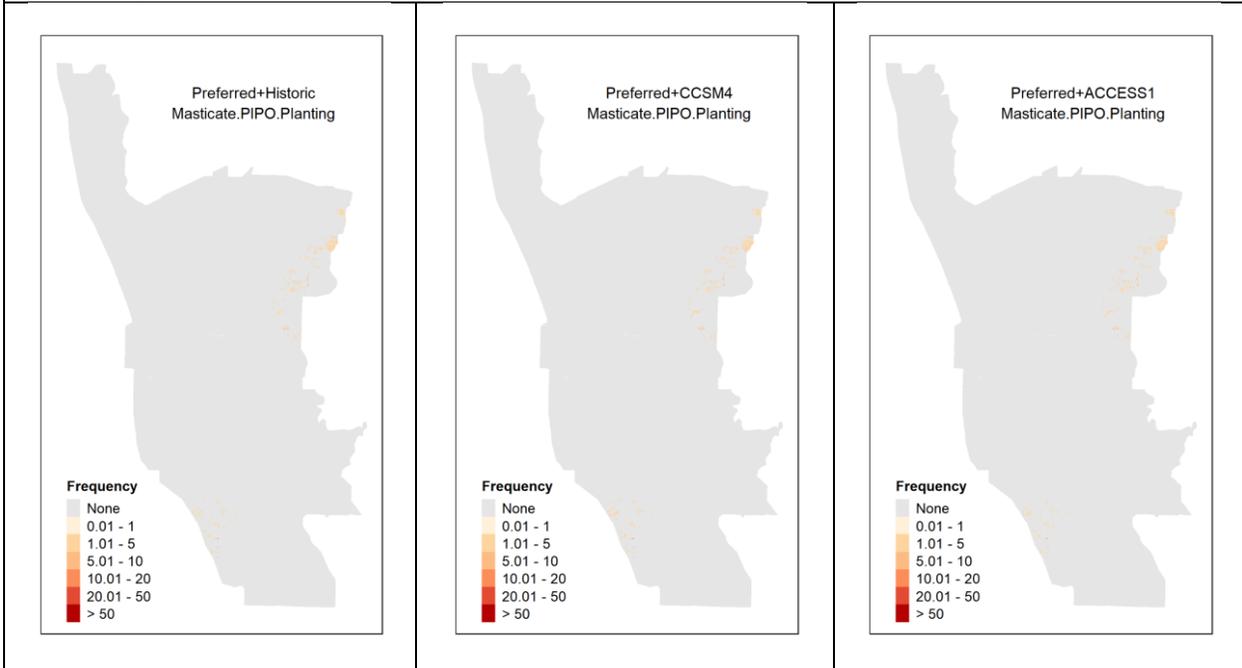


Figure 63. Masticate+PIPO-Planting in the Indian Peak-Pine Valley-Mountain Home landscape.

Treated Vegetation: Black sagebrush – U-D:SI, U-D:SI+AS, U-D:TEAU-D:TEA; Montane sagebrush steppe – U-D:SI, U-D:SI+AS, U-E:TEA

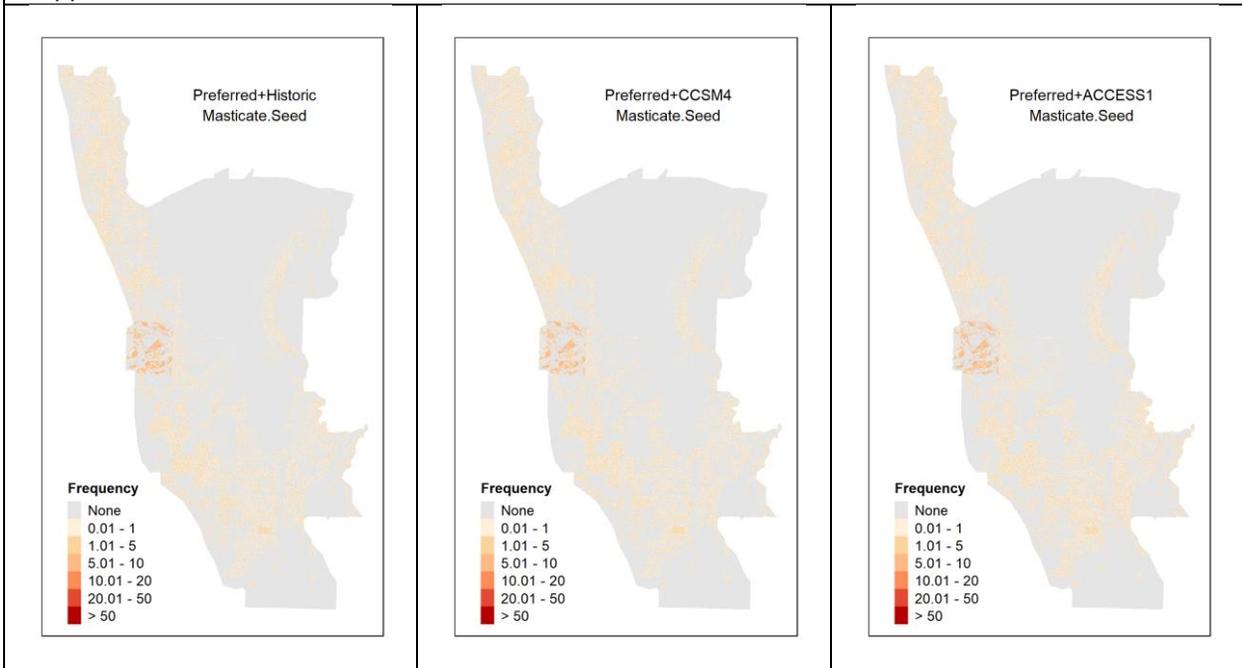


Figure 64. Masticate+Seed in the Indian Peak-Pine Valley-Mountain Home landscape.

