APPENDIX D

COARSE-FILTER CONSERVATION ELEMENT AND ANALYSES

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APPENDIX D-1

EVERGREEN FOREST WOODLAND COARSE-FILTER CONSERVATION ELEMENT ANALYSIS FOR THE MIDDLE ROCKIES ECOREGION

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1.0 INTRODUCTION

The evergreen forest woodland vegetation system encompasses nearly 25 percent of the Middle Rockies ecoregion. Because some of the Gap Analysis Program (GAP) Level 3 systems comprise very small portions of this ecoregion, it was necessary to combine them so that they would be representative of major forest and woodland systems in the Middle Rockies. This coarse-filter analysis focuses on the following five (5) GAP Level 3 Systems: Rocky Mountain Lodgepole Pine Forest, Rocky Mountain Subalpine Spruce-Fir Forest and Woodland, Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland, Middle Rocky Mountain Montane Douglas-fir Forest and Woodland, and Northwestern Great Plains – Black Hills Ponderosa Pine Woodland and Savanna.

A variety of the management questions (MQs) apply to this assemblage. Many of the MQs can be summarized into two primary questions: 1) where are the important areas for this assemblage? and 2) what is happening to those areas? The central focus of these two MQs is to document the current status of selected conservation elements (CEs) at the ecoregional scale and to evaluate how this status may change over a future time period. The first step is to identify suitable habitat for the CE within the ecoregion. Then, these areas are assessed relative to current and potential future change agent (CA) threats. CAs considered in this analysis include climate change, wildfire, and insect outbreak and disease.

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2.0 CONSERVATION ELEMENT DESCRIPTION

The Level 3 systems represented in this model are briefly described below.

2.1 ROCKY MOUNTAIN LODGEPOLE PINE FOREST

This forested system is widespread in upper montane to subalpine zones of the Montana Rocky Mountains on flats to slopes of all degrees and aspect, as well as valley bottoms. This system generally occurs on dry to intermediate sites with a wide seasonal range of temperatures and long precipitation-free periods in summer. Vegetation is dominated by lodgepole pine (*Pinus contorta*) with shrub, grass, or barren understories (Montana Field Guide 2011a).

Historically, the frequency of fires varied between 50 and 400 years and their severity resulted in a diverse mosaic of age classes and species mixtures. In fire-generated stands of similar age, trees become susceptible to mountain pine beetle (MPB) (*Dendroctonus ponderosae*) and lodgepole pine dwarf mistletoe (*Arceuthobium americanum*) infestations at approximately the same time, resulting in large-scale infestations and mortality. Very large scale, stand-replacing fires have occurred frequently throughout Montana during the past 20 years (Montana Field Guide 2011a). In addition, the 1988 Yellowstone fires burned approximately 1.4 million acres, which included areas in Idaho and Wyoming.

2.2 ROCKY MOUNTAIN SUBALPINE SPRUCE-FIR FOREST AND WOODLAND

This system is found on gentle to very-steep mountain slopes, high-elevation ridgetops, plateau-like surfaces, basins, alluvial terraces, well-drained benches, and inactive stream terraces. Forests are closed-to-open and usually dominated by Engelmann Spruce (*Picea engelmannii*) and/or Subalpine fir (*Abies lasiocarpa*), with taller shrubs in the understory (Crawford 2011).

A high-severity/low-frequency fire regime typically characterizes spruce-fir forests (Agee 1993). This results from the subalpine environment that influences flammability and fire spread and, in combination with weather, limits fires occurrences to only a few weeks in late summer (Jenkins et al. 2008). Large scale insect infestations may create conditions that lead to large, stand-replacement fires (Crawford 2011).

2.3 MIDDLE ROCKY MOUNTAIN MONTANE DOUGLAS-FIR FOREST AND WOODLAND

This system occurs from lower montane to lower subalpine environments and is prevalent on calcareous substrates. It is a Douglas-fir (*Pseudotsuga menziesii*) dominated system without any maritime floristic composition.

Fire disturbance intervals are as infrequent as 500 years and, as a result, individual trees and forests can attain great age on some sites (500 to 1,500 years). In the absence of disturbance, Douglas-fir is the only species that continues to regenerate under shaded conditions; it becomes dominant in undisturbed stands (Montana Field Guide 2011b).

In recent years, these forests have been subjected to prolonged periods of drought, creating conditions where stands are susceptible to outbreaks of Douglas-fir tussock moth (*Orgyia pseudotsugata*) and Douglas-fir bark beetle (*Dendroctonus pseudotsugae*) (Montana Field Guide 2011b).

2.4 NORTHWESTERN GREAT PLAINS – BLACK HILLS PONDEROSA PINE WOODLAND AND SAVANNA

This system occurs primarily on gentle-to-steep slopes along escarpments, buttes, canyons, rock outcrops, or ravines and can spread into the surrounding prairie system. These woodlands can be physiognomically variable, ranging from very sparse patches of trees on drier sites, to nearly closed-canopy forest stands on north slopes or in draws where available soil moisture is higher (NatureServe 2009).

This woodland and savanna system is primarily dominated by ponderosa pine (*Pinus ponderosa*) but sometime includes a sparse to relatively dense understory of Rocky mountain juniper (*Juniperus scopulorum*) with just a few scattered trees. An important component of this system in some areas (western Dakotas, Black Hills) is deciduous trees (quaking aspen [*Populus tremuloides*], etc.) which can sometimes be codominant with the ponderosa pine (NatureServe 2009).

In the absence of natural fire, periodic prescribed burns, selective thinning, and reduction of ladder and basal fuels to prevent crown fires can be used to maintain and restore this system to similar pre-settlement conditions (Montana Field Guide 2011c).

Threats to the system include surface fires, frequent on drier sites, and invasive cheatgrass (*Bromus tectorum*) induced by reduced associated grasses from grazing livestock (Montana Field Guide 2011c).

3.0 CONSERVATION ELEMENT DISTRIBUTION MAPPING

3.1 DATA IDENTIFICATION

The major datasets identified to map the distribution of the evergreen forest woodland CE were the GAP landcover and Landscape Fire and Resource Management Planning Tools Project (LANDFIRE) datasets. Both datasets have adequate coverage across the ecoregion and have been used in similar analyses. The evergreen forest and woodland distribution datasets are further described in Table D-1-1.

Table D-1-1. Data Sources for the Evergreen Forest Woodland Coarse-Filter Conservation Element Distribution Mapping for the Middle Rockies Ecoregion

Data Needs	Dataset Name	Source Agency	Type/Scale	Status	Use in REA
Terrestrial Systems					
Ecological Systems	GAP Land Cover Northwest Regional Gap Analysis Program (ReGAP) North Central GAP	U.S. Geological Survey (USGS)	Raster (30-meter [m])	Acquired	Yes
	LANDFIRE	LANDFIRE	Raster	Acquired	No
Soils Data	Soil Survey Geographic (SSURGO) State Soil Geographic (STATSGO2)	U.S. Department of Agriculture (USDA)	Raster or Polygon	Acquired	No

3.2 DISTRIBUTION MAPPING METHODS

To map distribution of evergreen forest and woodlands in the Middle Rockies ecoregion, Science Applications International Corporation (SAIC) used a mosaic of GAP data sources, including two of the National GAP landcover regions, the Northwest and North Central. The source data for the Northwest region was the Northwest Regional Gap Analysis Program (ReGAP) dataset, which improved upon the original Northwest GAP. The North Central region contains states that have not been covered by a ReGAP project. For these areas, the National GAP layer used data from the LANDFIRE project to create a seamless layer. The GAP was developed to help answer questions about species biodiversity and species habitat (USGS 2010). Its overall goal is to assist resource managers in decision making when there is a lack of information about the full range of species on the landscape. Once the data were downloaded, the two datasets were merged together to form a continuous layer of vegetation data across the four states. The continuous data layer was then clipped to the Middle Rockies ecoregion, at which point the Level 3 systems were extracted for review by the Rolling Review Team (RRT) (Figure D-1-1).

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4.0 CONCEPTUAL MODEL

The current status and potential future threat analyses were based on the system-level conceptual models, selected environmental variables (Key Ecological Attributes [KEAs]) likely to be at risk from the CAs, and the availability of data.

4.1 SYSTEM-LEVEL MODEL

The system-level model for the Middle Rockies evergreen forest and woodland system (Figure D-1-2) illustrates the major drivers across the top. The major drivers dictate where these vegetation systems occur throughout the ecoregion, while the CAs focus on what has potential to affect this CE over time. Below the CAs are the corresponding CA pathways that affect both the status and distribution of this CE across the Middle Rockies ecoregion. Listed below the CA pathways are the three categories of size, context, and condition for development of the KEAs for this coarse-filter CE. The KEAs were developed and refined through the rolling review process.

4.1.1 Wildfire

Pre-settlement fire regimes may have been characterized by frequent, low-intensity ground fires that maintained relatively open stands of a mix of fire-resistant species. Under present conditions the fire regime is mixed severity and more variable, with stand-replacing fire more common, and the forests are more homogeneous. With vigorous fire suppression, longer fire return intervals (FRIs) are now the rule, and multi-layered stands of Douglas-fir, ponderosa pine and/or grand fir provide fuel ladders, making these forests more susceptible to high-intensity, stand-replacing fires. In some areas of the Middle Rockies fire suppression and altered fire regimes have resulted in decreased stand diversity and increased fuel loads. Mortality due to bark beetles is also increasing fuel loads, creating conditions for severe, large-scale, catastrophic fires.

4.1.2 Insect Outbreaks and Disease

Native bark beetles such as MPB exist at endemic levels in Rocky Mountain conifer forests, causing a relatively low level of mortality that mostly affects older or stressed individuals (Samman and Logan 2000). Outbreaks occur when environmental conditions such as warmer temperatures promote large beetle populations and large numbers of susceptible host trees are available. MPB is a native species that has unique eruption outbreak characteristics and historically was largely confined to lower elevation lodgepole and ponderosa forests except during abnormal climatic events (Logan et al. 2010, Raffa et al. 2008). MPB also attacks larger trees, generally those of reproductive age, and must attack in mass in order to overcome the tree's defenses, so developmental synchronization (fostered by thermal regimes) and adult communications that coordinate a mass attack are critical to its success (Raffa et al. 2008). MPB is endemic in lodgepole-ponderosa pine forests and periodically temperature-driven eruptive outbreaks occur in these forests and in upper treeline five-needle pine forests and woodlands (the most recent having started in the 1980s).

Douglas-fir ecological systems are widespread in the ecoregion on a range of sites and elevations, and frequently involve associations of Douglas-fir with several other codominant tree species. For this reason, several insect damage agents may affect these systems, often acting in concert. Douglas-fir beetle (DFB) and Western spruce budworm (WSBW) have had significant outbreaks in Douglas-fir associations in the past decade. WSBW is a widespread defoliator in the Middle Rockies. Repeated defoliation events can decrease tree growth, cause mortality, or increase susceptibility of trees to other damage agents such as bark beetles.

4.1.3 Climate Change

Global climate change (GCC) effects and natural fire regimes are thought to have complex interactions with biotic mortality/damage agents. GCC is predicted to drive the upper tree line to higher elevations, although there may be local thermal refugia due to cold air drainage and aspect. Increased winter temperatures, longer growing seasons, and increased drought during the growing season may be playing major roles in MPB outbreaks. Fuel loads, FRIs, and severity may also be affected by GCC. GCC appears to exacerbate the effects of wildland fire and MPB outbreaks. Changes in precipitation and temperature are predicted to lead to more frequent drought stress on lodgepole-ponderosa pine forests, which will lead to greater vulnerability to MPB; this will in turn alter fuel loads and the fire regime, and, consequently, the age structure of woodlands and forests.

5.0 CHANGE AGENT ANALYSIS

A CA assessment was conducted on the evergreen CE for the Middle Rockies ecoregion with native 30-meter (m) raster data as the analysis unit. Based on the system-level model, KEAs were identified for the current status and future threat analyses, with a specific emphasis on the ability to measure impacts using existing geospatial data. For each analysis, a series of intermediate data layers were created based on the KEA indicators that are scored according to a designated metric and then ranked (good, fair, or poor). If necessary, data from multiple source datasets were combined.

Since the scale of the reporting unit is at the Hydrologic Unit Code (HUC) 12, a layer of 6^{th} level HUCs was extracted for the ecoregion. A geographic information system (GIS) process was iterated through the KEA indicators and determined the metric values associated with some watersheds. In other instances, sufficient published data indicated cut-off points for these values. These values were added as an attribute to the HUC 12 layer. The intermediate CA layers were then combined together to form a single layer outlining the current status or future threat status for each HUC.

Although numerous preliminary KEAs and indicators that may affect the evergreen forest woodlands were initially identified in the early phases of the REA, not all were included in this analysis because either the attribute or indicator was not suitable for a landscape level analysis or because data are not available to support the analysis. The specific indicators that could not be modeled are identified with an asterisk on Figure D-1-2. Further information on the data gaps for these indicators are discussed in the respective CA analyses contained in Appendix C.

For the KEAs that were determined to be duplicative, some were pixel-based, some were HUC-based, and others did not show any differentiation across the ecoregion. Table D-1-2 identifies the original KEAs and identifies which of those were used in the final CA analysis.

Table D-1-2. Key Ecological Attributes Retained or Excluded

Category	Key Ecological Attribute		Explanation
1. Size	a.	Size of Patches	This analysis was completed but not used because the RRT determined this was more of a fine-filter wildlife MQ.
2. Condition	a.	Vegetation Condition Class (VCC)	Retained to show the vegetation and fire regime departure in the ecoregion.
	b.	Invasive Species	Dropped due to insufficient data.
	c.	Insect Outbreak	Retained to show current outbreak of major insect threats in the ecoregion and future risk of outbreaks.
	d.	Future Protection	The analysis using the PADS databases was excluded because it did not capture the complexity of the issue/risk factor
3. Structure	a.	Fragmentation	Retained to show the fragmentation throughout the ecoregion.

5.1 CURRENT STATUS OF THE CONSERVATION ELEMENT

Table D-1-3 identifies the KEAs, indicators, and metrics that were used to evaluate the CAs and pathways affecting this CE across the ecoregion. The evergreen forest woodland process analysis is designed to create a series of intermediate layers that are primarily based on the wildfire and insect and disease outbreak CAs. The analysis is based on the geospatial data that was available.

5.1.1 Key Ecological Attribute Data Analysis for Current Status

For each of the KEAs listed in Table D-1-3, a discussion of the indicator, metric, metric rank and value, data source(s), and references is provided. Several indicators were used to assess the current threat status for the evergreen forests (Table D-1-3). This table was limited to landscape structure and condition based on spatially available attributes and key factors affecting evergreen forest woodlands in the ecoregion.

In most cases, the metrics used to identify attribute quality were based on available publications, coupled with expert analysis and professional judgment in association with data-driven metrics. This process was carried out through the establishment of a Forest and Woodlands RRT comprised of BLM Foresters. The RRT met periodically to contribute information and to analyze input attributes and outputs that were derived from various forms of spatial analyses in GIS. This process enabled the RRT to determine the efficacy of attributes, indicators, and metrics, as well as to ascertain the accuracy of each step of the modeling process. Weights were attributed to each metric in order to provide an overall score for all metrics combined, based on the reporting unit.

Table D-1-3. Key Ecological Attributes for the Evergreen Forest Woodland Coarse-Filter Conservation Element for the Middle Rockies Ecoregion

Category	Ecological Attribute	Indicator / Unit of Measure	Metric			Data Source	Citation	Weight
			Poor = 3	Fair = 2	Good = 1			
Landscape Structure	Structure	VCC	VCC 3	VCC 2	VCC 1	LANDFIRE	RRT Guidance	0.25
Landscape Condition	Insect outbreak	MPB Infestation on	>54%	21-54%	0-21%	Aerial Detection Survey (ADS)	RRT Guidance (Natural Breaks)	0.25
		"Other Beetle" Infestation	>53%	18-53%	0-18%	ADS	RRT Guidance (Natural Breaks)	0.25
		WSBW Infestation	>71%	26-71%	0-26%	ADS	RRT Guidance (Natural Breaks)	0.25

Analysis Unit = 30-m pixel
Reporting Unit = 6th level HUC

After much discussion, the evergreen forest woodlands RRT decided not to include patch size in the current status assessment. The decision was primarily made because there is no literature on optimum patch size for evergreen forest woodlands. All literature is focused on wildlife habitat requirements, which is included in the fine-filter CE analysis.

5.1.1.1 Vegetation Condition Class

For landscape structure, the LANDFIRE Vegetation Condition Class (VCC) data were used to show changes in vegetation and fuels from their historical condition. Three condition classes describe low departure (VCC 1), moderate departure (VCC 2), and high departure (VCC 3).For the Middle Rockies, a group of subject matter experts (SMEs) went through an exercise to illustrate fire regime (frequency and severity) departure. The historic biophysical setting (BpS) was attributed with a current fire severity and frequency and then compared with the reference (historic) fire frequency and severity for each type. From these data, we were able to develop a fire frequency departure map, a fire severity departure map, and then a composite map (which took the highest of either departure). This modified composite layer was used as the best indicator for potential threat to the evergreen forest from an uncharacteristic fire.

The VCC layer was extracted to the evergreen forest woodland layer. The data were already categorical, so VCC departure 1 was good, VCC departure 2 was fair, and VCC departure 3 was poor. The evergreen forest woodland VCC layer is displayed on Figure D-1-3.

5.1.1.2 Insect Outbreak

The bark beetles and the WSBW CAs are the greatest threats to evergreen forest woodlands. The Assessment Management Team (AMT) noted that the MPB is the most serious problem in the ecoregion; therefore, the RRT suggested that we analyze the MPB separate from other beetles and the WSBW. The "other beetles" discussed in this analysis that pose significant insect threats are the Douglas-fir beetle, Douglas-fir engraver beetle, pine engraver beetle, and spruce beetle. These beetles were combined together and analyzed as one threat for current status.

The U.S. Forest Service (USFS) Aerial Detection Survey (ADS) polygon data from 1994-2010 were used to map the insect presence in the evergreen forest woodland. The vector layers were converted to raster so they could be overlayed on the evergreen forest woodlands 30-m raster data. Zonal statistics were then run to determine the amount of infestation on evergreen forest woodland patches. The higher the percent infestation calculated from the analysis, the worse the score. The three classes of good, fair, and poor were determined using natural breaks. The natural breaks classifications were based on the inherent natural groupings in the data.

Figures D-1-4 through D-1-6 show the insect infestation score maps. Red displays patches with higher infestation, while green shows patches with lower infestation.

5.1.2 Current Status of Habitat

The individual KEA analysis provides the basis for the compilation of an overarching data layer that defines the current status of evergreen forest woodland habitat for each HUC across the Middle Rockies ecoregion. A method of aggregating scores was used to summarize overall status with regard to evergreen forest woodland habitat quality. Individual indicators can identify areas of potential risk to evergreen forest woodland populations, but aggregated scores can provide important information with relation to areas where evergreen forest woodland might encounter multiple CAs.

In order to create a combined score for each HUC unit based on varying levels of importance for each KEA, it is necessary to aggregate the data through a weighting process. The weighted sum tool was used to combine each analysis input map and create an overall current status map (Figure D-1-7). Equal weights were used when summing the indicators for the evergreen forest woodland.

The resulting output gives each evergreen forest woodland 30-m pixel a score based on current status. Figure D-1-7 displays these results; red indicates areas of poor status, while green indicates areas rated at a better current status based on the measured attributes.

The overall status score for each 6^{th} level HUC was assigned a current habitat quality rating of good, fair, or poor based on the natural breaks method. Statistics were run on the results from Figure D-1-7 to determine the average overall score. The overall result was then scored based on natural breaks. A higher overall status score would result in a rating of "poor" for the HUC, indicating that there are existing threats to the evergreen forest woodland based on the KEA metrics.

The results of the current status analysis based on the 6^{th} level HUC for the ecoregion are presented on Figure D-1-8. The overall current status results show relatively good-to-fair scores in the southern and southeastern portions of the ecoregion. Evergreen forests in areas such as the Bighorn Mountains, the Wind River Range, and Yellowstone National Park scored well for current status. However, areas in the north and northwest predominately scored poorly.

The results of the analysis for VCC showed a greater departure from historic conditions at lower elevations than at higher elevations (Figure D-1-3), although the Black Hills National Forest as a whole scored poorly for vegetation departure.

The insect infestation was shown to be wide spread, particularity for MPB infestation in the central, south-central, and southern regions of the Wind River Range (Figure D-1-4). The "other beetles" infestation areas with poor scores were more isolated.

A summary of the current status ratings based on the CE distribution is provided in Table D-1-4. The CE distribution layer was used to calculate the total number of square miles of CE habitat and a percentage of the total number of square miles per HUC that were rated as good, fair, or poor. The results of the current status assessment indicate that approximately 33 percent of the 6^{th} level HUC watersheds that intersect the evergreen forest distribution received an overall rating of good, 44 percent receiving an overall rating of fair, and 22.8 percent of the HUCs received an overall rating of poor.

Table D-1-4. Summary of Current Status Ratings for the Evergreen Forest

Overall Rating by 6th Level HUC	Total Square Miles[a]	Percentage of Total Square Miles[a, b]
Good	31,822	33.0
Fair	42,690	44.2
Poor	22,025	22.8

[a] These values include only the area of HUCs that intersect with the CE distribution layer.
[b] Values rounded to one decimal place.

5.2 FUTURE THREAT ANALYSIS

Future threat analysis was conducted for development, insect outbreak and disease, and climate change. Climate change was modeled based on a 15-km grid created for regional analysis. This analysis included a comparison of current climate patterns to future modeled climate patterns and resulted in the delta (change) output figures. Further details regarding the climate change analysis are provided in Appendix C-5.

Because of the inherent inaccuracies of the temporal scale of the future data, it is only possible to infer information pertaining to a subjective future period (rather than a specific time period) for some of these attributes. However, because of the limits placed on these data outputs, it is fair to assume that this model predicts the overall future potential for these attributes within this ecoregion.

5.2.1 Conservation Element-Specific Future Threats Analysis for Development and Insect Outbreak and Disease

5.2.1.1 Key Ecological Attributes Data Analysis for Future Threat Status

Table D-1-5 identifies the KEAs, indicators, and metrics that were used to evaluate the future threat CAs and pathways affecting this CE across the ecoregion (as illustrated on Figure D-1-1). The evergreen forest woodland analysis is designed to create a series of intermediate layers that are primarily based on the geospatial data available on the future projections for the CAs impacting this CE (Table D-1-5). Future KEAs were determined primarily by the availability of data relevant to the future status of the evergreen forest woodland.

Table D-1-5. Evergreen Forest Woodland Coarse-Filter Conservation Element Future Threat Attributes, Indicators, and Metrics for the Middle Rockies Ecoregion

Category	Ecological Attribute	Indicator / Unit of Measure	Metric			Data Source	Citation	Weight
			Poor = 3	Fair = 2	Good = 1			
Landscape Structure	Fragmentation	Distance Decay Proximity to anthropogenic layer	<0.31 miles	0.31-1.55 miles	>1.55 miles	Topologically Integrated Geographic Encoding and Referencing (TIGER), Integrated Climate and Land-Use Scenarios (ICLUS)	RRT Guidance	0.33
Landscape Condition	Insect Outbreak	Proximity to Insect Infestation	Insect Presence	0-2 miles	>2 miles	ADS	RRT Guidance based on Data	0.33

Analysis Unit = 30-m pixel
Reporting Unit = 6th level HUC

As with the current status analysis, the main CAs likely to cause risk to evergreen forest woodlands are the MBP, Western Spruce, Douglas-fir beetle, Douglas-fir engraver beetle, pine engraver beetle, and spruce beetle. There are no future models available for future insect/disease risks. Therefore, existing data were used based on several assumptions. For example, it is assumed that the closer an evergreen forest woodland stand is to an existing outbreak, the more likely it will be infested in the future. These insects were combined together and analyzed as one threat. For the future threat analysis, all insects were combined into one layer.

5.2.1.2 Fragmentation Potential

Originally, SAIC created a forest fragmentation index using a neighborhood analysis on the evergreen forest woodland layer. The analysis looked at each pixel classified as evergreen forest woodland and its neighbors. A 10x10 neighborhood was used for this analysis. There is no literature specific to the moving window size for this type of analysis. Several other windows were looked at, but the 10x10 window seemed most appropriate. The index is based on the number of evergreen forest woodland pixels surrounding each other.

This was presented to the RRT, but the ultimate decision was to use a distance decay method to determine potential fragmentation based on the proximity to development. The Integrated Climate and Land-Use Scenarios (ICLUS) 2030 was used by extracting the urban, exurban, and industrial categories and then merging it with the Topologically Integrated Geographic Encoding and Referencing (TIGER) roads for the entire ecoregion. A Euclidean distance proximity analysis was run from this anthropogenic layer and then scored. To maintain consistency with other coarse-filter analyses, scoring was based on KEAs from other coarse-filter CEs in the ecoregion. The resulting scoring classifications can be found in Table D-1-4. The fragmentation potential for the evergreen system is presented on Figure D-1-9.

5.2.1.3 Proximity to Insect Infestation

A Euclidean distance proximity analysis was run from the 1994-2010 USFS ADS polygon data. This analysis was completed based on the assumption the evergreen forest woodland stands closer to infestations are at higher risk in the future. The proximity analysis was extracted to the evergreen forest woodland and then scored based on Table D-1-4. The original scoring classification values were provided by the RRT. Those values were 0-5 miles = poor, 5-10 miles = fair, and >10 miles = good. However, with these values almost all evergreen patches were poor. SAIC then classified the data using 0-2 miles = poor; this resulted in most patches still rated as poor. The data were also evaluated using a quantile classification, resulting in patches with an infestation rated poor. Areas within 2 miles of an infested patch were scored fair and patches greater than 2 miles were scored good. This analysis was presented and accepted by the RRT. The proximity to insect infestation for the evergreen system is presented in Figure D-1-10.

5.2.2 Future Threats Overall Score

The future overall score was compiled using the methods described. Figure D-1-12 displays the overall combined score for future threats to evergreen forest woodlands, while Figure D-1-13 displays the overall combined score by 12-digit HUC. Equal weights were used when summing the threats for evergreen forest woodland.

The overall future threat map indicates predominately fair to poor habitat conditions based on potential development and insect outbreaks in middle portions of the Middle Rockies for the evergreen forest woodlands. Areas in the north-central portion of the ecoregion around Helena scored very poorly. Evergreen forests in the Black Hills area also scored poorly. However, there were some areas in and adjacent to Yellowstone National Park that scored well. Some forests in the Absaroka Range in northwestern Wyoming and south central Montana and areas in the northwest of the ecoregion also scored well.

Based on the scoring throughout the ecoregion, the results of fragmentation potential analysis (Figure D-1-9) have a fairly high potential due to roads and urban areas. Southern areas of the Black Hills National forest show up as being at higher risk for fragmentation. Though these areas are in a national forest, these data could be used to highlight areas of declining connectivity and a reduction in forest interior. The insect proximity analysis (Figure D-1-10) indicates that forests in the central and northwest portions of the ecoregion are at higher risk for insect infestation. Areas in and along the Black Hills

National Forest scored good and fair for future risk of infestation. Based on recent insect outbreaks and the predicted increase in temperatures, it is likely that the trend of severe bark beetle outbreaks will continue to occur.

5.2.3 Development

The ecoregion-wide future threat analysis was conducted, as presented in Appendix C-1, in addition to the KEA-specific analysis for development for this specific CE. For this broad assessment, development was limited to potential energy development and climate change, as this coarse filter appears to be at low risk from the threats from modeled urban growth based on the modeled growth for the ecoregion (Figure C-1-8) and potential agricultural development in forested areas.

5.2.3.1 Oil Production Potential

The future analysis characterized potential oil production areas rather than oil well locations (Figure C-1-4). These larger oil production extents were used to qualitatively assess the potential effect of future oil production activities. Although these areas are based on oil density data, the application of these data to future potential well site activity is unknown. Therefore, a carefully considered approach should be taken when assessing the effect of potential oil production areas on evergreen forest woodlands.

Most of the evergreen forest woodlands in this ecoregion are at low risk for oil production. The majority of potential oil production is limited to lower elevation areas in northern Wyoming. There is one area in north-central Montana that is at moderate risk from oil production development, but from an ecoregional scale it does not appear that evergreen forest woodlands are at a major risk from future oil production.

It is important to note that the Energy Policy and Conservation Act (EPCA) oil and gas data used in this assessment are based on the maximum potential for oil reserves within the Middle Rockies. As a result, these data are likely overly represented in these figures, and care should be taken in assessing the effects of oil and gas production within the constraints of this analysis.

5.2.3.2 Natural Gas Production Potential

The future analysis characterized potential gas production areas rather than actual gas well locations (Figure C-1-3). These larger gas production extents could be used to qualitatively assess the potential effect of future gas production activities. Although these areas are based on gas density data, the application of these data to future potential well site activity is unknown. Therefore, a carefully considered approach should be taken when assessing the effect of potential gas production areas on evergreen forest woodlands.

Most of the evergreen forest woodlands in this ecoregion are at low risk from gas production. The majority of potential gas production is limited to lower elevation areas in northern Wyoming where potential is limited. Like oil production, there is an area in north-central Montana that is at moderate risk from potential natural gas development, but from an ecoregional scale it does not appear that evergreen forest woodlands are at a high risk from future natural gas development.

5.2.3.3 Future Potential for Solar Development

As with wind energy, developers are less likely to site solar farms in forested areas versus more open areas. In addition, the elevations where this CE occurs are not conducive to solar development. This future potential analysis characterized the future potential for solar development based on the solar potential maps developed by the National Renewable Energy Laboratory (NREL). Although these maps are very crude, the highest potential risk for solar development is shown to occur primarily outside of the evergreen forest woodland distribution area; with the exception of some areas in the Black Hills and the Bighorn and Wind River Mountains, where evergreen forest woodlands are at low risk from future solar development.

5.2.3.4 Wind Turbine Potential

Wind energy development does not appear to be a risk to forests because developers would more likely site wind farms on open lands where clearing would not be required. However, the wind turbine potential map is presented on Figure C-1-7. Higher elevations within this ecoregion would be more susceptible to the risk of wind turbine development due to the higher wind speed levels within these areas. However, limited accessibility to these higher elevations could limit the range of wind turbine development to lower elevation mountainous regions.

The majority of the evergreen forest woodlands appear to be located in areas that are not favorable for wind development. Therefore, the risk of threat to this CE from wind development is considered minimal.

5.2.3.5 Overall Development Change Agent Future Threats

A fossil fuel energy output layer was created to address the MQs associated with future fossil fuels production. This layer was created by averaging the EPCA oil data layer with the EPCA gas data layer (Figure C-1-5). Most of the evergreen forest woodlands in the ecoregion appear to be at low risk for fossil fuels development in the Middle Rockies.

A renewable energy output layer was created to address the MQs associated with future renewable energy production. This layer was created by averaging the NREL wind speed data layer with the NREL solar energy data layer (Figure C-1-8). This output layer provides equal weighting to potential wind and solar energy production areas, and could therefore mischaracterize the effects of each. Unlike oil and gas, wind and solar energy are not necessarily closely associated with one another spatially. Photovoltaic solar arrays threaten the species by their effect on habitat availability. Solar arrays are diverse in scope and size and it is therefore difficult to create a clear correlation between habitat loss and solar energy production.

Because of the intricacies involved in the assessment of renewable energy production with regard to evergreen forest woodlands, a limited approach must be taken in this analysis. The majority of the evergreen forest woodlands in this ecoregion are considered to be at low risk from potential renewable energy production.

5.2.4 Climate Change Future Threats

It remains difficult to draw conclusions from the climate change data presented in this REA. Climate change models are highly variable and often difficult to predict. In this case, the resolution of the spatial data is an important factor to consider.

Increasing temperatures due to climate change allow more time for the MBP to complete its life cycle, which allows populations to grow more quickly than in the past (Bentz et al. 2007). The climate change figures contained in Appendix C-5 show an increase in the temperatures predicted to 2060. Increases in the mean annual temperature in the Middle Rockies ecoregion are predicted to range from 1.9-2.4 degrees Celsius (^{o}C). Based on the current trends of increased outbreaks associated with increased temperatures, it is assumed that there will be a higher population of MPB in the evergreen forest woodlands, likely increasing mortality.

In addition, the climate change figures contained in Appendix C-5 show the model for predicted precipitation change to 2060. Changes range from an increase to 99 millimeters (mm) to a decrease to 75 mm. This minimal change, coupled with the predicted increase in temperatures and altered fire regimes, could result in more frequent and severe fires.

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6.0 MANAGEMENT QUESTIONS

The relevant MQs for the evergreen forest woodland systems would include those defined as part of the Terrestrial Biotic Resources category. The overall MQ was: Where are the important regionally significant terrestrial features, functions, and services across the ecoregional landscape? This MQ was considered in implementing the GIS analyses. Emphasis was placed on the spatial relationship of attributes mentioned in the MQs and the evergreen forest woodland distribution model. Several examples of how the REA can be used to answer MQs (as noted in Appendix A) are provided below to demonstrate the functionality of the REA and to provide an opportunity to discuss data gaps that were identified during this REA.

6.1 HOW ARE THE EVERGREEN FORESTS DISTRIBUTED OVER THE LANDSCAPE?

Figure D-1-1 maps the ReGAP evergreen forest woodland systems across the ecoregion.

6.2 WHERE WILL CURRENT CONSERVATION ELEMENT VEGETATION TYPES BE AT GREATEST RISK FROM CHANGE AGENTS?

The full range of figures and analyses for evergreen forest woodland systems can be used to answer this complex MQ. The models created throughout this process were created to directly address the effects of CAs on evergreen forest woodland systems. All of the CAs were addressed spatially and described in detail in this section. The CAs were also spatially attributed to the distribution of the evergreen forest woodland. Figure D-1-11 represents the sum of Figures D-1-9 through D-1-10 by the 30-m analysis unit, while Figure D-1-12 represents the sum of all the threats at the 12-digit HUC reporting unit.

6.3 WHAT AREAS HAVE POTENTIAL FOR RESTORING CONSERVATION ELEMENT SPECIES HABITAT OR HABITAT CONNECTIVITY FOR CONSERVATION ELEMENT SPECIES, CURRENTLY AND IN THE FUTURE?

The fragmentation potential (Figure D-1-9) represents the potential for further fragmented evergreen forest woodland systems. It can also be used to show areas where future restoration may be the most beneficial. The fragmentation potential shows areas where restoration could potentially connect larger stands together.

6.4 WHERE WILL CONSERVATION ELEMENTS BE AT RISK FROM ALTERED FIRE REGIMES? WHERE ARE AREAS WITH POTENTIAL TO SHOW FUTURE INCREASES OR DECREASES IN WILDFIRE FREQUENCY OR INTENSITY?

Figure D-1-3 represents the VCC for the evergreen forest woodland. This figure represents changes in vegetation and fuels from their historical condition. For the Middle Rockies, a group of SMEs went through an exercise to illustrate fire regime (frequency and severity) departure. The historic BpS was attributed with a current fire severity and frequency, and then compared with the reference (historic) fire frequency and severity for each type. From these data, we were able to develop a fire frequency departure map, a fire severity departure map, and then a composite map (which took the highest of either departure). This modified composite layer was used as the best indicator for potential threat to the evergreen forest woodlands from an uncharacteristic fire.

6.5 WHICH INSECTS AND DISEASES MIGHT POSE A SIGNIFICANT FUTURE PROBLEM?

The bark beetles and WSBW are the greatest threats to the future of evergreen forest woodland systems. Figure D-1-10 displays which evergreen forest woodlands are in close proximity to current infestations. The assumption is that the evergreen forest woodland stands in close proximity to infestations are at risk in the future. Red displays patches with higher MPB infestation, while green shows areas with lower infestation.

6.6 WHERE WILL STATE AND FEDERAL HIGH-VALUED RESOURCE AREAS BE AFFECTED THROUGH CHANGES IN INTENSITY AND RANGE OF INSECTS AND DISEASE?

The MBP and the WPBR are the greatest threats to the future of the evergreen forest woodland systems. Figure D-1-10 displays evergreen forest woodlands in close proximity to current MPB and WPBR infestations. It is assumed that evergreen forest woodlands in close proximity to MBP and WPBR infestations are at risk in the future. Red displays patches with higher MPB infestation, while green shows patches with lower infestation.

6.7 HOW AND WHERE ARE FREQUENCY AND SEVERITY OF OUTBREAKS EXPECTED TO CHANGE IN RESPONSE TO CLIMATE CHANGE AND OTHER CHANGE AGENTS SUCH AS CHANGE IN FIRE FREQUENCY?

Based on the predicted increase in temperatures shown on the climate change models discussed in Appendix C-5, it is likely that the trend of severe bark beetle outbreaks will continue to occur. The climate change analysis predicts a temperature increase across the entire ecoregion; however, the analysis predicts a somewhat gradual gradient of higher temperatures from north to south. In addition, warming seasonal temperatures could increase the likelihood of more severe fires due to current fire regime departures.

6.8 WHERE ARE THE STANDS OF MAJOR TREE SPECIES THAT HAVE NOT BEEN IMPACTED BY INSECTS OR DISEASES?

Figures D-1-4 through D-1-6 display current infestation of the major insect threats to the evergreen forest woodland systems. Areas in green are stands that have been less impacted by insect infestation.

