Section II. Change Agents—Current and Future

Chapter 5. Wildland Fire

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Introduction

Wildland fire, which includes wildfire and prescribed fire, is a Change Agent that affects the ecological communities (hereafter, "communities") and ecosystems of the Wyoming Basin and is one of the Change Agents analyzed by the Rapid Ecoregional Assessment. This chapter describes (1) some of the long-term wildfire history in relationship to changing vegetation communities and (2) the recent wildland fire history in the Wyoming Basin. It also discusses potential changes in wildfire occurrence and size of future wildfire events for projected climate scenarios.

Paleo-Historical Wildfire

Wildfire rotations and regimes have varied greatly since the beginning of the Holocene period (roughly 11,500 years [yr] before present). These rotations and regimes show wide variation, both temporally and spatially, within and among the communities are influenced by a complex, interrelated set of climatic, vegetative, and disturbance patterns. "The variability recorded in the fire-history record is important because it contradicts the notion of a static fire-return interval…." (Whitlock and others, 2003, p.17).

Paleoecology and charcoal records indicate vegetation patterns and wildfire activity vary with climatic conditions. For example, Baker (1986) recorded ponderosa pine macrofossils in the Yellowstone area from 120,000−170,000 yr before present during the Sangamonian warm period, indicating very different climatic, vegetative, and disturbance regimes than present today. Gavin and others (2007) have noted greatly varying fire-return intervals for the Yellowstone Plateau from a fire return interval of approximately 90 years (10,000 yr before present) to an approximate 250-year fire return interval at the present time. An analysis of packrat midden contents documented the establishment, expansion, and contraction of Utah juniper, pinyon pine, and other coniferous and shrub species throughout the Wyoming Basin ecoregion over the last 40,000 yr (Jackson and Betancourt, 2006; Jackson and others, 2005). This includes rapid expansion of juniper to its current locations, beginning 2,800 yr before present. These records indicate that the region's vegetation has unique life-history characteristics that can lead to range expansions and contractions that may continue into the future. The vegetative communities in the Wyoming Basin are not static, but are highly dynamic in response to climatic conditions and disturbance regimes. The paleoecological record shows that changes in fire regime as a result of changing climate have sometimes driven rapid vegetative change, and the complex interactions between climate, vegetation, and disturbance will influence future vegetative communities and their resultant highly variable fire regimes (Whitlock and others, 2003**).**

Some intriguing new work by Odion and others (2014) indicates that in some areas the lower montane forests, primarily ponderosa pine and Douglas-fir, historically may have been dominated by "mixed-severity" fire regimes, including crown-fire events. The common belief that "low-severity" surface-fire regimes were characteristic of these more xeric forests may not align with historical reference conditions. See Chapter 1—Introduction and Overview, and background information on fire regimes in all chapters of Section III, for additional information on historical fire regimes.

Recent Wildland Fire

Wildfire plays a role in the Wyoming Basin ecoregion. We compiled fire-occurrence data from multiple sources (see Wildland Fire section in the Appendix). The 33-yr record of all wildfire occurrences in the ecoregion indicates that approximately 616,263 hectares (ha) (1,522,169 acres) or 3.7 percent of the ecoregion has been affected by wildfire from 1980−2012. The wildfires that met the minimum size (16.2 ha or 40 acres) for mapping are shown in figure 5–1. The annual average area burned is 18,674 ha (46,100 acres). The annual area burned is widely variable, ranging from a high of 130,207 ha (321,498 acres) in 2000 to zero area reported in 1982 (fig. 5–2). Wildfire can occur anywhere within the ecoregion but is concentrated in three communities: sagebrush steppe, foothills shrubland, and montane/subalpine. Of all wildfires, 94.5 percent occurred within these communities (table 5–1) in the 33-yr period.

Using fire occurrences from 1980 to 2012, the contemporary fire rotation was calculated to be 989 yr for sagebrush-steppe, 782 yr in the foothills shrubland, and 509 yr in the montane/subalpine communities in the Wyoming Basin (table 5−1). In other words, given recent burning rates, this is the length of time required for an area equal to the total area of a specific community to burn. Some portions of these communities likely will burn more frequently and other areas may burn less frequently; thus, mean fire-return intervals for individual points on the landscape (averaged over the same 33-yr period) also will be expected to vary, but the average mean fire-return interval across an adequate number of sample points on this landscape would also equal the calculated fire rotation years (that is, population mean fire-return interval = fire rotation) (from Romme, 1980; Baker, 2009). Other work done in the region by Baker (2006) calculates the historic fire rotation from 240−450 yr in the sagebrush vegetation types. The different ranges in fire rotations could be attributed to climatic patterns and changes in patterns of land use (fragmentation) as well as management actions such as wildfire suppression and grazing.

