Development Change Agent Package
Northern Great Basin Ecoregion

1 Introduction

Change agents (CAs) are natural or anthropogenic disturbances that influence the current and future status of conservation elements (CEs). CEs are resources of conservation and management interest such as wildlife species or ecological communities; i.e. they are the objects that the BLM intends to assess for status in the face of changing CA effects. The initial CAs for this ecoregion were outlined by the Assessment Management Team (AMT) in the SOW. Development is included as a CA for this REA because some areas in the Northern Basin and Range and Snake River Plains (NGB ecoregion) are experiencing an expansion of urban and exurban areas, an increase in transportation infrastructure, oil and gas exploration, construction of wind farms, and the modifications of the landscape by agricultural and hydrological development. Human development activities often have a more significant effect on landscapes than natural disturbances because they alter the availability of energy, water, and nutrients to ecosystems; increase the spread of exotic species; accelerate natural processes of ecosystem change; and adversely affect the structure and functioning of ecosystems.

This CA package provides the assessment of the current status and future threats that are anticipated due to CAs in the ecoregion. Information in this CA package includes a brief description of the change agent, some information on potential data sources and analytical methods for the assessment, and a listing of relevant management questions (MQ) for this CA.

2 Change Agent Package Review Process

2.1 Subject Matter Expert Review

Subject Matter Experts play a key role in ensuring that the REA reflects the best available data and modeling processes suitable for each conservation element and change agent. Subject Matter Experts were added to Rolling Review Teams comprised of SAIC scientists, SAIC GIS personnel, AMT member(s) and other subject matter experts from the Department of Interior or state agencies. Membership of the Rolling Review Teams is listed in Appendix A. To ensure consistency amongst the different Rolling Review Teams, the number of lead SAIC scientists was limited to only a few individuals. This ensured that there was a common approach, or framework, used among the different Rolling Review Teams and that one Rolling Review Team did not stray too far from the rest. The USGS, as peer reviewers, were invited to participate in Rolling Review Teams.

3 Change Agent Description

3.1 Change Agent Categories

Broad categories of the development CA were initially identified during Task 1. Specific subcategories were added or refined based on the results of the literature review of the potential impacts of CAs on CEs in this ecoregion as well as the evaluation of relevant and available data for the analysis. As reported in Memo 1-C, development CAs in this REA include the following categories:

3.1.1 Energy Development and Mining

The BLM serves as the lead agency in energy and sub-surface mineral rights (including surface management acres) management in this area because many of these resources occur on BLM lands. The BLM plays a critical role in facilitating the development of energy resources such as oil and gas, coal, geothermal, hydropower, solar, wind, and biomass through selling leases and permitting on public lands**.**

Development of these operations impacts habitats of CEs through habitat loss, soil compaction and erosion, habitat fragmentation and introduction of non-native plant species. Particular attention is required for mining and alternative energy developments due to the potential for landscape-scale indirect impacts such as habitat fragmentation, corridors for invasive species and human intervention, ignition sources for fire, groundwater extraction, erosion potential, and dust generation. Of particular concern are specific impacts on sensitive species, including removal of unique habitats, noise disturbance, and impairing access to habitat by blocking movement corridors. Impacts associated with hardrock mining arise from either tailings discharged into streams in the past that continue to impact water quality, or from treated mine effluent currently being discharged into streams. Open pit mines in the West are usually difficult to restore and revegetate following operations shut-downs because of poor soils and lack of water for plant re-establishment.

The potential impacts associated with renewable energy development are also considered in this REA. The NGB ecoregion contains high quality wind resources for renewable energy development based on wind resource ratings developed by the National Renewable Energy Lab (NREL). Industry interest in developing renewable energy projects on federal lands is expected to increase as wind development on private land is completed and demand for land with good wind potential grows (BLM 2012). Wind farms generate electricity without many of the environmental impacts associated with other generation facilities (e.g., air pollution, water pollution, mercury emissions, greenhouse gas emissions), but wind farm facilities also require land conversion and areas developed for power transmission and access roads may fragment wildlife habitats and turbine blades have been shown to kill migratory birds and bats.

Solar energy can be used to generate electricity, heat water, and heat, cool and light buildings in residential and commercial construction, and farming, ranching, recreation and other industries. The primary ecological and other land-use impacts that approach landscape scale of solar development relate to large, utility-scale photovoltaic (PV) and concentrating solar power (CSP) sites. A wide range of habitats, plant and animal species, and cultural and economic activities could be affected by widespread solar development of former open areas. The impacts of solar development include direct impacts, such as vegetation removal and soil disturbance, habitat fragmentation, and noise, in addition to indirect impacts such as changes in surface water quality because of soil erosion at the construction site. Aquatic species also can be affected—as can terrestrial and avian species that rely on aquatic habitats—if the water requirements of solar development result in substantial diversion of local water sources. Large-scale solar-thermal plants (like most conventional power plants) also require cooling water, which may be costly or scarce in desert areas.

Large areas covered by solar collectors also may affect plants and animals by interfering with natural sunlight, rainfall, and drainage. Although solar energy requires water consumption to rinse panels, mirrors, and reflectors to ensure maximum energy production, many solar configurations can reduce water consumption dramatically compared with conventional technologies that use evaporative cooling systems (i.e., cooling towers). The specific impacts of utility-scale solar development will depend on project location, habitat quality, solar technology employed, size of the development, and proximity to existing roads and transmission lines. Solar deployment may require land that was previously used for other applications (e.g., abandoned industrial, fallow agriculture, or former mining sites) or was previously undeveloped (USDOE 2012).

Geothermal energy provides a high-pressure steam that can be harnessed to generate electricity. The extraction of geothermal energy is accomplished without the large-scale movement of rock involved in mining operations (construction of mine shafts and tunnels, open pits, and waste heaps). Land areas required for geothermal developments would involve power plants and wells that vary with the local reservoir conditions and the desired power outputs and therefore may also contribute to habitat loss. An important issue previously associated with geothermal energy was the disposal of cooled water left after heat extraction or steam separation. Previously, such "waste" water was disposed of in surface ponds or rivers. Now, the common practice is to inject water through wells back into the subsurface. This not only minimizes the chance of contaminating surface waters, but it also provides replenishing water to help sustain a hydrothermal system (Duffield and Sass 2003).

The risk of collision and electrocution at electrical generation and transmission facilities is a significant hazard for birds and bats, in particular during migration which often occurs at night. Birds and bats are frequently killed in collisions with transmission lines and towers; raptors and other birds may also be electrocuted. Many migratory species typically fly at altitudes above rotor swept areas in wind farms when weather conditions are favorable. Risk may be greatest during take-off and landing where wind facilities abut stopover sites. However, poor weather conditions force birds to lower altitudes where they become more vulnerable to colliding with transmission lines and towers or wind turbines. Raptors are particularly vulnerable because they concentrate in high wind areas such as along ridge tops, upwind sides of slopes, and canyons to take advantage of wind currents that are favorable for hunting and traveling, as well as for migratory flights (National Wind Coordinating Collaborative 2010). These sites are often the best locations for wind energy production.

3.1.2 Urban, Exurban and Rural Development and Recreation

Urban, exurban and rural development includes residential, commercial, and industrial development in undeveloped or underdeveloped regions, or infilling in currently developed areas. Exurban development includes the expansion of neighborhoods outside of urban areas to form commuter communities and the addition of new communities, often second and vacation homes, into undeveloped areas that are bordered by natural ecosystems. Rural development generally refers to residential land use in relatively isolated and sparsely populated areas. Rural development has traditionally located in areas with large-scale land-intensive uses such as agriculture and forestry. Urban, exurban and rural population growth often requires municipal water and sewer services and infrastructure (roads, bridges, transmission lines, utility corridors, etc.) to accommodate expansion into developing areas. These types of development displace and fragment native habitats, create adverse disturbance-related effects on native wildlife, and promote the spread of invasive species and sometimes fire. Roads also allow more human access into wild areas and increase opportunities for illegal hunting, animal-vehicle collisions, and adding disturbance, noise, trash, and pollutants into habitats. Because of the potential for habitat fragmentation from exurban development and associated transportation and utility infrastructure, particular attention was focused in this analysis on planned, permitted, and leased development. This development category includes roadways and transmission facilities as well as those proposed or projected under reasonably foreseeable development scenarios in areas of intact habitat that are isolated from existing urban and industrial infrastructure.

Recreational use of the landscape may include developments with a footprint that displaces or degrades natural ecosystems or human presence in natural ecosystems. Ski resort areas and golf-centric developments not only require large amounts of land conversions but cause induced growth of second homes and transportation corridors that fragment and encroach on surrounding natural habitats. Dispersed recreational use of land in the NBR has grown significantly with increased use of off-road vehicles and increased backcountry recreation, resulting in disturbance issues for sensitive soils, vegetation, and wildlife species.

3.1.3 Agriculture

The Snake River Plain includes a large proportion of irrigated cropland in which potatoes, grain, sugar beets, beans, and alfalfa are the principal crops, in addition to rangeland. Growing biofuel crops or the use of food crops for fuel is also becoming common. Agricultural effects to native habitats include habitat alteration (conversion to farmland for crops and grazing), exotic weed and pest introductions and spread, and pollution from pesticides and fertilizers. Wind and water soil erosion also has a direct effect on habitat quality, making an area barren and unsuitable for plants that were native to that habitat. Excess nutrients that enter lakes and rivers as runoff can impact aquatic ecosystems. A recent topic of controversy in the region is the use of Concentrated Animal Feeding Operations (CAFOs), especially for dairy cattle, with regard to animal treatment, manure run-off, and odors.

3.1.4 Hydrological Uses

Surface water impoundments and diversions affect the timing and amounts of downstream flows, reducing connectivity and gene flow by affecting passage and survival of fish and other aquatic vertebrates, and curtailing flood events necessary to regenerate cottonwood and willow riparian communities. Groundwater extraction may change the height and fluctuations of groundwater tables, affecting regeneration of riparian communities and surface waters such as seeps, springs, or live stream segments. Lowering groundwater tables can affect sensitive aquatic invertebrate and vertebrate species, as well as plant species and entire habitats dependent on surface water or elevated groundwater tables (e.g., most riparian and wetland species). The condition of these aquatic and riparian communities is essential in arid regions for the survival of a great variety of resident and migratory wildlife species. Many listed and sensitive species in the ecoregion utilize aquatic and riparian habitats for essential life stages such as breeding, and their decline can be tied to the general degradation of water-dependent habitats in the West. Effects on these habitats can also lead to soil destabilization and erosion.

3.1.5 Military and other Federal Land Management

Evaluation of military activities as a change agent in the NBR ecoregion may include land use and disturbance-related effects of existing facilities, planned expansion of existing facilities, and uses of non-Department of Defense (DOD) public land for training missions. Effects of land management by other Federal agencies will also be evaluated, e.g., the land-use footprint of the Department of Energy's (DOE's) Idaho National Energy Lab located in the upper Snake River Plain.

3.1.6 Rangeland Treatments

Some traditional rangeland treatments were evaluated in this REA as a type of land development activity (separate from grazing effects). Altered vegetation communities (e.g., sagebrush suppression), the presence of fences, and diverted water sources for livestock have affected the distribution and migration and dispersal corridors of wildlife species. Evaluation of the use of these rangeland treatments and others such as prescribed fire may identify opportunities for habitat management and restoration.

3.2 Development Change Agent Effect Pathways

In general, human development CAs affect CEs by changing the total habitat area (habitat loss) and the suitability of available habitat (habitat degradation) for the CEs. Effects to individuals and populations (behavioral disturbance and direct mortality) may also result. Table 3-1 shows some of the ways in which the development CA and the potential effects relate to habitat loss and disturbance. This listing is not intended to be comprehensive but indicates some of the ways in which the analysis of this CA can proceed. In general, the effects of development can be grouped as follows:

- **Habitat Loss.** The effect pathways are relatively direct and result from land conversion from native ecosystems to human-dominated ecosystems. Conversion of native ecosystems to agriculture, urban, exurban, or industrial systems reduces the available habitat for CEs. In cases where CE species are able to occupy human-dominated ecological systems (such as pastures and croplands), habitat suitability is usually reduced relative to native ecosystems. Habitat loss includes the analysis of the extent (footprint) of the CA.
- **Habitat Degradation.** Degradation of habitats is related to proximity or adjacency to the offsite human development footprint and/or development-related activities. Indirect effects of human development and human activities on CEs include loss of habitat suitability due to changes in

water availability and quality, changes in availability or access to shelter, prey or forage resources; barriers to movement, and reduced suitability of habitat patches, among others. Pathways for habitat degradation often involve changes in ecological processes and increased variability in natural disturbance regimes: for example, water withdrawal can lead to greater variability in seasonal hydrograph and result in degradation or loss of wetlands, and loss of connectivity, spawning and rearing habitat for fish species. Indirect effects of human land use and activities can include increased spread of invasive species, predators, competitors, parasites, and disease organisms. Indirect effects are analyzed based on proximity or intensity of an adjacent human development activity and require analytical tools suited to measurement of intensity, interspersion, distance, or density.

- **Population Effects (Behavioral Disturbance and Direct Mortality).** Effects pathways include disruption of wildlife movement due to behavioral avoidance, disruption of reproductive cycles, increased risk of predation, accidental mortality due to collisions with vehicles, transmission infrastructure, electrocution, poaching, and mortality resulting from adverse management actions (e.g., management of mountain lion/human interactions). In stream barriers such as dams and impoundments, surface water diversions, alterations in channel configuration, and flow regimes affect the ability of fishes to migrate from spawning and rearing habitat, leading to population isolation, loss of genetic variability, and increased vulnerability to random events. Effect pathways related to behavioral responses or risk of mortality of a CE, require analytical tools such as inverse distance weighting, which considers distance, intensity or severity.

Table 3-1. Human Development Change Agents

Change Agent Category	Change Agent Activity	Effect Pathways	Interactions with other CAs	Affected CEs
• Urban Development • Exurban Residential • Industrial Development	• Dwellings, commercial and industrial facilities and associated land clearing) • New roads • New utility corridors	• Habitat loss: Land cover conversion from native ecological systems to human-dominated ecological systems • Habitat degradation: Fragmentation of suitable habitats, spread of invasive species, increased ignition sources, contaminant, nutrient, and sediment runoff into aquatic systems. • Behavioral/avoidance effects on wildlife species due to increased human access into native ecosystems • Population effects on wildlife species due to increased risk of mortality, disruption of reproductive cycles	• Transportation and transmission line/corridors • Fire • Invasive species	• Many coarse filter CEs: Increasingly foothills and lower montane ecological systems • Many fine filter CEs
• Transportation	• Roads, railroads, two track roads • Increased human access to habitats • Pathways for spread of invasives and trash • Animal-vehicle collisions	• Habitat loss: Land cover conversion from native ecological systems to transportation corridors and development sites. • Habitat degradation: Fragmentation of suitable habitats, spread of invasive plant seed vectors, increased ignition sources, contaminant and sediment runoff into aquatic systems, increased mass wasting, channelized or constrained stream flow. • Behavioral/avoidance effects on wildlife species due to increased human access into native ecosystems for fire suppression, energy site access, and recreation. • Population effects: Increased risk of mortality for wildlife species	• Urbanization (growth-induced expansion of transportation infrastructure)	• Greater sage-grouse • Mule Deer • Pronghorn • Golden eagle • Coldwater fish assemblage
• Transmission Lines/ Corridors	• Electric transmission; water, gas pipelines and associated land clearing • Pathways for spread of invasives	• Habitat loss: Land cover conversion from native ecological systems to transmission corridors. • Habitat degradation: Habitat fragmentation, increased human access into native ecosystems for infrastructure construction and maintenance. • Population effects: Increased risk of mortality for wildlife species: collision, electrocution, and increased predation	• Urbanization (growth-induced expansion of infrastructure)	• Golden eagle • Greater sage-grouse
• Energy Development	• Existing and leased oil and gas extraction sites and facilities • Existing and leased renewable energy sites and facilities (wind, solar, geothermal) • New roads • New utility corridors	• Habitat loss: Land cover conversion from native ecological systems to transmission corridors. • Habitat degradation: Habitat fragmentation and loss of connectivity, increased human access into native ecosystems for energy development, corridors for invasive species, ignition sources, groundwater extraction, discharge of pollutants into aquatic systems. • Population effects: Increased risk of mortality for wildlife species due to collisions with infrastructure, behavioral/avoidance due to increased human access into native ecosystems, disruption of reproductive cycles.	• Transportation • Transmission lines/corridors	• Many coarse-filter CEs and fine-filter CEs (pronghorn, mule deer, greater sage-grouse, golden eagle)

Table 3-1. Human Development Change Agents

Change Agent Category	Change Agent Activity	Effect Pathways	Interactions with other CAs	Affected CEs
• Agriculture	• Cropland, pastures, orchards • Surface water diversion (irrigation withdrawals) • Water quality effects from pesticides, fertilizers, soil loss • Rangeland improvements	• Habitat loss: Land cover conversion from native ecological systems to agricultural systems • Habitat degradation: Runoff conveying nutrient, sediment and contaminant loads	• Invasive species	• Many coarse filter CEs • Fine filter CEs: • Greater sage-grouse and coldwater fish
• Mineral Extraction	• Buildings, other structures, and associated land clearing • Large-scale land removal (open pits) • Toxic soils and water creation • Long-term effects (due to e.g., poor revegetation potential) • New roads • New utility corridors	• Habitat loss: Land cover conversion from native ecological systems to human-dominated ecological systems • Habitat degradation: Fragmentation of suitable habitats spread of invasive species, increased ignition sources, contaminant, nutrient, and sediment runoff into aquatic systems. • Population effects: Increased risk of mortality for wildlife species, behavioral/avoidance due to incr0eased human access into native ecosystems, disruption of reproductive cycles.	• Transportation	• Many coarse-filter CEs and fine-filter CEs
• Major Hydrologic Alterations	• Groundwater extraction, wells (municipal and industrial uses) • Surface water diversion (municipal, industrial or mining uses) • Flood control, dams, weirs, channelization, levees • On- and off-channel reservoirs and water storage	• Habitat loss and degradation: Loss of wetlands and riparian ecological systems extent and suitability due to reduced water table and surface water flows. • Habitat degradation for aquatic biota due to hydrograph (flow and depth) changes resulting from impoundments and channelization. • Population effects: Barriers to migration for aquatic biota, genetic isolation	• Agriculture, • Urban/industrial development • Energy development (water withdrawals and discharge of pollutants) • Mineral Extraction (water withdrawals and discharge of pollutants) • Fire regime (decreased fuel moisture) • Climate change	• Many coarse-filter CEs and fine-filter CEs

4 Data Sources, Methods, Models and Tools

4.1 Data Identification

Preliminary data needs for analysis of the Development CA are described in the following sections. Development CA data exists in a variety of formats and scales, covering many areas related to the analysis requirements. We were guided by the Management Questions in creating the preliminary list of Development CA data needs (Table 4-1). Identifying the best datasets and determining their level of quality is challenging due to the large number of datasets that were acquired and examined.

Table 4-1. Preliminary List of Development CA Data Needs

Data Required	Dataset Name	Source Agency	Type/ Scale	Status	Potential Use in REA
Agriculture	Cropland Data Layer	USDA NASS	56m	Acquired	Yes
	Agriculture Census	USDA	Raster (1:20 million)	Acquired	No
	Grazing Allotments / Pasture Boundaries	BLM / USFS	Polygon	Acquired	Yes
	Fences (Density 18km grid)	Sagemap	Raster	Available	No
	STATSGO Soils	NRCS	Polygon	Acquired	Yes
	SSURGO Soils	NRCS	Polygon	Acquired	Yes
	Surficial Geology	USGS	Polygon	Acquired	Yes
	Surficial Materials Lithology	USGS	Raster (1km)	Acquired	No
Hydrological Uses	National Hydrography Dataset	USGS	Vector	Acquired	Yes
	Watershed Boundary Database	USGS	Polygon	Acquired	Yes
	Aquifers	USGS	Polygon	Acquired	Yes
	National Inventory of Dams	USACE	Point	Data Gap	
	Fish Ladders	NHD	Point	Acquired	Yes
	Water Quality	NWIS	Point	Acquired	Yes
	Water Quantity	NWIS	Point	Acquired	Yes
	Pollution Source Points	EPA	Point	Acquired	Yes
	Groundwater extraction	USGS		Acquired	Yes
	Surface water diversion	USGS		Acquired	Yes
	Impaired Rivers and Lakes (303d)	EPA	Point	Acquired	Yes
Energy/ Transportation/ Mining	Oil and Gas Wells	BLM	Point	Acquired except OR	Yes
	Oil and Gas Pads	BLM	Polygon	Not Available	No
	Mines	USGS, States	Point	Acquired	Yes
	Potential mining (locatable, salable, leasable minerals)			Data Gap	
	Proposed Energy Developments and Corridors	BLM		Acquired	Yes
	Oil and Gas Developable Area and Strata Unit Area	Argonne National Laboratory	Polygon	Acquired	Yes
	Wind Resources	NREL	Polygon	Acquired	Yes
	Wind Turbines	FAA, USFWS	Point	Acquired	Yes
	Potential Geothermal	NREL/BLM	Polygon	Acquired	Yes
	Lands Targeted for Renewable Energy	BLM	Polygon	Acquired	Yes
	Section 368 Energy Corridors	Argonne National Library	Vector	Acquired	Yes
Transmission/ Communication	Towers	FCC		Acquired	Yes
	Transmission Lines	TIGER 2000	Polyline	Acquired	Yes
	Global Energy 2005	Global Energy	Polyline	Acquired	Yes
Human Population	Census Data	US Census Bureau / ICLUS	Vector	Acquired	Yes

Table 4-1. Preliminary List of Development CA Data Needs

Data Required	Dataset Name	Source Agency	Type/ Scale	Status	Potential Use in REA
	ESRI Streetmap	ESRI	Polyline	Acquired	Yes
	ICLUS	EPA	Model	Acquired	Yes
	Existing and Proposed ACECs, RNAs, NWRs, Wilderness Areas, NCAs, etc.	BLM	Polygon, Line,	Acquired	Yes
	Urban/ExUrban Areas	US Census Bureau/ICLUS	Polygon/ Raster	Acquired	Yes
	Human Footprint in West	USGS	Raster (180m)	Acquired	Yes
Military and other Federal land management	Military Expansion	Western Regional Partnership	Vector	Not Available	No[1]
Rangeland Treatments	Land Treatment Digital Library	USGS	Polygon	Acquired	Yes
Recreation	Developed recreation sites, designated recreation areas (OHV areas)	BLM	Vector	Acquired	Yes
Atmospheric deposition	Pollutant sources (dust, acid, mercury)	National Atmospheric Deposition Program	Raster	Acquired	Yes

Notes:
1 Probably data gap;

4.2 Development CA Modeling

A GIS-based multi-criteria evaluation (MCE) model incorporated within the spatial analysis model in ArcGIS was used in the assessment. MCE utilizes decision-making rules to combine the information from several criteria in the form of GIS layers. Multiple geographic layers are aggregated to produce a single index or map that shows the appropriateness of the land for a particular purpose or activity. The MCE approach is implemented with the ArcGIS platform using ModelBuilder. Each criterion can be controlled using a weighted sum analysis in order to produce an overall development layer or map.

5 Management Questions

5.1 General Development

Where are current locations of development CAs? (MQ 42)

The answer to this questions is fairly broad is scope as can be seen in Table 4-1 there are many types of development change agents that are displayed on maps in various conservation element packages.

Figure 5-1 shows the locations of developed or urban areas along with agricultural areas. Agricultural areas dominate the developed landscape focusing on the Snake River Plain in Idaho and in the basins between the ranges extending down into Utah. The area north of Malheur Lake is another large concentrated area of agriculture within Oregon while the rest of Oregon, Nevada and California have isolated pockets of agriculture. Urban centers within the ecoregion are mainly focused within the Snake River Plain in a corridor along the I-84/I-15 ranging from Boise to Idaho Falls. Boise is the largest city within the ecoregion and has nearby cities such as Caldwell, Meridian and Nampa adding to the urbanization of this area.

Figure 5-2 shows the location of communication towers and transmission lines within the ecoregion. The majority of the communication towers follows a similar pattern concentrating in the Snake River Plain and progressing towards Logan, UT and the east side of the Great Salt Lake. The rest of the ecoregion has a much lower concentration of towers mostly along major highways and other key locations to provide coverage for the area. The transmission lines shown in Figure 5-2 tend to concentrate along the Snake River Plain but there is also some major corridors head north south from Oregon and Idaho down through Nevada and Utah.

Figure 5-3 shows the major highways and interstates within the ecoregion. The major interstate is the I-84/I-15 heading from Oregon to Utah and Montana to Utah. Nevada has US 95 and US 93 running north/south in the ecoregion connecting Nevada with Idaho and Oregon. Many of these state and US highways are also corridors for transmission lines.

Figure 5-4 shows the major dams within the Northern Great Basin along with named streams and water bodies from the National Hydrographic Dataset. The major dams layer came from the national atlas, the USACE National Inventory of Dams was currently a data gap.

Where are areas of planned or potential development CAs? (MQ 43)

Identify planned or potential development is difficult for an entire ecoregion as most planning is conducted at a municipal or county level. The source of data that was used for determining the future locations of development were the Integrated Climate and Land Use Scenarios (ICLUS) developed by the EPA (2010). The ICLUS data predicts population change as well as housing density changes based on five different scenarios. For the purposes of the REA, the base case (or baseline) scenario was selected as the other scenarios added more uncertainty using predictions of migration and household sizes that expanded the number of possible outcomes depending on which one was chosen.

Figure 5-5 shows the predicted change in housing density based on the ICLUS modeling and use of the Spatially Explicit Regional Growth Model SERGoM (Theobald, 2001, 2003, 2005). A spatial operation was used to subtract the predicted housing density for 2060 from 2010 and then recoded to show what land use changed. ICLUS classifies the housing density as Urban being less than 0.25 acres per housing units, Suburban being 0.25 – 2 acres per housing unit, Exurban being 2 – 40 acres and rural over 40 acres. As displayed in Figure 5-5, the 83 percent of the housing density changes within the ecoregion between 2010 and 2060 will be rural becoming exurban. The second biggest housing density change (14 percent) will be exurban to suburban. The three areas within the ecoregion that appear to have the most housing density change will be Boise and its surrounding cities, Idaho Falls and the area north of Logan, UT. Boise appears to have the most exurban to suburban change while most of the other two areas seem to be mostly focused on rural to exurban.

Figure 5-6 shows the estimated population growth between 2010 and 2060 by county based on the ICLUS estimates (base case scenario). This figure shows that Canyon and Ada counties near Boise and Washoe county in Nevada are projected to have the most population growth. Washoe County contains Reno in its southern most part which is predicted to grow by over 375,000 people. Most of that growth will probably be outside of the ecoregion. Canyon and Ada are predicted to grow by 130,000 and 215,000 respectively by 2060. Cache county in Utah and Elko county in Nevada are two other locations with predicted growth over 50,000 people. Many of the counties in the ecoregion are predicted to have declining population growth by 2060.

Where do development CAs cause significant loss of ecological integrity? (MQ44)

The landscape integrity generated by the WGA (see Ecological Integrity summary) shows that the two main drivers of low landscape integrity are developed/agricultural areas and major roads. The majority of these agricultural areas are located in the Snake River Plain corridor and extend down between the ranges towards the Utah border. These areas are the lowest scoring in the Landscape Condition Model. Dams (Figure 5-4), improperly placed culverts, irrigation diversions, and other migration barriers have negatively affected fish and habitat and likely have interfered with metapopulation dynamics. As a result, populations have become increasingly fragmented and of lower integrity.

Where do current locations of CEs overlap with development CAs? (MQ 45)

This management question can be answered by referring to the Development section of each conservation element package. These sections cover development as a change agent and will include any references or support figures and would be best to reference them there than repeat here.

Where are areas of Department of Defense and Department of Energy use? (MQ 69)

Figure 5-7 shows locations of DOD and DOE land use within the ecoregion. The Northern Great Basin has a large Air Force Base at Mountain Home, Air National Guard Base in Boise and the Sierra Army Depot in California. Two large training areas within the ecoregion would be the Orchard Training Area and Saylor Creek Range. The DOE has the large Idaho National Engineering and Environmental Lab northwest of Idaho Falls.

5.2 Recreation and OHV

Where are areas with significant recreational use? (MQ 46)

Figure 5-8 shows the ski areas within the ecoregion with the majority of them being in Idaho. The size of the ski resorts and their resulting significance on conservation elements varies greatly from small isolate USFS recreation areas (Cedar Pass Ski Area) with no corresponding development to the largest in the ecoregion, Sun Valley which has large amounts of development surrounding the resort. Figure 5-9 shows various types of recreation from various sources such as BLM and USFS. Nevada and California had very limited spatial data with regards to recreation data so the Geographic Name Information System (GNIS) was used to help supplement this gap. GNIS mostly focused on state parks and wildlife refuges. The majority of these recreation sites listed in Figure 5-9 are camping, trailhead, water access points, or day use recreation sites. Most of these would be considered fairly low significance on conservation elements but with human recreation can often bring increased fire risk, aquatic or terrestrial invasives and disturbance. Off Highway Vehicle (OHV) is one form of recreation that can have significant impact and will be covered in the next management questions. Other recreation sites not included would also be listed in the Specially Designated Areas coarse filter to include Wild and Scenic Rivers, Wilderness Areas, National Conservation Areas, etc.

Where have designated recreation areas, such as for off-highway vehicle (OHV) use, affected CEs and invasive species? (MQ 47)

Figure 5-10 shows some of the OHV areas within the ecoregion based on available data. OHV areas were identified as a data gap for most of the ecoregion. Idaho and California were exceptions with available spatial data showing locations of open, limited and undesignated OHV areas. Oregon did have some smaller OHV recreation areas near Bend, OR and also some Backcountry Byways. The USFS for Humboldt and Toiyabe National Forest had some information on 4WD routes in their ranger districts in the ecoregion. Figure 5-11 shows TIGER roads classified as 4WD or private roads such as ranch or logging roads.

Where are other areas of likely high OHV use [as determined by modeling] that may affect CEs and invasive species? (MQ 48)

Figure 5-12 shows the travel time from urban areas (greater than 20,000 in population) to areas within two hours distance. Two hours was used based on earlier work by Idaho Department of Lands 2009 and their Idaho Forest Action Plan and represent a typical day-trip recreation event. A cost distance spatial operation was used to calculate the distance from urban areas within the ecoregion and 100 miles from the ecoregion. Figure 5-12 shows that the majority of Oregon, California and Nevada fall outside the two hour window from most of the urban areas. Bend, OR is the one exception for Oregon as it is a fairly large urban area just outside of the ecoregion. Idaho and the eastern part of the Utah have the most areas within two hours of an urban area.

Correlating invasive species and this area of OHV use near urban areas is difficult for two reasons. First the invasive species coverage originally being used (received a full coverage cheatgrass layer at the end of the REA) didn’t cover most of the ecoregion especially the area that was modeled within Idaho near urban areas. These areas have fairly dominant cheatgrass coverage (south side of Snake River Plain) but it is difficult to know using an ecoregional approach how much of an affect OHV has versus wildfire and other disturbance on these areas.

5.3 Energy and Mining

Where are the current locations of oil, gas, and mineral extraction? (MQ 49)

Figure 5-13 shows the location of mines based on the USGS Mineral Resource Data System (MRDS). There are only a handful of oil and gas wells within the ecoregion so based on the AMT’s recommendation, oil and gas wasn’t taken into consideration.

Where will locations of oil, gas, and mineral extraction potentially exist by 2025? (MQ 50)

As mentioned in the previous management question, oil and gas wasn’t evaluated for the ecoregion. There wasn’t any identifiable data source for predicting where future mining locations would be.

Where are the areas of potential future locations of Oil, Gas, and Mining (including gypsum) development (locatable, salable, and fluid and solid leasable minerals)? (MQ 51)

As mentioned in the previous management question, oil and gas wasn’t evaluated for the ecoregion. There wasn’t any identifiable data source for predicting where future mining locations would be.

Where do locations of current CEs overlap with areas of potential future locations of non-renewable energy development? (MQ 52)

As mentioned in the previous management question, oil and gas wasn’t evaluated for the ecoregion. The main source of oil and gas infrastructure would be the Ruby pipeline running from Oregon across Nevada and through Utah into Wyoming. The only spatial data that was available was for the Ruby pipeline was for Nevada with the other sections being a data gap. No map was created since only a partial dataset was available.

Where are the current locations of renewable energy development (solar, wind, geothermal, transmission)? (MQ 53)

Figure 5-14 shows the current locations of operating renewable energy facilities within the ecoregion. The most common type of renewable energy was wind. There are currently 25 wind facilities mostly in Idaho with one facility currently in Oregon. There is currently one active solar plant (Outback Solar) in Lake County in Oregon. There are currently four operating geothermal energy plants in the ecoregion in California, Nevada and Idaho. The source for the location and facility status was www.rnp.org. This website covers Oregon and Idaho where most of the renewable energy facilities are. Other websites were reviewed to determine renewable status in California, Nevada and Utah such as the University of Nevada at Reno's geothermal site dataset.

Where are the areas identified by the National Renewable Energy Laboratory (NREL) as potential locations for renewable energy development? (MQ 54)

Figures 5-15 through 5-18 show the results of NREL's potential locations for renewal energy for geothermal (Figure 5-15), Solar (Figures 5-16 and 5-17) and wind (Figure 5-18). Since transmission of energy from these potentially remote sites to where it will be used is an important issue, the available transmission lines were also added to the figures.

Where are the areas of low renewable and non-renewable energy development that could potentially mitigate impacts to CEs from potential energy development? (MQ 55)

Mule Deer

Based on the cumulative indicator score in the mule deer CE package, the lowest scoring area for mule deer was the Snake River Plain corridor. One area that is currently has no renewable energy development is from Steens Mountain across towards the Owyhee Mountain and into Nevada (between the Santa Rosa Range and Bull Run Range). There is currently only one transmission line that heads up near the Steens Mountain but there are some planned and proposed wind energy facilities on the Steens Mountain ridge since it is modeled as a high wind potential area. The area between Steens and the Owyhee's contains wilderness study areas, wild and scenic rivers and wilderness areas that would give additional protection from development.

Bighorn Sheep

Based on the cumulative indicator score in the bighorn sheep CE package, the Black Rock Range, Mays Canyon Range and Sheldon National Wildlife Refuge all appear to be high scoring areas but in areas with low suitability for wind energy facilities. These areas are in potential solar and geothermal suitable areas but since bighorn sheep is a higher elevation species, wind energy would probably be more of an impact. The Black Rock Range does contain several wilderness areas that would make creating new transmission lines difficult where they don't current exist.

Pronghorn

Based on the cumulative indicator score in the pronghorn CE package, similar to mule deer the Steens Mountain across towards the Owyhee Mountain and into Nevada (between the Santa Rosa Range and Bull Run Range) appears to be high scoring area for pronghorn that has low wind and solar potential. The area between Steens and the Owyhee's contains wilderness study areas, wild and scenic rivers and wilderness areas that would give additional protection from development.

Golden Eagle

Based on the cumulative indicator score in the golden eagle CE package, the Black Rock Range, Mays Canyon Range and Sheldon National Wildlife Refuge all appear to be high scoring areas but in areas with low suitability for wind energy facilities. The area to the south of the Owyhee Mountains also appears to be a suitable location with little wind resources potential and high levels of protection from wilderness areas and wild and scenic rivers. Some of these areas are in potential solar and geothermal suitable areas but wind turbines would be the greater impact to golden eagle. The Black Rock Range and Owyhee areas do contain several wilderness areas that would make creating new transmission lines difficult where they don't current exist.

Bald Eagle

Based on the cumulative indicator score in the bald eagle CE package, three areas stand out as with a low wind potential would be northeast of Idaho Falls near the Montana border, near Eagle Lake in California and by the Long Valley on the Nevada and California border.

Greater sage-grouse

Based on the cumulative indicator score in the greater sage-grouse CE package, the area between the Sheldon National Wildlife Refuge and the Black Rock Range were high scoring PPH areas with low renewable wind potential. In Oregon, the area within the Hart Mountain National Wildlife Refuge and to the north all had high scoring PPH with limited wind potential. The Poker Jim Ridge of Hart Mountain had the highest wind potential but development of wind energy facility and transmission line tie in would be difficult on a USFWS land.

Pygmy rabbit

Based on the cumulative indicator score in the pygmy rabbit CE package, the area between the Sheldon National Wildlife Refuge and the Black Rock Range were high scoring PPH areas with low renewable wind potential but some geothermal potential. In Oregon, the area within the Hart Mountain National Wildlife Refuge and to the north all had high scoring areas with limited renewable potential.

Where do current locations of CEs overlap with areas of potential future locations of renewable energy development? (MQ 56)

Mule Deer

Based on the mule deer distribution in the CE package, the summer WAFWA range includes the Steens Mountains which has an approved and a proposed wind energy site. Using the WAFWA boundaries, most of the ecoregion is suitable habitat for mule deer whether it be year round, summer or winter. Most new wind, solar or geothermal facilities will probably overlap with mule deer WAFWA range.

Bighorn Sheep

The main conflict for bighorn sheep's WAFWA range and potential renewable energy is the Steens Mountain range. This range has several approved and proposed wind energy facilities.

Pronghorn

Based on the pronghorn distribution within the CE package, some of the proposed wind energy sites are out of its primary range such as Steens Mountain but many are within its range. The wind parks and solar facility around Mountain Home as well as proposed sites near China Mountain and Gollaher Mountain are within the pronghorn range.

Golden Eagle

Figure 6-6 within the golden eagle CE package identifies the occurrence and proximity of wind turbines in relation to golden eagle habitat. Most of the wind turbine locations exist in close proximity to the population and transportation corridors in Idaho. In Oregon the area to the southwest of the Ochoco National Forest and the Malheur National Forest and the vicinity of Goose Lake and Summer Lake (South Central Oregon) are considered to be of lower quality. In Nevada the eastern edge of Humboldt National Forest and in Utah the western edge of the Bonneville Salt Flats are impacted by wind turbine activity. China Mountain along the Idaho and Nevada border was recently surveyed for golden eagle nests and is in the permitting process for wind energy development.

Bald Eagle

Renewable energy was not analyzed as a CA for the bald eagle. Although the golden eagle risks significant mortality from wind turbines, the bald eagle occupies habitat that is not closely associated with this renewable energy source.

Greater sage-grouse

Based on the greater sage-grouse PPH in the CE package, the main threat is the proposed development near China Mountain on the Nevada – Idaho border. This development is in the permitting process but along with the Cottonwood Wind Park which is currently in the planning stage. The China Mountain permit decision was postponed until BLM could finish an EIS on greater sage-grouse. There are also currently meteorological towers on Gollaher Mountain to the south east of China Mountain within greater sage-grouse PPH as well.

Pygmy rabbit

Based on the modeled suitable habitat in the pygmy rabbit CE package, the main intersection between pygmy rabbit and future locations of renewable energy would be the area south of Twin Falls near the Nevada border. There are several wind energy proposed sites in that area either proposed or permitted.

Where will locations of renewable energy [development] potentially exist by 2025? (MQ 57)

It was determined that renewable energy locations in permitting, approved or under construction currently would be online by 2025. There is a lot of uncertainty in that determination as there are many factors that would prevent approval and construction of facilities such as environmental approval, zoning changes, financial feasibility, agreement with energy purveyors, etc. Figure 5-19 shows locations of renewable energy facilities (solar and geothermal) that are in development or permitting process and Figure 5-20 show wind renewable energy facilities. The source of this data was rnp.org for solar and geothermal so the only information that was available was for Oregon and Idaho. The proposed projects may not be accurate as the data source for this information (rnp.org) website may be updated infrequently. Currently Idaho has no geothermal plants proposed or in permitting. These locations were left on Figure 5-19 since there were plans at one point to develop geothermal at these locations so there is a chance this might resurrect at some point by 2025. The proposed wind energy locations were a combination of rnp.org data for Idaho and Oregon and proposed wind turbine and meteorological tower locations within the ecoregion collected from the FAA.

5.4 Atmospheric Deposition

Where are areas affected by atmospheric deposition of pollutants, as represented specifically by nitrogen deposition, acid deposition, and mercury deposition? (MQ 70)

The National Atmospheric Deposition Program was the main data source for the maps created to answer this management question. There were five NADP sites within (or close) to the ecoregion with Logan, UT and Teton National Park sites just outside. Figure 5-21 shows the result of the mercury wet deposition for 2011 within the ecoregion. Figure 5-22 shows the total Nitrogen deposition or Inorganic Wet Deposition from Nitrate and Ammonium for 2011 within the ecoregion. Figure 5-23 shows the acid or Sulfur + Nitrogen wet deposition for 2011 within the ecoregion. Wind direction was collected from the Western Regional Climate Center and was obtained from airports near the ecoregion. The annual wind is displayed by the jet symbol pointing in the direction of prevailing annual wind.

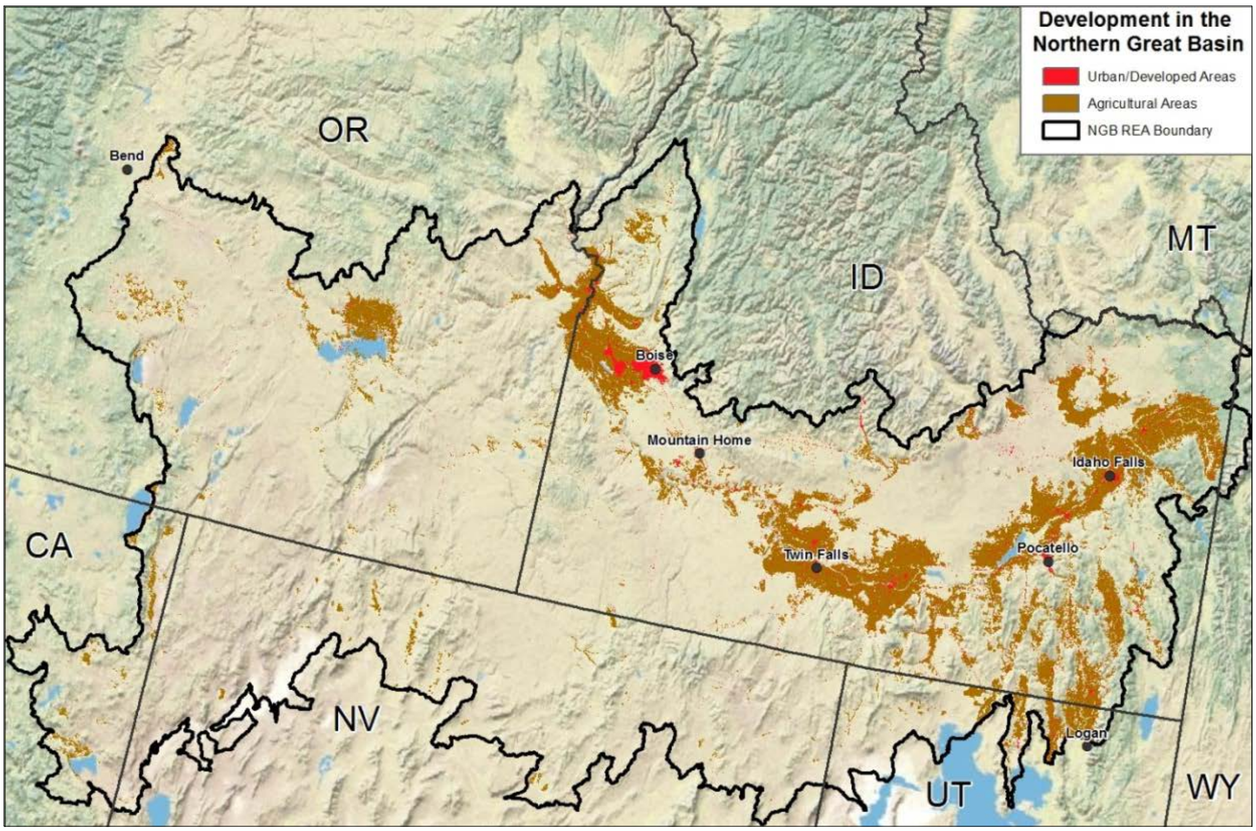

Figure 5-1. Agricultural and Urban / Developed Areas within the Northern Great Basin

