22 Northern Great Plains

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22 Northern Great Plains

Cameron, Montana

Key Message 1

Water

Water is the lifeblood of the Northern Great Plains, and effective water management is critical to the region's people, crops and livestock, ecosystems, and energy industry. Even small changes in annual precipitation can have large effects downstream; when coupled with the variability from extreme events, these changes make managing these resources a challenge. Future changes in precipitation patterns, warmer temperatures, and the potential for more extreme rainfall events are very likely to exacerbate these challenges.

Key Message 2

Agriculture

Agriculture is an integral component of the economy, the history, and the culture of the Northern Great Plains. Recently, agriculture has benefited from longer growing seasons and other recent climatic changes. Some additional production and conservation benefits are expected in the next two to three decades as land managers employ innovative adaptation strategies, but rising temperatures and changes in extreme weather events are very likely to have negative impacts on parts of the region. Adaptation to extremes and to longer-term, persistent climate changes will likely require transformative changes in agricultural management, including regional shifts of agricultural practices and enterprises.

Key Message 3

Recreation and Tourism

Ecosystems across the Northern Great Plains provide recreational opportunities and other valuable goods and services that are at risk in a changing climate. Rising temperatures have already resulted in shorter snow seasons, lower summer streamflows, and higher stream temperatures and have negatively affected high-elevation ecosystems and riparian areas, with important consequences for local economies that depend on winter or river-based recreational activities. Climate-induced land-use changes in agriculture can have cascading effects on closely entwined natural ecosystems, such as wetlands, and the diverse species and recreational amenities they support. Federal, tribal, state, and private organizations are undertaking preparedness and adaptation activities, such as scenario planning, transboundary collaboration, and development of market-based tools.

Key Message 4

Energy

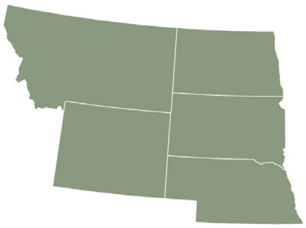
Fossil fuel and renewable energy production and distribution infrastructure is expanding within the Northern Great Plains. Climate change and extreme weather events put this infrastructure at risk, as well as the supply of energy it contributes to support individuals, communities, and the U.S. economy as a whole. The energy sector is also a significant source of greenhouse gases and volatile organic compounds that contribute to climate change and ground-level ozone pollution.

Key Message 5

Indigenous Peoples

Indigenous peoples of the Northern Great Plains are at high risk from a variety of climate change impacts, especially those resulting from hydrological changes, including changes in snowpack, seasonality and timing of precipitation events, and extreme flooding and droughts as well as melting glaciers and reduction in streamflows. These changes are already resulting in harmful impacts to tribal economies, livelihoods, and sacred waters and plants used for ceremonies, medicine, and subsistence. At the same time, many tribes have been very proactive in adaptation and strategic climate change planning.

Executive Summary



In the Northern Great Plains, the timing and quantity of both precipitation and runoff have important consequences for water supplies, agricultural activities, and energy production. Overall, climate projections suggest that the number of heavy precipitation events (events with greater than 1 inch per day of rainfall) is projected to increase. Moving forward, the magnitude of year-to-year variability overshadows the small projected average decrease in streamflow. Changes in extreme events are likely to overwhelm average changes in both the eastern and western regions of the Northern Great Plains. Major flooding across the basin in 2011 was followed by severe drought in 2012, representing new and unprecedented variability that is likely to become more common in a warmer world.

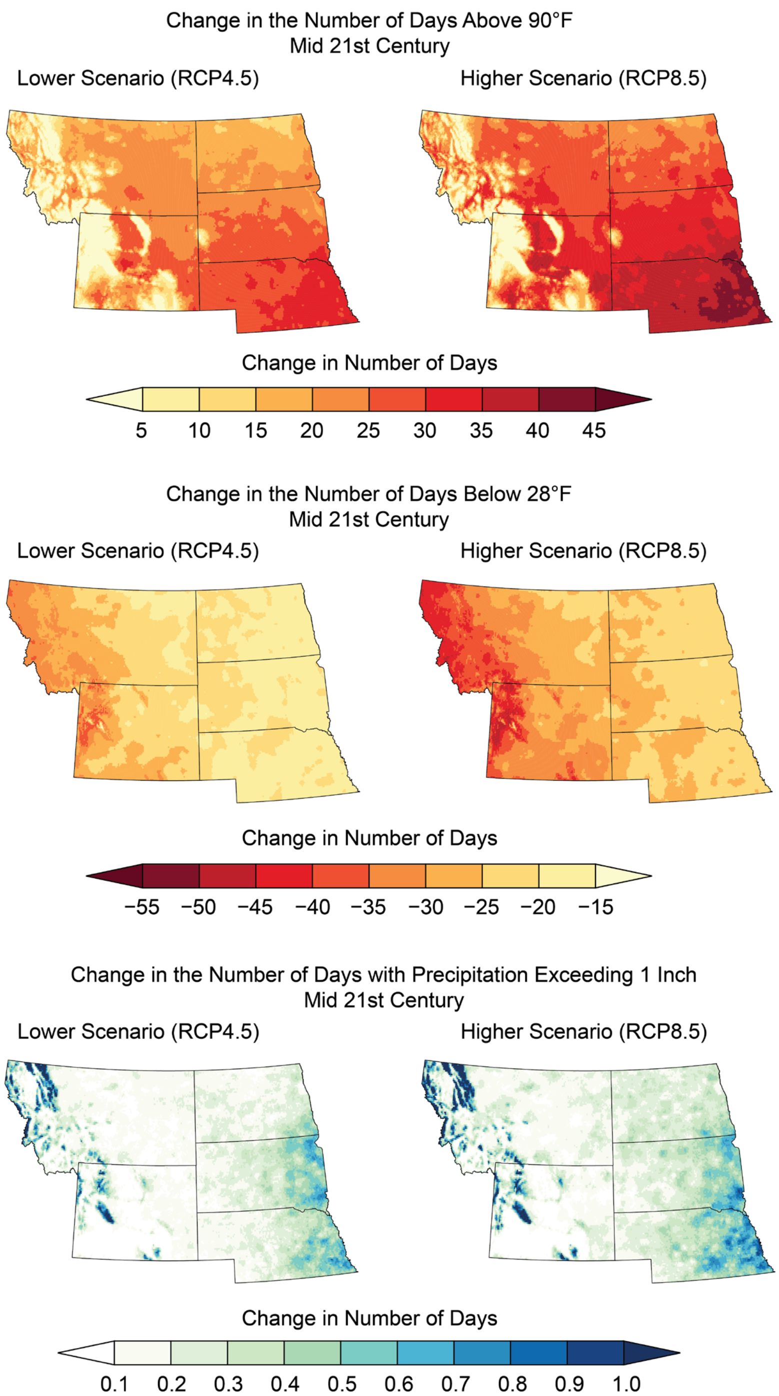
The Northern Great Plains region plays a critical role in national food security. Among other anticipated changes, projected warmer and generally wetter conditions with elevated atmospheric carbon dioxide concentrations are expected to increase the abundance and competitive ability of weeds and invasive species,[1,2] increase livestock production and efficiency of production,[3] and result in longer growing seasons at mid- and high latitudes.[4,5] Net primary productivity, including crop yields[6] and forage production,[7,8] is also likely to increase, although an increasing number of extreme temperature events during critical pollination and grain fill periods is likely to reduce crop yields.[9]

Ecosystems across the Northern Great Plains provide recreational opportunities and other valuable goods and services that are ingrained in the region's cultures. Higher temperatures, reduced snow cover, and more variable precipitation will make it increasingly challenging to manage the region's valuable wetlands, rivers, and snow-dependent ecosystems. In the mountains of western Wyoming and western Montana, the fraction of total water in precipitation that falls as snow is expected to decline by 25% to 40% by 2100 under a higher scenario (RCP8.5),[10] which would negatively affect the region's winter recreation industry.[11] At lower-elevation areas of the Northern Great Plains, climate-induced land-use changes in agriculture can have cascading effects on closely entwined natural ecosystems, such as wetlands,[12] and the diverse species and recreational opportunities they support.

Energy resources in the Northern Great Plains include abundant crude oil, natural gas, coal, wind, and stored water, and to a lesser extent, corn-based ethanol, solar energy, and uranium. The infrastructure associated with the extraction, distribution, and energy produced from these resources is vulnerable to the impacts of climate change. Railroads and pipelines are vulnerable to damage or disruption from increasing heavy precipitation events and associated flooding and erosion.[13] Declining water availability in the summer would likely increase costs for oil production operations, which require freshwater resources.[13] These cost increases will either lead to lower production or be passed on to consumers. Finally, higher maximum temperatures, longer and more severe heat waves, and higher overnight lows are expected to increase electricity demand for cooling in the summer, further stressing the power grid.[13]

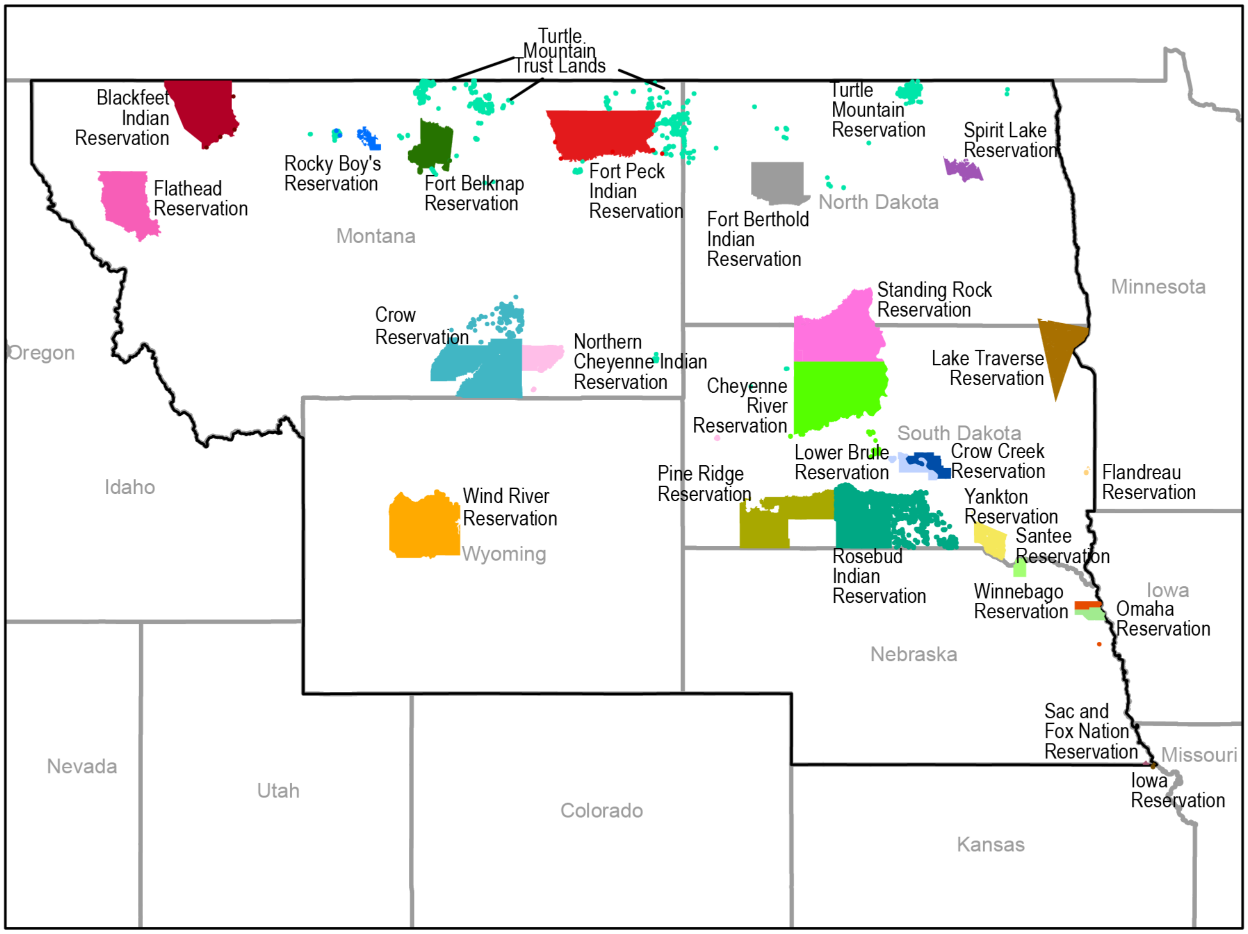
Indigenous peoples in the region are observing changes to climate, many of which are impacting livelihoods as well as traditional subsistence and wild foods, wildlife, plants and water for ceremonies, medicines, and health and well-being.[14,15,16,17,18,19,20,21,22,23,24,25,26] Because some tribes and Indigenous peoples are among those in the region with the highest rates of poverty and unemployment, and because many are still directly reliant on natural resources, they are among the most at risk to climate change (e.g., Gamble et al. 2016, Cozzetto et al. 2013, Espey et al. 2014, Wong et al. 2014, Kornfeld 2016, Paul and Caplins 2016, Maynard 2014, USGCRP 2017[18,24,25,27,28,29,30,31]).