Prescribed-fire activities take place across all jurisdictions and ownerships in the Wyoming Basin ecoregion, with an annual average of 1,862 ha (4,596 acres) treated by prescribed fire (fig. 5–2). Table 5–2 lists areas of prescribed fire, by community, from 1980–2012. Of the area burned by prescribed fire, 91 percent has been in the sagebrush steppe, foothill shrubland and montane/subalpine communities.

Current Climatic Effects on Wildfire

Large-scale climatic patterns can lead to regional synchronization of large wildfires (Brown and others, 2004). Swetnam and Betancourt (1998) note that the more synchronized wildfires are across the landscape, the stronger the climatic signal. Cursory analysis of the wildfire patterns in the three primary communities in the Wyoming Basin Ecoregion indicates a limited synchronicity in areas burned. Seven of the ten largest totals of burned area for all three communities occurred in 1988, 1996, 1999, 2000, 2002, 2006, and 2012. Five of the ten lowest totals of burned area for all three communities occurred in 1981–1984 and 1990 (fig. 5–2).

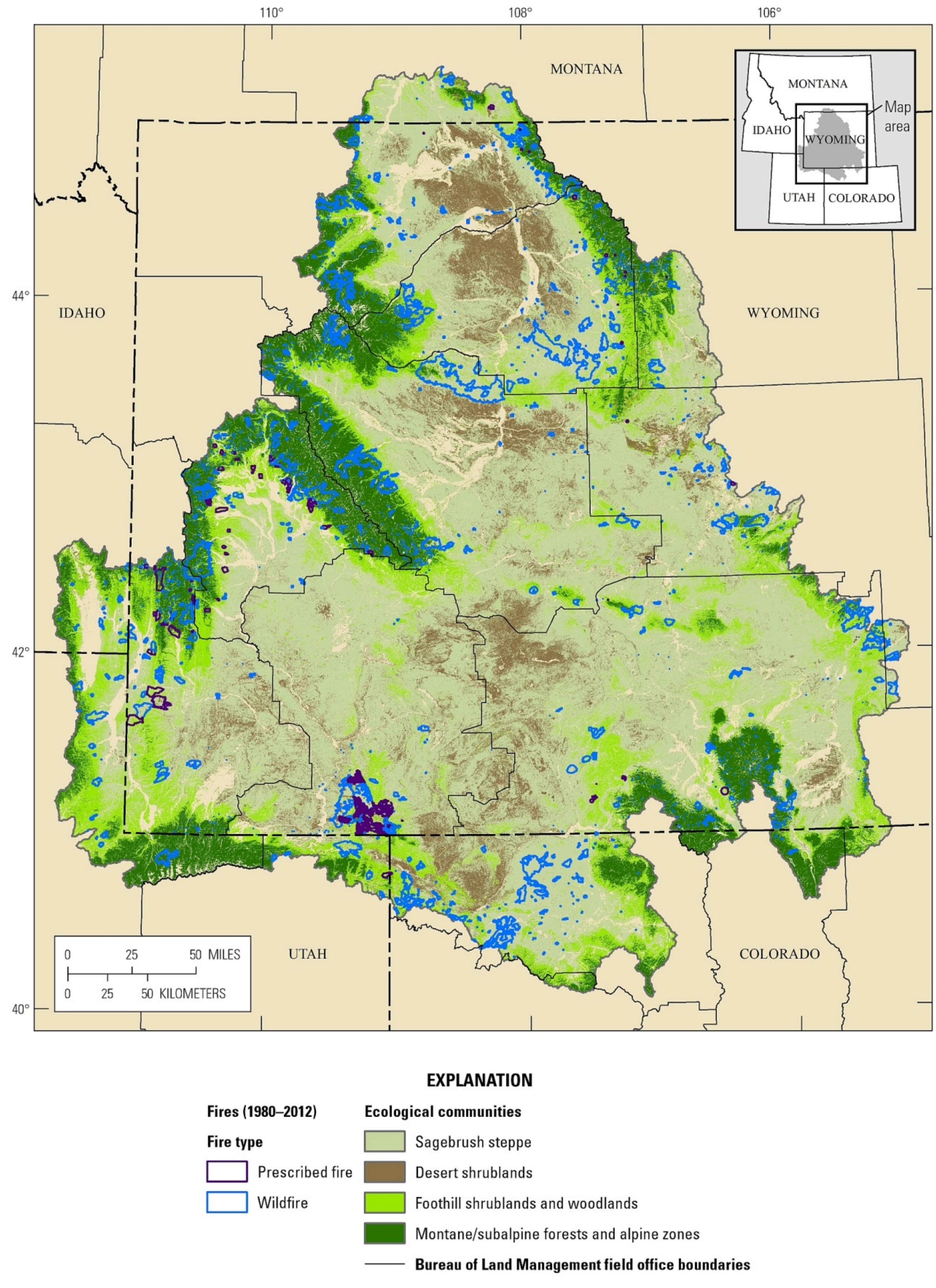

Figure 5-1. Wildfire and prescribed fire locations and perimeters (1980–2012) in the Wyoming Basin Rapid Ecoregional Assessment project area. Small wildfires are not visible at this scale. Minimum mapping acreage for wildfire is 16.2 hectares (ha) (40 acres). All prescribed fires are mapped.

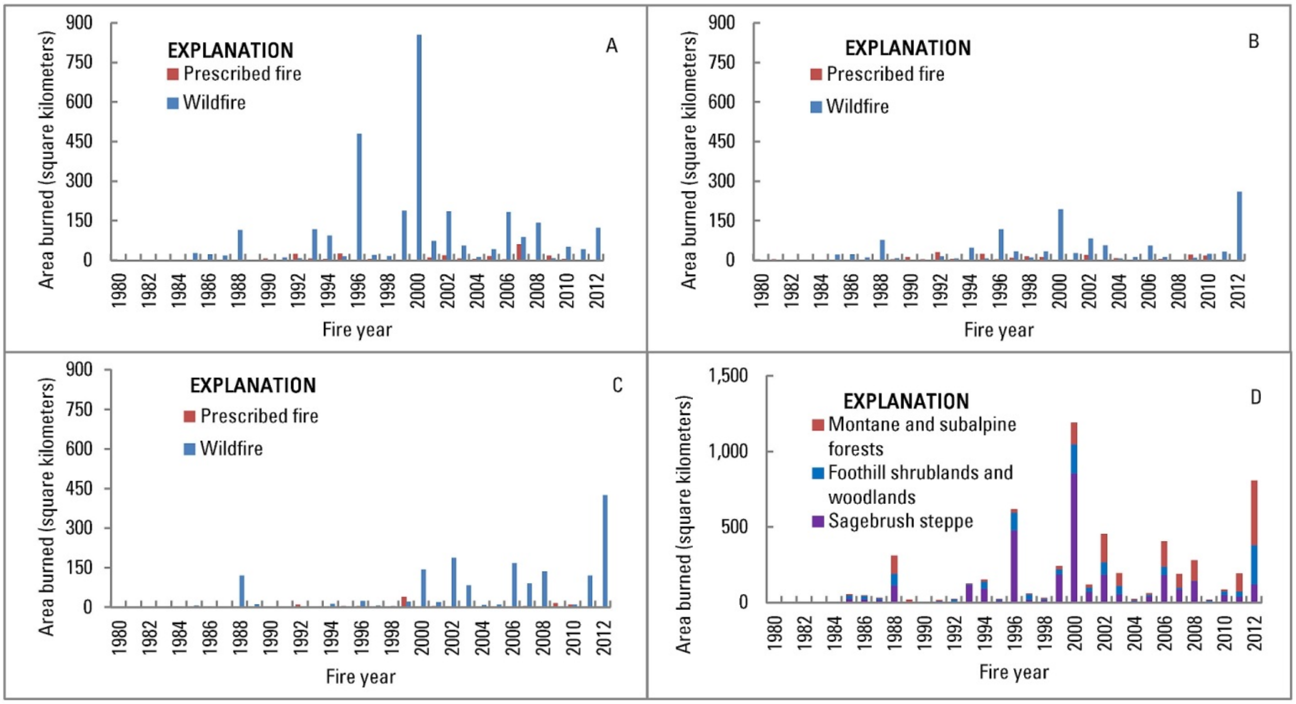

Figure 5-2. Area burned by wildfire and prescribed fire, by year, 1980−2012. Annual area burned in (*A*) sagebrush steppe; (*B*) foothill shrublands and woodlands; (*C*) montane/subalpine; and (*D*) all three major ecological communities.

Table 5-1. Large wildfire total area burned and annual average, by selected ecological community, in the Wyoming Basin Ecoregion, 1980−2012.