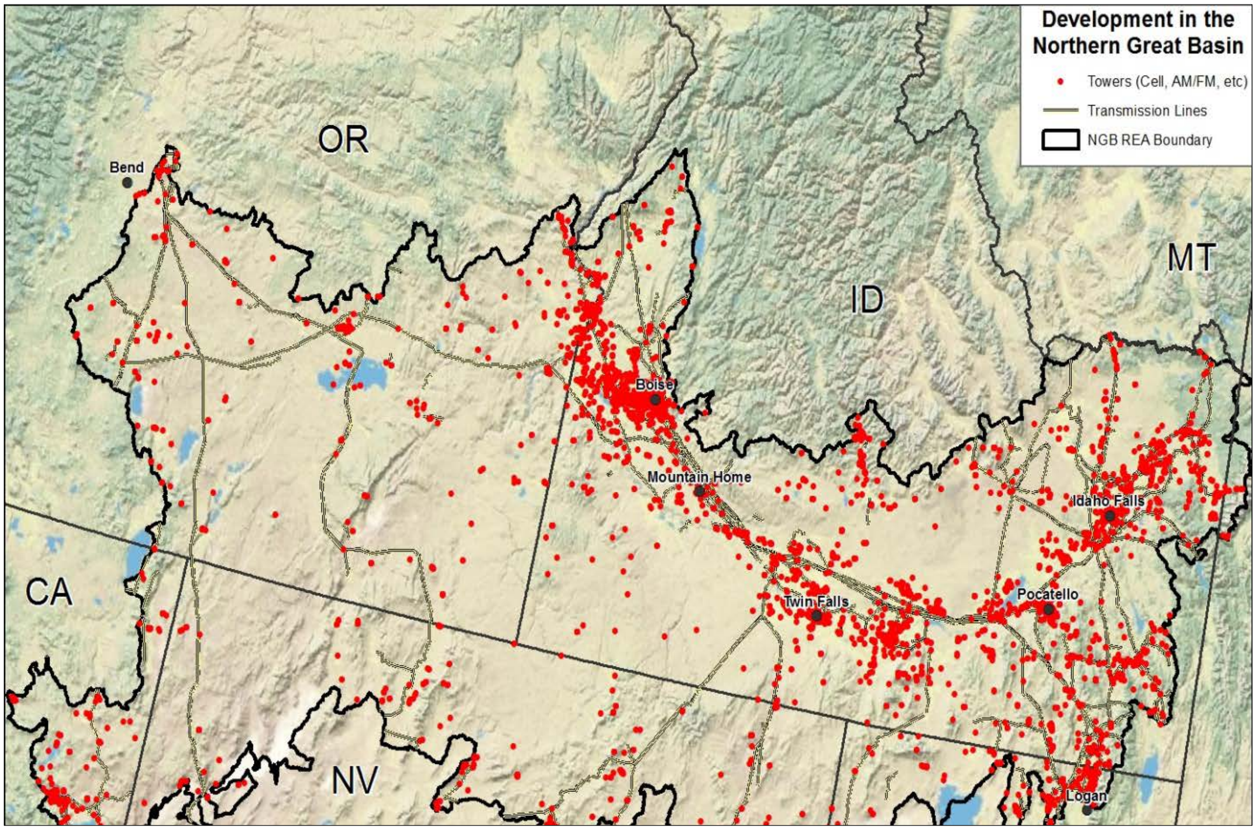

Figure 5-2. Towers and Transmission Lines within the Northern Great Basin

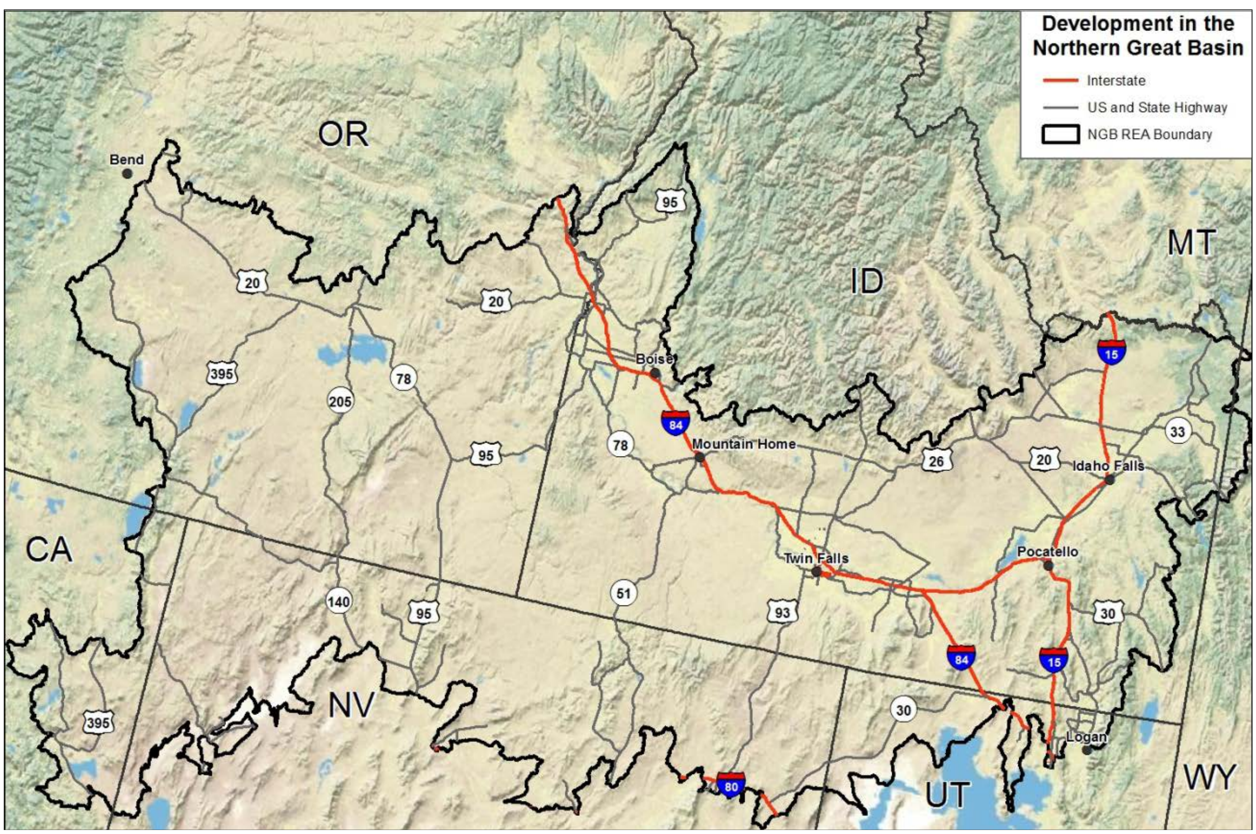

Figure 5-3. Major Highways and Interstates within the Northern Great Basin

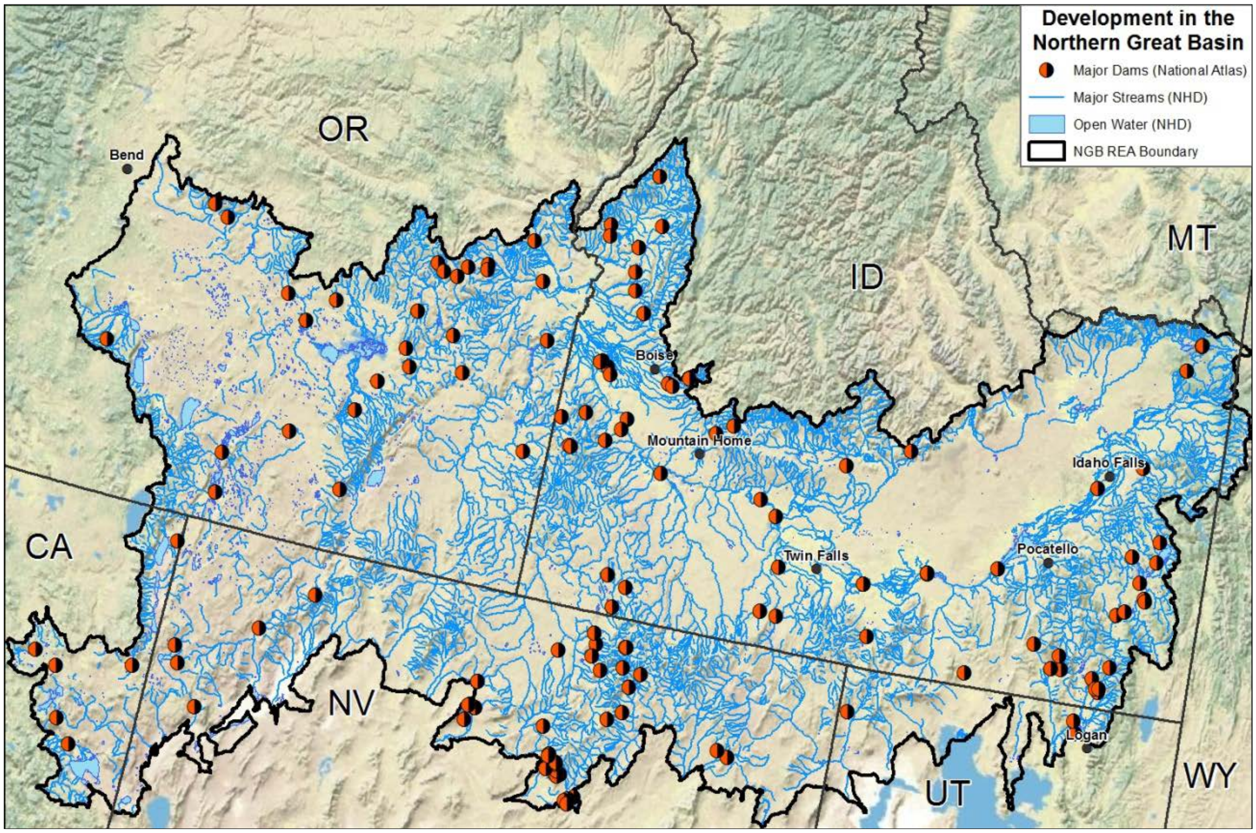

Figure 5-4. Major Dams, Streams and Water bodies within the North Great Basin

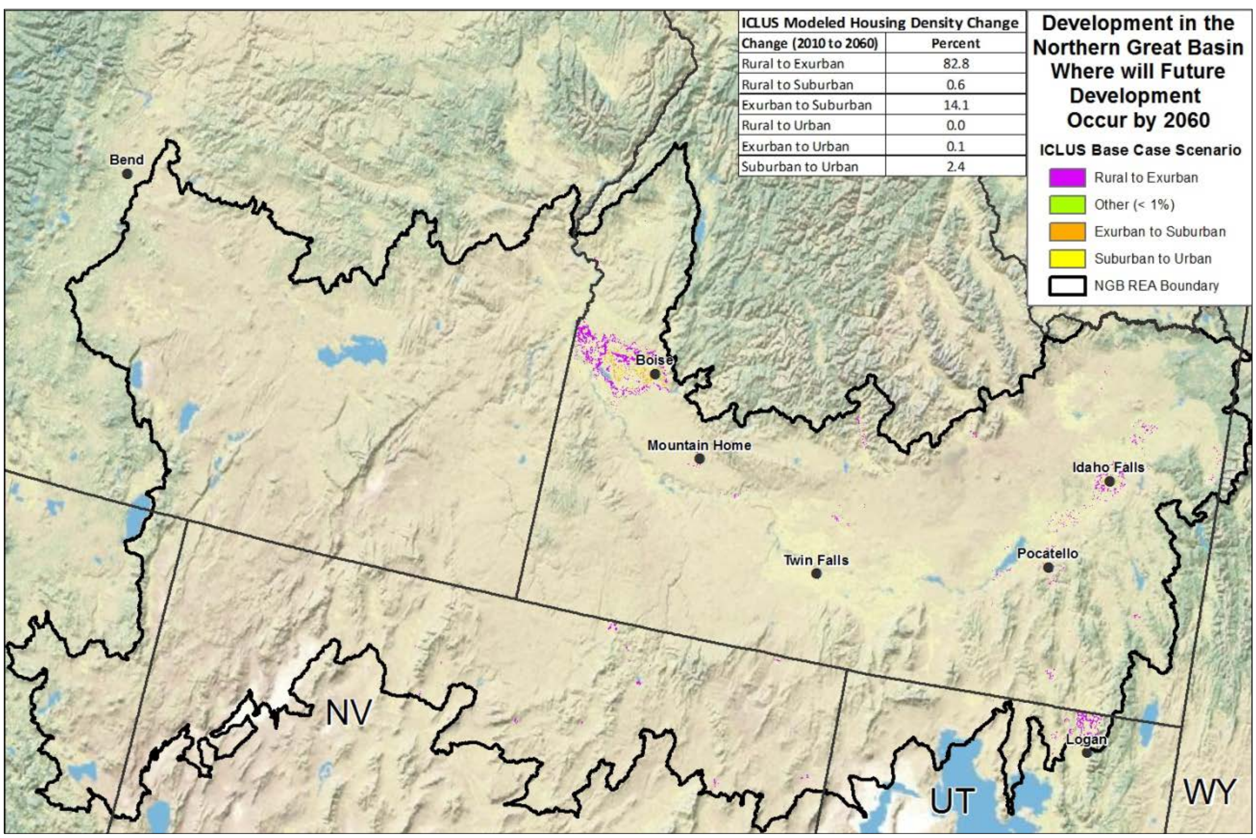

Figure 5-5. Predicted Urban Growth within the Northern Great Basin by 2060

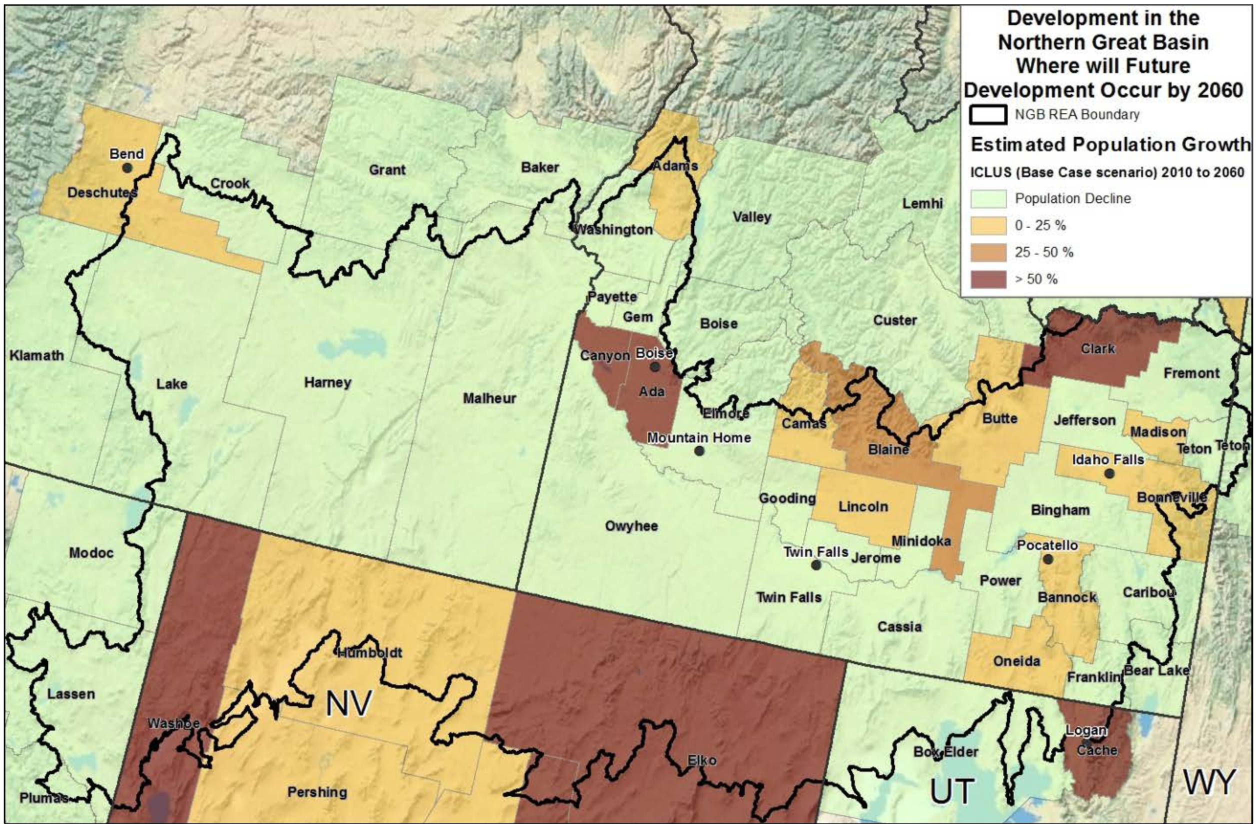

Figure 5-6. Predicted Population Growth by 2060 within the Northern Great Basin

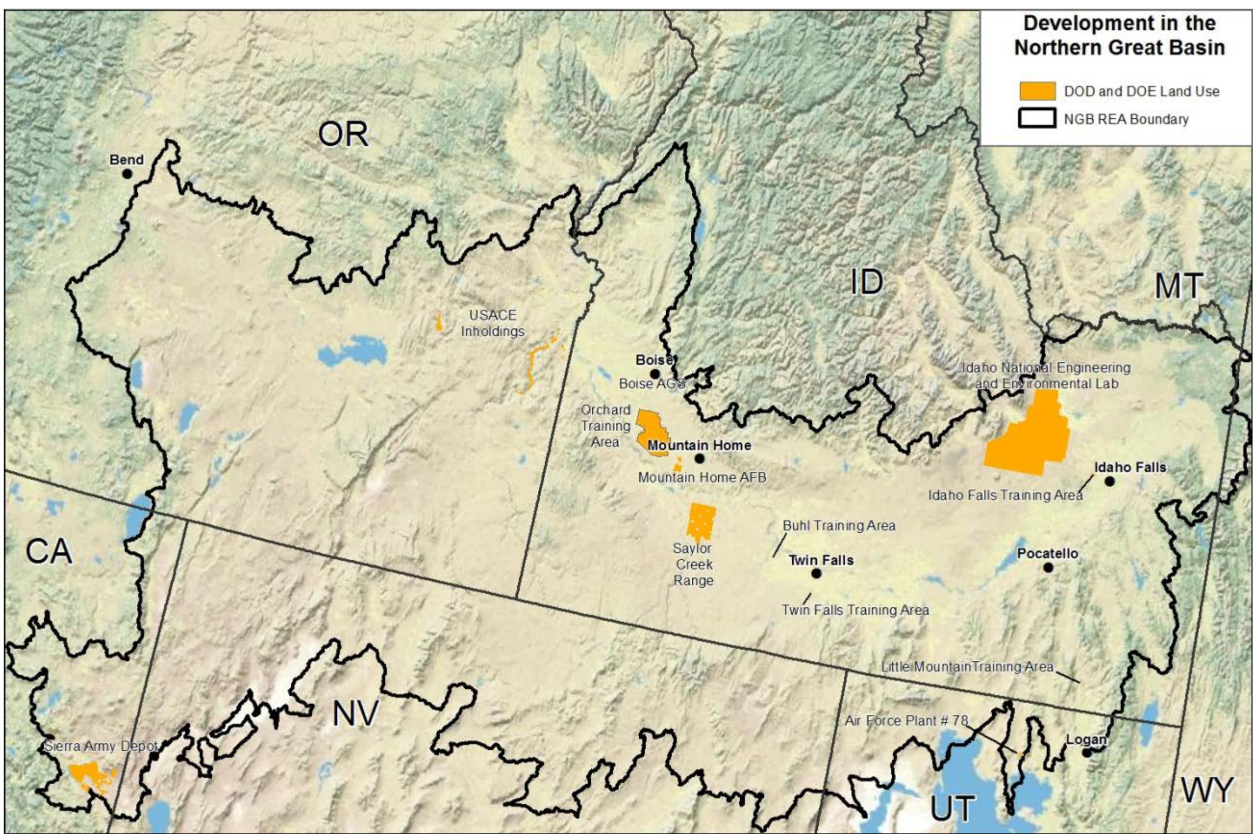

Figure 5-7. DOD and DOE Land Use within the Northern Great Basin

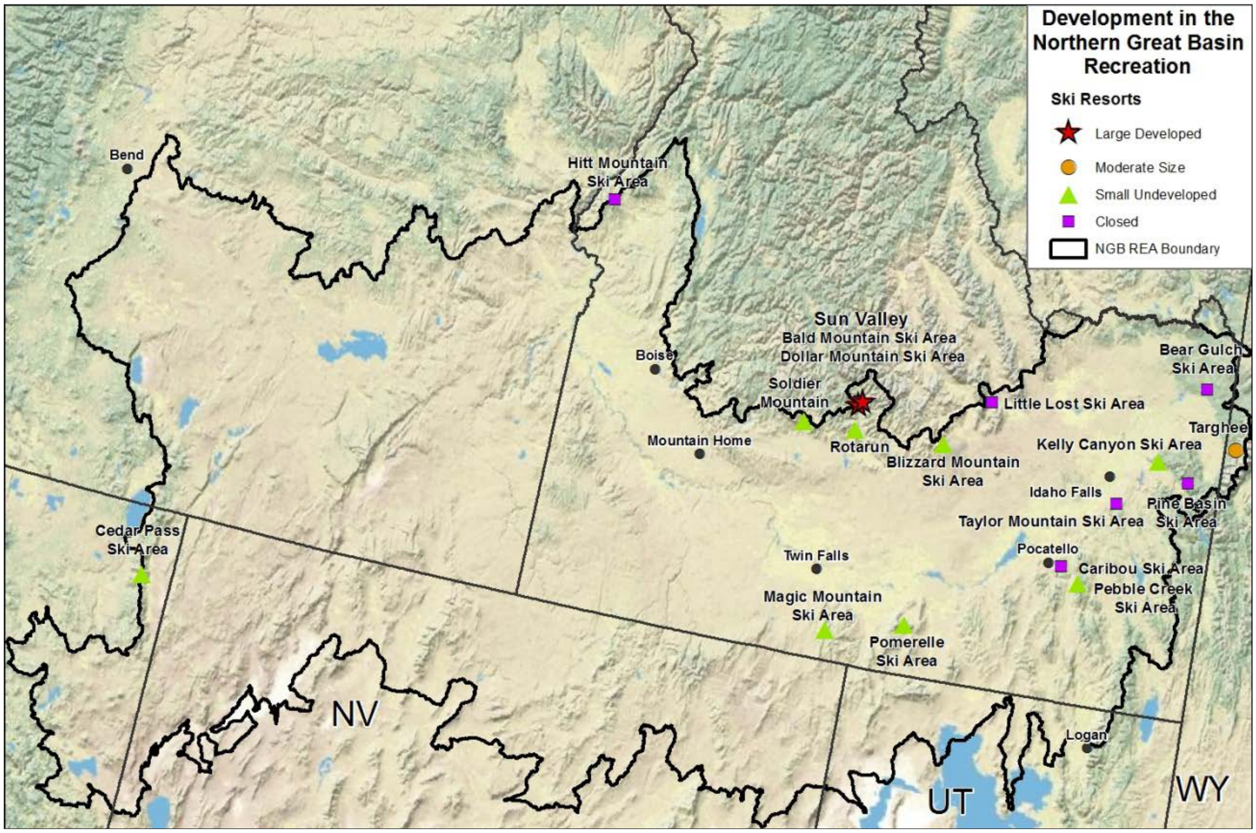

Figure 5-8. Ski Areas in the Northern Great Basin

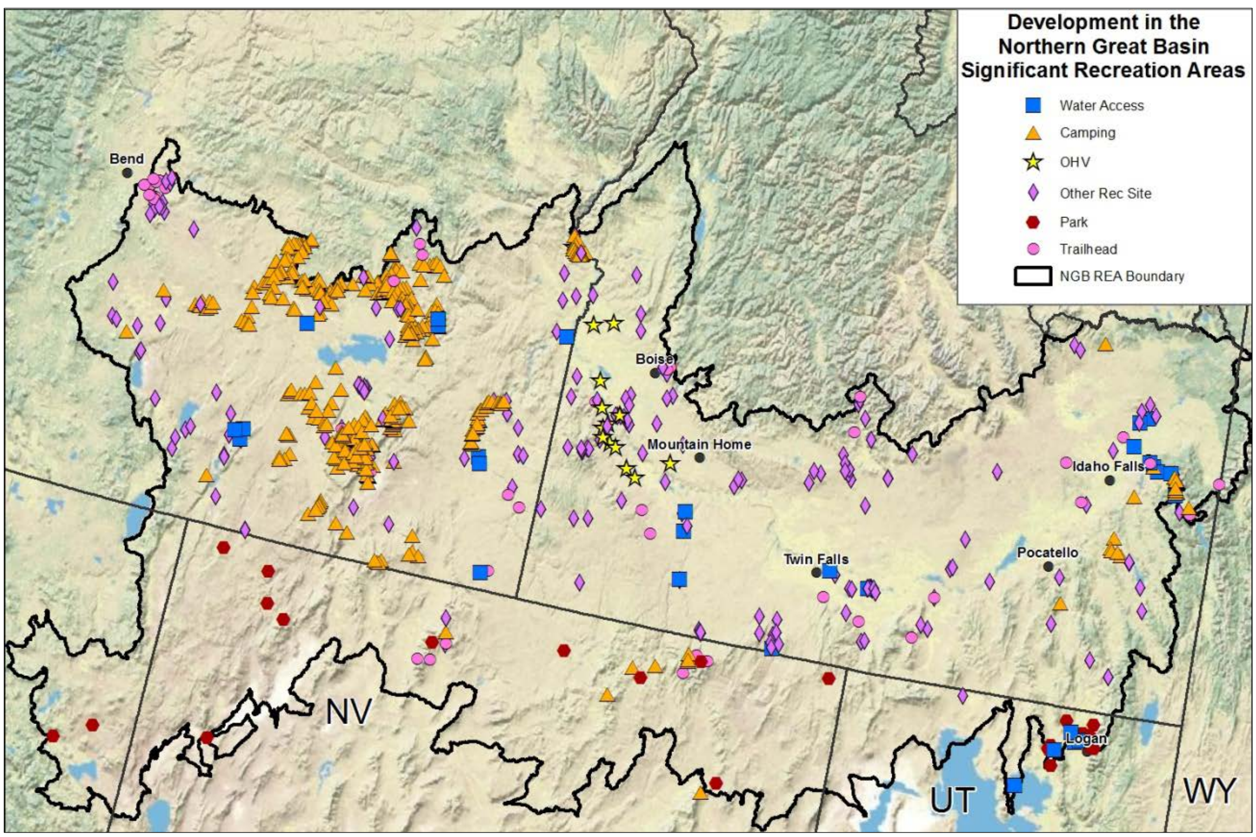

Figure 5-9. Recreation Areas within the Northern Great Basin

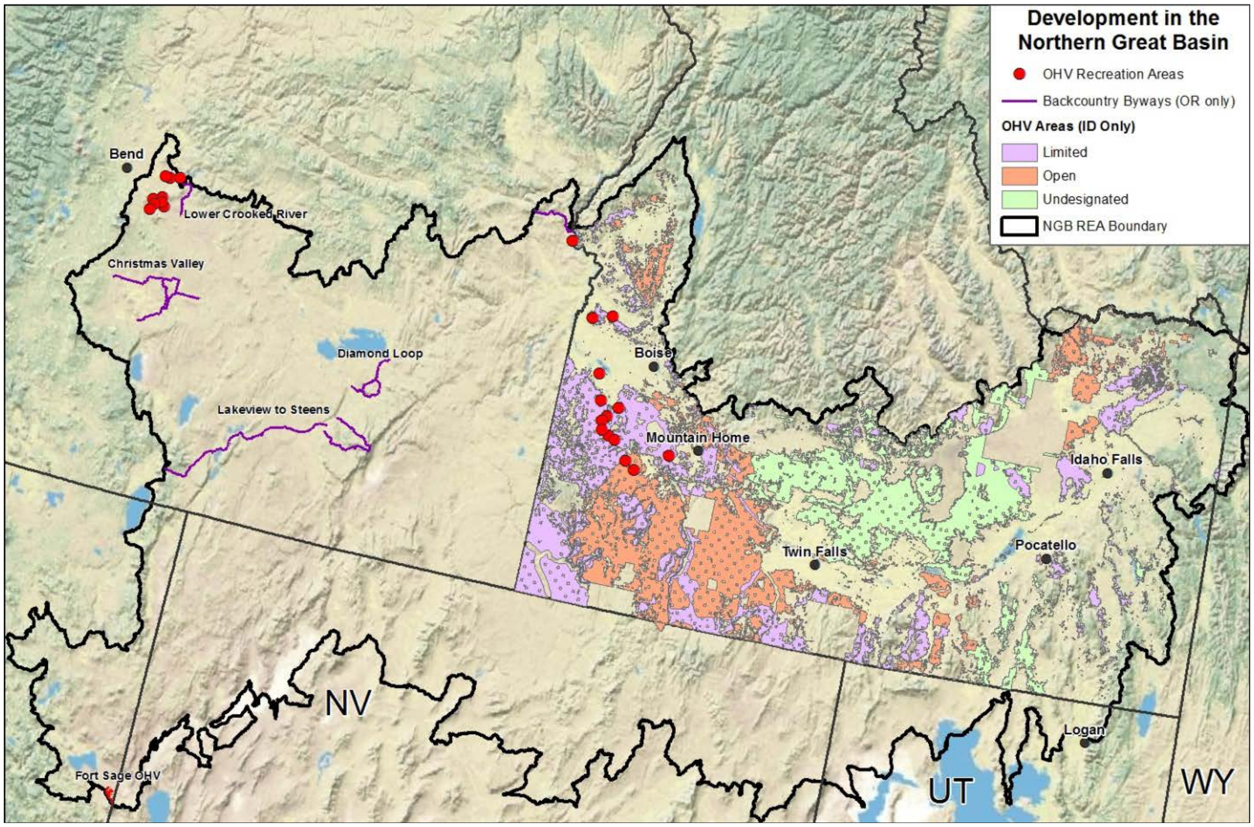

Figure 5-10. OHV Areas within the Northern Great Basin

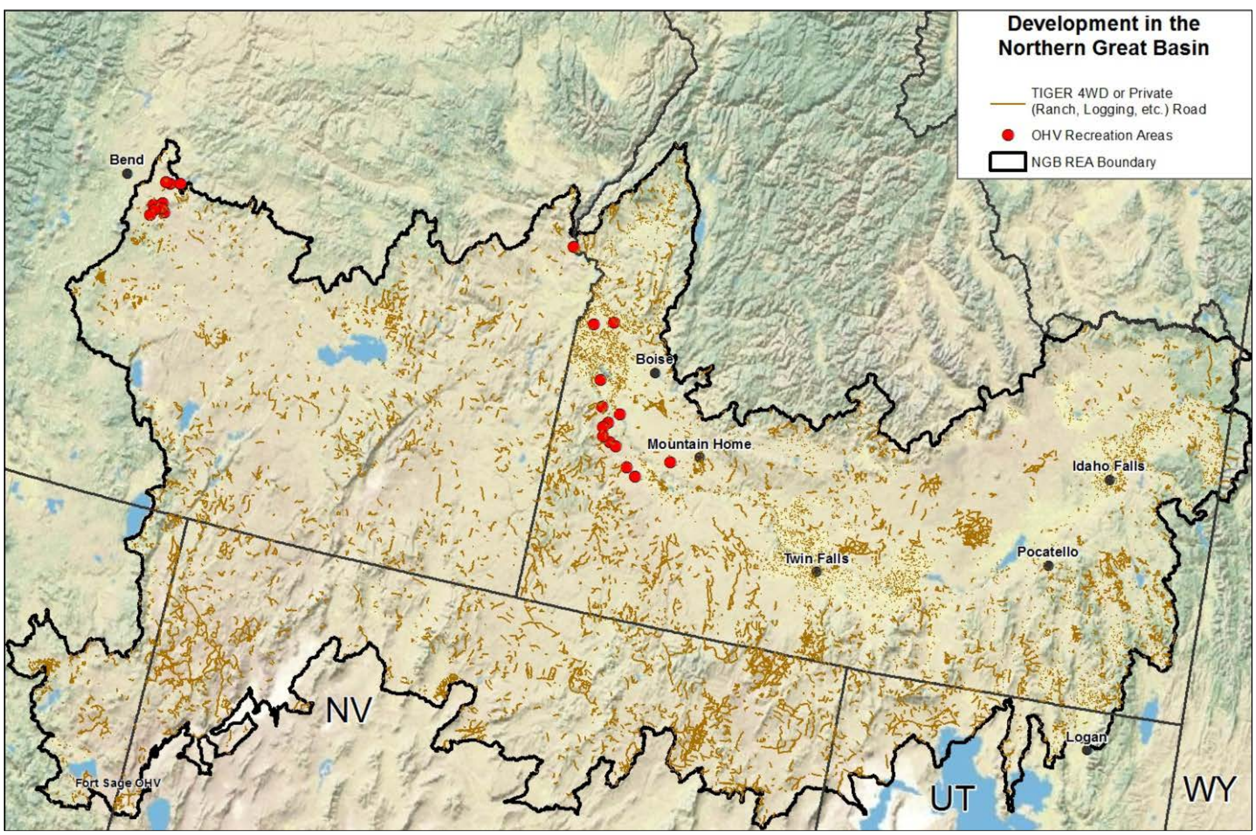

Figure 5-11. TIGER 4WD and Private (Ranches, Logging, etc.) Roads within the Northern Great Basin

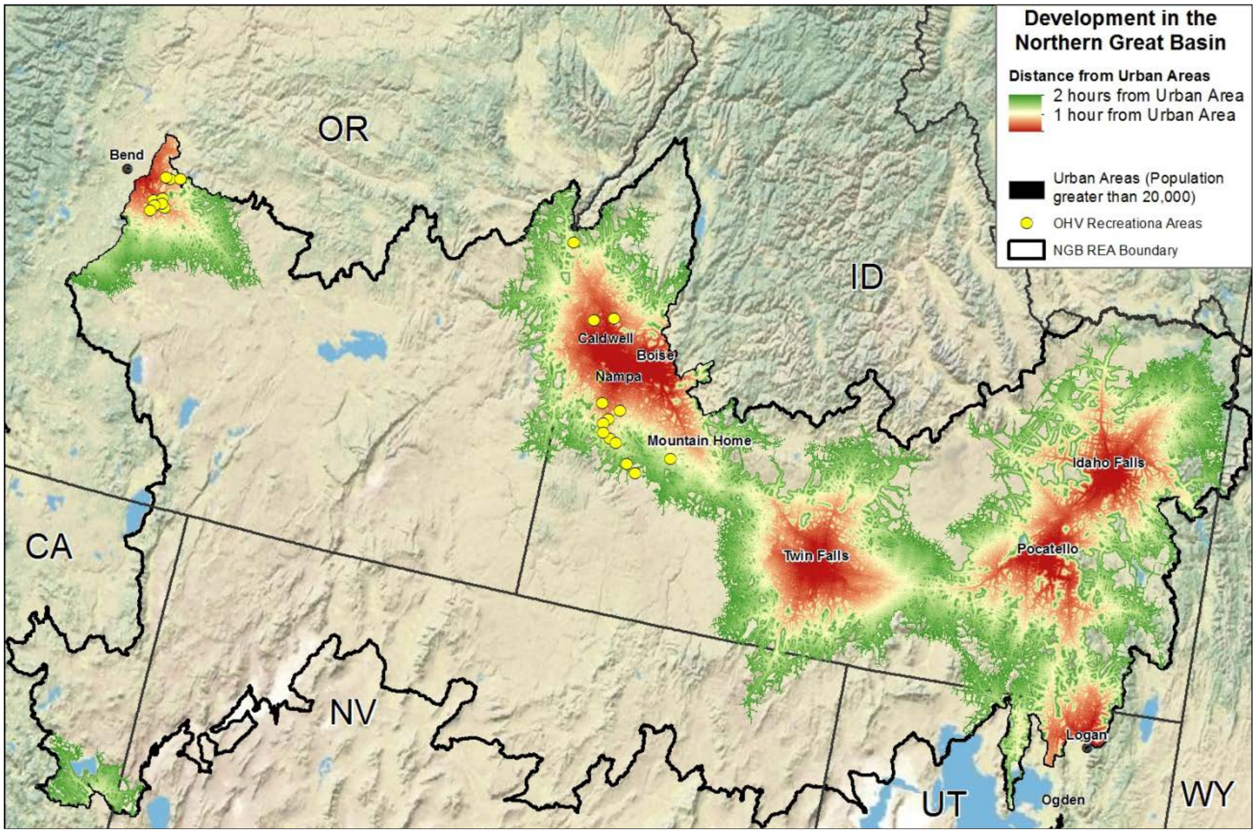

Figure 5-12. Areas within 2 Hours of Urban Areas

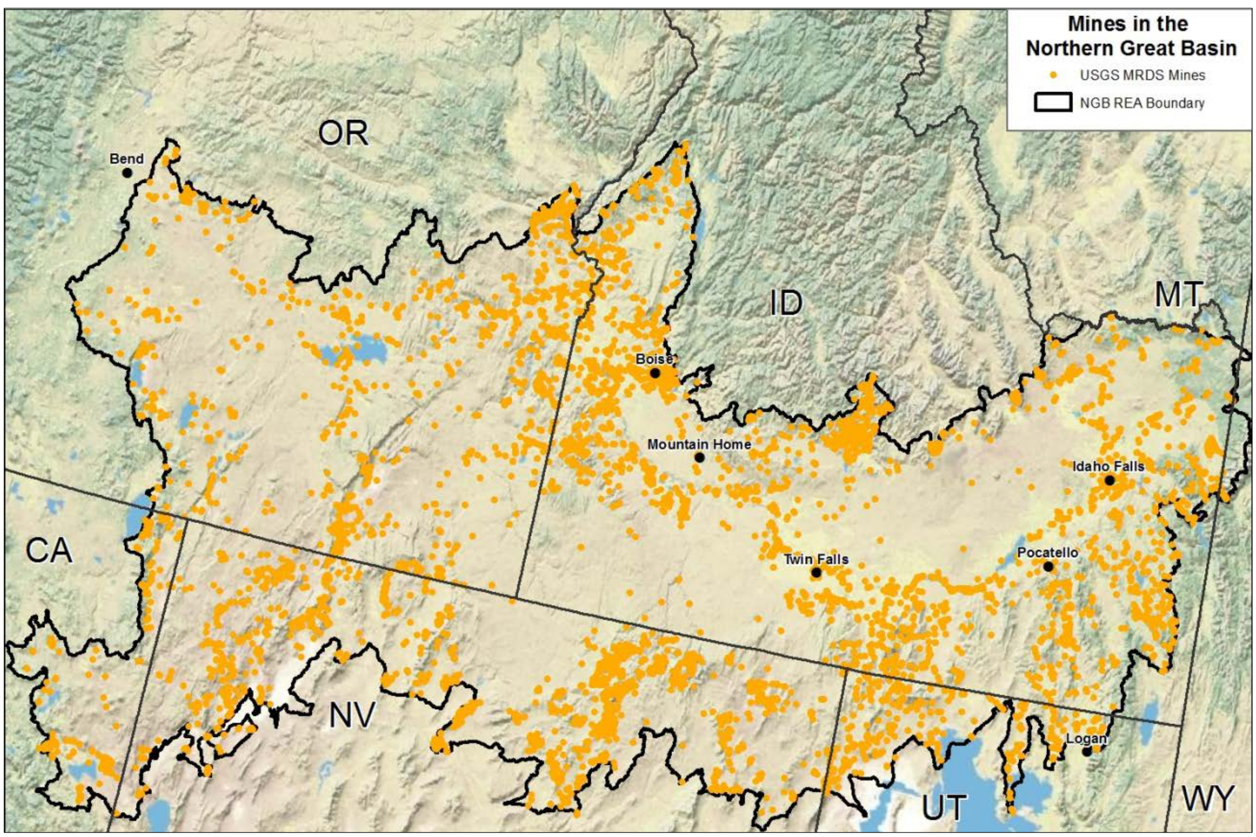

Figure 5-13. MRDS Mines in the Northern Great Basin

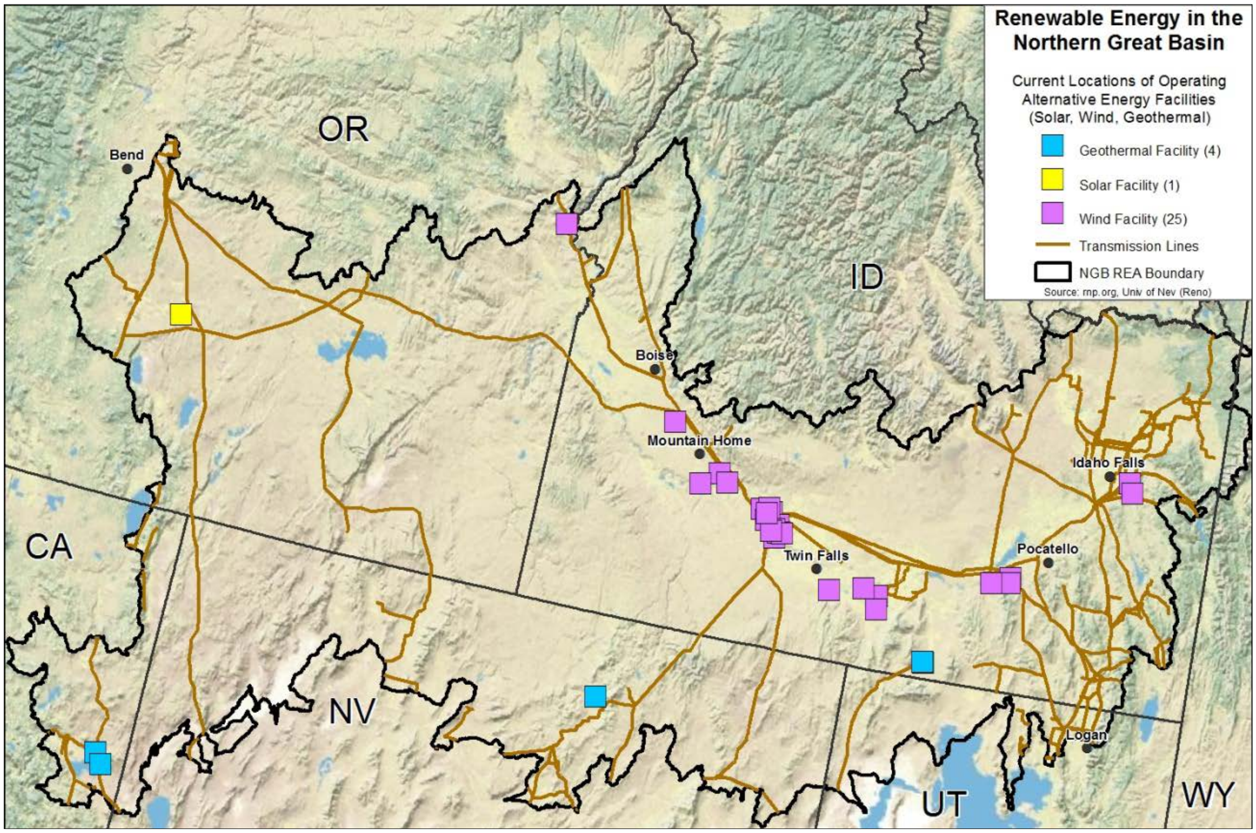

Figure 5-14. Renewable Energy Locations in the Northern Great Basin

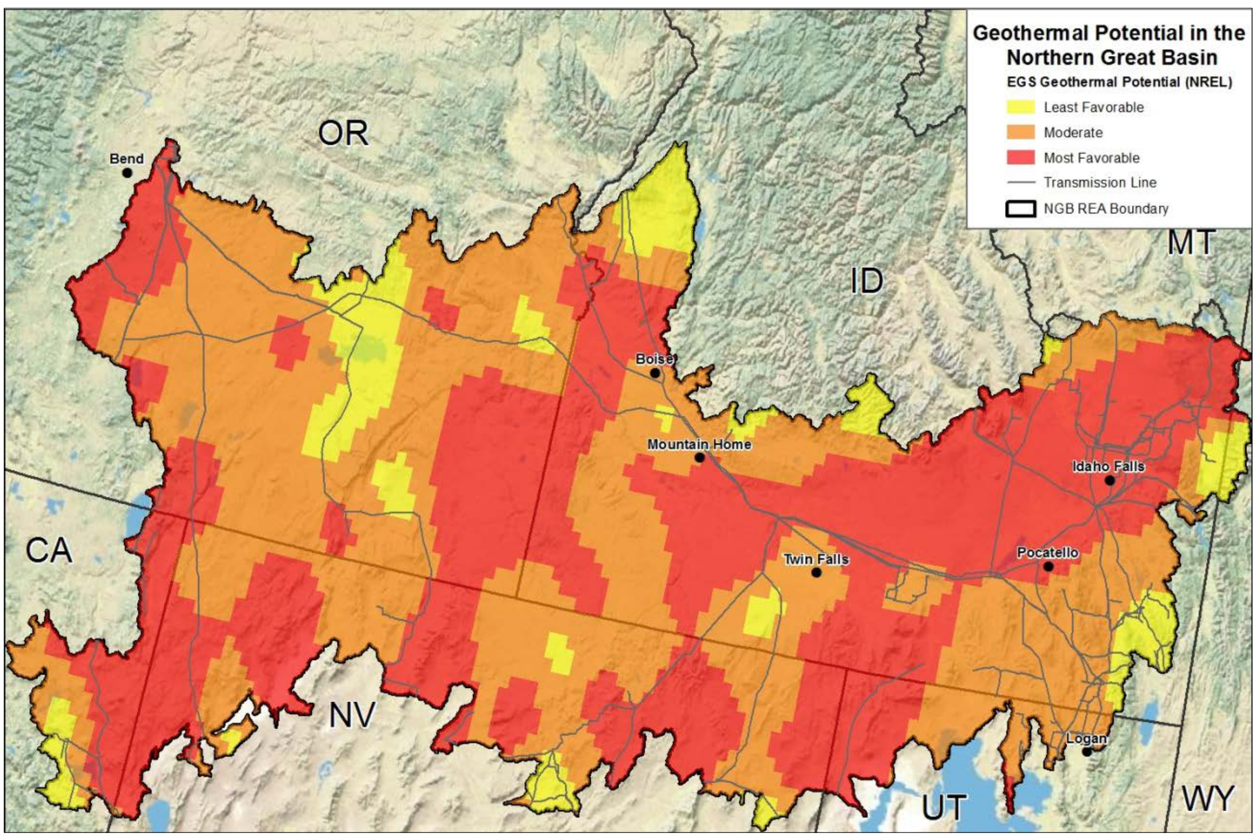

Figure 5-15. NREL Geothermal Potential in the Northern Great Basin

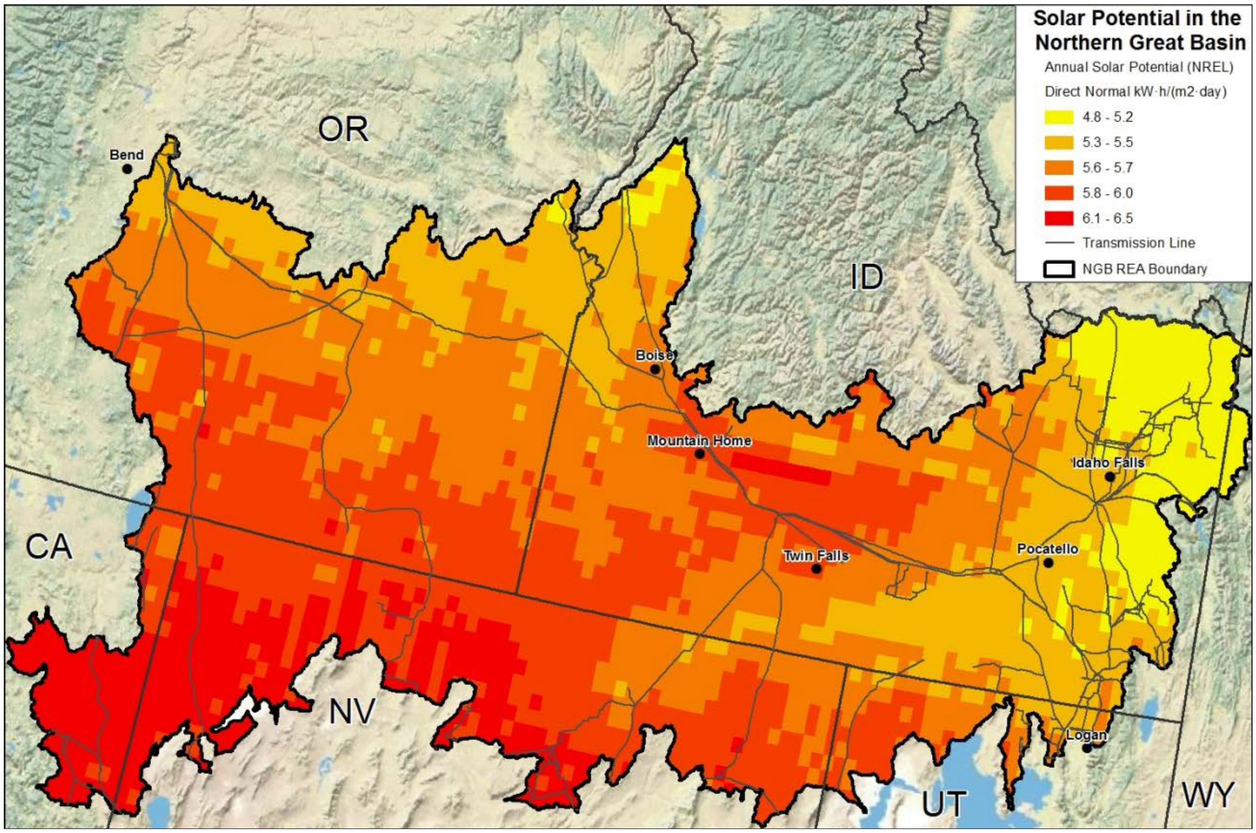

Figure 5-16. NREL Direct Solar Potential in the Northern Great Basin

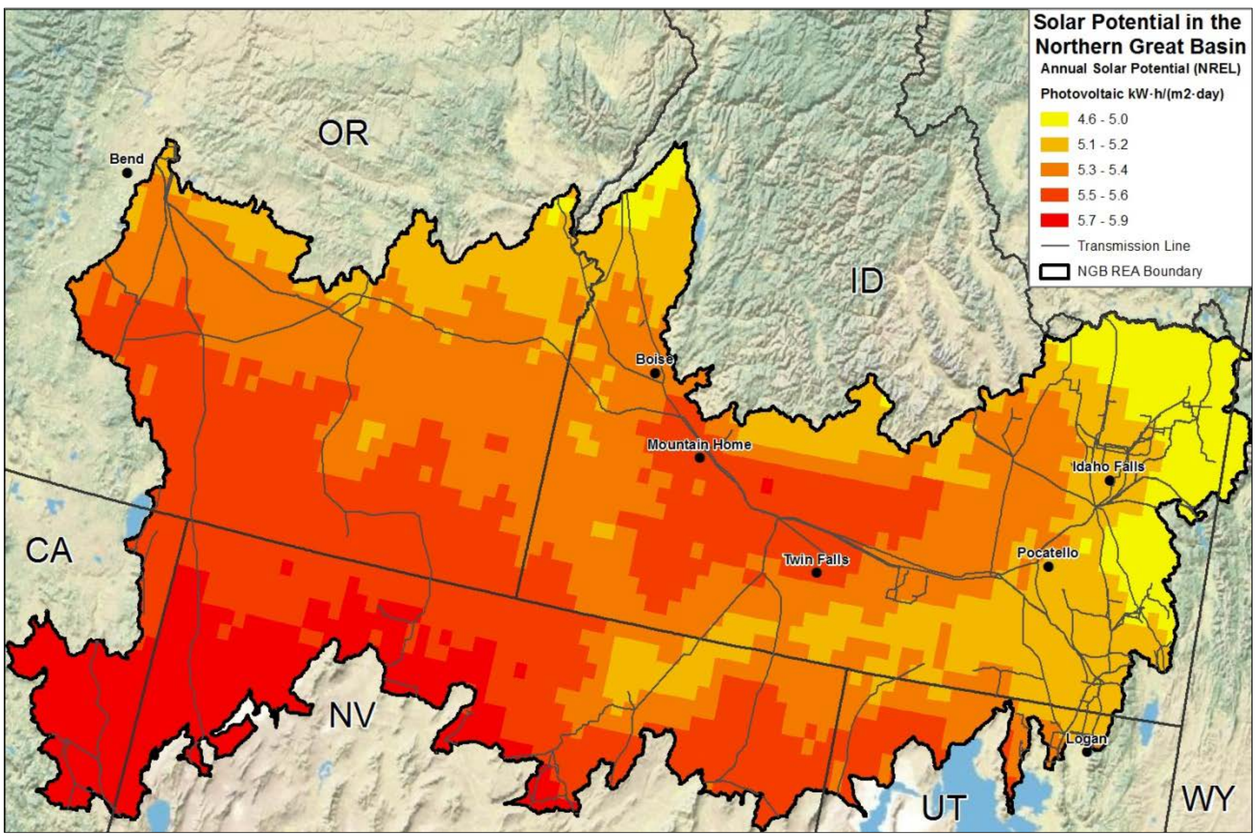

Figure 5-17. NREL Photovoltaic Solar Potential in the Northern Great Basin

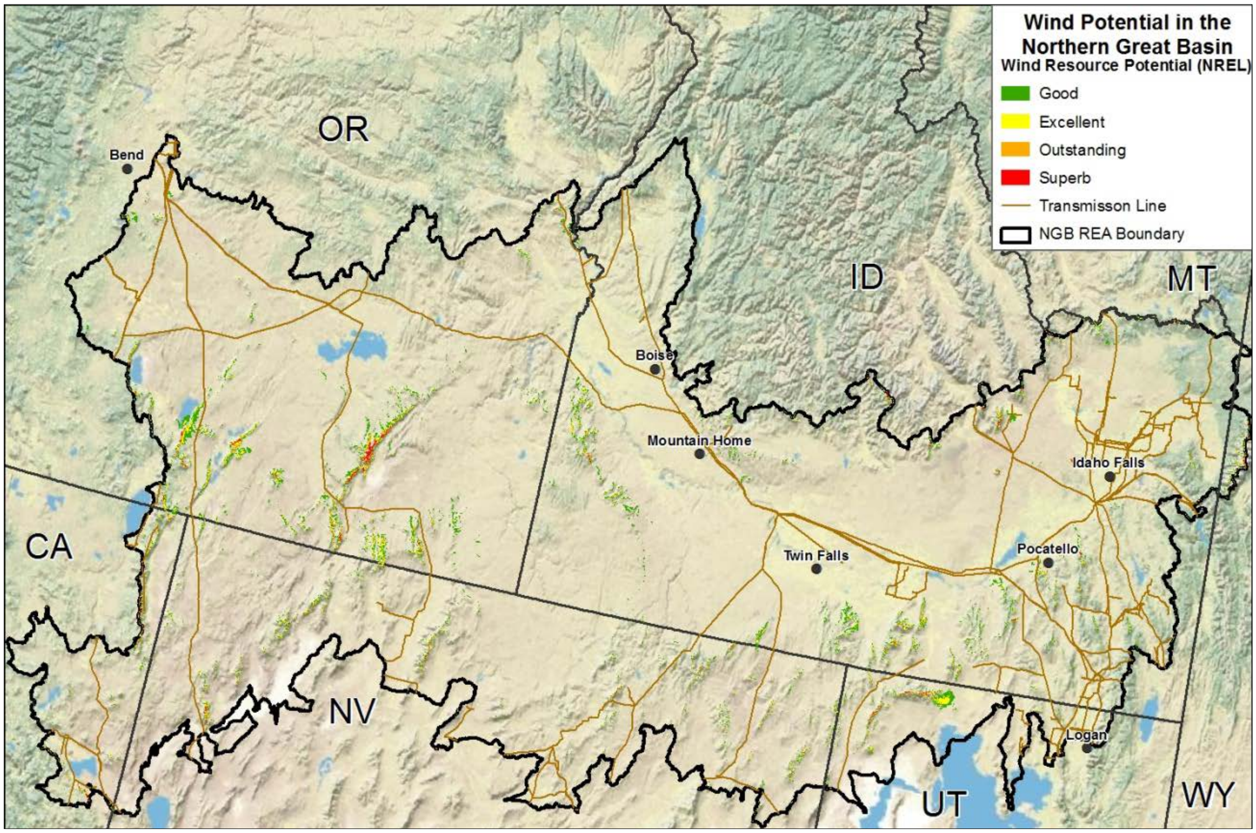

Figure 5-18. NREL Wind Potential (50m) in the Northern Great Basin

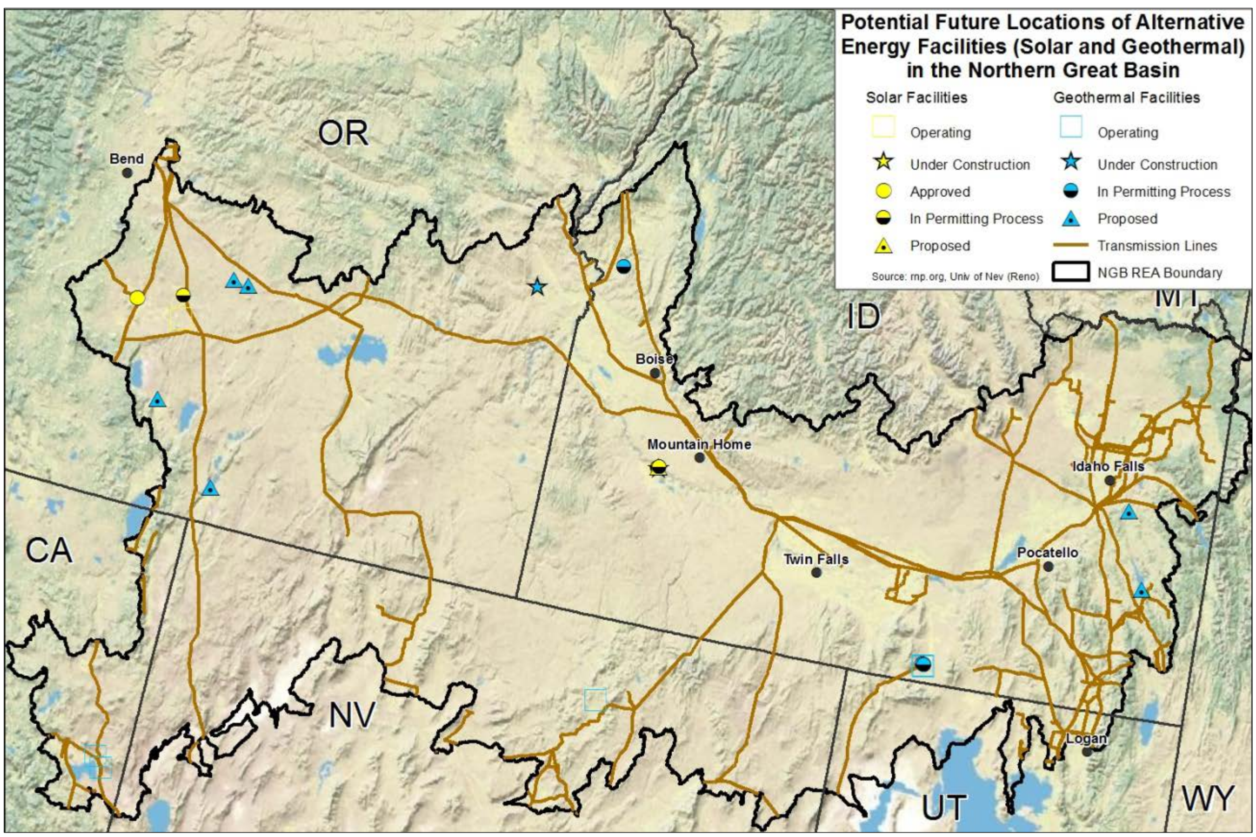

Figure 5-19. Alternative Energy Facilities Operating by 2025 in the Northern Great Basin

