Section III. Assessments of Communities

Chapter 11. Sagebrush Steppe

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Key Ecological Attributes

Distribution and Ecology

Sagebrush steppe is part of a vast semiarid desert system that extends north from northern Arizona and New Mexico to British Columbia and Saskatchewan, and from the eastern foothills of the Sierra Nevada and Cascade mountains to western North Dakota (Miller and others, 2011). It has been estimated that nearly half of the historical sagebrush shrublands may have been lost since Euro-American settlement (Miller and others, 2011). The Wyoming Basin, where sagebrush steppe is the dominant land cover, encompasses some of the most intact, contiguous expanses of the remaining sagebrush steppe.

In the Wyoming Basin, sagebrush steppe is dominated by two subspecies of big sagebrush: basin big sagebrush and Wyoming big sagebrush, which typically occur between elevations of 914 and 1,524 meters (m) (3,000 and 5,000 feet [ft], respectively) (Knight, 1994; Beetle and Johnson, 1982). A third subspecies, mountain big sagebrush, which typically occurs at higher elevations, is discussed in Chapter 13—Foothill Shrublands and Woodlands of this Rapid Ecoregional Assessment (REA). Basin big sagebrush is generally restricted to deep, fertile, and well-drained soils in valley bottoms and moist ravines, particularly in the Bighorn Basin and Wind River drainages and in the southwestern part of the ecoregion (Beetle and Johnson, 1982; Knight, 1994; Miller and others, 2011). Wyoming big sagebrush is more widespread in the Wyoming Basin, especially in warmer and drier upland settings (Knight, 1994). Other common shrub species include silver, black, and low sagebrush and rabbitbrush. Grasses, especially bunchgrasses, and forbs occur as an understory and in openings between shrubs (Knight, 1994).

Snow, which is the primary form of precipitation in the Wyoming Basin, exerts a strong influence on the distribution of sagebrush species (Knight, 1994). Soil moisture is generally greatest in the spring during snowmelt, and it generally decreases in mid-to-late summer to levels that can lead to plant stress and dormancy (Schlaepfer and others, 2012a). Sagebrush root systems extend as much as 1.9 m (6 ft) deep, thereby allowing access to more persistent soil moisture at lower depths (Schlaepfer and others, 2012a). Big sagebrush reproduces solely from seed, and although mature plants can tolerate summer drought, successful seedling establishment is generally believed to require below average temperatures and above average moisture early in the summer (Knight, 1994). Sagebrush seeds lack morphological characteristics that promote dispersal; thus, most seeds fall within 1 meter (3 ft) of the parent plant, although they can be blown considerable distances (Jacobs and others, 2011).

Landscape Structure and Dynamics

Sagebrush steppe, grasslands, and desert shrublands, which include saltbush and greasewood, can form heterogeneous mosaics in the Basin (Knight, 1994). The relative dominance of the various vegetation types depends on differences in precipitation, temperature, soils, topography, and past disturbance; historically this included fire and grazing by American bison and other large ungulates (Mack and Thompson, 1982; Miller and others, 2011). Big sagebrush is less tolerant of saturated or high-salinity soils than desert shrubland species, which can be dominant in those soil conditions (Knight, 1994; see Chapter 12─Desert Shrublands). Basin grasslands may become established immediately after fire in sagebrush steppe but also may occur locally where water is more limiting (Knight, 1994). Mixed grass and shortgrass prairies, which are common east of the Wyoming Basin, mostly fall within the project area buffer around the eastern ecoregion boundary.

Snowfall is typically greater west of the Continental Divide, which promotes large, high-density patches of sagebrush. East of the Divide, where snowfall is less reliable, sagebrush tends to be more sparse and patchy (Knight, 1994), and Wyoming big sagebrush sometimes forms small, isolated patches that are approximately 15 m (49.2 ft) across and taller and denser than the surrounding sagebrush. One hypothesis to explain this patch structure is that silt or sand accumulate on the lee side of taller shrubs, which also helps to accumulate snow. The favorable soil and moisture conditions subsequently promote increased establishment and growth of sagebrush in adjacent areas otherwise not conducive to Wyoming big sagebrush (Knight, 1994). The activities of burrowing small mammals, such as pygmy rabbits, can also create conditions favorable for the establishment of sagebrush in otherwise unsuitable contexts (Rowland and Leu, 2011).

Historically, sagebrush steppe frequently occurred in complex mosaics composed of stands in various successional stages resulting from natural disturbances, such as fire, drought, and insect outbreaks (Baker, 2011). Postfire recovery can take many decades because big sagebrush cannot resprout after burning and requires a local seed source for recolonization of burned patches. Because big sagebrush seeds generally do not disperse far and postfire survivorship is low, recovery rates of large burned areas can exceed 75 years, although recovery rates are highly variable (Baker, 2011).

Historical fire regimes and the effects of fire on landscape structure and dynamics of sagebrush steppe are poorly understood (Miller and others, 2011; Bukowski and Baker, 2013). Recent evidence suggests, however, that fire occurrence may have been less frequent and more variable spatially and temporally than commonly assumed (Miller and others, 2011). A recent study indicates that fire-rotation intervals varied from 171 to 342 years in Wyoming big sagebrush (Bukowski and Baker, 2013). Sagebrush lacks the fire adaptations observed in chaparral systems that historically had fire rotations on the order of 80 years, which is consistent with evidence of longer historical fire rotations in sagebrush (Baker, 2011). Such long fire rotations suggest that the occurrence of large fire years in sagebrush steppe is largely driven by climate and weather. Large, infrequent fires have accounted for much of the area burned, especially after a series of wet years that promoted a high continuity of fine fuels; generally, such periods are followed by long periods with smaller fires (Baker, 2011). Consequently, landscape structure has varied with time since the last episode of large fires (Bukowski and Baker, 2013). Slow recovery after fire can lead to fire-related variation in sagebrush density across the landscape for decades (Lesica and others, 2007; Wambolt and others, 2001). Historically, long fire rotations allowed sagebrush to reach maturity and dominate unbroken expanses for prolonged periods before the next large fire shifted dominance to grasslands and resprouting shrubs (Bukowski and Baker, 2013).

Associated Species of Management Concern

Sagebrush steppe supports a diversity of wildlife, including obligate and facultative sagebrush species such as pronghorn, white-tailed prairie dog, Great Basin pocket mouse, sagebrush sparrow, Brewer’s sparrow, sage thrasher, and sagebrush lizard (Keinath, 2004; Rowland and others, 2011). Species that occur in sagebrush steppe and mountain big sagebrush (in foothill shrublands and woodlands) evaluated as Conservation Elements for this REA include pygmy rabbit, greater sage-grouse, sagebrush sparrow, Brewer’s sparrow, and sage thrasher.

Change Agents

Development

Energy and Infrastructure

Energy development, one of the fastest growing threats to sagebrush steppe, is resulting in fragmentation, degradation, and loss of sagebrush and associated species (Finn and Knick, 2011; Knick, Hanserand others, 2011). Most of the recent energy development has occurred in several oil and gas fields, where shrubland patch sizes have decreased by 45 percent, largely because of roads developed to accommodate energy development (Finn and Knick, 2011). Some of the largest reserves of oil and gas and some of the best areas for potential wind development occur within the sagebrush steppe (Connelly and others, 2004), so future energy development is likely to further degrade this system (Finn and Knick, 2011).

Agricultural Activities

Agricultural drivers of change include mechanical and chemical treatments used to enhance livestock forage, some grazing practices, and conversion to cropland (Knick and others, 2011). Because sagebrush is not valued as forage for most livestock, it is frequently removed through prescribed burning or mechanical or herbicide treatments to promote and maximize the growth of grasses and forbs that support livestock grazing and game species such as elk (Rowland and Leu, 2011). After sagebrush removal, these areas are frequently seeded with nonnative grasses and forbs (Knick and Rotenberry, 1997). Historically, conversion to cropland also was a major source of loss and fragmentation in sagebrush steppe. By the mid-20th century, much of the arable land in sagebrush steppe was already converted to agriculture, but genetic modification of crops (for example, to increase drought tolerance) is widening the range of conditions in which some crops may be grown, so conversion from sagebrush steppe to cropland continues in some regions (Knick and others, 2011), generally outside of the Wyoming Basin (Sage-Grouse Initiative, 2015). Soils and biotic communities can be so altered by agricultural activities that sagebrush restoration becomes extremely difficult.

Biological soil crusts, highly specialized communities of cyanobacteria, mosses, and lichens, have been shown to play an important role in the ecology and resilience of sagebrush steppe on the Colorado Plateau and in the Great Basin (Belnap and Lange, 2003). In the desert Southwest, soil crusts are highly vulnerable to damage from livestock, but in the Wyoming Basin, they may play a more limited role and may be less sensitive to grazing as a result of evolutionary exposure to large herbivores (Muscha and Hild, 2006). Information for the Wyoming Basin, however, is limited and more research would help to clarify the ecological role and sensitivity of soil crusts in this ecoregion.

Altered Fire Regime

Until recently, it was believed that frequent prescribed burning, chaining, or other forms of disturbance were beneficial to sagebrush systems and associated wildlife species (Stoddart and others, 1975). Furthermore, fire suppression and the reduction of fine fuels from heavy livestock grazing are generally viewed as having led to diminished fire frequency in sagebrush steppe (Bukowski and Baker, 2013); however, a recent reconstruction of landscape structure and fire regimes using General Land Survey notes from the late 1800s challenges many assumptions about the role of fire in sagebrush steppe (Bukowski and Baker, 2013). Fire rotations in sagebrush steppe may have been longer than previously assumed, indicating that fire suppression may have limited effects on natural fire rotations in sagebrush steppe in the Wyoming Basin (Baker, 2011). It also has been suggested that dense stands of sagebrush may be promoted by grazing and fire suppression; however, dense sagebrush was common historically (Bukowski and Baker, 2013).