Treated Vegetation: Aspen woodland – C:Closed, D:Open, U-D:Depleted; Utah serviceberry – D:Open; Montane sagebrush steppe – D:Open, E:Closed

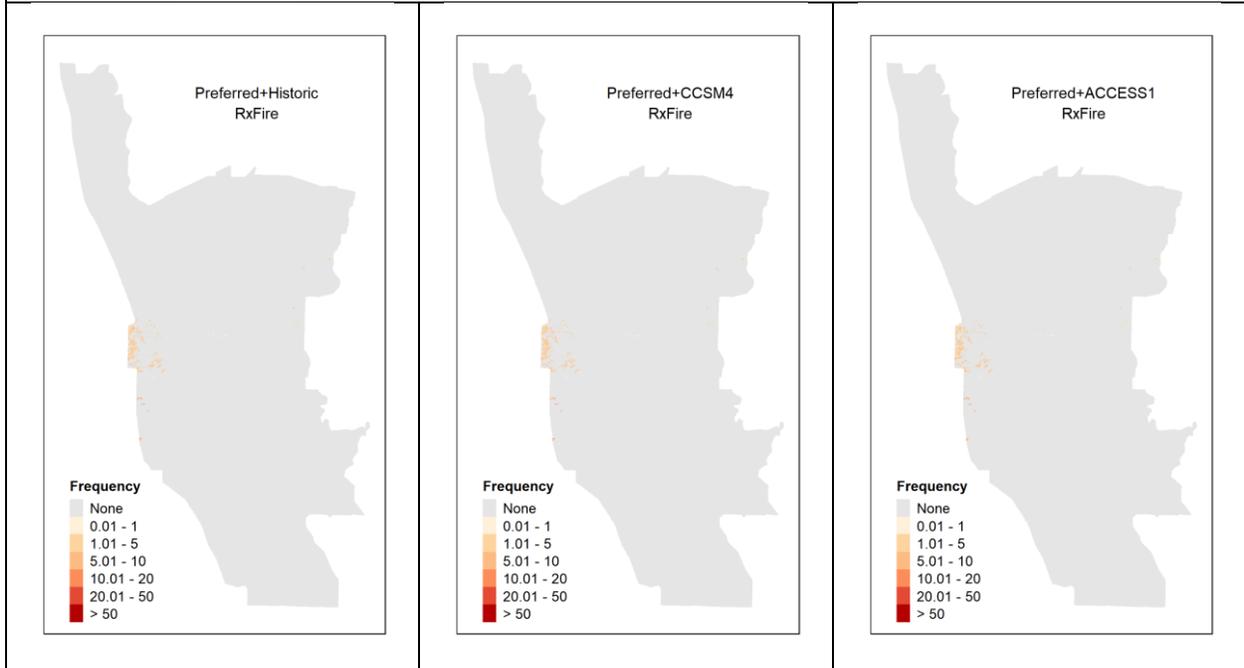


Figure 65. Prescribed fire (RxFire) in the Indian Peak-Pine Valley-Mountain Home landscape.

Treated vegetation: Black sagebrush – C:Closed, U-B:SAP+, U-C:SA+, U-C:SI, U-C:SI+AS; Low sagebrush – C:Closed, U-B:SAP, U-B:SAP+, U-C:Depleted, U-C:SA, U-C:SA+, U-C:TEA; Montane sagebrush steppe and Wyoming big sagebrush – D:Open, U-B:SAP, U-B:SAP+, U-C:Depleted, U-C:SA, U-C:SA+, U-D:SI, U-D:SI+AS; Wet meadow – U-C:TEA

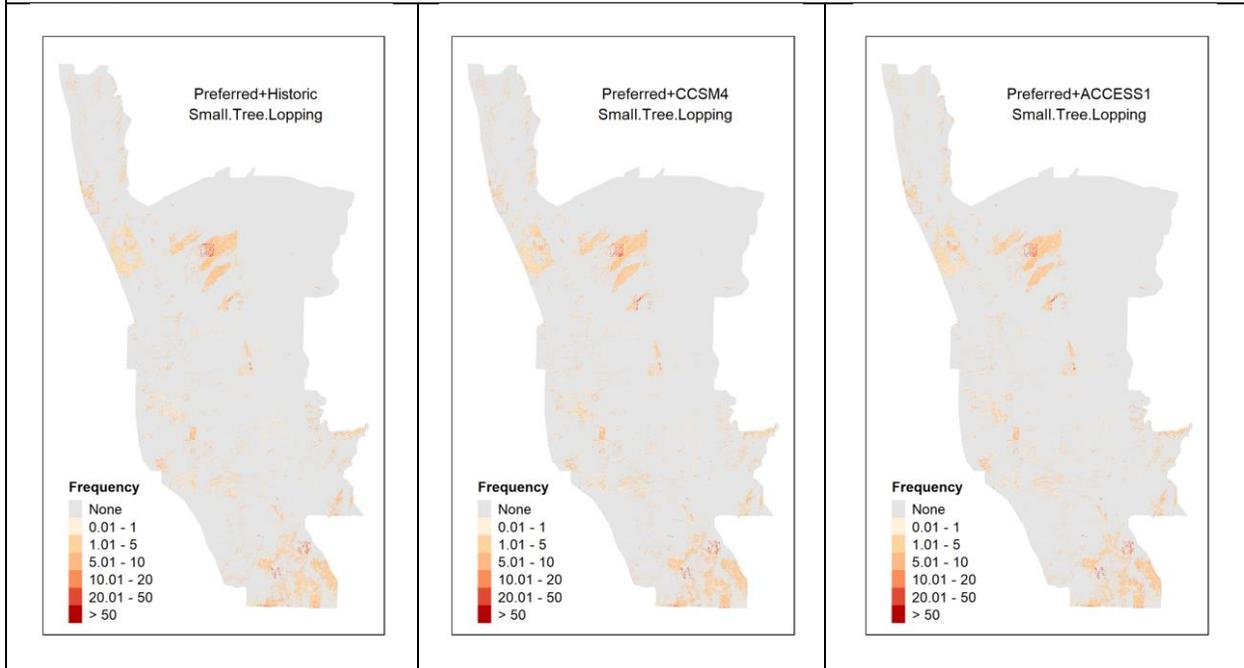


Figure 66. Small tree lopping in the Indian Peak-Pine Valley-Mountain Home landscape.

