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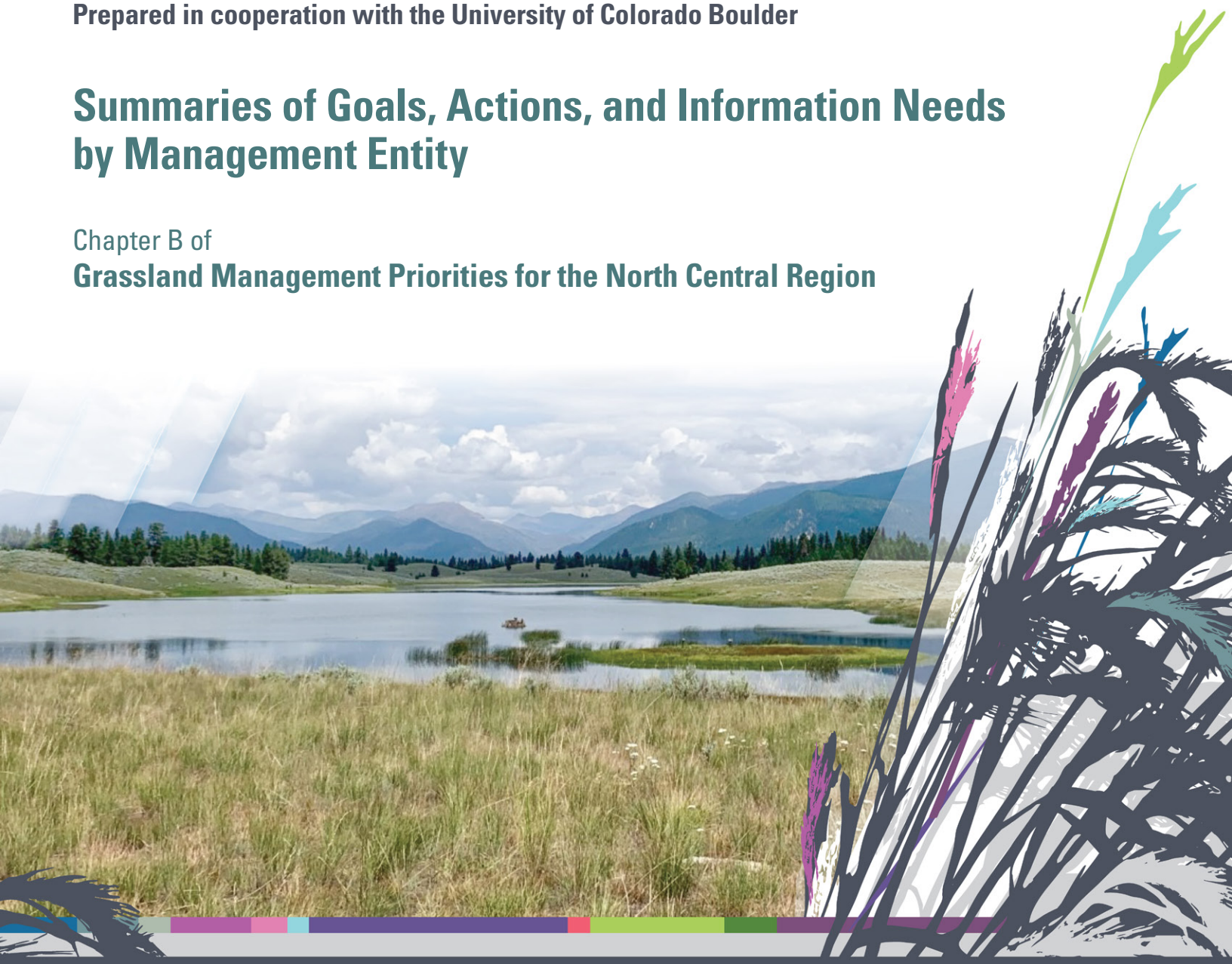
Climate Adaptation Science Centers
Prepared in cooperation with the University of Colorado Boulder

Summaries of Goals, Actions, and Information Needs by Management Entity

Chapter B of
Grassland Management Priorities for the North Central Region



Scientific Investigations Report 2025–5018–B

U.S. Department of the Interior
U.S. Geological Survey

Cover. Montana landscape under a cloudy sky (Photograph by Aubin Douglas, U.S. Fish and Wildlife Service).

Summaries of Goals, Actions, and Information Needs by Management Entity

Edited by Christine D. Miller Hesed and Heather M. Yocum

Chapter B of
Grassland Management Priorities for the North Central Region

Section B1.
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Section B4.
U.S. Department of Agriculture Forest Service

By Molly Cross, Christine D. Miller Hesed, and Sarah Jaffe

Section B5.
U.S. Department of Agriculture Natural Resources Conservation Service and Farm Service Agency

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Section B6.
Tribal Nations

By Shelby Ross, Christine D. Miller Hesed, Emily Boyd-Valandra, Stefan Gabriel Tangen, Anthony Warren Ciocco, and Sarah Jaffe

Section B7.
Colorado Parks and Wildlife

By Christine D. Miller Hesed and Sarah Jaffe

Section B8.
Kansas Department of Wildlife & Parks

By Jon P. Beckmann, Christine D. Miller Hesed, and Sarah Jaffe

Section B9.
Montana Fish, Wildlife & Parks

By Molly Cross, Christine D. Miller Hesed, and Sarah Jaffe

Section B10.
Nebraska Game and Parks Commission

By Ben Wheeler, Christine D. Miller Hesed, and Sarah Jaffe

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Preface

This report presents findings from the project "A Synthesis of Climate Impacts, Stakeholder Needs, and Adaptation in Northern Great Plains Grassland Ecosystems" (hereafter, "the Grasslands Synthesis Project") led by the U.S. Geological Survey (USGS) North Central Climate Adaptation Science Center (NC CASC). Grassland ecosystems in the North Central region support local economies, Tribal communities, livestock grazing, diverse plant and animal communities, and large-scale migrations of ungulates and multiple bird guilds. Understanding how climate change and variability will affect grassland ecosystems is crucial for successful management of grasslands into the future. The NC CASC began the Grasslands Synthesis Project in 2020 to establish a baseline of information to best serve resource managers and help meet regional grassland management goals. This project had two primary goals: (1) to synthesize management goals and challenges for grassland managers across the region and (2) to assess the state of the science and identify knowledge gaps for addressing these goals and challenges within the context of climate change.

As also described in chapter A, the NC CASC is a partnership among the USGS, the University of Colorado Boulder, and five consortium partners; from 2018 to 2024 the consortium partners were Conservation Science Partners, Great Plains Tribal Water Alliance, South Dakota State University, University of Montana, and Wildlife Conservation Society. The NC CASC is part of a network of regional Climate Adaption Science Centers that serve resource managers by developing the science and tools needed to address impacts of climate change on the Nation's land, water, fish, wildlife, and cultural heritage resources. The NC CASC serves Federal, State, and Tribal resource managers in Colorado, Kansas, Montana, Nebraska, North Dakota, South Dakota, and Wyoming.

The NC CASC recognizes the importance of private landowners for grassland conservation across the region primarily because of the proportion of land in the region held in private ownership; however, the mission of the Department of the Interior and the scope of this project limited the degree to which this report pertains to private landowners. The NC CASC indirectly serves private landowners by providing relevant climate science and tools to the Federal, State, and Tribal agencies, and nongovernmental organizations (NGOs) that partner with private landowners on grassland conservation and management; however, the NC CASC does not directly provide technical or financial service to private landowners. Furthermore, the data collection and analysis methods used to develop this report were not conducive to a thorough consideration of private landowners' grassland management goals, challenges, and information needs (refer to Miller Hesed and Yocum, 2026, sec. A1). Nevertheless, this report highlights the significance of working with private landowners on grassland conservation and describes ways other Federal, State, and Tribal agencies, and NGOs work with private landowners on grassland conservation.

The report is organized into two chapters. Chapter A, "Grassland Management Priorities for the North Central Region—Background, Methods, Goals, Challenges, Opportunities, and Information Needs" (Miller Hesed and Yocum, 2026) includes an executive summary that provides a high-level overview of the main findings of the grassland management priorities synthesis—including the information needed for grassland managers to be successful in meeting their goals in a changing climate—the background and methods for the synthesis (Miller Hesed and Yocum, 2026, sec. A1), an introduction to the North Central Grassland Ecoregions (Miller Hesed and Yocum, 2026, sec. A2), and the synthesis results (Miller Hesed and Yocum, 2026, secs. A3, A4). Multiple goals of grassland management and direct threats and contributing factors to grassland conservation are presented to provide important context. Seventy questions to support grassland management in a changing climate are identified. The varying effects of direct threats to grassland conservation and varying management opportunities across the five North Central Grassland Ecoregions—Tallgrass, Northern Mixed Grass, Central Mixed Grass, Shortgrass, and the Sagebrush–Grassland Ecotone—are discussed. This chapter could be of interest to anyone interested in a high-level synthesis of the factors most important for grassland conservation in a changing climate.

Finally, this report, chapter B, presents information for Federal (secs. B1–B5), State (secs. B7–B13), and Tribal agencies (sec. B6); NGOs (sec. B14); and partnerships (sec. B15) that manage or affect grasslands management in the North Central region. For each agency, organization, or partnership, information is presented on the organizational structure and mission, main grassland management actions, emerging challenges and opportunities, and information needs. These chapters could be of interest to anyone looking to collaborate with grassland management entities on shared interests in grassland management or research.

Acknowledgments

We are grateful to the members of the Climate and Ecology Working Group and the Advisory Committee for their feedback on an initial draft of this report. The Climate and Ecology Working Group consists of Marissa Ahlering (The Nature Conservancy), Katherine J. Chase (U.S. Geological Survey [USGS]), Shelley Crausbay (Conservation Science Partners), Ana D. Davidson (Colorado Natural Heritage Program), Julie Elliott (U.S. Department of Agriculture Natural Resources Conservation Service), Kevin Ellison (American Bird Conservancy), Jim Giocomo (American Bird Conservancy), David L. Hoover (U.S. Department of Agriculture Agricultural Research Service [ARS]), Toni Klemm (ARS), David Lightfoot (Museum of Southwestern Biology, University of New Mexico), Jeff M. Martin (South Dakota State University, Department of Natural Resource Management), Owen P. McKenna (USGS), Brian W. Miller (USGS, North Central Climate Adaptation Science Center), Christine D. Miller Hesed (University of Colorado Boulder, Cooperative Institute for Research in Environmental Sciences [CIRES], North Central Climate Adaptation Science Center), Danika Mosher (National Park Service Research Assistant, student contractor to USGS), R. Chelsea Nagy (University of Colorado Boulder, CIRES), Jesse B. Nippert (Kansas State University, Konza Prairie Biological Station), Jeremy Pittman (University of Waterloo, School of Planning), Lauren Porensky (ARS), Imtiaz Rangwala (University of Colorado Boulder, CIRES, North Central Climate Adaptation Science Center), Jilmarie Stephens (University of Colorado Boulder, CIRES, North Central Climate Adaptation Science Center), Amy J. Symstad (USGS), William Travis (University of Colorado Boulder, CIRES, North Central Climate Adaptation Science Center), David J. A. Wood (USGS), Heather M. Yocum (University of Colorado Boulder, CIRES, North Central Climate Adaptation Science Center), and Alexander V. Zale (USGS). The Advisory Committee included David Augustine (ARS), Katie Bills Walsh (ARS), Alice Boyle (Kansas State University), Anthony Warren Ciocco (Bureau of Indian Affairs), Lisa Dilling (University of Colorado Boulder, CIRES), Laura Edwards (South Dakota State University), Brad Guhr (Dyck Arboretum of the Plains), Brice Hanberry (U.S. Department of Agriculture Forest Service [FS]), Chris Helzer (The Nature Conservancy), Rachel Keen (Kansas State University), Doug Kluck (National Oceanic and Atmospheric Administration), Brian Obermeyer (The Nature Conservancy), Kim O'Keefe (University of Wisconsin–Madison), Graeme Patterson (JV8 Central Grasslands Conservation Initiative), Dave Pellatz (Thunder Basin Grasslands Prairie Ecosystem Association), Ronald Pritchert (U.S. Fish and Wildlife Service), Geri Proctor (FS), Madeleine Rubenstein (USGS), Alden Shallcross (Bureau of Land Management), Stefan Gabriel Tangen (Great Plains Tribal Water Alliance, North Central Climate Adaptation Science Center), Alisa Wade (USGS, North Central Climate Adaptation Science Center), Catherine Wightman (Northern Great Plains Joint Venture), and Ben Zuckerberg (University of Wisconsin–Madison).

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We also wish to thank the Management Priorities Working Group members Christine D. Miller Hesed, Heather M. Yocum, and Marissa Ahlering for writing the executive summary and Ben Wheeler (Pheasants Forever Inc. and Quail Forever) for his edits and additions to the executive summary. We also wish to thank James Rattling Leaf, Sr. (Great Plains Tribal Water Alliance, North Central Climate Adaptation Science Center) and Ian Tator (Wyoming Game and Fish Department) who supported data gathering and review. We are also grateful to Jane Wolken (University of Colorado Boulder, CIRES, North Central Climate Adaptation Science Center) for her help with editing and proofreading. Apart from figures BES1, B1, B3, B10, B23, and B27, all figures in this report were created by Sarah Jaffe (University of Colorado Boulder, CIRES).

Contents

Figures

Tables

Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
yard (yd)	0.9144	meter (m)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C = (°F - 32) / 1.8.$$

Datum

Altitude, as used in this report, refers to distance above the vertical datum.

Supplemental Information

Throughout the text, bold formatting is used to denote glossary terms.

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Abbreviations

AC	Advisory Committee
ACEP	Agricultural Conservation Easement Program
AIARMA	American Indian Agricultural Resource Management Act
ARS	Agricultural Research Service
AUM	animal unit month
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
CASC	Climate Adaptation Science Center
CCRP	Climate Change Response Program
CEWG	Climate and Ecology Working Group
CIRES	Cooperative Institute for Research in Environmental Sciences
CNAP	Colorado Natural Areas Program
CO–OP	Colorado Outdoor Partnership
CPW	Colorado Parks and Wildlife
CRP	Conservation Reserve Program
CSP	Conservation Stewardship Program
DOI	U.S. Department of the Interior
EIS	Environmental Impact Statement
EQIP	Environmental Quality Incentives Program
FSA	U.S. Department of Agriculture Farm Service Agency
FS	U.S. Department of Agriculture Forest Service
FWS	U.S. Fish and Wildlife Service
GIS	geographic information system
HUC	hydrologic unit code
IRA	Indian Reorganization Act
JV	Migratory Bird Joint Venture
JV8	JV8 Central Grasslands Conservation Initiative
KDWP	Kansas Department of Wildlife and Parks
LUP	land utilization projects
MFWP	Montana Fish, Wildlife & Parks
MPWG	Management Priorities Working Group

NAWMP	North American Waterfowl Management Plan
NC CASC	North Central Climate Adaptation Science Center
NCTC	National Conservation Training Center
NDGFD	North Dakota Game and Fish Department
NEPA	National Environmental Policy Act
NGO	nongovernmental organization
NGPC	Nebraska Game and Parks Commission
NIACS	Northern Institute of Applied Climate Science
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NWRS	National Wildlife Refuge System
PAD–US	Protected Areas Database of the United States
PLOTS	Private Land Open to Sportsmen
PPJV	Prairie Pothole Joint Venture
PPR	Prairie Pothole region
RAD	Resist-Accept-Direct
RBJV	Rainwater Basin Joint Venture
SAIC	Science Applications International Corporation
SDGFP	South Dakota Game, Fish and Parks
SGCN	species of greatest conservation need
SGI	Sage Grouse Initiative
SWAP	State wildlife action plan
TEK	traditional ecological knowledge
TNC	The Nature Conservancy
UMRGLRJV	Upper Missouri River and Great Lakes Region Joint Venture
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WAFWA	Western Association of Fish and Wildlife Agencies
WGFD	Wyoming Game and Fish Department
WRE	Wetland Reserve Easement
WWF	World Wildlife Fund

Summaries of Goals, Actions, and Information Needs by Management Entity

Edited by Christine D. Miller Hesed[1] and Heather M. Yocum[1]

Executive Summary

The **grasslands** in the **North Central region** (fig. BES1) are managed by a diverse group of Federal, State, and Tribal agencies; nongovernmental organizations (NGOs); partnerships; and private landowners (Miller Hesed and Yocum, 2026, fig. A8). This report highlights these various grassland management entities, provides background information on their mission and organizational structure, and describes some of their key grassland management activities, including the way in which each entity engages private landowners in grassland management. Each section also describes emerging challenges and opportunities and high-level information needs. To review and synthesis of grassland management-related documents (refer to Miller Hesed and Yocum, 2026, sec. A1) identified specific information needs, which are listed in appendix B1 to provide additional detail for anyone looking to collaborate with grassland management entities on shared interests in grassland management or research. Relevant information needs and text from Miller Hesed and Yocum (2026) are reproduced in this chapter using verbatim wording for consistency.

Federal Agencies

The U.S. Department of the Interior includes five bureaus, which affect grassland management in the North Central region: the Bureau of Land Management, the U.S. Fish and Wildlife Service, the National Park Service, the Bureau of Indian Affairs, and the U.S. Geological Survey (USGS). Three of these bureaus—the Bureau of Land Management, the U.S. Fish and Wildlife Service, and the National Park Service—own and manage substantial grassland acreage in the North Central region. The Bureau of Indian Affairs works with Tribal nations to manage Tribal grasslands. The USGS does not directly manage grasslands but affects their management by providing relevant science to decisionmakers and managers at the other four bureaus (USGS, 2022b). The USGS also partners with universities to form the regional Climate Adaptation Science Centers, which "teams scientists with natural and cultural resource managers and local communities to help fish, wildlife, waters, and lands across the country adapt to changing conditions" (USGS, 2022a).

The U.S. Department of Agriculture (USDA) also has many agencies that manage or affect the management of grasslands in the North Central region. The USDA Forest Service owns and manages all the national grasslands. Two other agencies of relevance to grassland management are the USDA Natural Resources Conservation Service and the Farm Service Agency. Although these agencies do not own or directly manage any grasslands, they affect the management of privately owned grasslands through contractual financial agreements with private landowners. These USDA agencies are informed by the Agricultural Research Service, which conducts research to deliver "cutting-edge, scientific tools and innovative solutions for American farmers, producers, industry, and communities to support the nourishment and well-being of all people; sustain our nation's agroecosystems and natural resources; and ensure the economic competitiveness and excellence of our agriculture" (USDA, 2021). In addition, grassland management is informed by two regional USDA Climate Hubs, which have a mission to "develop and deliver science-based, region-specific information and technologies, with USDA agencies and partners, to agricultural and natural resource managers that enable climate-informed decision-making, and to provide access to assistance to implement those decisions" (USDA, 2022). In the North Central region, the Northern Plains Climate Hub serves Colorado, Montana, Nebraska, North Dakota, South Dakota, and Wyoming and the Southern Plains Climate Hub serves Kansas.

[1]University of Colorado Boulder, Cooperative Institute for Research in Environmental Sciences, North Central Climate Adaptation Science Center.

Climate Adaptation Science Center (CASC) Regions

The CASCs collaborate across boundaries to address shared ecosystems, watersheds, and landscapes.

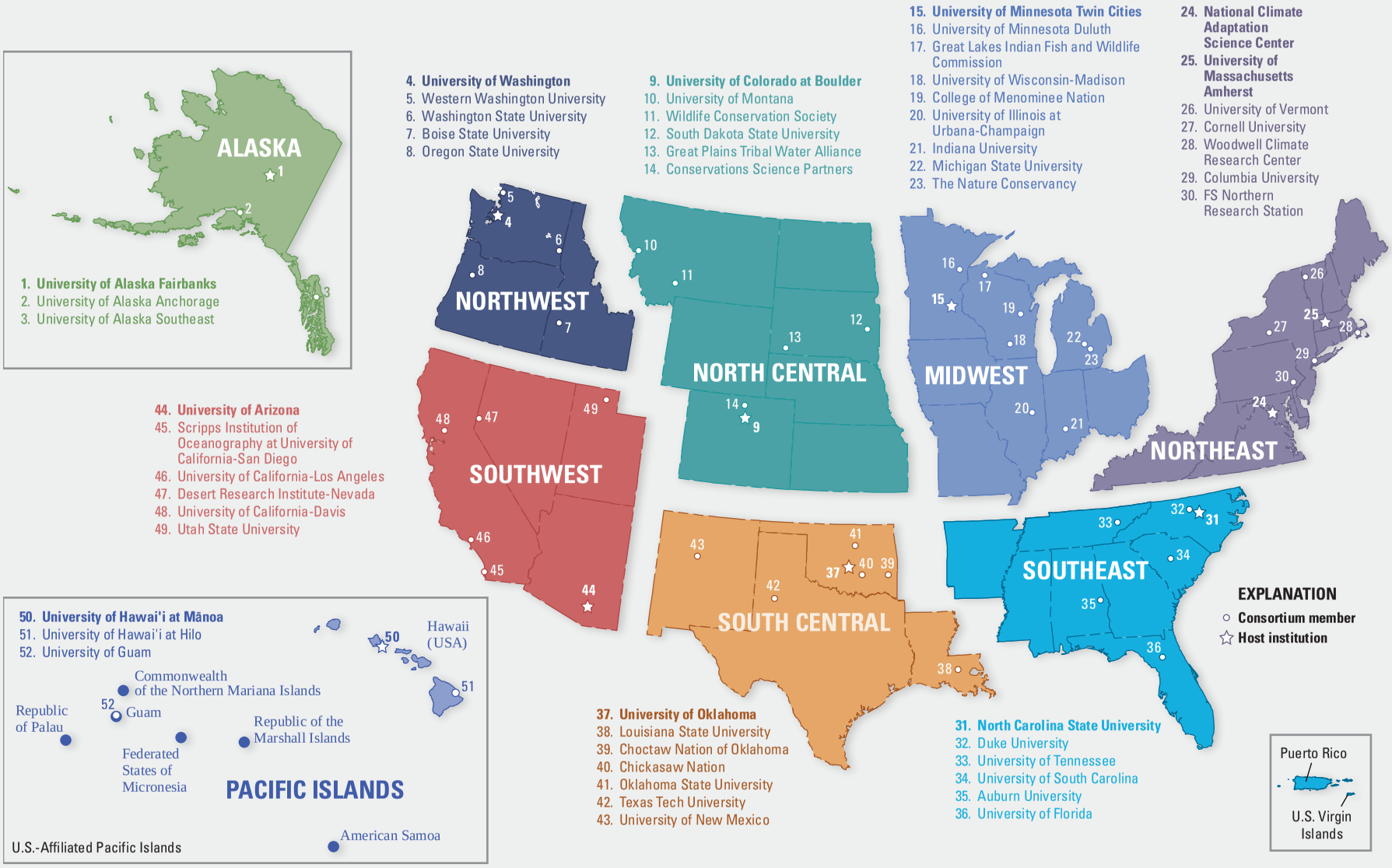


Figure BES1. The nine Climate Adaptation Science Center regions in the United States, affiliated Pacific islands, and associated territories overlain by the location of the National Climate Adaptation Science Center, host institutions, and consortium members (Miller Hesed and Yocum, 2026). FS, U.S. Department of Agriculture Forest Service.

Tribal Nations

The North Central Grassland Ecoregions are currently (2025) home to 27 federally recognized Tribes (sec. B6; Bureau of Indian Affairs, 2022). These Tribes are sovereign nations (hereafter referred to as "Tribes" or "Tribal nations") and are quite diverse in their history, traditions, and government. These Tribal nations have grassland management efforts and climate change adaptation plans in various stages of development. The "Tribal Nations" section (sec. B6) starts with a brief history of Tribal nations in the North Central Grassland Ecoregions and the changes that occurred because of westward expansion of European settlers and Federal policies. Then we present grassland management goals and challenges across these regional Tribal nations while highlighting some of the unique efforts and challenges at several individual Tribal nations. (refer to the "Limitations of the Literature Review" section in Miller Hesed and Yocum [2026, sec. A1] for a discussion of the methodological challenges in synthesizing Tribal grassland goals and information needs and how the challenges are addressed.)

State Agencies

Each of the seven States in the North Central region has a department for fish and wildlife management: Colorado Parks and Wildlife, Kansas Department of Wildlife & Parks, Montana Fish, Wildlife & Parks, Nebraska Game and Parks Commission, North Dakota Game and Fish, South Dakota Game, Fish and Parks, and Wyoming Game and Fish Department. The State agencies have key roles in grassland **conservation** and **reconstruction**. These agencies often work in partnership with Federal and Tribal agencies, NGOs, and private landowners. There are also efforts to work across State agencies, for example, the Western Grasslands Initiative (Western Association of Fish and Wildlife Agencies [WAFWA], 2011), which aims to conserve 3.6 million acres of additional grasslands in 11 Western States by working with stakeholders across those States to enhance, restore, and protect "habitats through the use of conservation easements, incentives, stewardship programs such as 'grass banking,' best management practices such as controlled burns and managed grazing, and acquisition" (WAFWA, 2011, p. 13). However, there is also a need for increased communication among State agencies, and many agencies expressed interest in learning more about successful conservation and climate change adaptation efforts in other States (Ernest Johnson, 2020; Yocum and others, 2023). When interagency planning does occur, it mostly revolves around issues of water resources, agriculture, energy development, transportation, infrastructure, housing, and urbanization (Ernest Johnson, 2020). State agencies also reported that there was more time devoted to planning for adaptation and insufficient time or capacity dedicated to implementing climate adaptation (Ernest Johnson, 2020).

Each State is congressionally mandated to create a State wildlife action plan, which identifies species of greatest conservation need and identifies habitats for priority action. A full list of these species for all seven States in the North Central region is available in Yocum and others (2023). In addition to the species of greatest conservation need, other grassland species of interest across the States in the North Central region include *Cynomys ludovicianus* (black-tailed prairie dog), *Tympanuchus pallidicinctus* (lesser prairie-chicken), *Vulpes velox* (swift fox), *Athene cunicularia* (burrowing owl), *Charadrius montanus* (mountain plover), *Buteo regalis* (ferruginous hawk), *Buteo swainsoni* (Swainson's hawk), and *Lanius ludovicianus* (loggerhead shrike; WAFWA, 2011).

A 2020 national survey queried State fish and wildlife management agencies on climate change adaptation actions, climate change-related concerns, barriers to climate change adaptation, where they find climate change information, and climate change information needs (Ernest Johnson, 2020). For all States in the North Central region (except for Colorado because they did not respond to the survey), 90 percent of respondents observed impacts from climate change, and 80 percent reported that their State agency had been directly impacted by climate change; however, only one-third reported that their agencies had taken direct action or adjusted regulations in response to climate change impacts (Ernest Johnson, 2020). State agencies have cited lack of funding, lack of capacity, and lack of agency leadership as barriers to climate change adaptation (Ernest Johnson, 2020; Yocum and others, 2023). Although the primary concern across all States was the loss, **fragmentation**, and degradation of habitats (WAFWA, 2011; Yocum and others, 2023), in Western States, climate change-related concerns included, in order from most concerning to least were drought and the changing amount or timing of precipitation, increasing temperatures, changing fire regimes, loss of snowpack, increases in extreme weather events, and increased flooding (Ernest Johnson, 2020). Western State agencies top concerns regarding the impacts of these changes in order from most concerning to least concerning were changes in population size, species distribution, **invasive species**, productivity, biodiversity, phenology, and commercial or recreational opportunities

(Ernest Johnson, 2020). State agencies wanted additional information on projected changes to habitats; more baseline information on species life cycles; and compound impacts of climate change, energy development, invasive species, land-use change, and development on grassland ecosystems (WAFWA, 2011; Ernest Johnson, 2020). Additionally, State agencies requested additional opportunities for training and capacity building to assess climate impacts and learn to apply climate change information and use available tools (WAFWA, 2011; Ernest Johnson, 2020). A list of best management practices under future climate conditions was also requested (WAFWA, 2011; Ernest Johnson, 2020) Additional information and specific research needs are available in appendix B1.

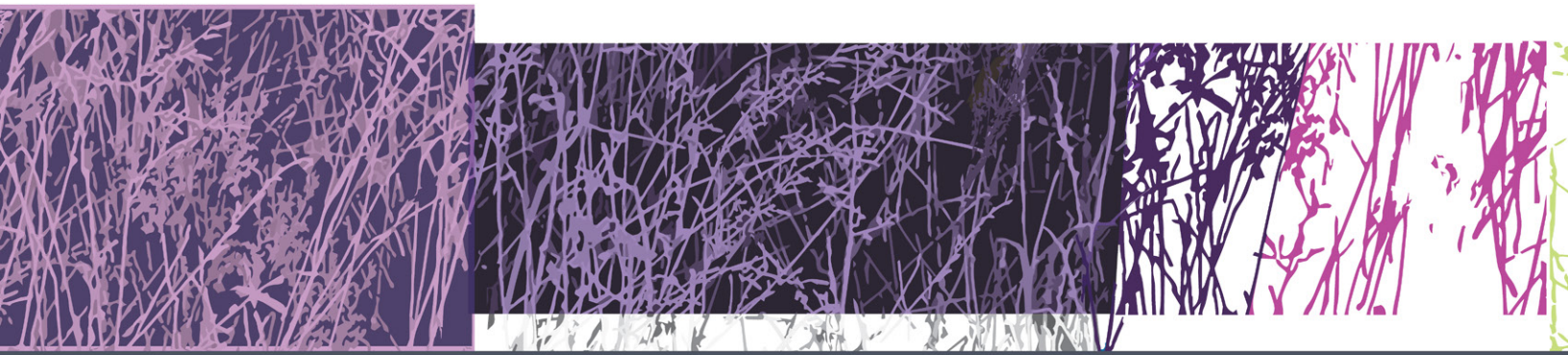
Nongovernmental Organizations and Partnerships

Outside of Federal, State, and Tribal agencies, NGOs, and partnerships have an important role in conservation and often serve as facilitators in collaborations across government agencies, conservation NGOs, and private landowners. NGOs and partnerships complement Federal and State agencies in many of their strengths. They are often smaller organizations that can be more flexible and take action more quickly than government agencies on short-term opportunities or challenges. They can also help maintain focus and efforts on long-term goals because they may be less affected by the shifting budgets and priorities that affect government agencies with new administrations (although budgetary uncertainty may occur from year-to-year). Sometimes NGOs and partnerships can serve as important checks and balances on government agencies, which can be important for promoting science-driven decisions for natural resources conservation. NGOs may also be better received by the public in areas where government mistrust is high. Finally, NGOs and formalized partnerships can more easily work across State and Federal boundaries and facilitate collaboration on conservation challenges that must be addressed at a regional scale.

Many NGOs and formal partnerships work in the grasslands of the North Central region. Two sections describe the way in which one NGO—"The Nature Conservancy" (sec. B14)—and one type of formalized partnership—"Migratory Bird Joint Ventures" (sec. B15)—address conservation issues in the grasslands of the North Central region. These organizations serve as examples for the types of management issues and information needs NGOs and formalized partnerships face, although other organizations and partnerships may have unique management issues and science needs.

Private Landowners

The North Central Climate Adaptation Science Center (NC CASC) recognizes the importance of private landowners for grassland conservation across the North Central region primarily because of the proportion of land held in private ownership. The NC CASC indirectly serves private landowners by providing relevant climate science and tools to the Federal, State, and Tribal agencies, and NGOs that partner with private landowners on grassland conservation and management; however, the NC CASC does not directly provide technical or financial service to private landowners. Furthermore, the data collection and analysis methods used to develop this report were not conducive to a thorough consideration of private landowners' grassland management goals, challenges, and information needs (refer to Miller Hesed and Yocum, 2026, sec. A1). Additional discussion of conservation on privately managed lands can be found in the "Grassland Management Goals, Challenges, and Information Needs" section in Miller Hesed and Yocum (2026, sec. A3).



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A pasture at the Grant-Kohrs Ranch National Historic Site (Photograph by M. Surber, National Park Service).

Section B1.
Bureau of Land Management

By Christine D. Miller Hesed[1] and Sarah Jaffe[2]

Background

An executive action in 1946 established the Bureau of Land Management (BLM) within the U.S. Department of the Interior by combining the General Land Office and the Grazing Service. The Federal Land Policy and Management Act (U.S. Public Law 94–579), which sets the primary direction for the BLM, was passed by the U.S. Congress in 1976 and established the multiple use mandate for the bureau. The BLM operates with a mission to "sustain the health, diversity, and productivity of public lands for the use and enjoyment of present and future generations" (BLM, 2021c). The BLM is tasked with managing public lands to support a variety of economic activities, including energy development, livestock grazing, mineral extraction, timber harvesting, and recreation, while also maintaining natural, cultural, and historical resources for present and future generations (BLM, 2021c). In addition to the BLM national headquarters, the BLM is organized into State, district, and field offices. Within the **North Central region**, the BLM has 3 State offices, 4 district offices, and 12 field offices that manage **grassland** acres (table B1).

Grassland Management

The BLM manages about 9.5 million acres in the **North Central Grassland Ecoregions** (table B2). As a bureau with a mandate to manage land for "multiple use and sustained yield" (BLM, 2021c), the BLM uses various management actions to balance human use of grasslands and **protection** of valuable ecosystem services and species. Because the BLM is managing for resource use and protection, a typical BLM management document considers how its actions will affect many aspects of the grassland system, including:

1. Physical resources (including air quality, soil, water, and cave and karst resources);
2. Mineral resources (including locatable and salable minerals, coal, oil, and gas);
3. Fire and fuels management (wildfire and prescribed fire);
4. Biological resources (including grassland and shrubland communities, vegetation, riparian and wetland resources, **invasive species** and pest management, fish and wildlife resources, and special status species);
5. Heritage and visual resources (including cultural, paleontological, and scenic resources);
6. Land resources (including forest products, lands and realty, renewable energy, rights of way, travel, recreation, lands with wilderness characteristics, and livestock grazing management);
7. Special designations (areas of critical environmental concern, wilderness study areas, scenic byways, and wild and scenic rivers); and
8. Socioeconomic resources (including social and economic conditions, health and safety, environmental justice, and Tribal treaty rights [BLM, 2015a, b]).

Because of the "multiple use and sustained yield" mandate, the BLM has a long history of developing management plans that consider conflicts between multiple management goals. For example, plans address many tradeoffs, including balancing oil and gas leasing and development with protection of wildlife habitat; reducing conflict between livestock grazing

Table B1. The Bureau of Land Management offices managing grassland in the North Central region, not including offices managing land in mountain ecoregions.

State office	District office	Field office
Colorado	Rocky Mountain	Royal Gorge
Montana/Dakotas	North Central Montana	Havre
Montana/Dakotas	North Central Montana	Malta
Montana/Dakotas	North Central Montana	Glasgow
Montana/Dakotas	North Central Montana	Lewistown
Montana/Dakotas	Eastern Montana/Dakotas	Billings
Montana/Dakotas	Eastern Montana/Dakotas	Miles City
Montana/Dakotas	Eastern Montana/Dakotas	North Dakota
Montana/Dakotas	Eastern Montana/Dakotas	South Dakota
Wyoming	High Plains	Buffalo
Wyoming	High Plains	Newcastle
Wyoming	High Plains	Casper

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and protection of sensitive watersheds; determining how much of each wilderness study area should be recommended for wilderness designation; identifying what public land should be sold, retained, and studied; and establishing what areas should be further considered for coal leasing (BLM, 2015a, b). In addition to balancing these often-competing goals on a multidecade basis, the BLM may also revise specific aspects of their management plans to account for new pressures and goals, such as increased public use (BLM, 2008, 2020) or a new national policy focus on renewable energy development (BLM, 2015a, 2020).

Many BLM management actions are focused on preventing grassland degradation while also allowing for use of the land (for example, grazing, mineral development, and recreation). Specific rangeland health standards (that is, desired conditions) and guidelines (that is, management techniques or practices) have been developed for BLM regions (for example, BLM, 1997). Key areas of grassland management for the BLM include (1) designating special management areas in which the grassland is not permitted to be converted to other uses, (2) management of herbaceous invasives, (3) grazing management, and (4) managing for species of greatest **conservation** need.

Designation of Special Management Areas

A key mechanism by which the BLM manages land for multiple uses and sustained yield is by designating areas for special management, which can be done in several different ways. The BLM, other Federal and State agencies, or the public may nominate an area as an area of critical environmental concern for its cultural, natural, historical, or scenic value. The BLM evaluates these nominations and designates them as "areas of critical environmental concern" if special management attention is needed to protect the area's value of significance (BLM, 1994, 2015b, 2020). Other natural areas that are sufficiently large may be designated as "lands with wilderness characteristics" to be managed for the provision of primitive recreation or solitude by closing the area for motorized use; closing the area to salable mineral development; excluding right-of-way; and prohibiting renewable energy development, commercial woodcutting, and all other surface-disturbing activities that are not compatible with the area's natural values (BLM, 2015a, 2020).

Specific actions can also be excluded from particular BLM lands. For example, renewable energy development has been excluded in the southern Big Horn Mountains in Wyoming (BLM, 2015a). Areas can also be designated for the avoidance or exclusion of transportation or utility corridor development (BLM, 2015b). Designation of important habitat areas is another way in which the BLM can prevent certain activities. For example, in the BLM's approach to managing *Centrocercus urophasianus* (greater sage-grouse), areas classified as "general habitat management areas" have some restrictions on allowable activities, whereas areas classified as "priority habitat management areas" have even more restrictions on what activities are allowed (BLM, 2015b, 2021a).

Herbaceous Invasive Species Management

The BLM uses integrated pest management (that is, using biological, physical, chemical, and cultural tools) to prevent the introduction and spread of invasive species and noxious weeds (BLM, 2015b, 2019). Maintaining, enhancing, and restoring native grassland species to decrease opportunities for invasive species establishment is another key approach to the BLM's invasive species management (BLM, 2021b). Wildfire, prescribed fire, and prescribed grazing are used as tools to help promote biodiversity of native species and control invasives (BLM, 2021b).

Table B2. North Central Grassland Ecoregion acres managed by the Bureau of Land Management.

Ecoregion[1]	Land managed by the Bureau of Land Management, in acres							
	Montana	Wyoming	Colorado	North Dakota	South Dakota	Nebraska	Kansas	Total
Tallgrass	0	0	0	299	0	0	0	299
Northern Mixed Grass[2]	466,668	7,910	0	21,898	122,380	1,273	0	620,129
Central Mixed Grass	0	0	35	0	1,991	3,377	1	5,403
Shortgrass	0	10,747	109,125	0	169	454	11	120,507
Sagebrush–Grassland Ecotone	7,013,780	1,546,476	2,667	37,099	156,594	515	0	8,757,131
Total	**7,480,453**	**1,559,892**	**109,160**	**59,297**	**280,007**	**5,619**	**12**	**9,494,440**

[1]Acreages include waterbodies within grassland ecoregions. Acreages are derived from the Protected Areas Database of the United States (U.S. Geological Survey Gap Analysis Project, 2020) and the development of ecoregions is defined in Miller Hesed and Yocum (2026), figure A5. Refer to section A1 in Miller Hesed and Yocum (2026).

[2]The acreage for the Northern Mixed Grass Ecoregion excludes that which falls within the Sagebrush–Grassland Ecotone.

Grazing Management

Livestock grazing is one of the primary uses of BLM grasslands. The BLM strives to manage grazing sustainably to maintain local economic benefits and protect resource values while simultaneously maintaining or improving grassland health (BLM, 1994, 2015b, c) and managing land in a way that is beneficial for grasslands. The BLM's national rangeland health standards and guidelines (BLM, 2001) include considerations of soil quality, erosion, and compaction (BLM, 2015b); water quality (BLM, 1997); and habitat for federally listed plant and animal species (BLM, 2015c). The BLM implements short-term grazing reductions as needed during drought or other emergencies and by assigning management categories (which help determine intensity of grazing, location of monitoring, and allocation of range improvement funds) to individual grazing allotments according to the resource conditions (BLM, 1994).

Managing for Species of Greatest Conservation Need

Much of the BLM grasslands in the North Central region provide habitat for animal and plant species of greatest conservation need, including the *Falco peregrinus* (Peregrine falcon), *Haliaeetus leucocephalus* (bald eagle), *Aquila chrysaetos* (golden eagle), migratory birds, *Cynomys gunnisoni* (Gunnison's prairie dog), *Vulpes velox* (swift fox), *Anaxyrus boreas* (western toad), *Corynorhinus townsendii* (Townsend's big-eared bat), *Eutrema penlandii* (Rollins; alpine fen mustard; U.S. Department of Agriculture Forest Service, undated), and *Eriogonum brandegeei* (Rydb; Brandegee's buckwheat; BLM, 2015b, c, 2019). The BLM field offices manage wildlife habitat using monitoring and inventory data and landscape-scale datasets to assess habitat quality and prioritize habitat **enhancement** projects (BLM, 2018, 2019). Vegetation treatments may be used to offset human impacts on key habitat (BLM, 2019). The BLM field offices may also work to promote public awareness of habitat conservation, management, and ecology (BLM, 2015b).

The BLM field offices in the North Central region put considerable effort into managing habitat for the greater sage-grouse (BLM, 2018, 2021a). Greater sage-grouse—found in the Sagebrush–Grassland Ecotone—have disappeared from most of their former range because of habitat loss and are continually threatened by the spread of invasive species and **fragmentation** and degradation of habitat from energy development. Specific strategies to protect, conserve, and enhance greater sage-grouse habitat vary by the particular issues for a field office, but may include maintaining sagebrush cover at or near the full potential of each ecological site (BLM, 2018) or establishing human disturbance or energy and mining facility density caps (BLM, 2015b). However, planning, coordinating, and monitoring for greater sage-grouse occurs at the regional and national levels (BLM, 2021b, c, 2022).

Emerging Challenges and Opportunities

In many ways, the grassland management challenges the BLM faces mirror challenges the North Central region faces: finding a way to balance human resource use and protection of grassland health, biodiversity, and resilience in ways that are locally relevant and regionally strategic while climate change increases uncertainty and the variability of conditions. Toward addressing that challenge, the BLM has begun developing landscape-level strategies to more effectively integrate conservation and development decision making (SAIC, 2012; BLM, 2015d, p. 1; Reese and others, 2017). Implementing regional strategies within the BLM's current (2025) structure—which is focused on programs and field office units—could be another challenge.

The specific challenges that climate change may pose for BLM management of grasslands includes shifting habitat areas, impacts on forage in grazing allotments, and managing for carbon storage (BLM, 2015d). These challenges likely will need to be addressed while BLM continues to account for impacts from wildlife, agriculture, invasive species, insect outbreak and disease, energy development, and urban and exurban growth (SAIC, 2012, p. ES–2). Efforts to include climate change to inform formulation of alternatives and need for adaptive management have thus far been denied by the U.S. Congress (Glicksman, 2017).

Information Needed

Given the breadth of BLM management objectives, their need for scientific information spans many topics (refer to Miller Hesed and others [2023] for a summary table of the relevance of synthesized information needs and app. B1 for BLM-specific information needs as articulated in grassland management-related documents); however, two general categories of information may be most relevant to the BLM within the context of climate change. First, there is a need for further development and refinement of landscape-level analyses to identify areas that will be suitable for various uses (including wildlife habitat conservation, livestock grazing, and renewable energy development) now and into the future. Second, there is a need for additional analysis of how grasslands can best be managed for carbon storage within a multiple use context.

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A herd of bison at the Wind Cave National Park in South Dakota (Photograph by National Park Service).

Section B2.
U.S. Fish and Wildlife Service

By Heather M. Yocum,[1] Christine D. Miller Hesed,[1] Aparna Bamzai-Dodson,[2] and Sarah Jaffe[3]

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We would like to thank Ronald Pritchert (U.S. Fish and Wildlife Service) for his edits and additions to this section.

Background

The U.S. Fish and Wildlife Service (FWS) mission is rooted in Federal efforts to study and address concerns about national fish and wildlife species that date back to the late 19th century. In 1871, the U.S. Congress established the Commission of Fish and Fisheries (a predecessor to the FWS), which had a mission to study and seek solutions to address declining fish populations (FWS, 2021f). Later, in 1896, the Division of Biological Survey was formed from the Division of Economic Ornithology and Mammalogy and renamed the Bureau of Biological Survey in 1905. Then, in 1940, the FWS was established when the Bureaus of Fisheries and Biological Survey were combined under the U.S. Department of the Interior (FWS, 2021f).

The FWS mission is to "work with others to conserve, protect, and enhance fish, wildlife, plants and their habitats for the continuing benefit of the American people" (FWS, 2021g). This primary focus on **conservation** and management of natural resources for the public makes the FWS unique among Federal agencies (FWS, 2021a). The FWS does allow for other land uses, such as recreation, timber cutting, and oil and gas drilling, but only as long as these land uses are compatible with the individual FWS unit's intended purpose. On some lands administered by the FWS, there are pre-existing property rights (for example, subsurface rights, easements, and rights-of-way), which could conflict with the FWS mission. Thus, the FWS may attempt to acquire these rights from willing sellers (Vincent, Bermejo, and Hanson, 2020, p. 5).

The FWS is also responsible for implementing key environmental laws, including the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.), the Migratory Bird Treaty Act of 1918 (16 U.S.C. 703–712 et seq.), the Pittman–Robertson Wildlife Restoration Act (16 U.S.C. 669 et seq.), and the Dingell–Johnson Sport Fish Restoration Act (16 U.S.C. 777 et seq.) to support wildlife and sportfish **restoration**; the Lacey Act (18 U.S.C. 42 et seq.), which prohibits illegal trafficking of wildlife; the North American Wetlands Conservation Act (16 U.S.C. 4401 et seq.) to promote voluntary conservation of wetlands on privately owned land; and the Marine Mammal Protection Act (16 U.S.C. 1361–1407 et seq.; FWS, 2021a). Implementing these laws includes the following:

- Working to protect and recover threatened and endangered species;
- Leading scientific research to provide information informing all Endangered Species Act listing decisions;
- Working with other Nations (particularly Canada and Mexico) to monitor and manage migratory birds;
- Restoring nationally significant fisheries;
- Enforcing Federal wildlife laws and regulating international wildlife trade;
- Conserving and restoring fish and wildlife habitat;
- Managing and distributing more than a billion dollars each year to States, territories, and Tribal nations for conservation through the State Wildlife Grant and other programs;
- Helping foreign governments conserve wildlife through international conservation efforts; and
- Fulfilling the agency's Federal Tribal trust responsibility (FWS, 2021a).

As of 2018, the FWS manages about 1,740,000 acres of federally owned land and wetlands within the grassland **ecoregions** across the seven States in the **North Central region** (Vincent, Bermejo, and Hanson, 2020, p. 9–10; FWS, 2021j; table B3). Most of this land is in the National Wildlife Refuge System (NWRS; 16 U.S.C. 668(dd)), which includes wildlife refuges, national monument areas, waterfowl production areas, and wildlife coordination units. Additional land is managed by the FWS as administrative sites, National Fish Hatcheries, or lands that the FWS manages on behalf of another agency (Vincent, Bermejo, and Hanson, 2020, p. 5). The FWS has eight regions of operation (fig. B1); all the States in the North Central region and Utah are in the FWS Mountain–Prairie region (also known as Region 6; FWS, 2021h).

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Table B3. North Central Grassland Ecoregion acres managed by the U.S. Fish and Wildlife Service.

Ecoregion[1]	Land managed by the U.S. Fish and Wildlife Service, in acres							
	Montana	Wyoming	Colorado	North Dakota	South Dakota	Nebraska	Kansas	Total
Tallgrass	0	0	0	42,350	82,365	8,929	25,527	159,171
Northern Mixed Grass[2]	76,813	0	0	454,102	106,400	134	0	637,450
Central Mixed Grass	0	0	0	0	16,572	206,060	22,280	244,911
Shortgrass	0	0	20,115	0	0	2,745	0	22,859
Sagebrush–Grassland Ecotone	673,693	0	1,278	328	0	0	0	675,299
Total	**750,507**	**0**	**20,115**	**496,780**	**205,337**	**217,867**	**47,807**	**1,738,413**

[1]Acreages include waterbodies within grassland ecoregions. Acreages are derived from the Protected Areas Database of the United States (U.S. Geological Survey Gap Analysis Project, 2020) and the development of ecoregions is defined in Miller Hesed and Yocum (2026), figure A5. Refer to section A1 in Miller Hesed and Yocum (2026).

[2]The acreage for the Northern Mixed Grass Ecoregion excludes that which falls within the Sagebrush–Grassland Ecotone.

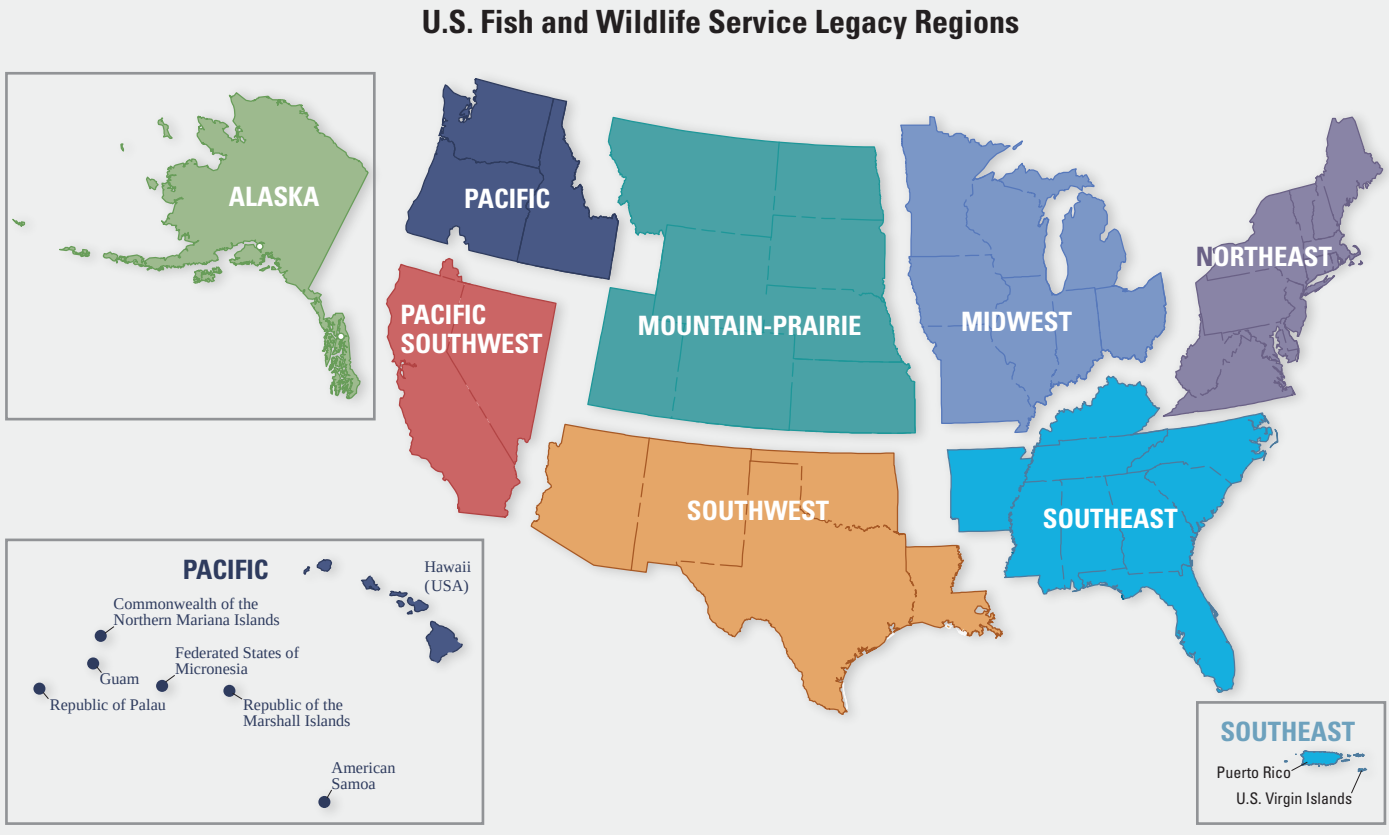

Figure B1. Schematic figure depicting the U.S. Fish and Wildlife Service eight legacy regions of operation across the United States and associated areas (modified from U.S. Fish and Wildlife Service [2022]).

Grassland Management

The FWS manages grasslands across the North Central region under special management areas such as the NWRS and Waterfowl Production Areas, by creating permanent and temporary easements on privately owned land, and administering programs to promote conservation, monitor water quality, and protect key species.

Designation of Special Management Areas

The FWS is responsible for the management and oversight of refuge area units through the NWRS, and conserves "areas for the **protection** and conservation of fish and wildlife that are threatened with extinction, wildlife ranges, game ranges, wildlife management areas, or waterfowl production areas" (16 U.S.C. 668(dd)). Individual units are created by Congressional legislation, Executive Order, or administrative action, each of which then reflect the specific intended purpose and goals of that unit. In the grasslands of the North Central region, the FWS manages a network of 49 National Wildlife Refuges and more than 2,800 Waterfowl Production Areas totaling almost 750,000 acres of waterfowl breeding and nesting areas. For example, in the Prairie Pothole region (PPR)—which includes parts of Montana, North Dakota, South Dakota, Nebraska, Minnesota, and Iowa (Mushet, 2016; Yocum and Ray, 2019)—FWS manages only about 12 percent of the lands but supports 24 percent of the duck breeding population for 13 species (Johnson and others, 2010; South Dakota Game, Fish and Parks, 2014; Dyke, Johnson, and Isakson, 2015; Prairie Pothole Joint Venture, 2017a, b; McKenna and others, 2021). In addition, Chase Lake National Wildlife Refuge, in the PPR of North Dakota, supports one of the largest breeding colonies of *Pelecanus erythrorhynchos* (American white pelicans) in North America (FWS, 2021d).

Additionally, FWS is responsible for designating critical habitat areas for endangered and threatened species, primarily at the time of their listing. Critical habitat areas include places whose biological or physical characteristics make them essential to the conservation of the species or that warrant special management considerations or protections. Critical habitat designations do not prevent all further development; they only prevent actions that will destroy or adversely modify critical habitat (FWS, 2021e). Additional information on critical habitat locations are also available from the FWS Environmental Conservation Online System (https://ecos.fws.gov/ecp/report/table/critical-habitat.html) and as geographic information system (GIS) data in ArcGIS (https://hub.arcgis.com/maps/fws::fws-hq-es-critical-habitat/about).

Easements

The FWS uses perpetual conservation easements with willing private landowners (present and future) to purchase a limited set of rights to protect **grassland** and wetland habitat acres (Baier, 2020). Grassland easements cannot be cultivated, and restrictions are placed on the timing of mowing, haying, and grass seed harvesting to maintain permanent vegetative cover for nesting species (FWS, 2020a). Wetland easements cannot be drained, filled, leveled, or burned, but they can be farmed, grazed, or hayed when they naturally dry (FWS, 2008). For example, the use of easements is a major conservation action for the FWS, and FWS administers more than 5,000 grassland easements totaling about 1.8 million acres and more than 22,000 wetland easements totaling about 1.6 million acres in the PPR alone (R. Pritchert, FWS, written commun., 2021) These conservation easements amount to 99 percent of all mapped conservation and **ranchland** easements in North Dakota and South Dakota. As of 2021, there is a waiting list of landowners interested in participating in conservation easements and related programs (North Dakota Game and Fish Department, oral commun., 2014; R. Pritchert, FWS, written commun., 2021). The annual sale of Federal duck stamps, which must be purchased by all waterfowl hunters, funds the purchase of easements (FWS, 2018).

Promoting Conservation on Private Land

The FWS helps support conservation, restore degraded grasslands, and prevent grassland **conversion** on private rangeland through the Partners for Fish and Wildlife Program, which "provides technical and financial assistance to landowners interested in restoring and enhancing wildlife habitat on their land" (FWS, 2021k, l). In 2020, the program invested nearly $1.9 million and leveraged more than $11.5 million in partner contributions in the North Central region States (table B4). This investment supported private landowners in enhancing and restoring more than 190 miles of streams and rivers, more than 198,000 upland acres, nearly 7,800 wetland acres, and 29 fish passage structures (FWS, 2021l). Conservation practices supported by Partners for Fish and Wildlife include mechanical, chemical, grazing, and prescribed fire techniques to combat woody encroachment; implementation of rotational grazing to promote biodiversity; enrollment in conservation easements; and provision of decision support tools to simultaneously promote habitat conservation and profitability of working lands (FWS, 2021l).