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APPENDIX D-1

FIGURES

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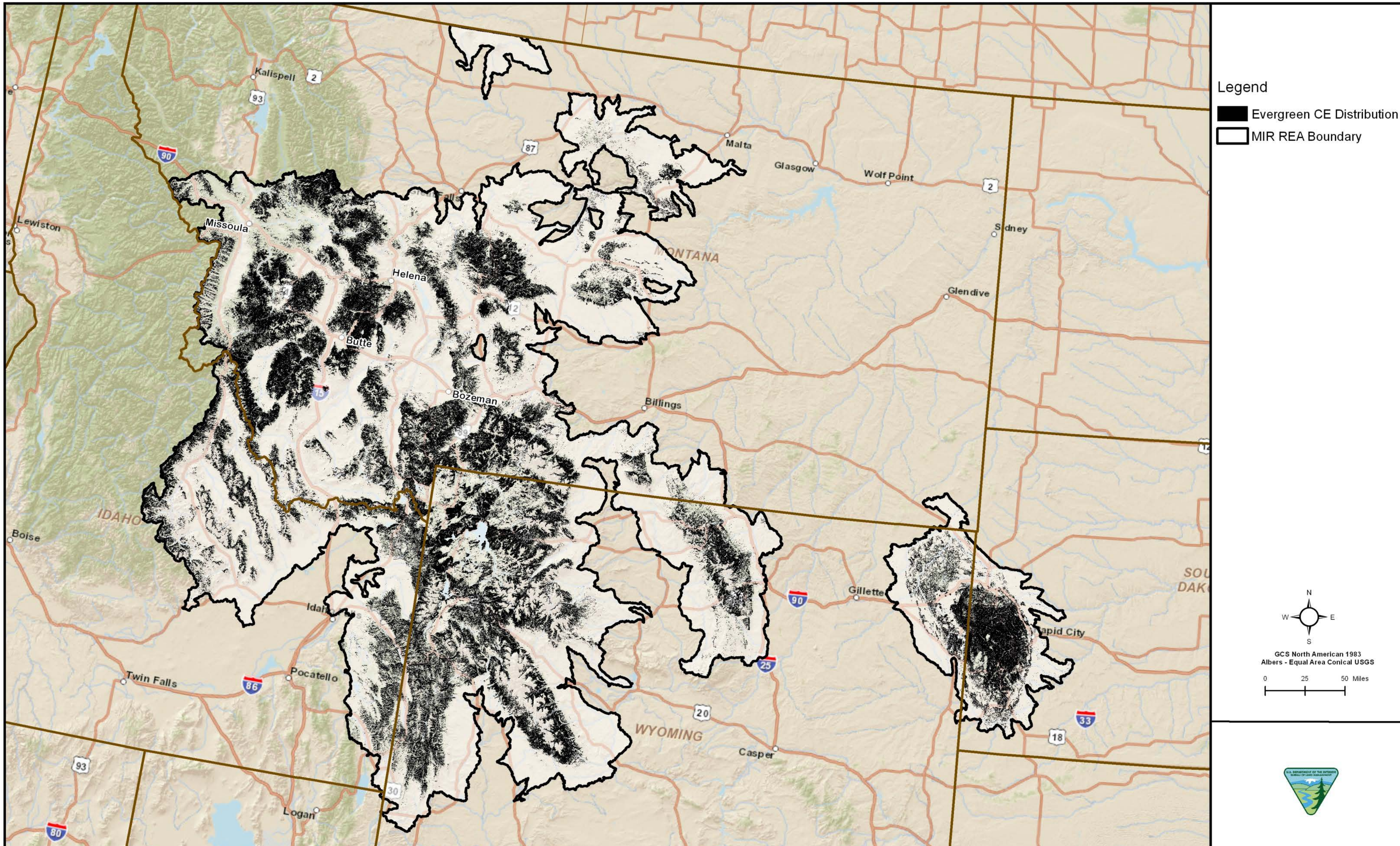

Figure D-1-1. Middle Rockies Evergreen Distribution

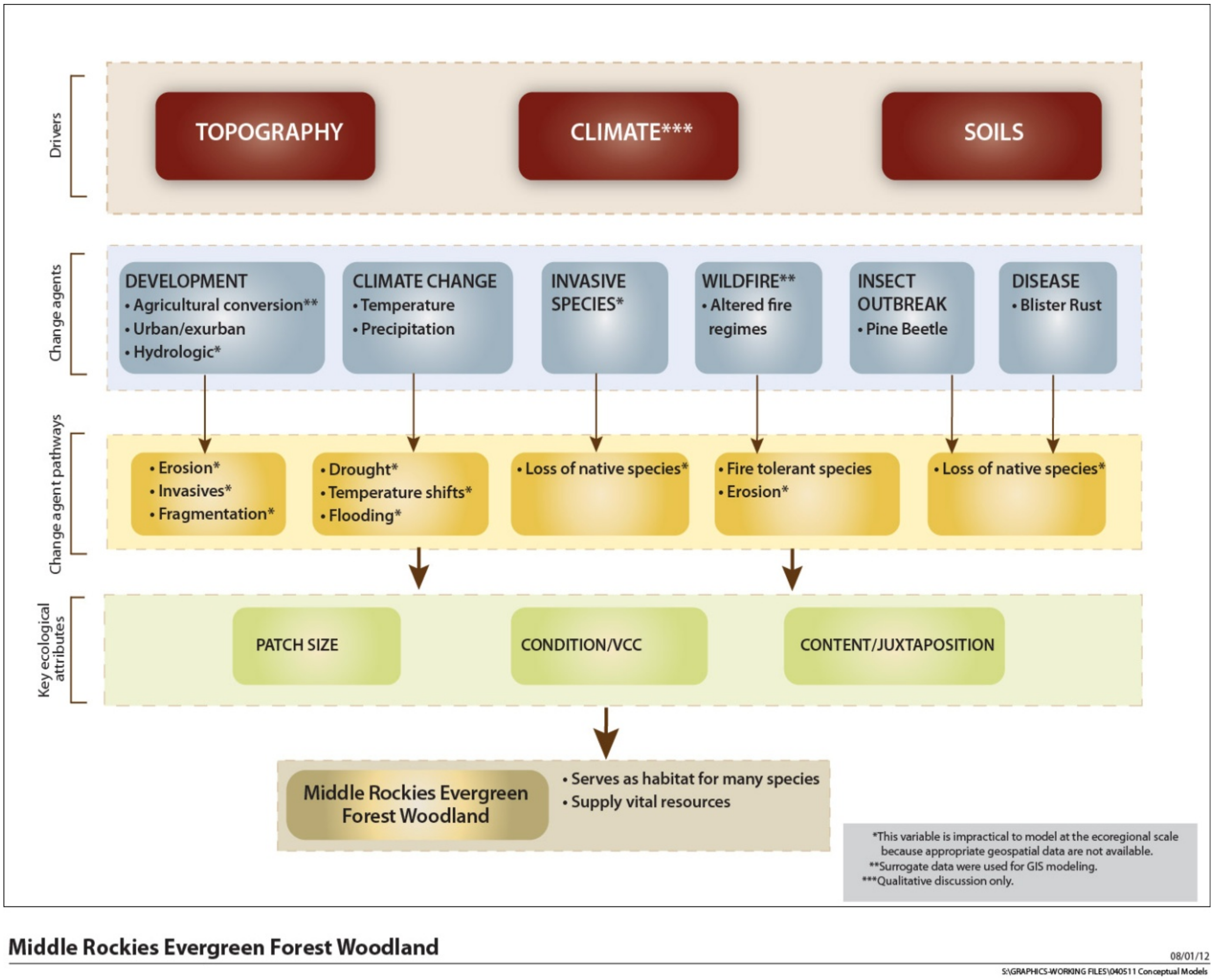

Figure D-1-2. Middle Rockies Evergreen System-Level Model

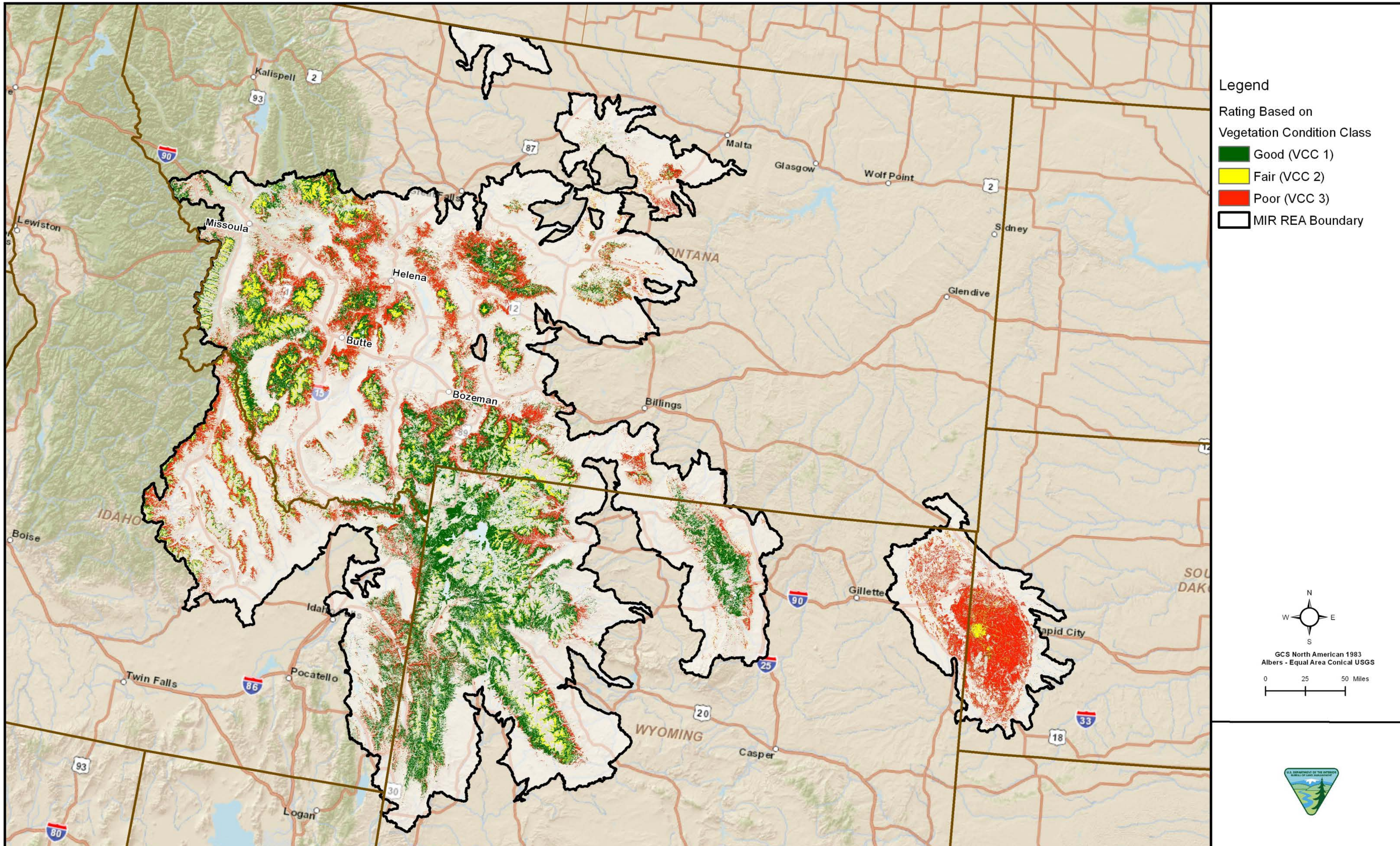

Figure D-1-3. Middle Rockies Evergreen Vegetation Condition Class

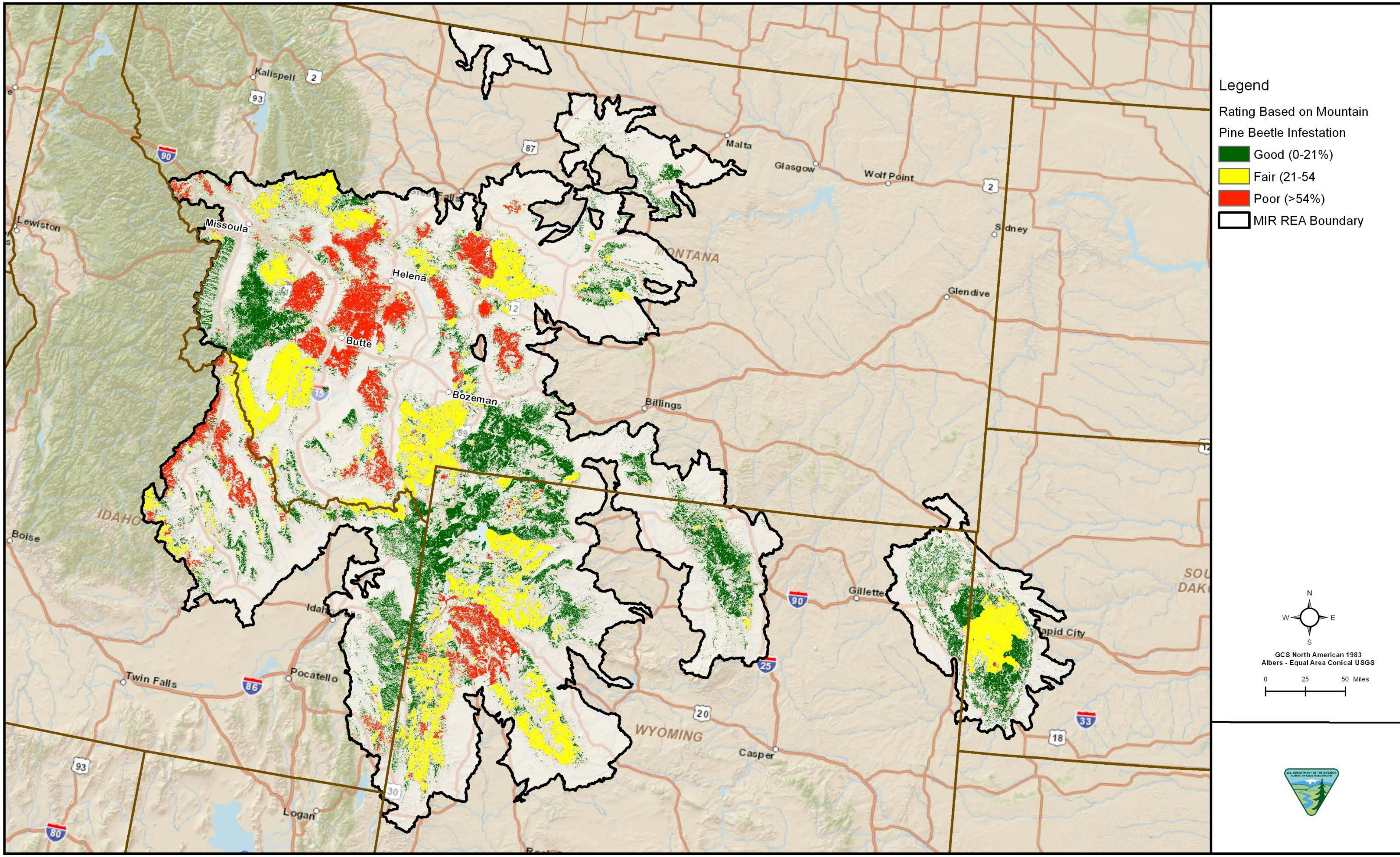

Figure D-1-4. Middle Rockies Evergreen Mountain Pine Beetle Infestation

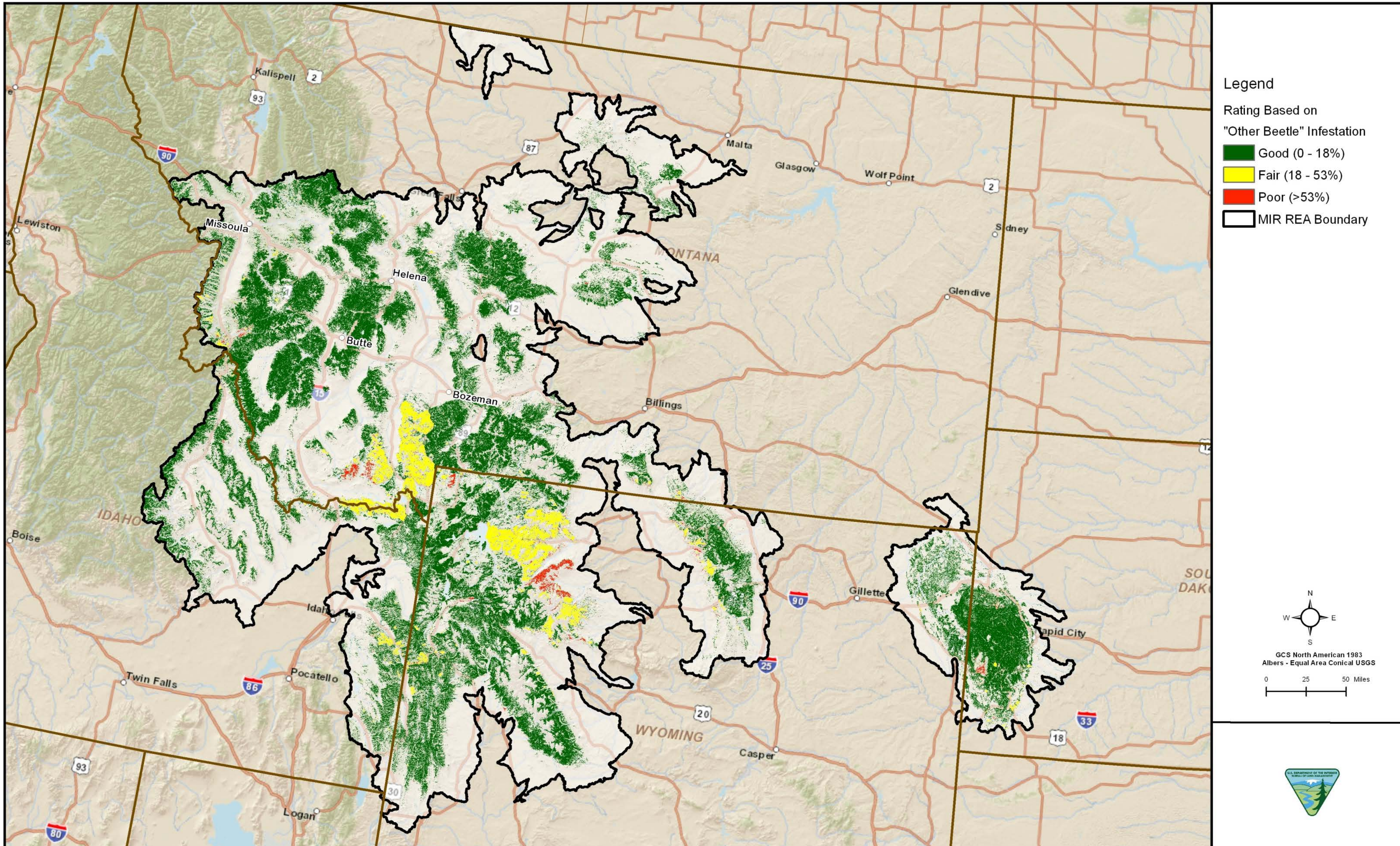

Figure D-1-5. Middle Rockies Evergreen "Other Beetle" Infestation

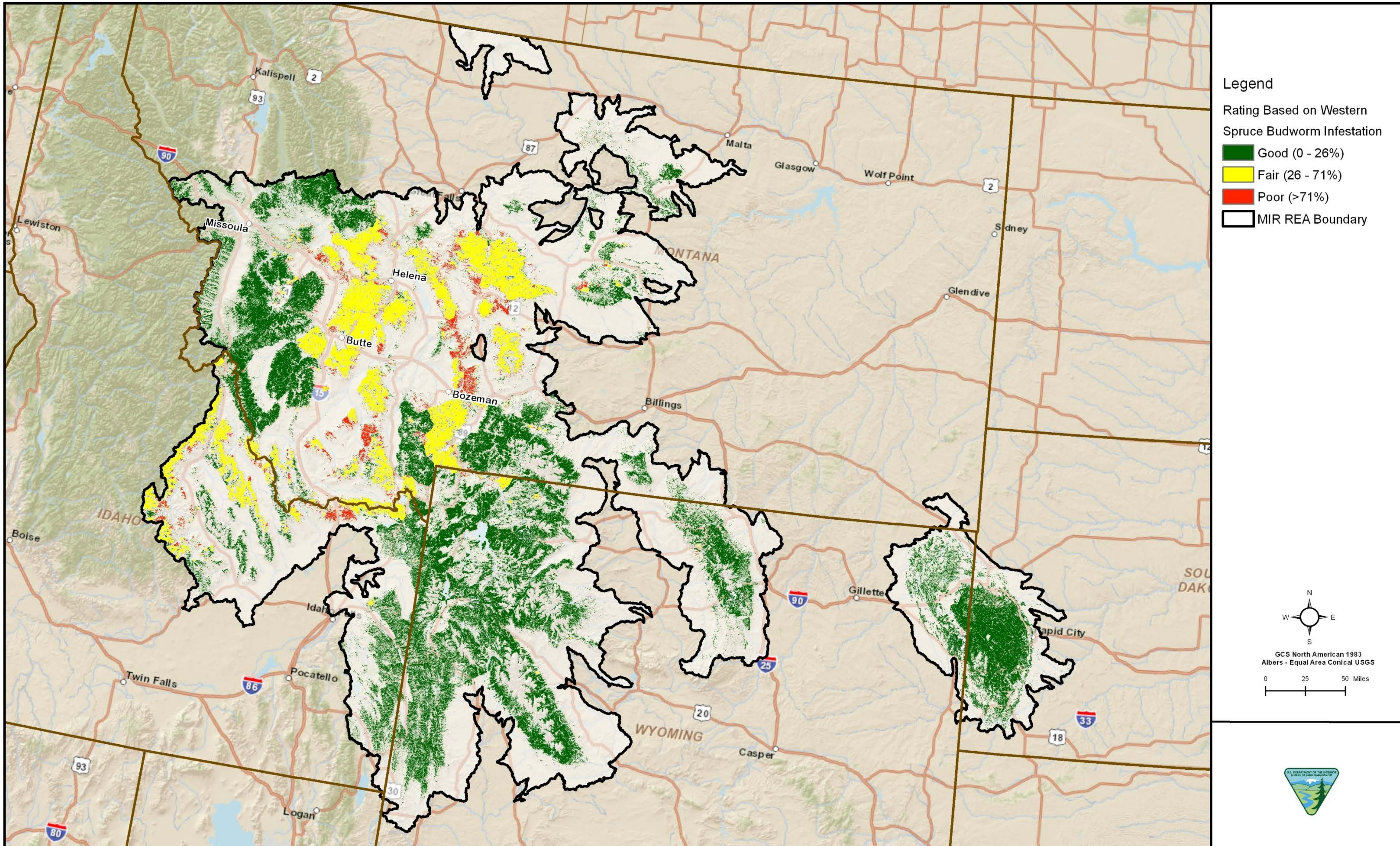

Figure D-1-6. Middle Rockies Evergreen Western Spruce Budworm Infestation

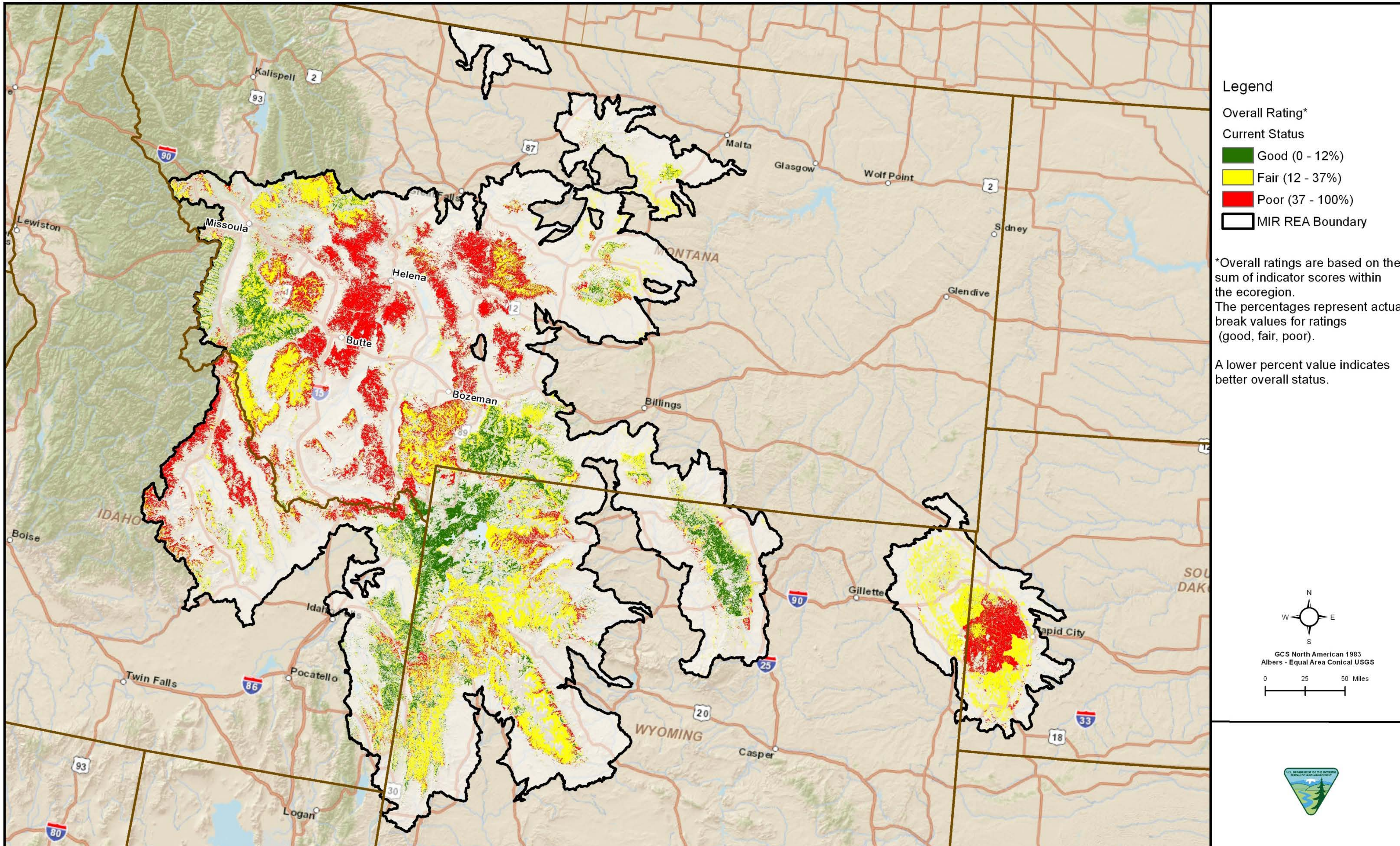

Figure D-1-7. Middle Rockies Evergreen Current Status

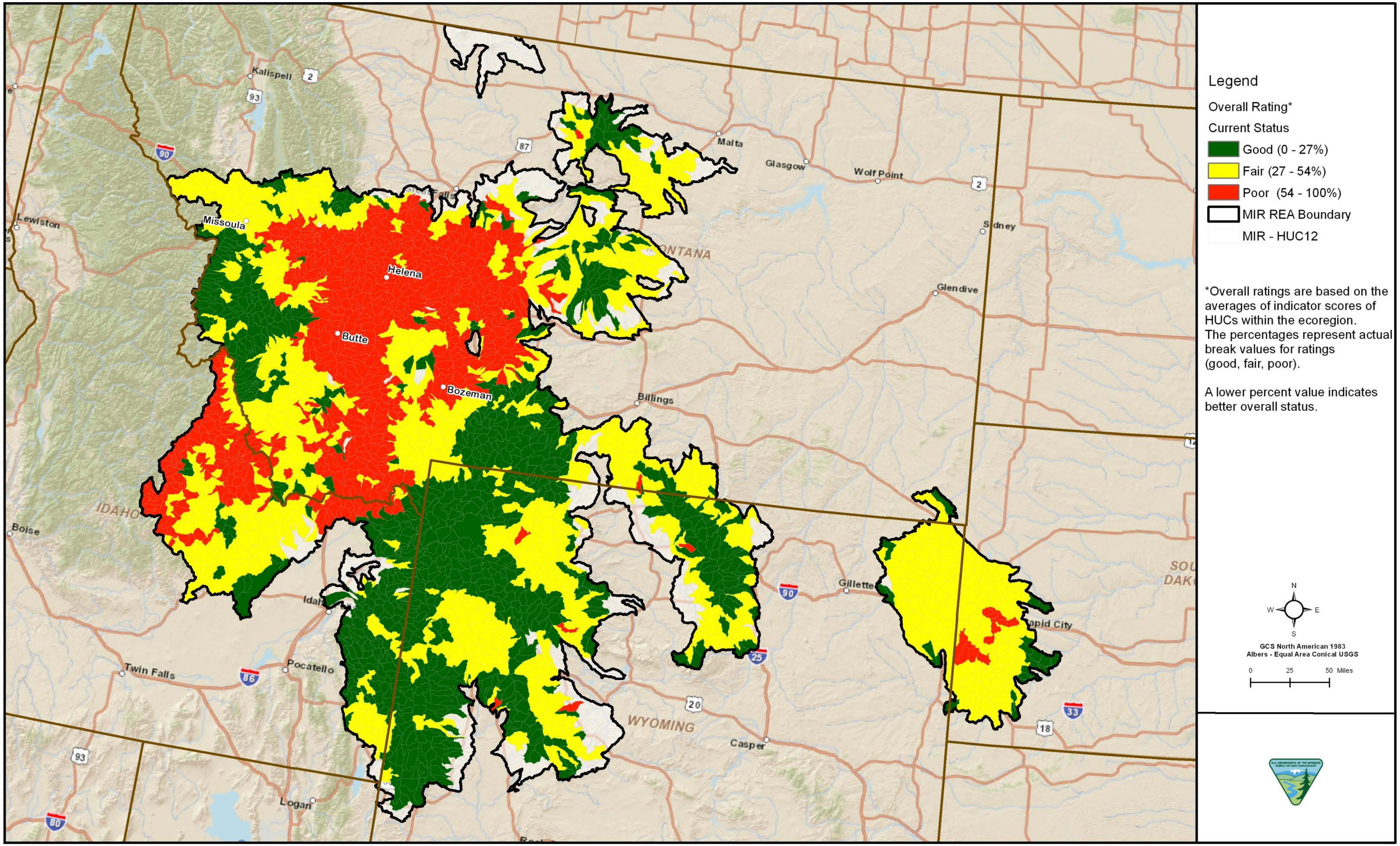

Figure D-1-8. Middle Rockies Evergreen Current Status by 6th Level Hydrologic Unit Code