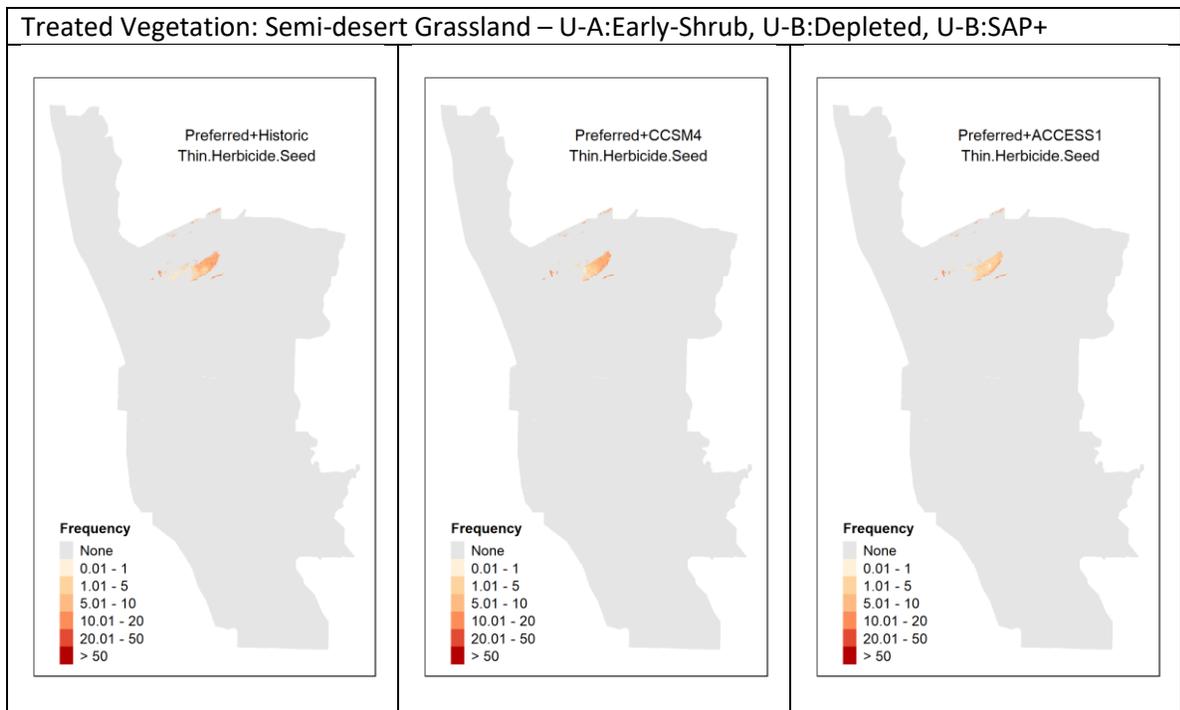


Figure 67. Thin+Herbicide+Seed in the Indian Peak-Pine Valley-Mountain Home landscape.

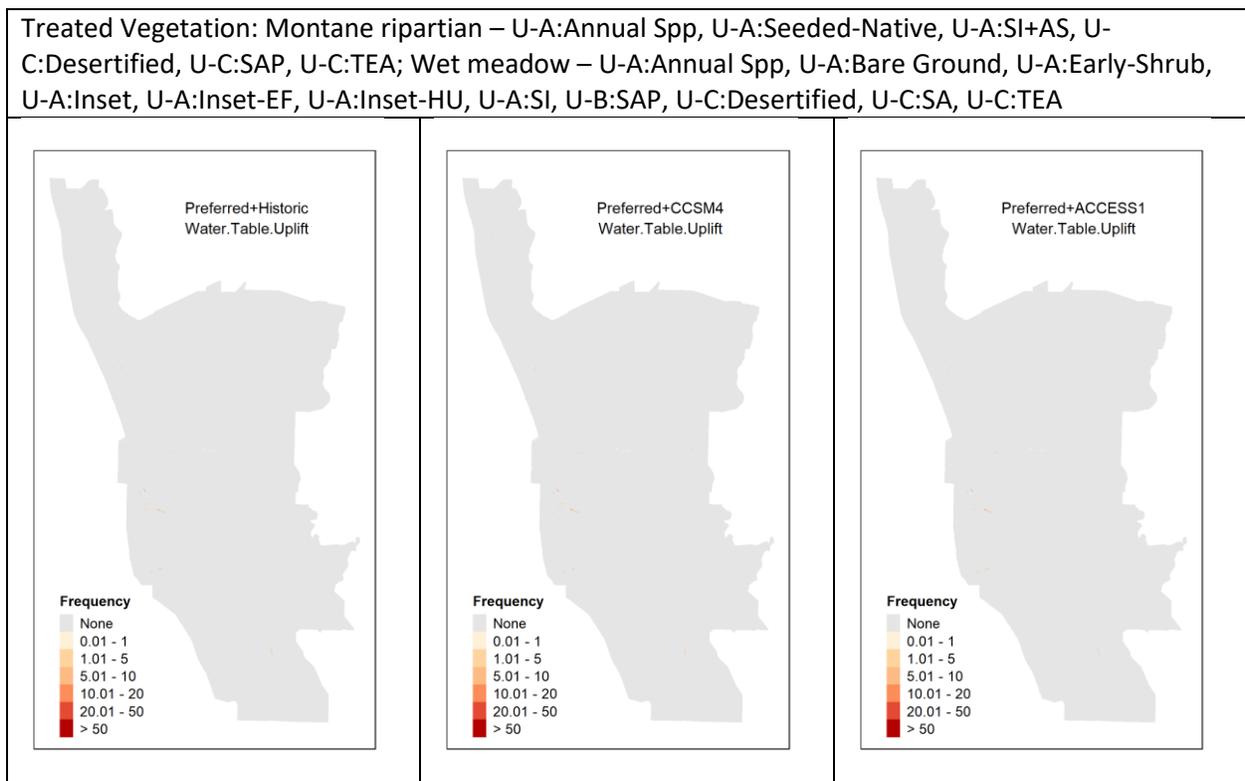


Figure 68. Water-Table-Uplift in the Indian Peak-Pine Valley-Mountain Home landscape.

Treated Vegetation: Dry meadow, montane riparian, saline Meadow, and wet meadow – all classes except U-A:EFT, U-A:EF, U-A:incised-EFT, and U-A:Inset-EFT.