[ha, hectare; no., number]

Ecological communities	Total area (ha)	Total area burned by wildfire (ha)	Total percent burned	Average annual area (ha) burned by wildfire	Percent of total wildfire in ecoregion	Fire rotation (no. years)[1]
Sagebrush steppe	9,008,500	300,491	3.34	9,106	48.8	989
Foothills shrubland	2,849,200	120,151	4.21	3,641	19.5	782
Montane/subalpine	2,490,300	161,563	6.48	4,896	26.2	509
Other (primarily riparian forests and desert shrublands)	2,532,500	34,058	1.34	1,032	5.5	2,454
Total all native communities	16,880,500	616,263	3.7	18,674	100	904

[1] Fire rotation is the length of time necessary for an area equal to the entire area of interest (the community) to burn. Size of the area of interest must be clearly specified. This definition does not imply that the entire area will burn during a cycle; some sites may burn several times and others not at all (Romme, 1980; Baker, 2009).

Table 5-2. Prescribed fire total area burned and annual average, by community, in the Wyoming Basin Ecoregion, 1980−2012.

[ha, hectare]

Ecological community	Total area treated by prescribed fire (ha)	Average annual area treated by prescribed fire (ha)	Percent total prescribed fire area (acre)
Sagebrush steppe	23,882	724	39
Foothill shrubland	21,131	640	34
Montane/subalpine	10,946	332	18
Other[1]	5,472	166	9
All native communities	61,431	1,862	100

[1] Primarily riparian forests and desert shrublands.

The montane/subalpine system is an "energy-limited" community that has a relatively mesic climate. The sagebrush steppe and foothill shrublands have a more xeric climate and are "moisture limited." Work on the interaction of climate, fire, and fuels in the Rocky Mountains indicated that, in the energy-limited montane and subalpine forests, climate has been the driving factor in occurrences of large wildfires, and suppression activities have played a limited role in these areas (Schoennagel and others, 2004). Schoennagel and others (2004) concluded that the long return intervals between naturally occurring wildfires have not been significantly modified by human activities. The lower-elevation, moisture-limited areas are the most affected by human actions, particularly in lower-elevation ponderosa pine, woodland, and shrubland ecosystems in the ecoregion. Overall, however, the apparent synchronization of very large wildfires that burn across a variety of ecological communities indicates the importance of climate as a major driver of wildfire (Littell and others, 2009).

Future Potential of Wildfire

Projected climate change could cause significant changes in wildfire frequency and extent. "Energy-limited" forested communities may have an increase in wildfire due to earlier melting of the snowpack and an increase in drying throughout the growing season, leading to vegetation conditions that are more conducive to burning. The "moisture-limited" communities may undergo a decrease in wildfire due to the reduced availability of moisture for growth of fine fuels (grass) (National Research Council, 2011). The length of the wildfire season has increased since the 1980s by an average of 78 days (Westerling and others, 2006). Westerling and others (2006) demonstrated the relationship between early spring snowmelt and frequency of wildfire in forested areas of the western United States.

To calculate the potential effects of climate change on wildfire, Liu and others (2013) and Brown and others (2004) used downscaled climate models to calculate projected changes in the Keetch-Byram Drought Index (KBDI) (Liu and others, 2013) and the Energy Release Component (ERC) (Brown and others, 2004). Both the KBDI and ERC are commonly used indices to project the potential and risk of wildfire. Liu and others (2013) found that, compared to the baseline of 1971−2000, the KBDI from 2041−2071 may increase by up to 20 percent throughout the Wyoming Basin, with the largest increases occurring annually in the fall. The potential increases could shift most of the Wyoming Basin into the high fire potential. The ERC work projects an increase in the number of days at the ERC threshold of 41−59 (ERC of more than 60 indicates potential for extreme fire events) (Brown and others, 2004). The greatest projected increases that exceeded the threshold are along the mountainous western portion of the Wyoming Basin. The lower-elevation, interior portions of the Wyoming Basin are not projected to have significant increases in ERC.

Potential Effects of Invasive Species on Wildfire

There is a significant potential for cheatgrass to expand in the Wyoming Basin (see Chapter 7—Climate Analysis and Chapter 6—Terrestrial Invasive Plant Species). This is due to complex feedback loops and synergistic interactions between rising CO_2 levels, changing precipitation patterns, reduced snowpacks at lower elevations, and changing patterns in wildfire. A significant expansion of cheatgrass could greatly increase both wildfire occurrence and size.