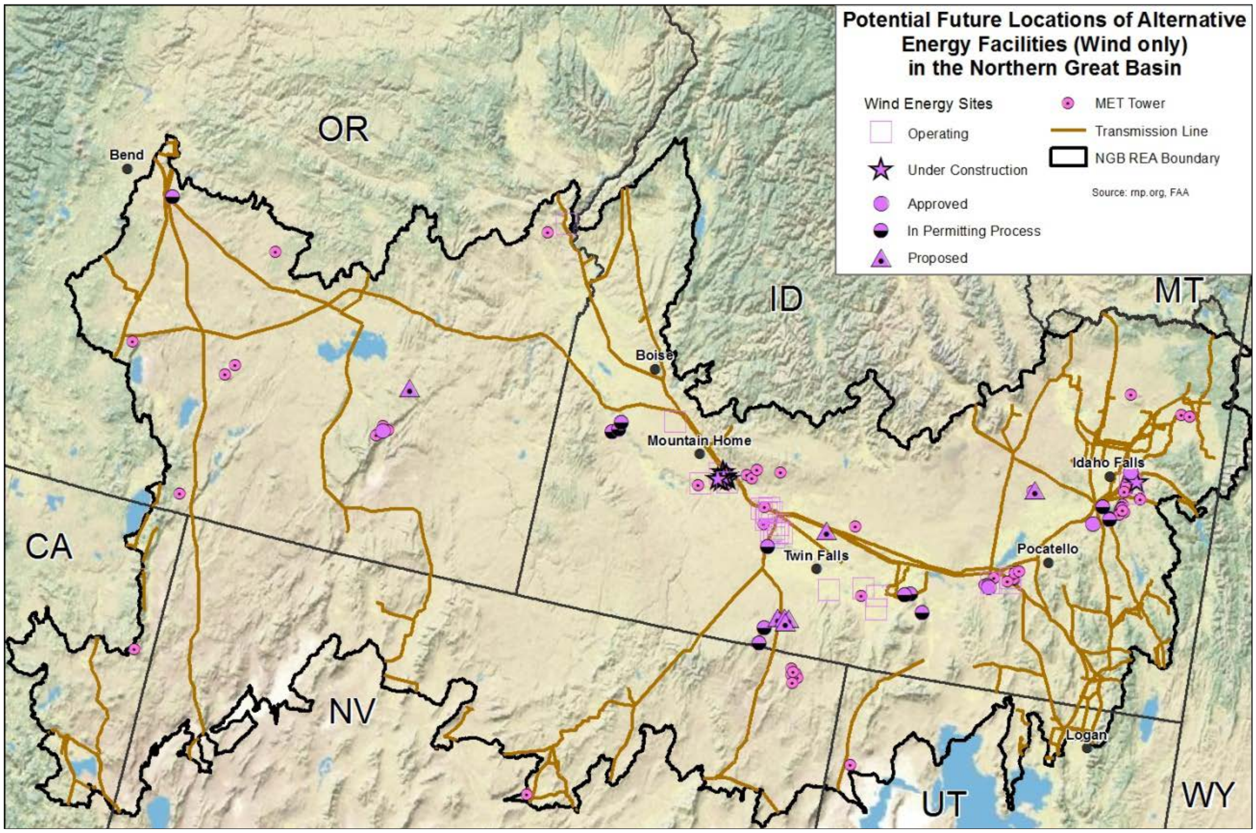

Figure 5-20. Wind Energy Facilities Operating by 2025 in the Northern Great Basin

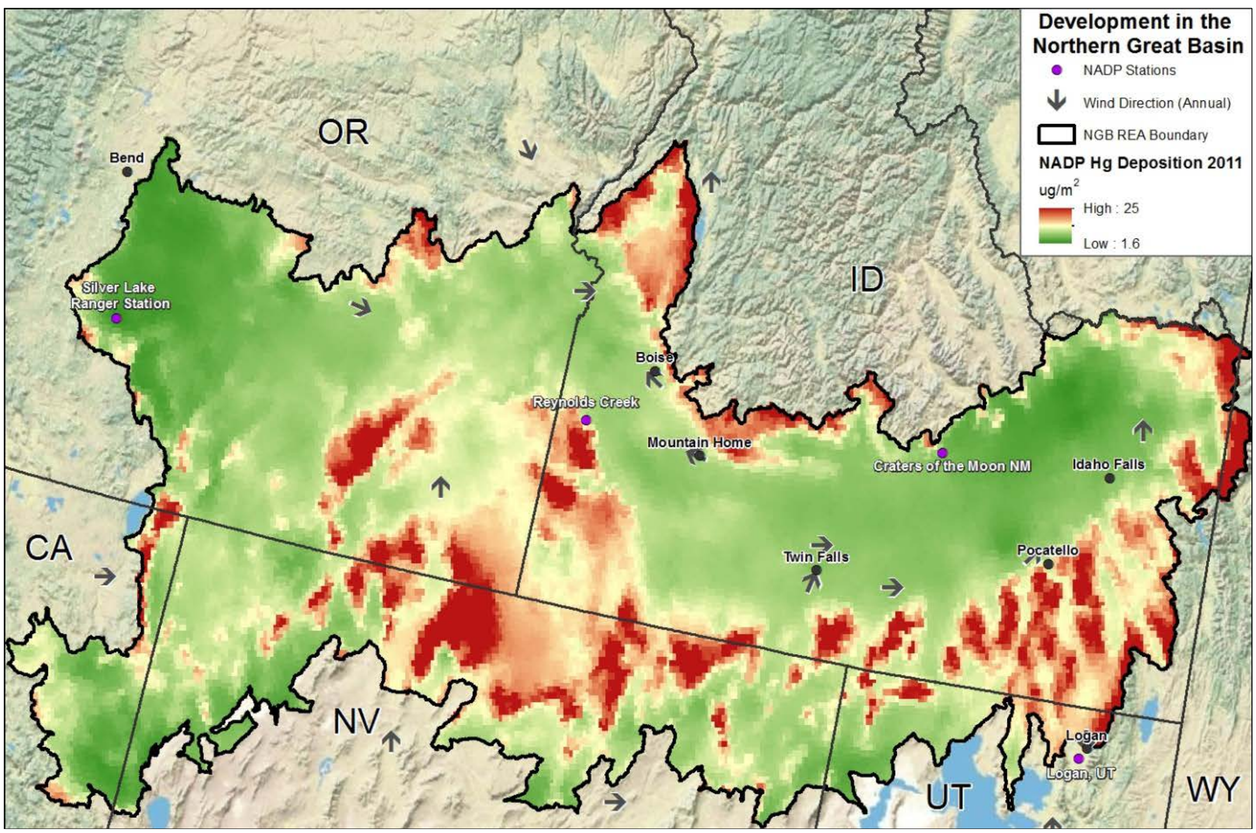

Figure 5-21. Total Mercury Wet Deposition (2011) in the Northern Great Basin

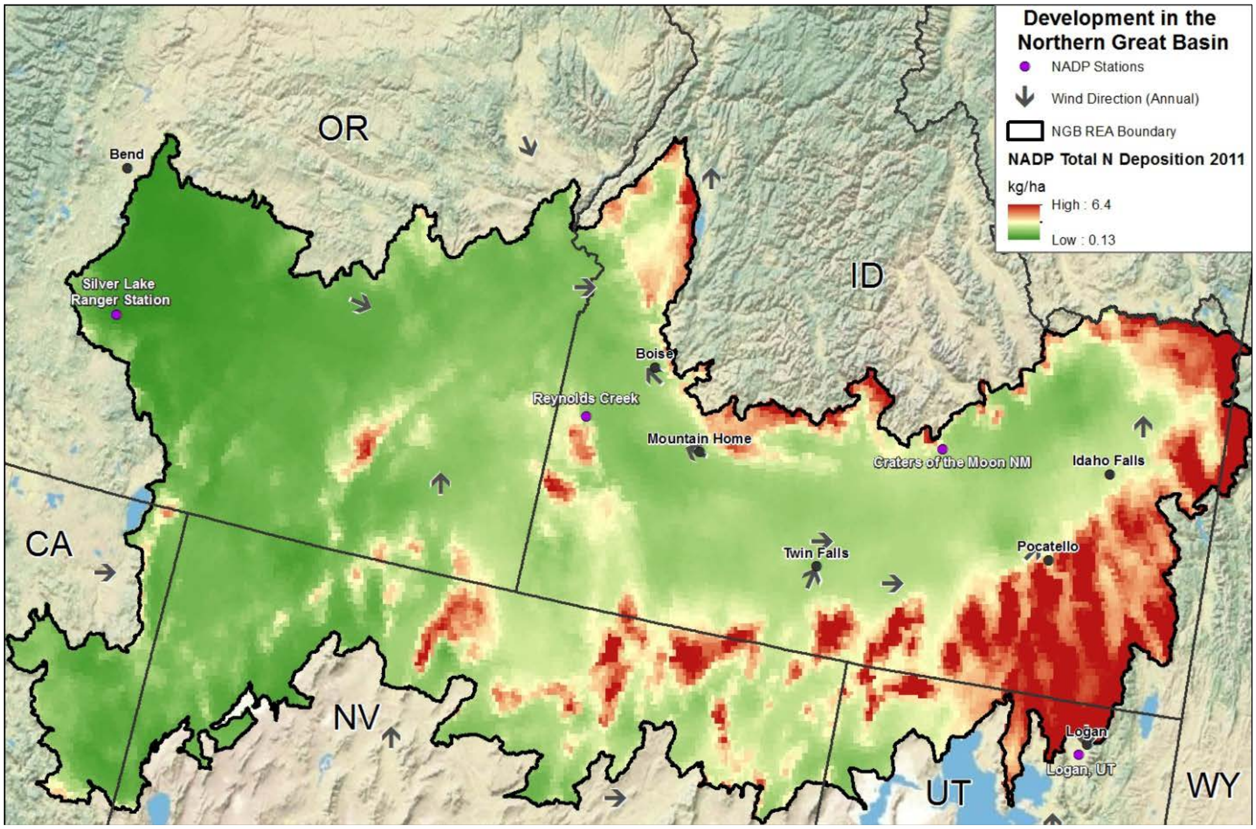

Figure 5-22. Inorganic Wet Deposition from Nitrate and Ammonium (2011) in the Northern Great Basin

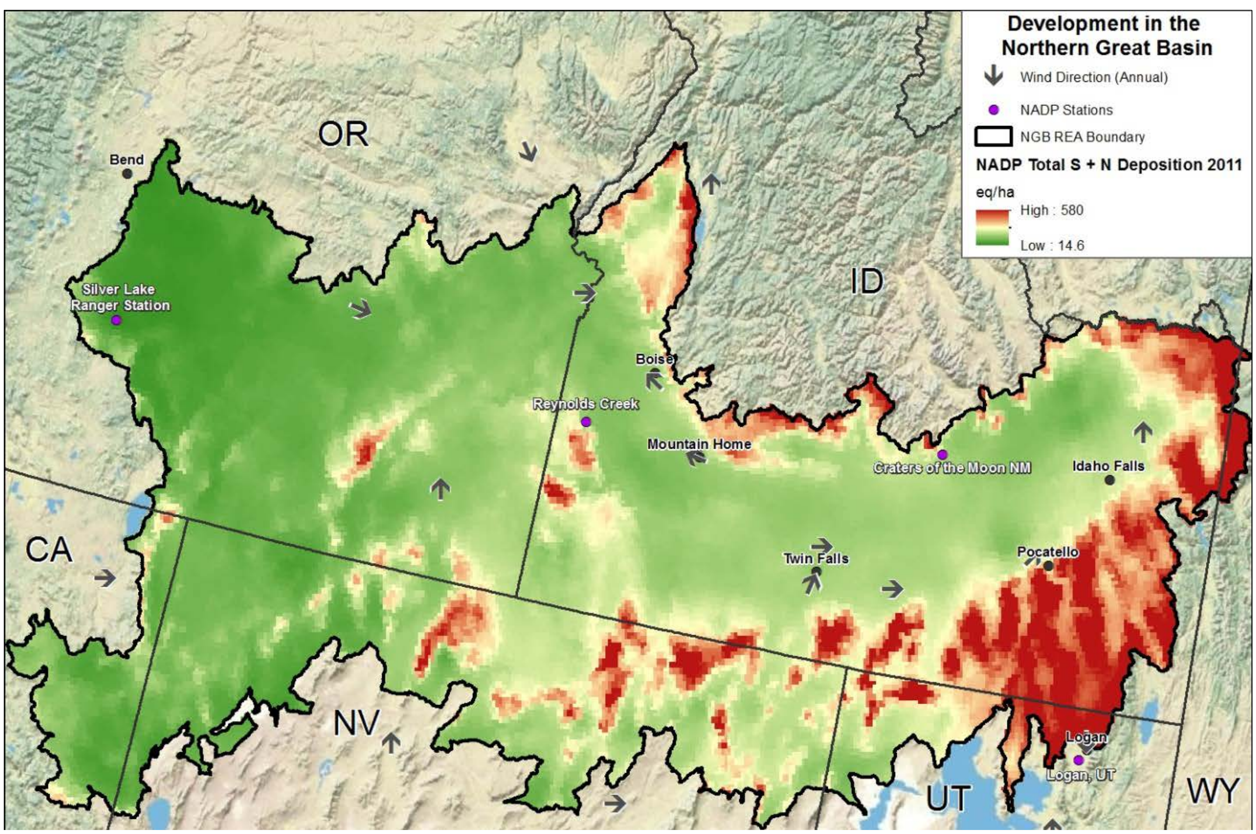

Figure 5-23. Sulfur + Nitrogen Wet Deposition (2011) in the Northern Great Basin

6 References

Bureau of Land Management (BLM) 2012. Briefing Statement, Subject: Renewable Energy. Montana State Office, Billings, MT. March. Available on internet at: http://www.blm.gov/pgdata/etc/medialib/blm/mt/blm_information/bps.Par.75562.File.dat/RenewableEnergy.pdf.

Duffield, W. A. and J.H. Sass. 2003. Geothermal Energy—Clean Power From the Earth's Heat. Circular 1249. U.S. Geological Survey, Reston, Virginia: 2003. Available on internet at: http://pubs.usgs.gov/circ/2004/c1249/c1249.pdf.

National Wind Coordinating Collaborative (2010). Wind Turbine Interactions with Birds, Bats, and Their Habitats: A Summary of Research Results and Priority Questions. Spring. Available on internet at: http://www1.eere.energy.gov/wind/pdfs/birds_and_bats_fact_sheet.pdf.

Theobald, DM. (2001) Land-use dynamics beyond the American urban fringe. Geogr Rev 91(3):544−564. Available online at http://www.amergeog.org/gr/jul01/Theobald-1st.pdf.

Theobald, DM. (2003) Targeting conservation action through assessment of protection and exurban threats. Conserv Biol 17(6):1624−1637.

Theobald, DM. (2005) Landscape patterns of exurban growth in the USA from 1980 to 2020. Ecol Soc 10(1):32. Available online at http://www.ecologyandsociety.org/vol10/iss1/art32/.

U.S. Department of Energy (USDOE). 2012. SunShot Vision Study. Prepared by the National Renewable Energy Laboratory, U.S Department of Energy. DOE/GO-102012-2037. February. Available on internet at: http://www1.eere.energy.gov/solar/pdfs/47927.pdf.

U.S. EPA. Land-Use Scenarios: National-Scale Housing-Density Scenarios Consistent with Climate Change Storylines (Final Report). EPA/600/R-08/076F, 2009

U.S. EPA. ICLUS Tools and Datasets. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-09/143F, 2010.

Wildfire Change Agent Package
for the Northern Great Basin Ecoregion

1 Introduction

Change agents (CA) are natural or anthropogenic disturbances that influence the current and future status of conservation elements (CEs). CEs are resources of conservation and management interest such as wildlife species or ecological communities; i.e., they are the objects that the BLM intends to assess for current status and future condition in the face of changing CA effects. The initial CAs for this ecoregion were outlined by the AMT in the SOW. Wildfire is a key ecological process that influences virtually all other ecosystem processes, and is included in this REA in order to assess how predicted changes in natural fire regimes at the landscape scale may affect resources of management concern.

This CA package provides the assessment of the current status and future threats that are anticipated due to CAs in the ecoregion. Information in this CA package includes a brief description of the wildfire change agent, some information on potential data sources and analytical methods for the assessment, and a listing of relevant MQs for this CA.

2 Change Agent Package Review Process

2.1 Subject Matter Expert Review

Subject Matter Experts play a key role in ensuring that the REA reflects the best available data and modeling processes suitable for each conservation element and change agent. Subject Matter Experts were added to Rolling Review Teams comprised of SAIC scientists, SAIC GIS personnel, AMT member(s) and other subject matter experts from the Department of Interior or state agencies. Membership of the Rolling Review Teams is listed in Appendix A. To ensure consistency amongst the different Rolling Review Teams, the number of lead SAIC scientists was limited to only a few individuals. This ensured that there was a common approach, or framework, used among the different Rolling Review Teams and that one Rolling Review Team did not stray too far from the rest. The USGS, as peer reviewers, were invited to participate in Rolling Review Teams.

3 Wildfire Change Agent Description

3.1 Wildfire Change Agent Description

Wildfire is a key ecological process in western ecosystems (Pyne 1992) that influences virtually all other ecosystem processes, such as landscape patterns and species diversity, nutrient cycling, hydrology and erosion, air quality, plant ecology, and the maintenance of wildlife habitats and biodiversity (Agee 1993; Noss and Cooperrider 1994; Dale *et al.* 2001; Swetnam and Betancourt 1997; Haire and McGarigal 2009). A natural fire regime describes the role fire would play across a landscape in the absence of human intervention (Agee 1993; Brown 1995); the assessment of the wildfire CA will address current and future changes in fire regimes that occur in the presence of human activity and other CAs. Human-influences in the NGB ecoregion have affected fire frequency, severity, and seasonality, including new ignition sources associated with development, fire suppression, and introduction of invasive plant species. Fire is also strongly influenced by weather and climate. Climate change/ fire interactions include increased area burned, variability and frequency of extreme fire weather, and length of fire seasons (Wotton and Flannigan 1993; Flannigan and Wotton 2001; Flannigan *et al.* 2005). Fire and climate change interact to enhance the spread of invasive plant species.

Some communities in the NGB are not maintained by fire and may be degraded by it. In the most fuel-limited (i.e., driest) systems, fire may have almost never occurred naturally. In the more xeric sagebrush and salt-desert shrub systems, the primary woody species are not fire-adapted or fire-dependent. Baker (2006) suggested that fire frequency in low sagebrush (*A. arbuscula*) may be a minimum of 325-450 years, 100-240 years in Wyoming big sagebrush (*A. tridentata* ssp. *wyomingensis*), and 70-200 years or more in mountain big sagebrush (*A. tridentata* ssp. *vaseyan*a). At the landscape scale, these rare disturbance events resulted in a mosaic of shrub and herbaceous dominated communities. However, the literature does not support that these communities were fire-dependent. Although fire is a natural disturbance in sagebrush systems, the literature suggests that a stable community becomes established relative to climate and soils, and other processes than fire contribute to shrub die-off and replacement (Barrett *et al.* 2010; Miller *et al.* 2011; McIver *et al.* 2010; or Chambers *et al.* 2007). Sagebrush communities are vulnerable to being replaced by cheatgrass, especially under conditions of higher fire frequency, ultimately resulting in a flashy annual grassland community maintained by fire. The presence of invasive species such as cheatgrass in arid lands has made fire more problematic in vegetation that historically experienced only occasional to periodic burning and whose dominant species lack adequate regeneration mechanisms such as resprouting, having fire-resistant seeds with fire stimulated germination, and/or having seed dispersal mechanisms consistent with rapidly recolonizing large burned areas.

3.2 Wildfire Effect Pathways

The wildfire CA affects conservation elements including natural vegetation communities and wildlife species and assemblages. In grassland and shrub communities, shorter fire return intervals tend to favor dominance by grass species and may remove the majority of woody vegetation. In these communities, longer fire return intervals allow shrub and woody vegetation to increase and become dominant or co-dominant with grass species. When fire return intervals become shorter, communities are typically in a non-equilibrium state (i.e. fire maintained seral disclimax) and maintain a multi-age structure and spatial patchiness of vegetation conditions. In general, the wildfire CA affects wildlife CEs by altering habitat availability (for cover, reproduction, hunting, and foraging) Human actions and climate change are the primary causes of changes in natural fire regimes that affect availability and suitability of habitats.

Table 3-1 shows some of the wildfire CA pathways and interactions with other CAs, and some of the affected CEs. This listing is not intended to be comprehensive but indicates some of the ways in which the analysis of the wildfire CA can proceed.

Table 3-1. Wildfire as a Change Agent

Effect Pathways	Interactions with other CAs	Affected CEs
• Temporary changes in habitat seral stage • Prolonged periods in non-equilibrium state, i.e. eliminating achievement of mature vegetative stages • Increased vulnerability to weed invasions, hampering natural early succession • Damage to soils and soil crusts, reducing opportunities for natural germination and vegetation replacement • Positive and adverse changes to wildlife habitats and behavior • Hydrologic conditions and processes • Nutrient cycling • Carbon release • Site productivity, rejuvenation potential • Change in microclimates • Removal of soil cover, erosion, watershed health	• Development may add to ignition sources • Development (e.g., timberland management, fire suppression adjacent to residential areas) alters natural fire regimes in native plant communities • Development may increase the spread of fire-prone invasive plants • Climate change may increase temperature, reduce precipitation, and exacerbate droughts • Climate change may increase storm frequency and increase lightning strikes • Invasive species may increase fuel loads and carry fires greater distances, increase fire frequency or duration, • Insect outbreaks and diseases cause tree mortality adding to fuel loads • Fire can control insects and diseases • Recreation potential diminished post-fire	• Many coarse filter vegetative CEs: especially those with highest fuel loads • Many fine filter CEs especially sagebrush obligates such as greater sage-grouse and pygmy rabbit; and mule deer which depend upon shrublands and habitat mosaics • Coldwater fish CEs that require cooler water temperatures and thus riparian vegetation that shades streams • Tree-roosting bats

As an example, the effects of fire on the mule deer (a CE in this assessment) habitat are varied. Under natural fire regimes, fire generally has a beneficial impact on spring or summer mule deer habitat, by stimulating earlier greenup the following spring, which increases availability and nutritional quality of forage and more herbaceous plants. However, fire regimes affected by the other CAs can facilitate invasive grasses, which have low values as mule deer forage, and reduce shrub cover. Mule deer generally seem to prefer recently burned areas that create mosaics of forage and cover, as long as herbaceous vegetation and re-sprouting browse species remain viable and nutritious (Hobbs and Spowart 1984). Fire suppression can facilitate conifer encroachment, canopy closure, and deterioration of herbaceous and shrub understories, also resulting in reduction of habitat extent and suitability. Fire suppression results in thickening of pine stands and, therefore, decreases in secondary stages of plant succession, which are important to mule deer.

A conceptual model showing the relationship between fire return interval and site characteristics in sage-steppe sites is shown in Figure 3-2. This model illustrates that with longer periods between fires (i.e., under comparatively moist cool conditions or with fire suppression) there is a high probability of woodland encroachment into areas of grass or shrub-dominated sagebrush steppe. This type of succession is not advantageous to some of the CEs (e.g., greater sage-grouse, mule deer) that depend on the sagebrush habitats that are renewed or maintained by natural fire intervals.

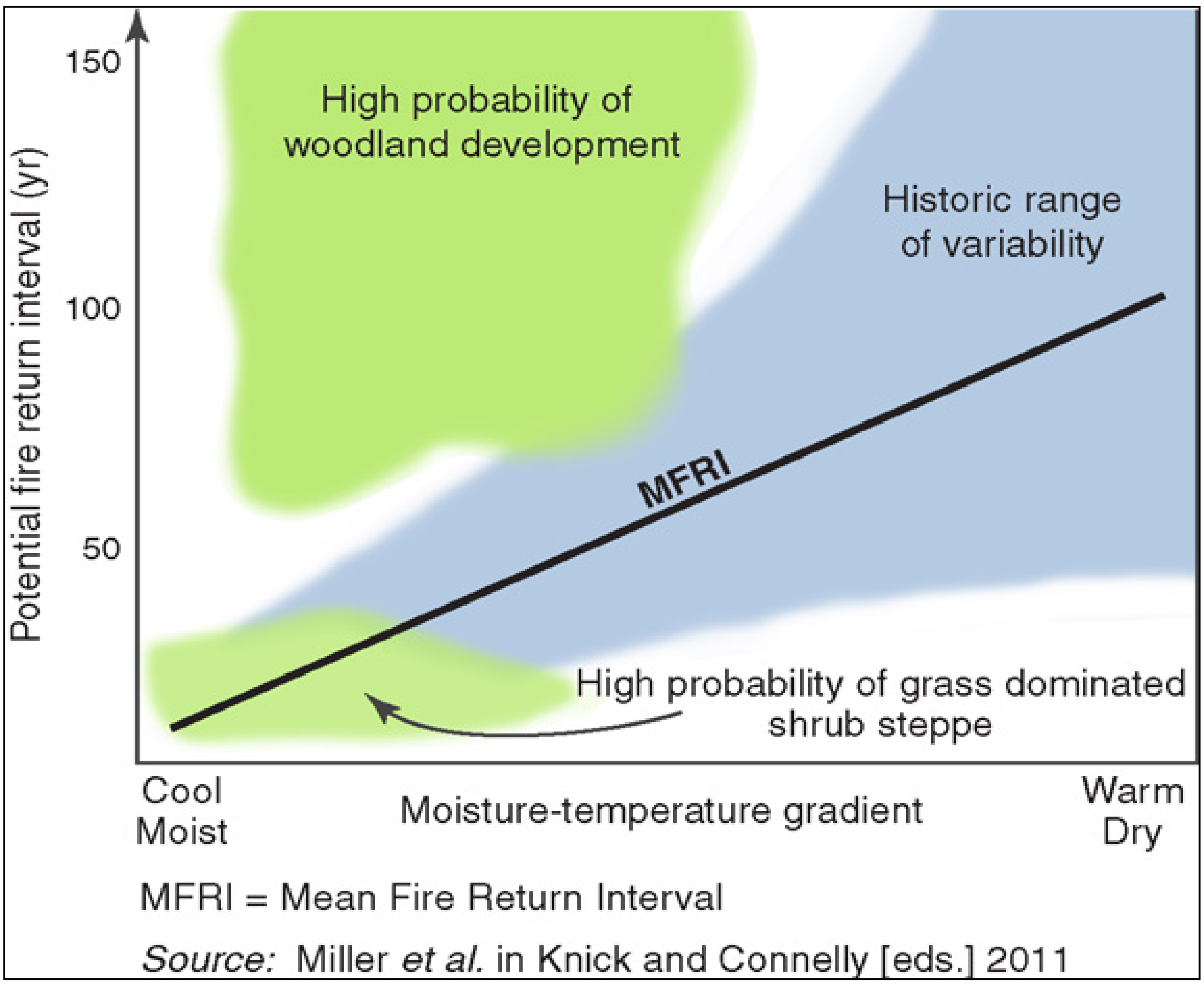

Figure 3-2. Conceptual Model Showing the Relationship between Potential Fire Return Interval (in years) and Moisture-temperature Gradient (Source: Miller et al. 2011)

4 Data Sources, Methods, Models and Tools

4.1 Data Identification

Preliminary data needs for analysis of the Wildfire CA are described in the following sections. Wildfire data exists in a variety of formats and scales, covering many areas related to the analysis requirements. We were guided by the MQs in creating the preliminary list of CA data needs (Table 4-1). Table 4-1 indicates some data sources acquired for this CA. Having both historical and current fire perimeters is important in being able to update modeled output based on recent fire activity that has occurred or to determine fire frequency. GeoMAC (an inter-agency collaboration) provides web mapping and spatial data downloading of recent and historic fire perimeters to fulfill this need. GeoMAC includes fire perimeter information from 2000 to present. Monitoring Trends in Burn Severity (MTBS) is another data source that tracks the fire perimeters but also the burn intensity. This dataset has wildfires from 1984-2010 currently available for download. In addition, the BLM has collected historic fire perimeter data. The AMT suggested that with the use of the MODIS database, we may be able to fill in missing spatial data that LANDFIRE does not capture. MODIS utilizes satellite imagery to record fire “hot spots” as point data that was used to identify hotspots outside of GeoMAC fire perimeter polygons. The 13 Anderson Fire Behavior Fuel Model (Anderson 1982) data from the LANDFIRE 2008 refresh represents distinct distributions of fuel loading found among surface fuel components (live and dead), size classes, and fuel types. The fuel models are described by the most common fire-carrying fuel type (grass, brush, timber litter, or slash).

Table 4-1. Preliminary List of CA Data Needs

Data Required	Dataset Name	Source Agency	Type/Scale	Status	Potential Use in REA
Fire History and Occurrence	GeoMAC Fire Perimeters (2000 – present)	Multi Agency	Polygon	Acquired	Yes
	Monitoring Trends in Burn Severity (1984 – 2010)	Multi Agency	Point, Polygon, Raster	Acquired	No
	MODIS	Multi Agency	Point	Acquired	Yes
	Western Fires 1870 - 2007	Sagemap	Polygon	Acquired	Yes
Forest Fuels	LANDFIRE 13 Anderson Fuel Model (FBFM 13)	USGS	Raster 30m	Acquired	Yes
	LANDFIRE Barton Scott 40 Fuel Model	USGS	Raster 30m	Acquired	Yes
Fire Regime Condition Class	LANDFIRE VCC	USGS	Raster 30m	Acquired	No
Burn Probability	FSIM Burn Probability	USGS/ NIFC	Raster 270m	Acquired	Yes

4.2 Data Modeling

The AMT decided that 1990 – 2012 was a suitable timeframe to model fire perimeters based on the accuracy of spatial data available. GeoMAC fire perimeters were the primary fire perimeter source of data from 2000 to present. Fire perimeters from 1990 – 1999 were extracted from the western fires dataset downloaded from Sagemap. The AMT and peer review team mentioned that based on their knowledge some fire perimeters were missing from some of the datasets. The 2000 to present GeoMAC dataset and Sagemap’s western fire perimeters matched up fairly well with the Idaho state datasets. Areas that were mentioned to be missing fire perimeters would be the Snake River Plain and near the Idaho National Laboratory. The Rolling Review Team suggested that FSim (Fire Simulation) model be used to determine burn probability rather than future fire potential. FSim data was created as a nation-wide dataset by USFS Missoula Fire Sciences Lab.

4.3 Data Gaps, Uncertainty and Limitations

4.3.1 Data Gaps

An attempt was made to update the LANDFIRE VCC using FRCC GIS toolset but the FRCC editor required users to modify the burn frequency and intensity of BPS data layers. This type of customization would be better done by a regional expert in wildfires in the Northern Great Basin so they can use their experience to modify these settings to generate updated FRCC.

4.3.2 Uncertainty

The FSim burn probability was modified to show equal areas of high, moderate and low burn probabilities similar to how the BLM Spatial Lab at the NOC was using the data to model the burn probability within the greater-sage grouse range. There may be better ways to try to extract high and low burn probabilities or other datasets that model fire potential but the rolling review team felt the FSim was the best data available. Also with the current greater sage-grouse EIS work being done, using a consistent data set seemed the most appropriate path forward. While the AMT mentioned that there were fire perimeters in the Snake River Plain and near the Idaho National Laboratory missing, comparing the Sagemap’s Western fires or GeoMAC perimeters to Idaho’s state dataset indicated there was little difference.

4.3.3 Limitations

FSim burn probability doesn’t model fire direction or course of travel just the propensity of a pixel to burn under various climate scenarios.

5 Management Questions

5.1 What is the frequency, size, and distribution of wildfire on the landscape? (MQ 35)

To determine the frequency, size, and distribution of wildfires within the ecoregion, fire activity from 1990 through 2012 was determined to be the most suitable timeframe for analysis. GeoMAC fire perimeters from were used as the primary data source of fire perimeters for the 2000 to 2012 timeframe. The 1990 through 2000 timeframe was extracted from the western fires (1870-2007) dataset from Sagemap. The fire perimeters were analyzed using spatial operations to determine the frequency of locations that fire perimeters have in common. The results of this analysis for the years 1990 – 2012 are shown in Figure 5-1. The 2012 fire season was one of the largest within this time frame with 3 large fires over 300,000 acres (Long Draw, Holloway, and Rush). These three fires mostly burned areas that mostly had not burned (except for a few small fire perimeters) in the period of 1990 - 2010. Figure 5-2 shows a shorter snapshot of fires from 2000 – 2012 which uses only GeoMAC fire perimeters.

The part of the ecoregion with the highest burn frequency is the Snake River Plain. There are some large tracts that have burned twice, shown in yellow and some smaller fire perimeters that have burned three times or more (shades of orange to red) in the 1990 – 2012 time period. The Saylor Creek bombing range is one isolated hot spot of frequent fires that is visible in Figure 5-1.

The size and abundance of wildfires has varied from year to year with an average of 194 wildfires per year from 1990 – 2012 (Figure 5-3). The 1996 and 1999 wildfire season produced the largest occurrences of wildfires but the total acreage of these wildfires remained relatively small by comparison to 2012. Increasing temperature due to climate change will result in longer wildfire seasons and larger areas burned (Chambers and Pellant 2008). Figure 5-4 shows the acreage of fires per wildfire season from 1990 – 2012. Comparing the early 1990's to the last five years shows that wildfire are becoming larger and more variable from year to year. Figure 5-5 shows the size of the largest five wildfires each year from 1990-2012. One area of uncertainty in using the wildfire perimeters and statistics is that there are two primary federal landowners (BLM and USFS) with possibly two different fire management strategies for their lands. These strategies may have altered in the last 22 years based on the latest fire ecology and best management practices for their lands.

5.2 What areas now have (high, medium, low) potential for fire based on fuels composition (e.g., invasive plants)? (MQ 36)

Fuels are combustible materials comprised of both living and dead vegetation that sustain wildfires. Fuel types vary in their flammability and in the height of flames they promote. Wildland fuels can also be described using vertical separation as ground, surface, ladder and aerial fuels. The LANDFIRE fuel loads data describe the composition and characteristics of both surface and canopy fuels.

The Rolling Review Team (RRT) recommended using two LANDFIRE fuel models to show areas of fuel composition for the ecoregion. Figure 5-6 shows the 13 Anderson fuel model for the ecoregion and Figure 5-7 shows the 40 Scott and Burgan fuel model. The legends contain codes for specific fuel types along with non burnable fuel models (Urban, Agriculture, Barren, etc.) where wildfire will not spread. The 13 Anderson fuel model defines all of its fuel types into 13 general classes. The 40 Scott and Burgan model uses codes representing the primary vegetation (GR: Grass, SH: Shrub, TU: Timber Understory, etc.) along with a number representing fuel load (higher number, higher fuel load). These codes represent long fuel descriptions that can be viewed at www.landfire.gov.

The 13 Anderson Fire Behavior Fuel Model (FBFM13) layer represents distinct distributions of fuel loading found among surface fuel components (live and dead), size classes, and fuel types. The fuel models are described by the most common fire-carrying fuel type (grass, brush, timber litter, or slash). This set contains more fuel models in every fuel type (grass, shrub, timber, slash) than Anderson's set of 13 (LANDFIRE 2013). This model focuses on prediction of spread rate and intensity at the peak fire season (Scott and Burgan 2005).

The 40 Scott and Burgan Fire Behavior Fuel Model (FBFM40) layer represents distinct distributions of fuel loading found among surface fuel components (live and dead), size classes, and fuel types. This set contains more fuel models in every fuel type (grass, shrub, timber, slash) than Anderson's set of 13. The number of fuel models representing relatively high dead fuel moisture content increased, and fuel models with an herbaceous component are now dynamic, meaning that loads shift between live and dead (to simulate curing of the herbaceous component) rather than remaining constant (LANDFIRE 2013). The 40 Scott Burgan fuel model allows for a wider range of fuel types and differentiates between arid (rainfall deficient in summer) and moist to humid climates (rainfall adequate year round) (Scott and Burgan 2005).

5.3 Where are areas that in the future will have high potential for fire? (MQ 37)

The RRT recommended using the Fire Simulation (FSim) model that models burn probability rather than attempting to model areas of high potential. Based on the metadata provided with the dataset, the FSim burn probability data was created by the USFS Missoula Fire Sciences Lab for the lower 48 States at a 270m cell resolution. FSim uses the latest LANDFIRE Refresh (2008) fuel, terrain and historical fire perimeters along with surface weather records and fire danger rating. The pixel value in the FSim dataset represent the number of times that pixel was burned by an FSim-modeled fire divided by the total number of annual weather scenarios simulated. The burn probability depicts only wildfire risk or the tendency of the pixel to burn and does not depict fire return intervals or routes of fire travel.

The FSim data was used in the greater sage-grouse EIS by the BLM Spatial Lab at the National Operations Center (NOC) and was provided in two formats.

1. The original nation-wide FSim burn probability layer, and
2. FSim burn probability data that was equalized (broken into equal area sections of high, moderate and low burn probabilities) for the greater sage-grouse (GSG) range.

Figure 5-8 shows the FSim burn probability as a nation-wide dataset with the values stretched from low to high while Figure5-9 the data focused on the Northern Great Basin. Figure 5-10 shows the data received from the BLM Spatial Lab where the FSim data was equalized across the GSG range. Based on the GSG range, the majority of the Northern Great Basin ecoregion was being classified as a high burn probability.

Figure 5-11 shows the results of a similar equalization but calibrated to the extent of the Northern Great Basin. In this figure, the areas of low, moderate and high burn probabilities are equal in area (not including unburnable areas) so it is easier to identify parts of the ecoregion with different burn probabilities. Unburnable areas in this ecoregion are usually agricultural land or developed land, open water, playas and other low lying basins dominated by salt desert shrub vegetation such as the Black Rock Wilderness Area in Nevada. The high burn probability locations in the ecoregion are within Idaho extending down into northeastern Nevada and northwestern Utah. Oregon and California have some small areas with the highest burn probability. Most of the high burn probability matches up well with the cheatgrass distribution that Peterson modeled in 2005 that was used in the Invasives CA package (except the higher elevation parts of the northeast Nevada and northwest Utah. Figure 5-12 shows recent fire perimeters on top of the FSim data to compare recent fire activity and FSim burn probability.