Invasives Species Management and Prescribed Disturbance

The Federal Insecticide Fungicide and Rodenticide Act (7 U.S.C. 136r–1) and U.S. Department of the Interior Integrated Pest Management policy (U.S. Department of the Interior, 2007) mandated that the FWS combat the spread of **invasive species** using Integrated Pest Management. The FWS works to prevent and control the spread of woody encroachment and invasion of herbaceous species on FWS lands using a combination of physical, chemical, and biological control methods and prescribed fire and grazing. The FWS promotes prescribed fire and grazing on private lands through the Partners for Fish and Wildlife Program (FWS, 2021l, k).

The FWS uses prescribed grazing as a tool to manage and improve wildlife habitat in select National Wildlife Refuges and waterfowl production areas. Prescriptive grazing is "the planned application of livestock grazing at a specified season, duration, and intensity to achieve specific vegetation objectives that are designed to meet the broader habitat and wildlife goals" (FWS, 2021c). Grazing is a component of the historical disturbance regimes, which created the grassland **prairies** in the North Central region, and the FWS uses grazing to control invasive plant species, reduce woody encroachment, and promote plant communities and habitat that will support animal species of interest. The FWS determines goals for habitat management and then determines the time and number of grazing animals needed to reach those goals by issuing grazing permits on an annual basis (FWS, 2021c). For example, in the North Central region, FWS allows grazing for 21,500 animal unit months on 450,000 acres at the Charles M. Russell National Wildlife Refuge in Montana. National Wildlife Refuges can also be opened to grazing as emergency relief to ranchers; for example, after the historical drought in 2016, the Charles M. Russell National Wildlife Refuge was opened for public grazing (U.S. Department of the Interior, 2017).

Water Quality and Quantity Management

The amount, timing (that is, seasonality), and quality of water flows in rivers and streams are important to terrestrial and aquatic plant and animal species, and the FWS monitors and manages water in the NWRS. The FWS collaborates with the Bureau of Reclamation, U.S. Army Corps of Engineers, private landowners, and other water managers to maintain quantity, quality, and timing of ecological flows to maintain habitats and determine instream ecological flow requirements to support breeding and other life cycle requirements for key terrestrial and aquatic species. Many aquatic species live in intensely managed river systems whose natural flows have been severely disrupted because of human use of water; infrastructure for water management like canals, dams, and reservoirs; and changing groundwater levels. The FWS establishes minimum ecological flows to maintain the habitat for some aquatic species such as *Notropis topeka* (topeka shiner) and *Macrhybopsis tetranema* (peppered chub), and mandates ecological releases from Bureau of Reclamation dams. If the species is endangered, the ecological water rights are considered before any other senior water rights holders.

The FWS includes a branch of air and water resources that "provides national coordination and support for the Refuge System's water resources through technical guidance and the development of data management tools" (FWS, 2021n). The FWS oversees water resource inventory and assessments to provide "a professional assessment of a refuge's water resources, including needs and threats as well as recommendations to address specific issues" (FWS, 2021n) and support planning for "future impacts to NWRS water resources" (FWS, 2012). The FWS also carries out the National Wetlands Inventory, which is a publicly available resource to track and map the distribution, type, status, and trends of wetlands in the United States (FWS, 2021i). Most of the information in the National Wetlands Inventory is from the 1980s and is being updated at a rate of 2 percent per year by the FWS and outside partners (FWS, 2021i).

Table B4. Partners for Wildlife investment and return in North Central region States.

[Data from U.S. Fish and Wildlife Service (2021l). Values include investments in areas outside of the grassland ecoregions in Colorado, Montana, and Wyoming. PFW, Partners for Wildlife; Partner contributions leveraged in dollars; —, no data]

State	PFW investment	Partner contributions leveraged	Stream and river miles	Upland acres	Wetland acres	Fish passage structures
Colorado	$175,597	1:4.6	3.51	2,457	977	4
Kansas	$284,376	1:7.6	59	18,896	259	—
Montana	$504,586	1:4	117	54,152	1,458	8
Nebraska	$300,060	1:9.2	5.79	32,539	889	14
North Dakota	$102,389	1:23	4.67	39,634	2,441	—
South Dakota	$274,956	1:7	—	45,190	1,379	—
Wyoming	$233,871	1:7.8	1.85	5,587	375	3
Total	**$1,875,835**	**11:9**	**191.82**	**198,455**	**7,778**	**29**

[1]Average ratio of Partners for Wildlife to partner contributions.

Management of Species of Greatest Conservation Need

The FWS is one of two Federal agencies with the authority to administer and enforce the Endangered Species Act, which seeks to prevent the extinction and assist in the recovery of critically imperiled species (the other is the National Marine Fisheries Service [also known as National Oceanic and Atmospheric Administration Fisheries], which is responsible for marine and anadromous species). Section 4 of the Endangered Species Act describes many particulars about the listing of a species, including the process by which a species may be directly considered for listing, how an individual or organization can petition for a species to be considered, the rulemaking procedures that the FWS must follow to support a determination, and the public notice and review process the FWS must use. In addition, Section 4 describes many parts of FWS species recovery efforts, including the identification and designation of critical habitat, creation of a species recovery plan, and factors for downlisting or delisting.

The **North Central Grassland Ecoregions** are home to many federally listed endangered and threatened species. The *Mustela nigripes* (black-footed ferret) is a federally endangered mammal that has a historical native range across the North Central grasslands (FWS, 2021b). A FWS 5-year review completed in 2020 reported that the black-footed ferret is in danger of extinction throughout all of its range because of the direct and indirect effects of sylvatic plague, lack of purposeful management of *Cynomys ludovicianus* (black tailed prairie dogs), which the black-footed ferret relies on for food and habitat, poisoning of prairie dogs at black-footed ferret reintroduction sites, the increasing frequency and severity of droughts caused by climate change, and declining genetic fitness (FWS, 2020b). The North Central region is also used as breeding habitat and stopover habitat in the spring and fall by migratory birds, such as the federally endangered *Grus americana* (whooping crane; FWS, 2021p) and *Charadrius melodus* (piping plover; FWS, 2021m). Whooping cranes have a historical range covering 32 States. As of 2021, only three whooping crane populations exist in the wild (a population that migrates from Alberta, Canada, to Texas; a population that migrates between Wisconsin and Florida; and a nonmigratory population in central Florida) and destruction of prairie nesting habitat as one of the key threats to their survival (FWS, 2021p). Additionally, this region is home to listed plant species, such as the federally threatened *Platanthera praeclara* Sheviak and M.K. Bowles (western prairie fringed orchid; FWS, 2021o). The FWS works to sustain and enhance this orchid's habitat through carefully prescribed burning and grazing.

Public Outreach and Education

The FWS engages with and educates the public about wildlife management, conservation, and endangered and threatened species in many different ways. National Wildlife Refuges are open to visitors, and many refuges have visitor centers where the public can access informational brochures, view educational exhibits, or talk to knowledgeable staff about wildlife conservation. National Wildlife Refuges also offer opportunities for the public to view wildlife by providing hiking trails, guided driving tours, photography blinds, and observation locations with spotting scopes. The FWS also maintains educational websites that include stories about wildlife conservation, lessons on wildlife biology, wildlife webcams, coloring pages, puzzles, videos, and podcasts (FWS, 2021j).

The FWS operates the National Conservation Training Center (NCTC) to provide conservation training and education to FWS employees and conservation partners (FWS, 2021a). One objective of the NCTC is to "work within the Service and with partners to offer a continuum of programs for young people throughout their developmental process that begins with a foundation of outdoor engagement, and continues with education opportunities that ultimately build support for and interest and participation in natural resource conservation" (FWS, 2015, p. 6). Programs related to this objective include the Directorate Fellows Program, which offers paid fellowships for graduate students to work on conservation projects, the Native Youth Community Adaptation and Leadership Congress, which allows Tribal high school students to learn about climate change and develop strategies to address its impacts in their communities, and the Federal Junior Duck Stamp Program, which allows students in grades K–12 to explore the natural world and learn about biology and wildlife management principles. The FWS also works with youth organizations to develop academic, leadership, and citizenship skills through field trips, environmental stewardship projects, and other activities.

Coordinating Collaboration Across Agencies and Organizations

The FWS coordinates management actions with many different agencies and organizations, for example, under the Endangered Species Act. Section 7 of the Endangered Species Act requires all Federal agencies to cooperate in endangered and threatened species conservation by consulting with the Secretary of the Interior (through the FWS) on any actions that may either have a direct effect on a listed species or on critical habitat. If an action is likely to affect a listed species, then the acting agency must prepare a biological assessment that identifies all listed species in the proposed project area, the likely impacts of the project on those species, and any conservation measures that the agency plans to take to minimize or offset those impacts. If the biological assessment concludes that a project is likely to adversely affect a listed species, then the FWS must formally issue a biological opinion as to whether the project will jeopardize the continued existence of the species or destroy or adversely modify designated critical habitat. In an analysis of 88,290 consultations carried out between 2008 and 2015, Malcom and Li (2015) found that no projects were stopped as a result of jeopardy or destruction and no adverse modification findings issued because of the viability of reasonable and prudent alternative actions. The success of the Endangered Species Act is a result of the FWS working with many partners, including project managers across agencies and with private landowners.

Using New Ways of Thinking

The FWS has fully adopted some new approaches and frameworks for conservation and other new approaches and frameworks are emerging within the agency. For example, the FWS has had success in using adaptive management to meet conservation goals (refer to Williams and others, 2007). The Resist-Accept-Direct (RAD) framework is emerging as a new way of thinking at the FWS (NCTC recently provided RAD framework training for their staff) but it is not yet formally incorporated into official planning processes.

Emerging Challenges and Opportunities

Like other Federal agencies, FWS faces challenges to achieving its grassland management goals. These challenges come from the diverse landscape of Federal agencies that manage the land where plant and animal species are found, from statutory or regulatory requirements that can make it difficult to adapt to climate change, and from the public perceptions of climate change risks. However, these challenges also offer opportunities to enhance and expand on previous grassland conversation successes.

Jurisdiction

The FWS does not manage or have jurisdiction across all the land that priority plant and animal species inhabit, use, or pass through, which adds an additional layer of complexity and can create challenges for fulfilling the FWS mission. This challenge means that the FWS partners with other agencies, private landowners, and nonprofit organizations, to achieve its conservation goals. As wildlife habitat shifts with the impacts of climate change, maintaining and expanding effective partnerships for wildlife conservation will likely become increasingly important.

Flexibility to Adapt Management to Address Climate Change

Some Federal laws, required processes, and responsibilities (for example, the National Environmental Policy Act and Endangered Species Act), which take precedence over other laws, may not allow agencies, like the FWS, enough flexibility to adaptively manage lands under a changing climate (Archie and others, 2012, 2014). For example, the Endangered Species Act is focused on individual species management, although it may be necessary to target conservation on the habitat or landscape scale to promote "healthy, functioning assemblages" to adapt to climate change (National Fish, Wildlife, and Plants Climate Adaptation Network, 2021, p. 50). The RAD framework is an emerging management paradigm in public agencies that helps to detail potential management pathways to deal with ecological change (National Fish, Wildlife, and Plants Climate Adaptation Network, 2021, p. 46).

Public Support for Managing for Climate Risks

Fish and wildlife management practitioners are sensitive to the risks of justifying conservation policies based on climate change information (Yocum and Ray, 2019). Furthermore, many of the most pressing conservation issues are happening on timescales much shorter than climate change (for example, land-use change, habitat loss, degradation, and **fragmentation** and it can be difficult to prioritize climate adaptation in the face of so many critical management issues (Yocum and Ray, 2019). Two of the "biggest hurdles to [climate change adaptation] implementation reported by FWS respondents were lack of perceived importance to public [and] lack of public awareness or demand to take action," (Archie and others, 2012, p. 27).

Information Needed

Numerous scientific questions are highly relevant to the grassland management goals and challenges of the FWS (refer to Miller Hesed and others [2023] for a summary table of the relevance of synthesized information needs and app. B1 for FWS-specific information needs as articulated in reviewed documents); however, three general areas of research may be of greatest relevance to the FWS.

First, as the Nation's premier conservation agency, understanding how climate change will impact species of greatest conservation need is a priority. The FWS requires information about the projected impacts of climate change at relevant scales and guidance on how to apply that information given the uncertainty of future climate change scenarios and impacts on priority habitats and species (Archie and others, 2012, p. 31; Yocum and Ray, 2019). Given that FWS has limited resources to conserve species of greatest conservation need, information to help the agency determine how to prioritize its efforts will be essential. A 2021 report by the National Fish, Wildlife, and Plants Climate Adaptation Network, "Advancing the National Fish, Wildlife, and Plants Climate Adaptation Strategy into a New Decade," recommended that the identification of the following would be useful for prioritizing conservation efforts:

- Areas where priority aquatic and terrestrial habitat overlap,
- Projected changes to species movements under a changing climate,
- Projected changes to plant communities under a changing climate,
- Identifying species that may not be able to migrate to more suitable habitats on their own, and

- Thresholds for identifying when climate refugia could no longer function (National Fish, Wildlife, and Plants Climate Adaptation Network, 2021, p. 64). Additional research assessing climate change impacts on priority species and habitats is also crucial, as is basic ecological and biological research on species life cycles to project potential climate change impacts on priority species. Organizations and State agencies that cooperate with the FWS have also expressed interest in having an updated National Wetland Inventory to inform conservation planning, priority setting, and to track land-use change patterns.

Second, understanding how grassland management can be strategically coordinated across management entities, jurisdictions, and borders is highly relevant for the FWS because the species they need to protect are on lands managed by many different governments, entities, groups, and individuals; in particular, understanding the structural barriers to greater coordination and how they can be overcome. Related assessment of the degree in which agency policies allow FWS flexibility in collaboration and management and where that flexibility might be enhanced is important for effective, coordinated management of climate change impacts.

Finally, understanding how adaptation approaches and frameworks can help contribute to successful management of grasslands amidst climate change could give the FWS additional tools for pursuing their grassland management goals. The "Advancing the National Fish, Wildlife, and Plants Climate Adaptation Strategy into a New Decade" report specifically recommends additional research on

- How the RAD framework applies to specific management questions;
- Identifying barriers, successes, and carrying out useful evaluation measures of adaptation projects and plans;
- Best practices for providing additional climate change adaptation training for staff;
- Management for future ecological conditions;
- How to apply and use monitoring results to inform conservation action, for example by identifying triggers, thresholds, and tipping points with concomitant action(s); and
- Understanding social–ecological–climatological feedback (for example, changes in land use) that may result in new opportunities or challenges to species and land management (National Fish, Wildlife, and Plants Climate Adaptation Network, 2021, p. 64).

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Grassland landscape in Montana
(Photograph by Bureau of Land Management).

Section B3.
National Park Service

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Background

The National Park Service (NPS) is a bureau within the U.S. Department of the Interior (DOI). The Organic Act of 1916 (16 U.S.C. 17 et seq.) established the NPS to conserve, as park units, "the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." The Antiquities Act of 1906 (54 U.S.C. 320301–320303) additionally provides authority to the President of the United States to declare "historic landmarks, historic and prehistoric structures, and other objects of historic or scientific interest" on Federal lands as national monuments. The NPS is organized into multi-State regions that manage individual parks and other important sites, such as battlefields, monuments, and lakeshores. The **North Central region** overlaps with NPS Regional Offices 5 and 7 that cover six DOI Unified Regions (3, 4, 5 and 6, 7, 8). Within the North Central region, the NPS has 35 units that manage **grassland** acres (table B5).

Grassland Management

The NPS manages approximately 304,000 acres of grassland in the North Central region (table B6). All NPS units are required to submit and follow park foundation documents. These documents serve as a basic guideline for a unit's management direction and future planning that adheres to the NPS core mission, laws, and policy. Every unit requires a unique document because each unit was created through different acts of the U.S. Congress. Within these documents is a dynamic portfolio that showcases implementation, comprehensive, and strategic plans; studies; and inventories. These plans, studies, and inventories provide supplemental information to the foundation document (for example, natural resources, business management, and visitor use and experience) and help aid monitoring and management (NPS, 2021a).

Table B5. National Park Service units managing grasslands in the North Central region.

[This table does not include national trails or rivers. NP, National Park; NHS, National Historic Site; NM, National Monument; NHP, National Historical Park; NB, National Battlefield]

State	Park units
Unified Regions 3, 4, 5	
North Dakota	Theodore Roosevelt NP
	Knife River Indian Villages NHS
	Fort Union Trading Post NHS
South Dakota	Badlands NP
	Wind Cave NP
	Jewel Cave NM
	Mount Rushmore National Memorial
	Minuteman Missile NHS
Kansas	Tallgrass Prairie National Preserve
Nebraska	Agate Fossil Beds NM
	Homestead NHP
	Scotts Bluff NM
Montana	Glacier NP
	Big Hole NB
	Fort Union Trading Post NHS
	Grant-Kohrs Ranch NHS
	Little Bighorn Battlefield NM
	Nez Perce NHP
	Yellowstone NP
Unified Regions 6, 7, 8	
Wyoming	Yellowstone NP
	Grand Teton NP
	Devils Tower NM
	Fort Laramie NHS
	Fossil Butte NM
Colorado	Dinosaur NM
	Rocky Mountain NP
	Black Canyon of the Gunnison NP
	Mesa Verde NP
	Great Sand Dunes NP and Preserve
	Bent's Old Fort NHS
	Colorado NM
	Florissant Fossil Beds NM
	Hovenweep NM
	Sand Creek Massacre NHS
	Yucca House NM

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[4]University of Colorado Boulder, Cooperative Institute for Research in Environmental Sciences.

Table B6. North Central Grassland Ecoregion acres managed by the National Park Service.

Ecoregion[1]	Land managed by the National Park Service, in acres							
	Montana	Wyoming	Colorado	North Dakota	South Dakota	Nebraska	Kansas	Total
Tallgrass	0	0	0	0	0	208	53	261
Northern Mixed Grass[2]	19	668	0	3,247	112,466	422	0	116,821
Central Mixed Grass	0	0	0	0	3,591	1,212	680	5,483
Shortgrass	0	0	3,805	0	8,155	5,244	0	17,205
Sagebrush–Grassland Ecotone	28,361	14,106	0	98,475	23,553	0	0	164,495
Total	**28,380**	**14,774**	**3,805**	**101,721**	**147,764**	**7,086**	**733**	**304,264**

[1]Acreages include waterbodies within grassland ecoregions. Acreages are derived from the Protected Areas Database of the United States (U.S. Geological Survey Gap Analysis Project, 2020) and the development of ecoregions is defined in Miller Hesed and Yocum (2026), figure A5. Refer to section A1 in Miller Hesed and Yocum (2026).

[2]The acreage for the Northern Mixed Grass Ecoregion excludes that which falls within the Sagebrush–Grassland Ecotone.

Grassland Protection

The establishment of NPS units has been driven by a number of factors, such as preserving history or the natural landscape that expresses a national heritage (NPS, 2006b). For example, the Tallgrass Prairie National Preserve in Kansas helps protect one of the few sizable patches of the tallgrass **prairie** ecosystem left in the United States. It also serves to preserve the cultural history and legacy of ranching within the Flint Hills (NPS, undated). The NPS recognizes the importance of ecosystem health as an outstanding resource, particularly those areas that have been largely **undisturbed**, such as the wetland vegetation communities in Great Sand Dunes National Park in south-central Colorado (NPS, 2019). The cultural connections, practices, and values of the various native North American Tribes are also important to the management and interpretation of NPS units, such as Devils Tower National Monument and Wind Cave National Park (Schuurman and others, 2019; Runyon and others, 2021). Public enjoyment and scientific study are also relevant factors in determining if an area will be included in the NPS system and how NPS units are managed, such as the reintroduction of *Bison bison* (bison) to areas of an NPS unit (Symstad and others, 2019).

Areas within NPS units may also warrant additional special designations (for example, experimental research areas, wilderness areas, and wild and scenic rivers) that can carry further management requirements or considerations. Designated wilderness areas within the NPS system that meet the criteria of the Wilderness Act (Public Law 88–577; an act to establish a National Wilderness Preservation System for the permanent good of the whole people, and for other purposes) and National Wilderness Preservation System are used to help study wilderness resources and values while also reducing the human effect to such resources. Human use of these areas must preserve the primeval and untouched nature of the resources, affecting a unit's ability to select and implement management actions (for example, wildland fire management; NPS, 2006b). As a result, the wilderness area designation is a further filter through which management goals and actions must be assessed; goals requiring intensive intervention may not be achievable or suitable in these places (Banasiak and others, 2015).

Although coordination with private landowners is not an overall mandate of the NPS, the NPS is responsible for managing livestock grazing on 94 units and several grazing management planning efforts are underway. For instance, Dinosaur National Monument—which has 10 grazing allotments that permit *Bos taurus* (cattle), *Ovis aries* (sheep), and *Equus caballus* (horses)—recently undertook climate change scenario planning in preparation for its grazing management planning process. The NPS units may also manage human-wildlife conflicts, such as *Cynomys* spp. (prairie dog) encroachment onto adjacent private **ranchlands** (NPS, 2007).

Prescribed Disturbance and Managing Invasives

The NPS units with flammable vegetation and regular sources of ignition are required to create a fire management plan in accordance with Federal fire policies and regulations (NPS, 2006b). For NPS units within the **North Central Grassland Ecoregions**, fire management plans often contain information and guidance regarding management of and response to wildland fires, along with planning for and implementing prescribed fires. Historical fire suppression has led to elevated fire risk in some areas (Banasiak and others, 2015) and is leading to management planning and action around fuels management. Prescribed fire is an increasingly common approach used in grasslands to eradicate invasive, nonnative plants and to restore and maintain **native prairie** plant communities (NPS, U.S. Fish and Wildlife Service [FWS], and The Nature Conservancy [TNC], 2006).

Fire plans for NPS units aim to mimic the natural process of wildfires while simultaneously reducing severe, negative effects to NPS resources and facilities. For example, the goal of Theodore Roosevelt National Park Fire Management Plan (NPS, 2004) is to "manage the park as a natural badlands ecosystem influenced by human activities over time, allowing natural processes to occur" while "managing the park's resources associated with Theodore Roosevelt and his life and times in the Badlands." Fire management is an essential tool to combat **invasive species** to achieve this goal of preserving the historical landscape for future generations to enjoy.

Multiple strategies, including current management, with specific goals or outcomes are considered within these fire management plans. Alternative strategies typically focus on park resources and effort, ecological outcomes, or no action. Within these strategies are levels of **protection** that are outlined with defined levels of fire use to restore and perpetuate natural processes (NPS, 2004). The preferred method for fire management takes the best components of each strategy with a focus on ecological impact. Fire suppression can not only enhance risks of catastrophic wildfire but can also reduce the diversity of native plant communities.

All plans heavily rely on consistent monitoring to identify situations that would require a rapid response and wildland fire predictions (through wildland fire situation analysis). Monitoring also aids in understanding the distribution of fuel loads to generate plans that would mimic natural fire regimes while simultaneously reducing risks of extreme fire events. However, the process of implementing prescribed fires has to follow not just NPS guidelines, but also the guidelines of other management entities, such as the FWS, Colorado State Land Board, or TNC. Additional clearances may also be required, such as permits for prescribed burning through a State's air quality control commission. Nonfuel treatments are reserved for areas with high visitor use, structures and developments, boundaries between NPS and FWS, cultural resource sites, and other areas with value (NPS, FWS, and TNC, 2006).

Some parks use reseeding to aid in plant community **restoration** in conjunction with fire because fire alone can lead to undesirable successional trends that may impede future restoration. For example, fire can promote the spread of nonnative, annual grasses and create monotypes. Short-lived perennials may also invade and thrive under certain fire intervals (NPS, 1999). Managers can sometimes reduce the risk of invasion through postfire seeding of native species. Invasive plant management teams prescribe and implement invasive plant management primarily through herbicide treatments. The Northern Great Plains Invasive Plant Management Team serves 14 parks in 4 States (Nebraska, North Dakota, South Dakota, and Wyoming; Hogan and Stoneburnener, 2021).

Grazing Management

Grazing management within NPS units primarily focuses on wildlife and noncommercial grazing (for example, bison), although some units allow agricultural grazing where mandated by right or law or where it is necessary to achieve desired resource conditions. Some NPS units in the North Central Grassland Ecoregions, for example, Great Sand Dunes National Park and Preserve (NPS, 2019) or Theodore Roosevelt National Park (NPS, 2010), develop and use ungulate (hoofed mammal) management plans to balance ungulate population numbers, hunting opportunities (where allowable), and general habitat quality and health. The agricultural grazing permitting process is nonhomogenous across NPS units, and some units issue and manage permits in partnership with local Bureau of Land Management (BLM) offices (NPS, 2006b). Some NPS units, such as Dinosaur National Monument, have assumed administration of their allotments from the BLM and are developing formal grazing management plans (L.C. Zeigenfuss, unpub. data, 2020).

Managing Animal Species of Greatest Conservation Need and Cultural Importance

The NPS units manage a diverse set of fish, wildlife, and habitat concerns, primarily on an individual unit level but with occasional cross-unit or regional coordination. The NPS Natural Resource Management policy states that physical and biological processes that shape ecological communities are a preservation concern rather than individual species (NPS, 2006b). There are exceptions for threatened or endangered species, species that are of cultural importance, and species that affect the overall physical and biological processes disturbed by human interference.

For instance, *Mustela nigripes* (black-footed ferret) is an endangered species the NPS focuses on when constructing management plans for some units in the North Central Grassland Ecoregions. However, instead of focusing only on the species, the NPS strategies also consider a variety of **contributing factors** that affect population numbers. One such contributing factor is that *Cynomys ludovicianus* (black-tailed prairie dog) is the black-footed ferret's primary prey and heavily affects their distribution. The Badlands National Park Northern Unit has a plan specifically for these prairie dogs because of their role as a keystone species, but their management is not as simple as promoting prairie dog expansion because prairie dogs can create issues for private landowners and producers near the park.

Bison are ecosystem engineers and of cultural importance for Native American Tribes in the North Central Grassland Ecoregions. For the past 100 years, bison have been a species of interest for the DOI; 10 herds have been established in 8 NPS units within the North Central Grassland Ecoregions. The Bison Conservation Initiative (https://www.nps.gov/articles/000/bison-conservation-initiative.htm) and the InterTribal Buffalo Council (https://itbcbuffalonation.org/) have informed NPS bison management for ecological and cultural uses. Herds are fragmented across NPS units because of prairie conversion, agriculture, and fencing. The DOI Region 5 NPS Bison Stewardship Strategy (Symstad and others, 2019) provides a framework for how bison might be managed across these NPS units by shifting from a livestock-based perspective to a wildlife stewardship approach and from emphasis on a single species to the ecosystem. Instead of being able to connect herds through corridors, because sociopolitical boundaries prevent them from doing so, Badlands National Park has expanded their bison range to promote genetic integrity of the herd, health of the mixed-grass prairie ecosystem, and visitor experience (NPS, 2016).

Emerging Challenges and Opportunities

There are a number of emerging challenges and opportunities for NPS management of grasslands in a changing climate, including issues related to public understanding of grasslands; the complex landscape of legal drivers, policy drivers, and economic incentives; coordination across management entities and jurisdictional boundaries; and the need for new approaches and frameworks for management.

Increasing Public Understanding of Grasslands

The Organic Act of 1916 mandates that the NPS conserve park resources and "provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for future generations," which has resulted in extensive interpretative and educational programming from national to unit-level scales (16 U.S.C. 5417 et seq). Interpretive programming provides factual information and also encourages individuals and communities to intellectually and emotionally connect with park resources and stories. The NPS units can use interpretation as a technique for engaging audiences in conversation around challenging topics, such as "the civic experience of our country; the complex, diverse ecology of our nation and the world; and the influence of global climate change" (NPS, 2006b). For NPS units that oversee the management of grassland habitats, interpretive programming provides an avenue to increase public understanding of the function and value of grasslands and how these characteristics might be affected by climate change.

Individual NPS units must balance many competing goals when developing interpretive programming, such as enhancing the visitor experience while simultaneously preserving or conserving a resource. For example, DOI Region 5 NPS units identified several common public outreach goals related to the coordinated management of bison herds: "maximize the number of healthy, wild bison that are visible to the public; maximize the safety of visitors; and maximize public understanding of the past, present, and future of bison and Native Americans in the Great Plains" (Symstad and others, 2019). Some of these goals might conflict (for example, increased number and visibility of bison might lead to more bison-vehicle collisions or interactions with visitors on foot). Although these goals specifically relate to bison, content about grassland habitats must be embedded within public outreach to provide visitors a holistic story about bison in the Great Plains. In addition to regular interpretive programming, NPS units conduct special government-to-government consultation and coordination with federally recognized Tribes in recognition of the cultural and spiritual importance of certain places and resources (NPS, 2006b). The Badlands National Park staff partner with the Oglala Sioux Tribe to ensure that management actions are consistent with Tribal practices and values and allow for continued traditional gathering and minimizing resource-use conflicts. Partnering with the Oglala Sioux Tribe also allows for coordinated management actions across the NPS unit and the adjacent Pine Ridge Indian Reservation (NPS, 2006a).

Addressing Legal Drivers, Policy Drivers, and Economic Incentives

All Federal agencies are required by the National Environmental Policy Act (NEPA; 43 U.S.C. 4321 et seq.) to assess the environmental impacts of any proposed actions to ensure that such factors are considered equally with others (for example, economic incentives) when making a decision. Under NEPA, NPS units must conduct an Environmental Assessment that either results in a finding of no significant impact or an Environmental Impact Statement (EIS). In addition to NEPA, NPS units must consider other Federal laws, such as the Native American Graves Protection and Repatriation Act (25 U.S.C. 32) and the National Historic Preservation Act (54 U.S.C. 300201–200321; NPS, 2006b).

For example, the North Unit of Badlands National Park produced an EIS in 2006 that provides alternative bison management options and describes the likely outcomes of each option (NPS, 2006a). The EIS outlines the desired future conditions for the next 15–20 years in terms of natural and cultural resource management, interpretation and education, visitor services, and other programs. The EIS then lists strategies for each future condition to address issues facing the park based on current information and trends. An EIS does not provide specific actions for a park to take, but rather informs a park's actions if it decides to take a specific course.

Although most parks generate revenue through visitor use, they provide additional economic value through ecosystem services. Carbon sequestration alone offsets more than one-fourth of the funds taxpayers provide for the entire NPS system (Banasiak and others, 2015). The allocation of funds to preserve and maintain ecosystem services is an emerging opportunity for the NPS.

Promoting Coordination of Action Across Management Entities

Many units within the NPS were created through the dispossession and forced relocation of Indigenous communities (Kantor, 2007). As a result, it is common for parks to include sacred sites and resources within their boundaries that are important to Native peoples. Although NPS units are mandated to conduct government-to-government consultation with Native Nations on activities that may affect trust resources, many parks also codevelop management plans with Indigenous communities

that are nearby or consider the unit their ancestral homeland (NPS, 2006b). For example, in the North Central Grassland Ecoregions, NPS units within DOI Region 5 coordinate with federally recognized Tribes to enhance stewardship of bison and to maximize the transfer of live, healthy bison to Tribal herds (Symstad and others, 2019).

In addition to working with Tribal nations, the NPS participates in interagency coordination with other management entities, most markedly around wildland fire management and response. For example, the Greater Sand Dunes fire management plan (NPS and others, 2006a) requires collaboration among the NPS, FWS, Colorado State Land Board, and TNC because of adjacent boundaries through the San Luis Valley, Baca National Wildlife Refuge, San Luis Valley National Wildlife Refuge Complex, Great Sand Dunes National Park and Preserve, and TNC's Medano-Zapata Ranch. Many of these entities also require their own fire management plans, such as the TNC fire management manual (Heumann, 2024) and the FWS Service Manual Part 621 (FWS, 2012). An interdisciplinary team across entities ensured that the fire plan encased goals and objectives that were shared across boundaries for joint operations to be achievable. The NPS intends to participate in potential future interagency planning efforts led by partners in areas adjacent to NPS unit boundaries.

Developing New Frameworks for Conceptualizing Problems and Solutions

The NPS national headquarters includes important program elements, such as the Climate Change Response Program (CCRP; under the Natural Resource Stewardship and Science Directorate) and the Park Planning, Facilities, and Lands Directorate. The CCRP has been instrumental in promoting awareness and understanding of climate change and its impacts, identifying adaptation options for individual NPS units, and advancing the field of climate adaptation (NPS, 2021b).

The primary approach that the CCRP uses for exploring the potential impacts of climate change and facilitating adaptation is scenario planning, a process for making plans that accounts for uncertainty by considering a range of possible outcomes. Resource managers and scientists identify a small set (usually 3–5) of plausible, divergent, challenging, and relevant climate futures for a given NPS unit (Lawrence and others, 2021). These detailed summaries of resource-relevant climate conditions illustrate the range of risk that managers could consider in their planning and decision making. Through a facilitated process, managers, scientists, and subject-matter experts then use this information to describe the range of climate change impacts, identify and evaluate potential management responses, and select appropriate and robust adaptation strategies (NPS, 2013, 2014; Runyon and others, 2020; Miller and others, 2022). To maximize the relevance and outcomes of scenario planning, it has been integrated with other NPS management planning processes (for example, resource stewardship strategies; NPS, 2020b).

In addition to leading the use of scenario planning for climate change adaptation, the CCRP is developing and using new frameworks for dealing with potentially irreversible ecological change. The Resist-Accept-Direct decision framework provides managers with a tool for examining the tradeoffs between "holding the line" (resisting change) and accepting or directing the trajectory of change (Schuurman and others, 2020). The CCRP is also assessing the ecological risks of using managed relocation, also known as assisted migration, as a climate adaptation strategy for at-risk species (Karasov-Olson and others, 2021). These emerging frameworks encourage managers to think beyond the **conservation** and restoration of ecosystems in their current or historical form to the identification of novel ecosystems that may emerge and thrive under future climate conditions. In the North Central Grassland Ecoregions, this novel future could mean anything from transformation of one type of grassland to another, to full-scale transformation between forest, shrubland, or grassland.

Information Needed

The NPS management objectives vary widely by unit, resulting in a need for scientific information across a variety of topics (refer to Miller Hesed and others [2023] for a summary table of the relevance of synthesized information needs and app. B1 for NPS-specific information needs as articulated in grassland management-related documents). Most NPS management plans focus on historical trends and distributions of vegetation and species to develop goals. Although this focus is shifting (for example, resource stewardship strategies for Devils Tower National Park [Schuurman and others, 2019; NPS, 2020a] and Wind Cave National Park [NPS, 2021c; Runyon and others, 2021] include updated climate-smart goals and activities), several science and information needs in regard to park management under a changing climate have emerged:

1. Quantitative information about ecological responses to climate change that can be used to develop and evaluate proposed alternative management strategies;
2. Evaluation of the tradeoffs between management actions to support one key resource that may be detrimental to another key resource; and
3. Approaches for translating potential climate impacts and tradeoffs into proactive solutions under the Resist-Accept-Direct framework that can be readily integrated into NPS plans and decisions.

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Prairie grasslands at the Theodore Roosevelt National Park
(Photograph by Jeff Zylland, National Park Service).

Section B4.
U.S. Department of Agriculture Forest Service

By Molly Cross,[1] Christine D. Miller Hesed,[2] and Sarah Jaffe[3]

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Background

The U.S. Department of Agriculture Forest Service (FS) was established by the U.S. Congress in 1905. The lands eventually designated as "national **grasslands**" in 1960 were initially known as land utilization projects (LUPs). Land utilization projects were a product of the land utilization program culminated by the Bankhead-Jones Farm Tenant Act of 1937 (7 U.S.C. 1000) when the Federal Government was authorized to purchase and restore damaged agricultural lands. Management of a part of those LUPs (about 3.8 million acres) was assigned to the FS in 1954 after being managed by several government agencies a few decades after the Dust Bowl. The mission of the FS is "to sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations" (FS, 2022a).

There are 20 national grasslands totaling approximately 3.8 million acres; most of these acres are in the **North Central region** where there are 11 national grasslands totaling 3,364,426 acres (tables B7 and B8). Several of these national grasslands are administered by national forest units, and four are administered by the Dakota Prairie Grasslands. The Dakota Prairie Grasslands is one of many administrative units that manage national grasslands as part of the National Forest System. Additional information on the history, origin, and overall legal management framework of national grasslands is available in the "National Grassland Management Primer" (Olson, 2997).

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Grassland Management

Originally established to protect clean water resources and provide timber, the FS was later directed by the U.S. Congress to manage forest and grasslands for multiple uses and benefits, including "water, forage, wildlife, wood, and recreation" (FS, 2022a). The FS accomplishes its mission through many activities, three of which are most directly related to grassland management: "Protection and management of natural resources on lands we manage; Research on all aspects of forestry, rangeland management, and forest resource utilization; Community assistance and cooperation with State and local governments, forest industries, and private landowners to help protect and manage non-Federal forest and associated range and watershed lands to improve conditions in rural areas" (FS, 2022a).

The National Forest Management Act of 1976 (16 U.S.C. 1600) requires the FS to develop land management plans to guide management of the 154 national forests, 20 grasslands, and 1 **prairie** that constitute the 193 million-acre National Forest System. This report reviewed four land and resource management plans for national grasslands in the North Central region (FS, 2001a, b, 2009, 2019).

Table B7. Acreage of national grasslands in the North Central region.

[Data from Olson (1997). NA, not applicable]

National grassland	Acreage	State
Buffalo Gap	597,178	South Dakota
Cedar River	6,717	North Dakota
Cimarron	108,175	Kansas
Comanche	435,359	Colorado
Fort Pierre	115,997	South Dakota
Grand River	154,981	South Dakota
Little Missouri	1,028,045	North Dakota
Oglala	94,480	Nebraska
Pawnee	193,060	Colorado
Sheyenne	70,268	North Dakota
Thunder Basin	560,166	Wyoming
Total	**3,364,426**	**NA**

As laid out in 36 CFR §219.2(b)(1), "A land management plan provides a framework for integrated resource management and for guiding project and activity decision making on a national forest, grassland, prairie, or other administrative unit. A plan reflects the unit's expected, distinctive roles and contributions to the local area, region, and Nation, and the roles for which the plan area is best suited, considering the agency's mission, the unit's unique capabilities, and the resources and management of other lands in the vicinity." They include plan components (standards, guidelines, desired conditions, and so forth) to maintain or restore the ecological integrity of terrestrial and aquatic ecosystems and watersheds in the plan area, including by maintaining or restoring their structure, composition, function, and connectivity; maintaining or restoring air, soil, water resources and riparian areas in the plan area; and providing for plant and animal diversity, taking into account the potential impacts of climate change, wildfire, and other stressors on the unit.

Plans are also required to provide for multiple uses and integrated resource management on National Forest System lands and consider a full range of uses and values, including timber, mining, grazing, energy, outdoor recreation, watershed, and fish and wildlife species. Plans must have standards or guidelines for integrated resource management to provide for ecosystem services and multiple uses in the plan area and must consider factors such as aesthetic values, air quality, cultural and heritage resources, ecosystem services, fish and wildlife species, forage, geologic features, grazing and rangelands, habitat and habitat connectivity, recreation settings and opportunities, riparian areas, scenery, soil, surface and subsurface water quality, timber, trails, vegetation, viewsheds, wilderness, and other relevant resources and uses. The required plan components include desired conditions, objectives, and suitability of lands (required components are defined in 36 CFR §219.7(e)(1)). Goals may be included as an optional plan component.

Land management plans must specify which plan components are applied unit wide, to a specific parcel of land, or to land of specific character; therefore, every plan must have management areas, geographic areas, or both. The plan may identify designated or recommended designated areas as management or geographic areas. The terms "management area" and "geographic area" describe how plan components apply to specific parcels of National Forest System land with locations shown on maps. Geographic areas are based on place, whereas management areas are based on purpose. The term "designated area" refers to a category of area or feature established by, or pursuant to, statute, regulation, or policy. If an area does not qualify as a designated area or has not been designated, but needs specific guidance, the responsible official may identify the area as a management or geographic area to apply specific plan components in the land management plan. Some plan components apply to areas of specific character (for example, riparian areas, roads, springs, streams, and wetlands) and are explained in the wording of the plan component itself.

Each national grassland management plan includes a plan monitoring program. Monitoring forms the basis for continuous improvement of the plan and provides information for adaptive management of the plan area. Plan monitoring programs comprise a set of monitoring questions and associated indicators to evaluate whether plan components are effective and appropriate and whether management is effective in maintaining or achieving progress toward desired conditions and objectives. These monitoring programs are often several pages long and include many monitoring questions that cover all the priorities in the plan.

This review focused on the biological resources (fish, wildlife, rare plants, fire, animal damage management, livestock grazing, and **invasive species** management) as detailed in the national grassland land management plans. (refer to app. A1 in Miller Hesed and Yocum [2026] for a full list of all grassland-relevant documents that were reviewed).

Table B8. North Central Grassland Ecoregion acres managed by the U.S. Department of Agriculture Forest Service.

Ecoregion[1]	Land managed by the U.S. Department of Agriculture Forest Service, in acres							
	Montana	Wyoming	Colorado	North Dakota	South Dakota	Nebraska	Kansas	Total
Tallgrass	0	0	0	117,007	0	0	0	117,007
Northern Mixed Grass[2]	507,581	101,228	0	183,809	871,387	49,808	0	1,713,813
Central Mixed Grass	0	0	24,048	0	91,692	259,968	92,210	467,919
Shortgrass	0	961	824,739	0	87,095	18,401	15,057	946,253
Sagebrush–Grassland Ecotone	1,412,396	1,416,077	42,945	1,070,431	385,802	27,753	0	4,355,404
Total	**1,920,001**	**1,517,281**	**848,788**	**1,371,247**	**1,381,890**	**355,930**	**107,267**	**7,502,404**

[1]Acreages include waterbodies, national grasslands, and national forests within grassland ecoregions. Acreages are derived from the Protected Areas Database of the United States (U.S. Geological Survey Gap Analysis Project, 2020) and the development of ecoregions is defined in Miller Hesed and Yocum (2026), figure A5. Refer to section A1 in Miller Hesed and Yocum (2026).

[2]The acreage for the Northern Mixed Grass Ecoregion excludes that which falls within the Sagebrush–Grassland Ecotone.

Grassland Protection and Reconstruction

The FS engages in grassland **conservation** and management through goals and objectives, standards and guidelines, management area direction, monitoring, and recommendations for special area allocation. These special areas are based on an analysis of alternatives proposed during the grassland land management planning process and consideration of the most recent and applicable science and research (Congressional Research Service, 2010).

An example of management area direction relates to *Cynomys leucurus* (white-tailed prairie dog) and *Cynomys ludovicianus* (black-tailed prairie dog; hereafter "prairie dog") management, which is addressed in several of the FS grassland management plans in the North Central region. One of the management approaches used by the FS is exemplified by the Record of Decision for Thunder Basin National Grassland (FS, 2020), which determined where prairie dog populations within the national grassland units will be protected and where they will be controlled (limited or removed) to minimize conflicts with neighboring landowners because prairie dogs are often considered a nuisance species on agricultural and ranch lands. This determination includes the use of specific management area plan components, such as guidelines on which prairie dog control agents can and cannot be used in certain areas, managing recreational shooting of prairie dogs, and use of rotational grazing to control prairie dog colonies. It also includes guidance on where and how to protect prairie dog populations, for example, by identifying areas that are off-limits to chemical control, addressing sylvatic plague, and managing vegetation to provide suitable habitat for prairie dogs (FS, 2020).

Grassland **reconstruction** is a major activity for the FS, and many of the reviewed documents referred to efforts to restore native grasslands and prairies by means of prescribed fire, invasive species removal, seed collections, plantings, reseeding, and livestock management (FS, 2017; Finch and others, 2019; Schrader-Patton and others, 2020).

Prescribed Disturbance and Invasives and Grazing Management

The **enhancement** and **maintenance** of grasslands are a major focus for the FS. Prescribed fire, grazing, and mowing are used to enhance grassland habitat (FS, 2012, 2014, 2017; Finch and others, 2019). Invasive species management focuses on the removal of woody vegetation in addition to preventing the spread or removing invasive herbaceous vegetation, and biocontrol of other pests (FS, 2017; Schrader-Patton and others, 2020). The FS administers grazing permits on national forests and grasslands and all reviewed national grassland plans discussed grazing management. These plans usually refer to grazing by livestock, which includes cattle but can also include other species such as *Bison bison* (bison).

Managing Species of Conservation and Cultural Importance

Management of species of conservation and cultural importance is a major focus for the FS. Within the "Fish, Wildlife and Rare Plants" section of the National Grassland land and resource management plans reviewed from the North Central region, there are many different species or species groups listed as priorities, for example, big game populations and movement, ground-nesting birds, waterfowl, recreational fisheries, bats, *Ovis canadensis* (bighorn sheep), *Antilocapra americana* (pronghorn), *Tympanuchus cupido* (greater prairie-chicken), *Centrocercus urophasianus* (sage grouse), *T. phasianellus* (sharp-tailed grouse), *Mustela nigripes* (black-footed ferret), *Charadrius montanus* (mountain plover), prairie dogs, *Athene cunicularia* (burrowing owls), *Vulpes velox* (swift fox), several raptors, and the *Platanthera praeclara* (western prairie fringed orchid; FS, 2001b, 2009, 2019). Additional information on species of greatest conservation need by State can be found in Miller Hesed and Yocum (2026) and in the "U.S. Fish and Wildlife Service" section.

Prairie dogs are a significant focus of several of the FS grassland management plans. Prairie dog management includes decisions about where and how to control compared to protect prairie dog populations; decisions are often driven by the habitat needs of associated species (FS, 2020). The Record of Decision for the Thunder Basin National Grassland 2020 plan amendment (FS, 2020) provides many details about the FS unit's approach to prairie dog management, and although it does not directly address climate change, it does consider drought. The Thunder Basin National Grassland plan sets a lower management objective for the number of acres of black-tailed prairie dog habitat and population distribution during drought conditions. The plan includes details about how to define the drought conditions that would trigger the lower acreage goal (that is, the number of consecutive years that an area experiences less than 75 percent of normal annual precipitation and what dates to use to calculate annual precipitation). It also encourages managers to consider measures to limit colony expansion during drought conditions (FS, 2020, p. 87). Although not explicitly mentioned in the plan, future precipitation projections could be analyzed to determine how often managers might expect these drought conditions to occur in the future.

Promoting Conservation on Private Grasslands

The FS land and resource management plans only address management actions on federally owned and managed national forests and grasslands. However, because of the extensive, intermingled land ownership on many of the grasslands, these plans do consider neighboring lands and private land conservation issues. The FS recognizes that there are interdependencies between adjacent public and private lands. One particularly notable example is how management actions related to prairie dog populations and habitat on national forests and grasslands affect neighboring private landowners (for example, FS, 2020). Prairie dogs are considered a species of conservation interest to FS, but many private landowners consider them a nuisance species. For this reason, national grassland management plans often discuss goals related to conserving prairie dogs and their habitat only within certain areas or to certain population levels to try and minimize how the populations on public lands affect neighboring landowners.

Another significant way the FS engages with neighboring private lands is through the management of grazing permits (FS, 2022c). In particular, the FS allows grazing associations to graze livestock on national grasslands, as documented in grazing agreements (a type of term grazing permit). Those associations also establish rules of management for their members and the associated private lands. This approach allows grazing opportunities on national grasslands and often has a favorable effect for securing sound land conservation practices on associated private lands. They are not leases because there are no rights associated with the permits on FS lands.

Other Management Areas—Recreation, Travel, and Water Management

Recreation is one of the core components or values of the multiuse mission of the FS. The management of recreational activities, roads, and trails are therefore an important tool for managing human-driven effects to grassland species and ecosystems on national forests and grasslands. Protecting water resources is also a main objective of the FS as evidenced in national grassland plans. For example, the first goal listed in the Thunder Basin National Grassland plan is “Improve and protect watershed conditions to provide water quality/quantity and soil productivity to support ecological functions and intended beneficial water uses” (FS, 2001b, p. I–2).

Emerging Challenges and Opportunities

There are a number of emerging challenges and opportunities for FS management of grasslands in a changing climate. Public awareness and education are areas of growth for the agency. As larger landscape approaches to management and restoration have increased in prominence, especially in response to challenges brought about by a changing climate, the FS is working more on coordination across entities and boundaries. Legal and policy processes are important drivers of FS efforts to understand and document environmental impacts of their work and therefore can be a place where climate change is relevant. Lastly, as a leader in the development of science and tools and frameworks for climate adaptation planning, the FS has opportunities to increase the accessibility and use of these resources.

Increasing Public Understanding of Grasslands

In two reviews of national grasslands management (FS, 1995, 1996), the FS identified a need for more communication and education about national grasslands. One outcome of the review was the creation of the National Grasslands Council that serves to facilitate communication and coordination of activities across national grassland unit boundaries and with grassland and other government interests. The FS also manages the National Grasslands Visitor Center in Wall, South Dakota, which is intended to provide the public with opportunities to learn and explore information about the 20 national grasslands and Midewin National Tallgrass Prairie (FS, 2022b). Many FS national grassland units have interpretive plans that provide guidance and resources aimed at educating the public about national grasslands and related opportunities. However, staff capacity does not always allow for a robust, interpretive program or resources at every unit.

Promoting Coordination of Action Across Agencies, Organizations, Jurisdictions, and Borders

One challenge that comes across clearly in the reviewed FS management documents is the FS is often considering ways to balance conservation goals on public lands they manage with livelihood goals of neighboring private lands. This challenge is illustrated in management plans surrounding species that are of conservation need while simultaneously considered a pest (for example, prairie dogs) by neighboring landowners. The FS also directly manages grazing permits for domestic livestock on national grassland and forest lands. Grazing associations are part of the management of the livestock component on many grasslands. The agency is authorized to recognize, cooperate with and assist local livestock associations in the administration of grazing on National Forest System land.

Addressing Legal and Policy Drivers

All Federal agencies are required by the National Environmental Policy Act (NEPA; 43 U.S.C. 4321 et seq.) to assess the environmental impacts of any proposed actions to ensure such factors are considered equally with others (for example, economic incentives) when making a decision. Under the NEPA, national forest and grassland units must conduct an Environmental Assessment that either results in a finding of no significant impact or an Environmental Impact Statement. For the FS, land and resource management plans must meet all laws, regulations, rules, and policies that are related to FS activities. Understanding how climate change may fit into these legal and policy processes is an increasing area of focus for the agency.

Increasing the Useability of Science, Tools, and Frameworks for Conceptualizing Problems and Solutions

The FS is a leader in the development of climate change adaptation science, planning, tools, and other related resources. Many programs within the FS support climate change research, planning, and implementation, including the regional research stations (https://www.fs.usda.gov/research/stations) and the Northern Institute for Applied Climate Science (NIACS; https://www.niacs.org/). These programs and other groups within the FS have developed resources and tools, such as the Climate Change Resource Center (https://www.fs.usda.gov/ccrc/), the Climate Change Adaptation Library for the Western United States (http://adaptationpartners.org/library.php), the Adaptation Workbook (https://adaptationworkbook.org), the Template for Assessing Climate Change Impacts and Management Options (https://taccimo.info/tbl_sector_list.php), the Climate Change Response Framework (https://forestadaptation.org), and the System for Assessing Vulnerability of Species Climate Change Tool (https://www.fs.fed.us/rm/grassland-shrubland-desert/products/species-vulnerability/savs-climate-change-tool.php), among many others. There are a growing number of examples of FS units using these tools (For example, the database managed by the NIACS climate adaptation demonstration sites at https://forestadaptation.org/adapt/demonstration-projects) as are other management entities.

The North Central grasslands provide many opportunities for research and the FS works closely with other management entities to support research projects that feedback into management decisions. For example, the Thunder Basin National Grassland works closely with a nonprofit that provides support to a variety of scientists who are doing research on the grassland (FS, 2001b, 2020), including projects on long-term and variable drought conditions and climate change effects on drought impacts to grassland ecosystems.

Information Needed

Although few climate change information needs for the FS were explicitly mentioned in the reviewed grassland management-related documents, there are a number of information needs that can be inferred. For more on FS information needs, refer to Miller Hesed and others (2023) for a summary table of the relevance of synthesized information needs and appendix B1 for FS-specific information needs as articulated in reviewed documents.

Climate change was explicitly mentioned in only one of the reviewed FS national grassland land and resource management plans. The management plan for the Pawnee National Grassland (FS, 2019) mentioned climate change in chapter 4 (“Monitoring and Evaluation”) “What stressors are impacting the Arapaho/Roosevelt/Pawnee? Can any trends in these stressors be related to climate change?” and identified the following indicators to monitor climate change impacts: extent and severity of wildfire and flood; timing, type and amount of precipitation (rain/snow); extent of insect and disease outbreaks; and changes in stream temperature” (FS, 2019, chap. 4, p. 396).

Although none of the other reviewed national grassland management plans mentioned climate change explicitly, all plans regularly mentioned climate-related phenomena, such as drought, flood, and wildfire. Within these plans, fire was mentioned most often. For example, as mentioned in the “Grassland Management” section, the Record of Decision for the Thunder Basin National Grassland 2020 plan amendment (FS, 2020) laid out different prairie dog colony objectives during drought compared to normal years and defined specific precipitation conditions that trigger the lower prairie dog colony acreage objective.

Even though the reviewed national grassland management plans do not largely focus on climate change, the climate change website hosted by the FS (Bagne and others, 2012) points to many ways that grasslands could be affected by climate change. The authors also list several grassland management responses to climate change, such as considering climate change in the management of habitat connectivity, livestock grazing, and habitat **restoration**, and efforts to anticipate climate changes and extreme weather events through scenario planning and other tools for planning for the future. However, the authors also noted that although there are many “management options to sustain grassland ecosystems under global change,” these are “mostly untested in their ability to maintain or enhance resource values into the future” (Bagne and others, 2012).

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The Blioux River Ranch in South Dakota
(Photograph by U.S. Department of Agriculture Natural Resources Conservation Service).

Section B5.
U.S. Department of Agriculture Natural Resources Conservation Service and Farm Service Agency

By Christine D. Miller Hesed[1]

Acknowledgments

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Background

Although this report focuses on Federal, State, and Tribal agencies; NGOs; and partnerships, private landowners are key players in **grassland** management and engaging with them is vital to efforts to conserve grassland habitat and species. This section provides a discussion of some of the programs through which the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) and Farm Service Agency (FSA) work with private landowners to encourage grassland **conservation** and sustainable management practices.

The NRCS and the FSA together implement the conservation title of the U.S. Farm Bill, which provides the most significant source of funding for private land conservation in the United States (Baier, 2020, p. 75). The NRCS was first established as the Soil Erosion Service in the U.S. Department of the Interior in 1933 in response to the Dust Bowl. In 1935, the U.S. Congress moved the agency to the USDA, renamed it the Soil Conservation Service, and finally renamed the agency the NRCS in 1994 (NRCS, 2021f). From an agency focused on erosion control, the NRCS has become the United States' leading agency for supporting, promoting, and funding conservation of soil, water, and habitat on private land (Baier, 2020 p. 78). The NRCS "provides America's farmers and ranchers with financial and technical assistance to voluntarily put conservation on the ground, not only helping the environment but agricultural operations, too" (NRCS, 2021a).

The FSA, which was originally established as the Farm Security Administration within the USDA in 1937, is primarily responsible for the administration of financial assistance programs and commodity pricing within the U.S. Farm Bill (FSA, 2021e). The agency's mission is to equitably serve "all farmers, ranchers, and agricultural partners through the delivery of effective, efficient agricultural programs for all Americans" (FSA, 2021d). The FSA helps to implement the conservation title of the U.S. Farm Bill by administering the U.S. Department of Agriculture Farm Service Agency Conservation Reserve Program (Baier, 2020, p. 79).

The NRCS and FSA are headquartered in Washington, D.C.; however, both agencies have a State office in each State and field offices that serve every county in the country. The NRCS conservation programs in each State are directed by a State conservationist and advised by a technical committee composed of representatives from Federal and State natural resource agencies, Tribal nations, environmental organizations, agricultural organizations, and agricultural producers (NRCS, 2021g). Field offices, known as USDA Service Centers, house NRCS, FSA, and the Office of Rural Development so that landowners can access multiple services at a single location (Baier, 2020, p. 80–81). This county-level structure helps to maximize flexibility and local decision making.