Potential Effects of Shifting Ecological Communities on Wildfire

There is a potential for significant shift of communities (that is, localized extinctions and expansions) in response to climatic conditions across the Wyoming Basin landscape. This shift also may be influenced by wildfire. Disturbances are often drivers for rapid changes in vegetative communities under changing climatic patterns (Johnstone and others, 2010; Littell and others, 2010a; Littell and others 2010b). Wildfire (and other disturbance agents) can act as agents of rapid change on vegetative communities. For example, in the energy-limited ponderosa pine community, ponderosa pine may be at risk of decline due to changing climate in the more xeric sites (Dodson and Root, 2013). This results from decreased availability of soil moisture, which is critical for seedling establishment and growth. Older trees, which can use deeper soil water, are not as sensitive to decreasing soil moisture (but see Allen and others [2010] regarding forest die-off). A stand-replacing wildfire that kills the ponderosa pine overstory could rapidly convert these forests to another forest type or shrubland- and grassland-dominated community if suitable conditions for seedling establishment and growth are no longer present due to changing climatic conditions.

The flammability of the landscape and fire rotations changes as new vegetative communities form. Keane and Loehman (2013) found that, under projected climate change, crown fires in the Central Yellowstone Plateau may increase in size and frequency, while forest basal area may decrease (a surrogate for stand structure). This may potentially shift this energy-limited, forested landscape to a more grass- and shrub-dominated landscape.

Projecting Future Area Burned for Ecosections in the Wyoming Basin Region

Littell and others (2009) and Littell and Gwozdz (2011) showed that the relation between area burned by fire and climate varies considerably across different ecosystems. The probable causes are differences in the way vegetation (fuels) responds to climatic factors, which in turn influences productivity (fuel availability) and fuel moisture (fuel flammability).

At the coarse scale of Bailey's ecoprovinces (Bailey, 1995; fig. 3 in Littell, 2011), the subregional differences in fuels can be masked by regional relationships that are "averaged" over large areas. To address this issue, Littell and others (2010) and Littell and Gwozdz (2011) introduced fire-climate regression models for Bailey's ecosections (fig. 5–3), one ecosystem classification level below the ecoprovince in the Bailey system, for the Pacific Northwest (Columbia Basin and western Montana). These finer-resolution models have fuel characteristics similar to those of ecoprovinces but have important consequences for fire behavior at finer scales. For example, variability in area burned in forested systems from 1980–2009 was primarily related to climate variables associated with lower-than-normal fuel moisture and hydrologic variables. In contrast, variability in area burned in nonforested systems was negatively related to variables affecting fuel moisture, but also to variables affecting vegetation productivity and fuel continuity due to increased precipitation and decreased temperature, among other factors.

