Threats Assessment for the Northern Great Plains Ecoregion

World Wildlife Fund Northern Great Plains Program
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Summary of Findings

Grasslands around the globe are among the least protected biomes, yet they provide important habitat for a diversity of species, as well as food, fuel, and fiber to sustain human populations. The Northern Great Plains ecoregion was chosen as one of World Wildlife Fund's (WWF) 15 priority landscapes around the world due to its relative intactness, rich biodiversity, and potential for conservation. In 2004, WWF and partners published an assessment of conservation opportunities in the Northern Great Plains ecoregion, entitled *Ocean of Grass*, which has guided the work of many organizations over the past decade. However, threats to the landscape have changed dramatically since data were gathered for the previous assessment. Oil and gas exploration using unconventional drilling techniques in the Williston Basin of western North Dakota was just beginning when the previous assessment was published. Likewise, wind energy was not considered in the previous assessment but has gained momentum across the ecoregion, particularly in the last five years. Below is a summary of findings related to threats across the ecoregion:

- Energy development, especially in the form of oil and gas in western North Dakota and coalbed methane and coal production in the Powder River Basin, has the potential to dramatically change the face of the landscape over the next 10-20 years. New estimates suggest that oil production could reach two million barrels per day in western North Dakota by 2025 and an additional 32,000-35,000 wells will be drilled by 2032.
- Acreage of land used to farm corn and soybeans has increased dramatically over the past 30 years. Soybeans now cover almost three million more acres than they did in the late 1970s, while corn acreage has increased by 1.1 million. Increasing government payments by 25% may lead to an additional one million acres of grassland lost to cropland. Climate change may lead to an 18% higher probability of converting grassland to cropland in some parts of the ecoregion.
- In the Northern Great Plains, approximately 5,000 km^2 of land in the US and 1,000 km^2 in Canada will need to be developed for wind energy in order for the two countries to meet their goal of producing 20% of their energy from wind by 2030.
- Terrestrial and aquatic invasive species are widespread across rangelands in the Northern Great Plains. Recent studies suggest that 21% of rangelands in the western US are moderately degraded either in the integrity of the biotic system, the hydrologic functioning of the system, or the stability of the soil, due to invasive species.
- Increases in temperature of up to 2.6°C (4.68°F) occurred in the Northern Great Plains during the period from 1951 to 2002. By the 2050s, temperatures may increase by an additional 5.7°C (10.26°F). Precipitation may decrease by up to 100 mm (3.64 in) in some parts of the ecoregion.
- Diseases, such as sylvatic plague and West Nile virus, are impacting black-tailed prairie dogs, black-footed ferrets, and greater sage-grouse, which are all species of conservation concern. In the Conata Basin alone, which was once a stronghold of prairie dog and ferrets populations, over 20,000 acres of prairie dog colonies have been affected by plague and essentially wiped out since 2008. West Nile virus is predicted to move westward into important sage-grouse habitat by 2030 due to climate change. This will stress already struggling populations.

- The density of roads has increased nearly three-fold in some areas within the Northern Great Plains over the past decade. Areas of high road density tend to be associated with high population densities and are also areas of oil and gas production, such as the Williston Basin in western North Dakota and the Powder River Basin in northeastern Wyoming.
- The construction of dams has greatly affected the character and flows of the Missouri River, which serves as the primary hydrological corridor across the ecoregion. Reductions in the total surface area by 50%, increases in velocity, and decreased sediment transport have led to the decline of pallid sturgeon and cottonwood forests, both of which rely on natural flows for reproduction.

The following report assesses how these threats have changed the face of conservation in the Northern Great Plains over the past decade and what impacts they have on species of conservation concern.

Introduction

Grasslands across the globe represent a unique ecosystem that sustains high levels of biodiversity, provides important ecosystem services, and sustains human populations through the production of food and fiber. Grasslands are diverse and productive ecosystems, yet they are among the least protected ecosystems around the world. Globally, on average, only 4.6% of grasslands are currently in protected area status (IUCN categories I-IV), and those lands that are not protected are facing myriad pressures (Hoekstra et al., 2005).

The Northern Great Plains (NGP) ecoregion in North America represents one of the best remaining opportunities for grassland conservation worldwide. The NGP, as defined by Forrest et al. (2004; Figure 1), covers approximately 279,000 mi^2 (722,600 km^2), or about 25% of the entire Great Plains, and encompasses parts of five US states and two Canadian provinces, stretching from southwestern Saskatchewan and southeastern Alberta in the north to the Nebraska Sandhills in the south.

Figure 1: The Northern Great Plains Ecoregion.

Due to the region's vast agricultural and energy resources, threats to the ecoregion create unique challenges to conservation. While human populations are generally declining in smaller towns across the region, hubs for energy development and tourism are experiencing population booms that are stressing infrastructure and housing development. Western North Dakota, eastern Wyoming, and southeastern Alberta are all currently experiencing the impacts of energy development and the accompanying boom in population. Western South Dakota's population has risen over the last census period (2000-2010), largely due to tourism opportunities around the Black Hills. In addition to these threats, the ecoregion also faces pressure from agricultural conversion, wind energy development, coal production, invasive species, climate change, diseases, fragmentation, and dams.

Oil and gas development

Oil and gas development is occurring on public, private, and tribal lands across the ecoregion. Major oil and gas developments within the US portion of the NGP boundary include the Williston Basin in western North Dakota and the Powder River Basin in eastern Wyoming (Figure 2). The Williston Basin covers approximately 201,000 mi^2 (520,590 km^2) in North Dakota, South Dakota, Montana, Saskatchewan, and Manitoba. The Powder River Basin covers about 24,000 mi^2 (62,160 km^2) in northeastern Wyoming and southeastern Montana.

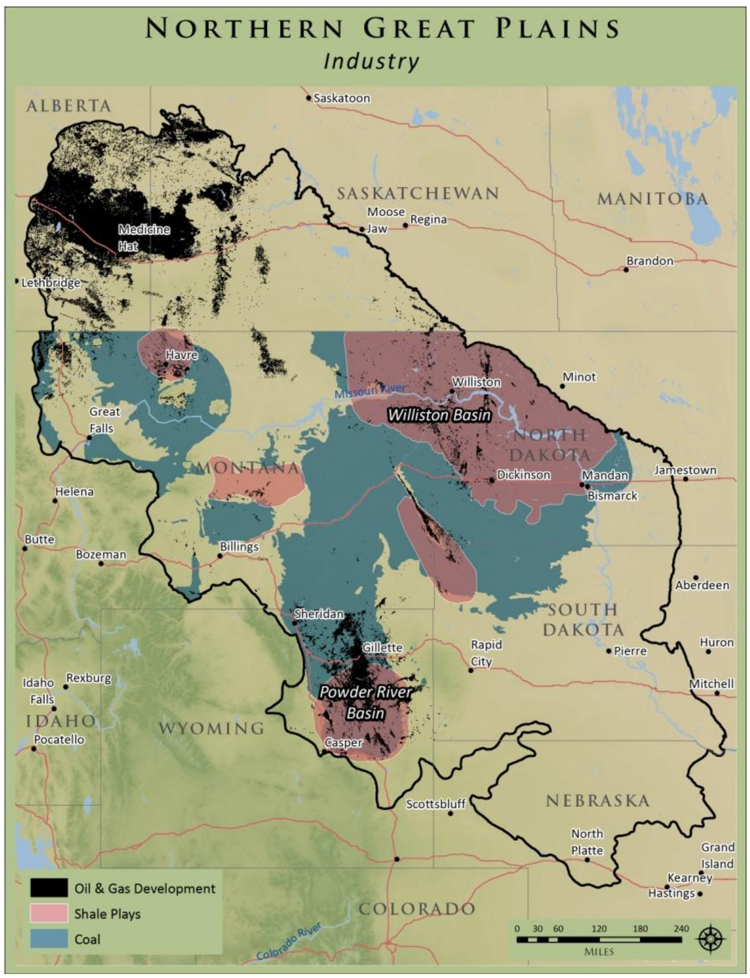

Figure 2: Location of oil and gas development, shale plays and coal fields in the NGP. Williston Basin and Powder River Basin are also highlighted.

Williston Basin

The Bakken Formation, which is the underlying geological substrate that holds the oil and gas resources within the Williston Basin, is the largest continuous oil accumulation in the contiguous US. The formation requires unconventional drilling methods (i.e., hydraulic fracturing or “fracking”) to recover the resources. The major threats associated with energy development in the Bakken Formation include the speed at which the resource is being developed, the potential for future development, and the unconventional method used for recovering the oil. As of April 2012, over 18 million barrels of oil were being produced monthly in North Dakota, with daily production in the hundreds of thousands of barrels (North Dakota Oil and Gas Division, 2012).

The majority of the oil production in the Bakken Formation is happening in four counties: Dunn, McKenzie, Mountrail, and Williams. Most of this development is occurring on private lands, with some production occurring on federal and tribal lands. These four counties alone produced over 16 million barrels of oil during April 2012 (North Dakota Oil and Gas Division, 2012). As of February 2012, five drilling rigs were active within the Dakota Prairie Grasslands (which is managed by the US Forest Service) in North Dakota, all of which are located within the Little Missouri National Grasslands. To date, the most significant oil fields, in terms of geographic size and oil production, within the Bakken Formation, are shown in Table 1.

Table 1: Most significant oil fields within the Bakken Formation.

Oil Field Name	County	State/Province
Viewfield	n/a	Saskatchewan
Daly Sinclair	n/a	Manitoba
Ross	Mountrail	North Dakota
Stanley	Mountrail	North Dakota
Sanish	Mountrail	North Dakota
Parshall	Mountrail	North Dakota
Mondak	McKenzie	North Dakota
Elm Coulee	Richland	Montana

The majority of the oil boom in the Bakken Formation has taken place since early 2004. According to estimates from the US Geological Survey (USGS), approximately 3.0-4.3 billion barrels of recoverable oil (mean=3.65 billion) are currently stored in the Bakken Formation (Pollastro et al., 2011). However, the USGS began a new study of resource potential in October 2011, which will be completed in late 2013, and new estimates are speculated to be around eight billion barrels of oil (Department of Interior [DOI], 2011). A separate study suggests that daily oil production may rise to two million barrels per day by 2025 (Associated Press, 2012). By comparison, the north slope of Alaska has already produced 15.7 billion barrels of oil and contains approximately an additional 6.1 billion barrels (Department of Energy, 2009). North Dakota currently estimates that approximately 2,000 new wells will be drilled each year for the next 10-20 years (McEnroe and Sapa, 2011), which means that only about 10% of the total projected wells are currently active on the landscape.

Hydraulic fracturing is the method used to recover oil from the Bakken Formation. Fracking, as it is commonly known, injects a mixture of sand, chemicals, and water (about a million gallons per well) down into a well that is drilled vertically 10,000 feet below the earth's surface and then curves horizontally. Once this mixture reaches the shale layer, the rock fractures and gas is released into fissures. These fissures are held open by the sand in the mixture, which forces the gas back up to the well on the surface. A leftover mixture of chemicals, water and sand is then pumped back up to the surface and deposited in open pits before going to a treatment facility. One of the major issues with this drilling method is the amount of water used per well. As of May 2012, 3,983 wells were producing in North Dakota alone, which equates to nearly four billion gallons of water (North Dakota Oil and Gas Division, 2012). Studies are currently underway by an interagency group (including the Department of Energy [DOE], Environmental Protection Agency [EPA], and USGS) to determine if and how brackish water may be used in order to limit the amount of potable water used in this process (DOI, personal communication, July 17, 2012). These studies will be completed in January 2013.

Another issue with fracking is that the chemicals that are injected into the well are generally not disclosed by the drilling companies and may leach into drinking water (Thompson, 2012). Companies are supposed to reinject the brine (the leftover wastewater) back into the ground, but spills are common; over 1,000 spills occurred in North Dakota in 2011 (Kusnetz, 2012). Moreover, disturbance associated with drilling rigs, as well as direct mortality, is impacting wildlife in the area. Twenty-eight birds were found dead in waste pits in North Dakota between May and June 2011, and seven companies faced fines under the Migratory Bird Treaty Act (MacPherson, 2011).

Other potential impacts from fracking include changes in behavior of some animals, including greater sage-grouse (*Centrocercus urophasianus*). Sage-grouse avoid areas of energy development due to noise from drilling rigs, the increase in predators along transmission lines, and disturbance and fragmentation of habitat. Greater sage-grouse once numbered 542 in North Dakota, but have been steadily declining since 2000 (North Dakota Game and Fish Department, 2010). Currently, the population of greater sage-grouse numbers less than 100 (a 2010 count found 66 birds) and hunting is closed. Greater sage-grouse are also threatened by West Nile virus (see below under Disease for more information), which is thought to have contributed to the decline in North Dakota, along with habitat destruction (North Game and Fish Department, 2010).

Other species that may potentially be affected by oil and gas development include large mammals, such as elk (*Cervus canadensis*), mule deer (*Odocoileus hemionus*), bighorn sheep (*Ovis canadensis*), and pronghorn (*Antilocapra americana*), as well as migratory grassland birds and sharp-tailed grouse (*Tympanuchus phasianellus*; McEnroe and Sapa, 2011). The North Dakota Game and Fish Department has initiated a five-year study on the impacts of oil and gas on sharp-tailed grouse and has co-funded a study on impacts to mule deer, but no additional studies are currently planned. Instead, biologists plan to use information from the oil and gas development in Wyoming (Jakle, 2012) to help guide their recommendations to oil and gas companies (Donovan, 2011). Following is a synopsis of the potential impacts of oil and gas on wildlife species.

- A 75% decline in mule deer, elk, and pronghorn migrations due to long-term habitat fragmentation;
- Data from Wyoming showing a 47% decline in mule deer densities in areas developed for oil and gas versus undeveloped areas;
- The potential for almost 6,000 new wells to be drilled within bighorn sheep range by 2021.
- Avoidance of developed areas by pronghorn;
- Avoidance by up to one mile of roads and active drilling wells by elk (McEnroe and Sapa, 2011).

More specific impacts to wildlife are detailed in a report from the North Dakota Game and Fish Department (Dyke et al., 2011). For mule deer, road density appears to be a primary impact of oil and gas development. Road densities of greater than three miles of road per square mile (4.8 km of road per 1.6 km^2) classify as moderately degraded habitat. Of the total mule deer range in North Dakota, 5.6% is impacted at this level (up from 1% in 1995), with 18% of primary range moderately degraded. Approximately 4,500 acres (1,821 ha) of primary mule deer range almost 7,200 acres (2,914 ha) of secondary range have been directly lost due to oil and gas wells, as of 2010. Mule deer start to avoid habitat within 1.6 to 2.2 miles (2.6 to 3.5 km) of a well and have been shown to have an alert response within 0.29 miles (0.47 km) of a well, which equates to four evenly spaced well pads per section (259 ha). Extreme impacts occur at a density of greater than 16 wells per section (259 ha) and greater than 80 disturbed acres (32 ha) per section (259 ha; Dyke et al., 2011).

Bighorn sheep populations may be less likely to recover from disturbance than other ungulates due to low dispersal rates and low birth rates. Bighorn sheep also tend to abandon habitat during and after disturbance. Recommendations are that well pads should be placed greater than 1,650 feet (503 m) and roads should be placed greater than 660 yards (604 m) from important lambing areas (Dyke et al., 2011).

In North Dakota, 34% of pronghorn range has a road density of 2-3 miles of road per square mile (3.2-4.8 km of road per 1.6 km^2), while 9% is affected at a rate of 3-5 miles of road per square mile (4.8-8.0 km of road per 1.6 km^2). Previous research has shown moderate impact to pronghorn populations at 1-4 pads per square mile (1.6 km^2), or 20 acres [8 ha] of disturbance per square mile (1.6 km^2), and high impact at 5-16 pads per square mile (1.6 km^2) or 20-80 acres [8-32 ha] of disturbance per square mile (1.6 km^2). Extreme impact occurs with more than 16 pads per square mile (1.6 km^2) or greater than 80 acres (32 ha) of disturbance per square mile (1.6 km^2; Dyke et al., 2011).

Elk habitat in North Dakota also has been impacted by oil and gas development. More than 17% of current elk habitat is occupied by well pads, with an estimate of 8,000 more well sites being developed within elk habitat over the next decade. The majority of the development is occurring near Killdeer, which represents the best elk habitat in North Dakota. Elk have been shown to prefer areas that are greater than 2,000 feet (607 m) from roads and up to 5,000 feet (1524 m) from active operations, such as wells. Road densities of 2.5 miles of road per square mile (4 km of road per 1.6 km^2) will decrease habitat effectiveness for elk (Dyke et al., 2011).

Between 1980 and 2010, sage-grouse populations declined by 78% in North Dakota. As of 2010, oil and gas development was impacting 25% of primary sage-grouse range and 72% of its total range. Well densities of one well per 1.6 square miles (4.1 km^2) can affect breeding populations; yet, development is occurring at a rate of 8 wells per 1.6 square miles (4.1 km^2) across much of their range. While research is ongoing for sharp-tailed grouse, many of the same impacts are expected to apply (Dyke et al., 2011).

About 6,700 acres (2,711 ha) of grassland bird habitat has been converted to well pads, leading to direct kills from landing in oil pits. Recommendations for buffered distances from wells vary depending on the species, including 0.25 miles (0.4 km) for Swainson's hawk and burrowing owl to 1.0 mile (1.6 km) for ferruginous hawk. Golden eagles, in particular, are sensitive to development and have been closely monitored to determine impacts from development. Currently, over 17% of their primary range has been impacted by oil and gas development, which is double the amount in 1995, and over 6% of secondary range has been impacted. Electrocution is one of the main associated causes of death, killing up to 43% of sampled populations in some areas. Current recommendations include no well pad development within 0.5 miles of primary habitat and no other activities (road traffic, etc.) within 0.5 miles (0.8 km) of primary habitat from February 1 to July 31 (Dyke et al., 2011).

Waterfowl are also impacted by oil and gas development. Death of waterfowl may occur due to open pits, powerline strikes, hydrogen sulfide poisoning, vehicle collisions and wetland degradation and water quality issues associated with development. By 2020, 10,330 additional permanent wetlands north and east of the Missouri River will have wells drilled within 328 feet (100 m) of them. Other aquatic resources, particularly lakes, are expected to be impacted by water usage for oil and gas development. Estimates project that 1,500-1,800 wells will be drilled per year, with each well using 1.5-4.0 million gallons (5,678-15,141 m^3) of water per year. This equates to between 69,000 and 331,000 acre-feet per year of water being used for oil and gas development for the next decade (Dyke et al., 2011).

Observations by staff of The Wildlife Society in North Dakota show that, while recommendations are being made to both oil and gas companies and the North Dakota Oil and Gas Division regarding conservation of wildlife resources in specific areas that are managed for wildlife, many of these recommendations are ignored. Summary observations include:

- A recommendation by the US Fish and Wildlife Service and Bureau of Land Management to move the location of a well pad and use a closed-loop system (as opposed to an open reserve pit) within the Lake Ilo National Wildlife Refuge, which was ignored by the oil and gas company;
- A decline from 63 overwintering elk in 2009-2010 to zero in 2010-2011 after construction of a road, three wells, and two pipelines in and around the Killdeer Wildlife Management Area;
- Numerous flooding events on well sites that carried drilling residue into aquatic habitats and led to fish kills (McEnroe and Sapa, 2011).

In addition to the sharp-tailed grouse study being conducted by the North Dakota Game and Fish Department, two additional studies are underway to determine the impacts of oil and gas development in the area on wildlife. One, which is funded by the Plains and Prairie Potholes Landscape Conservation Cooperative, will determine the effects of oil and gas development in North Dakota on grassland birds and is being conducted by the USGS (Plains and Prairie Potholes Landscape Conservation Cooperative, 2012). The second, which is jointly funded by the Bureau of Land Management, North Dakota Game and

Fish Department, North Dakota Industrial Commission, Oil and Gas Research Fund, and the Mule Deer Foundation, will examine impacts specifically to mule deer and is being conducted by North Dakota Game and Fish Department and the University of Missouri (Mule Deer Foundation, 2012). Both studies will begin in 2012 and will last one to three years.

In addition to direct impacts from construction of well pads and roads, the amount of housing and other infrastructure will also continue to grow with oil and gas development. A new report from the Center for Social Research at the University of North Dakota reports that the human population in North Dakota grew 5% from 2000 to 2010, which equates to an increase of over 30,000 people. By 2025, this number is expected to increase by 25%, reaching a total population in North Dakota of 841,820 people. The ten counties in the heart of energy development country will grow more than 50% by 2025. This represents a sharp detour from the past seven decades, when populations decreased in many western North Dakota counties during some or most of the decades since 1940. These new trends reflect a growth in the labor force of 23% from 1980-2010, mostly in the energy sector. As of June 2012, the unemployment rate was 3.2%, much lower than the national average of 8.4% at that time and the average compensation per job rose 4.5-69.2%, compared to a national average of 2.2%. The highest increases in compensation were in Divide, Dunn, McKenzie, Mountrail, Slope, Stark and Williams counties (Rathge et al., 2012).

Overall, the gross state product increased 7.6% from 2010 to 2011, and mining as a sector of the economy increased by 70%. Estimates for future drilling vary depending on the publication, but most conservative estimates suggest at least 32,000-35,000 addition wells will be drilled in the next 20 years (by 2032). This dramatic increase in the number of wells drilled has led to parallel increases in overall oil production, with projected production in 2012 almost seven times higher than production in 2000 (Figure 3). Natural gas production has also increased dramatically, from five million cubic feet (141, 584 m^3) per month in the late 1990s to 21 million cubic feet (594,653 m^3) in the month of June 2012. Furthermore, estimates suggest that nearly a third of this natural gas is being 'flared off' because pipelines and collection systems are overwhelmed. And studies suggest that production will increase regardless of price fluctuations because past trends show increased production despite decreases in price by up to 75% (Rathge et al., 2012).

Along with this development boom come associated changes in employment type and housing needs. The overall number of housing units grew by 13% from 2000 to 2010, with some western North Dakota counties seeing increases of 15%. However, because the bulk of the energy development did not occur until the end of that decade, projections suggest much faster growth is possible in the future. Average land values in southwestern North Dakota increased from 20 to 30% between 2011 and 2012, and over 30% across northern North Dakota during that year (Figure 4). North Dakota now has more miles of road per capita than any other state in the US, with 166 miles of road (267 km) for every 1000 people. Employment is expected to shift from temporary to permanent from now until 2036, and the total number of households is expected to triple in oil-impacted northwestern North Dakota by 2025. Population will also increase in this region during this time. For Divide, Williams, and McKenzie counties, population increases of 50-75% by 2025 are expected (Rathge et al., 2012).