Projected Changes in Very Hot Days, Cool Days, and Heavy Precipitation



Projected changes are shown for (top) the annual number of very hot days (days with maximum temperatures above 90°F, an indicator of crop stress and impacts on human health), (middle) the annual number of cool days (days with minimum temperatures below 28°F, an indicator of damaging frost), and (bottom) heavy precipitation events (the annual number of days with greater than 1 inch of rainfall; areas in white do not normally experience more than 1 inch of rainfall in a single day). Projections are shown as changes from the 1976–2005 average for the middle of the 21st century (2036–2065) for the lower and higher scenarios (RCP4.5 and RCP8.5). *From Figure 22.2 (Sources: NOAA NCEI and CICS-NC).*

Northern Great Plains Tribal Lands



The map outlines reservation and off-reservation tribal lands in the Northern Great Plains, which shows where the 27 federally recognized tribes have a significant portion of lands throughout the region. Information on Indigenous peoples' climate projects within the Northern Great Plains is described in Chapter 15: Tribes and Indigenous Peoples. *From Figure 22.7 (Sources: created by North Central Climate Science Center [2017] with data from the Bureau of Indian Affairs, Colorado State University, and USGS National Map)*.

Background

The Northern Great Plains has three distinct regional geographic features associated with a strong east-to-west gradient of decreasing precipitation and a stark rise in elevation at the montane western boundary. The eastern edge of the region includes a humid-continental climate and the Red River Valley, where the capacity to store water is often exceeded, leading to extensive flooding. A large swath of the central Northern Great Plains falls within the Upper Missouri River Basin. Much of this basin is arid to semiarid, and because temperatures and rates of evapotranspiration (the evaporation of water from the soil and transpiration from plants) are so high, only 9% of precipitation ultimately reaches the Missouri River as runoff. For comparison, other basins in the United States yield more than 40% runoff. In the mountainous far western part of the region, including central and western Wyoming and Montana, water dynamics are driven by large seasonal snowpack that accumulates in winter and early spring and provides critical resources for non-montane areas through runoff during the warm season.

These intraregional gradients in precipitation, temperature, and water availability drive east–west differences in land use and climate. The eastern portion of the region is characterized by rainfed row crop agriculture and is often subject to flooding. For example, Devils Lake in North Dakota is a closed basin, meaning that it has no natural outflows. The basin is often so full that it is prone to flooding the communities around it. Separately, the irrigated cropland and grazing lands in the central portion of the Northern Great Plains are critical for U.S. livestock production, yet the arid to semiarid climate is highly variable from year to year, which makes it difficult to manage agriculture, recreation, and cultural resources. The western portion of the region is devoted primarily to native ecosystems used for grazing and recreation, but dryland cropping is also important, and forestry is important in the far-western edge of the region. Coal, oil, and natural gas are produced throughout the Northern Great Plains.

The highly variable climate of the Northern Great Plains poses challenges for the sustainable use of water, land, and energy resources by competing urban, suburban, rural, and tribal populations. Climate change is expected to exacerbate those challenges, which include 1) effectively managing both overabundant and scarce water resources, 2) supporting adaptation of sustainable agricultural systems, 3) fostering conservation of ecosystems and cultural and recreational amenities, 4) minimizing risk to energy infrastructure that is vulnerable to climate change and extreme weather events, and 5) mitigating climate impacts to vulnerable populations.

Diverse land uses across the region are overlain with a quilt work of private, state, federal, tribal, and other land ownership. Many of these institutions foster adaptation to existing climatic variability (Figure 22.1). For example, the Missouri Headwaters Drought Resilience Demonstration Project was launched in July 2014 to demonstrate how federal, state, and local stakeholders can work together to build long-term drought resilience. The project leverages federal and state resources and engages communities in the development and implementation of local watershed drought resilience plans and activities. Led by the Montana Department of Natural Resources and Conservation, more than 10 federal agencies, 20 watershed groups, and 14 nongovernmental organizations are contributing to the project (see Missouri Headwaters Drought Resilience Demonstration Project 2015[32]). It is a replicable model that is producing concrete, on-the-ground results, including tools for drought monitoring, assessment, and forecasting. In another example,

Climate Change Impacts and Adaptation Across the Northern Great Plains

1

Impact: Flash droughts and high heat events illustrate challenges for sustainability of ranching operations, with emergent impacts on rural prosperity and mental health.

Response: Adaptive management frameworks, developed through management–science partnerships, proactively increase flexibility in operational decision-making to reduce economic and ecological risk.

2

Impact: Consecutive years of drought across the region force ranchers to consider selling off their herds.

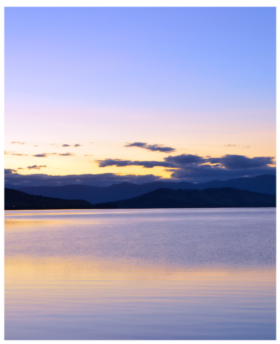
Response: Montana's Matador Ranch establishes a "grassbank" that allows local ranchers to pay discounted fees for access to additional grass during droughts in exchange for wildlife-friendly practices on their own operations.

3

Impact: Rising temperatures hasten the spread of invasive species in riparian ecosystems, threatening culturally significant native species and food sources in the Crow Indian (Apsaalooké) Reservation.

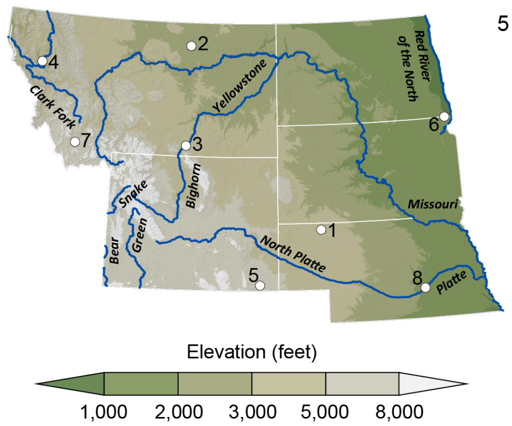
Response: The USDA NRCS Crow Agency worked with Little Big Horn College students to remove invasive populations along the Little Big Horn River. They also revegetated plains cottonwood in sandbars and developed riparian buffer zones.

4



Impact: Anticipated climate change impacts on cultural resources raise concerns within the leadership of the Confederated Salish and Kootenai Tribes.

Response: Tribal leaders developed their climate change strategic plan to address climate impacts and vulnerabilities drawing heavily on Traditional Ecological Knowledge.

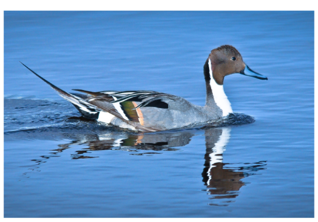


5

Impact: Greenhouse gas emissions from petroleum and natural gas production across the Northern Great Plains are among the highest in the Nation.

Response: Potential wind energy resources are among the largest in the Northern Great Plains.

6



Impact: The Prairie Pothole Region, considered the world's most productive habitat for waterfowl, is threatened by warming temperatures.

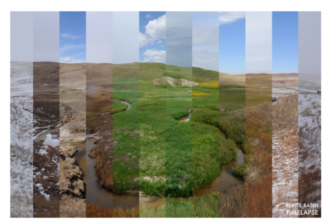
Response: The Prairie Pothole Joint Venture implements wetland and grassland protection, restoration, and enhancement projects to sustain populations of waterfowl, shorebirds, and prairie landbirds.

7

Impact: Changing runoff characteristics and increasing stream temperatures threaten water and ecological resources.

Response: The Beaverhead Drought Resiliency Plan was written to improve preparedness by reducing vulnerabilities to future drought events.

8



Impact: Increased growing season length and greater variability in temperature and precipitation stress critically important natural resources.

Response: The Platte Basin Timelapse project (PBT) uses time-lapse photography and multimedia storytelling to document life across the Platte River watershed.

Figure 22.1: The Northern Great Plains exhibits a high amount of geographical, ecological, and climatological variability, in part because of the dramatic elevation change across the region. The impacts of climate change throughout the Northern Great Plains include changes in flooding and drought, rising temperatures, and the spread of invasive species. Ranchers, tribal communities, universities, government institutions, and other stakeholders from across the region have taken action to confront these challenges. Photo credits: 1) Justin Derner, USDA Agricultural Research Service, 2) Kenton Rowe Photography, 3) Kurrie Jo Small, 4) Eugene Wilson (CC BY-NC 2.0), 5) Jacob Byk, 6) Benjamin Rashford, 7) Chris Carparelli, 8) Mariah Lundgren, University of Nebraska Platte Basin Timelapse Project.

Nebraska completed a statewide climate change assessment report in 2014.[33] Officials were then able to use this report to convene eight sector-based roundtable discussions in 2015, engaging more than 350 people, to identify a suite of key issues, strategies, and next steps to help develop a statewide climate change action plan.[34]

Key Message 1

Water

Water is the lifeblood of the Northern Great Plains, and effective water management is critical to the region's people, crops and livestock, ecosystems, and energy industry. Even small changes in annual precipitation can have large effects downstream; when coupled with the variability from extreme events, these changes make managing these resources a challenge. Future changes in precipitation patterns, warmer temperatures, and the potential for more extreme rainfall events are very likely to exacerbate these challenges.

Streamflow in the Northern Great Plains is driven by a number of factors. Because the Northern Great Plains is so far from the coasts and the modulating effect of the oceans, the regional climate system is prone to dramatic climate variability. The Upper Missouri River Basin (the region's primary surface water feature spanning all five states) is very sensitive to climatic fluctuations, resulting in extreme drought or flooding events roughly every decade over the past century.[35] The timing and quantity of both precipitation and runoff have important consequences for water supplies, agricultural activities, and energy production. Parts of the region are among the most arid in the Nation—for example, less than 10% of regional precipitation reaches streams and the Missouri River[36]—so relatively small changes in annual precipitation can produce large changes in runoff. High evaporation rates result in lower soil moisture and streamflow in the region relative to more humid parts of the country. Trends in annual runoff across the region over the past 50 years show a distinct east–west difference where the western portions show a decrease and eastern areas show an increase.[37] Soil moisture and snowpack have a major impact on streamflow, and as a result of these factors combined with variability in precipitation, the amount of annual streamflow can vary by as much as a factor of three from year to year.[35] In the western montane portion of the region, 39 glaciers contribute to streamflows through their seasonal melt process. These glaciers are experiencing sustained loss,[38] and, like global glacier losses over recent decades, local glacier losses are attributable to higher temperatures.[39,40] Glacier flows are critically important for local watersheds and ecosystems; however, their contribution to the entire Upper Missouri River Basin is very small. High variability in the proportion of precipitation that reaches streams in a given year, coupled with a relatively high frequency of extreme events (for example, heavy rainfall events and droughts), makes managing climate change impacts on water resources challenging. Major flooding across the basin in 2011 was followed by severe drought in 2012, representing new and unprecedented variability that is likely to become more common in a warmer world.

Given the losses in important snowpack water storage, reservoirs and groundwater represent critical buffers to climate impacts, since they have large storage capacity that can be filled during wet periods and withdrawn during dry periods. Evaporation rates exceed 100% of precipitation in some cases,[41] which results in a deficit of surface water and thus reliance upon groundwater. Groundwater and aquifer recharge rates[42] are relatively high in the region (including parts of Wyoming, South Dakota, Montana, and Nebraska) and seem sustainable given current rates of groundwater extraction.