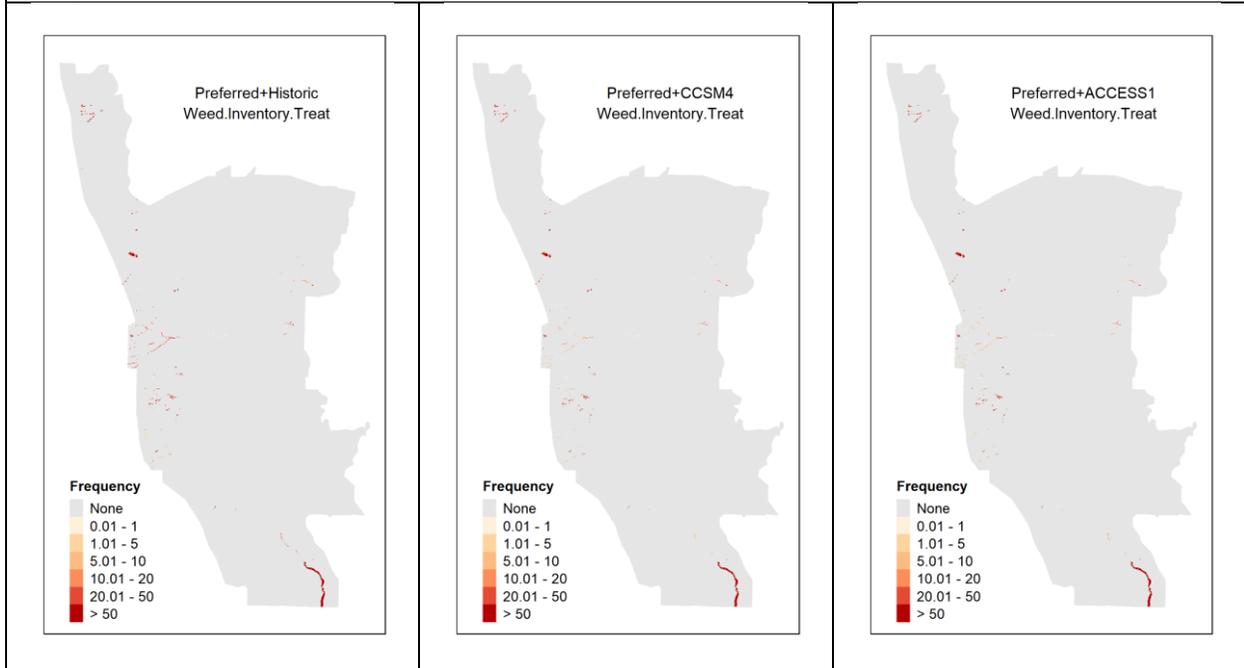


Figure 69. Weed-Inventory+Treat in the Indian Peak-Pine Valley-Mountain Home landscape.

## Total Expenditures

The greatest total expenditures over the 60-year period of simulation were made in the PREFERRED+ACCESS1 scenario (Table 33). This scenario required over \$1 million more than the other scenarios. The PREFERRED+ACCESS1 scenario was also the most expensive per time period, except during the 2035-2044 period when the PREFERRED+HISTORIC scenario was most expensive. During the 2035-2044 period, non-native annual species reached higher area in the PREFERRED+HISTORIC scenario due to more fire activity compared to other climates. Removal of conifers encroaching shrublands was the greatest cost in all scenarios, and was the primary reason for the greater expenditures in the PREFERRED+ACCESS1 scenario where tree-encroached shrublands experienced less burning.

Table 33. Total expenditures per scenario and per time period.

Scenario↓ Period→	2020-2024	2025-2034	2035-2044	2045-2077	Total
PREFERRED+HISTORIC	\$7,698,704	\$5,328,641	\$2,685,370	\$783,313	\$16,496,028
PREFERRED+CCSM4	\$7,603,484	\$5,262,563	\$2,480,045	\$789,460	\$16,135,552
PREFERRED+ACCESS1	\$7,848,052	\$6,652,197	\$2,492,285	\$820,179	\$17,812,713

## Discussions & Conclusions

Project objectives were to: (a) complete mapping of ecological systems and current vegetation classes in the Greater Indian Peak Mapping Area, (b) append the newly mapped vegetation to the Pine Valley-Mountain Home vegetation map, and (c) forecast the effects of the same six combined management and climate scenarios using state-and-transition vegetation computer simulations as in the Pine Valley-Mountain Home project for CCFO, but updated to include the IP WMA, SITLA land, private land, and additional BLM CCFO land.

### Mapping the Greater Indian Peak Project Area

About 77,000 acres of newly mapped vegetation was added to the previously mapped 232,000-acre Pine Valley-Mountain Home project area. Special effort was made to consistently map ecological systems and vegetation classes at the border of the new geography with the previously-mapped Hamlin Valley and Pine Valley-Mountain Home project areas. While the impetus for new mapping was to include the IP WMA between Pine Valley and Hamlin Valley, the added area's ownership was dominated in decreasing order by BLM, SITLA, IP WMA, and private lands. Updated map products that seamlessly stitched together the Greater Indian Peak Project and Pine Valley-Mountain Home Project areas were delivered to the UDWR and BLM in June 2020.

- A total area of 308,927 acres were mapped in the original 2017 and additional 2019 remote sensing effort.
- Lands managed by the BLM, UT Department of Natural Resources (IP WMA), private landowners, and SITLA, respectively, represented 86%, 3%, 3%, and 9% of the land area of the entire landscape.
- Of the 27 ecological systems found in the entire project area – not counting other land cover types such as barren, roads, developed, and water – the most abundant on both BLM lands and the entire landscape are (in decreasing order) black sagebrush, Wyoming big sagebrush-upland, montane sagebrush steppe, pinyon-juniper woodland, and winterfat. The ranking of ecological systems per their abundance varied on the other ownerships:
  - IP WMA: Given the higher elevations of this area, montane sagebrush steppe is the most widespread system followed by pinyon-juniper woodland, black sagebrush, and Utah serviceberry.
  - SITLA lands: The most abundant systems are (in decreasing order) black sagebrush, montane sagebrush steppe, Wyoming big sagebrush-upland, winterfat, and pinyon-juniper woodland.
  - Private lands: The most abundant systems are (in decreasing order) montane sagebrush steppe, Wyoming big sagebrush-upland, black sagebrush, pinyon-juniper woodland, Utah serviceberry, and curl-leaf mountain mahogany.
- The vegetation in the newly-mapped area was the same as in the Pine Valley-Mountain Home project area, except that dry wet meadows were prominent enough in the new geography to merit a new description and model. Dry wet meadows were found in the Pine Valley-Mountain Home area in small amounts, mostly as the outside concentric edge of wet meadows, but not as a stand-alone system. Other noteworthy observations were as follows:

- A large area of potentially ancient pinyon-juniper woodland, dominated by Utah juniper and with healthy understory, was found on shallow slopes just west of the Pine Valley Road and south of Indian Creek. This exceptional large stand deserves a dendrochronological assessment.
- Moister systems such as wet meadows, dry wet meadows, Utah serviceberry, aspen woodland, and aspen-mixed conifer were disproportionately more abundant on private lands. Montane riparian systems were disproportionately more abundant in the IP WMA, and secondly on private lands.

## Initial Conditions

### Ecological Systems

- Nineteen of 27 ecological systems (70%) were highly departed from desired future conditions based on Unified Ecological Departure in 2017 and 2019.
- Only juniper savanna and low sagebrush were lightly departed from desired future conditions.
- Systems moderately departed from desired future conditions were curl-leaf mountain mahogany, little-leaf mountain mahogany, mixed conifer, pinyon-juniper woodland, ponderosa pine and Stansbury cliffrose.
- The following thirteen focal systems were selected for management: aspen woodland, black sagebrush, calcareous grassland, dry wet meadow, montane riparian, montane sagebrush steppe, pinyon-juniper woodland, ponderosa pine, semi-desert grassland, Stansbury cliffrose, Utah serviceberry, wet meadow-montane, and Wyoming big sagebrush upland. While all thirteen focal systems were simulated, in this report we did not report on four of them: calcareous grassland, pinyon-juniper woodland, semi-desert grassland, and Stansbury cliffrose. Management actions for these four systems did not change from the previous report, because they: (1) were only or mostly found in the original Pine Valley-Mountain Home project area, and treatment rates did not change (calcareous grassland, semi-desert grassland); (2) had very small area (Stansbury cliffrose); or (3) involved low implementation rates to achieve a very specific goal (pinyon-juniper woodland).
- Among the focal management systems, three were moderately departed from desired future conditions (pinyon-juniper woodland, ponderosa pine and Stansbury cliffrose), while the remainder were highly departed from desired future conditions.

### Greater Sage-grouse Habitat Suitability Index

- The average habitat suitability index (HSI) for greater sage-grouse, calculated for the entire landscape where habitat could be present, was 29.96% based on the 2017 and 2019 interpreted imagery.
- The most widespread area of higher suitability was in the north-central part of the landscape, south of the northern-most expanses of winterfat and mixed salt desert scrub.
- Compared to HSI estimates in 2017 for the Pine Valley-Mountain Home project (Provencher et al. 2019), the additional land mapped in 2019 expanded the footprint of suitable habitat toward the west (i.e., toward the IP WMA), and improved habitat in the previously mapped

project area due to the beneficial influence of distance effects (for example, a wet meadow just on the unmapped side of the original project's boundary).

- The IP WMA itself contained moderately suitable habitat, which extended to the south and south-east within a few miles north of the Jackson Wash Road.
- An interesting aspect of the patchwork of more to less suitable habitat is the potential of connecting the central Pine Valley to the IP WMA through two primary corridors of moderately suitable habitat, which could be restored to better condition. One corridor loosely follows the main east-west road into the IP WMA from the Pine Valley Road, and the other corridor parallels to the north the Cougar Spar Road from the western project boundary to the Pine Valley Road. Land managers are well aware that the west slope below the IP WMA could one day be a connectivity corridor for sage-grouse to the Hamlin Valley population (Provencher et al. 2018).

## Management Results

### Expenditures

- The total 60-year budgets of PREFERRED MANAGEMENT scenarios ranged from \$16 million to \$17.8 million among the three climates, with about \$12 million spent before year 2035 as specified by land managers. Total cost increased with lower fire activity, because conifers encroaching into shrublands that were not removed by fire required mechanical tree removal for restoration, which was the most expensive activity in shrublands. The least fire activity was in all ACCESS1 climate scenarios.
- The greatest cost after year 2035 was for actions to convert non-native annual species dominated classes to seedlings of native species or mixed native and introduced species. The area dominated by non-native annual species was initially small in the landscape, but steadily increased with cumulative fires. The management scenarios incorporating the ACCESS1 climate produced the least area of the non-native annual species dominated class.
- Due to budget ceilings, many treatable areas were not treated. Doubling the BLM's budget, for example, resulted in its complete spending, i.e., no saturation of implementation rates. This effect was more pronounced on BLM lands and least pronounced in the IP WMA.
- Three systems accounted for 82% of total costs: black sagebrush for \$4 million to \$5.5 million, montane sagebrush steppe for about \$5.2 million, and Wyoming big sagebrush for \$4.4 million. By subtraction, nine other important systems with high wildlife value could be treated for \$3 million over 60 years.

### Ecological Systems

- Sixty years of simulations with additional active management (three PREFERRED MANAGEMENT scenarios) decreased the departure from reference conditions (lowered UED) in all ecological systems compared to simulations without additional management beyond the baseline (MINIMUM MANAGEMENT scenarios), except for montane sagebrush steppe and Wyoming big sagebrush.
- Management actions did not decrease the UED for montane sagebrush steppe and Wyoming big sagebrush from 100% departure, because extensive seedlings of mixed native and introduced species, which are uncharacteristic vegetation classes used by greater sage-grouse as they mature, replaced other uncharacteristic classes, such as non-native annual

species grassland and tree-encroached shrublands. As explained in Provencher et al. (2019), only the extensive use of pure native species mixtures in seedings can substantially lower UED as seedings mature.