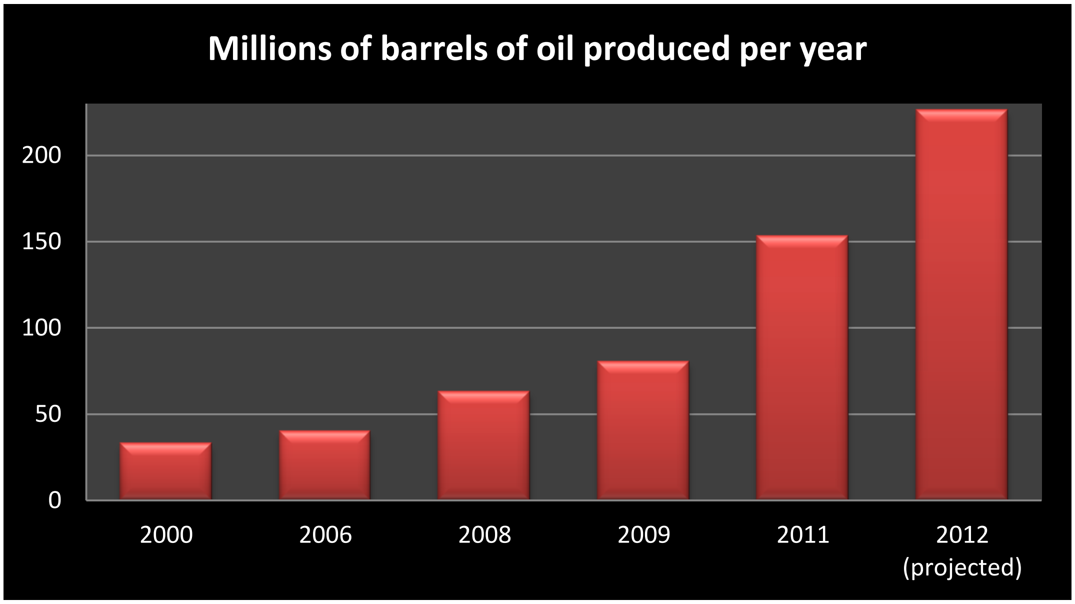

Figure 3: Oil production (in millions of barrels per year) in the Bakken from 2000-2012 (projected; Rathge et al., 2012).

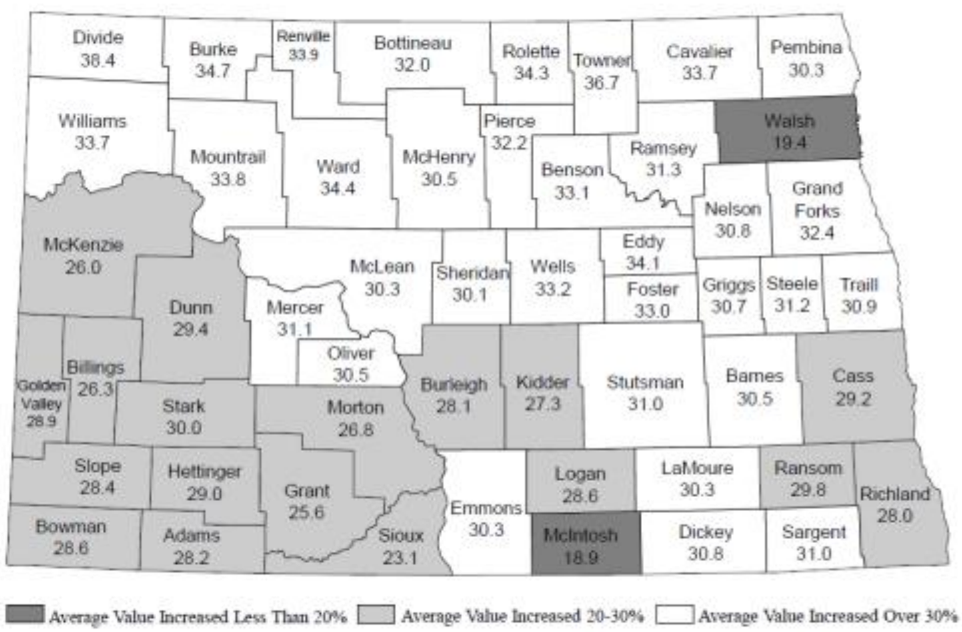

Figure 4: Percent change from 2011 to 2012 in the average value of all agricultural land in North Dakota by county (adapted from Rathge et al., 2012).

Powder River Basin

As much as the Bakken Formation has captured the attention of the public and conservationists over the past few years, oil and gas development in the Powder River Basin is also of great concern to the NGP ecoregion and its wildlife. According to a 2009 report, approximately 424 million barrels of oil are still unrecovered in the Powder River Basin (Anna, 2009). As of 2009, this area already produced 600 million barrels of oil from both conventional drilling and coalbed methane production (Anna, 2009). In addition, of the 438 million short tons of coal produced in Wyoming in 2011 (Energy Information Administration [EIA], 2012), 426 million came from the Powder River Basin (Bureau of Land Management, 2012).

In addition to oil and coal, the Powder River Basin is also a large producer of petroleum in the form of coalbed methane. Through 2006, the Powder River Basin had produced 2,314 billion cubic feet of coalbed methane, making it the number two coalbed methane producing area in the country behind the San Juan Basin, which is located on the Colorado-New Mexico border, and contains 66% of total coalbed methane in the US (EIA, 2007). The Powder River Basin has 12% of the total proved reserves for coalbed methane in the US and has estimates of recoverable reserves of 18.5 trillion cubic feet (EIA, 2007). Thus, only about 12.5% of the total recoverable coalbed methane available in the region had been produced as of 2007. Other coalbed methane resources within the ecoregion include 0.5 trillion cubic feet in the Williston Basin of western North Dakota and 1.2 trillion cubic feet in the North-Central Basin, along the northwestern edge of the NGP ecoregion (Figure 2 [see blue coal reserves in north-central Montana for an approximate location]; EIA, 2007).

Coalbed methane is the natural gas that exists within coal seams. In order to extract coalbed methane, the coal seam must be depressurized, which involves pumping out the water that is in the seam so that the methane will be released and flow up to the well. Like hydraulic fracturing, the amount of water consumed and the quality of the water that is a byproduct of this process are of concern. According to Keith et al. (2003), a coalbed methane well produces 5-20 gallons of water per minute; thus the average well, producing 12 gallons per minute, would produce 17,280 gallons of water per day. The water that is produced through this process is high in salinity and very high in sodium content, and is thus difficult to reuse and may be harmful to both soils and plants (Keith et al., 2003). The most saline and sodic waters in the Powder River Basin occur in the northwestern corner of the Basin in Montana (Keith et al., 2003). Some of the saline and sodic water is still being discharged directly into streams, due to grandfather clauses for older wells. Newer wells must have nearby holding ponds, where water is stored; however, many of these ponds are not lined, and water seeps back into the soil subsurface. While reverse osmosis, evaporation, and salt precipitation are all methods for treating water from coalbed methane developments, they are largely unfeasible at the scale that development is occurring (Keith et al., 2003). Injecting the water back into the ground is another method, used largely in the southwest in the San Juan Basin (Keith et al., 2003).

Mule deer, white-tailed deer (*Odocoileus virginianus*), bighorn sheep, pronghorn, greater sage-grouse, mountain plover (*Charadrius montanus*), black-tailed prairie dogs (*Cynomys ludovicianus*), and bald eagles (*Haliaeetus leucocephalus*) inhabit the area within the Montana portion of the Powder River Basin (Montana Fish, Wildlife, and Parks, 2012). Storage ponds provide breeding grounds for mosquitoes, which may then transmit West Nile virus to greater sage-grouse (see below under Disease for additional information).

Alberta and Saskatchewan

The portions of Alberta and Saskatchewan that are within the NGP boundary are also highly productive oil and gas regions. Southwestern Saskatchewan contains part of the Bakken formation, which is discussed above, and has more oil fields than gas fields, while the part of Alberta that is encompassed by the ecoregion contains mostly natural gas (Figure 2). As of August 2012, 1,969 total wells were producing in Saskatchewan, which is lower than the total of 2,176 wells the previous year (Government of Saskatchewan Energy and Resources, 2012).

Saskatchewan contains approximately 45.6 billion barrels of oil in its reserves, according to the most recent estimates (Government of Saskatchewan Energy and Resources, 2012). Current oil production places Saskatchewan as the sixth largest producer of oil across the US and Canada combined, and the second largest producer in Canada, behind Alberta. During 2011, 157.7 million barrels of oil were produced in Saskatchewan. Alberta, in contrast, contains significant oil reserves outside of the NGP ecoregion, and important natural gas reserves within the NGP ecoregion. Current estimates suggest reserves of 39 trillion cubic feet of natural gas within Alberta, much of which is contained within the eocregion, and an additional 500 trillion cubic feet of coalbed methane (Alberta Energy, 2008).

Keystone Pipeline

The existing portion of the Keystone Pipeline has been transferring crude and bitumen from the Athabasca oil sands to Oklahoma and Illinois since 2010. This original pipeline bisects the eastern portions of North Dakota, South Dakota, Nebraska, and Kansas and then splits into two branches: one that travels through Missouri and ends in Illinois, and a second that ends in Oklahoma (known as the Keystone-Cushing Extension). Two extensions to the pipeline are being proposed: the Keystone XL Pipeline, which would bisect the NGP ecoregion (Figure 5), and the Gulf Coast Project, which will transport crude and bitumen to Texas refineries. Of concern are the aboveground impacts to habitat and wildlife and its passage through the Nebraska Sandhills, where there is a potential for spills or leaks to affect the Ogallala Aquifer and the sensitive ecosystems in the sandhills. However, the route of the pipeline has since been moved to bypass the sandhills and, thus, the portion of the aquifer that is the closest to the soil surface and most vulnerable to spills (Parformak et al., 2012).

Of particular importance to the NGP is the pipeline’s route through northeastern Montana, where it enters the US from Canada, and its impacts on greater sage-grouse populations in that area (Figure 6). The greater sage-grouse was listed as endangered in Canada in 1998 and continues to experience population declines in both Canada and the US, where it has been petitioned for listing under the Endangered Species Act multiple times. As of the 2011 surveys, only 13 males were found in Alberta and 35 in Saskatchewan. The pipeline bisects two core areas for greater sage-grouse, as identified by the Natural Resources Conservation Service, or NRCS (see core areas #1 and #2 in Figure 6). Recent research suggests that sage-grouse migrate between these two core areas and that these populations of greater sage-grouse are sources for the endangered populations in southern Canada. In addition, the proposed location of pump station 10 is too close to core area #1 in Montana, and pump station 16 is 1.2 miles west of the "squaw creek" lek in northwestern South Dakota. Research on the intolerance of greater sage-grouse to development concludes that all pump stations and other permanent structures should be placed a minimum of two miles (3.2 km) from the nearest lek, with a preferred distance of greater than four miles (6.4 km) from active leks (Naugle et al., 2011).

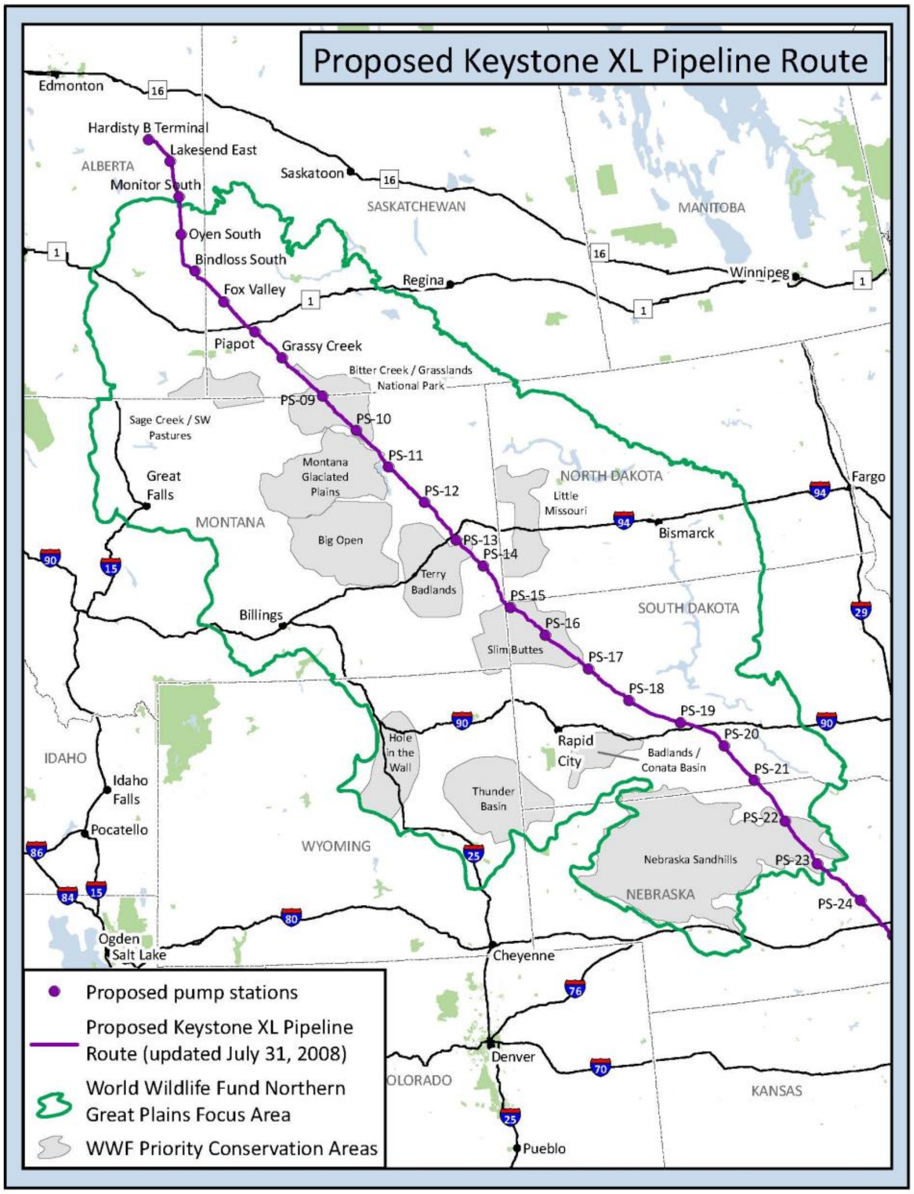

Figure 5: Approximate location of the proposed Keystone XL Pipeline and pump stations within the NGP.

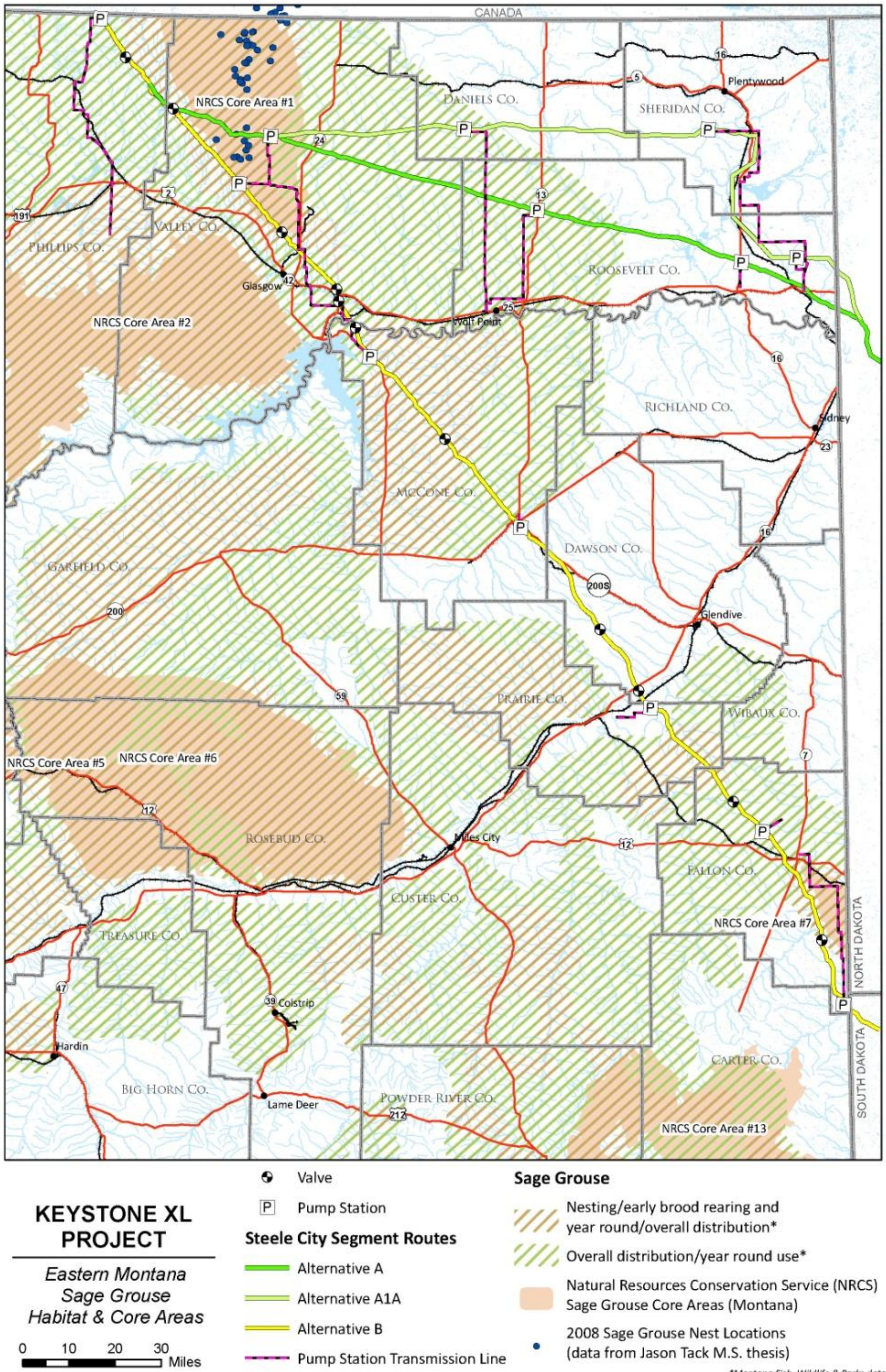

Figure 6: Approximate location of the Keystone XL Pipeline (yellow) in relation to greater sage-grouse core areas (light brown), as identified by NRCS.

The future status of the Keystone XL pipeline is unknown. Native American and First Nations communities have been outspoken in their opposition to the Keystone XL Pipeline, due to environmental concerns and the potential for significant impacts to natural resources upon which they rely. According to Transcanada (2012a), 150 First Nations communities are located within 50 km of their facilities in Canada, and 100 US Indian Reservations are located within 30 miles (48 km) of their facilities in the US President Obama has postponed the final decision on the XL portion of the pipeline until 2013, but supported the Gulf Coast Project on March 22, 2012 (Parformak et al., 2012). Construction of the Gulf Coast portion of the pipeline will start in summer 2012 and be completed at some point in 2013 (Transcanada, 2012b).

Potential future impacts

According to two recent studies (Copeland et al., 2009; Copeland and Evans, 2012; Figure 7), oil and gas development in the region and throughout the West will continue over the next 20 years. One possible scenario suggests that 3.7 million acres of sagebrush habitat and 1.1 million acres of grassland habitat across the western US may be impacted by 2029. Build-out scenarios suggest that areas that border current oil and gas development are the most likely to be developed and potential impacts could include up to a 19% decline in greater sage-grouse across its range from oil and gas development alone (Copeland et al. 2009). Data for Canada suggest that development is most likely to occur along the Alberta-Saskatchewan border within the ecoregion. This would impact a large region around and north of Medicine Hat, Alberta, and is likely to include mostly natural gas and coalbed methane development. Moreover, an increase in the number and distribution of storage ponds for coalbed methane may lead to increased incidence of West Nile virus in greater sage-grouse (see below under Disease for more information; Schrag et al., 2011). Pipeline ruptures, similar to the one on the Yellowstone River in July 2011 that spilled 42,000 gallons of oil in 56 minutes and cost ExxonMobil $135 million to clean up, may occur in new areas with the addition of the Keystone XL Pipeline (Brown, 2011).

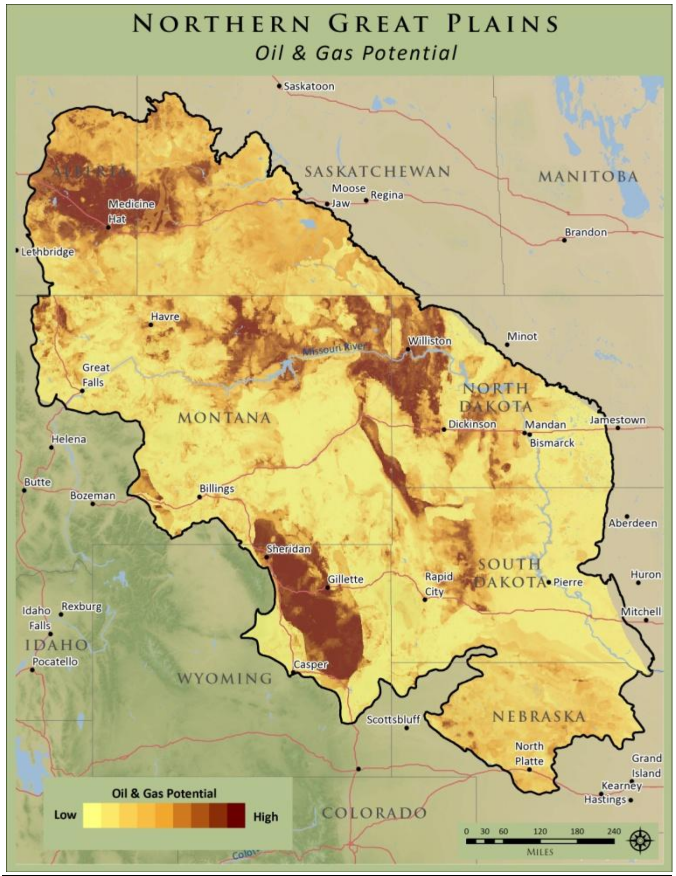

Figure 7: Oil and gas development potential throughout the NGP, based on geologic variables and current drilling trends (Copeland et al., 2009; Copeland and Evans, 2012).

Agricultural Conversion

The landscape of the NGP is dominated by two widespread land uses: cultivated agriculture, in the form of row crops, and rangeland, used for ranching. As of 2007, the Census of Agriculture reported that approximately 83% of land in the NGP is being used for agricultural purposes, with roughly 64% of this land being used for rangeland and 32% being used for cultivated cropland in some form. Total amount of land being used for agricultural purposes has changed very little over the last three census periods (1997, 2002, 2007). National Resources Inventory data suggest that people have been transitioning land between these agricultural uses, with nearly 2.9 million acres (969,907 ha) of rangeland lost between 1982 and 1997, the majority of which were converted to cultivated croplands (Rashford, 2010). Between 1978 and 2008, the average annual increase in crop acreage within the NGP was 0.9% (Figure 8), which is about 1.1 million acres (445,154 ha) over the 30-year period, and most areas that are converted to cultivated crops can be accurately predicted by their soil quality (Figure 9). As of 1997, approximately 36 million acres (14.6 million ha) or 29%, of land that was being used as rangeland has the appropriate soil quality to be converted to cultivated crops (land capability classes 1-4; Rashford, 2012).