Projected Changes in Very Hot Days, Cool Days, and Heavy Precipitation

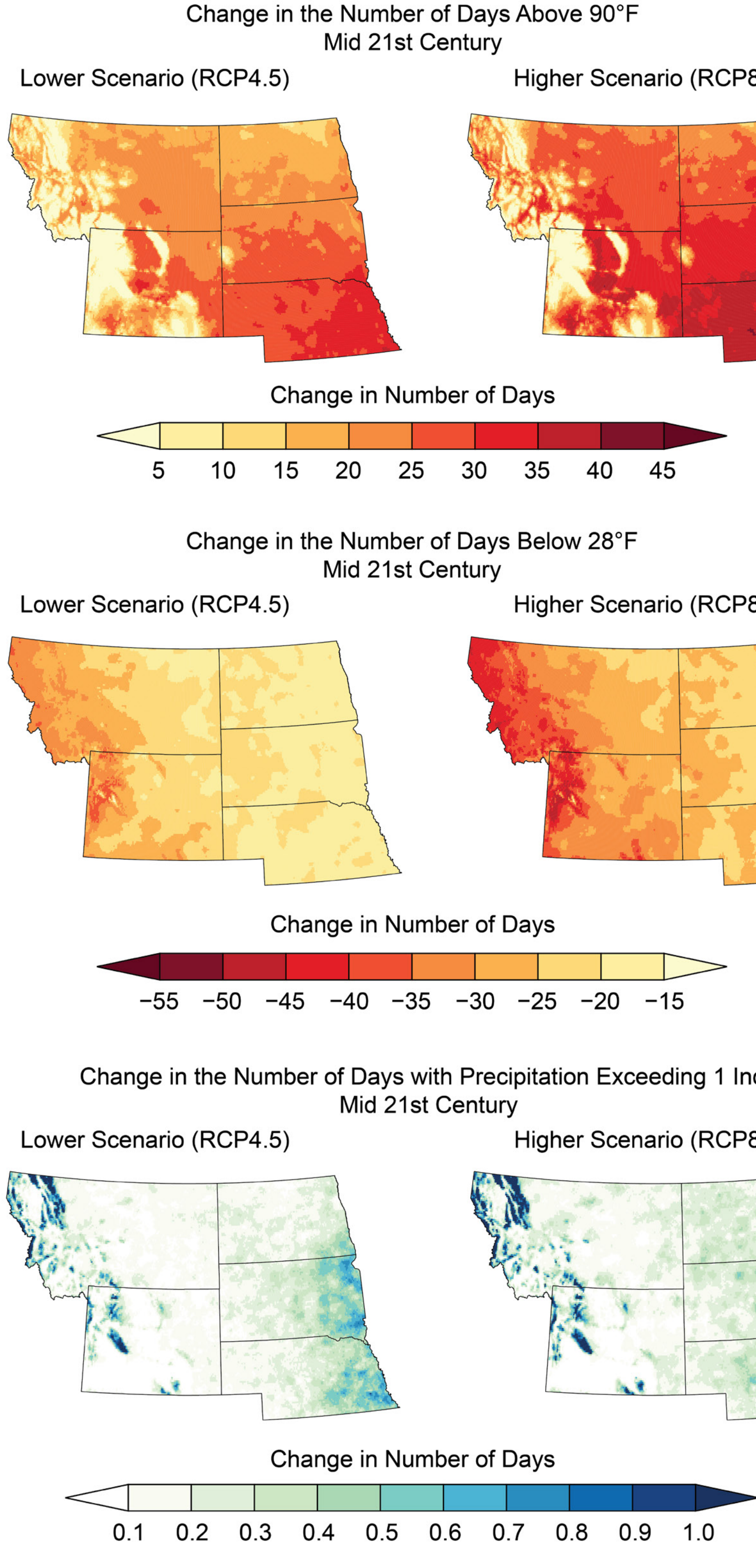


Figure 22.2: Projected changes are shown for (top) the annual number of very hot days (days with maximum temperatures above 90°F, an indicator of crop stress and impacts on human health), (middle) the annual number of cool days (days with minimum temperatures below 28°F, an indicator of damaging frost), and (bottom) heavy precipitation events (the annual number of days with greater than 1 inch of rainfall; areas in white do not normally experience more than 1 inch of rainfall in a single day). Projections are shown as changes from the 1976–2005 average for the middle of the 21st century (2036–2065) for the lower and higher scenarios (RCP4.5 and RCP8.5). Sources: NOAA NCEI and CICS-NC.

Hydrologic Changes Across the Northern Great Plains

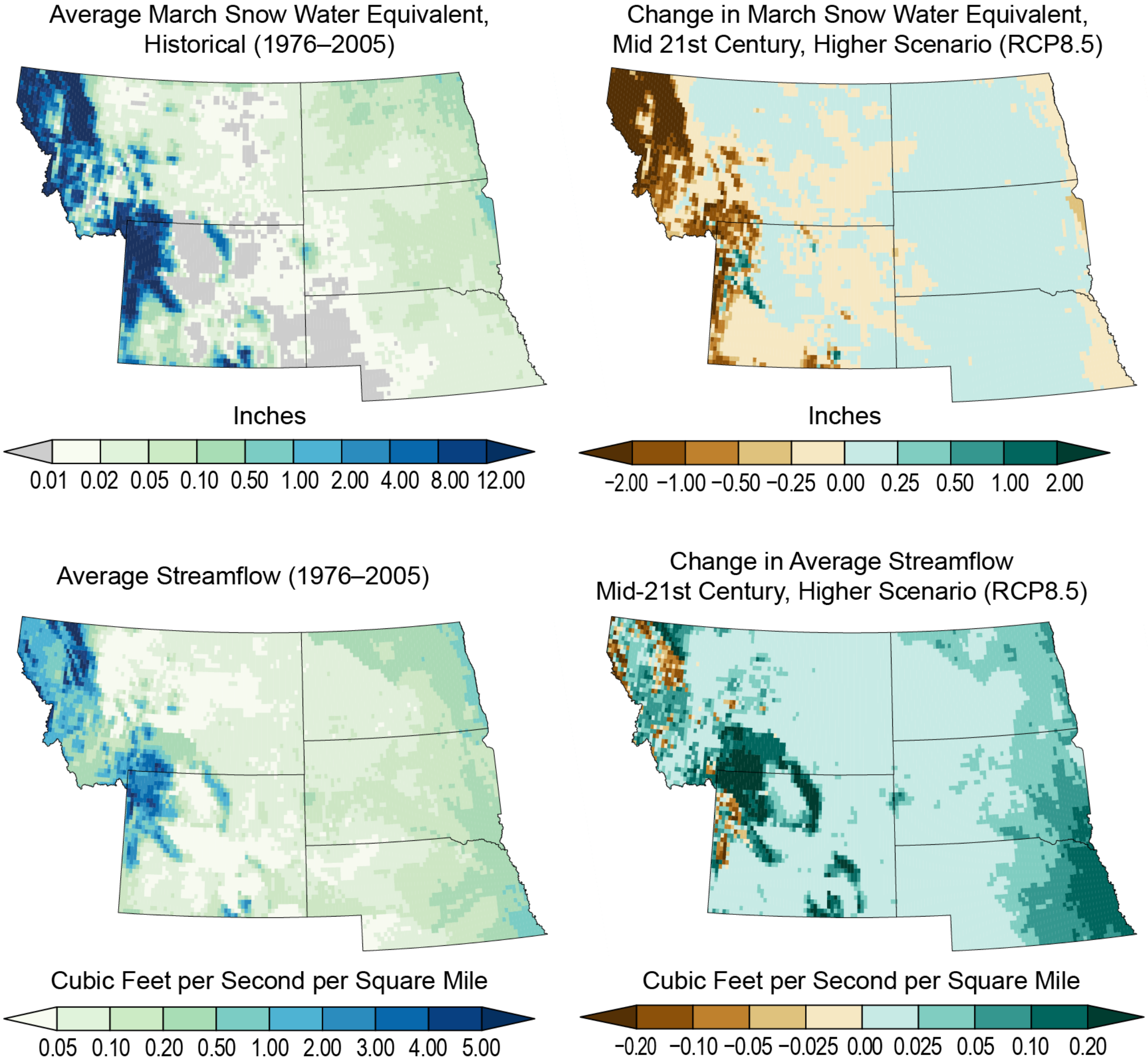


Figure 22.3 These maps show historical (left; 1976–2005) and projected changes (right; 2036-2065) under a higher scenario (RCP8.5) in average snowpack (top row) and annual streamflow (bottom row). Snowpack is measured in terms of snow water equivalent, or SWE—the depth in inches of the amount of water contained in the snowpack. The top two maps show average values for March to provide historical and future end-of-season estimates of SWE. This illustrates projected warming and potential snow loss. Projected decreases in snowpack across montane western regions in the upper-right plot are primarily the result of projected warming at the highest elevations. Projected increases in snow at lower elevations are less important, since those changes are relative to a much lower average (top left) than in montane regions. Similarly, annual streamflows are expected to increase across much of the eastern part of the region, with isolated but important decreases in the western highlands. In this context, streamflow refers to the sum of surface runoff and subsurface flow for each location in space. Sources: NOAA NCEI and CICS-NC.

Climate model projections paint a clear picture of a warmer future in the Northern Great Plains, with conditions becoming consistently warmer in two to three decades and temperatures rising steadily towards the middle of the century, irrespective of the scenario selected (Figure 22.2). This warming is projected to occur in conjunction with less snowpack and a mix of increases and reductions in the average annual water availability (Figure 22.3). Precipitation and streamflow projections show only modest changes, but many areas within the region are already subject to a high degree of year-to-year variability—both wet and dry years. Low-probability, but high-severity and high-impact, events are the result of large variability, including both extreme flood events like in 2011 and drought events like in 2012. This interannual variability implies greater uncertainty about future climate and about the potential for future flooding and drought.

An important takeaway is that the magnitude of variability overshadows the small projected decrease in average streamflow.[35] Changes in extreme events are likely to overwhelm average changes in both the eastern and western regions of the Northern Great Plains (Figure 22.2). Overall, climate models project an increase in the number of heavy precipitation events (events with greater than 1 inch per day) for much of the region, with the exception of the high-mountain areas in the southwestern portion. Societal risk increases any time natural conditions differ greatly from historical conditions,[43] with larger changes representing greater risks. Therefore, any large projected changes will require rethinking infrastructure design and operation. The probability for more very hot days (days with maximum temperatures above 90°F; Figure 22.2) is expected to increase, with potential impacts on agriculture, energy production, human health, streamflows, snowmelt, and fires. There are projected to be many fewer cool days (days with minimum temperatures less than 28°F, an indicator of damaging frost; Figure 22.2), with decreases of 30 days or more per year by mid-century. These changes would have important implications for the region's snowpack and consequently streamflow and water use.

Reservoir and groundwater storage are expected to be increasingly important as buffers against the impacts of increasing variability and to meet water demands during periods of shortage, especially in light of warming-driven losses in snowpack water and higher evapotranspiration rates, which reduce the total amount of water availability. It may be possible to move water between basins to alleviate flooding impacts, but this raises a new set of challenging hydrological and environmental issues. Future activities that increase water demand (population growth, expansion, or alteration of agriculture) will increase dependence on reservoir capacity and infrastructure integrity.

Key Message 2

Agriculture

Agriculture is an integral component of the economy, the history, and the culture of the Northern Great Plains. Recently, agriculture has benefited from longer growing seasons and other recent climatic changes. Some additional production and conservation benefits are expected in the next two to three decades as land managers employ innovative adaptation strategies, but rising temperatures and changes in extreme weather events are very likely to have negative impacts on parts of the region. Adaptation to extremes and to longer-term, persistent climate changes will likely require transformative changes in agricultural management, including regional shifts of agricultural practices and enterprises.

The Northern Great Plains region plays an important role in U.S. food security (see Tables 22.1 and 22.2), and agriculture has been integral to the history and development of the region. Agricultural uses in the region are diverse, including the largest remaining tracts of native rangeland in North America, substantial areas of both dryland and irrigated cropland and pasture, and mosaics of cropland and grazed grassland and forested lands. This region is home to 7.2% of U.S. farms (152,663) but 23.8% of the U.S. land in farms, encompassing 218 million acres with 22.4% of the total cropland, 21.9% of irrigated lands, 29.3% of U.S. pasture and rangeland, and nearly one-third (30.1%) of lands in conservation/wetland reserve programs.[44] Livestock production (beef and dairy cattle and hogs) is dominant in the region. Important crops include corn, soybeans, wheat, barley, alfalfa, hay, and a diversity of other crops such as potatoes, sugar beets, dry beans, sunflowers, millet, canola, and barley (see Tables 22.1 and 22.2).[44] The Northern Great Plains region contributes 12.7% of the market value of agricultural products sold in the United States despite having only 1.5% of the U.S. population.

Extensive precipitation and temperature gradients and inherently high climatic variability, both within and between years, result in highly variable conditions for agricultural enterprises in the Northern Great Plains. The region receives the majority of its precipitation during the spring months (April, May, and June), with a high degree of year-to-year variability.[45] A mix of private, state, federal, tribal, and other land ownership across the region promotes heterogeneity at landscape-to-regional scales, which enhances the provision of numerous ecosystem goods and services, such as wildlife habitat, including for pollinators.

Percent of National Total Livestock Animals in the Northern Great Plains (2012)

	Beef cows	Hogs and pigs	Sheep and lambs	Milk cows	Egg layers
% of National Total	21.9%	6.9%	18.4%	2.0%	3.5%

Table 22.1: The table shows the percent of the national total of livestock animals living in the Northern Great Plains in 2012. Source: U.S. Agricultural Census 2012.[44]

Percent of National Total Crop Commodities in 2012

	Corn for grain (bu)	Corn for silage/ greenchop (tons)	Wheat for grain (bu)	Spring wheat (bu)	Durum wheat (bu)	Oats for grain (bu)
% of National Total	20.2%	11.5%	30.4%	70.6%	72.2%	20.3%

	Barley (bu)	Soybeans (bu)	Dry edible beans and lentils (cwt)	Forage (tons)	Sunflower seed (pounds)	Sugarbeets (tons)
% of National Total	48.4%	16.3%	48.6%	13.8%	83.6%	27.2%

Table 22.2: The table shows the percent of the national total production for crop commodities produced in the Northern Great Plains in 2012. Units are bushels (bu), tons, hundredweight (cwt), or pounds. Source: USDA National Agricultural Statistical Survey 2012.[44]

The Northern Great Plains is currently experiencing a marked transition in agricultural land use involving the conversion of grassland to annual crops[46,47] and an increased prevalence of monoculture cropping.[48] From peak enrollment in the Conservation Reserve Program (10 million acres in 2007), enrollment declined by half by 2017, with the majority of these lands returning to cropland (60%), thereby losing ecosystem service benefits such as wildlife habitat and improved water and soil quality.[49] Changing land use in the eastern part of this region is an outcome of trends of above-average precipitation over the last 10–20 years, with some of those precipitation trends having been driven by expansion of agricultural land use.[50] In the western part of the region, genetic developments in crop cultivars and varieties that enhance suitability of drier land for crop production have led to expansion of dryland cropping.