The U.S. Farm Bill conservation programs are also facilitated by county-level Conservation Districts. From the early days of the Soil Conservation Service, Federal officials recognized the need for local organization, expertise, and leadership in carrying out conservation programs. Beginning in 1937 and continuing through subsequent decades, every State adopted legislation authorizing the formation of Soil Conservation Districts (Baier, 2020, p. 79). These districts enable local volunteers to plan and implement conservation practices based on local needs (Baier, 2020, p. 79) and help facilitate delivery of U.S. Farm Bill conservation programs to local landowners (Tran and Chuang, 1996).

The U.S. Farm Bill is an omnibus bill passed about every 5 years and funds a variety of conservation programs (Baier, 2020, p. 75). The U.S. Farm Bill conservation assistance programs are designed to address the fact that conservation does not usually increase profits. Implementation of the U.S. Farm Bill programs is carried out by the NRCS, FSA, and a host of partnerships between Federal and State agencies, Tribal nations, nongovernmental

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organizations, and agricultural producers. There are several mechanisms through which U.S. Farm Bill programs fund landowner conservation actions (table B9):

- Grants generally fund a single project or conservation action that should be completed within a few years. Grants are usually awarded to organizations who then work with private landowners to implement conservation practices.
- Cost-assistance payments cover part of the monetary cost of implementing a conservation action, such as constructing fences or replacing a windmill with a solar system. The method to determine payment rates has changed over time; although at one time these rates were based on actual costs at the county level. Since 2012, the payment rates span multiple States and are set at a national level.
- Incentive payments seek to reward the landowner for adopting new actions (called practices) or taking existing actions to a higher level. Payments are made based on the number of acres treated or length of linear structure upgraded, such as fences. Incentive payments may be determined by the costs associated with or the amount of income a landowner would forgo by implementing the conservation practice.
- Rental contracts are also decoupled from the cost of implementing the conservation practice, and instead, payments are made on an annual basis throughout the term of the contract (for example, 10–15 years). Rental rates commonly reflect commercial rental rates of similar land and create a steady income stream for the contractee. Landowners tend to find this funding mechanism most attractive when agricultural prices are low or they are more interested in a steady income, such as in retirement.
- Conservation easements involve the sale of certain development or land-use rights. The sale of these rights results in one large payment, which can be attractive to some landowners. Many easements are permanent; easements that are for a certain period (that is, term easements) are typically sold for about 75 percent the amount of a permanent easement (Baier, 2020, p. 41–46).

Table B9. The U.S. Farm Bill conservation programs and funding mechanisms.

[EQIP, Environmental Quality Incentives Program; CSP, Conservation Stewardship Program; CRP, Conservation Reserve Program; ACEP, Agricultural Conservation Easement Program; X, applicable; —, not applicable]

Program	Grants	Cost-assistance payments	Incentive payments	Rental contracts	Conservation easement
EQIP	X	X	X	—	—
CSP	—	—	X	—	—
CRP	—	X	X	X	—
ACEP	—	X	—	—	X

Grassland Management

The U.S. Farm Bill conservation programs have evolved over time and will likely continue to evolve to meet emerging conservation challenges. The most recent U.S. Farm Bill, passed in 2018, included four main conservation programs, along with many additional programs (Public Law 115–334; FSA, 2021a; NRCS, 2021h).

The Environmental Quality Incentive Program (EQIP).—EQIP provides funding to improve natural resources through improvements to soil health, conservation of water resources, improving air and water quality, and improving wildlife habitat (North American Bird Conservation Initiative, 2015; NRCS, 2021e). Through EQIP, landowners receive technical and financial assistance to plan or implement conservation practices on eligible lands, which include cropland, grassland, rangeland, pasture, wetlands, and other agricultural land. The EQIP is administered by NRCS and the primary U.S. Farm Bill program used by the NRCS Working Lands for Wildlife program. The EQIP also contains the Conservation Innovation Grants program, which funds the development of new methods and approaches for conservation (North American Bird Conservation Initiative, 2015, p. 27–31).

The Conservation Stewardship Program (CSP).—CSP provides annual incentive payments to participants for the environmental benefits participants produce across their land (NRCS, 2021c). These payments increase with increases in environmental benefits (that is, participants get paid more for higher levels of conservation). As much as 10 million acres are enrolled in the CSP each year. This program has especially benefited wildlife in the grasslands. Between 2009 and 2013, "Grazing Management for Wildlife" was among the top 10 **enhancements** chosen by landowners on the more than 14 million acres of rangeland and pasture enrolled in the program. In 2014, South Dakota had the largest enrollment in the program with more than 1.2 million acres enrolled (North American Bird Conservation Initiative, 2015, p. 32).

The Conservation Reserve Program (CRP).—The FSA is the oldest U.S. Farm Bill conservation program and provides annual rental payments to landowners for establishing conservation cover on ecologically important cropland and pastureland that is next to water (FSA, 2021b). The 2014 U.S. Farm Bill (Public Law 113–79) eliminated the previous Grassland Reserve Program, and instead allows for as much as 2 million acres of enrollment of working grasslands in Grassland CRP (North American Bird Conservation Initiative, 2015, p. 24; FSA, 2021c). Unlike other enrollments in CRP, working grasslands do not require a cropping history and allow for grazing and haying as part of the conservation plan (North American Bird Conservation Initiative, 2015, p. 35). The Conservation Reserve Enhancement Program is a special CRP option that focuses on practices to protect aquatic features from sedimentation and agricultural runoff or reduce drawdown of the Ogallala aquifer, while also providing wildlife habitat (North American Bird Conservation Initiative, 2015, p. 37; FSA, 2022).

The Agricultural Conservation Easement Program (ACEP).—ACEP funds voluntary easements on working lands (NRCS, 2024). There are two types of conservation easements in this program: Agricultural Land Easements and Wetland Reserve Easements. Agricultural Land Easements permanently protect agricultural lands from development and certain land uses. Wetland Reserve Easements protect wetlands permanently to the maximum duration allowed by State law or for 30 years (North American Bird Conservation Initiative, 2015, p. 25; Baier, 2020).

Grassland Protection

The U.S. Farm Bill programs can help prevent grassland **conversion** to agriculture or other land uses. The CSP can help keep grazing operations in business by incentivizing conservation practices that not only improve wildlife habitat, but also improve forage. Practices that help to support sustainable grazing operations help reduce the risk of conversion of working grasslands (North American Bird Conservation Initiative, 2015, p. 32). Under ACEP Agricultural Land Easements, land designated as "Grasslands of Special Environmental Significance" is protected from conversion to nongrazing uses. The 2014 U.S. Farm Bill also included a new provision known as Sodsaver, which aimed to address the unintended increase in grassland conversion to cropland that resulted from Federal farm programs. Sodsaver discourages landowners in the Prairie Pothole region (including Montana, North Dakota, South Dakota, and Nebraska) from converting native grasslands and **prairies** to annually tilled crops by reducing the amount of Federal crop insurance and noninsured crop disaster assistance benefits for those converted acres for 4 years (North American Bird Conservation Initiative, 2015, p. 23).

Grazing Management

The NRCS works with private landowners to develop sustainable grazing plans that balance grazing with the conservation of ecosystem services, species, and habitats. Components of grazing plans may vary by State, but may include identification and record of grazing, rest, and deferment periods; recommended stocking rates; actual stocking rates; dates for forage and feed supply evaluations; adjustments to the prescribed grazing schedule as determined necessary; and other pertinent treatment activities (NRCS, 2021b). The conservation focus helps determine the specific management objectives for each grazing plan. For example, a grazing plan to maintain or improve stream quality and function in a riparian area would consider factors, such as the ecological site potential; current resource conditions; the desired plant community for adequate stream stabilization and cover; the physical structure of stream channels (including streambank stability); balancing soils, water, and vegetative communities over time; and balancing the grazing of upland and riparian plant communities. Grazing lands managed for the benefit of wildlife would consider the habitat requirements to maintain or improve food and shelter for target species and adjust grazing intensity, duration, degree of use, and periods of rest or deferment to maintain or create the desired habitat conditions. Specific grazing management for wildlife considerations might be to control excessive vegetation growth; create trails, bugging areas, and food plots; reduce fuel buildup and wildfire risk; and reduce the need for prescribed burning, herbicides, or mechanical treatments (NRCS, 2021b).

Managing Species of Greatest Conservation Need

The U.S. Farm Bill programs have had a tremendous effect on increasing wildlife habitat on working lands. The EQIP provides most of the funding for NRCS's species-focused initiatives, including the Sage Grouse Initiative (SGI) and the Lesser Prairie Chicken Initiative. The EQIP also provides funding for priority species identified by Working Lands for Wildlife, a partnership between the NRCS and the U.S. Fish and Wildlife Service that guarantees that producers will remain compliant with the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.) regulatory responsibilities for up to 30 years if they implement and maintain high-priority conservation practices on land of high ecological value for conservation (North American Bird Conservation Initiative, 2015; Baier, 2020, p. 121). These initiatives have been highly successful at conserving wildlife species. For example, the SGI has helped prevent *Centrocercus urophasianus* (greater sage-grouse) from being listed under the Endangered Species Act. Using scientific data to target areas with high-density sage grouse populations, the EQIP-funded SGI restored more than 4.4 million acres of sagebrush habitat across 11 States (including in the Sagebrush–Grassland Ecotone; North American Bird Conservation Initiative, 2015, p. 28).

The EQIP has also been crucial for conserving *Tympanuchus pallidicinctus* (lesser prairie-chicken); although about 50 percent of the greater sage-grouse's range is on private land, 95 percent of the lesser prairie-chicken's range is on privately owned land. As of 2018, the Lesser Prairie Chicken Initiative had invested $41.6 million of NRCS funding to conserve more than 1.6 million acres of lesser prairie-chicken habitat by working with more than 800 private landowners (Baier, 2020, p. 92).

The CRP has also benefited wildlife, especially grassland-associated species, including waterfowl and *Phasianus colchicus* (ring-necked pheasants; North American Bird Conservation Initiative, 2015, p. 35). In North Dakota, biologists estimate that the CRP has helped increase annual duck counts by 90,000 in the Prairie Pothole region (North American Bird Conservation Initiative, 2015, p. 39). In South Dakota, the CRP has restored cropped wetlands to natural vegetative and hydrologic cover along with establishing grassland buffers to provide some of the most productive waterfowl nesting habitat on the continent (North American Bird Conservation Initiative, 2015, p. 38).

Emerging Challenges and Opportunities

Through U.S. Farm Bill programs, NRCS, FSA, and partnering organizations have made significant strides toward conserving grassland and associated wildlife and ecosystem functions on private land; however, these entities will face many challenges as climate change impacts ecological systems and agricultural production. Increasing flexibility in program requirements so private landowners can continue to make a living while conserving grasslands and other ecosystems will likely be crucial for continued enrollment in these conservation programs. Additionally, with so many acres on private lands moving in and out of various easement agreements in any given year, it can be difficult to understand how these areas contribute to goals to increase habitat connectivity. There are opportunities to understand how programs on private lands contribute to landscape-scale conservation goals for grassland ecosystems.

Information Needed

Because of the diversity of programs that the NRCS and FSA work to implement on private land, many of the identified information needs are relevant to these agencies (Miller Hesed and others, 2023). Understanding how climate change may impact the effectiveness of a suite of conservation practices, including practices to control herbaceous and woody invasives, maintain and improve water quality and aquatic systems, provide habitat for wildlife, and maintain diverse and heterogeneous landscapes, will be crucial for the NRCS and FSA as they continue to work with and advise private landowners on meeting conservation objectives. Better understanding of effective incentives to encourage landowners to enroll private lands in conservation programs, or to manage lands more sustainably for grassland habitat, are also needed. Another highly relevant question for the NRCS and FSA is how relevant science and tools can be made more accessible to landowners so they can adjust conservation and production practices appropriately amidst the increased climate variability that is projected across the **North Central region**.

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Bison grazing under a rainbow
(Photograph by National Park Service).

Section B6.
Tribal Nations

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Background

The **North Central Grassland Ecoregions** are currently (2025) home to 27 federally recognized Tribes (table B10; Bureau of Indian Affairs [BIA], 2022b). These Tribes are sovereign nations (hereafter referred to as "Tribes" or "Tribal nations") and quite diverse in their history, traditions, and government. Tribal nations in the North Central Grassland Ecoregions have diverse goals for the management of their grasslands and face unique challenges in meeting them. These Tribal nations are at various stages in the development of their grassland management efforts and climate change adaptation plans.

Native Americans have lived on the **Great Plains** for thousands of years (Roos and others, 2018) and many Tribal nations in the North Central Grassland Ecoregions have oral histories that describe the creation of the first people in the Great Plains at specific sites that are still considered sacred (National Parks Service [NPS], 2020). Native Americans in the Great Plains often relied on *Bison bison* (bison; however, "buffalo" is the preferred common name for this species for many regional Tribal nations [Hinshaw Patent, 2006; Schneider, 2023] and will therefore be the term used in this section). In particular, Native Americans in the Great Plains often practiced a nomadic lifestyle that followed the buffalo herds (National Fish Wildlife and Plants Climate Adaptation Network, 2021a), particularly after obtaining *Equus caballus* (horses) in the late 18th century (Wissler, 1914). The relationship to the land and the environment was a reciprocal one which viewed humans as integrated into the natural system as opposed to separate from it (Pierotti and Wildcat, 2000). By the early 19th century, westward expansion of the U.S. Government increased, pushing waves of non-Indigenous settlers into the North Central Grassland Ecoregions (Hämäläinen, 2016, 2019). This large-scale migration of non-Indigenous settlers into Indigenous lands fundamentally changed intertribal dynamics, increased stress on natural resources, and altered the socioecological balance of grassland systems.

In 1830, President Andrew Jackson signed the Indian Removal Act (25 U.S.C. 174), which initiated a period of forced relocation of Tribal communities starting in the east and southeast moving them onto lands in the west, predominantly in the Great Plains. In 1851, the U.S. Congress passed the Indian Appropriations Act (25 U.S.C. 211), which created the Indian reservation system and forced Native Americans to live inside confined areas. Reservation lands were often outside of their homelands and of poor quality for hunting or agricultural use (Prucha, 1995). In addition, the Indian Appropriations Act required that Indians give up hunting to become farmers on land often unsuitable for farming. During this time, the U.S. Military issued a directive that buffalo be slaughtered as a way control American Indians of the Great Plains (National Park Service [NPS], 2018). About 10–15 million buffalo were slaughtered in the Great Plains in a little more than 10 years; it is estimated that fewer than 1,000 buffalo remained by the 1890s (Taylor, 2011; NPS, 2018). The decimation of buffalo further devastated Native Americans on the Great Plains (NPS, 2018); across the United States, the American Indian population declined from approximately 600,000 in 1800 to 237,000 in the 1890s (Thornton, 1987, p. 32).

In 1887, President Cleveland signed the Act to Provide for the Allotment of Lands in Severalty to Indians on the Various Reservations (commonly known as the Dawes Act;

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Table B10. Tribal nations in the North Central Grassland Ecoregions.

[NA, not applicable]

Tribal nation[1]	Location
Assiniboine and Sioux Tribe of the Fort Peck Indian Reservation, Montana	Montana
Blackfeet Tribe of the Blackfeet Indian Reservation of Montana	Montana
Cheyenne River Sioux Tribe of the Cheyenne River Reservation, South Dakota	South Dakota
Chippewa Cree Indians of the Rocky Boy's Reservation, Montana	Montana
Crow Creek Sioux Tribe of the Crow Creek Reservation, South Dakota	South Dakota
Crow Tribe of Montana	Montana
Flandreau Santee Sioux Tribe of South Dakota	South Dakota
Fort Belknap Indian Community of the Fort Belknap Reservation of Montana[2]	Montana
Iowa Tribe of Kansas and Nebraska	Kansas and Nebraska
Kickapoo Tribe of Indians of the Kickapoo Reservation in Kansas	Kansas
Little Shell Band of Chippewa Indians of Montana	Montana
Lower Brule Sioux Tribe of the Lower Brule Reservation, South Dakota	South Dakota
Northern Cheyenne Tribe of the Northern Cheyenne Indian Reservation, Montana	Montana
Oglala Sioux Tribe	South Dakota
Omaha Tribe of Nebraska	Nebraska
Ponca Tribe of Nebraska	Nebraska
Prairie Band Potawatomi Nation	Kansas
Rosebud Sioux Tribe of the Rosebud Indian Reservation, South Dakota	South Dakota
Sac & Fox Nation of Missouri in Kansas and Nebraska	Kansas and Nebraska
Santee Sioux Nation, Nebraska	Nebraska
Sisseton-Wahpeton Oyate of the Lake Traverse Reservation, South Dakota	North Dakota and South Dakota
Spirit Lake Tribe, North Dakota	North Dakota
Standing Rock Sioux Tribe of North & South Dakota	North Dakota and South Dakota
Three Affiliated Tribes of the Fort Berthold Reservation, North Dakota[3]	North Dakota
Turtle Mountain Band of Chippewa Indians of North Dakota	North Dakota, South Dakota, and Montana
Winnebago Tribe of Nebraska	Nebraska
Yankton Sioux Tribe of South Dakota	South Dakota

[1]Five Tribal nations in the North Central region were not included because they are outside of the North Central Grassland Ecoregions and in high-altitude, mountainous grassland ecoregions. The ecology and management challenges differ from that of North Central grasslands and are not addressed in this report.

[2]Fort Belknap Indian Community of the Fort Belknap Reservation of Montana includes the Assiniboine and Gros Ventre Tribes.

[3]Three Affiliated Tribes of the Fort Berthold Reservation, North Dakota include Mandan, Hidatsa, and Arikara Tribes.

25 U.S.C. 9), which broke many reservations into individual allotments for the exclusive use and benefit of individual Native American heads of households, while still held in trust by the Federal Government (Treuer, 2019, p. 146). Individual ownership of land was a paradigm shift and fundamentally changed the way Tribal members were encouraged to interact with the environment. Through the Dawes Act, 160 acres were allotted to the head of each Native American family or 80 acres to each single adult. Many Native Americans did not want to farm, and Native Americans who did often could not afford the seeds and equipment required to do so (Indian Land Tenure Foundation, 2022; National Archives, 2022). After land was allotted to Native Americans, the rest was sold to European settlers through the Homestead Act of 1862 (Public Law 37–64, 12 Stat. 392). Additional Tribal land was lost to tax foreclosure auctions when the 1906 Burke Act (25 U.S.C. 349) gave the Secretary of the Interior authority to transfer allotted land out of trust by making it subject to taxes without the knowledge of the allottee (Indian Land Tenure Foundation, 2022). By 1934, the policies of the allotment period reduced American Indian landholdings nationwide from 138 million acres to 48 million acres, or a reduction of about two-thirds (Debo, 1973; Treuer, 2019, p. 150).

In 1934, the U.S. Congress passed the Indian Reorganization Act (IRA; 25 U.S.C. 461 et seq.; as of December 5, 2024, is renumbered 25 U.S.C. 5101 et seq.), which ended the system of allotment and urged Tribes to establish their own constitutions and governments according to a BIA model of Tribal constitutions and charters that often bore little resemblance to traditional Tribal governance systems (Treuer, 2019, p. 206; Frye and Parker, 2021, p. 233). Tribal nations had 18 months to vote to accept or reject the governance as outlined in the IRA. Acceptance meant access to Federal development funds administered by the BIA and extensive Federal oversight, whereas rejection allowed Tribes to maintain more autonomy at the cost of access to Federal resources (Frye and Parker, 2021, p. 233). Of the Tribal nations in the North Central Grassland Ecoregions, 20 voted to adopt an IRA government and 7 did not.

The changes in the North Central Grassland Ecoregions during these 100 years are critical for understanding the current context of Tribal resource management today. The restructuring of land ownership and Tribal governance altered the way Native Americans interact with the natural world and resulted in varying levels of grassland management capacity and control. Although many Tribes retained treaty rights to use natural resources, management was often performed top down by the BIA. The Indian Self-Determination Act and Education Assistance Act of 1975 (25 U.S.C. 450(f) et seq.; as of December 8, 2024, is renumbered 25 U.S. C. 5301(f) et seq.), also known as Public law 93–638 and often referred to as "638," fostered another major policy shift in Tribal lands whereby Tribes gained some capacity and agency over management of their natural resources by Public law 93–638 contracts and compacts with the Federal Government—an arrangement that persists to the present day. The Indian Self-Determination and Education Assistance Act was followed by the American

Indian Agricultural Resource Management Act in 1993 (25 U.S.C. 3701; also known as AIARMA) that established the basic structure of Integrated Resource Management Plans, including Agricultural Resource Management Plans as guiding documents for Tribal management of natural resources. The AIARMA clarifies Tribes exert significant authority in determining the nature of their Integrated Resource Management Plans. However, as an unfunded mandate, the BIA and Tribes have often struggled to complete these essential planning documents.

Many Tribes struggle to piece together a patchwork of small and short-term funding sources. Disputes over restrictions on the use of 638 funds are also commonplace, often enabling on-the-ground projects but severely limiting personnel capacity and training. Furthermore, internal bureaucratic structure varies widely among Tribes. Some Tribal nations have no formal natural resource management department or program. These differences in Federal–Tribal arrangements and internal Tribal structures affect the process and the effectiveness of grassland management.

As of 2023, Tribal nations manage about manage about 19 million acres on reservations in the North Central Grassland Ecoregions; this acreage represents about 6 percent of the total area in the North Central Grassland Ecoregions (table B11; fig. B2). Tribal lands include three different basic types of ownership—trust land, allotments, and fee land (refer to Brewer and others, 2016). Trust land is owned by the U.S. Government, management control and oversight by the BIA, but the beneficial interest (that is, the right to benefit from the land) remains with the Tribal Government. The title of allotments is also held by the U.S. Government, but the beneficial use is for Native individuals. Fee lands are owned by individuals whether they are native or nonnative. All three of these land types may exist within or outside a reservation boundary. Many Tribal nations are in the process of returning lands to the Tribal Government. For example, the Rosebud Sioux Tribe of the Rosebud Indian Reservation, South Dakota established a Tribal Land Enterprise office in 1943 to buy back lands that were once within the original boundaries of the Rosebud Reservation (Tribal Land Enterprise, 2018). Some of the lands purchased by the Tribal Land Enterprise office go through the process to be put back into trust for the Rosebud Sioux Tribe of the Rosebud Indian Reservation, South Dakota (Tribal Land Enterprise, 2018).

Although colonization has significantly altered Tribal governance, many Tribal nations continue to pursue a strong ethic of land stewardship. This land stewardship ethic stems from the long-held Indigenous perception of humanity as an equal part of the natural processes within an ecosystem, rather than as central to or separate from the ecosystem (Pierotti and Wildcat, 2000). This interconnection with the natural surroundings is a large part of Native American identity and informs the belief that balance must be maintained to support a positive relationship between land and humanity (Berkes and others, 2000; Donatuto and others, 2016; Richmond and Big-Canoe, 2018; National Fish Wildlife and Plants Climate Adaptation Network, 2021a). For example, Indigenous peoples generally strive to embody traditional teachings of not taking more than what is needed from the land and recognizing that poor stewardship prioritizing economic gain at the expense of biodiversity creates imbalances in the system which in turn cause problems for humanity (Cheyenne River Sioux and National Wildlife Federation, 2001). These cultural beliefs and practices may account for the recent findings that biodiversity thrives on Indigenous lands (Intergovernmental Platform on Biodiversity and Ecosystem Services, 2019, p. 31).

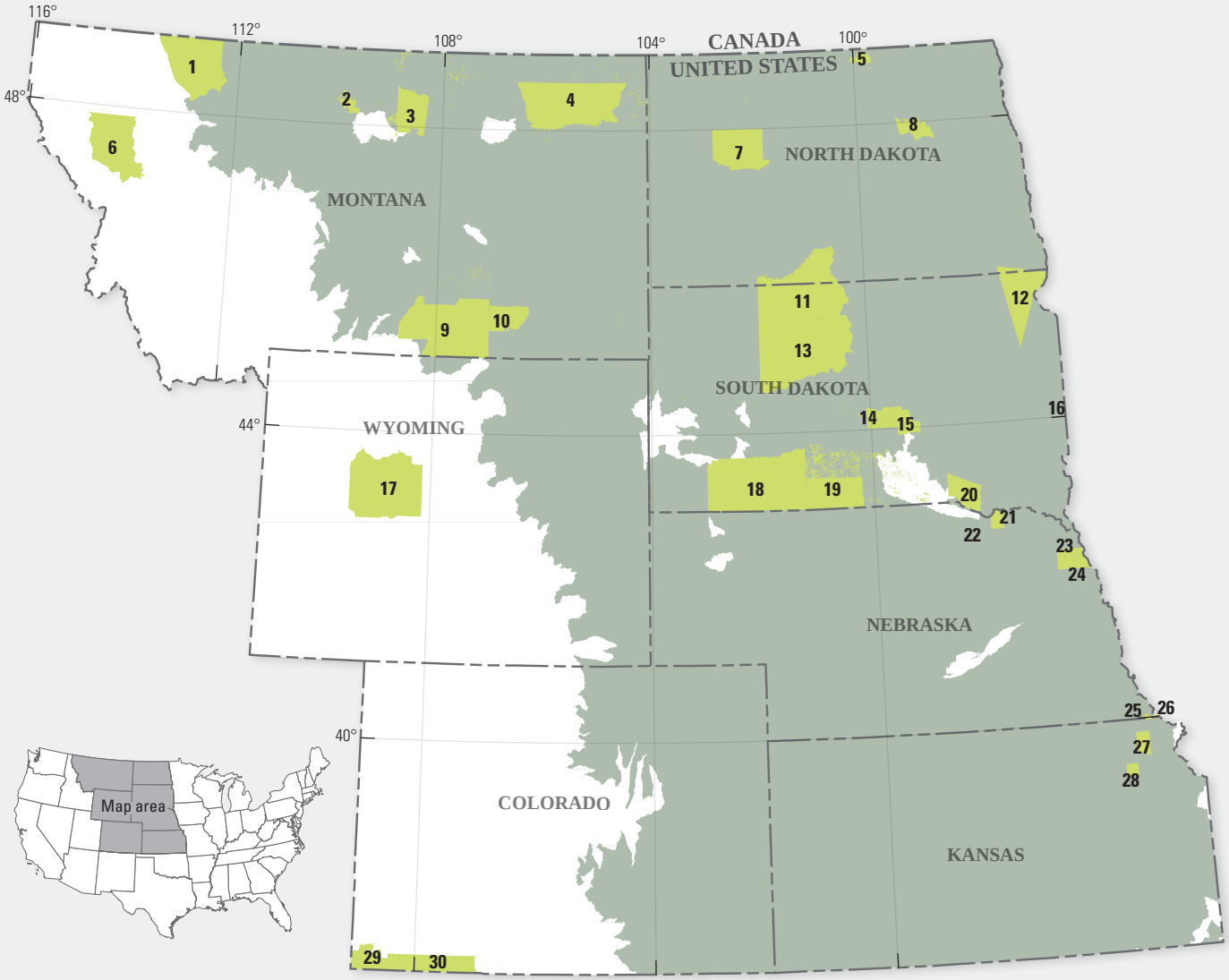
Despite many examples of strong environmental ethics, Tribes often face difficult tradeoffs between economic development and environmental stewardship. As global trends have shown, poverty alleviation is often a necessary precursor to addressing environmental concerns (Duraiappah, 1998; Masron and Subramaniam, 2019). For example, the Three Affiliated Tribes of the Fort Berthold Reservation, North Dakota, which lies on top of the Bakken Formation, has opted to take advantage of its location by opening the reservation lands to oil and gas extraction. This decision was made by the Tribal Council to increase their economic independence. As a result, the Three Affiliated Tribes of the Fort Berthold

Table B11. North Central Grassland Ecoregions acres managed by Tribal nations (in conjunction with the Bureau of Indian Affairs to varying degrees).

Ecoregion[1]	Land managed by Tribal nations, in acres							
	Montana	Wyoming	Colorado	North Dakota	South Dakota	Nebraska	Kansas	Total
Tallgrass	0	0	0	73,559	897,927	103,752	239,778	1,315,016
Northern Mixed Grass[2]	1,854,899	0	0	2,087,921	6,725,295	39,782	0	10,707,898
Central Mixed Grass	0	0	0	0	2,131,317	295,574	0	2,426,891
Shortgrass	0	0	0	0	281,770	0	0	281,770
Sagebrush–Grassland Ecotone	4,215,988	261	0	0	0	0	0	4,216,249
Total	**6,070,887**	**261**	**0**	**2,161,480**	**10,036,310**	**439,108**	**239,778**	**18,947,823**

[1]Acreages include waterbodies within grassland ecoregions. Acreages are derived from the Protected Areas Database of the United States (U.S. Geological Survey Gap Analysis Project, 2020) and the development of ecoregions is defined in Miller Hesed and Yocum (2026), figure A5. Refer to section A1 in Miller Hesed and Yocum (2026).

[2]The acreage for the Northern Mixed Grass Ecoregion excludes that which falls within the Sagebrush–Grassland Ecotone.



EXPLANATION

Tribal nation lands

North Central Grassland Ecoregion

Tribal nation names

1. Blackfeet Tribe of the Blackfeet Indian Reservation of Montana
2. Chippewa Cree Indians of the Rocky Boy's Reservation, Montana
3. Assinibine and Sioux Tribes of the Fort Peck Indian Reservation, Montana
4. Assiniboine and Sioux Tribes of the Fort Peck Reservation, Montana
5. Turtle Mountain Band of Chippewa Indians of North Dakota
6. Confederated Salish and Kootenai Tribes of the Flathead Reservation
7. Three Affiliated Tribes of the Fort Berthold Reservation, North Dakota
8. Spirit Lake Tribe, North Dakota
9. Crow Tribe of Montana
10. Northern Cheyenne Tribe of the Northern Cheyenne Indian Reservation, Montana
11. Standing Rock Sioux Tribe of North and South Dakota
12. Sisseton-Wahpeton Oyate of the Lake Traverse Reservation, South Dakota
13. Cheyenne River Sioux Tribe of the Cheyenne River Reservation, South Dakota
14. Lower Brule Sioux Tribe of the Lower Brule Reservation, South Dakota
15. Crow Creek Sioux Tribe of the Crow Creek Reservation, South Dakota
16. Flandreau Santee Sioux Tribe of South Dakota
17. Eastern Shoshone Tribe of the Wind River Reservation, Wyoming and Northern Arapaho Tribe of the Wind River Reservation, Wyoming
18. Oglala Sioux Tribe
19. Rosebud Sioux Tribe of the Rosebud Indian Reservation, South Dakota
20. Yankton Sioux Tribe of South Dakota
21. Santee Sioux Nation, Nebraska
22. Ponca Tribe of Nebraska
23. Winnebago Tribe of Nebraska
24. Omaha Tribe of Nebraska
25. Sac & Fox Nation of Missouri in Kansas and Nebraska
26. Iowa Tribe of Kansas and Nebraska
27. Kickapoo Tribe of Indians of the Kickapoo Reservation in Kansas
28. Prairie Band Potawatomi Nation
29. Ute Mountain Ute Tribe
30. Southern Ute Indian Tribe of the Southern Ute Reservation, Colorado

Figure B2. Map of the Tribal nations and North Central Grassland Ecoregion. Additional Tribes not shown here may also have ties to land in the North Central region. Data from the Protected Area Database of the United States (U.S. Geological Survey Gap Project Analysis, 2020).

Reservation, North Dakota offers Tribal members monetary resources, social programs, and modern infrastructure, which facilitates the further development of the community and individual community members' well-being (Mandan, Hidatsa, & Arikara Nation Energy Division, 2013).

The decision of the Three Affiliated Tribes of the Fort Berthold Reservation, North Dakota to extract oil and gas has come at a cost; the drinking water for Tribal nations and others in the North Central Grassland Ecoregions are threatened because of the possibility of contamination. The development of the Dakota Access Pipeline, which sparked national protests, transports oil from the Bakken Formation to the Gulf Coast, crossing the Missouri River at the northern border of the Standing Rock Sioux Tribe of North & South Dakota Reservation (Estes, 2019; Gilio-Whitaker, 2019). Pipelines are vulnerable to damage from flooding and erosion (U.S. Department of Energy, 2015), and a break in the Dakota Access Pipeline could contaminate the drinking water that is piped from the Missouri River to many of the reservations on the western side of South Dakota (Estes, 2019). In addition, a leak could allow oil to seep into the Ogallala aquifer and threaten the water supply for drinking water and irrigation across an even greater area (Song, 2011).

This situation highlights the challenges Tribal nations face in navigating Federal policies and other social pressures. Additionally, the development of agricultural economies on marginal lands may have ensured reliance on Federal funding because of an inability to achieve economic sustainability. Tribal nations are in a challenging position where they must weigh the tradeoffs between economic development, cultural preservation, environmental **conservation**, and autonomy.

Grassland Management

Modern reservations are exceedingly small areas of land compared to the traditional homelands of Tribal nations in the North Central Grassland Ecoregions. However, these reservations contain some of the last intact, native ecosystems and **undisturbed** lands in the region, including 10 percent of unplowed grasslands (First Nations Development Institute, 2018; Lark, 2020; World Wildlife Fund, 2021). The management of natural resources is economically and culturally important to Tribal nations (Hendrickson and others, 2016). Native species of **prairie** grasses and forbs exist in abundance on these remaining undisturbed areas, and many Tribal nations aim to protect and maintain these grasslands. For example, the Cheyenne River Sioux Tribe of the Cheyenne River Reservation, South Dakota is a leading example of this effort by dedicating 47,000 acres of land as a conservation area to restore grasslands and promote the natural production of native plants and habitats (Cheyenne River Sioux and National Wildlife Federation, 2001). Increasingly, Tribal nations are working together toward the goal of more unified land management based on Indigenous knowledge and best available science.

Soil Health

The specific grassland management goals and activities of Tribal nations vary according to their particular ecoregion, traditions, and resource management capacity. There is not a lot of literature on traditional ecological knowledge of soil; however, many Tribes hold the traditional understanding that there is life in the soil that cannot be seen and is important to the overall health of the ecosystem. Each Tribal nation may have a unique relationship with the soil and various ways of characterizing that relationship. A traditional, Indigenous understanding is that soil has a spirit, is a living part of nature, and should be respected as a relative to all the natural world (Kimmerer, 2013). Traditional, Indigenous fire practices were conducted to benefit plant production and to enrich the soil by replenishing the nutrients. Soil health is a continual objective for Tribal resource management of the grasslands (Blackfeet Nation, 2018).

Recognition of the importance of soil in ecosystem function is fitting with Indigenous epistemologies which have been broadly characterized as emphasizing holism rather than reductionism (Mebratu, 1998). Many Indigenous practices directly and indirectly affect soil health, from dryland agricultural techniques in the Southwest (Martinez and Johnson, 2010), to prescribed fire on the Great Plains eliciting prairie growth and buffalo grazing (Kimmerer and Lake, 2001). Whether through direct intervention or the indirect effects of holistic social-ecological systems approaches (Martin and others, 2010), the soil health benefits of Indigenous lifeways has long been noted, and the North Central grasslands are no exception. Further research into the connections between soil conditions and traditional ecological knowledge, including historical cultural practices, of regional Tribal nations is needed.

Conservation of Culturally Important Plants

A big concern for Tribal nations across the North Central Grassland Ecoregions is the **protection** and conservation of the culturally significant plants (table B12) within reservation boundaries. There has been a continuous increase in the number of nonnative plants and noxious weeds on reservation lands across the North Central Grassland Ecoregions (table B13). Tribal members have concerns that invasive plants and noxious weeds are changing not only the aesthetic of the landscape, but also affecting the soil health to no longer favor native grasses and plants that are endemic to the region (Rosebud Sioux Tribe of the Rosebud Indian Reservation, South Dakota, oral commun., 2009–21). There have been efforts by Tribal nations to develop programs to help identify noxious weeds and mitigate their effect (Cheyenne River Sioux and National Wildlife Federation, 2001; Goodwin and Longknife, 2013; Martin and others, 2020). For example, the Fort Belknap Indian Community of the Fort Belknap

Reservation of Montana strategic plan for managing noxious weeds included prevention of new infestations, frequent surveying of high-risk sites for weeds, eradication through "adopt a patch" initiatives that use reward and recognition systems, education and engagement of the Tribal community by designing projects based on local knowledge and concerns, and mapping and controlling infestations using weed-specific protocols (Goodwin and Longknife, 2013, p. 4).

Anthoxanthum nitens (Weber) Y. Schouten & Veldkamp (also known as *Hierochloe odorata* (L.) Beauv. and *Hierochloe hirta* (Schrank) var. *arctica* (J.Presl) G. Weim and commonly known as sweetgrass; NRCS, 2002) is a critical, culturally significant plant under threat in the North Central grasslands. An aromatic, cool-season perennial that grows 10–24 inches in height, sweetgrass has long been used by Tribes in the North Central Grassland Ecoregions. Its enticing, sweet-smelling

Table B12. Culturally significant plants for Tribal nations in the North Central Grassland Ecoregions.

[This table is not an exhaustive list of culturally significant plants on Tribal lands, nor does it list every Tribal nation to which each plant is culturally important. This table provides examples of culturally important plants identified either by a relevant publication (Martin and others, 2020) or from informal conversations with Tribal members. ssp., subspecies; spp. several species of]

Common name	Scientific name	Tribal nations
Bitterroot	*Lewisia rediviva* Pursh	Crow Tribe of Montana
Buffalo berries	*Shepherdia argentea* (Pursh) Nutt.	Rosebud Sioux Tribe of the Rosebud Indian Reservation, South Dakota
Chokecherry	*Prunus virginiana* L.	Rosebud Sioux Tribe of the Rosebud Indian Reservation, South Dakota
Cottonwood	*Populus deltoides ssp. Monilifera* (Aiton) Eckenw.	Rosebud Sioux Tribe of the Rosebud Indian Reservation, South Dakota
Echinacea	*Echinacea angustifolia* DC.	Crow Tribe of Montana
Flat cedar	*Thuja occidentalis* L.	Rosebud Sioux Tribe of the Rosebud Indian Reservation, South Dakota
Mint	*Mentha arvensis* L.	Crow Tribe of Montana
Plum	*Prunus americana* Marshall	Rosebud Sioux Tribe of the Rosebud Indian Reservation, South Dakota
Red willow	*Salix laevigata* Bebb	Rosebud Sioux Tribe of the Rosebud Indian Reservation, South Dakota
Sweet sage	Unknown	Crow Tribe of Montana
Sweetgrass	*Anthoxanthum odoratum* L., *Hierochloe odorata* (L.) Beauv., or *Hierochloe hirta* (Schrank) var. *arctica* (J.Presl) G. Weim	Rosebud Sioux Tribe of the Rosebud Indian Reservation, South Dakota
Wild berries	Various spp.	Crow Tribe of Montana
Wild onion	*Allium canadense* L.	Crow Tribe of Montana
Wild turnip	*Pediomelum esculentum* (Pursh) Rydb. (formerly known as *Psoralea esculenta* Pursh)	Crow Tribe of Montana

Table B13. Nonnative plants of concern for Tribal nations in the North Central Grassland Ecoregions.

[This is neither an exhaustive list of exotic plants of concern on Tribal lands, nor does it list every Tribal nation that is confronted with these exotic plants. This table provides examples of invasive plants and noxious weeds identified by some of the Tribal nations in the North Central grasslands. These plants may be invasive species, noxious weeds (that is, plants formally designated by Federal, State, or county government as harmful to humans, agriculture, or ecosystems [Sheley and others, 1999]), or both. Cheyenne River Sioux and National Wildlife Federation, 2001; Goodwin and Longknife, 2013; and Martin and others, 2020. spp., several species of]

Common name	Scientific name	Tribal nations
Canada thistle	*Cirsium arvense* (L.) Scop.	Cheyenne River Sioux Tribe of the Cheyenne River Reservation, South Dakota and Fort Belknap Indian Community of the Fort Belknap Reservation of Montana
Cheatgrass	*Bromus tectorum* L.	Cheyenne River Sioux Tribe of the Cheyenne River Reservation, South Dakota
Dalmation toadflax	*Linaria dalmatica* (L.) Mill.	Fort Belknap Indian Community of the Fort Belknap Reservation of Montana
Diffuse knapweed	*Centaurea diffusa* Lam.	Fort Belknap Indian Community of the Fort Belknap Reservation of Montana
Field bindweed	*Convolvulus arvensis* L.	Fort Belknap Indian Community of the Fort Belknap Reservation of Montana
Houndstongue	*Cynoglossum officinale* L.	Fort Belknap Indian Community of the Fort Belknap Reservation of Montana
Leafy spurge	*Euphorbia esula* L.	Cheyenne River Sioux Tribe and Fort Belknap Indian Community of the Fort Belknap Reservation of Montana
Russian olive	*Elaeagnus angustifolia* L.	Crow Tribe of Montana
Saltcedar	*Tamarix* spp.	Fort Belknap Indian Community of the Fort Belknap Reservation of Montana
Spotted knapweed	*Centaurea stoebe* L.	Crow Tribe of Montana and Fort Belknap Indian Community of the Fort Belknap Reservation of Montana
Yellow sweet clover	*Melilotus officinalis* (L.) Lam.	Cheyenne River Sioux Tribe of the Cheyenne River Reservation, South Dakota

aroma is thought to facilitate a positive mental state, and it has been used in spiritual ceremonies to invite good intentions in one's prayers and thoughts. Its pleasing perfume was also one reason sweetgrass was commonly used by Indigenous peoples as decoration, worn in the hair, and woven into hats (Kindscher, 1992; Kimmerer, 2013).

Sweetgrass was also used medicinally by various Tribes. The Blackfeet Tribe of the Blackfeet Indian Reservation of Montana used sweetgrass tea to treat coughs and sore throats, to ease women's bleeding after giving birth, and to stop venereal infections in men (Kindscher, 1992). Sweetgrass was also commonly traded among Tribes. Even Tribes currently (2025) located in the Rocky Mountains, such as the Confederated Salish and Kootenai Tribes of the Flathead Reservation, traditionally made tea from sweetgrass to treat colds, fevers, and relieve sharp internal pains (Kindscher, 1992).

Indigenous peoples in the North Central Grassland Ecoregions have become aware, through observation, that sweetgrass is extremely sensitive to the climatic shifts induced by climate change. The decreasing abundance of sweetgrass has been observed by elders in the Rosebud Sioux Tribe of the Rosebud Indian Reservation, South Dakota (E. Boyd-Valandra, Indigenous Conservation Consultant, oral commun., 2021).

Grazing Management

The agricultural lifestyle was forced upon many Tribal nations in the Great Plains as part of the Federal policy of assimilation (National Park Service [NPS], 2021). Over time Great Plains Tribes adapted for survival, and now, ranching and farming are a cornerstone of the identities and economies for some Tribal members (Iverson, 1995; Hendrickson and others, 2016). Tribal nations have varying levels of control over the management of their grazing lands, because native and nonnative peoples can lease Tribal land for grazing and these leases are most often managed by the BIA rather than by Tribal nations. As the impacts of climate change are continually felt across the North Central Grassland Ecoregions, Tribal nations are concerned that grazing policies adapt to support the health of grassland ecosystems and the economic sustainability of grazing (Hendrickson and others, 2016).

Grazing rental rates are a key component of economic sustainability on reservations. They are set by the BIA for all Tribal allotments and for Tribal land when the Tribal nation has not established a rate (refer to "Grazing Permits" [25 CFR. § 166.400(b)]). Concerns have been raised over conflicting objectives between the historical BIA emphasis on maximizing economic return (BIA, 1984, p. 6) and Tribal efforts to restore biodiversity and holistic grassland health. The "Range Management—General Grazing Regulations Handbook" reissued by the BIA in 1984 states that "Within the framework of the prevailing line authority and land ownership complexities the range manager promotes a program of full production, sustained yield use, and development and improvement of the grazing resource for the economic benefit of the Indian people" (BIA, 1984, p. 6). Some Tribal nations are working to change this economic prioritization; however, the lack of enforceable regulations for cattle grazing on Tribal land is a broadly shared concern for Tribes across the North Central Grassland Ecoregions when considering grassland management (Cheyenne River Sioux and National Wildlife Federation, 2001; New Century Environmental LLC and Winnebago Tribe of Nebraska, 2017; Great Plains Tribal Water Alliance, 2020).

Tribal nations are also increasingly concerned about the economic sustainability of ranching for their Tribal members (Terry Tatsey, Senior Advisor to Blackfeet Tribe of the Blackfeet Indian Reservation of Montana, oral commun., 2021; also refer to High Plains Journal, 2004; Shoemaker, 2006). Climate change directly impacts the vegetative growth of grasslands, increasing the difficulty of predicting the quantity and quality of forage that will be available for livestock. The rate at which ranchers lease land for grazing is based on a price per animal unit month (AUM)—the amount of forage required by one animal for one month—which may be determined by the Tribe or by the BIA, particularly for some individual, Tribal allotment lands (25 CFR § 166.400(b)). For some BIA-administered leases, concerns have been raised over fair market values of Tribal lands and Tribal allotments in relation to private lands and Federal public lands. A report published by Farmers' Legal Action Group explains the following:

> "Many Indian ranchers have objected that the grazing rates set by BIA are too high in comparison to off-reservation rates on other federal lands. Although BIA has a legal responsibility as trustee to maximize the benefits to Indian landowners for whom the rent is collected, rates set by the BIA are often four to five times higher than their off-reservation competitors pay to the BLM or the United States Forest Service. BIA sets these rates by establishing average "fair market" rental rates, based on appraisal methods including a survey of other sales and leases of private land in the region. However, this survey system is often based on rates for land parcels that are not comparable in size or degree of development to those trust parcels which Indian producers seek to lease, and this disadvantages Indian farmers and ranchers who seek to make effective use of Indian resources" (Shoemaker, 2006 p. 29).

Although higher AUM rates generate more money for the owners of Tribal allotments (Brown and others, 1982; Johnny, 1991), it puts considerable economic strain on ranchers, many of whom are Tribal members, who lease the land. The strain on ranchers will be exacerbated if climate change reduces the amount of forage available such that ranchers are paying for more AUMs than are actually provided by the leased land. Maintaining ranching as a viable economic opportunity for Native Americans is of great concern to Tribal nations (Terry Tatsey, Blackfeet Tribe of the Blackfeet Indian Reservation of Montana Senior Advisor, oral commun., 2021).

Buffalo Reintroduction and Management

Buffalo are of particular spiritual, cultural, and economic importance to the Tribal nations of the Great Plains. Before colonization, these Tribal nations were nomadic peoples who followed the buffalo across the grasslands. These Tribes traditionally used every part of the buffalo for food, utensils, tools, ceremonies, clothing, housing material, and other purposes. In addition, many Native Americans in the North Central region have a deep spiritual relationship with the buffalo. Some Native American cultures consider the buffalo a relative and others see themselves as "buffalo people" and descended from them (for example, Cheyenne River Sioux and National Wildlife Federation, 2001).

In the late 1800s, the centrality of buffalo to Tribal peoples on the Great Plains was exploited by the Federal Government to force Tribal nations to comply with their policy of agricultural settlement on reservations (Isenberg, 2012). Non-Indigenous settlers in the Great Plains were encouraged to shoot buffalo as they migrated west into Native American territory. A whole market economy developed around shooting buffalo for sport and exporting the hides to markets in the East and Europe. Hunters would take buffalo hides and sometimes skulls and leave the remaining animal (meat and bones)—a sacred, traditional resource—to decay on the plains (fig. B3). Millions of buffalo were exterminated over the course of a decade until the buffalo was nearly extinct (Taylor, 2011; NPS, 2021). This extermination forced Tribal communities to assimilate into settled, monoagricultural practices on reservations for survival.

The proper management of buffalo populations can help improve the health of grassland ecosystems, and many Tribal nations in the North Central Grassland Ecoregions manage buffalo herds within designated conservation areas (Shamon and others, 2022). When provided adequate space to roam, buffalo grazing helps support a heterogeneous and biodiverse landscape (Kohl and others, 2013). Buffalo are also better adapted to withstand weather extremes than cattle (Plumb and Dodd, 1993, p. 639–640), a trait which may become increasingly important as the climate changes (Intergovernmental Panel on Climate Change, 2021). In addition to the ecological benefits of buffalo, Tribal nations highly value buffalo **restoration** programs because of the connection the buffalo provide to Tribal culture (Cheyenne River Sioux and National Wildlife Federation, 2001; Doyle and others, 2013; Becker and others, 2015, 2020; Martin and others, 2020; Fort Belknap Indian Community, 2023).

Figure B3. Photograph of a pile of *Bison bison* (bison or buffalo) skulls, circa 1892. Photograph modified from the Detroit Public Library Burton Historical Collection, 2011, accessed from Wikimedia Commons at https://en.m.wikipedia.org/wiki/File:Bison_skull_pile.jpg.

Conservation of Wildlife

Indigenous peoples of the Great Plains understand that all wildlife play an important role in grassland ecology and are valuable components of grassland ecosystems; nevertheless, certain species of grassland wildlife are of particular conservation concern for Tribal nations in the North Central Grassland Ecoregions. Some Tribal nations are concerned about the loss of bird species and other declines in wildlife populations that are important for commercial hunting and small mammals that are used in traditional medicine and support native grassland ecosystems (table B14). The *Cynomys ludovicianus* (black-tailed prairie dog) and *Mustela nigripes* (black-footed ferret) have been the focus of at least two Tribal grassland restoration efforts (Cheyenne River Sioux and National Wildlife Federation, 2001).

Emerging Challenges and Opportunities

Tribal nations face many unique challenges and opportunities as they manage grasslands in a changing climate. These challenges and opportunities generally relate to legal and policy drivers, economic incentives, availability of usable science and tools, and frameworks conceptualizing problems and solutions (refer to the "Contributing Factors" section in Miller Hesed and Yocum, 2026, sec. A3); however, the tribally relevant issues are quite distinct.

Tribal Land Ownership

A primary barrier to Tribal nations' management of their grasslands is that their land base is much diminished. The allotment of individual land ownership initiated by the Dawes Act of 1887 enabled the BIA to forcefully assimilate Native American families into the settled, agrarian lifestyle. Land ownership is crucial to the existence of modern Tribal nations and without a land base many Tribes face termination (that is, ending the relationship between the U.S. Government and Tribal nation by no longer acknowledging the sovereignty of the Tribe). Thus, additional land entities, such as the Rosebud Sioux Tribe of the Rosebud Indian Reservation, South Dakota Tribal Land Enterprise office, have prioritized building back a diminished land base. However, these types of offices can further add to the complicated landscape of Tribal land ownership and sometimes create hindrances or conflicts among land management entities.

Tribal land is a complicated patchwork of different ownership types, posing challenges for cohesive grassland management strategies. In particular, there are many limitations to what can be done to land held in trust. For example, it is difficult to enroll land held in trust into conservation easements. In addition, because land held in trust is leased for a short period and then may be leased to a different family, there is a disincentive for long-term planning and investment in the land (Dippel and others, 2020).

There are many opportunities to address these challenges. Many Tribal nations are expanding their land base through the U.S. Department of the Interior (DOI) Land Buy-Back Program for Tribal Nations (DOI, 2022a) or by purchasing land using gaming or other revenue streams. Other opportunities for expanding the Tribal land base include reparation from Land Grant Universities (Lee and Ahtone, 2020; Nash, 2019) and the development of Native American land trusts (Ptak, 2015; BIA, 2022a; DOI, 2022b; National Congress of American Indians, 2022). Another strategy is developing unified land codes and protocols among the various land management entities, which could help reduce barriers to implementation of grassland management strategies.

Funding and Capacity

An ongoing challenge for Tribal nations is obtaining funding to increase their capacity to manage grasslands in a changing climate (Status of Tribes and Climate Change Working Group, 2021). Tribal nations often find that they must compete against each other for the small amount of money that is available to them. For example, of the $2 billion that foundations gave to environmental causes annually between 2014 and 2019, only 0.5 percent of that money was awarded to environmental organizations and causes in Tribal nations (Foxworth, 2020). Tribal nations need greater funding to enhance their capacity to manage grasslands in a changing climate.

One opportunity to increase funding for Tribal nations' resource management could be to develop programs that could provide monetary compensation in exchange for land management that provides ecological services, such as carbon storage. For example, Tribal nations already have some of the last **intact grasslands** in the North Central Grassland Ecoregions (Lark, 2020) and could receive some compensation for that service from U.S. Farm Bill programs.

In addition, there is an opportunity to engage Tribal resource managers in the earliest stages of research and project development to help ensure that ongoing projects are meeting Tribal needs (Hendrickson and others, 2016). For example, funders could consult with Tribal resource managers before releasing a funding announcement to ensure that the types of projects they fund will address concerns for Tribal nations.

Table B14. Wildlife of conservation concern for Tribal nations in the North Central Grassland Ecoregions.

[This table is neither an exhaustive list of wildlife of conservation concern for Tribal nations, nor does it list every Tribal nation to which each animal is important. This table provides examples of important wildlife identified in Tribal reports (Cheyenne River Sioux and National Wildlife Federation, 2001; Doyle and others, 2013; Goodwin and Longknife, 2013; Hendrickson and others, 2016; New Century Environmental LLC and Winnebago Tribe of Nebraska, 2017; Great Plains Tribal Water Alliance, 2020; Martin and others, 2020)]

Common name	Scientific name	Tribal nations
	Bird	
American robin	*Turdus migratorius*	Crow Tribe of Montana
American widgeon	*Mareca americana*	Cheyenne River Sioux Tribe of the Cheyenne River Reservation, South Dakota Crow Tribe of Montana
Baird's sparrow	*Ammodramus bairdii*	Fort Belknap Indian Community of the Fort Belknap Reservation of Montana
Bald eagle	*Haliaeetus leucocephalus*	Cheyenne River Sioux Tribe of the Cheyenne River Reservation, South Dakota
Bobwhite quail	*Colinus virginianus*	Winnebago Tribe of Nebraska
Burrowing owl	*Athene cunicularia*	Cheyenne River Sioux Tribe of the Cheyenne River Reservation, South Dakota Fort Belknap Indian Community of the Fort Belknap Reservation of Montana
Chestnut-collared longspur	*Calcarius ornatus*	Fort Belknap Indian Community of the Fort Belknap Reservation of Montana
Ferruginous hawk	*Buteo regalis*	Fort Belknap Indian Community of the Fort Belknap Reservation of Montana
Golden eagle	*Aquila chrysaetos*	Cheyenne River Sioux Tribe of the Cheyenne River Reservation, South Dakota Fort Belknap Indian Community of the Fort Belknap Reservation of Montana
Greater prairie-chicken	*Tympanuchus cupido*	Crow Tribe of Montana Oglala Sioux Tribe
Greater sage-grouse	*Centrocercus urophasianus*	Crow Tribe of Montana Fort Belknap Indian Community of the Fort Belknap Reservation of Montana
Long-billed curlew	*Numenius americanus*	Fort Belknap Indian Community of the Fort Belknap Reservation of Montana
Black-billed magpie	*Pica hudsonia*	Crow Tribe of Montana
Mallard	*Anas platyrhynchos*	Cheyenne River Sioux Tribe of the Cheyenne River Reservation, South Dakota Crow Tribe of Montana
McCown's longspur	*Calcarius mccownii*	Fort Belknap Indian Community of the Fort Belknap Reservation of Montana
Mountain bluebird	*Sialia currucoides*	Crow Tribe of Montana
Mountain plover	*Charadrius montanus*	Fort Belknap Indian Community of the Fort Belknap Reservation of Montana
Mourning dove	*Zenaida macroura*	Crow Tribe of Montana
Ring-necked pheasant	*Phasianus colchicus*	Oglala Sioux Tribe Winnebago Tribe of Nebraska
Northern pintail	*Anas acuta*	Cheyenne River Sioux Tribe of the Cheyenne River Reservation, South Dakota Crow Tribe of Montana
Piping plover	*Charadrius melodus*	Winnebago Tribe of Nebraska
Sprague's pipit	*Anthus spragueii*	Fort Belknap Indian Community of the Fort Belknap Reservation of Montana
Wild turkey	*Meleagris gallopavo*	Crow Tribe of Montana
Wilson's snipe	*Gallinago delicata*	Crow Tribe of Montana
	Mammal	
Antelope	*Antilocapra americana*	Cheyenne River Sioux Tribe of the Cheyenne River Reservation, South Dakota Fort Belknap Indian Community of the Fort Belknap Reservation of Montana Oglala Sioux Tribe
Black-footed ferret	*Mustela nigripes*	Cheyenne River Sioux Tribe of the Cheyenne River Reservation, South Dakota Fort Belknap Indian Community of the Fort Belknap Reservation of Montana
Black-tailed prairie dog	*Cynomys ludovicianus*	Cheyenne River Sioux Tribe of the Cheyenne River Reservation, South Dakota Fort Belknap Indian Community of the Fort Belknap Reservation of Montana Standing Rock Sioux Tribe of North & South Dakota
Coyote	*Canis latrans*	Cheyenne River Sioux Tribe of the Cheyenne River Reservation, South Dakota Fort Belknap Indian Community of the Fort Belknap Reservation of Montana Oglala Sioux Tribe
Elk	*Cervus canadensis*	Cheyenne River Sioux Tribe of the Cheyenne River Reservation, South Dakota Crow Tribe of Montana Oglala Sioux Tribe
Mule deer	*Odocoileus hemionus*	Cheyenne River Sioux Tribe of the Cheyenne River Reservation, South Dakota Crow Tribe of Montana Fort Belknap Indian Community of the Fort Belknap Reservation of Montana Oglala Sioux Tribe Winnebago Tribe of Nebraska
White-tailed deer	*Odocoileus virginianus*	Cheyenne River Sioux Tribe of the Cheyenne River Reservation, South Dakota Crow Tribe of Montana Fort Belknap Indian Community of the Fort Belknap Reservation of Montana Oglala Sioux Tribe Winnebago Tribe of Nebraska

Baseline and Current Data

Another challenge Tribal nations face in managing their grasslands is a lack of baseline and current data to help understand changes on the landscape and how management may address them (Hendrickson and others, 2016). Under AIARMA, Tribal management plans are supposed to be updated every 10 years; however, Tribal nations are observing the land change at an increasing rate because of climate change (Blackfeet Nation, 2018). Developing a dataset that includes past, current, and projected information on drought, temperature, precipitation, and extreme weather events on Tribal lands will likely be crucial for effective grassland management in a changing climate. Some baseline inventory and monitoring of forage and wildlife species is still lacking for Tribal lands (E. Boyd-Valandra, Indigenous Conservation Consultant, oral commun., 2021).