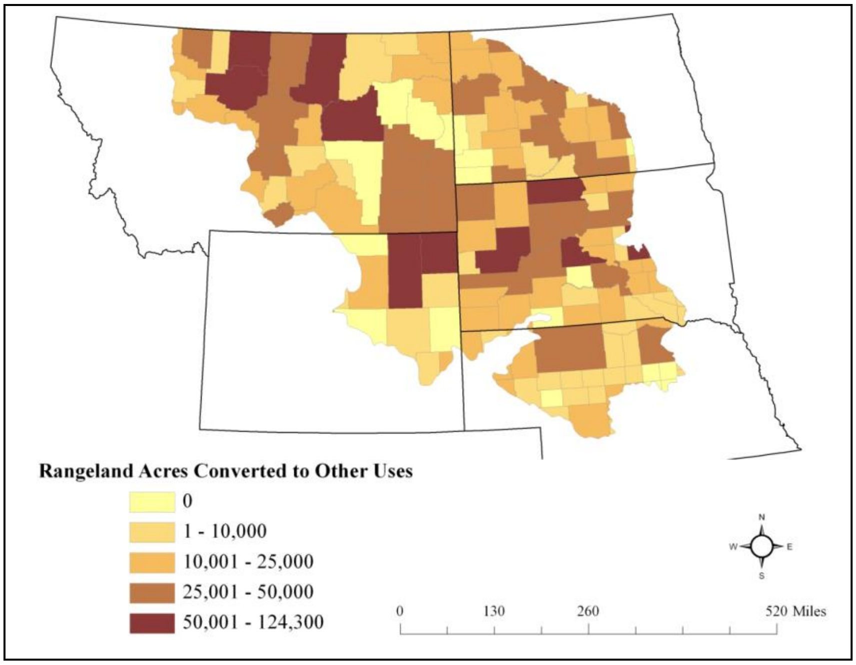

Figure 8: Total acreage, by county, of rangeland converted to cropland (1982 – 1997).

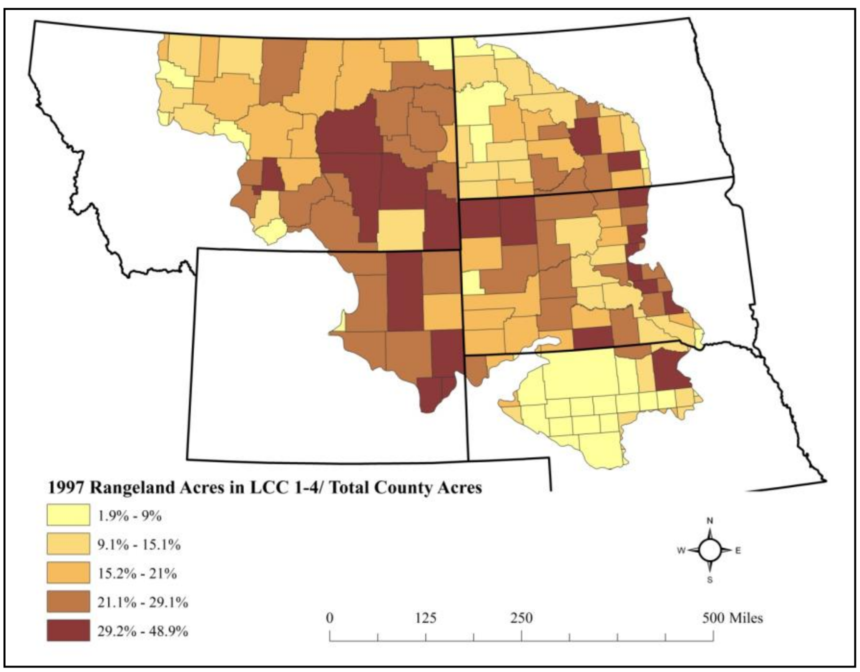

Figure 9: Percent of total acreage per county with rangelands that have high-quality soils suitable for cultivation.

In addition to biophysical characteristics, economic incentives also drive conversion of rangeland to cropland. Yields for the major crops grown in the NGP have increased significantly in the last 20 years (corn yields increased 50%, wheat and soybean yields increased approximately 16%). Net returns for wheat, corn, and soybeans are all at or near their 30-year high (Figure 10). Higher returns may continue to incentivize landowners to convert rangeland and pasture to cultivated cropland. Growth in acreage of soybeans, corn, and wheat accounted for the majority of the increase in crop acreage, with corn and soybeans playing a larger role in the last decade (1998-2008). Soybean acreage, in particular, increased substantially over the last 30 years, with an average annual growth rate of 14.5%. This growth implies an increase in soybean acreage of nearly three million acres (1.2 million ha), but only a small proportion of this (12%) came in the form of conversion of rangeland to soybean acreage. Instead, soybeans were planted in favor of other crops on already cultivated lands. Corn acreage increased less dramatically (approximately 1.1 million acres [445,200 ha], 1978-2008) and the growth in corn acreage has been most dramatic in the last decade with an increase of over 680,000 acres (275,200 ha). Again, only 7% of the new acreage growing corn was a direct conversion of rangeland to cultivated cropland. The majority of the acreage came in the form of a shift from wheat or hay production (Figures 11-15; Rashford, 2010).

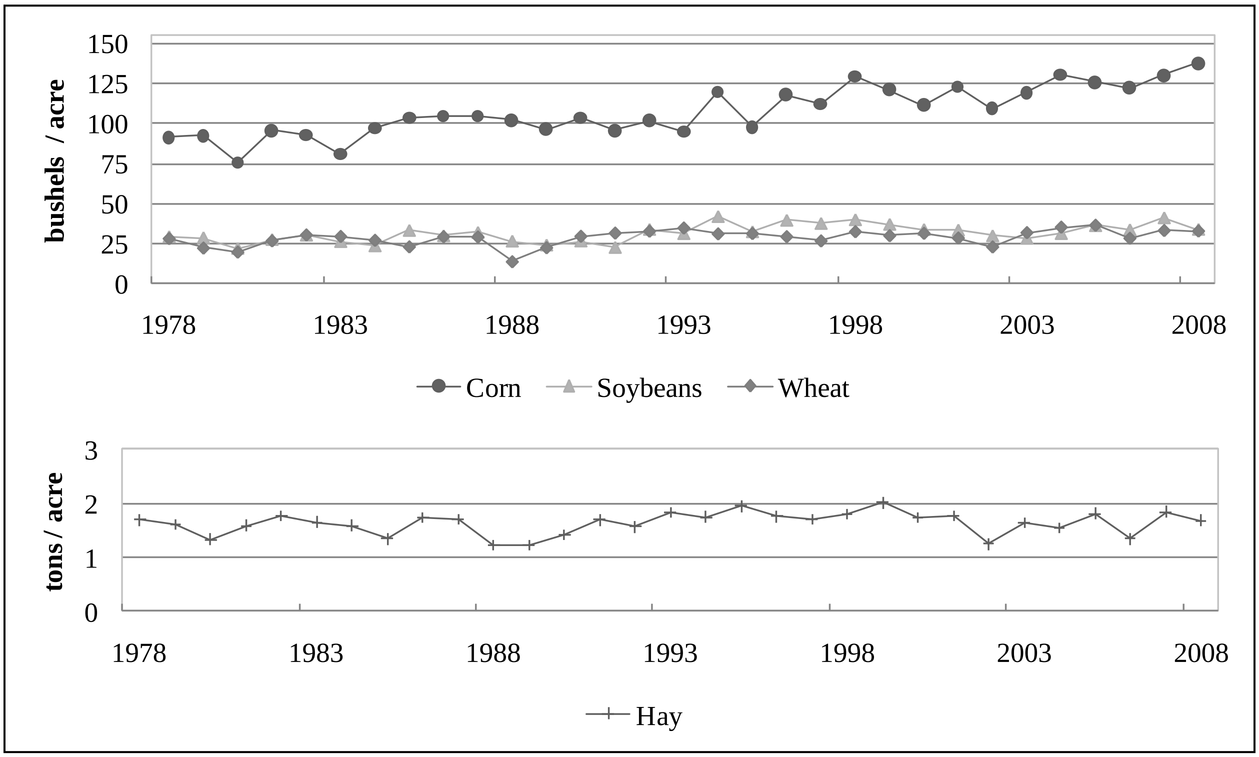

Figure 10: Yields for corn, soybeans, wheat, and hay (1978–2008).

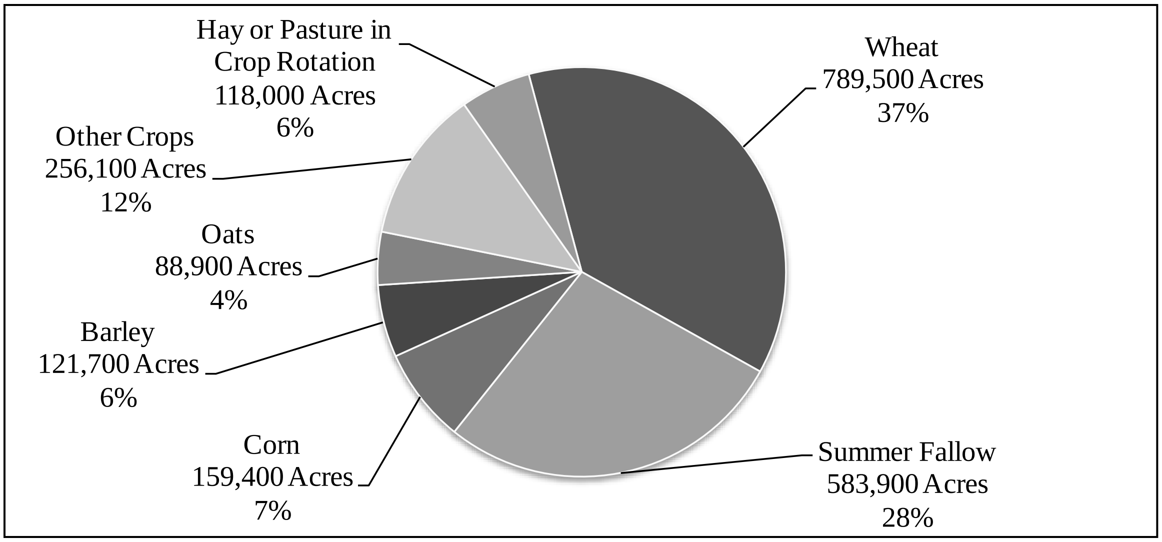

Figure 11: Transitions from rangeland to cultivated agriculture; percentage of transitions by crop or use type (1982-1997).

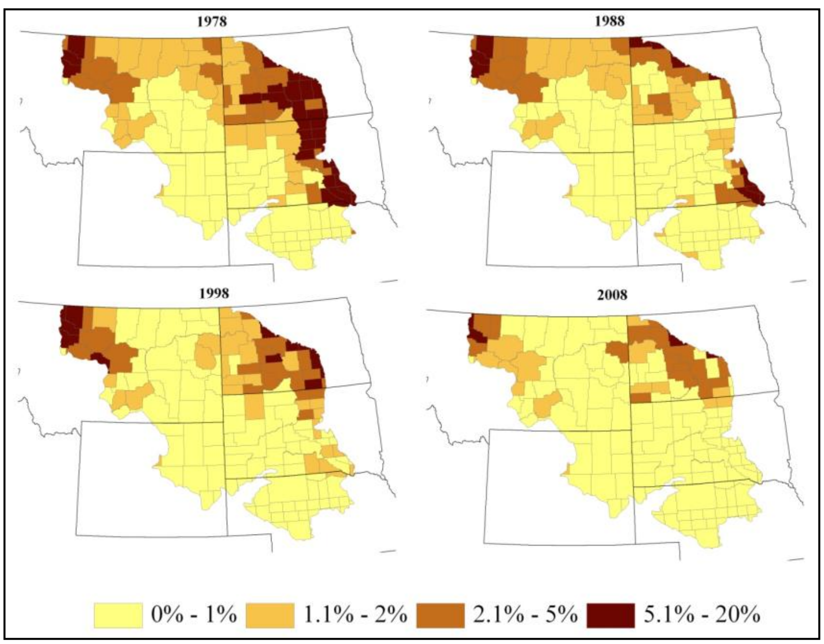

Figure 12: Harvested acres of oats and barley (1978-2008).

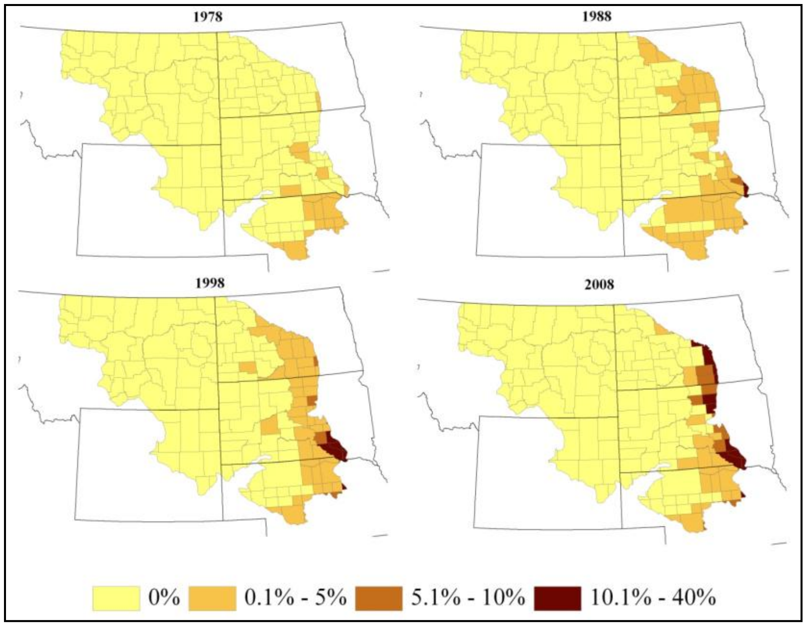

Figure 13: Harvested acres of soybeans (1978-2008).

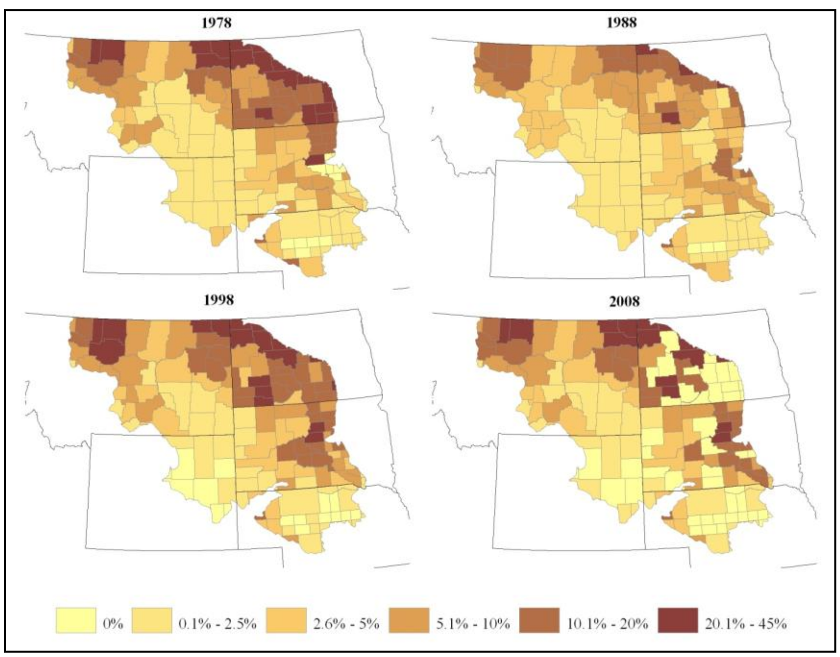

Figure 14: Harvested acres of wheat (1978-2008).

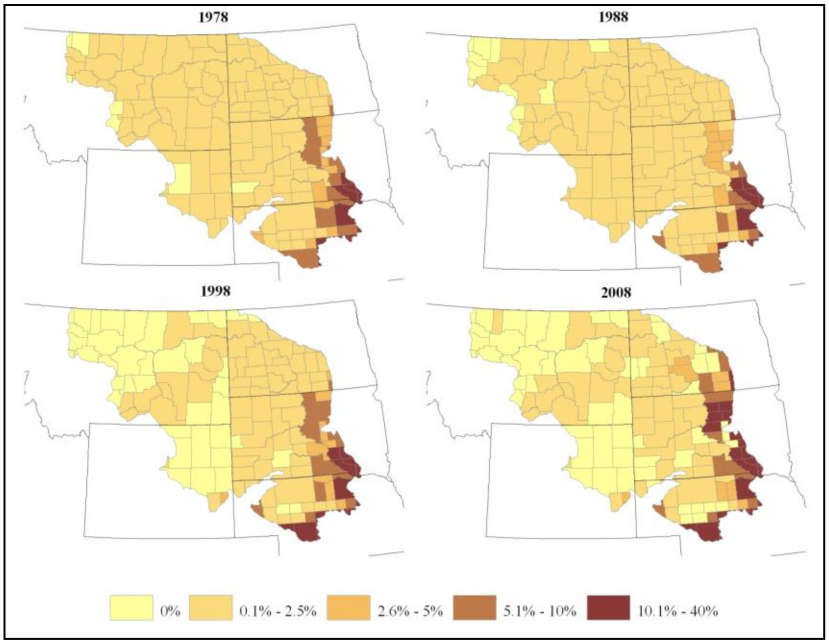

Figure 15: Harvested acres of corn (1978-2008).

Conversion of native grassland for cultivated cropland may have significant negative effects on a variety of grassland birds, including sprague's pipit (*Anthus spragueii*), mountain plover, and greater sage-grouse. All three of these species have either been petitioned for listing under the Endangered Species Act or are currently listed as "warranted but precluded" (US Fish and Wildlife Service, 2010); thus, their dwindling population sizes make them more vulnerable to other disturbances, such as oil and gas development. Some mammals, including swift fox (*Vulpes velox*), which rely on contiguous blocks of land, may be negatively affected by these changes, as plowing up of native prairie will cause either direct destruction of their habitat or will fragment potential migration corridors.

Potential Future Impacts

In September 2010, WWF and the University of Wyoming began a project funded by the Plains and Prairie Potholes Landscape Conservation Cooperative to examine more closely the impacts of crop prices and subsidies, climate change, and biofuel crops on the conversion of grassland to cropland in the NGP. Using the Cropland Data Layer, developed by the US Department of Agriculture National Agricultural Statistics Service, we are developing predictions of land-use conversion at a 30 m^2 resolution across the US portion of the NGP (Figure 16). This new analysis suggests that there are many acres currently in grassland that would be suitable for growing crops, even under current climate and economic conditions, and that the majority of this acreage occurs along the eastern edge of the ecoregional boundary in North Dakota and South Dakota (Figure 16; Rashford, 2012).

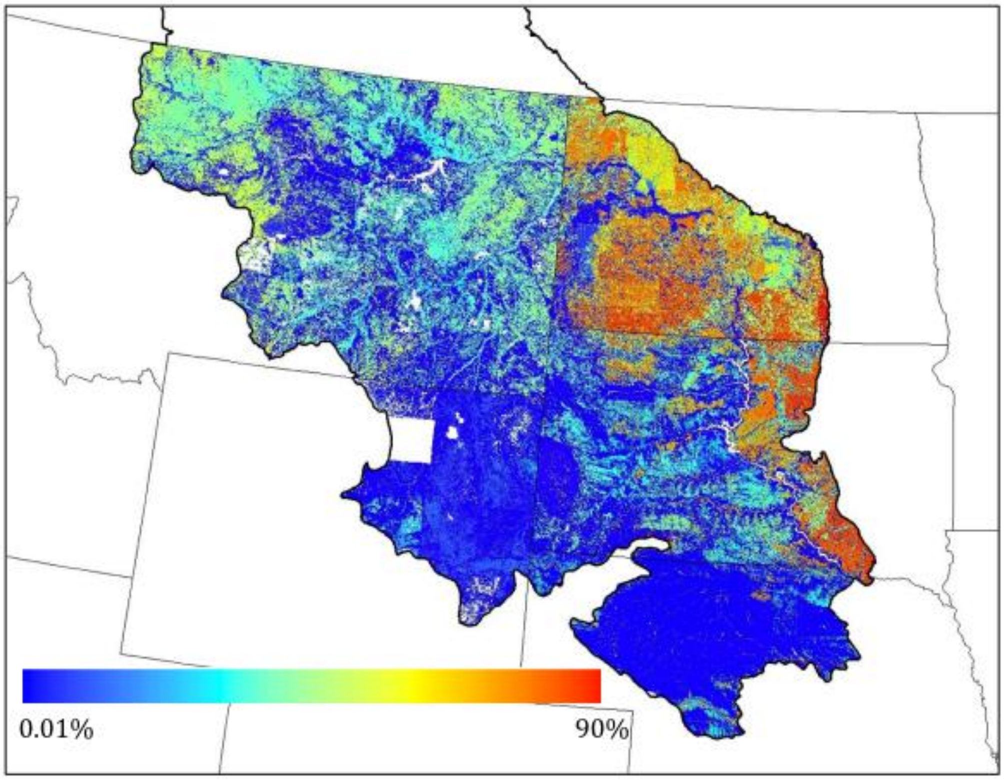

Figure 16: Predicted probability of observing cropland on current grassland plots given current climate and economic conditions. [Note: empty regions represent excluded land covers (e.g., public or tribal land) or regions with no data.]

Preliminary results suggest that, holding all else steady, an increase in crop prices will lead to an increase in the number of parcels that are converted to cropland on all but those areas with the poorest soil quality. Specifically, an increase in crop prices by 10% will lead to an average increase in probability of converting from grassland to cropland by 0.3%, while a 25% increase in crop prices will lead to a 0.9% increase in the probability of conversion. This 0.9% increase translates to almost a million acres (404,685 ha) converted across the US portion of the NGP ecoregion. However, in areas that have high soil quality, an increase in crop prices of 10% leads to an increase in the probability of conversion of 4% to 10% depending on the soil quality (areas with higher soil quality have a higher probability of conversion). These changes largely occur along the eastern edge of the ecoregion in North and South Dakota, while many areas in Montana, Wyoming and Nebraska have poor soils that are not able to support cultivation using current crop types and cropping techniques (Figure 17; Rashford, 2012).