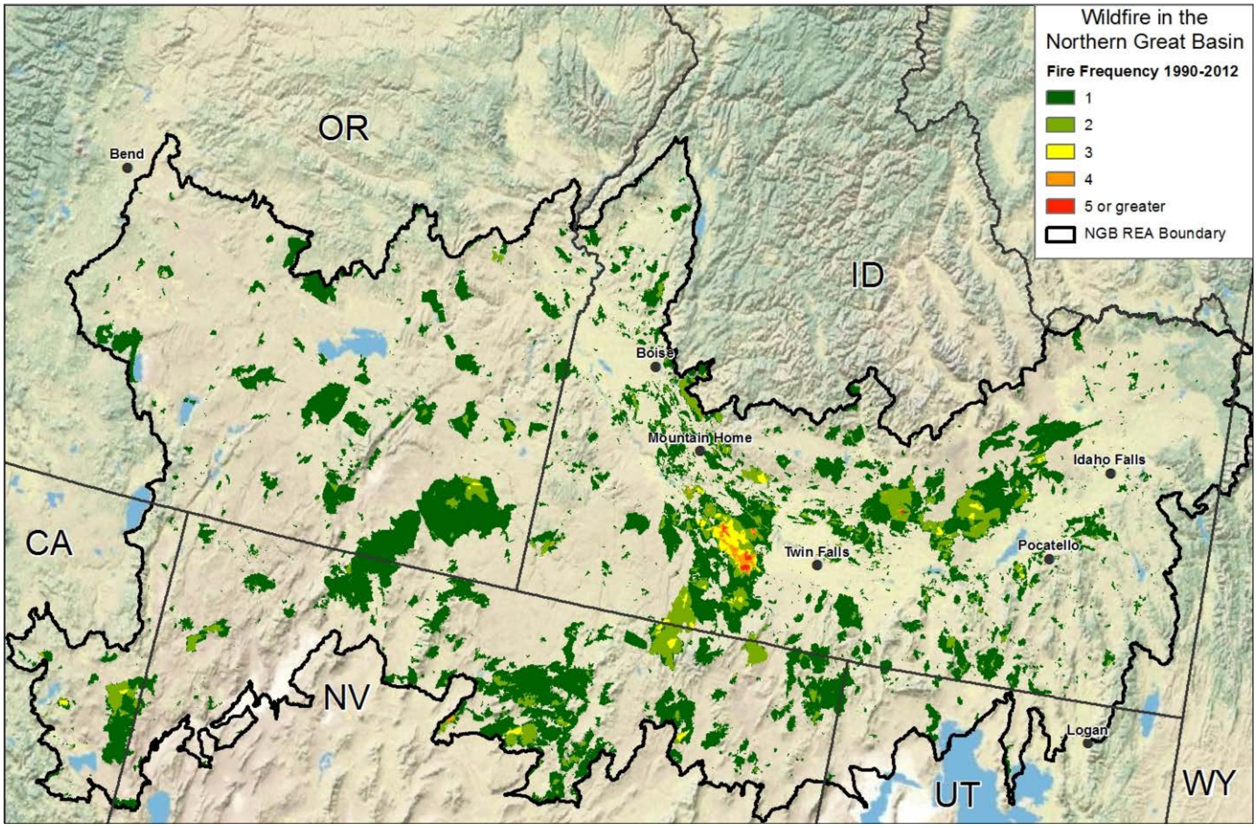

Figure 5-1. Fire Frequency (1990 – 2012) in the Northern Great Basin

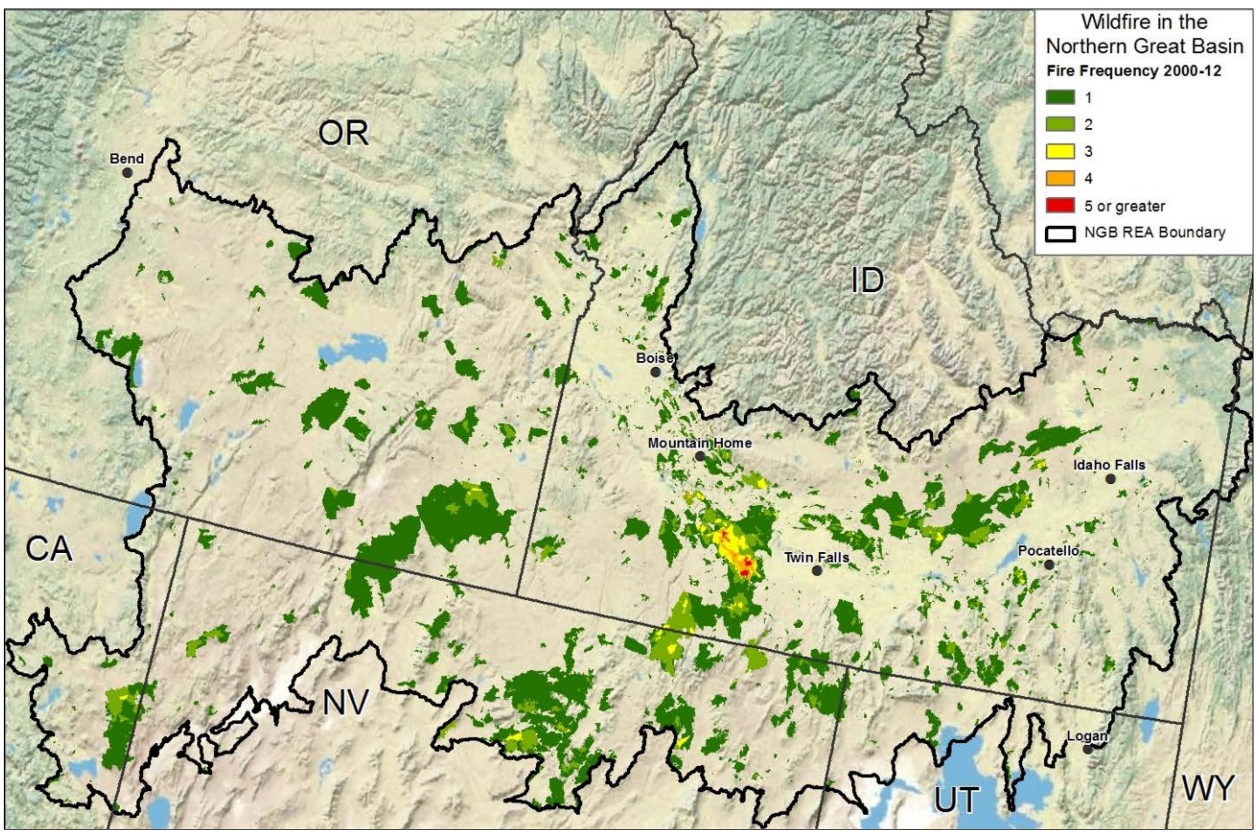

Figure 5-2. Fire Frequency (2000 – 2012) in the Northern Great Basin

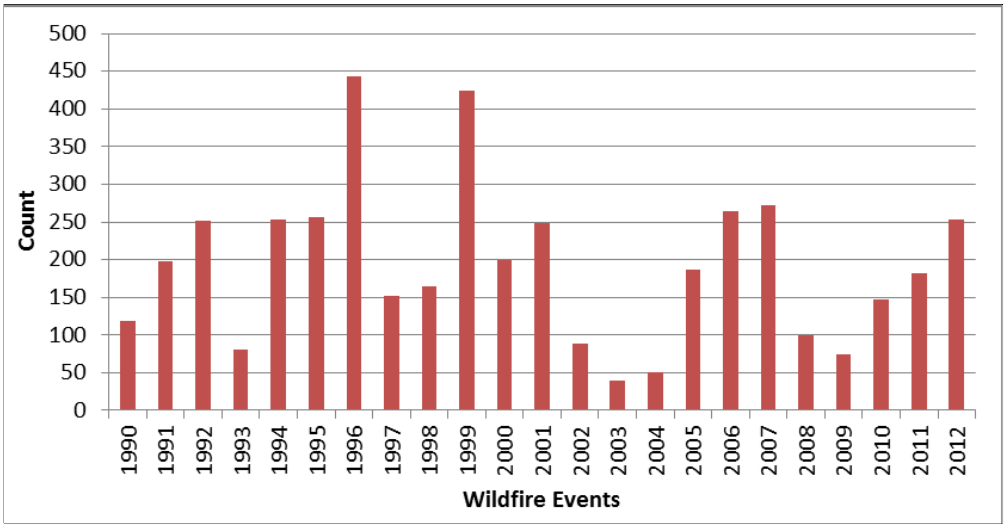

Figure 5-3. Wildfire Events 1990 - 2012

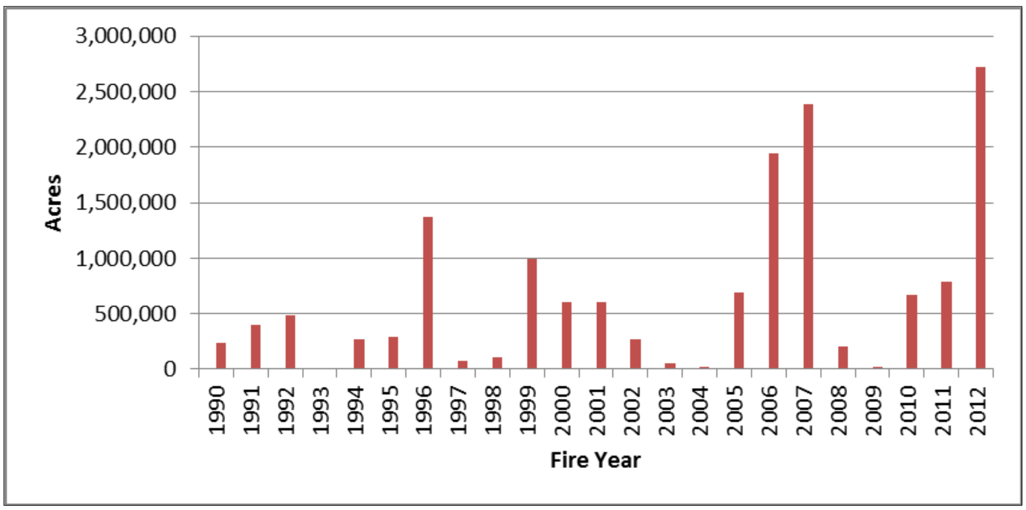

Figure 5-4. Area burned by Wildfire 1990-2012

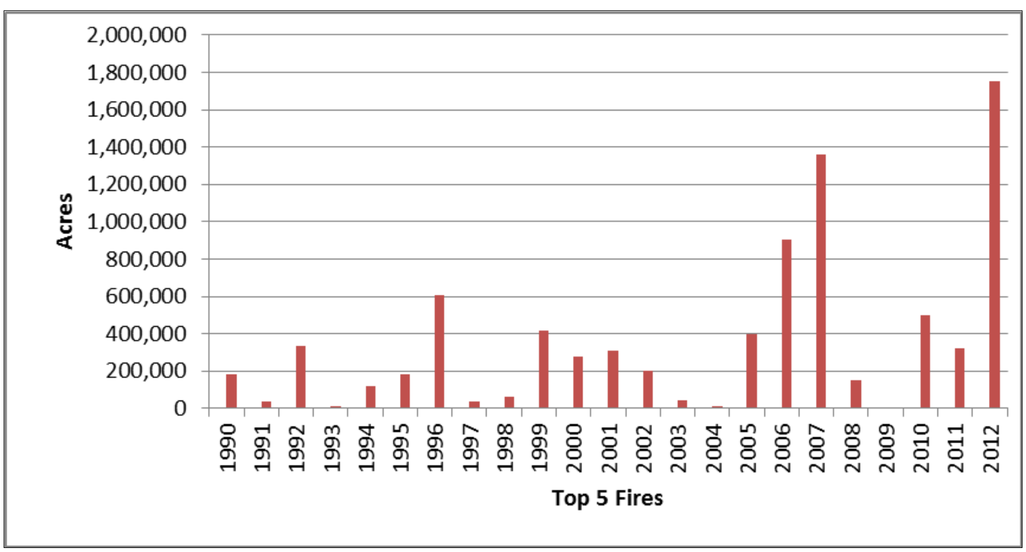

Figure 5-5. Acreage of the Largest 5 Wildfires

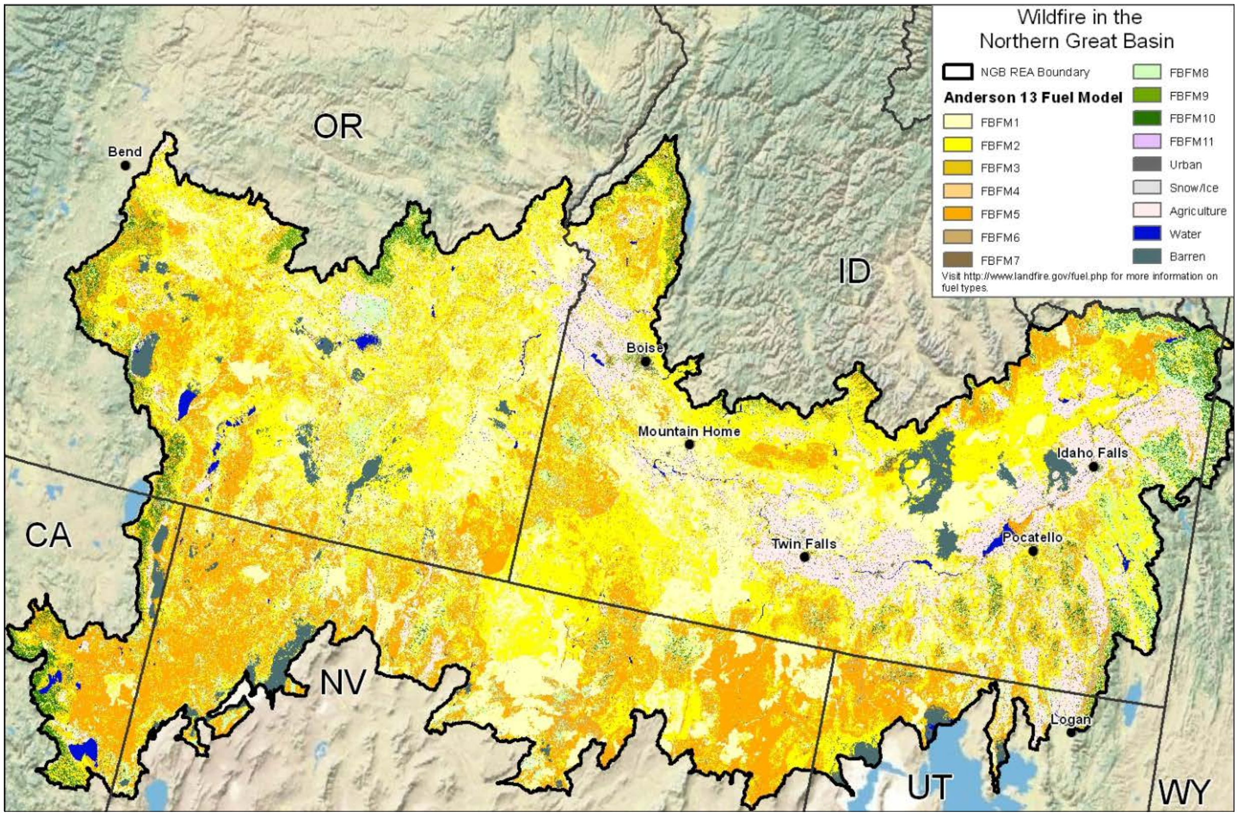

Figure 5-6. 13 Anderson Fuel Model for the Northern Great Basin

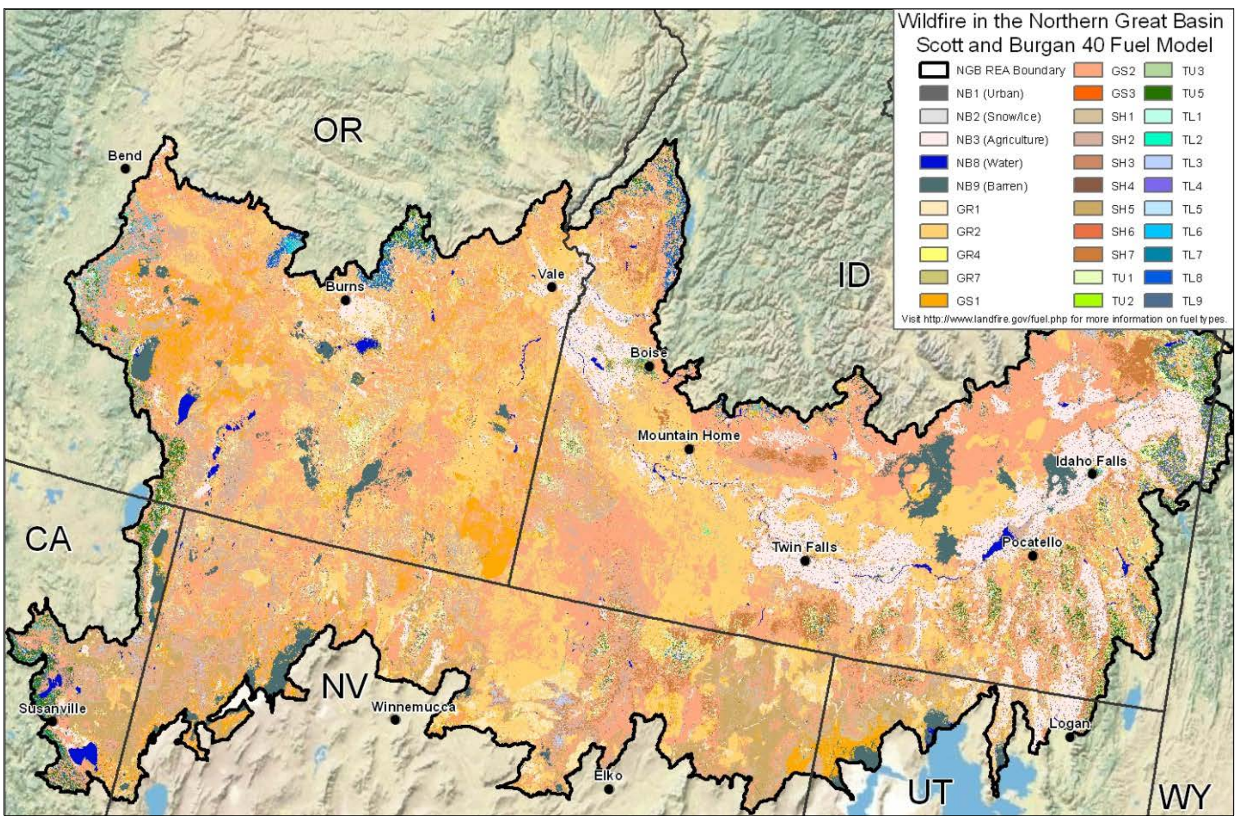

Figure 5-7. 40 Scott and Burgan Fuel Model for the Northern Great Basin

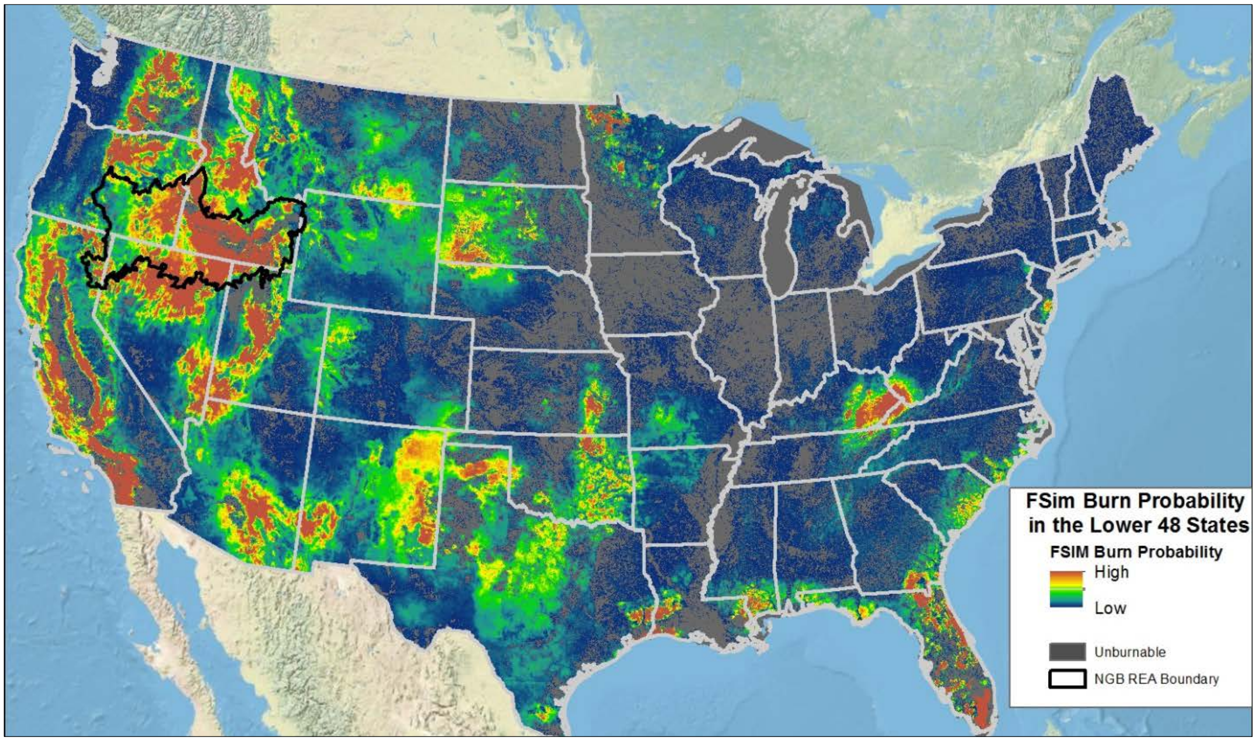

Figure 5-8. Nation-wide FSim Dataset of Burn Probability in the Lower 48 States

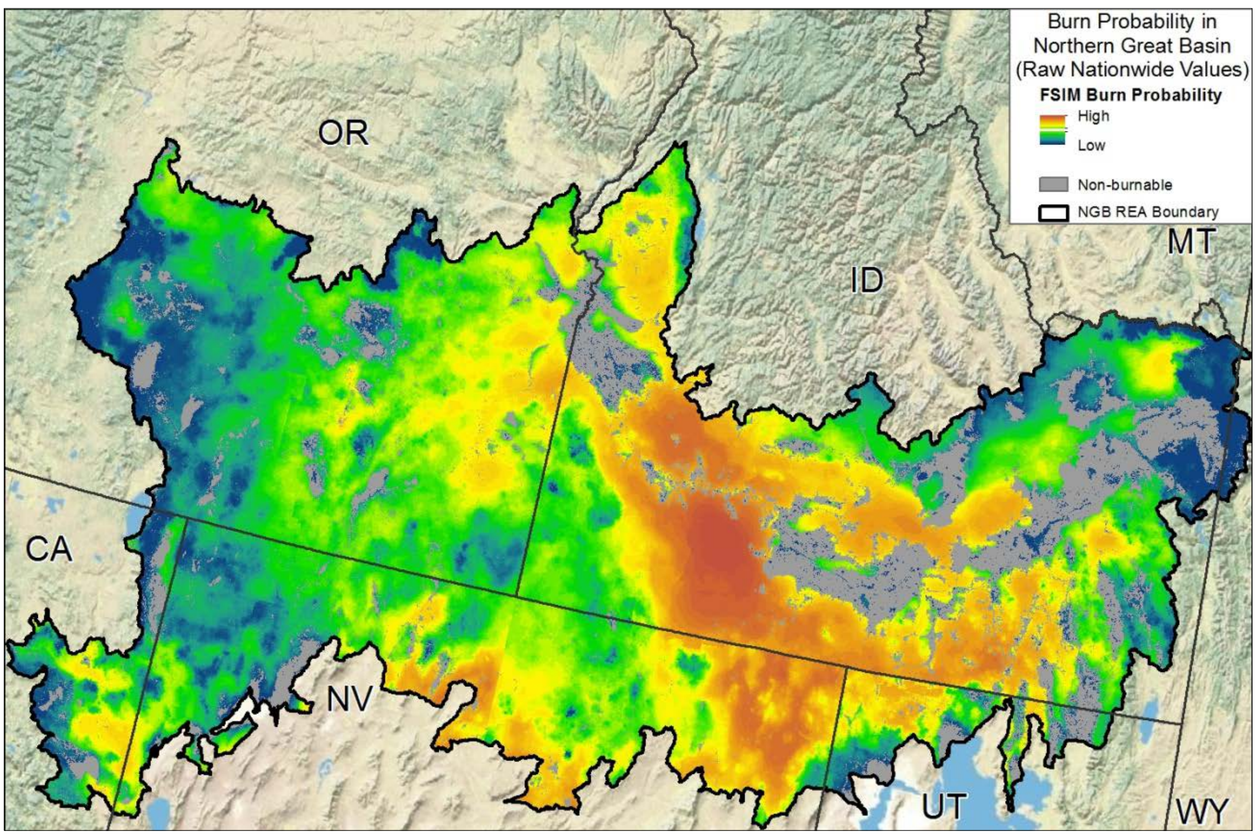

Figure 5-9. FSim Burn Probability based on Nation-wide Dataset

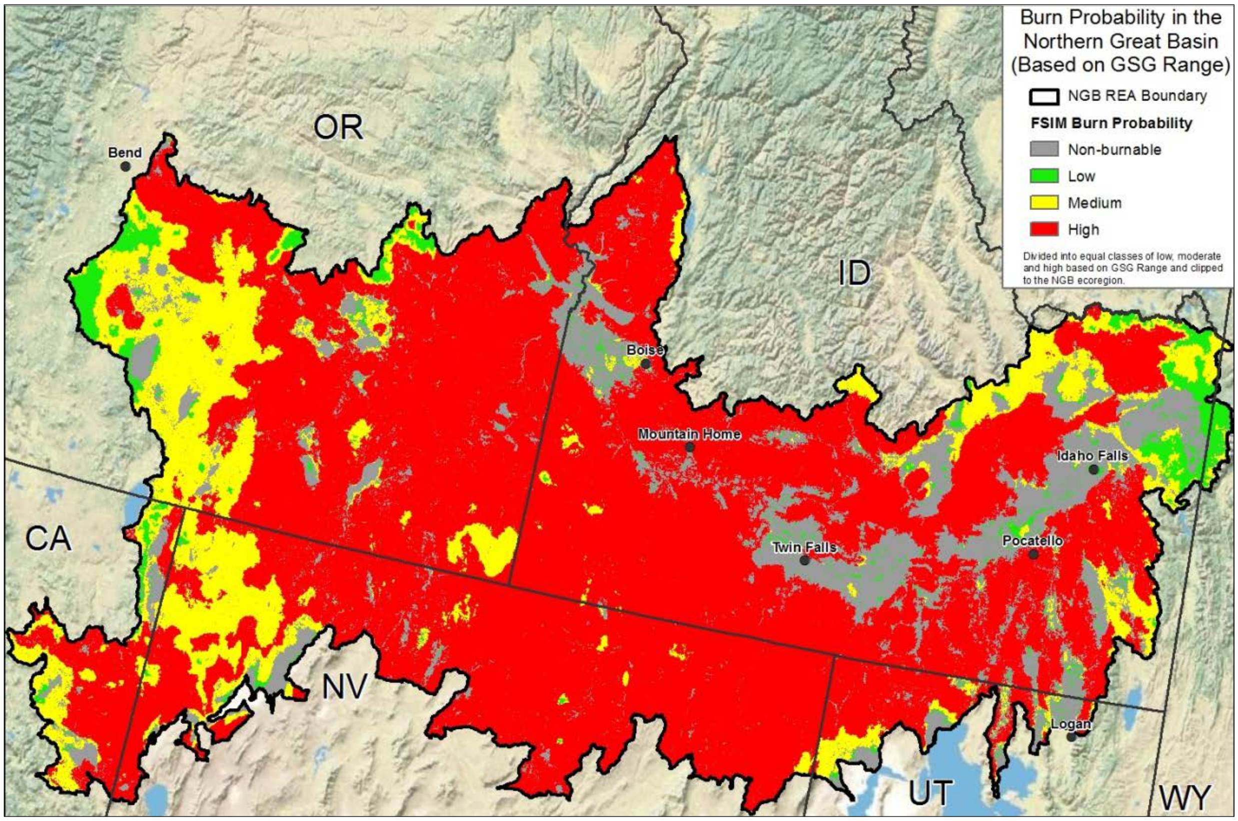

Figure 5-10. FSim Burn Probability Equalized to the GSG Range

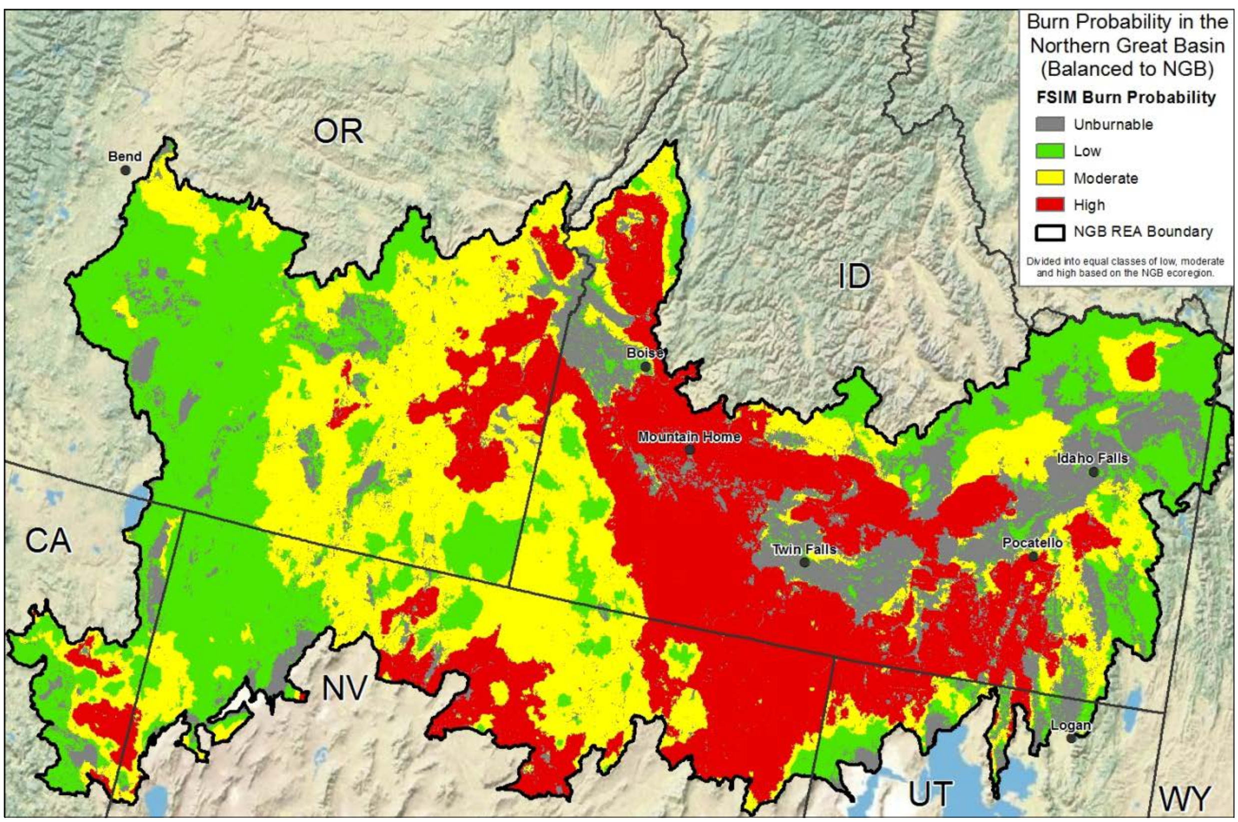

Figure 5-11. FSim Burn Probability Layer Equalized to the Extent of the Northern Great Basin

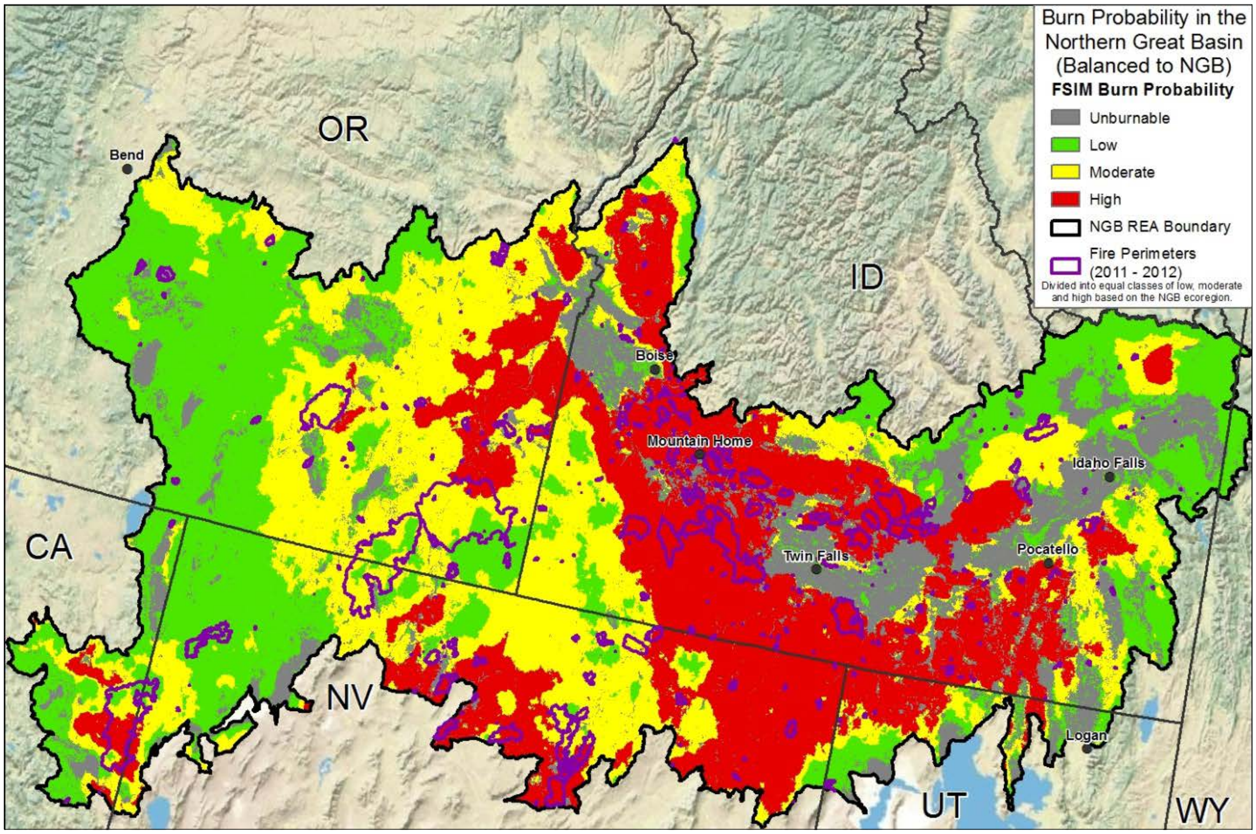

Figure 5-12. GeoMAC Fire Perimeters (2011-12) and FSim Burn Probability for the Northern Great Basin

6 References

Agee, J.K. 1993. Fire ecology of Pacific Northwest forests. Island Press, Washington, D.C., USA.

Anderson . 1982. Information on the 13 Anderson Fire Behavior Fuel Model developed in 1982 with data from the LANDFIRE 2008 incorporated. Available at: http://www.landfire.gov/NationalProductDescriptions1.php.

Baker, W.L. 2006. Fire and Restoration of Sagebrush Ecosystems. Wildlife Society Bulletin 34:177-185.

Baker, W.L. 2009. Fire Ecology in Rocky Mountain Landscapes. Island Press.

Barrett, S., D. Havlina, J. Jones, W. Hann, C. Frame, D. Hamilton, K. Schon, T. Demeo, L. Hutter, and J. Menakis. 2010. Interagency Fire Regime Condition Class Guidebook. Version 3.0. Interagency Fire Regime Condition Class website, USDA Forest Service, US Department of the Interior, and The Nature Conservancy. Available at: www.frcc.gov.

Chambers, J.C. and M. Pellant. 2008. Climate change impacts on northwestern and intermountain United States rangelands. Society for Range Management publication available on internet at: http://www.fs.fed.us/rm/pubs_other/rmrs_2008_chambers_j001.pdf. June.

Cram, D.S., T.T. Baker, J. BorenJ, and C. Edminster. 2003. Inventory and classification of wildland fire effects in silviculturally treated v. untreated forest stands of New Mexico and Arizona. *In*: Proceedings: Second International Wildland Fire Ecology and Fire Management Congress and Fifth Symposium on Fire and Forest Meteorology, Orlando, FL. November.

Dale, V., L. Joyce, S. McNulty, R. Neilson, M. Ayres, M. Flannigan, P. Hanson, L. Irland, A. Lugo, C. Peterson, D. Simberloff, F. Swanson, B. Stocks, and B. Wotton. 2001. Climate change and forest disturbance. BioScience 51: 723-734. doi: 10.1641/0006-3568(2001)051[0723:CCAFD]2.0.CO;2.

Flannigan, M.D. and Wotton, B.M. 2001. Climate, weather and area burned. *In:* Forest Fires: Behavior & Ecological Effects. E.A. Johnson and K. Miyanishi (eds.) pp. 335–357. Academic Press, New York.

Flannigan M.D., K.A. Logan, B.D. Amiro, *et al*. 2005. Future area burned in Canada. Climatic Change, 72,1-16.

Haak, A.L., J.E Williams, D.J. Isaak, A.H. Todd, C.C. Muhlfeld, J.L. Kershner, R.E. Gresswell, S.W. Hostetler, and H.M. Neville. 2010. Results of LANDFIRE wildfire analysis. Raster digital data. Reston, VA: U.S. Geological Survey.

Haire, S.L. and K. McGarigal. 2009. Changes in fire severity across gradients of climate, fire size, and topography: a landscape ecological perspective. Fire Ecology 5(2): 86-108. doi: 10.4996/fireecology.0502086.

Hobbs, N.T. and R.A. Spowart. 1984. Effects of prescribed fire on nutrition of mountain sheep and mule deer during winter and spring. Journal of Wildlife Management. 48(2): 551-560.

Houghton, R.A. and J.L. Hackler. 2000. Changes in terrestrial carbon storage in the United States. I: The roles of agriculture and forestry. Global Ecology and Biogeography 9: 125-144. doi: 10.1046/j.1365-2699.2000.00166.x.

Hungerford, R.D., M.G. Harrington, W.H. Frandsen, K.C. Ryan, and G. J. Niehoff. 1990. Influence of Fire on Factors That Affect Site Productivity. Paper presented at the Symposium on Management and Productivity of Western-Montane Forest Soils, Boise, ID, April. Available on internet at: http://forest.moscowfsl.wsu.edu/smp/solo/documents/GTRs/INT_280/Hungerford_INT-280.php.

LANDFIRE 2013. http://www.landfire.gov/fuel.php

Lentile, L.B., F.W. Smith, and W.D. Shepperd. 2006. Influence of topography and forest structure on patterns of mixed severity fire in ponderosa pine forests of the South Dakota Black Hills, USA. International Journal of Wildland Fire 15: 557–566.

Noss, R.F. and A.Y. Cooperrider. 1994. Saving Nature's Legacy. Island Press, Wash. D.C. 416 pp.

Oregon Communities at Risk Assessment. 2006. Multi-agency assessment of fire danger risk potential available on internet at: http://www.nwfireplan.gov/communityasst/oregon/2006CommunitiesAtRiskAssessmentHIGHRISKCARONLY.pdf. Accessed September 11, 2011.

Pyne, S. 1997. Fire in America: a cultural history of wildland and rural fire, 2nd ed. Seattle, WA: University of Washington Press. 680 p.

Swetnam, T.W. and J. L. Betancourt. 1997. Mesoscale disturbance and ecological response to decadal climatic variability in the American Southwest. Journal of Climate 11: 3128-3147.

Westerling, A.L., H.G. Hidalgo, and T.W. Swetnam. 2006. Warming and earlier spring increase western US forest wildfire activity. Science 313: 940-943. doi: 10.1126/science.1128834.

Wotton B.M. and M.D. Flannigan. 1993. Length of the fire season in a changing climate. Forestry Chronicle, 69,187-192.

Invasive/Introduced Species and Insects/Disease Northern Great Basin

1 Introduction

The invasive/introduced species CA includes terrestrial and aquatic introduced and exotic plant and animal species that have become entrenched in portions of the NGB and have resulted in adverse effects on native flora and fauna, including CEs. Insect outbreaks and disease alter natural communities and wildlife occurrences through direct mortality or loss of vigor, and changes in vegetation composition in natural communities.

This CA package provides the assessment of the current status and future threats that are anticipated due to CAs in the ecoregion. Information in this CA package includes a brief description of the invasive/introduced species CA and the insects/disease CA, some information on potential data sources and analytical methods for the assessment, and a listing of relevant MQs for this CA.

2 Change Agent Package Review Process

2.1 Subject Matter Expert Review

Subject Matter Experts play a key role in ensuring that the REA reflects the best available data and modeling processes suitable for each conservation element and change agent. Subject Matter Experts were added to Rolling Review Teams comprised of SAIC scientists, SAIC GIS personnel, AMT member(s) and other subject matter experts from the Department of Interior or state agencies. Membership of the Rolling Review Teams is listed in Appendix A. To ensure consistency amongst the different Rolling Review Teams, the number of lead SAIC scientists was limited to only a few individuals. This ensured that there was a common approach, or framework, used among the different Rolling Review Teams and that one Rolling Review Team did not stray too far from the rest. The USGS, as peer reviewers, were invited to participate in Rolling Review Teams.

3 Change Agents Description

An invasive species is defined in the BLM Integrated Vegetation Management Handbook as “Plants that are not part of (if exotic), or are a minor component of (if native), the original plant community or communities that have the potential to become a dominant or co-dominant species on the site if their future establishment and growth is not actively controlled by management interventions, or are classified as exotic or noxious plants under state or federal law. Species that become dominant for only one to several years (e.g., short-term response to drought or wildfire) are not invasive plants” (BLM 2008). Invasive species are often associated with human land use and other activities. This CA package also includes an analysis of introduced animal species that are of particular threat to CEs, such as game fish introduced into waters containing native fish and the Columbia spotted frog.

3.1 Change Agent Categories

Broad categories of these change agents were initially identified during Task 1 and refined based on the results of the literature review of the potential impacts on CEs in this ecoregion as well as the evaluation of relevant and available data for the analysis. As reported in Memo 1-C invasive species, insect and disease CAs in this REA include the following categories:

3.1.1 Cheatgrass, Medusahead, and other Invasive Grasses

The AMT specified that cheatgrass (*Bromus tectorum*), medusahead (*Taeniatherum caput-medusae*), ventenata (*Ventenata dubia*), and other annual invasive grasses should be covered in this analysis. Cheatgrass invades open areas created by fire and other disturbance in sagebrush ecosystems (National Invasive Species Council 2006). Cheatgrass outcompetes native perennial grasses under disturbance regimes such as repeated wildfires and profoundly influences fire regimes. Cheatgrass increases the continuity of fine-textured fuel which promotes larger and more frequent fires. Because the fire return interval is shortened, perennial vegetation is unable to completely recover before the next fire. Perennial vegetation is eventually reduced resulting in dominance by cheatgrass or medusahead. Medusahead infestations, although less widespread than cheatgrass in this ecoregion, similarly outcompete native plant species, increase the risk of large, severe wildfire, and form monocultures. Medusahead and ventenata are less widespread than cheatgrass but are also expanding their ranges.

3.1.2 Invasive Forbs

In response to comments on change agents in Memo 1, the AMT requested an effort to assess invasive non-native forbs (no-grass herbs) such as skeletonweed, knapweeds, whitetop, and others for which spatial data may be compiled by states. In general, exotic forbs establish in disturbed habitats and outcompete native plants, forming monocultures. Biological controls have been introduced for some invasive forb species with varying success. Many are noxious to wildlife and livestock.

3.1.3 Invasive Woody Plants (Russian-olive, tamarisk)

Saltcedar or tamarisk (*Tamarix* spp.) and Russian-olive (*Eleagnus angustifolia*) are invasive woody plants that establish in riparian habitats, often outcompeting native plants (Shafroth *et al.* 1995). Both species are present in the Great Basin, and Kerns *et al.* (2009) predicted that the range of tamarisk will expand within the NGB ecoregion in response to climate change. Dense stands of these shrubby trees can replace native willows, increase soil salinity, and increase water loss from riparian system (Lovich 1996). The presence of tamarisk in particular is associated with dramatic changes in geomorphology (including narrowing of stream channels), groundwater availability, soil chemistry, fire frequency, plant community composition, and native wildlife diversity (Graf 1978; Howe and Knoft 1991; Sala et al 1996; Anderson 1996; Lovich and de Gouvenain 1998).

3.1.4 Aquatic Invasive Species

Introduced aquatic animal species have become an issue in some western lakes, ponds, and reservoirs and often have adverse effects on native species. A major issue for the three NGB fish CEs and the spotted frog is the increasing presence of introduced species (often game fish such as rainbow and brook trout) that compete with the native species for habitat and food sources, hybridize with native fish species, or become predators on native aquatic species. For the white sturgeon in particular, non-native fish species prey on eggs, larvae and younger juveniles before they reach a viable size (Israel *et al.* 2009). Small populations of Columbia spotted frogs are threatened by invasive predatory fish species (salmonids and bass) and bullfrogs.

Other invasive species such as New Zealand mudsnails (*Potamopyrgus antipodarum*), quagga/zebra mussels (*Dreissena spp*), and Asian clams (*Corbicula fluminea*) adversely affect aquatic systems in various ways, encrusting substrates including the shells of native mussels, altering algae communities, producing waste, and dominating food webs (USGS 2012). New Zealand mudsnails are present in the

Snake River basin; the remaining species are not widespread in the western states at present but the waterways are vulnerable to introductions through boater activities.

3.1.5 Insect Outbreaks

Concerns over insect outbreaks in the western states have focused on forested habitats, which may be of greater concern in adjacent ecoregions such as the Middle Rockies. However, higher elevations in the NGB have forest stands that are dominated by Douglas-fir and other conifers, and thus are vulnerable to outbreaks of bark beetles (*Dendroctonus* spp.), western spruce budworm (*Choristoneura occidentalis*) and other insects. Aroga moth, which defoliates sagebrush, had a multi-state outbreak in 2012 following more localized outbreaks since the mid-2000s. Periodic outbreaks of locusts and Mormon crickets affect salt desert shrub communities. The frequency, scale, and effects of rangeland insect outbreaks are not well-known and have received comparatively little study relative to outbreaks in forested systems.

3.1.6 Diseases

Diseases of plants and animals have become more prominent in recent years and are a threat to several CEs chosen for the NGB. West Nile virus (WNV) is a source of mortality in greater sage-grouse (GSG) in some parts of the country since its introduction in 1999, and has the greatest potential for population-level effects among all parasites and infectious diseases identified in GSG (Christiansen and Tate 2011). WNV has been identified in GSG populations in ten states and may result in persistent low-level mortality and possibly severe outbreaks leading to local and regional population declines (Walker and Naugle 2011). Chytrid fungus and ranavirus are serious diseases affecting amphibians such as the Columbian spotted frog. White-nose syndrome, a fungal disease that is killing hibernating bats in eastern North America, may potentially spread into western states. Bacterial pneumonia causes severe respiratory disease and/or acute pneumonia in wild bighorn sheep populations and is a rising concern in Idaho, Nevada, Oregon and Utah because of the potential for transmission from domestic sheep. Not yet of serious concern in the NGB is chronic wasting disease, which affects mule deer and so far is concentrated in mid-western and northern Rockies states. Whirling disease is now present in Idaho and the significance of this and other diseases as CAs for native coldwater fishes is unknown at present but can be a serious problem in hatcheries where fish are densely confined.

Plant community CEs also have been affected by disease issues. In recent years, many aspen stands (which are typically many clones interconnected by roots) in other ecoregions have exhibited declines resulting from the effects of several change agents including climate change and mortality from biotic vectors. Pathogens primarily infect aspen clones already stressed by factors such as drought, insects, wind damage, heavy livestock and wildlife use. Climate change effects such as hotter and drier conditions may weaken the trees making them more vulnerable to insect attack and disease.

Cheatgrass die-off is discussed later in Section 4.2.3 and is the focus of a study conducted for the Northern Great Basin by Stephen Boyte, Bruce Wylie, Don Major and Mathew Rigge. The cheatgrass data was received at the end of the REA but its report will be a valuable resource for mapping the yearly extent of cheatgrass, areas where cheatgrass die-off is occurring and management implications for addressing cheatgrass die-off. The die-offs are of management concern since they offer opportunities for restoration, the introduction of other invasives, and loss of good spring forage (Baughman and Meyer 2013).

3.2 Change Agent Effect Pathways and Interactions

Invasive plants alter the relative abundance of native plant species for one (or often many) of the following reasons: they outcompete native species for water, nutrients, light and space; can be allelopathic, inhibit other species' growth; produce abundant seed; have fast growth rates; begin growth earlier in the season than native species; may exploit the entire soil profile for water and nutrients; have no natural enemies; and are often avoided by large herbivores that prefer native plants (Olsen 1999). Invasive fish and wildlife have the potential to displace native wildlife through competition, hybridization, and predation. Thus, invasive species may profoundly alter plant and animal community composition.

The direct effects of invasive species may also lead to alterations to ecological processes that native species and humans depend on for survival (NISC 2006). Damaging impacts of invasive infestations may include reduced ecosystem productivity, decreased carrying capacity for wildlife and livestock, lowered recreational values, increased soil erosion, decreased water quality, and loss of native species. As native vegetation becomes displaced, further alternations in natural ecosystem processes occur including changes in fire frequency and nutrient cycling.

Invasive species may interact with other CAs such as human development, wildfire and climate change to exacerbate the loss or degradation of native vegetation communities and wildlife populations. In particular, the expansion of invasive species is associated with human land use and other activities that disturb natural habitats. Linear developments such as roads and transmission lines provide effective vectors and the preferred disturbed habitat for invasive plant species. Similarly, recreational boating involving trailering of boats among water bodies in the region provides a movement corridor for aquatic invasives. The impacts of invasive species can be further exacerbated by over fertilization of soils, increasing atmospheric CO2 concentration, and climate change (USFS 2012). Increasing atmospheric CO_2 can accelerate the growth of opportunistic plant species and may be a factor in expansion of invasive annual grasses and juniper in recent decades. Similarly, deposition of atmospheric nitrogen may promote the growth of weedy species that are able to respond to its availability more rapidly than slower growing native species.

Table 3-1 depicts some of the pathways and interactions among these CAs and potentially affected CEs in the NGB ecoregions.

Table 3-1. Invasive/Introduced Species & Insects/Disease as Change Agents

Change Agent Category	Effect Pathways	Interactions with other CAs	Affected CEs
Invasive Terrestrial • Plants Annual grasses • Exotic forbs • Invasive woody plants	• Can change landscape and vegetative structure and composition • Can inhibit natural community succession • Can use vital water, light, space, and nutrients needed by native plants • Provide poorer forage for native wildlife, pollinators, livestock, wild horses and burros •	• Climate change may make some areas more susceptible to weed spread if weeds are more drought or heat tolerant than native species • Invasive plants can increase fire spread, frequency or durations that opens habitat to additional weed spread • Plants weakened by insects or disease may be less able to compete with weeds • May be spread by livestock in overgrazed or trampled areas and via their feed (e.g., hay)	• Most coarse filter vegetative CEs • Riparian Habitat • Cottonwood Galleries • Specially Designated Areas of Ecological Value • Livestock Grazing • Wild Horse & Burro Areas • Vulnerable Soils
Aquatic Invasive and Introduced Species • Mollusks • Non-native fishes • Bullfrogs	• Compete with native wildlife for habitat, cover, and food • Become predators on native wildlife • Hybridize with native fishes	• Spread may increase with changing climate effects (e.g., warmer water temperatures) • Spread may increase with human development and recreation • May spread or harbor insects and disease that affect native species	• Open Water • Perennial Streams & Rivers • Wetlands • Springs & Seeps • Coldwater Fish Assemblage • White Sturgeon • Bull Trout • Columbia Spotted Frog
Insect Outbreaks	• Episodic outbreaks are natural ecological processes; however, some outbreaks have been unusually widespread and severe • Typical winter mortality of some insect pests not occurring in recent years	• Can be enhanced with changing climate effects (e.g., warmer winters) • Species weakened by disease or drought may be more vulnerable to attack • May precede or follow wildfire	• Aspen • Other Conifers
Diseases	• Spread is assisted when native species unnaturally crowded into smaller habitats • Artificial situations (e.g., hatcheries) may introduce to native stock	• Can be enhanced with changing climate effects (e.g., warmer winters) • Human land uses and practices may promote spread (e.g., domestic sheep to bighorn sheep, humans entering bat caves) • May be enhanced following other environmental factors such as fire, insect outbreaks, pesticide use, introduced animals	• Greater sage-grouse • Bighorn sheep • Bats • Columbia Spotted Frog • Coldwater Fish Assemblage • Bull trout • White Sturgeon • Mule Deer (?) • Aspen • Other Conifers (?)

4 Data Sources and Modeling

4.1 Data Identification

Data needs (Table 4-1) for analysis for the Invasive/Introduced Species and Insects/Disease CA are described in the following sections. Data exist in a variety of formats and scales, covering many areas related to the analysis requirements. The main data source BLM uses for tracking invasive terrestrial plant species is the National Invasive Species Information Management System (NISIMS). Not all BLM state or field offices submit their data to NISIMS so the data distribution is limited to ones that do. Oregon state office has their own invasive dataset and Nevada tracks invasives through the Natural Heritage Program. The invasive species occurrences currently within NISIMS, BLM Oregon and Nevada Natural Heritage are shown in Figure 4-1. The data distribution is fairly well populated for some locations and species but lacking in some regions such as Oregon. Figure 4-2 is a graph showing the abundance of species observations (minimum 100 occurrences). The aquatic invasive detections in the ecoregion are shown in Figure 4-3. The cheatgrass distribution and risks are covered in Section 5.

Table 4-1. Preliminary List of CA Data Needs

Data Needs	Dataset Name	Source Agency	Type/ Scale	Status	Potential Use in REA
Terrestrial Occurrence Data	National Invasive Species Information Management System (NISIMS)	BLM	Polygon	Acquired	Yes
	BLM Idaho State Weed Data	BLM	Polygon	Acquired	Yes
	BLM Oregon State Weed Data	BLM	Polygon	Acquired	Yes
	Nevada Weed Data	Natural Heritage	Polygon	Acquired	Yes
	Cheatgrass	Peterson 2006, 2007	Raster	Acquired with Data Gap	Yes
	Cheatgrass	USGS/EROS	Raster	Acquired	Yes
	Soils, for potential natural vegetation types	NRCS	Polygon	Acquired	No
Aquatic Occurrence Data	USFS Aquatic Invasives	USFS	Point	Acquired	Yes
	Introduced Fish			Data Gap	
Insect outbreaks and Sudden Aspen Decline	Aerial Disease Detection Surveys	USFS		Acquired	Yes
Disease	Chytrid Fungus, Whirling and other Fish Diseases, West Nile Virus,			Data Gap	No

4.2 Uncertainty

The NISIMS (National Invasive Species Information Management System) is the BLM database for tracking invasives. The data within it must be sent in from state or field offices to be included so it is not a complete dataset. The data in Figure 4-1 shows where invasives have been located but areas shown without invasives in Figure 4-1 could have invasives, they just haven’t been surveyed or the information hasn’t been provided to NISIMS or the state datasets.

4.3 Analysis of Cheatgrass Distribution and Risk

4.3.1 Cheatgrass Distribution

The distribution of cheatgrass in the NGB REA was mapped primarily using data from Peterson (2006, 2007) and supplemented with data from Bradley and Mustard (2005) to provide the greatest coverage in the REA (Figure 5-1, Table 5-1). The Peterson data are based on Landsat imagery combined with modeling parameters (elevation-Nevada or average minimum temperature-Owyhee Uplands) while the Bradley and Mustard data are based on Landsat and AVHRR imagery and the AVHRR 1 km data were used to map the distribution. The Peterson data are continuous and should be considered to be a percent cover index rather than pure percent cover due to the modeling approach. Additionally, Peterson did not separate annual grass cover into separate distributions for the various species but the overwhelming amount is due to cheatgrass cover. Bradley and Mustard determined presence and absence of cheatgrass with presence constituting areas that were clearly dominated by cheatgrass such as monocultures or where it was the dominant herbaceous species around shrubs. Peterson noted that field verification showed that some areas were actually dominated by *Poa secunda* or by medusahead (Noted on Figure 5-1). While Peterson's data are continuous, he noted clear breaks in either the accuracy or detectability of cheatgrass and those breaks were preserved in the distribution mapping.

Table 5-1. Cheatgrass extent in the NGB REA

Peterson Coverage						Bradley Coverage		Total Coverage	REA
Category	0	>0 to <10%	10 to 25%	>25%	Total	Absent	Present	Area	Area
Acreage	10,774,872	11,647,635	8,001,865	3,096,759	33,521,130	17,197,037	7,940,230	58,658,397	63,787,043

SAIC was able to obtain the Singh and Glenn (2009) and Clinton *et al.* (2009), but not Clinton *et al.* 2010, cheatgrass mapping data sets for the Big Desert area in Idaho and Utah to compare the Bradley and Mustard (2005) (Figures 5-2 and 5-3). The results are shown overlaid on those of Bradley and Mustard (2005) to illustrate the range of variability that might be observed in cheatgrass mapping using different model parameters, spatial scales, and seasons.

The study of Singh and Glenn (2009) was conducted to demonstrate the potential utility of relatively low-cost "spectral stacking" in lieu of expensive hyperspectral imagery to map cheatgrass. They used four Landsat 7 Enhanced Thematic Mapper Plus scenes from 2002 that spanned the period when cheatgrass rapidly changes from green to dead (April 7, April 23, May 25, and June 26). Note that field sampling to calibrate the imagery was conducted in the Spring of 2004 because the necessary cloudless imagery for the appropriate period was only available for 2002.

Clinton *et al.* (2009) took a unique approach using the concept of a meta-predictor variable routine in the model to choose the best ensemble of predictor variables (microclimatic, topographic, and biotic) for each pixel. Two Landsat Thematic Mapper images (Spring and Summer) with 30-meter spatial resolution and 8-bit radiometric resolution (bands 1, 2, 3, 4, 5, and 7) were used in their study. Topographic data were obtained from the National Elevation Dataset with a spatial resolution of one arc-second (approximately 27.35 meters) to derive slope, aspect, sin(aspect) and cos(aspect). Field training data were collected over the 2005 and 2006 summer seasons (see Clinton *et al.* 2009 for details). See Clinton *et al.* (2009) for a full description of their modeling methods. The data shown in Figure 5-3 are continuous but were binned into the same categories as used by Peterson (2006, 2007) for purposes of visual comparison (See Figure 5-1).

Comparisons of both Singh and Glenn (2009) and Clinton *et al.* (2009) show the increased resolution that can be obtained using differing distribution modeling methods. In contemplating the utility of this increased resolution data we caution that it may be overly precise given the dynamic seasonal changes in the density and thus apparent distribution changes of cheatgrass.

4.3.2 Cheatgrass Invasion Risk Assessment

The data of Meinke *et al.* (2009) were used to produce the cheatgrass invasion risk assessment map. Those data were produced through modeling potential cheatgrass habitat separately for the Northern Great Basin and the Snake River Plain (2 km resolution) and using logistic regression to score each pixel and then rank the grid cells into 10 decilies with the top 5 deciles reported and mapped. The urban and agricultural cover types were extracted from the Landfire EVT dataset resampled to 2160 and used to remove portions of the Meinke *et al.* dataset where there was overlap. USGS 90 m digital elevation model data and STATSGO soil data (depth to rock, soil pH, soil salinity, and available water capacity) were used for the Snake River Plain model while the elevation data were excluded from the Northern Great Basin model. The resulting map was compared to the Peterson data (2006, 2007) and the Bradley and Mustard data (2005) and where those data indicate existing cheatgrass dominance those areas were "blacked" out on the map as already dominated by cheatgrass.

We caution that the Bradley and Mustard (2005), Peterson (2006, 2007), and Meinke *et al.* (2009) datasets were provided as gridded raster data in three different geographic projections. In order to work with the data one projection, Peterson (2006) (NAD83 UTM Zone 11), was selected as the primary projection and the other two datasets wee reprojected to the primary projection. Re-projection of the raster data introduced spatial distortions into the raster data and SAIC recommends that the resulting data be used for regional comparisons within the NGB REA but not fine scale quantitative analysis of geographical areas of small extent.

Note that there are potential exceptions in the Owyhee Uplands for areas that are actually dominated by medusahead (Peterson 2006, 2007) as generally indicated in Figure 5-1. These areas cannot be separated out at the level of the NGB REA analysis.

The cheatgrass habitat model results of Meinke *et al.* (2009) for moderate to high cheatgrass conducive habitat with the existing areas dominated by cheatgrass removed provide three clear patterns (Figure 5-4). First, essentially all of the moderate to high vulnerable areas to cheatgrass invasion in Idaho are already dominated by cheatgrass. Second, there is a substantial area in northwestern Utah that was not dominated by cheatgrass at the time of the distribution mapping. Third, there are substantial areas of moderate to high vulnerable areas to cheatgrass invasion in the Owyhee Upland, northwestern Nevada, and northeastern California that are not dominated by cheatgrass.

4.3.3 Cheatgrass Die-off Probability Assessment

Wylie *et al.* 2010 defined cheatgrass die-off as the reduced production, or absence, of cheatgrass in previously invaded areas during years of adequate precipitation (Boyte *et al.* 2012) and have provided data that cover most of the NGB REA (Figure 5-5). Their analysis was conducted using eMODIS NDVI 250-meter imagery, Peterson's results (2006, 2007), combined with regression-tree and decision tree models, and the Ecosystem Performance Anomaly (EPA) approach (Boyte *et al.* 2012; Gu *et al.* 2012; Wylie *et al.* 2012). The first step of the process created a cheatgrass distribution model based on piece-wise multiple regression of number of factors (NDVI index or relative spring to summer photosynthesis, spring NDVI, summer NDVI, SURGO soils data available water capacity, elevation, an unspecified wetness index, and the NRCS MLRA expert opinion land classification by soil scientists (soils, climate, geology, and land use). The second step of the process created a distribution map based on 2000-2010 imagery and piece-wise multiple regression of number of factors (Petersons data, precipitation, elevation, slope, and aspect). This result produces an Actual Ecosystem Performance (AEP) value for a particular year. To generate an Expected Ecosystem Performance value the pixel mean was compared to the pixel median for the 200-2010 period. This result was then relativised using a piece-wise multiple regression on PRISM climate data (precipitation, maximum temperature, and minimum temperature) for defined seasonal periods (October, November to February, March, April, and May) to calculated an Expected Ecosystem Performance (EEP) value. The difference between the AEP and The

EEP is considered to be an anomaly (Ecosystem Performance Anomaly or EPA) which is analogues to a disturbance of cheatgrass cover. Each pixel was then analyzed using a piece-wise multiple regression for factors that were correlated with the EPA value (maximum temperature, minimum temperature, precipitation, soil water capacity, elevation, NRC MLRA, nlcd, cti, lfesp, soc, nslp, and sslp – italicized factors were not defined).

The results suggest that the greatest extent of die-off will be in the Snake River plains, north central Nevada, and the Owyhee Uplands (Figure 5-5). SAIC cautions that these results should be considered to be preliminary and applied on a regional basis and to very local situations due to the multiple inclusion of the same or correlated factors in the modeling process and the use of Model I instead of Model II regression approaches (Sokal and Rohlf 1995; Legendere 2012) with the regression forced through the origin as illustrated in Figure 5-3 of Wylie *et al.* (2012) which resulted in a reduced slope coefficient and a tendency to produce more frequent EPAs. There is some indication that this may have been corrected in the analysis but the methods are not stated fully (Wylie *et al.* 2012). Additionally, cheatgrass die-off is the result of seedling mortality during germination and may be persistent or temporary and appears to depend on both the genotype of the pathogen and environmental conditions at the time of germination (Meyer *et al.* 2012).

4.4 Interactions with Other Change Agents

Climate change effects such as hotter and drier conditions may weaken the trees (such as aspen and other conifer coarse filter conservation elements) making them more vulnerable to insect attack and disease. With respect to invasive weeds, climate envelope modeling indicates that cheatgrass habitat suitability would be reduced in the ecoregion if climate changes results in increased precipitation during the summer (June-September) (Bradley 2009). This change would favor native shrubs that continue growing through the summer months. Based on the Hostetler 2060 climate modeling predictions, June is projected to have a slight increase in precipitation with July and August mostly the same level of precipitation with isolated areas of increased and decreased precipitation. Therefore it is not clear how changes in summer precipitation will impact cheatgrass habitat suitability. The replacement of native vegetation with invasives such as cheatgrass and other annual grasses will also increase the fire frequency. Invasives such as cheatgrass increase the burn probability and can be the first to recolonize recently burned areas. Disturbance from development often provides bare ground habitat that invasives can colonize and then outcompete native plants. Movement of livestock from one area another can facilitate the expansion of herbaceous weed species. Bacterial pneumonia can spread from domestic sheep to wild Bighorn sheep.

5 Management Questions

MQ 38. What is the current distribution of invasive species included as CAs?

The current distribution of invasives is shown by NISIMS occurrences in Figure 4-1, by aquatic invasive detections in Figure 4-3, and by cheatgrass distribution in Figure 5-1.

MQ 39. What is the relative abundance or intensity of effect of invasive species included as CAs (dominant/non-dominant, presence/absence, or not detected)?

The relative abundance of various invasive species is shown in Figure 4-2 from the NISIMS database. In addition Figure 5-1 provides a range of cover estimates for cheatgrass from Peterson (2006,2007). The number of detections of aquatic invasives is shown in Figure 4-3.

MQ 47. Where have designated recreation areas, such as for off-highway vehicle (OHV) use, affected CEs and invasive species?