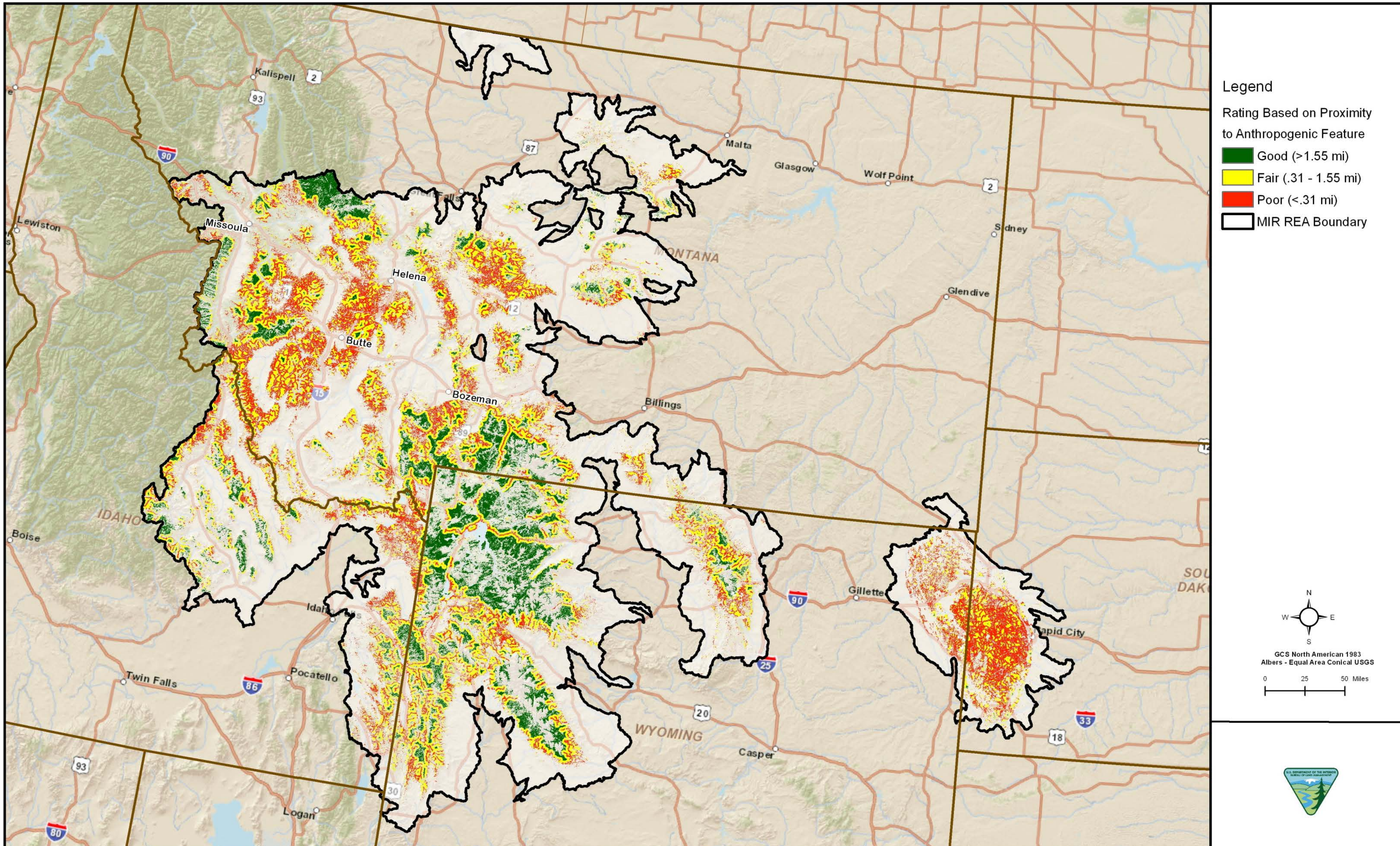

Figure D-1-9. Middle Rockies Evergreen Fragmentation Potential

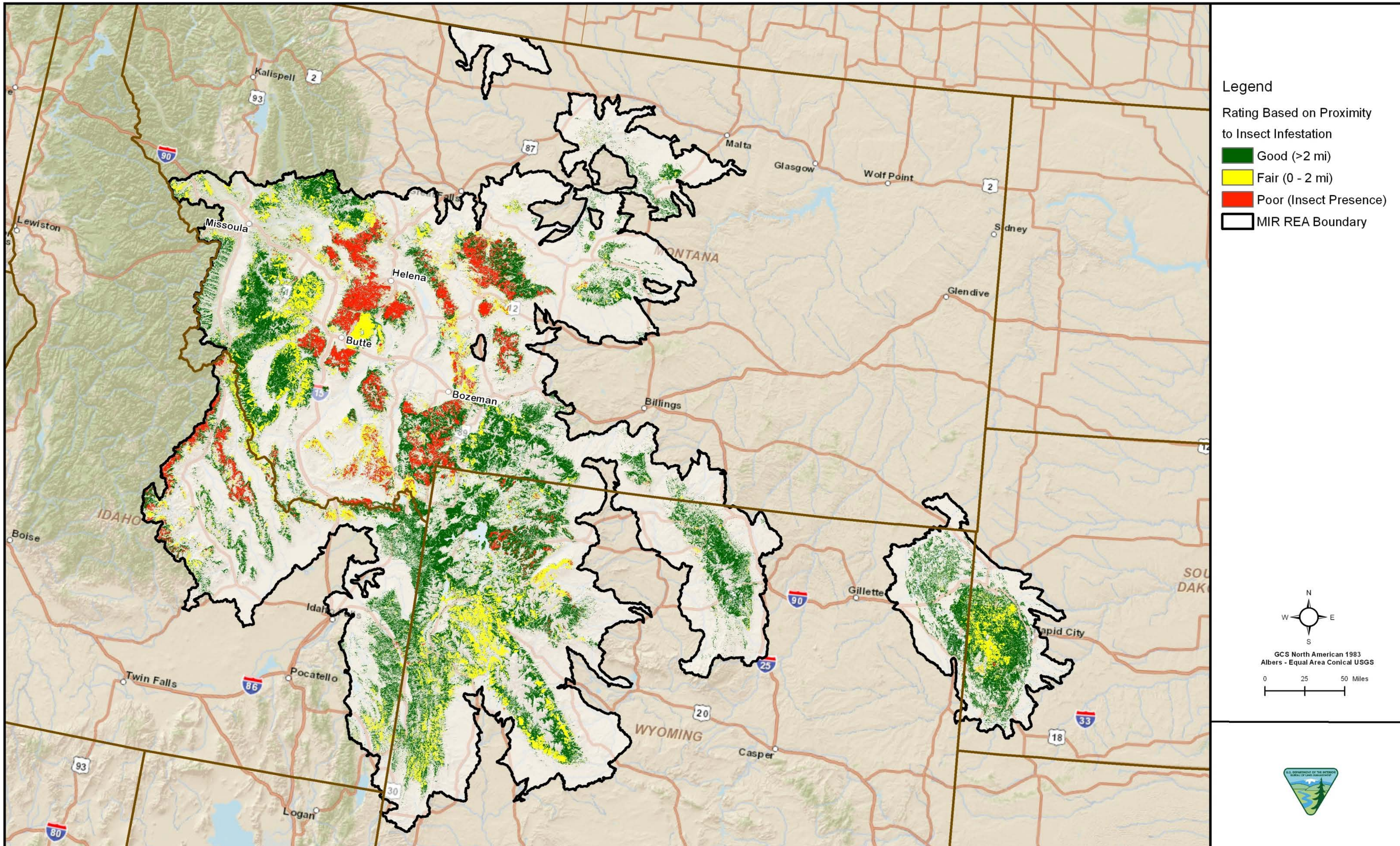

Figure D-1-10. Middle Rockies Evergreen Insect Proximity Analysis

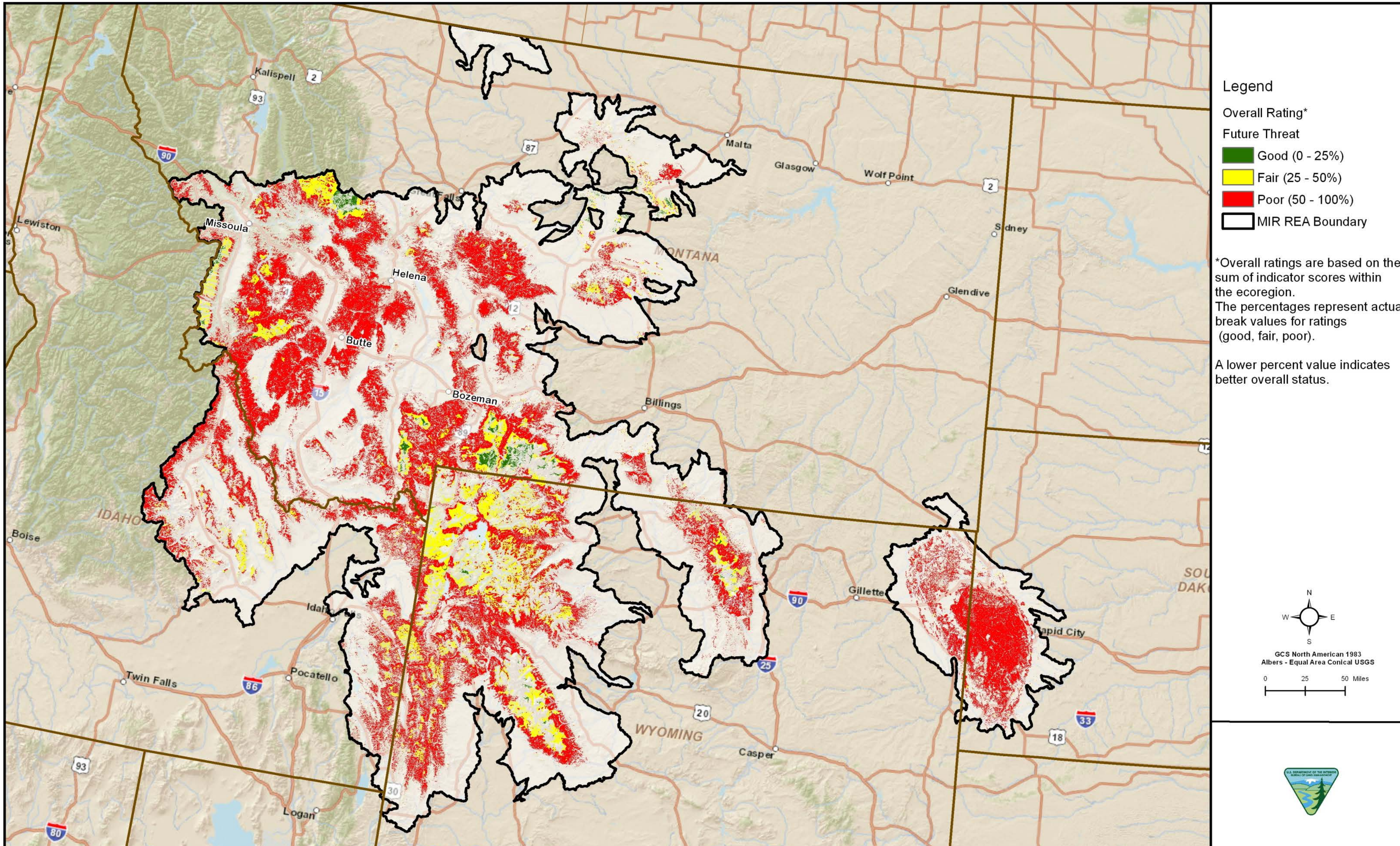

Figure D-1-11. Middle Rockies Evergreen Future Threat

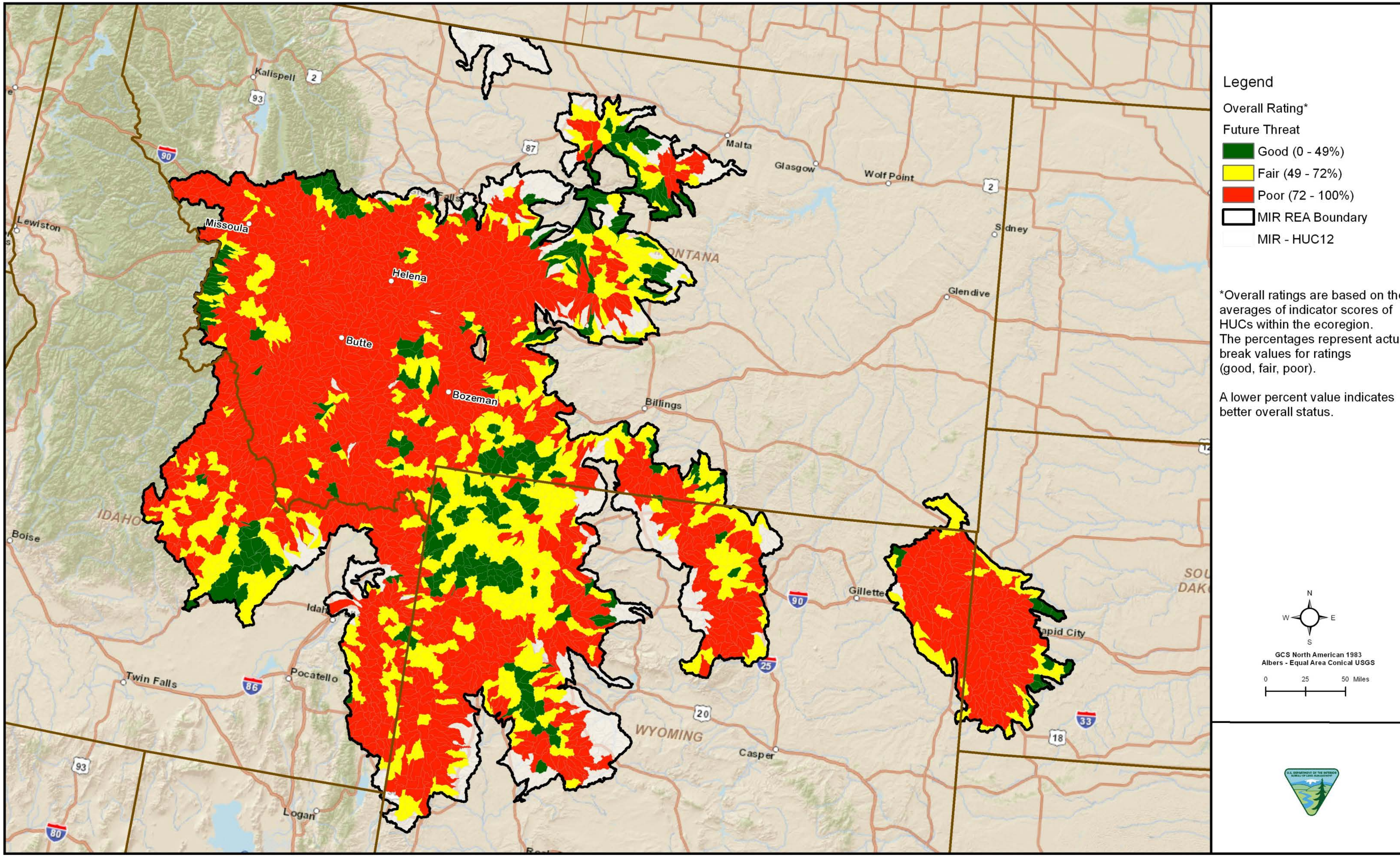

Figure D-1-12. Middle Rockies Evergreen Future Threat by 6th Level Hydrologic Unit Code

APPENDIX D-2

DECIDUOUS FOREST WOODLANDS COARSE-FILTER CONSERVATION ELEMENT FOR THE MIDDLE ROCKIES ECOREGION

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1.0 INTRODUCTION

Deciduous forest woodland vegetation systems encompass nearly 2 percent of the Middle Rockies ecoregion. Many of the Level 3 deciduous forest woodland systems in this ecoregion are associated with riparian. Therefore, this coarse-filter conservation element (CE) analysis will focus only on the Rocky Mountain Aspen Forest and Woodland Level 3 system.

A variety of the management questions (MQs) apply to this assemblage. Many of the MQs can be summarized into two primary questions: 1) where are the important areas for this assemblage? and 2) what is happening to these areas? The central focus of these two MQs is to document the current status of selected CEs at the ecoregional scale and to evaluate how this status may change over a future time period. The first step is to identify suitable habitat for the CE within the ecoregion. Then, these areas were assessed relative to current and potential future change agent (CA) threats.

It should be noted that due to the relatively small amount of deciduous forests in the ecoregion and the lack of threat data, only two CAs were analyzed for the deciduous forest CA analysis; CAs considered in this analysis include wildfire and development. In addition, Sudden Aspen Decline (SAD) is a major threat to Aspen. However, there is little geospatial data available for mapping SAD.

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2.0 CONSERVATION ELEMENT DESCRIPTION

The Level 3 systems represented in this model are briefly described below.

2.1 ROCKY MOUNTAIN ASPEN FOREST

This system describes mesic forests and woodlands dominated by quaking aspen (*Populus tremuloides*) without a significant conifer component (<25 percent relative tree cover). This widespread ecological system is more common in the southern and central Rocky Mountains, but occurs in the montane and subalpine zones throughout much of Montana north into Canada. Conifers that may be present, but are never co-dominant, include subalpine fir, Engelmann spruce (*Picea engelmannii*), white spruce (*Picea glauca*), ponderosa pine (*Pinus ponderosa*), and Douglas-fir. Depending on available soil moisture and other factors like disturbance, the understory structure may be complex (with multiple shrub and herbaceous layers), or simple (with just an herbaceous layer). The herbaceous layer may be dense or sparse, dominated by graminoids or forbs (Montana Field Guide 2012).

Stands can occur on gentle to moderate slopes, in swales, or on level sites. At lower elevations, occurrences are found on cooler, north aspects and mesic sites. Elevations generally range from 1,493 to 2,743 meters (m) (4,900-9,000 + feet [ft]), but occurrences can be found at lower elevations in some regions. Soils are usually deep and well developed with rock often absent from the soil. Soil texture ranges from sandy loam to clay loams (Montana Field Guide 2012).

Climate is temperate with a relatively long growing season, typically cold winters, and deep snow. Distribution of this system is primarily limited by adequate soil moisture required to meet its high evapotranspirative demand, length of growing season, and temperatures. Mean annual precipitation where these systems occur is generally greater than 38 centimeters (15 inches) and typically greater than 51 centimeters (20 inches), except in semi-arid environments where occurrences are restricted to mesic microsites (such as seeps) or areas below large snow drifts (Montana Field Guide 2012).

Occurrences of this system originate and are maintained by stand-replacing disturbances such as avalanches, crown fire, insect outbreak, disease and windthrow, or clearcutting by man or beaver, within the matrix of conifer forests. In recent years, many aspen stands have exhibited mortality from biotic vectors. These pathogens mainly infect clones already stressed by drought, insects, wind damage, heavy livestock and wildlife use, and similar factors (Montana Field Guide 2012).

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3.0 CONSERVATION ELEMENT DISTRIBUTION MAPPING

3.1 DATA IDENTIFICATION

The major datasets identified to map the distribution of the deciduous forest woodland CE were the Gap Analysis Program (GAP) landcover and Landscape Fire and Resource Management Planning Tools Project (LANDFIRE) datasets. Both datasets have adequate coverage across the ecoregion and have been used in similar analyses. The deciduous forest distribution datasets are further described in Table D-2-1.

Table D-2-1. Data Sources for the Deciduous Forest Woodlands Coarse-Filter Conservation Element Distribution Mapping for the Middle Rockies

Data Needs	Dataset Name	Source Agency	Type/Scale	Status	Use in REA
Terrestrial Systems					
Ecological Systems	GAP Landcover Northwest Regional Gap Analysis Program (ReGAP) North Central GAP	U.S. Geological Survey (USGS)	Raster (30-m)	Acquired	Yes
	LANDFIRE	LANDFIRE	Raster	Acquired	No
Soils Data	Soil Survey Geographic (SSURGO) State Soil Geographic (STATSGO2)	U.S. Department of Agriculture (USDA)	Polygon	Acquired	No

3.2 DISTRIBUTION MAPPING METHODS

To map distribution of deciduous forest woodlands in the Middle Rockies ecoregion, Science Applications International Corporation (SAIC) used a mosaic of GAP data sources, including two of the National GAP landcover regions, the Northwest and North Central. The source data for the Northwest region was the Northwest Regional Gap Analysis Program (ReGAP) dataset, which improved upon the original Northwest GAP. The North Central region contains states that have not been covered by a ReGAP project. For these areas, the National GAP layer used data from the LANDFIRE project to create a seamless layer. The GAP was developed to help answer questions about species biodiversity and species habitat (USGS 2010). Its overall goal is to assist resource managers in decision making when there is a lack of information about the full range of species on the landscape. Once the data were downloaded, the two datasets were merged together to form a continuous layer of vegetation data across the four states. The continuous data layer was then clipped to the Middle Rockies ecoregion, at which point the Level 3 system was extracted for review by the Rolling Review Team (RRT) (Figure D-2-1).

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4.0 CONCEPTUAL MODEL

The current status and potential future threat analyses were based on the system-level model, selected environmental variables (Key Ecological Attributes [KEAs]) likely to be at risk from the CAs, and the availability of data.

4.1 SYSTEM-LEVEL MODEL

The system-level model for the Middle Rockies deciduous forest woodland system (Figure D-2-2) illustrates the major drivers across the top. The major drivers dictate where these vegetation systems occur throughout the ecoregion, while the CAs focus on what has potential to affect this CE over time. Below the CAs are the corresponding CA pathways that affect both the status and distribution of this CE across the Middle Rockies ecoregion. Listed below the CA pathways are the three categories of size, context, and condition for development of the KEAs for this coarse-filter CE. The KEAs were developed and refined through the rolling review process.

4.1.1 Wildfire

Like other deciduous forests, Aspen requires disturbance to regenerate and to become more established. Without disturbances like fire, Aspen is at risk to conifer encroachment. High conifer mortality due to bark beetle infestation is also increasing fuel loads, which could lead to more intense wildfires. These intense wildfires may be too severe for the Aspen stands to survive.

4.1.2 Development

In the Middle Rockies, development is a moderate issue compared to SAD, climate change, and altered fire regimes. However, due to increasing population growth and urban-to-rural migration trends, fragmentation is a definite factor shaping the landscape. Development fragments deciduous forests, degrading and reducing the amount of stands. Fragmentation from development and agricultural pressures reduces the viability of forest management and environmental benefits such as ecological stability of flora and fauna (Bowers and Daniels 1997). The increase in small isolated patches and space between forests decreases habitat connectivity and forest interior.

4.1.3 Climate Change

Drought has been known to cause the loss of seral aspen stands and contribute to a decline in aspen regeneration. In recent years, there have been dramatic die-offs of aspen. The phenomenon has been termed SAD. Due to lack of data, SAD was not included in the CA analysis. However, a brief discussion is warranted due to its importance to the species.

SAD is characterized by rapid onset of mortality, in which dying stands have little to no regeneration or recruitment. Recent research indicates that SAD is caused by several interacting factors, including site-related factors (low elevations, south and south-west aspects, open stands), higher temperatures, and drought stress (Hogg et al. 2008; Rehfeldt et al. 2008; Worrall et al. 2008; Fairweather et al. 2008; St. Clair et al. 2010; Worrall et al. 2010). SAD has been highly correlated to hydrologic failures in trees due to drought. The region experienced a significant drought from 1999-2004, immediately prior to the current episode of aspen dieback (Hoffman 2008). The impacts of SAD are consistent with projected effects of climate change.

Surveys in the Intermountain Region have reported different patterns of aspen mortality, such as the prevalent damage agents and susceptibility of different stem sizes (Guyon and Hoffman 2011). Some stands experiencing dieback were still capable of regenerating, although recruitment may be below the threshold suggested for successful aspen recruitment (O'Brien et al. 2010). Steed and Kearns (2010) reported that rapid stand decline (SAD) noted in Colorado was not prevalent in Montana and northern Idaho surveys undertaken in the Northern Region. Patterns of mortality detected in ground survey plots indicated that mortality had occurred over many years. Nonetheless, aspen is declining in many areas of

Montana and southern Idaho (Idaho Department of Lands 2010), likely caused by a combination of factors including increased conifer encroachment due to fire suppression, diseases and insects, and heavy ungulate grazing on regeneration. Drought may be an important factor in future mortality (Steed and Kearns 2010).

5.0 CHANGE AGENT ANALYSIS

A current status assessment was conducted on the deciduous forest woodland CE for the Middle Rockies ecoregion with native 30-m raster data as the analysis unit. Based on the system-level model, KEAs were identified for the current status with a specific emphasis on the ability to measure impacts using existing geospatial data. For each analysis, a series of intermediate data layers were created based on the KEA indicators, which are scored according to a designated metric and then ranked (good, fair, or poor). If necessary, data from multiple source datasets were combined.

Since the scale of the reporting unit is at the Hydrologic Unit Code (HUC) 12, a layer of 6^{th} level HUCs was extracted for the ecoregion. A geographic information system (GIS) process was iterated through the KEA indicators and determined the metric values associated with some watersheds. In other instances, sufficient published data indicated cut-off points for these values. These values were added as an attribute to the HUC 12 layer. The intermediate CA layers were then combined together to form a single layer outlining the current status or future threat status for each HUC.

Although numerous preliminary KEAs and indicators that may affect the deciduous forest woodlands were initially identified in the early phases of this Rapid Ecoregional Assessment (REA), not all were included in this analysis because either the attribute or indicator was not suitable for a landscape level analysis or because data are not available to support the analysis. The specific indicators that could not be modeled are identified with an asterisk on Figure D-2-2. Further information on the data gaps for these indicators are discussed in the respective CA analyses contained in Appendix C.

For the KEAs that were determined to be duplicative, some were pixel-based, some were HUC-based, and others did not show any differentiation across the ecoregion. Table D-2-2 identifies the original KEAs and which were used in the final CA analysis.

Table D-2-2. Key Ecological Attributes Retained or Excluded

Category	Key Ecological Attribute	Explanation
1. Size	a. Size of Patches	This analysis was completed but not used because the RRT determined this was more of a fine-filter wildlife MQ.
2. Condition	a. Vegetation Condition Class (VCC)	Retained to show the vegetation and fire regime departure in the ecoregion.
	b. Invasive Species	Dropped due to insufficient data.
3. Structure	a. Fragmentation	Retained to show the fragmentation throughout the ecoregion.

5.1 CURRENT STATUS OF THE CONSERVATION ELEMENTS

Table D-2-3 identifies the KEAs, indicators, and metrics that were used to evaluate the CAs and pathways affecting this CE across the ecoregion. The deciduous forest woodland process analysis is designed to create a series of intermediate layers that are primarily based on the wildfire and insect and disease outbreak CAs. The analysis is based on the geospatial data that was available.

5.1.1 Key Ecological Attribute Data Analysis for Current Status

For each of the KEAs listed in Table D-2-3, a discussion of the indicator, metric, metric rank and value, data source(s), and references is provided. Only two indicators were used to assess the current threat status for the deciduous forest woodlands (Table D-2-3). This table was limited to size and landscape context based on spatially available attributes and key factors affecting deciduous forests in this ecoregion.

In most cases, the metrics used to identify attribute quality were based on available publications, coupled with expert analysis and professional judgment in association with data-driven metrics. Weights were attributed to each metric in order to provide an overall score for all metrics combined, based on the reporting unit.

Table D-2-3. Key Ecological Attributes for the Deciduous Forest Woodlands Coarse-Filter Conservation Element for the Middle Rockies Ecoregion

Category	Ecological Attribute	Indicator/Unit of Measure	Metric			Data Source	Citation	Weight
			Poor = 3	Fair = 2	Good = 1			
Landscape Structure	Structure	VCC	VCC 3	VCC 2	VCC 1	LANDFIRE	RRT Guidance	0.50
	Fragmentation	Distance Decay Proximity to anthropogenic layer	<0.24 miles	0.24-0.81 miles	>0.81 miles	Integrated Climate and Land-Use Scenarios (ICLUS), Topologically Integrated Geographic Encoding and Referencing (TIGER)	RRT Guidance (Natural Breaks)	0.50

Analysis Unit = 30-m pixel
Reporting Unit = 6th level HUC

After much discussion, the deciduous forest woodlands RRT decided not to include patch size in the threat assessment. The decision was primarily made because there is no literature on optimum patch size for deciduous forest woodlands. All literature is focused on wildlife habitat requirements, which are included in the fine-filter CE analysis.

5.1.1.1 Vegetation Condition Class

For landscape structure, the LANDFIRE Vegetation Condition Class (VCC) data were used to show changes in vegetation and fuels from their historical condition. Three condition classes describe low departure (VCC 1), moderate departure (VCC 2), and high departure (VCC 3). For the Middle Rockies, a group of subject matter experts (SMEs) went through an exercise to illustrate fire regime (frequency and severity) departure. The historic biophysical setting (BpS) was attributed with a current fire severity and frequency, and then compared with the reference (historic) fire frequency and severity for each type. From these data, we were able to develop a fire frequency departure map, a fire severity departure map, and then a composite map (which took the highest of either departure). This modified composite layer was used as the best indicator of potential threat to the deciduous forest woodland from an uncharacteristic fire.

The VCC layer was extracted to the deciduous forest woodland layer. The data were already categorical, so VCC departure 1 = good, VCC departure 2 = fair, and VCC departure 3 = poor. The deciduous forest woodland VCC layer is displayed on Figure D-2-3. Because of the characteristics of this ecoregion, deciduous forests are not a major vegetation component; therefore, the results of this analysis are difficult to discern at a landscape level. The results of this analysis in the predominant areas of the ecoregion where these forests occur (in eastern Idaho) generally returned good results for this KEA.

5.1.1.2 Fragmentation

Originally, SAIC created a forest fragmentation index using a neighborhood analysis on the deciduous forest woodland layer. The analysis looked at each pixel that is classified as deciduous forest woodland and its neighbors. A 10x10 neighborhood was used for this analysis. There is no literature specific to the moving window size for this type of analysis. Several other windows were examined, but the 10x10 window seemed most appropriate. The index is based on the number of deciduous forest woodland pixels surrounding each other.

This index was presented to the RRT, but it was ultimately decided that we would the use a distance decay method to determine fragmentation based on the proximity to development. The Integrated Climate and Land-Use Scenarios (ICLUS) 2010 was used by extracting the urban, exurban, and industrial categories and then merging the Topologically Integrated Geographic Encoding and Referencing (TIGER) roads for the entire ecoregion. A Euclidean distance proximity analysis was run from this anthropogenic layer, then scored (Figure D-2-4). To maintain consistency with other coarse-filter analyses, scoring was based on KEAs from other coarse-filter CEs in the ecoregion. This original scoring was poor = 0 – 0.5 kilometers (km), fair = 0.5 km – 2.5 km, and good = >2.5 km. However, due to the relatively small amount of deciduous forest woodlands present on the CA analysis, these scores were altered slightly using quantile breaks. The resulting scoring classifications can be found in Table D-2-3. As with the VCC, the results of this analysis are difficult to identify at a landscape level, the larger deciduous forests of eastern Idaho generally returned poor-to-fair scores for this analysis.

5.1.2 Current Status of Habitat

The individual KEA analysis provides the basis for the compilation of an overarching data layer that defines the current status of deciduous forest habitat for each HUC across the Middle Rockies ecoregion. A method of aggregating scores was used to summarize overall threats with regard to deciduous forest woodland habitat quality. Individual threats can identify areas of potential risk to deciduous forest woodlands, but aggregated scores can provide important information with relation to areas where deciduous forest woodlands might encounter multiple threats.

In order to create a combined score for each HUC unit based on varying levels of importance for each key attribute, it was necessary to aggregate the data through a weighting process. The weighted sum tool was used to combine each analysis input map to create an overall Current Status Map (Figure D-2-5). Equal weights were used when summing the threats for the deciduous forest woodlands.

The resulting output gives each deciduous forest woodland 30-m pixel a score based on current status. Figure D-2-6 displays these results; red indicates areas of poor status, while green indicates areas rated at better current status based on the measured attributes.

The overall threat score for each 6th level HUC was assigned a current habitat quality rating of good, fair, or poor based on the natural breaks method. Statistics were run on the results from Figure D-2-5 to determine the average overall score. The overall result was then scored based on natural breaks. A higher overall threat score would result in a rating of "poor" for the HUC, indicating that there are existing threats to the forests based on the KEA metrics.

It should be noted that when displaying results at the 6th level HUC watershed, a few isolated 30-m pixels will determine the score for that watershed (thus potentially scoring a watershed as poor); however this may be misrepresentative due to the lack of pixels classified as that vegetation type.

The results of the current status analysis based on the 6th level HUC for the ecoregion are presented in Figure D-2-6. In general, the current status of the deciduous forests throughout this ecoregion returned fair-to-good results for the overall current status assessment based on the KEAs.

A summary of the current status ratings based on the CE distribution is provided in Table D-2-4. The CE distribution layer was used to calculate the total number of square miles of CE habitat and a percentage of the total number of square miles per HUC that were rated as good, fair, or poor. The results of the current status assessment indicate that approximately 30 percent of the 6th level HUC watersheds that intersect the deciduous forest woodland distribution received an overall rating of good, a similar percentage received an overall rating of fair, and the highest percentage of HUCs (38.7 percent) received a rating of poor.

Table D-2-4. Summary of Current Status Ratings for the Deciduous Forest Woodland

Overall Rating by 6th Level HUC	Total Square Miles[a]	Percentage of Total Square Miles[a, b]
Good	25,742	30.9
Fair	25,270	30.4
Poor	32,210	38.7

[a] These values include only the area of HUCs that intersect with the CE distribution layer.
[b] Values rounded to one decimal place.

5.2 FUTURE THREAT ANALYSIS

Future threats were evaluated for development for a short-term time horizon (5 to 10 years) and for climate change for a long-term time horizon (50-year; 2050 to 2069). Future spatial data for development was limited to potential energy development and climate change, as discussed in the development CA analysis presented in Appendix C-1. Because of the low risk to deciduous forests from agricultural conversion and urban development, an analysis of these two development CAs was not completed. Climate change was modeled based on a 15-km grid created for regional analysis. The analysis included a comparison of current climate patterns to future modeled climate patterns and resulted in the delta (change) output figures. Further details regarding the climate change analysis is provided in Appendix C-5.

Because of the inherent inaccuracies of the temporal scale of the future data, it is only possible to infer information pertaining to a subjective future period (rather than a specific time period) for these attributes. However, because of the limits placed on these data outputs, it is fair to assume that this model predicts the overall future potential for these attributes within this ecoregion. It is an upper limit of potential growth and should therefore be carefully applied to future estimates of their effect on coarse-filter CEs.

5.2.1 Development Change Agent

Because deciduous forests do not appear to be at risk from threats related to modeled urban growth and potential agricultural development, future threat analysis for development was limited to potential energy development and climate change.

5.2.1.1 Oil Production Potential

The future analysis characterized potential oil production areas rather than oil well locations (Figure C-1-4). These larger oil production extents were used to qualitatively assess the potential effect of future oil production activities. Although these areas are based on oil density data, the application of these data to future potential well site activity is unknown. Therefore, a carefully considered approach should be taken when assessing the effect of potential oil production areas on deciduous forests.

Deciduous forests appear to be at low risk from potential oil production. Most of the deciduous forest are located in eastern Idaho, outside the areas for potential oil production.

It is important to note that the Energy Policy and Conservation Act (EPCA) oil and gas data used in this assessment are based on the maximum potential for oil reserves within the Middle Rockies. As a result, these data are likely overly represented in these figures, and care should be taken in assessing the effects of oil and gas production within the constraints of this analysis.

5.2.1.2 Natural Gas Production Potential

The future analysis characterized potential gas production areas rather than actual gas well locations (Figure C-1-3). These larger gas production extents could be used to qualitatively assess the potential effect of future gas production activities. Although these areas are based on gas density data, the application of these data to future potential well site activity is unknown. Therefore, a carefully considered approach should be taken when assessing the effect of potential gas production areas on grasslands.

Most of the deciduous forests in this ecoregion will likely remain unaffected by gas production. The majority of potential gas production is limited to areas around the Bighorn Mountains, where gas potential is limited. There is an area in north-central Montana at potential risk for natural gas development, but from an ecoregional scale deciduous forests do not appear to be at risk from future natural gas development.

5.2.1.3 Future Potential for Solar Development

This future potential analysis characterized the future potential for solar development based on the solar potential maps developed by the National Renewable Energy Laboratory (NREL). Although these maps are very crude, the highest potential for solar development is shown to occur outside of the deciduous forest distribution area (with the exception of some areas in the Black Hills). However, these are relatively minor distributions; overall, it does not appear that deciduous forests are at risk from future solar development.

5.2.1.4 Wind Turbine Potential

Wind energy development does not appear to be a risk to forests because developers would more likely site wind farms on open lands where clearing would not be required. However, the wind turbine potential map is presented in Figure C-1-7. Higher elevations within this ecoregion would be more susceptible to the threat of wind turbine development due to the higher wind speed levels within these areas. However, limited accessibility to these higher elevations could limit the range of wind turbine development to lower-elevation mountainous regions.

The majority of the deciduous forests appear to be located in areas that are at lower risk for potential wind development. Therefore, the risk to this CE from wind development is considered minimal.

5.2.1.5 Overall Development CA Future Threats

A fossil fuel energy output layer was created to address the MQs associated with future fossil fuels production. This layer was created by averaging the EPCA oil data layer with the EPCA gas data layer (Figure C-1-5). Most of the deciduous forests in the Middle Rockies ecoregion do not appear to be at risk from future fossil fuels production.

A renewable energy output layer was created to address the MQs associated with future renewable energy production. This layer was created by averaging the NREL wind speed data layer with the NREL solar energy data layer (Figure C-1-8). This output layer provides equal weighting to potential wind and solar energy production areas, and could therefore mischaracterize the effects of each. Unlike oil and gas, wind and solar energy are not necessarily closely associated with one another spatially. Photovoltaic solar arrays threaten the species by their effect on habitat availability. Solar arrays are diverse in scope and size and it is therefore difficult to create a clear correlation between habitat loss and solar energy production.

Because of the intricacies involved in the assessment of renewable energy production with regard to deciduous forests, a limited approach must be taken in this analysis. The majority of the deciduous forests in this ecoregion do not appear to be at risk from the threat of future renewable energy production.

5.2.2 Climate Change Future Threats

5.2.2.1 Ecoregion Climate Change Analysis

From a climate change perspective, temperature and precipitation are the factors that would most affect deciduous forests. Based on review of the climate change analysis, temperature and precipitation changes appear to be relatively minor across the areas where deciduous forests occur in the Middle Rockies ecoregion. The deciduous forests in eastern Idaho could experience modest decreases in annual precipitation, but mean annual temperatures would remain relatively unchanged.

It remains difficult to draw conclusions from the data presented in this REA. Climate change models are highly variable and often difficult to predict. In this case, the resolution of the spatial data is an important factor to consider.

Based on the analysis conducted for the ecoregion, as presented in Appendix C-5, it appears that temperature and precipitation changes will be minor in the deciduous forests of the Middle Rockies. However, the combined impacts of localized drought and episodic insect infestations could negatively affect deciduous forests in the future.

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6.0 MANAGEMENT QUESTIONS

The relevant MQs for the deciduous forest woodland would include those defined as part of the Terrestrial Biotic Resources category. The overall MQ was: Where are the important regionally significant terrestrial features, functions, and services across the ecoregional landscape? This MQ was considered in implementing the GIS analyses. Emphasis was placed on the spatial relationship of attributes mentioned in the MQs and the deciduous forest woodland distribution model. Several examples of how the REA can be used to answer MQs (as noted in Appendix A) are provided below to demonstrate the functionality of the REA and to provide an opportunity to discuss data gaps that were identified during this REA.

6.1 HOW ARE THE DECIDUOUS FOREST WOODLANDS DISTRIBUTED OVER THE LANDSCAPE?

Figure D-2-1 maps the ReGAP deciduous forest woodlands across the ecoregion.

6.2 WHERE WILL THE CURRENT CONSERVATION ELEMENT VEGETATION TYPES BE AT GREATEST RISK FROM CHANGE AGENTS?

The full range of figures and analyses for the deciduous forest woodlands can be used to answer this complex MQ. The models created throughout this process were created to directly address the effects of CAs on the deciduous forest woodlands. All of the CAs were addressed spatially and described in detail in this section, and all of the CAs were spatially attributed to the distribution of the deciduous forest woodlands. Figure D-2-5 represents the sum of Figures D-2-3 and D-2-4 by the 30-m analysis unit, while Figure D-2-6 represents the sum of all the threats at the 12-digit HUC reporting unit.

6.3 WHAT AREAS HAVE POTENTIAL FOR RESTORING CONSERVATION ELEMENT SPECIES HABITAT OR HABITAT CONNECTIVITY FOR CONSERVATION ELEMENT SPECIES, CURRENTLY AND IN THE FUTURE?

The fragmentation potential (Figure D-2-4) represents the potential for further fragmented deciduous forest woodlands. It can also be used to show areas where future restoration may be the most beneficial. The fragmentation potential shows areas where restoration could potentially connect larger stands together.

6.4 WHERE WILL CONSERVATION ELEMENTS BE AT RISK FROM ALTERED FIRE REGIMES? WHERE ARE THE AREAS WITH POTENTIAL TO SHOW FUTURE INCREASES OR DECREASES IN WILDFIRE FREQUENCY OR INTENSITY?

Figure D-2-3 represents the VCC for the deciduous forest woodlands. This figure represents changes in vegetation and fuels from their historical condition. For the Middle Rockies, a group of SMEs went through an exercise to illustrate fire regime (frequency and severity) departure. The historic BpS was attributed with a current fire severity and frequency, and then compared with the reference (historic) fire frequency and severity for each type. From these data, we were able to develop a fire frequency departure map, a fire severity departure map, and then a composite map (which took the highest of either departure). This modified composite layer was used as the best indicator for potential threat to the deciduous forest woodland from an uncharacteristic fire.

6.5 HOW AND WHERE ARE FREQUENCY AND SEVERITY OF OUTBREAKS EXPECTED TO CHANGE IN RESPONSE TO CLIMATE CHANGE AND OTHER CHANGE AGENTS SUCH AS CHANGE IN FIRE FREQUENCY?

The climate change analysis predicts an increase across the entire ecoregion; however, the analysis predicts a somewhat gradual gradient of higher temperatures from north to south. In addition, warming seasonal temperatures could increase the likelihood of more severe fires due to current fire regime departures.