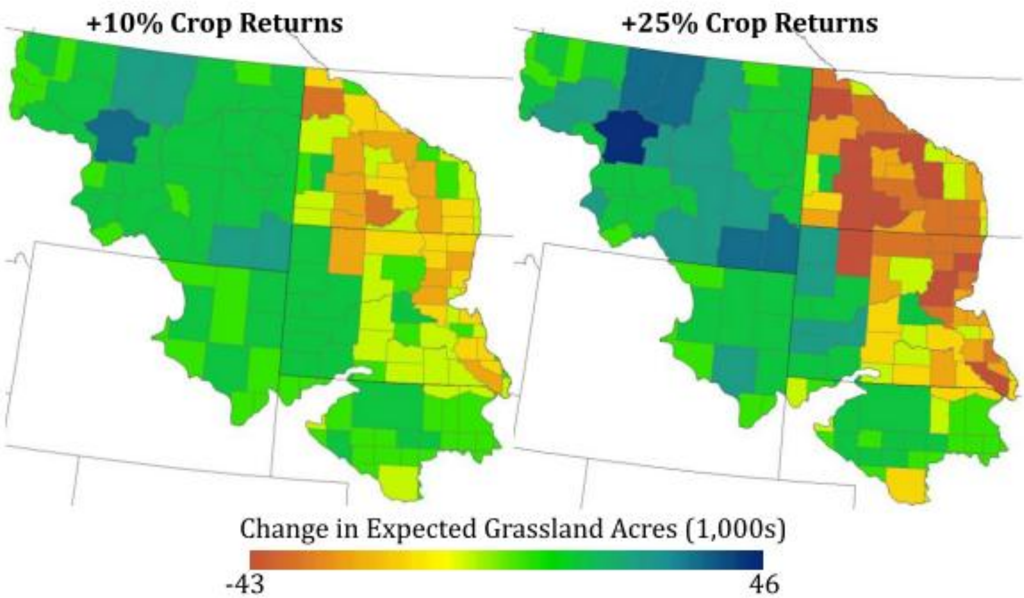

Figure 17: Change in expected acres in grassland (in 1,000s), given a 10% increase in crop prices (left) and a 25% increase in crop prices (right).

Changes in the amount of government payments (e.g., crop insurance, disaster payments) can also substantially change the probability of converting grassland to cropland. Currently, government payments vary across the ecoregion from $0 to $32.47 per acre (0.4 ha), with an average of $8.31 per acre (0.4 ha). Removal of all government payments reduces the probability of converting grassland to cropland by 3% on average, but leads to a reduction of almost 30% in some areas, particularly those that have more marginal soils, specifically in the western portions of North and South Dakota and eastern portions of Montana and Wyoming (Figure 18). In total, the elimination of all government payments translates to an increase in grassland of 5.5 million acres (2.2 million ha; Figure 18-19; Rashford, 2012).

As expected, an increase in government payments leads to an increase in the probability of grassland being converted to cropland. A 10% increase in government payments increases the probability of conversion by 0.5% on average, and up to 3% in some areas. Likewise, a 25% increase in government payments increases the probability of converting grassland to cropland by 1% on average, with potential increases of 9%. Increasing government payments leads to decreases in the number of acres in grasslands, with higher increases in payments leading to lower total number of acres in grassland. Increasing payments by 10% leads to 600,000 acres (242,811 ha) of grasslands lost, while increasing payments by 25% leads to 1.5 million acres (607,028) of grasslands lost (Figure 20; Rashford, 2012).

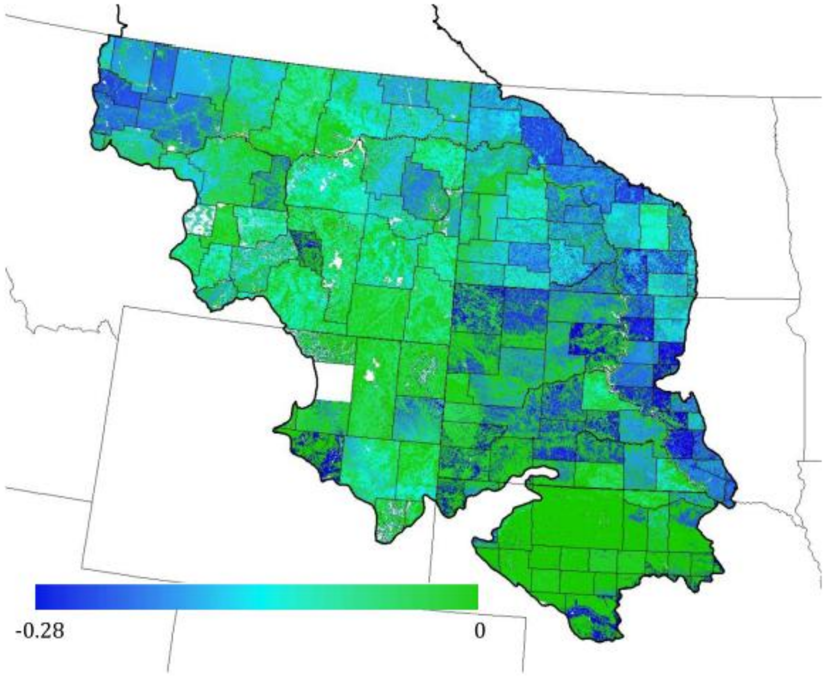

Figure 18: Change in the probability of observing cropland, given the elimination of all government payments.

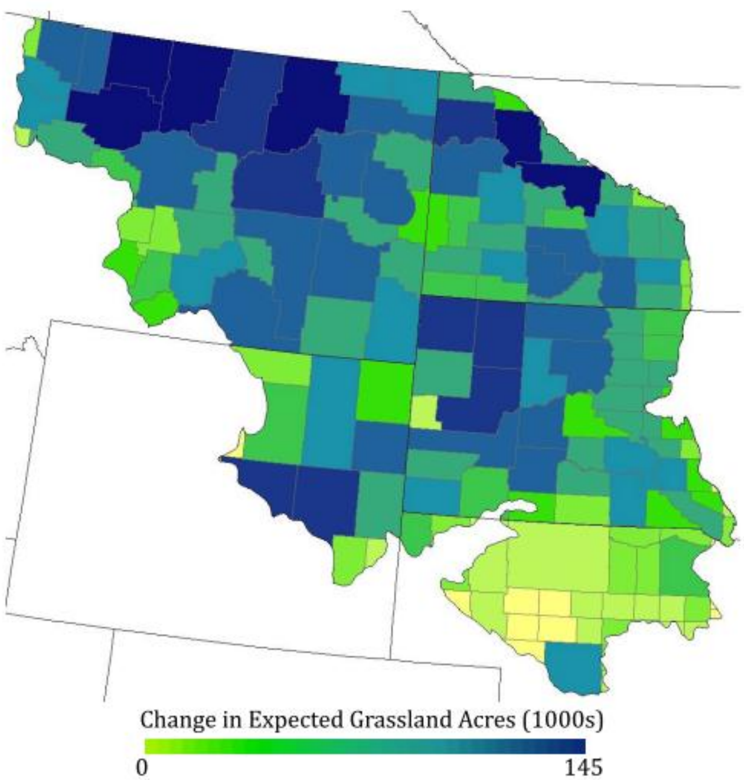

Figure 19: Change in the expected acres (in 1,000s) of grassland by county, given the elimination of all government payments.

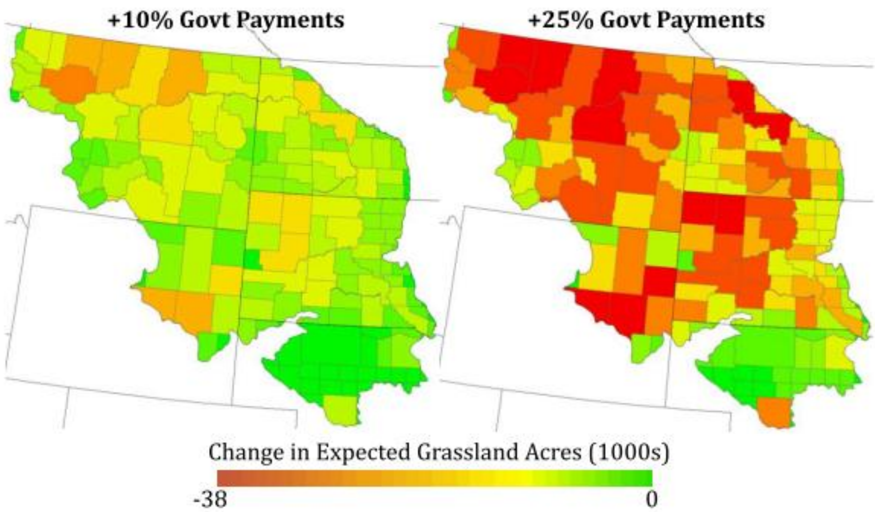

Figure 20: Change in the expected acres (in 1,000s) of grassland by county, given increases in government payments by 10% (left) and 25% (right).

Climate change may also lead to increased suitability for growing crops across the NGP. Under the A2 emissions scenario (see below under 'Climate Change' for a definition of this scenario), three global circulation models were used to detect potential trends in future suitability of climate variables to support cropland. Generally, the A2 scenario tends to predict warmer and drier conditions for the NGP; however, substantial variation occurs across the models and across the NGP. In general, areas that become warmer and drier are less likely to support crops, while areas that become warmer and wetter may be more suitable for crops. Increasing probability of conversion from grassland to cropland, by up to 18% in some areas, occurs along the eastern edge of the ecoregion under all three models used. Decreasing probabilities occurred in Montana and Wyoming, by up to 26% under some models. These changes are mirrored under the A1b and B1 emissions scenarios (Figure 21; Rashford, 2012).

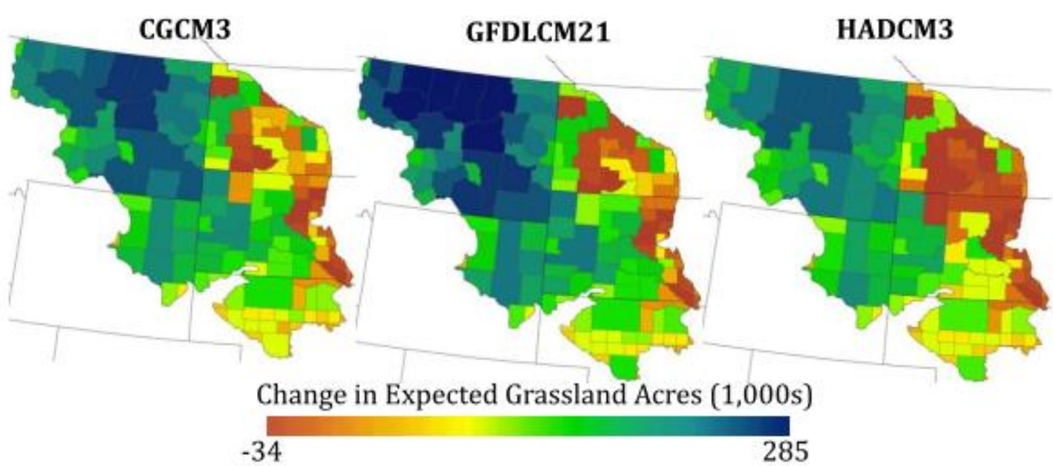

Figure 21: Change in the expected acres (in 1000s) of grassland by county, given changes in climate under three global circulation models.

A recent study by Mehaffey et al. (2012) suggests that the Energy Independence and Security Act of 2007 will drive the conversion of additional acreage in the U.S. Midwest for planting corn to provide ethanol to meet the mandate. By 2020, the study suggests that 25 million acres of rotational cropping will be converted to continuous corn cropping, and North and South Dakota are expected to see increases in corn planting of up to 20% in some locations within the NGP ecoregional boundary. Soybean rotation is also expected to increase in some areas of the NGP. The area most likely to be affected is western South Dakota, which is also the area that could be largely affected by the elimination of government payments (Figure 18).

One factor related to the conversion of grassland to cropland that is not addressed in this study is the influence of land prices. Agricultural land prices have increased substantially in the last decade and show few signs of stabilizing. According to the US Department of Agriculture Economic Research Service (2012), farm real estate values increased by 10-20% on average across Montana, Wyoming, North Dakota, and Nebraska, and 20-30% in South Dakota, during the period from 2001-2004. This trend continued from 2007-2009, with increases of 10-20% in North and South Dakota and Nebraska, and 0-10% in Wyoming. In 1997, the price per acre of land throughout the NGP was approximately $100-500, depending on location (Forrest et al., 2004). Prices have increased by about 100% in western North Dakota since that time and by up to 300% in some areas of South Dakota, and current rates of increase in value are around or above 30% per year in some areas, especially North and South Dakota (Dyke et al., 2012; Janssen and Pflueger, 2012). Land prices east of the NGP ecoregion, in the heart of the Corn Belt, have reached above $10,000 per acre at recent auctions (Nixon and Eligon, 2012).

Wind Development

Wind energy resources in some parts of the NGP have led to nicknames like “the Saudi Arabia of wind”, and wind energy potential is of “good” or better (e.g., excellent, outstanding, superb) classification throughout most of North and South Dakota within the NGP ecoregion, eastern Wyoming, portions of central Montana, and southwestern Saskatchewan (based on potential wind speeds; National Renewable Energy Laboratory, 2011; Environment Canada, 2008). As of January 2012, approximately 5.2 gigawatts (GW) of wind energy are currently in operation in the NGP, with 32 GW of additional wind energy proposed in the region. In order for the US to meet its goal of producing 20% of its energy from wind by 2030, an additional 241 GW of terrestrial wind energy development will be required, with 25 GW in the NGP. Goals for Canada will require an additional 5 GW of development within the NGP boundary. Assuming an estimated 0.38 mi^2 (1 km^2) of land per 5 MW of wind produced, future wind production will require 1,930 mi^2 (5,000 km^2) within the five US states of the NGP and 386 mi^2 (1,000 km^2) within the two Canadian provinces (Fargione et al., 2012).

Impacts of wind energy development to species may come in the form of direct mortality, habitat loss and degradation, or avoidance behavior. Studies currently underway show that bats may be particularly affected by direct mortality from wind turbines, as are some bird species of conservation concern, including whooping cranes (*Grus americana*), golden eagles (*Aquila chrysaetos*), ferruginous hawks (*Buteo regalis*), and burrowing owls (*Athene cunicularia*; Fargione et al., 2012). Both whooping cranes and golden eagles are imperiled species. In addition, greater sage-grouse and lesser prairie chickens

(*Tympanuchus pallidicinctus*) avoid tall structures, and US Fish and Wildlife Service recommendations suggest that wind energy development be restricted within five miles (eight km) of active leks (Manville, 2004).

Using data on lands within the NGP that are already disturbed, WWF and The Nature Conservancy (TNC) developed an analysis of wind energy potential on lands that have relatively low value for wildlife (i.e., already disturbed). The analysis showed that 1,065 GW of wind energy development is available on already disturbed lands, which included mostly cropland, but also developed lands, roads, railroads, pipelines and oil/gas wells. However, only 34% of current wind energy developments are sited on already disturbed lands, and only 30% of proposed wind energy developments are proposed for already disturbed lands (Figure 22; Fargione et al., 2012).

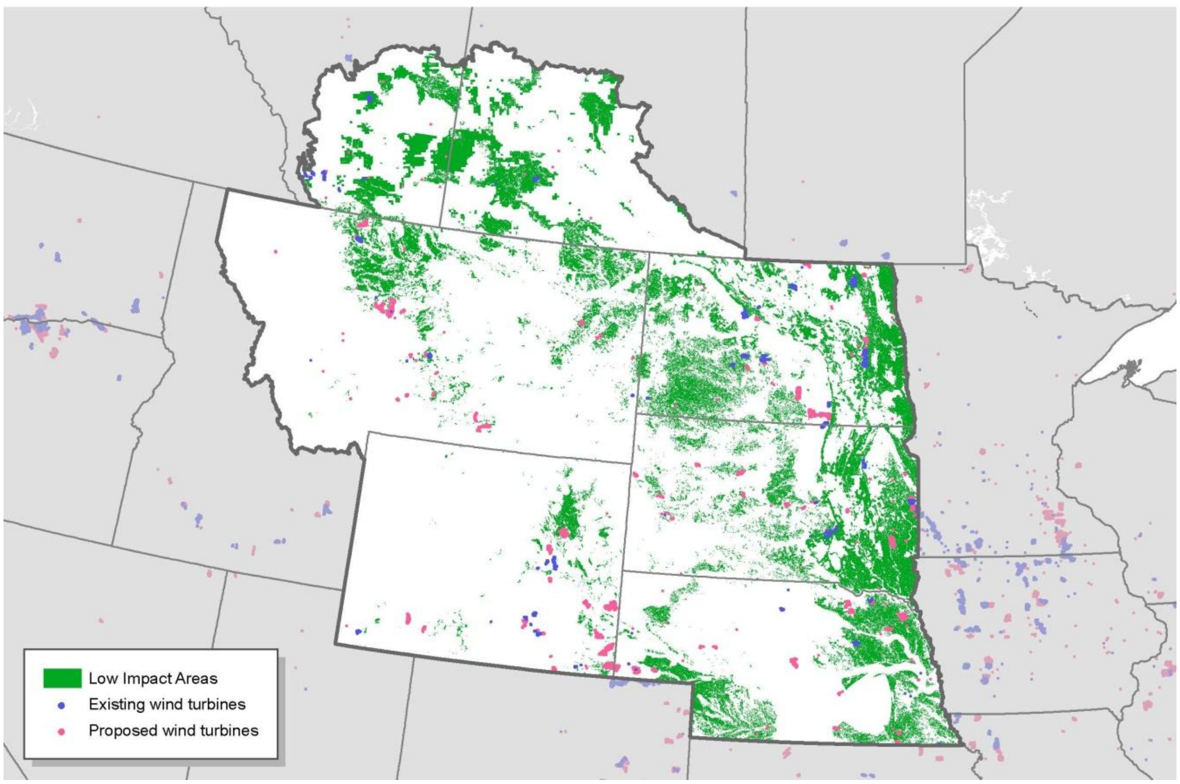

Figure 22: Location of existing and proposed wind turbines in relation to low-impact areas for wind energy within the five US states of the NGP and portions of Saskatchewan and Alberta.

One of the biggest limitations to developing wind energy projects in low-impact areas is the location of transmission lines to carry the electricity from rural areas to more populated urban centers. The American Wind Energy Association has developed a map of transmission lines that would be necessary to meet the goal of providing 20% of the nation's electricity from wind energy (Figure 23; American Wind Energy Association, 2012).

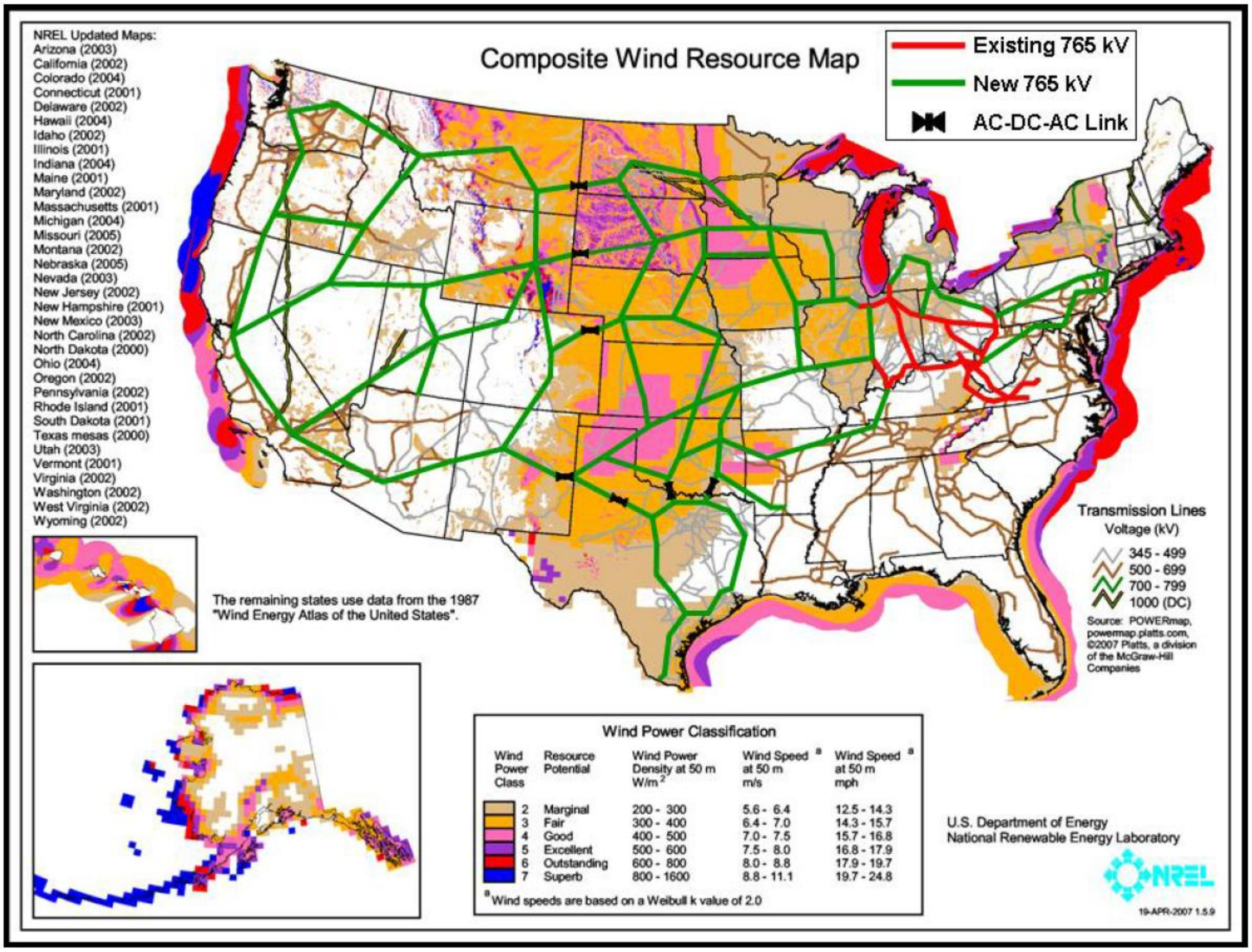

Figure 23: Proposed location of new transmission lines to meet the goal of producing 20% of the United States' energy requirements from wind energy (AWEA, 2012).

<u>Invasive and Non-Native Species</u>

Invasive species, both terrestrial and aquatic, impact the biotic integrity and hydrologic function of rangelands across the western US and across the globe. Because invasive species generally out-compete native species, the overall biological functioning of a system is degraded by their presence and they may compromise the overall species richness and composition of the ecosystem. According to a recent study, approximately 21% of rangelands (as defined by the National Resources Inventory) across the western US are moderately degraded in biotic integrity, hydrologic function, or soil stability, while almost 10% are moderately degraded across all three of these attributes. Almost half of all rangelands in the western US support non-native species, and these species represent more than half of all plant cover (Herrick et al., 2010).