Climate Adaptation Planning

Tribal nations in the North Central Grassland Ecoregions are at various stages in their climate adaptation planning. Tribal nations that have not yet started planning for climate change can learn from other Tribal nations in the **North Central region** that have. Many of the climate adaptation plans conducted so far by or for Tribal nations in this region (for example, Blackfeet Nation, 2018; Fort Belknap Indian Community, 2023) include sections dedicated to the discussion of pathways for improving partnerships and collaborative efforts between Tribes and non-Tribal entities (Federal, State, nonprofits, and so forth). At the core of these proposed pathways is the understanding that Tribal nations require that their input to climate change plans be respected.

Information Needed

Given the diversity of grassland management goals and challenges among Tribal nations, many of the information needs identified in the "Grassland Management Goals, Challenges, and Information Needs" section in chapter A are highly relevant (refer to Miller Hesed and Yocum, 2026, sec. A3). However, two general research questions may be of highest value to Tribal nations.

First, understanding how climate change will impact the availability of culturally important grassland species is important for Tribal nations' traditional practices and their economies (Jantarasami and others, 2018, p. 589). Specifically, Tribal nations may want to understand how climate change shifts the range of culturally or economically important species. The shift in range for important species is especially relevant as Native Americans may be limited to hunting, collecting, or trapping particular species within reservation boundaries (Jantarasami and others, 2018, p. 589). Complementary studies that can quantify or monetize the impact of climate change on Tribal nations' economic activities will also be important (Jantarasami and others, 2018, p. 589).

Second, understanding how climate change will impact water quality and quantity is of great importance to Tribal nations in the North Central Grassland Ecoregions. More specifically, how will climate change impact water access, rights, and availability for Tribal nations (Jantarasami and others, 2018, p. 589)? Will the increasing frequency and severity of drought increase the human use of groundwater and, if so, how will drought impact the availability of water for plants and wildlife?

Summary

Throughout the past 200 years, top-down Federal policies have had profound effects on Tribal communities and grassland ecosystems in the North Central Grassland Ecoregions and nearly exterminated many Tribal nations and wildlife species. These Tribal nations are still pursuing environmental stewardship and are increasingly concerned about the impacts of climate change, including what that means for the remaining intact grassland ecosystems. A new paradigm prioritizing Tribal decision making, goals, and sovereignty can help Tribes adapt to a rapidly changing climate. This new paradigm may benefit from integrating traditional ecological knowledges and Western science. There are barriers to this process, however, shifting the existing paradigm and reprioritizing management processes are critical for conserving existing grasslands and supporting Tribal communities.

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Prairie sunflowers in the grasslands of Great Sand Dunes National Park and Preserve (Photograph by Patrick Myers, National Park Service).

Section B7.
Colorado Parks and Wildlife

By Christine D. Miller Hesed[1] and Sarah Jaffe[2]

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We wish to thank David Klute (Colorado Parks and Wildlife) for his edits and suggestions for this section.

Background

Colorado Parks and Wildlife (CPW) was created in 2011, when the Colorado Division of Wildlife merged with the Colorado State Parks (CPW, 2021a). The CPW is in charge of balancing the **conservation** of wildlife and habitat with recreation needs of the State (CPW, 2021i). The agency mission is to "perpetuate the wildlife resources of the state, to provide a quality state parks system, and to provide enjoyable and sustainable outdoor recreation opportunities that educate and inspire current and future generations to serve as active stewards of Colorado's natural resources" (CPW, 2021e). The CPW's strategic plan outlines six goals: (1) conserve wildlife and habitat to ensure healthy sustainable populations and ecosystems, (2) manage State parks for world class outdoor recreation, (3) achieve and maintain financial sustainability, (4) maintain dedicated personnel and volunteers, (5) increase awareness and trust for CPW, and (6) connect people to Colorado's outdoors (CPW, 2015b).

In 2018, the Colorado General Assembly passed the Hunting, Fishing, and Parks for Future Generations Act (Senate Bill 18–143, General Assembly of the State of Colorado, 2018) that lays out 10 specific goals for CPW to meet by 2025:

1. Increase the number of hunters and anglers in Colorado,
2. Partner with stakeholder to develop strategies to engage all outdoor recreationists,
3. Recruit and retain qualified employees,
4. Support access programs on public and private lands,
5. Increase and improve the State's big game populations,
6. Identify and begin planning for the development of a new Colorado State park,
7. Reduce the repair backlog for the dams that pose the highest risks to life and property,
8. Increase the number of fish stocked in Colorado water,
9. Reduce the large capital construction and **maintenance** backlog, and
10. Reduce the need to list additional State trust species under the Endangered Species Conservation Act of 1973 (Public Law 93–205, 87 Stat. 884) by partnering with private landowners (CPW, 2020, p. 4).

The CPW regulations and policies are set by a citizen board known as the Colorado Parks and Wildlife Commission. The 11 members of the commission are appointed by the Governor and confirmed by the State Senate for 4-year terms. These Commission members must comprise 3 agricultural producers, 3 recreationalists (one of whom must be from a nonprofit, no-take wildlife organization), 3 sportspersons (one of whom must be an outfitter), and 2 members at large. In addition, at least four of the members must be from the region to the west of the Continental Divide. The Commissioner of Agriculture and the Executive Director of the Department of Natural Resources also serve as ex officio members of the Commission (CPW, 2015b, 2021b).

Grassland Management

The western half of Colorado is mountainous, whereas the eastern half is part of the **North Central Grassland Ecoregions**—predominantly the Shortgrass Ecoregion with small areas of the Sagebrush–Grassland Ecotone and the Central Mixed Grass Ecoregion (table B15; fig. B4). Within Colorado's grassland **ecoregions**, most land (86 percent) is managed by private landowners followed by State agencies (8 percent; figs. B5–B6*A*, *B*).

Table B15. North Central Grassland Ecoregion acres managed by Colorado State agencies.

Ecoregion[1]	Acres
Tallgrass	0
Northern Mixed Grass[2]	0
Central Mixed Grass	3,352
Shortgrass	2,027,717
Sagebrush–Grassland Ecotone	29,537
Total	**2,031,069**

[1]Acreages include waterbodies within grassland ecoregions. Acreages are derived from the Protected Areas Database of the United States (U.S. Geological Survey Gap Analysis Project, 2020) and the development of ecoregions is defined in Miller Hesed and Yocum (2026), figure A5. Also refer to section A1 in Miller Hesed and Yocum (2026).

[2]The acreage for the Northern Mixed Grass Ecoregion excludes that which falls within the Sagebrush–Grassland Ecotone.

[1]University of Colorado Boulder, Cooperative Institute for Research in Environmental Sciences, North Central Climate Adaptation Science Center.
[2]University of Colorado Boulder, Cooperative Institute for Research in Environmental Sciences.

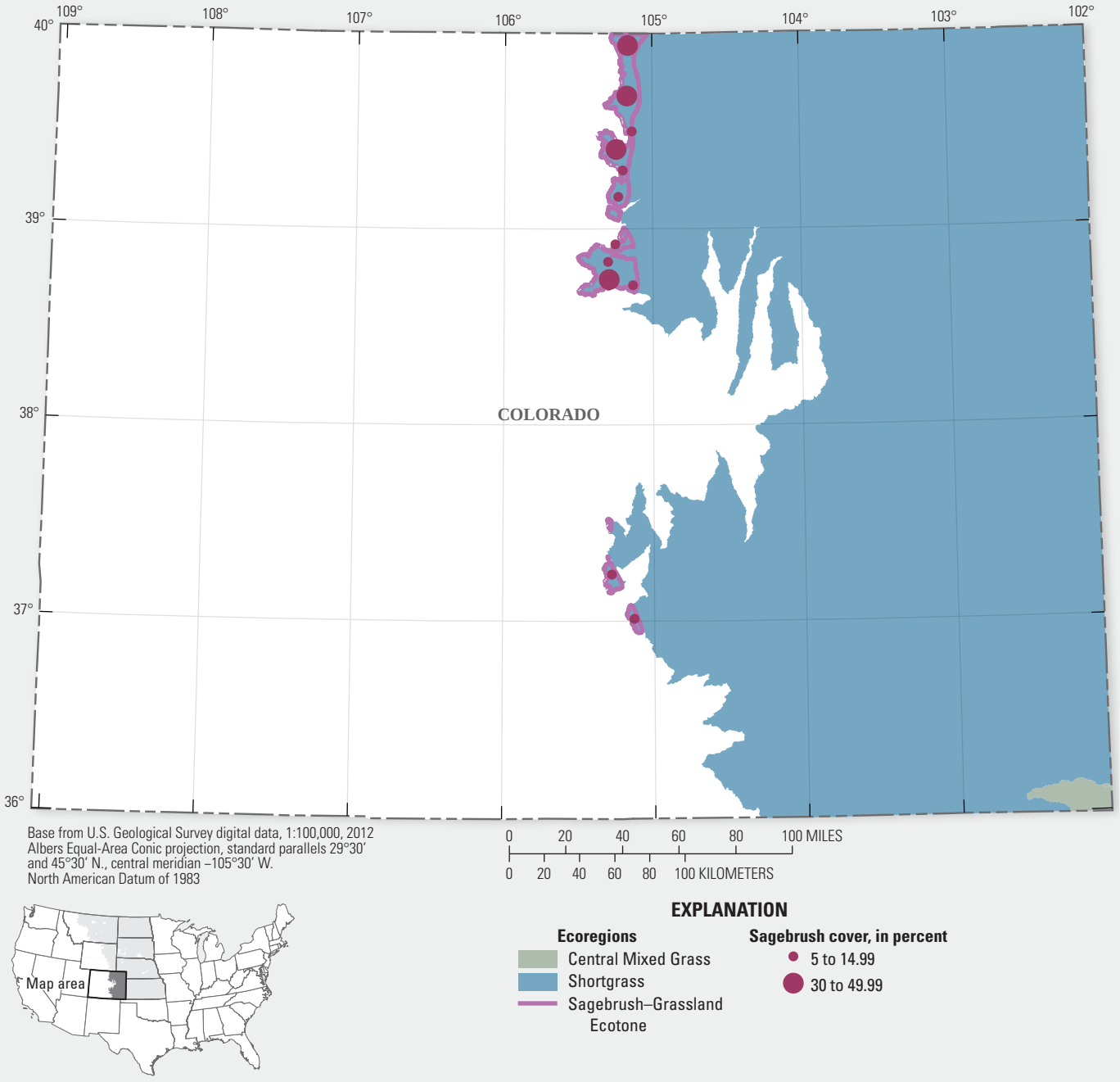

Figure B4. Map showing the grassland ecoregions in Colorado. This map was created using data from LANDFIRE's biophysical settings (LANDFIRE, 2020), The Nature Conservancy's Terrestrial Ecoregions (The Nature Conservancy, 2019), and the U.S. Geological Survey sagebrush biome data (Jeffries and Finn, 2019).

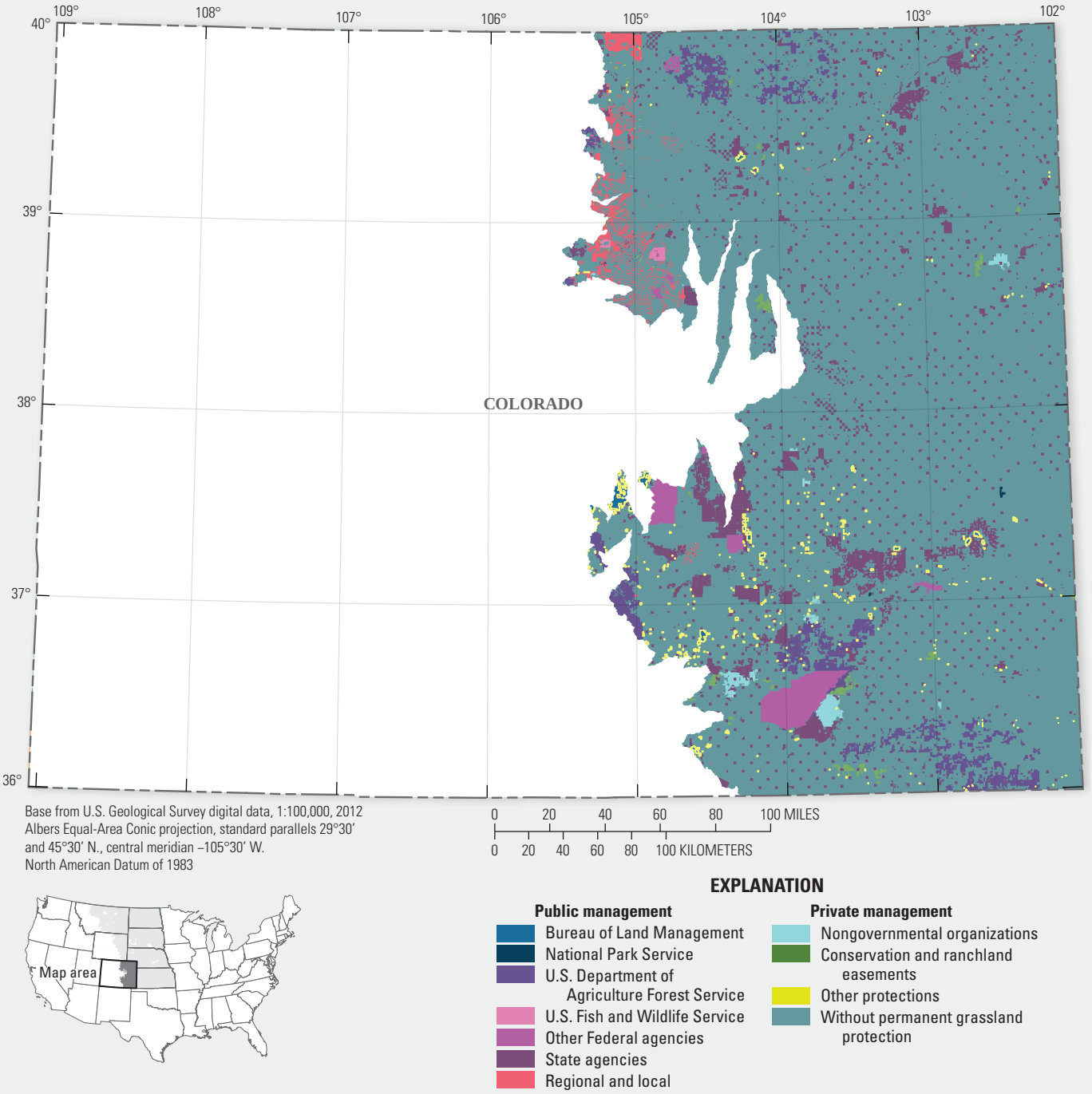

Figure B5. Map showing land management in the grassland ecoregions in Colorado. Colors indicate which entity manages the land. The landowner is sometimes, but not always, the same as the manager. Data from the Protected Areas Database of the United States (U.S. Geological Survey Gap Analysis Project, 2020).

As of 2021, CPW currently manages 41 State parks, more than 350 State wildlife areas, all Colorado's wildlife, and various recreational programs (CPW, 2021a). The agency's approach to wildlife management includes research, **protection** of habitat through land acquisitions and partnerships, and providing technical assistance and guidance to private landowners (CPW, 2021a).

Designation of Protected and Special Management Areas

Grasslands are included in CPW's designation of lands through State parks, State wildlife areas, and the Colorado Natural Areas Program (CNAP). The CNAP was established in 1977 and recognizes and protects areas that have unique or high-quality natural features, including grasslands.

Colorado natural areas are designated by CNAP through land management agreements with landowners, which include Federal, State, and local government agencies and private landowners (CPW, 2021b). The CPW protects and manages land in their network of 42 State parks, of which about one-fourth of the land include grasslands (CPW, 2021c). The newest State park, Fishers Peak, is a 19,200-acre property that connects the eastern grasslands with foothills and mountains in the west, and protects an important link among populations of *Cervus canadensis* (elk), *Odocoileus hemionus* (mule deer), *Odocoileus virginianus* (white-tailed deer), *Puma concolor* (mountain lion), and *Ursus americanus* (black bear) in the grasslands and populations in the mountains (CPW, 2020, p. 20). The CPW also manages approximately 350 State wildlife areas on State or privately owned land that provide hunting, fishing, and wildlife-related recreation to the public (CPW, 2021h).

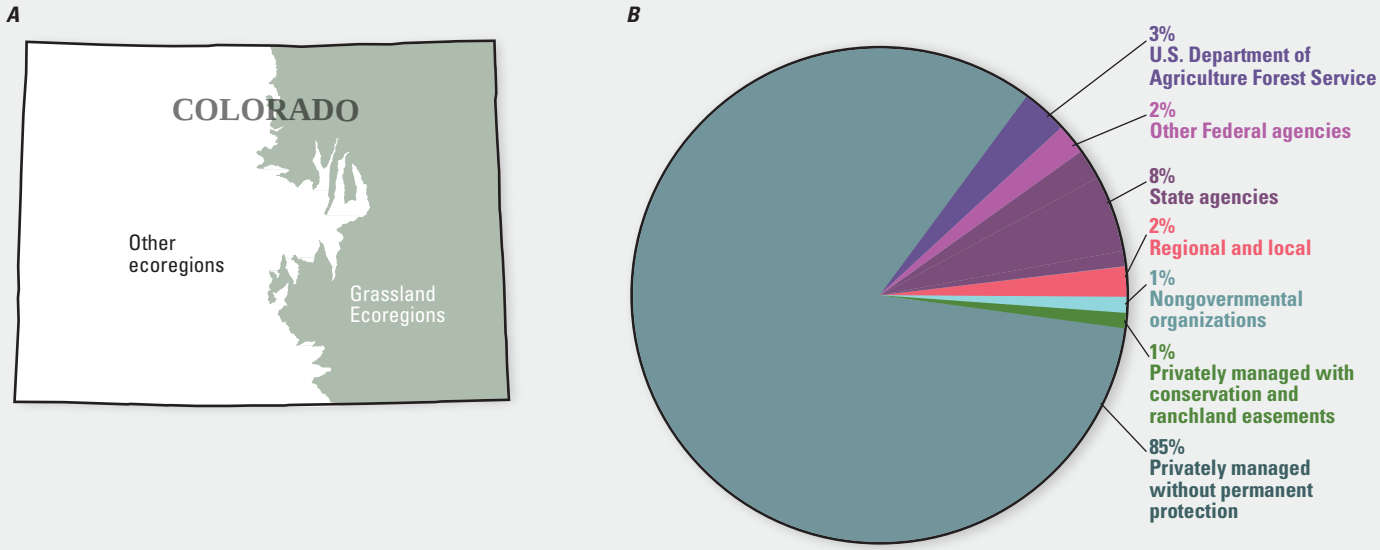

Figure B6. *A*, Map showing the extent of grassland ecoregions within Colorado and *B*, the proportion of Colorado grassland ecoregions managed by government agencies, Tribal nations, and private landowners. These proportions are estimated from acreage data from the Protected Areas Database of the United States (U.S. Geological Survey Gap Analysis Project, 2020). Non-Federal entities managing less than 0.5 percent of land in the grassland ecoregions are not included. Percentages do not add to 100 because of rounding. "Other Federal Agencies" includes, from most to least land managed, Federal agencies not discussed in this report and the Bureau of Land Management, U.S. Fish and Wildlife Service, and the National Park Service because the proportion of land managed by each of these agencies is less than 0.5 percent in Colorado.

Managing Species of Greatest Conservation Need

Wildlife conservation is of central importance to CPW, and they manage wildlife and habitat using focused research, careful land use, and cooperative partnerships (CPW, 2020, p. 26). The CPW spent more than $10.1 million on research, population status monitoring, reintroduction, and habitat **restoration** and protection for threatened and endangered species in fiscal year 2020 (CPW, 2020, p. 26).

The CPW's management of grassland wildlife is guided by their State wildlife action plan (SWAP; CPW; 2015a). The SWAP describes four general categories of actions aimed at managing or restoring species of greatest conservation need. Species management actions include disease management, maintaining wildlife populations at levels that will support a healthy habitat, and reducing nest predators. Species recovery actions include provision of artificial nesting boxes or platforms and maintenance of genetic integrity and connection within and among populations. Species reintroduction includes moving species to their historical range or reintroducing extirpated native species. Finally, CPW also works to conserve species outside their natural habitat through captive breeding, gene banking, and artificial propagation (CPW, 2015a, p. 81–82).

Although the SWAP is the primary document guiding current (2023) wildlife management actions, in reference to grassland species of greatest conservation need, the SWAP references another CPW plan, "The Conservation Plan for Grassland Species" (Colorado Division of Wildlife, 2003). This plan focuses on the viability of *Cynomys ludovicianus* (black-tailed prairie dog) and its associated species, which include the *Charadrius montanus* (mountain plover), *Athene cunicularia* (burrowing owl), *Vulpes velox* (swift fox), and *Buteo regalis* (ferruginous hawk; Colorado Division of Wildlife, 2003, p. 1). There are 12 objectives for promoting viability of these grassland species:

1. Meet occupied acreage and distribution targets;
2. Produce and support long-term monitoring of population trends and distribution of shortgrass species;
3. Encourage private landowners to protect these species through voluntary, nonregulatory, incentive-based partnerships;
4. Increase awareness of the need for grassland conservation;
5. Collaborate with the Colorado Department of Agriculture to develop a regulatory framework related to the use of toxicants or shooting to control black-tailed prairie dogs causing damage to private property;
6. Use adaptive management to account for social and ecological changes to the system;
7. Initiate, continue, and stimulate new research to identify, minimize, eliminate, or mitigate causes for declines for shortgrass associated wildlife species;
8. Partner with Federal, State, and local government agencies to promote conservation of grassland species on public lands;
9. Encourage acquisition and management of city and county open space on suitable grassland habitat along the front range;
10. Establish shared responsibility across the front range and Colorado's eastern plains for conservation of the black-tailed prairie dog and associated species;
11. Support and encourage public education and wildlife viewing opportunities; and
12. Work to develop substantial increase in funding for conservation of grassland species (Colorado Division of Wildlife, 2003).

Promoting Conservation on Private Grasslands

The CPW promotes conservation on privately owned grasslands in many different ways. In addition, partnering with private landowners to designate grasslands as Colorado natural areas and incentivizing conservation of grassland-associated wildlife on private lands, CPW also works with private landowners through the Ranching for Wildlife Program, the Colorado Wildlife Habitat Program, and the Pheasant Habitat Improvement Program (CPW, 2020, p. 17; CPW, 2021f).

Ranching for Wildlife Program.—The program began in 1986 to build a wildlife management partnership between CPW and participating landowners and to increase public hunting access on private land. Enrolled landowners are required to improve habitat on their land for game and nongame wildlife and allow public hunting access to individuals who successfully draw a hunting license from CPW. More than 1.2 million acres of private **ranchland** was enrolled in this program as of fiscal year 2020 and more than 50,000 acres have applied active wildlife habitat improvements each year (CPW, 2021g).

Colorado Wildlife Habitat Program.—The program provides opportunities for private landowners to voluntarily protect wildlife habitat (in grasslands and other ecosystems) through conservation easements or purchase of the land by CPW. Since 2006, this program has established conservation easements on 253,000 acres and purchased an additional 30,000 acres to manage for wildlife habitat (CPW, 2021d).

Pheasant Habitat Improvement Program.—The program began in 1992 as a cooperative effort among CPW, Pheasants Forever Inc., and local Pheasants Forever chapters to assist landowners in maintaining and enhancing habitat for *Phasianus colchicus* (ring-necked pheasant; CPW, 2021f). Other

grassland species also benefit from this program, including *Colinus virginianus* (northern bobwhite), *Callipepla squamata* (scaled quail), *Tympanuchus cupido* (greater prairie-chicken), *Tympanuchus pallidicinctus* (lesser prairie-chicken), grassland songbirds, pollinating insects, white-tailed deer, and mule deer. Since its beginning, the Pheasant Habitat Improvement Program has engaged with several hundred landowners to provide more than 292,840 acres of habitat for pheasants and associated species (CPW, 2020, p. 27).

Grassland Reconstruction

Cropland has displaced much of the former grassland ecosystem in Colorado. The CPW is working to reconstruct grassland through the Corners for Conservation Program. This program works with private landowners to reconstruct grasslands in small corners of agriculturally unproductive land, including the farmed dryland corners where center pivot irrigation systems are used and areas around playa wetlands. This program has established 523 individual grassland plantings between 2015 and 2020. These newly reconstructed grasslands include a diversity of wildflowers and grasses that attract a variety of pollinating insects, create excellent nesting and brood habitat for upland birds, and provide high quality forage for white-tailed deer and mule deer (CPW, 2020, p. 17, 20).

Promoting Coordinated Action Across Management Entities

The CPW partners and coordinates conservation efforts with many different management entities. The Colorado Outdoor Partnership (CO–OP) is one example of this coordinated effort. The CO–OP provides a platform for organizations to work together on developing an appropriate balance between conservation and outdoor recreation in Colorado. Participating organizations represent outdoor recreation, conservation, stewardship, agriculture, and government. Together CO–OP works to develop a coordinated, statewide approach to conservation and outdoor recreation that also encourages locally driven initiatives in support of the CO–OP mission (CPW, 2020, p. 11).

Emerging Challenges and Opportunities

Rising temperatures, increased climate variability, and other impacts from climate change are likely to interact with other threats to Colorado's grasslands, including **invasive species**, disturbance from human use, and **fragmentation** from development and subdivision of ranches (CPW, 2015a, p. 297). At the same time, Colorado's population is forecasted to grow to nearly 8 million residents by 2040 (a 40 percent increase from the population in 2015), which will put additional pressures on Colorado's grasslands (CPW, 2015a, p. 8). Continuing to manage Colorado grasslands for recreation and conservation amid these additional pressures will potentially require CPW to maintain and build upon its network of collaborators from the private and public sectors.

Information Needed

The CPW relies on scientific inventory and monitoring of wildlife to help inform management actions; however, additional scientific inquiry will help CPW continue to manage grasslands as the climate changes (refer to Miller Hesed and others [2023] for a summary table of the relevance of synthesized information needs and app. B1 for CPW-specific information needs as articulated in grassland management-related documents.) The Colorado SWAP calls for increased study of the ways in which climate change is expected to impact wildlife and habitat (CPW, 2015a). Another high priority area for research is understanding the ways in which climate change will interact with ecological processes such as fire, grazing, shrub invasion, and the spread of invasive species (CPW, 2015a, p. 301). Scientific study of how humans are likely to respond to climate change (that is, adaptation and mitigation strategies) will also help CPW anticipate additional pressures that may be put on Colorado's natural areas (CPW, 2015a).

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Tallgrass Prairie National Preserve in Kansas
(Photograph by National Park Service).

Section B8.
Kansas Department of Wildlife & Parks

By Jon P. Beckmann,[1] Christine D. Miller Hesed,[2] and Sarah Jaffe[3]

Background

The Kansas Department of Wildlife & Parks (KDWP) is the public steward of the State's natural resources (table B16; fig. B7). The KDWP originated in 1905 as the Kansas Fish and Game Department to oversee hunting licenses (KDWP, undated a). The KDWP mission is to (1) conserve and enhance Kansas' natural heritage, wildlife, and habitats to ensure future generations the benefits of the State's diverse living resources; (2) provide the public with opportunities for use and appreciation of the natural resources of Kansas, consistent with the **conservation** of those resources; and (3) inform the public of the status of the natural resources of Kansas to promote understanding and gain assistance with this mission. The KDWP works to achieve its mission through the following program elements: State parks, hunting, fishing, boating, conserving habitats and species, enforcing the law, and information and education (KDWP, undated b).

The KDWP is led by a Secretary who is appointed by the Governor (KDWP, undated a). The Governor also appoints a bipartisan commission, which comprises seven members. The commission advises the Secretary and the "Secretary approves regulations governing outdoor recreation and fish and wildlife resources in Kansas" (KDWP, undated a). KDWP has five divisions: Executive Services, Administrative Services, Wildlife, Boating and Fisheries, and Law Enforcement (KDWP, undated b). The KDWP manages 318,000 acres of terrestrial, State land (fig. B8). Because about 97–98 percent of land in Kansas is privately owned (fig. B9*A, B*), KDWP has numerous programs to support conservation on private land.

Grassland Management

Part of the KDWP mission is to conserve and enhance native **grasslands** and the associated wildlife and habitats to ensure future generations the benefits of the State's diverse grassland types. Several transition zones of different grasslands occur in Kansas. Most moisture (about 75–85 percent depending on location) falls as rain during warm months and the remainder falls as snow from November through March. There is a large gradient from the east to the west across the State with areas approaching 40–45 inches of moisture per year in the southeastern part of Kansas and less than 15–20 inches of moisture per year in western Kansas. As a result, Kansas contains three broad classifications of North American grasslands:

1. The tallgrass **prairie** (the most endangered ecosystem in North America that has less than 4 percent of the original extent remaining; the largest intact, contiguous tract of tallgrass prairie in North America is the Flint Hills region of eastern Kansas);
2. The mixed grass prairie of central Kansas; and
3. The shortgrass prairie in the western third of Kansas (fig. B7).

As such, the management goals and challenges vary across Kansas grasslands. As of 2023, the goals and objectives in the grasslands of Kansas revolve around the following three issues: (1) halt and reverse the transition of grasslands into eastern deciduous forest and other woody encroachment through the use of prescribed fire and mechanical brush removal; (2) reestablish warm season, native grasses in areas where nonnatives (for example, *Bromus inermis* Leyss. [smooth brome] or **invasive species** (for example, *Lespedeza cuneata* (Dum. Cours.) G. Don [sericea lespedeza], and *Bothriochloa* spp. [collectively referred to as "Old World Bluestems"; U.S. Department of Agriculture Forest Service, 2018]) have been established; and (3) establish connectivity and heterogeneity of various grassland habitats and species composition (for example, allow the forb component of grasslands to establish instead of a monocultures of grass). The KDWP is also concerned that grassland acreage enrolled in Federal programs, such as the U.S. Department of Agriculture Farm Service Agency Conservation Reserve Program (CRP) through the Farm

Table B16. North Central Grassland Ecoregion acres managed by Kansas State agencies.

Ecoregion[1]	Acres
Tallgrass	88,112
Northern Mixed Grass[2]	0
Central Mixed Grass	86,018
Shortgrass	13,503
Sagebrush–Grassland Ecotone	0
Total	**187,633**

[1]Acreages include waterbodies within grassland ecoregions. Acreages are derived from the Protected Areas Database of the United States (U.S. Geological Survey Gap Analysis Project, 2020) and the development of ecoregions is defined in Miller Hesed and Yocum (2026), figure A5. Also refer to section A1 in Miller Hesed and Yocum (2026).

[2]The acreage for the Northern Mixed Grass Ecoregion excludes that which falls within the Sagebrush–Grassland Ecotone.

[1]Kansas Department of Wildlife & Parks.

[2]University of Colorado Boulder, Cooperative Institute for Research in Environmental Sciences, North Central Climate Adaptation Science Center.

[3]University of Colorado Boulder, Cooperative Institute for Research in Environmental Sciences.

Services Agency (FSA), has declined since the last decade of the 20th century and fewer acres of grassland habitats are available across the State on private lands as of 2023. For example, there were close to 500,000 acres of CRP contracts that expired in Kansas alone between September 2021 and September 2022.

The primary management actions of KDWP in grassland habitats reflect the complex challenges for grasslands and fall under several broad categories of action. The KDWP biologists work on public and private lands and engage in several cost-share and incentive-based programs to help private landowners conserve, protect, and enhance grassland habitats across the State. One such program is KDWP's Habitat First program (https://ksoutdoors.com/Services/Private-Landowner-Assistance/Wildlife-Biologists/Habitat-First-Program). The goal of this incentive-based program is to work with private landowners to create, enhance, and restore various habitats across the grasslands of Kansas. This program makes a one-time payment, and the acres are not enrolled in a multiyear contract. The Habitat First program saw increased landowner interest by the 6th year, and in 2020, saw Kansas incentivize 177 projects statewide (J. Beckmann, KDWP, written commun., 2021). Overall, KDWP spent $439,371 for direct incentive payments to landowners for 13,434 acres of enhanced wildlife habitat (J. Beckmann, KDWP, written commun., 2021).

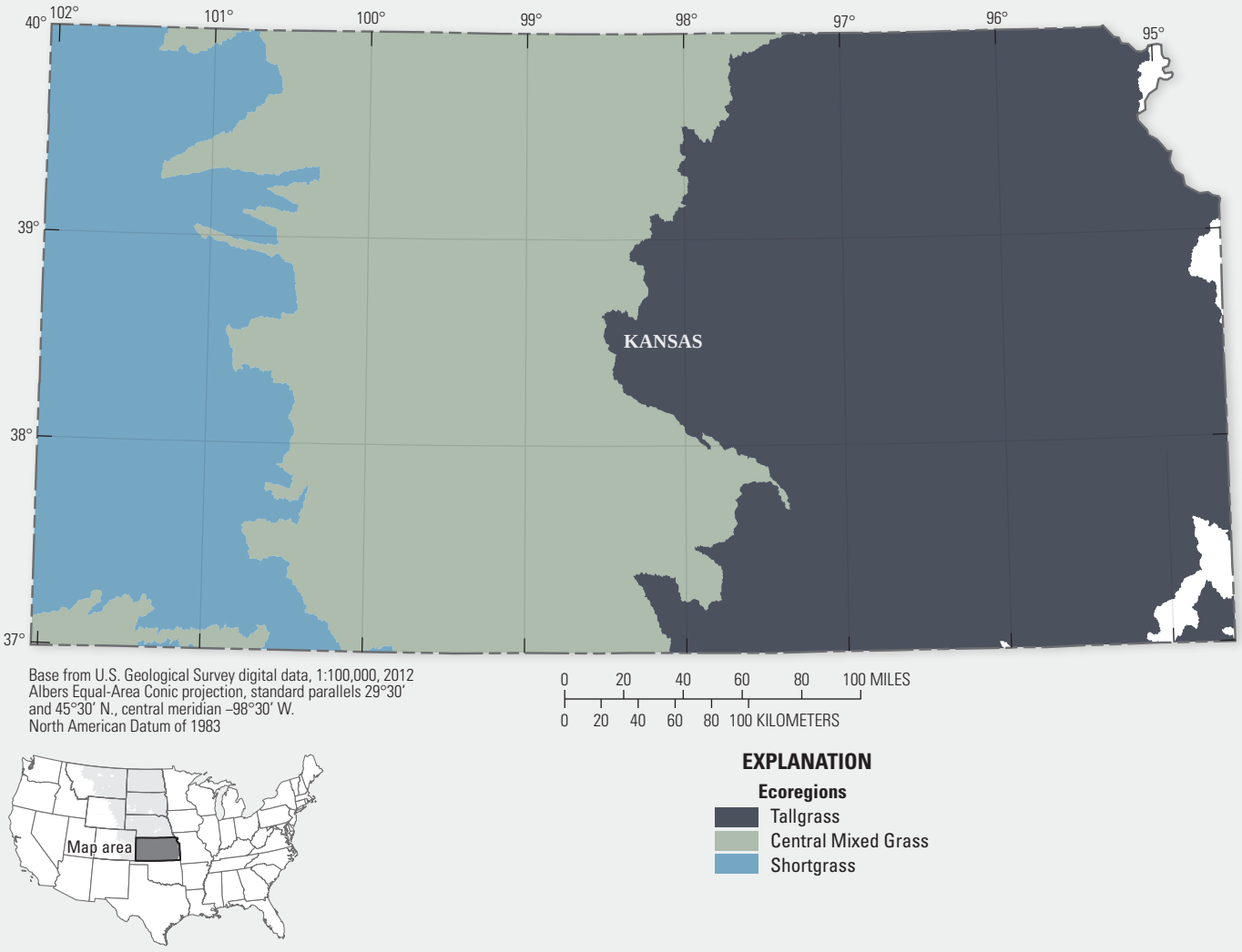

Figure B7. Map showing the grassland ecoregions in Kansas. This map was created using data from LANDFIRE's biophysical settings (LANDFIRE, 2020) and The Nature Conservancy's Terrestrial Ecoregions (The Nature Conservancy, 2019).

In 2018, KDWP began a new Habitat Specialists Program in partnership with Habitat Forever, a subsidiary of Pheasants Forever, Inc., where hired habitat biologists focus on grassland habitat **restoration**. Each of these positions overlaps priority ecological focus areas identified in the KDWP's State wildlife action plan (SWAP; Rohweder, 2015). The Habitat Specialists positions focus on the key conservation issues in four ecological focus areas (refer to table B17), and there are plans to hire additional Habitat Specialists in future years.

In addition to the State's Habitat First program and the Habitat Specialists Program, KDWP biologists also work with private landowners that are interested in wildlife or grassland habitat **enhancement** and **protection** as technical service providers or to guide them towards Federal programs, such as CRP, the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) Wildlife Environmental Quality Incentives Program or various easement and conservation programs in Kansas. Additional information on approaches to grassland conservation by KDWP are in the Kansas SWAP (Rohweder, 2015). Beginning in 2022, KDWP continued to work with NRCS as they rolled out a new **Great Plains** Grassland Initiative through the Environmental Quality Incentives Program funding and KDWP opted-in to the new Working Lands for Wildlife Northern Bobwhite Initiative, which focuses

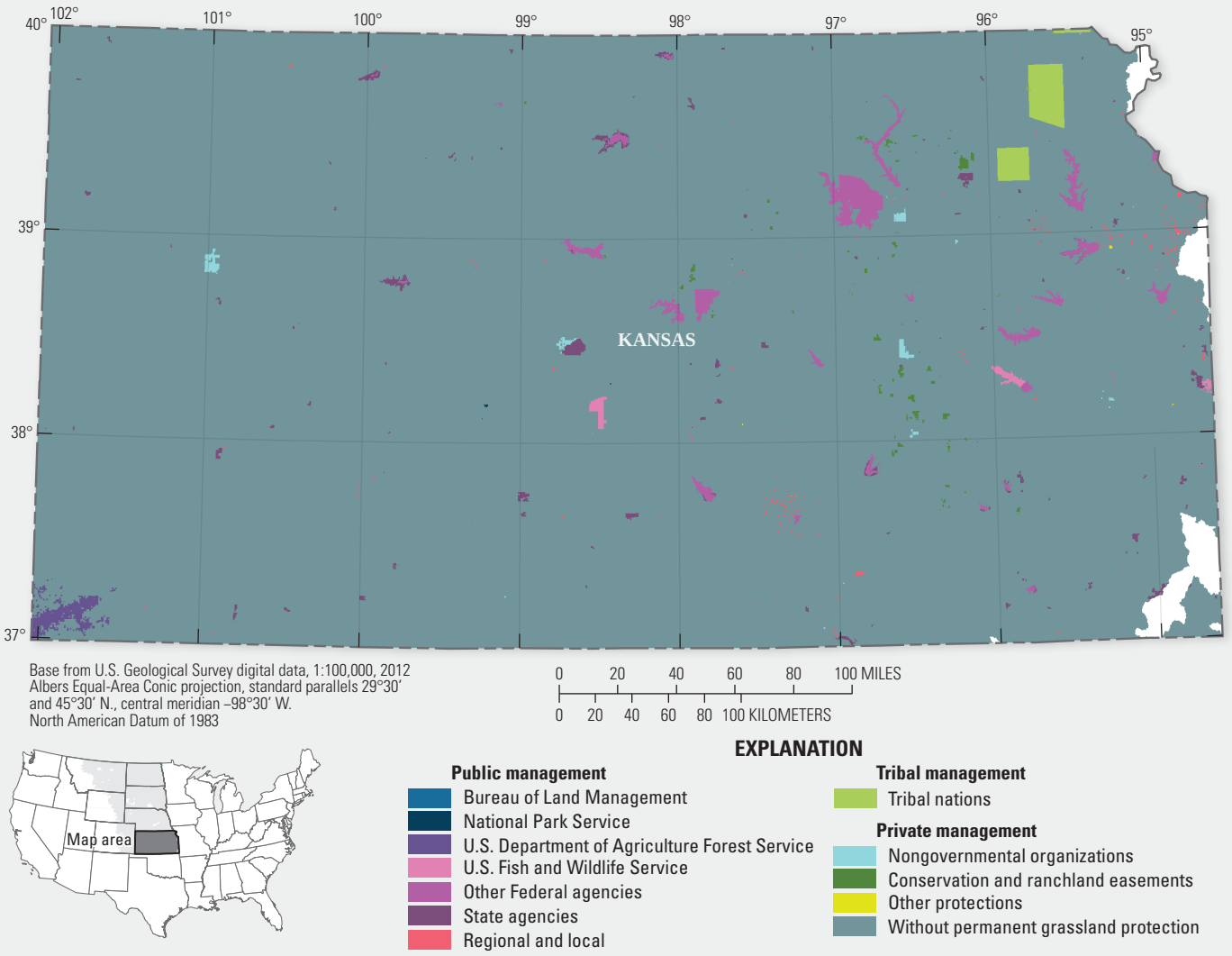

Figure B8. Map showing land management in the grassland ecoregions in Kansas. Colors indicate which entity manages the land. The landowner is sometimes, but not always, the same as the manager. This map was created using data from the Protected Areas Database of the United States (U.S. Geological Survey Gap Analysis Project, 2020).

on grasslands across multiple States. The following is a nonexhaustive list of the Federal programs available for grassland conservation in Kansas:

General Conservation Reserve Program.—CRP is a 10–15-year program that pays an annual rental payment based on soil types. An applicant is required to enroll during an application period for this program. The CRP is administered by the FSA.

Continuous Conservation Reserve Program.—The Continuous Conservation Reserve Program is a 10–15-year program that pays an annual rental payment based on soil types and sign-up and practice incentive payments. The difference from the general CRP program is that the applicant can enroll their acres at any time. The Continuous Conservation Reserve Program is administered by the FSA.

Wetland Reserve Easement (WRE).—This program is administered by the NRCS and is a good option for a landowner that wants to restore and provide long-term protection of wetlands within grasslands. The WRE offers a 10-year restoration option, a 30-year easement, or a permanent easement on the wetland and adjacent acres. The restoration option provides as much as 75 percent of the cost to restore the wetland. The conservation easement payment is based on the fair market value of the land and easement the applicant is interested in.

Emerging Challenges and Opportunities

All native, temperate grasslands in Kansas have experienced major, sometimes profound, losses of habitat from agriculture, range management, and urban development. Although each grassland type has unique conservation challenges, there is a similarity of several issues across all Kansas grasslands. This section provides a summary of the challenges KDWP biologists and managers face in each of the three grassland types within Kansas and the opportunities to address each challenge.

Shortgrass Prairie

Shortgrass prairies evolved under intense heterogeneous grazing by *Cynomys ludovicianus* (prairie dogs) and *Bison bison* (bison). Conversely, current (2023) range management practices strive to graze rangelands uniformly. These practices remove or inhibit heterogeneous grazing effects across landscapes and do not favor the specific habitat requirements of many species, particularly grassland birds. Insufficient grazing has led to the invasion of grasslands by shrubs and forbs.

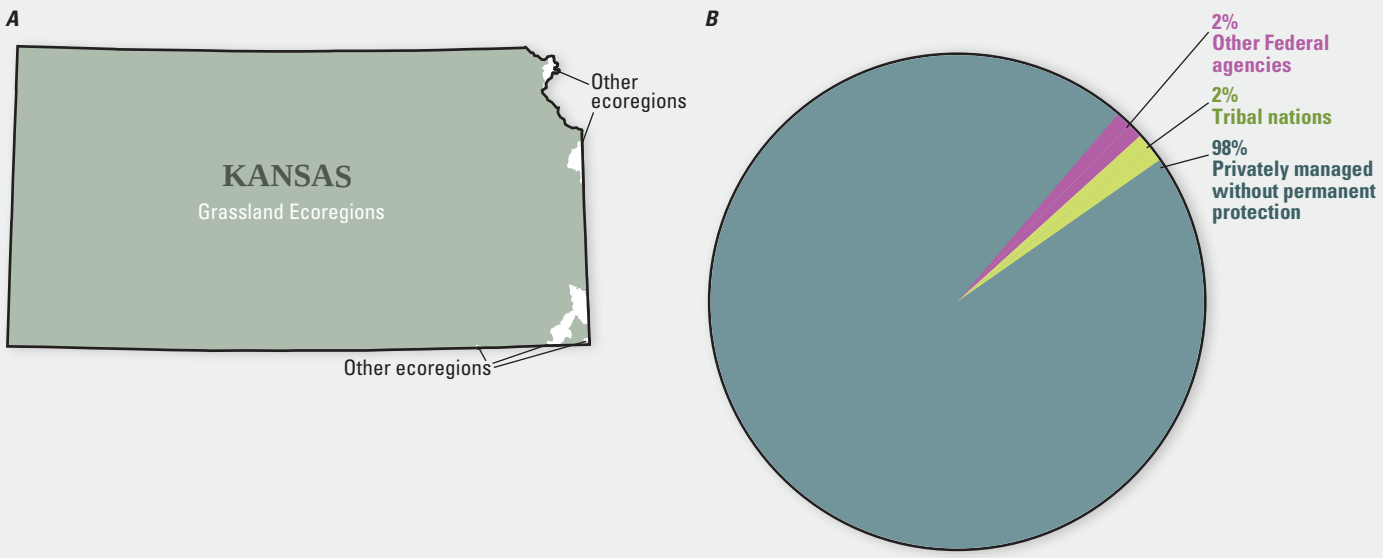

Figure B9. *A*, Map showing the extent of grassland ecoregions within Kansas and *B*, the proportion of Kansas grassland ecoregions managed by government agencies, Tribal nations, and private landowners. These proportions are estimated from acreage data from the Protected Areas Database of the United States (U.S. Geological Survey Gap Analysis Project, 2020). Non-Federal entities managing less than 0.60 percent of land in grassland ecoregions in the State are not included. "Other Federal Agencies" includes, from most to least land managed, Federal agencies not discussed in this report and the U.S. Department of Agriculture Forest Service, U.S. Fish and Wildlife Service, National Park Service, and Bureau of Land Management because the proportion of land managed by each of these agencies is less than 0.5 percent in Kansas.

The lowering of the aquifer and groundwater tables in western Kansas through center-pivot irrigation are of concern. As such, there is a focus by KDWP on playa lake conservation in the western part of Kansas as integral components of diversity of habitats in grassland ecosystems.

In places where CRP grasslands still occur, many of the older grass stands have become too thick because of a lack of moderate levels of active midcontract management (for example, no light disking, prescribed fire, or light grazing for 1–2 years during the 15–20-year CRP contract with FSA). As a result of these thick, overgrown stands of grass, very few grassland birds (for example, *Colinus virginianus* [northern bobwhite] or *Tympanuchus* spp. [prairie chickens]) and other small to medium-sized taxa will use these grasslands becuase they are too thick to navigate.

Tallgrass Prairie

Habitat loss from forest succession, a consequence of fire suppression and human development, has led to severely fragmented and isolated grasslands. Fire suppression and the resultant encroachment of woody vegetation are major management problems for tallgrass prairie in Kansas. In the tallgrass prairie region of eastern Kansas (for example, the Flint Hills region), there are several major scientific concerns: (1) the effect of annual spring prescribed fires compared to variable timing and scale of prescribed fires on biodiversity of plants and animals because annual prescribed fire has in some places created a monoculture of grass stands of the same vertical height structure; (2) the lack of burning in other areas of the Flint Hills region that is leading to a loss of the most endangered grassland ecosystem in North America because of woody vegetation encroachment; and (3) invasive species, such as sericea lespedeza and Old World Bluestem, and how to control those invasive species are a major concern for the tallgrass prairie region of eastern Kansas. There is a need to understand the efficacy and effects of fall burning compared to spring burning of tallgrass prairie. In the tallgrass prairie, brush removal through mechanical means and prescribed fire has not been able to keep pace with woody vegetation encroachment in many areas. In the southern tallgrass prairie of Kansas, encroachment by *Juniperus virginiana* L. (eastern redcedar), *Gleditsia triacanthos* L. (honeylocust), and *Ulmus americana* L. (American elm) and *Ulmus pumila* L. (Siberian elm) are a concern, whereas in the northern Flint Hills eastern redcedar, *Cornus drummondii* C.A. Mey. (roughleaf dogwood), and *Rhus glabra* L. (smooth sumac) and *R. aromatica* Aiton (fragrant sumac) represent woody plant invasion. Management practices, such as prescribed fire, selective cutting, and herbicidal treatments, are common tools in wildlife management for grasslands in Kansas but were underrepresented in the literature review, which could be a problem because these practices are functional and useful management techniques in grasslands.

The prevailing driver of grassland **conversion** is the profitability of cropland relative to grassland agriculture. When crop prices are high, conversion rates are amplified because returns on cropland increasingly outweigh the costs and risks associated with plowing new land (Lark, 2020). Once prairie is converted, however, the transformation is permanent, and its functionality may never return to its precultivated state. Robust, counterincentives are thus necessary to withstand undulations in market pressures and preserve remaining prairie throughout generations.

Despite the focus of many management entities and NGO partners on improving vital rates for species of conservation need, surprisingly few strategies address population management and offered little direction on optimizing demographic responses (for example, survival and nest success) in response to climate variability or change (LeDee and others, 2021). As LeDee and others (2021)

Table B17. Ecological focus areas targeted by the Kansas Habitat Specialists Program, top conservation issues in each area, and primary management actions used to address those issues.

[For additional information refer to Rohweder (2015)]

Ecological focus area	Conservation issues	Primary habitat management practices (through 2022)
Smoky Hills	Invasive (native and nonnative) woody and herbaceous plants, which modify habitat and reduce water availability during drought.	Invasive tree control, chemical vegetation control, and prescribed fire.
Playa Landscape	Grassland conversion and improper grazing regimes, which result in habitat loss and fragmentation. Draining wetlands and row crop cultivation degrades water quality because of agricultural runoff and sedimentation.	Mowing and disking to prepare for establishing plants in playa basins; planting cover crops in playa basins, mechanical vegetation control, and prescribed fire.
Neosho River	Infrequent use of prescribed fire, invasive woody and herbaceous plants, and degradation of wetland habitats in Wetland Reserve Easements.	Invasive tree control, prescribed fire, edge feathering and downed tree structures, and waterfowl food plots.
Flint Hills	Invasive woody and herbaceous plants, which modify habitat.	Invasive tree control, chemical and mechanical vegetation control, and prescribed fire.

pointed out, a potential reason for the lack of direction on population management is that most scientific studies focus on quantifying the effects of climate change on species occurrences and ranges (Ehrlén and Morris, 2015), whereas climate-demographic linkages and future projections are more difficult (Van der Putten and others, 2010). Finally, persistent challenges in developing climate adaptation strategies include a lack of empirically tested approaches.

Information Needed

Although numerous information needs identified by this synthesis are highly relevant to KDWP (refer to Miller Hesed and others [2023] for a summary table of the relevance of synthesized information needs and app. B1 for DWP-specific information needs as articulated in grassland management-related documents), several key areas of scientific research and information related to climate change emerged. First, there is a need to understand how climate change will impact the efficacy and ability to perform prescribed burns. This need is in addition to the need to better understand how different timing, varied schedules, and scale of prescribed fires can be used to control woody and herbaceous invasive species and improve habitat quality and biodiversity in grasslands. Changes in climate may reduce the time periods when prescribed burning can be accomplished safely, which may restrict the variability of timing and scale of burns that can be used.

Second, additional information is needed on how to best promote grassland conservation on private lands. Additional research on how to incentivize and encourage private landowners to participate in existing Federal or State programs, to improve those programs, or research on other mechanisms to incentivize conservation would support efforts to expand conservation efforts. This incentivization of conservation will be key because climate change may affect private landowners' decisions and adaptation choices. Third, additional research is needed on how climate change will impact woody encroachment and the current methods used to combat it (refer to table B17).

Finally, additional research is needed on how to best conserve wetland habitats like playa lakes under a changing climate. Playa lakes are already being lost and degraded because of agricultural conversion and changes in the water table because of irrigation, so how climate change will impact agriculture, irrigation, and water management may have important implications for these prairie wetland habitats. Better remote sensing and land cover data are also needed to identify and monitor changes on the landscape, including areas where woody encroachment is just beginning, and areas where playa lakes are in danger of being degraded or lost.

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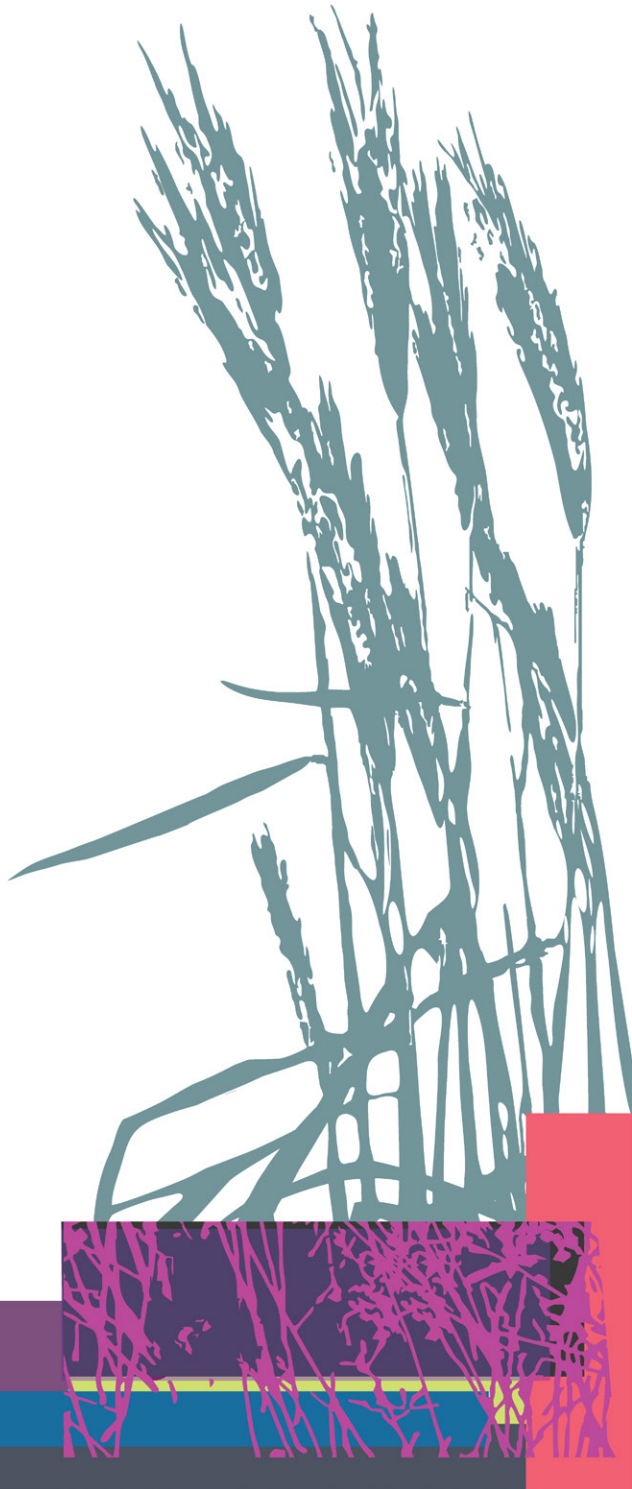

Montana landscape under a cloudy sky
(Photograph by Aubin Douglas, U.S. Fish and Wildlife Service).