Despite a long history of high year-to-year variability,[45] producers are experiencing a changing climate and increasing weather variability and extreme conditions that are outside the ranges they have dealt with in the past.[51] Producers' daily and annual decision-making depends on market conditions for seeds and products, agronomic constraints, and climate change-related variables.[52] The decision-making process is challenged by a lack of experience with analogous climatic conditions in the past, thus increasing risks for land managers. This dependence on historical experience highlights the importance of the human element in the resilience of social–ecological systems, which have traditionally been viewed from the biophysical perspective.[53]

Temperature increases of 2°–4°F projected by 2050 for the Northern Great Plains under the lower scenario (RCP4.5) are expected to result in an increase in the occurrence of both drought and heat waves; these projected trends would be greater under the higher scenario (RCP8.5). The amount, distribution, and variability of annual precipitation in the Northern Great Plains are anticipated to change, with increases in winter and spring precipitation of 10%–30% by the end of this century and a decrease in the amount of precipitation falling as snow under a higher scenario (RCP8.5).[54] Summer precipitation is expected to vary across the Northern Great Plains, ranging from no change under a lower scenario (RCP4.5) to 10%–20% reductions under a higher scenario (RCP8.5).[54] Further, the frequency of heavy precipitation events is projected to increase, with an increase of about 50% in the frequency of two-day heavy rainfall events by 2050 under the higher scenario (RCP8.5). The amount falling in single-day heavy events is projected to increase 8%–10% by mid-century depending on scenario.[54] Although fewer hail days are expected, a 40% increase in damage potential from hail due to more frequent occurrence of larger hail is predicted for the spring months by mid-century under a higher scenario (RCP8.5).[55] Even with increases in precipitation, warmer temperatures are expected to increase evaporative demand, leading to more frequent and severe droughts.[56] Some of the negative effects of drying in a warmer climate are likely to be offset by elevated atmospheric carbon dioxide (CO_2) concentrations, which directly stimulate plant growth and increase plant water-use efficiency.[3]

The warmer and generally wetter conditions projected for some of the Northern Great Plains, coupled with elevated atmospheric CO_2 concentrations, are expected to

1. increase soil water availability during the primary growing season in the northern part of the region and decrease it the southern parts;[1,9]

2. increase the number of extreme temperature events (high daytime highs or nighttime lows) during critical pollination and grain fill periods, which will very likely reduce crop yields;[6,9]

3. lead to declining yield for crops[6] and forages[7,8] due to increasing temperatures, some of which will be offset by increasing CO_2;

4. increase the abundance and competitive ability of weeds and invasive species;[1,2]

5. alter plant phenology–for example, earlier onset of spring (Ch. 1: Overview, Figure 1.2j)[57] and earlier flowering of plants;[58]

6. decrease the quality of forage available to livestock;[3,59,60]

7. increase livestock production and efficiency of production due to greater net primary productivity and longer growing seasons;[3]

8. result in longer growing seasons at mid- and high latitudes;[4,5] and

9. increase the range and fecundity of crop pests.[9]

All of these changes will require increased flexibility in resource management.[61,62,63]

Adaptation for agricultural land use for the next 20–30 years, or to the mid-21st century, will be most effective when decision-making integrates biophysical, social, and economic components. Proactive learning opportunities that integrate experimental and experiential knowledge—such as lessons learned from early adopters—can help enhance decision-making. After all, many adaptations have already been implemented by a subset of producers in this region, providing opportunities for assessment, further development, and adoption. Context-specific decision-making for operations can also be improved through science–management partnerships, which aim to build adaptive capacity while being sensitive to multiple production, conservation, and environmental goals. Transfer of this adaptive knowledge in a timely manner to producers in the field through novel, multipronged communication efforts will assist land managers in more effectively and resiliently responding to the changes to come (see Case Study "Adaptive Rangeland Management"). The climate changes projected over the longer term (through the end of this century) are likely to require transformative changes in agricultural management, including regional shifts of agricultural practices and enterprises.[61,64]

Case Study: Adaptive Rangeland Management

Highly variable precipitation in the Northern Great Plains makes it difficult for managers to balance forage availability with animal demand. An emergent focus is on management strategies that are adaptive rather than prescriptive. But adaptive solutions require collaboration, often among stakeholders with different production and conservation goals. For example, grassbanking, in which ranchers lease land from property owners at a discount in exchange for carrying out conservation-related projects on their pastures, requires management strategies that can successfully deal with this variability. They can also require engagement between different land ownership types, including privately owned land, leased land, state lands, and federal lands. At The Nature Conservancy's Matador Ranch in north central Montana, local ranchers pay reduced grazing fees to graze their cattle on the Matador in exchange for wildlife-friendly and ecologically sound practices on their own operations, where a ranch management plan is required and sodbusting is prohibited. Each year, Conservancy staff and the ranchers develop a grazing plan for the Matador to reach production and ecologically based management goals, including the diverse vegetation structure needed by imperiled grassland birds and greater sage-grouse. In 2017, the Matador Grassbank ranches encompassed over 280,000 acres of private and public leased land. Working cooperatively, the Conservancy and grassbank members improved habitat for imperiled wildlife species on more than 340,000 acres, all while creating conditions that allow for sustainable ranch operations across variable and changing climatic conditions.

Learning how better decisions are made in the face of climate variability is a challenging research topic and one that also requires close collaboration—in this case between stakeholder groups and scientists. Another project, the Collaborative Adaptive Rangeland Management (CARM) experiment, which started in 2012 with a series of meetings involving ranchers, conservation/environmental organizations, and public land managers, is an example of such a research project. Conducted at a ranch-level scale for relevance to producers and managers, the research seeks to determine how adaptive rangeland management can be implemented in a manner that effectively responds to current and changing rangeland and weather/climatic conditions, incorporates active learning, and includes management decisions from a diverse stakeholder group based on quantitative, repeatable measurements collected at multiple spatial and temporal scales. An 11-person stakeholder group determined goals for vegetation, livestock, and wildlife. Specific objectives were developed for each, and testable hypotheses were derived for the scientists. The group also identified the need for baseline data and subsequent monitoring data to inform decisions made within the year, as well as from year to year. Following the implementation of more sustainable grazing management and prescribed fire treatments in 2014, interpretation of the monitoring data regarding progress towards accomplishing the desired objectives provided the opportunity for stakeholders and scientists to engage in shared learning and co-production of knowledge. CARM is a promising model for collaborative research that develops science-based management recommendations for multiple rangeland goals and objectives.

Key Message 3

Recreation and Tourism

Ecosystems across the Northern Great Plains provide recreational opportunities and other valuable goods and services that are at risk in a changing climate. Rising temperatures have already resulted in shorter snow seasons, lower summer streamflows, and higher stream temperatures and have negatively affected high-elevation ecosystems and riparian areas, with important consequences for local economies that depend on winter or river-based recreational activities. Climate-induced land-use changes in agriculture can have cascading effects on closely entwined natural ecosystems, such as wetlands, and the diverse species and recreational amenities they support. Federal, tribal, state, and private organizations are undertaking preparedness and adaptation activities, such as scenario planning, transboundary collaboration, and development of market-based tools.

Ecosystems across the Northern Great Plains provide recreational opportunities and other valuable goods and services that are ingrained in the region's cultures and at risk in a changing climate. Recreationists enjoyed roughly 13.1 million days of fishing in the region in 2011, along with 10.8 million days of hunting and 8.7 million days of wildlife-watching. The region contains two dozen national parks, monuments, and historic sites. This subset of outdoor recreationists alone—among a wider population who pursue additional outdoor recreation activities in the region—spent over $4.9 billion on these activities during 2011 ($5.2 billion in 2015 dollars).[65,66,67,68,69]

Climate change affects recreation through three pathways: 1) direct impacts to the ecosystems and wildlife or fish populations of interest (for example, increasing water temperature impacting coldwater fish survival); 2) changes in environmental conditions that directly affect recreationists (for example, increased water temperatures resulting in brief river closures for angling to minimize additional stress on sensitive fish species); and 3) effects of adaptation policies on habitat quality or recreational enjoyment (for example, energy policies that result in higher fuel costs, making distant trips more expensive).[70] These three pathways have not been fully quantified for most recreational systems, within or beyond the Northern Great Plains, and the third pathway is only speculative—it has not yet been documented in the scientific literature. Scientific understanding is most complete for the first pathway—the extent and ways in which climate change affects ecosystems that support outdoor recreation.[70]

Climate-related impacts are already being felt in the region's terrestrial and aquatic ecosystems, as well as the local economies that depend upon them. Climate-driven changes in snowpack, spring snowmelt, and runoff have resulted in more rapid melting of winter snowpack and earlier peak runoff due to rapid springtime warming.[71,72,73] These effects have resulted in lower streamflows, especially in late summer.[74] Lower flows, combined with warmer air temperatures, have caused stream temperatures to rise.[75,76,77] These conditions are negatively affecting aquatic biodiversity (e.g., Hotaling et al. 2017[78]) and ecosystem functions of riparian areas (areas along the banks of rivers and streams; e.g., Tonkin et al. 2018[79]), with important consequences for local economies that depend upon river-based recreation. For example, higher stream temperatures are accelerating the hybridization and genetic dilution of native trout species with nonnative trout species.[80] Similarly, shifts in habitat suitability in favor of warmwater fish species are projected to reduce the value of coldwater fishing in the Northern Great Plains by $25 million per year under RCP4.5 by the end of the century and by $66 million per year under RCP8.5 (in 2015 dollars).[81] Higher stream temperatures are already increasing the vulnerability of coldwater fish species to diseases, such as proliferative kidney disease (PKD).[82,83,84] PKD killed thousands of native mountain whitefish in Montana during 2016, which triggered a month-long closure of 180 miles of the Yellowstone River to all water-based recreation.[85] Economic impacts to local communities are still being quantified, but initial estimates range from $360,000 to $524,000 (in 2014 dollars; range is from $363,600 to $529,240 in 2015 dollars).[86]

In the mountainous areas of the region, climate change is impacting snow-dependent ecosystems and economies. In Wyoming and Montana, for example, higher-than-normal winter and fall temperatures and low summer precipitation are enabling severe mountain pine beetle outbreaks in whitebark pine.[87] Whitebark pine is a keystone species of high-elevation ecosystems, providing a critical seed source for more than 20 wildlife species, creating microenvironments that allow other tree species to establish, and influencing snowpack dynamics.[88,89] Whitebark pine is also an important cultural resource for some tribes in the region.[90]

In the future, warmer temperatures and changes in precipitation are expected to decrease the extent and duration of snow cover across much of the northern hemisphere. In the mountains of western Wyoming and western Montana, the fraction of total water in precipitation that falls as snow (from October 1 to March 31) is expected to decline by 25% to 40% by 2100 under a lower scenario (RCP4.5).[10] The last day of the snow season is also expected to arrive earlier in the spring. Under a lower scenario (RCP4.5), it is expected to occur roughly 20 days sooner by 2050 and 30 days sooner by 2100. Under a higher scenario (RCP8.5), it is expected to occur 80 days sooner by 2100.[10] This would negatively affect the region's winter recreation industry, including snowmobiling, cross-country skiing, and downhill skiing.[11]

Under a lower scenario (RCP4.5), the season length for cross-country skiing and snowmobiling in northwestern Wyoming and western Montana is expected to decline by 20% to 60% by 2090.[11] Under the higher scenario (RCP8.5), the projected decline is more severe: 60% to 100%.[11] Similar losses in season length are projected for the region's downhill skiing industry—a $275 million industry.[11] The number of visitors to downhill ski areas is, therefore, expected to decline. Under RCP4.5, visitors are projected to decline by 13% by 2050 and 22% by 2090 (holding population constant); under RCP8.5, projected declines are 19% by 2050 and 49% by 2090.[11] Similar declines are projected for the region's $4.6 million cross-country ski industry and $2.3 million snowmobiling industry (in 2015 dollars).[11] Such reductions in visitor numbers would cause ripple effects across the local economies of snow-dependent communities.