As a part of this assessment, WWF derived data on terrestrial invasive plant species and aquatic invasive species within the US portion of the ecoregion. Terrestrial invasive plant species were ranked by abundance across the five US states, with duplicate species removed. Data were then aggregated by total number of most abundant species (n=31) per county (Table 2). Counties along the western edge of the ecoregion in the US have the highest number of terrestrial invasive species per county, while those counties along the eastern edge of the ecoregion have the lowest number (EDDMapS, 2012).

Table 2: Most abundant invasive terrestrial plant species in the US counties within the NGP.

Absinth wormwood	Curly dock	Houndstongue	Russian knapweed
Big chickweed	Dalmation toadflax	Leafy spurge	Russian-olive
Bull thistle	Dyer's woad	Musk thistle	Stinkgrass
Canada thistle	Field bindweed	Perennial pepperweed	Western salsify
Catnip	Field brome	Perennial sowthistle	Wild buckwheat
Cheatgrass	Field pennycress	Prickly lettuce	Yellow sweetclover
Common mullein	Flixweed	Purple loosestrife	Yellow toadflax
Crested wheatgrass	Green foxtail	Reed canarygrass	

For aquatic invasive species, location data were requested from USGS' Non-indigenous Aquatic Species program. Data include locations of non-native fish across the US portion of the ecoregion. The data suggest that invasive species are found in large rivers and small streams, as well as lakes, throughout the ecoregion. The top five most common non-native fish (by number of point locations in the database) are common carp (*Cyprinus carpio*), northern pike (*Esox lucius*), brown trout (*Salmo trutta*), black bullhead (*Ameiurus melas*), and largemouth bass (*Micropterus salmoides*). Aquatic invasive plant species of concern include *Egeria densa*, *Hydrilla verticillata*, Eurasian watermilfoil (*Myriophyllum spicatum*), curly-leaf pondweed (*Potamogeton crispus* L.), flowering rush (*Butomus umbellatus*), purple loosestrife (*Lythrum salicaria*), salt cedar (*Tamarix* spp.), and yellow flag iris (*Iris pseudacorus*). Also of concern are the mollusks zebra mussel (*Dreissena polymorpha*), New Zealand mudsnail (*Potamopyrgus antipodarum*), and the mammal nutria (*Myocastor coypus*; USGS, 2012).

Climate change

Based on recent scientific research, the speed of climate change in the world's temperate grasslands is likely to outpace the amount of protected area currently available, leaving grasslands more vulnerable to change than other ecosystems (Loarie et al., 2009). Using spatially interpolated climate trend data from 1951-2002, average annual temperatures increased by up to 2.6°C (4.68°F), with the greatest increases in the northern and eastern portions of the ecoregion (Appendix A). Spring and winter temperatures are increasing more quickly than summer and fall temperatures. Averaged over the entire year, precipitation is increasing most in the southeastern portion of the ecoregion, by up to 130 mm (5.12 in) in areas of South Dakota and Nebraska (Appendix A). These increases in precipitation are primarily occurring in spring and fall. Areas along the Montana-North Dakota border have seen decreases in precipitation over the 51-year period, some by as much as 80 mm (3.15 in).

Table 3 shows a summary of future predicted changes in climate for the 2050s, a time period that generally serves as an average for the 30-year period from 2040-2069. The changes predicted by these models suggest that overall climatic conditions in the NGP will be more similar to current conditions in the northern part of the southern Great Plains by the middle of the century. For example, increases in temperature by 4°C (7.2°F) will put the NGP roughly in the average annual temperature range of Kansas, northern Oklahoma, and central New Mexico. Increasing precipitation will make conditions similar to current precipitation levels in eastern Nebraska and western Kansas (National Oceanic and Atmospheric Administration [NOAA], 2010).

Table 3: Predicted future changes in temperature and precipitation averaged across the Northern Great Plains Ecoregion by the 2050s. *Season corresponds to the season during which the majority of the models predict the amount of change will occur.

Scenario	Variable	Value	Range	Season*
Both scenarios	Mean highest increase temperature	4.18°C (7.52°F)	2.5-5.7°C (4.5-10.26°F)	Summer
	Mean lowest increase temperature	1.46°C (2.63°F)	0.1-3.0°C (0.18-5.4°F)	Spring/Winter
	Mean increase precipitation	64 mm (2.52 in.)	31-106 mm (1.22-4.17 in.)	Spring
	Mean decrease precipitation	-41 mm (-1.62 in.)	-1-(-79) mm (-0.04-[-3.11] in.)	Summer
A1B	Mean highest increase temperature	4.3°C (7.79°F)	3.1-5.7°C (5.58-10.26°F)	Summer
	Mean lowest increase temperature	1.68°C (3.02°F)	0.6-3.0°C (1.08-5.4°F)	Spring/Winter
	Mean increase precipitation	65 mm (2.57 in.)	31-106 mm (1.22-4.17 in.)	Spring
	Mean decrease precipitation	-39 mm (-1.54 in.)	-1-(-79) mm (-0.04-[-3.11] in.)	Summer/Fall
A2	Mean highest increase temperature	4.02°C (7.42°F)	2.5-5.6°C (4.5-10.08°F)	Summer/Winter
	Mean lowest increase temperature	1.25°C (2.25°F)	0.1-2.5°C (0.18-4.5°F)	Spring/Winter
	Mean increase precipitation	63 mm (2.48 in.)	36-92 mm (1.42-3.62 in.)	Spring
	Mean decrease precipitation	-41 mm (-1.62 in.)	-10-(-78) mm (-0.39-[-3.07] in.)	Summer

Some trends appear when looking across all models, which are outlined below.

- The next 40 years are expected to bring more substantial increases in temperature and changes in precipitation than the past 50 years, along with more variability overall.
- On average (across models and emissions scenarios), predictions suggest an increase in average annual temperature of about 4°C (7.2°F) by the middle of the century and increases in spring precipitation by about 63 mm (2.5 in).
- Warming is predicted to occur more during the summer and fall seasons, as opposed to the historical trends of warmer spring and winter seasons.
- Spring and winter seasons are expected to have the smallest increases in temperature, in the range of 2-3°C (3.6-5.4°F).
- No decreases in temperature are predicted.
- The largest decreases in precipitation will be during the summer season where precipitation is likely to decrease by 38mm (1.5 in), which represents a 50% decrease in the driest portions and a 15% decrease in the wettest portion of the ecoregion.
- Hotter and drier summers are predicted across the region.

Climate change and grassland ecosystems

Grasslands in the NGP have withstood droughts and floods for centuries and have co-evolved with grazing mammals and fire to produce a highly diverse system that is naturally resilient to both stochastic events and varying disturbance regimes. Paleoecological data on grasslands demonstrate that previous droughts led to decreases in productivity, increases in erosion, and shifts in species composition, whereas humid periods led to increases in productivity, abundant fuels for fire, and stabilization of soils (Clark, 2002). Future changes

EMISSIONS SCENARIOS (IPCC, 2000)

A1B: The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B).

A2: The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slower than in other storylines.

in the distribution of grasslands may come in a variety of forms that include changing species composition, directional shifts in movements (east-west or north-south), and range contractions. Some studies suggest a possible east-to-west shift in the forest-prairie transition zone due to increasing suitability for woody species to inhabit what is currently grassland and shrubland (Bachelet et al., 2003). Other modeling studies suggest a directional shift northward for many grassland vegetation types, given increases in temperatures and steady to slightly decreasing available moisture, which may lead to novel vegetative communities (Thorpe, 2010).

Potential shifts in species composition may also come in the form of shifting plant functional groups. C_3 species, which have lower rates of carbon dioxide uptake than C_4 plants, tend to dominate the more northern reaches of the NGP, including Montana, North Dakota, Alberta, Saskatchewan, and parts of Wyoming. C_3 species are commonly referred to as cool-season, but their distribution relies on more than just temperatures. Epstein et al. (1997) found correlations with soil types and textures as well, while also predicting a potential decrease in distribution with a 2°C increase in mean annual temperature. Meanwhile, C_4 species, which generally have higher rates of carbon dioxide uptake resulting in enhanced photosynthesis, are generally referred to as warm-season species and some studies have suggested that elevated summer temperatures and increased summer rainfall (but overall drier conditions) may lead to increased dominance of these species (Ehleringer et al., 1997).

Many mammals in the NGP will be either directly or secondarily impacted by changes in grassland productivity caused by climate change. Models of grassland productivity for Saskatchewan have suggested potential decreases in the overall amount of grass produced under future climate scenarios. Decreases may occur more slowly in northern parts of the region, with steady production rates over the next two decades, followed by decreases later in the century, depending on the future climate scenario (Thorpe et al. 2004). Other studies predict steady production in the northern part of the region and decreasing production in the southern part of the region by 2030 under most climate-change scenarios, specifically in southwestern South Dakota (Schrag, 2011).

Recent studies have shown that changes in the timing and amount of precipitation lead to decreases in the quality of forage, thus changing the number of animals that an acre of land can support. For instance, late-summer precipitation leads to more leaf and less stem in tallgrass prairies and, thus, weight gain in bison, whereas mid-summer precipitation results in the opposite effect (Craine et al., 2009). According to calculations from the Natural Resources Conservation Service in South Dakota, in five counties surrounding Conata Basin in South Dakota, the average number of acres needed per 'animal unit month' (AUM, defined as one mature cow weighing approximately 1,000 lbs. and one calf up to six months old) is approximately 13.23. Thus, according to Schrag (2011), under future conditions impacted by potential climate change, landowners in western South Dakota can expect to need up to 24 acres of land per AUM to maintain the same number of cattle (Natural Resources Conservation Service, personal communication, March 13, 2012).

Climate change and grassland species

Climate change will directly and indirectly affect birds and other wildlife. Using species distribution models, Peterson (2003) predicted that bird species in the Great Plains were more likely than species in other regions of the US to experience both changes in the location of habitat as well as reductions in suitable habitat due to climate change (in some cases, up to 35%). However, historic trend data do not suggest that grassland birds are currently being heavily impacted by climate change. The annual State of the Birds Report (North American Bird Conservation Initiative, 2009) suggests that grassland bird species are among the most threatened group of birds overall, but most grassland species show low or medium vulnerability to climate change (North American Bird Conservation Initiative, 2010) and are the only group of birds that show a southward (as opposed to the predicted northward) latitudinal shift in their range over the last 40 years, by about 10 miles on average. It is likely that a lack of information regarding what grassland birds are responding to on a site-by-site basis is contributing to the lack of ability to predict how climate change may impact grassland birds in the future.

In addition to birds, some plains-associated mammals are likely to experience impacts from climate change. The black-footed ferret is the most endangered mammal in North America and its populations are dependent upon healthy prairie dog communities. These species are both susceptible to sylvatic plague, a disease that has decimated prairie dog communities across the Great Plains and western US (see below under Disease for more information). The link between climate and plague is not completely understood, but some studies have shown a positive association between plague outbreaks and the previous year's spring precipitation (Collinge et al., 2005; Snäll et al., 2008) and correlations between current and predicted climate and the spatial extent of the disease (Nakazawa et al., 2007). There also appears to be some association between plague outbreaks and temperature, where warm days (temperature greater than 26.7°C [80°F]) are positively associated with outbreaks, while hot days (temperature greater than 29.4°C [85°F]) are negatively associated with outbreaks (Collinge et al., 2005; Snäll et al., 2008).

Climate change and sagebrush ecosystems

While grasslands generally are likely to persist in some form under future climate change, sagebrush systems may prove somewhat more vulnerable to predicted future climate change. Based on modeled species distributions under six future climate scenarios, increases in summer precipitation could lead to decreases in the overall extent of two species of sagebrush by 2030: the Wyoming big sagebrush (*Artemisia tridentata* var. *wyomingensis*) and silver sagebrush (*Artemisia cana*). Decreases are predicted to be small—about 6% across Montana, North Dakota, South Dakota, and Wyoming—but suggest that increasing moisture availability may lead to less overall suitable habitat for sagebrush. However, decreases in summer precipitation may lead to increases in the extent of habitat, although increases will be smaller—about 3-5% across the region (Schrag et al., 2011). The spatial distribution of sagebrush habitat is expected to shrink into the core of its range—southwestern Wyoming—as opposed to moving directionally. This result suggests that habitats at the fringes currently are less likely to persist in the future (Neilson et al., 2005; Schrag et al., 2011). In addition, Wyoming big sagebrush is expected to be more significantly impacted than silver sagebrush.

Perhaps more importantly than the direct impacts of climate change on sagebrush is the interaction among climate change, fire, sagebrush, and cheatgrass (*Bromus tectorum* L.). Cheatgrass is an invasive plant that leads to a reduction in fire return intervals (i.e., more frequent fires), native species diversity, forage quality, and crop yields (Bradley, 2009). Increases in fire return intervals and invasion of habitat are a double threat for species like sagebrush, which tend to be either fire intolerant or slow to repopulate areas after fire (Montana Natural Heritage Program, 2007). Models of the distribution of cheatgrass across the western US show maximum range expansion when there is a decrease in summer precipitation and suggest that the ideal range of precipitation for cheatgrass (0-50 mm during the summer season) overlaps substantially with the ideal range of precipitation for Wyoming big sagebrush (15-60 mm during the summer season; Bradley, 2009; Schrag et al., 2011).

Climate change, ecological processes and industry

Although the effects of climate change on many species in the NGP may play out in an indirect manner, impacts to processes are likely to be direct and possibly more severe. For example, water demand is predicted to outpace supply in many counties by 2050, leading to shortages for both human and agricultural uses. Wildfires are also likely to be directly impacted by climate change. A recent study showed that the relationship between the extent of historic fires and climate variables was strong throughout the Great Plains. The model predicts that increasing temperatures by 1°C (1.8°F) will increase the median annual area burned by 393% in the Great Plains (National Research Council 2010). Increases in fire may lead to overall decreases in the amount of sagebrush habitat in the NGP. Using a spatial vegetation succession model that incorporates fire, one study suggested that increases in fire of only 2-48% in the NGP could lead to decreases of up to five million ha of sagebrush habitat (Ritter, 2008). Cheatgrass, a rapid invader after fire, may outcompete and suppress sagebrush.

EXAMPLES OF C_3 AND C_4 SPECIES

(common to the Northern Great Plains)

C_3: wheat, barley, potatoes, soybeans, sugar beets, oats, rye, peas, needle-and-thread grass, threadleaf sedge, western wheatgrass

C_4: corn, sorghum, lentils, blue grama, buffalograss, little bluestem

The impacts of climate change on agricultural crops are likely to vary both spatially and by crop type. Research has shown that crops that use the C_3 photosynthetic pathway, such as wheat, are likely to experience increases in yield under increased carbon dioxide concentrations. Increased CO_2 concentrations stimulate photosynthesis in these crops and cause stomata (i.e., pores on the leaves) to shrink, which decreases water loss. Recent research suggests that increases in yield of up to 14% may be seen if atmospheric carbon dioxide levels reach 580 parts per million (ppm); the current level is 388 ppm. However, when increasing temperatures are taken into account, the positive effects of increases in CO_2 concentrations are negated for C_3 crops once the warming reaches 2-3°C (3.6-5.4°F). In contrast, crops that use the C_4 photosynthetic pathway, like corn, are likely to experience steady to slightly decreasing yields. For C_4 plants, any increase in temperature is likely to drive down crop yields. In addition, pollinators are likely to be affected by mismatched timing between their phenology (i.e., timing of migration) and that of flowering plants, and this could have significant impacts on agriculture in the region. Increasing nighttime temperatures may also lead to smaller fruits and grains, and some crops may experience an increased risk of episodic frost damage due to generally warmer temperatures, which lead to earlier spring-time growth before the frost-free period begins (Prasad et al., 2008).

Hunting and fishing also produce significant revenues in the region. Revenue gained through hunting and fishing permits funds many state wildlife agencies, and small communities throughout the region experience an economic boost from hunting-related tourism. Total revenue spent on hunting, fishing, and wildlife watching in the five US states in the NGP was $1.1 billion in 2006 (Freese et al., 2009). Big game populations are likely to be impacted by climate change in a variety of ways. Some diseases that have yet to hit northern populations may be facilitated by warming temperatures. Decreasing forage quality may affect carrying capacities for many game species as grasses become more fibrous and less nutrient-dense. Possible shifts in populations, with fewer mule deer, which require nutrient-dense food sources, and more elk, which are more adaptable to marginal habitat and food sources, may occur. White-tailed deer are not expected to experience much of a change in occurrence due to climate change, unless widespread changes in habitat occur (Bipartisan Policy Institute, 2008).

Disease

Diseases, including sylvatic plague and West Nile virus, affect species of conservation concern across the NGP.

Sylvatic plague

Sylvatic plague was introduced to North America at the turn of the century, but has only been highly active in black-tailed prairie dog communities since the late 1980s or early 1990s. Plague is transmitted to prairie dogs through fleas and once a colony is hit mortality rates can be greater than 90%. Dusting with pesticides to kill plague-infested fleas is currently the only way to keep plague out of prairie dog colonies, but it is time intensive and expensive to maintain for long periods of time. A sylvatic plague vaccine, which would immunize prairie dogs against the plague, is currently being tested for effectiveness across the prairie dog range. This effort is being led by the USGS and Black-Footed Ferret Recovery Implementation Team; trials are underway currently in Colorado and the vaccine will be tested across the range in 2013 (USGS, 2012).

Sylvatic plague has occurred throughout the NGP, including in Pine Ridge, Northern Cheyenne, and Fort Belknap Indian Reservations, among other areas. Data on the spread of plague is available for Conata Basin and American Prairie Reserve lands: plague was discovered in Conata Basin on May 13, 2008. Over 20,000 acres (8,094 ha) of prairie dogs have been affected by plague since 2008, with the highest acreage affected in 2008 and 2009. Active prairie dog colonies have fallen from 328 in 2009 to 80 in 2011, and the mean size of the colonies has fallen from 8.4 acres to 2.1 acres. Cost in 2011 for plague mitigation within the active plague zone was $255,384, which covered mitigation on 12,711 acres (5,143 ha) at a cost per acre of around $20 (Griebel, 2011). In 2012, 13,576 acres were dusted, which covered

648,460 burrows (Griebel, 2012). Burrows must be dusted at least once every 12 months to ensure continued survival.

On the Sun Prairie property of the American Prairie Reserve, prairie dog colonies have been relatively stable to increasing since 2008. Since 2007, plague has been present two years—2007 and 2011—and caused a 5.2% decrease in annual colony growth in 2011. On the White Rock property, 12% of prairie dog occupied acres were 'plagued out' in 2011. The number of acres with prairie dogs present in 2008 was 218.4 (88.3 ha) and rose to 314.4 (127.2 ha) in 2012 (Bly, personal communication, July 24, 2012).

West Nile virus

West Nile virus began to spread in the US in 1999 in New York and has steadily marched westward ever since. West Nile virus is harmful to humans, livestock (such as horses), birds, and other animals. In 1999, 62 total cases were reported by the Centers for Disease Control and Prevention (CDC). In 2003, 9,862 cases were reported in humans, with 264 fatalities (Figures 24-25). Expansion of the range of West Nile virus to the NGP occurred in 2002 and 2003, and the virus has now been identified in all 50 states (CDC, 2011). Activity decreased in the late 2000s, although 2011 showed a very high occurrence of West Nile virus in Blaine County, Montana. In 2012, the number of cases increased again, to 5,128 cases, with 229 deaths, as of November 14, 2012 (Figure 26; CDC, 2012a).

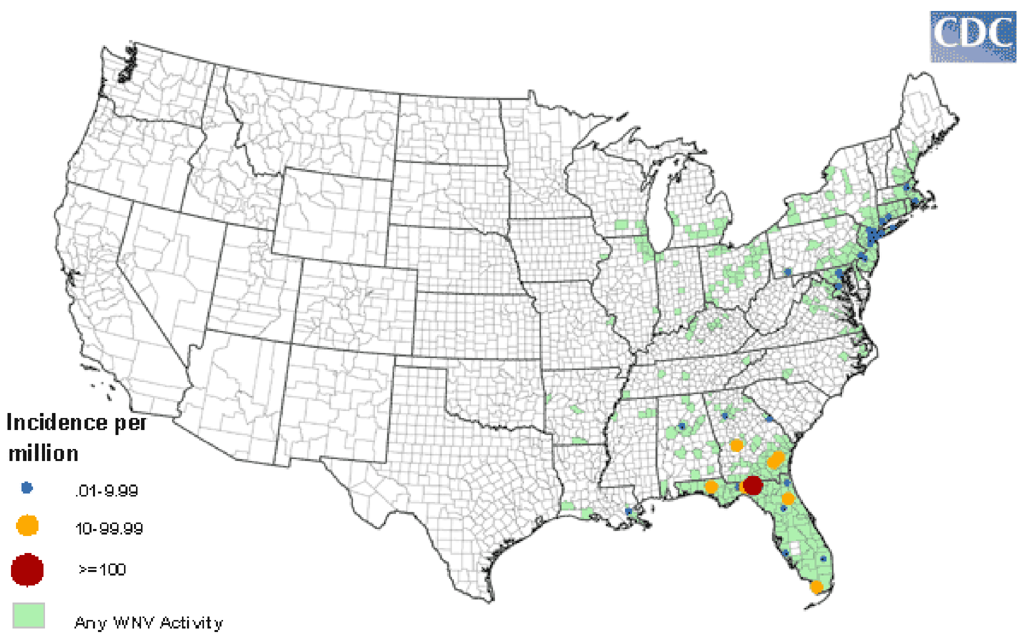

Figure 24: Incidence of West Nile virus in the US in 2001 (CDC, 2011).

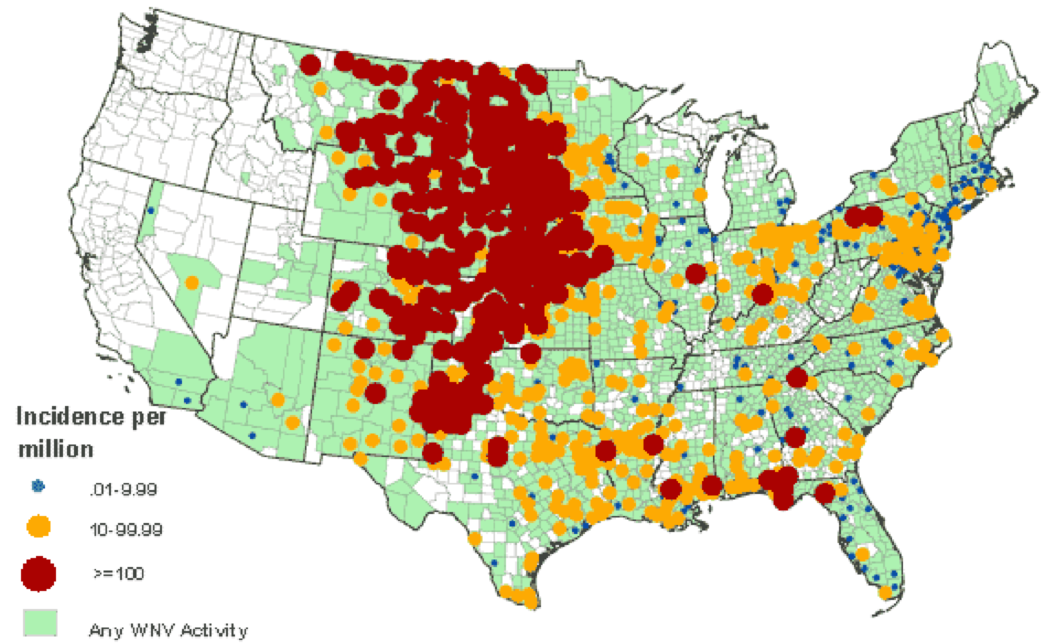

Figure 25: Incidence of West Nile virus in the US in 2003 (CDC, 2011).