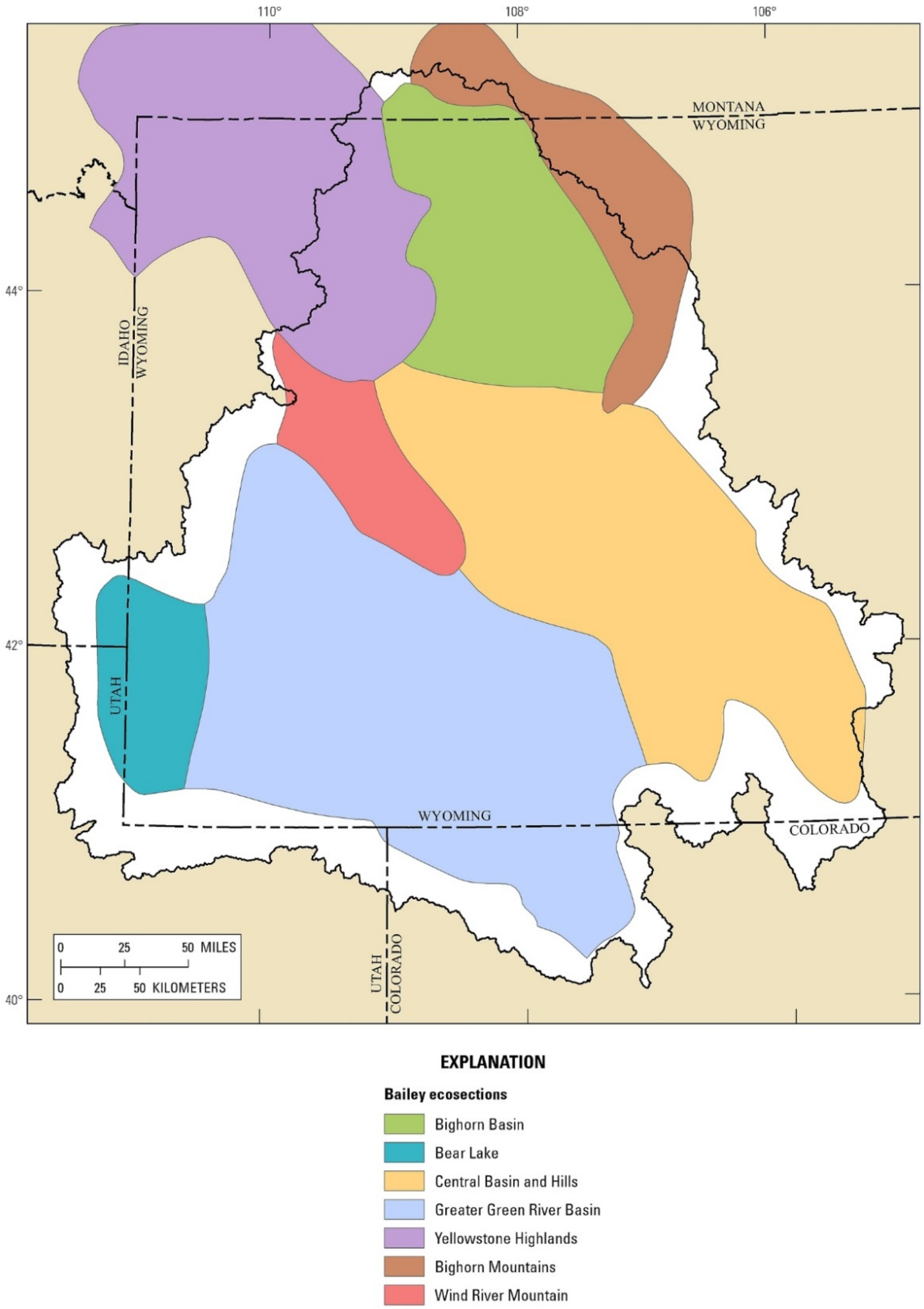

Figure 5-3. Bailey ecosections used for fire-climate modeling and projections of future fire in the Wyoming Basin Rapid Ecoregional Assessment project area.

The hydrologic output required for assessing the relationship between fire and climate for the Wyoming Basin Ecoregion was developed by Littell and others (2011) (see Wildland Fire section in the Appendix for listing of variables). In the analysis described in this chapter, we used climatic and hydrologic variables that have been associated with fire activity, including temperature, precipitation, soil moisture, snow pack (estimated by snow-water equivalent), relative humidity, vapor-pressure deficit, potential evapotranspiration, and actual evapotranspiration.

To understand fire-climate relationships among ecosections within the Wyoming Basin ecoregion (fig. 5–3), we followed methods in Littell and others (2010) and Littell and Gwozdz (2011) and aggregated observations of area burned from the National Interagency Fire Management Integrated Database, based on administrative unit.

We evaluated 1980−2006 data for area burned to eliminate duplicate observations and other obvious attribution errors. We then assigned total area burned to the appropriate Bailey's ecosection using the percentage of area burned reported for protected areas under the jurisdiction of the U.S. Department of Agriculture Forest Service (hereafter, Forest Service), National Park Service, U.S. Fish and Wildlife Service, Bureau of Land Management, the Bureau of Indian Affairs, and where reported on private and State lands. Summary statistics describing the distribution of area burned are presented in table 5–3. Most of the annual records are dominated by low annual acreage burned, with a few years of large acreage burned.

Table 5-3. Historical (1980−2006) area burned, by ecosection, and estimated percentiles, in the Wyoming Basin Ecoregion project area.

[ha, hectare]

		Area burned (ha) 1980−2006				
Ecosection	Area (ha)	Mean	Median	90th percentile	95th percentile	99th percentile
Yellowstone Highlands section	3,463,650	219	92	7,645	29,586	225,727
Bighorn Mountains section	1,339,790	19	17	285	1.142	2,450
Wind River Mountain section	777,886	4	1	125	391	3,099
Bighorn Basin section	1,979,330	185	248	1,685	3,068	12,335
Bear Lake section	790,610	2	1	6	57	184
Central Basin and Hills section	4,057,690	353	301	2,382	6,782	18,622
Greater Green River Basin section	5,085,790	301	299	2,919	6,894	11,934

We then developed regressions of area burned as a function of climate, and then considered climate in the two years prior to the observed fire season, similar to what was done by Littell and others (2009). Relationships among fire size and intensity and climate facilitation of fire (for example, increased productivity or fuel production) were generally weak compared to the relationships between fire size and intensity and variables indicating moisture limitation. The snow-water equivalent in winters prior to the fire season was a secondary, negative predictor of fire size and intensity in both the Bighorn Basin and Central Basin and Hills sections, indicating that some role of winter drought is evident independent of summer water demand. The regression models used for future projections are described in the Wildland Fire section in the Appendix. We were able to develop acceptable models for all ecosections except the Bear Lake section (see table A-20 in the Appendix).