At lower-elevation areas of the Northern Great Plains, natural ecosystems are often embedded within agricultural landscapes. Climate-induced land-use changes in agriculture can, therefore, have cascading effects on closely entwined natural ecosystems, such as wetlands,[12] and the diverse species and recreational opportunities they support. Technological and economic forces within agriculture are also driving land-use changes, which accelerate the degradation of wetlands. For example, in South Dakota and North Dakota, changing climatic and market conditions have enabled agriculture shifts from pasture to small grains, or small grains to corn and soybeans.[12] Nearly 40% of these land-use changes have occurred within 300 feet of neighboring wetlands, reducing the quantity of wetlands and the quality of their ecological functions (see Case Study "Wetlands and the Birds of the Prairie Pothole Region").[46] For example, conversion of pasture to cropland or of winter-seeded crops to spring-seeded crops reduces waterfowl nest survival by increasing habitat fragmentation, which makes nests more vulnerable to predation.[91,92] Tillage in newly converted fields also increases the risk of soil being washed into nearby wetlands, reducing their biological productivity and floodwater storage capacity.[93] These changes have cascading effects not only on wetland-dependent waterfowl but also on shorebirds, fish, amphibians, aquatic insects, and plants. Waterfowl hunting and watching are important cultural and economic activities in rural communities of the Northern Great Plains.[94] In South Dakota alone, hunters spent $84.7 million in 2015–2016 on migratory bird hunting (in 2016 dollars; $83.9 in 2015 dollars).[95]

Higher temperatures, reduced snow cover, and more variable precipitation would make it increasingly challenging to manage the region's valuable wetlands, rivers, and snow-dependent ecosystems to sustain today's levels of natural amenities and associated recreational opportunities. Federal, tribal, state, and private organizations are undertaking preparedness and adaptation activities, including scenario planning, to discuss current climate-driven challenges and envision future challenges and responses. The North Central Climate Adaptation Science Center, for example, has facilitated scenario planning exercises for southwestern South Dakota in the vicinity of Badlands National Park and for central North Dakota in the vicinity of Knife River Indian Villages National Historic Site.[96] The Crown Adaptation Partnership—a transboundary team of scientists and resource managers from the United States, Canada, and Tribes/First Nations—is collaborating on climate change adaptation strategies across multiple jurisdictions to enhance resilience of the Crown of the Continent Ecosystem in northern Montana, southwestern Alberta, and southeastern British Columbia.[97] Finally, private organizations have been partnering with researchers to develop "payments-for-ecosystem services," an emerging tool to address land-use change on private agricultural acreage.[98] This market-based tool, when designed appropriately, can encourage private landowners to provide wetlands, wildlife habitat, pollinator habitat, and other valued ecosystem services rather than converting land to uses that produce fewer ecosystem services.[99,100]

Photo taken along the White River in Badlands National Park, South Dakota in September 2016. Photo credit: Christian Collins (CC BY-SA 2.0).

The region's valued ecosystems and recreational opportunities are being affected by climate change to an extent not fully understood, but increasingly being studied. Existing knowledge is primarily based on local and regional case studies, often about specific recreational activities or individual wildlife species. This makes comprehensive assessment a challenge and highlights the need for additional work to fill remaining gaps.[101]

Case Study: Wetlands and the Birds of the Prairie Pothole Region

The North American Prairie Pothole Region (PPR) is a globally important natural resource, a portion of which covers northern and eastern North Dakota, eastern South Dakota, and far northern Montana. The PPR hosts nearly 120 species of wetland-dependent birds representing 21 families[102] and provides prime nesting and migratory habitat for waterbirds, including ducks and shorebirds.[103,104] Estimates suggest that 50% to 75% of all North American waterfowl hatch in the PPR.[105]

Aerial view of the Prairie Pothole Region in South Dakota. Photo credit: © Patrick Ziegler/iStock/GettyImages.

Climate change is affecting wetlands and the bird species they support in the Northern Great Plains, both directly and indirectly. Changes in spring precipitation affect wetlands directly because spring snowmelt, runoff, and refill influence wetland hydrology (including the number of days with standing water and water depth) and plant cover.[106] A warmer climate, if not offset by enough additional precipitation, will shrink wetland areas in the PPR and reduce waterfowl and shorebird habitat. To offset a temperature increase of 5.4°F (3°C), precipitation would need to increase by 20% or more.[106] If a 5.4°F (3°C) increase in average annual temperature occurs and is only offset by a 10% increase in average annual precipitation, much of the wetland habitat in the PPR will be lost.[107,108] Densities of wetlands are predicted to decline on average by 20% to 25% by mid-century under a higher scenario (RCP8.5).[109] In a warmer and drier climate, much of the PPR will be too dry to support historical levels of waterfowl nesting and production,[106] with one study projecting that 28 of 29 species studied will lose range in the future under the higher scenario (RCP8.5).[102]

Wetland and bird losses due to climate change are exacerbated by agricultural land-use change in the PPR, with grasslands and pastures being converted to wheat, corn, and soybeans.[12,46] The degradation of wetland function due to land-use change (Figure 22.4) is driven in part by the increasing profitability of row crops under higher temperatures and increased precipitation in the eastern Dakotas.[12] Land-use change in agriculture to less wetland-friendly crops is also driven by policy and market forces tied indirectly to climate. The ethanol industry's rise in the mid-2000s, for example, contributed to increases in corn prices.[110] Rising prices triggered a north-westward expansion of the historical Western Corn Belt into the PPR, and into close proximity to wetlands.[46] As a result, grassland nesting bird populations are declining faster than any other group of birds in North America.[111,112] Grassland conversion rates such as these (Table 22.3) have not been seen in the Corn Belt since the rapid mechanization of U.S. agriculture in the 1920s and 1930s.[113]

Case Study: Wetlands and the Birds of the Prairie Pothole Region, *continued*

Land-Cover and Land-Use Changes for the Prairie Pothole Region

	Changes in Area (thousands of acres)		
State	Grassland to Corn/Soy	Corn/Soy to Grassland	Grassland Net Loss
Nebraska	309	247	62
North Dakota	320	100	220
South Dakota	632	181	451
Montana	n/a	n/a	n/a
Total	**1,261**	**528**	**733**

Table 22.3: This table shows changes in land cover and land use in the Northern Great Plains portion of the Prairie Pothole Region (PPR), by state, from 2006 to 2011. Note: Montana was not included in the analysis of changes in the PPR cited here, so comparable statistics are not available. Map-based estimates of grassland conversion in Montana from 2008–2012, though not specifically for the PPR, are available from other studies.[47,114] Source: adapted from Wright and Wimberly 2013.[46]

Reductions in Grassland Area in the Prairie Pothole Region

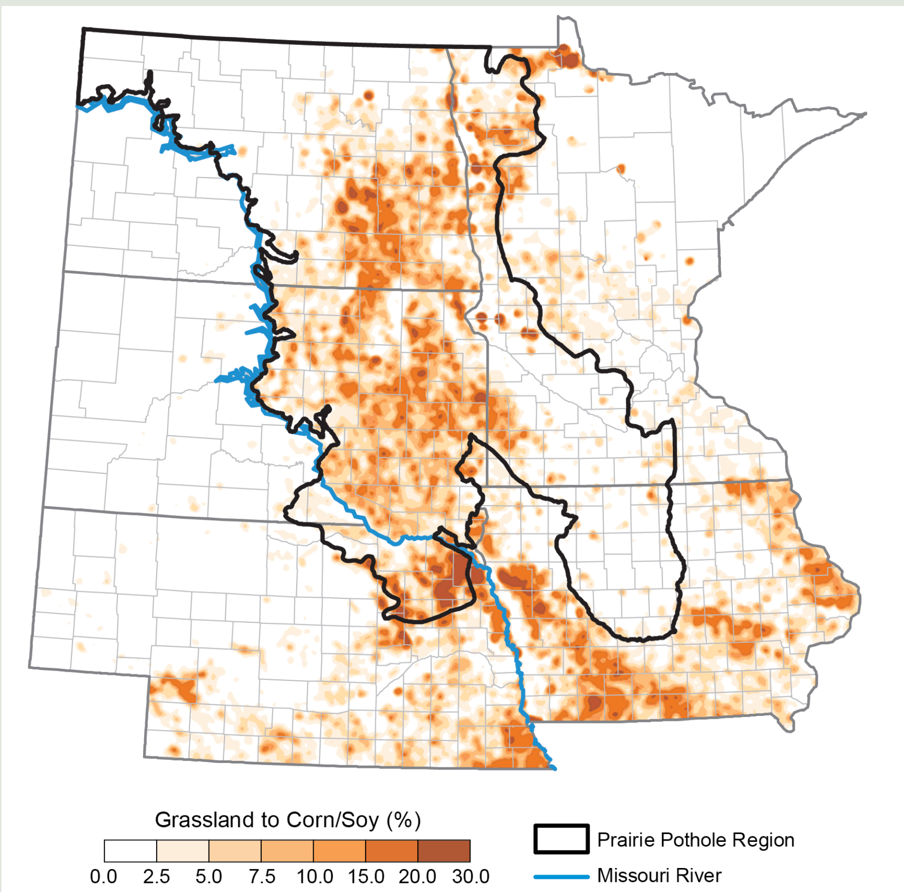


Figure 22.4: The figure shows the loss of grassland to corn/soy between 2006 and 2011 in the eastern states of the Northern Great Plains (Nebraska, South Dakota, and North Dakota), expressed as a percentage of 2006 grassland acres. Outlined in black is the boundary of the U.S. portion of the Prairie Pothole Region, a substantial portion of which was converted from grassland to corn/soy between 2006 and 2011. Source: adapted from Wright and Wimberly 2013.[46]

Key Message 4

Energy

Fossil fuel and renewable energy production and distribution infrastructure is expanding within the Northern Great Plains. Climate change and extreme weather events put this infrastructure at risk, as well as the supply of energy it contributes to support individuals, communities, and the U.S. economy as a whole. The energy sector is also a significant source of greenhouse gases and volatile organic compounds that contribute to climate change and ground-level ozone pollution.

Energy resources in the Northern Great Plains include abundant crude oil, natural gas, coal, wind, stored water, and, to a lesser extent, corn-based ethanol, solar energy, and uranium. The infrastructure associated with the extraction, distribution, and energy produced from these resources is vulnerable to the impacts of climate change, including increasing average temperatures and heat waves, decreasing water availability in the summer, and an increase in the frequency and severity of heavy precipitation events leading to floods.[13]

Energy infrastructure vulnerabilities relate to how fuel is transported and how energy is produced, generated, transmitted, and used. For example, railroads and pipelines are vulnerable to damage or disruption from increasing heavy precipitation events and associated flooding and erosion.[13] Summer heat waves also damage railroad tracks and are expected to reduce thermoelectric power plant and transmission line capacity,[13] though estimates of the likelihood, timeframe, or magnitude of such impacts are limited. Higher temperatures are likely to lower the yields of crops used for biofuels while shifting northward the range in which certain biofuel crops (such as corn) can be cultivated.[13] Biorefineries are vulnerable to decreasing water availability during drier summers and periods of drought.[13] Declining water availability in the summer would likely increase costs for oil production operations, which require freshwater resources.[13] These cost increases will lead either to reduced production or be passed on to consumers. Finally, higher maximum temperatures, longer and more severe heat waves, and higher overnight lows are expected to increase electricity demand for cooling in the summer, further stressing the power grid.[13] Increasing demands for electricity in response to increasing temperatures are projected to increase costs to the power system by approximately \$13–\$18 million per year by 2050 under the higher scenario (RCP8.5) and \$42–\$80 million per year by 2090 under the same scenario (in 2015 dollars).[81]

These risks to the energy sector are likely to negatively impact individuals, communities, and the economy, and are also likely to require new planning and preparedness options for the short and long term. While such efforts have already begun, more widespread and coordinated strategies would help maximize risk reduction to the energy sector.

Examples of energy sector resilience solutions include actions like railroad preventive maintenance, upgrades, and reliability standards; water-efficient cooling technologies for thermoelectric power plants, such as recirculating or wet–dry hybrid systems; and programs that reduce total and peak electricity demand.[13] Such programs, often run by electric utilities, use rebates and cash incentives to encourage customers to purchase more efficient appliances and equipment like lighting, pumps, water heaters, and air conditioners.

The energy sector is also a significant source of greenhouse gas emissions in the Northern Great Plains, as illustrated in Figure 22.6.[81] Methane is released during the production, processing, transmission, storage, and distribution of natural gas. CO_2 and methane are released during the production, transportation, and refining of petroleum. Coal mining also releases methane. CO_2 is emitted from the combustion of coal and natural gas to produce electricity and from the combustion of petroleum for transportation.[117] Natural gas and petroleum systems also emit volatile organic compounds, or VOCs, that contribute to the formation of ground-level ozone pollution. Climate change is generally expected to increase such ozone pollution in the future throughout much of the United States, in part due to higher temperatures and more frequent stagnant air conditions (Ch. 13: Air Quality). Unless offset by additional emissions reductions of ozone precursors, these climate-driven increases in ozone are forecast to cause premature deaths, hospital visits, lost school days, and acute respiratory symptoms.[118]

Floodwaters Surround Nuclear Power Plant in Nebraska

Figure 22.5: Floodwaters from the Missouri River surround the Omaha Public Power District's Fort Calhoun Station, a nuclear power plant just north of Omaha, Nebraska, on June 20, 2011. The flooding was the result of runoff from near-record snowfall totals and record-setting rains in late May and early June (NWS 2012).[115] A protective berm holding back the floodwaters from the plant failed, which prompted plant operators to transfer offsite power to onsite emergency diesel generators. Cooling for the reactor temporarily shut down, but spent fuel pools were unaffected.[116] Photo credit: Harry Weddington, U.S. Army Corps of Engineers.