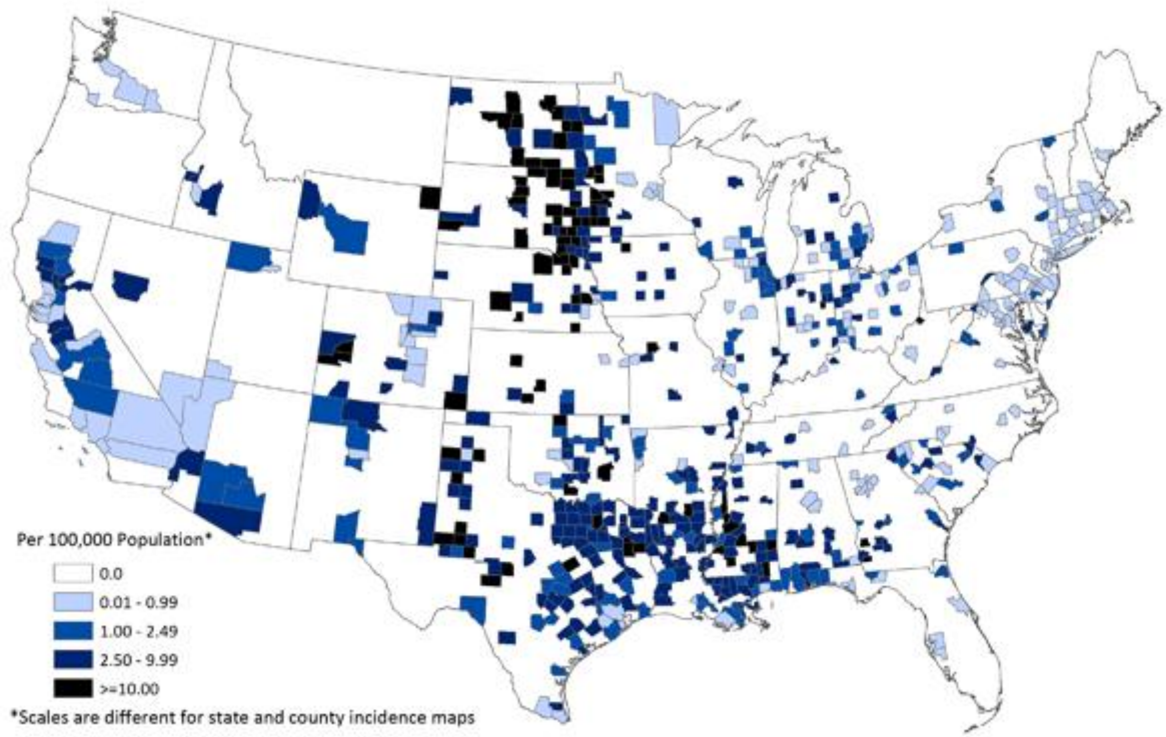

Figure 26: Incidence of West Nile virus by county in 2012 (CDC, 2012a).

West Nile virus is of particular concern within the NGP for greater sage-grouse. During droughts, greater sage-grouse move to water earlier in the season, which puts them at risk of contact with mosquitoes for a longer period than usual and during a time of the year when mosquitoes are virulent (Naugle et al., 2004). Given the large number of both natural and artificial (e.g., stock ponds) water sources throughout important sagebrush habitat in the NGP, risk of infection is prevalent in most places, including important "core areas" (as described above in the Keystone XL Pipeline section). Mosquitoes transmit West Nile virus to greater sage-grouse after temperatures have reached a certain threshold for multiple days in a row. In the Northern Great Plains, this threshold is 27.7°C (82°F). Given future predicted changes in temperature over the next two decades, West Nile virus will likely be transmitted to greater sage-grouse in higher-elevation areas (along the Rocky Mountain front), where it currently is not able to be transmitted due to insufficient temperatures, within the next two decades (Schrag et al., 2011).

Chronic Wasting Disease

Chronic wasting disease impacts mule deer, white-tailed deer, elk and moose populations across the NGP. It was first documented in wild mule deer populations in 1981 and is passed from animal to animal through close contact and contaminated food and water supplies. It often spreads quickly in captive populations and in feeding grounds. Chronic wasting disease is fatal. Four of the five US states within the NGP reported the presence of chronic wasting disease in 2012 (Figure 27; CDC, 2012b).

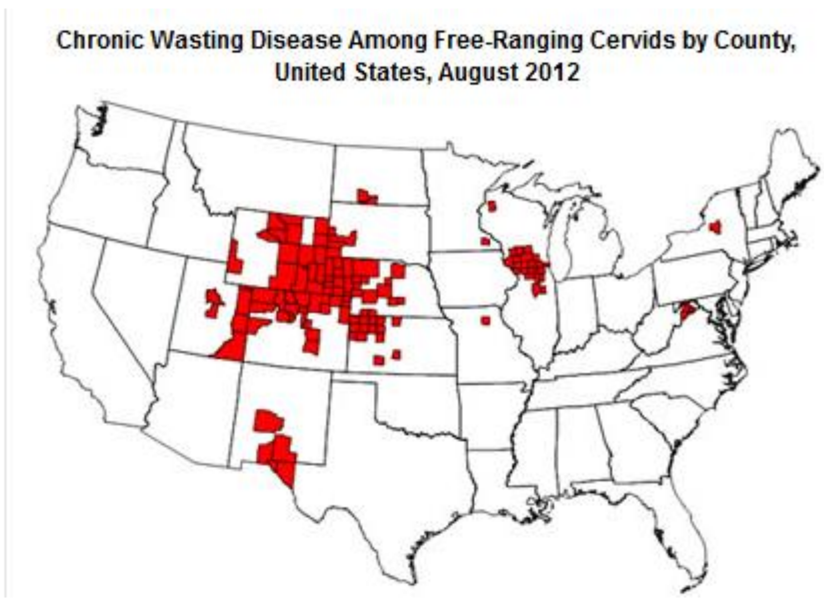

Figure 27: Incidence of chronic wasting disease by county in 2012 (CDC, 2012b).

Fragmentation

Fragmentation of the West by highways, railroads, fences, and dams has been occurring for centuries. Fragmentation of a grassland landscape can cause disturbances to wildlife movement patterns, direct mortality of animals, increased spread of invasive species, and direct habitat loss.

Roads

While the general pattern of road density has not changed substantially since 2000 (Forrest et al., 2004), the magnitude of road density is much higher now than during the previous survey period (2011 data versus 2000 data). For example, in 2000, there were up to a maximum of 14 miles (22.5 km) of road per square mile; in 2011, there were up to 40 miles (64.3 km) of road per square mile (US Census Bureau, 2011; Forrest et al., 2004). Areas with high road density are located near larger cities and towns, as expected, as well as in areas of significant oil and gas exploration, such as western North Dakota and northeastern Wyoming. For instance, Gillette, Wyoming, which had a population size of less than 30,000 people at the 2010 Census, has 36 miles (59.7 km) of road per square mile. This is the same density as Billings, Montana, and Bismarck, North Dakota, which are cities with significantly higher population sizes.

Fences

In a rangeland-dominated landscape, the presence of fences is unavoidable. Fencing causes behavioral changes among migratory animals, including mammals and birds, as well as direct mortality. Of particular concern in the NGP are impacts to pronghorn and greater sage-grouse, especially in areas of northern Montana and southern Saskatchewan and Alberta, which serve as migratory corridors for these animals (Tack, 2006). According to a new report (Paige, 2012, p.7), two studies from 2005 and 2006 documented the following mortalities due to fencing in rangelands in Utah and Colorado:

- “One ungulate per year for every 2.5 miles (4 km) of fencing.
- Most animals died (69% of juveniles and 77% of adults) by getting caught in the top two wires while trying to jump a fence.
- Juveniles are eight times more likely to die in fences than adults.
- Mortalities peaked during August, when fawns were weaned.
- Woven wire fence topped with a single strand of barbed wire was the most lethal fence type.
- 70% of all mortalities were on fences higher than 40 inches (1 m).”

Unfortunately, little data exist at the ecoregional scale to assess the relative fragmentation of the landscape by fences, either in the form of fence locations or fence type. A study completed by WWF’s Conservation Science Program modeled the location and density of fences in all or portions of 13 counties in northern Montana, along the border with Canada. The study found nearly ubiquitous fencing across all counties within the study area, but densities were highest along the Milk and Marias Rivers and lowest along the Missouri River as it flows through the Charles M. Russell National Wildlife Refuge (Jakes et al., 2011).

A set of guidelines for wildlife-friendly fencing were released this year for Wyoming, which could apply throughout the NGP. These fences attempt to find a compromise between containing livestock and providing for wildlife movement across the landscape. Suggestions include:

- “A maximum height of 42 inches (1.07 m), with a preferred height of 40 inches (1.01 m) or less.
- At least 12 inches (0.3 m) between the top two wires.
- A bottom wire or rail at least 16 inches (0.4 m) and preferably 18 inches (0.45 m) above the ground.
- Smooth wire or rail for the top; smooth wire or rail for the bottom.
- Preferably, no vertical stays. If used, consider stiff plastic or composite stays, or regularly maintain wire stays that are easily bent.
- Posts at 16.5-foot (5 m) intervals.
- Gates, drop-downs, or other passages where wildlife concentrate and cross.
- Increase visibility with a PVC cover, high-visibility wire, flagging, or a top rail.”

Site-specific and species-specific information are also included in these guidelines (Paige, 2012, p.10).

Transmission lines/pipelines

The location of transmission lines and pipelines across the NGP is highly correlated with available energy resources. Densities of natural gas, crude oil and refined products pipelines are highest in western North Dakota/eastern Montana, in order to transport products from the Bakken formation, and in eastern Wyoming, in order to transport coal and other products from the Powder River Basin, and throughout Saskatchewan and Alberta. Transmission lines generally follow the same trends and are correlated closely with the location of major roadways across the ecoregion. However, the density of transmission lines in eastern Montana (near the C.M. Russell National Wildlife Refuge) and in the Nebraska Sandhills appears to be lower than in other parts of the ecoregion (Bentek Energy, 2012; Figure 28).

Because pipelines are buried, impacts to terrestrial wildlife tend to be minimal and occur mostly during the construction of the pipeline. However, impacts to aquatic resources can be great if ruptures occur. In contrast, transmission lines can cause avoidance behavior, particularly for some bird species, and may also increase predation of some grassland and shrubland birds by acting as perches for raptors (Naugle et al., 2011).

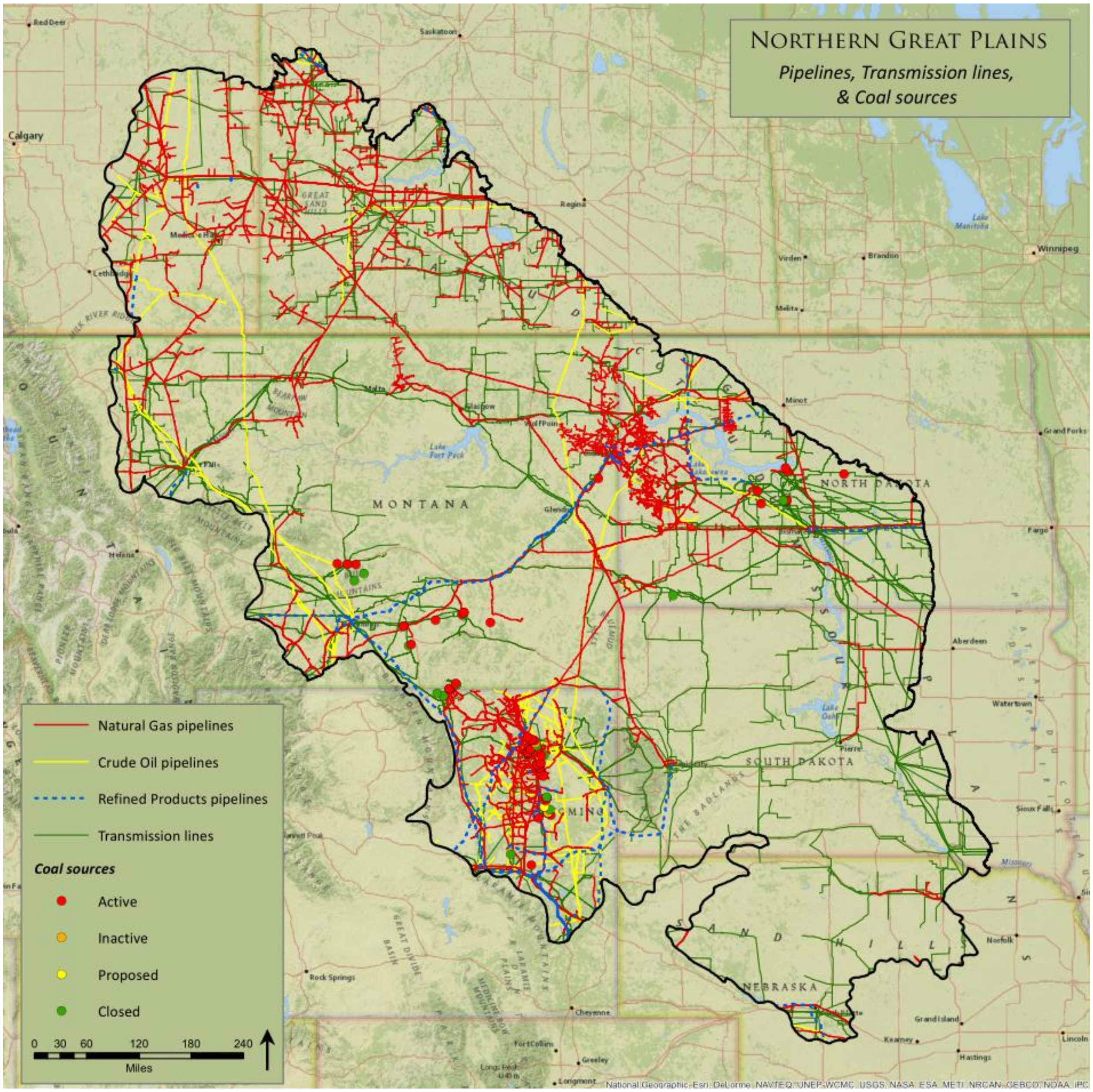

Figure 28: Location of natural gas, crude oil and refined products pipelines, transmission lines and coal sources in the NGP (Bentek Energy, 2012).

Dams and stock ponds

The NGP includes two of North America's most famous rivers: the Missouri, made famous by the voyage of Lewis and Clark, and the Yellowstone, which is the longest free-flowing river in the contiguous US. Large dams, defined for our purposes as being over 50 feet (15.24 m) high, with a normal storage capacity of at least 5,000 acre-feet (0.006 m^3) or a maximum storage capacity of 25,000 acre-feet (0.03 km^3) or more, are prevalent across the NGP landscape, on both large and small rivers (National Atlas of the United States, 2012). Over 100 such dams exist within the ecoreigonal boundary and their impacts to species and riverine ecosystems are significant. Because our program includes work with species, our discussion of dams henceforth will focus on their impacts on pallid sturgeon (*Scaphirhynchus albus*) and cottonwood gallery forests.

Pallid sturgeon have been listed under the Endangered Species Act since 1990. They are adapted to living along river bottoms and are dependent upon natural river flows to create the diverse river-bottom habitat in which they flourish. Within the NGP, pallid sturgeon are located in the Missouri River above Fort Peck Reservoir and in the Missouri and lower Yellowstone Rivers between Fort Peck Dam and Lake Sakakawea. All of the pallid sturgeon's habitat has been altered in some way, either through impoundment, channelization, or other types of alteration. Two of the recovery priority areas are located within the NGP ecoregion: one on the Missouri River from the mouth of the Marias River to the headwaters of the Fort Peck Reservoir, and the other on the Missouri River from Fort Peck Dam to the headwaters of Lake Sakakawea, including the Yellowstone River upstream to the mouth of the Tongue River (EPA, 2007, p.9). Estimates suggest that the construction of dams on the Missouri River have:

- "reduced the surface area by one-half;
- doubled current velocity;
- decreased habitat diversity;
- decreased sediment transport."

These alterations have led to buried gravel bars and the loss of sediment-deposited sandbars, upon which pallid sturgeon are dependent during reproduction. Currently, most reproduction occurs at fish hatcheries, with very few occurrences of natural reproduction occurring in the past 30 years (EPA, 2007).

A lack of natural river flood patterns also alters cottonwood gallery forests, which provide important riparian habitat for birds. The construction of dams has decreased river flows and flood events on the Missouri River to the point that natural regeneration of cottonwood forests is nearly non-existent. Cottonwood forests provide important nesting habitat for a variety of birds, especially the bald eagle, which needs large trees in which to build nests (Missouri River Recovery Program, 2012). According to Scott et al. (1997), more than 70% of trees are established during years when flows reach 1400 m^3 per second (equivalent to almost 50,000 cubic feet per second) or in the two years following such an event along the Missouri River in Montana. Currently, the Missouri River Recovery Program is developing a management plan that targets restoration of cottonwood forests along the Missouri River, and the Plains and Prairie Potholes Landscape Conservation Cooperative is funding the development of models that project future trends in cottonwood recruitment and the impacts of changes on songbird populations.

Stock ponds, which are artificial water bodies developed for use primarily by cattle, are prevalent across the NGP. While data on their distribution is sparse, it is likely that thousands exist at even a landscape scale. Stock ponds are likely having some impact on the flow of small, perennial streams across the prairie landscape and, subsequently, the aquatic biodiversity of these streams.

Conclusions

Many of the threats considered in this report are either emerging threats or threats whose magnitude has changed substantially in the past decade. Threats are directly impacting humans, wildlife, and habitat and indirectly exacerbating other threats, as is the case with climate change. The impacts of these threats to priority species, habitat availability, and human livelihoods are considerable, and coordinated strategies will be essential to protect these resources for future generations. The Northern Great Plains and other temperate grasslands worldwide represent high biodiversity and provide important ecosystem services for human populations, and their conservation is essential to future generations.

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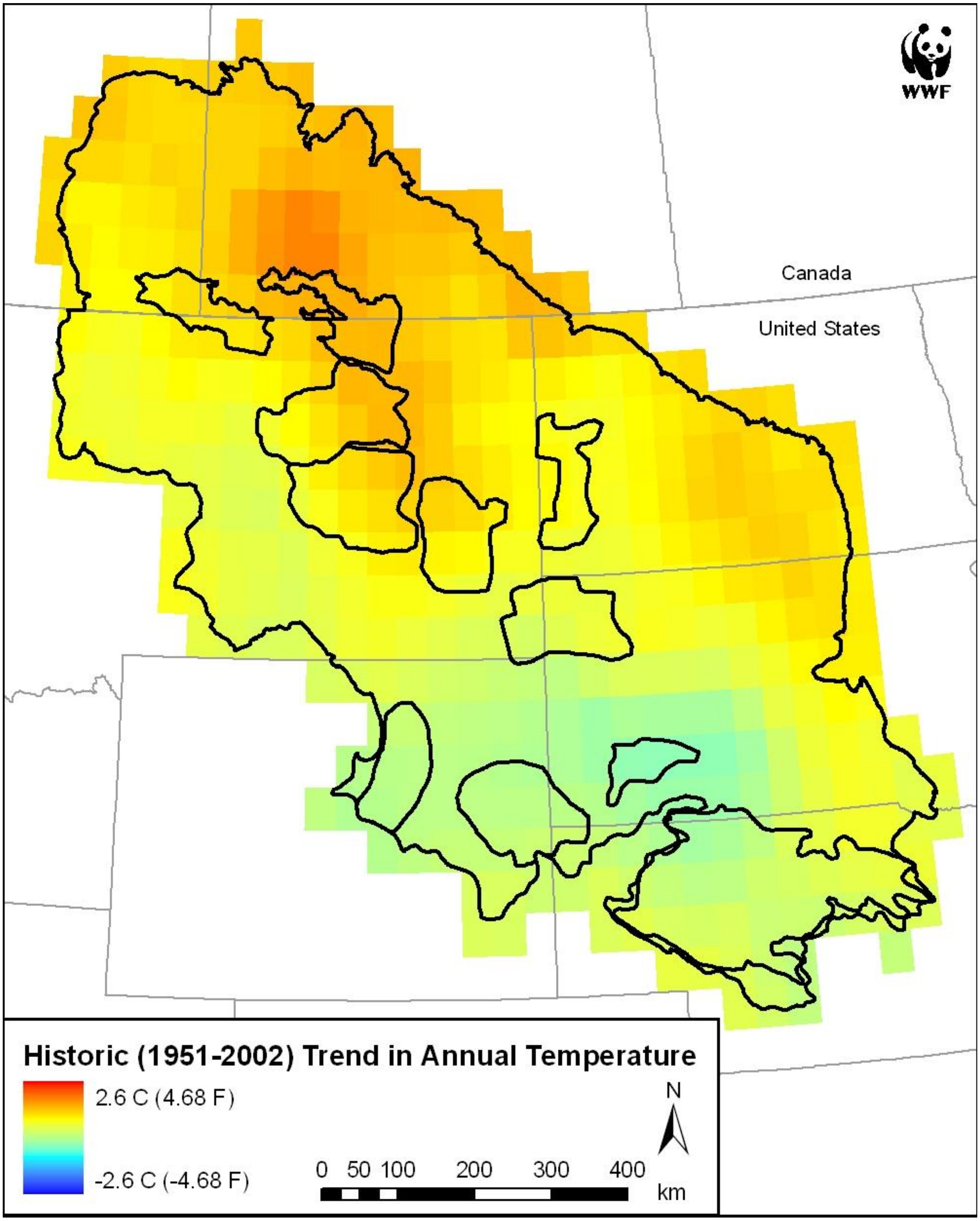
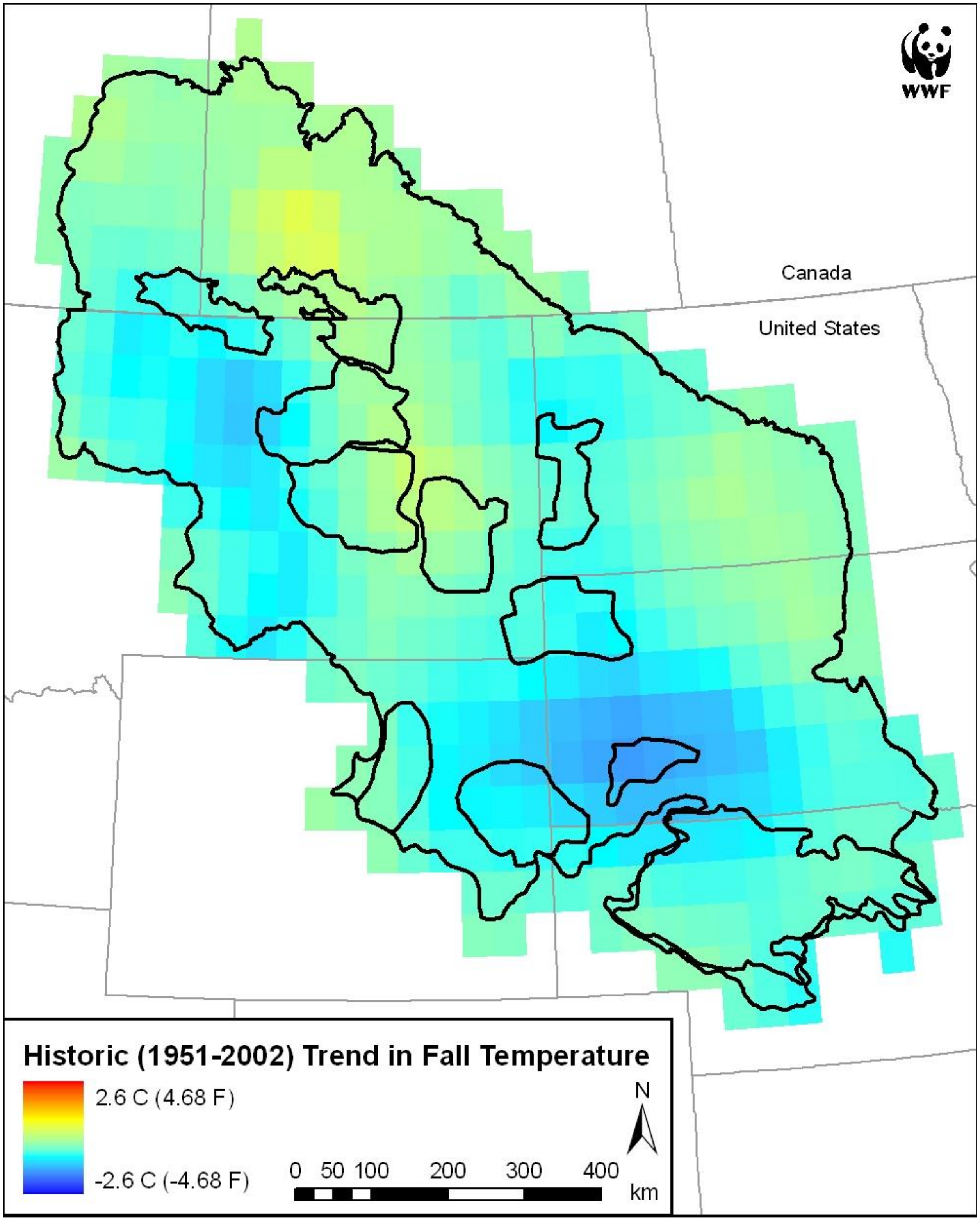
Appendix A