Cheatgrass invasion can increase fire frequency. This has occurred throughout much of the northern Great Basin and Snake River Plain (Miller and others, 2011), but it is much less common in the Wyoming Basin, where current fire rotations are similar to historical fire regimes (Bukowski and Baker, 2013). In contrast, heterogeneity within the fire perimeter may differ from historical patterns. On average, recent fires have left 20 percent of the area unburned compared to an estimated 3.5 percent left unburned historically (Bukowski and Baker, 2013). The greater patchiness observed within recent burns may result from many roads and reduction of fine fuels by grazing, which reduces fuel continuity and could result in greater patchiness within burn perimeters (Bukowski and Baker, 2013).

Another common view is that altered fire regimes and recent periods of favorable climate have contributed to juniper expansion into sagebrush steppe (Davies and others, 2011; Miller and others 2011). An alternative hypothesis is that the ecotone between juniper woodlands and sagebrush-dominated communities in the western United States is naturally dynamic in response to climate variability over decades or centuries (Romme and others, 2009; Bukowski and Baker, 2011). Although juniper may be expanding locally in many areas, evidence of range-wide expansion of juniper into sagebrush is equivocal (Romme and others, 2009). Altered fire rotations (historically on the order of 150−600 years) in the sagebrush-juniper ecotone are not expected to be the primary factor limiting juniper expansion (Bukowski and Baker, 2011). Other potential causes of juniper expansion include loss of competition from native grasses and forbs, enhanced seed dispersal related to livestock grazing, natural recovery from past disturbances, and climate conditions conducive to tree establishment (Baker, 2011). Consequently, restoration of fire regimes to historical conditions may not be effective at eliminating juniper expansion (Baker, 2011; Bukowski and Baker, 2013) (see Chapter 17—Juniper Woodlands).

Bukowski and Baker (2013) acknowledge that their analysis results carry some degree of ambiguity and uncertainty; nevertheless, their results challenge many widely held views about historical sagebrush steppe landscapes, and they suggest that sagebrush systems may have considerable inherent variation that cannot be generally assumed to be the result of human activities. Consequently, restoration of sagebrush systems will benefit from local-scale analysis of past sagebrush conditions (Bukowski and Baker, 2013). Baker (2011) and Bukowski and Baker (2013) caution that the increasing use of prescribed fire and other factors, such as invasive species and climate change, that can alter fire frequency and intensity could reduce the distribution and abundance of sagebrush. The cumulative effects of the large-scale loss and fragmentation of sagebrush ecosystems from development, compounded by the long recovery times for sagebrush steppe increase the concern that large fires could have detrimental effects on the distribution and integrity of sagebrush ecosystems (Baker, 2011).

Invasive Species

In the Wyoming Basin, nonnative plant species, including cheatgrass, crested wheatgrass, Russian thistle, and halogeton are threatening the integrity of sagebrush steppe (Nielsen and others, 2011). Cheatgrass is of particular concern. Currently, cheatgrass dominance occurs only in localized areas of the Wyoming Basin, but because it is widely distributed, typically at low densities, throughout the Basin, its potential to spread rapidly after fire is a significant management concern.

Climate Change

Climate change has the potential to affect the distribution of sagebrush steppe within the Wyoming Basin. Because the range of projected temperatures for the Wyoming Basin are within the range tolerated by sagebrush, the degree to which sagebrush steppe expands or contracts likely will depend on the amount and timing of precipitation (Schlaepfer and others, 2012b). The interactive effects of climate change and nonnative species could result in shorter fire-return intervals, which could lead to conversion of sagebrush to annual grasslands (Rowland and Leu, 2011).

Rapid Ecoregional Assessment Components Evaluated for Sagebrush Steppe

A generalized, conceptual model was used to highlight some of the key ecological attributes and Change Agents affecting sagebrush steppe (fig. 11–1). Key ecological attributes addressed by the REA include (1) the distribution of sagebrush, (2) landscape structure (patch sizes and structural connectivity), and (3) landscape dynamics (fire occurrence and sagebrush-juniper ecotone dynamics) (table 11–1). The Change Agents evaluated include development and climate change (table 11–2). Ecological values and risks used to assess the conservation potential of sagebrush steppe by township are summarized in table 11–3. Core and Integrated Management Questions and the associated summary maps and graphs are provided in table 11–4.

Methods Overview

To map the baseline distribution of sagebrush steppe, we included all sagebrush LANDFIRE Existing Vegetation Types except for mountain big sagebrush, which is included in the foothill shrublands and woodlands community. We also included adjacent, low-elevation (< 2,600 m [8,530 ft]) grassland areas, which include postfire sagebrush steppe classified as grasslands and prairie grasslands that occur outside the ecoregion but within the project area buffer. All grassland Existing Vegetation Type cells within a 210-m (689-ft) buffer that were dominated by sagebrush steppe were included in the sagebrush steppe community.

We assessed development levels in sagebrush steppe using the Terrestrial Development Index (TDI) map, and used the resulting output to calculate patch size and structural connectivity metrics. We mapped the structural connectivity of relatively undeveloped areas (TDI score ≤1 percent) at three interpatch distances on the basis of connectivity analysis; local (0.45 km [0.28 mi]), landscape (2.46 km [1.53 mi]), and regional (3.18 km [1.98 mi]) levels. We used development levels to identify areas that may function as barriers or corridors by overlaying relatively undeveloped habitat patches on the TDI map. To assess fire frequency and extent, the perimeters of fires in sagebrush steppe since 1980 were compiled from several data sources (table 11–1).

To evaluate potential change in the distribution of sagebrush steppe, we used the sagebrush shrublands bioclimatic envelope model developed by Rehfeldt and others (2012) for climate scenario I, the Canadian Centre for Climate Modelling and Analysis Model version 3 (CCCM3) (emissions scenario A2) in 2030. It is important to note that their biome classification included mountain big sagebrush in sagebrush shrublands. Current and projected bioclimatic envelopes were used to identify areas where sagebrush steppe had the potential to increase, decline, or remain the same. We then overlaid the resulting map with the baseline sagebrush steppe map to identify existing areas that have the potential to change for climate scenario I.

Landscape-level ecological values (area of sagebrush steppe) and risk (TDI score) were compiled into an overall index of conservation potential for each township (table 11–3). See Chapter 2—Assessment Framework and the Appendix for additional details on the methods. Landscape-level values and risks, and conservation potential rankings are intended to provide a synthetic overview of the geospatial datasets developed to address Core Management Questions in the REA. Because rankings are very sensitive to the input data used and the criteria used to develop the ranking thresholds, they are not intended as stand-alone maps. Rather, they are best used as an initial screening tool to compare regional rankings in conjunction with the geospatial data for Core Management Questions and information on local conditions that cannot be determined from regional REA maps.

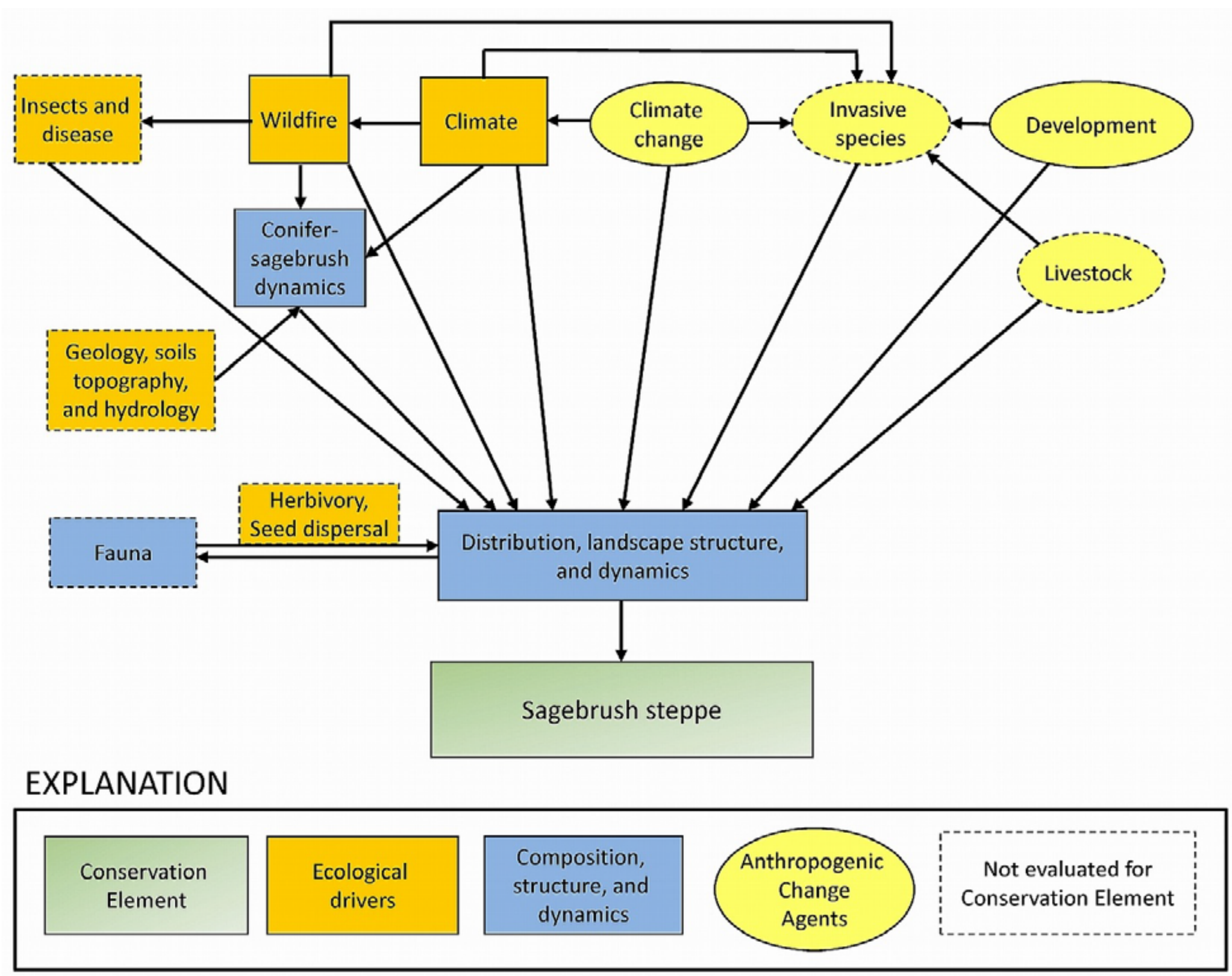

Figure 11–1. Generalized conceptual model for sagebrush steppe for the Wyoming Basin Rapid Ecoregional Assessment (REA). Biophysical attributes and ecological processes regulating the occurrence, structure, and dynamics of sagebrush steppe are shown in orange rectangles; additional ecological attributes are shown in blue rectangles; and anthropogenic Change Agents that affect key ecological attributes are shown in yellow ovals. The dashed lines indicate components not addressed by the REA. Livestock and invasive plants are Change Agents that were not addressed for sagebrush steppe because of the lack of region-wide data.