It is difficult to determine the causality of invasive species spread with the data at the ecoregional scale. However, recreation (boats), machinery and OHV use can transport invasive plant species from one location to the other through clothing and vehicles. The locations of some of the designated recreation areas and OHV areas are shown in Figure 5-9 and Figure 5-10 in the Development CA package.

MQ 48. Where are other areas of likely high OHV use [as determined by modeling] that may affect CEs and invasive species?

Other likely areas of OHV use are on private ranchlands. The private and 4WD roads from the TIGER dataset are shown in Figure 5-11 of the development package. The intensity of OHV use will be highest in close proximity to urban and suburban area.

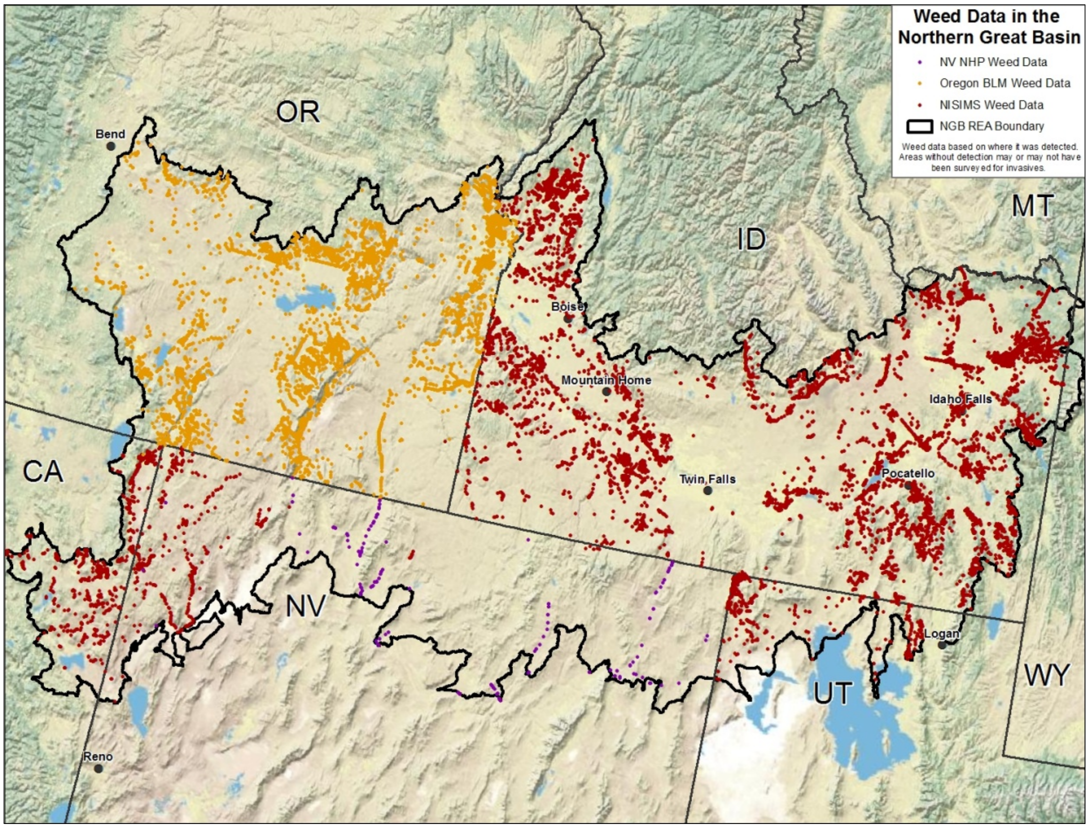

Figure 4-1. Invasive Species within the NGB Ecoregion (NISIMS, NNHP, BLM Oregon)

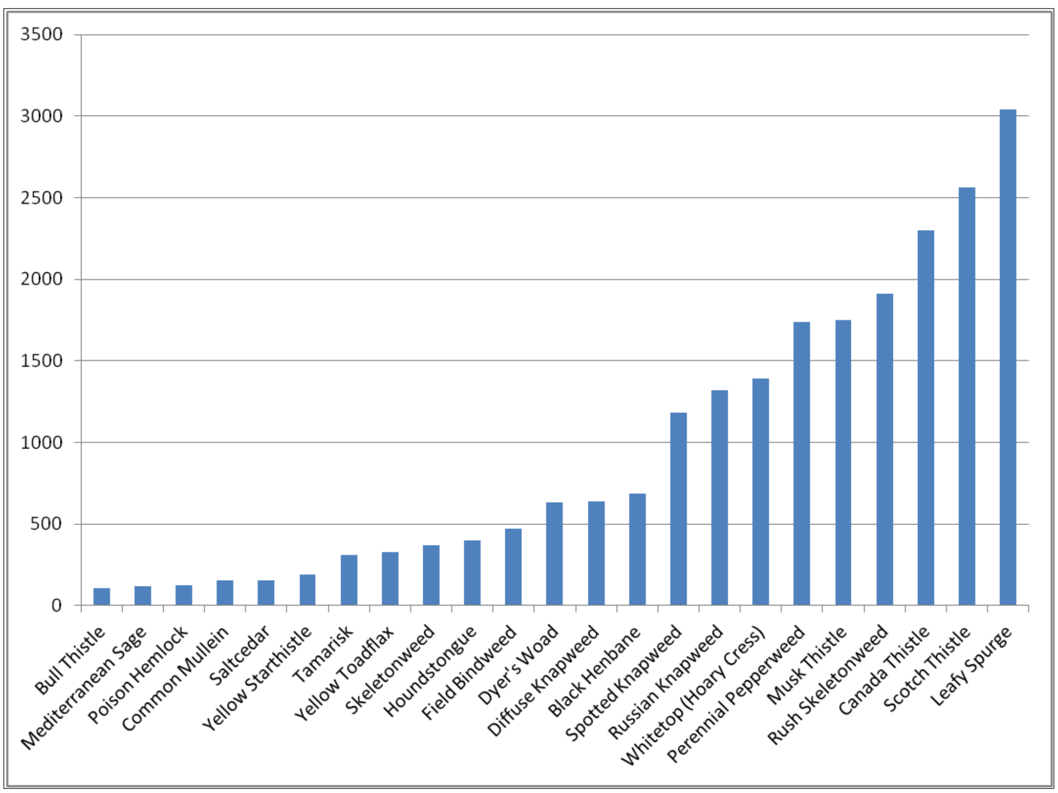

Figure 4-2. Invasive Species Occurrences in NGB Ecoregion within NISIMS (min. 100 occurrences)

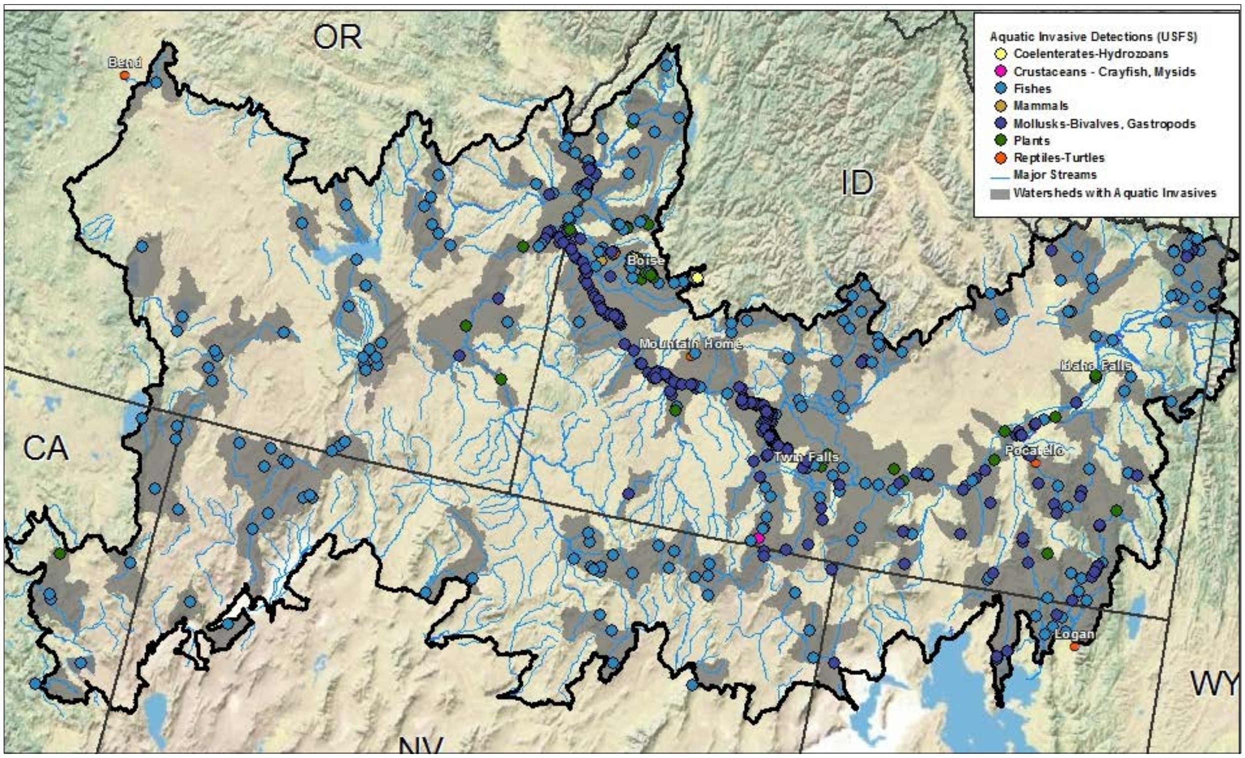

Figure 4-3. Invasive Aquatic Detections

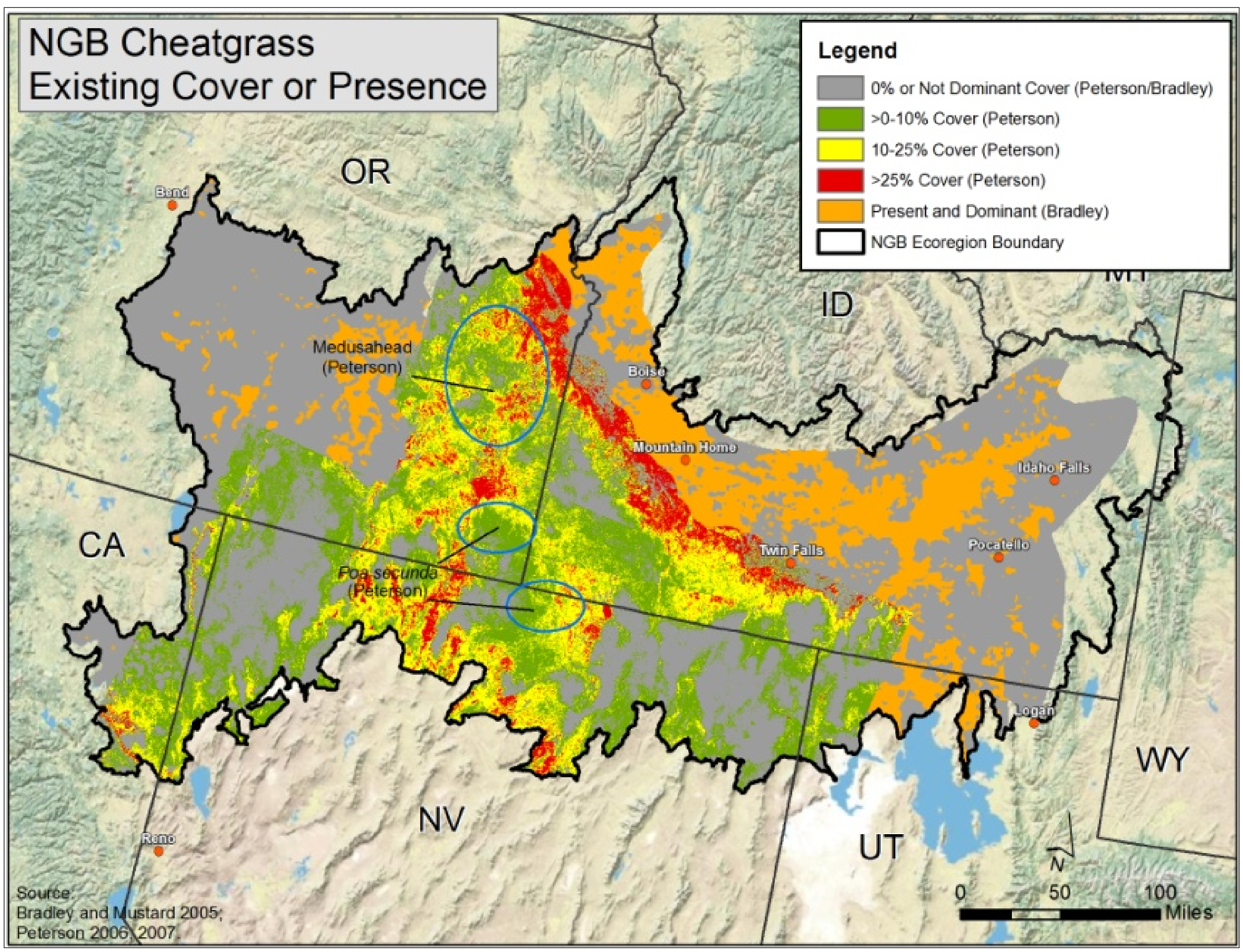

Figure 5-1. Cheatgrass Distribution in the NGB REA

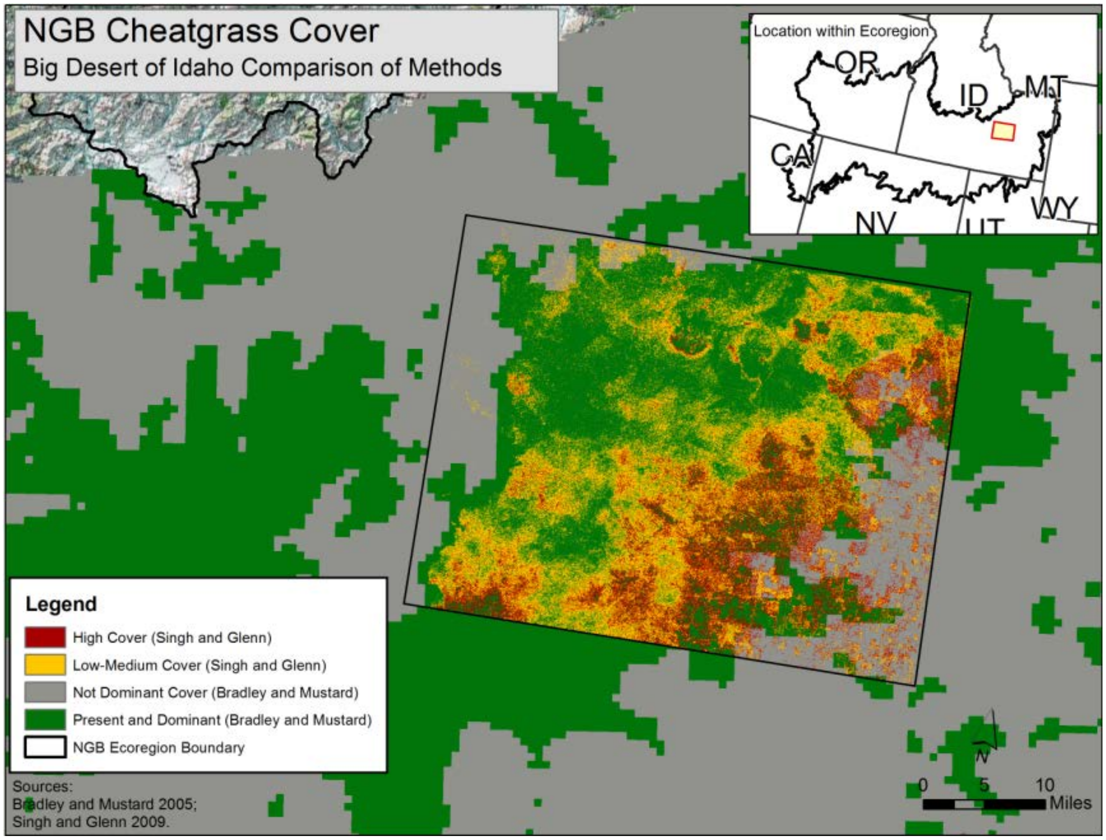

Figure 5-2. Comparison of Singh and Glenn (2009) Mapping in the Big Desert with Bradley and Mustard (2005)

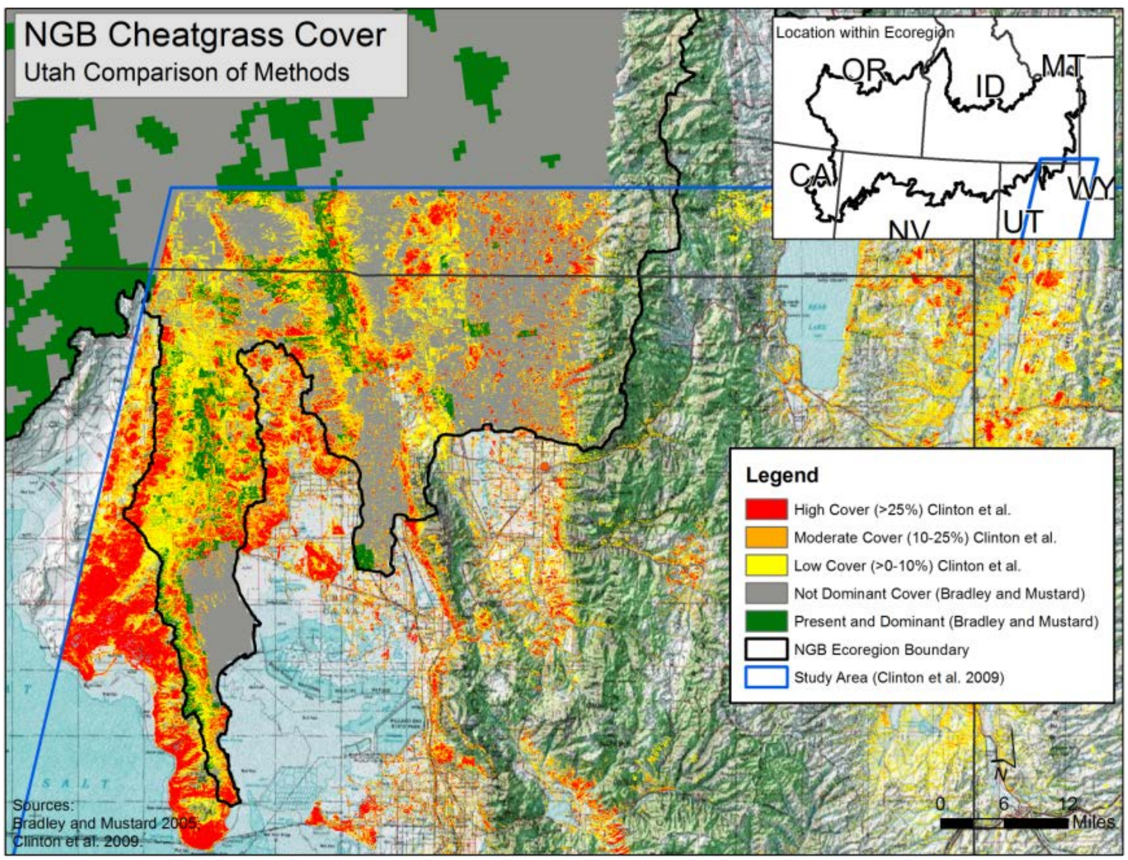

Figure 5-3. Comparison of Clinton et al. (2009) Mapping in Northern Utah with Bradley and Mustard (2005)

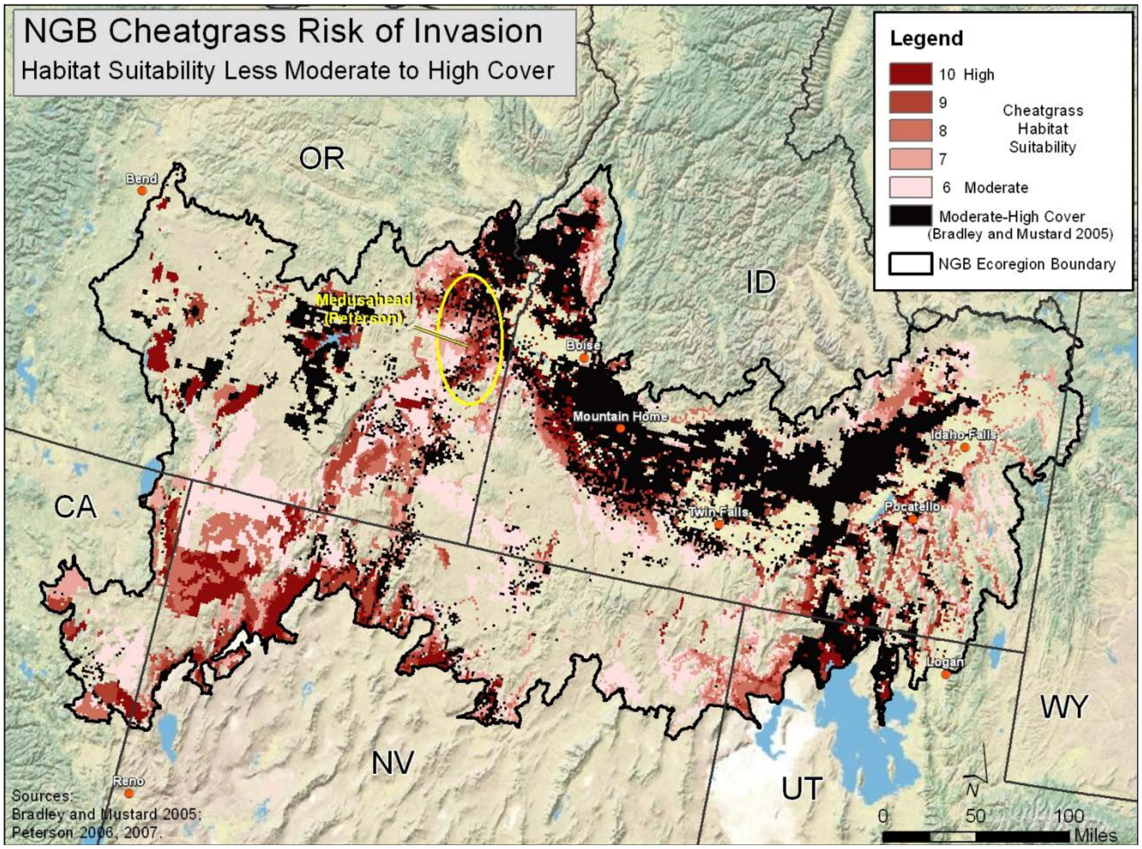

Figure 5-4. Potential Risk of Cheatgrass Invasion

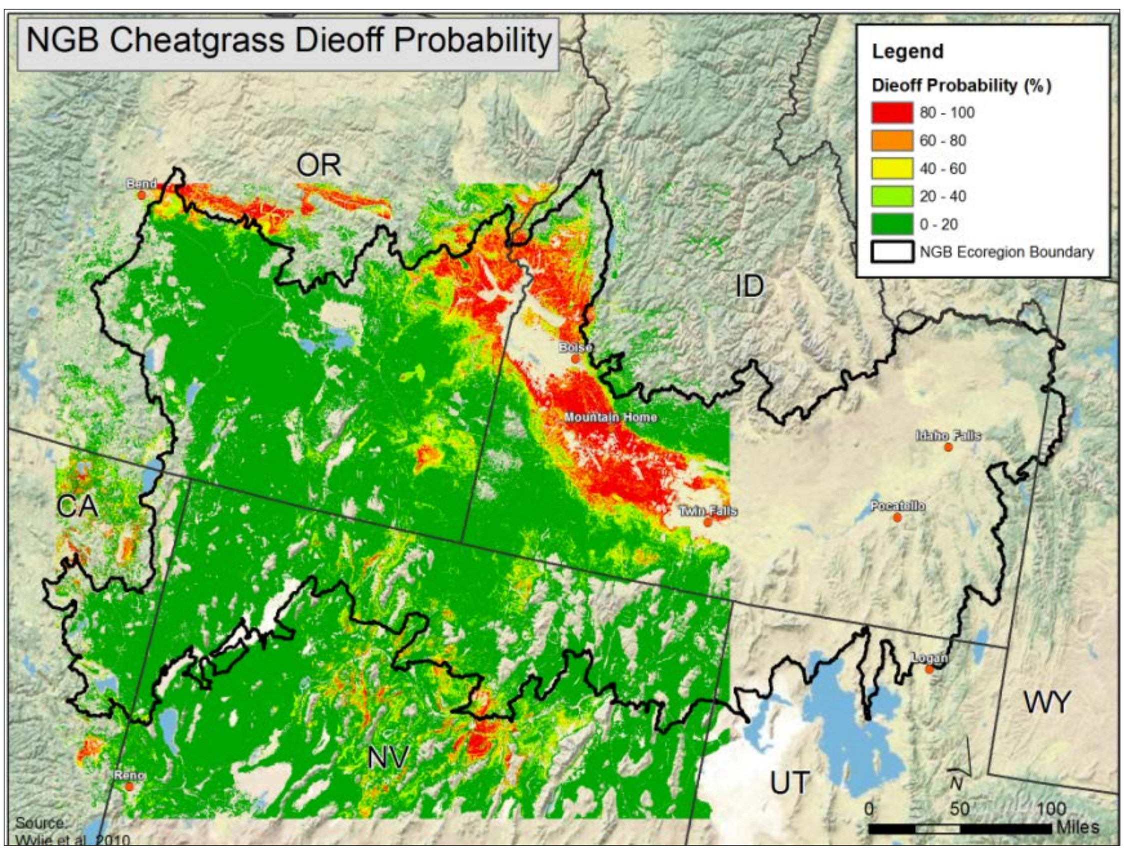

Figure 5-5. Cheatgrass Die-off Probability

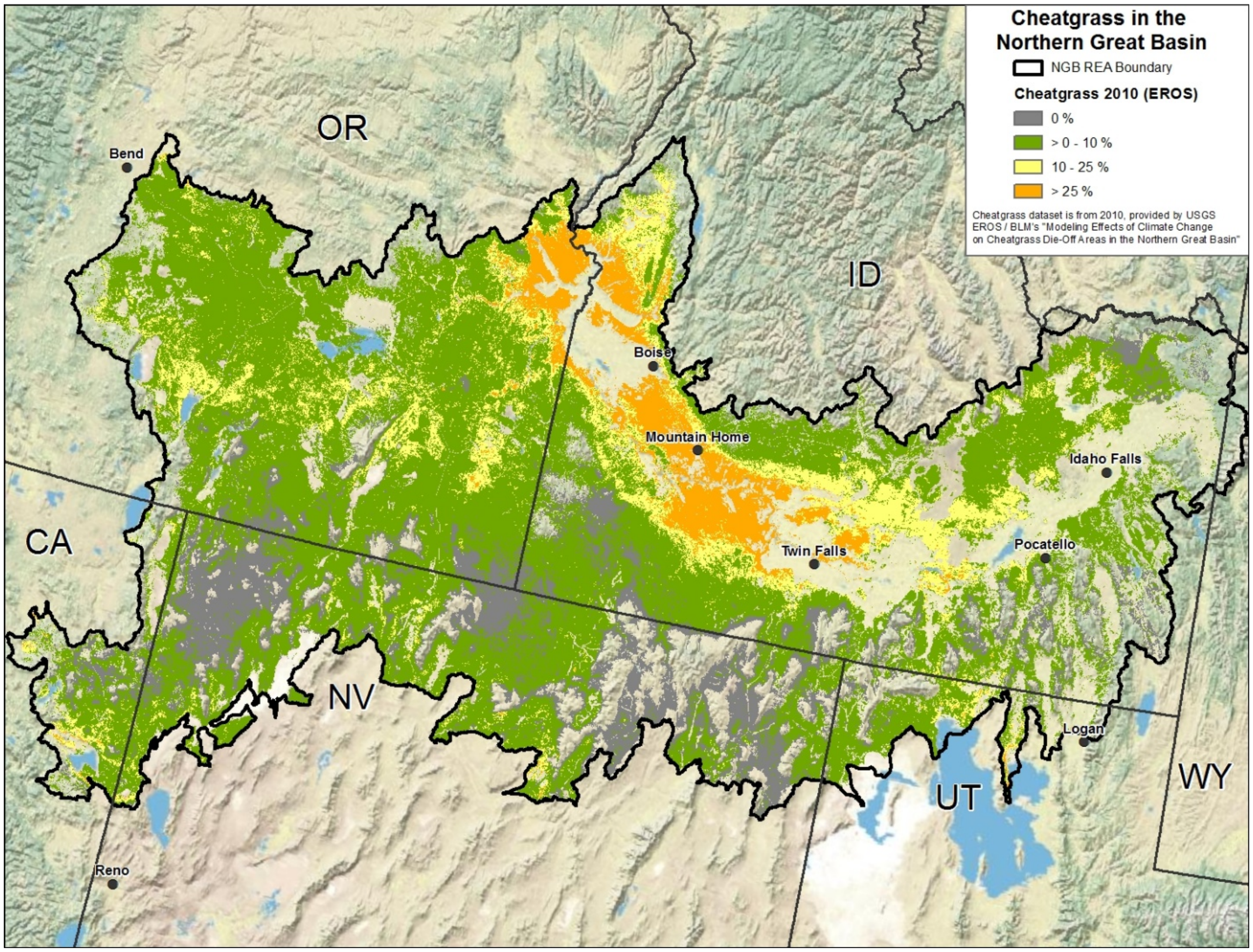

Figure 5-6. Cheatgrass Coverage in 2010 (EROS/USGS 2012)

6 References

Anderson, B.W. 1996. Salt cedar, revegetation and riparian ecosystems in the southwest. In M. Kelly, E. Wagner, and P. Warner, editors. Proceedings California Exotic Pest Plant Council Symposium 4:1998:7-10.

Boyte, S.P., B.K. Wylie, D.J. Major. 2012. Mapping interannual cheatgrass production and die-off using remote sensing and ecological models. Great Basin Fire Science Delivery Project. Cheatgrass die-off in the Great Basin: quantifying spatial extents and potential causal mechanisms of cheatgrass die-off. Webinar presentation, March 6, 2012. http://www.gbfiresci.org/webinars-and-workshops/

Bradley, B.A. and J.F. Mustard. 2005. Identifying land cover variability distinct from land cover change: cheatgrass in the Great Basin. Remote Sensing of Environment 94:204-213.

Christiansen, T.J. and C.M. Tate. 2011. Parasites and infectious diseases of greater sage-grouse. In: Chapter 8 of Greater Sage-Grouse: Ecology and Conservation of a Landscape Species and Its Habitats. S.T. Knick and J.W. Connelly (eds.). Published for the Cooper Ornithological Society, University of California Press.

Clinton, N.E., P. Gong, Z. Jin, B. Xu, and Z. Zhu. 2009. Meta-prediction of *Bromus tectorum* invasion in central Utah, United States. Photogrammetric Engineering & Remote Sensing 75:689-701.

Clinton, N.E., Potter, C., Crabtree, B., Genovese, V., Gross, P., Gong, P. 2010. Remote sensing based time-series analysis of cheatgrass (*Bromus tectorum* L.) phenology. Journal of Environmental Quality 39:955-963.

Graf, W.L. 1978. Fluvial adjustments to the spread of tamarisk in the Colorado Plateau region. Geological Society of America bulletin 89(10):1491-1501.

Gu, Y., S.P. Boyte, B.K. Wylie, and L.L. Tieszen. 2012. Identifying grasslands suitable for cellulosic feedstock crops in the Greater Platte River Basin: dynamic modeling of ecosystem performance with 250 m eMODIS. Global Change Biology, Bioenergy 4: 96-106.

Howe, W.H. and F.L. Knopf 1991. On the imminent decline of Rio Grande cottonwoods in central New Mexico. Southwestern Naturalist 36(2):218-224.

Israel, J., A. Drauch and M. Gingras. 2009. Life History Conceptual Model for White Sturgeon (*Acipenser transmontanus*). California Department of Fish and Game Delta Regional Ecosystem Restoration and Implementation Program (DRERIP). 54 pp.

Kerns, B.K., Naylor,B.J., Buonopane,M. Parks, C.G., Rogers, B. 2009. Modeling tamarisk (Tamarix spp.) habitat and climate change effects in the northwestern United States. Invasive Plant Science and Management 2:200-215. Legendre, P. Model II regression user's guide, R edition. Comprehensive R Archive Network. Downloaded 01/15/2013. http://cran.r-project.org/

Lovich, J.E. 1996. A Brief Overview of the Impact of Tamarisk Infestation on Native Plants and Animals. In: Proceedings of the Saltcedar Management Workshop, June 12, 1996, Rancho Mirage, CA.

Lovich, J.E. and R.C. de Gouvenain. 1998. Saltcedar invasion in desert wetlands of the southwestern United States: ecological and political implications. In S.K. Majumdar, E.W. Miller and F.J. Brenner, editors. Ecology of Wetlands and Associated Systems. Pennsylvania Academy of Sciences.

Meinke, C.W., S.T. Knick, and D.A. Pike. 2009. A spatial model to prioritize sagebrush landscapes in the Intermountain West (U.S.A) for restoration. Restoration Ecology 17:652-659.

Meyer, S., P. Weisberg, E. Leger, B. Geary, Z. Aanderud, and J. Beckstead. 2012. Exploring the causes and consequences of cheatgrass die-offs in the Great Basin. Great Basin Fire Science Delivery Project. Cheatgrass die-off in the Great Basin: quantifying spatial extents and potential causal mechanisms of cheatgrass die-off. Webinar presentation, March 6, 2012. http://www.gbfiresci.org/webinars-and-workshops/

National Invasive Species Council (NISC). 2006. Invasive Species Definition Clarification and Guidance White Paper. U.S. Department of the Interior. Washington, DC. Website accessed at http://www.invasivespecies.gov/ISAC/White%20Papers/ISAC_Definititions_White_Paper_FINAL_VERSION.pdf.

_____. 2012. U.S. Department of the Interior. Washington, DC. Website accessed at http://www.invasivespecies.gov.

Natural Resources Conservation Service (NRCS) 2012, United States Department of Agriculture. U.S. General Soil Map (STATSGO2). Available online at http://soildatamart.nrcs.usda.gov. Accessed June 20, 2012.

Olson, B.E. 1999. Impacts of noxious weeds on ecologic and economic systems. *In*: Biology and Management of Noxious Rangeland Weeds, R.L. Sheley and J.K. Petroff, eds. Oregon State University Press, Corvallis, OR. Made available by BLM on internet at: ftp://blm-92-59.blm.gov /pub/blmlibrary/UserRequests/Jorgensen/08.pdf.

Peterson, E.B. 2003. Mapping Percent Cover of the Invasive Species *Bromus tectorum* (Cheatgrass) over a Large Portion of Nevada from Satellite Imagery. Prepared for U.S. Fish and Wildlife Service, Nevada State Office, Reno, NV. Available online at: http://www.landscapeecology.com/Info/Peterson_2003_Cheatgrass.pdf.

Peterson, E.B. 2005. Estimating cover of an invasive grass (Bromus tectorum) using tobit regression and phenology derived from two dates of Landsat ETM+ data. International Journal Remote Sensing 26:2491-2507.

Peterson, E.B. 2006. A map of invasive annual grasses in Nevada derived from multitemporal Landsat 5 TM imagery. Report prepared for the USBLM, Nevada state office. Reno, Nevada.

Peterson, E.B. 2007. A map of invasive annual grasses in the Owyhee Uplands, Spring 2006, derived from multitemporal Landsat 5 TM imagery. Report prepared for the USBLM, Nevada state office. Reno, Nevada.

PRISM Climate Group. 2010. Parameter Elevation Regressions on Independent Slopes Model climate mapping system. Oregon State University, Corvallis, OR. Available on internet at: http://prism.oregonstate.edu.

Sala, A., S.D. Smith and D.A. Devitt. 1996. Water use by *Tamarix ramosissima* and associated phreatophytes in a Mojave Desert floodplain. Ecological Applications 6(3):888-898.

Shafroth, P.B., G.T. Audble and M.L. Scott. 1995. Germination and establishment of the native plains cottonwood (Populus deltoides Marshall subsp. Monilifer) and the exotic Russian-olive (Elaeagnus angustifolia L. Conservation Biology 9(5): 1169-1175.

Singh, N. and N.F. Glenn. 2009. Multitemporal spectral analysis for cheatgrass (*Bromus tectorum*) classification. International Journal of Remote Sensing 30:3441-3462.

Sokal, R.R. and F.J. Rohlf. 1995. Biometry: The principles and practice of statistics in biological research. W.H. Freeman, 3rd ed., New York.

Tausch, R.J. 2008. Invasive Plants and Climate Change. U.S. Department of Agriculture, Forest Service. Climate Change Resource Center. Website accessed at http://www.fs.fed.us/ccrc/topics/invasive-plants.shtml.

U.S. Census Bureau. 2012. 2010 Census TIGER/Line® Shapefiles Technical Documentation. Issued June 14. Available on internet at: http://www.census.gov/geo/www/ tiger/tgrshp2010/ TGRSHP10SF1.pdf.

U.S. Forest Service (USFS). 2012. Invasive species research. Rocky Mountain Research Station, Fort Collins, CO. Website available at http://www.rmrs.nau.edu/invasive_species.

USGS. 2010. Landfire Existing Vegetation Type. Wildland Fire Science, Earth Resources Observation and Science Center, U.S. Geological Survey. Data downloaded January 8, 2013.

U.S. Geological Service (USGS). 2012. Non-indigenous aquatic species. U.S. Geological Survey website available online at http://nas.er.usgs.gov/default.aspx.

Velman, W. 2012. Email on updated invasive species information from Wendy Velman, Botany Program Lead, BLM MT/DK, Montana State Office, Billings, MT to Anthony D Caselton and Jamie A. Leiendecker, SAIC, Inc. Sent April 24, 2012.

Walker, B.L. and D.E. Naugle. 2011. West Nile virus ecology in sagebrush habitat and impacts on greater sage-grouse populations. *In:* Chapter 9 of Greater Sage-Grouse: Ecology and Conservation of a Landscape Species and Its Habitats. S.T. Knick and J.W. Connelly (eds.). Published for the Cooper Ornithological Society, University of California Press.

Wylie, B.K., S.P. Boyte, and D.J. Major. 2010. Mapping Cheatgrass Dieoff in the Northern Great Basin using Ecosystem Performance Modeling. USGS Earth Resources Observation and Science Center. Data downloaded January 8, 2013.

Wylie, B.K., S.P. Boyte, and D.J. Major. 2012. Ecosystem performance monitoring of rangelands by integrating modeling and remote sensing. Rangeland Ecology & Management 65:241-252.

Livestock Grazing Change Agent Package
Northern Great Basin

1 Introduction

Successful completion of this REA will in part be based on a sound understanding of the landscape-scale change agents (CAs) and their potential impact on ecological values throughout the Northern Great Basin (NGB) ecoregion. CAs are natural or anthropogenic disturbances that influence the current and future status of conservation elements (CEs). The initial CAs for this ecoregion were outlined by the Assessment Management Team (AMT) in the Scope of Work.

The AMT determined that livestock grazing was appropriately identified both as a CA and a CE and developed a series of grazing-oriented management questions (MQs) accordingly. This is due to the fact that if monitored properly grazing can be an effective tool used to improve the health of native rangelands and grasslands, and manage introduced species (seeded and invasive grasses),or, if mismanaged, can reduce the quality of those lands.

This CA package provides the assessment of the current status and future threats that are anticipated due to CAs in the ecoregion. Information in this CA package includes a brief description of the livestock grazing CA, some information on potential data sources and analytical methods for the assessment, and a listing of relevant MQs for this CA.

2 Change Agent Package Review Process

2.1 Subject Matter Expert Review

Subject Matter Experts play a key role in ensuring that the REA reflects the best available data and modeling processes suitable for each conservation element and change agent. Subject Matter Experts were added to Rolling Review Teams comprised of SAIC scientists, SAIC GIS personnel, AMT member(s) and other subject matter experts from the Department of Interior or state agencies. Membership of the Rolling Review Teams is listed in Appendix A. To ensure consistency amongst the different Rolling Review Teams, the number of lead SAIC scientists was limited to only a few individuals. This ensured that there was a common approach, or framework, used among the different Rolling Review Teams and that one Rolling Review Team did not stray too far from the rest. The USGS, as peer reviewers, were invited to participate in Rolling Review Teams.

3 Livestock Grazing Change Agent Description

3.1 Livestock Grazing Change Agent Effect Pathways

The AMT made the decision to include an analysis of livestock grazing in the NGB REA (whereas most of the earlier REAs did not specifically address livestock grazing as a CA) to recognize the impacts of livestock grazing (both positive and negative) as a CA and land management tool in the ecoregion. The management of livestock grazing is also a major responsibility of the BLM in the western U.S. Livestock grazing can affect the vegetation community structure and composition, woody plant regeneration, riparian area health, nutrient cycling, fire fuel availability, wildlife forage amounts, soil stability and compaction, invasive species spread, and many other ecosystems aspects that relate to other CAs and CEs (Freilich *et al.* 2003; Holechek *et al.* 1982; Yeo 2005). Table 3-1 lists some of these effects pathways that intersect with other CAs and CEs in the NGB. This listing is not intended to be comprehensive but indicates some of the ways in which the analysis of this CA can proceed.

Table 3-1. Livestock Grazing as a Change Agent

Change Agent Habitat Category	Change Agent Level of Effects[1]	Effect Pathways	Interactions with other CAs	Affected CEs
Riparian/ Wetland Habitats	High	• Depending upon condition of habitat and grazing intensity, grazing can change vegetation structure and composition • Can be used to reduce fire fuel levels and deter tree encroachment • If not managed properly, grazing can have severe effects on riparian areas (streambank stability, stream morphology, water quality, soil erosion/ sedimentation) • Lands maintained for grazing offer undeveloped, open space buffers from development and habitat for wildlife (but can also cause habitat fragmentation due to access roads, fences, and livestock congregation areas) • Livestock can aid in spread of invasive species or can be used for their removal (e.g., goats) • Riparian areas tend to be resilient and recover in short timeframes while shrubland degradation may take longer to recover.	• Development for urban, suburban, exurban and rural uses usually are incompatible with grazing allotments; cropland development may utilize quality rangelands • Climate change may exacerbate droughts and thus reduce forage production for grazing and soil and vegetation moisture, which increases fuels that carry fire • Grazing may increase or reduce invasive species, which offer poor forage value, some are toxic to livestock, and may increase fuel loads to carry fires further distance, longer duration, or more frequently than normal • Diseases and insects can also affect livestock and spread quickly and easily in large herds	• Many coarse filter vegetative CEs that include grasslands and shrublands and in some areas aspen • Coarse filter aquatic habitat including riparian, cotton-wood galleries, streams and rivers, springs and seeps, wetlands, and open water • Many fine filter CEs that share habitats with livestock including greater sage-grouse, pronghorn, and mule deer; and bighorn sheep are affected by domestic sheep • Vulnerable soils are affected by compaction, trampling, and altered nutrient cycling • Fish CEs can be affected if streams are over-utilized by livestock • Wild Horse and Burro Areas may compete for rangelands and forage • Other Specially Designated Areas, some may not be compatible with grazing
Shrublands	Moderate			
Grasslands	Low			

Note: [1] Levels given are typical examples given usual resilience of these habitats. Level of effects will depend upon grazing seasons, duration, intensity, habitat health and forage present, and other factors in the area.

Some of these aspects are measurable and able to map geospatially and some may not be. Livestock management improvements such as the addition of fencing, development of springs, and woody plant reduction may have positive or adverse effects on wild horses and burros and wildlife habitat availability and access; however, since these improvements are more development-oriented, are discussed in the Development CA package.

The BLM has a long history of livestock management and continues to monitor and collect data on the health of individual grazing allotments that each field office manages by tracking whether allotments meet standards and guidelines. In addition, the USGS analyzed BLM range health assessments for grazing allotments to review the land health of these allotments (USGS 2011). There was not a complete coverage of range health assessments across the NGB ecoregion and there also were differences between how states conduct or assess rangeland health. Another difficulty with the range health assessment study was that if one part of a grazing allotment wasn’t meeting the standard, the entire allotment was coded as not meeting standards. This caused an over-estimation of the amount of grazing land not meeting rangeland health standards. Once areas are identified that are not meeting standards or progressing towards meeting standards, BLM must make changes in livestock grazing management within one year. These range health assessment data can also be combined with mapping of sensitive/vulnerable habitat areas or future development projects to find areas of concern and in need of additional management actions. Areas more vulnerable to erosion and trampling by livestock, such as slopes, thin soils, wetland and riparian areas, and concentration areas (feedlots, loading areas) can also be identified geospatially. In a similar manner, areas identified as needing additional grass fuel removal can be pinpointed and grazing strategies can be employed to meet fuels management objectives where local data verify the need for fine fuels management or longer seasons to reduce the risk of carrying wildfire.

As grazing affects other resources, so may the effects of climate change affect the types and amounts of forage available on grazing allotments. The distribution of both plant species and vegetation communities is determined by temperature and precipitation gradients in the intermountain West (Chambers and Pellant 2008). Since it is believed climate change may affect these variables, grazing resources may also be affected.

4 Data Sources, Methods, Models and Tools

4.1 Data Identification

Preliminary data needs for analysis of the Livestock Grazing CA are described in the following sections. Since the REA process is a landscape level data-intensive effort utilizing geospatial tools but grazing is managed locally through grazing allotments, the AMT struggled with how best to understand and analyze locally managed but regionally important grazing effects within the framework of the REA. Nearly all BLM-managed lands in the NGB contain grazing allotments leased to the public and the amount and types of grazing data is vast but likely differs across field offices. Specific challenges to evaluating grazing within the REA process include: 1) the availability and consistency of data scaled for the ecoregion is questionable; 2) the historic and current effects on the landscape are ubiquitous in the west; 3) available data may be limited to identified allotments and authorized potential grazing intensity, but may not reflect actual or future use; and 4) the management and decision process related to types, intensity, and ecological considerations likely differ across field offices.

Table 4-1 indicates some data sources acquired for this CA that include BLM mapping of grazing allotments and other databases that will assist in determining land condition under different grazing regimes. All vector datasets applicable to the NGB were clipped and merged to the ecoregion boundary to create one layer. Raster datasets were extracted and mosaicked together to create one 30-meter raster grid. Outputs will include raster datasets with a 30-meter raster grid showing vegetation condition class (VCC), and fuels data may be used to answer the MQ on where grazing could reduce continuity of fine fuels, which could potentially reduce size and spread of fire. However, ignition potential isn't likely to be changed.

Table 4-1. Preliminary List of CA Data Needs

Data Required	Dataset Name	Source Agency	Type/Scale	Status	Potential Use in REA
Grazing Locations and Seasons	BLM Grazing Allotments	BLM	Polygons	Acquired	Yes
	USFS Grazing Allotments	USFS	Polygons	Acquired	Yes
	Range-wide Assessment of Livestock Grazing	USGS	Polygon	Acquired	Yes
	Land Treatment Digital Library	USGS	Polygon	Acquired	Yes
	Pasture Boundaries	BLM	Polygon	Acquired	Yes
Land Condition	Vegetation Classes	LANDFIRE, ReGAP	Raster 30m	Acquired	Yes

4.2 Data Modeling

Grazing allotments were acquired for BLM and USFS lands within the ecoregion. Pasture boundaries (used as a surrogate for fences) were also acquired for BLM grazing allotments but were not available for all USFS allotments. Land Treatment Digital Library (LTDL) was used as the primary source for land treatment.

4.3 Data Gaps, Uncertainty and Limitations

4.3.1 Data Gaps

Fences are one of the main alterations to the landscape to allow grazing. Pasture boundaries were used as a surrogate for fences in lieu of actual fence data. There are fences and other alterations that won't be represented in the analysis. Pasture boundaries were only available for BLM land and weren't provided for USFS grazing allotments.

Other livestock management infrastructure such as troughs, corrals, pipelines were not available throughout the ecoregion.

The spatial data gathered on grazing was limited to BLM and USFS land. Private or state managed grazing or range improvements were not mapped or considered.

The actual use of grazing allotments broken down by pastures used along with numbers of animals and time frame the pasture was used.

4.3.2 Uncertainty

There is some uncertainty with the USGS Rangeland Health study examining whether the grazing allotments were meeting rangeland standards. Different BLM state offices have varying standards measuring rangeland health. Also, not all field offices contributed data so there also gaps in the analysis. Many of the allotments also had standards not completed or had no data.

5 Management Questions

Where are the current livestock grazing allotments? (MQ 24)

Figure 5-1 shows the location of BLM and USFS grazing allotments within the Northern Great Basin. The majority of the ecoregion contains grazing allotments however land ownership within an allotment may include other lands including but not limited to state, private, tribal lands, and wildlife refuges. Most of the areas that don't contain grazing allotments are agricultural areas such as the Snake River Plain and southeastern Idaho. Other notable gaps in grazing allotments would be tribal land such as the Duck Valley Reservation that spans the Idaho and Nevada border as well as the Sheldon National Wildlife Refuge in northwest Nevada and the Hart Mountain Antelope Refuge in Oregon. Figure 5-2 displays the locations of domestic sheep grazing allotments along with the WAFWA Bighorn sheep distribution. The proximity of domestic sheep to Bighorn sheep is of concern due to disease transmission from domestic to wild sheep. The Bighorn sheep conservation element package contains more detailed information on the risks of disease transmission.

Figure 5-3 displays the results of the USGS review of BLM land health assessment records for grazing allotments within the Northern Great Basin. The review shows grazing allotments that are meeting and not meeting land health standards. Some of the challenges in this review included:

- Different states have different measures of land health,
- If a one part of the grazing allotment wasn't meeting the standard, the whole grazing allotment was coded as not meeting the standard,
- There are many data gaps or areas where the standards are not completed so the complete picture in the ecoregion cannot be fully assessed.

This figure was previously included under the management question related to vegetation resiliency but reviewers felt that it didn't accurately portray resiliency so the land health standards review information is included with this management question.

Where will CAs (excluding climate change) overlap grazing allotments under each time scenario? (MQ 25)

Development

As shown in Figure 5-4, agricultural lands are mostly excluded from grazing allotments along with developed areas. Wind energy turbine locations occur within some grazing allotments as displayed on Figure 5-4 but their largest effect would be from service roads and infrastructure created within the project footprint. Of all the aspects of development, the largest impact of development on grazing allotments would be roads and fences (Freilich *et al.* 2003). Roads are vectors for transmitting invasives and also allow for possible sources of ignitions of wildfires. Figure 5-5 shows the mean distance to roads within each grazing allotment for the ecoregion. The majority of the grazing allotments have a fairly high amount of roads ranging from private ranch roads to 4WD and OHV roads. Nevada along with Idaho have grazing allotments that include some wilderness areas (Black Rock Desert, and Owyhee wilderness areas) where roads density would be lower than other areas of the ecoregion. Fences will be covered in more detail under MQ 76 that discusses modifications of rangeland for grazing. Mines are also a development feature that would be contained within grazing allotments. The main data source for mines is the Mineral Resources Dataset from the USGS that provide spatial point data but not size or extent of the mines. Most mines will also have roads associated with them that will be captured in the distance to roads on Figure 5-5.

Wildfire

Fire frequency within the Northern Great Basin from 1990-2012 is displayed in the Figure 5-6. In 2012 there were three large fires over 300,000 acres in extent (Long Draw, Holloway, and Rush) that were mostly within grazing allotments in Oregon, Nevada and California. Increasing temperature due to climate change will result in longer fire seasons and larger areas burned (Chambers and Pellant 2008). The area south of Mountain Home and west of Twin Falls has been the most frequently burned area of grazing allotments within the last two decades. Wildfire can alter the vegetation and cause conversion to annual grasses such as cheatgrass and can also result in temporary closure of the grazing allotment to allow for reseeding and rehabilitation. Figure 5-7 shows the FSim burn probability for the ecoregion within each grazing allotment (most common burn probability within a grazing allotment). Idaho and Nevada have the most grazing allotments in the high category while Oregon also has some in the high category but the majority of the Oregon allotments are in the low to moderate probability category.