Greenhouse Gas Emissions from Fuel Production

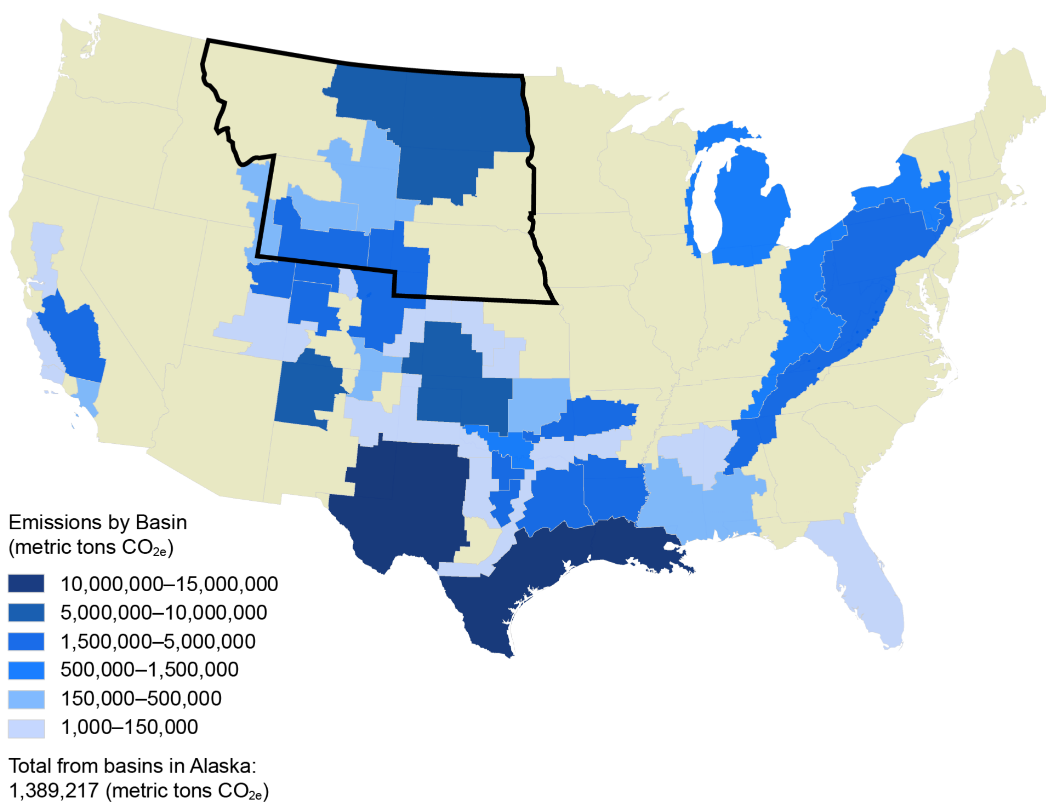


Figure 22.6: Greenhouse gas emissions (shown here in metric tons of carbon dioxide equivalent, or CO_{2e}, per geologic basin) from petroleum and natural gas production facilities in the Northern Great Plains are among the highest in the United States. The data used to produce this map are from EPA's Greenhouse Gas Reporting Program, which only includes facilities that emit 25,000 metric tons of CO_{2e} or more annually.[117] Each production facility must provide the total emissions from all their well pads in a geologic basin. Source: adapted from EPA 2017.[117]

Strategies being employed in the region to reduce greenhouse gas emissions from the energy sector include increasing the performance of coal-fired power plants; offsetting fossil fuel-fired generation with renewable energy; conducting methane leak detection and repair programs using remote sensing technologies at natural gas operations; upgrading the equipment used to produce, store, and transport oil and gas; and demand-side management of electricity use.

Key Message 5

Indigenous Peoples

Indigenous peoples of the Northern Great Plains are at high risk from a variety of climate change impacts, especially those resulting from hydrological changes, including changes in snowpack, seasonality and timing of precipitation events, and extreme flooding and droughts as well as melting glaciers and reduction in streamflows. These changes are already resulting in harmful impacts to tribal economies, livelihoods, and sacred waters and plants used for ceremonies, medicine, and subsistence. At the same time, many tribes have been very proactive in adaptation and strategic climate change planning.

The rich cultural heritage of the Northern Great Plains began with the region's Indigenous peoples who are now in 27 federally recognized tribes, 1 state-recognized tribe in Montana, and several unrecognized tribes in addition to the myriad Native Americans spread throughout the towns, cities, and rural areas of the region (Figure 22.7). Because tribes and Indigenous peoples are among those in the region with the highest rates of poverty and unemployment, and because many are still directly reliant on natural resources, they are among the most at risk to climate change.[24,25,27,28,29,30,31]

Indigenous peoples in the region are observing many climate and seasonality changes to their natural environment and ecosystems, many of which are impacting livelihoods as well as traditional subsistence and wild foods, wildlife, plants and water for ceremonies and medicines, and health and well-being (see Case Study "Crow Nation and the Spread of Invasive Species").[14,15,16,17,18,19,20,21,22,23,24,25,26] Specifically, tribal elders and natural resource managers in the region have observed seasonal changes, such as those in hydrological cycles, phenology, bird migrations, and bear hibernation cycles, as well as reduced availability of traditional plant-based foods and the decline in pine tree species. There is also a mismatch between traditional stories and current climate and seasons.[14,19] They are also experiencing significant impacts to subsistence fisheries and riparian ecosystem health, including declines in salmon, trout, frogs, and mussels as a result of reduced streamflow and warmer water temperatures.[19,26,119,120] Extreme heat and declines in traditional plants (such as sage, cottonwoods, and cattails) are already impacting summer outdoor ceremonies when participants fast and camp for days.[19] In addition, tribes are experiencing increased fire frequency and intensity, and climate projections that show increased fire risks for the region are causing concern for the health of forests, wildlife, freshwater systems and fisheries, and human health.[14,19]

Northern Great Plains Tribal Lands

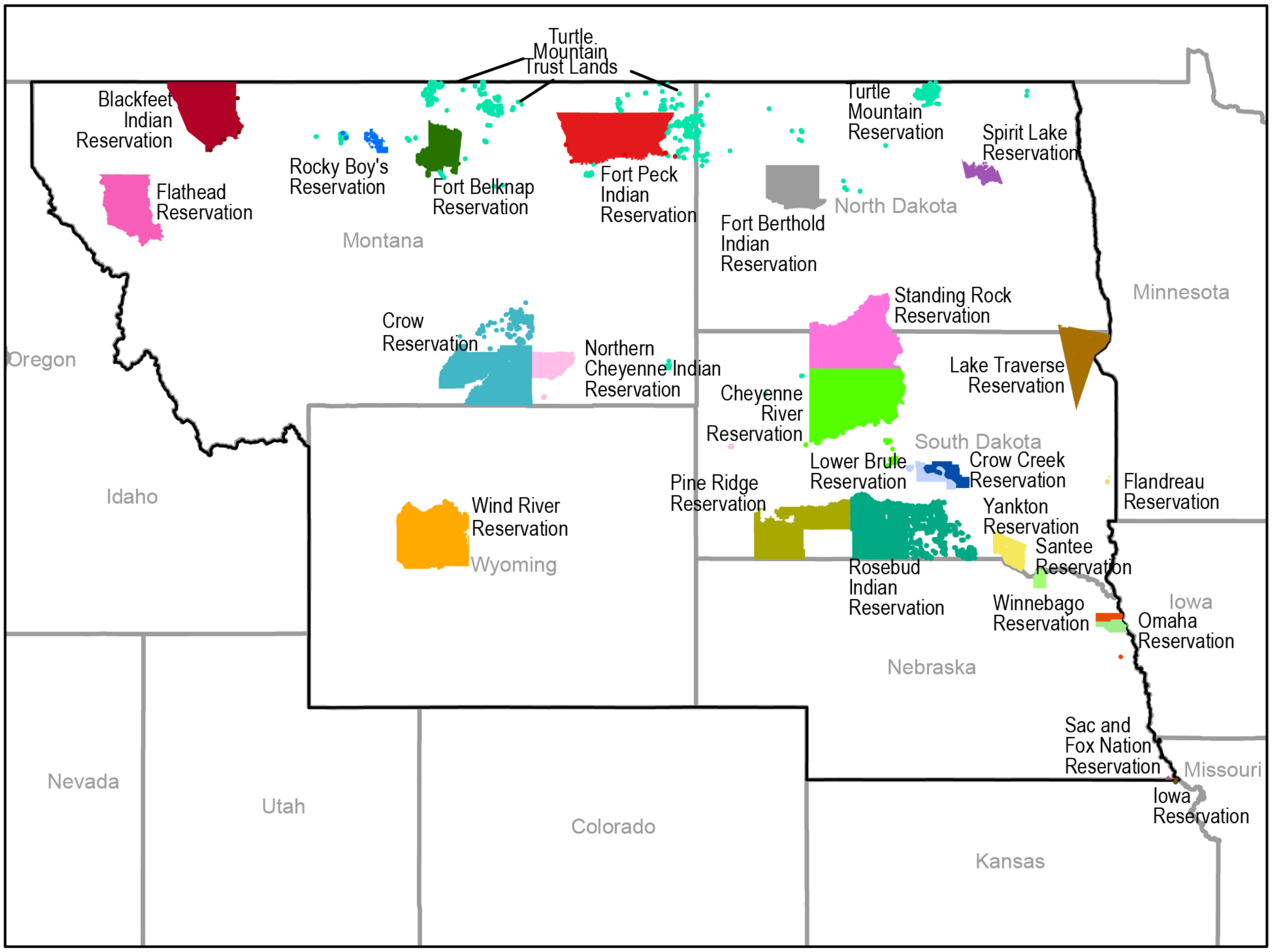


Figure 22.7: The map outlines reservation and off-reservation tribal lands in the Northern Great Plains, which shows where the 27 federally recognized tribes have a significant portion of lands throughout the region. Information on Indigenous peoples' climate projects within the Northern Great Plains is described in Chapter 15: Tribes and Indigenous Peoples. Sources: created by North Central Climate Science Center (2017) with data from the Bureau of Indian Affairs, Colorado State University, and USGS National Map.

To the Indigenous peoples of the Northern Great Plains, the Lakota phrase Mni wiconi means "water is life." Water plays significant cultural, religious, and economic roles across tribal communities that transcend consumptive water use. Because water is so integral, these communities are particularly sensitive to climate change impacts on water in the form of extreme flooding and droughts, changes in snowpack, and changes in the timing of precipitation events. These climate sensitivities, along with substandard water infrastructure and complex institutions and water rights, all combine to create water insecurity.[14,18,19,20,23,24,28,120,121,122,123,124] In the Northern Great Plains, just under 29,000 (76%) Indigenous households are in need of new or improved sanitation facilities, and approximately 5,000 households lack safe water supply, sewage facilities, or both.[125] The total cost to remediate sanitation facility deficiencies in the region was estimated at around $280 million according to a 2015 annual report from the Indian Health Service.[125] Climate change has already begun to exacerbate the problem of disruptions to water supplies from decreased water availability, as happened in 2003 when Standing Rock Reservation ran completely out of water during drought.[28]

Case Study: Crow Nation and the Spread of Invasive Species

A warming climate is projected to hasten the spread of invasive species within riparian ecosystems.[134,137,138,139] Indigenous populations who harvest and hold sacred flora and fauna along rivers within the semiarid region of south central Montana are particularly vulnerable.[140] Post-reservation settlement of Treaty Tribes and multiple land policies aimed at assimilation of Native American Tribes in the United States created a checkerboard of land ownership within reservation boundaries. The Apsaalooké, or Crow, Reservation was established after the Fort Laramie Treaty of 1886 and is located within the mountains and valleys along the Little Bighorn and Bighorn Rivers in south central Montana.[141] Promotion of agriculture in the late 19th century, along with the establishment of divergent dams for floodplain irrigation, resulted in decreased water flows, affecting the natural pulse of these river systems and their associated native riparian species. Cascading effects of river regulation, along with intentional planting of the invasive species Russian olive (*Elaeagnus angustifolia* L.) during the Indian Emergency Conservation Work era of the 1930s, have drastically altered natural vegetation within these watersheds (Figure 22.8). These complex networks of policy and culture determine the ways in which land and riparian regimes were drastically changed. The resulting conditions favored invasive plants and ecosystem degradation.[142]

The Apsaalooké, or Crow, people regularly harvest riparian plant species for food, ritual, and ceremonial uses. For example, plains cottonwood (*Populus deltoides*, Marsh) and willow (*Salix sp.* L.) are used for ceremonial (sweat lodge and Sun Dance) purposes. Crow Elders indicated that they must travel on average more than 15 miles farther now than they did 25 years ago to locate cottonwoods of specific sizes. They also find it difficult to locate and harvest traditional food sources such as chokecherry (*Prunus americana* L.) and buffalo berry (*Shepherdia argentea* Pursh., Nutt.). What was once a cottonwood- and willow-dominated river system is now dominated by Russian olive. Populations of salt cedar are likewise increasing along both the Bighorn and Little Bighorn Rivers and associated floodplains. Projections using habitat species distribution models suggest that Russian olive plants will continue to spread in the next 10 years as a result of increasing temperatures and precipitation (Figure 22.8). Continued spread of Russian olive species ultimately threatens the ability of the Crow people to harvest culturally important riparian species that provide subsistence, medicine, and plant species used in ceremony.[140]

The Russian olive invasion is a challenge throughout the Northern Great Plains. Here, the trees grow on ranchland on the Crow Indian Reservation. Photo credit: Kurrie Jo Small.