Table 11−1. Key ecological attributes and associated indicators of baseline sagebrush steppe[1] for the Wyoming Basin Rapid Ecoregional Assessment.

[km, kilometer; mi, mile]

Attributes	Variables	Indicators
Amount and distribution	Total area	Distribution derived from LANDFIRE[1]
Landscape structure	Patch size	Patch-size frequency distribution
	Structural connectivity[2]	Inter-patch distance that provides an index of structural connectivity for baseline patches at local, landscape, and regional (0.06 km; 0.04 mi) levels
Landscape dynamics	Fire occurrence[3]	Locations of fires and annual area burned since 1980
	Sagebrush-juniper ecotone dynamics	See Chapter 17— Juniper Woodlands

[1] Baseline conditions are used as a benchmark to evaluate changes in the total area and landscape structure of sagebrush steppe due to Change Agents. Baseline conditions are defined as the potential current distribution of sagebrush steppe derived from LANDFIRE Existing Vegetation Types without explicit inclusion of Change Agents (see Chapter 2—Assessment Framework and the Appendix).

[2] Structural connectivity refers to the proximity of patches at local, landscape, and regional levels but does not reflect species-specific measures of connectivity. See Chapter 2—Assessment Framework.

[3] See Wildland Fire section of the Appendix.

Table 11−2. Anthropogenic Change Agents and associated indicators influencing sagebrush steppe for the Wyoming Basin Rapid Ecoregional Assessment.

[mi^2, square miles; km, kilometer; mi, mile]

Change Agents	Variables	Indicators
Development	Terrestrial Development Index[1]	Percent of sagebrush in seven development classes using a 16-km^2 (6.18-mi^2) moving window
		Patch size frequency distribution for sagebrush steppe that is relatively undeveloped or has a low development score compared to baseline conditions
		Inter-patch distances that provide an index of structural connectivity for relatively undeveloped patches at local (0.45 km; 0.28 mi), landscape (2.46 km; 1.53 mi), and regional (3.18 km; 1.98 mi) levels
Climate change	Projected temperature and precipitation	Potential distribution of sagebrush steppe derived from the projected distribution of the bioclimatic envelope in 2030[2]

[1] See Chapter 2—Assessment Framework.

[2] Bioclimatic envelope represents the climatic conditions conducive for sagebrush shrublands, derived from Rehfeldt and others (2012) for climate scenario I (Canadian Centre for Climate Modelling and Analysis Model, ver. 3, emissions scenario A2).

Table 11−3. Landscape-level ecological values and risks for sagebrush steppe. Ranks were combined into an index of conservation potential for the Wyoming Basin Rapid Ecoregional Assessment.

	Variables[1]	Relative rank Lowest	Medium	Highest	Description[2]
Values	Area	<35	35−79	>79	Percent of township classified as sagebrush steppe
Risks	Terrestrial Development Index (TDI)	<1	1−3	>3	Mean TDI score by township

[1] Township was used as the analysis unit for conservation potential on the basis of input from the Bureau of Land Management. A minimum area threshold of total area per township was established for each Conservation Element to minimize the effects of extremely small areas and put greater emphasis on large areas (see table A-19 in the Appendix).

[2] See tables 11–1 and 11–2 for description of variables.

Table 11−4. Management Questions addressed for sagebrush steppe for the Wyoming Basin Rapid Ecoregional Assessment.

Core Management Questions	Results
Where is baseline sagebrush steppe, and what is the total area?	Figure 11–2
Where does development pose the greatest threat to baseline sagebrush steppe, and where are the relatively undeveloped areas?	Figures 11–3 and 11–4
How has development fragmented baseline sagebrush steppe, and where are the large, relatively undeveloped patches?	Figures 11–5 and 11–6
How has development affected the structural connectivity of sagebrush steppe relative to baseline conditions?	Figure 11–7
Where are potential barriers and corridors that may affect animal movements among relatively undeveloped sagebrush steppe patches?	Figure 11–8
Where are sagebrush-juniper ecotones with potential for juniper expansion?	Chapter 17— Juniper Woodlands
Where have recent fires occurred in baseline sagebrush steppe, and what is the total area burned per year?	Figures 11–9 and 11–10
What is the potential distribution of sagebrush steppe in 2030?	Figure 11–11

Integrated Management Questions	Results
How does risk from development vary by land ownership or jurisdiction for sagebrush steppe?	Table 11–5, Figure 11–12
Where are the townships with the greatest landscape-level ecological values?	Figure 11–13
Where are the townships with the greatest landscape-level risks?	Figure 11–13
Where are the townships with the greatest conservation potential?	Figure 11–14

Key Findings for Management Questions

Where is baseline sagebrush steppe, and what is the total area (fig. 11–2)?

- Sagebrush steppe is the dominant community in the Wyoming Basin and covers 90,085 square kilometers (km^2) (34,782 square miles [mi^2]), which is about half of the project area.
- Sagebrush steppe includes early successional postfire sagebrush, some of which has been converted to cheatgrass. Prairie grasslands occur as large patches along the east side of the project area, outside of the ecoregion proper.

Where does development pose the greatest threat to sagebrush steppe, and where are the relatively undeveloped areas (figs. 11–3 and 11–4)?

- Development is widely distributed across sagebrush steppe within the Wyoming Basin (fig. 11–3).
- A total of 23.5 percent of the sagebrush steppe is relatively undeveloped (TDI score $\leq$1 percent), and approximately 21 percent has high levels of development, as indicated by TDI scores >5 percent (fig. 11–4).

How has development fragmented baseline sagebrush steppe, and where are the large, relatively undeveloped patches (figs. 11–5 and 11–6)?

- Baseline sagebrush steppe patches are generally very large, with approximately 44 percent occurring in patches >5,000 km^2 (1,930.5 mi^2) and 74 percent occurring in patches >500 km^2 (193.1 mi^2) (fig. 11–5).
- Development has effectively fragmented sagebrush steppe into smaller patches relative to baseline conditions. All relatively undeveloped sagebrush steppe occurs in patches <5,000 km^2 (1,930 mi^2).
- The largest relatively undeveloped patches are northeast and southeast of Rock Springs (fig. 11–6).

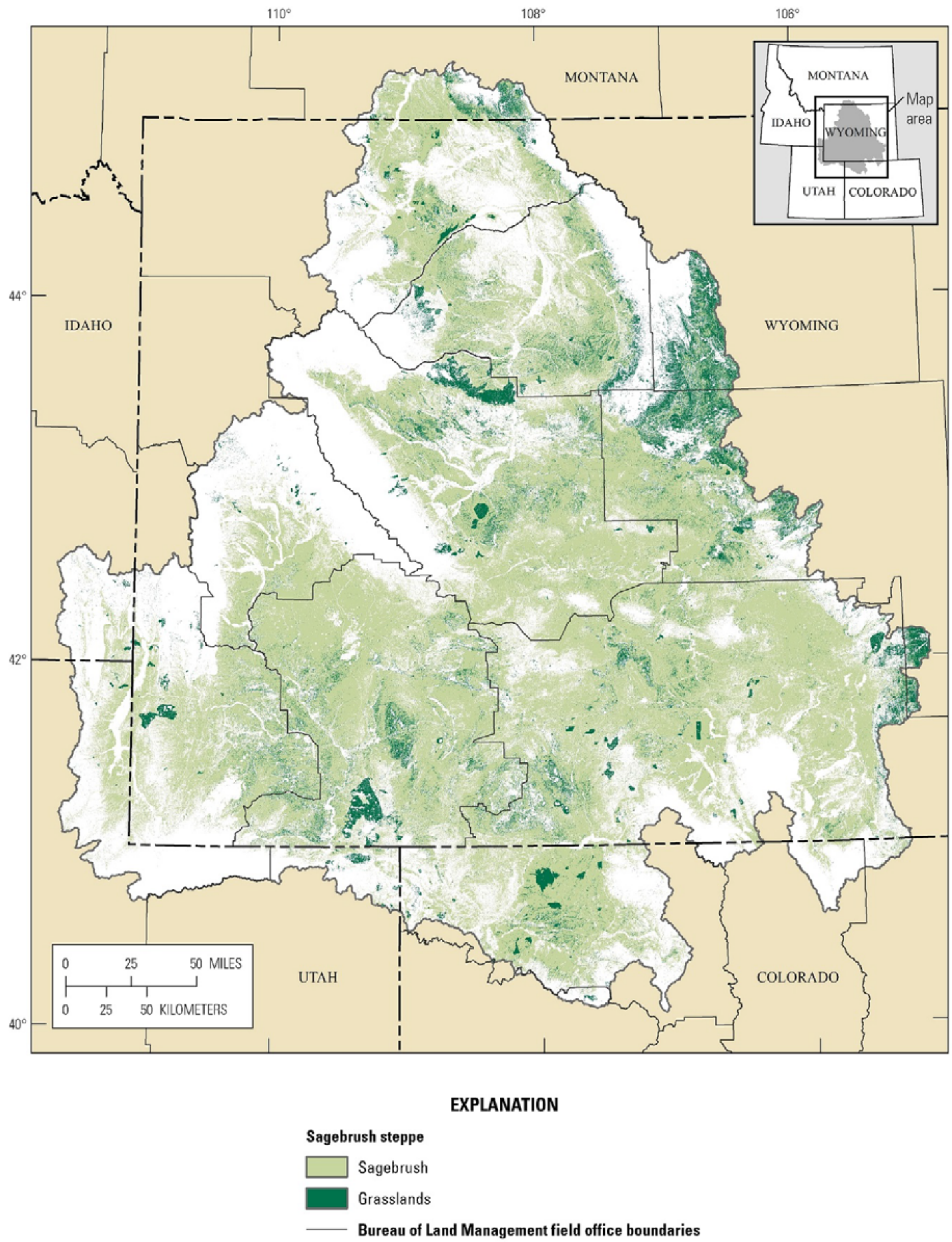

Figure 11–2. Distribution of baseline sagebrush steppe in the Wyoming Basin Rapid Ecoregional Assessment project area. Grasslands include early succession postfire sagebrush and other grassland types that occur in areas dominated by sagebrush steppe.