Invasives

Figure 5-8 shows the dominance of cheatgrass within the ecoregion based on the EROS USGS study showing the distribution from 2010. The dominant locations of cheatgrass, based on this study, are along the edge of the Snake River Plain with isolated pockets in Nevada and Oregon mostly due to disturbance. Increasing dominance of cheatgrass can convert typical fire return intervals from 60 – 110 years to 3 – 5 years and create a homogenous landscaped dominated by invasive species (Chambers and Pellant 2008).

Where will grazing allotments experience significant deviations from normal climate variation? (MQ 26)

Reviewing the climate change package shows that annual precipitation is predicted to increase by 2060. The majority of that precipitation is projected to arrive during the winter and spring with a decrease in precipitation in the months of July and August. Drought during the hottest and driest summer months (July and August) may increase demands for water delivery as natural water sources may dry up earlier, decrease forage regrowth and alter the animal unit months (AUMs) for the allotment. Climate variability and frequency of floods and droughts is predicted to increase (Chambers and Pellant 2008).

Where is structure of vegetation CEs affected by livestock grazing? (MQ 71)

Historically, livestock grazing has affected the structure of most vegetation CEs in the ecoregion, ranging from sagebrush systems to riparian systems. Current livestock grazing management practices have emphasized sustainability and reduced impacts on vegetation. However in many cases the effects of past livestock grazing practices endure to the present, to the extent that it is difficult to reconstruct historic vegetation conditions prior to the introduction of domestic livestock. Unmanaged grazing affects communities in several ways, reducing or eliminating palatable species, increasing erosion through removal of vegetation cover, trampling vegetation, soils, and biological soil crusts, creating compacted trails where runoff is concentrated, and by causing stream banks to collapse and erode. In some cases livestock grazing can reduce the risk of wildfire by reducing density of vegetation but it has also historically contributed to increased wildfire risk by facilitating the spread of invasive species that are easily ignited and form a more or less continuous cover capable of carrying fire from shrub to shrub. Prolonged historical droughts magnified livestock effects on the landscape. Although effects of historic grazing are nearly ubiquitous in the ecoregion, riparian systems and sagebrush systems probably have experienced the biggest changes from grazing.

Since grazing allotments cover most of the ecoregion, the five vegetation coarse filters were analyzed to determine the percentage of each within the allotments. Table 5-1 lists the percentage of each of the vegetation coarse filters.

Table 5-1 Percentage of Coarse Filter within Grazing Allotment

Vegetation Coarse Filter	Percentage within Grazing Allotment
Other Conifer	39%
Aspen	74%
Combined Juniper	80%
Sagebrush (all types)	83%
Low Sagebrush	87%
WY / Basin Big Sagebrush	83%
Mountain Big Sagebrush	82%
Salt Desert Shrub	79%

Where can livestock grazing be used to reduce wildfire risk in areas with herbaceous fuel loads and proximity to high-probability ignition locations (roads, train tracks, lightning etc.)? (MQ 72)

Modeling for this management question was completed by taking ignition sources (roads and railroads) and overlapping them with areas known to have a high wildfire risk or wildfire frequency. These layers were combined to show areas where grazing may be used to reduce wildfire risk. An additional step requested was to include the WAFWA bighorn sheep boundaries because disease transmission between domestic sheep and bighorn sheep is of concern in the ecoregion. The WAFWA boundaries were buffered 23 km (Singer *et al.* 2001), which was the minimum distance from domestic sheep used in the bighorn sheep conservation element. Figure 5-9 shows the resulting locations of where grazing could be used to reduce wildfire risk. This modeling produced several aspects of uncertainty,

1. Fuel loads, presence of invasives or annual grasses would need to be verified in a more focused or site-specific process to determine whether grazing would help reduce fire risk. There was limited available regional mapping of cheatgrass or other annual grasses for the ecoregion (especially the northeastern part of the ecoregion that was highlighted by the modeling).
2. Figure 5-9 highlights areas that have been burned previously, that burn frequently or that have a high burn probability. These areas will be much more prevalent and visible at the scale of the maps being used in the REA. Roads and railroads will be difficult to see but if using the data in a GIS may provide more areas that can be used to reduce wildfire risk than simply areas that have previously burned or have high burn probability.

Where will livestock grazing have the potential to increase fire frequency as a result of increased cover of annual grasses (high, medium, low)? (MQ 73)

This management questions was difficult to answer with the available datasets and at an ecoregional scale. One of the main elements of this management question is where grazing or overgrazing may allow cheatgrass (or annual grasses) become more dominant. Elevation was one aspect that was mentioned by the rolling review team that will affect cheatgrass as it is limited by cold temperatures which effect plant growth and reproduction (Chambers and Pellant 2008). An increase in temperatures due to climate change could alter upper limits for cheatgrass and expand areas with increased cover of annual grasses. The USFS lists the range of elevations for cheatgrass to be below 7,000 ft (2,134 m) which would include most of the grazing allotments within the ecoregion except for the highest ranges in Nevada (Jarbidge, Bull Run), Oregon (Steens Mountain) and the northeastern edges of the ecoregion. The cheatgrass data used in the REA is limited in area and only covers half of the ecoregion. Since there were a couple levels of uncertainty, no map or analysis done at the ecoregion scale. This question may be better answered using a step down approach where grazing effects and cheatgrass dominance can be more precisely measured and quantified.

Where are areas in the landscape with various (low, medium, high) levels of resilience to livestock grazing (based upon ecological site and existing vegetation)? (MQ 74)

The method recommended by the Rolling Review Team was to use the WGA's Large Intact Blocks (LIB) to determine the grazing allotments with the greatest amount of intact blocks. The LIBs and the ecologic integrity modeling do not describe ecological resiliency. Since a clear methodology to define resiliency within a ecoregional framework and with data sources available, using the WGA's LIBs was an approach used within the REA. Cheatgrass models may provide a surrogate for resiliency but a recent cheatgrass layer with complete coverage of the ecoregion was acquired at the end of the REA process so this wasn't pursued. LIBs are areas extracted from the modeled landscape condition model to identify discrete areas of high landscape integrity. The LIBs are divided into three levels representing the top 1/3 of the blocks (Level 1) through to the lowest quality 1/3 of blocks (Level 3). Figure 5-10 shows the percentage of each grazing allotment that contains a Level1 LIB. The majority of the grazing allotments with Level 1 LIBs are in Nevada with a few grazing allotments with 100 percent Level 1 LIB in the allotment such as in the Black Rock Desert Wilderness and Craters of the Moon National Monument. Figure 5-11 shows a similar analysis calculating the percentage of Level 2 LIB within each grazing allotment. The majority of Nevada allotments all are over 50 percent while the southern parts of Oregon and Idaho along with the northern edges of the ecoregion in Idaho are also over 50 percent. LIBs do not incorporate either ecological site or existing vegetation therefore the main attributes identified are areas without physical disturbance.

Where has the landscape been modified for purposes of livestock grazing and management (sagebrush elimination, fences, plantings, water sources, etc.)? (MQ 75)

There were two main data sources recommended by the Rolling Review Team to identify where the landscape has been modified for the purposes of livestock grazing. These are pasture boundaries and the Land Treatment Digital Library (LTDL). Pasture boundaries were acquired for BLM grazing allotments but were not available for all of the USFS grazing allotments as well as private and state lands. Pasture boundaries are subdivisions of a grazing allotment and usually correspond to the locations of fences. The density of fences is likely to be higher in exurban and agricultural areas. Figure 5-12 shows the location of pasture boundaries for BLM grazing allotments in the Northern Great Basin. The LTDL was created by the USGS Forest and Rangeland Ecosystem Science Center based on submissions of land treatments from BLM field offices. The USGS categorized and digitized, where necessary, the boundaries of land treatments within the ecoregion. Land treatments types mostly included seedings and habitat restoration for post-fire rehabilitation. Treatments also included fuel reductions, protective fencing and closures, weed and erosion control, etc. The locations of land treatment boundaries within the ecoregion can be seen in Figure 5-13. For more detailed information on land treatments for specific areas, the land treatment digital library should be consulted to view all of the types of treatments that occurred, status and date of treatment. The most common land treatments within the ecoregion is for the purposes of post wildfire rehabilitation. This usually involves re-seeding for erosion control and prevent invasion of invasive species not specifically for livestock grazing. To fully answer this management question, a step-down effort would be required to examine the individual land treatment project and all the components that were included.

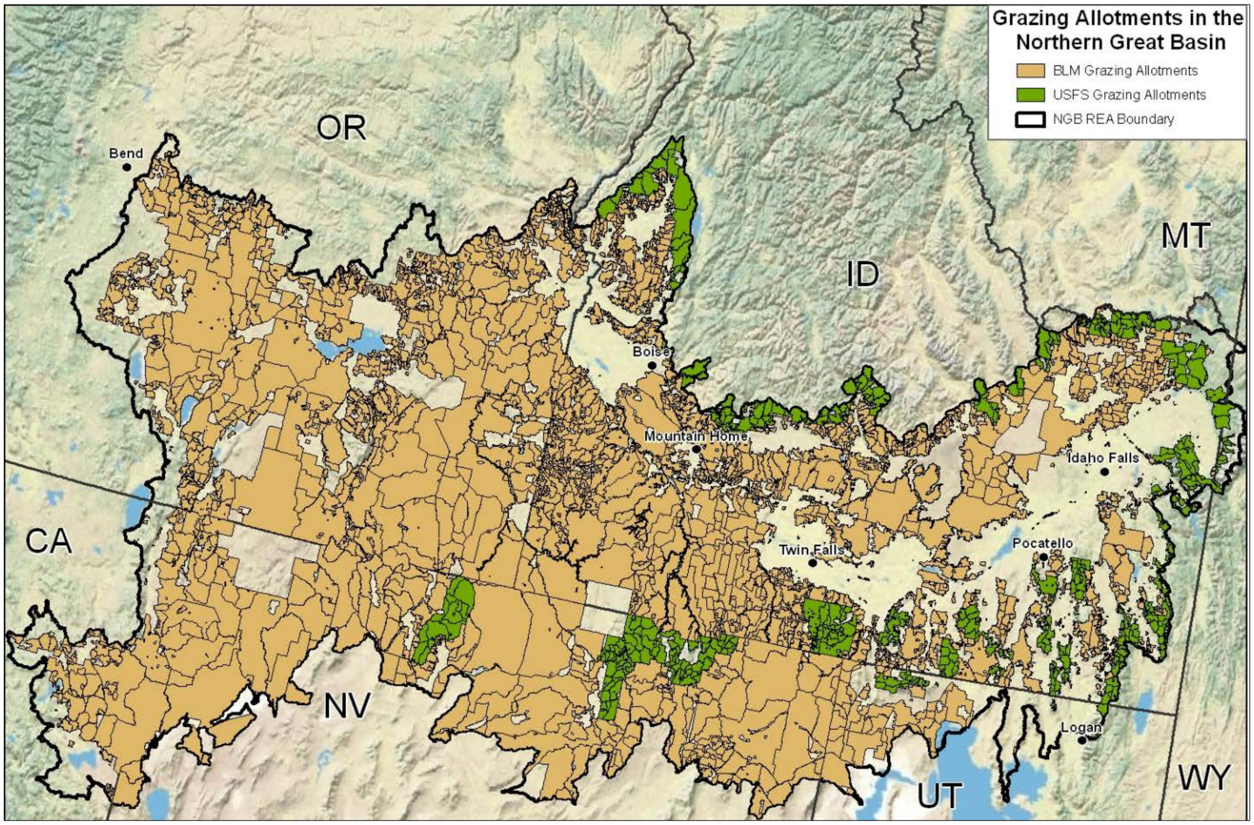

Figure 5-1. Location of Grazing Allotments in the Northern Great Basin

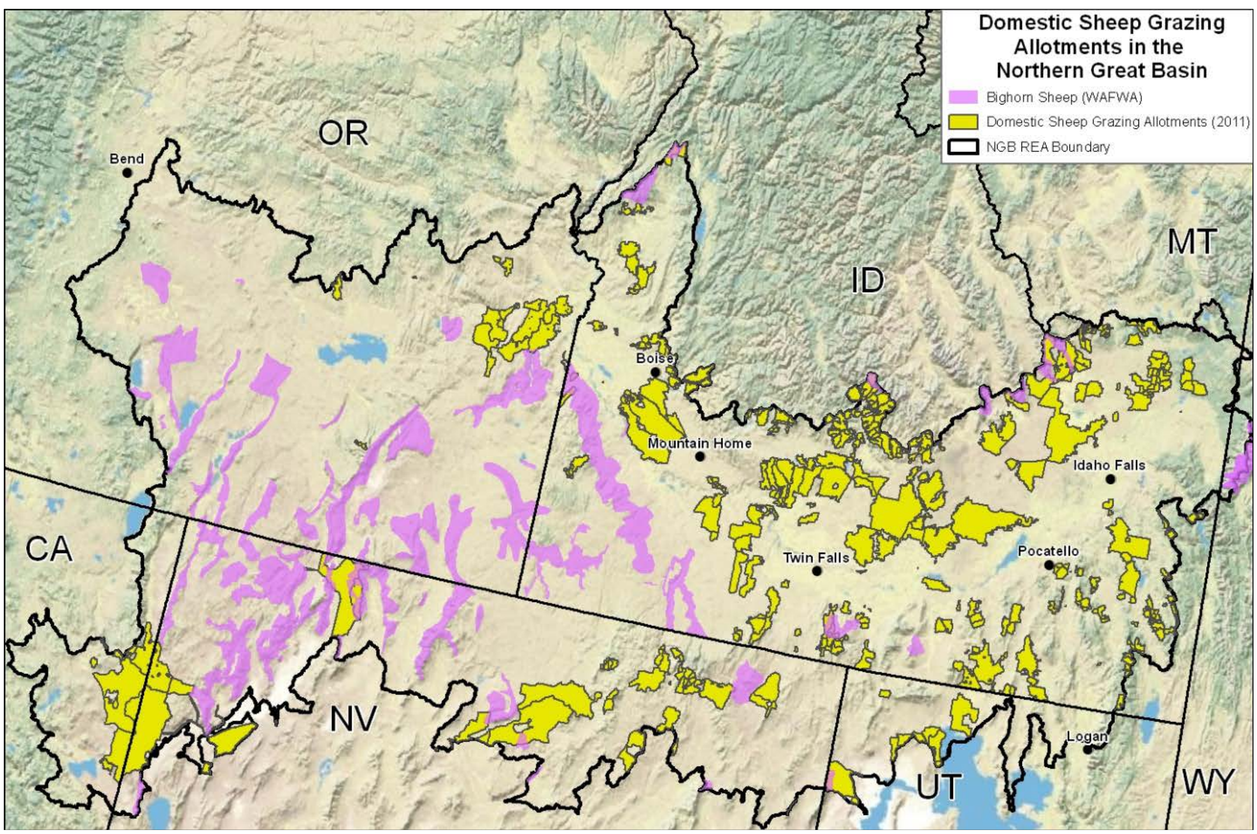

Figure 5-2 Domestic Sheep Grazing Allotments in the Northern Great Basin

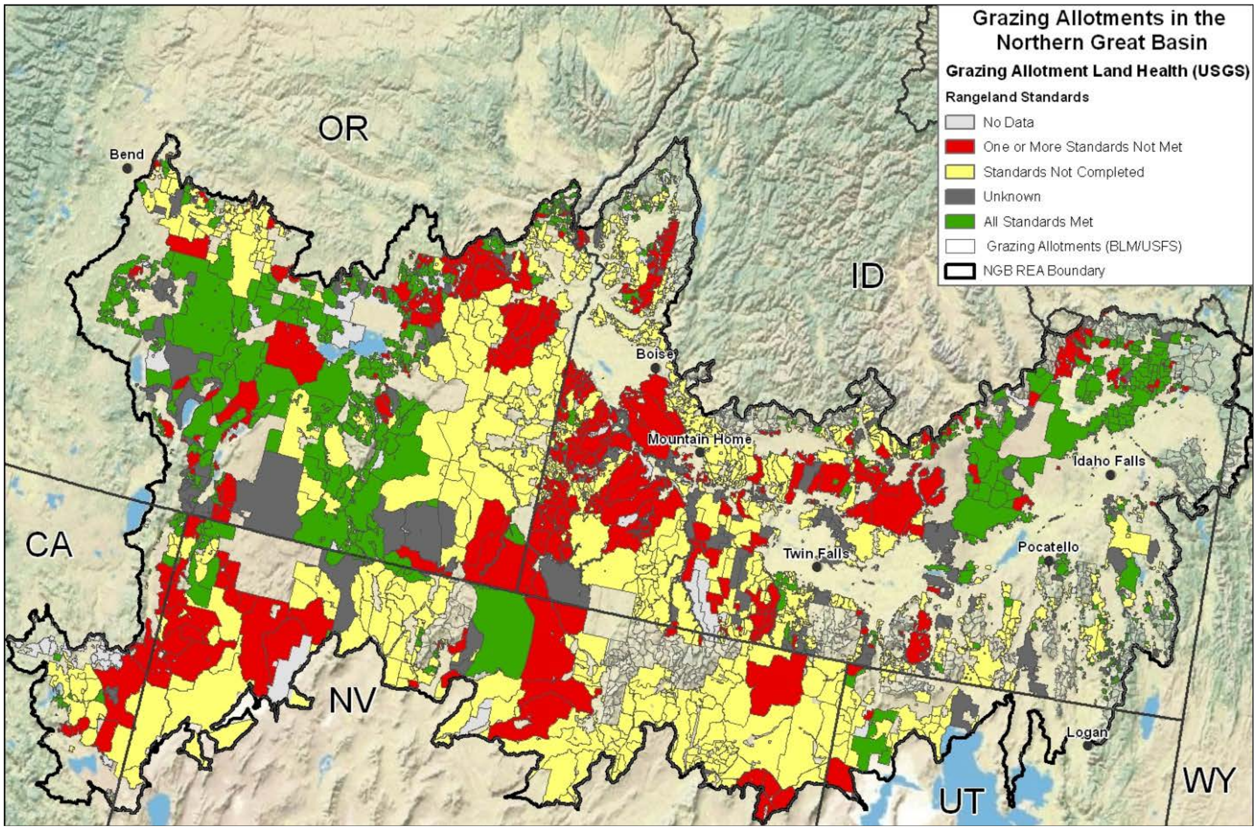

Figure 5-3. Grazing Allotment Rangeland Health (USGS 2011)

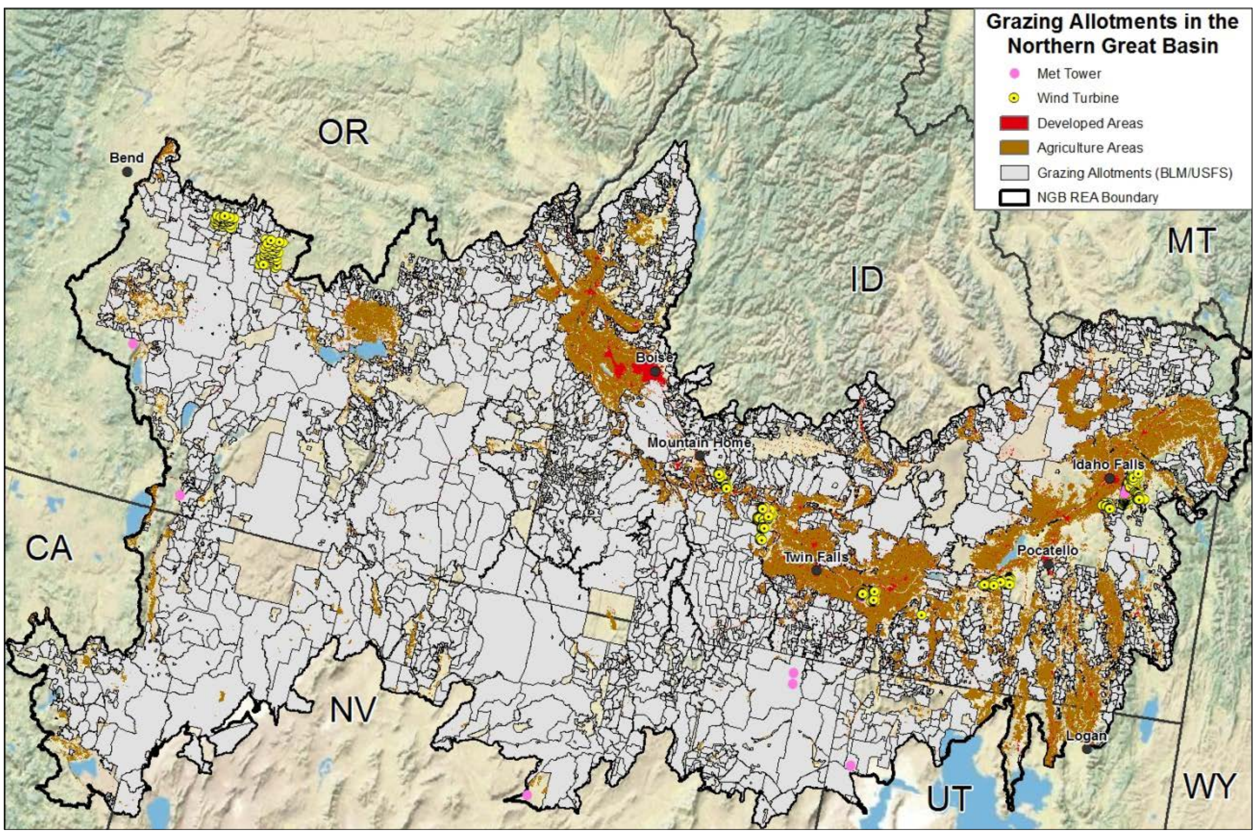

Figure 5-4. Development near Grazing Allotments in the Northern Great Basin

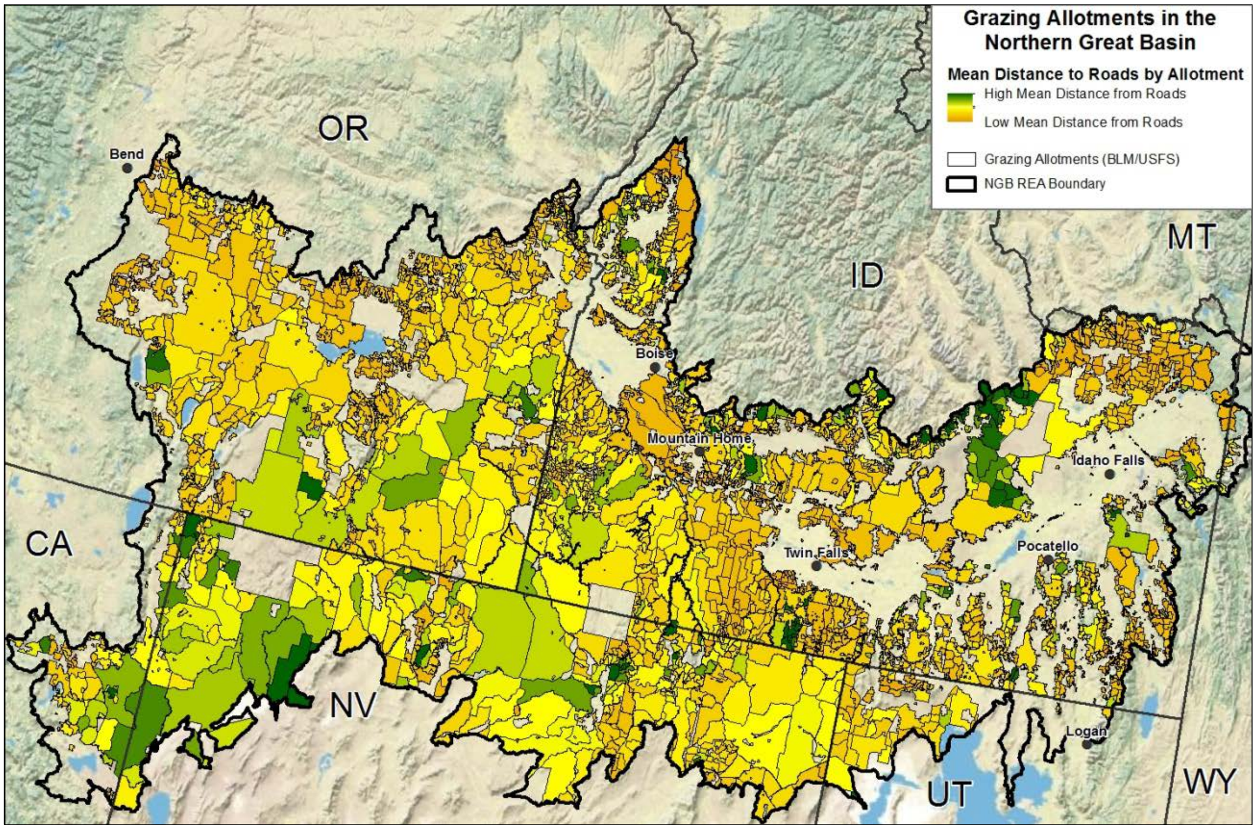

Figure 5-5. Mean Distance to Roads by Grazing Allotment in the Northern Great Basin

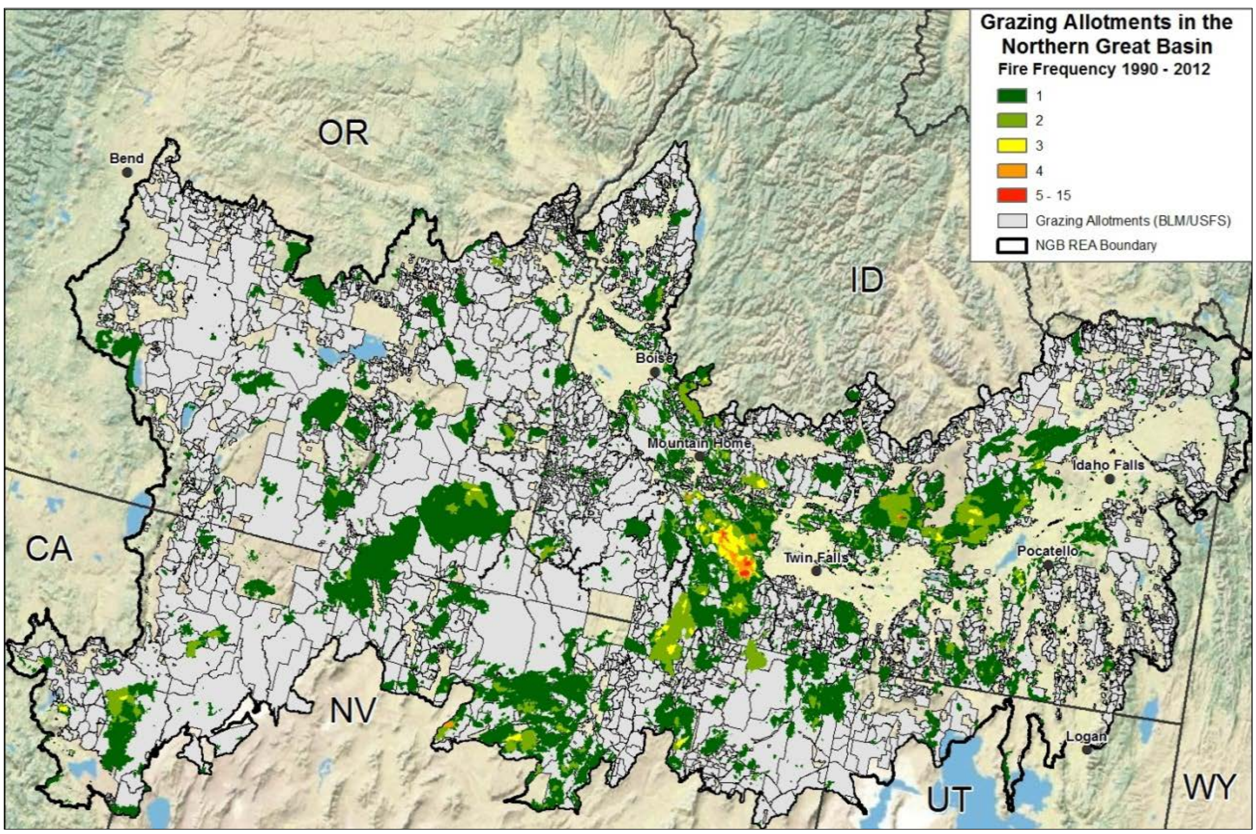

Figure 5-6. Fire Frequency 1990 – 2012 in the Northern Great Basin

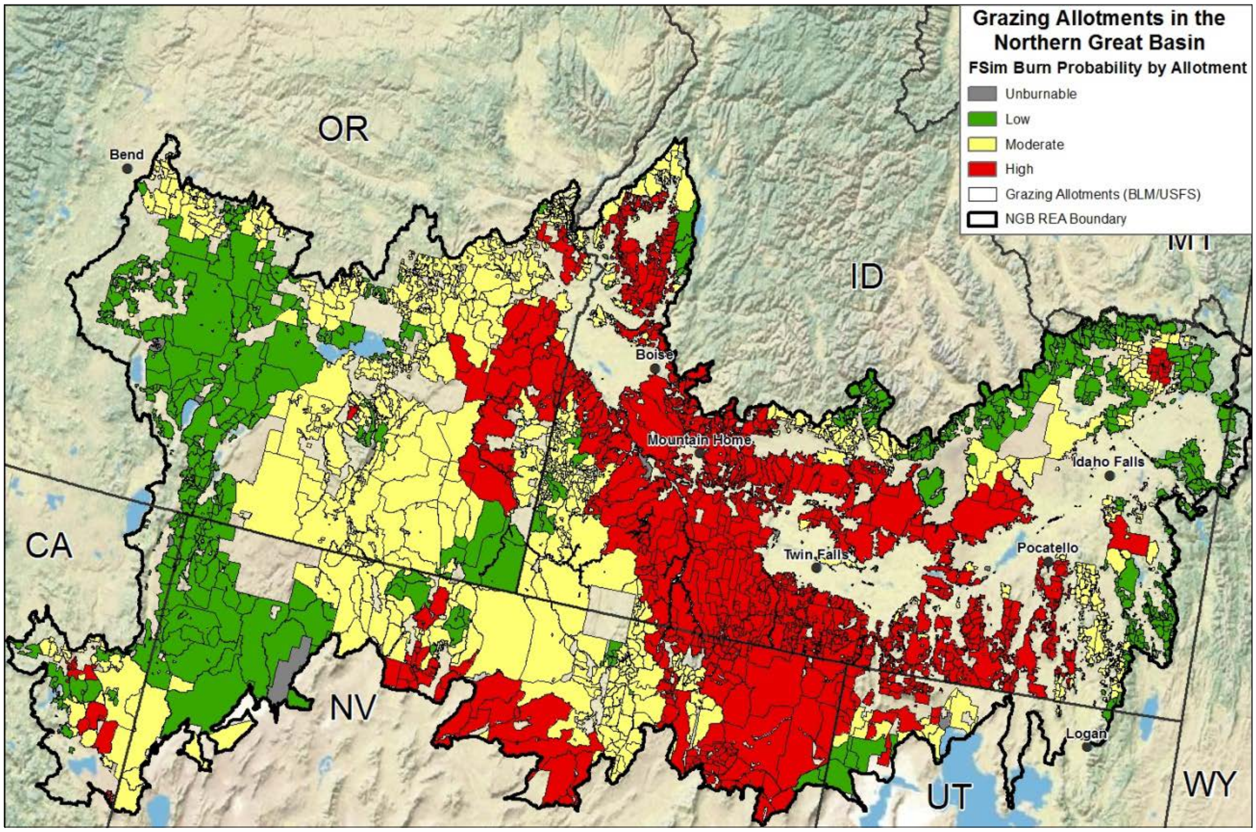

Figure 5-7. FSim Burn Probability within Grazing Allotments in the Northern Great Basin

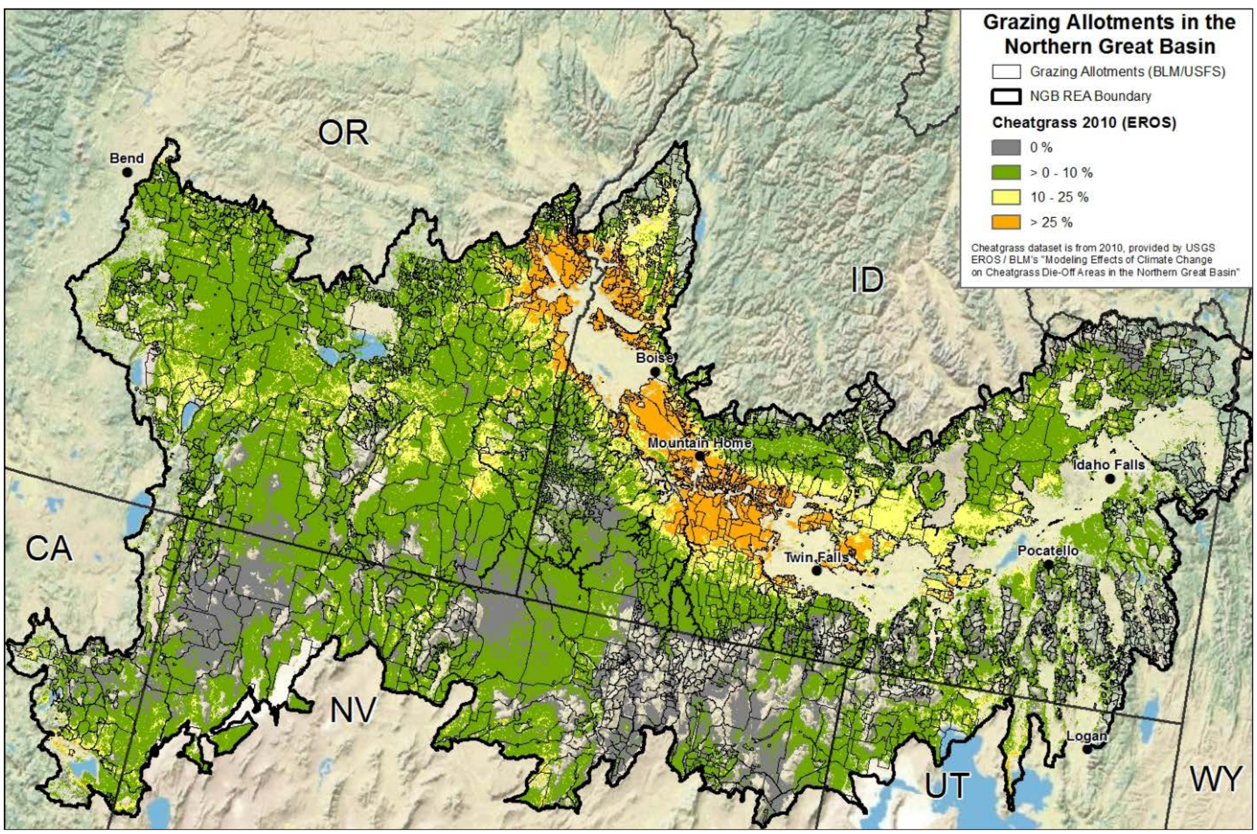

Figure 5-8. Cheatgrass within Grazing Allotments in the Northern Great Basin (USGS/EROS 2010)

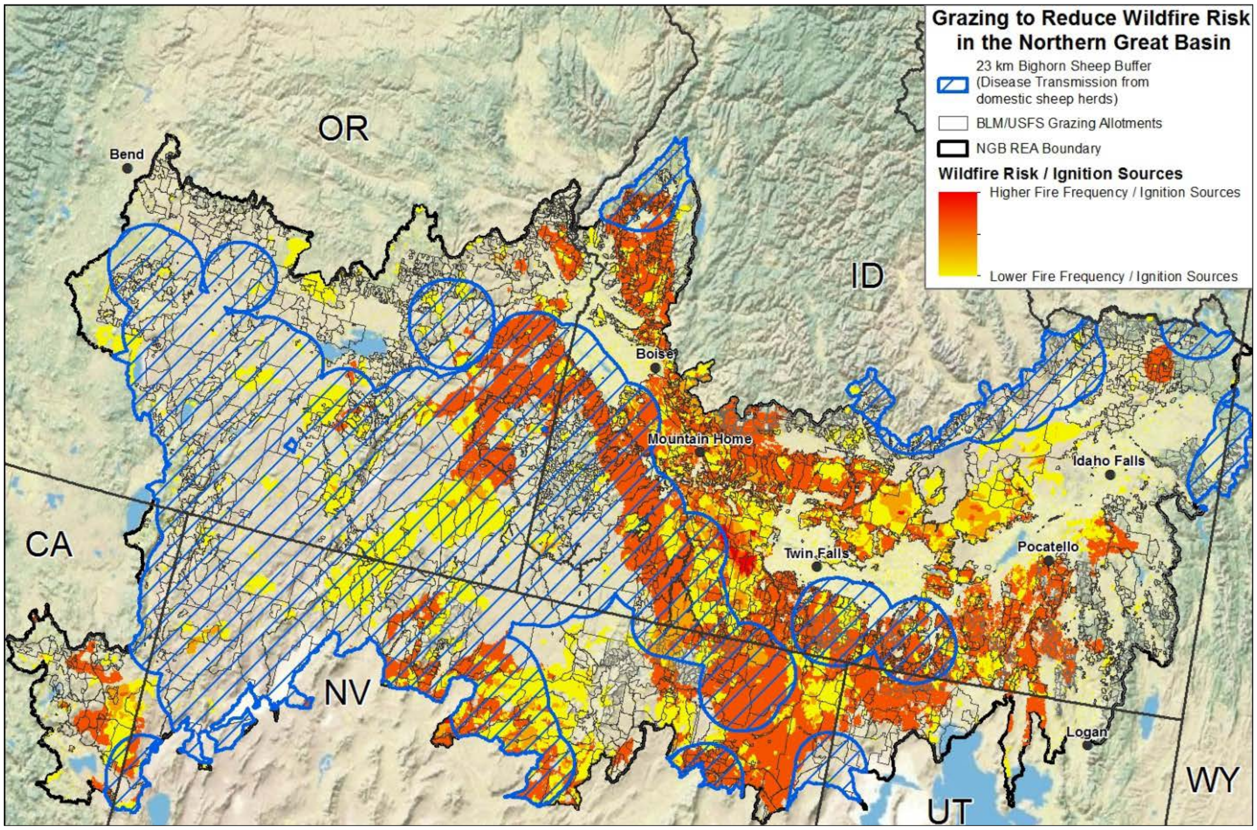

Figure 5-9. Locations of Frequently Burned Areas and Ignition Sources

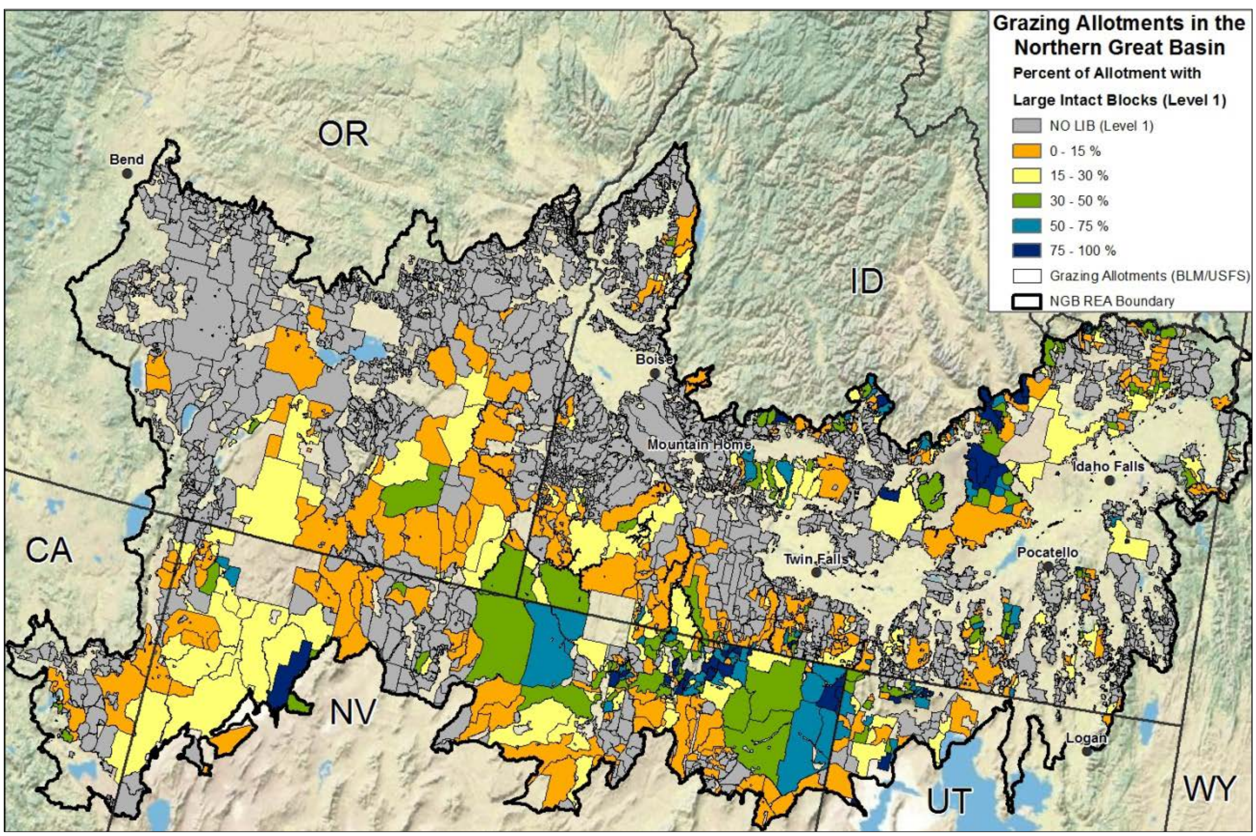

Figure 5-10. Percent of Grazing Allotment in WGA LIB Level 1

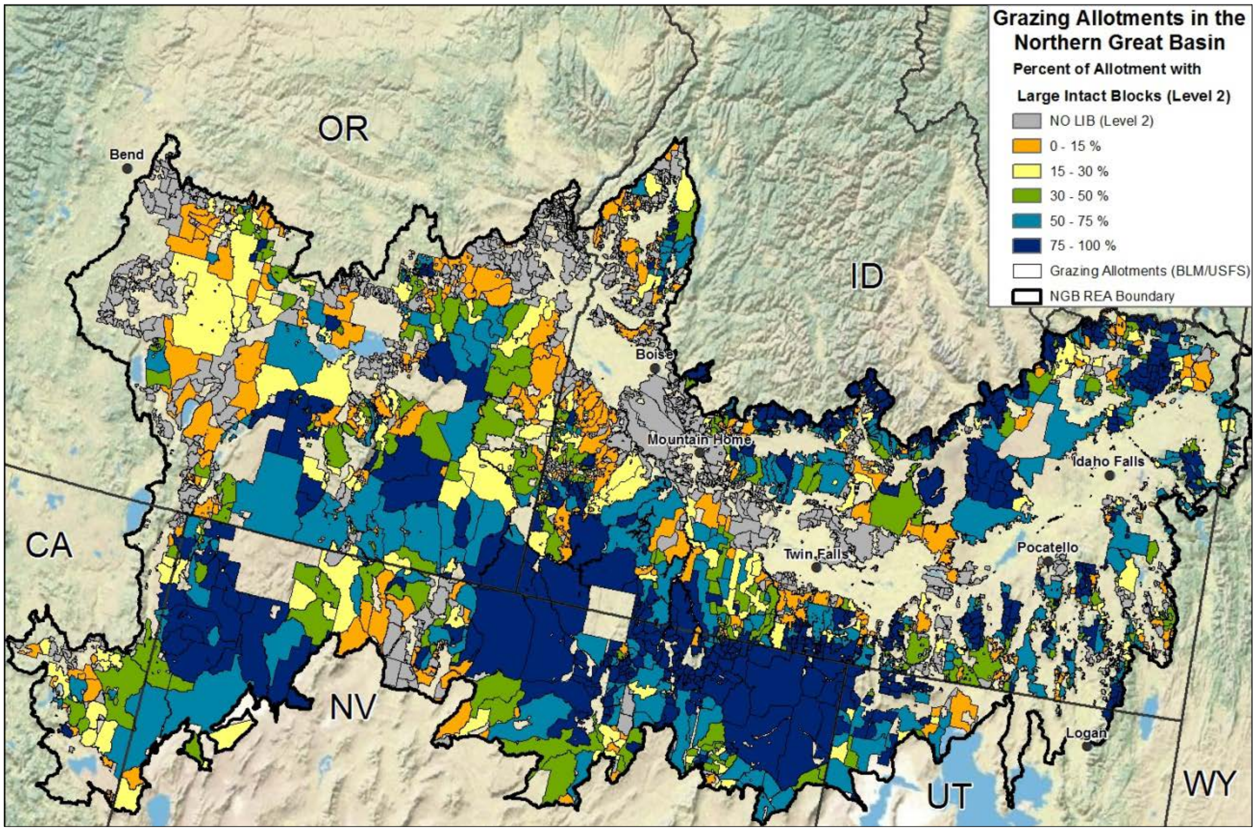

Figure 5-11. Percent of Grazing Allotment in WGA LIB Level 2

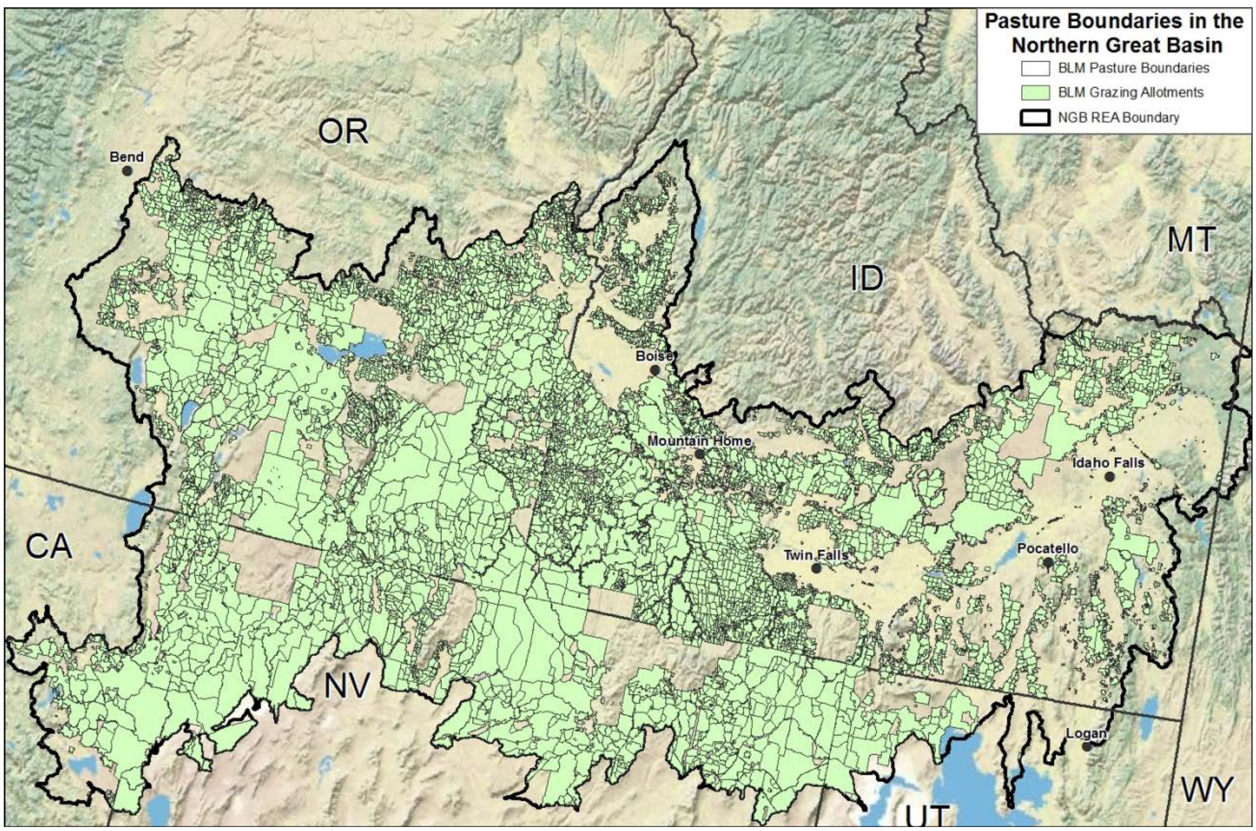

Figure 5-12. Location of Pasture Boundaries within BLM Grazing Allotments

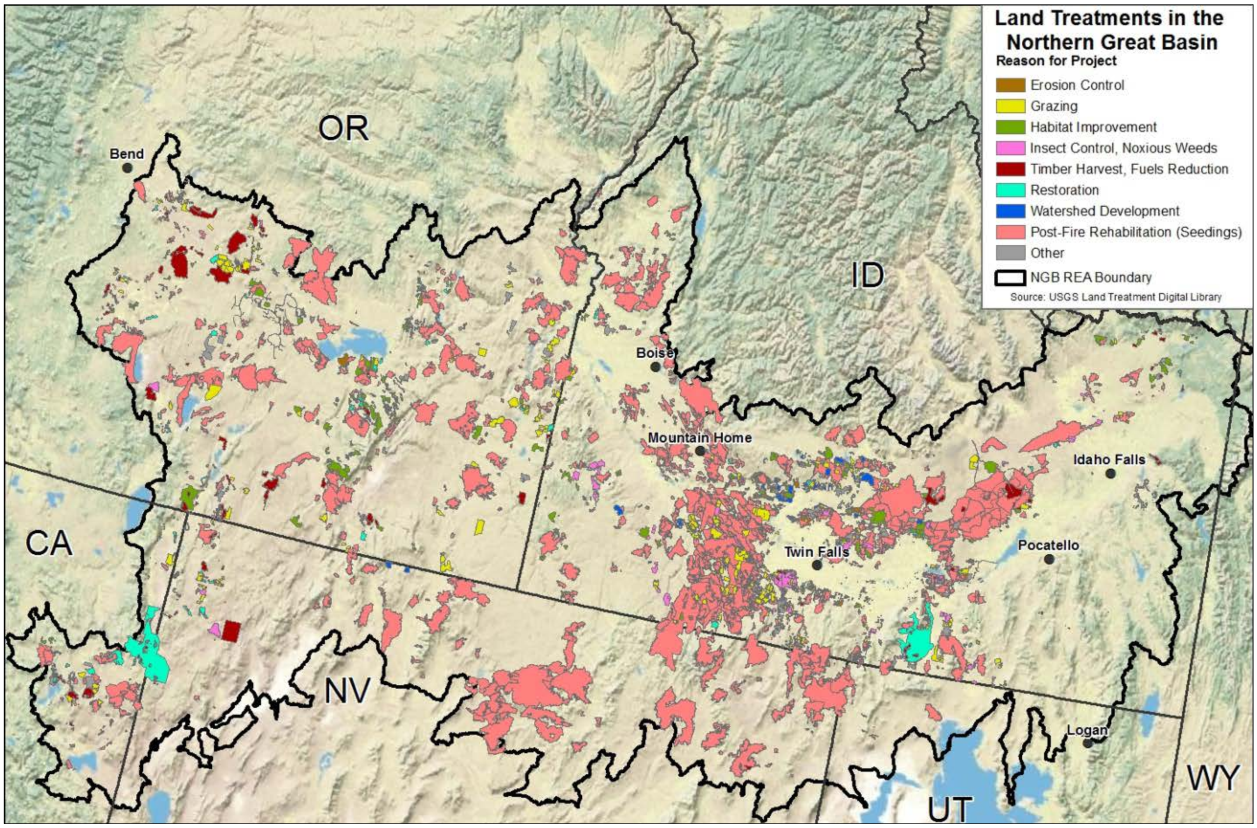

Figure 5-13. Land Treatments from the Land Treatment Digital Library (USGS)

6 References

Barrett, S., D. Havlina, J. Jones, W. Hann, C. Frame, D. Hamilton, K. Schon, T. Demeo, L. Hutter, and J. Menakis. 2010. Interagency Fire Regime Condition Class Guidebook. Version 3.0. Interagency Fire Regime Condition Class website, USDA Forest Service, US Department of the Interior, and The Nature Conservancy. Available at: www.frcc.gov.