#### Greater Sage-grouse

- Without management actions (three MINIMUM MANAGEMENT scenarios), sage-grouse habitat degraded from 2017 to 2077 (Habitat Suitability Index decreased). Habitat degradation was least in the MINIMUM+ACCESS1 scenario because less fire was simulated, whereas the MINIMUM+HISTORIC and MINIMUM+CCSM4 scenarios achieved the same habitat conditions under greater fire activity.
- All PREFERRED MANAGEMENT scenarios significantly increased the Habitat Suitability Index of sage-grouse. Habitat improvements were significantly greater with the lesser fire activity of the PREFERRED+ACCESS1 scenario, whereas the PREFERRED+HISTORIC and PREFERRED+CCSM4 scenarios were statistically similar.
- The most suitable areas for sage-grouse were (1) in the northern half of the landscape approximately extending from the IP WMA to the northeast, in a SW-NE oriented swath; and (2) in the southeastern part of the landscape, east of Pine Valley Road and south of Jockey Road.
- Many areas of habitat suitability in future years (i.e., after 2047) were matured seedings of mixed native and introduced species that generally had longer fire return intervals that escaped large fires or had time to undergo woody succession. Spatial differences among climates for PREFERRED MANAGEMENT scenarios generally resulted in more widespread and larger habitat improvements in these zones, although small habitat improvements were also observed in other areas farther away from the Pine Valley lek.
- Small changes in the absolute value of sage-grouse Habitat Suitability Index after implementation of management actions, such as from 26% to 29%, translated to marked spatial differences.

#### Unified Ecological Departure or Sage-grouse Habitat Suitability Index?

Unified Ecological Departure and sage-grouse Habitat Suitability Index are different metrics. Ecological departure is non-spatial and is estimated per ecological system (Low et al. 2010), whereas Habitat Suitability Index is spatial and estimated for whole landscapes (Boyce and McDonald 1999). Managers may use both metrics to justify management actions. However, standard practices of vegetation management invariably focus on prescriptions tailored to each ecological system's soil potential (Monsen et al. 2004; Provencher et al. 2013) that may be better matched to ecological departure assessments. The choice of management objectives, therefore, needs to be explicit about prioritizing actions for ecological systems relative to benefits for special single species such as sage-grouse.

UED may have limited value to measure ecological improvement for sagebrush-dominated systems at lower elevations, and sometimes higher elevations, where sage-grouse spend a considerable portion of their life cycles. High UED values might encourage some managers to treat vegetation classes that contribute most to departure with the expectation that UED will decrease over time in treated areas. This expectation is not met at lower elevations because restoration often creates uncharacteristic vegetation classes, where non-native annual

grasslands and tree-encroached shrublands are replaced with mixed introduced and native species seedings. These large seedings contribute to departure as would any other uncharacteristic classes, even discounting the allowable percentage threshold for no-penalty departure specific to seedings. Higher-elevation systems and lower-elevation moist systems will be more likely to show UED reductions with treatments because they already contain reference classes, and pure native species mixtures can be seeded at higher elevations (Monsen et al. 2004). Native species seedings also become undistinguishable from reference classes over time.

While UED was not consistently responsive to large amounts of restoration, Habitat Suitability Index responded to the effects of treatments and climate. Despite million-dollar investments in restoration, significant differences in the Habitat Suitability Index between MINIMUM and PREFERRED MANAGEMENT scenarios rarely exceeded 3% in absolute value (i.e., 29%-26%). This was expected because resource selection functions incorporate important physical characteristics of the landscape that do not change at all, such as distance to roads, leks, and moist summer vegetation for chick rearing (Gibson et al. 2016; Kane et al. 2017). Therefore, absolute values of 2%-3% change in habitat suitability might represent a sizable improvement to sage-grouse demography. The increase of Habitat Suitability Index might also mirror reduction in UED (smaller values are better) for multiple systems, if the focal species such as greater sage-grouse requires a diversity of habitat resources, (USFWS 2013).

#### Land Management and Climate Timing

Provencher et al. (2019) discussed that future climate might force the hand of managers by prioritizing early-future restoration over late-future restoration, because results showed that seedings failed more often when increasingly frequent droughts coincided with seeding years. This was especially dire if the ACCESS1 climate was predicted as a likely future. In this report, the conclusion of erring towards early-future restoration did not change, although the unequal seeding levels among climates prevented an apple-to-apple comparison. For the HISTORIC and CCSM4 climates, which had comparable seeding rates, differences in the A:SI class areas in black sagebrush increased with years up to about 2,000 acres more in the HISTORIC than CCSM4 climates. In other words, seeding earlier is easier and cheaper.

#### Implementation Rates

Implementation rates that likely reflect a future climate were presented in Provencher et al. (2019) for the CCSM4 climate, as a compromise between the current (HISTORIC) climate and the worse-case (ACCESS1) climate. Results in that earlier report were restricted to BLM lands, so that report contained only one summary table of implementation rates and costs. However, four different land ownerships were simulated in this IP-PV-MH project, so four tables of rates and costs under the CCSM4 climate are presented here (Tables 34-37).

**Table 34. Summary of realized implementation rates and costs of management actions in focal ecological systems on IP WMA-managed lands during four time periods under the PREFERRED+CCSM4 scenario.**

Ecological System Treatment or Management Action	Cost/Acre	Sum of Acres/Interval (Avg of 10 runs)				60-Year Total Cost
		2020-2024	2025-2034	2035-2044	2045-2077	
<b>Black Sagebrush</b>						
Chainsaw-Thinning	\$112.50	1.9	0.0	0.0	0.0	
Masticate+ Seed	\$577.50	119.8	192.4	45.3	74.1	
Small-Tree-Lopping	\$150.00	33.8	0.0	0.0	0.0	
Cost →		\$63,714	\$111,120	\$26,187	\$42,781	\$243,803
<b>Montane Riparian</b>						
Chainsaw-Thinning	\$1500.00	0.0	7.2	0.0	0.0	
Exotic-Control	\$360.00	0.0	0.0	0.0	1.8	
Water-Table-Uplift	\$500.00	0.2	0.0	0.0	0.0	
Weed-Inventory+ Treat	\$253.00	5.0	13.9	14.2	43.8	
Cost →		\$1,377	\$4,602	\$3,596	\$11,746	\$21,322
<b>Montane Sagebrush Steppe</b>						
Masticate+ Seed	\$577.50	1774.1	21.4	20.3	40.7	
RxFire	\$100.00	251.6	0.0	0.0	0.0	
Small-Tree-Lopping	\$150.00	196.8	0.0	0.0	0.0	
Cost →		\$1,079,224	\$12,368	\$11,726	\$23,516	\$1,126,835
<b>Utah Serviceberry</b>						
Chainsaw-Thinning	\$112.50	38.9	0.0	0.0	0.0	
Masticate+ Seed	\$577.50	32.7	0.0	0.0	0.0	
RxFire	\$100.00	249.5	0.0	0.0	0.0	
Cost →		\$48,209	\$0	\$0	\$0	\$48,209
<b>Wet Meadow-montane</b>						
Exotic-Control	\$360.00	0.0	0.0	0.0	0.1	
Small-Tree-Lopping	\$500.00	0.4	0.0	0.0	0.0	
Weed-Inventory+ Treat	\$253.00	0.0	11.0	9.2	30.6	
Cost →		\$50	\$2,774	\$2,318	\$7,774	\$12,916