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APPENDIX D-2

FIGURES

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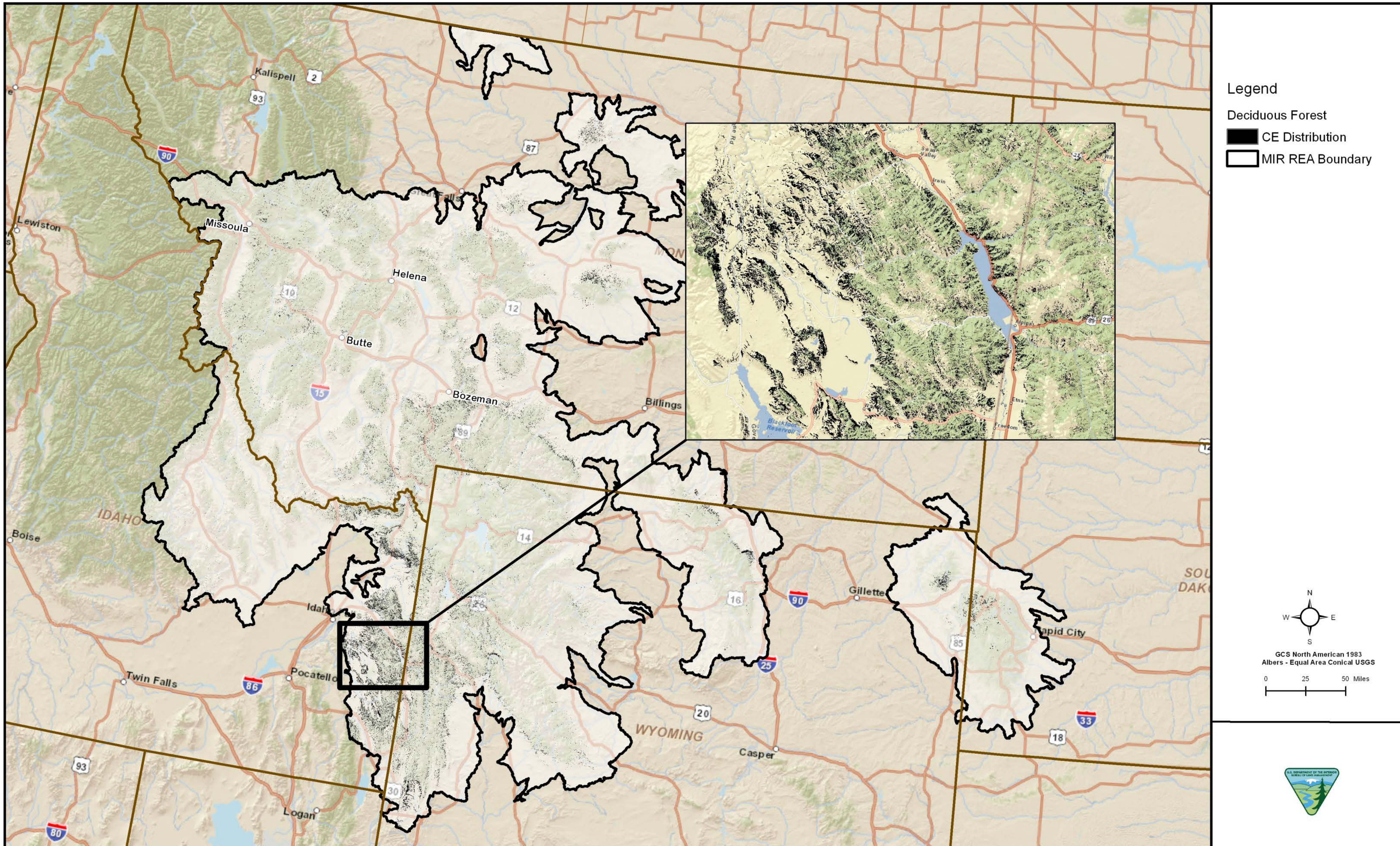

Figure D-2-1. Middle Rockies Deciduous Forest Woodland Distribution

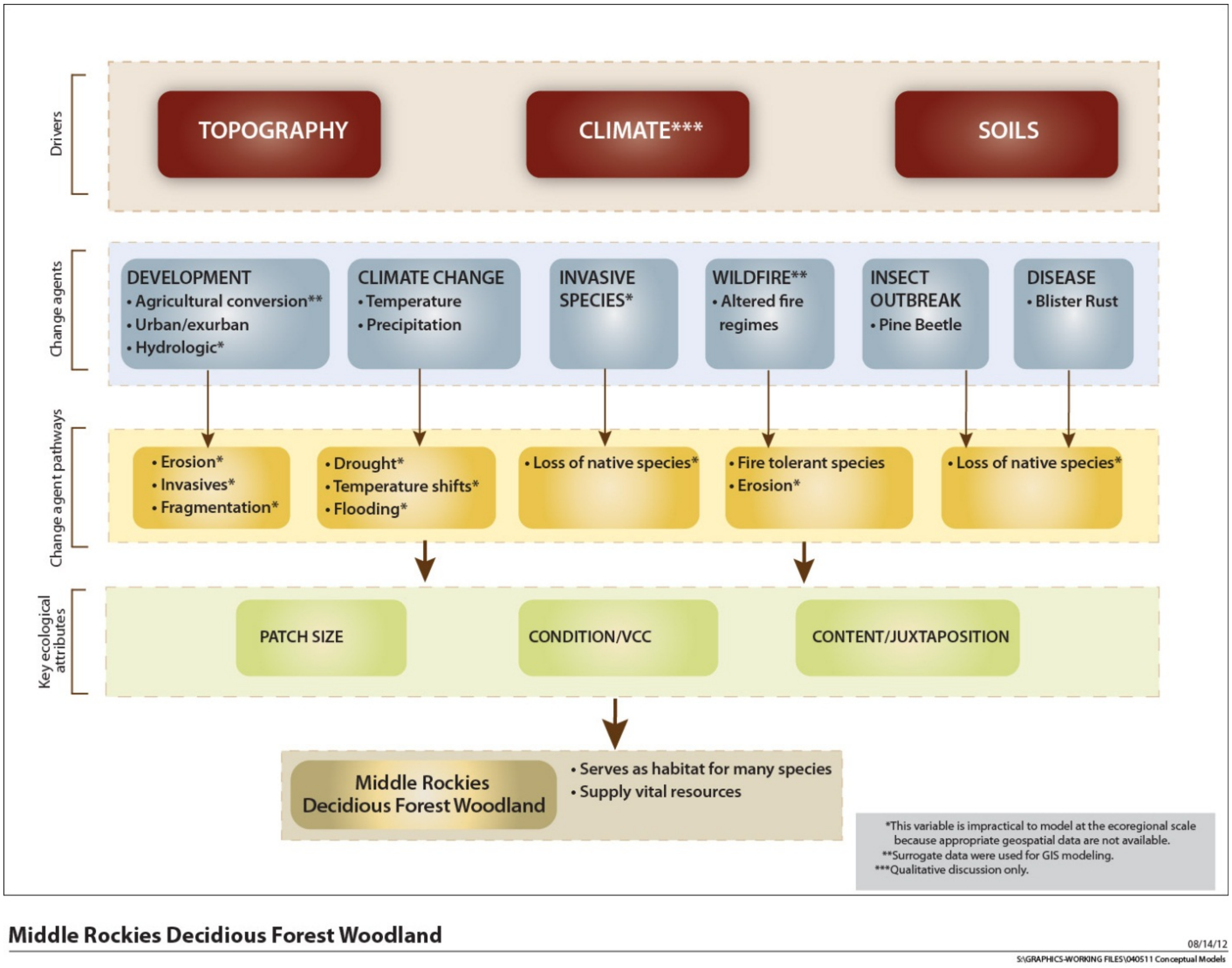

Figure D-2-2. Middle Rockies Deciduous Forest Woodland System-Level Model

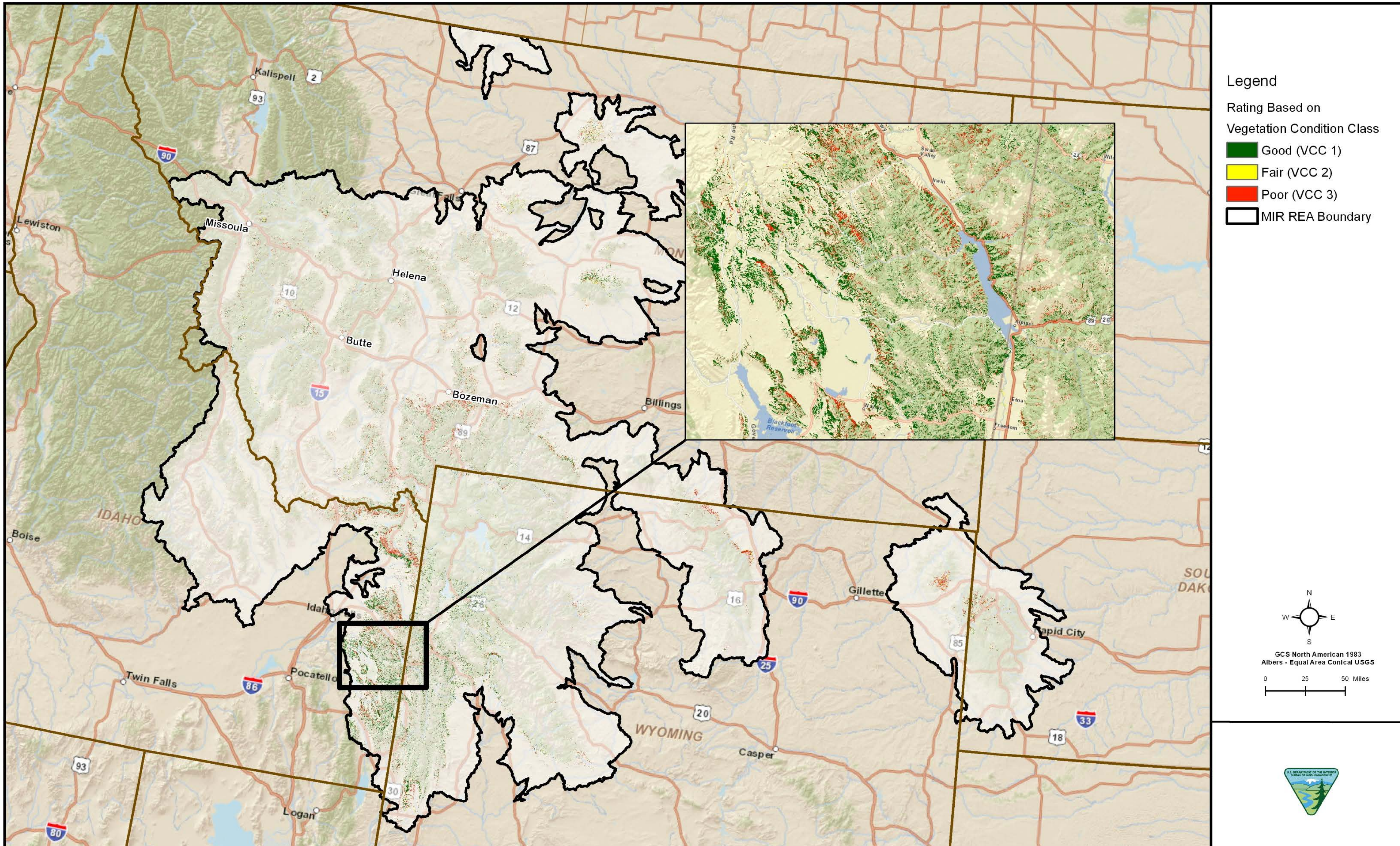

Figure D-2-3. Middle Rockies Deciduous Forest Vegetation Condition Class

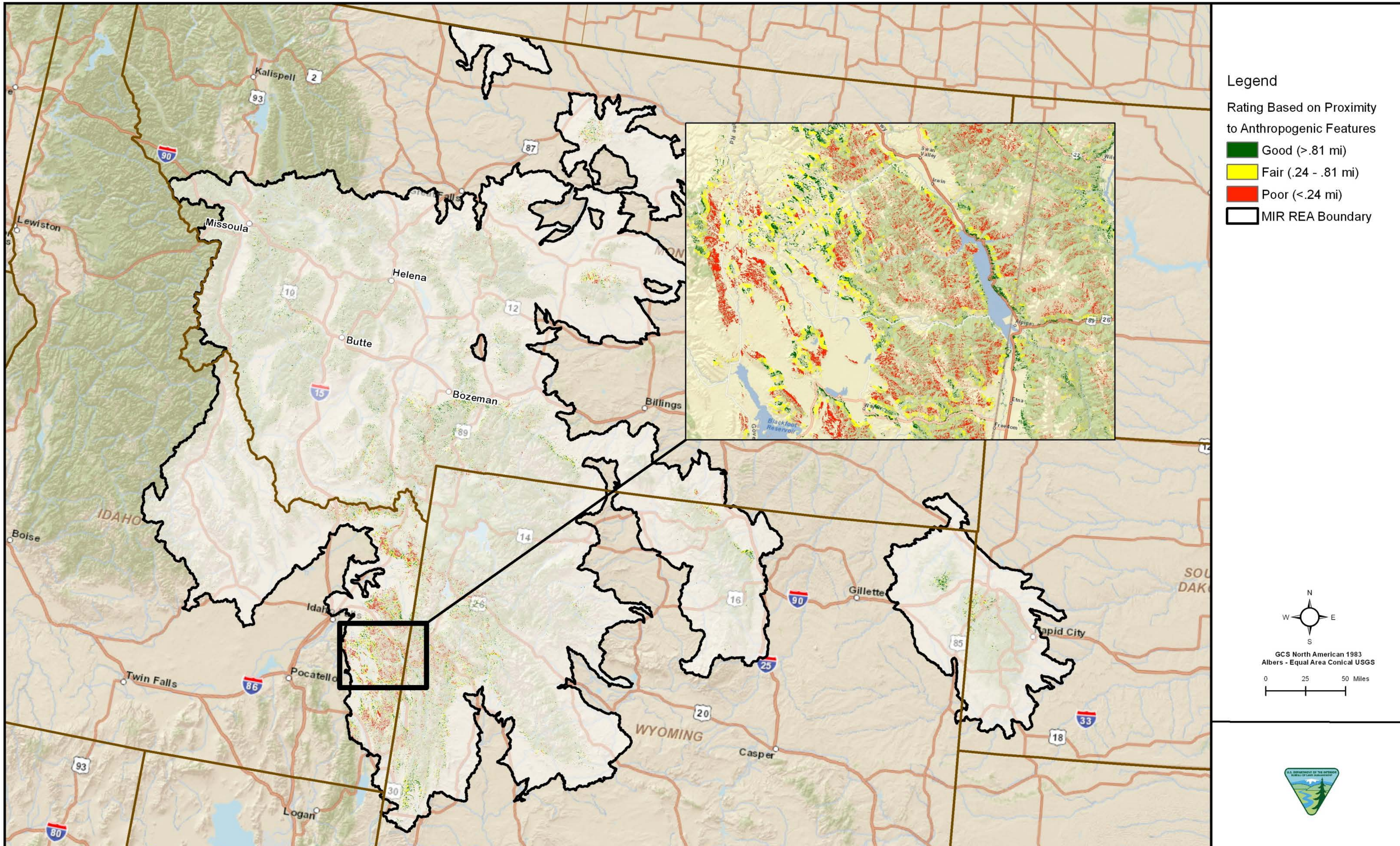

Figure D-2-4. Middle Rockies Deciduous Forest Fragmentation

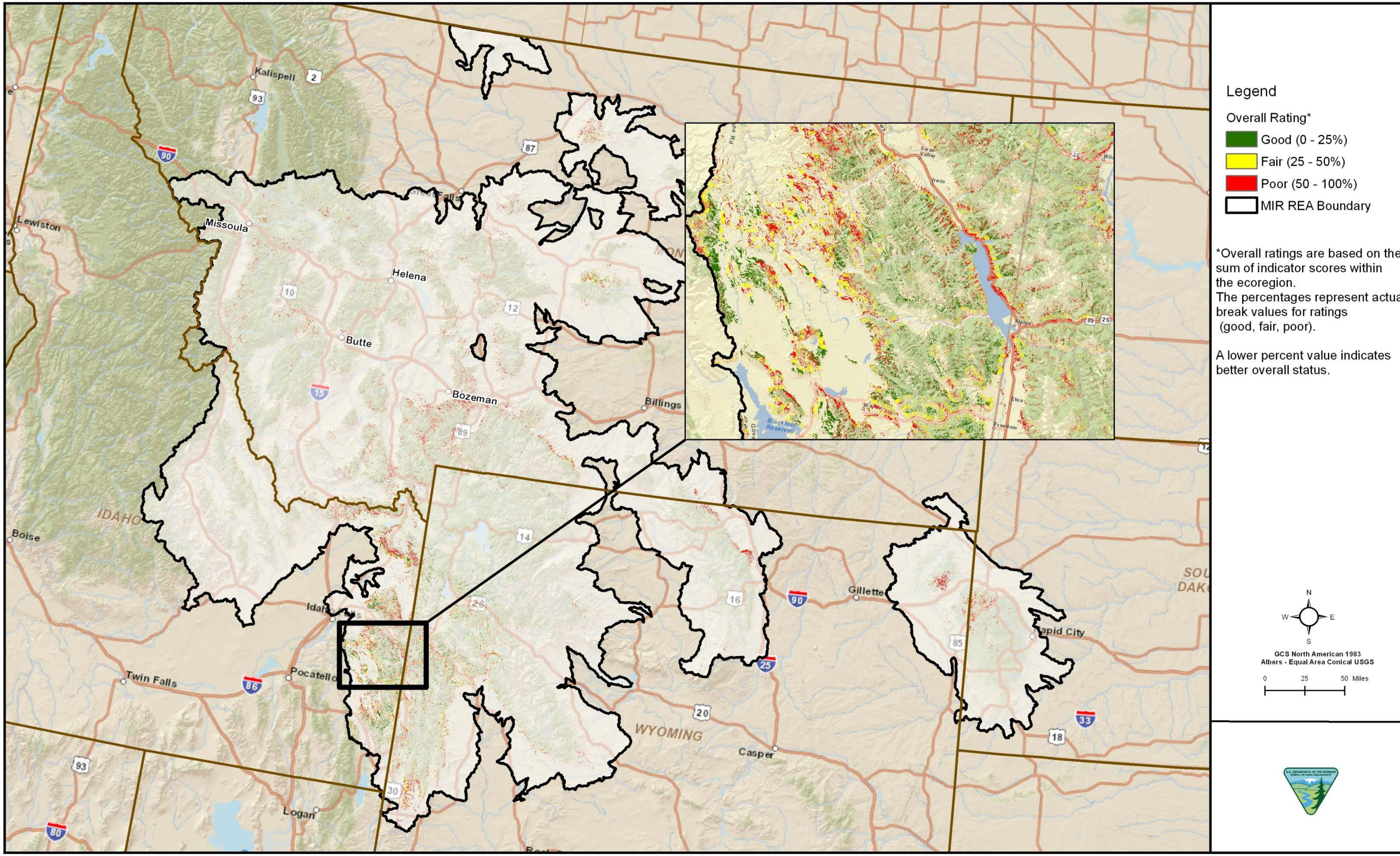

Figure D-2-5. Middle Rockies Deciduous Forest Current Status

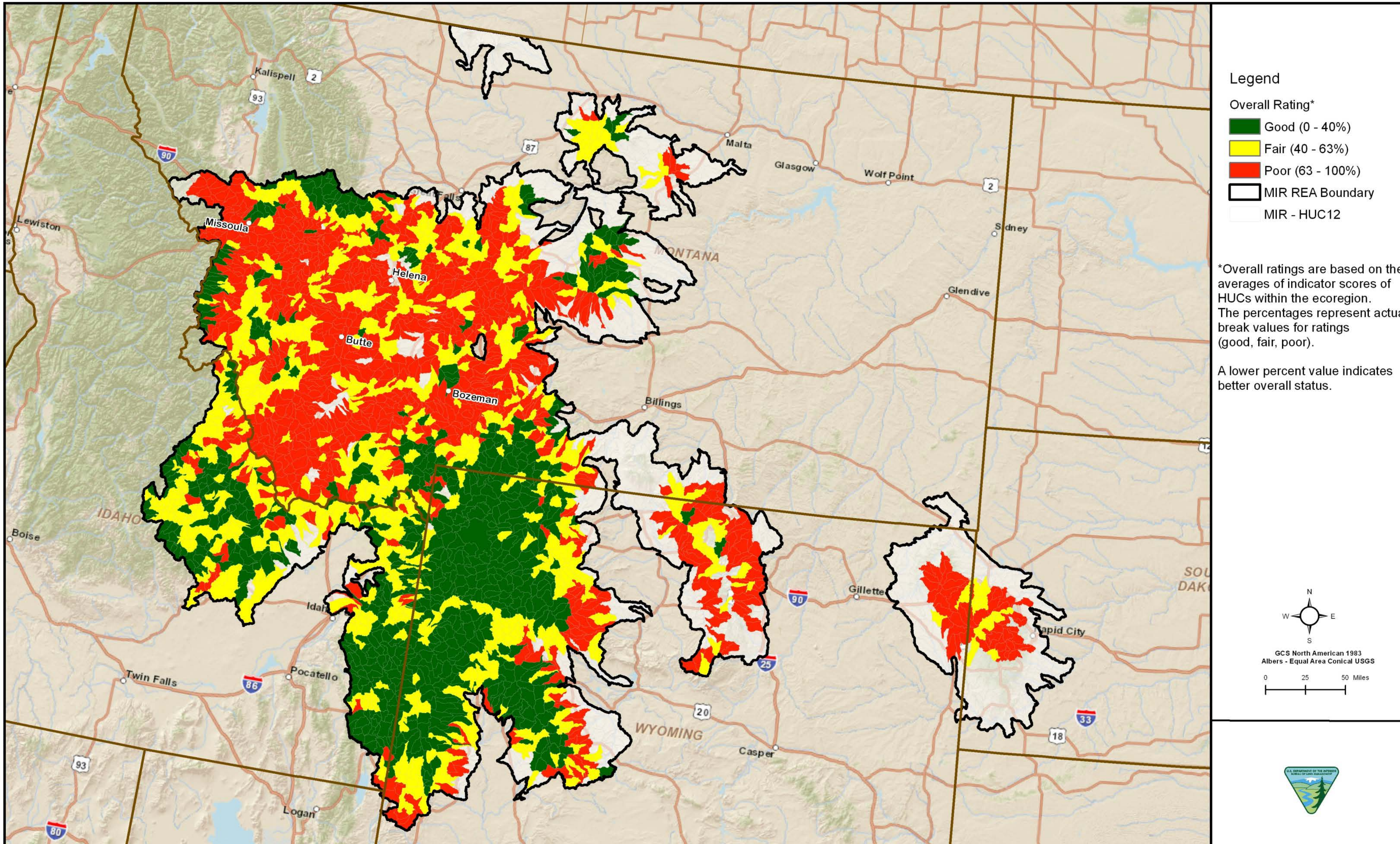

Figure D-2-6. Middle Rockies Deciduous Forest Current Status by 6th Level Hydrologic Unit Code

APPENDIX D-3

GRASSLAND VEGETATION SYSTEMS COARSE-FILTER CONSERVATION ELEMENT ANALYSIS FOR THE MIDDLE ROCKIES ECOREGION

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1.0 INTRODUCTION

The grassland vegetation system encompasses approximately 18 percent of the Middle Rockies ecoregion and the 5th level Hydrologic Unit Code (HUC) boundary. Most of the large contiguous grasslands are within the 5th HUC buffer. The Northwestern Great Plains Mixedgrass Prairie and the Northern Rocky Mountain Lower Montane, Foothill, and Valley Grassland level 3 systems dominate the grasslands of the Middle Rockies ecoregion. This coarse-filter conservation element (CE) analysis will focus on these two Level 3 systems.

A variety of the management questions (MQs) apply to this assemblage. Many of the MQs can be summarized into two primary questions: 1) where are the important areas for this assemblage? and 2) what is happening to those areas? The central focus of these two MQs is to document the current status of selected CEs at the ecoregional scale and to evaluate how this status may change over a future time period. The first step is to identify suitable habitat for the CE within the ecoregion. Then, these areas are assessed relative to current and potential future change agent (CA) threats. CAs considered in this analysis include wildfire and development.

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2.0 CONSERVATION ELEMENT DESCRIPTION

The Level 3 systems represented in this model are briefly described below.

2.1 NORTHWESTERN GREAT PLAINS MIXED-GRASS PRAIRIE

Located on uplands, slopes, and creek bottoms, this system covers much of the eastern two-thirds of Montana, interrupted only by wetland/riparian areas or sand prairies. Vegetation is a mixture of mid and short grasses with western wheatgrass (*Pascopyrum smithii*) usually dominant. Frequent fires and large numbers of migrating herbivores contributed to the historical diversity of plant species in this system (Montana Field Guide 2011a).

Fire and grazing are the primary drivers of this system. Drought can also impact the system, in general favoring the shortgrass component at the expense of the mid-height grasses. Major threats include conversion to agricultural land uses, prolonged drought, and invasion by non-native species (Montana Field Guide 2011a).

2.2 NORTHERN ROCKY MOUNTAIN LOWER MONTANE, FOOTHILL, AND VALLEY GRASSLAND

This system occurs at lower montane-to-foothill elevations in the mountains and large valleys. Precipitation ranges from 20-30 inches per year, much in the form of snow and spring rains. Vegetation in this system includes cool-season, perennial bunchgrasses and forbs, sometimes with a sparse shrub layer. This system ranges from small meadows to open parks surrounded by conifers within lower montane forests in the mountains surrounding the Columbia Basin, and as foothill and valley grasslands below the lower tree line (Crawford 2011).

A high-frequency fire regime, along with soil drought and herbivory, retards shrub and tree invasion, resulting in a patchy distribution of shrubs and trees when present. Isolation of grassland patches by fragmentation may also limit seed dispersal of native shrubs, leading to persistence of the grassland (Crawford 2011).

Major threats to this system include invasion by non-native species, livestock practices, fire regime alteration, direct soil surface disturbance, and fragmentation (Crawford 2011).

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3.0 CONSERVATION ELEMENT DISTRIBUTION MAPPING

3.1 DATA IDENTIFICATION

The major datasets identified to map the distribution of this CE were the Gap Analysis Program (GAP) landcover and Landscape Fire and Resource Management Planning Tools Project (LANDFIRE) datasets. Both datasets have adequate coverage across the ecoregion and have been used in similar analyses. The grassland distribution datasets are further described in Table D-3-1.

Table D-3-1. Data Sources for Grassland Vegetation Systems Coarse-Filter Conservation Element Distribution Mapping for the Middle Rockies Ecoregion

Data Needs	Dataset Name	Source Agency	Type/Scale	Status	Use in REA
Terrestrial Systems					
Ecological Systems	GAP Landcover Northwest Regional Gap Analysis Program (ReGAP) North Central GAP	U.S. Geological Survey (USGS)	Raster (30-meter [m])	Acquired	Yes
	LANDFIRE	LANDFIRE	Raster	Acquired	No
Soils Data	Soil Survey Geographic (SSURGO) State Soil Geographic (STATSGO2)	U.S. Department of Agriculture (USDA)	Polygon	Acquired	No

3.2 DISTRIBUTION MAPPING METHODS

To map distribution of the grassland coarse-filter CE in the Middle Rockies ecoregion, Science Applications International Corporation (SAIC) used a mosaic of GAP data sources, including two of the National GAP landcover regions, the Northwest and North Central. The source data for the Northwest region was the Northwest Regional Gap Analysis Program (ReGAP) dataset, which improved upon the original Northwest GAP. The North Central region contains states that have not been covered by a ReGAP project. For these areas, the National GAP layer used data from the LANDFIRE project to create a seamless layer. The GAP was developed to help answer questions about species biodiversity and species habitat (USGS 2010). Its overall goal is to assist resource managers in decision making when there is a lack of information about the full range of species on the landscape. Once the data were downloaded, the two datasets were merged together to form a continuous layer of vegetation data across the four states. The continuous data layer was then clipped to the Middle Rockies ecoregion, at which point the Level 3 systems were extracted for review by the Rolling Review Team (RRT) (Figure D-3-1).

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4.0 CONCEPTUAL MODEL

The current status and potential future threat analyses were based on the system-level model, selected environmental variables (Key Ecological Attributes [KEAs]) likely to be at risk from CAs, and the availability of data.

4.1 SYSTEM-LEVEL MODEL

The system-level model for the Middle Rockies grassland system illustrates the major drivers across the top (Figure D-3-2). The major drivers dictate where these vegetation systems occur throughout the ecoregion, while the CAs focus on what has potential to affect this CE over time. Below the CAs are the corresponding CA pathways, which affect both the status and distribution of this CE across the Middle Rockies ecoregion. Listed below the CA pathways are the three categories of size, context, and condition for development of the KEAs for this coarse-filter CE. The KEAs were developed and refined through the rolling review process.

4.1.1 Wildfire

Fire is a primary driver of grassland systems. Historically, frequent indigenous anthropogenic fires and large numbers of migrating bison and other herbivores contributed to plant species and plant community diversity within these systems. Pre-settlement fire frequency occurred at intervals ranging from 3 to 20 years (Umbanhowar 1996). The elimination of bison and frequent fire intervals disrupted plant community dynamics, leading to a decrease in plant community diversity. In the absence of fire, grassland systems may be susceptible to woody plant or cacti invasion. The dynamics of species changes in grassland systems is a function of climate, but the magnitude of these changes is greatly influenced by the intensity of fire frequency.

4.1.2 Development

In the Middle Rockies, development is a moderate issue compared to climate change and altered fire regimes. However, due to increasing population growth and urban-to-rural migration trends, fragmentation is a definite factor shaping the landscape. Development fragments grassland systems by separating contiguous areas of habitat into smaller patches isolated from one another. Fragmentation from development and agricultural pressures reduces the viability of management and environmental benefits, such as ecological stability of flora and fauna (Bowers and Daniels 1997). With increased agricultural practices, grassland systems that have been disturbed by previous cultivation or over-grazing may support large numbers of invasive or non-native plant species.

4.1.3 Climate Change

Climate change may pose major threats to grassland systems. Warming seasonal temperatures could increase the likelihood of more severe fires due to current fire regime departures. Changes in precipitation may cause prolonged extreme drought, reducing the density and cover of short grasses by as much as 80 percent and reducing bunchgrasses and native forbs to almost zero (Albertson 1937). During prolonged drought, native forbs are rapidly replaced by non-native invasive forbs.

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5.0 CHANGE AGENT ANALYSIS

A current status assessment was conducted on the grasslands CE for the Middle Rockies ecoregion with native 30-meter (m) raster data as the analysis unit. Based on the system-level model, KEAs were identified for the current status analyses, with a specific emphasis on the ability to measure impacts using existing geospatial data. For each analysis, a series of intermediate data layers were created based on the KEA indicators which are "scored" according to a designated metric and then ranked (good, fair, or poor). If necessary, data from multiple source datasets were combined.

Since the scale of the reporting unit is at the HUC 12, a layer of 6th level HUCs was extracted for the ecoregion. A geographic information system (GIS) process was iterated through the KEA indicators and determined the metric values associated with some watersheds. In other instances, sufficient published data indicated cut-off points for these values. These values were added as an attribute to the HUC 12 layer. The intermediate CA layers were then combined together to form a single layer outlining the current status or future threat status for each HUC.

Although numerous preliminary KEAs and indicators that may affect the grasslands were initially identified in the early phases of this Rapid Ecoregional Assessment (REA), not all were included in this analysis because either the attribute or indicator was not suitable for a landscape level analysis or because data are not available to support the analysis. The specific indicators that could not be modeled are identified with an asterisk on Figure D-3-2. Further information on the data gaps for these indicators are discussed in the respective CA analyses contained in Appendix C.

For the KEAs that were determined to be duplicative, some were pixel-based, some were HUC-based, and others did not show any differentiation across the ecoregion. Table D-3-2 identifies the original KEAs and identifies which of those were used in the final CA analysis.

Table D-3-2. Key Ecological Attributes Retained or Excluded

Category	Key Ecological Attribute	Explanation
1. Size	a. Size of Patches	This analysis was completed and included as a KEA used in the current status assessment.
2. Condition	a. Vegetation Condition Class (VCC)	Retained to show the fire return interval (FRI) for the ecoregion.
	b. Invasive Species	Dropped due to insufficient data.
3. Structure	a. Fragmentation	Added to show the fragmentation throughout the ecoregion.
	b. Connectivity	Retained to show potential habitat connectivity.

5.1 CURRENT STATUS OF THE CONSERVATION ELEMENT

Table D-3-3 identifies the KEAs, indicators, and metrics that were used to evaluate the CAs and pathways affecting this CE across the ecoregion. The grassland process analysis is designed to create a series of intermediate layers that are primarily based on the wildfire and insect and disease outbreak CAs. The analysis is based on the geospatial data available.

5.1.1 Key Ecological Attribute Data Analysis for Current Status

For each of the KEAs listed in Table D-3-3, a discussion of the indicator, metric, metric rank and value, data source(s), and references is provided. Only two indicators were used to assess the current threat status for the grasslands (Table D-3-3). This table was limited to size and landscape context based on spatially available attributes and key factors affecting grasslands in the ecoregion.

In most cases, the metrics used to identify attribute quality were based on available publications, coupled with expert analysis and professional judgment in association with data-driven metrics. Equal weights were attributed to each metric in order to provide an overall score for all metrics combined, based on the reporting unit.

Table D-3-3. Key Ecological Attributes for the Grasslands Vegetation Systems Coarse-Filter Conservation Element for the Middle Rockies Ecoregion

Category	Ecological Attribute	Indicator / Unit of Measure	Metric			Data Source	Citation	Weight
			Poor = 3	Fair = 2	Good = 1			
Size	Patch Size	Acres	<692	692-11,937	>11,937	ReGAP/GAP	RRT Guidance (Geometric Interval classification)	0.25
Landscape Structure	Structure	Mean FRI (years)	0-10 or >80	10-20 or 60-80	20-60	LANDFIRE	RRT Guidance	0.25
	Fragmentation	Distance Decay Proximity to anthropogenic layer (meters)	<500 m	500 to 2,500 m	>2,500 m	Integrated Climate and Land Use Scenarios (ICLUS) Topologically Integrated Geographic Encoding and Referencing (TIGER)	Professional judgment; Herkert (1994); Johnson and Igl (2001)	0.25
	Connectivity	Percent of similar habitat (1-kilometer [km] neighborhood)	<15%	15-30%	>30%	ReGAP/GAP		0.25

Analysis Unit = 30-m pixel
Reporting Unit = 6th level HUC

5.1.1.1 Patch Size

Patch size for the grassland coarse-filter CE was determined by finding acres of contiguous sets of 30-m raster cells. After reviewing the patch size analysis, it appears an artifact of satellite imagery is to have a high number of isolated pixels and to overestimate large numbers of contiguous pixels. This results in large variations of values and made it difficult to score size based on appropriate sizes of grassland across the Middle Rockies ecoregion. After much discussion with the RRT, it was decided to allow the data to dictate the scoring.

There are several ways to classify the data for scoring and, in most cases, it was decided to use Jenk's Natural Breaks. However, due to the issues with the variation in the size of patches, the Geometric Interval Classification was used. Geometric intervals are used to delineate classes based on groupings inherent in the data. The Geometric Interval Classification attempts to balance the changes in the middle values and the extreme values.

Figure D-3-3 is a graphical representation of patch size for the grassland coarse-filter CE. Red displays low scoring patches, where green shows higher scoring patches.

5.1.1.2 Mean Fire Return Interval

For landscape structure, the LANDFIRE Vegetation Condition Class (VCC) data were used to show changes in vegetation and fuels from their historical condition. For the Middle Rockies, a group of subject matter experts (SMEs) went through an exercise to illustrate fire regime (frequency and severity) departure. The historic biophysical setting (BpS) was attributed with a current fire severity and frequency and then compared with the reference (historic) fire frequency and severity for each type. From these data, a map of current fire frequency intervals was created. These data were then used to score grassland FRIs based on the current fire frequency from information provided by the RRT (Table D-3-3). This proved to be very helpful, as an error was found in the LANDFIRE 2008 refresh 1.1 data. Based on the LANDFIRE 2008 refresh 1.1 data, the longest mean FRI interval was 25 years. The fire frequency layer was extracted to the grassland layer and used in the grassland current status weighted summary analysis (shown in Figure D-3-4).

5.1.1.3 Fragmentation

The Integrated Climate and Land Use Scenarios (ICLUS) 2010 was used by extracting the urban, exurban, and industrial categories and then merging the Topologically Integrated Geographic Encoding and Referencing (TIGER) roads for the entire ecoregion. A Euclidean distance proximity analysis was run from this anthropogenic layer. The proximity analysis was then extracted to the grassland coarse-filter CE (Figure D-3-5). This layer was then scored based on the assumption that grasslands closer to roads and urban areas are more fragmented (Table D-3-3).

5.1.1.4 Connectivity

The grassland coarse-filter distribution layer was used to perform a neighborhood analysis to determine the extent of grassland within the 1-kilometer (km) neighborhood. The neighborhood analysis looks at the relationship of each pixel and the pixel surrounding it using a spatial analyst function. The resulting layer provided the percent grassland within the 1-km neighborhood. This layer was then extracted to the grassland coarse-filter layer and scored based on the metrics in Table D-3-3 (see Figure D-3-6).

5.1.2 Current Status of Habitat

The individual KEA analysis provides the basis for the compilation of an overarching data layer that defines the current status of grassland habitat for each HUC across this ecoregion. A method of aggregating scores was used to summarize overall threats with regard to grassland habitat quality. Individual threats can identify areas of potential risk to grasslands, but aggregated scores can provide important information with relation to areas where grasslands might encounter multiple threats.

In order to create a combined score for each HUC based on varying levels of importance for each key attribute, it was necessary to aggregate the data through a weighting process. The weighted sum tool was used to combine each analysis input map to create an overall Current Status Map (D-3-7). Equal weights were used when summing the threats for the grassland.

The resulting output gives each grassland 30-m pixel a score based on current status. Figure D-3-7 displays these results; red indicates areas of poor status, while green indicates areas rated at better current status based on the measured attributes.

The overall threat score for each 6th level HUC was assigned a current habitat quality rating of good, fair, or poor based on the natural breaks method. Statistics were run on the results from Figure D-3-7 to determine the average overall score. The overall result was then scored based on natural breaks. A higher overall threat score would result in a rating of poor for the HUC, indicating that there are existing threats to grasslands based on the KEA metrics.

It should be noted that when displaying results at the 6th level HUC watershed, a few isolated 30-m pixels will determine the score for that watershed (thus potentially scoring a watershed as poor). However, this may be misrepresentative due to the lack of pixels classified as that vegetation type.

The results of the current status analysis based on the 6th level HUC for the ecoregion are presented on Figure D-3-8. Grassland areas in the western portions of the Middle Rockies returned good results, while grasslands more centrally located scored fair to poor. Grasslands in the western portions are much larger, less fragmented, and are a dominate vegetation type in these areas. Grasslands in the central areas of the Middle Rockies are smaller and are found at lower elevations. These areas are predominated by higher elevation montane forests. It appears that patch size, which effects the fragmentation and connectivity of the grasslands, has a major influence on the current status output.

In areas where grassland systems are concentrated from the patch size analysis, the overall score predominantly returned good results, while small isolated patches returned poor results. These very small patches of grassland tend to skew the results of the current status analysis and make it appear worse than it actually is. This is one of the inherent problems with rolling the analysis up to the watershed level. Figure D-4-7 shows the results of this analysis displayed by 30-m pixel. Compared to the analysis presented at the HUC level (Figure D-3-8), this figure presents a clearer depiction of the analysis.

A summary of the current status ratings based on the CE distribution is provided in Table D-3-4. The CE distribution layer was used to calculate the total number of square miles of CE habitat and a percentage of the total number of square miles per HUC that were rated as good, fair, or poor. The results of the current status assessment indicate that approximately 72 percent of the 6th level HUC watersheds that intersect the grassland distribution received an overall rating of fair or poor.

Table D-3-4. Summary of Current Status Ratings for the Grassland System

Overall Rating by 6th Level HUC	Total Square Miles[a]	Percentage of Total Square Miles[a, b]
Good	29,097	28.5
Fair	29,213	28.6
Poor	43,954	43.0

[a] These values include only the area of HUCs that intersect with the CE distribution layer.
[b] Values rounded to one decimal place.

5.2 FUTURE THREAT ANALYSIS

Future threats were evaluated for development for a short-term time horizon (5 to 10 years) and for climate change for a long-term time horizon (50-year; 2050 to 2069). Future spatial data for development was limited to potential energy development, agriculture, urban growth, and climate change, as discussed in the development CA analysis presented in Appendix C-1. Climate change was modeled based on a 15-km grid created for regional analysis. The analysis included a comparison of current climate patterns to future modeled climate patterns and resulted in the delta (change) output figures. Further details regarding the climate change analysis are provided in Appendix C-5.

Because of the inherent inaccuracies of the temporal scale of the future data, it is only possible to infer information pertaining to a subjective future period (rather than a specific time period) for these attributes. However, because of the limits placed on these data outputs it is fair to assume that this model predicts the overall future potential for these attributes within this ecoregion. It is an upper limit of potential growth and should therefore be carefully applied to future estimates of their effect on coarse filters.

5.2.1 Development Change Agent

Future spatial data for development was limited to potential energy development, modeled urban growth, and potential agricultural development, as discussed in the development CA analysis presented in Appendix C-1.

5.2.1.1 Agricultural Growth

Conversion to agriculture is one of the most predominant current and future CAs for grasslands. Grain prices will increase commensurate with world population levels, and the production of crops will need to increase accordingly. Since no future agricultural models exist for use within this ecoregion, a model was created using surrogate data to derive potential future agricultural areas. This analysis was similar to that which was completed for the current status. Figure C-1-1 in Appendix C-1 shows the State Soil Geographic (STATSGO) soil classification types are 1 through 4. Although this information can be portrayed spatially, there is no way to temporally show this future threat. The politics of government subsidized agriculture programs are uncertain and dictate the temporal nature of this CA. Alternatively, this analysis considered the maximum potential for future agricultural areas within this ecoregion.

Figure C-1-1 shows the results of the analysis, indicating potential habitat loss due from potential agricultural land development. Because most of this ecoregion is dominated by forests, mountains, and foothills, the grasslands in this ecoregion are located where the current and future potential for agricultural development exists. Therefore, grasslands in this ecoregion do appear to be at risk from future agricultural development.

5.2.1.2 Future Growth of Urban Areas

Urban growth has the potential to affect grasslands habitat similar to agricultural development. In this ecoregion, minor portions of grasslands are currently in close proximity to urban/suburban populations.

The ICLUS model is a universally accepted model created by the USEPA for use in future climate change modeling; the ICLUS model provides spatial data that can be used to determine the future extent of urban areas for various time periods. The model uses U.S. Census data to predict urban growth. The ICLUS future urban extent for the year 2060 was used in this analysis. Figure C-1-2, Future Urban Growth Potential, shows the results of the analysis.

Based on review of the map, it does not appear that urban growth needs to be considered as high a risk to this CE as agriculture. The ICLUS model indicates urban growth will occur around Livingston and areas south of Missoula. However, these areas do not contain the majority of grasslands in this ecoregion.