For the projections in this report, we used future downscaled climate and hydrologic projections from Littell and others (2011), aggregated by Bailey ecosection level. The mean climate variables for the 2040s (2030–2059) and 2080s (2070–2099) were available from Littell and others (2011) and were used in the regression models to project the expected area burned given the mean climate estimates. We developed projections for an ensemble of 10 global climate models for the Special Report on Emissions Scenarios, emissions scenario A1B (Nakicenovic and others, 2000) (see the Wildland Fire section in the Appendix for details on methods).

It is important to note that these projected values are derived from the mean future climate projected for the ecosections and not the full range of variability encountered in the 20th and 21st centuries. Better estimates of the *range* of projected future fire responses could be developed with interannual time series of future projections (which exist, but have not yet been aggregated to the scale of the fire data). This is particularly key for fire responses, which have a nonlinear distribution.

Mean area burned is projected to increase by the 2040s in all ecosections except the Bighorn Mountains section, (table 5–4; fig. 5–4). In all ecosections except the Yellowstone Highlands section, the potential increase in total area burned is more than 1,000 ha (2471.1 acres) for the composite of 10 global climate models (GCMs) and any individual bracketing GCM. By the 2080s, increases in area burned are projected to be considerably larger (and proportionally large even for the Wind River Mountain section) except in the Bighorn Mountains section, where area burned is projected to decrease. This potential for increasing area burned may be driven by increased flammability of fuels. Future composite projections of mean area burned are clearly outside the modeled confidence intervals for the historical mean for the Yellowstone Highlands and Wind River Mountain sections for the 2040s and 2080s and for Bighorn Basin section in the 2080s (fig. 5–4).

The projected mean area burned for each of the ecosections in the Wyoming Basin Ecoregion indicates the potential for an increase in fire activity throughout the ecoregion. For all ecosections except the Yellowstone Highlands, the historical and projected area burned acreages are comparatively small even though the percent of change is very large in some ecosections. This suggests that the potential for climatically driven disturbance effects on the rate of landscape evolution within the Wyoming Basin Ecoregion may be less rapid than that projected for some systems in which fire occurrence appears much more sensitive to climate and, possibly, where fuels are more contiguous or abundant.

Table 5-4. Projections of mean area burned for the composite global climate models using A1B scenario (see Wildland Fire section in the Appendix) historical (1980–2006) area burned, by ecosection, and estimated percentiles, in the Wyoming Basin Ecoregion project area.

Ecosection	1980–2006 Historical modeled	Hectares burned 2040 Composite	2040 Range	2080 Composite	2080 Range
Yellowstone Highlands section	169	1,219	208–5,116	4,792	425–1,779
Bighorn Mountains section	21	15	8–18	12	5–20
Wind River Mountain section	5	38	17–59	183	53–1,158
Bighorn Basin section	185	637	514–939	1,085	842–1,605
Central Basin and Hills section	27	149	122–249	632	200–1,962
Greater Green River Basin section	355	554	333–1,059	633	289–2,355

There are four key considerations in interpreting the projected values for mean area burned.

1. Unlike much larger areas or ecosections in other parts of the West, the ecosections in the Wyoming Basin Ecoregion have low amounts of area burned on average, but very high amounts of area burned in the most extreme years compared to an "average year." This creates statistical challenges whereby the models may not perform as well as over larger areas.
2. As noted in table 5–3, the mean area burned is very low compared to the 90th, 95th, and 99th percentiles. The full range of extreme values was not evaluated, however.
3. When using seasonal projections of climate, it is assumed the future fire season will be similar to the length of the recent (1980–2006) fire seasons. It is possible that the fire season may begin earlier and/or last longer, which could render these projections conservative for the mid-21st century. It is also possible that vegetation communities may shift.
4. These models assume that both ignitions and vegetation distribution are similar to historical norms. This assumption may not be valid late in the 21st century if fires (along with changes in land use) lead to vegetative shifts, thereby creating novel landscapes unlike those used as a baseline for the current historical modeling scenarios.