Section B9.
Montana Fish, Wildlife & Parks

By Molly Cross,[1] Christine D. Miller Hesed,[2] and Sarah Jaffe[3]

Acknowledgments

We wish to thank Kristina Smucker (Montana Fish, Wildlife & Parks) for her edits and suggestions for this section.

Background

The mission of Montana Fish, Wildlife & Parks (MFWP) is to provide for "the stewardship of the fish, wildlife, parks, and recreational resources of Montana, while contributing to the quality of life for present and future generations" (MFWP, undated a). MFWP is managed by the Director's Office, which guides and manages policy, planning, program development, guidelines, and budgets. The Director of the agency is appointed by the Governor. The Director's Office works closely with the Governor's Office, the Montana State Legislature, and the seven-member Fish and Wildlife Commission (appointed by the Governor) and Parks Board (MFWP, undated b); the agency also engages with Montana's Tribal nations and Federal agencies. MFWP is organized into seven regions that span the State (fig. B10). The agency has a Wildlife Division that manages big game species, upland game birds, waterfowl, furbearers, and other nongame species. The Wildlife Division also manages more than 100 wildlife management areas and the Habitat Montana Program (MFWP, undated d), which carries out **conservation** easement and land acquisition work. The MFWP also operates divisions focused on fisheries, parks, enforcement, and communication and education (MFWP, undated c).

Grassland Management

Grasslands in Montana largely fit into one of two categories: lowland grassland **prairies** in the eastern two-thirds of the State, and montane grasslands 1,800–8,000 feet in elevation (MFWP, 2015). In addition, the State has some significant *Artemesia* spp. (sagebrush) steppe ecosystems (table B18; fig. B11), which include a mix of shrubs, grasses, and forbs, and are home to many sagebrush and grassland species (MFWP, 2015). Within Montana's grassland **ecoregions**, land managed by private landowners is interspersed with large areas of land managed by Federal and State agencies and Tribal nations (figs. B12 and B13*A*, *B*).

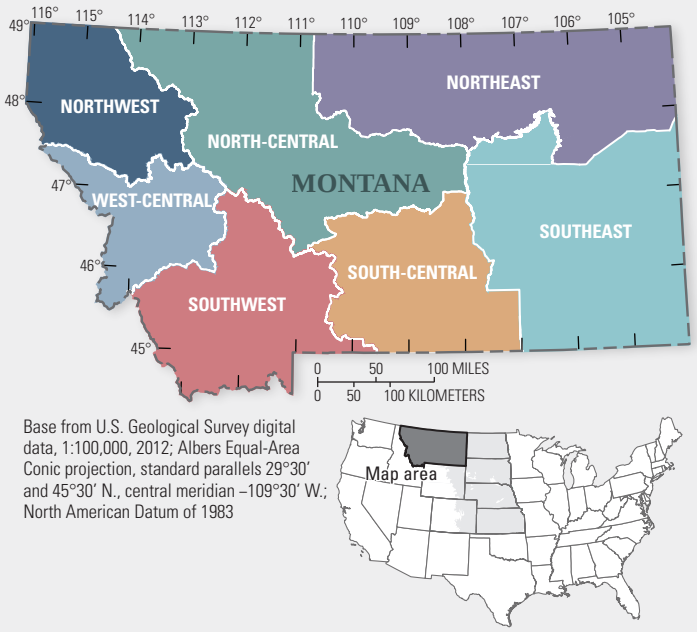

Figure B10. Map showing the Montana Fish, Wildlife & Parks management regions (modified from Montana Fish, Wildlife & Parks [undated a]).

Table B18. North Central Grassland Ecoregion acres managed by Montana State agencies.

Ecoregion[1]	Acres
Tallgrass	0
Northern Mixed Grass[2]	1,015,476
Central Mixed Grass	0
Shortgrass	0
Sagebrush–Grassland Ecotone	2,861,259
Total	**3,876,735**

[1]Acreages include waterbodies within grassland ecoregions. Acreages are derived from the Protected Areas Database of the United States (U.S. Geological Survey Gap Analysis Project, 2020) and the development of ecoregions is defined in Miller Hesed and Yocum (2026), figure A5. Also refer to section A1 in Miller Hesed and Yocum (2026).

[2]The acreage for the Northern Mixed Grass Ecoregion excludes that which falls within the Sagebrush–Grassland Ecotone.

[1]Wildlife Conservation Society.

[2]University of Colorado Boulder, Cooperative Institute for Research in Environmental Sciences, North Central Climate Adaptation Science Center.

[3]University of Colorado Boulder, Cooperative Institute for Research in Environmental Sciences.

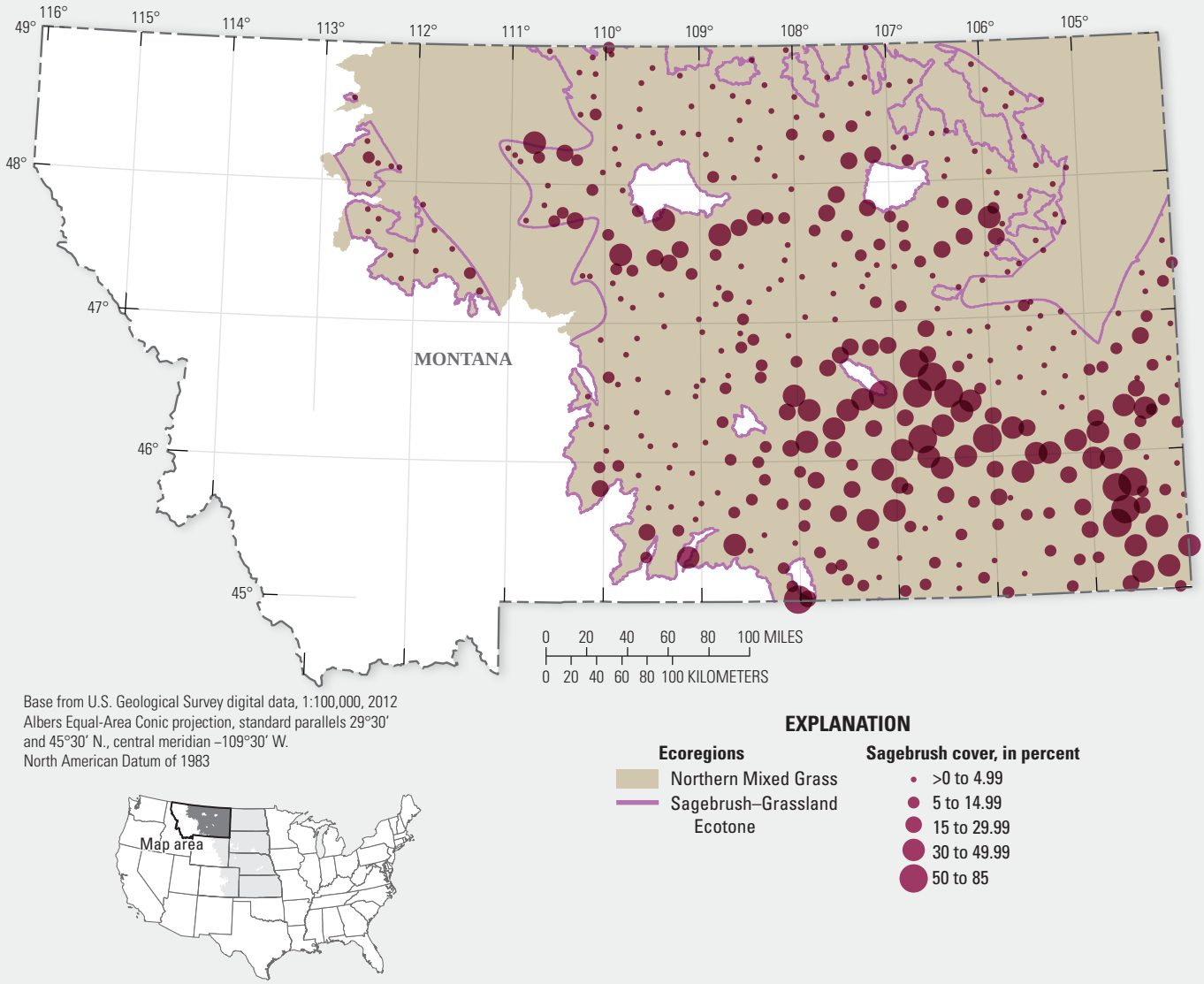

Figure B11. Map showing the grassland ecoregions in Montana. This map was created using data from LANDFIRE's biophysical settings (LANDFIRE, 2020), The Nature Conservancy's Terrestrial Ecoregions (The Nature Conservancy, 2019), and the U.S. Geological Survey sagebrush biome data (Jeffries and Finn, 2019). >, greater than.

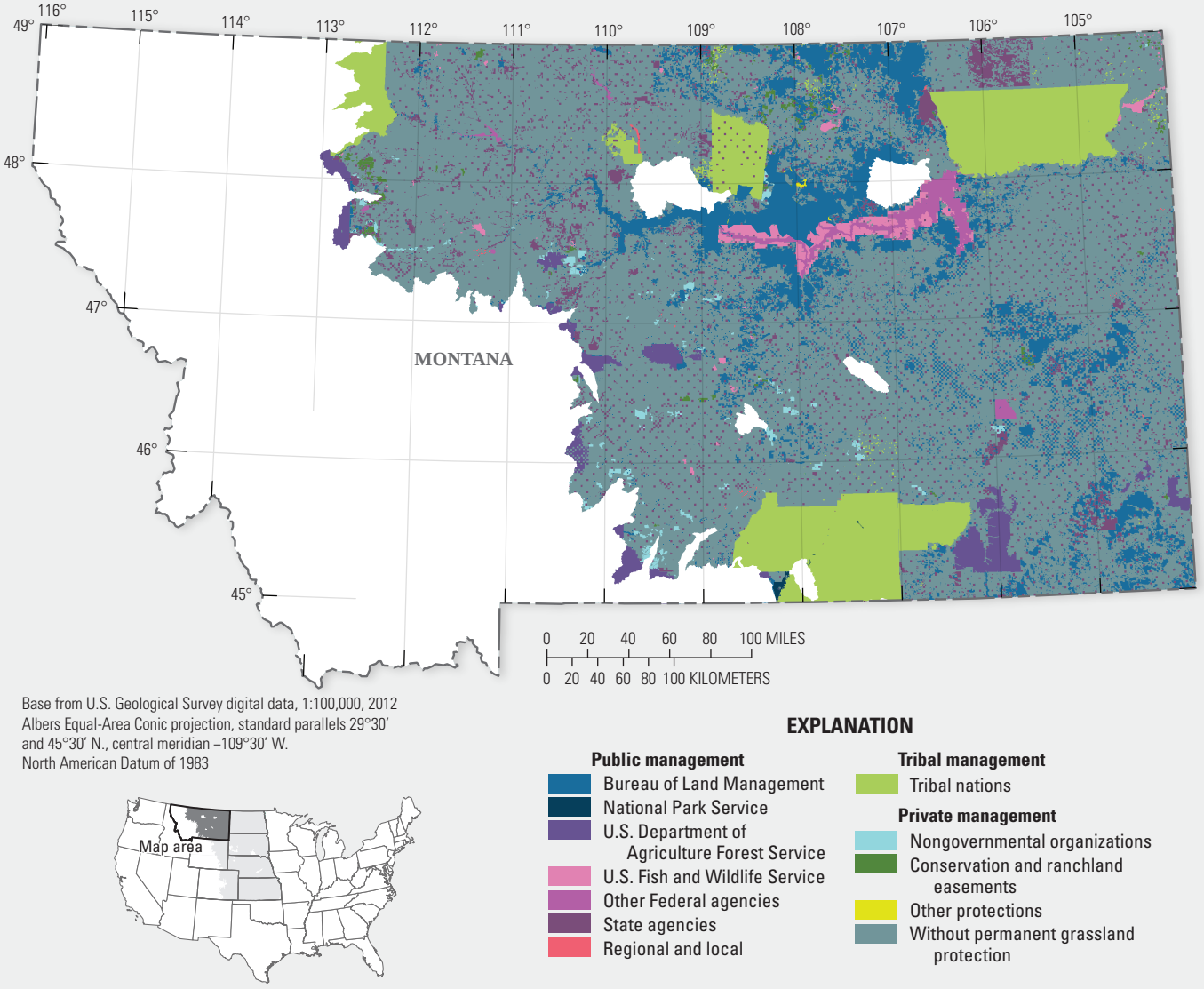

Figure B12. Map showing land management in the grassland ecoregions in Montana. Colors indicate which entity manages the land. The landowner is sometimes, but not always, the same as the manager. This map was created using data from the Protected Areas Database of the United States (U.S. Geological Survey Gap Analysis Project, 2020).

The Montana State Wildlife Action Plan (SWAP) includes lists of species of greatest conservation need in the two grassland types and the sagebrush steppe part of the State (MFWP, 2015). Goals for MFWP grassland work generally focus on providing for viable populations of grassland-associated wildlife such as upland game birds, grassland songbirds, raptors, mammals, and a few reptiles and amphibians.

Grassland Protection

The MFWP engages in grassland **protection** activities primarily by means of conservation easements, land acquisitions, the designation of special management areas, and policy and nonregulatory guidance. Conservation easements and long-term leases are a key tool used by MFWP to slow the rate of grassland habitat loss from **conversion** to residential development or row crop agriculture (MFWP, 2017). The MFWP Wildlife Division also manages the Habitat Montana program (MFWP, undated d), which provides funding to support conservation easement and land acquisition work. These land protection efforts are key to MFWP's efforts to "provide access to resources, prevent further habitat **fragmentation**, preserve natural habitat function . . . [and] . . . provide large, connected habitat patches across the state that are resilient to existing impacts and future threats" (MFWP, 2015, p. 60).

The MFWP also issues recommendations and other forms of nonregulatory guidance on land management and development (MFWP, 2017), such as the Fish and Wildlife

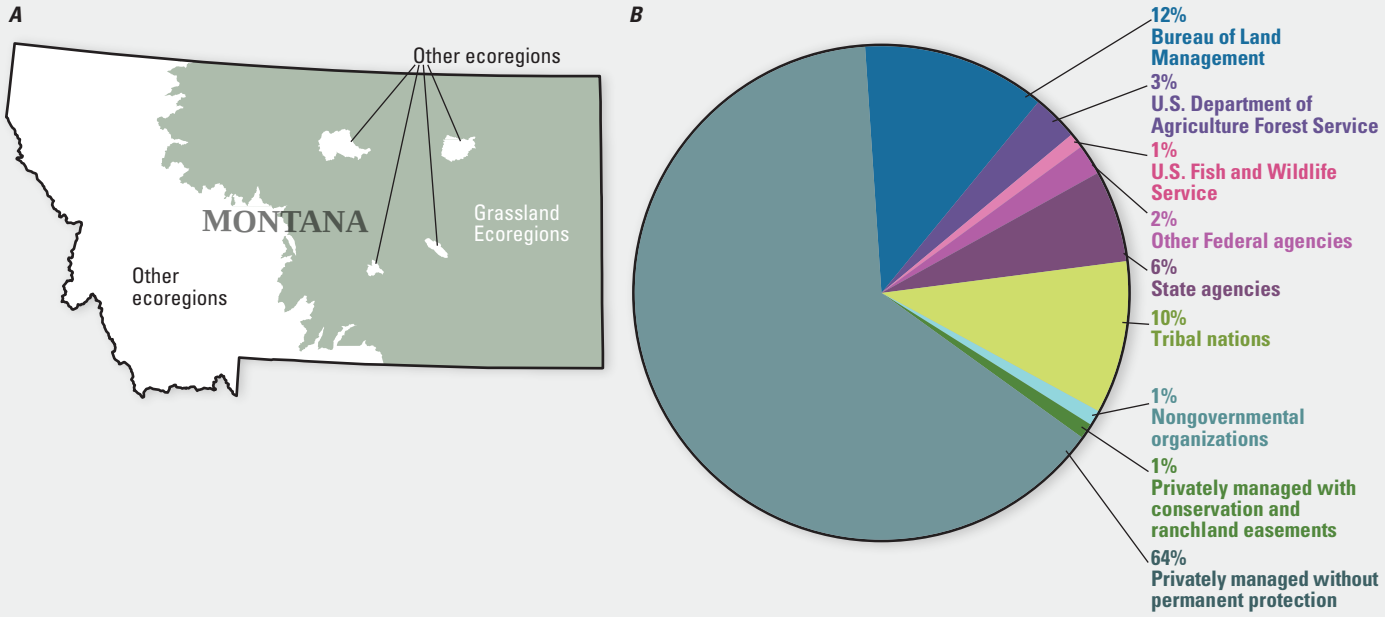

Figure B13. *A*, Map showing the extent of grassland ecoregions within Montana and *B*, the proportion of Montana grassland ecoregions managed by government agencies, Tribal nations, and private landowners. These proportions are estimated from acreage data from the Protected Areas Database of the United States (U.S. Geological Survey Gap Analysis Project, 2020). Non-Federal entities managing less than 0.5 percent of land in the grassland ecoregions in the State are not included. "Other Federal Agencies" includes, from most to least land managed, Federal agencies not discussed in this report and the National Park Service because the proportion of land managed by National Park Service is less than 0.5 percent in Montana.

recommendations for subdivision development (MFWP, 2012). In the 2015 Montana SWAP, the agency indicated that recommendations for oil and gas development and wind energy development are also in preparation (MFWP, 2015).

Grassland Enhancement and Maintenance

The MFWP engages in a wide range of grassland **enhancement** and **maintenance** actions, primarily through various kinds of agreements with private landowners. For example, the MFWP Working Grasslands Initiative details a range of "voluntary, non-regulatory, incentive-based options to help willing landowners maintain viable agricultural operations while also maintaining important wildlife habitat" (MFWP, 2017, p. 4). These options include working with private landowners to convert marginal croplands to grass-based agriculture and assisting with infrastructure, such as fencing and water structures, cost-share assistance for buying seed, and other forms of funding assistance (MFWP, 2017). These actions and other actions described in the Working Grasslands Initiative are important to MFWP for addressing two key threats to grassland wildlife—**invasive species** and climate change: "Keeping high priority grassland in good range condition that increases resiliency to new and increasing threats is likely our best strategy for preparing for a changing climate and minimizing the spread of invasive species" (MFWP, 2017, p. 13).

Additional strategies for maintaining or improving native grassland and sagebrush steppe are detailed in guidelines for developing "Candidate Conservation Agreements with Assurances" with private landowners (U.S. Fish and Wildlife Service [FWS], 2003) and the "Upland Game Bird Enhancement Program Strategic Plan" (MFWP, 2011). These plans include actions such as:

1. Restricting activities that result in habitat loss or fragmentation;
2. Developing grazing management plans that are compatible with wildlife habitat needs, support native vegetation cover, composition, and structure, and reduce grazing effects to wetlands and riparian areas;
3. Prescribed fire;
4. Minimizing the introduction and spread of invasive species, including removing encroaching conifers;
5. Avoiding and minimizing disturbances to breeding and nesting activities, nests, and young birds from human activities;
6. Avoiding direct mortality of focal bird species because of human activities, including fence collisions and increased roosting sites for avian predators;
7. Providing food resources (for example, unharvested grains), including emergency supplemental feeding;
8. Planting shelterbelts and woody cover to provide winter hiding and thermal cover and, some winter food resources; and
9. Releases or transplants of species of conservation importance.

The 2015 Montana SWAP included even more general strategies and actions that the agency engages in for terrestrial community types directly and through partnerships (MFWP, 2015). These actions addressed threats including habitat fragmentation, contamination, land management, wind energy, recreation, climate change, land-use change, and invasive species. For climate change, the two actions listed were "evaluate current climate science models and recommended actions," and "collect baseline data in order to document shifting range limits (latitude and elevation) of SGCN [species of greatest conservation need] and CTGCN [community types of greatest conservation need]" (MFWP, 2015, p. 63). Much of MFWP's grassland conservation work is done in partnership with private landowners by means of agreements and incentive-based programs. The Montana SWAP also indicated that agency managers "Actively participate with private landowners, watershed groups, NGOs, state and federal government agencies, local governments, tribes, land trusts, conservation districts, and other interested parties to: ensure work plans consider wildlife habitat needs during planning and implementation; ensure effective cooperation; work collaboratively; and to promote SGCN and habitat conservation while maintaining private land management objectives" (MFWP, 2015, p. 59).

Grassland Reconstruction

The MFWP engages in habitat **reconstruction** and **restoration** efforts directly on State-managed Wildlife Management Areas and by means of partnerships with private landowners and other management entities. For example, the MFWP Working Grasslands Initiative indicates that the MFWP "is also interested to work with willing landowners and conservation partners to help transition non-native vegetation (for example, crested wheatgrass) to native grass stands (for example, western wheatgrass)" (MFWP, 2017, p. 13). For greater sage-grouse and declining grassland songbirds, MFWP encourages landowners to restore marginal cropland to facilitate recovery of sagebrush or native grassland habitats and to restore drained wetlands and degraded streams and riparian ecosystems (FWS, 2003). For upland game birds, MFWP also encourages the restoration of wetland ecosystems (MFWP, 2011).

Emerging Challenges and Opportunities

The MFWP focuses on addressing many of the same challenges surrounding grassland conservation that other managers in the **North Central region** face, including conversion to cropland agriculture, energy development, subdivision development, and invasive species. MFWP also strives to help public and private landowners and managers balance wildlife habitat needs with working ranching operations. The agency acknowledges the challenges that climate change poses for grassland ecosystems and associated wildlife. Therefore, promoting coordination of action across management entities and jurisdictional borders and trying to increase the availability and application of usable science and tools are significant challenges for the agency.

Information Needed

The documents related to grassland management by MFWP and partners that were reviewed for this report did not include any direct references to specific climate change-related science needs, although climate change was mentioned in a few documents and information needs can be inferred. Refer to Miller Hesed and others (2023) for a summary table of the relevance of synthesized information needs and appendix B1 for MFWP-specific information needs as articulated in reviewed documents.

The Montana SWAP (MFWP, 2015) does reference climate change as a threat to aquatic and terrestrial species, including some grassland and sagebrush species, such as the greater sage-grouse. Climate-related factors, such as extreme drought and fire, are also important to grassland and sagebrush ecosystems. The Montana SWAP also included a few actions for addressing climate change that relate to the evaluation of climate change and its impacts—namely, to evaluate climate science models, recommend management actions and collect baseline data to document shifting range limits for species and ecosystems of greatest conservation need (MFWP, 2015). The Montana Working Grasslands Initiative also briefly referenced climate change in one of their reports: “Impacts to Montana’s grasslands from climate change are difficult to predict. Keeping high priority grassland in good range condition that increases resiliency to new and increasing threats is likely our best strategy for preparing for a changing climate and minimizing the spread of invasive species” (MFWP, 2017).

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Sunflowers blooming in the Nebraska Sandhills
(Photograph by U.S. Geological Survey).

Section B10.
Nebraska Game and Parks Commission

By Ben Wheeler,[1] Christine D. Miller Hesed,[2] and Sarah Jaffe[3]

Background

The Nebraska Game and Parks Commission (NGPC) serves as the State public agency entrusted with managing the fish and wildlife natural resources of Nebraska (table B19; fig. B14). Specifically, the mission of NGPC is the "stewardship of the state's fish, wildlife, park, and outdoor recreation resources in the best long-term interests of the people and those resources" (NGPC, 2022a). This mission is manifested through regulation, education and outreach, science-based research and monitoring, and active management. The NGPC headquarters is in Lincoln, Nebraska, and statewide operations are organized into 4 geographical districts and 13 specialty divisions.

In 1879, the Nebraska State legislature formed the foundation for public fish and wildlife resource management in the State (NGPC, 2022a). After iterations as the Nebraska Fish Commission and then the Nebraska Game and Fish Commission, the current (2025) NGPC is led by a panel of 9 governor-appointed commissioners—representing 8 districts and 1 member at large—who provide guidance to the Director regarding NGPC priorities and activities. The NGPC operates and manages several State parks, State recreational areas, and wildlife management areas, and also provides management to some landholdings administered by other public agencies (for example, the Bureau of Reclamation) throughout the State (NGPC, 2022b).

Grassland Management

The NGPC **grassland** management is guided by several sources, the most important of which is the Nebraska State wildlife action plan (SWAP), which is called "The Nebraska Natural Legacy Project" (Schneider and others, 2011). The plan's mission statement is to "implement a blueprint for conserving Nebraska's flora, fauna and natural habitats through the proactive, voluntary **conservation** actions of partners, communities and individuals" (Schneider and others, 2011, p. 1). The plan identifies four grassland regions throughout the State: tallgrass **prairie**, mixed grass prairie, sandhills, and shortgrass prairie. The mixed grass prairie and sandhills correspond to the Central Mixed Grass Ecoregion, the tallgrass prairie corresponds to the Tallgrass Ecoregion, and the shortgrass corresponds to the Shortgrass Ecoregion (fig. B14). The tallgrass prairie is in the eastern part of the State, the shortgrass prairie is in the western part of the State, and the mixed grass and sandhills prairies are in the central part of the State. Although some management actions and challenges are shared across all grassland **ecoregions** in the State, other management actions are unique to particular ecoregions. Many of the grassland conservation actions targeted in The Nebraska Natural Legacy Project fall into the following categories: (1) preventing loss and **fragmentation** of current grasslands, (2) preventing degradation and restoring historical processes of current grasslands, and (3) reestablishing grasslands on retired agricultural croplands (Schneider and others, 2011).

Preventing and Addressing Grassland Loss and Fragmentation

Conversion of grassland to cropland is listed by the SWAP as a threat to grasslands in all ecoregions (Schneider and others, 2011; also refer to Miller Hesed and Yocum, 2026, sec. A3). The NGPC engages in a variety of practices to protect current grasslands on public and private lands. These practices include designating special management areas, promoting and assisting in management actions that enhance grassland profitability, voluntary-based land acquisitions, and protective conservation easements (Schneider and others, 2011). Through leadership and partnership with ancillary conservation programs and organizations, the NGPC promotes involvement in private land conservation projects that address important grassland conservation issues while also maintaining economic merit for private

Table B19. North Central Grassland Ecoregion acres managed by Nebraska State agencies.

Ecoregion[1]	Acres
Tallgrass	41,082
Northern Mixed Grass[2]	13,289
Central Mixed Grass	115,772
Shortgrass	34,238
Sagebrush–Grassland Ecotone	49
Total	**204,431**

[1]Acreages include waterbodies within grassland ecoregions. Acreages are derived from the Protected Areas Database of the United States (U.S. Geological Survey Gap Analysis Project, 2020) and the development of ecoregions is defined in Miller Hesed and Yocum (2026), figure A5. Also refer to section A1 in Miller Hesed and Yocum (2026).

[2]The acreage for the Northern Mixed Grass Ecoregion excludes that which falls within the Sagebrush–Grassland Ecotone.

[1]Pheasants Forever Inc. and Quail Forever.

[2]University of Colorado Boulder, Cooperative Institute for Research in Environmental Sciences, North Central Climate Adaptation Science Center.

[3]University of Colorado Boulder, Cooperative Institute for Research in Environmental Sciences.

landowners and livestock producers. For example, through the Nebraska Natural Legacy Project, NGPC personnel and partnering conservation professionals cooperate with landowners to provide technical and financial incentives for using conservation practices, such as mechanical removal of invasive woody species and prescribed fire, which will target contemporary grassland conservation issues while also promoting profitability of their grassland-based livestock operation.

The NGPC also works to help reconstruct previously converted grasslands. The NGPC and partners promote the use of agricultural land retirement programs, such as the U.S. Department of Agriculture Farm Service Agency Conservation Reserve Program (Schneider and others, 2011). The Conservation Reserve Program is a voluntary program that provides an annual financial incentive to private landowners to take their land out of crop production and plant it as a grassland community for 10–15 years (refer to the "U.S. Department of Agriculture Natural Resources Conservation Service and Farm Service Agency" section).

Addressing Grassland Degradation

The SWAP lists altered frequency, duration, and intensity of natural disturbance processes, especially fire and grazing, as a factor that has affected biodiversity in all grassland ecoregions in Nebraska (Schneider and others, 2011). Historical interactions of fire and grazing species occurred in all Nebraska grassland ecoregions. Fire suppression and chronic overgrazing

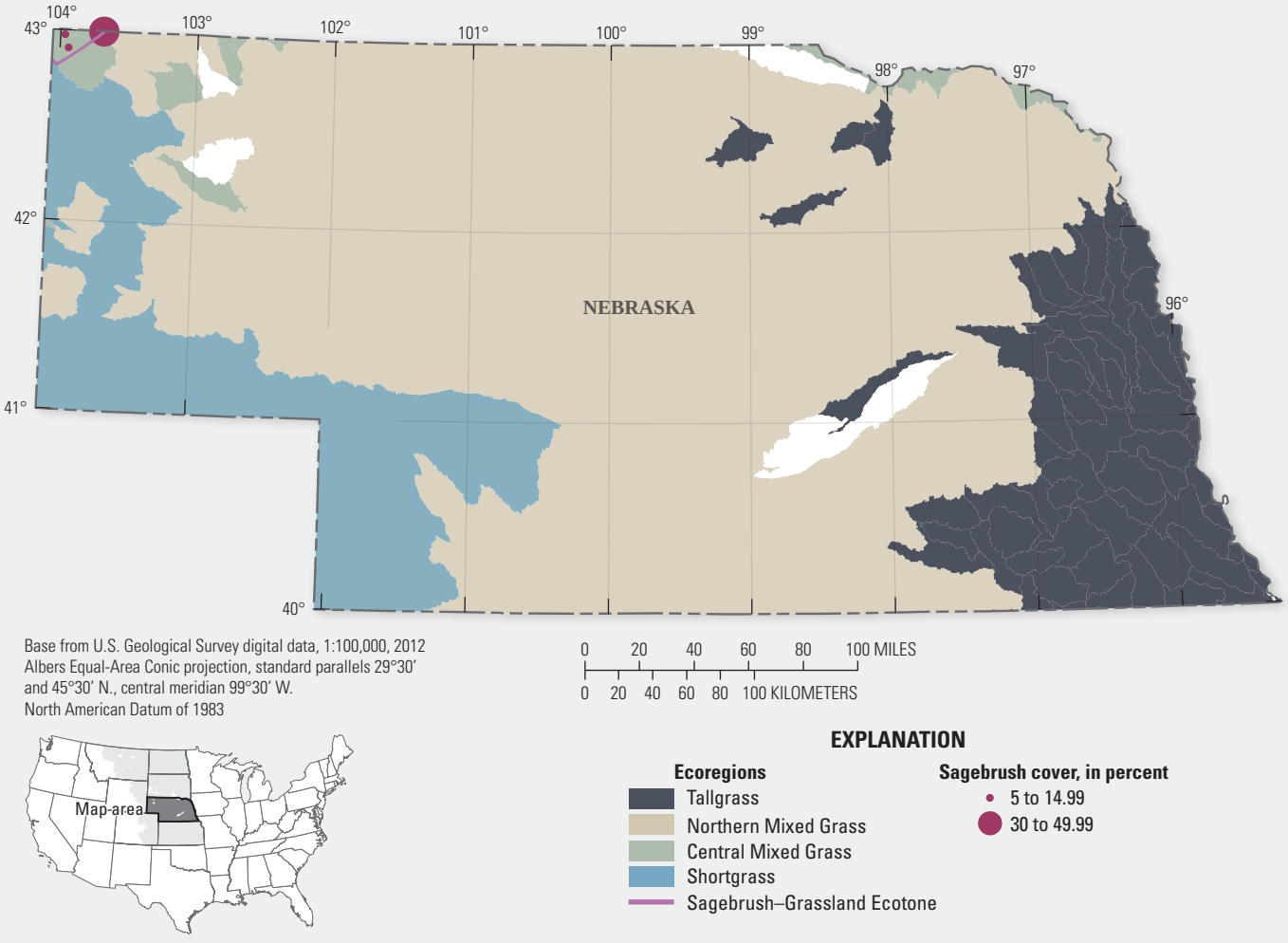

Figure B14. Map showing the grassland ecoregions in Nebraska. This map was created using data from LANDFIRE's biophysical settings (LANDFIRE, 2020), The Nature Conservancy's Terrestrial Ecoregions (The Nature Conservancy, 2019), and the U.S. Geological Survey sagebrush biome data (Jeffries and Finn, 2019).

led to the establishment and encroachment of invasive herbaceous and woody plant species, such as *Bromus inermis* Leyss. (smooth brome), *Bromus tectorum* L. (cheatgrass), and *Juniperus virginiana* L. (eastern redcedar) and an overall less diverse plant community. On public and private grasslands, the NGPC engages in practices to restore these processes on grasslands and enhance plant community diversity. These practices include the use of prescribed fire, mechanical and chemical removal of invasive woody and herbaceous plants, and installment of infrastructure to aid in sustainable grazing practices (Schneider and others, 2011). Funding provided for these activities typically occurs as a cost share program, and often, funding for an individual project is pooled from multiple partnering conservation sources.

Promoting Conservation on Private Grasslands

Most of Nebraska's land is privately owned (figs. B15 and B16*A*, *B*); therefore, the NGPC acknowledges that meaningful conservation and management of wildlife and natural resources cannot occur solely on public land. The NGPC maintains voluntary, incentive-based programs and partnerships with landowners to aid private land conservation initiatives. Often, the projects that stem from these initiatives involve cooperation with other Federal and State agencies and nongovernmental organizations.

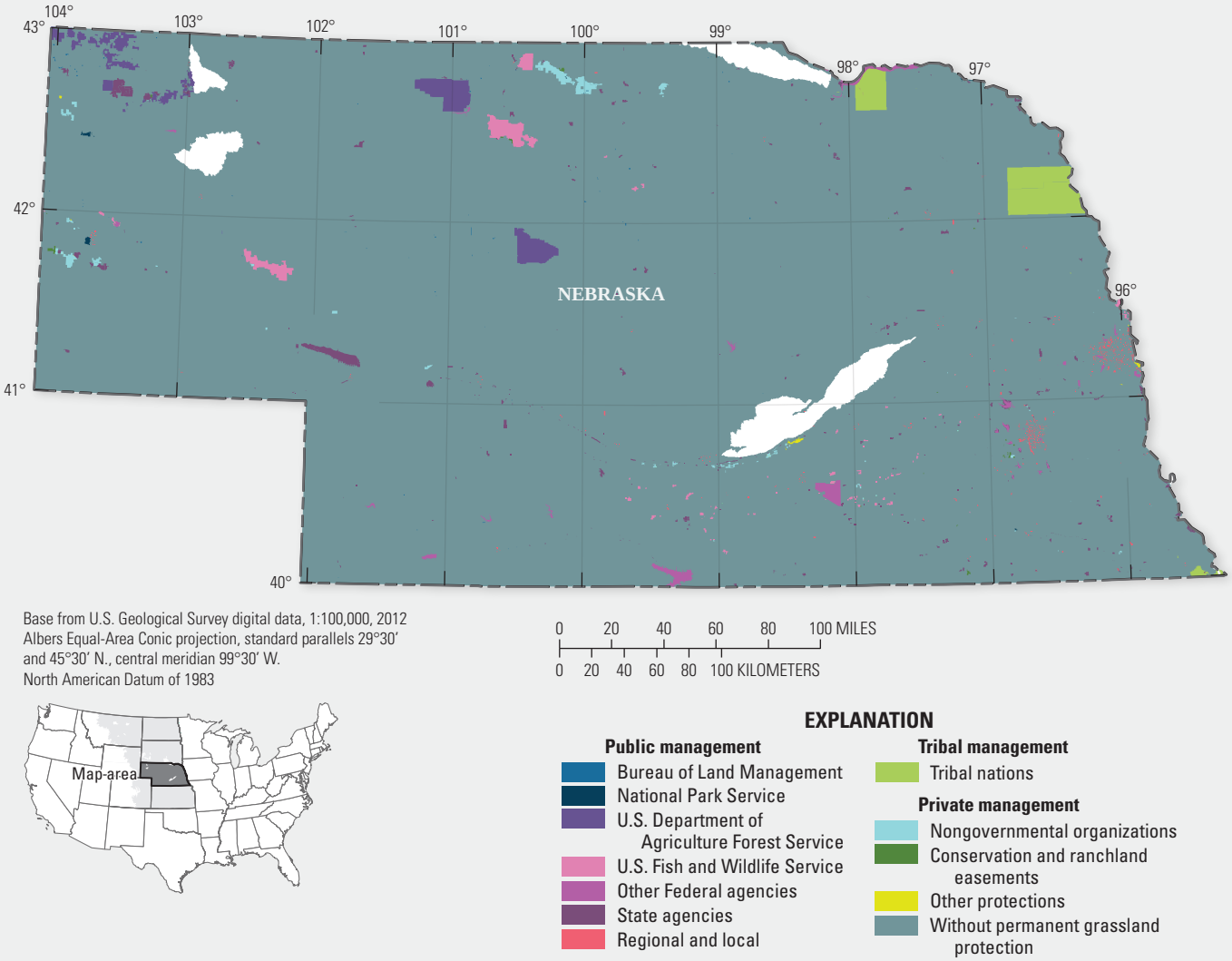

Figure B15. Map showing land management in the grassland ecoregions in Nebraska. Colors indicate which entity manages the land. The landowner is sometimes, but not always, the same as the manager. Data from the Protected Areas Database of the United States (U.S. Geological Survey Gap Analysis Project, 2020).

Private land projects either sponsored by the NGPC or partnered with other conservation agencies and organizations frequently draw from more than one funding source, including funding through grants; U.S. Farm Bill (Public Law 115–334) programs; direct and indirect revenue from hunting and angling license fees; and other Federal, State, and sometimes private sources. For additional information on conservation programs on private land, refer to section 5 or Baier (2020).

The NGPC places great emphasis in partnering with private landowners toward incentive-based grassland conservation solutions that can promote biodiversity and grassland health while maintaining the sustainability of grasslands for profitable livestock production. The NGPC also engages in strategic planning to deliver conservation projects that are complementary to other projects. The Nebraska Natural Legacy Project, for example, identifies 40 biologically unique landscapes where focused attention and funding can have more additive benefits than a simpler opportunistic approach across the entire State.

Emerging Challenges and Opportunities

The NGPC experiences several challenges in accomplishing grassland management. A recurring theme throughout the SWAP is a lack of awareness of the importance of biological diversity and ecological processes by stakeholders in all grassland ecoregions. Although some landowners may be willing and interested to learn this information, educational opportunities are limited. Additionally challenging is a hesitancy for trust and collaboration between agricultural producers and conservation communities stemming from past conflicts pertaining to issues such as water management and threatened and endangered species conservation (Schneider and others, 2011).

Nebraska is ranked among the top 10 States for wind energy potential, and the SWAP cites challenges with placement of wind turbines and associated facilities in

Figure B16. *A*, Map showing the extent of grassland ecoregions within Nebraska and *B*, the proportion of Nebraska grassland ecoregions managed by government agencies, Tribal nations, and private landowners. These proportions are estimated from acreage data from the Protected Areas Database of the United States (U.S. Geological Survey Gap Analysis Project, 2020). Non-Federal entities managing less than 0.5 percent of land in the grassland ecoregions in the State are not included. "Other Federal Agencies" includes, from most to least land managed, the U.S. Fish and Wildlife Service, Federal agencies not discussed in this report, National Park Service, and Bureau of Land Management because the proportion of land managed by each of these named agencies is less than 0.5 percent in Nebraska.

areas of high ecological integrity. This concern is listed specifically for all grassland ecoregions in Nebraska (Schneider and others, 2011). Furthermore, concerns about the installation of an interstate oil pipeline through unfragmented grassland is listed as a challenge specifically for the sandhills, which are part of the Central Mixed Grass Ecoregion (Schneider and others, 2011).

Most of the climate change related challenges listed within the SWAP regard the uncertainty of how wildlife and ecosystems will respond and adapt to a continually changing climate (Schneider and others, 2011). The rate, magnitude, and nature of climate change may impact how individual species can persist and adapt based upon the plasticity of their phenology and mobility, for example. Emphasis is also placed on the uncertainty of how associated deleterious ecosystem stressors, like how **invasive species**, pests, and pathogens may respond to climate change. The NGPC intends to address climate change with an adaptive management approach and prioritize conservation actions in areas that may act as climate refugia for some species (Schneider and others, 2011).

Information Needed

Although many information needs identified by this synthesis report are highly relevant to NGPC (refer to Miller Hesed and others, 2023), a primary information need in Nebraska related to climate change is a thorough inventory of species, habitat, and community distribution. Being predominantly private land, information gaps may occur across many areas. Continued monitoring and documentation and development of long-term datasets of the distribution and abundance of species and natural communities in the context of changing land use and ecosystem stresses are needed. In addition, the SWAP cites the need for initial and regularly refined climate change vulnerability assessments for individual species and natural communities (Schneider and others, 2011). For a more complete and detailed list of NGPC-specific information needs as articulated in the reviewed documents, refer to appendix B1.

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Aerial view of prairie potholes
(Photograph by U.S. Fish and Wildlife Service).

Section B11.
North Dakota Game and Fish

By Heather M. Yocum,[1] Christine D. Miller Hesed,[1] and Sarah Jaffe[2]

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Background

The mission of the North Dakota Game and Fish Department (NDGFD) is to protect, conserve, and enhance fish and wildlife populations and habitat for sustained public consumptive and nonconsumptive use (NDGFD, 2019b). In 1909, the Game and Fish Board of Control was established to regulate hunting, and the NDGFD was formally established in 1930 (Wilson, 2005; NDGFD, 2019c). The NDGFD is one of many State agencies under the direction of the Governor, and the Director is appointed by the Governor. There is also an 8-member advisory board composed of 4 landowners and 4 hunters or anglers that serves as a liaison between the public and the NDGFD.

North Dakota's **grasslands** are predominantly northern mixed grasslands dominated by warm and cool season grasses and sedges (table B20; fig. B17). The Tallgrass Ecoregion covers about 7,518,580 acres in North Dakota; however, only about 4,464,000 acres of tallgrass **prairie** remain in the State, which is mostly in the Red River Valley of the North. The Northern Mixed Grass Ecoregion covers about 37,801,215 acres in North Dakota. This **ecoregion** contains the Coteau des Prairies (also known as the Missouri Coteau; about 10,215,000 acres) in the east, a transition zone between short and tallgrass prairie species known as the Drift Prairie (about 16,900,000 acres), and a semiarid region known as the Missouri Slope region (about 10,768,000 acres) in the west (Dyke and others, 2015). Replanted grassland (that is, land that was plowed, cropped, then replanted to hay, tame, or native grass) constitute an additional 10,768,000 acres (5 percent of the State; Dyke and others, 2015). A full description of key habitat areas targeted for **conservation** by the NDGFD and their partners can be found in the North Dakota State Wildlife Action Plan (SWAP; Dyke and others, 2015).

North Dakota grasslands are part of the Prairie Pothole region (PPR), defined by seasonal and ephemeral wetlands in depressions left by the last ice age. Wetlands in the PPR are generally classified as "temporary" (that is, existing in early spring and after big rains), "seasonal" (that is, existing only in the spring and summer), "semipermanent" (that is, existing except in dry years), and "permanent" (Dyke and others, 2015, p. 8). These prairie wetlands are one of the most important breeding habitats in the world for migratory waterfowl, and support a wide variety of insects, aquatic species, and grassland birds. For example, the world's largest breeding colony of *Pelecanus erythrorhynchos* (American white pelican) is at Chase Lake National Wildlife Refuge. The grasslands in North Dakota also support a number of endangered, threatened, or other species of interest, including grassland songbirds like the *Ammodramus bairdii* (Baird's sparrow), *Numenius americanus* (long-billed curlew), *Charadrius melodus* (piping plover), *Charadrius montanus* (mountain plover), and *Centrocercus urophasianus* (greater sage-grouse). Full descriptions of these species are available in Dyke and others (2015); a full list of species of greatest conservation need is available in Miller Hesed and others (2023). Hunting is an important social and economic activity in the State, and important game species include *Odocoileus virginianus* (white tailed deer), *Phasianus colchicus* (ring-necked pheasant), and many species of

Table B20. North Central Grassland Ecoregion acres managed by North Dakota State agencies.

Ecoregion[1]	Acres
Tallgrass	38,317
Northern Mixed Grass[2]	771,716
Central Mixed Grass	0
Shortgrass	0
Sagebrush–Grassland Ecotone	136,993
Total	**947,025**

[1]Acreages include waterbodies within grassland ecoregions. Acreages are derived from the Protected Areas Database of the United States (U.S. Geological Survey Gap Analysis Project, 2020) and the development of ecoregions is defined in Miller Hesed and Yocum (2026), figure A5. Refer to section A1 in Miller Hesed and Yocum (2026).

[2]The acreage for the Northern Mixed Grass Ecoregion excludes that which falls within the Sagebrush–Grassland Ecotone.

[1]University of Colorado Boulder, Cooperative Institute for Research in Environmental Sciences, North Central Climate Adaptation Science Center.

[2]University of Colorado Boulder, Cooperative Institute for Research in Environmental Sciences.

waterfowl such as *Anas platyrhynchos* (mallards), *Anas acuta* (northern pintail), and *Branta canadensis* (Canada goose). Hunting and fishing constitute the third largest economic sector in the State, after oil and gas extraction and agriculture, and contributes an estimated $2.1 billion annually to the State economy and accounts for 59 percent of spending in rural areas (Ndembe, Bangsund, and Hodur, 2019). Habitat loss, primarily because of private land coming out of the U.S. Department of Agriculture Farm Service Agency Conservation Reserve Program (CRP), and agricultural **conversion** driven by high commodity prices, meant that 49,000 fewer deer hunting licenses were issued in 2017–18 compared to 2011–12 (Ndembe, Bangsund, and Hodur, 2019, p. 61).

Compared to other Western States, North Dakota has less land protected under the jurisdiction of Federal or State agencies; of the 44,452,480 acres that constitute North Dakota, less than 4 million acres are owned in fee title by State and Federal land management agencies. Most land in North Dakota is privately owned (Dyke and others, 2015; figs. B18 and B19*A*, *B*).

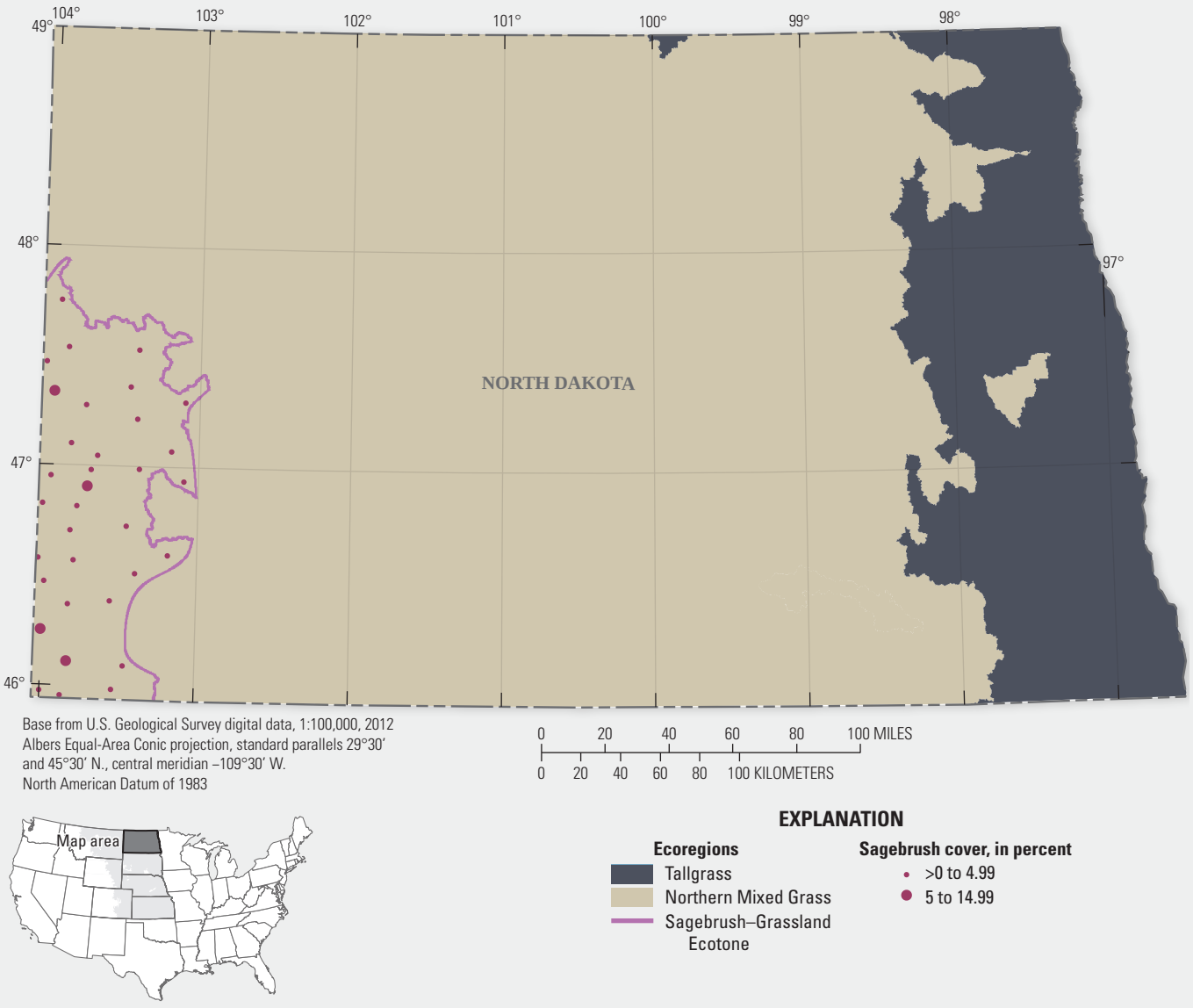

Figure B17. Map showing the grassland ecoregions in North Dakota. This map was created using data from LANDFIRE's biophysical settings (LANDFIRE, 2020), The Nature Conservancy's Terrestrial Ecoregions (The Nature Conservancy, 2019), and the U.S. Geological Survey sagebrush biome data (Jeffries and Finn, 2019). >, greater than.

Grassland Management

Because so much of the land in North Dakota is privately owned, NDGFD works with land managers and nonprofit agencies to manage grasslands. The NDGFD manages grasslands for multiple uses, and these grasslands may be set aside for conservation or they may be leased out to private landowners for grazing, haying, or mowing (Dyke and others, 2015).

Grassland Protection

Both NDGFD personnel and nonprofit organizations report that there is a strong sentiment against the Federal or State Government acquiring additional land for conservation in North Dakota (Yocum and Ray, 2019). As such, the NDGFD collaborates with private and nonprofit organizations like Ducks Unlimited, Delta Waterfowl, the National Audubon Society, Prairie Potholes Joint Venture, and others to purchase and manage land and carry out wildlife research.

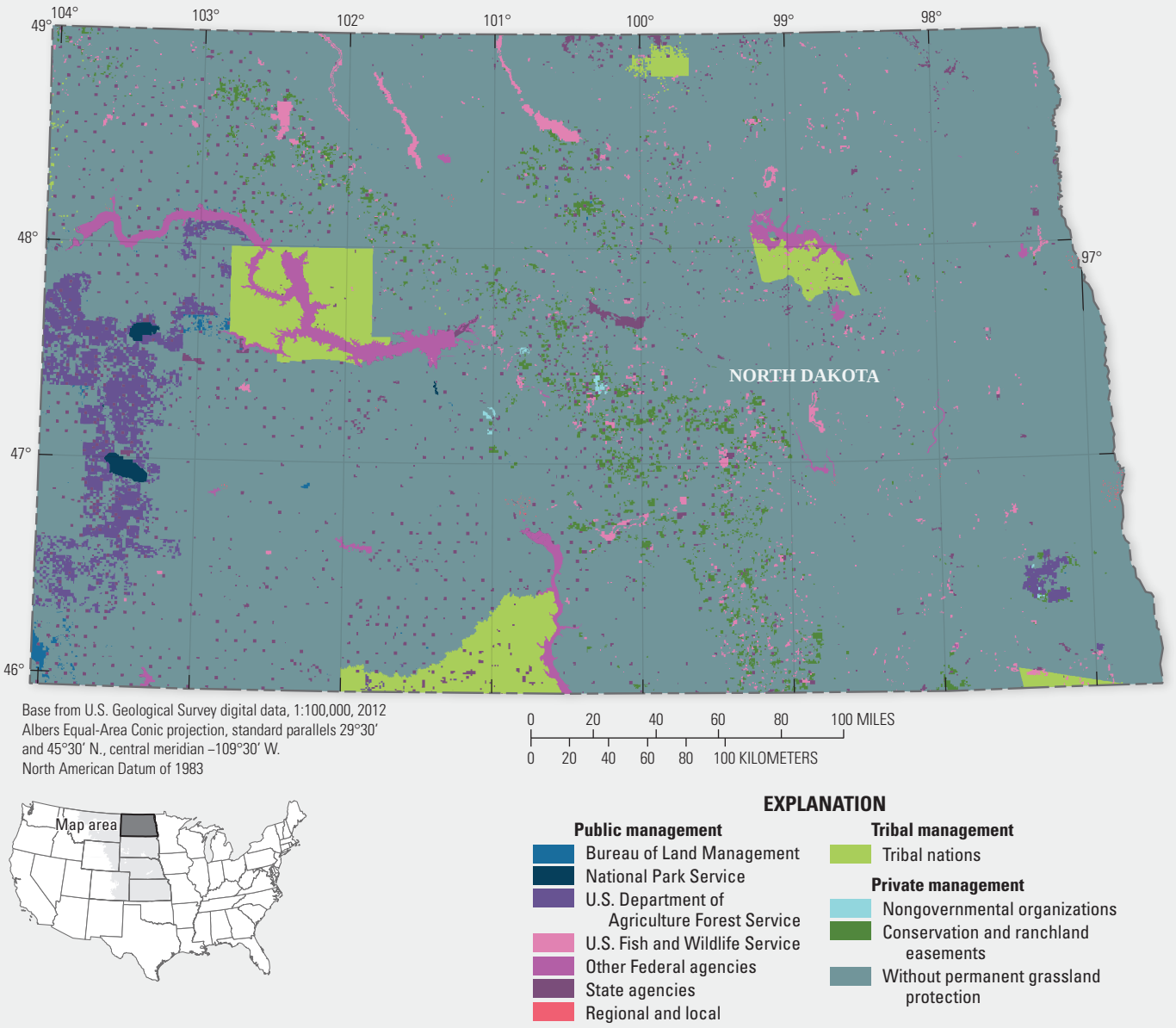

Figure B18. Map showing land management in the grassland ecoregions in North Dakota. Colors indicate which entity manages the land. The landowner is sometimes, but not always, the same as the manager. This map was created using data from the Protected Areas Database of the United States (U.S. Geological Survey Gap Analysis Project, 2020).

Managing Species of Greatest Conservation Need

The NDGFD's SWAP identified conservation actions for species of greatest conservation need (Dyke and others, 2015; refer to Miller Hesed and others, 2023). These actions include offering incentives to protect, enhance, and restore habitat; urging ecologically responsible ordinances and suitable reclamation standards; promoting and supporting holistic grazing; using best management practices; and carrying out public education and outreach on the ecological services provided by species of greatest conservation need (Dyke and others, 2015, p. 31–32).