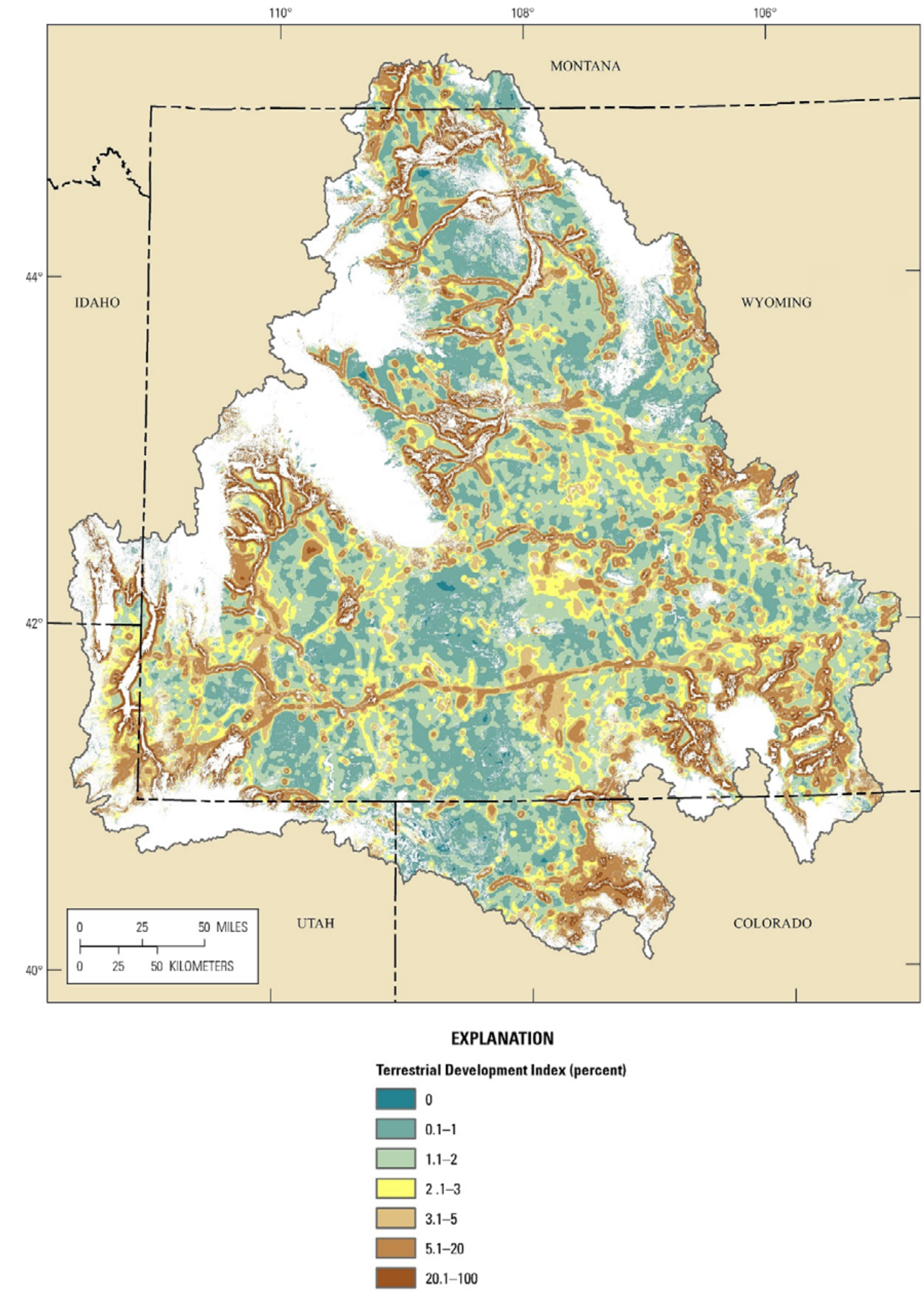

Figure 11–3. Terrestrial Development Index scores for sagebrush steppe in the Wyoming Basin Rapid Ecoregional Assessment project area.

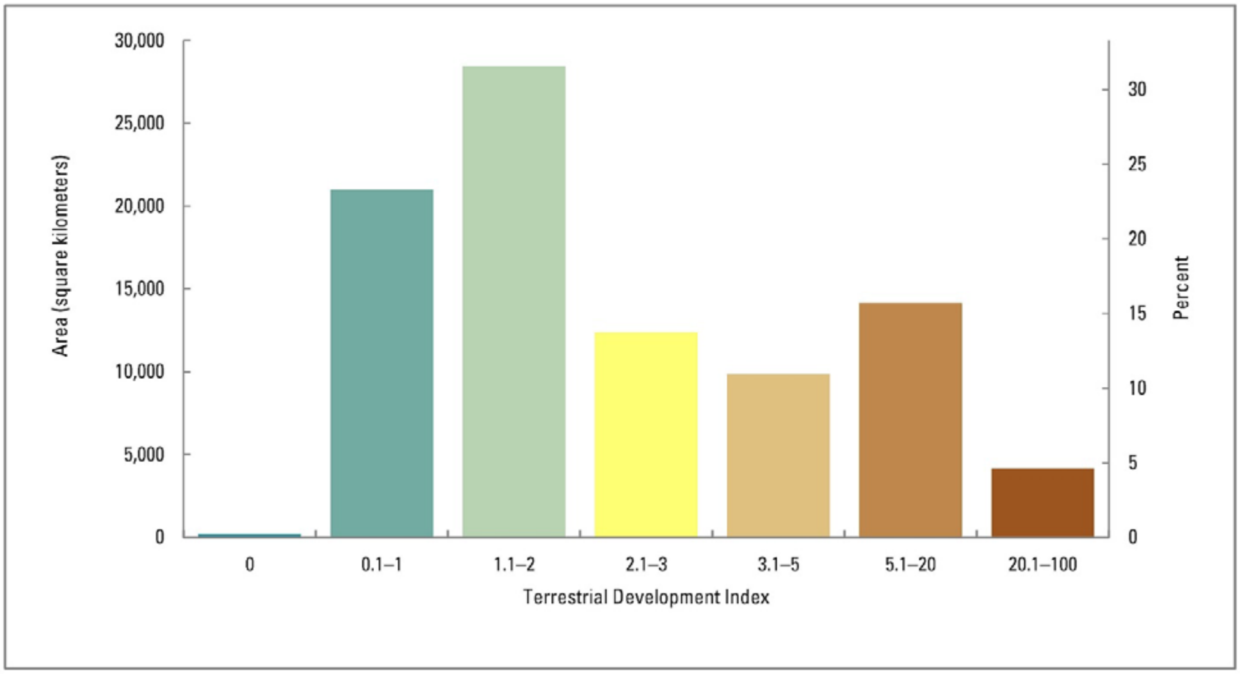

Figure 11–4. Area and percentage of baseline sagebrush steppe as a function of the Terrestrial Development Index score in the Wyoming Basin Rapid Ecoregional Assessment project area.

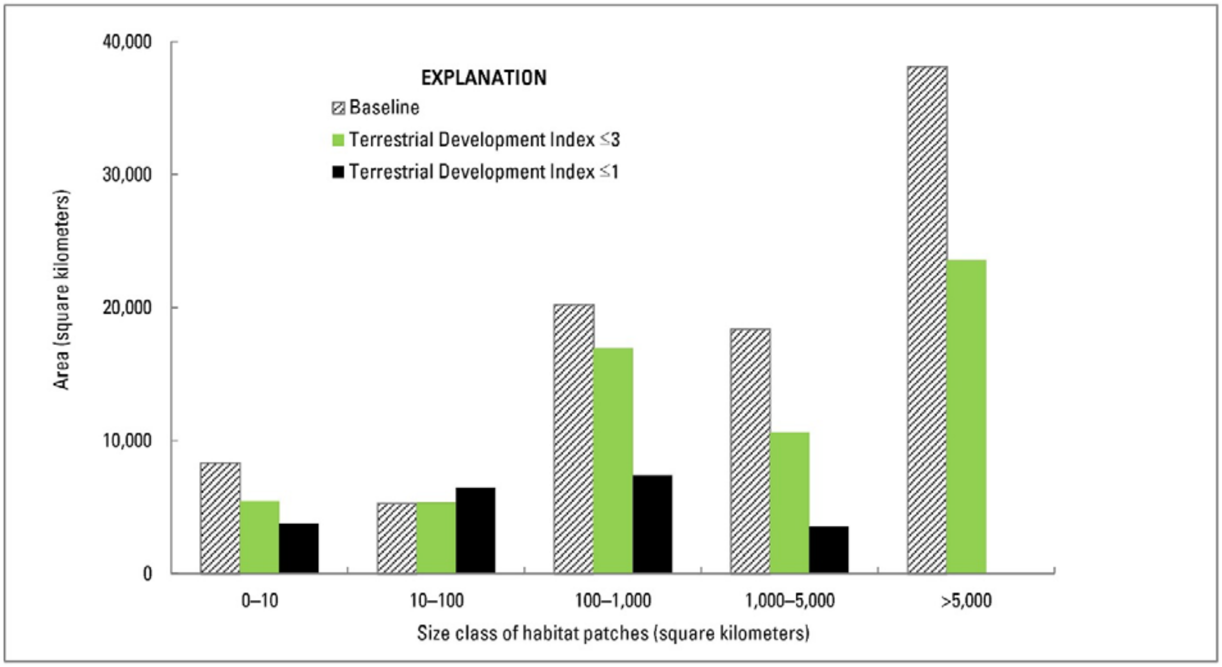

Figure 11–5. Area of sagebrush steppe as a function of patch size for baseline conditions and two development levels: (1) Terrestrial Development Index (TDI) score <u><</u>3 percent, and (2) TDI score <u><</u>1 percent (relatively undeveloped areas) in the Wyoming Basin Rapid Ecoregional Assessment project area.