Case Study: Crow Nation and the Spread of Invasive Species, *continued*

Projected Expansion of Russian Olive Habitat

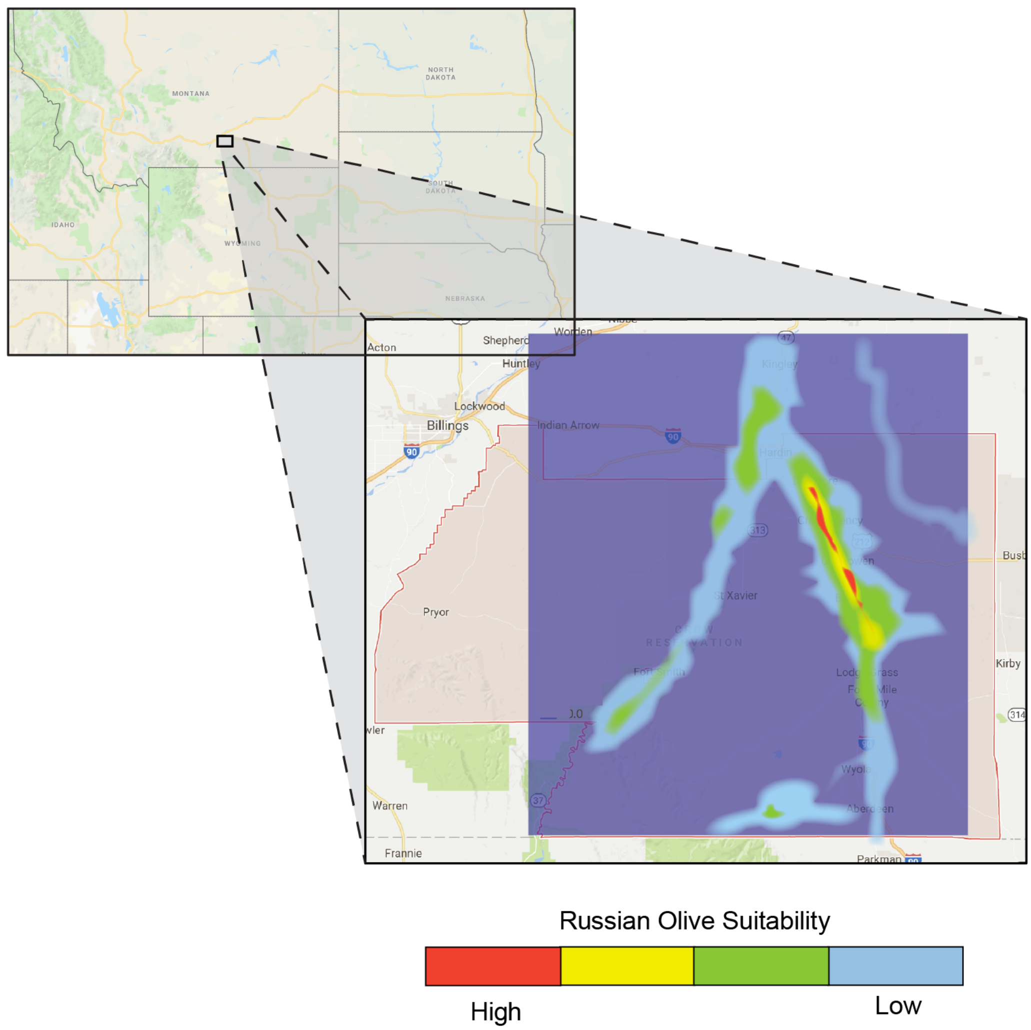


Figure 22.8: The map shows the projected expansion by 2021 of Russian olive habitat. Warmer colors indicate favorable habitat for future spread of Russian olive based on mapped presence points along the Little Bighorn and Bighorn Rivers within the Crow Indian Reservation in south central Montana. The Crow Reservation is outlined and shaded in red. Purple areas are outside of the suitability zone. Source: University of Arizona. Map data © 2018 Google, INEGI.

Reservation Irrigation Projects: Deferred Maintenance and Replacement Costs

Irrigation Project	Deferred Maintenance for FY 2014	Replacement Value
Blackfeet	$26,000,000	$50,000,000
Flathead	$82,000,000	$237,000,000
Fort Belknap	$8,000,000	$19,000,000
Fort Peck	$13,000,000	$33,000,000
Crow	$17,000,000	$59,000,000
Wind River	$30,000,000	$93,000,000
Total	**$176,000,000**	**$491,000,000**

Table 22.4: This table shows deferred maintenance and replacement costs for U.S. Bureau of Indian Affairs irrigation projects on six Northern Great Plains reservations (in 2014 dollars). Source: U.S. Government Accountability Office 2015.[126]

Agriculture, particularly livestock ranching, is a primary tribal livelihood in the region, and warmer temperatures and changes to water cycles (for example, reduced snowpack, earlier transition from snow to rain, and reduced or early runoff) pose a large threat and are already drying soils, reducing forage production, increasing livestock stress, and reducing water availability for irrigation systems throughout the region.[20,120] Reservations in the region would require a combined $176 million in maintenance or $491 million to replace neglected and failing Bureau of Indian Affairs irrigation systems (Table 22.4).[126] High leakages and inefficiencies in these systems hinder effective management of water and irrigation systems for climate change.[20]

Tribes have unique water rights and layers of relevant state and federal laws (for example, the Winters Doctrine and state water rights adjudication, and Prior Appropriation laws in the West). Climate change impacts on water resources are very likely to be compounded by these legal complexities, especially in cases where state water laws supersede tribal water codes and water rights during times of scarcity, such as at Wind River Reservation, where the Wyoming Supreme Court ruled that the state has primary authority.[20,123,127,128] Indigenous people in the region are also very concerned about the consequences of major oil pipelines passing through the region. Their concerns are in part focused around potential leaks, which would impact water resources already stressed by climate change. This concern is further intensified by the reality that climate change is projected to damage infrastructure in the region, including pipelines, through extreme storm or precipitation events that cause flooding.[54,56,121]

Disaster management is another area of great concern for the Northern Great Plains tribes. Over the last two decades, tribes have experienced unusually catastrophic fires, floods, and droughts that are already straining response capacities,[25] and climate change is expected to increase the need for the ability to fight fires, floods, and droughts.[14,16,25,129,130,131] Severe droughts in this century have resulted in serious impacts, such as tribal ranchers liquidating herds and reservations possessing no water at all.[28] Extreme hydrological events on the region's reservations are also happening in quick succession, such as the 2011 floods followed by severe drought and fire in 2012.[19,20,25,28] Each event strains the response capacity, and for the many tribes struggling with a lack of disaster preparedness, successive events compound the challenge.[25,28] This has widespread impacts on tribal economies and livelihoods, domestic and municipal water supplies, and health and well-being.

Many climate adaptations are underway in Northern Great Plains Indigenous communities, but tribes also face unique legal and regulatory barriers because of post-colonial resettlement and reservation impacts of land fragmentation and uneven regulation by federal agencies. For example, the trust relationship with the Federal Government, where the Federal Government holds the titles of tribal lands "in trust" for the tribes, requires federal permission for many aspects of land and resource management.[14,15,16,17,18,20,25,131,132,133,134,135] Outside of these limitations, however, the tribes do have control over the reservations' built environment and housing. For example, the Oglala Lakota Nation (Pine Ridge) in South Dakota has created a sustainability plan that includes off-grid, climate-resilient housing and sustainable agriculture.[16,17,122,136] Other climate adaptation examples include Flathead Reservation's strategic climate planning for multiple sectors and species of cultural and economic importance; several South Dakota tribes' climate vulnerability assessment and drought planning; Wind River Reservation's drought assessment and preparedness; Northern Cheyenne Tribe's Integrated Resource Management Planning that will include climate change; and Fort Belknap's climate adaptation plan, which integrated planning with fire, forestry, and invasives management.[14,20,25] The InterTribal Buffalo Council also has drought and climate adaptation grants to prepare tribal bison herd managers in the region and beyond for climate impacts to bison pastures and water sources. There are multiple tribal initiatives that focus on climate and Indigenous knowledge-based education, outreach, and information sharing between tribes. For example, the Northern Cheyenne Indigenous land-based science learning program offers apprenticeships for youth interested in bio-cultural restoration science. The program, which sits in the tribe's Department of Environmental Protection and Natural Resources, aims to increase tribal knowledge around Indigenous and western sciences and thus enable youth to reclaim their responsibility to the land. Also, the Blackfeet and Confederated Salish and Kootenai Tribes collaborated on a regional workshop with First Nations throughout the region to share ideas and strategies and provide support for tribal climate adaptation planning.[25] Tribes are increasingly drawing on their deep, place-based connections to natural cycles and Indigenous knowledge, combined with western technical sciences, to respond to and prepare for climate change.[14,15,16]

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Traceable Accounts

Process Description

The chapter lead (CL) and coordinating lead author (CLA) developed a list of potential contributing authors by soliciting suggestions from the past National Climate Assessment (NCA) author team, colleagues and collaborators throughout the region, and contributors to other regional reports. Our initial list of potential authors also included CL nominees submitted to the U.S. Global Change Research Program (USGCRP). The CL and CLA discussed the Northern Great Plains, which was part of the larger Great Plains region for the Third National Climate Assessment (NCA3), with each of these nominees and, as part of that discussion, solicited suggestions for other nominees. This long list of potential contributing authors was pared down by omitting individuals who could not contribute in a timely fashion, and the list was finalized after reconciliation against key themes within the region identified by past NCA authors, the CL and CLA, and contributing author nominees. The team of contributing authors was selected to represent the region geographically and thematically, but participants from some states who had agreed to contribute were eventually unable to do so. Others were unable to contribute from the start. The author team is mostly composed of authors who did not contribute to NCA3.

The CL and CLA, in consultation with past NCA authors and contributing author nominees, identified an initial list of focal areas of regional importance. The author team then solicited input from colleagues and regional experts (identified based on their deep ties to scientific and practitioner communities across the region) on their thoughts on focal areas. This list informed the agenda of a region-wide meeting held on February 22, 2017, with core locations in Fort Collins, Colorado, and Rapid City, South Dakota. The main purpose of this meeting was to seek feedback on the proposed list of focal areas. With this feedback, the author team was able to refine our focal areas to the five themes comprising the Key Messages of the Northern Great Plains regional chapter. Of these, recreation/tourism is a focus area that is new from NCA3.

Key Message 1

Water

Water is the lifeblood of the Northern Great Plains, and effective water management is critical to the region's people, crops and livestock, ecosystems, and energy industry. Even small changes in annual precipitation can have large effects downstream (*very high confidence*); when coupled with the variability from extreme events, these changes make managing these resources a challenge (*very high confidence*). Future changes in precipitation patterns, warmer temperatures, and the potential for more extreme rainfall events are very likely to exacerbate these challenges (*very likely, high confidence*).

Description of evidence base

Multiple lines of research have shown that as a result of its high aridity, changes in water availability in the Northern Great Plains region are highly sensitive to small changes in climate.[35,36,143,144] Despite large differences in climate from the western mountains to the eastern plains, the reliance upon reservoir storage to regulate water supplies is ubiquitous—to provide water during times of drought and to mitigate flood waters during deluges.

Natural reservoirs, groundwater, and snowpack are at risk to varying degrees. Reservoir vulnerability was recently analyzed to assess sustainable pumping rates,[42] while snow and especially glaciers appear to be in steady decline in recent decades,[38] attributed to global climate warming[39] that is projected to continue.[145]

Major uncertainties

While there is high confidence in future increases in temperature, uncertainties exist as to the changes in precipitation and runoff. Perhaps most important are the uncertainties in the degree of precipitation variability from year to year and within season (based on information dating to the 1950s).[35,52] These uncertainties are very likely to overwhelm the projected modest increases in precipitation.

Uncertainties exist in agricultural demands for water, reservoir operation protocols, and changes in extreme events.

Description of confidence and likelihood

There is *high confidence* that temperatures will rise in the region, which will *likely* produce less snowfall and smaller mountain snowpacks. There is *very high confidence* in the downstream consequences of these changes.