Chambers, J.C. and M. Pellant. 2008. Climate change impacts on northwestern and intermountain United States rangelands. Society for Range Management publication available on internet at: http://www.fs.fed.us/rm/pubs_other/rmrs_2008_chambers_j001.pdf. June.

Freilich, J.E., J.M. Emlen, J.J. Duda, D.C. Freeman, and P.J. Cafaro. 2003. Ecological Effects of Ranching: A Six-Point Critique. BioScience Forum 53 (8): 759-765. August.

Holechek, J.L., R. Valdez, S.D. Schemnitz, R.D. Pieper, and C.A. Davis. 1982. Manipulation of Grazing to Improve or Maintain Wildlife Habitat. Wildlife Society Bulletin 10 (3): 204-210. Autumn.

U.S. Geological Survey (USGS). 2011. OFR 2011-1263. Range-Wide Assessment of Livestock Grazing Across the Sagebrush Biome. http://pubs.usgs.gov/of/2011/1263/

USGS. 2012. Digital land treatment library. USGS Forest and Rangeland Ecosystem Center Field Station.

Yeo, J.L. 2005. Effects of Grazing Exclusion on Rangeland Vegetation and Soils, East Central Idaho. Western North American Naturalist 65(1): 91–102.

Climate Change Agent Package
Northern Great Basin Ecoregion

1 Introduction

Change agents are natural or anthropogenic disturbances that influence the current and future status of conservation elements. Conservation elements are resources of conservation and management interest such as wildlife species or ecological communities; i.e., they are the objects that the BLM intends to assess for current status and future condition in the face of changing change agent effects. The initial change agents for this ecoregion were outlined by the AMT in the SOW. Climate change is included in this ecoregion in order to assess how predicted changes in climate may affect resources across the landscape because climate change has the potential to directly and indirectly affect organisms and communities by changing the locations where species and communities can exist. This change agent package provides an assessment of the current status and future threats that are anticipated due to climate change in the ecoregion. Information includes a brief description of climate change as a change agent, some information on potential data sources and analytical methods for the assessment, and a listing of relevant management questions for this change agent.

2 Change Agent Package Review Process

2.1 Subject Matter Expert Review

Subject Matter Experts play a key role in ensuring that the REA reflects the best available data and modeling processes suitable for each conservation element and change agent. Subject Matter Experts were added to Rolling Review Teams comprised of SAIC scientists, SAIC GIS personnel, AMT member(s) and other subject matter experts from the Department of Interior or state agencies. Membership of the Rolling Review Teams is listed in Appendix A. To ensure consistency amongst the different Rolling Review Teams, the number of lead SAIC scientists was limited to only a few individuals. This ensured that there was a common approach, or framework, used among the different Rolling Review Teams and that one Rolling Review Team did not stray too far from the rest. The USGS, as peer reviewers, were invited to participate in Rolling Review Teams.

3 Change Agent Description

3.1 Climate Change Agent Description

It is a central premise of biogeography that climate exerts a dominant control over the natural distribution of species, as well as range expansions and contractions (Andrewartha and Birch 1954; MacArthur, R.M. 1972); therefore it is expected that future climate change will have a significant impact on the distribution of species (Pearson and Dawson 2003). A review of evidence for species and community responses to climate change indicated changes in the phenology and distribution of plants and animals are occurring in all well-studied marine, freshwater, and terrestrial groups. (Parmesan 2006).

It is also understood that there will be a number of factors other than climate that contribute to the current or future distribution of CEs, and projections of impacts require better mechanistic understanding of ecological, behavioral, and evolutionary responses to complex patterns of climate change, and in particular to impacts of extreme weather and climate events. Therefore, a method of assessing a small number of important characteristics of current and future climate at a given location is necessary to relate that information to other ecological factors that control the distribution of the species or community (Fagre *et al.* 2009; Littell *et al.* 2010). In most cases, it is not known how or even if the various climatic characteristics and ecological characteristics at a specific site are important to the distribution of the CE so what is required are predictive models for current and future climate.

3.2 Climate Change CA Types of Effects & Pathways

Climate change may include, but is not limited to, changes in temperature averages and extremes, precipitation amounts, distribution, and seasonality, and frequency and duration of drought periods. Climate change is also likely to affect species and communities by affecting the frequency and distribution of fire and occurrences of invasive species, disease, and insect outbreaks. Although there is a view that climate change toward warmer-drier conditions would cause communities to move northward or to higher elevations, in actuality species will respond individually to climate change and new species associations may result. Human-caused barriers to movement may affect the ability of species or communities to move in response to changing conditions and become genetically isolated.

Table 3-1 shows some of the ways in which the Climate Change CA affects other CAs and CEs. This listing is not intended to be comprehensive but indicates some of the ways in which the analysis of the effects of this CA can proceed. The predicted future changes in temperature regimes such as lowest winter and highest summer temperatures received may affect which species occupy associated habitats.

As an example, climate change is likely to influence habitat availability and distribution for mule deer in the ecoregion. The primary impacts of climate change on mule deer and their habitats are through (a) effects of changing moisture and temperature regimes on forage resources (i.e., productivity, species composition, and nutrient content are affected by drought, late frosts, etc.), and (b) snow depths on winter ranges and migration corridors. Population abundance and the size of future ranges will depend on forage availability and quality. Global warming patterns are projected to lead to loss of sagebrush winter ranges and expansion of coniferous communities, which will reduce habitat quality of winter range (Lutz *et al.* 2003). Generally, ecoregional differences in the impact to mule deer populations are expected to occur as climate change progresses (deVos and McKinney 2007). Within the NGB, expanded distribution of woody species, reduced nutritional quality of forages, increased frequency of stand-converting wildfires, and spread of invasive plants and insects have increased in the past 150 years, resulting in different biotic communities and interactions between species (Cox *et al.* 2009).

Snow depth over approximately 18 inches precludes the use of winter range by deer (Gilbert *et al.* 1970). Since reduced snowfall is projected to occur in much of western North America as a result of climate change, the importance of traditional winter ranges for mule may be reduced, and new areas may see increased winter use. Climate change is thought to negatively affect abundance and distribution of mule deer in hotter and drier ecoregions, while in ecoregions where extreme winters limit these populations in some years, short-term effects on abundance and distribution may be positive, but long-term effects are uncertain. As global climate change progresses, the extent of these changes and altered biological interactions are expected to increase.

Table 3-1. Climate Change as a Change Agent

Change Agent Category	Change Agent Types of Effects	Effect Pathways	Interactions with other CAs	Affected CEs
Temperature	Increases and Decreases	• Snow depths • Frost dates • Winter low temperatures • Summer high temperatures • Altered water availability at specific times of the year • Dates ice formation and thaw on water bodies • Vegetation phenology - blooming and senescence periods, pollinator timing • Species range shifts • Insect availability for insectivores (bats, birds) • Seasonal migration, hibernation timing • Changing spring frosts affecting berry, nut and fruit production • Water temperatures • Floods, storms and extreme events	• Development may reduce habitat and movement corridors available to species having to cope with climate effects • Exacerbated natural droughts causing low soil and vegetation moisture, that promote the spread of wildfire fire; increased storms increases lightning strikes as ignition sources • Changing conditions favor some invasive grass species, which can also increase fuel loads and carry fires greater distances, longer duration, or higher frequency than normal • Changing conditions favor some diseases and insect outbreaks (e.g., less-severe winters allow insects' proliferation)	• Most coarse filter vegetative CEs • Most fine filter CEs especially those that depend on small niche habitats that can be quickly altered by changing moisture or temperatures (e.g., springs & seeps, spotted frog) • Fish CEs can be affected if they depend upon certain water temperatures and amounts being available
Precipitation	Amounts and Timing			

4 Data Sources and Modeling

4.1 Data Identification

Table 4-1. Preliminary List of CA Data Needs

Data Required	Dataset Name	Source Agency	Type/Scale	Status	Potential Use in REA
Future Climate Model	USGS / Hostetler	Oregon State U.	15 km	Acquired except for 1980 - 1999	Yes
Current Climate Model	NCEP	Oregon State U	15 km	Acquired except for 1980 - 1999	Yes
Current Climate Model	PRISM	Oregon State U.	800 m	1971 - 2000	Yes

4.2 Data Modeling

Two classes of predictive climate models were used for this assessment:

- Coarse scale spatial resolution Global Climate Model (GCM) output converted into fine scale spatial resolution for temperature or precipitation using the Parameter-elevation Regressions on Independent Slopes Model (PRISM) and,
- Coarse scale spatial resolution GCM output converted into medium scale spatial resolution for a number of climatic variables using the USGS Regional Climate Model (RegCM3) for the ecoregion.

4.3 Data Limitations

Extreme values (minimums and maximums) are important for considering the effects of climate change on organisms, however, the processed data that are available for public use are monthly averages. Those monthly averages are then averaged over the two decade current and future periods, and subsequently averaged across the seasonal periods described above. Those three averaging processes produce arbitrary maximum and minimum values that bear no relationship to the actual maximum and minimum values experienced by organisms within the ecoregion. Therefore, the arbitrary nature of those maximum and minimum outputs outweigh the value of including them on the map. For that reason, the analysis uses mean values only.

Climate envelope models were not completed for the ecoregion. Envelope modeling requires high spatial resolution data which has shown to be unreliable (Beier *et al.* 2012). If coarse resolution climate data (Hostetler's 15 km data for example) is used, it generally does not provide enough detail for climate for a particular species. In addition, the climate data that goes into the climate models is general and does not include key factors that control the distribution of the species (fire, grazing, etc.).

4.4 Analysis of Future Climate Change on Ecoregion Conditions

The NGB ecoregion lies within a region with complex topographic relief which affects temperature and precipitation at a wide variety of spatial and temporal scales (Figures 5-1 to 5-7) (Williams Jr. 1972; Mock 1996; Daly 2006). Additionally, the distribution of weather stations in the area is very sparse and they are generally not located in the mountains and so don't detect orographic effects (Mock 1996). Mountain ranges that contribute to those effects include the Blue Mountains, Hart Mountain, Poker Jim Ridge, and Steen's Mountain in the west, the northward extensions of the parallel ranges of the Great Basin to the south, the Middle Rockies to the east, and the Boise and Sawtooth ranges to the north. The projection of Owyhee Mountains northward along the western border of Idaho almost bisects the NGB ecoregion. The Snake River Plain and the Owyhee Uplands are large areas of low to moderate topographic relief while relatively narrow basins are present within most of the ranges along the southern boundary of the ecoregion.

Seasonality of precipitation in the ecoregion is primarily Winter-Spring with orographic enhancement in May in some areas. June is a transition to the generally dry summer months. During the transition period from late May through June, the combination of a thermal trough paralleling the Pacific Coast and generally located just west of the Cascades, an upper-level trough, and remnants of mid-latitude cyclones moving through the region from the Gulf of Alaska can push strong flows of marine air through the Columbia River Gorge and the passes of the Cascades. The marine air is channeled through the Snake River Plain by the mountain ranges to the north and south and causes localized west to east moving fronts which can result in violent thunderstorms (Williams Jr. 1972; Mock 1996). The intensity of the marine air push decreases after June. In July and August the North American Monsoon can locally enhance summer precipitation but those effects are most pronounced to the south of the ecoregion (Mock 1996) except in the unique case of extra-tropical conversion of tropical cyclones (Wood and Ritchie 2012a, 2012b). Average temperatures are generally around freezing or below freezing during the winter, are slightly above freezing in the valleys and slightly below freezing in the uplands during spring, are hot in the valleys and warm in the uplands during spring, and cool in the fall.

The climate of the Northern Great Basin is also greatly affected by a number of external drivers. A correlation analysis of winter precipitation from 1926-2007 with the Southern Oscillation Index indicates that the area of the ecoregion lies in a transition zone between the southwest, which is negatively correlated with the index, and the northwest, which is positively correlated with the index. Two exceptions occur as the Owyhee Uplands are similar to the Northwest while the area within Utah is similar to the Southwest (Wise 2010). When the positive and negative phases of the Pacific Decadal Oscillation and the Atlantic Multi-decadal Oscillation are also considered a complex spatial response is clearly indicated (Wise 2010). Rain shadow effects east of the Cascades are prominent but variable being strong during La Niña events due to northern storm tracks and weak during El Niño events with their characteristic southern storm track and corresponding warm fronts (Siler *et al.* 2012).

Multi-decadal PRISM data were acquired and mapped for the lower 48 states to characterize the seasonality of climate patterns within the ecoregion (Figures 5-1 to 5-7). Based on those data, and considering characteristics of temperature and precipitation that are important for the CEs and other CAs, RegCM3 (Hostetler *et al.* 2011) predictions for current and future climate were analyzed across five periods within a year: 1) March through May (transition period and spring); 2) June (important late spring precipitation); 3) July and August (hot season with convective storms); 4) September and October (transition period to winter, and; 5) November through February (winter snow precipitation season) (after Ge and Gong 2009). Snow water equivalent for the months of March and April was analyzed as a surrogate variable to approximate late winter changes in snow pack depth. Additionally, convective precipitation for July and August was also analyzed.

The results of the climate change analysis are presented as a series of figures consisting of three subfigures generated using the Hostetler *et al.* (2011) (RegCM3) 15 km pixel regional climate change model data: 1) the 1980 to 1999 baseline period with data from the NCEP reanalysis (Saha *et al.* 2010); 2) the 2050 to 2069 predicted future climate period (ensemble mean of three driving GCMs, ECH5, GMA2, and GFDL), and 3) the predicted change (predicted future climate value minus baseline climate value). The mean temperature data (centigrade) for each month within each respective five seasonal periods were averaged to calculate the mean temperature for a particular seasonal period. For precipitation (RT = sum of frontal and convective), the model output of mean millimeters per day precipitation for a particular month was multiplied by the number of days in the month to calculate the mean amount of precipitation in a month. The monthly means were then summed to calculate the total amount of precipitation within each of the seasonal periods. Snow water equivalent (SWE) was obtained directly from the model output. Total convective precipitation (RC) model output of mean millimeters per day precipitation for July and August was multiplied by the number of days in those months to calculate the mean amount of precipitation in each month and the results were summed to calculate the total amount of RC for the July and August period.

Because the ecoregion lies within the overlapping spatial buffers of the Northwest and Southwest RegCM3 domains that were necessary to ensure realistic forcing by the GCMs there are slight differences in the model output depending on the domain used. The “blend” option in the ArcGIS Mosaic to New Raster tool was adopted as recommended by Steven Hostetler (pers.comm. December, 2012). When this option is used the resulting output cell values within the overlapping areas are a blend of values that overlap and is weighted based on the distance from the pixel to the edge of each pixels domain within the area of overlap.

The climate parameters analyzed (temperature, precipitation, SWE, and RC) measure different physical properties and have different scales. Precipitation, both PT and RC, and SWE have the property of accumulating a quantity and are represented on a zero to maximum scale with a very broad range (0 to 3,000 millimeters). Also, cumulative totals of precipitation and SWE are not inherently meaningful without an environmental context (e.g. when the precipitation occurs can be almost as important as the cumulative amount of precipitation – basin versus mountain). In contrast, temperature in degrees centigrade ranges from below freezing to above freezing and the freezing point of water greatly determines biological activity. Additionally, temperature cannot accumulate and occurs within a relatively contracted range (-20 to 30^{0}C). For these reasons, precipitation and temperature are depicted differently in the figures. For temperature, the baseline and future intervals also include an interval centered on zero that represents the freezing point of water while the range for the change figure was broken into relatively fine intervals due to the relatively narrow range of the modeled change. In contrast, for the precipitation (PR and PC) and SWE subfigures, each interval was defined relative to the range within each of the five seasonal periods. Additionally, the ranges depicted in the legends for both temperature and precipitation were chosen to enhance the reader's ability to understand the information in a static image without supplemental information such as elevation. Therefore, within a particular figure, the ranges presented in the legend were contracted for mountainous areas and expanded for low elevation areas so that the data could be interpreted biologically. It is anticipated that managers of individual projects will use the data in a GIS, consider the climate data with other data such as Digital Elevation Models, clip the data to the extent of the area of interest, and the intervals in the legend modified appropriately.

4.5 Temperature

4.5.1 Existing Pattern

The Snake River Plain and the basins along the southern border of the ecoregion were warmer than the mountain ranges or the Owyhee Uplands in every season. The 15 km pixel resolution of the data did not permit the clear visualization of the inter mountain basins and valleys.

4.5.2 Annual

The model forecast predicts no change in annual temperature across the entire ecoregion (Figure 5-8).

4.5.3 November to February

In general, no temperature change is predicted for the Snake River Plain while the areas from the Owyhee Uplands westward as well as the toe of the Boise Mountains are predicted to warm by about 1 degree C during this period (Figure 5-9). Long-term snow, climate, and streamflow trends at the Reynolds Creek in the Owyhee Mountains, have measured increasing temperatures from 1962 to 2006 at all elevations. The increase in temperature has resulted in decreasing proportion of snow to rain at all elevations. As a result, streamflow has seasonally shifted to larger winter and early spring flows and reduced late spring and summer flows (Nayak *et al.* 2010). The predicted increase in temperatures from November to February, indicate that the trend of decreasing proportions of snow to rain is likely to continue from the Owyhee Uplands westward in the future.

4.5.4 March to May

This period is especially important because of the potential effect of temperature on March and April SWE. The model forecast predicts a cooling of about -0.5 degree C during this period (Figure 5-10). Given that the average temperature most of areas that are not on the plains or in basins are near freezing during this period, this cooling trend may contribute to increase added SWE from March to May by lowering the temperature in those areas below freezing.

4.5.5 June

The western portion of the ecoregion, except for the Owyhee Uplands and the toes of the Boise Mountains and Middle Rockies, is predicted to warm by about 1 degree C during this period (Figure 5-11). The Snake River Plain and the mountain ranges of northeastern Nevada and northwestern Utah are predicted to remain unchanged.

4.5.6 July and August

Except for a band of pixels along the Idaho-Oregon border, the average temperature in the middle and lower Snake River Plains and Owyhee Uplands is predicted to remain the same (Figure 5-12). The basin and range topography across the southern border of the ecoregion will warm by about 0.8 degree C during this period.

4.5.7 September and October

The model forecast predicts no change in temperature across the entire ecoregion for this period (Figure 5-13).

4.6 Precipitation and SWE

4.6.1 Existing Pattern

The general precipitation pattern for the mountainous areas of the ecoregion is for storms to begin moving through the mountains of the western part of the ecoregion in September and October with the majority of the precipitation falling from November through June (Mock 1996; Wise 2012). The exception to this pattern is pattern is the May maximum in southern Oregon and Idaho and in the upper Snake River Plain.

4.6.2 Annual

Overall, there will be a slight increase in the basins, valleys, and uplands and large increases in the mountains (Figure 5-14). It is not clear why there are substantial decreases along the northern border of the ecoregion but they may be caused by localized rain shadow effects.

4.6.3 November to February

The general pattern is for increased precipitation in the mountains and uplands and no changes in the basins or the lower elevations of the Owyhee Uplands (Figure 5-15). The increases are approximately 5 percent to 15 percent of the average for the entire year. However, based on observed measurements at Reynolds Creek in the Owyhee Mountains, the increasing temperatures in November to February could continue the trend of a decreasing proportion of snow to rain from the Owyhee Uplands, westward.

4.6.4 March to May

The general pattern is similar to that for November to February with increased precipitation in the mountains and uplands and no changes in the basins or the lower elevations of the Owyhee Uplands (Figure 5-16). The increases are smaller and approximately 2 percent to 10 percent of the average for the entire year.

4.6.5 June

The model predicts slight increases in the mountains and either no change or a very slight change in the basins, lower elevations of the Owyhee Uplands, and Snake River Plains (Figure 5-17). The western half of the ecoregion is predicted to become slightly warmer during June (Figure 5-11) so the slight increase in precipitation may offset some of the increased evapotranspiration demand.

Climate envelope modeling indicates that cheatgrass habitat suitability will be reduced in the ecoregion if climate changes results in increased precipitation during the summer (June-September) (Bradley 2009) but it is not clear if the predicted increase will meet that threshold when the predictions for July and August are included.

4.6.6 July and August

Most of the ecoregion is not modeled to experience a change in precipitation. Some isolated mountain ranges will have a slight increase in precipitation (Figure 5-18).

4.6.7 September and October

Most of the ecoregion will experience slightly reduced precipitation with the toes of the northern mountain ranges predicted to have slight increases (Figure 5-19).

4.7 Convective Precipitation (July & August)

An area extending from the Blue Mountains to the middle Snake River Plains and another at the toe of the Middle Rockies are predicted to experience a slight increase in convective precipitation while the remainder of the ecoregion will not change or experience a slight decrease (Figure 5-20). Interpreting this result in terms of its impact on fire ignitions is difficult without further modeling because of the complex topography in the ecoregion and the coarse resolution of RegCM3. Therefore, in this analysis all convective precipitation events were combined in contrast to Hostetler *et al.* (2003) who, in a more general analysis, imposed an upper precipitation threshold to eliminate "wet" convective storms which might not generate ignitions. Hostetler *et al.* (2003) found that RegCM (an earlier version of RegCM3) simulated convective storms in the west well in comparison to historical fire seasons and found that widespread convective outbreak in the region in 1996 (a very high ignition period) was due to convective storms generated by a subtropical ridge over the Great Basin, a weak upper level trough moving from the Gulf of Alaska, and a surface thermal low centered in the Great Basin (Hostetler *et al.* 2003). See the discussion in the "Summer Precipitation Sources Outside of Modeling Domain" section which follows for more discussion of summer convective precipitation mechanisms.

4.8 Snow Water Equivalent

While there are a number of papers detailing how the snow pack in the West has changed in recent years, a recent analysis of the raw data casts doubt on the quality of data used in those reports. For example, Christy (2012) found that despite a number of earlier reports, for all of California no statistically significant trends in monthly snowfall totals during the periods of record (up to 133 years) nor in the most recent 50 years were found (Christy 2012). This finding contradicts reports of declining snow deposition primarily by showing and removing, to the extent possible, systematic problems in the data that are primarily due to treating no data as zeros. The paper does not address whether earlier snow melt is occurring (Christy 2012). Assuming that similar record keeping and data problems exist outside of California then it is not possible to use existing long term data sets to detect trends in snow fall amounts. If we assume that the snow fall data in the ecoregion data are of good quality, Abatzoglu's analysis found a widespread decrease in mountain snowpack in the western U.S. at lower elevations due to a phase change of the Pacific-North American pattern (positive after the late 1970s) with some anthropogenic atmospheric forcing (Abatzoglu 2011). However, Abatzoglu's results show little effect within the ecoregion boundaries.

Temperature, precipitation, snow, and streamflow data have been carefully measured for forty-five water years (1962 to 2006) in the valley bottom, mid-elevation, and high-elevation sites in the Reynolds Creek Experimental Watershed in the Owyhee Mountains. The analysis of the data has found increasing temperatures at all elevations. The proportion of snow to rain has decreased at all elevations with the most significant decreases at the mid elevations and low elevations. Maximum seasonal snow water equivalent has decreased at all elevations. However, there has been no significant changes in water year total precipitation or streamflow. Streamflow has shown a seasonal shift, stronger at high elevations and delayed at lower elevations, to larger winter and early spring flows and reduced late spring and summer flows (Nayak *et al.* 2010). Based on the modeled increase in temperature in November to February the proportion of snow to rain could continue to decrease in the future from the Owyhee Uplands westward.

However, model forecast for temperature from March to May predicts a cooling of about -0.5 degree C during this period. Based on the model results for both March and April SWE (Figures 5-21 and 5-22), the mountains within the ecoregion will experience a slight to moderate increase in SWE in late spring while SWE in the basins, lower elevations of the Owyhee Uplands, and Snake River Plains will remain the same. Precipitation during the March to May period will also increase in the mountains and the average temperature across the ecoregion will decrease by about -0.5 degree C during this period which suggests an increase in snowfall.

4.9 Post Wildfire Wind Erosion Effects on Snow Pack Duration

While climate change projections indicate a significant increase in mean SWE during March and April, the deposition of dust from post fire dust storms within the ecoregion on snow in downwind mountain ranges (see Germino *et al.* 2012) (both NGB and Middle Rockies (MR) for example) could have immediate and severe impacts on both terrestrial (wolverine and pika) and aquatic (salmonids) sensitive status species. Dust generated in the Great Basin and deposited on snow in the San Juan Mountains of Colorado was calculated to have reduced seasonal snow cover by 18 to 35 days (Painter *et al.* 2007). Similar effects within the boundaries of the ecoregion and the Middle Rockies ecoregion would have direct impacts on sensitive status species winter den habitat and stream hydrology.

4.10 Summer Precipitation Sources Outside of Modeling Domain

Existing GCM predictions of drying in the southwest US are generated by the reduction of winter season precipitation and not by changes in the North American Monsoon (NAM) (Segar and Vecchi 2010). However, the current GCMs do a poor job of simulating patterns of sea surface temperature (SST) change in tropical Pacific Ocean and existing climate in the western US is very sensitive to small changes in the temperature and location of SSTs (Segar and Vecchi 2010). This suggests that there may be some surprising results that are not included in the domains of the models. The discussion below briefly describes an historical precedent and some potential drivers of change in the NAM based on very recent research. This potential change is not likely to occur by 2069 and while speculative should be considered as a very remote alternative scenario.

The Great Basin was a much more humid region 10,000 years ago when it was dominated by large lakes. In contrast to much of the past literature, very recent results have found that the maximum highstands (sea level) of Lake Lahontan and Lake Bonneville were due to the transport of moisture northwards from the tropics during a summer monsoon and not a southerly shift in the winter Westerlies (Lyle *et al.* 2012). Additionally, the northwestern shift in the monsoon was caused by Pacific sea surface temperatures rather than those of the Gulf of California and neither the modern seasonal SST cycle nor El Niño/Southern Oscillation patterns provides valid analogues (Barron *et al.* 2012; McClymont *et al.* 2012).

Trend analysis of the NAM from 1948-2004 shows a decrease in July precipitation and an increase in precipitation in August and September (Grantz *et al.* 2007) and provides two hypotheses: 1) Reduced July precipitation is correlated with higher Tropical Pacific SSTs and lower North Pacific SSTs in the winter and spring leading to wetter conditions at that time of year in the southwest. These conditions slow the heating of the Southwest delaying the arrival of the NAM as it migrates northward from Mexico, and; 2) Warmer SSTs off California and in the Gulf of California drive the increased precipitation in August and September. However, a more recent study found that the future of the North American Monsoon is poorly predicted because the current GCMs do a poor job of simulating patterns of SST change in tropical Pacific Ocean and there are widely varying projections among the models (Segar and Vecchi 2010).

The NAM is caused by a number of complex drivers that vary in scale and which result in summer precipitation through convective storms starting in June in Mexico and moving north into the Southwest in July, August, and September (National Weather Service Climate Prediction Center 2006; Vera 2006). There is extensive spatial and temporal variability in the NAM surges into the U.S. that is the subject of intense study because of its importance to the hydrology of Arizona, Colorado, and New Mexico.

The largest NAM surges are associated with tropical cyclones (Higgins and Shi 2005) and the study of tropical cyclones induced surges is very active. The eastern North Pacific is climatologically the most active basin for tropical cyclone (depressions, storms, and hurricanes) formation (Corbosiero *et al.* 2009). Figure 2 in Corbosiero *et al.* illustrates how the Great Basin lies just to the northwest of the area where 35-40 percent of annual precipitation occurs during the summer and a shift of that higher precipitation area to the northwest would double the annual amount of precipitation in the Great Basin. California/Nevada track tropical cyclones that interact with cutoff cyclones situated off the coast of California do not need to make landfall as major storms to significantly increase summer precipitation. These storms and their interactions with extratropical cyclones moving eastward into the northwest are more likely to occur in September when evapotranspiration rates in the Great Basin are rapidly decreasing (Corbosiero *et al.* 2009) and thus are more likely to recharge soil moisture.

Tropical cyclones that originate in the eastern Pacific generally fall into five categories including one that recurves to the north or northwest bringing precipitation to the west coast of the US. The fifth category doesn't fit any of the usual patterns and is described in (Wood and Ritchie 2012a). Tropical cyclones in the northern eastern Pacific can transition into extra-tropical cyclones, recurve into the Pacific Northwest, and bring heavy and extensive precipitation to regions that are rarely impacted by tropical cyclones (Wood and Ritchie 2012a). Extra-tropical transitioning of tropical cyclones to intense storms is common in many ocean basins but not the eastern Pacific of North America. However some TCs in the eastern Pacific do transform to storms although they are rare (Wood and Ritchie 2012a). Tropical storm Ignacio (1997) is a case of a tropical cyclone that caused precipitation in the southwest and then retained its symmetry and went through extra-tropical conversion and caused precipitation in northern California and the Pacific Northwest (Wood and Ritchie 2012b). It likely formed to the west and north of the typical Inter-tropical Convergence Zone (ITCZ) wave zone due to convective activity moving west from Mexico, was steered north by strong ridge of the Bermudian high, interacted with the remnants of an earlier strong tropical cyclone that had moved far out into the Pacific, and then transitioned into an extra-tropical cyclone. Sea surface temperatures were not elevated despite the fact that it was an El Nino year (Wood and Ritchie 2012b).

Given that the spatial extent of the primary drivers of the current of the North American Monsoon do not extend northward as far as the locations of former Lake Lahontan and Lake Bonneville, the extra-tropical transitioning of tropical cyclones described above offers an alternative scenario that is not accounted for in GCMs or in RegCM3.

5 Management Questions

The climate change analysis in Section 5 and associated figures provides forecasts of expected variations in temperature and precipitation through five key periods throughout the year. These forecasted deviations from the normal climate variation can be applied to answer the following management questions as they relate to CEs and their habitats. Each CE has a discussion on how climate change will potentially impact it in the future. Therefore answers to these questions can be found in each individual conservation element package.

MQ 5. Where are species CEs whose current locations or suitable habitats overlap with the potential future distribution of CAs (other than climate change)?

MQ 8. Where will landscape species and species assemblage CEs (not including white sturgeon and cave bat species, and limited to winter and/or summer range for mule deer, pronghorn winter range) experience climate outside their current climate envelope?

MQ 12. Where will current locations of native plant communities experience significant deviations from normal climate variation?

MQ 23. Where will Wild Horse and Burro Management Areas experience significant deviations from normal climate variation?

MQ 26. Where will grazing allotments experience significant deviations from normal climate variation?

MQ 29. Where will current vulnerable soil types experience significant deviations from normal climate variation?

MQ 64. Where will changes in climate be greatest relative to normal climate variability?

MQ 65. Given anticipated climate shifts and the direction shifts in climate envelopes for CEs, where are potential areas of significant change in extent such as ecotones?

MQ 66. Where are vegetation CEs that will experience significant deviations from normal climate variation?

MQ 67. Where are wildlife CE habitats that will experience significant deviations from normal climate variation?

MQ 68. Where will aquatic CEs experience significant deviations from historic climate variation that potentially could affect the hydrologic and temperature regimes of these aquatic CEs?

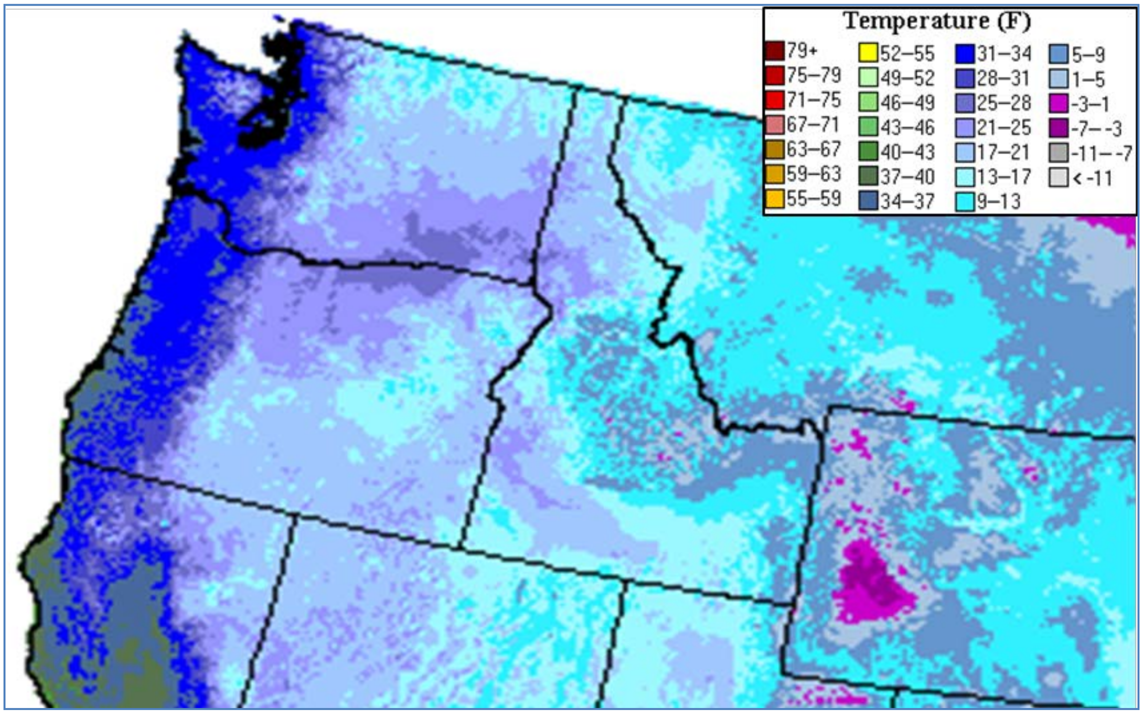

Figure 5-1. Minimum Temperature – January Climatology (1971-2000) (PRISM)

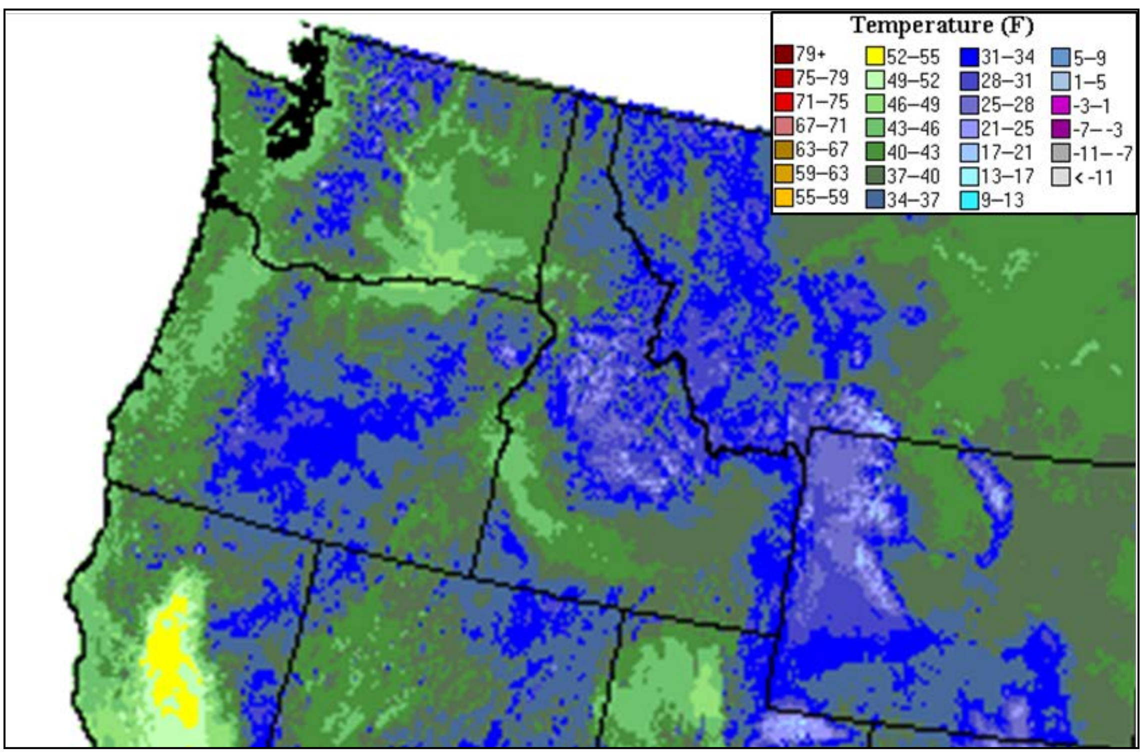

Figure 5-2. Minimum Temperature – May Climatology (1971-2000) (PRISM)

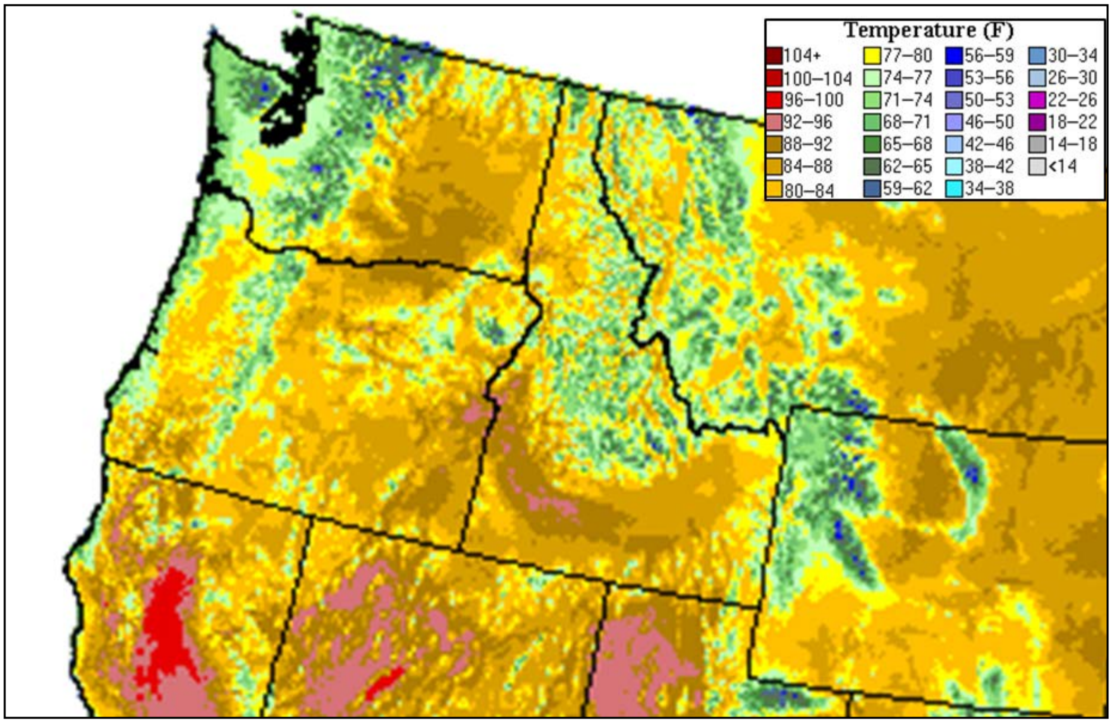

Figure 5-3. Maximum Temperature –July Climatology (1971-2000) (PRISM)

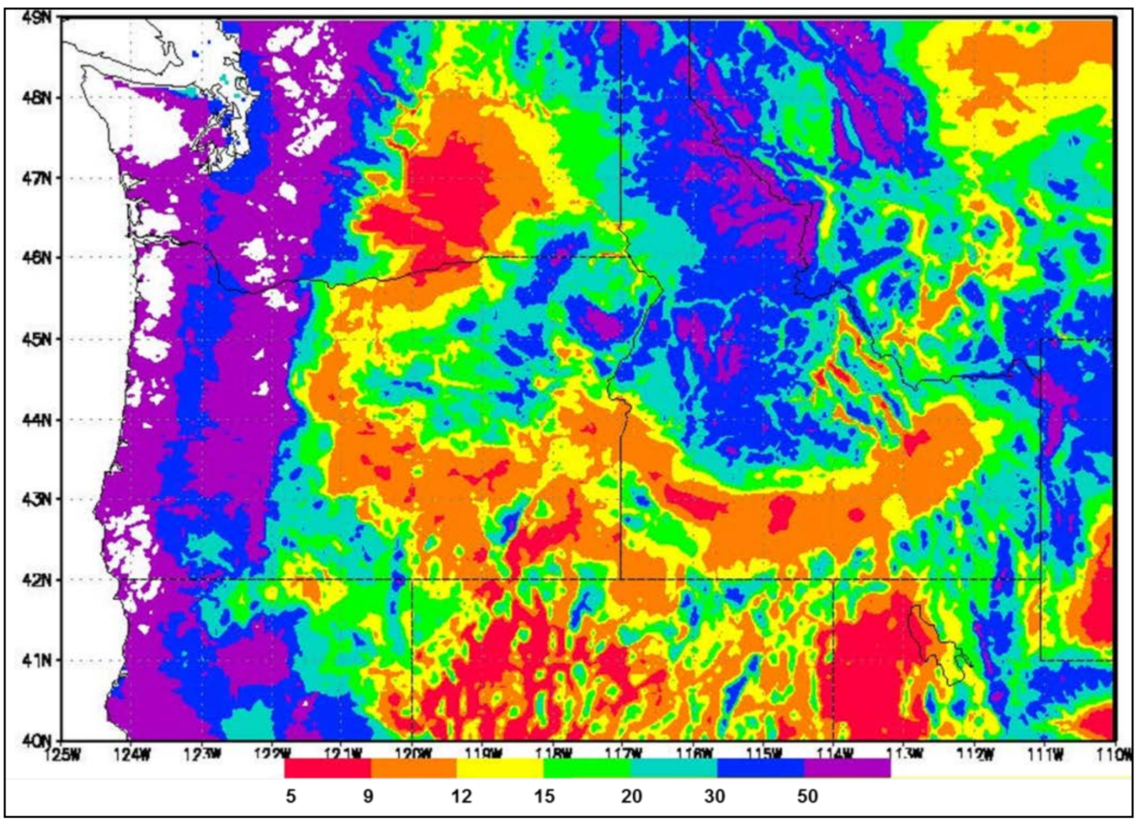

Figure 5-4. Mean Annual Precipitation (Inches) (1971-2000) (PRISM)

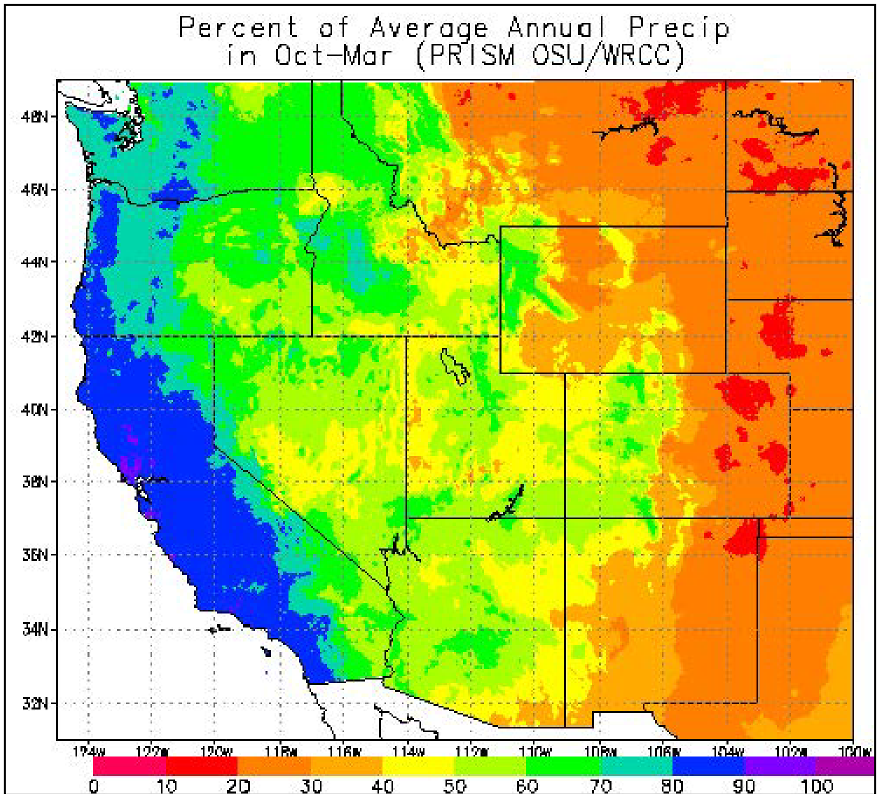

Figure 5-5. Percent of Average Annual Precipitation (Oct-Mar)

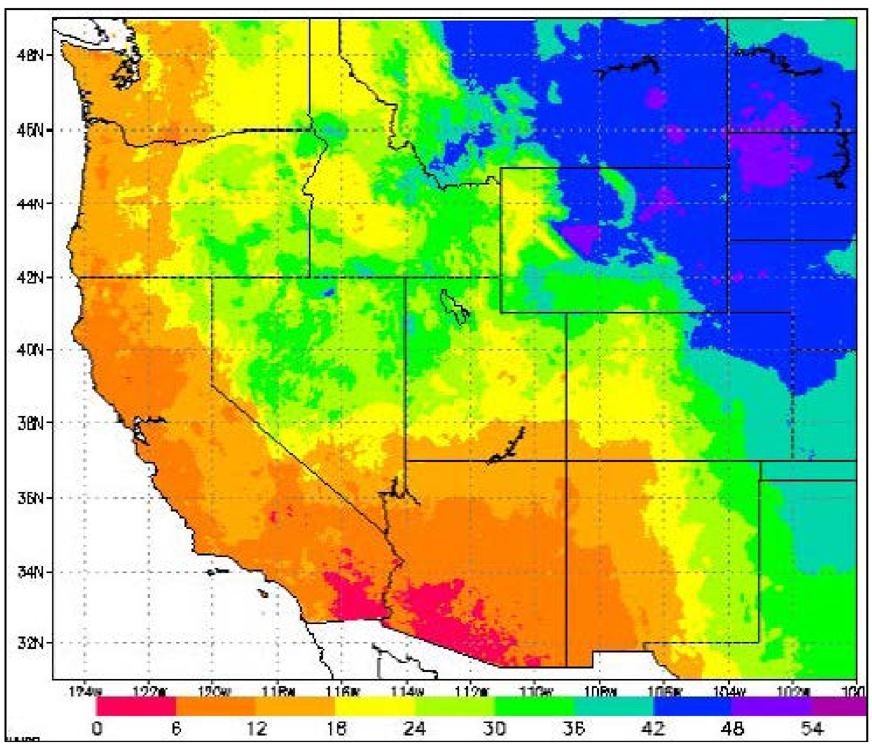

Figure 5-6. Percent of Average Annual Precipitation (April to June)

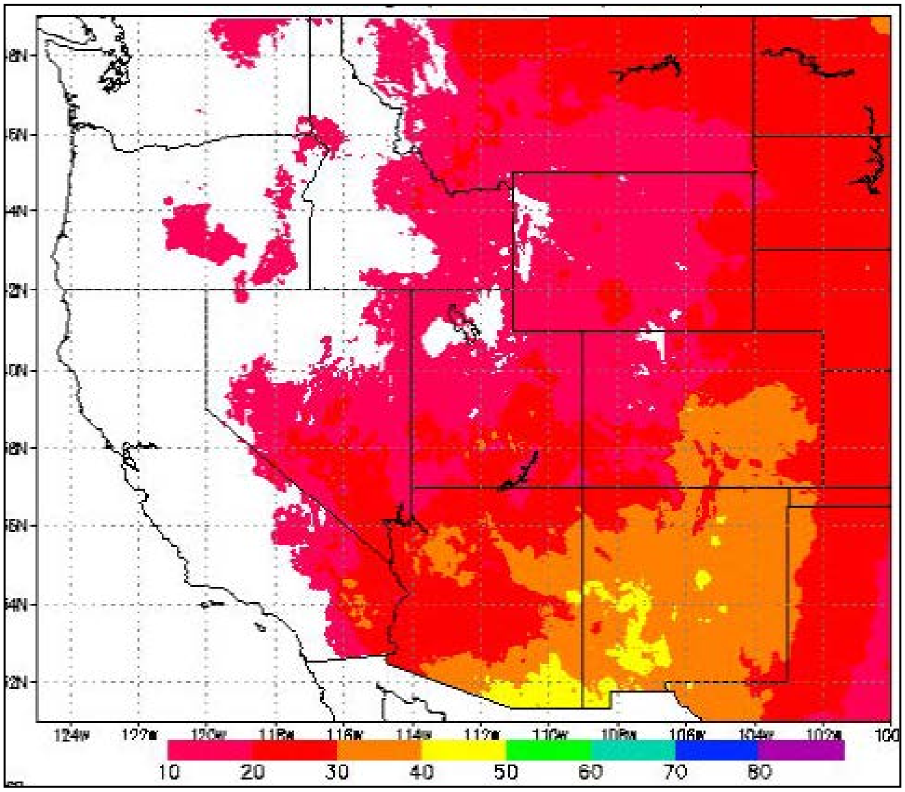

Figure 5-7. Percent of Average Annual Precipitation (July and August)

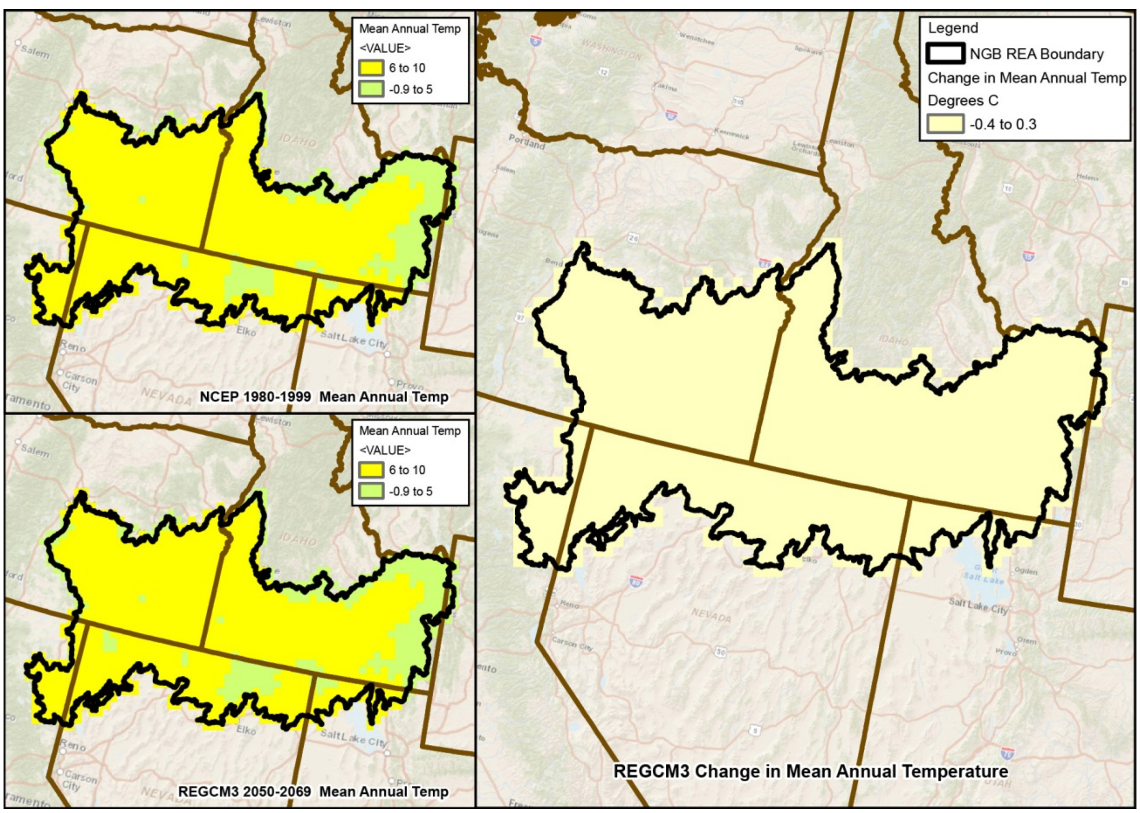

Figure 5-8. Mean Annual Temperature (Current top left, Future bottom left) and Forecasted Change (right)