Promoting Conservation on Private Grasslands

The NDGFD cooperates extensively with private landowners and leverages Federal, nonprofit, and privately funded programs to conserve grassland and wetland habitat on private lands. North Dakota's Private Land Initiative aims to conserve habitat for fish and wildlife, provide cost-share assistance to landowners for protecting and enhancing wildlife habitat, and provide public access to fish and wildlife resources on private land (NDGFD, 2019d). These goals support habitat development and access for hunting through the Private Land Open to Sportsmen (PLOTS) program (NDGFD, 2019e).

Figure 19. *A*, Map showing the extent of grassland ecoregions within North Dakota, and *B*, the proportion of North Dakota grassland ecoregions managed by government agencies, Tribal nations, and private landowners. These proportions are estimated from acreage data from the Protected Areas Database of the United States (U.S. Geological Survey Gap Analysis Project, 2020). Non-Federal entities managing less than 0.5 percent of land in the grassland ecoregions in the State are not included. "Other Federal Agencies" includes, from most to least land managed, Federal agencies not discussed in this report and the National Park Service and Bureau of Land Management because the proportion of land managed by each of these agencies is less than 0.5 percent in North Dakota.

Through the Wildlife Food Plots Seed Promotion Program, private landowners can receive technical and financial assistance to establish winter food plots for wildlife (NDGFD, 2019g). Landowners can also find support to enhance, protect, or restore grassland through the Working Lands Program or wetland habitats through the federally funded Wetland Reserve Easement Incentive Program (NDGFD, 2019f, h). Landowners are compensated for allowing public access to existing CRP land through the CRP Access Program (NDGFD, 2019a).

Increased cuts to the federally funded CRP mean that demand to participate in many of these programs outstrips funding in North Dakota. Although NDGFD personnel noted that this means they can select the best tracts of land to put into the CRP, it also means that there are opportunities for enrolling additional land which are unrealized (Yocum and Ray, 2019). Furthermore, there is also a mismatch between easement timelines and long-term conservation to meet State conservation targets and flexibility for landowners. For example, CRP contracts are often for 10–15 years, but land can be converted after that time, which has increasingly occurred in North Dakota in recent years. Perpetual easements are most beneficial for most conservation goals, but are not as popular with landowners (Baier, 2020). Other programs offer alternatives to perpetual easements, including the U.S. Department of Agriculture Agricultural Conservation Easement program and the Agricultural Land Easements Program (Baier, 2020).

Emerging Challenges and Opportunities

Like other States in the **North Central region**, loss, **fragmentation**, and degradation of grasslands are the most prevalent threats to grassland conservation. Most of the land in North Dakota is privately owned and managed (Dyke and others, 2015; fig. B18). However, the NDGFD collaborates with nonprofit organizations and works with landowners to leverage Federal conservation programs.

The NDGFD identified agricultural conversion and oil and gas development as the primary threats to grassland ecosystems in the State. From 2000 through 2020, grasslands have been lost by conversion to agriculture at an increasing rate (WWF, 2020, 2021). Increased precipitation brought by a warm, wet trend in North Dakota's climate made it possible to grow corn and soybean row crops in areas that were previously better suited to wheat cultivation or rangeland. This cycle was likely not because of climate change, but rather is within the range of natural variability for the northern **Great Plains** (Ballard and others, 2014; Seager and others, 2018); however, the effects of these changes could signal the types of agricultural changes and grassland conversion that may take place under a changing climate. Between 2004 and 2014, decreased enrollment in CRP contributed to the conversion of 3.7 million acres to corn and soybean row crops (Wimberly and others, 2017, p. 161). The shale oil boom, which uses hydraulic fracturing (also known as "fracking") to extract fossil fuels from the Bakken Formation in North Dakota has brought economic prosperity to some rural communities and Tribal nations; however, the infrastructure needed to develop these resources has led to additional grassland loss, fragmentation, and degradation. Other threats identified by the NDGFD, in order of greatest to least threatening, are invasive plant species, other (unspecified) human dimensions, wildfire suppression, livestock farming and ranching, urban development, and agricultural and forestry effluents (Dyke and others, 2015).

Information Needed

Research on several issues is highly relevant to the NDGFD's work to conserve North Dakota's grasslands (refer to Miller Hesed and others, 2023). Understanding how climate change will affect precipitation; temperature; and related water quality, quantity, and availability may be the most important research question for the NDGFD because water is critical to the habitat of fish and wildlife species in North Dakota and cropping in the State. For a more complete and detailed list of NDGFD-specific information needs, refer to appendix B1. Specific questions identified in NDGFD management plans include the following:

1. Is increased precipitation in North Dakota the new normal under a changing climate? Or is it likely to return to a drier state?
2. How will changes in timing and amount of precipitation affect the PPR, and the suitability of the habitat for breeding migratory waterfowl and other species of interest?
3. How will changes in precipitation affect agriculture in the State (and in turn, impact grassland conversion)?

Another research topic of high relevance for NDGFD conservation of grasslands is understanding how to avoid grassland loss. In particular, research related to promoting conservation on privately owned grasslands is highly relevant to the work of the NDGFD. The NDGFD is also interested in understanding where and how renewable energy can be developed to minimize the extent and effect of grassland conversion. Related to energy development, a NDGFD management plan specifically asks how energy development infrastructure will affect grassland birds and other grassland species (for example, avoidance patterns, roadkill, and so forth). Finally, new ways of conceptualizing and approaching the problem of climate change interactions with grassland conservation is highly relevant to the NDGFD. Interactive models, maps, and tools that can help **grassland managers** make decisions to support the conservation of grassland systems and species as the climate changes will likely be important.

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A pasture at the Grant-Kohrs Ranch National Historic Site
(Photograph by M. Surber, National Park Service).

Section B12.
South Dakota Game, Fish and Parks

By Heather M. Yocum,[1] Christine D. Miller Hesed,[1] and Sarah Jaffe[2]

Acknowledgments

We wish to thank Paul Coughlin (South Dakota Game, Fish and Parks) for his edits and suggestions.

Background

Founded in 1918, the South Dakota Game, Fish and Parks (SDGFP) mission is to "serve and connect people and families to the outdoors through effective management of our state's parks, fisheries and wildlife resources" (SDGFP, 2021, 2022b). Originally known as the Division of Game and Fish, the agency was tasked with managing game and nongame fish and wildlife species and their habitats, undertaking research to support management, and regulating recreation and hunting (South Dakota State Historical Society, undated). In 1945, the Division of Game and Fish was combined with the Board of Parks, and renamed the SDGFP (South Dakota State Historical Society, undated). The SDGFP aims to maintain or restore at least 10 percent of the primary historical ecosystems in each of South Dakota's ecoregions (SDGFP, 2014, p. 113). State agencies including SDGFP manage approximately 2 percent of the grassland ecoregions in South Dakota.

All five **North Central Grassland Ecoregions** are in South Dakota; most of the State is in the Northern Mixed Grass Ecoregion (table B21; fig. B20). Nearly half of South Dakota's land remains as grassland (about 23 million acres). In western South Dakota, 70–90 percent of land is classified as "grassland" and is "dominated by rolling, native grasslands with as little as 10–30%" of land converted to crop production (South Dakota Grassland Coalition, 2017, p. 9–10). Towards the southeast corner of the State, land use increases to predominately row crops (from 20–80 percent of land cover), and native grasslands are increasingly found along riparian areas (South Dakota Grassland Coalition, 2017, p. 9–10). In 2010, the U.S. Census of Agriculture reported that "approximately 75% of the state's 23,000 farm and ranch operations graze livestock" (South Dakota Grassland Coalition, 2017, p. 4). Hunting on public and private land is a major economic driver as well, and more than 400,000 out-of-State hunters contribute approximately $220 million to the South Dakota economy each year.

Loss, degradation, and fragmentation of grasslands is a major concern for the SDGFP. More than 100,000 acres of grassland were converted into row crops in 2005–06, and this rate has accelerated in recent years (U.S. Government Accountability Office, 2007). Between 2006 and 2012, South Dakota lost 1.8 million acres of grassland to row crop conversion, urban development, or inundation (SDGFP, 2014). These high rates of conversion are partly because of the large amount of land that is managed by private landowners (figs. B21 and B22*A*, *B*).

Grassland Management

The SDGFP outlines management actions to address grassland loss, fragmentation, and degradation (SDGFP, 2014, p. 169–170). These management actions include collecting baseline data and assessing and mapping existing ecosystems, habitats, and species distributions. The SDGFP is also working to identify conservation opportunity areas. These efforts aim to increase habitat quality and connectivity by identifying and conserving larger contiguous habitat blocks that may be managed by different management entities or private landowners. The SDGFP is also prioritizing restoration projects that increase habitat block sizes and heterogeneity, or that create corridors to connect intact habitat blocks. The SDGF recognizes the need to simplify the process for accessing funds and technical support for private landowners and to create new incentive systems to encourage

Table B21. North Central Grassland Ecoregion acres managed by South Dakota State agencies.

Ecoregion[1]	Acres
Tallgrass	101,131
Northern Mixed Grass[2]	714,797
Central Mixed Grass	49,250
Shortgrass	1,680
Sagebrush–Grassland Ecotone	241,453
Total	**1,098,841**

[1]Acreages include waterbodies within grassland ecoregions. Acreages are derived from the Protected Areas Database of the United States (U.S. Geological Survey Gap Analysis Project, 2020) and the development of ecoregions is defined in Miller Hesed and Yocum (2026), figure A5. Also refer to section A1 in Miller Hesed and Yocum (2026).

[2]The acreage for the Northern Mixed Grass Ecoregion excludes that which falls within the Sagebrush–Grassland Ecotone.

[1]University of Colorado Boulder, Cooperative Institute for Research in Environmental Sciences, North Central Climate Adaptation Science Center.

[2]University of Colorado Boulder, Cooperative Institute for Research in Environmental Sciences.

landowners to contribute to State ecosystem diversity goals. These incentive systems include identifying policy options and resources to increase economic benefits and making conservation more competitive with agricultural uses of land, particularly in the eastern part of the State (also known as the "corn belt"). Other SDGFP efforts to prevent grassland loss, fragmentation, and degradation include improved monitoring and mapping of grassland habitats and species, working with partners to "improve existing and develop new tools and methodologies to restore native ecosystem diversity," and evaluating restoration effectiveness (SDGFP, 2014, p. 185–186).

Promoting Conservation on Private Grasslands

The SDGFP works with private landowners to conserve, improve, and reconstruct grassland ecosystems. To do this work, SDGFP collaborates with Federal agencies, other State agencies, and nonprofit and private organizations. The following are some examples of these collaborations but should not be considered an exhaustive list.

One example is the Grasslands Coalition, which aims to improve grasslands by working with agricultural producers and other grassland managers (South Dakota Grassland Coalition, 2022). Together with the South Dakota Association of Conservation Districts, the South Dakota

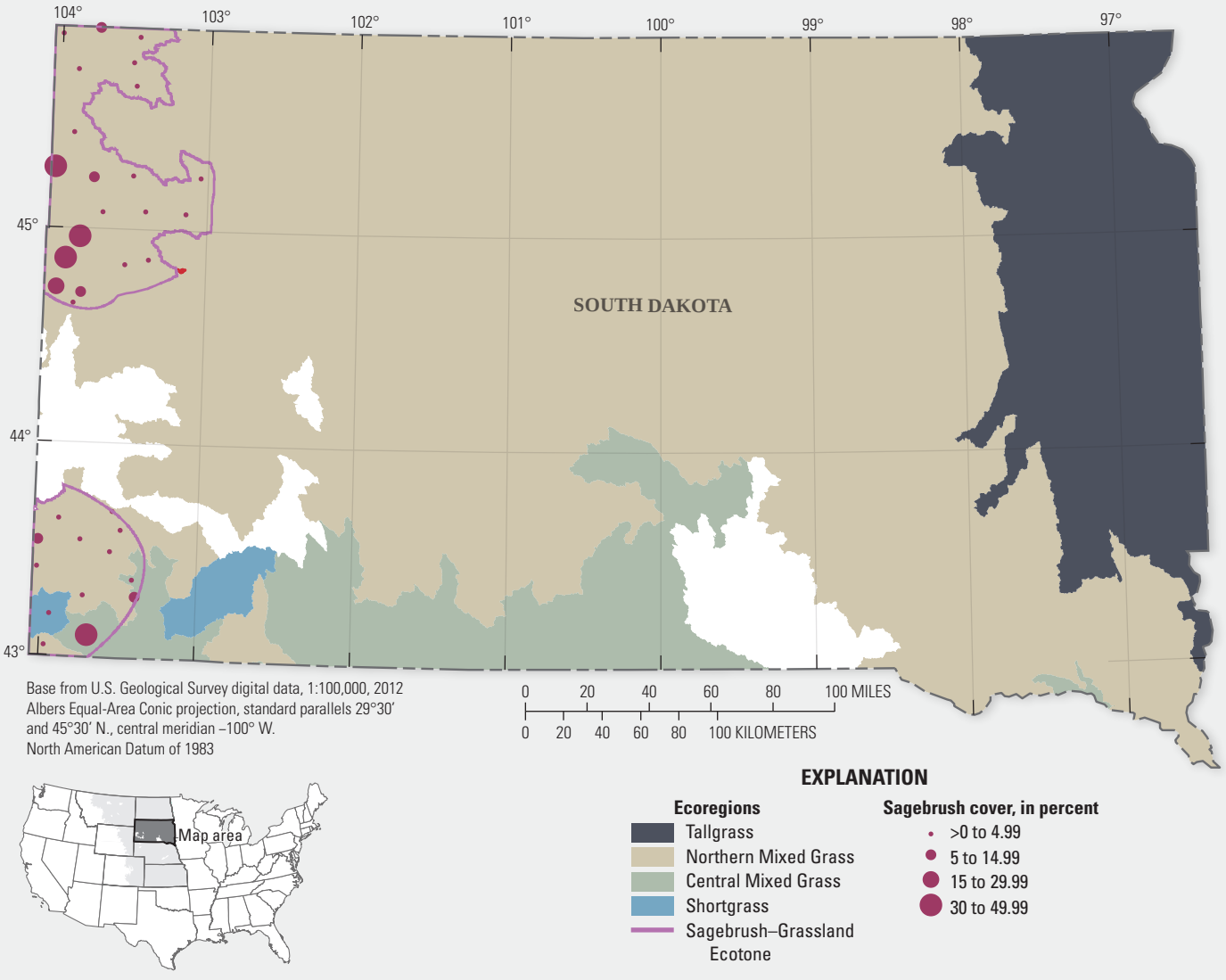

Figure B20. Map showing the grassland ecoregions in South Dakota. This map was created using data from LANDFIRE's biophysical settings (LANDFIRE, 2020), The Nature Conservancy's Terrestrial Ecoregions (The Nature Conservancy, 2019), and the U.S. Geological Survey sagebrush biome data (Jeffries and Finn, 2019). >, greater than.

Grassland Coalition's collaborative "Grassland Management and Planning Project" (funded through the South Dakota Department of Environment and Natural Resources) works with ranchers to provide technical assistance, tours, workshops, and a "grazing school" to promote sustainable best practices for grazing management (South Dakota Conservation Districts, undated). The Grasslands Coalition is targeting 50,000 acres and working to improve grassland condition from low quality to high quality (South Dakota Grassland Coalition, 2017) in part by reducing nonpoint source contamination (for example, sediment, nutrients, and fecal runoff) by improving rangeland conditions. Another example is work with the Prairie Potholes Joint Venture (http://ppjv.org), a collaboration that leverages Federal and private conservation funding to restore and protect high-priority wetland and grassland habitat to support migratory birds and waterfowl (refer to sec. B15 for additional information on the Joint Ventures).

The SDGFP also funds several programs that can be used instead of Federal conservation programs like the U.S. Department of Agriculture Farm Service Agency Conservation Reserve Program (for example, SDGFP, 2022a). The Second Century Working Lands Habitat Program promotes grassland conservation and improvement on private working lands by providing one-time payments of $150 per acre plus seed resources to landowners to plant grass and flower mixes on cropland for 5 years. Landowners are allowed to hay or

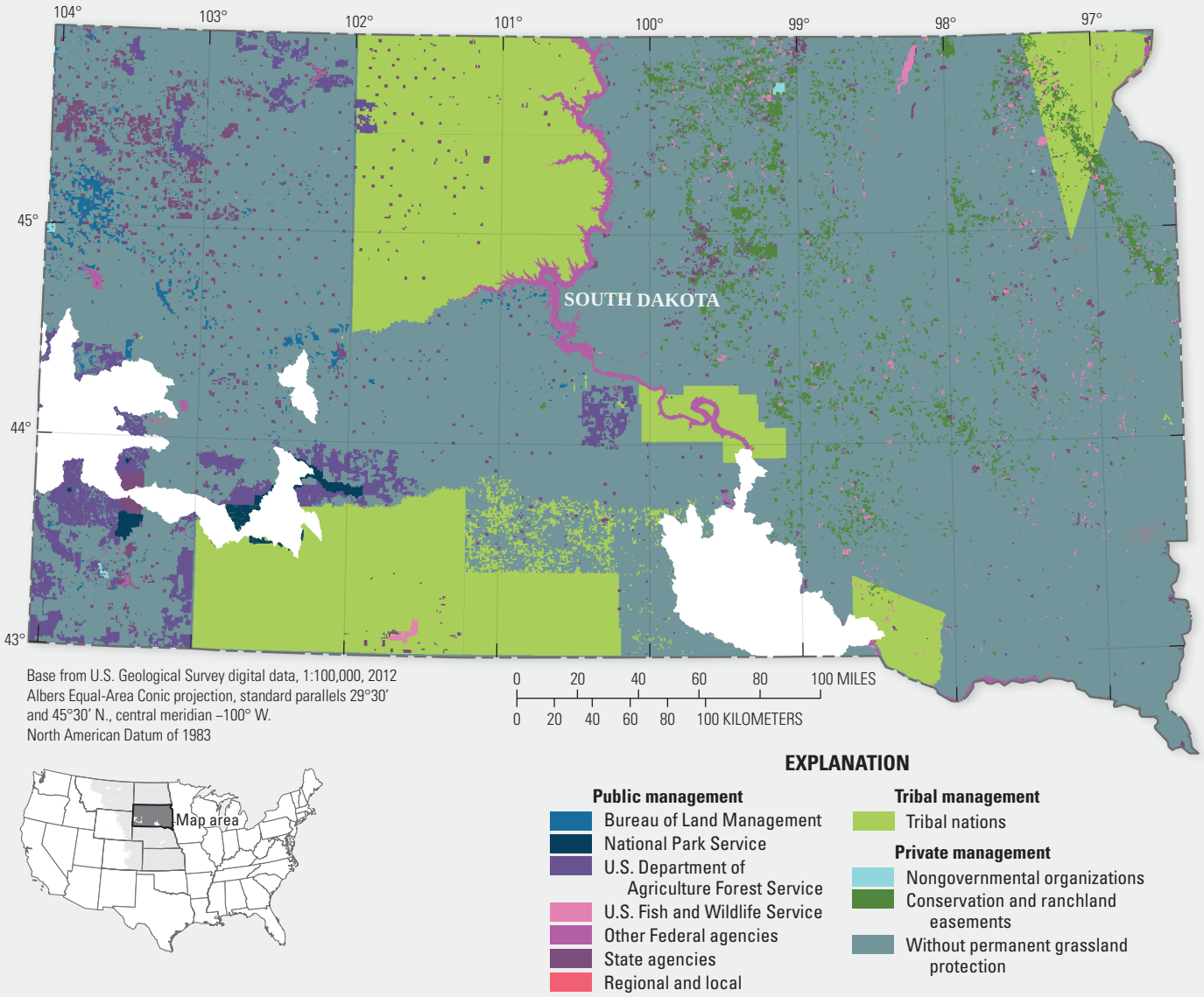

Figure B21. Map showing land management in the grassland ecoregions in South Dakota. Colors indicate which entity manages the land. The landowner is sometimes, but not always, the same as the manager. This map was created using data from the Protected Areas Database of the United States (U.S. Geological Survey, 2020).

graze enrolled land from August 1 to March 1, and haying is limited to half the total acreage annually or the entire area once every 2 years. Additionally, through the Walk-in Area Program, landowners can receive annual access incentive-based payments, plus a one-time bonus of $10 per acre per year to allow public access for hunting. The Food Habitat Plot Program provides annual payments of $20 per acre (or $40 for walk-in areas) plus seed mixes to plant corn, sorghum, and brood mix on between 10 and 30 acres of land to provide winter food sources for wildlife. The Woody Habitat Program is a one-time cost-share program to conserve, protect, and restore working grasslands and wetlands and support winter habitat and ground-level cover for wildlife. The Nesting Habitat Program provides reimbursement up to $150 per acre for creating habitat for ground-nesting birds. The Habitat Fencing Program reimburses landowners for putting up wildlife-friendly fencing (SDGFP, 2022a).

Emerging Challenges and Opportunities

The major challenges for conserving grasslands in South Dakota are direct and indirect habitat change, including land conversion to agriculture or development; degradation because of loss of natural disturbance systems such as fire suppression, altered grazing regimes, Cynomys ludovicianus (black-tailed prairie dog) control, flood control, and Castor canadensis (American beaver) dam removal; and accidental or intentional introduction of nonnative and invasive species; and climate change (SDGFP, 2014, p. 88–9).

Additionally, the South Dakota State Wildlife Action Plan identified issues that impacted grassland habitat conservation or the conservation of grassland obligate species (SDGFP, 2014, p. 137–39). Challenges related to row crop agricultural practices include the timing of field cultivation or mowing, which can

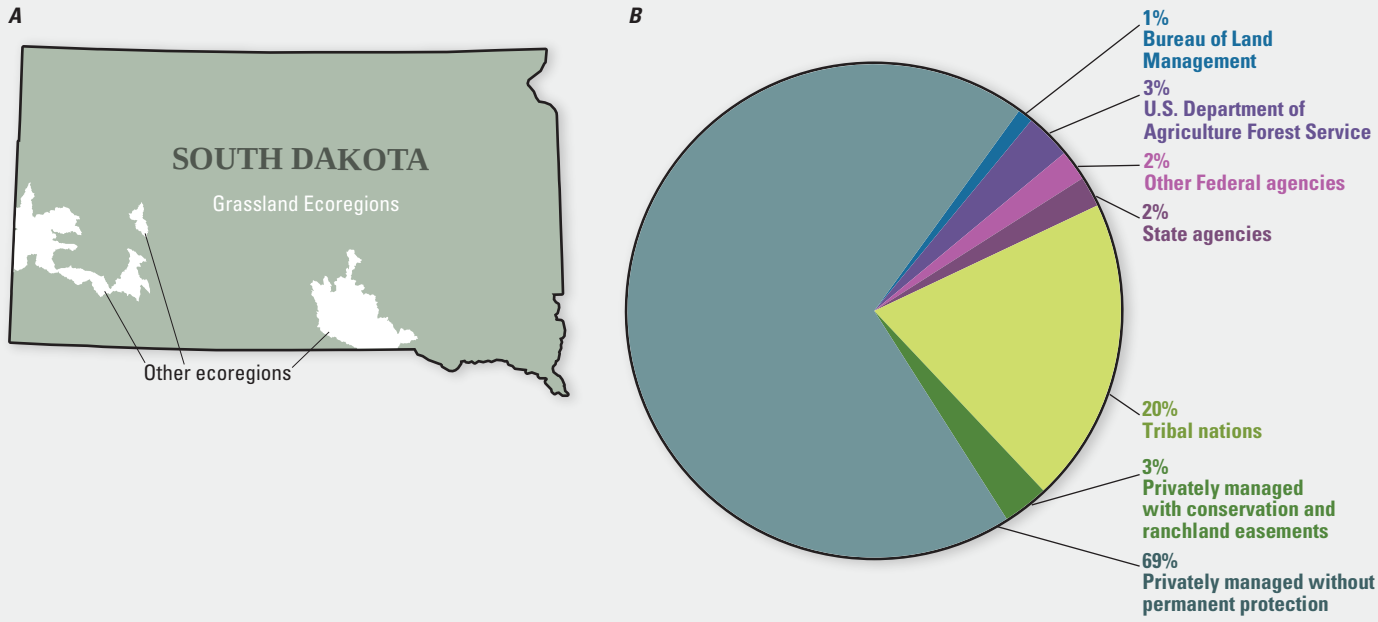

Figure B22. *A*, Map showing the extent of grassland ecoregions within South Dakota and *B*, the proportion of South Dakota grassland ecoregions managed by government agencies, Tribal nations, and private landowners. These proportions are estimated from acreage data from the Protected Areas Database of the United States (U.S. Geological Survey Gap Analysis Project, 2020). Non-Federal entities managing less than 0.5 percent of land in the grassland ecoregions in the State are not included. "Other Federal Agencies" includes, from most to least land managed, Federal agencies not discussed in this report and the U.S. Fish and Wildlife Service and National Park Service because the proportion of land managed by each of these agencies is less than 0.5 percent in South Dakota.

destroy the nests of ground-nesting birds; applications of poisons, pesticides, or herbicides that affect species directly or through the prey they eat; fragmentation of grassland habitat by row crop agriculture that can affect species movement; and an increase in predator species, which have adapted well to human habitation and prey on ground-nesting birds or other species of conservation need. Challenges associated with grazing include trampled nests when grazing occurs during nesting season; stock tanks that may trap and drown birds, mammals, or other species; degradation of water quality from feedlot runoff; spillover of diseases from domesticated animals to wild species; and an increase in parasitic bird species that have adapted to live with domestic livestock but harm ground-nesting bird species. Mining and energy development pose threats related to disturbing breeding sites during breeding and nesting season; exposure to contaminants; infrastructure to access these areas, which further fragments grassland habitat; and direct mortality of birds, bats, and other species from vehicle strikes or wind turbines. For a full list of these concerns with additional details, refer to the South Dakota State Wildlife Action Plan (SDGFP, 2014, p. 137–39).

Information Needed

Research on several issues is highly relevant to SDGFD's work to conserve South Dakota's grasslands (refer to Miller Hesed and others, 2023). For a more complete and detailed list of information needs specific to SDGFD, refer to appendix B1. One research topic of high relevance for the SDGFP's work to conserve grasslands is understanding how to avoid grassland loss. In particular, research related to promoting conservation on privately owned grasslands is highly relevant to the work of SDGFP. New ways of conceptualizing and approaching the problem of climate change interactions with grassland conservation is highly relevant to SDGFP. Interactive models, maps, and tools that can help grassland managers make decisions to support the conservation of grassland ecosystems and species as the climate changes will be important.

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Thunder Basin National Grassland, Wyoming
(Photograph by Jordan Sampson, U.S. Department of Agriculture Forest Service).

Section B13.
Wyoming Game and Fish Department

By Christine D. Miller Hesed[1] and Sarah Jaffe[2]

Acknowledgments

We wish to thank Chelsea Ramage and Ian Tator with Wyoming Game & Fish Department for their edits and suggestions.

Background

The Wyoming Game & Fish Department (WGFD) is charged with providing "an adequate and flexible system for the control, management, **protection**, and regulation of all Wyoming wildlife" (WGFD, 2022b). The mission of WGFD is "Conserving Wildlife, Serving People" (WGFD, 2019). The WGFD laid out six goals in its 2019 strategic plan (WGFD, 2019). To ensure viable populations of Wyoming's fish and wildlife, WGFD will (1) protect fish and wildlife by providing effective and efficient management and law enforcement, (2) conserve and protect diverse and sustainable habitat for fish and wildlife, and (3) prevent the introduction and spread of **invasive species** in Wyoming (WGFD, 2019). WGFD also aims to serve the residents of Wyoming by (1) improving communications, outreach, and education to foster appreciation, engagement, and understanding of fish and wildlife **conservation**; (2) encouraging and promoting diverse fish and wildlife-based experiences for all users; and (3) ensuring the long-term effectiveness of the agency by inspiring and empowering a highly motivated workforce and securing sustainable funding (WGFD, 2019).

The policies and decisions of the WGFD are overseen by the Wyoming Game and Fish Commission. The Commission was established in 1921 to provide citizen oversight to the WGFD and consists of 7 officials appointed by the Governor and approved by the Senate for 6-year terms (WGFD, 2022a). The Commission works with the WGFD Director, who oversees a Deputy Director of Internal Operations and a Deputy Director of External Operations (fig. B23). More than 350 personnel work at the WGFD to manage more than 800 species of wildlife across Wyoming (WGFD, 2022a). The WGFD works to achieve its mission with a variety of programs, including aquatic wildlife management, bird farms, conservation education, conservation engineering, external research, feedgrounds, habitat management and protection, and terrestrial wildlife management (WGFD, 2020a). The work of the WGFD is predominantly funded by hunters and anglers, and 80 percent of funding comes from license fees and excise taxes on fishing and hunting equipment (WGFD, 2022a). Additional funds come from multiple sources including grants, fees, and stamps (WGFD, 2022a).

Wyoming has three of the five **North Central Grassland Ecoregions**: Northern Mixed Grass, Shortgrass, and Sagebrush–Grassland Ecotone (table B22; fig. B24). Within these grassland **ecoregions**, most land (75 percent) is managed by private landowners; however, the Bureau of Land Management, U.S. Department of Agriculture Forest Service, and Wyoming State agencies each manage 8 percent of the land in the grassland ecoregions (figs. B25 and B26*A*, *B*).

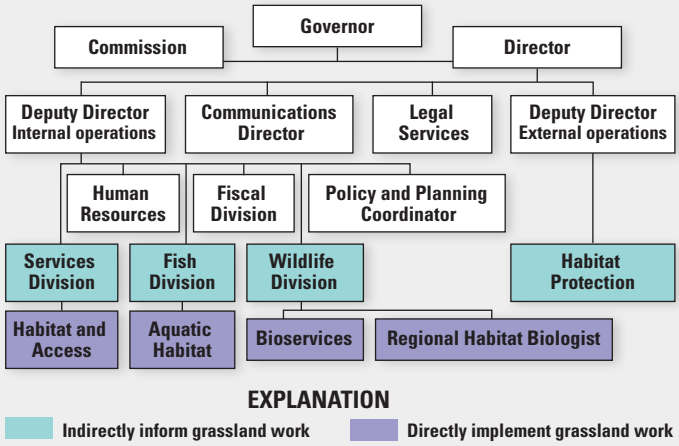

Figure B23. Graphic showing the Wyoming Game and Fish Department organizational chart showing work units with primary and direct responsibility for implementing work on grasslands and work units that indirectly inform those departments in their grassland work (modified from Wyoming Game and Fish Department, 2020b).

Table B22. North Central Grassland Ecoregion acres managed by Wyoming State agencies.

Ecoregion[1]	Acres
Tallgrass	0
Northern Mixed Grass[2]	67,130
Central Mixed Grass	636
Shortgrass	163,341
Sagebrush–Grassland Ecotone	1,439,878
Total	**1,629,320**

[1]Acreages include waterbodies within grassland ecoregions. Acreages are derived from the Protected Areas Database of the United States (U.S. Geological Survey Gap Analysis Project, 2020) and the development of ecoregions is defined in Miller Hesed and Yocum (2026), figure A5. Also refer to section A1 in Miller Hesed and Yocum (2026).

[2]The acreage for the Northern Mixed Grass Ecoregion excludes that which falls within the Sagebrush–Grassland Ecotone.

[1]University of Colorado Boulder, Cooperative Institute for Research in Environmental Sciences, North Central Climate Adaptation Science Center.

[2]University of Colorado Boulder, Cooperative Institute for Research in Environmental Sciences.

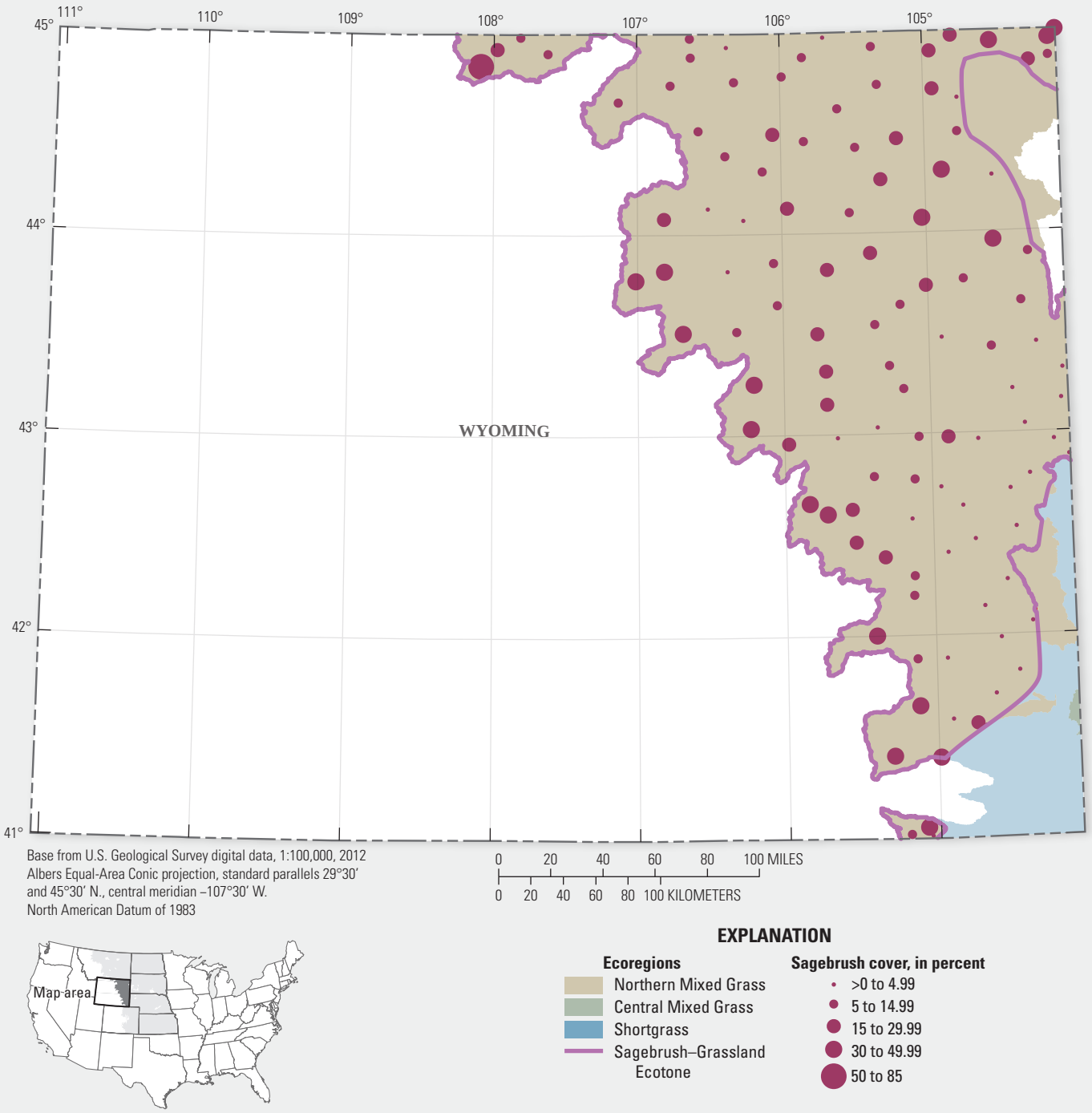

Figure B24. Map showing the grassland ecoregions in Wyoming. This map was created using data from LANDFIRE's biophysical settings (LANDFIRE, 2020), The Nature Conservancy's Terrestrial Ecoregions (The Nature Conservancy, 2019), and the U.S. Geological Survey sagebrush biome data (Jeffries and Finn, 2019). >, greater than.

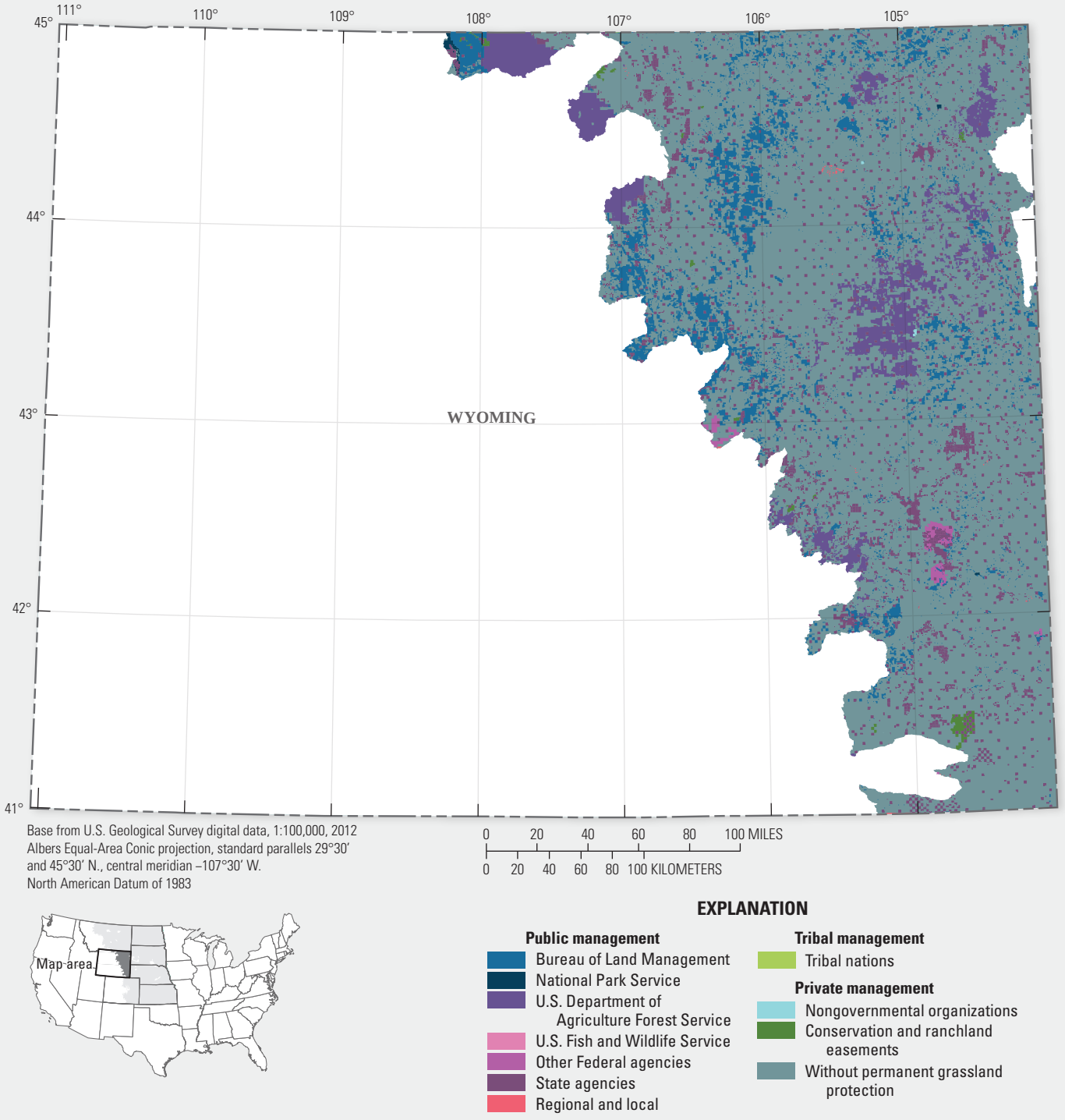

Figure B25. Map showing land management in the grassland ecoregions in Wyoming. Colors indicate which entity manages the land. The landowner is sometimes, but not always, the same as the manager. Data from the Protected Area Database for the United States (U.S. Geological Survey Gap Analysis Project, 2020).

Grassland Management

The WGFD identified grasslands as one of six priority habitats in their Statewide Habitat plan (WGFD, 2020b) and the State wildlife action plan (WGFD, 2017). The WGFD formalized cooperative strategies to address conservation needs of Wyoming's grasslands and associated wildlife in "A Plan for Bird and Mammal Species of Greatest Conservation Need in Eastern Wyoming" (Crowe and others, 2006), revisited their grassland management strategies to incorporate climate adaptation actions in the Wyoming wildlife action plan in 2017 (WGFD, 2017), and updated the strategic habitat plan (renaming it the "Statewide Habitat Plan") in 2020 (WGFD, 2020b). The goals outlined in the Statewide Habitat Plan (WGFD, 2020b) are to conserve, protect, and restore aquatic and terrestrial wildlife habitats and migrations. To accomplish these goals, the current (2023) grassland management priorities for the WGFD include (1) protecting grasslands from **conversion** and degradation from energy development, (2) reducing the spread and establishment of invasive, nonnative plant species, (3) promoting landowners' adoption of management actions to improve the quality of grasslands, and (4) increasing collaboration among management entities.

Grassland Protection

Unlike many other States in the **North Central region**, the primary threat for grassland loss in Wyoming is not conversion to cropland, but rather energy development—especially wind energy development (WGFD, 2017). The WGFD primarily works to mitigate the effects of wind energy development by avoiding energy development in biologically sensitive areas and directing mitigation funds to nearby high-value wildlife locations (WGFD, 2017, p. III–7–12). Ongoing inventory of grasslands to identify habitat suitable for species of greatest conservation need is an important part of this approach (WGFD, 2017, p. III–7–12). The WGFD also provides policy and nonregulatory guidance for management actions in Wyoming's grasslands, including reviewing management actions proposed by Federal and State agencies, industry, private landowners, and agency staff during the early phases of energy development planning (WGFD, 2017, p. III–7–12). The WGFD also works to protect grassland from conversion by working with willing landowners to put their land in easements (WGFD, 2017, p. III–7–13 to 15).

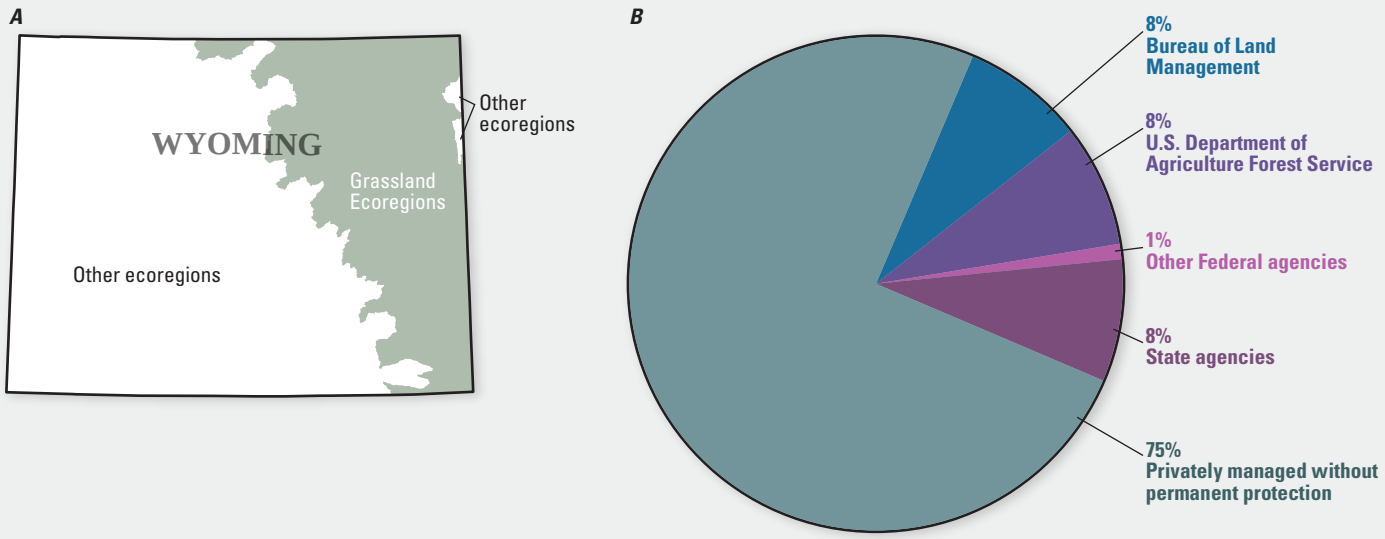

Figure B26. *A*, Map showing the extent of grassland ecoregions within Wyoming and *B*, the proportion of Wyoming grassland ecoregions managed by government agencies, Tribal nations, and private landowners. These proportions are estimated from acreage data from Protected Area Database for the United States (U.S. Geological Survey Gap Analysis Project, 2020). Non-Federal entities managing less than 0.5 percent of land in the grassland ecoregions in the State are not included. "Other Federal Agencies" includes, from most to least land managed, Federal agencies not discussed in this report and the National Park Service (NPS) because the proportion of land managed by NPS is less than 0.5 percent in Wyoming.

Reducing Invasive Plant Species

The WGFD works with Federal and local partners to reduce the spread and establishment of invasive plant species (WGFD, 2017, p. III–7–13–15). The State has established 23 weed and pest control districts, which manage crews that treat invasive species along public roads and in the backcountry. Weed and pest control districts also provide public and professional education on weed prevention, identification, and treatment and offer cost-sharing assistance to help private landowners combat invasive plant species. Another organization, The Wyoming Weed Management Association, was established in 2006 to promote collaboration on invasive plant control among various management entities. Wyoming also has 40 Coordinated Resource Management teams, most of which work on weed management, among other goals. The WGFD habitat biologists and land managers provide expertise for these invasive species groups in addition to working to control invasive species on WGFD-managed lands (WGFD, 2017, p. II–3–5).

Promoting Enhancement and Maintenance of Privately Owned Grasslands

The WGFD has many approaches to promote the **enhancement** and **maintenance** of privately owned grasslands, including incentives-based programs, conservation easements, education and outreach, and collaborating with nongovernmental organizations and other management entities to support conservation. For example, WGFD personnel and the U.S. Fish and Wildlife Service Partners for Fish and Wildlife Program provide technical and financial assistance to support management actions on private lands that benefit wildlife (WGFD, 2017, p. III–7–11). Examples of habitat enhancements promoted on private grasslands include flexible grazing systems to promote wildlife habitat, invasive plant treatments, incorporation of multiple natural disturbances (for example, prescribed fire and grazing), and protection of water and aquatic systems. Cost-sharing or other incentives help to encourage landowner participation (WGFD, 2017, p. III–7–11).

The Thunder Basin Grasslands Prairie Ecosystem Association is a notable collaboration among private landowners, nonprofit organizations, and natural resource agencies—including the WGFD—to manage the ecosystem within a designated 931,192-acre area in the Sagebrush–Grassland Ecotone in eastern Wyoming. Members of the association work together to balance enhancement and maintenance of habitat for species of greatest conservation need with sustainable economic benefits from ranching and coal, methane, oil, and gas production (WGFD, 2017, p. III–7–11).

Promoting Coordination of Action Across Management Entities

Recognizing the advantages of coordinating wildlife conservation efforts across management entities, the WGFD works to facilitate collaborative work with many different conservation organizations. For example, in 2006, WGFD published “A Plan for Bird and Mammal Species of Greatest Conservation Need in Eastern Wyoming” to formalize proactive strategies that will facilitate cooperative work among the WGFD and other agencies, landowners, and the public on grassland conservation (WGFD, 2017, p. III–7–11). The WGFD also collaborated with representatives from the U.S. Fish and Wildlife Service, Albany and Carbon County Weed and Pest, County Commissioners, Audubon Wyoming, Trout Unlimited, Wyoming Natural Diversity Database, Sonoran Institute, the U.S. Department of Agriculture Natural Resources Conservation Service, Bureau of Land Management Rawlins Field Office, University of Wyoming Cooperative Extension Service, the Shirley Basin-Bates Hole Sage-Grouse Working Group, and local ranchers to develop the “Shirley Basin-Laramie Rivers Conservation Action Plan,” which described strategies to address threats to important species and habitats in the area (WGFD, 2017, p. III–7–11–12).

Emerging Challenges and Opportunities

The WGFD faces many challenges in managing grasslands to protect, enhance, and restore wildlife habitat. First, although incentives-based and cost-sharing programs have been successful at engaging willing landowners in wildlife-friendly management actions, the residents of Wyoming strongly value individual freedoms and oppose excessive government intervention (WGFD, 2017, p. II–1–7). This culture makes it challenging to implement programs or policies on private land that would offer more permanent protection of wildlife habitat. As climate change impacts and stresses ecosystems and economies, landowners may be motivated to abandon wildlife-friendly management in the future. The challenge for the WGFD and other grassland conservation partners will be to continue to find grassland management approaches that can benefit the economic sustainability of landowners and the species of greatest conservation need within the context of increasing variability and uncertainty from climate change.

Another challenge for the WGFD is to determine where wind energy development can do the least harm to wildlife. An incomplete understanding of how wind energy development

affects different wildlife, coupled with the sometimes conflicting priorities of other agencies, makes it difficult for the WGFD to minimize or mitigate these effects. Furthermore, wind energy projects are often proposed in a phased or piecemeal fashion, which does not account for the cumulative effects of multiple projects in a geographic area; thus, making it difficult for the WGFD to evaluate the current or future effects of these projects on wildlife.

Finally, climate change presents a formidable challenge to managing grasslands for wildlife. The WGFD biologists and land managers must not only consider the ways in which climate change will impact wildlife but must also consider how climate change and other factors will interact and affect wildlife. Identifying management actions that can address a range of issues for grasslands and grassland species will be important for adapting to climate change.

Information Needed

Scientific inquiry on a variety of topics is relevant to WGFD management of grasslands amidst a changing and increasingly variable change, although two primary areas of information needs emerged from this review. Refer to Miller Hesed and others (2023) for a summary table of the relevance of synthesized information needs and appendix B1 for WGFD-specific information needs as articulated in reviewed documents.

The first is to develop criteria to inform land-use designation that can support thriving ecosystems and flourishing human communities in a changing climate. Key to the development of this criteria is to understand where and how energy can be developed to minimize the extent and effect of grassland conversion and degradation. In addition, understanding how key habitats might shift will likely be important for efficient use of conservation funds to protect, maintain, and enhance wildlife habitat in grasslands.

A second area of scientific inquiry is understanding how current management actions to protect wildlife, water quality, and manage invasive species may need to change to remain effective in reaching conservation goals. These changes in management actions could also be informed by the development of novel approaches and frameworks that allow resource biologists, land managers, and decisionmakers to better assess the impact of climate change and climate change interactions with other stressors on grassland ecosystems and improve coordination of efforts at the landscape scale.

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Northern mixed grasslands at Little Bighorn Battlefield National Monument (Photograph by Marian Doane, National Park Service).

Section B14. The Nature Conservancy

By Marissa Ahlering[1]

Background

Founded in 1951 and started as a land trust for places of biodiversity significance in the United States, The Nature Conservancy (TNC) is now one of the largest **conservation** nonprofit organizations globally. The mission of TNC is "to conserve the lands and waters on which all life depends" (TNC, 2022b), and the TNC vision is to create a world in which people and nature can thrive (TNC, 2022a). Organizationally, and in the **Great Plains**, conservation goals include addressing climate change (mitigation and adaptation), conserving lands and waters (**protection** and management), and promoting sustainable agriculture (ranching and cropping; TNC, 2022b).

In the United States, TNC is structured with divisions and business units. Divisions comprise multiple business units and business units comprise individual States or occasionally, multiple States. The **North Central region** includes parts of the Great Plains and Western divisions. Within this structure, TNC works on issues that range from on-the-ground management and protection to State and national policy.

Grassland Management

Grassland conservation is a priority for TNC in this region, and thriving grasslands require processes such as grazing and fire. With the loss of free-roaming *bison bison* (bison) and the prevalence of fire suppression, grassland management is an important conservation action and is crucial on public and private lands in the region.

Addressing Grassland Loss, Fragmentation, and Degradation

The Nature Conservancy uses many different management actions to maintain or improve grassland condition and ecosystems across the Great Plains, and these actions are often dependent on regional context, local context, past land-use history, and current condition. In the North Central region, TNC prioritizes working with ranchers on sustainable grazing issues and managing for climate adaptation and resilience, and these priorities drive management actions and information needs.

The Nature Conservancy is still active in protection, and the accelerating loss of grassland means protection strategies are often at the forefront of TNC's work. The Nature Conservancy focuses on the protection of untitled native grassland that has high biodiversity or resilience value where possible. They work with partners, such as the U.S. Fish and Wildlife Service or the U.S. Department of Agriculture Natural Resources Conservation Service to help direct public funds for multiple conservation benefits. Generally, the goal of this work is to reduce habitat loss and **fragmentation** because of cropland or housing development **conversion** and has a focus on sites predicted to be resilient to climate change (as shown with TNC's Resilient and Connected Lands Network Resilient Land Mapping Tool [https://maps.tnc.org/resilientland/]).

Maintaining the biodiversity value, resilience, and condition of remaining grasslands are also management goals. The Nature Conservancy implements prescribed fire, grazing, brush control, and invasive plant species management across the Great Plains to achieve these goals. Management strategies often focus on increasing heterogeneity to produce a shifting mosaic of habitat using these management actions. For example, the Smoky Valley Ranch and Niobrara Valley Preserve use prescribed fire and grazing with an adaptive management approach to promote biodiversity (M. Bain, TNC, written commun., 2016). In addition to promoting biodiversity, many of these actions also enhance ecological functioning, such as carbon storage or water quality.

In particularly fragmented parts of the landscape, TNC also works to reconstruct grasslands (TNC, written commun., 2000). For example, a key focus of some of the work around the Niobrara Preserve in Nebraska is to develop and test **prairie** reconstruction strategies on old croplands and improve biodiversity values on degraded areas through overseeding (TNC, written commun., 2017a). **Reconstruction** of grasslands is also a connectivity strategy to foster climate adaptation for grassland biodiversity and species of concern. The Nature Conservancy has mapped climate resilience across the United States to help guide this work (Anderson and others, 2014).

Direct management actions on TNC lands or partner lands are a priority, but other key goals for management are to affect and enhance conservation actions across a broader landscape. The Nature Conservancy lands can often serve as test cases to develop improved fire, grazing, or invasive plant species management techniques that can then be used more effectively or efficiently by other management entities. Successful implementation of conservation goals, strategies, and key actions on TNC preserves can provide a proof of concept for partners and private landowners and help achieve larger landscape conservation goals (M. Bain, TNC, written commun., 2016).

[1]The Nature Conservancy.

Promoting Conservation on Private Lands

The Nature Conservancy's footprint on the landscape is small compared with privately held land, especially in the Great Plains. Therefore, for conservation actions to have an effect, TNC strives to work alongside private landowners to adopt conservation practices that will benefit the landowner and the environment.

Private landowners are integral to conservation success in the Great Plains. Working with private landowners in the sustainable and regenerative agriculture realm is increasingly a central part of TNC's work given its focus on tackling climate change and promoting ecosystems and biodiversity. Working with row crop farmers to improve soil health and water quality can improve a farmer's income, store carbon, and promote freshwater biodiversity. Similarly, working with ranchers to improve rangeland health also has clear benefits for carbon, water, biodiversity, and the farmers' operations (Ahlering and others, 2021).

Emerging Challenges and Opportunities

The ecological and structural challenges that TNC faces are similar to other conservation agencies and NGOs. The Nature Conservancy works on ecological challenges at all scales. Because TNC owns and manages conservation lands, site-level ecological issues, such as **invasive species**, altered disturbance regimes, and woody encroachment are a constant challenge. At the landscape scale, TNC also works on issues such as fragmentation from conversion to agriculture or housing developments and mitigation hierarchies for energy development (Hise and others, 2022). Structurally, TNC faces challenges with limited staff capacity and restrictions on funding from granting agencies or donors.

The conservation opportunities TNC provides are often around policy advocacy and partner coordination. The Nature Conservancy works on county, State, and Federal policy issues across the Great Plains, often in conjunction with partners. As a nonprofit, TNC has the ability to comment on and advocate for conservation issues that government agencies do not. Finally, TNC has the ability to bridge science and application and interagency barriers. As a science-driven, conservation organization, TNC often serves as a convener of scientists and conservation practitioners, which is valuable for driving conservation outcomes (for example, Ahlering and others, 2020).

Information Needed

The Nature Conservancy identified many science needs across the North Central region that range from localized issues to regional knowledge gaps. This section provides a list that exemplifies the range of science needs determined by TNC managers and conservation practitioners (TNC, written commun., 1999, 2000, 2017a, b; Ahlering and others, 2020). Refer to Miller Hesed and others (2023) for a summary table of the relevance of synthesized information needs and appendix B1 for TNC-specific information needs as articulated in reviewed documents.