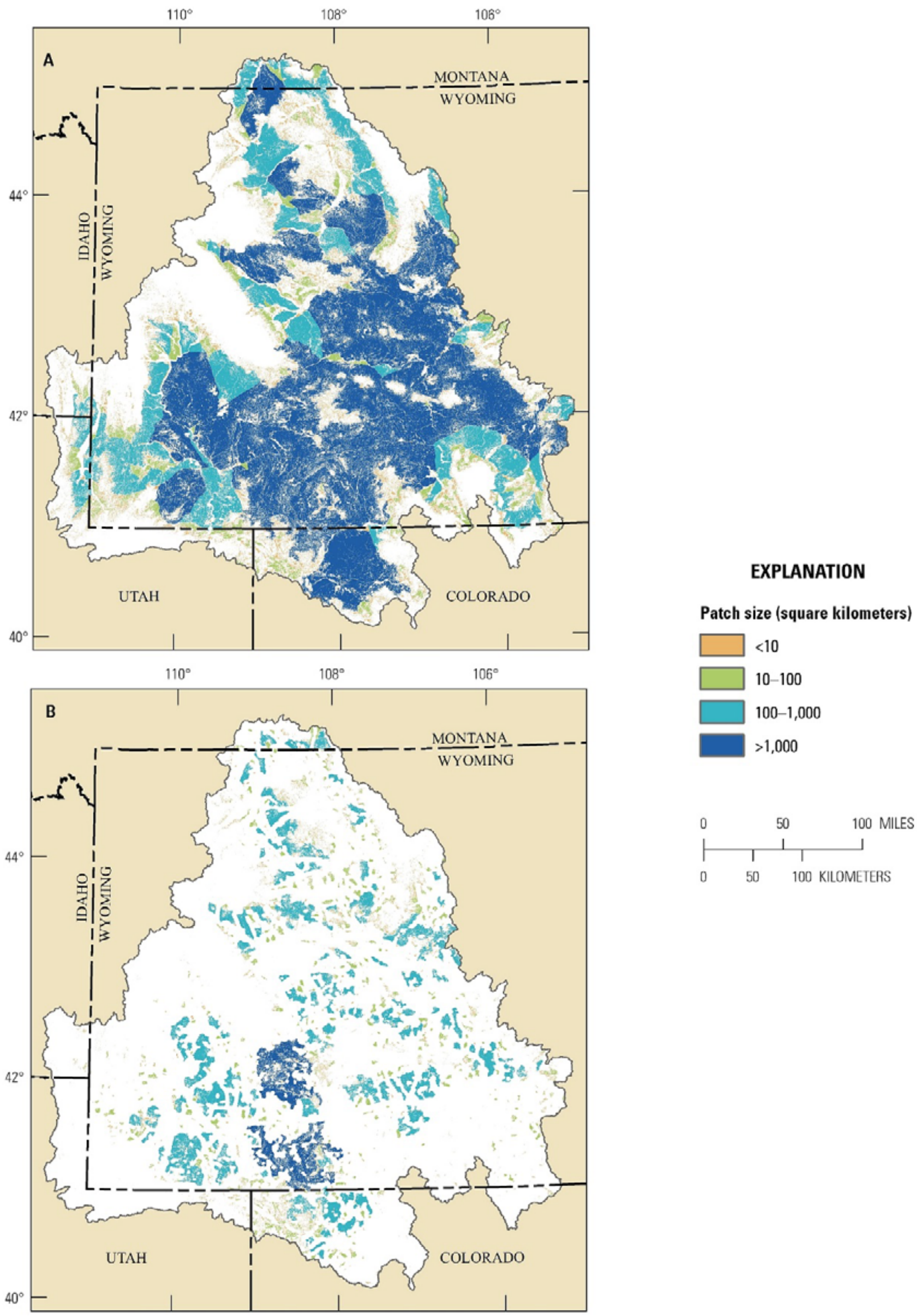

Figure 11–6. Patch sizes of sagebrush steppe in the Wyoming Basin Rapid Ecoregional Assessment project area for (*A*) baseline conditions and (*B*) relatively undeveloped (Terrestrial Development Index score ≤1 percent).

How has development affected the structural connectivity of sagebrush steppe relative to baseline conditions (fig. 11–7)?

- Baseline sagebrush steppe is highly connected, with local, landscape, and regional connectivity occurring at an interpatch distance of 0.06 km (0.04 mi).
- Development has greatly diminished the structural connectivity of the largest patches of relatively undeveloped sagebrush steppe. Relatively undeveloped areas are highly fragmented and local-level connectivity is 0.45 km (0.28 mi), landscape-level connectivity is 2.46 km (1.53 mi), and regional-level connectivity is 3.18 km (1.98 mi).
- Patches of highly connected, relatively undeveloped areas (local, landscape, and regional connectivity) are distributed throughout the Basin. Areas with high local- and landscape-level connectivity may facilitate dispersal and seasonal movements of organisms sensitive to disturbance, whereas sagebrush steppe with only regional-level connectivity may have value as stepping stones or stopover sites across developed or otherwise unsuitable habitat.

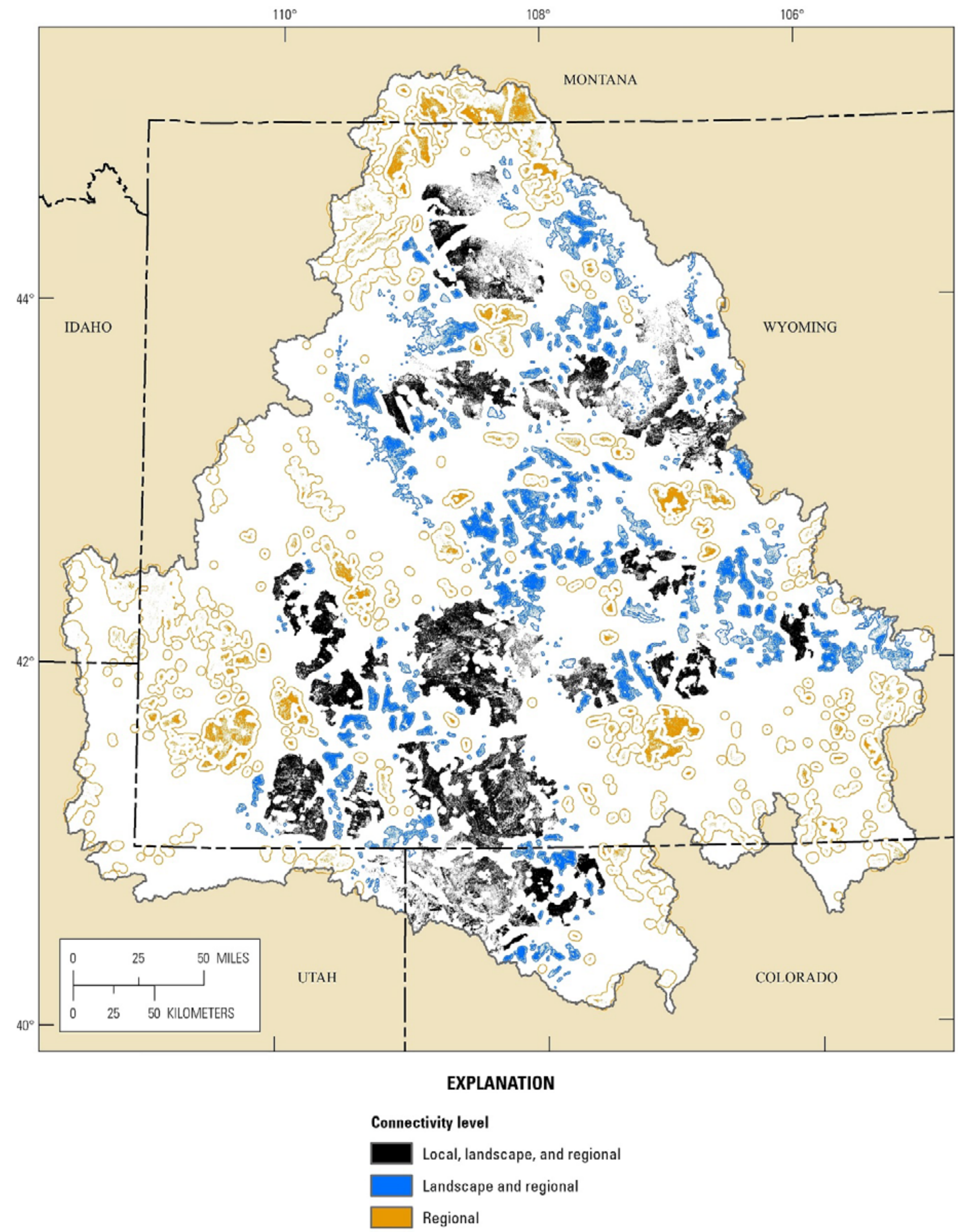

Figure 11–7. Structural connectivity of relatively undeveloped patches of sagebrush steppe in the Wyoming Basin Rapid Ecoregional Assessment project area. Black polygons include large and highly connected patches. Blue polygons include patches that contribute to landscape and regional connectivity. Orange polygons represent isolated clusters of patches surrounded by developed areas or other cover types.

Where are potential barriers and corridors that may affect animal movements among relatively undeveloped sagebrush steppe patches (fig. 11–8)?