5.2.1.3 Oil Production Potential

This future analysis characterized potential oil production areas rather than oil well locations (Figure C-1-4). These larger oil production extents were used to qualitatively assess the potential effect of future oil production activities. Although these areas are based on oil density data, the application of these data to future potential well site activity is unknown. Therefore, a carefully considered approach should be taken when assessing the effect of potential oil production areas on grasslands.

The grasslands of this ecoregion appear to be at low risk from potential development of oil production areas. However, areas in eastern Wyoming, east of Gillette, appear to be at risk from oil development.

It is important to note that the Energy Policy and Conservation Act (EPCA) oil and gas data used in this assessment are based on the maximum potential for oil reserves within the Middle Rockies. As a result, these data are likely over-represented in these figures, and care should be taken in assessing the effects of oil and gas production within the constraints of this analysis.

5.2.1.4 Natural Gas Production Potential

This future analysis characterized potential gas production areas rather than actual gas well locations (Figure C-1-3). These larger gas production extents could be used to qualitatively assess the potential effect of future gas production activities. Although these areas are based on gas density data, the application of these data to future potential well site activity is unknown. Therefore, a carefully considered approach should be taken when assessing the effect of potential gas production areas on grasslands. Most of the grasslands in this ecoregion are at low risk from potential gas production. The majority of potential gas production is limited to northeastern Wyoming. There is one area in western Wyoming that has high potential for natural gas development, but no grasslands occur in this area. From an ecoregional scale, it does not appear that grasslands are at risk from future natural gas development.

5.2.1.5 Future Potential for Solar Development

This future potential analysis characterized the future potential for solar development based on the solar potential maps developed by the National Renewable Energy Laboratory (NREL). Although these maps are very crude, the highest potential for solar development is shown to occur in northwestern Wyoming and west of Rapid City. With the exception of this area west of Rapid City, it does not appear that grasslands are at risk from future solar development.

5.2.1.6 Wind Turbine Potential

The U.S. Fish and Wildlife Service (USFWS) wind turbine data contained attribute information for current and future wind turbine locations. However, the future turbine locations dataset was very limited in number, as most turbines will presumably be erected in the very near future. Therefore, an alternative data set was used to determine the potential areas for erecting wind turbines over a long-term period. The future wind turbine locations were based on the availability of suitable wind speeds.

Data characterized by the NREL was used to create a potential future wind turbine area data layer. A full description of the methods and processes implemented to create this data layer and its corresponding scoring system can be found on Figure C-1-7, Future Wind Projections. Wind Power Classes were characterized as low, moderate, or high for direct comparison to the current wind condition.

The potential threats to grasslands relative to future wind energy development are presented on Figure C-1-7. Higher elevations within this ecoregion are more susceptible to the threat of wind turbine development due to the higher wind speed levels within these areas. However, limited accessibility to these higher elevations could limit the range of wind turbine development to lower elevation mountainous regions. Because wind turbine potential is higher at higher elevations, these areas do not seem to pose an overall risk to grasslands of this ecoregion. With the exception of some of the grasslands in the northeast portion of this ecoregion, the majority of grasslands do not appear to be at risk from wind farm development. In addition to the physical disturbance that wind turbines can have on grasslands, bird mortality is also a concern. The proximity of grasslands and wetlands (where the majority of our nation's waterfowl migrate through) should be considered when future wind farm development is planned in this area. Although this assessment is primarily qualitative, the spatial distribution of grasslands and mid-level elevation wind turbine potential overlap is apparent. There is potential for negative effects on grasslands within the eastern portion of the ecoregion if wind turbine production increases in these areas.

5.2.1.7 Overall Development Change Agent Future Threats

A fossil fuel energy output layer was created to address the MQs associated with future fossil fuels production. This layer was created by averaging the EPCA oil data layer with the EPCA gas data layer (Figure C-1-5). Most of the grasslands in the ecoregion will likely remain unaffected by fossil fuels production in the Middle Rockies. The majority of potential fossil fuels production is limited to northwestern Wyoming.

A renewable energy output layer was created to address the MQs associated with future renewable energy production. This layer was created by averaging the NREL wind speed data layer with the NREL solar energy data layer (Figure C-1-8). This output layer provides equal weighting to potential wind and solar energy production areas, and could therefore mischaracterize the effects of each. Unlike oil and gas, wind and solar energy are not necessarily closely associated with one another spatially. Photovoltaic solar arrays threaten the species by their effect on habitat availability. Solar arrays are diverse in scope and size, and it is therefore difficult to create a clear correlation between habitat loss and solar energy production.

Because of the intricacies involved in the assessment of renewable energy production with regard to grasslands, a limited approach must be taken in this analysis. The majority of the grasslands in this ecoregion are not considered to be at risk from the threat of renewable energy production.

5.2.2 Climate Change Future Threats

5.2.2.1 Ecoregion Climate Change Analysis

From a climate change perspective, temperature and precipitation are the factors that would most affect grasslands. In general, the climate change results indicate that the majority of the temperature and precipitation changes will occur at higher elevations, above where the majority of the grasslands in this ecoregion occur. The western and northern mountain ranges could experience modest increases in annual precipitation, while the basins will remain relatively unchanged.

The same patterns appear to be true for temperatures. While temperatures in the mountains will experience slight increases, temperatures in the basins will remain relatively unchanged.

Climate change presents many different issues relating to grasslands. However, it remains difficult to draw conclusions from the data presented in this REA. Climate change models are highly variable and often difficult to predict. In this case, the resolution of the spatial data is an important factor to consider.

Based on the analysis conducted for the ecoregion, as presented in Appendix C-5, it does not appear that grasslands are at a high risk from temperature or precipitation changes in the Middle Rockies. However, the combined impacts of increased temperatures, invasive species, localized drought, and conversion of lands to agricultural uses could negatively affect grasslands in the future.

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6.0 MANAGEMENT QUESTIONS

The relevant MQs for the grassland system would include those defined as part of the Terrestrial Biotic Resources category. The overall MQ was: Where are the important regionally significant terrestrial features, functions, and services across the ecoregional landscape? This MQ was considered in implementing the GIS analyses. Emphasis was placed on the spatial relationship of attributes mentioned in the MQs and the grassland distribution model. Several examples of how the REA can be used to answer MQs are provided below to demonstrate the functionality of the REA and to provide an opportunity to discuss data gaps that were identified during this REA.

6.1 HOW ARE THE GRASSLANDS DISTRIBUTED OVER THE LANDSCAPE?

Figure D-3-1 maps the ReGAP grasslands across the ecoregion.

6.2 WHERE WILL CURRENT CONSERVATION ELEMENT VEGETATION TYPES BE AT GREATEST RISK FROM CHANGE AGENTS?

The full range of figures and analyses for the grassland system can be used to answer this complex MQ. The models created throughout this process were created to directly address the effects of CAs on the grasslands. All of the CAs were addressed spatially and described in detail in this section, and all of the CAs were spatially attributed to the distribution of the grassland. Figure D-3-7 represents the sum of Figures D-3-3 through D-3-6 by the 30-m analysis unit, while Figure D-3-8 represents the sum of all the threats at the 12-digit HUC reporting unit.

6.3 WHICH AREAS HAVE POTENTIAL FOR RESTORING CONSERVATION ELEMENT SPECIES HABITAT OR HABITAT CONNECTIVITY FOR CONSERVATION ELEMENT SPECIES, CURRENTLY AND IN THE FUTURE?

The fragmentation potential (Figure D-3-5) represents the potential for further fragmented grassland systems. It can also be used to show areas where future restoration may be the most beneficial. The fragmentation potential shows areas where restoration could potentially connect larger stands together.

6.4 WHERE WILL CONSERVATION ELEMENTS BE AT RISK FROM ALTERED FIRE REGIMES? WHERE ARE AREAS WITH POTENTIAL TO SHOW FUTURE INCREASES OR DECREASES IN WILDFIRE FREQUENCY OR INTENSITY?

Figure D-3-4 represents the VCC for the grassland. This figure represents changes in vegetation and fuels from their historical condition. For the Middle Rockies, a group of SMEs went through an exercise to illustrate fire regime (frequency and severity) departure. The historic BpS was attributed with a current fire severity and frequency, and then compared with the reference (historic) fire frequency and severity for each type. From these data, we were able to develop a fire frequency departure map, a fire severity departure map, and then a composite map (which took the highest of either departure). This modified composite layer was used as the best indicator for potential threat to the grassland system from an uncharacteristic fire. These maps should be used with caution, as this metric is known to be less precise in grassland systems.

6.5 HOW AND WHERE ARE FREQUENCY AND SEVERITY OF OUTBREAKS EXPECTED TO CHANGE IN RESPONSE TO CLIMATE CHANGE AND OTHER CHANGE AGENTS SUCH AS CHANGE IN FIRE FREQUENCY?

The climate change analysis predicts slight temperature increases across the entire ecoregion; however, the analysis predicts a somewhat gradual gradient of higher temperatures from north to south. In addition, warming seasonal temperatures could increase the likelihood of more severe fires due to current fire regime departures.

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APPENDIX D-3

FIGURES

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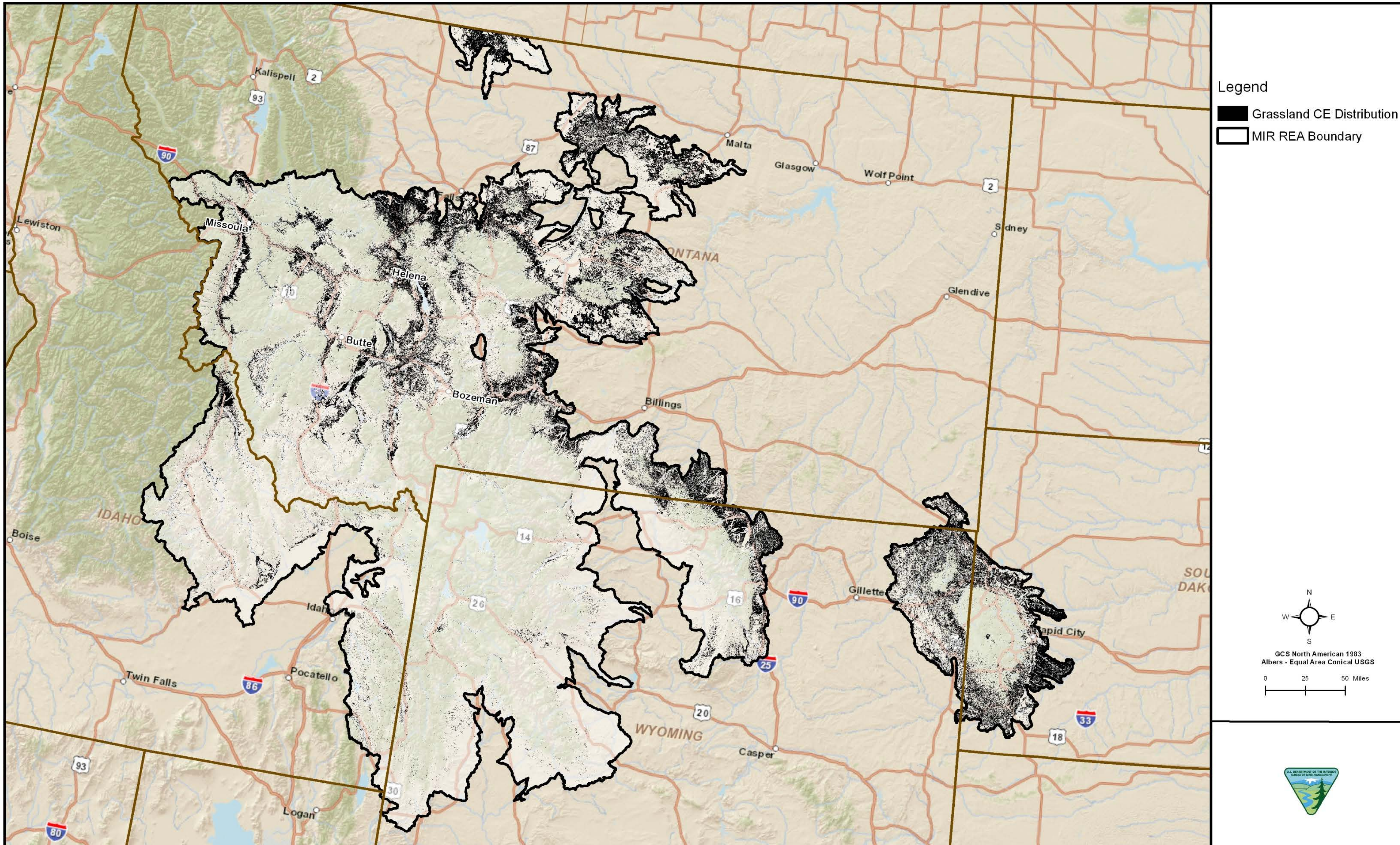

Figure D-3-1. Middle Rockies Grassland Distribution

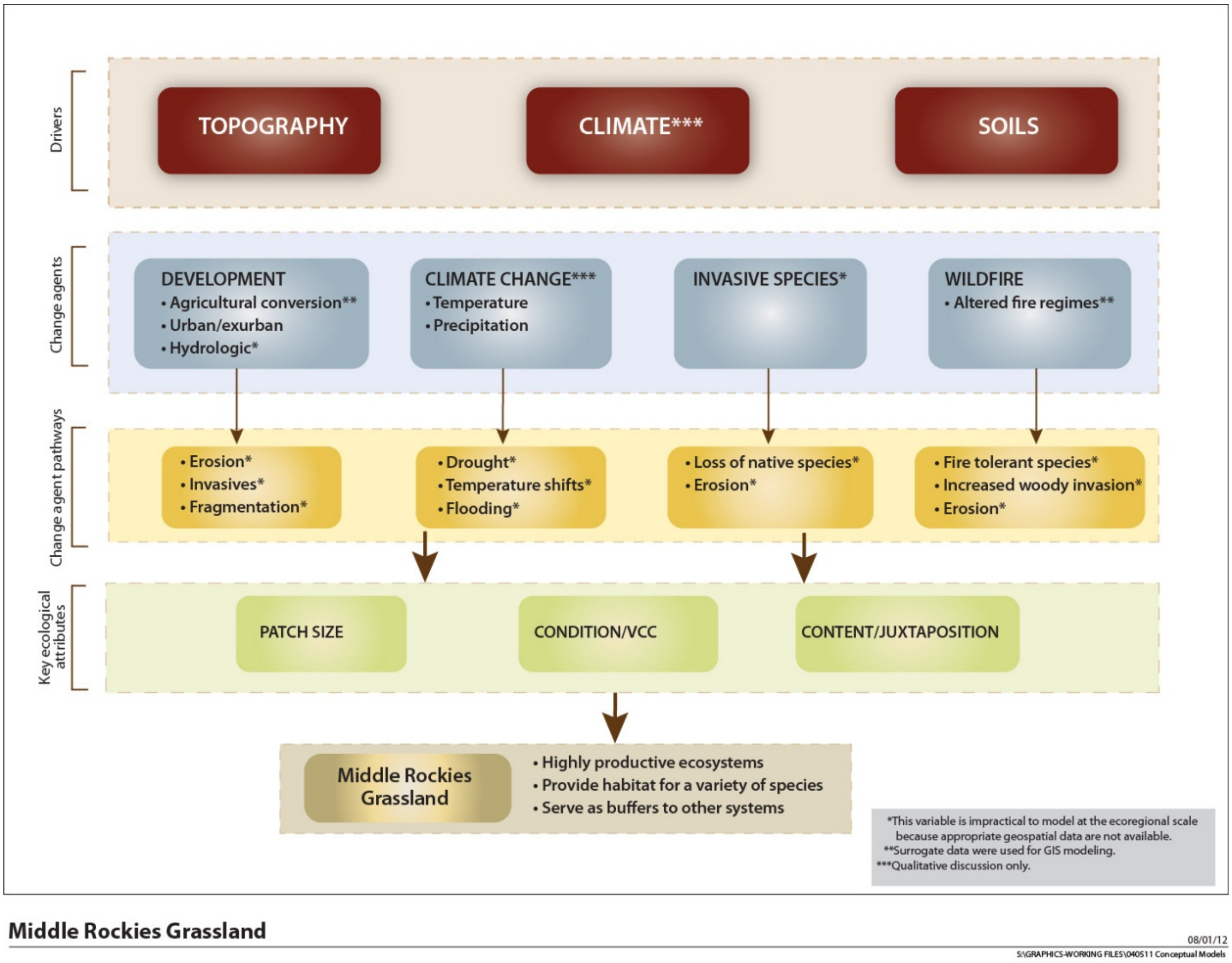

Figure D-3-2. Middle Rockies Grassland System-Level Model

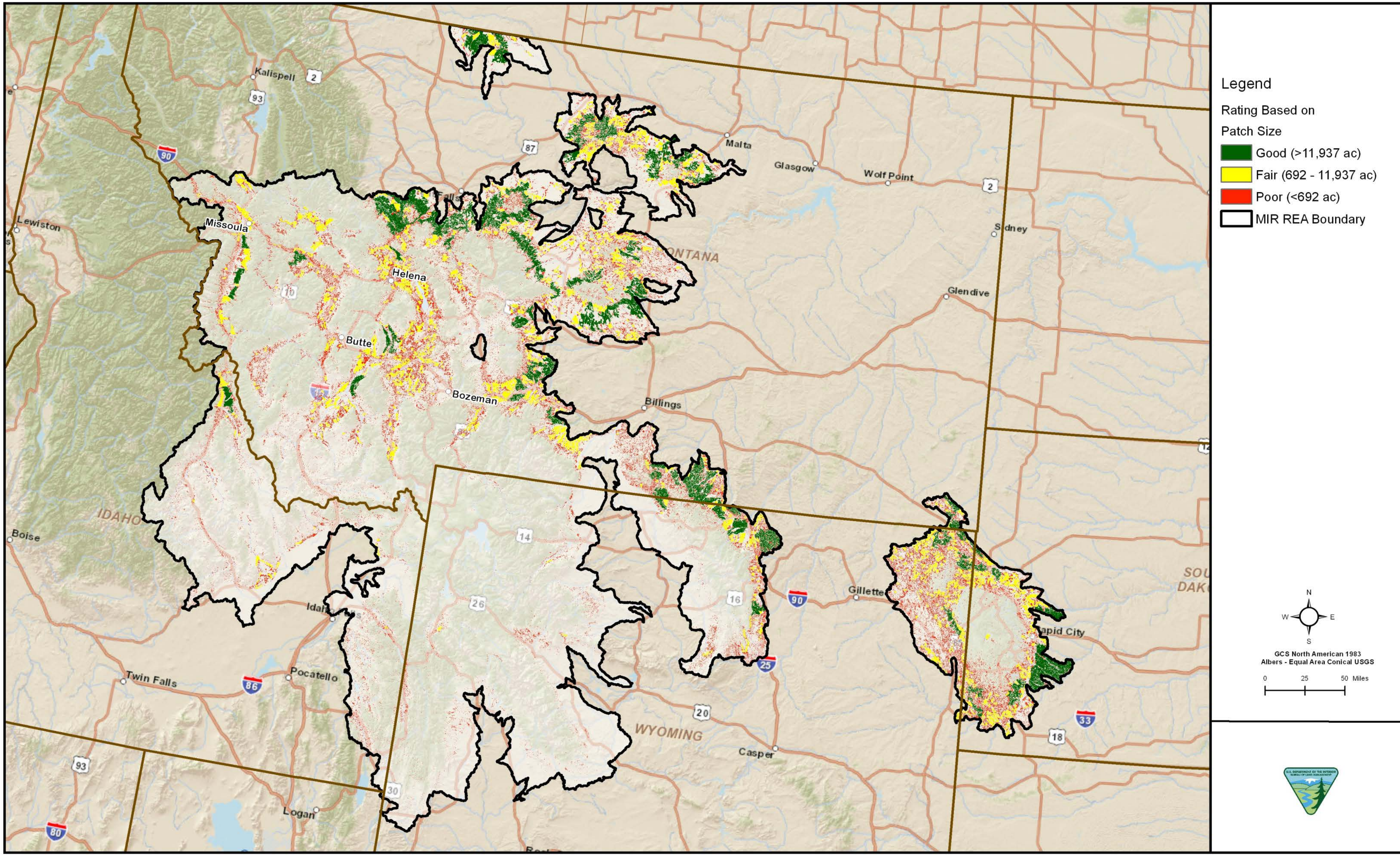

Figure D-3-3. Middle Rockies Grassland Patch Size

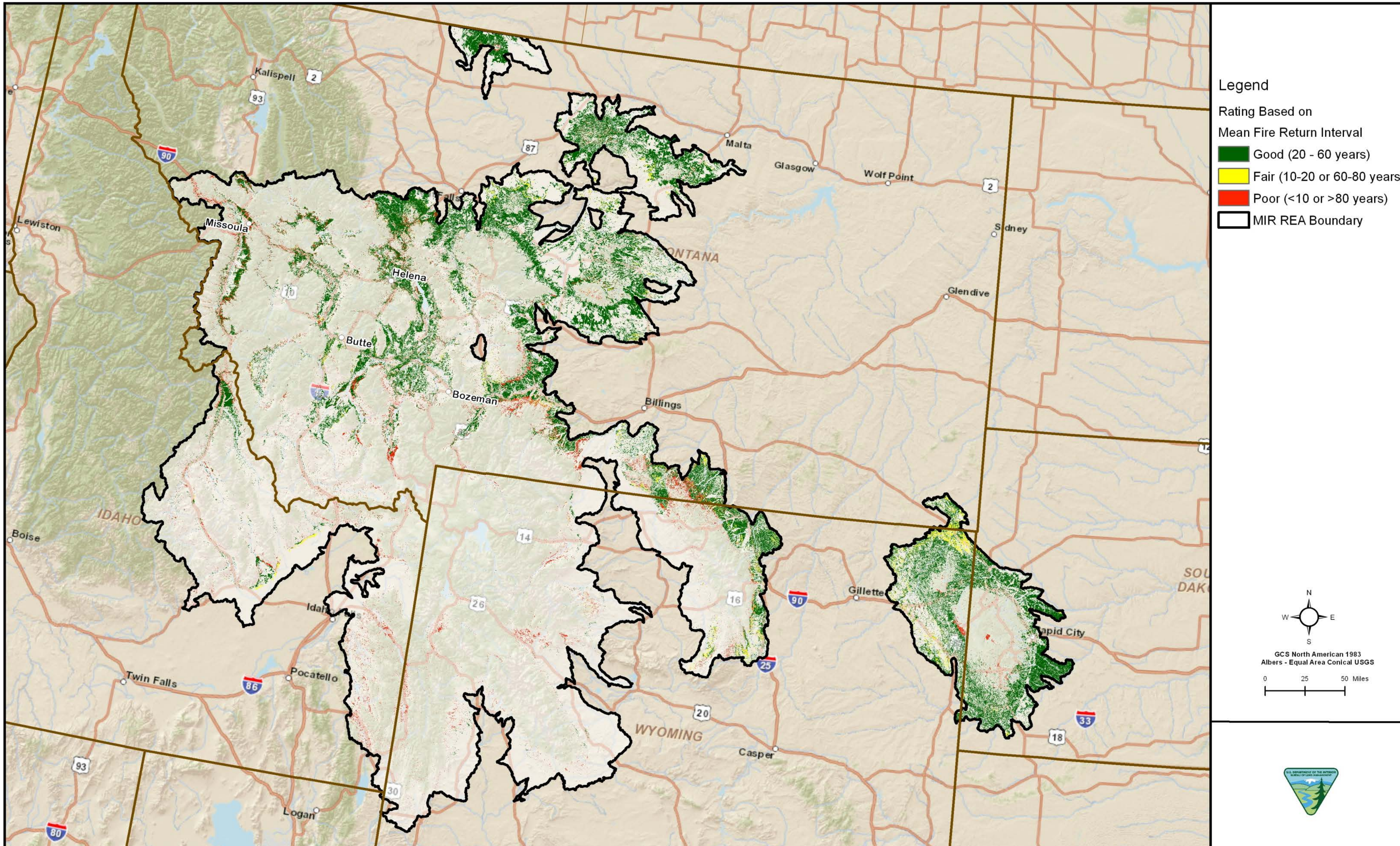

Figure D-3-4. Middle Rockies Grassland Mean Fire Return Interval

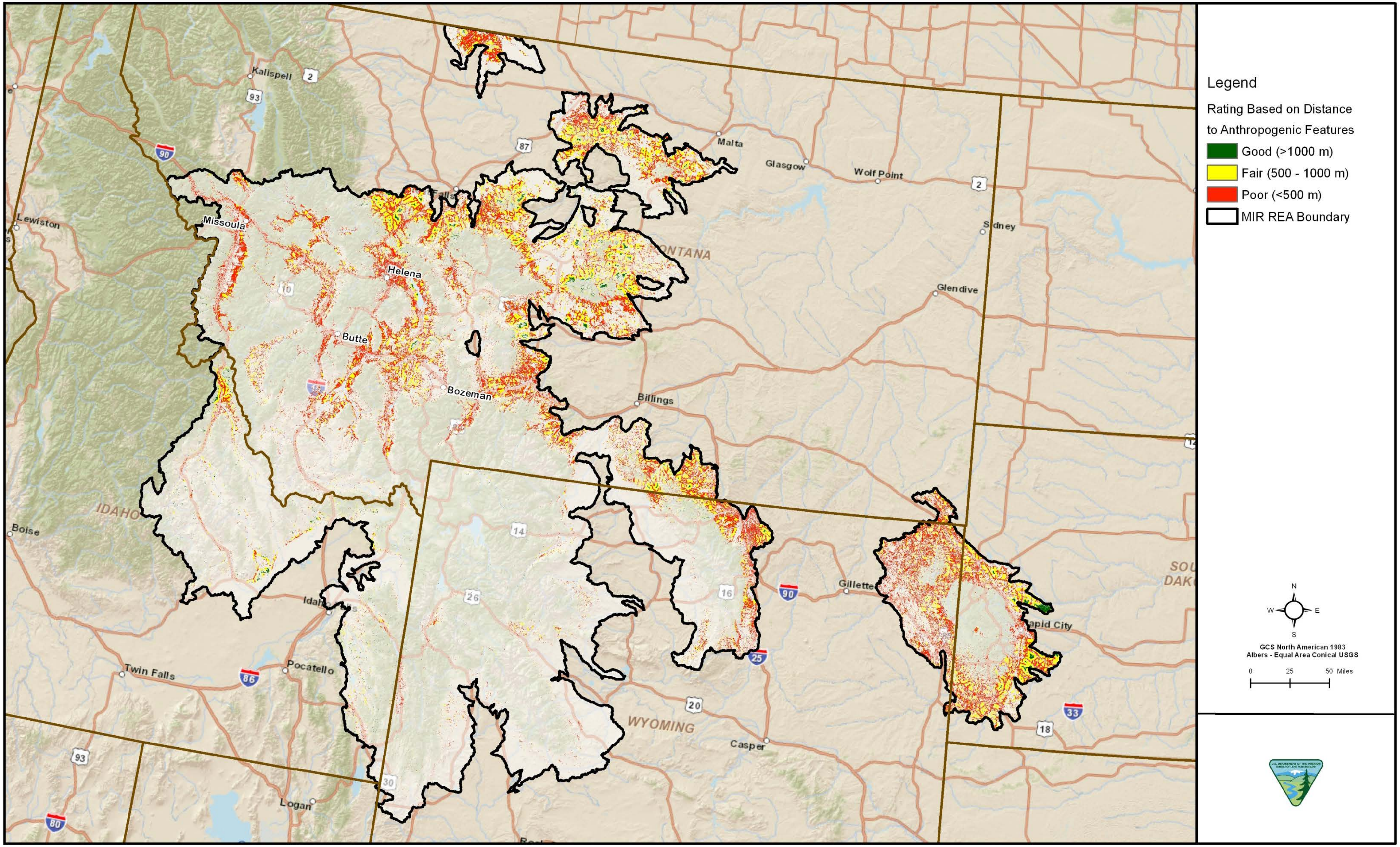

Figure D-3-5. Middle Rockies Grassland Fragmentation

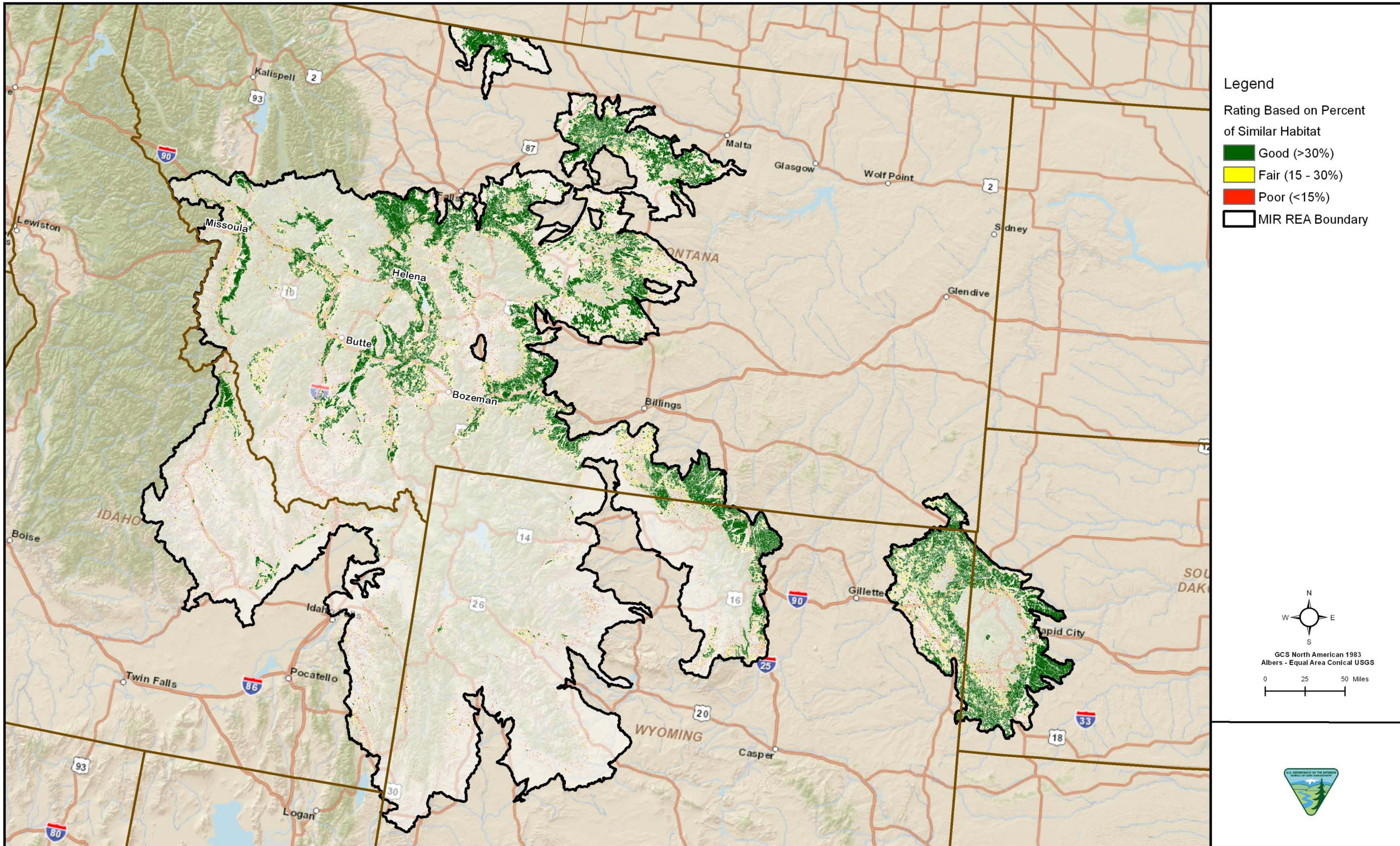

Figure D-3-6. Middle Rockies Grassland Connectivity

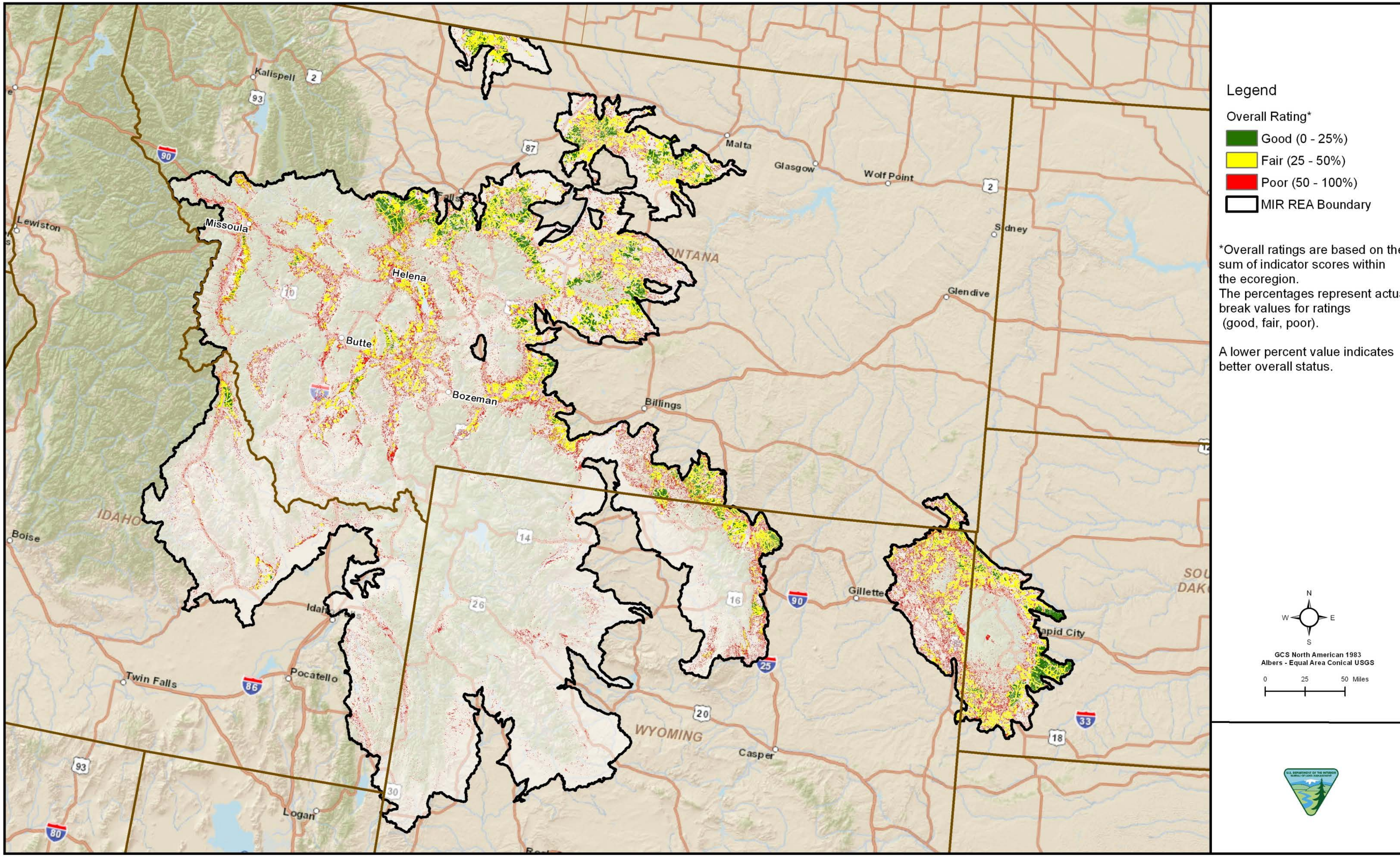

Figure D-3-7. Middle Rockies Grassland Current Status

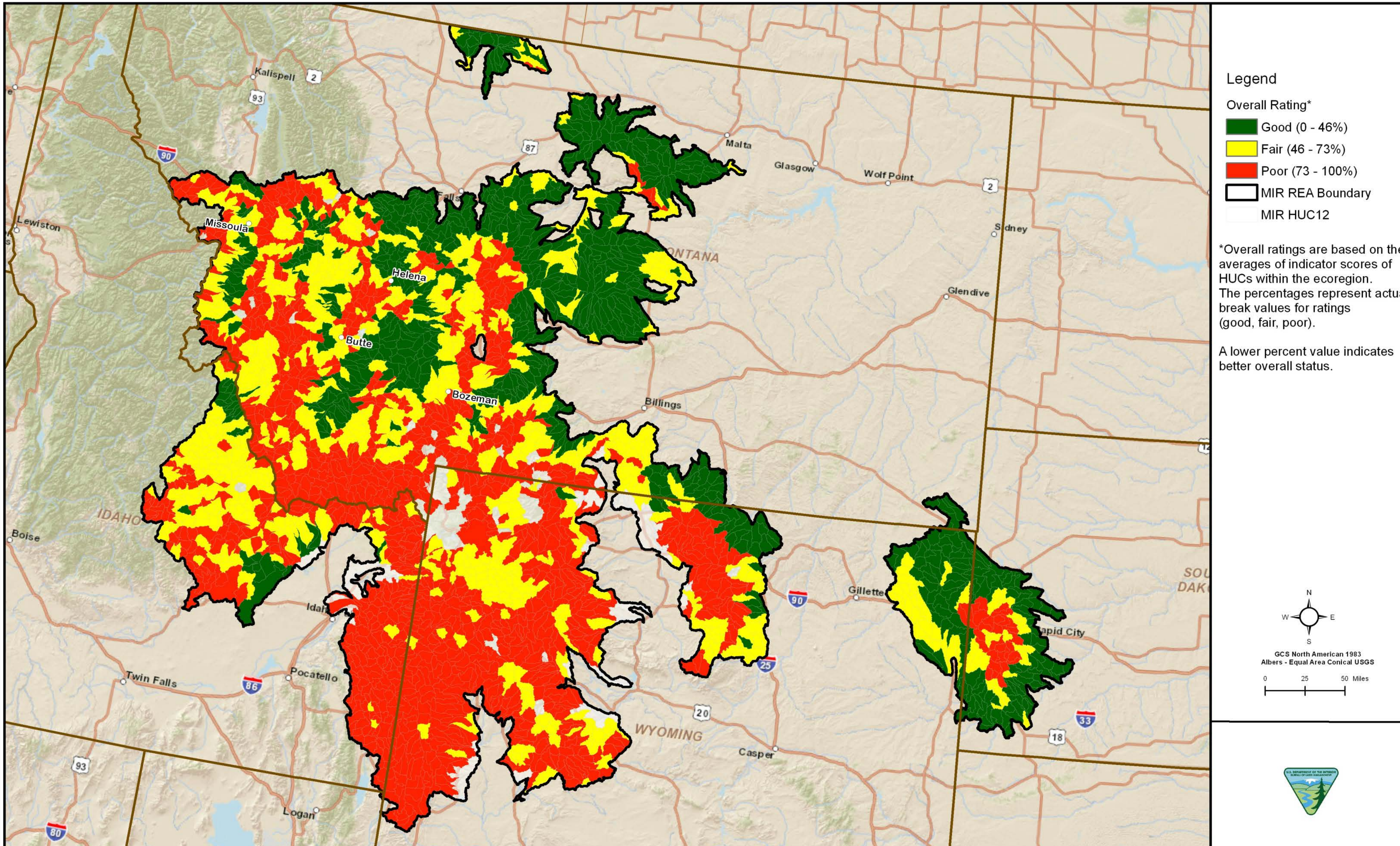

Figure D-3-8. Middle Rockies Grassland Current Status by 6th Level Hydrologic Unit Code

APPENDIX D-4

SHRUBLAND VEGETATION SYSTEMS COARSE-FILTER CONSERVATION ELEMENT ANALYSIS FOR THE MIDDLE ROCKIES ECOREGION

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1.0 INTRODUCTION

Encompassing nearly 28 percent of the Middle Rockies ecoregion, shrubland vegetation systems are the most predominant vegetation class in this ecoregion. Because some of the Gap Analysis Program (GAP) Level 3 systems comprise very small portions of this ecoregion, it was necessary to combine them so that they would be representative of major shrubland systems in the Middle Rockies. This coarse-filter analysis will focus on the following four GAP Level 3 Systems; Inter-Mountain Basins Montane Sagebrush Steppe, Inter-Mountain Basins Big Sagebrush Steppe, Inter-Mountain Basins Big Sagebrush Shrubland, and Wyoming Basins Dwarf Sagebrush Shrubland and Steppe. The aggregation and crosswalk process for vegetation systems allows evaluation of a reduced number of coarse-filter conservation elements (CEs), while retaining the capability to evaluate nested geospatial data on every Level 3 mapping unit within or across divisions.