The Nature Conservancy's conservation work and information needs generally focus more on community or ecosystem level questions than species-level questions. However, some keystone species are important to understand for managing a system. For example, the need for a working model for *Cynomys ludovicianus* (black-tailed prairie dog) and *Mustela nigripes* (black-footed ferret) management, especially on private lands, would benefit the entire prairie system. Most of TNC's identified science needs involve current condition and inventory of biodiversity; ecosystem process, connections (for example, grasslands and freshwater), and reconstruction; and the interface between social and ecological systems. Examples of some of these science questions include the following:

1. What management practices promote efficient groundwater use and promote clean water while still maintaining high agricultural productivity?
2. What is the current population status for native biodiversity, both terrestrial and freshwater?
3. How do we ensure adaptability of our remnant and restored grasslands in fragmented landscapes?
4. How and where should we be sourcing seed for grassland reconstruction to promote genetic diversity and adaptability? Identify the need for developing seed provenance tools for climate change in the North Central region.
5. Are there economic consequences to a private livestock operator's bottom line to maintaining soil health or productivity in resilient grassland and wetland complexes, and are there cultural or social obstacles to implementing best practices?

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Sturnella neglecta (western meadowlark) in the grasslands of the North Central region (Photograph by Sandra Uecker, U.S. Fish and Wildlife Service).

Section B15. Migratory Bird Joint Ventures

By Kimberly Hall[1]

Acknowledgments

I would like to thank Graeme Patterson (JV8 Central Grasslands Conservation Initiative) and Catherine Wightman (Northern Great Plains Joint Venture) for their edits and additions to this section.

Background

Migratory Bird Joint Ventures (JVs) are a set of collaborative partnerships organized under the North American Waterfowl Management Plan (NAWMP), which was signed in 1986 by the United States and Canada and in 1994 by Mexico (Anderson and others, 2018). The implementation section of the original plan (U.S. Fish and Wildlife Service [FWS], Environment Canada, and Canadian Wildlife Service, 1986, p. 17) called for the establishment of joint venture action groups to plan, fund, implement, and evaluate joint venture projects, that is, projects that are deemed a priority for meeting broad migratory waterfowl population and habitat objectives on a continental scale. The diversity of partner groups engaged in JV projects includes Federal and State science and management agencies, county and local governments, land trusts and other nongovernmental organizations (NGOs), Tribal resource managers, academic researchers, private landowners, agricultural producers, and private corporations. The phrase "think continentally, integrate locally" is described as the mantra of JV participants (NAWMP, 2018, p. 11), whereas the combination of the overarching plan and the JV network are credited as "the catalyst for much of the wetland habitat **conservation** work in North America for more than 30 years" by Anderson and others (2018, p. 250).

Although JVs were originally focused on waterfowl, in 1999, JVs expanded their focus to include other migratory birds and sometimes other species, although many retain a strong emphasis on waterfowl habitat, which aligns with the interests and expertise of key collaborators (Migratory Bird Joint Ventures, 2017c; Anderson and others, 2018, p. 250). In addition to the NAWMP, JVs may address conservation goals and objectives identified under plans and conservation initiatives focusing on other bird groups, such as the "North American Waterbird Conservation Plan," the "Partners in Flight Landbird Conservation Plan," and the "U.S. Shorebird Conservation Plan" (Migratory Bird Joint Ventures, 2017d). For example, Partners in Flight establishes population objectives for birds at the continental scale (Partners in Flight, 2016), and JVs carry out regionally specific work in support of those objectives (Migratory Bird Joint Ventures, 2017d). Most JVs are delineated based on specific regions and habitats (for example, the playa lakes, Rainwater Basin Joint Venture [RBJV], and Prairie Pothole JVs), but there are a few JVs focused on a specific species (for example, *Anas rubripes* [American black ducks]) or group of species (for example, 15 species of sea ducks).

In recent decades, in addition to expanding the suite of species addressed, the emphasis of JVs has added significant outreach components to their original focus on supporting continental-scale species population goals through local and regional actions to increase or improve habitat. This increased emphasis on engagement can be illustrated through changes to the NAWMP, which has been updated multiple times since 1986 (NAWMP, 2024). A significant revision in 2012, and addendum in 2014, broadened the scope of the plan to specifically target challenges related to engaging with people and building public understanding and support for conservation efforts (NAWMP, 2018). In that revision, waterfowl managers and others networked through the JVs agreed on three focal goals: (1) sustaining waterfowl populations at levels that supported human use, (2) protecting habitat to support waterfowl populations and other key functions, and (3) increasing engagement with and support from the public for conservation. The 2014 addendum further articulated objectives and measures for the goal of broadening the constituency for conservation of waterfowl and wetlands (NAWMP, 2018, p. 4).

The JVs are coordinated and supported by the FWS and have various plan committees (for example, the NAWMP Committee) that often play important roles in supporting and evaluating progress toward population and habitat objectives. Each JV has a volunteer management board that is responsible for tasks such as establishing priorities and direction, supervising JV coordinators, and approving funding for conservation projects. For example, in 2022 the management board for the Northern Great Plains JV consisted of 19 people from multiple Federal and State agencies, NGOs, a regional grazing collaborative, and a corporation (Northern Great Plains Joint Venture, 2022). Many volunteer management boards include representation from agriculture-related Federal agencies, such as the U.S. Department of Agriculture Natural Resources Conservation Service, or private landowner coalitions (for

[1]The Nature Conservancy.

example, the regional grazing collaborative). In addition to the management board, each JV draws from the expertise of one or more technical committees comprised of ecological scientists, land managers, and other regional experts.

The U.S. Geological Survey North Central Climate Adaptation Science Center (CASC) geography overlaps all or part of six JV focal geographies: the Prairie Pothole JV (PPJV), Northern Great Plains JV, RBJV, Intermountain West JV, Playa Lakes JV, and Upper Mississippi River and Great Lakes Region JV. The geographic extent of JVs vary (fig. B27), as does the number of staff and their roles (table B23). Given that **grassland**, wet meadow, and **prairie** pothole habitats have been highly converted, they are critical focal habitats for the **Great Plains** region's JVs. Grasslands and embedded wetlands have been targeted for conservation and compatible land-use (that is, sustainable grazing) strategies.

The eight JVs that span the North American Great Plains (four of the JVs in the North Central CASC region—the PPJV, Northern Great Plains JV, RBJV, and Playa Lakes JV—plus the Oaks and Prairies JV, Prairie Habitat JV, Rio Grande JV, and Sonoran JV; fig. B27) joined together to elevate their collective conservation efforts across the interconnected landscape. The collaboration is known as the JV8 Central Grasslands Conservation Initiative (JV8; JV8, 2022). The JV8 is catalyzing work across the breeding, migration, and wintering habitats used by grassland birds during their annual cycle in the United States, Canada, and Mexico. As of 2024, the JV8 has completed a Great Plains grassland assessment (Fields and Barnes, 2019) to understand the extent of **undisturbed** native grasslands across the trinational geography. In October 2020, they hired a Conservation Director to drive the creation and implementation of the JV8 strategy (JV8, 2021) and coordinate conservation efforts of JVs and their partners to address causes of declining grassland bird populations across the JV8 regions.

Grassland Management

A key role of the JVs in meeting the objectives of the NAWMP is to translate continental-scale bird population objectives to local or regional levels, which informs management, **protection**, and **restoration** of key habitats (NAWMP, 2018), including grasslands and embedded wetlands. To link habitat goals to continental bird population objectives, the JVs integrate locally and regionally relevant science, especially on population dynamics and energetics, to identify quantitative habitat needs. Once these habitat needs are identified, they work collaboratively with JV participants to plan and implement conservation. Conservation approaches in grasslands often involve work with ranchers or agricultural producers, for example, the RBJV partners with Nebraska Cattlemen to connect cattle producers with landowners that are interested in helping sustain wetlands through grazing (RBJV, 2022). The type of science used to inform projects has shifted throughout the several decades since the first JVs were first established. The original scientific approaches emphasized identification of suitable habitat and high intensity population management methods, like predator protection and control; efforts have now shifted toward providing the information needed to inform perpetual protection of habitat (for example, through fee acquisition or easements) and restoration (Anderson and others, 2018). Thus, the emphasis of JVs is on developing, synthesizing, and applying the science needed to support implementation of projects that will improve and protect habitat and population numbers for focal species, complemented by an increasing emphasis on social science to build public support for these efforts. In 2018, the NAWMP Committee also encouraged the JVs to take a more active role in policy (NAWMP, 2018).

A key characteristic of JV collaborations and associated projects is that participation is voluntary; the NAWMP states that "Joint Venture projects should be implemented through facilitating agreements negotiated and agreed to by all those wishing to participate" (FWS, Environment Canada, and Canadian Wildlife Service, 1986, p. 17). Programs supported by JVs are nonregulatory, and projects occur on public and private lands. The power to catalyze conservation comes from the JVs' work to build partnerships that can pull expertise, capacity, and funds from diverse sources, and leverage Federal or State grant funding. The "Birds and Habitats" page of the JV website highlights the statistic that "Since 1986 Joint Venture partnerships have leveraged every dollar of Congressional funds 34:1 to help conserve 22 million acres of essential habitat" (Migratory Bird Joint Ventures, 2017a). Expanding the acres metric to include "conserve, enhance, and restore," the 2018 NAWMP update describes benefits to more than 50 million acres of habitat across North America through the work of JVs and partners (NAWMP, 2018, p. 8). Easements on private lands and efforts through the U.S. Department of Agriculture Farm Service Agency Conservation Reserve Program (CRP) have been important in the United States, and partnerships with the agricultural community are key, as are policy efforts that target prevention of wetland drainage (Anderson and others, 2018, p. 255).

A main source of funding for the habitat work that is pursued by JVs are grants under the North American Wetlands Conservation Act (NAWCA; 16 U.S.C. 4401), which supports conservation for habitat of all wetland-dependent bird species. The U.S. Congress mandated that some of these funds must be spent outside of the United States, which helps support a continental approach to conservation. The NAWCA grants also require at least a 1 to 1 match to be provided by non-Federal funds, which in the United States commonly comes from States (typically through hunting-related fees) and NGOs, although many other partners have also provided matching funds (Anderson and others, 2018, p. 251). The NGOs focused on protection of migratory waterfowl, most notably Ducks Unlimited, have played a key role in JV efforts by raising awareness of declines in waterfowl and their habitats and in funding and implementing wetland conservation (Anderson and Padding, 2015).

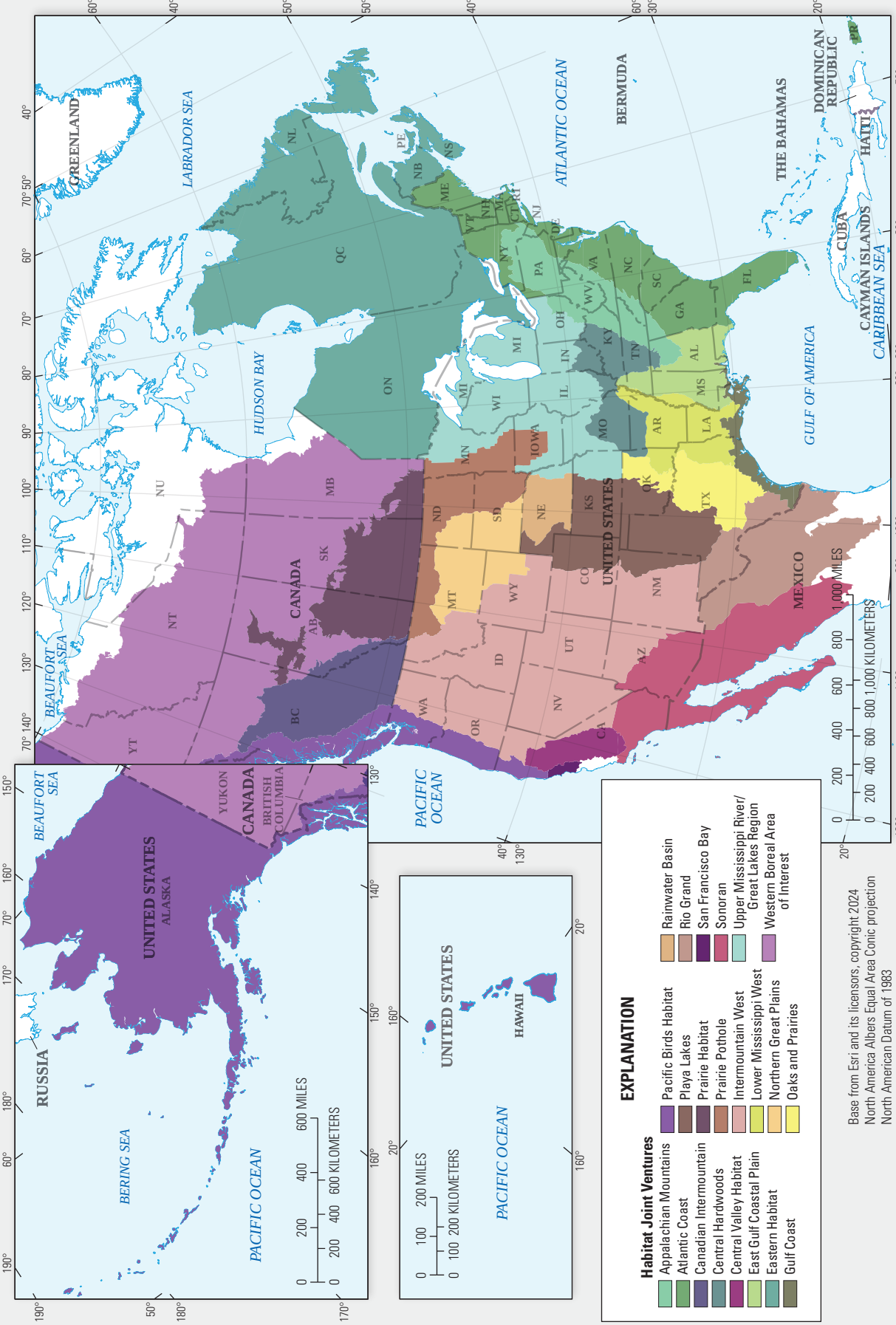

Figure B27. Map showing the Habitat Joint Ventures geographic extent. Modified from U.S. Fish and Wildlife Service (2022).

Emerging Challenges and Opportunities

The content presented in this section is based on a review of three JV plans from a range of dates (Upper Missouri River and Great Lakes Region Joint Venture [UMRGLRJV], 2007; RBJV, 2013; PPJV, 2017a); more current information is available on JV websites, and researchers and managers interested in the work of a specific JV can refer to their specific implementation plan because grassland conservation efforts vary somewhat according to the geography of a particular JV. The intent of this section is to provide broad examples and context that help inform comparisons with entities described in other sections. Key information needs for the JVs are summarized below. In addition to the research needs summarized here, a list of additional specific information needs that were identified from the review of JV documents is included in appendix B1.

The key challenge that JVs address is loss of habitat for birds, which they tackle by coordinating and helping to fund collaborative approaches to protect, enhance, and restore habitats, with the goal of implementing specific projects that support healthy bird populations. In general, the challenges JVs are addressing relate to targeting and funding investments in protection, **enhancement**, and restoration of habitat, although some of the collaborations and science they support targets management of agricultural land; for example, paying for infrastructure to support sustainable grazing partnerships (RBJV, 2022).

The drivers of habitat loss are complex and often vary at regional and local scales; this variation and need for site-specific partnerships for project-scale implementation was a key motivator for the creation of JVs. Within the North Central CASC geography, key drivers of grassland and wetland-dependent bird declines include expansion and intensification of agriculture, encroachment of woody vegetation into grassland habitat, and loss of grass-like habitats because of an agricultural shift from production of grain crops to soybeans and corn. Wetland drainage and **conversion** are also critical concerns. Losses of grasslands and wetlands are continuing and strongly affected by changes in various U.S. Farm Bill programs (including subsidies), and commodity prices (that is, changes in the CRP), and the safety net provided by the Federal Crop Insurance Program that lowers the risk farmers incur when converting grassland to cropland; UMRGLRJV, 2007; RBJV, 2013; PPJV, 2017a). Enrolling private landowners in programs that promote wildlife-friendly agricultural practices or perpetual protection of habitat is a high priority for JVs (PPJV, 2017a). Threats to ranching livelihoods and conversion of ranches to cropland were also emphasized as critical threats in the JV documents from the Rainwater Basin and Prairie Pothole regions, as were challenges related to use of grasslands for wind power and other energy development and related infrastructure.

Climate change, and specifically changes in hydrology, are also a key concern for JVs, especially JVs that continue to emphasize waterfowl habitat objectives. Loss of wetlands

Table B23. Organizational information for Joint Ventures in the North Central region.

[Information compiled from Migratory Bird Joint Ventures (2017b). Staff position focal areas relate to grassland management and policy in addition to Joint Ventures coordinators and science coordinator. Focal areas for staff positions and numbers of staff are likely to change, but these numbers and descriptions indicate relative size and capacity for addressing grassland issues. FWS, U.S. Fish and Wildlife Service; NGO, nongovernmental organization; GIS, geographic information system; NRCS, Natural Resources Conservation Service]

Name	Year established	City of contact(s)	Organization type and lead	Number of staff	Staff position focal areas
Intermountain West	1994	Missoula, Montana	FWS lead, partnered with stand-alone NGO	15	Very large focal region, primarily west of the Great Plains. Focal areas emphasize conservation and management of sagebrush rangeland habitats and related water resources and wet meadows. Positions focus on strategic partnerships, GIS, coordination of various sagebrush or water partnerships, and technology transfer.
Northern Great Plains	2004	Clancy, Montana, and Windsor, Colorado	Ducks Unlimited	5	Focus on grasslands, shrubs-steppe, wetland, and riparian habitats of the northern plains to benefit birds and private agricultural producers. Emphasis on connecting producers to conservation programs and habitat improvement methods with positions that include GIS, science integration, outreach, and communication.
Playa Lakes	1988	Erie, Colorado	Stand-alone NGO	9	Short- and mixed-grass prairies across the south-western plains, 97 percent of which is privately owned. Highlights the importance of playas and groundwater with focal strategies emphasizing partnerships with the agriculture sector to improve habitats. Roles include conservation delivery and planning, GIS, social science, coordination, and communication.
Prairie Pothole	1987	Denver, Colorado	FWS and Ducks Unlimited	4	Emphasis on protection, restoration, and enhancement of prairie pothole wetlands (northern plains) and associated grassland habitats and primarily working with agricultural producers to deploy voluntary conservation practices. Positions include science integration and communication.
Rainwater Basin	1992	Grand Island and Wood River, Nebraska	FWS, NRCS, and NGO	7	Focus on playa wetlands and mixed grass-prairies bird habitats in south-central Nebraska and partnering primarily with ranchers and other agricultural producers. Positions focus on GIS, habitats, coordination of a cattle grazer network, and communication.
Upper Mississippi River/Great Lakes	1993	Bloomington, Minnesota, and East Lansing, Michigan	FWS	4	Covers a wide range of habitats from boreal forests and Great Lakes coastal wetlands to floodplain habitats and tallgrass remnants. All birds are addressed, but emphasis on waterfowl and shorebird habitats and linking habitats to population numbers. Positions include a bird conservation modeler.

in the PPJV region has led to changes in hydrology that shifted some wetlands toward lakes, increased flooding, and created a sustained condition of spring and summer drought in some intensively drained sections of the Prairie Pothole region (PPJV, 2017a) Issues related to loss of key ecosystem dynamics (for example, fire, variable grazing, and flooding) and related effects of invasive plant species are also noted as concerns and linked to management approaches in the RBJV plan (RBJV, 2013). These plans also express broad concern for the rate of climate change and likelihood of resultant biodiversity loss.

The strong agricultural presence and reluctance of producers to modify their practices was identified as a challenge in the PPJV plan (PPJV, 2017a); similarly, the RBJV plan (RBJV, 2013) noted a historical lack of trust and collaboration between the agricultural and conservation communities. As a network, the JVs describe an increasing need for investing in social science to help them understand the human dimensions of protecting waterfowl and other birds through habitat conservation and maintaining a funding stream through hunting and other revenue sources (NAWMP, 2018, p. 6). However, as leaders in multipartner collaborations, JVs also provide many demonstrations of creative, effective collaborations. The 2018 update (NAWMP, 2018) described several case studies of JV activities that balance water availability for wildlife, ranching, and crop production in grassland **ecoregions**.

Information Needed

The JVs' information needs span many topics (refer to Miller Hesed and others, 2023); however, several general categories of information may be most relevant to JVs within the context of climate change. For a more complete and detailed list of information needs specific to JVs, refer to appendix B1. First, the strong tie among bird population data assessed at continental scales and the role of JVs as implementation drivers at regional and local scales highlights the importance of understanding how climate change will impact birds and their habitats. Updating population models and management approaches to deal with directional change, rather than an assumption of stationarity of climate drivers, is especially needed (Anderson and others, 2018, p. 255). This concept is reflected in the UMRGLRJV (2007) plan within a detailed set of population and habitat-related research questions. Similarly, the PPJV implementation plan states "One of the major challenges of addressing climate change effects on fish and wildlife is identifying and addressing uncertainty in our understanding of future climate change and how that change will affect ecological systems" (PPJV, 2017a, p. 26).

The PPJV also identified the need to evaluate "the direct and indirect impacts of climate to ensure conservation delivery has long term resilience in the U.S. PPR" (PPJV, 2017b, p. 19). Aligned with this need, the JVs identify a need to have a better understanding of changes in precipitation, hydrology, and the extent and duration of wetlands resources, and call out key spatial datasets (for example, improved wetland maps and restorable basins inventory maps to identify places where drained wetlands could be restored).

An improved understanding of what motivates people to engage in and support efforts to protect habitat has been elevated to a top objective for the JV network. The JVs also emphasize human dimensions in their descriptions of research needs. Examples of human dimensions research include collaborative studies to identify "win–win" practices that benefit agricultural producers or ranchers and conservation and work to quantify ecosystem services and economic benefits from protection of grasslands and wetlands (PPJV, 2017a).

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Glossary

conservation The protection, maintenance, and restoration of biodiverse, heterogeneous grassland ecosystems and their ecological processes.

contributing factors Factors that indirectly affect grasslands and are largely shaped by social, historical, cultural, economic, and political contexts.

conversion The transformation of grasslands to another land cover and use, such as cropping or development.

ecoregion A geographic region with biophysical characteristics that support a particular type of ecosystem (for example, tallgrass prairie); ecoregions may not be entirely composed of their characteristic ecosystems in situations where some part of the region has been converted to alternative land cover and land uses.

ecosystem A community of organisms and the physical environment in which they interact.

enhancement Management efforts to improve the quality of an existing grassland, for example, by working to reduce invasive species and promote native species and biodiversity.

fragmentation When grassland loss results in the breaking up of large grassland tracts into smaller, more isolated tracts that are often unable to support the same level of biodiversity and ecological function.

grassland Any grass-dominated area, whether native or reclaimed prairie, ranchland, or improved grassland (that is, grassland that has been seeded to provide improved forage for livestock).

grassland managers Individuals who develop grassland management plans, implement those plans on the ground, or both.

Great Plains A geographic area also known as the central grasslands of North America; it stretches from Canada to Mexico; is bordered by the Rocky Mountains to the west; and, to the east, covers most of Iowa, Illinois, and smaller parts of Minnesota and Missouri, but otherwise generally transitions to woodland along the east edge of the North Central States (Miller Hesed and Yocum, 2026, fig. A3).

intact grasslands As defined by the World Wildlife Fund, grassland that has not been converted to cropland since at least 2014—the year the World Wildlife Fund began tracking conversion of grassland to cropland (World Wildlife Fund, 2021).

invasive species A nonnative species that is able to spread and dominate in its new ecosystem and causes, or is likely to cause, harm to environments, economies, or human health. Not all nonnative species are invasive.

maintenance Efforts to ensure that a grassland does not become degraded.

native prairie Prairie that contains native plant species and which has existed, unconverted, since before European colonization of the Great Plains.

North Central Grassland Ecoregions Geographic regions within the North Central region that have the biophysical properties that support grassland ecosystems (as opposed to wooded or mountainous ecosystems), this area includes most of North Dakota, South Dakota, Nebraska, and Kansas, and eastern parts of Montana, Wyoming, and Colorado.

North Central region A geographic region composed of the States of Montana, Wyoming, Colorado, North Dakota, South Dakota, Nebraska, and Kansas.

prairie A type of grassland that contains a diverse mix of native grass and forb species.

protection Efforts to prevent grasslands from being converted to other land types, such as cropland or urban development.

ranchland Grassland that is primarily used for commercial livestock grazing.

reconstruction The process by which land that has been converted to cropland or development is re-established as grassland through the demolition or cessation of existing land use, replanting and reintroductions of native species, and other interventions.

restoration Includes the reconstruction and enhancement of grasslands.

undisturbed Never developed, tilled, or mechanically disturbed.

Prescribed fire line at the Tallgrass Prairie National Preserve in the Kansas Flint Hills (Photograph by National Park Service).

Appendix B1. Information Needs as Articulated in or Inferred from Grassland Management-Related Documents

By Heather M. Yocum,[1] Christine D. Miller Hesed,[1] Jon P. Beckmann,[2] Aparna Bamzai-Dodson,[3] Kimberly R. Hall,[4] Molly Cross,[5] Marissa Ahlering,[4] Emily Boyd-Valandra,[6] Danika Mosher,[7] and Ben Wheeler[8]

This appendix presents information needs as they were articulated in the grassland management-related documents that were reviewed by the Management Priorities Working Group (MPWG). This information was consolidated and synthesized as part of the effort to generate the list of 70 management-relevant questions listed in full in Miller Hesed and others (2023). Because specific details could not all be retained as the working groups synthesized information needs across multiple ecoregions and management entities, this appendix provides unsynthesized information directly from the source so that researchers interested in working on applied science may have a better sense of what information is most needed to support managers at specific agencies, departments, and organizations. The relevant information needs are reproduced from Miller Hesed and Yocum (2026) in this appendix using verbatim wording for consistency.

Some of the research and information needs listed below are directly related to climate change, whereas other information needs are more general but must be informed by research and science that account for complex effects of climate change on grassland ecosystems and management. Some of the information needs are quoted directly from the documents we reviewed, whereas other information needs were inferred by the MPWG during the review process. For example, if a document listed the effects of drought on specific plant or animal species as a major management concern, we inferred that changes in the frequency or severity of drought because of climate change is an information need. Although many of the reviewed documents were written from a management perspective, some documents were written by researchers. These specific examples of information needs are not exhaustive, but rather listed in this appendix to provide an additional level of detail and nuance to increase the ability of the research community to respond to these information needs.

[1]University of Colorado Boulder, Cooperative Institute for Research in Environmental Sciences, North Central Climate Adaptation Science Center.

[2]Kansas Department of Wildlife & Parks.

[3]U.S. Geological Survey, North Central Climate Adaptation Science Center.

[4]The Nature Conservancy.

[5]Wildlife Conservation Society.

[6]Sicangu Lakota Oyate (Rosebud Sioux) Tribe; Biologist and Indigenous Conservation Consultant.

[7]National Park Service Research Assistant, student contractor to U.S. Geological Survey North Central Climate Adaptation Science Center.

[8]Pheasants Forever Inc. and Quail Forever.

Bureau of Land Management

In addition to the information needs summarized in the "Bureau of Land Management" section, the following additional information needs are described in the documents reviewed that were related to the Bureau of Land Management (BLM). Additional needs identified by BLM management plans for specific management areas include the following:

- Additional ecological and climate science to "identify habitat thresholds necessary to sustain well-distributed healthy populations of . . . wildlife species . . ." under a changing climate" (BLM, 2018, p.4).

- Presence–absence and habitat surveys to identify current and future habitats for particular species of interest (BLM, 1994). For example, *Ammodramus bairdii* (Baird's sparrow), a species of greatest conservation need (SGCN) in the northern Great Plains, lacks information, as do many other species, which impede the ability to assess vulnerability to climate change.

Rapid ecoregional assessments (REAs) are the BLM's "first step toward a broader initiative to systematically develop and incorporate landscape-scale information into the evaluation and eventual management of public land resources" (Science Applications International Corporation [SAIC], 2012, p. ES1). These reports are commissioned by the BLM and are meant to help inform management decisions. The "Northwestern Plains Rapid Ecoregional Assessment" (SAIC, 2012) identified the following research needs and information gaps:

- "Data gaps for Baird's sparrow's specific response to climate change were identified. The assessment rating was largely based on "unknown" scores calculated when assessing factors that influence vulnerability such as distribution to barriers, dispersal and movements, sensitivity to temperature and moisture changes (historical thermal/hydrological niche), reliance on interspecific interactions to generate habitat, and dietary versatility." (SAIC, 2012, p. 70).

- Better information on nonnative and invasive species (SAIC, 2012, p. ES–5), potentially in the form of "national or ecoregion-wide data sources" (SAIC, 2012, p. 87).

- "Future studies that provide point occurrence data along with bioclimatic factors could be used with spatial models to estimate the actual and potential distribution of non-native species richness, cover, and the probability of occurrence. These models could also provide an indication of how environmental variables contribute to these distributions, and can also be useful for directing control and assessing impact to natural resource assets and management objectives (Barnett et al. 2006) [source not included in "References" list]." (SAIC, 2012, p. ES–5).

- Additional standardization and (or) integration of data. There is a need to increase collection and sharing of "geospatial information about resource conditions, change agents (CAs) such as wildland fire, and on-the ground management activities" to coordinate across agencies, especially for organizations like the BLM, which are adjacent to many other parcels of land managed by various actors (p. 1). There is also a "lack of consistent scale and comprehensive datasets for [disease]" (SAIC, 2012, p. ES–5).

The two-volume "Southern Great Plains Rapid Ecoregional Assessment" (Reese and others, 2017) identified the following research needs. Some of these research needs are directly related to climate change, whereas other research needs are issues that would be worsened by climate change:

- Better information on nonnative and invasive species (Reese and others, 2017, p. 108).

- How are human activities, including recreation, affecting nesting birds?

- Additional ecological data on private land enrolled in the U.S. Department of Agriculture Farm Service Agency Conservation Reserve Program (CRP) to enable improved landscape-scale studies. These areas have not been included in REAs because of data limitations (Reese and others, 2017, p. 43).

- Finer-scale ecological datasets. Regional datasets are too broad to speak to local ecological conditions (Reese and others, 2017, p. 107).

- Improved understanding of historical fire regimes (Reese and others, 2017, p. 108).

- Develop "assessment methods" and metrics that "promote consistency in management decisions" (Reese and others, 2017, p. 109).

- Identify and describe "ecological characteristics that promote ecosystem resilience in rapidly changing ecological conditions" (Reese and others, 2017, p. 109).

Altered fire regimes

- "What are the effects of fire on communities and wildlife habitats and forage?" (Reese and others, 2017, p. 109).

- "How have wildlife habitats and communities been degraded (presence of invasive woody species, loss of Quercus havardii (Rydberg) (shinnery oak)) because of improper fire management, including lack of fire?" (Reese and others, 2017, p. 109).

- "Where has ecological conversion of communities occurred as a result of fire exclusion?" (Reese and others, 2017, p. 109).

- "Where can prescribed fire be reintroduced to maintain shortgrass prairie?" (Reese and others, 2017, p. 109).

- "Where has erosion increased because of increased fire frequency or intensity?" (Reese and others, 2017, p. 109).

Shrub dynamics

- "How can we manage *Juniperus virginiana* (Linnaeus) (eastern redcedar) (mostly privately owned), mesquite, and *Juniperus monosperma* (one-seeded juniper)?" (Reese and others, 2017, p. 109).

Terrestrial development

- "How has development altered air quality?" (Reese and others, 2017, p. 110).

- "How has oil and gas development affected ferruginous hawk nesting?" (Reese and others, 2017, p. 110).

- How has development fragmented baseline habitat as a whole and for particular species of interest (also refer to Reese, Carr, and Burris, 2018)?

Aquatic development

- "How does water withdrawal (including reduced flow, water quality, dewatering, impoundments, and seasonal dynamics) affect aquatic species (freshwater mussels, fish communities, and fish hosts)?" (Reese and others, 2017, p. 110).

- "How does altered flow regime, channelization, and inundation of habitat affect birds (especially the habitat for the interior least tern and its forage fish species and playa lakes for the snowy plover)?" (Reese and others, 2017, p. 110).

- "How does aquatic development affect water quality and salinity changes?" (Reese and others, 2017, p. 110).

- "How are successional changes in lakes and reservoirs (siltation) affecting habitat heterogeneity?" (Reese and others, 2017, p. 110).

- "How are aquatic communities (rivers, streams, riparian areas, non-playa wetlands, playas, and saline lakes) being affected by water development?" (Reese and others, 2017, p. 110).

- "Where are toxic algae blooms occurring in lakes and reservoirs?" (Reese and others, 2017, p. 110).
- "How is water demand contributing to ecological changes in areas experiencing prolonged drought?" (Reese and others, 2017, p. 110).
- "What are the expected ecological communities after currently irrigated areas are abandoned because of aquifer depletion?" (Reese and others, 2017, p. 110).

Invasive species

- "How are invasive species affecting populations and habitats of native species?" (Reese and others, 2017, p. 110).
- "What areas are potentially at risk from invasive species expansion?" (Reese and others, 2017, p. 110).
- "What is the distribution of invasive species?" (Reese and others, 2017, p. 110).

Climate change

- "What is the phenology of grasslands for changing climates?" (Reese and others, 2017, p. 110).
- "How could flooding or drying projected by climate change scenarios affect playa wetlands (including as habitat for conservation elements)?" (Reese and others, 2017, p. 110).
- "How will climate change affect livestock practices on the landscape?" (Reese and others, 2017, p. 110).
- "How will drought affect conservation elements?" (Reese and others, 2017, p. 110).
- "How will climate change affect water demand, and what are the concomitant effects on conservation elements?" (Reese and others, 2017, p. 110).
- "What are the potential hydrological changes related to and the effects of changing climates?" (Reese and others, 2017, p. 110).

Poisoning, Herbicides, and Pesticides

- "How does poisoning intended for coyotes inadvertently affect swift fox?" (Reese and others, 2017, p. 110).
- "How is the dune sagebrush lizard affected by herbicides?" (Reese and others, 2017, p. 110).
- "How does pesticide use in agricultural croplands affect forage for wildlife?" (Reese and others, 2017, p. 110).
- "How does chemical contamination affect the interior least tern's prey base and burrowing owls?" (Reese and others, 2017, p.110).
- "How does control of prairie dogs affect ferruginous hawks?" (Reese and others, 2017, p. 110).

In addition, the following research needs were inferred based on the MPWG's document review:

- A better understanding of the structural and (or) institutional obstacles to implementing adaptive actions. For example, REAs are not available for every region and are not required for decision making. These REAs are done parcel by parcel, so it is difficult to coordinate at the landscape level to achieve landscape-level conservation goals.
- Centralized grassland database with ecological data (species presence–absence data, habitat location and quality, land-use change, and so forth) with geographic information systems (GIS) layers that could be incorporated into or compatible with existing planning tools.

U.S. Fish and Wildlife Service

In addition to the research needs summarized in the "U.S. Fish and Wildlife Service" section, the following additional information needs are described in the report, "Advancing the National Fish, Wildlife, and Plants Climate Adaptation Strategy into a New Decade" (National Fish Wildlife and Plants Climate Adaptation Network, 2021):

- The authors note that "our most significant recommendation is for the addition of a new Strategy goal that focuses on the need and opportunities to better integrate people into climate adaptation efforts [sic] fish, wildlife, plants, and the ecosystems on which people depend. This recommendation is meant to address the current and historical underrepresentation of Black, Indigenous, and other communities of color in conservation plans and projects" (National Fish Wildlife and Plants Climate Adaptation Network, 2021, p. 3). This necessitates interdisciplinary research to:
  - "Consider the implications of shifting land use, driven by societal change, as well as climate change, in management decisions. Those shifts may result in new opportunities or challenges to species and land management and should be incorporated into planning and implementation actions" (National Fish Wildlife and Plants Climate Adaptation Network, 2021, p. 64).
  - "Recognize that Indigenous knowledges (IKs) are valid and valuable systems of knowledge, grounded in relationships with places and species, developed over millennia of observation and active resource management, equal in value to Western science and crucial for addressing climate change impacts in an inclusive way. The values that drive most IKs, like reciprocity, balance, respect, and interconnectedness, are critical for the sustainability of long-term

adaptation decisions. IKs should be sought in keeping with the principle of free, prior, and informed consent and used appropriately in partnership with the Indigenous communities and knowledge holders to whom they belong" (National Fish Wildlife and Plants Climate Adaptation Network, 2021, p. 64).

  - "Ensure that management interventions and allocation of resources for climate adaptation assess and include the needs of marginalized communities, under their direction and according to their goals, through equitable and meaningful consultation and engagement. Marginalized communities are often more vulnerable to disruptions caused by climate change" (National Fish Wildlife and Plants Climate Adaptation Network, 2021, p. 64).

- Evaluation and documentation of adaptation projects and plans, especially as they pertain to the success (or not) of management practices and their relationship to adaptation (National Fish, Wildlife, and Plants Climate Adaptation Network, 2021, p. 64). This evaluation should include conservation projects that were not explicitly adaptation projects, but could provide adaptation benefits:

  - "Many conservation projects may provide ancillary adaptation benefits, but were not done intentionally to respond to climate change impacts, thus leaving these projects undocumented in the adaptation literature. Alternatively, some projects were completed specifically to respond to climate change impacts, but may still remain undocumented as such because of the politicization of climate change. Past attempts have been made to track and highlight implementation progress, such as the Taking Action Progress Report and the Next Steps: A Report on Implementation (National Fish, Wildlife, and Plants Climate Adaptation Joint Implementation Working Group, 2014, 2015)" (National Fish Wildlife and Plants Climate Adaptation Network, 2021, p. 50).

- Create "best management practices to guide practitioners on alignment and coordination of the Strategy across both sectors and agencies. This will ensure greater mainstreaming of climate adaptation with a focus on natural resources" (National Fish, Wildlife, and Plants Climate Adaptation Network, 2021, p. 66).

- "Conduct an in-depth crosswalk and assessment of federal, state, tribal, and nonprofit adaptation plans to identify areas of accomplishments and barriers to implementing the Strategy. Additionally, develop key strategies to help agency personnel better quantify and record effort related to climate adaptation actions" (National Fish, Wildlife, and Plants Climate Adaptation Network, 2021, p. 64).

For the U.S. Fish and Wildlife Service (FWS) work on privately owned lands, additional social science research is needed on landowner decision making and how to incentivize proconservation actions, especially with respect to the following:

- How to "encourage producers to take sensitive lands out of crop production for extended periods of time and restore wildlife habitat on these lands" (National Fish, Wildlife and Plants Climate Adaptation Partnership, 2012, p. 82).

- How to "encourage producers to maintain grassland habitat" (National Fish, Wildlife and Plants Climate Adaptation Partnership, 2012, p. 82).

- How to "encourage producers to adopt agricultural production and land use strategies that are resilient under changing conditions and that benefit agriculture, fish, and wildlife" (National Fish, Wildlife and Plants Climate Adaptation Partnership, 2012, p. 82).

- How to "improve estimates of ecosystem services to better link conservation compensation with the environmental services producers provide" (National Fish, Wildlife and Plants Climate Adaptation Partnership, 2012, p. 82).

- How to "encourage producers to adopt wildlife-friendly practices" (National Fish, Wildlife and Plants Climate Adaptation Partnership, 2012, p. 82), such as limiting mowing to particular times of the season when it is least disruptive to breeding or migrating birds, for example, by not mowing May 1–July 15 (Vickery and others, 2000, p. 76).

In addition to the general information on species and habitats, for FWS work with migratory birds, researchers have identified the following additional information needs:

- Understanding "the effects of rising temperatures on spatial distributions of migratory birds during the breeding and nonbreeding seasons" (Rubenstein and others, 2020, p. 1).

- Understanding the "climate-driven changes to avian community composition through homogenization and loss of specialists" (Rubenstein and others, 2020, p. 1).

- Understanding "the effects of decreased precipitation on abundance in the breeding season" (Rubenstein and others, 2020, p. 1).

- Understanding the "effects of rising temperatures on abundance in the nonbreeding season"(Rubenstein and others, 2020, p. 1).

- "Finding ways to effectively account for climate-driven uncertainty within the context of natural resource management is therefore critical to meeting management objectives" (Rubenstein and others, 2020, p. 2).

- "Establishing a management-relevant research program for migratory birds and climate change, therefore, requires identifying and understanding the most relevant sources of climate change uncertainty for migratory bird management" (Rubenstein and others, 2020, p. 2).
- "U.S. Fish and Wildlife Service has an intensive, complex decision-making process for identifying high-priority parcels of land that will contribute to migratory bird conservation through permanent acquisition or easement. Climate change introduces several uncertainties into this decision-making process, and additional climate change research should help to support more informed decision making regarding habitat acquisition" (Rubenstein and others, 2020, p. 2).
- Research on how changes in precipitation patterns and winter severity will affect migratory bird abundance (Rushing and others, 2020).
- Better information on specific actions to support bird populations in the face of climate change, specifically, "Given the focus of many conservation agencies on improving vital rates for species of managerial interest, it was surprising that few strategies addressed population management and offered little direction on optimizing demographic responses (for example, survival, nest success) in response to climate variability or change. A potential reason for this is that most scientific studies focus on quantifying the effects of climate change on species occurrences and ranges (Ehrlén and Morris 2015), whereas climate-demographic linkages and future projections are more difficult (Van der Putten et al. 2010)." (LeDee and others, 2021).
- Identify and protect large grassland sites (greater than 100 hectares) in tallgrass ecosystems (Vickery and others, 2000, p. 76).
- Identify areas with a variety of habitat types to prioritize for conservation: "protect and manage enough sites to provide sufficient diversity of grassland habitats ranging from wet sedge meadows to dry, xeric grasslands. At the local level, large grassland sites should usually be managed to include a mosaic of management prescriptions, including both recently disturbed (that is, burned, grazed, mowed) and undisturbed grassland areas" (Vickery and others, 2000, p. 76).
- Improved information on "the winter distribution, winter ecology, and winter habitat requirements of many grassland birds" (Vickery and others, 2000, p. 77).
- "Monitor and document the efficacy of grassland management practices, including measuring the long-term responses of birds to management." (Vickery and others, 2000, p. 77).
- "Develop cost-effective methods of monitoring reproductive success."(Vickery and others, 2000, p. 77).
- "Develop techniques for grassland creation, restoration, and enhancement which benefit grassland birds. In the past, development of restoration techniques has focused on plant ecology, failing to recognize the needs and contributions of birds and other wildlife to the restoration of a functioning ecosystem" (Vickery and others, 2000, p. 77).

Overall, FWS and other fish and wildlife managers would benefit from additional research on:

- Approaches to developing climate adaptation strategies that are empirically tested and evaluated (LeDee and others, 2021).
- Identifying clear linkages among (1) monitoring; (2) specific thresholds or indicators; and (3) management actions: "strive to eliminate monitoring dead ends by defining quantitative triggers for acting in response to monitoring (Nie and Schultz, 2012)." (Meretsky and Fischman, 2014, p. 10).

National Park Service

In addition to the research needs summarized in the "National Park Service" section, the following additional information needs are described in the documents reviewed that were related to the National Park Service (NPS), organized by the National Park unit.

Wind Cave National Park (King and others, 2013)

- More rigorous process for building and validating climate change scenarios would make the resulting conclusions more robust to public scrutiny.
- Need for quantitative models to better understand the range of possible vegetation changes under different future climates and various management decisions.
- Fire is a key regulator of the abundance and distribution of many species that is not addressed in species range models.
- Monitoring changes in phenology and forage quality would improve understanding of the importance of these factors for wildlife.

Great Sand Dunes National Park and Preserve (NPS, 2019)

- Field studies to understand grazing regimes with *Bison bison* (bison), including experimental design with data collection in areas before bison are introduced and then again after introduction of a low-density herd. This information could inform bison grazing management to support wetland vegetation communities in key areas.

- Additional research on the effect of smoke from fires to wildlife, tourism, and other affected communities.
- Research on the effectiveness of fuel break and fuel reduction zones.
- How does the changing fire regime affect *Lynx canadensis* (Canada lynx) habitat currently and into the future?

Devils Tower National Monument (Schuurman and others, 2019)

- Targeted monitoring is needed to understand the rates and nature of vegetation community changes and the forces that drive them.

Theodore Roosevelt National Park (NPS, 2008)

- Studies or surveys to assess Fire Regime Condition Class are needed.

Carbon Sequestration

- Banasiak and others (2015) noted the need for additional research on carbon sequestration, including NPS ability to manage carbon sequestration and other ecosystem services across different units, and the "spatial and temporal heterogeneity in carbon sequestration rates across the NPS" (Banasiak and others, 2015, p. 23).

U.S. Department of Agriculture Forest Service

In addition to the information needs summarized in the "U.S. Department of Agriculture Forest Service" section, the following additional information needs are described in the documents reviewed that were related to the U.S. Department of Agriculture (USDA) Forest Service (FS).

Finch and others (2019) offered a fairly extensive list of climate-related research needs. This report summarized discussions at a 2018 workshop, and although there were many participants from the USDA, this information is likely broadly relevant to managers even outside of USDA. Participants were separated into several subgroups focused on working lands, native wildlife and biological diversity, native plants and pollinators, invasive species, wildland fire and prescribed fire, energy development, weather, water, and climate. Each priority area section of the report included research needs, many of which were not directly related to climate variability and change. However, there were climate-specific research needs identified in each priority area, and an entire discussion group focused on climate change. The following are direct excerpts from the report on explicitly climate-related research needs:

- "Peer-reviewed syntheses of the best science available on the complex problems facing land managers and producers in the Great Plains. A synthesis on drought in forests and rangelands in the United States has been published (Vose et al. 2016), but more focused syntheses are needed for the Great Plains" (Finch and others, 2019, p. 52).
- "A peer-reviewed consensus briefing paper on climate change in the Great Plains that communicates benchmarks, indicators, or anthropogenic triggers of climate change in a manner that producers can understand. Such a briefing paper would help producers project, prepare for, and respond to prolonged drought and other manifestations of climate change. A good place to start is the Great Plains chapter of the 2014 National Climate Assessment (Shafer et al. 2014)" (Finch and others, 2019, p. 52).
- "Drought projection tools for producers and land managers that include estimates of the lead time required for a given response (for example, 6 months) to help them plan whether to move cattle or plant crops, and to project crop failures" (Finch and others, 2019, p. 52).
- "Development of risk scenarios to help managers understand and respond to the uncertainty inherent in climate models" (Finch and others, 2019, p. 52).
- "Translations, user guides, and user application websites transferring research data, results, and models into operational management recommendations to bridge communication gaps between managers and researchers on climate, weather, and water topics. The high volume and diversity of data can be daunting for managers, and the relevance and applicability of research results need to be conveyed through techniques such as face-to-face meetings and demonstrations that go beyond traditional communications such as journal publications" (Finch and others, 2019, p. 52).
- "Development of tools and techniques for monitoring and assessing changes in vegetation, and biotic populations and communities in response to climate change" (Finch and others, 2019, p. 53).
- "Development of maps showing spatial variation and projections of change over time and across spatial scales" (Finch and others, 2019, p. 53).

- "Development of documents, videos, and workshops to help managers better understand, identify, and mitigate social and economic pressures associated with or magnified by climate change" (Finch and others, 2019, p. 53).
- "Managers, researchers, and private landowners recognized climate change as a challenge to the continued use of Great Plains grasslands. Participants expressed concern about the influence of increased atmospheric concentrations of carbon dioxide and warmer and drier conditions on the distribution and phenology of grassland plants. Additionally, drought and its effects on the ecology and economics of the Great Plains were identified as a major challenge. Landowners identified economic challenges, including declines in the price of beef and effects of uncertainty in climate and weather projections on their business operations" (Finch and others, 2019, p. 9).
- "Determination of changes in the distributions and populations of species affected by climate change, drought, and other stressors, and design of methods for mitigating stressors" (Finch and others, 2019, p. 20).
- "Develop and test methods for improving the resiliency of plant communities in the face of drought, climate change, and other stressors" (Finch and others, 2019, p. 25).
- "Develop guidance for best management practices for livestock grazing in different grassland types and under different environmental conditions" (Finch and others, 2019, p. 25).
- "More experiments and models examining the effects of different scenarios of climate change and other environmental changes on the distribution and abundance of individual invasive species" (Finch and others, 2019, p. 36).
- "Determination of the value and risk of using prescribed fire as a restoration tool through use of experimental treatments and modeling under different scenarios of climate, drought, and weather" (Finch and others, 2019, p. 42).

Friggens and others (2012) describe a range of climate science needs related to climate change vulnerability assessments and a list of needs related to plant conservation and restoration (specifically, developing genetic transfer guidelines to mitigate climate change impacts in grasslands, shrublands, and desert ecosystems of the Western United States):

Climate Change Vulnerability Assessments

- "Continue to refine our capacity to identify new community composition; this work has the highest priority because of its relevance to inform future management needs and best courses of action" (Friggens and others, 2012, p. 125).
- "Improve accuracy of models and methods used to generate climate change predictions and habitat suitability maps. This includes continued development and improvement of habitat response models (both mechanistic and correlative) for animal and plant species. In addition, distribution models for forest and rangeland habitats and species should incorporate dispersal mechanisms" (Friggens and others, 2012, p. 125).
- "Develop and refine systems for assessing plant species vulnerability" (Friggens and others, 2012, p. 125).
- "Develop physiologically based models of species occurrence" (Friggens and others, 2012, p. 125).
- "Identify measures of species adaptive capacity" (Friggens and others, 2012, p. 125).
- "Build tools to identify synergistic effects of climate change, species interactions, and other disturbances" (Friggens and others, 2012, p. 125).
- "Integrate management scenarios with scenarios for climate change" (Friggens and others, 2012, p. 125).
- "Identify the appropriate framework for analyzing vulnerability with respect to adaptation strategies, including potential application of existing frameworks (e.g., National Center for Ecological Analysis and Synthesis)" (Friggens and others, 2012, p. 125).
- "Develop new frameworks for creating adaptation strategies that integrate vulnerability with management decision processes" (Friggens and others, 2012, p. 125).
- "Complete cost benefit analyses that incorporate multiple scenarios, including the validity of inaction as an option. Passive restoration techniques may be more cost effective and feasible for many areas . . . and should be considered among management options" (Friggens and others, 2012, p. 125).
- "Identify and implement methods to make tools more available and useful for decision makers" (Friggens and others, 2012, p. 125).

Plant Conservation and Restoration

- "Develop risk assessment tools for selecting seeding and planting sites to reduce negative impacts and the incidence of failures" (Friggens and others, 2012, p. 129–130).
- "Continue development of provisional and species-specific seed zones and seed transfer guidelines" (Friggens and others, 2012, p. 129–130).
- "Refine tools for identifying and mapping future environments suitable for these species" (Friggens and others, 2012, p. 129–130).
- "Provide recommendations for developing seed production areas of genetically diverse populations pre-adapted to climatic change and other environmental perturbations" (Friggens and others, 2012, p. 129–130).
- "Examine autecology and adaptive characteristics of key restoration species and species at risk from climate change and other biotic and abiotic stressors (species that are long-lived, inbreeding, or characterized by small or disjunct populations or species with low genetic variation and rare species)" (Friggens and others, 2012, p. 129–130).
- "Research and develop approaches for managing genetic variation to influence plant response to climate change; enhance and conserve genetic diversity within seed zones; and promote natural migration, gene flow (establish outlier populations) and assisted migration. Examine completed research on native species and species specific seed zones for generalizations regarding such areas as specificity in environmental requirements, capacity for in situ adaptation to climate change, and potential rates of migration" (Friggens and others, 2012, p. 129–130).
- "Provide for ex situ and in situ conservation" (Friggens and others, 2012, p. 129–130).
- "Develop a simple, readily accessible tool for nursery managers, seed producers, and land managers to help them move plants across the landscape in a genetically appropriate manner to conserve genetic diversity, facilitate current management decisions, and provide a foundation for reaction to climate change" (Friggens and others, 2012, p. 129–130).
- "Investigate the intersection of socioeconomic, environmental, and philosophical debate toward a better understanding of the difficult decisions associated with assisted colonization of plants and animals to new locations. A decision support matrix that conceptualizes and quantifies the advantages and disadvantages of assisted colonization is required. Use paleobotanic and paleoclimatic data to further understand and model plant community evolution from the last glaciation to contemporary associations, and how those processes can be leveraged toward ensuring development of new, non-analogous ecosystems under evolving climate conditions" (Friggens and others, 2012, p. 129–130).

In a review of the extent, productivity, and health of U.S. rangelands for the FS, Reeves and Mitchell (2012) flagged a number of issues related to climate change and rangeland health and management:

- "Impact of changes in climate on rangeland vegetation growth and distribution spatially-explicit to identify areas where rangeland vegetation will respond favorably vs. [versus] poorly" (Reeves and Mitchell, 2012, p. 69).
- "Ecosystem models capable of simulating rangeland ecosystem behavior while considering multiple processes and stressors" (Reeves and Mitchell, 2012, p. 69).
- "Improved understanding of how rising CO_2 [carbon dioxide] levels complicates relationships between temperature and precipitation and grassland species composition and productivity – [sic] what will be the net effect of changes in climate and CO_2 on grassland plant communities?" (Reeves and Mitchell, 2012, p. 69).
- "How will climate change and increased CO_2 affect management decisions about livestock stocking rates and grazing systems (via changes in forage quality and quantity)? Are there other ecosystem services that can be provided by grasslands as the climate changes? Will those be affected?" (Reeves and Mitchell, 2012, p. 72–73).

Bruner (2019) described a research project being done by students at The University of Colorado Boulder that addresses questions of relevance to cattle grazing decisions:

- How and why grassland pasture systems will respond to extreme precipitation events and other climate changes.

Schrader-Patton and others (2020) described a tool for mapping phenological changes (PhenoMap [https://research.fs.usda.gov/pnw/products/dataandtools/interactivemaps/phenomap]) which they link to management decisions:

- "Monitoring vegetation phenology is important for managers at several scales. Across decades, changes in the timing, pattern, and duration of significant life cycle events for plant groups can foreshadow shifts in species assemblages that can affect ecosystem services. In the shorter term, managers need phenological information to time activities such as grazing, ecological restoration plantings, biocontrol of pests, seed collection, and wildlife monitoring" (Schrader-Patton and others, 2020, p. 1).

State Fish and Wildlife Agencies—General

In addition to the research needs summarized in the "Grassland Management Entities" section, the following additional climate-related, or climate impact-related, information needs are described in the documents reviewed that were related to the State fish and wildlife agencies. The Western Association of Fish and Wildlife Agencies (Western Association of Fish and Wildlife Agencies [WAFWA], 2011) and the Association of Fish and Wildlife Agencies (Ernest Johnson, 2021) conducted information needs assessments with State fish and wildlife agencies and found the following information gaps in common across States in the North Central Climate Adaptation Science Center region:

- Better understanding of the impacts to grassland species related to climate change, energy development, invasive plant species, and human encroachment or development in grassland habitats (WAFWA, 2011).
- Additional research on the impacts of climate change on habitats with regard to energy development, population growth, and flooding (WAFWA, 2011).
- Additional information on species lifecycles, including "population distribution, genetics, and species ecology to increase knowledge of grassland species life-stage requirements (that is, brooding areas for lesser prairie-chickens, burrow densities needed for [black-footed] ferret reproduction, etc. [and so forth]) and evaluate the success of those conservation actions implemented by the coalition affecting these factors." (WAFWA, 2011, p. 16).
- "Best management practices under expected future conditions was reported as the top product or information that would be most helpful to the respondent's agencies (67%). Additionally, examples of successful adaptation implementation (61%) and climate impacts on specific species or habitats (61%) were also identified as helpful products or information. Preferred mechanisms for accessing information included webinars (75%), workshops/in-person trainings (67%), and online resources, such as databases (49%)" (Ernest Johnson, 2021, p. 9–10).
- Additional opportunities for training and capacity building for State agency personnel to understand and apply climate change information and tools. Only 12 percent of the respondents from the national survey of State agencies had internal, climate change-related training available to them, and none reported that such training was mandatory for staff (Ernest Johnson, 2021).