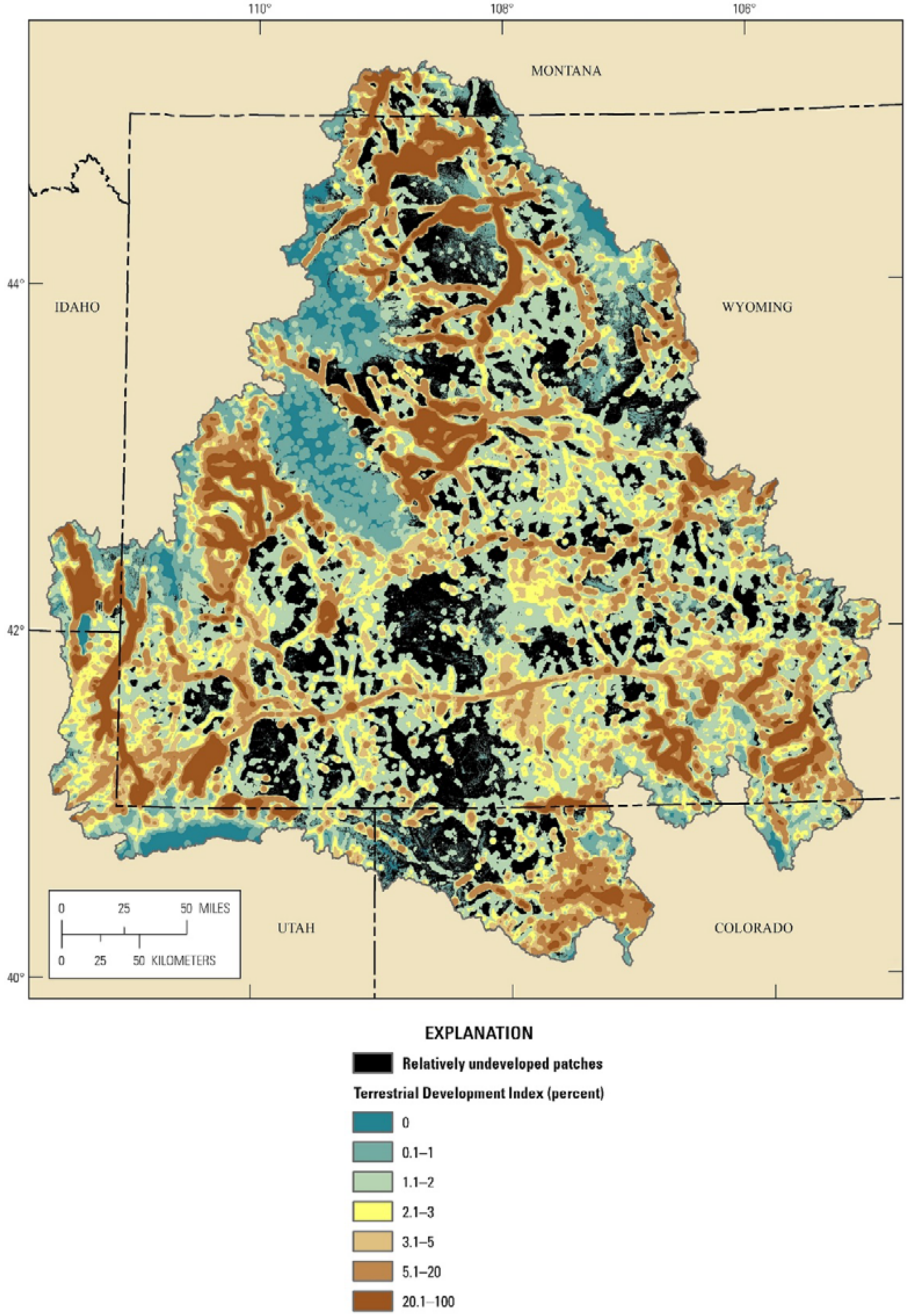

Figure 11–8. Potential barriers and corridors as a function of the Terrestrial Development Index (TDI) score for lands surrounding relatively undeveloped foothill shrublands and woodlands. Higher TDI scores (for example, >5 percent) represent potential barriers to movement among relatively undeveloped patches. Lower TDI scores (for example, <2 percent) represent potential corridors for movements among patches.

Where have recent fires occurred in baseline sagebrush steppe, and what is the total area burned per year (figs. 11–9 and 11–10)?

- Typically only a small fraction of sagebrush steppe has burned each year since 1980. Cumulatively, 3.6 percent (3,217 km^2 [1,242.1 mi^2]) of sagebrush steppe has burned since 1980.
- In most years, fires were small and burned only a small part of sagebrush steppe with most of the area burned by fires occurring in 1996 and 2000 (figs. 11–9 and 11–10).

What is the potential distribution of sagebrush steppe in 2030 (fig. 11–11)?

- The distribution of bioclimatic conditions conducive for sagebrush shrublands is projected to contract by 2030 for climate scenario I (fig. 11−11*A*), with the potential for considerable contraction in the distribution of sagebrush steppe (fig. 11−11*B*). The central part of the Wyoming Basin may provide a stronghold for sagebrush steppe for this climate scenario.
- By 2090, all three climate scenarios projected the potential for broad-scale contraction of the sagebrush shrublands envelope within the Basin; figure 2−18 includes additional climate scenarios and time periods. These results indicate the potential vulnerability of sagebrush steppe to projected climate change.
- An ensemble climate model projected little change in the distribution of sagebrush shrublands in the Wyoming Basin (Schlaepfer and others, 2012b) because precipitation can vary considerably among climate projections. The difference in results among studies suggests that sagebrush shrublands may be most sensitive to decreases in precipitation but more tolerant of the projected temperature increases.

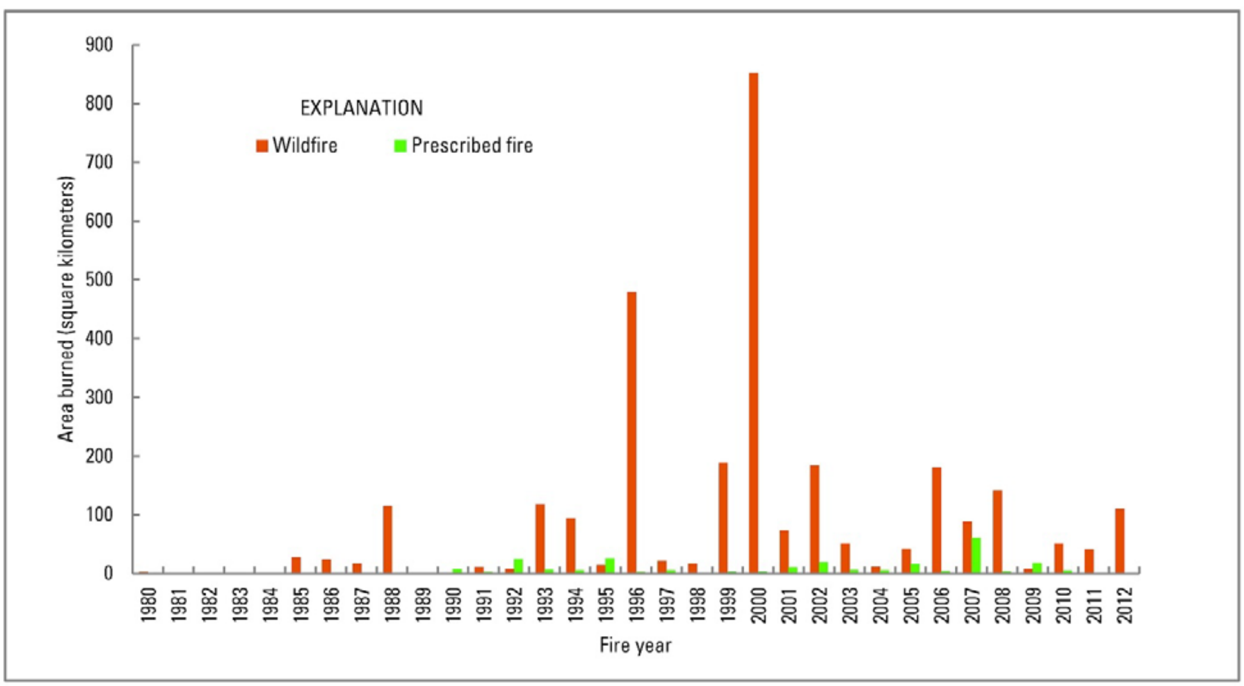

Figure 11–9. Annual area burned by wildfires and prescribed fires in baseline sagebrush steppe since 1980 in the Wyoming Basin project area.