**Table 35. Summary of realized implementation rates and costs of management actions in focal ecological systems on BLM-managed lands during four time periods under the PREFERRED+CCSM4 scenario.**

Ecological System Treatment or Management Action	Cost/Acre	Sum of Acres/Interval (Avg of 10 runs)				60-Year Total Cost
		2020-2024	2025-2034	2035-2044	2045-2077	
<b>Aspen Woodland</b>						
Chainsaw-Thinning	\$112.50	7.7	0.0	0.0	0.0	
Fence	\$10,000.00	43.5	0.0	0.0	0.0	
RxFire	\$300.00	68.4	0.0	0.0	0.0	
Cost →		\$486,455	\$0	\$0	\$0	\$486,455
<b>Black Sagebrush</b>						
2xChaining+ Seed	\$202.50	3693.0	0.0	0.0	0.0	
Chaining+ Plateau+Seed	\$160.00	2170.6	0.0	0.0	0.0	
Chainsaw-Thinning	\$112.50	1265.0	0.0	0.0	0.0	
Forb+Grass-Native-Seeding+ Chaining	\$160.00	249.8	0.0	0.0	0.0	
Herbicide-Plateau+Seed	\$117.50	1249.9	0.0	0.0	0.0	
Masticate+ Seed	\$577.50	1761.8	1756.3	0.0	0.0	
Cost →		\$2,441,694	\$1,014,285	\$0	\$0	\$3,455,979
<b>Dry Wet Meadow</b>						
Exotic-Control	\$360.0	0.0	0.1	0.3	1.9	
Thin	\$150.00	0.0	0.0	4.5	0.0	
Weed-Inventory+ Treat	\$253.00	25.6	50.7	47.9	167.6	
Cost →		\$6,471	\$12,858	\$12,915	\$43,082	\$75,326
<b>Montane Riparian</b>						
Exotic-Control	\$360.00	0.0	0.0	0.2	2.3	
Water-Table-Uplift	\$500.00	0.0	9.0	0.4	0.0	
Weed-Inventory+Treat	\$253.00	24.7	43.7	44.5	150.6	
Cost →		\$6,246	\$15,549	\$11,533	\$38,909	\$72,236
<b>Montane Sagebrush Steppe</b>						
Chaining+ Native-Seed	\$205.00	0.0	1634.7	1635.0	0.0	
Forb+Grass-Native-Seeding+ Chaining	\$160.00	0.0	1995.2	994.7	0.0	
Masticate+ Seed	\$577.50	0.0	1489.8	2258.0	0.0	
Small-Tree-Lopping	\$150.00	0.0	1693.6	1640.4	345.5	
Cost →		\$0	\$1,768,778	\$2,044,398	\$51,820	\$3,864,996
<b>Pinyon-Juniper Woodland</b>						
Chainsaw-Thinning	\$150.00	787.5	0.0	0.0	0.0	
Masticate+Native-Seed	\$617.50	0.0	403.2	0.0	0.0	
Cost →		\$118,118	\$249,004	\$0	\$0	\$367,122
<b>Ponderosa Pine</b>						
Chainsaw-Thinning	250.00	0.0	0.0	42.3	39.9	
Masticate+PIPO-Planting	1,100.00	0.0	0.0	401.2	0.0	
Cost →		\$0	\$451,908	\$9,974	\$25,064	\$486,946
<b>Semi-Desert Grassland</b>						
Thin+Herbicide+Seed	\$115.00	0.0	1308.5	70.8	0.0	
Cost →		\$0	\$150,480	\$8,143	\$0	\$158,624

**Table 35. Summary of realized implementation rates and costs of management actions in focal ecological systems on BLM-managed lands during four time periods under the PREFERRED+CCSM4 scenario.**

Ecological System Treatment or Management Action	Cost/Acre	Sum of Acres/Interval (Avg of 10 runs)				60-Year Total Cost
		2020-2024	2025-2034	2035-2044	2045-2077	
<b>Stansbury Cliffrose</b>						
Chainsaw-Thinning	\$112.50	0.0	11.3	0.0	0.0	
Cost →		\$0	\$1,268	\$0	\$0	\$1,268
<b>Utah Serviceberry</b>						
Chainsaw-Thinning	\$112.50	0.0	244.7	0.0	0.0	
Cost →		\$0	\$27,534	\$0	\$0	\$27,534
<b>Wet Meadow-montane</b>						
Exotic-Control	\$360.00	8.6	4.4	20.7	103.0	
Fence	\$2,200.00	40.9	26.2	0.0	0.0	
Water-Table-Uplift	\$500.00	80.7	149.8	148.4	570.0	
Weed-Inventory+ Treat	\$253.00	8.6	4.4	20.7	103.0	
Cost →		\$113,388	\$114,030	\$44,984	\$187,343	\$459,745
<b>Wyoming Big Sagebrush- upland</b>						
Chaining+ Native-Seed	\$205.00	558.4	0.0	0.0	0.0	
Chaining+ Plateau+ Seed	\$192.50	1674.7	0.0	0.0	0.0	
Chaining+ Seed	\$165.00	1980.3	0.0	0.0	0.0	
Forb+ Grass-Native-Seeding+ Chaining	\$160.00	2488.9	0.0	0.0	0.0	
Masticate+ Herbicide+ Seed	\$605.00	2496.2	1698.0	0.0	0.0	
Small-Tree-Lopping	\$150.00	2506.5	1003.7	1001.3	1907.3	
Cost →		\$2,860,004	\$1,102,583	\$75,097	\$143,049	\$4,180,732