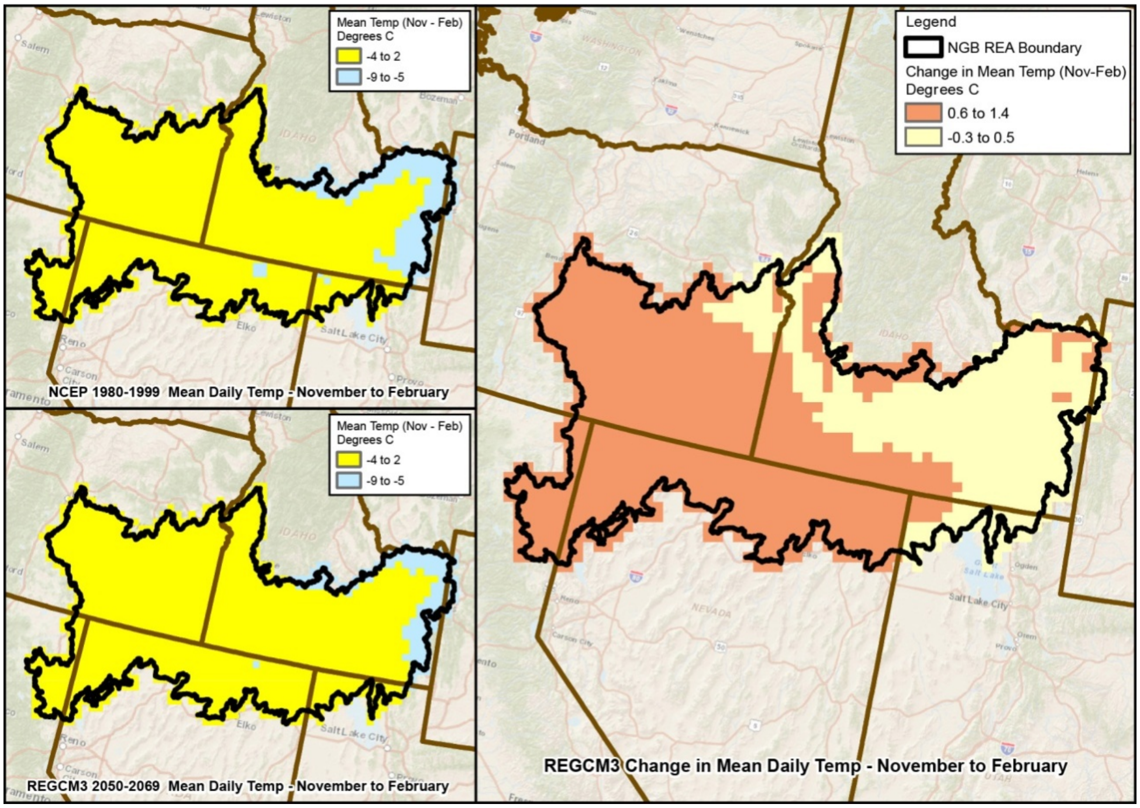

Figure 5-9. November to February Temperature and Forecasted Change

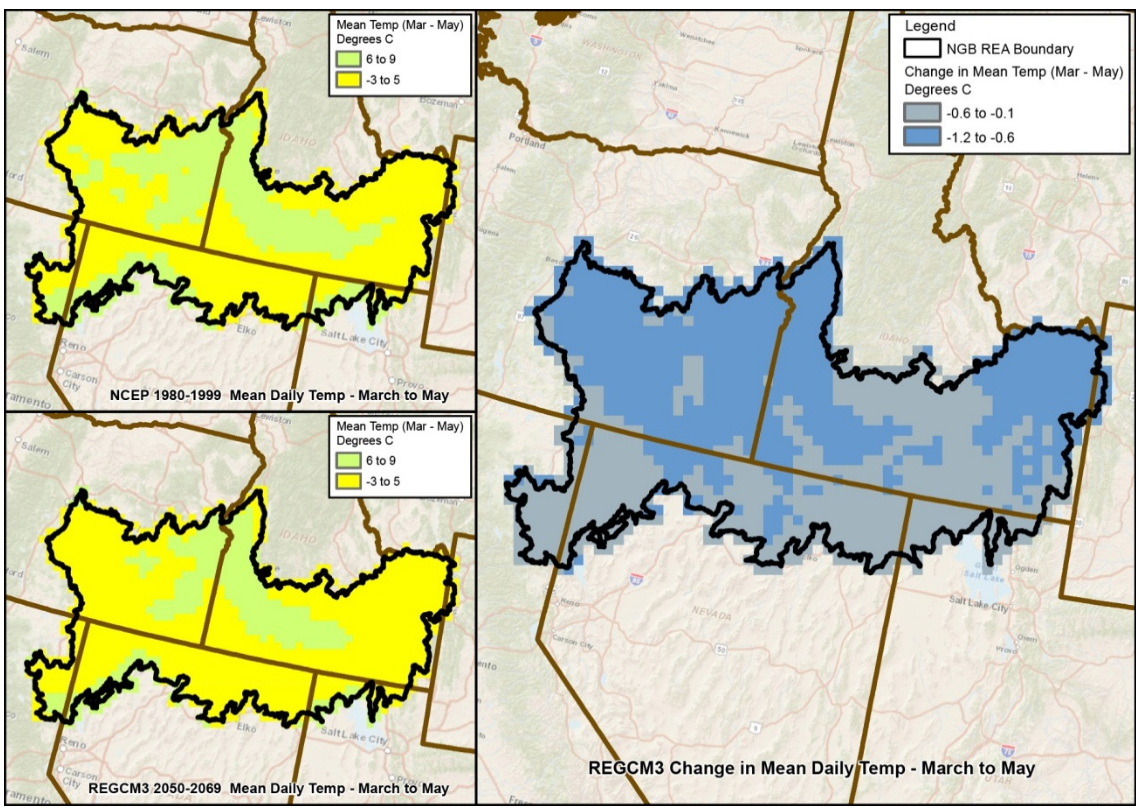

Figure 5-10. March to May Temperature and Forecasted Change

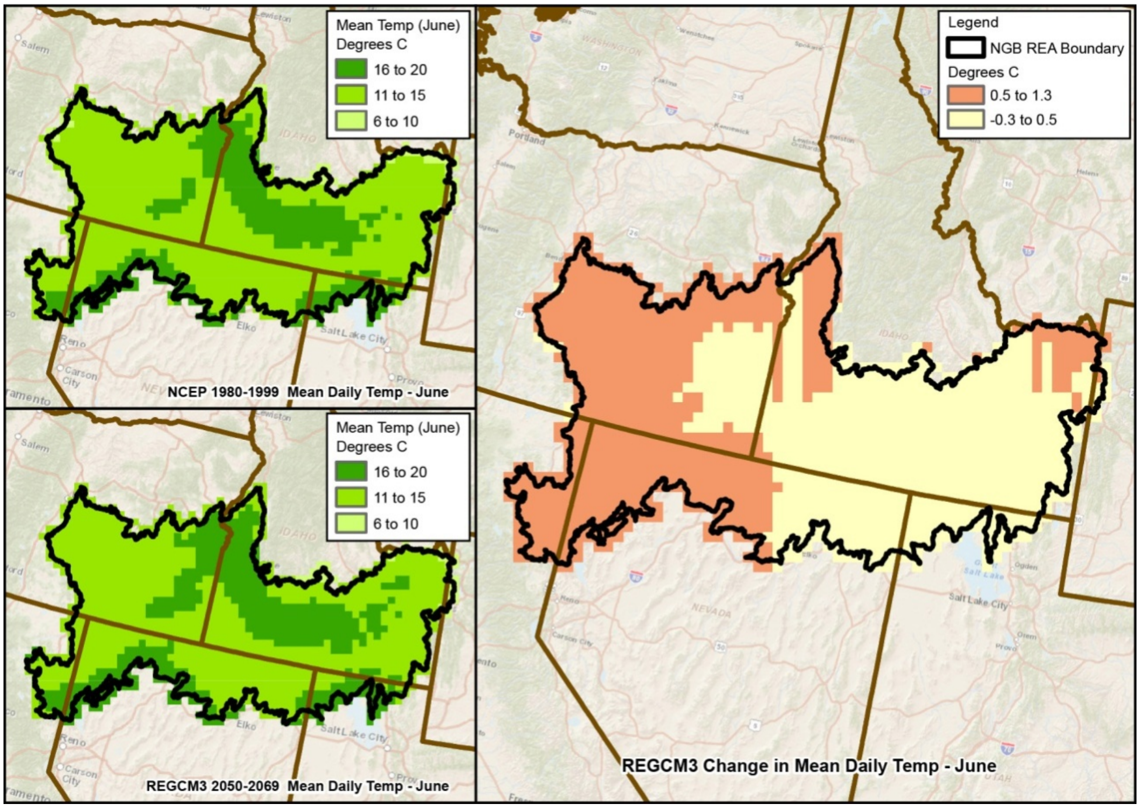

Figure 5-11. June Temperature and Forecasted Change

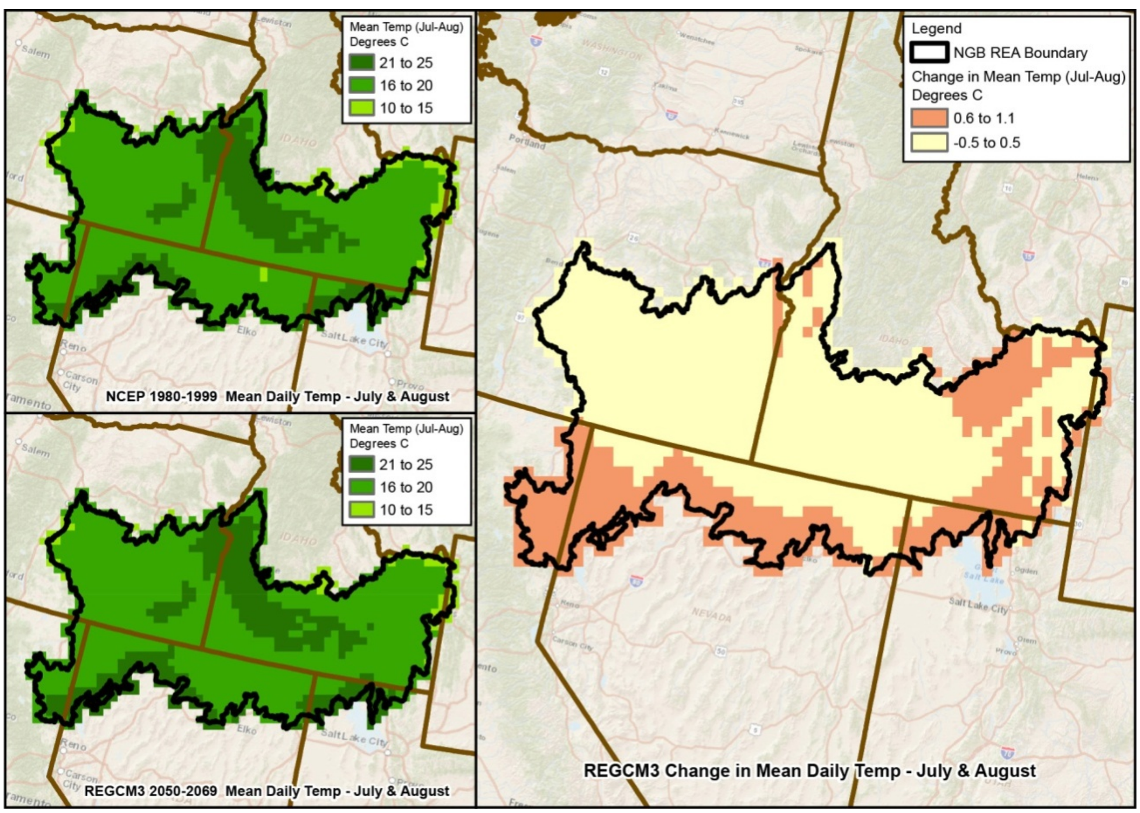

Figure 5-12. July and August Temperature and Forecasted Change

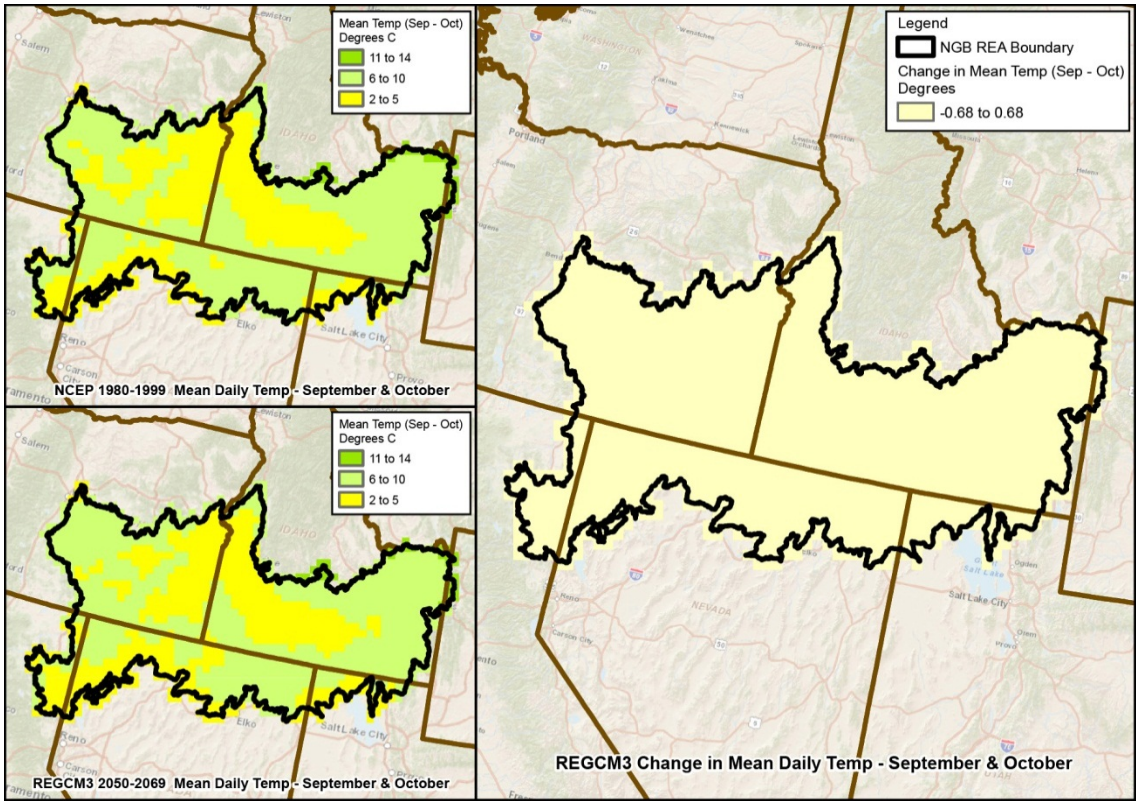

Figure 5-13. September and October Temperature and Forecasted Change

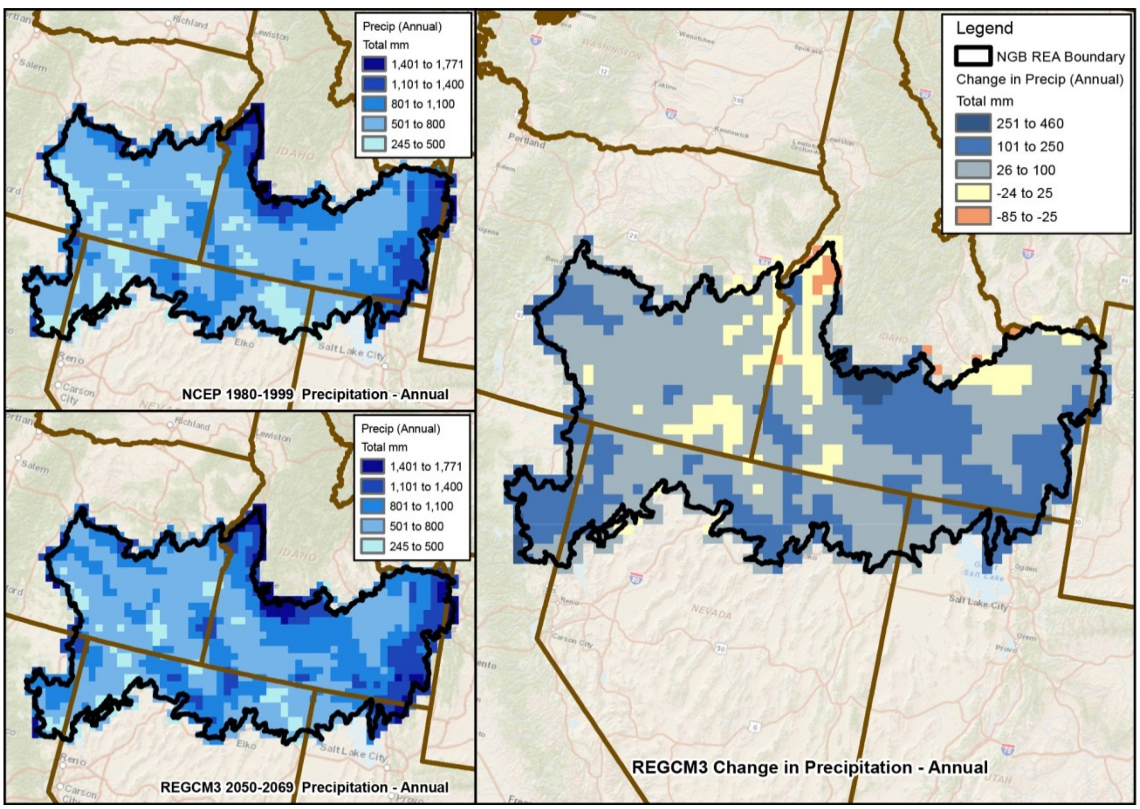

Figure 5-14. Annual Precipitation and Forecasted Change in Selected Ranges

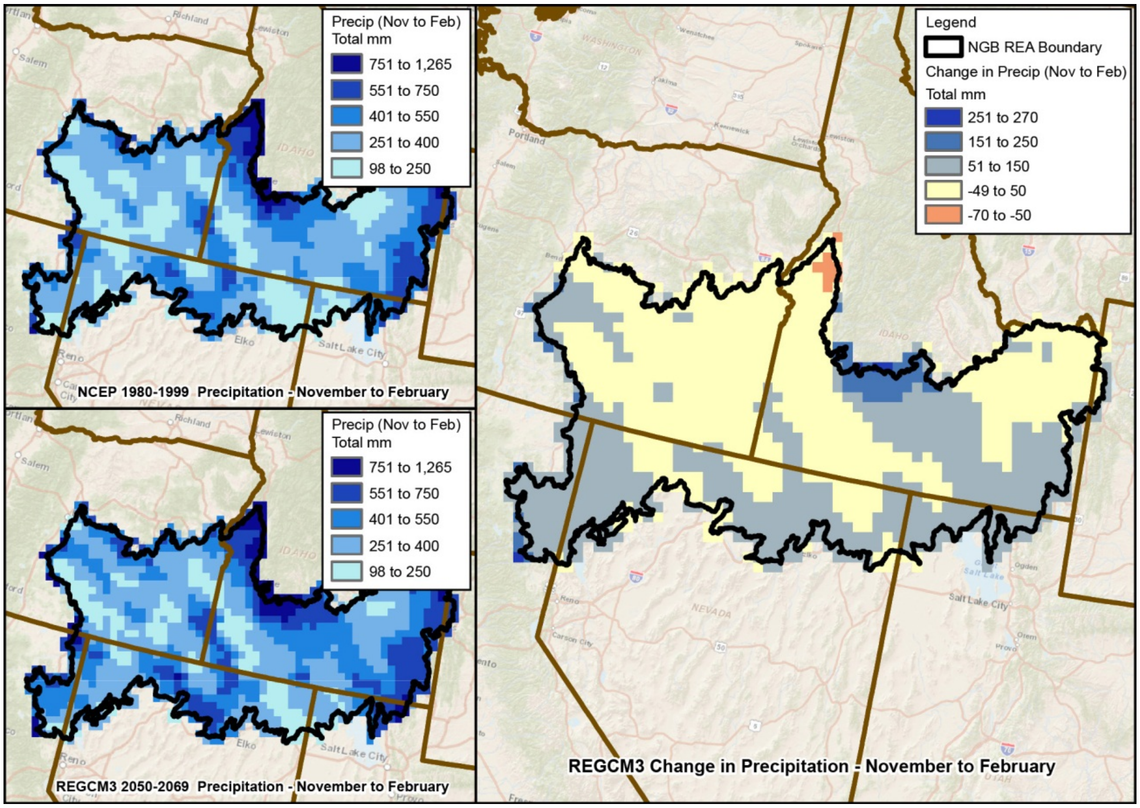

Figure 5-15. November to February Precipitation and Forecasted Change

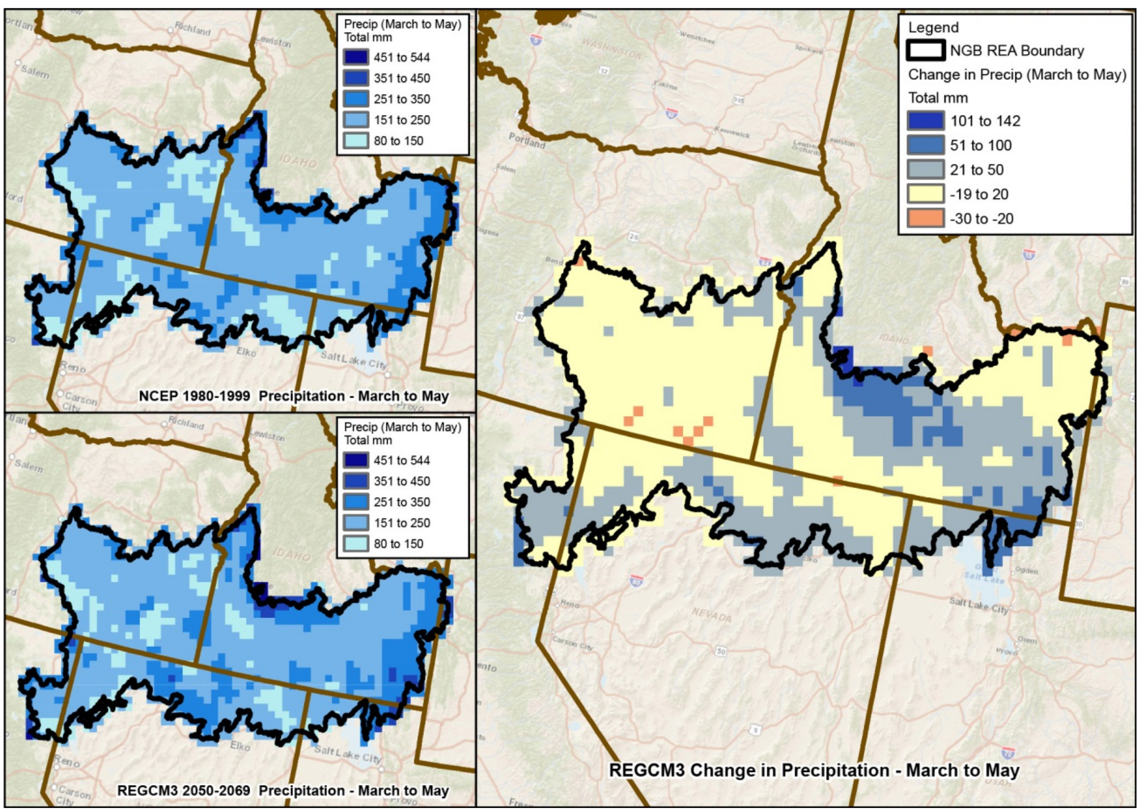

Figure 5-16. March to May Precipitation and Forecasted Change

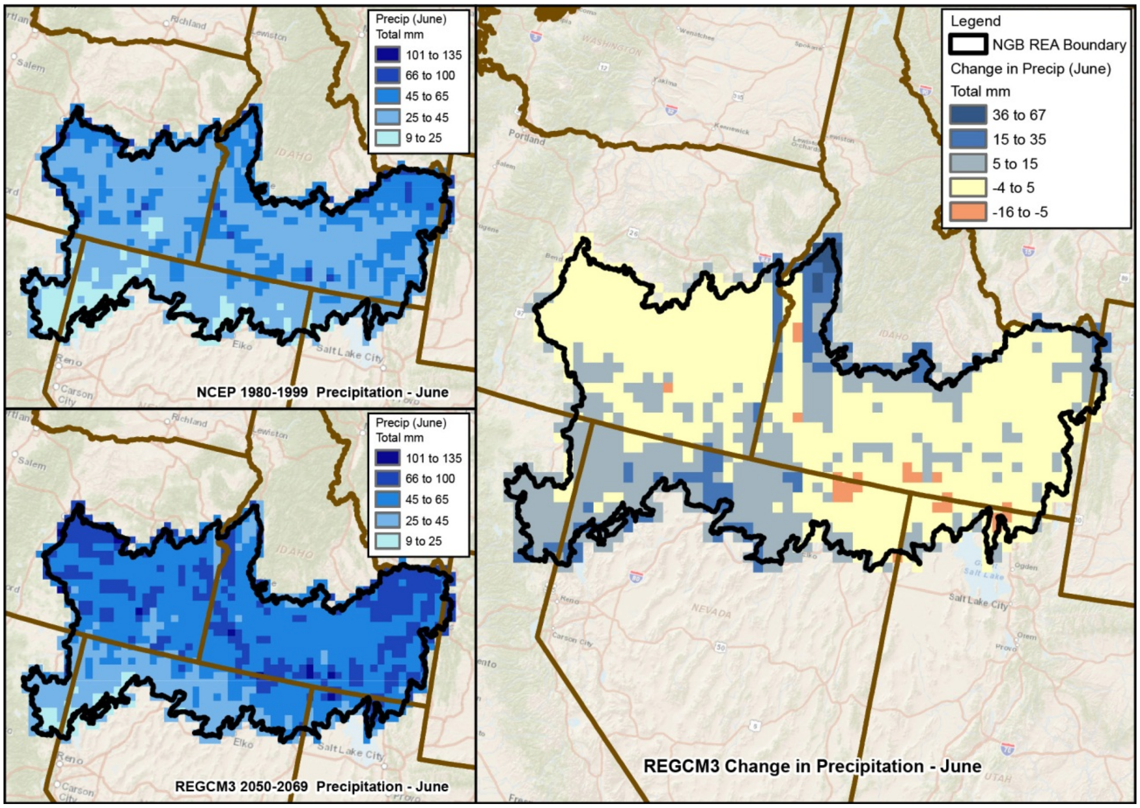

Figure 5-17. June Precipitation and Forecasted Change

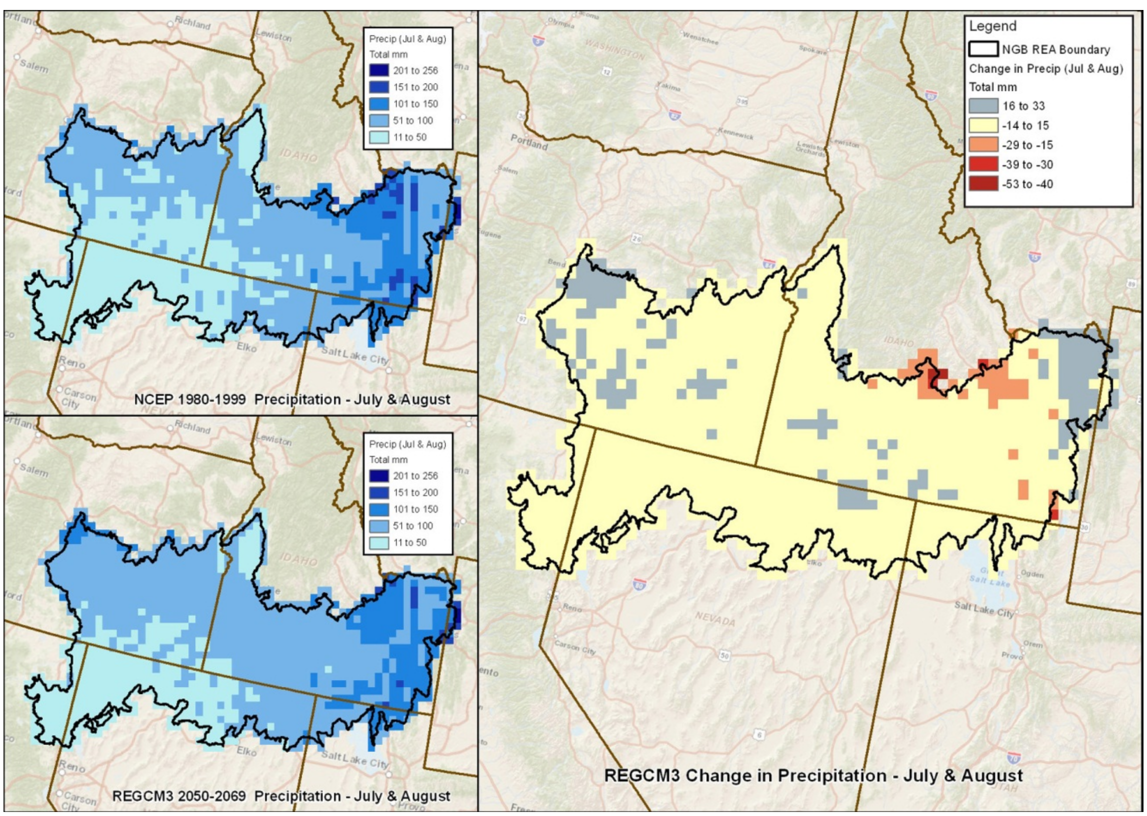

Figure 5-18. July and August Precipitation and Forecasted Change

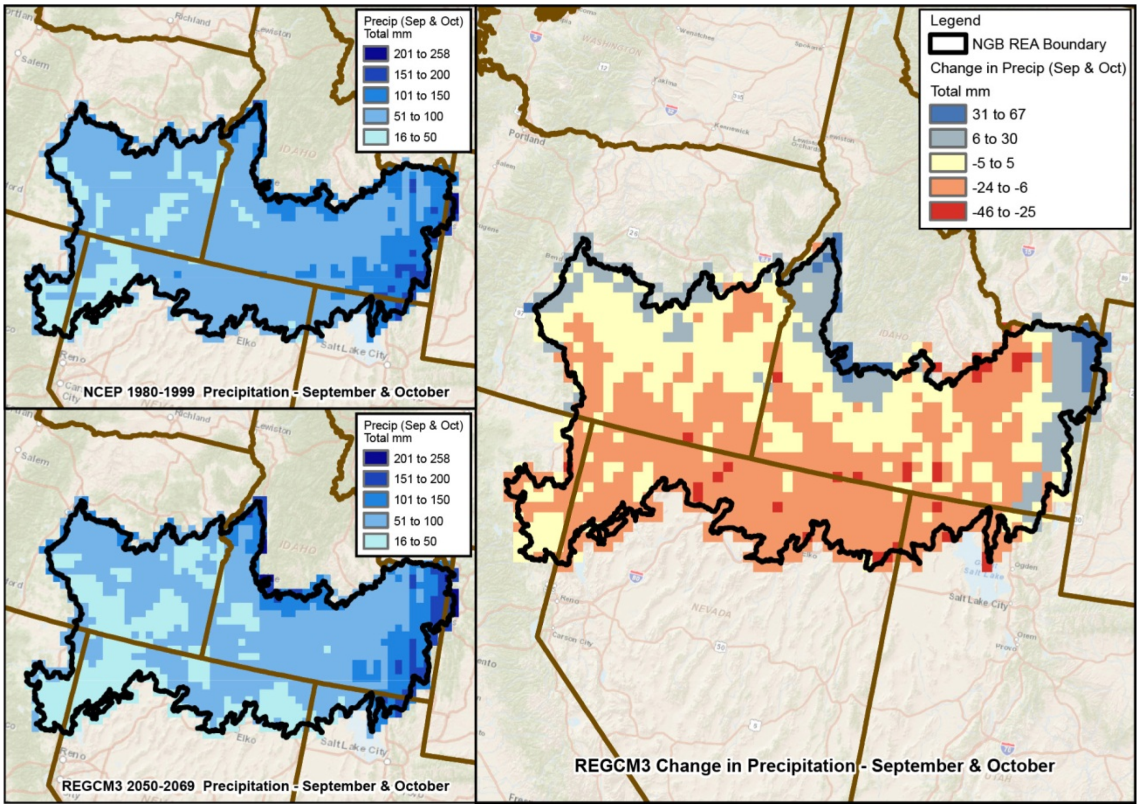

Figure 5-19. September to October Precipitation and Forecasted Change

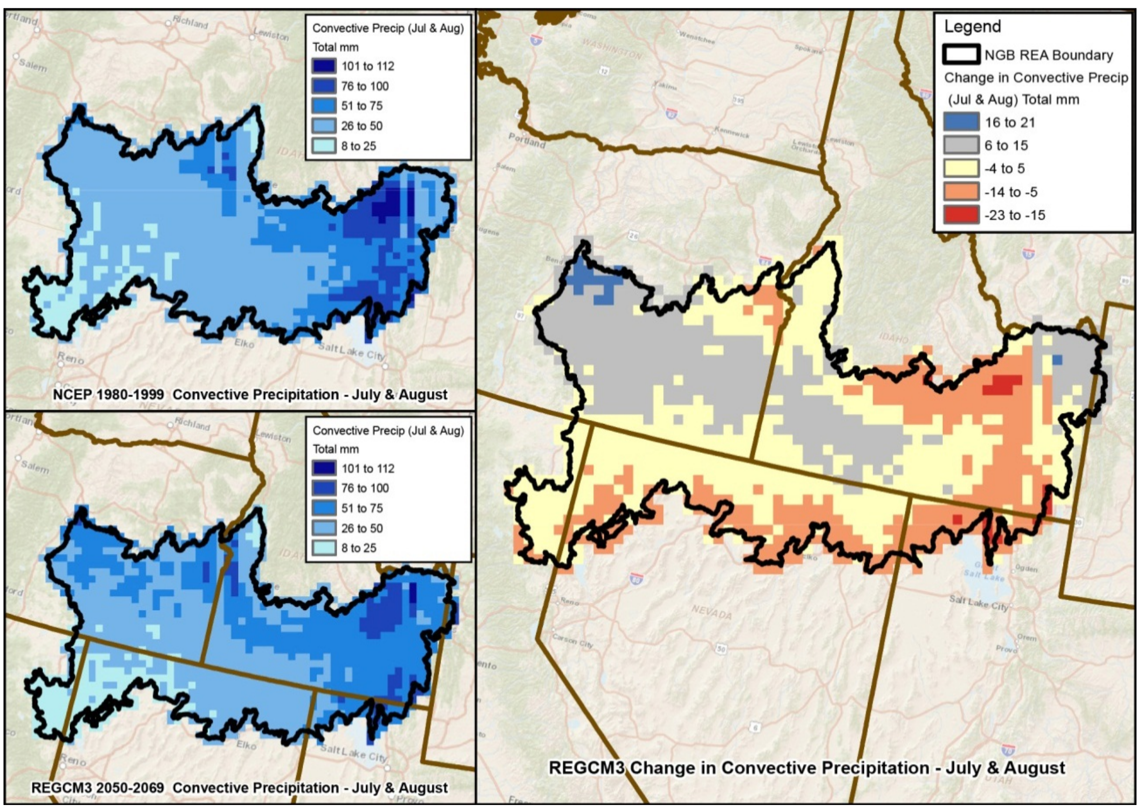

Figure 5-20. July and August Convective Precipitation and Forecasted Change

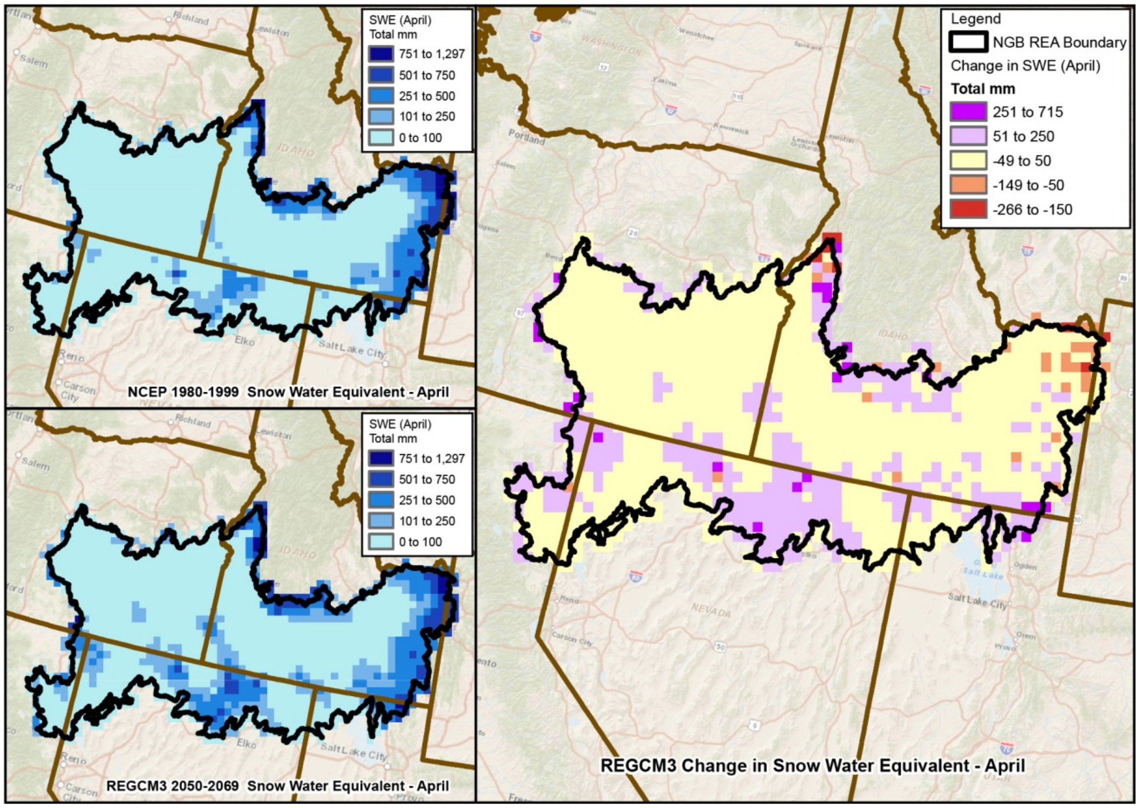

Figure 5-21. April Snow Water Equivalent and Forecasted Change

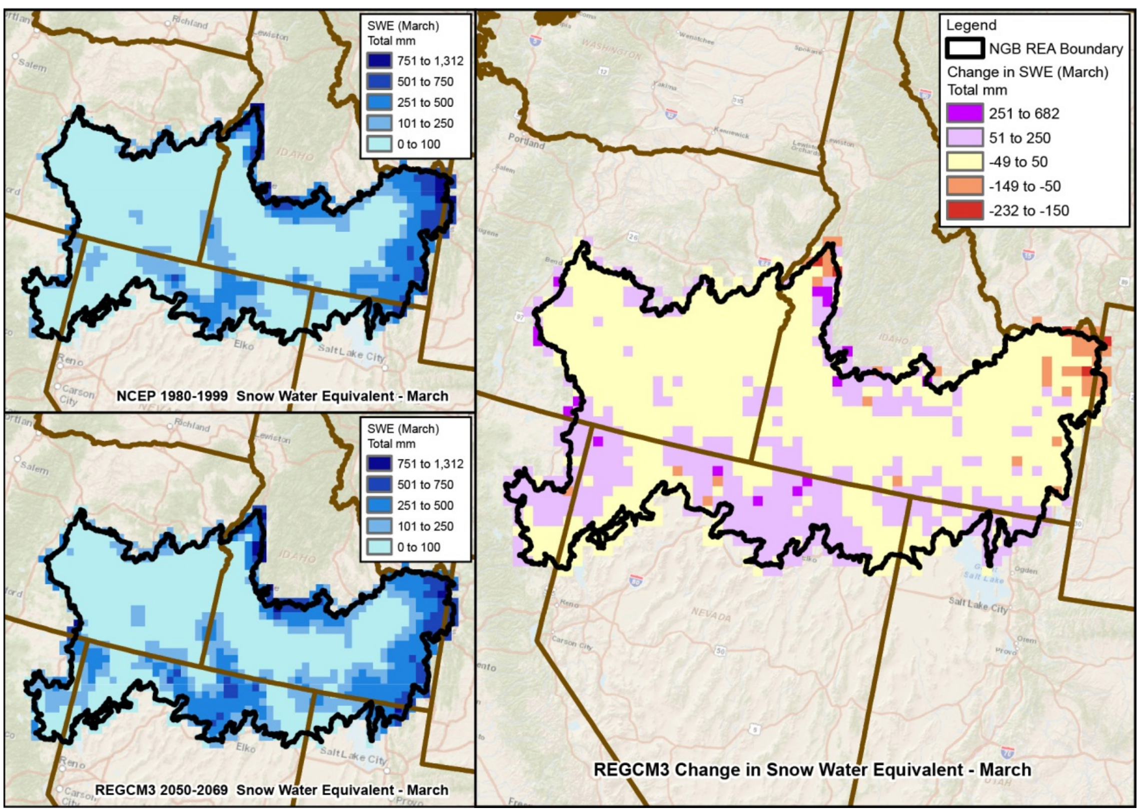

Figure 5-22. March Snow Water Equivalent and Forecasted Change

6 References

Abatzoglu, J.T. 2011. Influence of the PNA on declining mountain snowpack in the western United States. International Journal of Climatology 31:1135-1142.

Adger, W.N., N.W. Arnella, and E.L. Tompkins. 2005. Successful adaptation to climate change across scales. Global Environmental Change 15: 77–86.

Andrewartha, H.G., and L.C. Birch. 1954. The Distribution and Abundance of Animals. Univeristy of Chicago Press. Chicago, IL.

Barron, J.A., S.E. Metcalfe, J.A. Addison. 2012. Response of the North American monsoon to regional changes in ocean surface temperature. Paleoceanography 27: 10.1029/2011PA002235.

Beier, C.M., S.A. Signell , A. Lutman, A.T. DeGaetano. 2012. High-resolution climate change mapping with gridded historical climate products. Landscape Ecol (2012) 27:327–342.

BLM. 2008. H-1740-2 - INTEGRATED VEGETATION MANAGEMENT HANDBOOK

Bradley, B. 2009. Regional analysis of the impacts of climate change on cheatgrass invasion shows potential risk and opportunities. Global Change Biology 15:196-208.

Baughman, O.W. and S.E. Meyer. 2013. Is Pyrenophora semeniperda the Cause of Downy Brome (Bromus tectorum) Die-offs? Invasive Plant Science and Management 6(1):105-111. 2013

Christy, J.R. 2012. Searching for information in 133 Years of California snowfall observations. Journal of Hydrometerology 13: 895-912.

Corbosiero, K.L., M.J. Dickinson, and L.F. Bosart. 2009. The contribution of eastern north Pacific tropical cyclones to the rainfall climatology of the southwest United States. Monthly Weather Review 137:2415-2435.

Cox, M., D.W. Lutz, T. Wasley, M. Fleming, B. B. Compton, T. Keegan, D. Stroud, S. Kilpatrick, K. Gray, J. Carlson, L. Carpenter, K. Urquhart, B. Johnson, and C. McLaughlin. 2009. Habitat Guidelines for Mule Deer: Intermountain West Ecoregion. Mule Deer Working Group, Western Association of Fish and Wildlife Agencies.

Daly, C. 2006. Guidelines for assessing the suitability of spatial climate data sets. International Journal of Climatology 26: 707–721.

deVos, J.V. Jr. and T. McKinney. 2007. Potential Impacts of Global Climate Change on Abundance and Distribution of Elk and Mule Deer in Western North America. Final Report to the Western Association of Fish and Wildlife Agencies. Available online at: http://www.createstrat.com/i/globalwarmingdoc2.pdf.

Edwards, M. and A.J. Richardson. 2004. Impact of climate change on marine pelagic phenology and trophic mismatch. Nature 430: 881-884. August.

Ge, Y. and G. Gong. 2009. Physical mechanisms linking the winter Pacific-North American Teleconnection pattern to spring North American snow depth. Journal of Climate 22:5135-5148.

Germino, M. J. Sankey, A. Hoover, N. Glenn, and N. Wagenbrenner. 2012. Fire, Wind, and Water: Landscape change and its relationship to development. Presentation at the WMMA Meeting, Idaho Falls, Idaho. August, 2012.

Grantz, K., B. Rajagopalan, M. Clark, and E. Zagona. 2007. Seasonal shifts in the North American Monsoon. Journal of Climate 20:1923-1935.

Higgins, R.W. and W. Shi. 2005. Relationships between Gulf of California moisture surges and tropical cyclones in the Eastern Pacific Basin. Journal of Climate 18:4601-4620.

Hostetler, S., P.J. Bartlein, J.O. Holman, A.M. Solomon, and S.L. Shafer. 2003. Using a regional climate model to diagnose climatological and meteorological controls of wildfire in the western United States. Fifth Symposium on Fire and Forest Meterology. American Meteorological Society, 16-20 November. Orlando, FL.

Hostetler, S.W., J.R. Adler, and A.M. Allan. 2011. Dynamically downscaled climate simulations over North America: methods, evaluation, and supporting documentation for users. U.S. Geological Survey Open-File Report 2011-1238.

Lutz, D. W., and 7 co-authors. 2003. Impacts and changes to mule deer habitat. *In*: Mule Deer Conservation: Issues and Management Strategies. J.C. deVos, Jr., M.R. Conover, and N.E. Hedrick, editors. Berryman Institute Press, Utah State University, Logan.

Lyle, M., L. Heusser, C. Ravelo, M. Yamamoto, J. Barron, N.S. Diffenbaugh, T. Herbert, and D. Andreasen. 2012. Out of the tropics: the Pacific, Great Basin lakes, and late Pleistocene water cycle in the western United States. Science 337:1629-1633.

MacArthur, R.M. 1972. Geographical Ecology. Harper & Row. New York.

McClymont, E.L., R.S. Ganeshram, L.E. Pichevin, H.M. Talbot, B.E. van Dongen, R.C. Thunell, A.M. Haywood, J.S. Singarayer, and P.J. Valdes. 2012. Sea-surface temperature records of Termination 1 in the Gulf of California: Challenges for seasonal and interannual analogues of tropical Pacific climate change. Paleoceanography 27: 10.1029/2011PA002226.

McIver, J.D., M. Brunson, S. Bunting, J. Chambers, N. Devoe, P. Doescher, J. Grace, D. Johnson, S. Knick, R. Miller, M. Pellant, F. Pierson, D. Pyke, K. Rollins, B. Roundy, G. Schupp, R. Tausch, D. Turner. 2010. The Sagebrush Steppe Treatment Evaluation Project (SageSTEP): A Test of State-and-Transition Theory. RMRS-GTR-237. USDA Forest Service General Technical Report, Rocky Mountain Research Station, Ft. Collins, CO. 16 p.

Mock, C.J. 1996. Climate controls and spatial variations of precipitation in the western United States. Journal of Climate 9:1111-1125.

National Weather Service Climate Prediction Center. 2006. The North American Monsoon. Reports to the Nation. http://www.cpc.ncep.noaa.gov/products/outreach/Report-to-the-Nation-Monsoon_aug04.pdf

Nayak, A., Marks, D., Chandler, D.G., and Seyfried, M. Long-term snow, climate, and streamflow trends at the Reynolds Creek Experimental Watershed, Owyhee Mountains, Idaho, United States. Water Resources Research, Vol. 46.

Painter, T.H., A.P. Barrett, C.C. Landry, J.C. Neff, M.P. Cassidy, C.R. Lawrence, K. E. McBride, and G.L. Farmer. 2007. Impact of disturbed desert soils on duration of mountain snow cover. Geophysical Research Letters 34: L12502, doi:10.1029/2007GL030284.

Parmesan, C. and G. Yohe. 2003. A globally coherent fingerprint of climate change impacts across natural systems. Nature 421: 37-42. January.

Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. Annual Review of Ecology, Evolution, and Systematics. 37:637-69.

Pearson, R.G and T.P. Dawson. 2003. Predicting the impacts of climate change on the distribution of species: are bioclimate envelope models useful? Global Ecology & Biogeography 12: 361–371.

Ritchie, E.A., K.M. Wood, D.S. Gutzler, and S.R. White. 2011. The influence of eastern Pacific tropical cyclones remnants on the southwestern United States. Monthly Weather Review 139:192-210.

Saha, S., S. Moorthi , H. Pan, X. Wu, J. Wang, S. Nadiga, P. Tripp, R. Kistler, J. Woollen, D. Behringer, H. Liu, D. Stokes, R. Grumbine, G. Gayno, J. Wang, Y. Hou, H. Chuang, H. Juang, J. Sela, M. Iredell , R. Treadon, D. Kleist, P. Van Delst, D. Keyser, J. Derber, M. Ek, J. Meng, H. Wei, R. Yang, S. Lord, H. van den Dool, A. Kumar, W. Wang, C. Long, M. Chelliah, Y. Xue, B. Huang, J. Schemm, W. Ebisuzaki, R. Lin, P. Xie, M. Chen, S. Zhou, W. Higgins, C. Zou, Q. Liu, Y. Chen, Y. Han, L. Cucurull , R. Reynolds, G. Rutledge, and M. Goldberg. 2010. The NCCP climate forecast system reanalysis. Bulletin of the American Meteorological Society: DOI:10.1175/2010BAMS3001.1:1015-1057.

Sala, O.E., F.S. Chapin , J.J. Armesto, E. Berlow, J. Bloomfield, R. Dirzo, E. Huber-Sanwald, L.F. Huenneke, R.B. Jackson, A. Kinzig, R. Leemans, D.M. Lodge, H.A. Mooney, M. Oesterheld, N. L. Poff, M.T. Sykes, B.H. Walker, M. Walker, and D.H. Wall. Global Biodiversity Scenarios for the Year 2100. Science 287(5459): 1770-1774.

Scott, Joe H.; Burgan, Robert E. 2005. Standard fire behavior fuel models: a comprehensive set for use with Rothermel's surface fire spread model. Gen. Tech. Rep. RMRS-GTR-153. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 72 p.

Seager, R. and G.A. Vecchi. 2010. Greenhouse warming and the 21st century hydroclimate of southwestern North America. Proceedings of the National Academy of Sciences 107:21277-21282.

Siler, N., G. Roe, and D. Durran, 2012. On the dynamical causes of variability in the rain-shadow effect: a case study of the Washington Cascades. Journal of Hydrometeorology doi: http://dx.doi.org/10.1175/JHM-D-12-045.1.

USGCRP (U.S. Global Climate Research Program). 2012. Our Changing Planet. A report by the U.S. Global Change Research Program and the Subcommittee on Global Change Research, a supplement to the President's budget for fiscal year 2012. National Science and Technology Council, Washington, D.C.

Vera, C., W. Higgins, J. Amador, T. Ambrizzi, R. Garreaud, D. Gochis, D. Gutzler, D. Letterman, J. Marengo, C.R. Mechoso, J. Nogues-Paegle, P.L. Silva Dias, and C. Zhang. 2006. Toward a unified view of the American Monsoon system. Journal of Climate 19: 4977-5000.

Walther, G-R., E. Post, P. Convey, A. Menzel, C. Parmesan, T. J. C. Beebee, J-M. Fromentin, O. Hoegh-GuldbergI, and F. Bairlein. 2002. Ecological responses to recent climate change. Nature 416: 389-395. March.

Wang, S., R.R. Gillies, E.S. Takle, and W.J. Gutowski, Jr. 2009. Evaluation of precipitation in the Intermountain Region as simulated by the NARCCAP regional climate models. Geophysical Research Letters 36:10.1029/2009GL037930.

Williams Jr., P. 1972. Western region synoptic analysis – problems and methods. NOAA Technical Memorandum NWS WR71.

Wise, E.K. 2010. Spatiotemporal variability of the precipitation dipole transition zone in the western United States. Geophysical Research Letters 37:L07706.

Wise, E.K. 2012. Hydroclimatology of the US Intermountain West. Progress in Physical Geography 36:458-469.

Wood, K. M. and E. A. Ritchie, 2012a. A 40-year climatology of extratropical transition in the eastern North Pacific. Extended abstract presented at: 30th Conference on Hurricanes and Tropical Meteorology; 2012 April 15-20; Ponte Vedra Beach, Florida.

Wood, K. M. and E. A. Ritchie. 2012b. The unusual behavior and precipitation pattern associated with tropical storm Ignacio (1997). Monthly Weather Review 140:3347-3360.