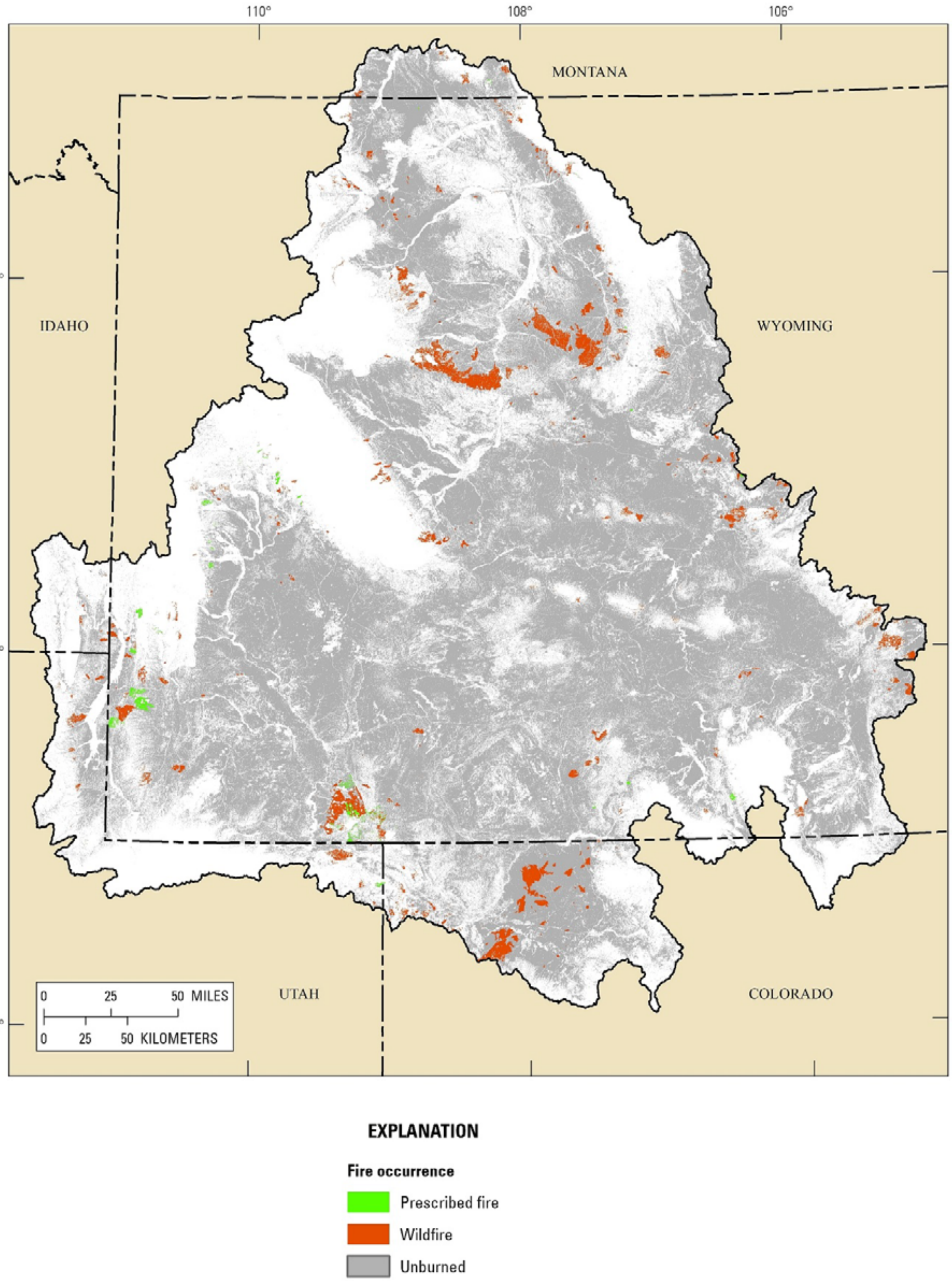

Figure 11–10. Occurrence of wildfires and prescribed fires in baseline sagebrush steppe since 1980 in the Wyoming Basin Rapid Ecoregional Assessment project area.

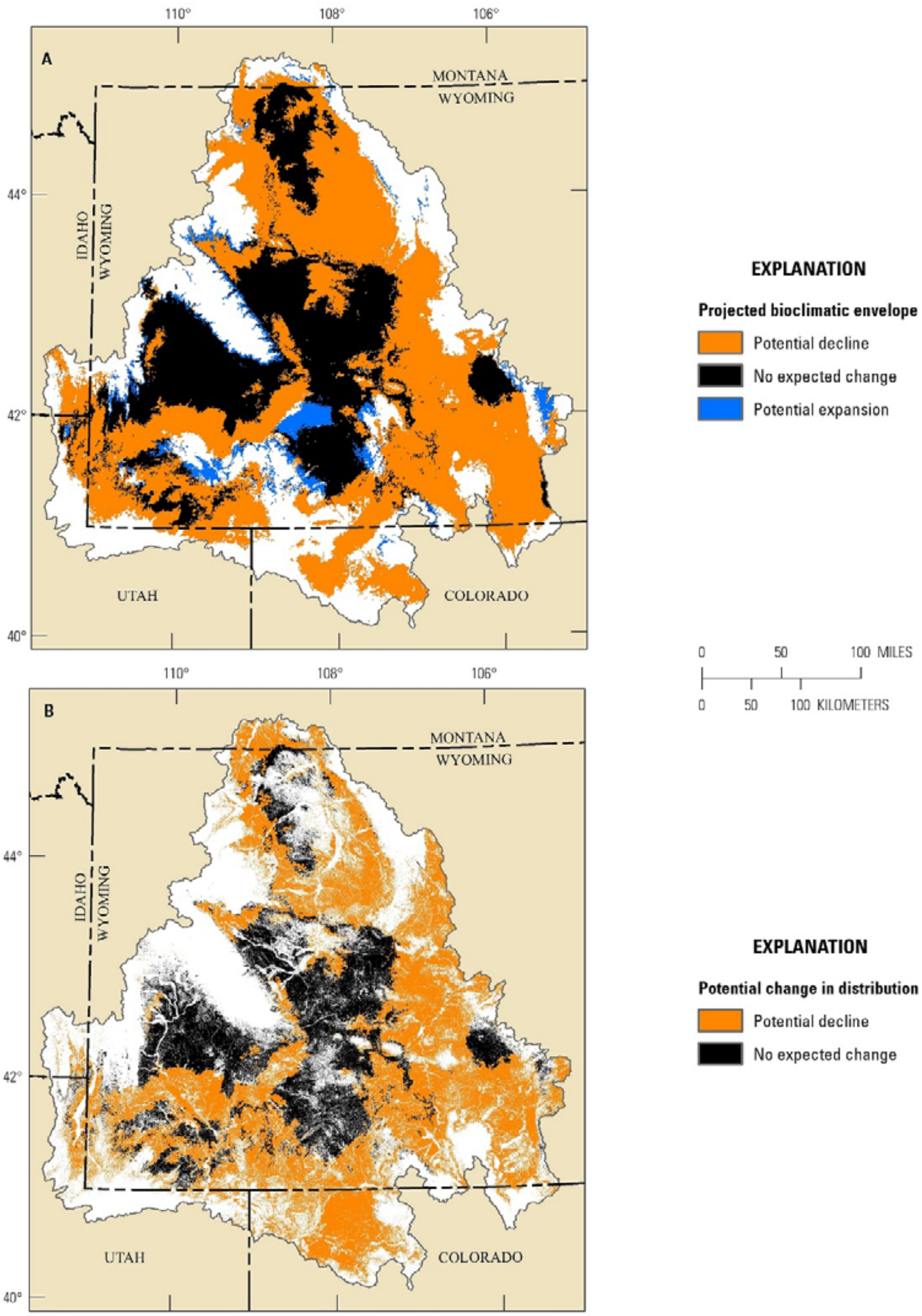

Figure 11–11. Potential effects of climate change on sagebrush shrublands in the Wyoming Basin Rapid Ecoregional Assessment project area. (*A*) Projected changes in the bioclimatic envelope for sagebrush shrublands derived from Rehfeldt and others (2012) for climate scenario I in 2030. Orange indicates areas with potential for decline because current and projected envelope distributions do not coincide. Black indicates areas not expected to change because the current and projected envelope distributions overlap. Blue indicates potential for expansion into areas that are outside the current envelope distribution. (*B*) Potential changes in baseline sagebrush shrublands derived from overlap with the projected bioclimatic envelope distribution (as represented in *A*).

How does risk from development vary by land ownership or jurisdiction for sagebrush steppe (table 11–5, fig. 11–12)?

- Currently, the Bureau of Land Management (BLM) manages about half of all sagebrush steppe in the Wyoming Basin (table 11–5).
- Compared to all other lands, BLM lands encompass the lowest proportion of sagebrush steppe with the greatest risk from development compared to all other land ownerships or jurisdictions (fig. 11–12).
- Tribal lands encompass the greatest proportion of sagebrush steppe with the lowest risk from development, followed by all Federal lands, including BLM lands (fig. 11–12).

Table 11−5. Area and percentage of sagebrush steppe by land ownership or jurisdiction in the Wyoming Basin Rapid Ecoregional Assessment project area.

[km^2, square kilometers]

Ownership or jurisdiction	Area (km^2)	Percent of area
Bureau of Land Management	46,472	51.6
Private	29,902	33.7
State/County	6,194	6.9
Tribal	4,127	4.6
Other Federal[1]	2,883	3.2
Private conservation	440	0.5

[1] National Park Service, Department of Defense, Department of Energy, Bureau of Reclamation, U.S. Department of Agriculture Forest Service, and U.S. Fish and Wildlife Service.

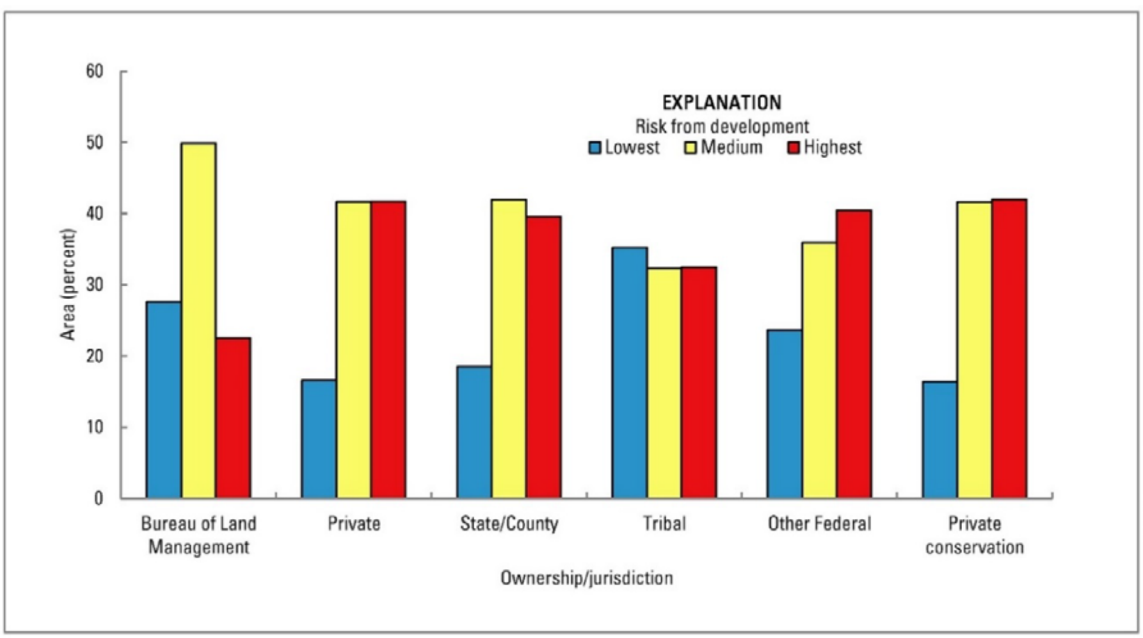

Figure 11–12. Relative ranks of risk from development, by land ownership or jurisdiction, for sagebrush steppe in the Wyoming Basin Rapid Ecoregional Assessment project area. Rankings are lowest (Terrestrial Development Index [TDI] score <1 percent), medium (TDI score 1−3 percent), and highest (TDI score >3 percent).