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2.0 CONSERVATION ELEMENT DESCRIPTION

The Level 3 systems represented in this analysis are briefly described below.

2.1 INTER-MOUNTAIN BASINS MONTANE SAGEBRUSH STEPPE

This matrix-forming ecological system includes sagebrush communities occurring at montane and subalpine elevations across the western United States. Colorado occurrences are found primarily on the west slope, often in proximity to big sagebrush shrublands. The system shows an affinity for mild topography, fine soils, and some source of subsurface moisture (Colorado Natural Heritage 2005).

If trees are present, they are widely scattered and mature. Species richness is often high, and native grasses are dominant. Sagebrush resprouts vigorously following spring fire, and prescribed burning may increase shrub cover. Conversely, fire in the fall may decrease shrub abundance. The condition of most sagebrush steppe has been degraded due to fire suppression and heavy livestock grazing (Colorado Natural Heritage 2005).

2.2 INTER-MOUNTAIN BASINS BIG SAGEBRUSH STEPPE

Much like Inter-Mountain Basins Big Sagebrush Shrubland, this system also occurs as extensive matrix types on level-to-gently rolling plains, plateaus, sideslopes, and toeslopes, and as small and large patches in dissected landscapes such as breaks and badlands. Vegetation is sagebrush dominant (with perennial herbaceous components typically contributing greater than 25 percent vegetative cover), and consists mostly of rhizomatous and bunch-form grasses, with a diversity of perennial forbs (Montana Field Guide 2011b).

The natural fire regime of this ecological system maintains a patchy distribution of shrubs, so the general aspect of the vegetation is steppe shrubland. In the absence of natural fire, periodic low intensity prescribed burns can be used to maintain and restore this system to similar pre-settlement conditions. Low-intensity prescribed fire is used to reduce sagebrush cover to increase herbaceous forage, and to improve habitat quality for sage grouse and other wildlife by creating a mosaic of burned and unburned patches (Montana Field Guide 2011b).

Threats to this system include invasion by non-native species, livestock practices, fire regime alteration, direct soil surface disturbance, and complexes of prairie dog towns (Montana Field Guide 2011b).

2.3 INTER-MOUNTAIN BASINS BIG SAGEBRUSH SHRUBLAND

This system occurs as an extensive matrix on level-to-gently rolling plains, on toeslopes, and in valley bottoms, as well as in small and large patches in dissected landscapes such as breaks and badlands. It is found in broad basins between mountain ranges, on plains, and on foothills. In Montana, it occurs as a result of historic and current overgrazing practices and can be considered a disclimax expression of sagebrush steppe (Montana Field Guide 2011a).

Perennial herbs contribute less than 25 percent of the vegetative cover and consist mostly of graminoids, which can vary greatly in composition depending on the surrounding vegetation type. Dominant grasses can be either rhizomatous or bunch grasses. Perennial forb diversity is quite variable depending on site and treatment; with livestock use the number of introduced species can easily exceed eight on a given site (Montana Field Guide 2011a).

In the absence of natural fire, periodic prescribed burns can be used to maintain and restore this system to similar pre-settlement conditions. Low-intensity prescribed fire is used to reduce sagebrush cover, to increase herbaceous forage, and to improve habitat quality for sage grouse and other wildlife by creating a mosaic of burned and unburned patches (Montana Field Guide 2011a).

2.4 WYOMING BASINS DWARF SAGEBRUSH SHRUBLAND AND STEPPE

This system is composed of dwarf sagebrush shrubland and shrub-steppe that forms matrix vegetation and large patches on the margins of high-elevation basins. It occurs in southwest and south-central Montana on sites that are gently to moderately sloping, particularly on dry, windswept hills and ridges that may be oriented to any aspect (Montana Field Guide 2011c).

This system is characterized as steppe vegetation, occurring in areas where precipitation is limiting for tree growth. Vegetation includes a short-shrub stratum in which dwarf-shrubs (<30 centimeters tall) contribute at least two-thirds of the woody canopy. Black sage (*Artemisia nova*) is usually dominant in this system. The herbaceous component includes both rhizomatous and bunchgrasses, cushion plants, and other low-growing forbs (Montana Field Guide 2011c).

Threats to the system include fire and grazing livestock. Grazing practices also lead to a decrease in associated grasses and an increase in the spread of cheatgrass. Sites invaded by cheatgrass are changing the dynamics of this system by increasing fire potential, severity, and spread (Montana Field Guide 2011c).

3.0 CONSERVATION ELEMENT DISTRIBUTION MAPPING

3.1 DATA IDENTIFICATION

The major datasets identified to map the distribution of the shrubland system CE were the GAP landcover and Landscape Fire and Resource Management Planning Tools Project (LANDFIRE) datasets. Both datasets have adequate coverage across the ecoregion and have been used in similar analyses. The shrubland distribution datasets are further described in Table D-4-1.

Table D-4-1. Data Sources for the Shrubland Vegetation Systems Coarse-Filter Conservation Element Distribution Mapping for the Middle Rockies Ecoregion

Data Needs	Dataset Name	Source Agency	Type/Scale	Status	Use in REA
Terrestrial Systems					
Ecological Systems	GAP Landcover	U.S. Geological Survey (USGS)	Raster (30-meter [m])	Acquired	Yes
	LANDFIRE	LANDFIRE	Raster	Acquired	No
Soils Data	Soil Survey Geographic (SSURGO) State Soil Geographic (STATSGO2)	U.S. Department of Agriculture (USDA)	Raster	Acquired	No

3.2 DISTRIBUTION MAPPING METHODS

To map distribution of the shrubland system in the Middle Rockies ecoregion, Science Applications International Corporation (SAIC) used a mosaic of GAP data sources, including two of the National GAP landcover regions, the Northwest and North Central. The source data for the Northwest region was the Northwest Regional Gap Analysis Program (ReGAP) dataset, which improved upon the original Northwest GAP. The North Central region contains states that have not been covered by a ReGAP project. For these areas, the National GAP layer used data from the LANDFIRE project to create a seamless layer. The GAP was developed to help answer questions about species biodiversity and species habitat (USGS 2010). Its overall goal is to assist resource managers in decision making where there is a lack of information about the full range of species on the landscape. Once the data were downloaded, the two datasets were merged together to form a continuous layer of vegetation data across the four states. The continuous data layer was then clipped to the Middle Rockies ecoregion, at which point the Level 3 systems were extracted for review by the Rolling Review Team (RRT) (Figure D-4-1).

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4.0 CONCEPTUAL MODEL

The current status and potential future threat analyses were based on the system-level model, selected environmental variables (Key Ecological Attributes [KEAs]) likely to be at risk from the change agents (CAs), and the availability of data.

4.1 SYSTEM-LEVEL MODEL

The system-level model (Figure D-4-2) for the Middle Rockies shrubland systems illustrates the major drivers across the top. The major drivers dictate where these vegetation systems occur throughout the ecoregion, while the CAs focus on what has potential to affect this CE over time. Below the CAs are the corresponding CA pathways that affect both the status and distribution of this CE across the Middle Rockies ecoregion. Listed below the CA pathways are the three categories of size, context, and condition for development of the KEAs for this coarse-filter CE. The KEAs were developed and refined through the rolling review process.

4.1.1 Wildfire

Fire and grazing constitute the primary dynamics affecting shrubland systems, although drought has also been an impact in the past decade. The natural fire regime of sagebrush systems maintains a patchy distribution of shrubs, so in disturbance-free areas, steppe systems would be typical. However, shrubs increase following heavy grazing and/or with fire suppression. Heavy grazing can lead to a decrease in native bunchgrasses and an increase in exotic grasses and other species. Historically, fire impacts these shrublands at a frequency of every 50 to 100 years, but these systems will persist for longer periods. All shrub species regenerate following low-to-moderate intensity fires by re-sprouting from the root systems. Fire suppression may have allowed an invasion of trees into some of these shrublands, but in many cases sites are too xeric for tree growth. Under present conditions, the fire regime is mixed severity and more variable, with stand-replacing fires being more common in adjacent forested habitats.

4.1.2 Development

In shrubland systems within the Middle Rockies, development is a moderate issue as compared to climate change and altered fire regimes. Development issues within this system include areas where there may be extensive fossil fuel and renewable energy development. Energy development directly affects this coarse-filter CE through construction and road clearing through shrublands. This type of development is known to not only directly affect shrublands through the conversion of these habitats to developed habitats, but also through indirect effects such as increasing the spread of invasive species.

4.1.3 Climate Change

Shifts in temperature and precipitation will not only have direct impacts on shrublands, but will exacerbate many of the existing stresses to these ecosystems. Climate change has the potential to change the dynamics of shrubland systems and exacerbate wildfire. An increase in temperature could result in earlier and longer fire seasons (Westerling et al. 2006). Threats such as fragmentation and habitat loss, poor management, invasive species, and altered fire regimes have the potential to cause shrubland systems to become more vulnerable to the impacts of climate change over time.

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5.0 CHANGE AGENT ANALYSIS

Although changes caused by development, climate change, wildfire, and invasive species all affect shrublands in similar ways, there are differences in the severity of the system's response to each CA. For the purposes of this REA, each of the CAs was assumed to have similar effects on each of the Level 3 shrubland systems; therefore, a separate discussion on the effects of the CAs on each of the systems is not necessary.

The natural fire regime of these ecological systems has been greatly altered; therefore, shrub cover can be highly variable (Wright et al, 1979). The natural fire regime of shrubland systems maintains a patchy distribution of shrubs, so the general aspect of the vegetation is steppe shrubland. In the absence of natural fire, periodic, low-intensity prescribed burns can be used to maintain and restore this system to similar pre-settlement conditions. Low-intensity prescribed fire is used to reduce sagebrush cover, increase herbaceous forage, and improve habitat quality for sage grouse and other wildlife by creating a mosaic of burned and unburned patches (Montana Field Guide 2011a). Threats include invasion by non-native species, livestock practices, fire regime alteration, direct soil surface disturbance, and complexes of prairie dog towns. Changes to the system dynamics increase fire potential, severity, and spread (Montana Field Guide 2011b).

Once the system-level model was developed, indicators for the KEAs were identified with a specific emphasis on the ability to measure the KEA using existing geospatial data. The indicators will assist with answering the management questions (MQs) that relate to what is happening to the CE across the ecoregion. Although an initial list of KEAs was developed for this analysis, the list had to be revised based on the availability of data (Table D-4-2).

Table D-4-2. Key Ecological Attributes Retained or Excluded

Category	Key Ecological Attribute	Explanation
1. Size	a. Size of Patches	Data were used to illustrate where the large patches of this vegetation type are located.
2. Condition	a. Mean fire return interval (FRI)	Mean FRI was used to quantify the average period between fires to describe one component of the historical fire regime.
	b. Invasive Species	Data Gap-No analysis completed.
3. Structure	a. Fragmentation	Proximity to show anthropogenic disturbance.
	b. Connectivity	A moving window analysis was used to show juxtaposition of blocks of shrubland across the landscape.

5.1 CURRENT STATUS OF THE CONSERVATION ELEMENT

Table D-4-3 identifies KEAs, indicators, and metrics that can be used to evaluate factors affecting this CE across the ecoregion. The shrubland process analysis is designed to create a series of intermediate layers that are primarily based on the development and wildfire CAs. The analysis is based on the geospatial data that was currently available.

5.1.1 Key Ecological Attribute Data Analysis for Current Status

For each of the KEAs listed in Table D-4-3, a discussion of the indicator, metric, metric rank and value, data source(s), and references is provided. Only two indicators were used to assess the current threat status for the shrubland system (Table D-4-3). This table was limited to size and landscape context based on spatially available attributes and key factors affecting shrublands in the ecoregion.

In most cases, the metrics used to identify attribute quality were based on available publications, coupled with expert analysis and professional judgment in association with data-driven metrics. Equal weights were attributed to each metric in order to provide an overall score for all metrics combined, based on the reporting unit.

Table D-4-3. Key Ecological Attributes for the Shrubland Vegetation Systems Coarse-Filter Conservation Element for the Middle Rockies Ecoregion

Category	*Attribute	Indicator / Unit of Measure	Metric*			Data Source	Weight
			Poor = 3	Fair = 2	Good = 1		
Size	Patch Size	Acres	<3,361	3,361-57,993	>57,993	ReGAP	0.25
Condition	Habitat Condition	Mean FRI	0 –10 years	10 – 20 years	20 –25 years	LANDFIRE	0.25
Context	Fragmentation	Distance to anthropogenic	<0.5 kilometer (km)	0.5 km – 2.5 km	>2.5 km	Linear Features; Power lines; Oil and Gas Wells Pads, ReGAP	0.25
	Connectivity	Distance to similar habitat	<15 percent	15-30	>30 percent	ReGAP	0.25

*All analysis units were 30-m pixels and reporting units were Hydrologic Unit Code (HUC) 12.

5.1.1.1 Patch Size

Patch size for the shrubland coarse-filter CE was determined by finding acres of contiguous 30-meter (m) raster cells. After reviewing the patch size analysis, it appears an artifact of satellite imagery is to have a high number of isolated pixels and to overestimate large numbers of contiguous pixels. This results in large variations of values and made it difficult to score size based on appropriates sizes of shrubland across this ecoregion. After much discussion with the RRT, it was decided to allow the data to dictate the scoring.

There are several ways to classify the data for scoring. The Jenk's Natural Breaks method was used for this analysis. However, due to the issues with the variation in the size of patches, the Geometric Interval Classification was used. Geometric intervals are used to delineate classes based on groupings inherent in the data. The Geometric Interval Classification attempts to balance the changes in the middle values and the extreme values.

Figure D-4-3 is a graphical representation of patch size for the shrubland coarse-filter CE. Red displays low scoring patches, while green shows higher scoring patches.

5.1.1.2 Mean Fire Return Interval

For landscape structure, the LANDFIRE Vegetation Condition Class (VCC) data were used to show changes in vegetation and fuels from their historical condition. For the Middle Rockies, a group of subject matter experts (SMEs) went through an exercise to illustrate fire regime (frequency and severity) departure. The historic biophysical setting (BpS) was attributed with a current fire severity and frequency, and then compared with the reference (historic) fire frequency and severity for each type. From these data, a map of current fire frequency intervals was created. These data were then used to score shrubland fire return intervals based on the current fire frequency from information provided by the RRT (Table D-4-3). This proved to be very helpful, as an error was found in the LANDFIRE 2008 refresh 1.1 data. Based on the LANDFIRE 2008 refresh 1.1 data, the longest mean fire return interval (FRI) was 25 years. The fire frequency layer was extracted to the shrubland layer and used in the shrubland current status weighted-summary analysis (Figure D-4-4).

5.1.1.3 Fragmentation

The Integrated Climate and Land Use Scenarios (ICLUS) 2010 was used by extracting the urban, exurban, and industrial categories and then merging the Topologically Integrated Geographic Encoding and Referencing (TIGER) roads for the entire ecoregion. A Euclidean distance proximity analysis was run from this anthropogenic layer. The proximity analysis was then extracted to the shrubland coarse-filter

CE (Figure D-4-5). This layer was then scored based on the assumption that shrublands closer to roads and urban areas are more fragmented (Table D-4-3).

5.1.1.4 Connectivity

The shrubland coarse-filter distribution layer was used to perform a neighborhood analysis to determine the extent of shrubland within the 1-kilometer (km) neighborhood. The neighborhood analysis looks at the relationship of each pixel and the pixel surrounding it using a spatial analyst function. The resulting layer provided the percent shrubland within the 1-km neighborhood. This layer was then extracted to the shrubland coarse-filter layer and scored based on the metrics in Table D-4-3 (see Figure D-4-6).

5.1.2 Current Status of Habitat

The individual KEA analysis provides the basis for the compilation of an overarching data layer that defines the current status of shrubland habitat for each Hydrologic Unit Code (HUC) across this ecoregion. A method of aggregating scores was used to summarize overall threats with regard to shrubland habitat quality. Individual threats can identify areas of potential risk to shrublands, but aggregated scores can provide important information with relation to areas where shrublands might encounter multiple threats.

In order to create a combined score for each HUC based on varying levels of importance for each key attribute, it was necessary to aggregate the data through a weighting process. The weighted sum tool was used to combine each analysis input map to create an overall Current Status Map (Figure D-4-7). Equal weights were used when summing the threats for the shrubland.

The resulting output gives each shrubland 30-m pixel a score based on current status. Figure D-4-7 displays these results; red indicates areas of poor status, while green indicates areas rated at better current status based on the measured attributes.

The overall threat score for each 6th level HUC was assigned a current habitat quality rating of good, fair, or poor based on the natural breaks method. Statistics were run on the results from Figure D-4-7 to determine the average overall score. The overall result was then scored based on natural breaks. A higher overall threat score would result in a rating of poor for the HUC, indicating that there are existing threats to shrublands based on the KEA metrics.

The results of the current status analysis based on the 6th level HUC for the ecoregion are presented on Figure D-4-7. The results of the current status analysis based on the 6th level HUC for the ecoregion are presented on Figure D-4-8. Large shrubland areas located along the southern edges of the Middle Rockies returned good results. Shrublands in the western portions of the ecoregion adjacent to national forests also scored well. Shrublands in these portions are much larger and less fragmented. Shrublands more centrally-located in the ecoregion scored fair to poor. Shrubands in the central areas of the Middle Rockies are smaller and more fragmented. It appears that patch size, which affects the fragmentation and connectivity of the shrublands has a major influence on the current status output.

Concentrated patches of shubland savanna systems returned predominantly good results overall, while small, isolated patches returned poor results. These very small patches of shrubland and savanna tend to skew the results of the current status analysis and make it appear worse than it actually is. This is one of the inherent problems with rolling the analysis up to the watershed level. Figure D-4-7, which shows the pixel-based results, provides a clearer picture into the results of the analysis as compared to when it is rolled up to the HUC level.

A summary of the current status ratings based on the CE distribution is provided in Table D-4-4. The CE distribution layer was used to calculate the total number of square miles of CE habitat and a percentage of the total number of square miles per HUC that were rated as good, fair, or poor. The results of the current status assessment indicate that the majority (70 percent) of the 6th level HUC watersheds that intersect the shrubland systems received an overall rating of fair or poor.

Table D-4-4. Summary of Current Status Ratings for the Shrubland System

Overall Rating by 6th Level HUC	Total Square Miles[a]	Percentage of Total Square Miles[a, b]
Good	29,216	29.5
Fair	38,143	38.5
Poor	31,617	31.9

[a] These values include only the area of HUCs that intersect with the CE distribution layer.
[b] Values rounded to one decimal place.

5.2 FUTURE THREAT ANALYSIS

Future threats were evaluated for development for a short-term time horizon (5 to 10 years) and for climate change for a long-term time horizon (50-year; 2050 to 2069). Future spatial data for development was limited to potential energy development and climate change, as discussed in the development CA analysis presented in Appendix C-1. Climate change was modeled based on a 15-km grid created for regional analysis. This analysis included a comparison of current climate patterns to future modeled climate patterns and resulted in the delta (change) output figures. Further details regarding the climate change analysis are contained in Appendix C-5.

Because of the inherent inaccuracies of the temporal scale of the future data, it is only possible to infer information pertaining to a subjective future period rather than a specific time period for these attributes. However, because of the limits placed on these data outputs it is fair to assume that this model predicts the overall future potential for these attributes within this ecoregion. It is an upper limit of potential growth and should therefore be carefully applied to future estimates of their effect on coarse filters.

5.2.1 Development Change Agent

Future spatial data for development was limited to potential energy development area, modeled urban growth, and potential agricultural development, as discussed in the development CA analysis presented in Appendix C-1.

5.2.1.1 Agricultural Growth

Conversion of shrubland to agriculture is a predominant current and future CA for shrubland systems. Grain prices will increase commensurate with world population levels and the production of crops will need to increase accordingly. Since no future agricultural models exist for use within this ecoregion, a model was created using surrogate data to derive potential future agricultural areas. This analysis was the same as that which was completed for the current status. Figure C-1-1 in Appendix C-1 shows the State Soil Geographic (STATSGO) soil classification types are 1 through 4. Although this information can be portrayed spatially, there is no way to temporally show this future threat. This analysis considered the maximum potential for future agricultural areas within this ecoregion. Figure E-3-12 shows the results of the analysis, indicating that shrublands are at risk from potential agricultural land development.

5.2.1.2 Future Growth of Urban Areas

The potential effects of urban growth on shrubland habitat are similar to those of agricultural development. Minor portions of shrubland are currently in close proximity to urban/suburban populations In the Middle Rockies ecoregion.

The ICLUS model is a universally accepted model created by the U.S. Environmental Protection Agency (USEPA) for use in future climate change modeling; the ICLUS model provides spatial data that can be used to determine the future extent of urban areas for various time periods. The model uses U.S. Census data to predict urban growth. The ICLUS future urban extent for the year 2060 was used in this analysis. Figure C-1-8, Future Urban Growth Potential, shows the results of the analysis. The highest density of growth appears to be near Idaho Falls, Idaho, and Rapid City, South Dakota. However, these areas do not contain dense shrubland systems.

Based on review of Figure C-1-8, it does not appear that urban growth needs to be considered as high a risk to this CE.

5.2.1.3 Oil Production Potential

This future analysis characterized potential oil production areas rather than oil well locations (Figure C-1-4). These larger oil production extents were used to qualitatively assess the potential effect of future oil production activities. Although these areas are based on oil density data, the application of these data to future potential well site activity is unknown. Therefore, a carefully considered approach should be taken when assessing the effect of potential oil production areas on shrublands.

Although the majority of the shrublands located in Idaho and western Wyoming appear to be at low risk from oil production development, shrublands near the Bridger-Teton National Forest and shrublands on the western border of the island of the Middle Rockies appear to be at high risk of potential future oil production.

It is important to note that the Energy Policy and Conservation Act (EPCA) oil and gas data used in this assessment are based on the maximum potential for oil reserves within the Middle Rockies. As a result, these data are likely overly represented in these figures, and care should be taken in assessing the effects of oil and gas production within the constraints of this analysis.

5.2.1.4 Natural Gas Production Potential

This future analysis characterized potential gas production areas rather than actual gas well locations (Figure C-1-3). These larger gas production extents could be used to qualitatively assess the potential effect of future gas production activities. Although these areas are based on gas density data, the application of these data to future potential well site activity is unknown. Therefore, a carefully considered approach should be taken when assessing the effect of potential gas production areas on shrubland systems. As with the oil production areas, with the exception of shrublands near the Bridger-Teton National Forest, most of the shrubland systems in this ecoregion are at a low risk from potential gas production.

5.2.1.5 Future Potential for Solar Development

This future potential analysis characterized the future potential for solar development based on the solar potential maps developed by the National Renewable Energy Laboratory (NREL). Although these maps are very crude, a high potential for solar development is shown to occur within the shrublands distribution area. Therefore, shrublands do appear to be at risk from potential future solar development.

5.2.1.6 Wind Turbine Potential

The U.S. Fish and Wildlife Service (USFWS) wind turbine data contained attribute information for current and future wind turbine locations. However, the future turbine locations dataset was very limited in number as most turbines will be erected in the very near future. Therefore, an alternative data set was used to determine the potential areas for erecting wind turbines over a long-term period. The future wind turbine locations were based on the availability of suitable wind speeds.

Data characterized by the NREL was used to create a potential future wind turbine area data layer. A full description of the methods and processes implemented to create this data layer and its corresponding scoring system can be found in Appendix C-1. Wind Power Classes were characterized as low, moderate, or high for direct comparison to the current wind condition (Figure E-3-10).

The potential threats to shrubland systems relative to future wind energy development are presented on Figure C-1-7. Higher elevations within this ecoregion are at higher risk from wind turbine development due to the higher wind speed levels within these areas. However, limited accessibility to these higher elevations could limit the range of wind turbine development to lower elevation mountainous regions. In addition to the physical disturbance that wind turbines can have on shrubland, bird mortality is also a concern. Proximity to shrublands (where the majority of habitat for the Greater-sage grouse occurs) should be considered when future wind farms are planned for development in this area. Although this assessment is primarily qualitative, the spatial distribution of shrubland and mid-level elevation wind turbine potential overlap is apparent.

5.2.1.7 Overall Development Change Agent Future Threats

A fossil fuel energy output layer was created to address the MQs associated with future fossil fuels production. This layer was created by averaging the EPCA oil data layer with the EPCA gas data layer (Figure C-1-5). As mentioned in the above oil and gas sections, parts of this CA do appear to be at risk from oil and gas development; however, the large area of shrublands in Idaho and western Wyoming appears to be at low risk from this CA.

A renewable energy output layer was created to address the MQs associated with future renewable energy production. This layer was created by averaging the NREL wind speed data layer with the NREL solar energy data layer (Figure C-1-8). This output layer provides equal weighting to potential wind and solar energy production areas, and could therefore mischaracterize the effects of each. Unlike oil and gas, wind and solar energy are not necessarily closely associated with one another spatially. Photovoltaic solar arrays threaten the species by their effect on habitat availability. Solar arrays are diverse in scope and size, and it is therefore difficult to create a clear correlation between habitat loss and solar energy production.

Because of the intricacies involved in the assessment of renewable energy production with regard to shrubland systems, a limited approach must be taken in this analysis. The majority of the shrubland systems in the Middle Rockies ecoregion are considered to be at low risk from potential renewable energy production.

5.2.2 Climate Change Future Threats

5.2.2.1 Ecoregion Climate Change Analysis

From a climate change perspective, temperature and precipitation are the factors that would most affect shrubland systems. Climate change presents many different issues relating to shrublands. However, it remains difficult to draw conclusions from the data presented in this REA. Climate change models are highly variable and often difficult to predict. In this case, the resolution of the spatial data is an important factor to consider.

Based on the analysis conducted for the ecoregion, as presented in Appendix C-5, future temperature and precipitation changes appear to be minor in the areas of this ecoregion where shrublands occur. However, the combined impacts of increased temperatures, localized drought, and conversion of lands to agricultural uses could negatively affect shrublands in the future.

6.0 MANAGEMENT QUESTION

The relevant MQs for the shrubland system include those defined as part of the Terrestrial Biotic Resources category. The overall MQ was: Where are the important regionally significant terrestrial features, functions, and services across the ecoregional landscape? This MQ was considered in implementing the geographic information system (GIS) analyses. Emphasis was placed on the spatial relationship of attributes mentioned in the MQs and the shrubland distribution model. Several examples of how the REA can be used to answer MQs are provided below; these examples demonstrate the functionality of the REA and provide an opportunity to discuss data gaps that were identified during this REA.

6.1 HOW IS SHRUBLAND DISTRIBUTED OVER THE LANDSCAPE?

Figure D-4-1 maps the ReGAP sparse vegetation across the ecoregion.

6.2 WHERE WILL CURRENT CONSERVATION ELEMENT VEGETATION TYPES BE AT GREATEST RISK FROM CHANGE AGENTS?

The full range of figures and analyses for the shrubland system can be used to answer this complex MQ. The models created throughout this process were created to directly address the effects of CAs on the shrubland system. All of the CAs were addressed spatially and described in detail in this section, and all of the CAs were spatially attributed to the distribution of the shrubland. Figure D-4-7 represents the sum of Figures D-4-4 and D-4-6 by the 30-m analysis unit, while Figure D-4-8 represents the sum of all the threats at the 12-digit HUC reporting unit.

6.3 WHAT AREAS HAVE POTENTIAL FOR RESTORING CONSERVATION ELEMENT SPECIES HABITAT OR HABITAT CONNECTIVITY FOR CONSERVATION ELEMENT SPECIES, CURRENTLY AND IN THE FUTURE?

The fragmentation potential (Figure D-4-6) represents the potential for further fragmented shrubland systems. It can also be used to show areas where future restoration may be the most beneficial. The fragmentation potential shows areas where restoration could potentially connect larger stands together.

6.4 WHERE WILL CONSERVATION ELEMENTS BE AT RISK FROM ALTERED FIRE REGIMES? WHERE ARE AREAS WITH POTENTIAL TO SHOW FUTURE INCREASES OR DECREASES IN WILDFIRE FREQUENCY OR INTENSITY?

Figure D-4-4 represents the VCC for the shrubland systems. This figure represents changes in vegetation and fuels from their historical condition. For the Middle Rockies, a group of SMEs went through an exercise to illustrate fire regime (frequency and severity) departure. The historic BpS was attributed with a current fire severity and frequency, and then compared with the reference (historic) fire frequency and severity for each type. From these data, we were able to develop a fire frequency departure map, a fire severity departure map, and then a composite map (which took the highest of either departure). This modified composite layer was used as the best indicator for potential threat to shrubland systems from an uncharacteristic fire. These maps should be used with caution, as this metric is known to be less precise in shrubland systems

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APPENDIX D-4

FIGURES

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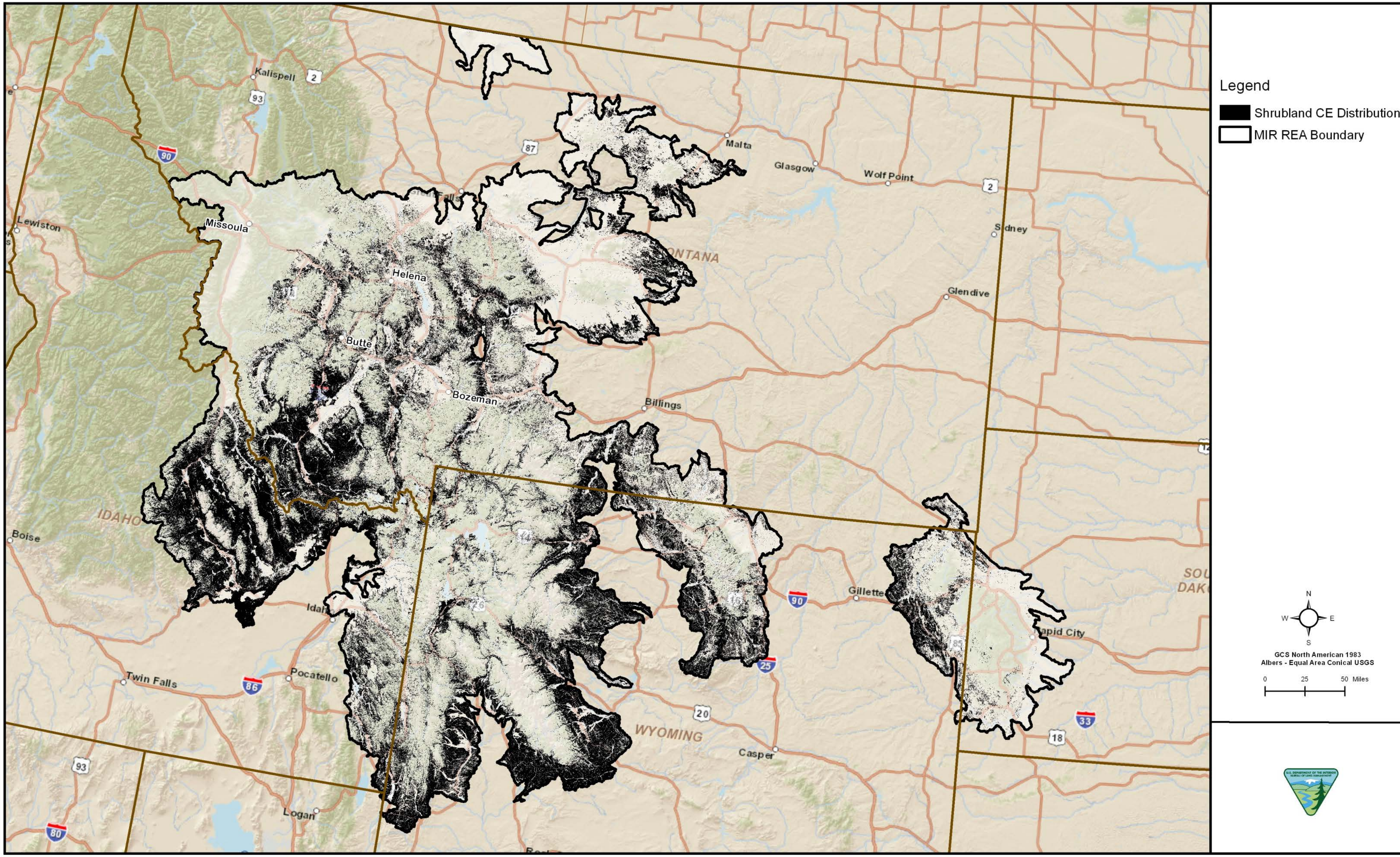