Key Message 2

Agriculture

Agriculture is an integral component of the economy, the history, and the culture of the Northern Great Plains. Recently, agriculture has benefited from longer growing seasons and other recent climatic changes (*very high confidence*). Some additional production and conservation benefits are expected in the next two to three decades as land managers employ innovative adaptation strategies (*very likely, high confidence*), but rising temperatures and changes in extreme weather events are very likely to have negative impacts on parts of the region (*very likely, very high confidence*). Adaptation to extremes and to longer-term, persistent climate changes will likely require transformative changes in agricultural management, including regional shifts of agricultural practices and enterprises (*very likely, high confidence*).

Description of evidence base

Several lines of research have shown that agricultural productivity is likely to increase in rangelands across the region with increasing atmospheric carbon dioxide (CO_2) and warming,[3,7,8] with no yield changes likely for small grain crops (for example, wheat) and yield reductions likely for row crops (for example, corn) in dryland croplands.[6] The competitive ability of weeds (primarily perennial forbs such as *Linaria dalmatica* and annual grasses such as *Bromus tectorum*) is likely to increase as well, with corresponding impacts to forage production,[1,2] as phenology is altered[57,58] and the growing season lengthens.[4,5] Forage quality is expected to decline,[3,59,60] and crop yields are likely to decrease if extreme temperature events (high daytime highs or nighttime lows) occur during critical pollination and grain fill periods.[9]

Numerous lines of research have addressed adaptation strategies for various parts of the agricultural sector[9,61,63,146,147,148]

Major uncertainties

While there is high confidence in future increases in temperature, uncertainties exist as to the changes in extreme events, including the spatiotemporal aspects of high-intensity rainfall events, snowstorms, and hailstorms. Perhaps most important are the uncertainties in the degree of precipitation variability from year to year[35] that influence decision-making calendars for agricultural producers.

Description of confidence and likelihood

There is *very high confidence* that longer growing seasons have already benefited agriculture in parts of the Northern Great Plains. There is *very high confidence* that increases in temperatures and atmospheric CO_2 will *likely* increase production potential for the agricultural sector in the short term (the next 10–20 years) and that current adaptations already being implemented by a subset of producers in this region provide opportunities for assessment, further development, and adoption by the larger population of agricultural managers. There is *very high confidence* that rising temperatures and changes in extreme weather events are very *likely* to have negative impacts on parts of the region. Over the longer-term (through the end of the 21st century), predicted climate changes may require transformative changes in agricultural management, including regional shifts of agricultural practices and enterprises (*very likely*, *high confidence*).[61,64]

Key Message 3

Recreation and Tourism

Ecosystems across the Northern Great Plains provide recreational opportunities and other valuable goods and services that are at risk in a changing climate (*very high confidence*). Rising temperatures have already resulted in shorter snow seasons, lower summer streamflows, and higher stream temperatures and have negatively affected high-elevation ecosystems and riparian areas, with important consequences for local economies that depend on winter or river-based recreational activities (*high confidence*). Climate-induced land-use changes in agriculture can have cascading effects on closely entwined natural ecosystems, such as wetlands, and the diverse species and recreational amenities they support (*very high confidence, likely*). Federal, tribal, state, and private organizations are undertaking preparedness and adaptation activities, such as scenario planning, transboundary collaboration, and development of market-based tools.

Description of evidence base

State-level surveys, conducted roughly every five years, have consistently documented that the public spends millions of days each year (over $30 million in 2011) participating in nature-based recreation activities in the Northern Great Plains (e.g., U.S. Department of the Interior and U.S.

Department of Commerce 2008, 2013a, 2013b, 2014a, 2014b[65,66,67,68,69]). The implications of climate change for outdoor recreation, and tourism more broadly, have been studied extensively around the globe (see summaries in Scott et al. 2012, Rosselló and Santana-Gallego 2014, Brice et al. 2017[101,149,150]). Region-specific studies are only a small subset of this large body of literature, so our understanding of potential impacts of climate change on outdoor recreation in the Northern Great Plains is sometimes inferred from other regions with similar characteristics (e.g., Hari et al. 2006[83]). Region-inclusive studies are available (e.g., Wobus et al. 2017[11]) for the sectors most obviously affected by climate change (such as winter recreation). Our understanding is most complete about the implications of climate change for the ecosystems upon which outdoor recreation in the Northern Great Plains depends.[70] For example, the implications of climate change for wetlands and waterbirds in the Prairie Pothole Region, upon which much bird hunting and bird watching in the region depend,[104,105] have been studied extensively over the past several decades (e.g., Johnson and Poiani 2016, Wright and Wimberly 2013[46,106]). The role of agricultural land-use change (as a function of climate change as well as complex technological, policy, and market factors) in the degradation of wetland function in the region—for example through increased soil erosion and resulting wetland sedimentation or upland habitat fragmentation and resulting increases in waterfowl nest predation—has also been thoroughly assessed (e.g., Rashford et al. 2016, Sofaer et al. 2016[12,109]).

Major uncertainties

Climate change is expected to disrupt local economies that depend on winter-based or river-based recreational activities. However, the magnitudes of these effects are uncertain. This is due largely to uncertainties about the preferences of recreationalists and the extent to which they will adapt by shifting the timing and location of their activities or by substituting towards a different set of recreational activities. For example, although climate change will make it more difficult to supply high-quality downhill skiing opportunities, this effect will be stronger in lower-elevation areas. Therefore, some skiers might adapt by simply traveling to higher-elevation downhill ski areas. Others might compensate for the shorter ski season at their favorite lower-elevation mountain by shifting some of their recreational time to an alternative outdoor activity, such as winter mountain biking. Given the potential diversity of individual preferences for adapting outdoor recreation activities to climate change, it is challenging to project with certainty the future potential impacts to recreation-dependent economies, but the impact will be larger and more immediate for some industries and companies (e.g., low-altitude ski resorts).

Another source of uncertainty is the reliance, in some cases, on scientific studies from other geographic locations to infer what the impacts of climate change might be for ecosystems, species, or recreationalists within the Northern Great Plains. For example, the effects of increased stream temperature on the susceptibility of coldwater fish species to diseases in the region are based largely on studies conducted in European coldwater fisheries.

Regarding wetlands in the Prairie Pothole Region, uncertainty about their abundance in the future arises from uncertainty about future government policies that would either exacerbate or mitigate climate-induced losses. For example, future versions of the Farm Bill may contain language that directly encourages wetland preservation (e.g., through conservation-compliance requirements) or unintentionally leads to wetland degradation (e.g., through higher subsidies for row crop insurance).

Description of confidence and likelihood

We know with *very high confidence* that ecosystems across the Northern Great Plains provide recreational opportunities and other valuable goods and services. We know with *very high confidence* that climate change is *very likely* affecting abiotic factors that influence these ecosystems, such as snowfall, spring snowmelt, runoff, and stream temperatures. There is *high* confidence that these abiotic factors are *likely* to affect high-elevation ecosystems and riparian areas in the Northern Great Plains. Greater confidence could be gained by conducting studies specifically within the Northern Great Plains, as opposed to drawing inferences from studies conducted in other regions of the world with similar characteristics. The consequences of ecosystem changes for local economies in the region that depend on winter-based or river-based recreational activities are currently being debated in the scientific literature, due to uncertainty about potential individual behavioral responses to changes in the recreational environment. Based on a limited number of case studies, effects of climate change on outdoor recreation-based economies are *as likely as not* to be negative, but this is only known with *medium confidence*. We know with *very high confidence*, however, that some natural ecosystems that local economies depend upon—in this specific case, wetlands in the Northern Great Plains—are *likely* to be negatively affected by climate-induced changes in agricultural land use. In turn, we know with *high confidence* that wetland declines will *very likely* harm the diverse species and recreational amenities they support. Uncertainty about future policies that could influence agricultural land-use decisions and wetland conservation outcomes precludes a higher confidence level or higher likelihood.

Key Message 4

Energy

Fossil fuel and renewable energy production and distribution infrastructure is expanding within the Northern Great Plains (*very high confidence*). Climate change and extreme weather events put this infrastructure at risk, as well as the supply of energy it contributes to support individuals, communities, and the U.S. economy as a whole (*likely, high confidence*). The energy sector is also a significant source of greenhouse gases (*very likely, very high confidence*) and volatile organic compounds that contribute to climate change and ground-level ozone pollution (*likely in some areas, very high confidence*).

Description of evidence base

Fossil fuel and renewable energy production/distribution infrastructure is expanding within the Northern Great Plains, including oil and natural gas pipelines, natural gas compressor stations and storage tanks, natural gas processing plants, natural gas-fired power plants, high-voltage power lines and substations, wind farms, and even a new oil refinery and a new biorefinery in recent years (both began operations in 2015).

A number of oil and natural gas pipelines are being constructed or have been completed in recent years. In particular, the Dakota Access Pipeline began commercial service June 1, 2017, transporting crude oil from the Bakken/Three Forks production areas in North Dakota, through South Dakota and Iowa, to Pakota, Illinois. While pipelines are vulnerable to damage or disruption from heavy precipitation events and associated flooding and erosion,[13] their increased use could eliminate hundreds of rail cars and trucks needed to transport crude every day. This reduces the exposure of these modes of transportation to rising temperatures, heat waves, and floods.[13] Other oil and gas production and distribution infrastructure is similarly vulnerable to heavy precipitation events and flooding.

The region relies on rail lines to transport coal, and these lines are vulnerable to rising temperatures, heat waves, and floods.[13] There is ample evidence of rail line vulnerability to extreme weather.[151]

Damage to thermoelectric power plants and electric power transmission lines from extreme weather such as heat waves and wildfires has been documented, and the risk is expected to increase.[13,152]

The U.S. Department of Energy (DOE) Energy Risk Profiles (1996–2014) highlight the risks to energy infrastructure in the United States from natural hazards. For example, in North Dakota, thunderstorms and lightning had the highest frequency of occurrence and property loss during this timeframe. DOE also has a series of comprehensive documents on U.S. energy sector vulnerabilities to climate change[13,153] that identify important climate-related vulnerabilities for fuel transport, electricity generation, and electricity demand.

There is substantial evidence that the energy sector is a significant source of greenhouse gases that contribute to climate change, in particular from power plants, oil and gas systems, and refineries.[117]

Major uncertainties

Cold waves are projected to be less intense in the future, reducing the risk of disruptions from cold to energy infrastructure.[13]

There is not yet substantial agreement among sources as to how a changing climate will ultimately affect wind resources in the United States in general and in the Northern Great Plains in particular.[153]

Projected increases in precipitation in the Northern Great Plains are likely to benefit hydropower production, but this will vary by location. For example, it is known that in the Columbia River Basin, decreasing summer streamflows will reduce downstream hydropower production, and increasing winter and early spring streamflows will increase production.[13] In the Missouri River Basin, projected seasonal declines in precipitation in the southern and western portion of the region are likely to reduce the water available to generate hydropower.[13]

Biofuel feedstocks from crops and forage grown in the Northern Great Plains are vulnerable to climate change, but the net impacts on biofuel production are uncertain.[13]

It is well understood that ground-level ozone (O_3) is created by chemical reactions between volatile organic compounds in the presence of sunlight and would be exacerbated by climate change. What is less understood is the sensitivity of regional climate-induced O_3 changes, and the science of modeling climate and atmospheric chemistry to understand future conditions.

Description of confidence and likelihood

There is *high confidence* that climate change and extreme weather events will *likely* put energy supply and infrastructure of various types at risk. There is *high confidence* that the energy sector is a *very likely* a significant source of greenhouse gases contributing to climate change. There is *very high confidence* that volatile organic compounds contribute to climate change and ground-level ozone pollution, and it is *likely* that this will worsen in the future in some areas.

Key Message 5

Indigenous Peoples

Indigenous peoples of the Northern Great Plains are at high risk from a variety of climate change impacts, especially those resulting from hydrological changes, including changes in snowpack, seasonality and timing of precipitation events, and extreme flooding and droughts as well as melting glaciers and reduction in streamflows (*likely, very high confidence*). These changes are already resulting in harmful impacts to tribal economies, livelihoods, and sacred waters and plants used for ceremonies, medicine, and subsistence (*very high confidence*). At the same time, many tribes have been very proactive in adaptation and strategic climate change planning (*very likely, very high confidence*).

Description of evidence base

Multiple lines of research have shown that hydrological changes and changes in extremes have resulted in deleterious impacts to Indigenous peoples.[14,18,19,20,23,24,28,121,122,123,124] During times of drought, decreased water availability negatively impacts tribal communities and livelihoods such as ranching, and already stressed water systems and infrastructure do not provide the necessary water to sustain Indigenous communities and reservations.[20,28,154]

Major uncertainties

The impacts of climate change in the Northern Great Plains are expected to increase risks to Indigenous reservations, communities, and livelihoods. However, there is uncertainty about how Indigenous people will be able to respond. Much of this uncertainty is due to unsettled water rights, multijurisdictional complexities, and federal funding and policies.

Description of confidence and likelihood

There is *very high confidence* that rising temperature and increases in flooding, runoff events, and drought are *likely* to lead to increases in impacts to reservations and other Indigenous communities. There is *very high confidence* that climate changes are already resulting in harmful impacts on tribal economies, livelihoods, and culture. However, the actual impacts and response capacities will depend on the response of regulatory systems and funding amounts.

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