Colorado Parks and Wildlife

In addition to the research needs summarized in the "Colorado Parks and Wildlife" section, the following additional climate-related, or climate impact-related, information needs are described in the documents reviewed that were related to the State of Colorado.

In the Colorado State Wildlife Action Plan (SWAP; Colorado Parks and Wildlife [CPW], 2015) and other reports, CPW also noted the following information needs:

- Improve the understanding of the "responses of non-target species to management and conservation practices (for example, grazing prescriptions, pinyon juniper removal). Incomplete knowledge inhibits our ability to identify and interpret potential threats and decide on appropriate course(s) of action" (CPW, 2015, p. 79).
- Additional "data on impacts of energy development" (CPW, 2015, p. 301).
- Resolve uncertainty about projected future climate scenarios and ecological response:
  - "Under two widely-used climate change models (National Assessment Synthesis Team 2000), as levels of atmospheric CO_2 increase, the predicted scenario for much of the range of mixed-grass prairie in the Central Shortgrass Prairie Ecoregion is a shift away from grassland to either shrubland/woodland (under increased precipitation conditions) or arid land (under decreased precipitation)" (CPW, 2015, p. 299).
  - "Climate projections for mid-century indicate that the eastern plains of Colorado will experience significant temperature increases, and an increase in drought days. Although the dominant species of this habitat are well adapted to warm and dry conditions, blue grama in particular can be slow to recover from drought. Warmer and drier conditions could lead to a shift in the relative abundance of shortgrass prairie species, with the resulting development of novel plant communities. In particular, warmer night-time temperatures are likely to favor cool-season species, both native and exotic. However, due to uncertainties in future precipitation patterns, the effect of increasing temperatures on this habitat is difficult to predict" (CPW, 2015, p. 300–301).
- More information on how climate change will impact disturbance regimes (for example, fire) and ecological processes (for example, shrub invasion; CPW, 2015, p. 301).

The Colorado Division of Wildlife (2003) noted the need for additional information on presence–absence, and life cycles, of grassland species to support decision making and climate change adaptation:

- "Data are inadequate to define specific target objectives for shortgrass-associated species."
- "Population trend data are available for a number of grassland bird species, but in many cases are inadequate for monitoring birds with low population densities and broad distribution."

For the *Tympanuchus cupido*, (greater prairie-chicken), *T. pallidicinctus* (lesser prairie-chicken), and *T. phasianellus* (plains sharp-tailed grouse), Vodehnal and Haufler (2008) noted the following information needs:

- Identify, map, and continuously monitor and evaluate "current habitat conditions at finer scales to develop more accurate assessments of ecosystem diversity and prairie grouse habitat" (Vodehnal and Haufler, 2008, p. 71).
- "Measure and document quantities and distribution of current ecosystem conditions that meet desired ecosystem criteria" (Vodehnal and Haufler, 2008, p. 71).

From the information in this report, the MPWG also inferred the need for more information on prairie grouse habitat distribution and quality under various climate change scenarios to identify areas for future protection, restoration, or recovery.

Kansas Department of Wildlife & Parks

In addition to the research needs summarized in the "Kansas Department of Wildlife & Parks" section, the MPWG identified a need for improved land cover data for the playa lakes regions in Kansas. The Playa Lakes Joint Venture area implementation plan for the Shortgrass Prairie Bird Conservation Region (18) of Kansas (PLJV, 2008b) evaluates landcover using images that were mostly taken in 1992 and 2004. Updated landcover data are needed to effectively manage the landscape for bird species of greatest conservation need.

Montana Fish, Wildlife and Parks

In addition to the research needs summarized in the "Montana Fish, Wildlife and Parks" section, Montana Fish, Wildlife and Parks (MFWP; MFWP, 2015) noted the following information and research needs that would support general species and habitat management and climate change adaptation:

- "Complete better mapping of Montana wetlands through completion of the National Wetland Inventory and associated ground-truthing" (MFWP, 2015, p. 62).
- "Complete [an] inventory of rare biota that are often associated with these habitats" (MFWP, 2015, p. 62).
- "Collect baseline data in order to document shifting range limits (latitude and elevation) of SGCN" (MFWP, 2015, p. 63).
- "After wildland fires, monitor sites for noxious weeds and control as needed" (MFWP, 2015, p. 64).
- "Support research efforts on selective control for cheatgrass" (MFWP, 2015, p. 64).
- "Work with [private] landowners and DNRC [Montana Department of Natural Resources and Conservation] to promote CRP [Conservation Reserve Program] or CRP-like programs to minimize additional conversions to cultivation agriculture" (MFWP, 2015, p. 64).
- Additional research on how climate change and disturbance regimes interact: "The dynamics of species changes in this system is a function of climate, but the magnitude of these changes is greatly influenced by the intensity of grazing and fire frequency" (MFWP, 2015, p. 51).
- Better understanding of "the influence of habitat characteristics, landscape heterogeneity, and conservation actions on breeding season vital rates to identify high quality breeding habitat characteristics, population modeling, and the impact of conservation actions on populations" for grassland birds, sharp-tailed grouse, and black-tailed prairie dog (MFWP, 2015, p. 25).
- More information on the "impacts of energy development (infrastructure and fragmentation) on populations" of all grassland indicator species (MFWP, 2015, p. 25).
- Additional research on the "vital rates and limiting factors during all seasons (breeding, migration, or winter) for migratory species to identify what point of the life cycle is driving [wildlife] population declines. This will help to inform if our strategy should focus on maintaining breeding habitat or if additional restoration of breeding habitat is needed," especially for grassland birds (MFWP, 2015, p. 25).
- Identification of habitat needed for maintenance of connectivity, and the impact of anthropogenic features and conservation actions on maintenance of connectivity for swift fox and *Antilocapra Americana* (pronghorn; MFWP, 2015, p. 25).
- Additional research on the "value of existing CRP and other conservation lands as habitat in Montana" for grassland birds, swift fox, pronghorn, and sharp-tailed grouse (MFWP, 2015, p. 25).
- More information on the "relative value of transitioning non-native grass to native grass stands" for all grassland indicator species (MFWP, 2015, p. 25).

- "Evaluation of existing monitoring programs for their effectiveness in evaluating the impacts of this grassland conservation strategy on grassland indicator species and targets, and development of new/refined protocols as necessary" (MFWP, 2015, p. 25).

Epstein and others (2021) also suggested the need for the interdisciplinary research on the following topics related to grassland conservation and climate change adaptation in area in and around the Charles M. Russell (CMR) region of Montana:

- "We identified three prominent issues—changing land use patterns, changing climate and disturbance regimes, and the influence of land management practices on biodiversity—where additional information was needed to characterize uncertainty, address research gaps, and represent areas of potential trade-offs" (Epstein and others, 2021, p. 4).
- "[M]ore research is needed to evaluate the applicability of specific management approaches (for example, grazing management, managing other herbivory, fire) across the variable entirety of the Great Plains (Augustine and Derner 2015)" (Epstein and others, 2021, p. 5).
- Impact of market forces and policies on land use in the region: "Currently, diverse and interacting market and policy forces are driving new and sometimes conflicting land use outcomes, resulting in uncertainty about the future of the range and farmland use regimes in the CMR region . . . Taken as a whole, the policy and market landscape affecting conservation practice in the CMR region reveals inconsistencies as well as a generalizable uncertainty about their interactive effects—how one set of approaches and policies triggers and results in linked changes to land use decisions" (Epstein and others, 2021, p. 5–6).
- The following additional information was described on the interactions among disturbance regimes, climate change, and land management practices:
  - "Interactions between climate and . . . herbivory, fire, woody encroachment, productivity, and interactions between all of the above . . . [and] CO_2 fertilization impacts on vegetation . . . [P]lanning for conservation action in the CMR region requires an acute understanding of [climate changes and impacts], particularly their variability, to frame how ecosystem baseline conditions will evolve and change in the years ahead" (Epstein and others, 2021, p. 6–7).
  - "Together, these interactions underscore a need for further social-ecological research to disentangle how climate, fire, and grazing interact so that managers can anticipate and prepare for future change" (Epstein and others, 2021, p. 7).
- Increased collaboration between researchers and land managers is needed: " . . . our review suggests that enhancing biodiversity in the CMR region SES requires collaborative research–management approaches to provide the information needed for adaptive governance. Rather than single entities approaching conservation independently on individual parcels, we recommend a networked design in which researchers and land managers develop shared databases and aggregate site- or property-level data to better support multiscalar and interscalar biodiversity research" (Epstein and others, 2021, p. 7).
- "Future research attention to the nexus of social, ecological, and political dynamics is critical to advancing equity alongside conservation goals. In the case of the CMR, this focus suggests an unanswered but important question for regional conservation practice: How can local communities be partners in large-scale conservation initiatives and share in the prosperity that can come with the restoration activities associated with global conservation status (Belsky 2011)?" (Epstein and others, 2021, p. 8).
- Additional research on the "the complexity and interconnections among . . . multiple drivers of social-ecological change" that "make future trajectories of the native rangeland system and the conservation projects working to restore and conserve them highly uncertain (Stoy et al. 2018)." (Epstein and others, 2021, p. 8).

The Prairie Pothole Joint Venture (PPJV) identified the following research and information needs in the "Montana State Tactical Plan" (PPJV, 2017a):

- "A rigorous landscape-scale assessment of waterfowl population recruitment in the Montana Prairie Pothole Region (PPR)" (PPJV, 2017a, p. 19).
- "Completion of the National Wetland Inventory update" (PPJV, 2017a, p. 19).
- "A restorable wetland basins inventory" (PPJV, 2017a, p. 19).
- "An evaluation of how wetland degradation may be impacting breeding bird reproduction and survival" (PPJV, 2017a, p. 19).
- "Quantification of ecosystem services and economic benefits generated by wetland and grassland conservation in Montana" (PPJV, 2017a, p. 19).
- "Research on what motivates the public and landowner to support wetland and grassland conservation within the PPJV administrative area" (PPJV, 2017a, p. 19).

- "Grassland bird breeding vital rates, full life-cycle demographics, and habitat quality assessments for targeting management actions. The PPJV is currently funding research projects with Montana State University and Bird Conservancy of the Rockies to investigate grassland bird vital rates and habitat quality" (PPJV, 2017a, p. 19).
- "An evaluation of the direct and indirect impacts of climate change to ensure conservation delivery has long-term resilience for the PPR" (PPJV, 2017a, p. 19).
- Additionally, research studies (for example, Dahl, 2014; Niemuth and others, 2014; Lark and others, 2015) investigate how landscape changes relate to anthropogenic impacts (for example, pattern tile drainage, grassland conversion) and climatic changes (for example, wetland hydroperiod; PPJV, 2017a).

Nebraska Game and Parks Commission

In addition to the research needs summarized in the "Nebraska Game and Parks Commission" section, the Nebraska SWAP (Schneider and others, 2011) identified the following specific information needs related to grassland habitat and species conservation or to climate change adaptation:

- "Establish an interdisciplinary working group that can develop a shared vision for the judicious use of limited water resources by developing drought mitigation strategies, alternative cropping/irrigation methods, etc. that conserve and enhance biological diversity and lead to increased economic sustainability" (Schneider and others, 2011, p. 46).
- Better understanding of the impacts and responses of species and ecosystems to climate change: "We need to increase our understanding of these impacts and responses in order to develop and implement more effective conservation strategies. Means of filling these knowledge gaps include vulnerability assessments, monitoring, experiments, and modeling" (Schneider and others, 2011, p. 40).
- Research on best practices to "implement strategies to make the working landscape matrix more permeable to species dispersal" (Schneider and others, 2011, p. 50).

Additional Research to Help Managers Prioritize Actions

- "There is a need to develop long-term monitoring systems that are strategically designed to evaluate climate change impacts and species and ecosystem responses. With so much uncertainty surrounding the impacts of climate change and how species and ecosystems will respond, it is vital to design and implement monitoring programs that can provide the best science-based information possible . . . Monitoring for climatic change and associated impacts can be carried out as a stand-alone effort or by integrating relevant variables into existing monitoring efforts" (Schneider and others, 2011, p. 206).
- There is a need to evaluate annual population monitoring efforts for target species [for example, *Haliaeetus leucocephalus* (bald eagle), *Charadrius melodus* (piping plover), *Sterna antillarum* (interior least tern), greater prairie-chicken, *Scaphirhynchus albus* (pallid sturgeon), and *Ellipsoptera nevadica lincolniana* (Salt Creek tiger beetle) and determine which additional species to monitor closely because this type of annual monitoring is expensive and time consuming (Schneider and others, 2011, p. 208).
- "There is a need to develop a set of best management practices for natural communities that maintain and enhance their biodiversity value. Monitoring responses of individual community types to various management practices will be a key component in developing those guidelines. Both formal experimentation testing different management practices, as well as monitoring existing practices on managed lands, will be needed. Floristic quality assessment is one approach that may be used for evaluating responses to treatments. One could also monitor responses of indicator species or exotic species within the community" (Schneider and others, 2011, p. 209).
- "There is a need to fill critical information gaps on the distribution, abundance, conservation status, threats, biology and ecology of at-risk species and natural communities. Below is a list of priority inventory and research projects that are needed to fill critical data gaps, provide baseline information for monitoring, and provide the knowledge needed to develop more effective conservation actions" (Schneider and others, 2011, p. 209).

Biological Inventory—Species

- "For a number of the Tier I species [species that are globally or nationally most at risk of extinction], there were not enough documented occurrences of populations to fully meet the goals set for those species. Inventory of additional populations of these species should be a priority. There is also a strong need to assess the condition/viability of each population during inventory work . . . Conduct inventory work to better document the distribution and abundance of Tier II at-risk species [species that are not at risk from a global or national perspective but are rare or imperiled within Nebraska]. Inventory work should be prioritized based on gaps in knowledge and the imperilment status of the species. In general, our inventory needs are greatest for invertebrates (both terrestrial and aquatic) and non-vascular plants" (Schneider and others, 2011, p 211, app. 8).
- "Develop predictive models of species distribution for at-risk species to guide survey work and increase inventory efficiency. Inventory the distribution and spread of key invasive species including garlic mustard

(*Alliaria petiolata*), purple loosestrife (*Lythrum salicaria*), Eurasian phragmites (*Phragmites australis australis*), Russian-olive (*Elaeagnus angustifolia*), saltcedar (*Tamarix spp.*), and zebra mussel (*Dreissena polymorpha*)" (Schneider and others, 2011, p. 211).

- "Conduct long-term monitoring studies to evaluate changes in distribution and abundance of selected Tier I species that have been assessed to be highly vulnerable to climate change" (Schneider and others, 2011, p. 211).
- "There were insufficient documented occurrences of some of the natural community types to fully meet the goals set for those communities. Inventories identifying high-quality examples of each of these types should be a high priority" (Schneider and others, 2011, p. 211).
- "Develop a classification for aquatic systems (lakes, rivers, streams). Conduct inventories to identify high-quality examples of each type" (Schneider and others, 2011, p. 211).

Landscapes

- "Inventory priority landscapes for additional high-quality examples of Tier I species and natural communities. Identifying other occurrences at these existing sites will increase the efficiency of the conservation effort. For example, the Central Loess Hills BUL [biologically unique landscape] has been identified as a high priority for inventory work" (Schneider and others, 2011, p. 212).

Biological Research—Species

- "Conduct research to better understand the biology/ecology of at-risk species" (Schneider and others, 2011, p. 212).
- "Evaluate the habitat requirements of at-risk species including the size, condition and landscape context of habitat(s) needed to sustain viable populations" (Schneider and others, 2011, p. 212).
- "Evaluate the feasibility and efficacy of captive rearing. Develop captive rearing techniques for highly imperiled species that will require reintroduction efforts to recover the species (for example, Salt Creek tiger beetle)" (Schneider and others, 2011, p. 212).
- "Conduct studies to evaluate the impact of invasive species on native flora and fauna" (Schneider and others, 2011, p. 212).
- "Evaluate the invasive threat potential of candidate invasive species" (Schneider and others, 2011, p. 212).
- "Develop control mechanisms for invasive species that have a high impact on at risk species and natural communities" (Schneider and others, 2011, p. 212).
- "Conduct climate change vulnerability assessments for selected Tier II species" (Schneider and others, 2011, p. 212).

Natural Communities

- "Increase understanding of ecological processes influencing communities; investigate grazing, fire, and hydrology, and the natural mosaic of disturbance and patch types in a landscape" (Schneider and others, 2011, p. 212).
- "Identify thresholds for ecosystem-function impairment that affect the viability of at-risk species and biological diversity" (Schneider and others, 2011, p. 212).
- "Conduct studies to evaluate the effects of management practices (for example, burning, grazing, haying, hydrologic manipulation) on the composition, structure and function of natural communities" (Schneider and others, 2011, p. 212).
- "Develop best management practices to promote native species diversity and maintain ecological processes in different community types" (Schneider and others, 2011, p. 212).
- "Develop habitat restoration techniques for those community types for which there is the greatest need of restoration and the least known about restoration (for example, saline wetlands, freshwater streams)" (Schneider and others, 2011, p. 213).
- "Conduct studies to evaluate the success of habitat restoration projects" (Schneider and others, 2011, p. 213).
- "Conduct climate change vulnerability assessments for selected natural community types" (Schneider and others, 2011, p. 213).

Conservation and Environmental Education Research

- "Determine the most critical and requested education materials and develop a priority listing for areas of needs" (Schneider and others, 2011, p. 213).
- "Determine the need for additional educators who are trained in nature education" (Schneider and others, 2011, p. 213).
- "Conduct an inventory of outdoor education and nature centers in Nebraska and identify areas of the state that would benefit from new centers" (Schneider and others, 2011, p. 213).

Nature-Based Recreation Research

- "Conduct statewide and regional economic impact studies of hunting, fishing, wildlife viewing, and other nature-based recreation to determine the economic benefits of these activities. Conduct a marketing assessment of current and potential nature-based tourism clients to identify user needs and wants" (Schneider and others, 2011, p. 213).

- "Conduct studies to determine the wants/needs/satisfaction level of constituents that participate in non-consumptive, wildlife-dependent recreation and determine the availability of sites/facilities to support that recreation" (Schneider and others, 2011, p. 213).
- "Inventory sites on public and private lands currently providing opportunities and access for wildlife viewing, nature and wildlife interpretation, and evaluate the potential and need for enhancing existing opportunities and access" (Schneider and others, 2011, p. 213).
- "Identify and inventory sites that would provide new opportunities and access for wildlife viewing and nature and wildlife interpretation" (Schneider and others, 2011, p. 213).

Economic Research

- "Conduct studies to evaluate the economic importance of nature tourism in Nebraska" (Schneider and others, 2011, p. 213).
- "Conduct research on trends in economic development and population demographics in the state and assess their potential impact on biodiversity conservation" (Schneider and others, 2011, p. 213).
- "Conduct research to assess the economic viability of habitat restoration. For example, evaluate the economic benefits of grazing restored wetlands compared to cropping flood-prone land" (Schneider and others, 2011, p. 214).

Human Dimensions Research

- "Conduct surveys to determine public attitudes towards biological diversity, conservation and management practices" (Schneider and others, 2011, p. 214).
- "Assess the success of methods of outreach to landowners and land managers in engaging them in wildlife-friendly practices and conservation programs" (Schneider and others, 2011, p. 214).

The MPWG also inferred the following research needs based on a review of the Nebraska SWAP (Schneider and others, 2011):

- Improved modeling capability to identify potential future habitats for species under different climate change scenarios to target those areas for conservation to include "heterogeneous and complex" sites with "microhabitats" within "intact landscapes" to support the greatest diversity of species and "facilitate species movement" (refer to Schneider and others, 2011, p. 54–55).
- Social science research to understand prioritizing for what, for whom, and who gets input into setting those priorities.

North Dakota Game and Fish

In addition to the research needs summarized in the "North Dakota Game and Fish" section, the following additional information needs are described in the documents reviewed that were related to the State of North Dakota. In the North Dakota Tactical Plan, the PPJV suggested the following information needs regarding grassland and wetland habitats, migratory grassland birds, and waterfowl in North Dakota (PPJV, 2017b):

- Additional information on different bird groups: "Currently, the four bird groups differ markedly in what is known concerning their population status, habitat requirements, and understanding of factors that most affect population change" (PPJV, 2017b, p. ES–7).
- "An updated National Wetland Inventory for North Dakota" (PPJV, 2017b, p. ES–7).
- "A restorable basins inventory for North Dakota" (PPJV, 2017b, p. ES–7).
- "Evaluating how wetland contaminants may be impacting PPJV bird reproduction and survival" (PPJV, 2017b, p. ES–7).
- "Quantifying ecosystem services and economic benefits generated by wetlands and grass-lands within the PPJV administrative area" (PPJV, 2017b, p. ES–7).
- "Understanding what motivates the public and landowner to support wetland and grassland conservation within the PPJV administrative area" (PPJV, 2017b, p. 19).
- "Evaluating how wetland drainage, basin consolidation, connectivity, and pattern tile drainage may be impacting wetland-dependent species in North Dakota" (PPJV, 2017b, p. 19).
- "Evaluating how soil health practices benefit ground nesting birds" (PPJV, 2017b, p. 19).
- "Evaluation of tile setbacks for impacts to wetlands" (PPJV, 2017b, p. 19).
- "Acquire/develop a process to obtain growing season/spring aerial imagery to improve the NRCS Certified Wetland Determination process and align with the wet portion of the growing season" (PPJV, 2017b, p. 19).
- "Evaluating energy development and impacts to waterfowl productivity" (PPJV, 2017b, p. 19).
- "Evaluating cross-seasonal use of priority wetland habitats within the PPR" (PPJV, 2017b, p. 19).

- "Evaluating the direct and indirect impacts of climate change to ensure conservation delivery has long term resilience in the U.S. PPR" (PPJV, 2017b, p. 19).
- "Evaluating wetland degradation (for example, salinity, siltation, pesticides) in cropped landscapes and the effect on breeding waterfowl" (PPJV, 2017b, p. 19).

Similarly, the PPJV also describes the following research needs to support waterfowl, grassland birds, and shore birds (Barnes and others, 2017):

- For shorebirds "Much basic research needs to be conducted to better understand habitat use, distribution, and vital rates" (Barnes and others, 2017, p. 26).
- More research to reduce uncertainty about the impacts of climate change on ecological systems and particular species:
  - "One of the major challenges of addressing climate change effects on fish and wildlife is identifying and addressing uncertainty in our understanding of future climate change and how that change will affect ecological systems" (Barnes and others, 2017, p. 26).
  - "Moreover, validation of spatial models has been, and will continue to be, an important PPJV science priority" (Barnes and others, 2017, p. 34).

Finally, in their report from a climate scenarios planning meeting with resource managers in North Dakota, Fisichelli and others (2016) noted the need for "time-based decision trees" to support managers in identifying "what options to pursue in the near future, and what options to add in the future at key decision points, based on indicators" (p. 28).

South Dakota Game, Fish and Parks

In addition to the research needs summarized in the "South Dakota Game, Fish and Parks" section, South Dakota Game, Fish and Parks (SDGFP) identified the following specific research and information needs related to climate change adaptation and grassland conservation (SDGFP, 2014):

- "Survey remaining native prairie on a recurring basis" (SDGFP, 2014, p. 185–86).
- "Update National Wetlands Inventory maps" (SDGFP, 2014, p. 185–86).
- "Map riparian corridor habitats assess grassland habitats throughout the state during grassland bird migration and breeding seasons" (SDGFP, 2014, p. 185–86).
- "Determine quality of untilled prairie" (SDGFP, 2014, p. 185–86).
- "Determine minimum size of a "large" intact grassland habitat block for wildlife species in South Dakota" (SDGFP, 2014, p. 185–86).
- Need additional research to improve the "ability to quantify the cumulative effects of indirect alteration on today's ecosystem diversity . . . " possibly through "better satellite imagery and processing methods" (SDGFP, 2014, p. 91). This additional research should include impacts of fire suppression, interaction between fire and grazing (which has been altered with agriculture), loss of black-tailed prairie dog colonies, filling in of wetlands, the effects of sedimentation and agricultural chemical runoff or excavating to increase pond depth for livestock on the quality of wetland habitats, and how all these processes interact with climate change.
- A need for additional information on historical fire regimes because it is difficult to replicate "the timing and intensity of natural fire regimes" (SDGFP, 2014, p. 91).
- Clarification on projected changes in temperatures—especially July temperatures—and related impacts on C_3 (cool season) and C_4 (warm season) grasses for each major land resource area in South Dakota:
  - "Using von Fischer et al.'s (2008) range for C_3 vs. C_4 dominance, we see that presently nearly all MLRAs [major land resource areas] are within the mixed C_3 and C_4ranges identified by 65.1 to 76.3 °F [degrees Fahrenheit]. This is consistent with the fact that South Dakota is presently considered primarily a mixedgrass C_3/C_4 condition. . . . However, predicted climate change models indicate that all but one MLRA will move above the 76.3 °F (24.6 °C [degrees Celsius]) upper bounds by 2099. Although precipitation appears to play a secondary role in determining competitive advantage, C_4 grasses are also able to use the reduced summer moisture resources more effectively than C_3 species, indicating that C_4 species will likely become more dominant under the von Fischer et al. (2008) model" (SDGFP, 2014, p. 102).
- A need for better monitoring of ecosystems to determine baseline and suitability for conservation actions (for example, will actions help meet conservation targets); information to identify and "describe historical disturbance states" to support restoration efforts; "monitoring and research to support the ecosystem diversity component" of the SWAP (targeted mostly internal to SDGFP; SDGFP, 2014, p. 181–184).

The Nature Conservancy report, "Ecoregional Conservation in the Black Hills," (Hall and others, 2002) described information needs for the Black Hills region of

South Dakota. Although this region is comprised mostly of forest and mountains, it also includes, and is surrounded by, grasslands, and therefore identified research needs for this region are included in this appendix.

For South Dakota In General

- Additional information about habitat conditions, species distribution, and threats on private lands.
- Additional research on how to define minimum area requirements for focal systems—that is, how big does an area need to be to capture large scale, key processes like "fire, insect outbreaks, wildlife populations, and flooding" (Hall and others, 2002, p. 31).

For the Black Hills Specifically

- "The effects of the Jasper Fire on ecoregional conservation targets and sites (see sections II and IV)" (Hall and others, 2002, p. 36).
- "A refinement of the terrestrial ecological systems classification and a method to more systematically identify occurrences (see section III)" (Hall and others, 2002, p. 36).
- "A better understanding of the composition and functionality of terrestrial and aquatic system types so that goals and viability can be better assessed (see sections III and IV)" (Hall and others, 2002, p. 36).
- "Resources to identify new occurrences or relocate older occurrences of plant and animal targets (see section III)" (Hall and others, 2002, p. 36).
- "Resources for inventory of the portfolio sites to identify more fully what targets they capture (see Appendix 6—priority should be given to targets that do not meet conservation goals)" (Hall and others, 2002, p. 36).
- "A better understanding of the size, condition and landscape context criteria for species targets (see section III)." (Hall and others, 2002, p. 36).

The MPWG inferred the following information needs regarding conserving grassland and wetland habitats and supporting migratory grassland birds and waterfowl in South Dakota from the "South Dakota State Tactical Plan—A supplement to the 2017 Prairie Pothole Joint Venture Implementation Plan," the PPJV (PPJV, 2017d):

- How and to what extent do current best practices for grassland management (including row crop, grazing, and other agricultural uses) also support adaptation to a changing climate? Which practices are maladaptive?
- How will changes in precipitation related to climate change (and related human adaptation options and actions) impact surface water runoff (for example, rates, amounts, and frequency), and in turn, impact nonpoint source contamination into waterways (for example, agriculture runoff, salinity, siltation, and pesticides)? What impact will this contamination have on reproduction, survival, and habitat quality for waterfowl and aquatic species?
- How will climate change impact the expansion of row crops northward into South Dakota into areas that were not previously suitable for row crop expansion, and what impact will this expansion have on suitable habitat for species of interest? How will climate change effect the transition from cereal crops (for example, wheat and barley), which provide minimal cover to breeding waterfowl and migratory birds, to corn and soybean crops, which provide almost no cover for them?
- How will changes in demand for biofuels and food affect grassland conversion and agricultural expansion?
- Take on inventory and mapping of ecosystems identifying the location and condition of key habitats, including identification of habitat areas that are key to biodiversity and ecosystem diversity objectives for South Dakota.
- Update the National Wetlands Inventory to identify the spatial extent and distribution of wetlands to determine carrying capacity for waterfowl habitat and to document changes over time to help prioritize conservation actions and inform hydrological and biological models (PPJV, 2017d, p. 25).
- Update the Restorable Basins Inventory to identify the spatial extent and distribution of drained wetlands that could be targeted for restoration (PPJV, 2017d, p. 25).
- Additional research is needed to increase the understanding of public motivation for conservation on private and public lands is needed (for example, landowner attitudes; PPJV, 2017d, p. 25; also refer to SDGFP, 2014).
- Additional research is needed to increase understanding of human-induced changes to water: wetland drainage, changes due to tiling, ditching, and consolidation, as well as connectivity leading to larger wetland ponds and related impacts on wildlife (waterfowl, game species like pheasants, grouse, and deer; PPJV, 2017d, p. 26).
- Evaluate tile setbacks for impacts to wetlands: "In order to maintain compliance with federal Farm Bill programs, landowners wishing to install drain tile must consult with NRCS to review the project affected fields and determine setback distances to any wetlands embedded within the project area. NRCS offices within the PPJV area receive hundreds of these requests annually impacting thousands of acres. The intent of

these "minimal effect" determinations is to allow the drainage improvements on uplands to proceed while minimizing potential impacts on wetlands. Questions remain over potential effects lowering water tables surrounding wetland basins may have on pothole wetlands. A complete evaluation of current setback distances would elevate these concerns and reduce any unintended drainage that may be occurring" (PPJV, 2017d, p. 27).

- Identify potential "win-win" scenarios among agricultural producers, rural communities, and the conservation community to maintain and improve human livelihoods and conserve grasslands and grassland species (for example, sustainable farming practices to improve soil health, reduced tillage, and crop rotations). It is unclear which of these practices, if any, have benefits for grassland species like ground-nesting birds (PPJV, 2017d, p. 26).
- Quantify ecosystem services and economic benefits from wetlands and grasslands (PPJV, 2017d, p. 26).
- Create an improved statistical abundance model which could aid in predicting occupancy and density of *Branta canadensis* (Canada geese) in South Dakota and improve management efforts. This effort could also improve understanding of potential future population density and movement under current and projected climate conditions (PPJV, 2017d, p. 26).
- Inform adaptive management efforts by monitoring and evaluating the hydroclimate system, ecological system, and human system (for example, land use change) to detect changes through time and across the landscape (PPJV, 2017d, p. 31).
- "Considering the great amount of uncertainty associated with anthropogenic impacts and climate change, continuing to intensively monitor habitat and populations to detect changes through time appears to be a reasonable approach for PPJV partners." (PPJV, 2017d, p. 30, table 3).
- "Understanding human-induced changes to water: wetland drainage, changes due to tiling, ditching, and consolidation, as well as connectivity leading to larger wetland ponds and related impacts on wildlife" (PPJV, 2017d, p. 26).

Finally, in their report from a climate scenarios planning meeting with resource managers in South Dakota, Fisichelli and others (2016) noted that additional work is needed to embed the scenario planning outcomes into planning and decisions about the on-the-ground implementation of the climate change adaptation options (Fisichelli and others, 2016, p. 34).

Wyoming Game and Fish Department

In addition to the research needs summarized in the "Wyoming Game and Fish Department" section, the following additional information needs are described in the reviewed documents that were related to the State of Wyoming. Some information needs are directly related to climate change, whereas other information needs will have complex interactions with the changing climate. In their SWAP, Wyoming Game and Fish Department (WGFD) identified the following additional specific research and information needs related to climate change adaptation and grassland conservation (WGFD, 2017):

- General improvement in uncertainty in projected changes to precipitation and temperature.
- Additional information on how climate will impact biological and physical systems like nutrient cycling.
- Information on the velocity of climate change (for example, how fast can changes be expected to occur).
- Coordinated GIS information to support landscape-level planning for growth and conservation. As of 2017, this information is divided across different entities and there is no current system to track statewide growth, land-use change, subdivisions, energy development, and so forth. Development is happening faster than conservation and there is no way to easily track it.
- Need GIS information on current habitat location and quality, including high priority habitats (for example, those habitats with a high density of SGCN or that are part of migration corridors).
- Need information on species distribution.
- Need research on how to increase public awareness about fragmentation.
- Develop common terminology for growth planning and conservation.
- Need research on how to educate "first time landowners about rural living issues, wildlife, and so forth" (WGFD, 2017, p. II–2–13).
- Need more information on the effects of energy development on species.
- Need cumulative environmental impact statements that consider the cumulative impacts of multiple projects. Environmental impact statements are only evaluated on a project-by-project basis so may not provide a full picture of effects on a larger scale.
- Need to identify performance indicators and goals for conservation planning and efforts to mitigate effects of oil and natural gas development on wildlife.

- Additional resources to keep BLM resource management plans up to date for effective planning and monitoring.
- Need better funding to identify best practices to reclaim oil and natural gas sites.
- Need to increase and update existing GIS data.
- Need additional information on projected effects on foraging quality.
- Need additional education and training for staff with regard to climate change.
- Need to coordinate with other agencies to help make regulations and laws that consider climate change impacts.
- Need more public outreach and education about climate change impacts.
- Need to conduct climate change vulnerability analysis for key species.
- Need to model future species distribution with regard to climate change (WGFD, 2017, p. II–4–21).
- Need to assess impacts of climate change on disease and species (WGFD, 2017, p. II–4–24).
- Need to promote connectivity and identify and prioritize where to protect corridors (WGFD, 2017, p. II–4–24).
- Need to develop standard monitoring protocols (WGFD, 2017, p. II–4–24).
- "Evaluate the feasibility of developing approaches to model future species distribution based on multiple drivers, including climate change" (WGFD, 2017, p. II–4–21).
- "Build databases and produce maps depicting future species distribution including climate as a driver as a long-term consideration. The SWAP includes current distribution maps for SGCN. Consideration should be given to developing maps of the potential future distribution of both SGCN and non-SGCN species based on key drivers of distribution, including climate factors" (WGFD, 2017, p. II–4–21).
- Evaluate "the feasibility of using current species distribution maps to model the future distribution of species is a first step to understanding the potential impacts of climate change on individual species" (WGFD, 2017, p. II–4–21).
- Identify additional "baseline information [that] may be needed to produce maps that accurately depict future species distribution contingent upon multiple drivers" (WGFD, 2017, p. II–4–21).
- "Downscaled climate data and finer-scale climate models may be necessary to make appropriate species management decisions in the future, and the availability of this data should be evaluated. Modeling future species distributions and developing a clearer understanding about future climate scenarios across Wyoming will require more precise information about temperature and precipitation predictions. Through regional partnerships involving scientists and organizations that are working on downscaling climate data to a relevant level for wildlife managers, assess the availability and quality of downscaled climate models for Wyoming and identify information gaps to guide development of finer scale models" (WGFD, 2017, p. II–4–21).
- "Assess the impacts of climate on disease dynamics. Incorporate this information in ongoing disease monitoring, and enhance disease distribution mapping, both current and projected . . . Additional research on the influence of climate factors on disease incidence and/or prevalence would complement existing knowledge and may benefit wildlife managers in the future by allowing them to establish a network of early detection sites where future cases of disease are likely to emerge given climate conditions and other factors" (WGFD, 2017, p. II–4–21).
- "WGFD should also work with other agencies to understand the links between climate and mountain pine beetle, as the drastic alteration of Wyoming's conifer forests or precautionary closure of public lands will have significant implications for future wildlife and habitat management" (WGFD, 2017, p. II–4–21).
- Promote connectivity as outlined in the statewide habitat plan and conduct vulnerability analysis for habitats on a regular basis.
- "Uncertainty surrounding future climate change will compound difficulties for incorporating historic disturbance regimes into habitat management activities. The implications of climate change on historic [sic] disturbance regimes should be reviewed and incorporated into habitat management and conservation activities as scientific knowledge improves. Possible climate warming may result in major changes in historic disturbance regimes, plant and animal dynamics, and hydrological responses, and may further result in entirely unfamiliar species communities (Botkin et al. 2007). Existing climate-modeling science needs to be improved and validated to predict alterations to historic disturbance regimes in specific habitats . . . Further, bioclimatic models that are increasingly being explored to predict the future range of certain species may be oversimplifying a process that is contingent upon factors other than climate" (WGFD, 2017, p. II–5–12–13).

- "Research into localized climate change and associated ecological responses should be continually reviewed and considered in habitat conservation planning and wildlife species conservation and management" (WGFD, 2017, p. II–5–12–13).
- "The potential effects of climate change should be monitored to determine alterations to historic disturbance regimes and appropriate management responses. . . . Greater habitat diversity associated with integrating disturbance regime principles into management practices will increase ecosystem resilience to climate change (Joyce et al. 2000). Research and habitat monitoring data related to climate change should continually be reviewed and adaptive management principles applied to disturbance regime management practice" (WGFD, 2017, p. II–5–16).
- "In cooperation with research entities, monitor the effects of climate change, including extended periods of drought. Research should be conducted on the potential effects of climate change on native and nonnative prairie plants and their composition. Prairie grasses, shrubs, and invasive weedy species may have different responses to changing levels of atmospheric carbon dioxide. Additionally, decreasing soil moisture resulting from increasing temperatures may also impact the current structure of prairie grasslands. Increase monitoring of multiple ecological outcomes of habitat disturbances and treatments and how these interact with one another" (WGFD, 2017, p. III–7–15).

The Nature Conservancy

In addition to the research needs summarized in the "The Nature Conservancy" section, the following additional information needs are described in the reviewed documents that were related to The Nature Conservancy (TNC). Some are directly related to climate change, whereas others will have complex interactions with the changing climate. These specific examples are not exhaustive, but rather listed here to provide an additional level of detail and nuance to increase the ability of the research community to respond to these information needs; they are organized by area or unit.

From the "Niobrara Valley Preserve—Three Year Management Plan—2017–2019" (TNC, written commun., 2017a):

- "Quantify the economic and social factors driving land management decisions by Sandhills ranchers and other land managers. How important are weight gains, stocking rate, labor, etc? Incorporate those factors into the development and export of strategies to those audiences" (TNC, written commun., 2017a, p. 2).
- "Develop science and provide a working model for prairie dog and black-footed ferret management on private lands" (TNC, written commun., 2017a, p. 53, 56).

From the "Ecoregional Planning in the Northern Great Plains Steppe" (TNC, written commun., 1999):

- Additional information needed to remedy the lack of biological inventory information.
- Improved information on species population sizes and trends for invertebrates, fish, and plants (TNC, written commun., 1999, p. 44).
- Improved information on disturbance regimes, especially as it pertains to how to set conservation targets and how to define minimum functional units to provide the needed habitat quality, size, and heterogeneity for grassland obligate species (TNC, written commun., 1999, p. 44).
- Additional research on the socioeconomic drivers of land-use change and supporting conservation initiatives.

From the "Platte River Prairies—Three Year Management Plan" (TNC, written commun., 2017b):

- Notes the need to test and demonstrate agricultural practices that promote efficient water use and help promote clean water while still maintaining high agricultural productivity (TNC, written commun., 2017b, p. 4, 8). This research need connects to the strong relationship among Platte River dynamics, groundwater dynamics, the grassland disturbance regime, and groundwater availability.
- "How do restored sites compare to prairie remnants in terms of value to native species?" (TNC, written commun., 2017b, p. 6).
- What seed mixes will be optimal under a changing climate, and how to "improve the pipeline of seeds for restoration (most seeds for restoration are harvested by hand, and seed mixes for restoration include 150-222 species)?" (TNC, written commun., 2017b, p. 6).
- How well are current outreach efforts working to influence the behavior of private landowners adjacent to the TNC area? (TNC, written commun., 2017b, p. 9).

Migratory Bird Joint Ventures

In addition to the research needs summarized in the "Migratory Bird Joint Ventures" section, the following additional information needs are described in the documents reviewed that were related to the JVs. Some are directly related to climate change, whereas others will have complex interactions with the changing climate. These specific examples are not exhaustive, but rather are listed here to provide an additional level of detail and nuance to increase the ability of the research community to respond to these information needs they are organized by area or unit.

The Upper Mississippi River and Great Lakes Region Joint Venture [UMRGLRJV] 2007 Implementation Plan (UMRGLRJV, 2007) identified the following research and information needs:

- "Evaluation priorities include (1) appraise population and habitat parameters and test assumptions used in planning, (2) improve key digital spatial datasets, (3) assess response to conservation effort, and (4) refine biological models that result in more efficient and effective bird habitat conservation decisions" (UMRGLRJV, 2007, p. 1).
- "Determine status and trends of populations. Conduct statistically valid monitoring to estimate population size (breeding, migration, and wintering) and track changes in abundance, relative abundance, and distribution at scales relevant to the JV. New or enhanced monitoring approaches will be required, particularly for secretive marshbirds and shorebirds" (UMRGLRJV, 2007, p. 47).
- "Determine causes of population change. Track bird habitat change within the region, specifically quantity and quality of key cover types critical to increasing carrying capacity. Incorporate climate change monitoring data into population and habitat assessments" (UMRGLRJV, 2007, p. 47).
- "Evaluate conservation efforts. Conduct a complete land cover inventory every 5–10 years, supplemented with periodic model-based estimates of change in land cover types most important to birds. Determine relative importance of JV conservation effort by ecological regions and evaluate bird response (e.g. [for example], change in population size and distribution, use days, vital rates, or physical condition)" (UMRGLRJV, 2007, p. 47).
- "Inform conservation design. Improve monitoring of patch or subpopulation persistence, extinction, and colonization by priority breeding species (JV focal species). Assess migratory stopover use (i.e. [that is], duration, number of stops, chronology) at staging and wintering areas" (UMRGLRJV, 2007, p. 47).

Refining Breeding Habitat Models

- "Test model assumptions and build and refine models that predict how populations of priority breeding species (JV focal species) respond to habitat change." (UMRGLRJV, 2007, p. 48). This research could specifically address the following:
  - "1. Breeding bird density estimates and specific aspects of habitat quality most related to changes in density" (UMRGLRJV, 2007, p. 48).
  - "2. Factors limiting breeding season vital rates (e.g., nest success, adult female survival, and young survival)" (UMRGLRJV, 2007, p. 48).
  - "3. Influence of vital rates on population growth" (UMRGLRJV, 2007, p. 48).
  - "4. Predicted distribution and abundance in response to habitat quantity, habitat quality, and conservation alternatives" (UMRGLRJV, 2007, p. 48).
  - "5. Vulnerability to climate change, especially those species and associated ecosystems of greatest concern" (UMRGLRJV, 2007, p. 48).

Conducting Behavioral Research

- "Improve understanding of migration corridor selection, movement chronology, and human influences on migrating and wintering populations to better predict habitat needs and target conservation areas." (UMRGLRJV, 2007, p. 48). This research could specifically address the following:
  - "1. Migration corridor identification, duration of stay at stopover locations, and total non-breeding use days in the region" (UMRGLRJV, 2007, p. 48).
  - " 2. Optimum spatial arrangement of cover types within and between migrating and wintering habitat, including inter-wetland distances, and juxtaposition with upland cover types such as cropland, human developments, and permanent natural cover." (UMRGLRJV, 2007, p. 48)
  - "3. Effective and efficient mitigation of potential human-induced limiting factors (e.g., disturbance, water quality, pollutants, contaminants, and sedimentation)" (UMRGLRJV, 2007, p. 48).

Evaluating Nonbreeding Habitat

- Examine habitat objectives and use at multiple scales and build models to evaluate habitat carrying capacity for priority migrating and wintering populations (JV focal species)." (UMRGLRJV, 2007, p. 48). This research could specifically address the following:

- "1. Refined estimates of migrating and wintering populations, particularly for waterbirds, landbirds, and shorebirds" (UMRGLRJV, 2007, p. 49).
- " 2. Retrospective analyses (using historic data) of carrying capacity based on energy requirements and availability (bioenergetics)" (UMRGLRJV, 2007, p. 49).
- "3. Analyses and models to predict expected carrying capacity in the face of changing habitat conditions (e.g., climate change, wet vs. dry years, with/without habitat programs, continued habitat loss, etc.)" (UMRGLRJV, 2007, p. 49).

The PPJV identified the following research and information needs in the Montana State Tactical Plan (PPJV, 2017a):

- "A rigorous landscape-scale assessment of waterfowl population recruitment in the Montana Prairie Pothole Region (PPR)" (PPJV, 2017a, p. 19).
- "Completion of the National Wetland Inventory update" (PPJV, 2017a, p. 19).
- "A restorable wetland basins inventory" (PPJV, 2017a, p. 19).
- "An evaluation of how wetland degradation may be impacting breeding bird reproduction and survival" (PPJV, 2017a, p. 19).
- "Quantification of ecosystem services and economic benefits generated by wetland and grassland conservation in Montana" (PPJV, 2017a, p. 19).
- "Research on what motivates the public and landowner to support wetland and grassland conservation within the PPJV administrative area" (PPJV, 2017a, p. 19).
- "Grassland bird breeding vital rates, full life-cycle demographics, and habitat quality assessments for targeting management actions. The PPJV is currently funding research projects with Montana State University and Bird Conservancy of the Rockies to investigate grassland bird vital rates and habitat quality" (PPJV, 2017a, p. 19).
- "An evaluation of the direct and indirect impacts of climate change to ensure conservation delivery has long-term resilience for the PPR" (PPJV, 2017a, p. 19).
- "Additionally, research studies (e.g., Dahl 2014, Niemuth et al. 2014, Lark et al. 2015) investigate how landscape changes relate to anthropogenic impacts (e.g., pattern tile drainage, grassland conversion) and climatic changes (e.g., wetland hydroperiod)" (PPJV, 2017a, p. 24).

In the "North Dakota Tactical Plan—A Supplement to the 2017 Prairie Pothole Joint Venture Implementation Plan," the PPJV (2017b) suggested the following information needs regarding grassland and wetland habitats and migratory grassland birds and waterfowl in North Dakota:

- Additional information on different bird groups: "Currently, the four bird groups differ markedly in what is known concerning their population status, habitat requirements, and understanding of factors that most affect population change" (PPJV, 2017b, p. ES 7).
- "An updated National Wetland Inventory for North Dakota" (PPJV, 2017b, p. ES 7).
- "A restorable basins inventory for North Dakota" (PPJV, 2017b, p. ES 7).
- "Evaluating how wetland contaminants may be impacting PPJV bird reproduction and survival" (PPJV, 2017b, p. ES 7).
- "Quantifying ecosystem services and economic benefits generated by wetlands and grasslands within the PPJV administrative area" (PPJV, 2017b, p. ES 7).
- "Understanding what motivates the public and landowner to support wetland and grassland conservation within the PPJV administrative area" (PPJV, 2017b, p. 19).
- "Evaluating how wetland drainage, basin consolidation, connectivity, and pattern tile drainage may be impacting wetland-dependent species in North Dakota" (PPJV, 2017b, p. 19).
- "Evaluating how soil health practices benefit ground nesting birds" (PPJV, 2017b, p. 19).
- "Evaluation of tile setbacks for impacts to wetlands" (PPJV, 2017b, p. 19).
- "Acquire/develop a process to obtain growing season/spring aerial imagery to improve the NRCS Certified Wetland Determination process and align with the wet portion of the growing season" (PPJV, 2017b, p. 19).
- "Evaluating energy development and impacts to waterfowl productivity" (PPJV, 2017b, p. 19).
- "Evaluating cross-seasonal use of priority wetland habitats within the PPR" (PPJV, 2017b, p. 19).
- "Evaluating the direct and indirect impacts of climate change to ensure conservation delivery has long term resilience in the U.S. PPR" (PPJV, 2017b, p. 19).
- "Evaluating wetland degradation (for example, salinity, siltation, pesticides) in cropped landscapes and the effect on breeding waterfowl" (PPJV, 2017b, p. 19).

Similarly, the PPJV also described the following research needs to support waterfowl, grassland birds, and shore birds (Barnes and others, 2017).

- For shorebirds "Much basic research needs to be conducted to better understand habitat use, distribution, and vital rates" (Barnes and others, 2017, p. 26).
- More research to reduce uncertainty about the impacts of climate change on ecological systems and particular species:
  - "One of the major challenges of addressing climate change effects on fish and wildlife is identifying and addressing uncertainty in our understanding of future climate change and how that change will affect ecological systems" (Barnes and others, 2017, p. 26).
  - "Moreover, validation of spatial models has been, and will continue to be, an important PPJV science priority" (Barnes and others, 2017, p. 34).

In the "South Dakota State Tactical Plan—A Supplement to the 2017 Prairie Pothole Joint Venture Implementation Plan," the PPJV (2017d) suggested the following information needs regarding conserving grassland and wetland habitats and supporting migratory grassland birds and waterfowl in South Dakota:

- How and to what extent do current best practices for grassland management (including row crop, grazing, and other agricultural uses) also support adaptation to a changing climate? Which practices are maladaptive?
- How will changes in precipitation related to climate change (and related human adaptation options and actions) impact surface water runoff (for example, rates, amounts, frequency), and in turn impact nonpoint source pollution into waterways (for example, agriculture runoff, salinity, siltation, pesticides)? What impact will this have on reproduction, survival, and habitat quality for waterfowl and aquatic species?
- How will climate change impact the expansion of row crops northward into South Dakota into areas that weren't previously suitable for row crops, and what effect will this impact have on suitable habitat for species of interest? How will climate change impact the transition from cereal crops (for example, wheat and barley) which provide minimal cover to breeding waterfowl and migratory birds, to corn and soybean crops, which provide almost no cover for them?
- How will changes in demand for biofuels and food effect grassland conversion and agricultural expansion?
- Inventory and mapping of ecosystems identifying the location and condition of key habitats. Include habitat areas that are key to biodiversity or ecosystem diversity objectives for South Dakota.
- The 1985 National Wetlands Inventory needs to be updated to identify the spatial extent and distribution of wetlands to determine carrying capacity for waterfowl habitat and to document changes through time to help prioritize conservation actions and inform hydrological and biological models (PPJV, 2017d, p. 25).
- Restorable Basins Inventory to identify the spatial extent and distribution of drained wetlands that could be targeted for restoration (PPJV, 2017d, p. 25).
- Additional research on understanding public motivation for conservation on private and public lands (for example, landowner attitudes; PPJV, 2017d, p. 25; also refer to SDGFP, 2014).
- Understanding human-induced changes to water: wetland drainage, changes due to tiling, ditching, and consolidation, as well as connectivity leading to larger wetland ponds and related impacts on wildlife (waterfowl, game species like pheasants, grouse, and deer; PPJV, 2017d, p. 26).
- Evaluate tile setbacks (the distance drainage tile must be from wetlands) for effects on wetlands: "In order to maintain compliance with federal Farm Bill programs, landowners wishing to install drain tile must consult with NRCS to review the project affected fields and determine setback distances to any wetlands embedded within the project area. NRCS offices within the PPJV area receive hundreds of these requests annually impacting thousands of acres. The intent of these "minimal effect" determinations is to allow the drainage improvements on uplands to proceed while minimizing potential impacts on wetlands. Questions remain over potential effects lowering water tables surrounding wet-land basins may have on pothole wetlands. A complete evaluation of current setback distances would elevate these concerns and reduce any unintended drainage that may be occurring" (PPJV, 2017d, p. 26).
- Identify potential "win-win" scenarios among agricultural producers, rural communities, and the conservation community to maintain and improve human livelihoods and conserve grasslands and grassland species (for example, sustainable farming practices to improve soil health, reduced tillage, crop rotations). It is unclear which of these practices, if any, have benefits for grassland species like ground-nesting birds (PPJV, 2017d, p. 26).
- Quantifying ecosystem services and economic benefits from wetlands and grasslands (PPJV, 2017d, p. 26).
- An improved statistical abundance model which could aid in predicting occupancy and density of Canada geese in South Dakota and improve management efforts. This

effort could also improve understanding of potential future population density and movement under current and projected climate conditions (PPJV, 2017d, p. 26).

- Monitoring and evaluation of the hydroclimate system (precipitation, wetland hydroperiods), the ecological system (upland and wetland habitats, species presence and abundance surveys such as the Four Mile Square Surveys), and anthropogenic impacts (for example, pattern tile drainage, grassland conversion) to detect changes through time and across the landscape (temporal and spatial scales) is needed to inform adaptive management efforts (PPJV, 2017d, p. 31).

- "Upland and wetland habitats are monitored periodically through programs such as the Four Mile Square Survey and Waterfowl Breeding Population and Habitat Survey and through research studies (see Loesch et al 2014 [sic] [Loesch and others, 2012], Dahl 2014, Niemuth et al. 2014, Lark et al. 2015) to understand how changes relate to anthropogenic impacts (for example, pattern tile drainage, grassland conversion) and climatic changes (for example, wetland hydro-period). These monitoring efforts provide the foundation to inform and adapt management and conservation activities accordingly as spatial and temporal changes in priority habitats occur in the future. Considering the great amount of uncertainty associated with anthropogenic impacts and climate change, continuing to intensively monitor habitat and populations to detect changes through time appears to be a reasonable approach for PPJV partners" (PPJV, 2017d, p. 30, table 3).

- Understanding human-induced changes to water: wetland drainage, changes due to tiling, ditching, and consolidation, as well as connectivity leading to larger wetland ponds and related impacts on wildlife (waterfowl, game species like pheasants, grouse, and deer; PPJV, 2017d, p. 26).

The Playa Lakes JV also identified the following research and information needs (PLJV, 2008a, b, c):

For Colorado

- "Address policy-level issues at local, state, and national levels to ensure that beneficial conservation opportunities continue or are improved (e.g., CRP, NAWCA [North American Wetlands Conservation Act], etc.)" (PLJV, 2008a, p. 23).

- "Develop spatially-explicit models and other decision support tools to provide better direction regarding the type and location of habitat actions that will provide the greatest benefit for priority bird populations" (PLJV, 2008a, p. 23).

- "Explore the impacts of additional factors, beyond habitat availability, that may be impacting bird populations in the planning region (e.g., habitat fragmentation, predation, disease, contaminants, etc.)" (PLJV, 2008a, p. 23).

- "Develop management actions to address these factors as needed" (PLJV, 2008a, p. 23).

- "Conduct research to better understand the relationship between priority waterbirds and their habitats during the nonbreeding period. This information is needed to develop appropriate conservation strategies, but is currently lacking for most species" (PLJV, 2008a, p. 23).

- "Spatially-explicit conservation recommendations provide more direct focus for conservation efforts, may improve the efficacy of conservation delivery and outcomes, and may improve cost-effectiveness in light of limited budgets" (PLJV, 2008a, p. 9).

For Kansas

- There is a need for improved land cover data for the playa lakes regions in Kansas:

  - For example, the authors have evaluated the landcover from Oklahoma GAP and a newer landcover layer of eastern red cedar (ERC) developed by Oklahoma NRCS covering several counties in BCR 19 (over 4.5 million acres and just over 25% of the entire BCR). The images used for analysis in Oklahoma GAP were mostly taken in 1992 and the images for the ERC layer were taken in 2004, a gap of twelve years. We overlaid the older Oklahoma GAP layer with the newer ERC layer and, determined those areas originally classified as non-woodland and currently (2008) classified as ERC. These rates of conversion, if they hold true for Kansas, would have a large effect on the numbers used in determining habitat goals for breeding landbirds. If corrected habitat acreages were run back through PLJV models, it would reduce the current estimated carrying capacity of most priority birds (PLJV, 2008b).

For Nebraska

- "Develop spatially-explicit models and other decision support tools to provide better direction regarding the type and location of habitat actions that will provide the greatest benefit for priority bird populations" (PLJV, 2008c, p. 21).

- "Evaluate the accuracy of current habitat acreage estimates from GIS; these estimates are important parameters for carrying capacity models used to develop habitat recommendations" (PLJV, 2008c, p. 21).

- "Work with local land managers and land owners to implement on-the-ground habitat actions that forward the goals stated in this Plan" (PLJV, 2008c, p. 21).

- "Coordinate with resource management agencies, conservation organizations, and local working groups to use existing programs to direct programmatic resources to forward the goals stated in this plan. Develop new programs to fill gaps as needed" (PLJV, 2008c, p. 21).

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