Data produced by ClimateWizard (c) The University of Washington and The Nature Conservancy, 2009.
Original data source: Climatic Research Center and Tyndall Centre.



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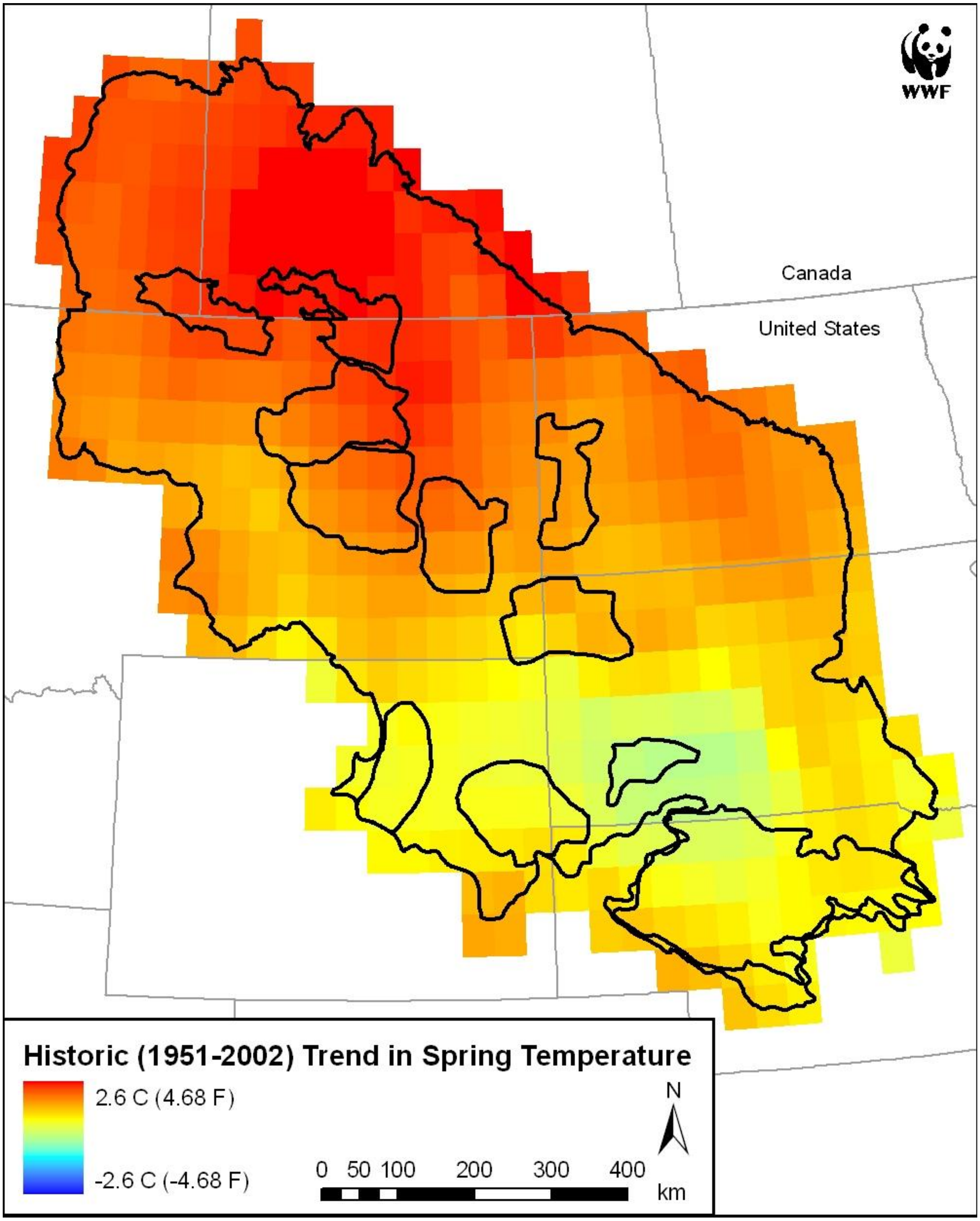

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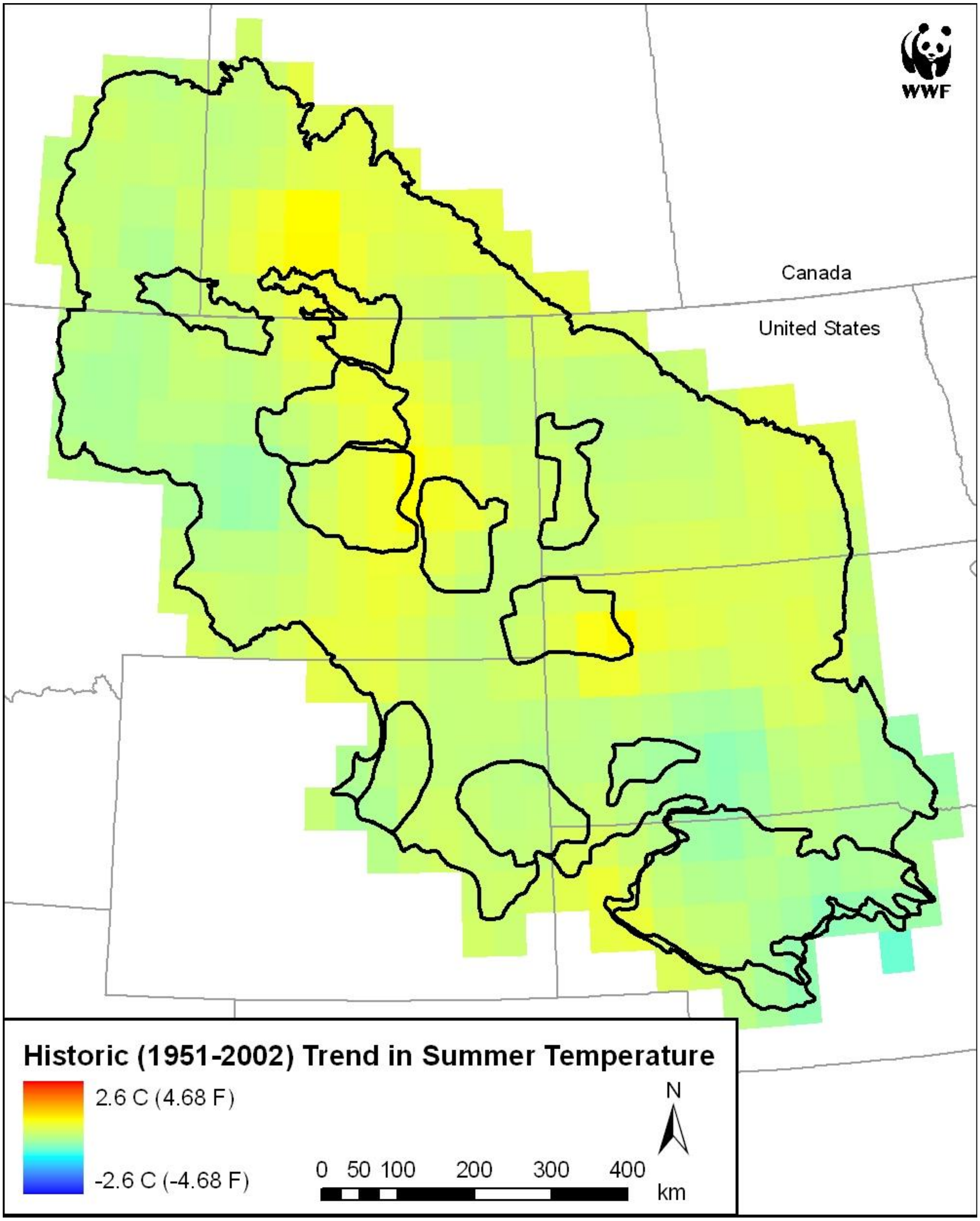

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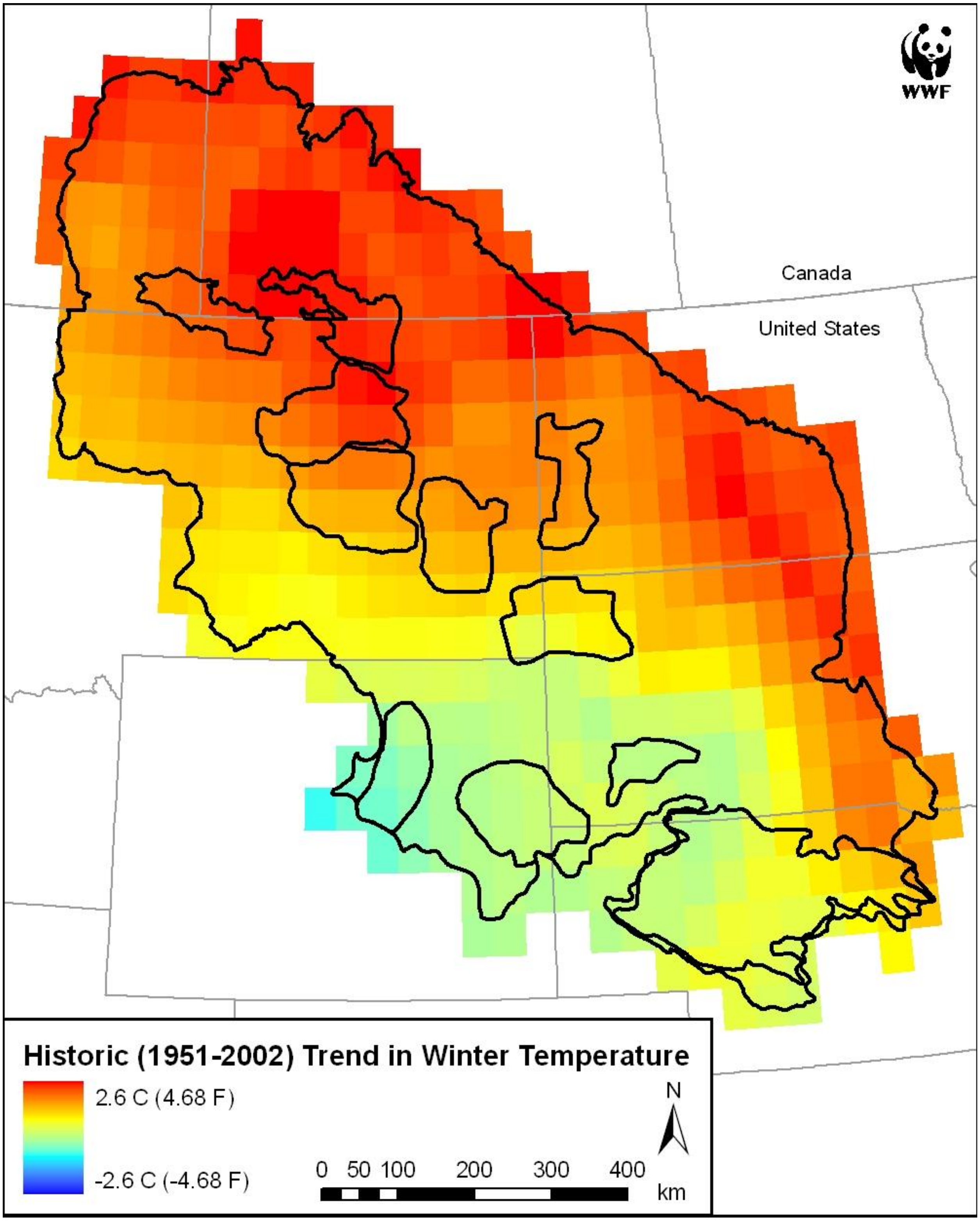
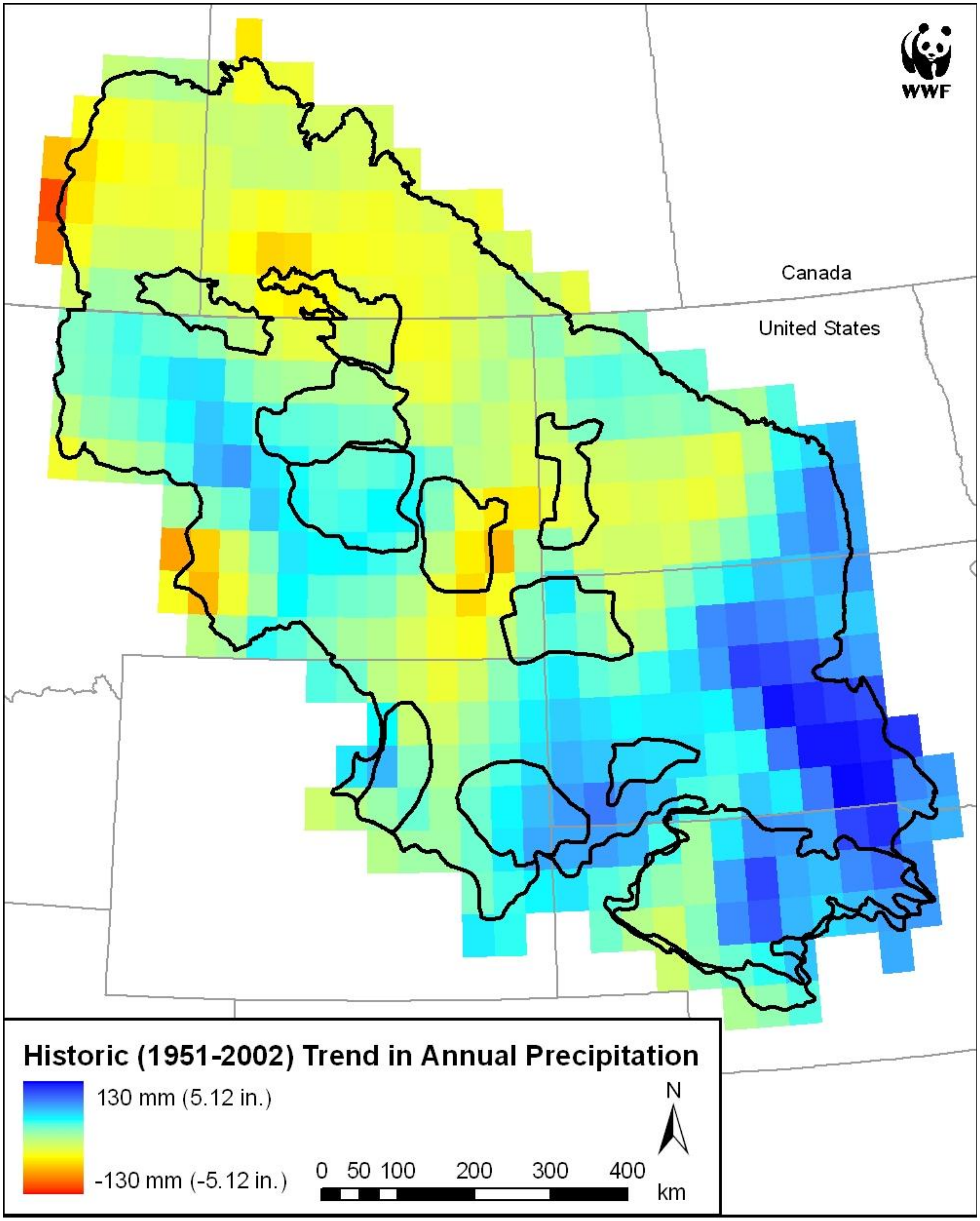


Data produced by ClimateWizard (c) The University of Washington and The Nature Conservancy, 2009.
Original data source: Climatic Research Center and Tyndall Centre.



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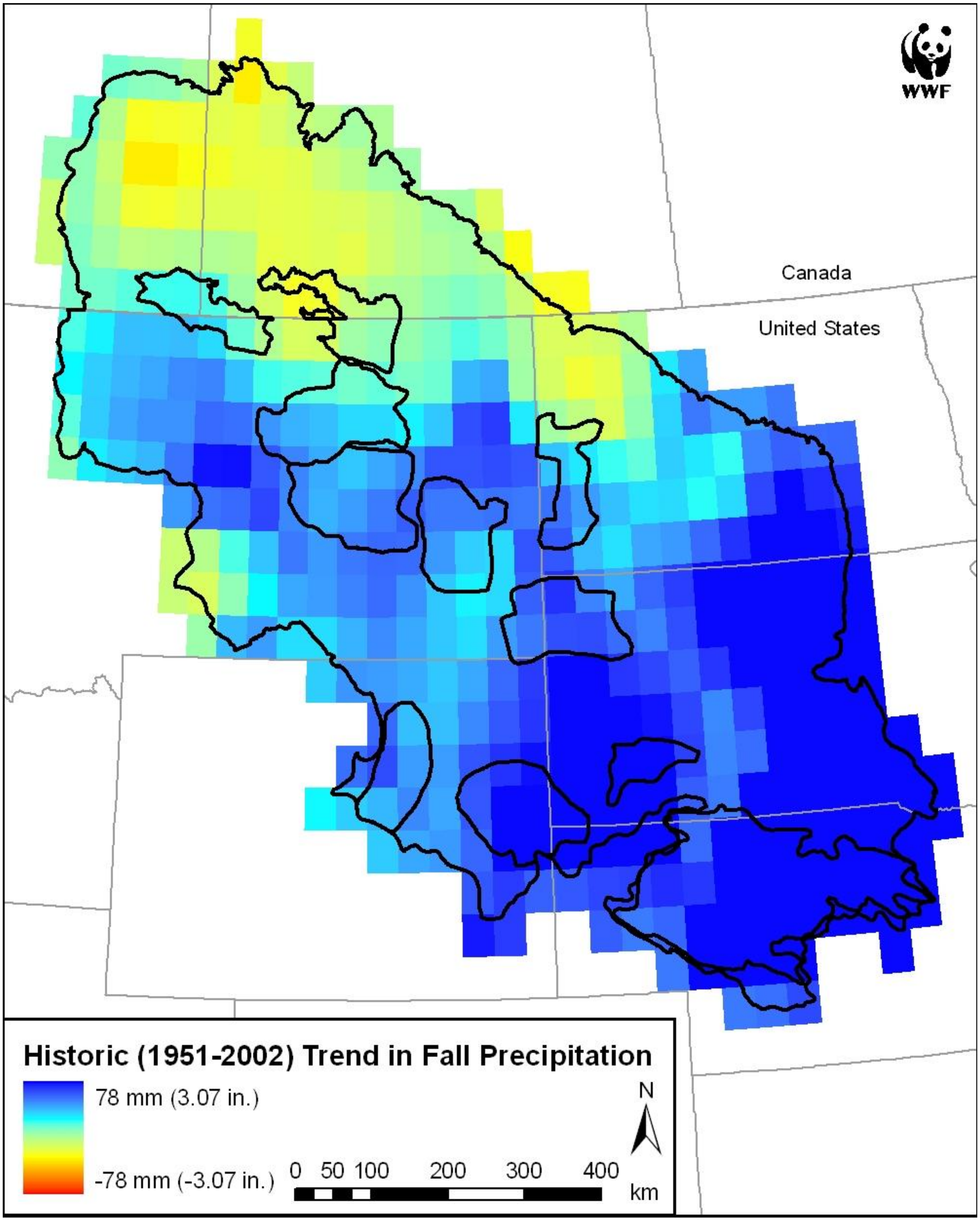