Figure D-4-1. Middle Rockies Shrubland Distribution

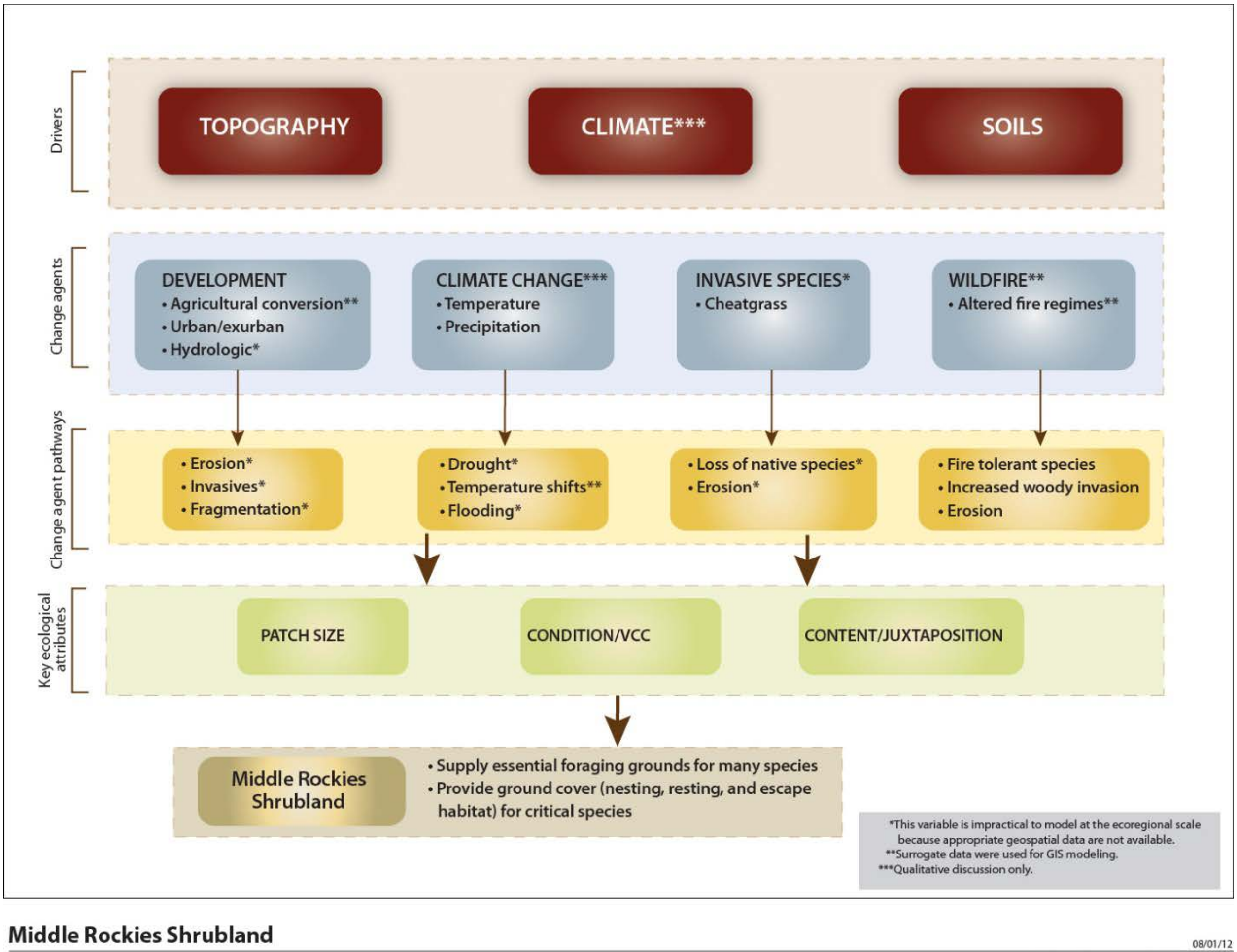

Figure D-4-2. Middle Rockies Shrubland System-Level Model

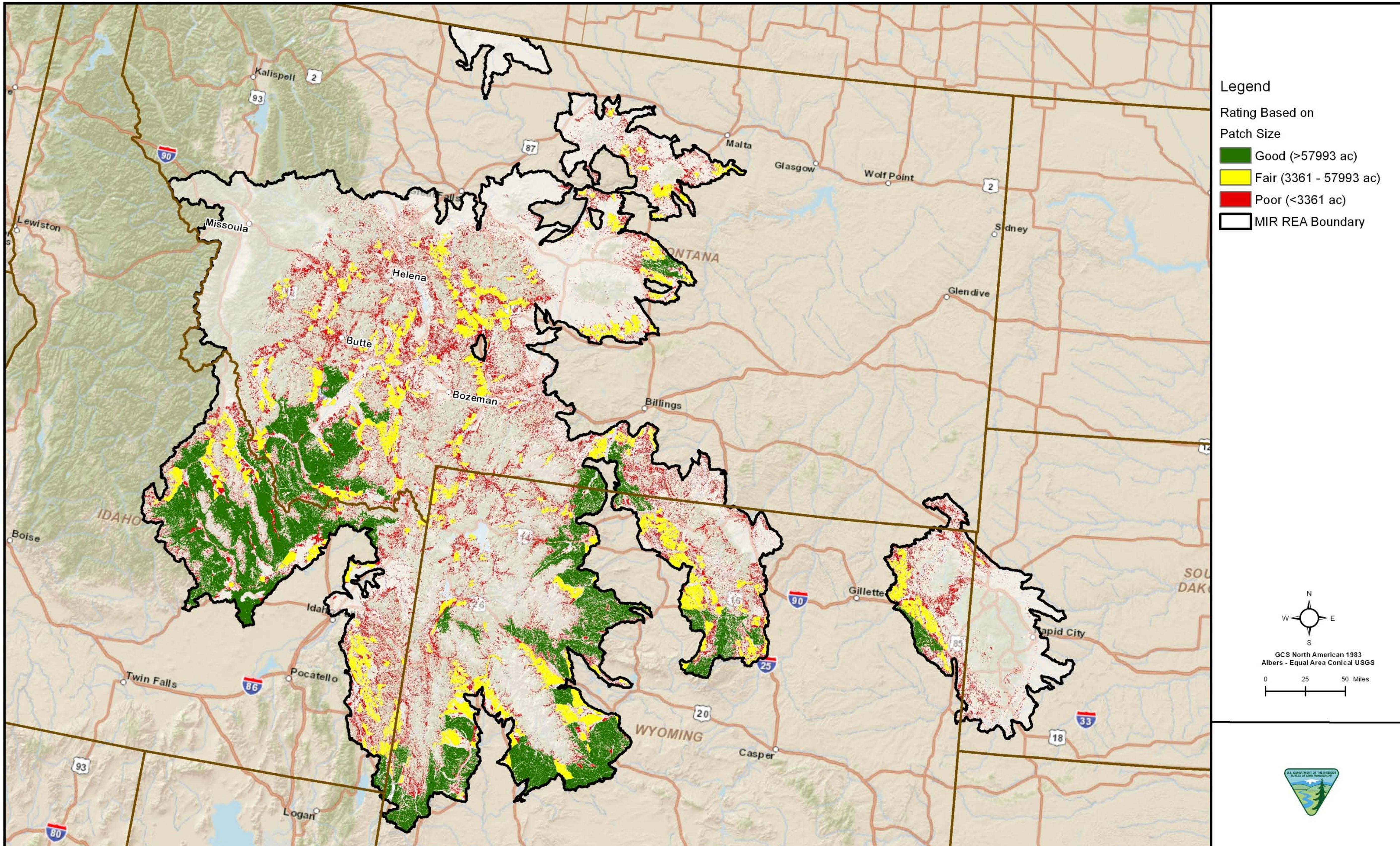

Figure D-4-3. Middle Rockies Shrubland Patch Size

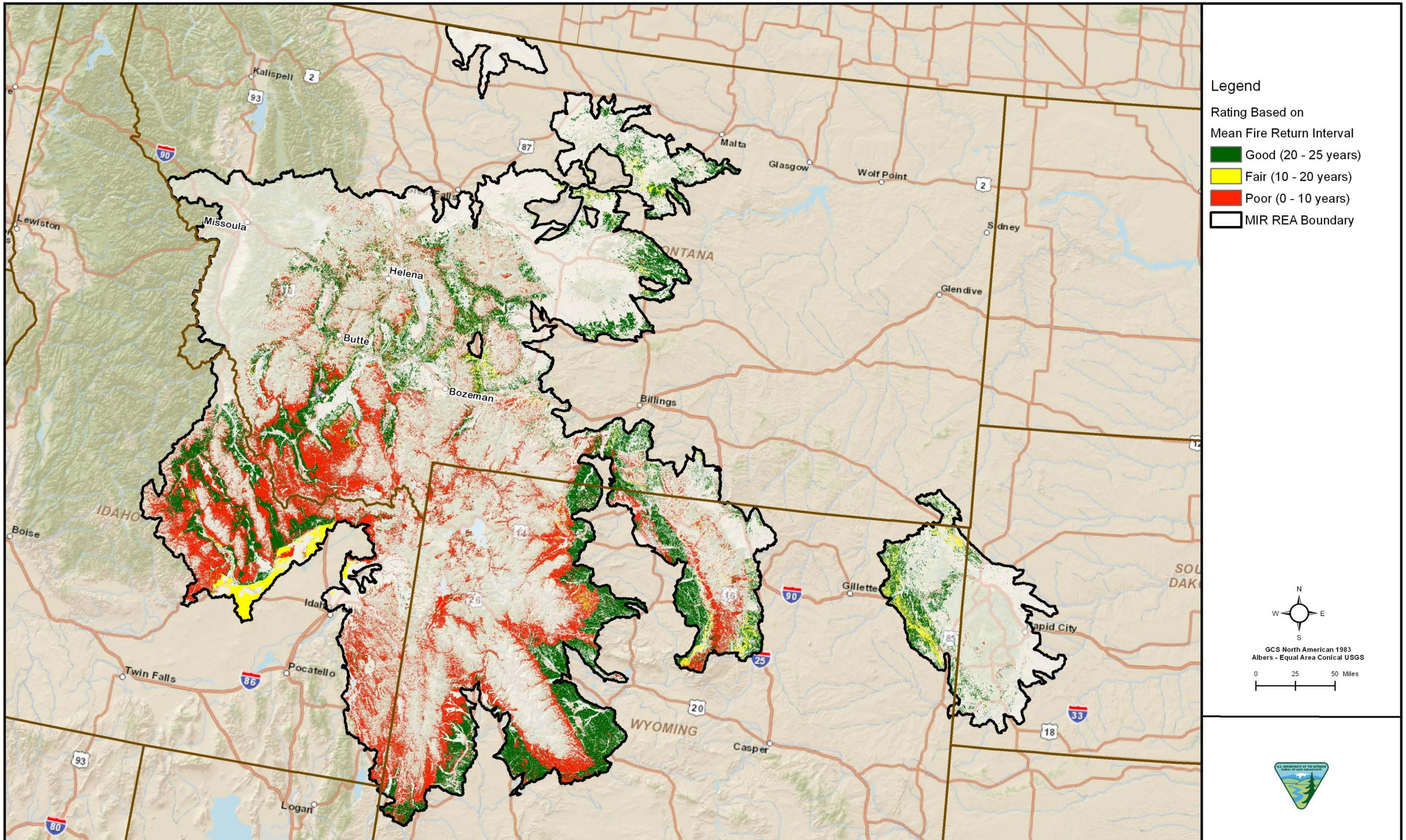

Figure D-4-4. Middle Rockies Shrubland Mean Fire Return Interval

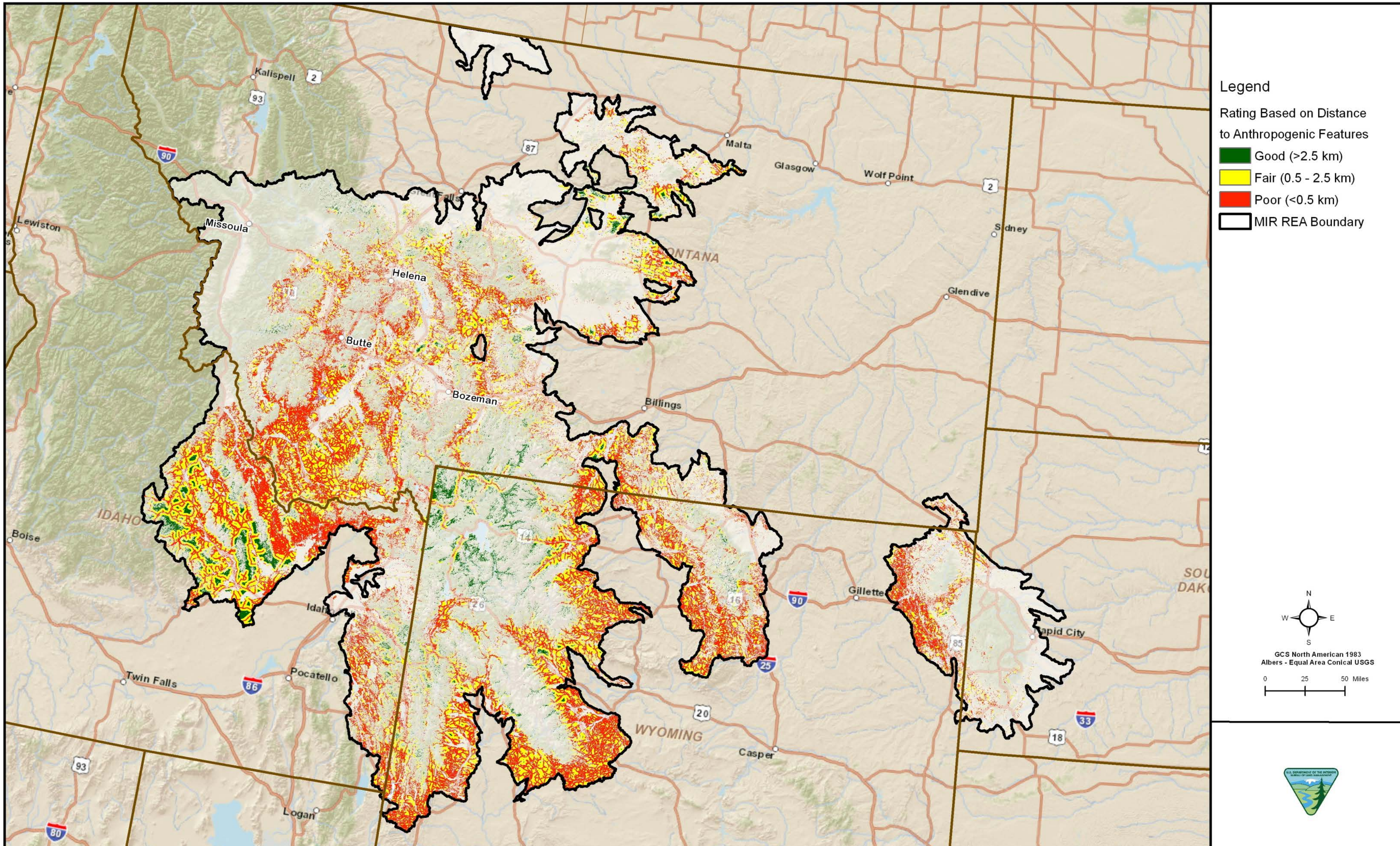

Figure D-4-5. Middle Rockies Shrubland Fragmentation

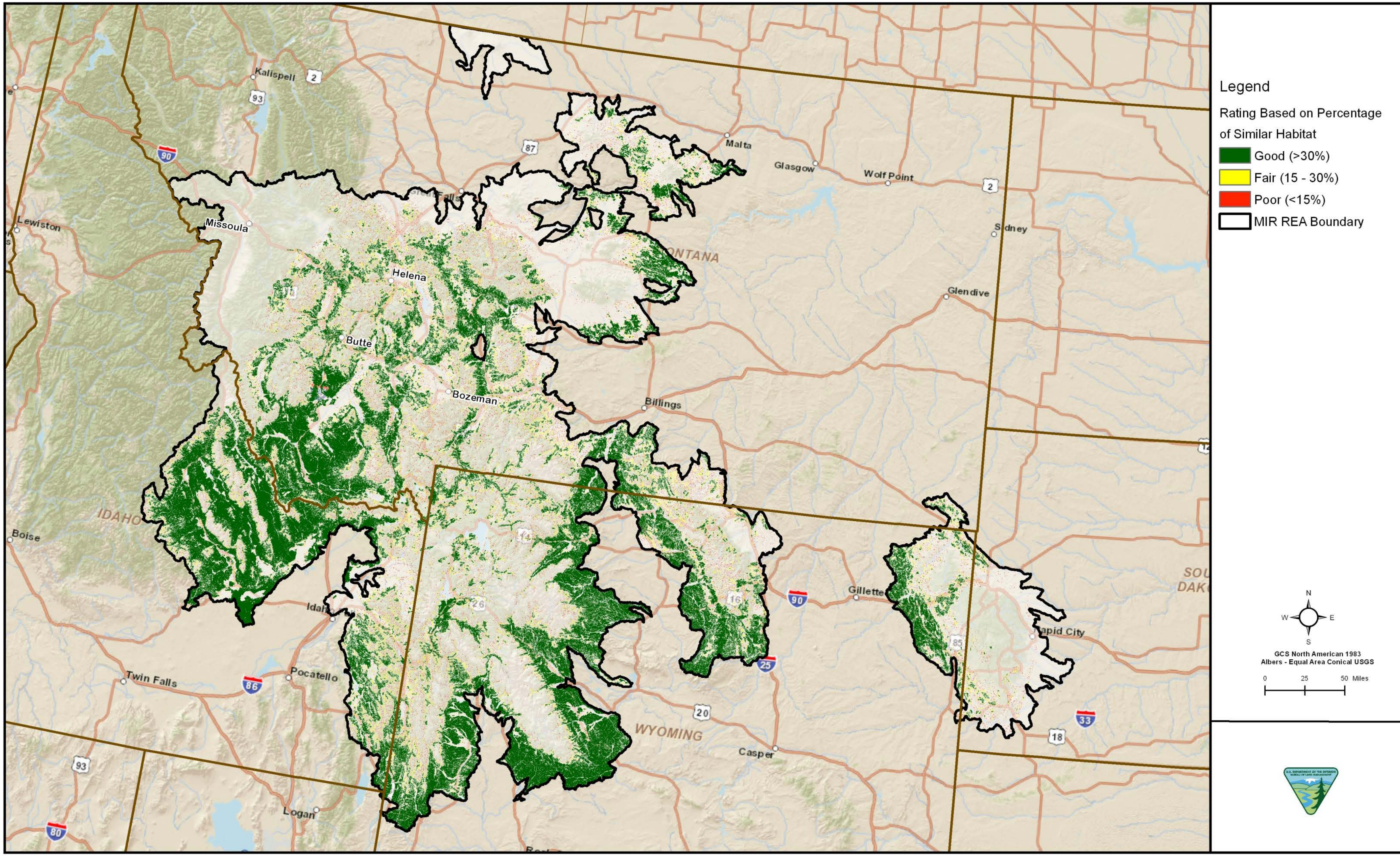

Figure D-4-6. Middle Rockies Shrubland Connectivity

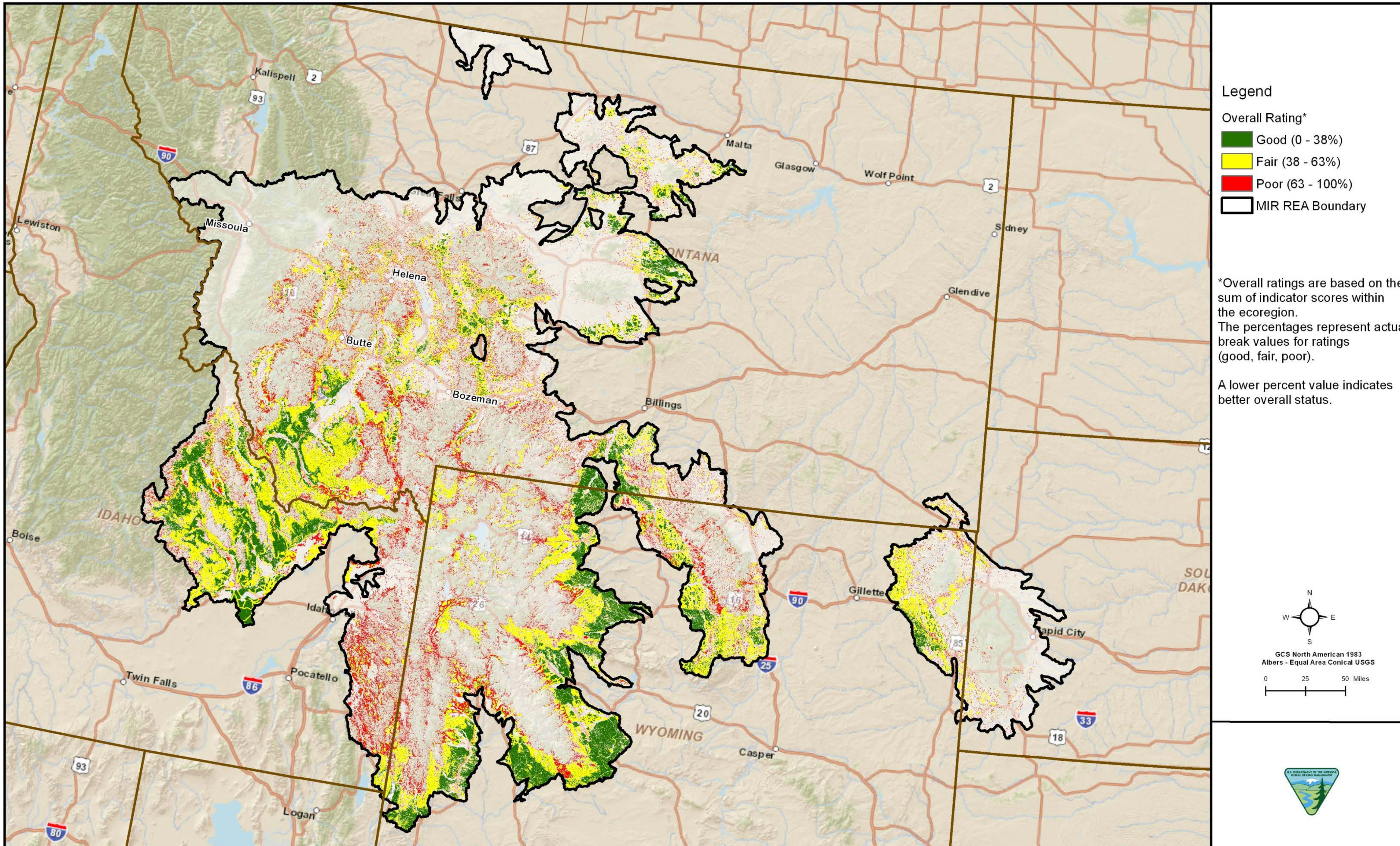

Figure D-4-7. Middle Rockies Shrubland Current Status

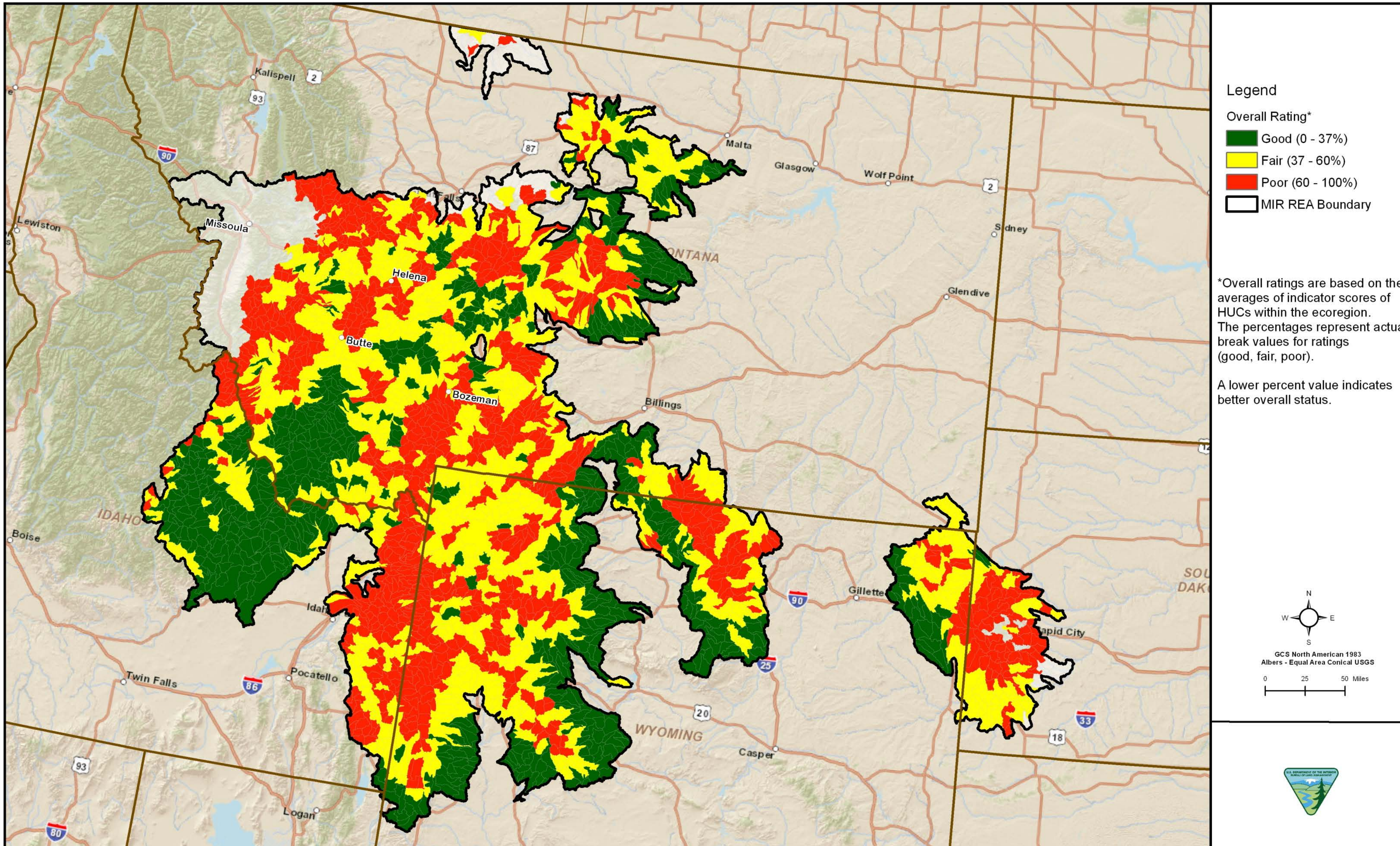

Figure D-4-8. Middle Rockies Shrubland Current Status by 6th Level Hydrologic Unit Code

APPENDIX D-5

RIPARIAN VEGETATION SYSTEMS COARSE-FILTER CONSERVATION ELEMENT ANALYSIS FOR THE MIDDLE ROCKIES ECOREGION

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1.0 INTRODUCTION

Riparian vegetation systems encompass nearly 4 percent of the Middle Rockies ecoregion. The Middle Rockies riparian coarse-filter conservation element (CE) is mainly comprised of deciduous forest and woodland areas along streams and rivers, but also includes shrublands and flats throughout the ecoregion. Originally, three categories of forest and woodland systems, including this coarse-filter were to be combined. These included: 1) deciduous 2) evergreen and 3) riparian, with each of these categories containing representative Gap Analysis Program (GAP) Level 3 systems as described below. However, after initiating the evaluation it was apparent that the riparian system needed to be evaluated separately from the other systems.

There were significant data gaps in performing a change agent (CA) analysis for riparian vegetation systems. The most significant risk to riparian areas is invasive species such as tamarisk and Russian olive. As discussed in Appendix C-3, invasive species were found to be a significant data gap. Grazing is also a major threat to riparian areas, but the REA does not investigate grazing.

Eight Level 3 GAP systems cover the riparian coarse filter. These include the following: Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland, Inter-Mountain Basins Greasewood Flat, Introduced Riparian and Wetland Vegetation, Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland, Northwestern Great Plains Riparian, Rocky Mountain Subalpine-Montane Riparian Shrubland and Woodland, Great Plains Floodplain Systems, and Western Great Plains Riparian Woodland and Shrubland.

A variety of the management questions (MQs) apply to this assemblage. Many of the MQs can be summarized into two primary questions: 1) where are the important areas for this assemblage? and 2) what is happening to those areas? The central focus of these two MQs is to document the current status of selected CEs at the ecoregional scale and to evaluate how this status may change over a future time period. The first step is to identify suitable habitat for the CE within the ecoregion. Then, these areas are assessed relative to current and potential future CA threats. CAs considered in this analysis include wildfire, development, and climate change.

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2.0 CONSERVATION ELEMENT DESCRIPTION

The Level 3 systems represented in this assemblage are briefly described below.

2.1 GREAT BASIN FOOTHILL AND LOWER MONTANE RIPARIAN WOODLAND AND SHRUBLAND

This system is dependent on a natural hydrologic regime, especially annual-to-episodic flooding. Occurrences are found within the flood zone of major rivers and the associated islands, sand or cobble bars, and along adjacent streambanks. It can occur as a large, wide patch on mid-channel islands in larger rivers or as narrow bands along small, rocky canyon tributaries and on well-drained benches. It is also typically found in backwater channels and other perennially wet but less-scoured sites, such as floodplains swales, and irrigation ditches. Because of the frequent disturbance regime, this system usually occurs as a mosaic of shrub and tree-dominant communities (Montana Field Guide 2011c).

Alteration of hydrology by dams and diversions are major influences on the structure, composition, and function of this community. Heavy grazing by cattle or, in some cases by elk and deer, along these streams and rivers can result in increased erosion and can eliminate the vegetative regeneration of cottonwood sprouts. In sites where there is prolonged disturbance, shrub cover will decrease, resulting in a more open canopy (Montana Field Guide 2011c).

2.2 INTER-MOUNTAIN BASINS GREASEWOOD FLAT

This ecological system occurs throughout much of the western United States in intermountain basins and extends onto the western Great Plains and into central Montana. Greasewood flats are typically found near drainages on stream terraces and flats, and on alluvial fans along streams or arroyos, or they may form rings around playas. Vegetation includes a mosaic of multiple communities, with open-to-moderately-dense shrublands dominated or co-dominated by greasewood (*Sarcobatus vermiculatus*) (NatureServe 2011).

Because greasewood flats are tightly associated with saline soils and groundwater that is near the surface, the primary ecological process that maintains greasewood flats is groundwater recharge. They are large patch systems confined to specific environments defined by hydrologic regime, soil salinity, and soil texture (Colorado Natural Heritage Program 2005c).

2.3 INTRODUCED RIPARIAN AND WETLAND VEGETATION

This system occurs where riparian and wetland species have been introduced to areas of altered landscapes as a result of land use practices, such as grazing. Historic and contemporary land use practices have impacted hydrologic, geomorphic, and biotic structure and function of riparian areas. Human land uses both within the riparian area and in adjacent and upland areas have fragmented many riparian reaches, which has reduced connectivity between riparian patches and riparian and upland areas (Rocchio 2011).

2.4 NORTHERN ROCKY MOUNTAIN LOWER MONTANE RIPARIAN WOODLAND AND SHRUBLAND

This system includes riparian woodland and shrubland consisting of deciduous, coniferous, and mixed conifer-deciduous trees and shrubs that occur on streambanks and river floodplains in the lower montane and foothill zones of the Northern Rocky Mountains. Woodlands are often dominated by black cottonwoods (*Populus balsamifera* ssp. *Trichocarpa*), the key indicator species, and by an understory of shrubs, ferns, and forbs (Rocchio 2011).

Annual flooding is a key ecological process that results in a diversity of patch types such as woodlands, shrublands, wet meadows, and marshes. The moisture associated with riparian areas promotes lower fire frequency compared with adjacent uplands. Wet meadows seldom burn and when they do, they typically recover within a single growing season (Rocchio 2011).

Threats to this system include grazing livestock and land use practices such as agricultural development, roads, dams, and other flood-control activities (Rocchio 2011).

2.5 NORTHWESTERN GREAT PLAINS RIPARIAN

Being located primarily in the buffer of this ecoregion, this system is associated with perennial to intermittent or ephemeral streams found on alluvial soils in highly variable landscape settings, from confined deep-cut ravines to wide, braided streambeds. Channel migration occurs in less-confined areas, but within a more narrow range than would occur in broad, alluvial floodplains. Communities within this system range from riparian forests and shrublands to tallgrass wet meadows and gravel/sand flats. Dominant species include black cottonwoods and an understory of shrubs, ferns, and forbs (Montana Field Guide 2011a).

Flooding is the key ecosystem process, creating suitable sites for seed dispersal and seedling establishment, and controlling vegetation succession. Like floodplain systems, riparian systems are often subjected to overgrazing and/or agriculture and can be heavily degraded, with salt cedar (*Tamarix ramosissima*) and Russian olive (*Eleagnus angustifolia*) replacing native woody vegetation and regrowth. Groundwater depletion and lack of fire have resulted in additional species changes (Montana Field Guide 2011a).

2.6 ROCKY MOUNTAIN SUBALPINE-MONTANE RIPARIAN SHRUBLAND AND WOODLAND

This riparian system is comprised of seasonally-flooded shrublands, forests, and woodlands at montane to subalpine elevations of the Rocky Mountains. Shrub systems occur as linear bands lining stream banks and alluvial terraces in narrow-to-wide, low-gradient valley bottoms and floodplains with sinuous stream channels (Montana Field Guide 2011d). Forests and woodlands are dominated by coniferous tree species including grand fir, subalpine fir, and Engelmann spruce, and range from narrow streamside forests lining confined low-order mountain streams, to stands along broader, meandering tributaries (Montana Field Guide 2011e).

Stochastic flood events and variable fluvial conditions are crucial to the development of establishment sites for riparian plants, and act as a primary control on plant succession. Flooding creates and destroys sites for the establishment of vegetation through the transport and accumulation of coarse sediment (Montana Field Guide 2011d).

Threats to the system include grazing practices along narrow, low-order streams resulting in increased erosion and channel downcutting. Sites that are subjected to heavy grazing practices may transition to an herbaceous understory consisting of introduced grasses and forbs such as Kentucky bluegrass (*Poa pratensis*) and Canadian thistle (*Cirsium arvense*). In addition, fire suppression, timber harvest, and reduced flood frequency can affect the succession of riparian communities (Montana Field Guide 2011e).

2.7 GREAT PLAINS FLOODPLAIN SYSTEMS

Comprised geographically of Northwestern Great Plains Floodplain, Western Great Plains Floodplain, and Western Great Plains Floodplain Systems, dominant communities within this system range from floodplain forests to wet meadows to gravel/sand flats, linked by underlying soils and flooding regimes. Hydrologic dynamics are largely driven by snowmelt and rainfall originating in their headwater watersheds, rather than local precipitation events (Montana Field Guide 2011b).

In the absence of disturbance, periodic flooding of fluvial and alluvial soils and channel migration will create depressions and backwaters that support a mosaic of wetland and riparian vegetation, whose composition and structure is sustained, altered, and redistributed by hydrology. In disturbed systems, exotic grasses become dominant (especially in the absence of episodic flooding), and the systems cannot return to their original state without substantial management intervention (Montana Field Guide 2011b).

2.8 WESTERN GREAT PLAINS RIPARIAN WOODLAND AND SHRUBLAND

This system is found in the riparian areas of medium and small rivers and streams. Dominant vegetation overlaps broadly with portions of large river floodplain systems, but the overall abundance of vegetation is generally lower. Vegetation may be a mosaic of communities that are not always tree or shrub dominated. Communities within this system range from riparian forests and shrublands to tallgrass wet meadows and gravel/sand flats (Colorado Natural Heritage Program 2005b).

Threats to the system include areas subjected to heavy grazing and/or agriculture that can be heavily degraded. Additionally, groundwater depletion and lack of fire have created additional species changes (Colorado Natural Heritage Program 2005b).

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3.0 CONSERVATION ELEMENT DISTRIBUTION MAPPING

3.1 DATA IDENTIFICATION

The major datasets identified to map the distribution of the riparian CE were the Gap Analysis Program (GAP) landcover and Landscape Fire and Resource Management Planning Tools Project (LANDFIRE) datasets. Both datasets have adequate coverage across the ecoregion and have been used in similar analyses. The riparian forest distribution datasets are further described in Table D-5-1.

Table D-5-1. Data Sources for the Riparian Vegetation Systems Coarse-Filter Conservation Element Distribution Mapping for the Middle Rockies Ecoregion

Data Needs	Dataset Name	Source Agency	Type/Scale	Status	Use in REA
Terrestrial Systems					
Ecological Systems	GAP Landcover Northwest Regional Gap Analysis Program (ReGAP) North Central GAP	U.S. Geological Survey (USGS)	Raster (30-meter [m])	Acquired	Yes
	LANDFIRE	LANDFIRE	Raster	Acquired	No
Soils Data	Soil Survey Geographic (SSURGO) State Soil Geographic (STATSGO2)	U.S. Department of Agriculture (USDA)	Raster	Acquired	No

3.2 DISTRIBUTION MAPPING METHODS

To map distribution of riparian systems in the Middle Rockies ecoregion, Science Applications International Corporation (SAIC) used a mosaic of GAP data sources, including two of the National GAP landcover regions, the Northwest and North Central. The source data for the Middle Rockies ecoregion was the Northwest Regional Gap Analysis Program (ReGAP) dataset, which improved upon the original Northwest GAP. The North Central region contains states that have not been covered by a ReGAP project. For these areas, the National GAP layer used data from the LANDFIRE project to create a seamless layer. The GAP was developed to help answer questions about species biodiversity and species habitat (USGS 2010). Its overall goal is to assist resource managers in decision making when there is a lack of information about the full range of species on the landscape. Once the data were downloaded, the two datasets were merged together to form a continuous layer of vegetation data across the 4 states. The continuous data layer was then clipped to the Middle Rockies ecoregion, at which point the Level 3 systems were extracted for evaluation by the Rolling Review Team (RRT) (Figure D-5-1).

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4.0 CONCEPTUAL MODEL

4.1 SYSTEM-LEVEL MODEL

The system-level conceptual model for the Middle Rockies riparian forest systems (Figure D-5-2) illustrates the major drivers across the top. The major drivers dictate where these vegetation systems occur throughout the ecoregion, while the CAs focus on what has potential to affect this CE over time. Below the CAs are the corresponding CA pathways that affect both the status and distribution at this CE across the Middle Rockies ecoregion. Listed below the CA pathways are the three categories of size, context, and condition for development of the Key Ecological Attributes (KEAs) for this coarse-filter CE. The KEAs were refined through the rolling review process.

4.1.1 Wildfire

Fire most likely once played a very important role in controlling the shrubby/woods components of these communities. Like other forest systems, fire suppression has caused and continues to cause change in this system. Fire suppression has resulted in riparian systems becoming choked with not only species that have not traditionally occurred in riparian systems, but also invasive species such as Russian olive and tamarisk. In addition, similar to other riparian forests, Aspen systems require disturbance to regenerate and become more established. Without disturbances like fire, Aspen is at risk to conifer encroachment. Conifers have replaced Aspen over much of Aspen's historic range (Stam et al. 2008). Widespread conifer mortality from spruce bark beetles leave heavy fuel loads, leading to more intense fires than these areas have evolved with. These more intense fires may be too severe for Aspen to survive.

4.1.2 Development

In the Middle Rockies riparian systems, development is a moderate issue as compared to climate change and altered fire regimes. However, due to increasing population growth and urban-to-rural migration trends, fragmentation is a definite factor shaping the landscape. Development fragments riparian forests, degrading and reducing the amount of stands. Fragmentation from development and agricultural pressures reduces the viability of forest management and environmental benefits, such as ecological stability of flora and fauna (Daniels and Bowers 1997). The increase in small isolated patches and in space between forests decreases habitat connectivity and forest interior.

4.1.3 Climate Change

Drought has been known to cause the loss of seral aspen stands and contribute to a decline in aspen regeneration. In recent years, there have been dramatic die-offs of aspen. The phenomenon has been termed Sudden Aspen Decline (SAD). Due to lack of data, SAD was not included in the CA analysis. However, due to its importance to the species, a brief discussion is warranted.

SAD is characterized by rapid onset of mortality in which dying stands have little to no regeneration or recruitment. Recent research indicates that SAD is caused by several interacting factors including site-related factors (low elevations, south and south-west aspects, open stands), higher temperatures, and drought stress (Hogg et al. 2008; Rehfeldt et al. 2008; Worrall et al. 2008; Fairweather et al. 2008; St. Clair et al. 2010; Worrall et al. 2010). The Middle Rockies ecoregion experienced a significant drought from 1999-2004, immediately prior to the current episode of aspen dieback (Hoffman 2008). The impacts of SAD are consistent with projected effects of climate change.

Surveys in the Intermountain Region have reported different patterns of aspen mortality, such as the prevalent damage agents and susceptibility of different stem sizes (Guyon and Hoffman 2011). Some stands experiencing dieback were still capable of regenerating, although recruitment may be below the threshold suggested for successful aspen recruitment (O'Brien et al. 2010). Steed and Kearns (2010) reported that rapid stand decline (SAD) noted in Colorado was not prevalent in Montana and northern Idaho surveys undertaken in the Northern Region. Patterns of mortality detected in ground survey plots indicated that mortality had occurred over many years. Nonetheless, aspen is declining in many areas of

Montana and southern Idaho (Idaho Department of Lands 2010), likely caused by a combination of factors including increased conifer encroachment due to fire suppression, diseases and insects, and heavy ungulate grazing on regeneration. Drought may be an important factor in future mortality (Steed and Kearns 2010).

Riparian areas throughout the ecoregion might be some of the first areas to show signs of stress from climate change. Warmer temperatures provide more conducive environments for invasives like tamarisk that actively soak up shallow ground water, making these areas more conducive to species not normally identified in these areas. Existing vegetation along streams not only provides refuge for a variety of wildlife, but also maintains the thermodynamics of streams and water bodies sheltered by riparian vegetation. As the riparian vegetation is replaced with non-native vegetation, the thermodynamics and wildlife habitat of these areas has the potential to be altered.

5.0 CHANGE AGENT ANALYSIS

Although changes caused by development, climate change, wildfire, and invasive species all effect riparian systems in similar ways, the severity of the systems' response to each of the CAs is different. However, for the purposes of this Rapid Ecoregional Assessment (REA), each of the CAs will be assumed to have similar responses to each of the Level 3 riparian systems; therefore, a separate discussion on the effects of the CAs on each of the different Level 3 systems is not necessary.