Where are the townships with the greatest landscape-level ecological values and where are the townships with the greatest landscape-level risks (fig. 11–13)?

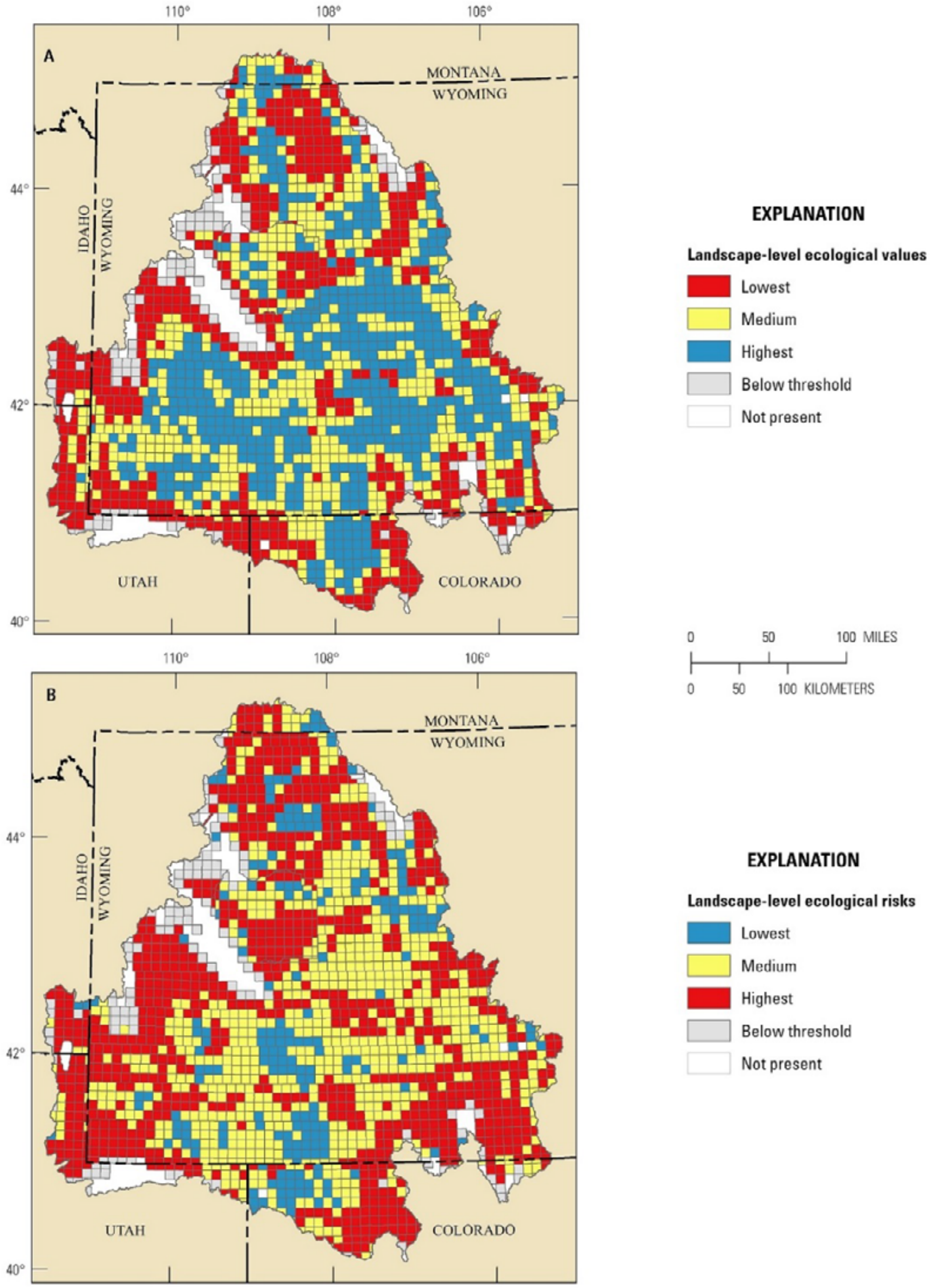

Figure 11–13. Ranks of landscape-level ecological values and risks for sagebrush steppe, summarized by township, in the Wyoming Basin Rapid Ecoregional Assessment project area. (*A*) Landscape-level values based on area, and (*B*) landscape-level risks based on Terrestrial Development Index (see table 11–3 for overview of methods).

Where are the townships with the greatest conservation potential (fig. 11–14)?

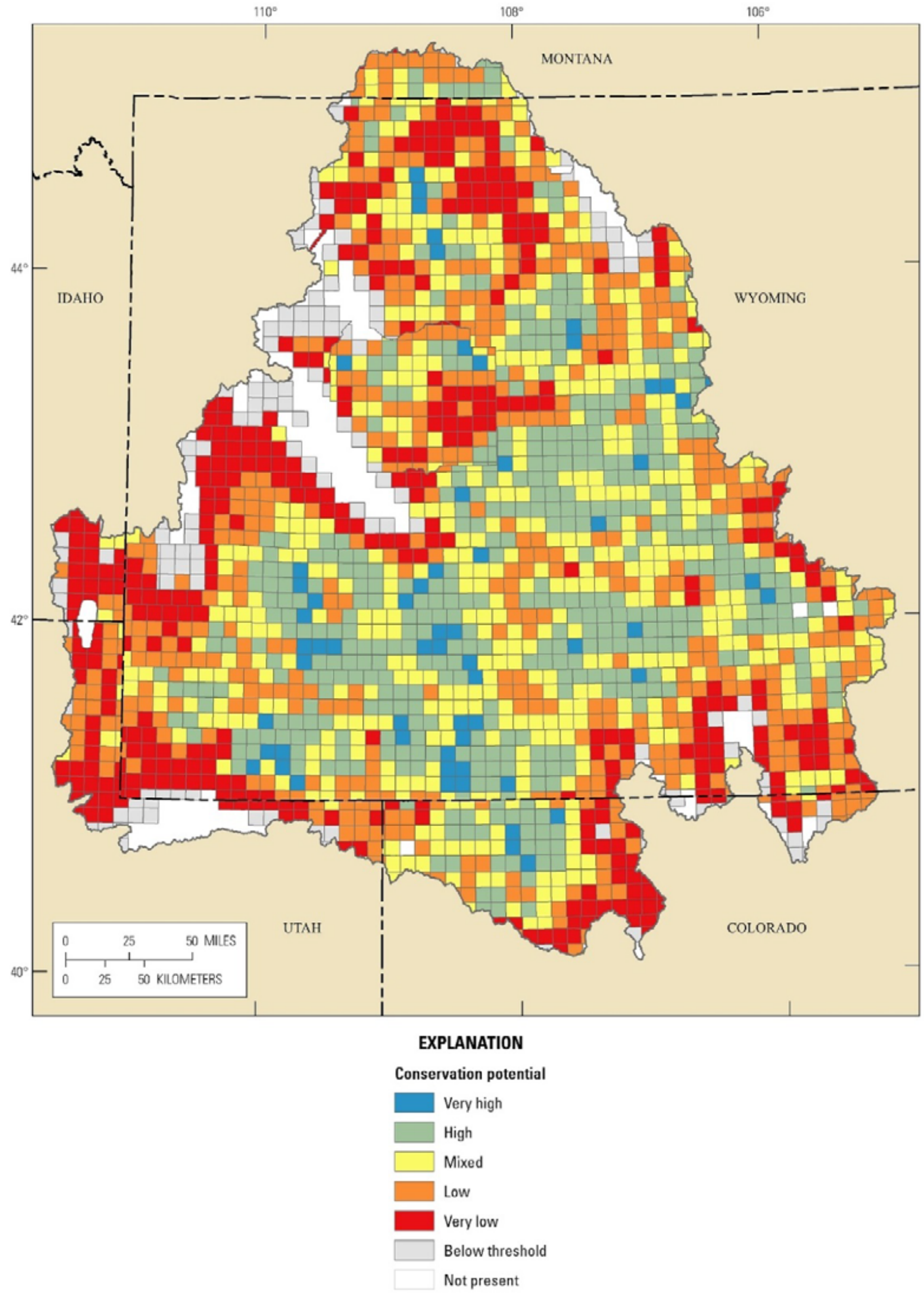

Figure 11–14. Conservation potential of sagebrush steppe, summarized by township, in the Wyoming Basin Rapid Ecoregional Assessment project area. Highest conservation potential identifies areas that have the highest landscape-level values and the lowest risks. Lowest conservation potential identifies areas with the lowest landscape-level values and the highest risks. Ranks of conservation potential are not intended as stand-alone summaries and are best interpreted in conjunction with the geospatial datasets used to address Core Management Questions.

Summary

Sagebrush steppe is widely distributed in the Wyoming Basin, accounting for approximately 53.4 percent of the project area. Development is pervasive and only 23.5 percent of the sagebrush steppe in the Basin is relatively undeveloped. Although sagebrush steppe was once highly connected within the Basin, development (including roads, energy, and agriculture) has fragmented and decreased the structural connectivity of sagebrush steppe. Much of the sagebrush steppe that remains relatively undeveloped occurs in scattered patches, most of which are <1,000 km^2 (386.1 mi^2); only two patches of relatively undeveloped sagebrush steppe >1,000 km^2 (386.1 mi2) remain within the Basin, representing <4 percent of the total area of baseline sagebrush steppe.

Data limitations make it difficult to evaluate regional patterns in sagebrush steppe dynamics because the dynamics occur on a time scale of decades to centuries. Given these limitations, there was little evidence to support widespread risk of either juniper expansion or altered fire regimes in the Wyoming Basin as a result of human activities; thus, human-caused expansion of juniper woodlands into sagebrush steppe does not appear to be a regionwide problem (see Chapter 17—Juniper Woodlands). Since 1990, little sagebrush steppe has burned in the Wyoming Basin, therefore recent fires appear to be consistent with the frequency and size of historical fire patterns (see Chapter 5—Wildland Fire). If cheatgrass becomes more common in the region, however, fire could pose a much greater threat in the future.

On the basis of current rates of development, particularly for energy development, sagebrush steppe is expected to undergo further fragmentation, loss, and degradation. The potential risk from invasive species and projected climate change could further compound these problems.

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