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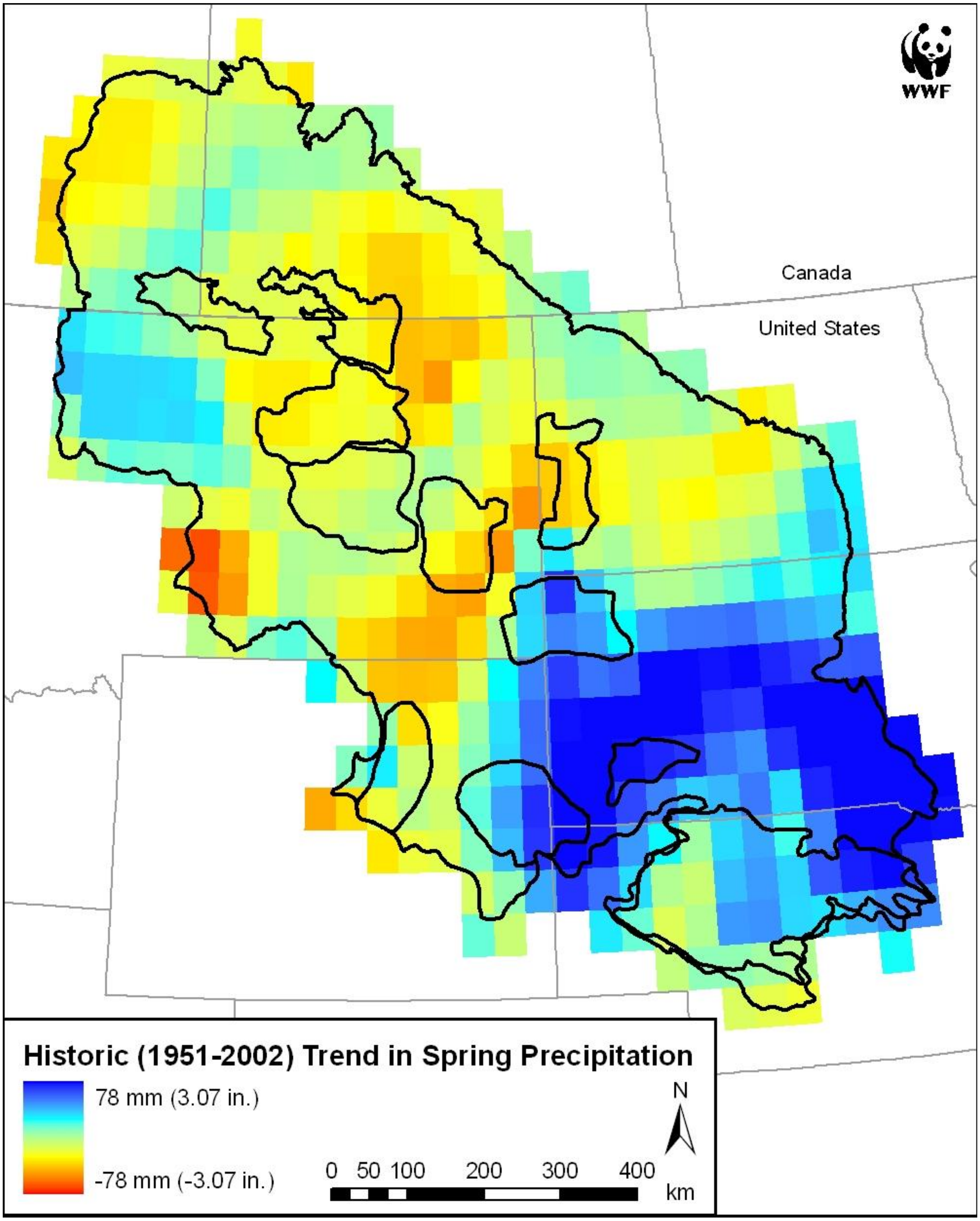

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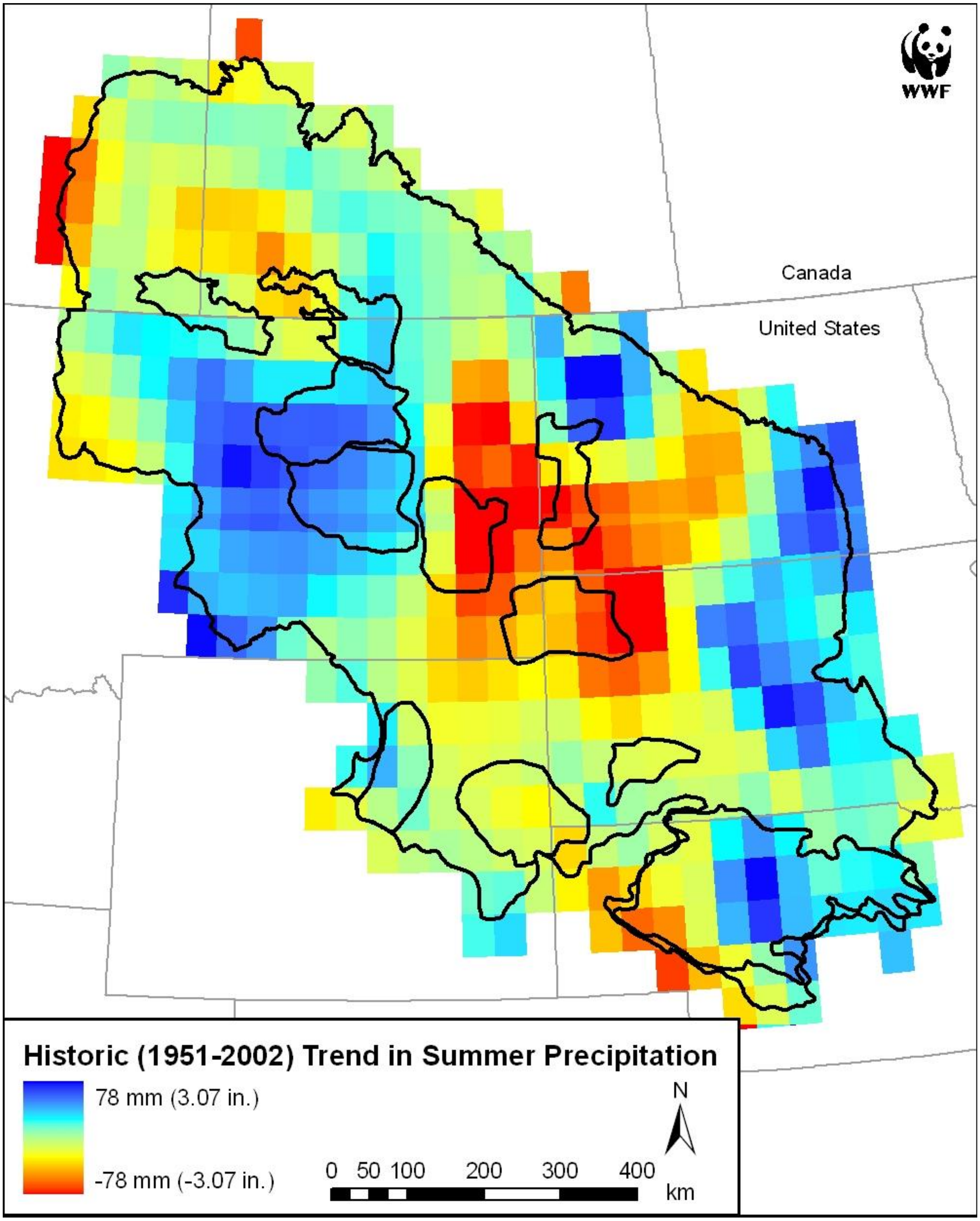

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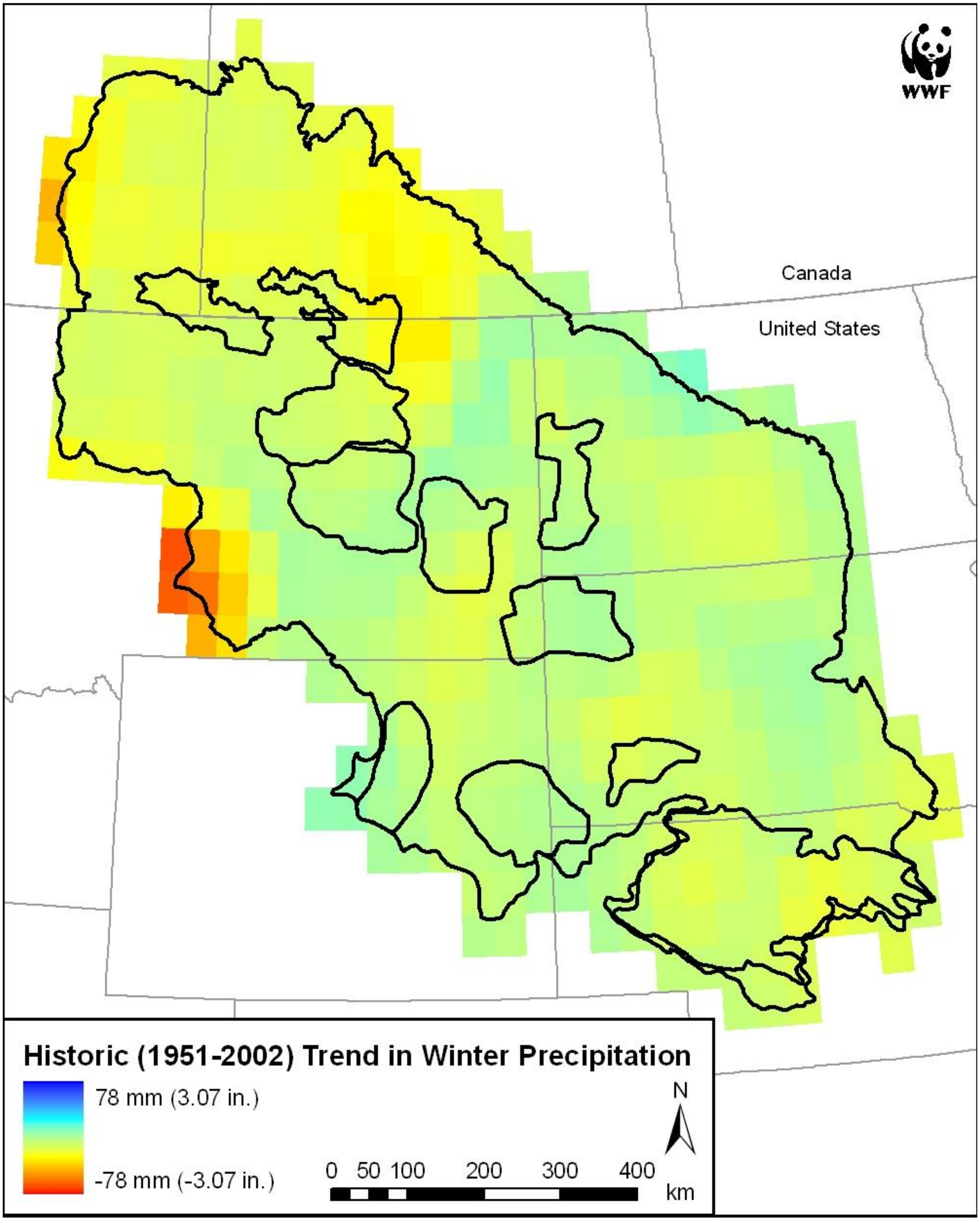

Data produced by ClimateWizard (c) The University of Washington and The Nature Conservancy, 2009.
Original data source: Climatic Research Center and Tyndall Centre.

Appendix B

Following is a list of all data layers acquired for the threats assessment, along with the source and/or citation. All data layers can be accessed through the Northern Plains Conservation Network Interactive Web Map, except for those with asterisks (*) below. Data sources with asterisks are proprietary or sensitive information that can be included in hard-copy maps, but not online.

Data Layer	Source/Citation
Age of farm operators	US: http://www.agcensus.usda.gov/Publications/2007/index.php; 2007 National Agricultural Statistics Service, US Dept. of Agriculture; Statistics Canada, 2006 Census of Agriculture, Farm Data and Farm Operator Data, catalogue no. 95-629-XWE.
Age Structure: Single Years of Age and Sex	Source: US Census Bureau, 2010 Census., Statistics Canada
Amphibian distributions	IUCN 2010. IUCN Red List of Threatened Species. Version 2010.4. http://www.iucnredlist.org>. Downloaded on 23 May 2012.
Approximate location of Keystone XL proposed pipeline*	Digitized from Transcanada map, 2011
Average income - Canada	Statistics Canada. Table 202-0602 - Distribution of after-tax income of individuals, 2010 constant dollars, annual, CANSIM (database).
Bat distributions	National Atlas of the United States, February 28, 2012, http://nationalatlas.gov; Bat Conservation International, Inc.
Bighorn sheep distribution	Patterson, B. D., G. Ceballos, W. Sechrest, M. F. Tognelli, T. Brooks, L. Luna, P. Ortega, I. Salazar, and B. E. Young. 2007. Digital Distribution Maps of the Mammals of the Western Hemisphere, version 3.0. NatureServe, Arlington, Virginia, USA., Montana Fish, Wildlife & Parks, Wyoming Game & Fish
Bird distributions	Ridgely, R. S., T. F. Allnutt, T. Brooks, D. K. McNicol, D. W. Mehlman, B. E. Young, and J. R. Zook. 2007. Digital Distribution Maps of the Birds of the Western Hemisphere, version 3.0. NatureServe, Arlington, Virginia, USA.
Bison: existing herds	Wildlife Conservation Society (2008)
Bison: historic range	Hornaday, W.T. 1889. The extermination of the American bison, with a sketch of its discovery and life history: Report of the National Museum. Washington, DC: US Government Printing Office.
Black-footed ferret existing reintroduction sites	Kristy Bly (kristy.bly@wwfus.org)
Black-footed ferret historic occurrence sites	Anderson, E., S.C. Forrest, T.W. Clark and L. Richardson. 1986. Paleobiology, Biogeography, and Systematics of the Black-footed Ferret, (Audubon and Bachman), 1851. Great Basin Naturalist Memoirs 8:11-62.
Black-footed ferret proposed reintroduction sites	Kristy Bly (kristy.bly@wwfus.org)

Black-tailed prairie dog existing complexes	WWF NGP BTPD Database (MT: Montana Natural Heritage Program and US Bureau of Indian Affairs; ND: S. Johnson, NDGF, January 2008 and Dakota Prairie Grasslands; WY: Wyoming Natural Diversity Database. 2011. Data compilation for S. Olimb, completed January 12, 2011. Unpublished report. Wyoming Natural Diversity Database, University of Wyoming, Laramie, Wyoming; SD: Kempema, S. L. F., C. Marsh, and K. Marsh. 2009. Colony acreage and distribution of the black-tailed prairie dog in South Dakota, 2008. South Dakota Department of Game, Fish and Parks Wildlife Division Report Number 2009-02, Pierre, South Dakota. 30 pages, US Forest Service/Wall Ranger District and Pine Ridge Reservation; SK: Parks Canada, Grassland National Park)
Black-tailed prairie dog historic range	Patterson, B. D., G. Ceballos, W. Sechrest, M. F. Tognelli, T. Brooks, L. Luna, P. Ortega, I. Salazar, and B. E. Young. 2007. Digital Distribution Maps of the Mammals of the Western Hemisphere, version 3.0. NatureServe, Arlington, Virginia, USA.
Breeding bird distributions and relative abundances	Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski, Jr., and W. A. Link. 2011. The North American Breeding Bird Survey, Results and Analysis 1966 - 2009. Version 3.23.2011 USGS Patuxent Wildlife Research Center, Laurel, MD
Canada land ownership	Conservation Areas Reporting and Tracking System (CARTS), http://www.ccea.org/en_carts.html, (CAN, downloaded 4/17/12)
Canada wetlands and water bodies	North American Land Change Monitoring System (NALCMS), http://www.cec.org/Page.asp?PageID=924&SiteNodeID=565
Canada Wind Potential	Environment Canada (2008) Canadian Wind Energy Atlas. http://www.windatlas.ca/en/index.php.
Canadian Northern Great Plains oil and gas predictive model	Holly Copeland and Jeffrey Evans. The Nature Conservancy. October 2012.
Coal Fields of the US	National Atlas of the United States, February 28, 2012, http://nationalatlas.gov
Coal Mines and sources*	Bentek Energy, 2012 (purchased)
Commission for Environmental Cooperation (CEC) grassland priority areas	Commission for Environmental Cooperation, http://www.cec.org/
Crude pipelines*	Bentek Energy, 2012 (purchased)
Cultural/historically important sites	National Park Service, US Department of the Interior. National Register of Historic Places.
Education: Percentage with bachelors degree or greater education	US Census Bureau, 2010 Census; Statistics Canada. Table 109-0300 - Census indicator profile, Canada, provinces, territories, health regions (2011 boundaries) and peer groups, every five years, CANSIM (database).
Education: Percentage with high school or greater education	US Census Bureau, 2010 Census.; Statistics Canada. Table 109-0300 - Census indicator profile, Canada, provinces, territories, health regions (2011 boundaries) and peer groups, every five years, CANSIM (database).

Electric transmission lines*	Bentek Energy, 2012 (purchased)
Elk distribution	Montana Fish, Wildlife & Parks, Wyoming Game and Fish, North Dakota Game and Fish, South Dakota Game, Fish and Parks, Nebraska Game and Parks, NatureServe. 2012. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: June 21, 2012).
Fence locations and density (for 13 counties in Montana)*	Jakes, A., Poor, E.E., Loucks, C., Suitor, M. Modeling fence location and density at a landscape-level scale. In progress.
Fire regimes	LANDFIRE: LANDFIRE 1.1.0 Fire regime group layer. US Department of Interior, Geological Survey. [Online]. Available: http://landfire.cr.usgs.gov/viewer/ [2012, March 26].
Fish distributions	NatureServe. 2010. Digital Distribution Maps of the Freshwater Fishes in the Conterminous United States. Version 3.0. Arlington, VA. USA. "Data provided by NatureServe."
Fish Habitat Degradation Risk - Generalized	National Fish Habitat Action Plan (NFHAP), http://www.fishhabitat.org/
Future climate precipitation and temperature scenarios: CCC	Canadian Centre for Climate Modeling and Analysis, Climate Research Branch, Environment Canada, A1b Emissions Scenario, Global climate model output, from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset (Meehl et al., 2007), were downscaled as described by Maurer et al. (2009) using the bias-correction/spatial downscaling method (Wood et al., 2004) to a 0.5 degree grid, based on the 1950-1999 gridded observations of Adam and Lettenmaier (2003).
Future climate precipitation and temperature scenarios: GFDL	US Department of Commerce, NOAA, Geophysical Fluid Dynamics Laboratory, USA, A1b Emissions Scenario, Global climate model output, from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset (Meehl et al., 2007), were downscaled as described by Maurer et al. (2009) using the bias-correction/spatial downscaling method (Wood et al., 2004) to a 0.5 degree grid, based on the 1950-1999 gridded observations of Adam and Lettenmaier (2003).
Future climate precipitation and temperature scenarios: UKMO	Hadley Center for Climate Prediction and Research, Met Office, UK, A1b Emissions Scenario, Global climate model output, from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset (Meehl et al., 2007), were downscaled as described by Maurer et al. (2009) using the bias-correction/spatial downscaling method (Wood et al., 2004) to a 0.5 degree grid, based on the 1950-1999 gridded observations of Adam and Lettenmaier (2003).
Gas pipelines*	Bentek Energy, 2012 (purchased)

Gray wolf	Patterson, B. D., G. Ceballos, W. Sechrest, M. F. Tognelli, T. Brooks, L. Luna, P. Ortega, I. Salazar, and B. E. Young. 2007. Digital Distribution Maps of the Mammals of the Western Hemisphere, version 3.0. NatureServe, Arlington, Virginia, USA.
Greater sage-grouse core areas	Doherty, K.E. 2008. Sage-grouse and energy development: integrating science with conservation planning to reduce impacts. Dissertation, University of Montana, Missoula, Montana, USA.
Greater sage-grouse distribution	Connelly, J. W., S. T. Knick, M. A. Schroeder, and S. J. Stiver. 2004. Conservation Assessment of Greater Sage-grouse and Sagebrush Habitats. Western Association of Fish and Wildlife Agencies. Unpublished Report. Cheyenne, Wyoming.
Greater sage-grouse leks	Montana Natural Heritage Program (mtnhp.org/), North Dakota Game and Fish Department (gf.nd.gov/), Wyoming Game and Fish Department (wgfd.wyo.gov/), Fish and Wildlife Management Information System (FWMIS, http://xnet.env.gov.ab.ca/imf/imfAlbertaUserAgreeSubmit.jsp?site=fw_mis_pub), SD Game, Fish and Parks (gfp.sd.gov/), SK Conservation Data Centre (www.biodiversity.sk.ca/)
Grizzly bear	Patterson, B. D., G. Ceballos, W. Sechrest, M. F. Tognelli, T. Brooks, L. Luna, P. Ortega, I. Salazar, and B. E. Young. 2007. Digital Distribution Maps of the Mammals of the Western Hemisphere, version 3.0. NatureServe, Arlington, Virginia, USA.
Growth rate/change	Source US Census Bureau: State and County QuickFacts. Data derived from Population Estimates, American Community Survey, Census of Population and Housing, State and County Housing Unit Estimates, County Business Patterns, Nonemployer Statistics, Economic Census, Survey of Business Owners, Building Permits, Consolidated Federal Funds Report
Historic (1951-2002) Trend in Annual Temperature and Precipitation	Data produced by ClimateWizard © The University of Washington and The Nature Conservancy, 2009. Original data source: Climatic Research Center and Tyndall Centre.
Human footprint	Last of the Wild Data Version 2, 2005 (LWP-2): Global Human Footprint data set (HF). Wildlife Conservation (WCS) and Center for International Earth Science Information Network (CIESIN).;
Human Influence Index	Last of the Wild Data Version 2, 2005 (LWP-2): Global Human Influence Index (HII). Wildlife Conservation (WCS) and Center for International Earth Science Information Network (CIESIN).
Hydrologic impairment	EPA Office of Water, http://www.epa.gov/waters
Important bird areas	National Audubon Society. February 2012. Important Bird Areas Database, Boundary Digital Data Set. Ivyland, Pennsylvania. Canada: http://www.ibacanada.ca/explore_how.jsp?lang=en

Intact habitat in the Northern Great Plains (generalized)	Land Cover for Agricultural Regions of Canada, circa 2000; http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1226330737632&lang=eng Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and Wickham, J., 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, PE&RS, Vol. 77(9):858-864.
Invasive species - aquatic	USGS - Aquatic non-indigenous spp. (5/2/12), http://nas.er.usgs.gov/
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Road density	US Census Bureau, Geography Division TIGER Line Files 2011 (US); Statistics Canada 2011 Road Network File (Canada)
Shale Play Boundaries	US Energy Information Administration (http://www.eia.gov/pub/oil_gas/natural_gas/analysis_publications/maps/maps.htm#field)
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US Land Ownership	The Conservation Biology Institute. May 2010. PAD-US 1.1 (CBI Edition). Corvallis, Oregon.
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