Since the scale of the reporting unit is at the Hydrologic Unit Code (HUC) 12, a layer of 6th level HUCs was extracted for the ecoregion. A geographic information system (GIS) process was iterated through the KEA indicators and determined the metric values associated with some watersheds. In other instances, sufficient published data indicated cut-off points for these values. These values were added as an attribute to the HUC 12 layer. The intermediate CA layers were then combined together to form a single layer outlining the current status or future threat status for each HUC.

Once the ecological process model was developed, indicators for the KEAs were identified with a specific emphasis on the ability to measure the KEA using existing geospatial data. The indicators will assist with answering the MQs that relate to what is happening to the CE across the ecoregion.

5.1 CURRENT STATUS OF THE CONSERVATION ELEMENT

The RRT did not discuss any specific KEAs to evaluate the current status of this coarse-filter CE. In the absence of that discussion, we evaluated the aquatic threat analysis for the fish assemblage for this ecoregion. Several of the KEAs identified in the aquatic threat analysis were specifically done within the riparian area. Those KEAs were adopted for that analysis to evaluate the current status of riparian areas.

Table D-5-2 identifies the KEAs, indicators, and metrics that were used to evaluate the CAs and pathways affecting this CE across the ecoregion. The riparian forest process analysis is designed to create a series of intermediate layers that are primarily based on the development CAs. The analysis is based on the geospatial data that was available.

Table D-5-2. Key Ecological Attributes for the Riparian Vegetation Systems Coarse-Filter Conservation Element for the Middle Rockies Ecoregion

Category	Ecological Attribute	Indicator / Unit of Measure	Metric*			Data Source	Citation
			Poor = 3	Fair = 2	Good = 1		
Landscape Structure	Fragmentation	Percent of Riparian Corridor with Natural Landcover	<25	>25-80	>80	National Land Cover Dataset (NLCD) - 2006	USDA 2011
		Percent of Riparian Corridor in Agricultural use (cropland)	>60	>30-60	<30	NLCD - 2006	Stagliano 2007
Context	Development	Percent of Riparian Corridor in Impervious	>10	>5-10	<5	NLCD - 2006	Wang et al. 2008

The riparian area used in the threat analysis was a 40-meter (m) buffer around both National Hydrography Dataset (NHD) streams and shorelines; this was used to create a single riparian area layer for riparian assessments. The buffering of the shorelines was done to accurately represent riparian areas for wide rivers or reservoirs.

5.1.1 Key Ecological Attribute Data Analysis for Current Status

The KEAs, indicators, and metrics listed in Table D-5-2 can be evaluated using geospatial data. It is important to note that some attributes/indicators that could affect this CE are not included in this table because either the KEA is not suitable for a landscape level analysis or because data are not available to support the analysis. However, for indicators where spatial data may not be available, surrogate measurements were used. After evaluation of the riparian forests, it was decided not to include patch size in the current status assessment. The decision was primarily made because there is no literature on optimum patch size for riparian forests. All literature is focused on wildlife habitat requirements, which is included in the fine-filter CE analysis.

Where possible, data gaps were identified for future data gathering efforts. In some cases, a proxy amenable to geospatial analysis has been identified. A data gap exists with regard to invasive species due to the current lack of large-scale geospatial datasets covering the ecoregion and the inability to identify a suitable surrogate.

5.1.1.1 Percent of Riparian Corridor with Natural Landcover

This KEA was included to show the relative fragmentation of riparian areas throughout the ecoregion. The metrics for this KEA were adopted from the fish assemblage KEA. The output from this KEA indicates that most of the riparian areas within the watersheds of agricultural areas are some of the most fragmented areas in the ecoregion (Figure D-5-3).

5.1.1.2 Percent of Riparian Corridor in Agricultural Use (Cropland)

This KEA is similar to the previous KEA, but it specifically only includes agricultural land uses from the National Land Cover Dataset (NLCD). This KEA was also adopted from the fish assemblage KEA table that was completed for this ecoregion, but the metric was adopted from Stagliano (2007). The output for this KEA is shown on Figure D-5-4. Although agriculture is not as prominent in the Middle Rockies ecoregion as in the Northwestern Plains, the areas of riparian forests in the Middle Rockies are located in areas of the ecoregion that are more conducive to agriculture. Areas in eastern Idaho, central Montana, and western South Dakota appear to currently include greater than 60 percent of the watershed in agricultural use.

5.1.1.3 Percent of Riparian Corridor in Impervious

This KEA was developed to show the relative context of anthropogenic development near riparian areas. This KEA was adopted from a study in Michigan designed to show the potential impacts of impervious surface to water bodies (Wang et al. 2008). In addition, this KEA was used in the fish assemblage CA analysis. The results of this KEA analysis are quite different from the previous two in that there are only a few areas in this ecoregion that have relatively large impervious areas, and those are concentrated around the urban areas (Figure D-5-5). Therefore, the majority of the riparian areas in this ecoregion do not appear to currently be at risk from the development of impervious surface.

5.1.2 Current Status of Habitat

The individual KEA analysis provides the basis for the compilation of an overarching data layer that defines the current status of riparian forest habitat for each HUC across this ecoregion. A method of aggregating scores was used to summarize overall threats with regard to riparian forest habitat quality. Individual threats can identify areas of potential risk to riparian forests, but aggregated scores can provide important information with relation to areas where riparian forests might encounter multiple threats. However, the aggregated scores can also dilute the results if one of the KEAs overshadows the others, which is the case with the agricultural KEA.

In order to create a combined score for each HUC unit based on varying levels of importance for each key attribute, it was necessary to aggregate the data through a simple summation by HUC. The summation combined each analysis input map to create an overall Current Status Map (Figure D-5-6). The overall current status map is very similar to the agricultural output map and, although much of the ecoregion appears to be at a low risk to threats related to the development CAs, the riparian areas located near agriculture are at the highest risk.

A summary of the current status ratings based on the CE distribution is provided in Table D-5-3. The CE distribution layer was used to calculate the total number of square miles of CE habitat and a percentage of the total number of square miles per HUC that were rated as good, fair, or poor. The results of the current status assessment indicate that approximately 83 percent of the 6th level HUC watersheds that intersect the riparian systems distribution received an overall rating of good, compared to the approximately 17 percent that received an overall rating of fair or poor.

Table D-5-3. Summary of Current Status Ratings for the Riparian Vegetation System

Overall Rating by 6th Level HUC	Total Square Miles[a]	Percentage of Total Square Miles[a, b]
Good	88,050	82.7
Fair	14,991	14.1
Poor	3,372	3.2

[a] These values include only the area of HUCs that intersect with the CE distribution layer.
[b] Values rounded to one decimal place.

5.2 FUTURE THREAT ANALYSIS

Future threats were evaluated for development for a short-term time horizon (5 to 10 years) and for climate change for a long-term time horizon (50-year; 2050 to 2069). Future spatial data for development was limited to potential energy development and climate change as discussed in the development CA analysis presented in Appendix C-1. Climate change was modeled based on a 15-km grid created for regional analysis. This analysis included a comparison of current climate patterns to future modeled climate patterns and resulted in the delta (change) output figures. Further details regarding the climate change analysis are contained in Appendix C-5.

5.2.1 Development Change Agent

Future spatial data for development was limited to potential energy development and potential agricultural development, as discussed in the development CA analysis presented in Appendix C-1.

5.2.1.1 Agricultural Growth

Grain prices will increase commensurate with world population levels and the production of crops will need to increase accordingly. Since no future agricultural models exist for use within this ecoregion, a model was created using surrogate data to derive potential future agricultural areas. This analysis was the same as to that which was completed for the current status. Figure C-1-1 in Appendix C-1 shows the State Soil Geographic (STATSGO) soil classification types are 1 through 4. Although this information can be portrayed spatially, there is no way to temporally show this future threat. This analysis considered the maximum potential for future agricultural areas within this ecoregion.

Figure E-3-12 shows the results of the analysis, indicating potential habitat loss due to potential future agricultural land development. Because most of this ecoregion is dominated by forests, mountains, and foothills, the riparian areas in this ecoregion are located where the current and future potential for agriculture development exists. Therefore, riparian areas are at low risk to agricultural development.

5.2.1.2 Oil Production Potential

This future analysis characterized potential oil production areas rather than oil well locations (Figure C-1-4). These larger oil production extents were used to qualitatively assess the potential effect of future oil production activities. Although these areas are based on oil density data, the application of these data to future potential well site activity is unknown. Therefore, a carefully considered approach should be taken when assessing the effects of potential oil production areas on riparian areas.

Overall, the riparian areas of this ecoregion appear to be at low risk from the development of oil production areas. However, areas in eastern Wyoming, east of Gillette, and southern portions of the ecoregion appear to be at a high risk of potential oil development.

It is important to note that the Energy Policy and Conservation Act (EPCA) oil and gas data used in this assessment are based on the maximum potential for oil reserves within the Middle Rockies. As a result, these data are likely overly represented in these figures, and care should be taken in assessing the effects of oil and gas production within the constraints of this analysis.

5.2.1.3 Natural Gas Production Potential

This future analysis characterized potential gas production areas rather than actual gas well locations (Figure C-1-3). These larger gas production extents could be used to qualitatively assess the potential effect of future gas production activities. Although these areas are based on gas density data, the application of these data to future potential well site activity is unknown. Therefore, a carefully considered approach should be taken when assessing the effects of potential gas production areas on riparian areas.

Most of the riparian areas in this ecoregion are at low risk to potential gas production. The majority of potential gas production is limited to northeastern Wyoming. There is an area in western Wyoming that indicates high potential risk for natural gas development. From an ecoregional scale, it appears that riparian areas are at low risk from future natural gas development.

5.2.1.4 Future Potential for Solar Development

This future potential analysis characterized the future potential for solar development based on the solar potential maps developed by the National Renewable Energy Laboratory (NREL). Although these maps are very crude (Figure C-1-6), the highest potential for solar development is shown to occur in northwestern Wyoming, west of Rapid City. With the exception of this area west of Rapid City, it does not appear that riparian areas are at a high risk from the threats related to future solar development.

5.2.1.5 Wind Turbine Potential

The U.S. Fish and Wildlife Service (USFWS) wind turbine data contained attribute information for current and future wind turbine locations. However, the future turbine locations dataset was very limited in number as most turbines will presumably be erected in the very near future. Therefore, an alternative dataset was used to determine the potential areas for erecting wind turbines over a long-term period. The future wind turbine locations were based on the availability of suitable wind speeds.

Data characterized by the NREL was used to create a potential future wind turbine area data layer. A full description of the methods and processes implemented to create this data layer and its corresponding scoring system can be found in Appendix C-1. Wind Power Classes were characterized as low, moderate, or high for direct comparison to the current wind condition.

The potential risk to riparian areas relative to future wind energy development is presented on Figure C-1-7. Higher elevations within this ecoregion are at higher risk of wind turbine development due to the higher wind speed levels found at these elevations. However, limited accessibility to these higher elevations could limit range of wind turbine development to lower elevation mountainous regions. Because the greatest wind turbine potential occurs at higher elevations, this CA does not seem to pose an overall risk to riparian areas located at lower elevations of this ecoregion. With the exception of some of the riparian areas in the northeast portion of this ecoregion, the majority of riparian areas do not appear to be at risk from the threats related to wind farm development. In addition to the physical disturbance that wind turbines can have on riparian areas, bird mortality is also a concern. The proximity to riparian areas should be considered when future wind farms are planned for development in this area. Although this assessment is primarily qualitative, the spatial distribution of riparian areas and mid-level elevation wind turbine potential overlap is apparent. There is potential for negative effects on riparian areas within the eastern portion of the ecoregion if wind turbine production increases in these areas.

5.2.1.6 Overall Development Change Agent Future Threats

A fossil fuel energy output layer was created to address the MQs associated with future fossil fuels production. This layer was created by averaging the EPCA oil data layer with the EPCA gas data layer (Figure C-1-5). Most of the riparian areas in the ecoregion will likely remain unaffected by fossil fuels production in the Middle Rockies.

A renewable energy output layer was created to address the MQs associated with future renewable energy production. This layer was created by averaging the NREL wind speed data layer with the NREL solar energy data layer (Figure C-1-8). This output layer provides equal weighting to potential wind and solar energy production areas, and could therefore mischaracterize the effects of each. Unlike oil and gas, wind and solar energy are not necessarily closely associated with one another spatially. Photovoltaic solar arrays threaten the species by their effect on habitat availability. Solar arrays are diverse in scope and size, and it is therefore difficult to create a clear correlation between habitat loss and solar energy production.

Because of the intricacies involved in the assessment of renewable energy production with regard to riparian areas, a limited approach must be taken in this analysis. The majority of the riparian areas in this ecoregion are considered to be at low risk from potential renewable energy development.

5.2.2 Climate Change Future Threats

5.2.2.1 Ecoregion Climate Change Analysis

From a climate change perspective, temperature and precipitation are the factors that would most affect riparian areas. In general, the climate change results indicate that the majority of the temperature and precipitation changes will occur at higher elevations, above where the majority of the riparian areas in this ecoregion occur. The western and northern mountain ranges could experience modest increases in annual precipitation, while the basins will remain relatively unchanged.

The same patterns appear to be true for temperatures. While temperatures in the mountains will experience slight increases, temperatures in the basins will remain relatively unchanged. Climate change presents many different issues relating to riparian areas. However, it remains difficult to draw conclusions from the data presented in this REA. Climate change models are highly variable and often difficult to predict. In this case, the resolution of the spatial data is an important factor to consider.

Based on the analysis conducted for the ecoregion, as presented in Appendix C-5, it appears that some areas have the potential to gain slight amounts of precipitation while precipitation in other areas will slightly decrease. The mean annual temperature delta maps show approximately 2 to 2.4 degree Celsius (^{o}C) temperature increases. The combined impacts of increased temperatures, localized drought, and conversion of lands to agricultural uses could negatively affect riparian areas in the future.

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6.0 MANAGEMENT QUESTIONS

The relevant MQs for the riparian system include those defined as part of the Terrestrial Biotic Resources category. The overall MQ was: Where are the important regionally significant terrestrial features, functions, and services across the ecoregional landscape? This MQ was considered in implementing the GIS analyses. Emphasis was placed on the spatial relationship of attributes mentioned in the MQs and the riparian distribution model. Several examples of how the REA can be used to answer MQs (as noted in Appendix A) are provided below; these examples demonstrate the functionality of the REA and provide an opportunity to discuss data gaps that were identified during this REA.

6.1 HOW ARE THE RIPARIAN SYSTEMS DISTRIBUTED OVER THE LANDSCAPE?

Figure D-5-1 maps the ReGAP riparian systems across the ecoregion.

6.2 WHERE WILL CURRENT CONSERVATION ELEMENT VEGETATION TYPES BE AT GREATEST RISK FROM CHANGE AGENTS?

The full range of figures and analyses for the riparian systems can be used to answer this complex MQ. The models created throughout this process were created to directly address the effects of CAs on the systems. All of the CAs were addressed spatially and described in detail in this section, and all of the CAs were spatially attributed to the distribution of the systems. Figure D-5-6 represents the sum of Figures D-5-3 through D-5-5 by the HUC 12 analysis unit.

6.3 WHICH AREAS HAVE POTENTIAL FOR RESTORING CONSERVATION ELEMENT SPECIES HABITAT OR HABITAT CONNECTIVITY FOR CONSERVATION ELEMENT SPECIES, CURRENTLY AND IN THE FUTURE?

The fragmentation potential (Figure D-5-3) represents the potential for further fragmented riparian systems. It can also be used to show areas where future restoration may be the most beneficial. The fragmentation potential shows areas where restoration could potentially connect larger stands together.

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APPENDIX D-5

FIGURES

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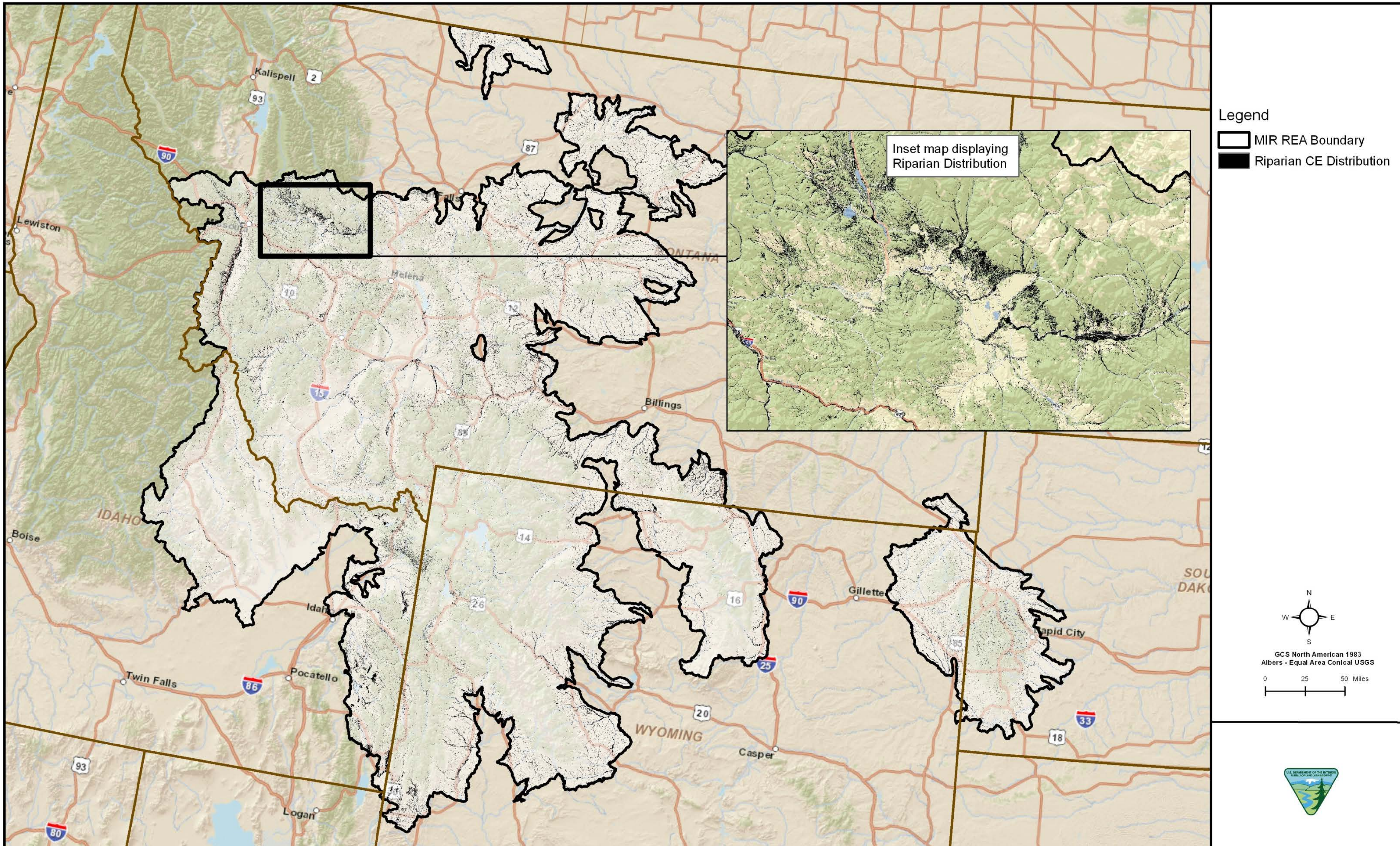

Figure D-5-1. Middle Rockies Riparian Forest Distribution

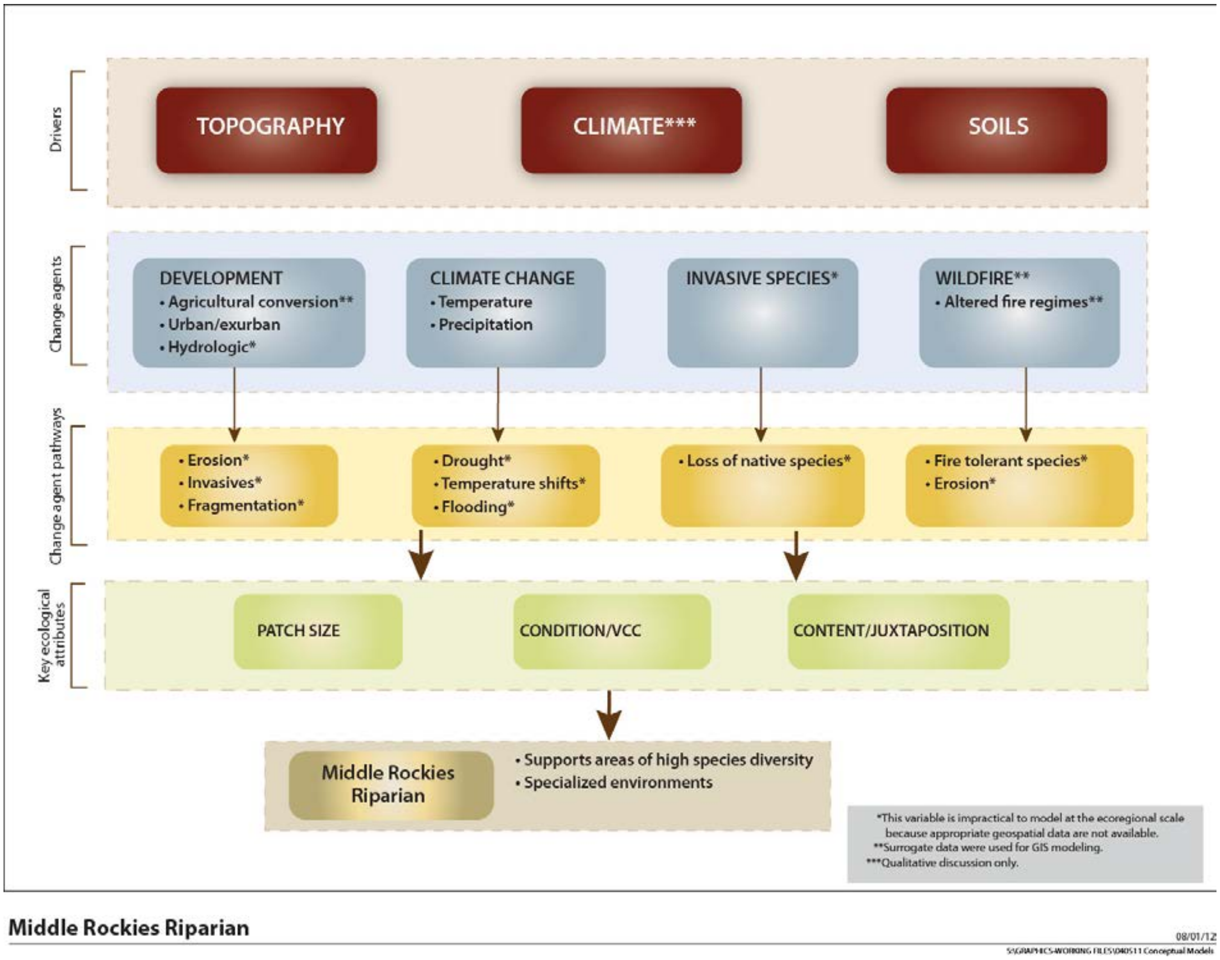

Figure D-5-2. Middle Rockies Riparian Forest System-Level Model

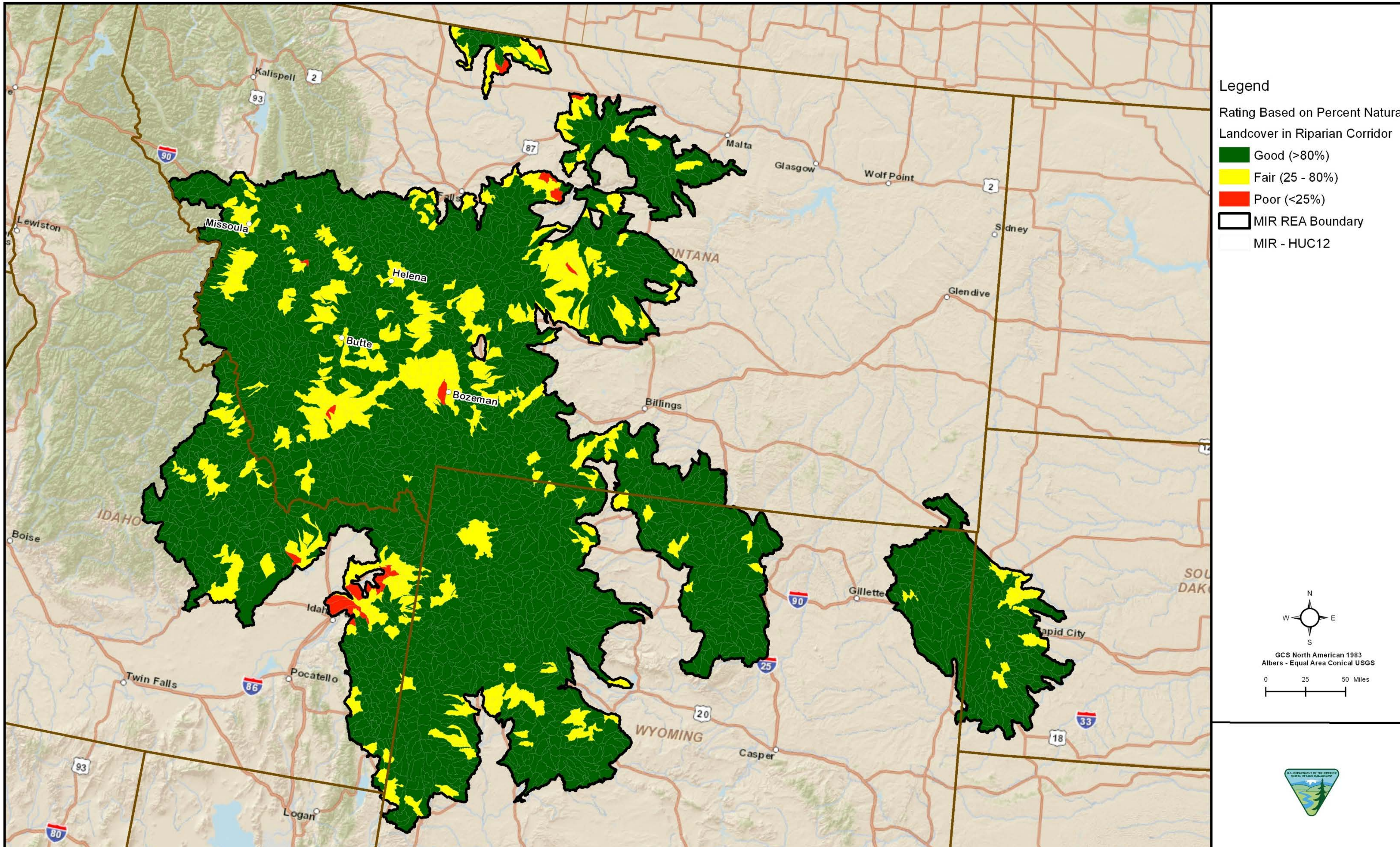

Figure D-5-3. Natural Landcover in Riparian Forest Corridors

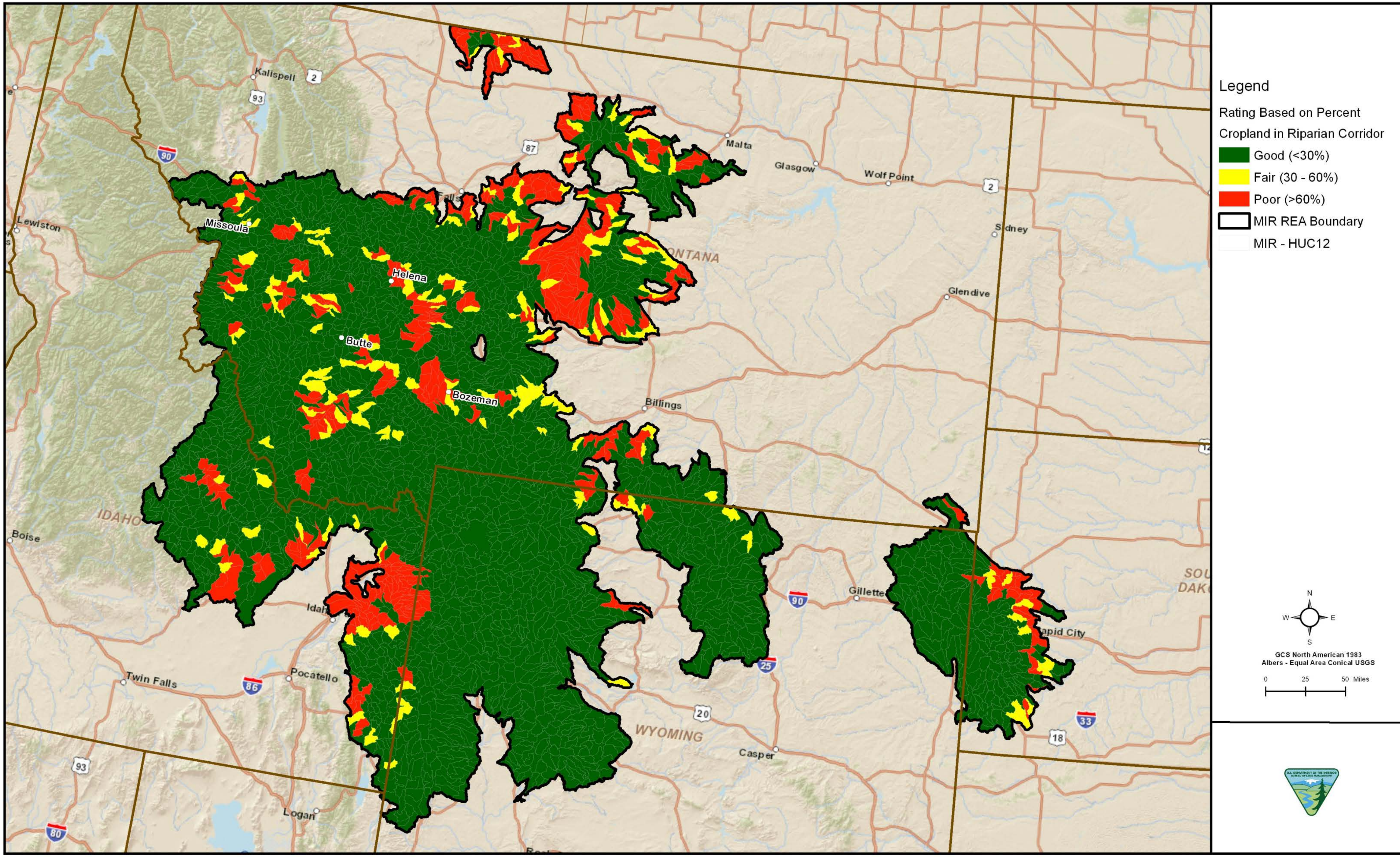

Figure D-5-4. Percent Cropland in Riparian Forest Corridors

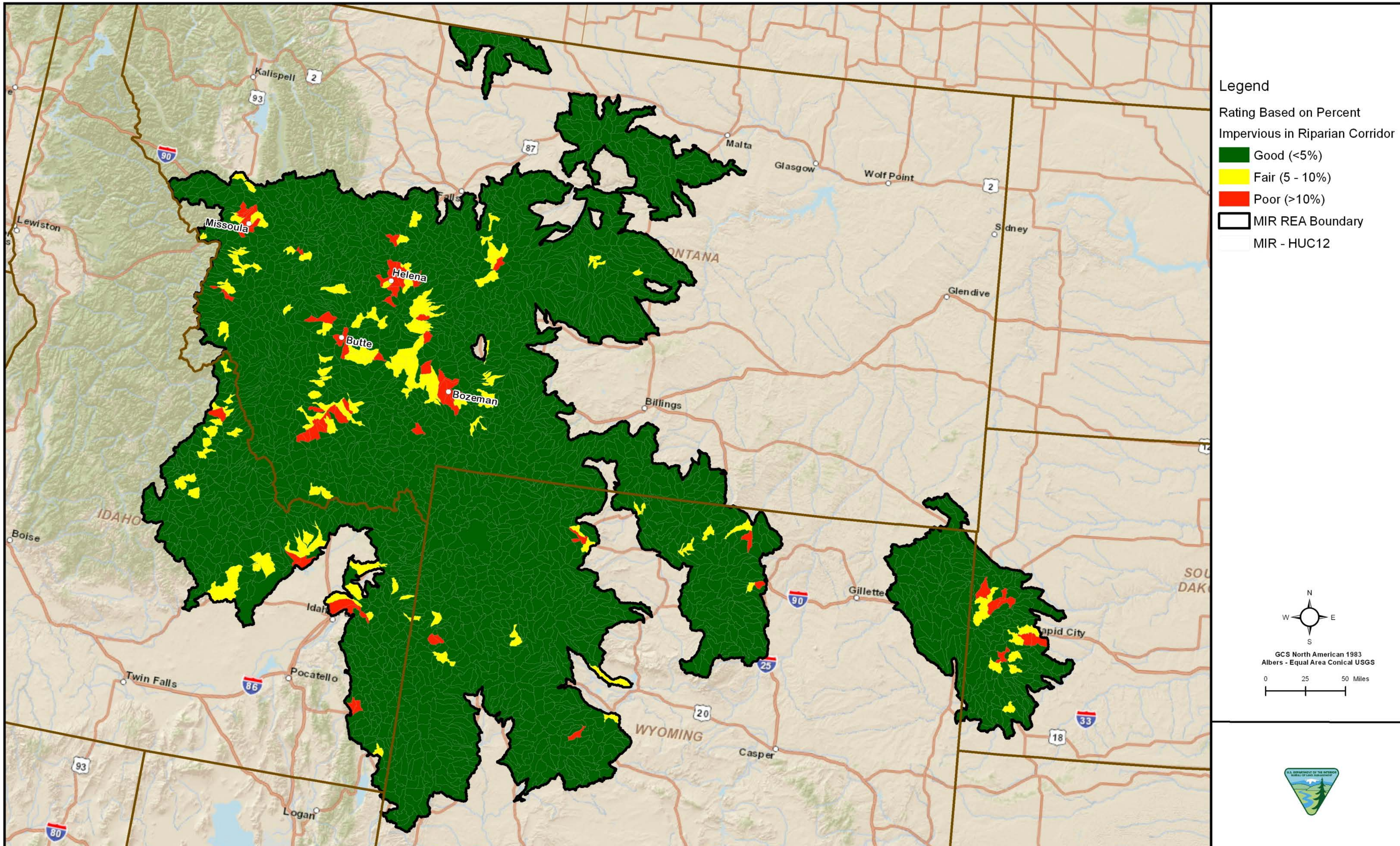

Figure D-5-5. Imperviousness in Riparian Forest Corridors

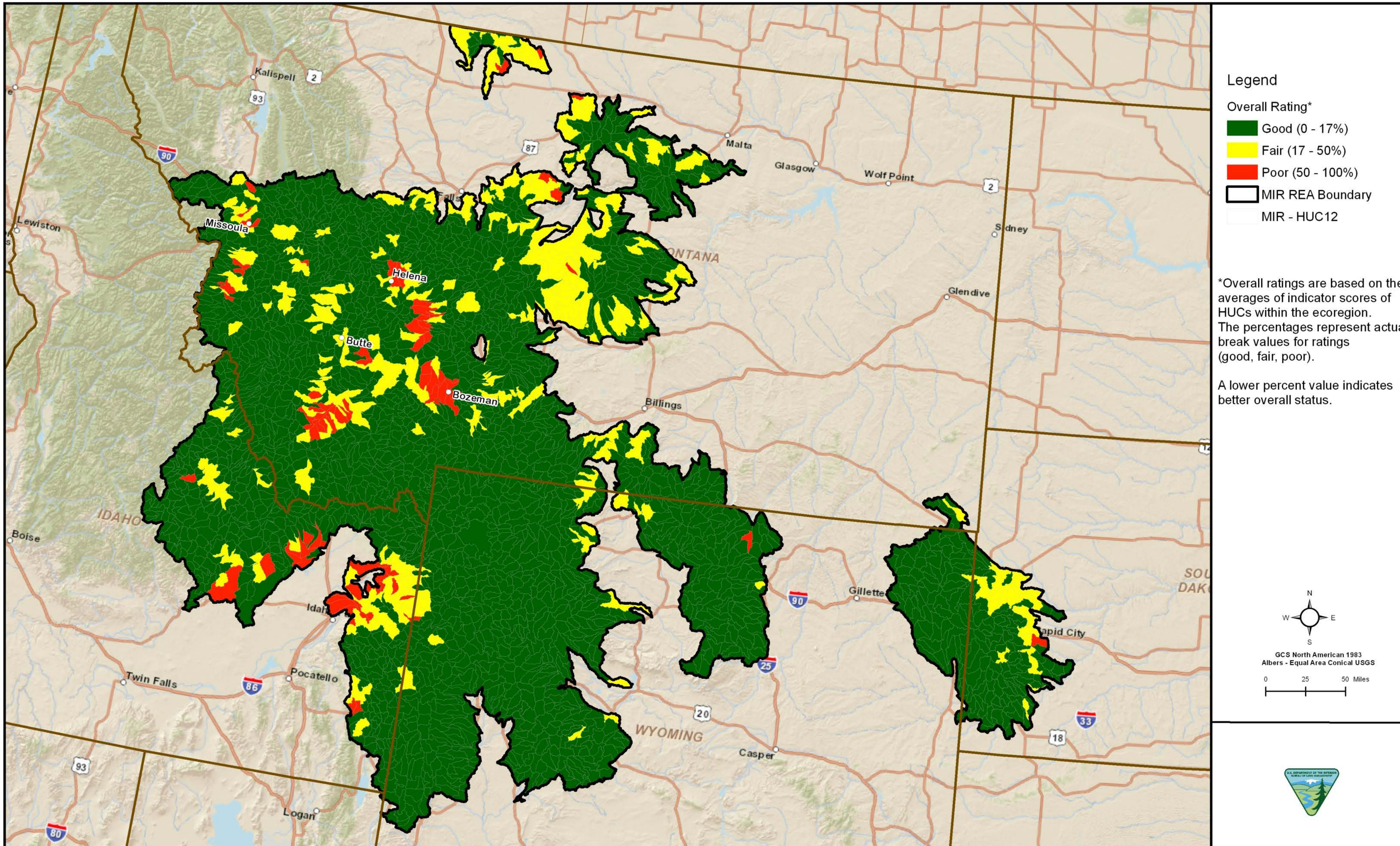

Figure D-5-6. Middle Rockies Riparian Forest Current Status by Hydrologic Unit Code 12