**Table 36. Summary of realized implementation rates and costs of management actions in focal ecological systems on private lands during four time periods under the PREFERRED+CCSM4 scenario.**

Ecological System Treatment or Management Action	Cost/Acre	Sum of Acres/Interval (Avg of 10 runs)				60-Year Total Cost
		2020-2024	2025-2034	2035-2044	2045-2077	
<b>Aspen Woodland</b>						
Chainsaw-Thinning	\$112.50	0.0	1.6	0.0	0.0	
Cost →		\$0	\$175	\$0	\$0	\$175
<b>Black Sagebrush</b>						
Chainsaw-Thinning	\$112.50	5.4	0.0	0.0	0.0	
Masticate+ Seed	\$577.50	125.8	0.0	0.0	0.0	
Cost →		\$73,265	\$0	\$0	\$0	\$73,265
<b>Montane Riparian</b>						
Exotic-Control	\$360.00	3.0	3.5	7.3	18.3	
Weed-Inventory+Treat	\$253.00	0.8	2.2	2.5	6.4	
Cost →		\$1,283	\$1,806	\$3,283	\$8,194	\$14,566
<b>Montane Sagebrush Steppe</b>						
Masticate+ Seed	\$577.50	0.0	100.0	0.0	0.0	
Small-Tree-Lopping	\$150.00	0.0	145.5	71.1	16.4	
Cost →		\$0	\$79,574	\$10,658	\$2,462	\$92,694
<b>Ponderosa Pine</b>						
Masticate+PIPO-Planting	1,100.00	0.0	47.6	0.0	0.0	
Cost →		\$0	\$52,401	\$0	\$0	\$52,401
<b>Utah Serviceberry</b>						
Chainsaw-Thinning	\$112.50	0.0	66.2	0.0	0.0	
Cost →		\$0	\$7,443	\$0	\$0	\$7,443
<b>Wet Meadow-montane</b>						
Exotic-Control	\$360.00	10.3	11.6	33.9	121.7	
Fence	\$2,200.00	0.0	10.7	9.5	0.0	
Small-Tree-Lopping	\$112.50	0.2	0.0	0.0	0.0	
Water-Table-Uplift	\$500.00	10.8	11.1	15.8	59.0	
Weed-Inventory+ Treat	\$253.00	10.0	10.2	15.4	68.3	
Cost →		\$6,471	\$33,880	\$41,893	\$58,753	\$140,998
<b>Wyoming Big Sagebrush-upland</b>						
Masticate+ Herbicide+ Seed	\$605.00	57.2	0.0	0.0	0.0	
Small-Tree-Lopping	\$150.00	24.5	0.0	99.5	100.0	
Cost →		\$36,468	\$0	\$7,466	\$7,502	\$51,436

**Table 37. Summary of realized implementation rates and costs of management actions in focal ecological systems on SITLA-managed lands during four time periods under the PREFERRED+CCSM4 scenario.**

Ecological System Treatment or Management Action	Cost/Acre	Sum of Acres/Interval (Avg of 10 runs)				60-Year Total Cost
		2020-2024	2025-2034	2035-2044	2045-2077	
<b>Aspen Woodland</b>						
Chainsaw-Thinning	\$112.50	1.6	0.0	0.0	0.0	
Cost →		\$180	\$0	\$0	\$0	\$180
<b>Black Sagebrush</b>						
2xChaining+ Seed	\$202.50	142.0	0.0	0.0	0.0	
Chaining+ Native-Seed	\$205.00	326.0	0.0	280.7	0.0	
Chainsaw-Thinning	\$112.50	280.1	0.0	0.0	0.0	
Masticate+ Seed	\$577.50	250.3	0.0	0.0	0.0	
Small-Tree-Lopping	\$150.00	142.0	0.0	0.0	0.0	
Cost →		\$264,737	\$0	\$57,941	\$0	\$322,679
<b>Dry Wet Meadow</b>						
Thin	\$150.00	0.0	0.0	1.5	0.0	
Weed-Inventory+ Treat	\$253.00	12.5	19.1	18.6	61.8	
Cost →		\$3,151	\$4,839	\$4,933	\$15,625	\$28,548
<b>Montane Riparian</b>						
Exotic-Control	\$360.00	0.0	0.0	0.1	2.3	
Water-Table-Uplift	\$500.00	0.0	2.8	0.0	0.0	
Cost →		\$0	\$1,401	\$32	\$825	\$2,258
<b>Montane Sagebrush Steppe</b>						
Chaining+ Native-Seed	\$205.00	0.0	0.0	137.4	0.0	
Masticate+ Seed	\$577.50	0.0	0.0	50.1	0.0	
Small-Tree-Lopping	\$150.00	0.0	310.7	14.5	0.0	
Cost →		\$0	\$46,603	\$59,260	\$0	\$105,863
<b>Ponderosa Pine</b>						
Masticate+PIPO-Planting	1,100.00	0.0	26.6	0.0	0.0	
Cost →		\$0	\$25,735	\$0	\$0	\$25,735
<b>Utah Serviceberry</b>						
Chainsaw-Thinning	\$112.50	0.0	12.0	0.0	0.0	
Cost →		\$0	\$1,351	\$0	\$0	\$1,351
<b>Wet Meadow-montane</b>						
Water-Table-Uplift	\$500.00	0.0	0.0	0.2	1.8	
Weed-Inventory+ Treat	\$253.00	3.2	6.8	6.9	28.6	
Cost →		\$818	\$4,832	\$3,284	\$7,889	\$16,824
<b>Wyoming Big Sagebrush-upland</b>						
Chaining+ Native-Seed	\$205.00	228.2	0.0	0.0	0.0	
Chaining+ Plateau+ Seed	\$192.50	87.2	0.0	0.0	0.0	
Chaining+ Seed	\$165.00	24.9	0.0	0.0	0.0	
Masticate+ Herbicide+ Seed	\$605.00	0.0	0.0	0.0	0.0	
Small-Tree-Lopping	\$150.00	188.3	0.0	0.0	0.0	
Cost →		\$200,625	\$22,606	\$11,339	\$49,320	\$283,890

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