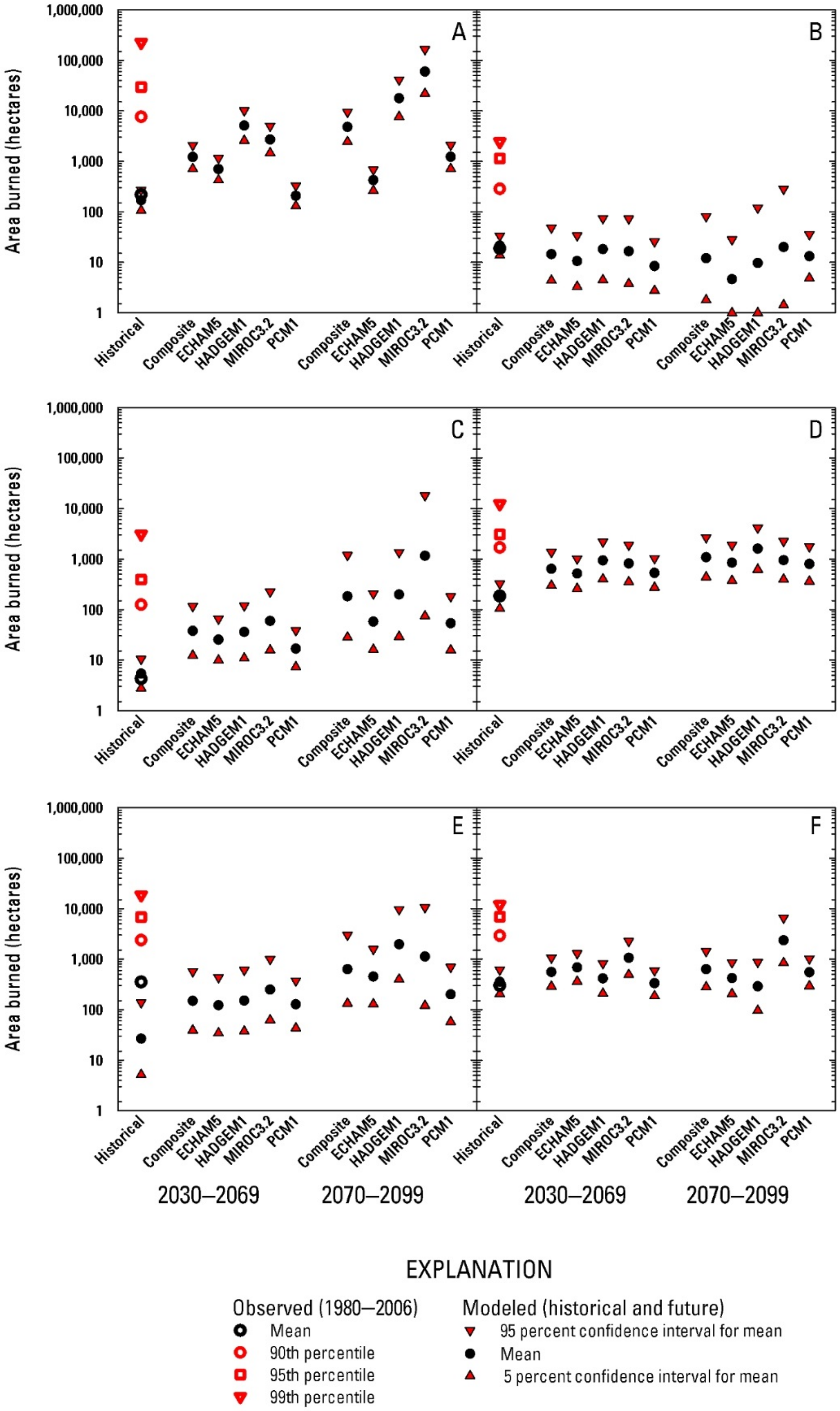

Figure 5-4. Historical observed (1980−2006), modeled historical, and projected area burned for 2040s (2030−2059) and 2080s (2070−2099) for Bailey's ecosections. (*A*) Yellowstone Highlands; (*B*) Bighorn Mountains; (*C*) Wind River Mountains; (*D*) Bighorn Basin; (*E*) Central Basin and Hills; and (*F*) Green River Basin, from downscaled historical and future climate and hydrologic projections (Littell and others, 2011) and statistical fire-climate models in table 5–4. A composite-average of 10 CMIP3 GCMs (see text) and four downscaled climate models (ECHAM5, HADGEM1, MIROC3.2. and PCM1) were used to develop projections for 30-year windows centered on the 2040s (2030−2059) and the 2080s (2070−2099) under emissions scenario SRES A1B. "Observed" refers to observed fire totals during the historical period, while "modeled historical" refers to each statistical model's ability to model the observed area burned from historical climate. Note that modeled historical for ecosection 342F underpredicts historical area burned, likely due to assignment of historical averages to lagged climatic effects.

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