FLASH DROUGHT

LESSONS LEARNED FROM THE 2017 DROUGHT ACROSS THE U.S. NORTHERN PLAINS AND CANADIAN PRAIRIES

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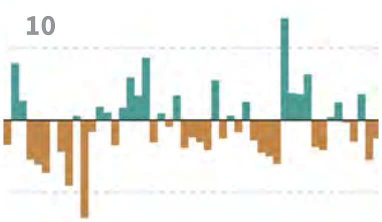

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Fall 2016
Unusually warm conditions lengthened the fall growing season, depleting soil moisture in some areas.

February 2017
Warm temps caused early melt of plains snowpack while soils were still frozen, resulting in run-off without adding to soil moisture.

March 2017
Prior to drought onset, soils with adequate soil moisture were observed throughout much of the region, especially in Montana.

April–May 2017
Precipitation was much below-normal at a critical time for pasture, rangelands, forage, and both winter and spring wheat.

May 2017
Flash drought began. Soil moisture declined rapidly in conjunction with near-record-low precipitation. Above-normal temps and wind speeds mid-May to mid-June increased evapotranspiration.

May–June 2017
Lower forage production for grazing forced ranchers to significantly reduce their herds by selling cattle earlier than usual.

Early June 2017
Montana's Fort Peck Indian Reservation was in D1 (Moderate) drought with noticable effects on native and cultivated plant communities.

EXECUTIVE SUMMARY

The 2017 drought was a rapid-onset event for northeast Montana, the Dakotas, and the Canadian Prairies during the spring and summer of 2017. It was the worst drought to impact the U.S. Northern Plains in decades and it decimated crops across the region, resulting in $2.6 billion in agricultural losses in the U.S. alone, not including additional losses in Canada. The unique circumstances of this drought created an opportunity to evaluate and improve the efficacy of drought-related coordination, communication, and management within the region in preparation for future droughts.

DROUGHT EVOLUTION

- In the spring months prior to drought onset, soils with adequate soil moisture were observed throughout much of the region. It is important to note that in Fall of 2016, abnormally-warm conditions lengthened the Fall growing season in some areas. This may have depleted soil moisture at a time when vegetative growth has normally ended and soil moisture is recharged with rainfall. These preceding conditions may have contributed to drought development in some areas.
- A warm February in 2017 caused early melt of plains snowpack while soils were still frozen, resulting in run-off without adding to soil moisture recharge.
- Precipitation was much below-normal in April and May, a critical time for pasture, rangelands, forage, and both winter and spring wheat. The hardest-hit areas saw the driest May–July season on record during 2017, dating back to at least 1895.
- Above-normal temperatures continued into the spring. Above-normal wind speeds from mid-May to mid-June 2017 contributed to increased evapotranspiration.
- Rapid deterioration of soil moisture conditions continued during June and July 2017, pushing the U.S. Northern Plains and southern Canadian Prairies into D2 (Severe) to D4 (Exceptional) drought, according to the U.S. Drought Monitor (USDM) and the North American Drought Monitor (NADM).

▲ Abandoned ranch near Roy, Fergus County, Montana. Credit: Kevin Hyde, Montana Climate Office

June 8, 2017
Governor Daugaard activated South Dakota's State Drought Task Force to address escalating drought and coordinate a response.

June–July 2017
Soil moisture declined rapidly, pushing the region into D2 (Severe) to D4 (Exceptional) drought. June and July were the driest and hottest on record, dating back to at least 1895.

July 7, 2017
More than 200 cows and calves were found dead in a pasture in Saskatchewan due to salt poisoning, heat stress, and dehydration.

July 8, 2017
The Magpie Fire burned 5,100 acres in North Dakota.

July 16, 2017
The Wanblee Timber Fire burned 5,305 acres in South Dakota.

July 19, 2017
The Lodgepole Complex Fire burned 270,000 acres in Montana, tying for the largest wildfire in the U.S. in 2017.

July 31, 2017
U.S. Dept. of Interior allowed emergency grazing relief in Charles M. Russell Wildlife Refuge for ranchers who lost grazing land due to the Lodgepole Complex Fire.

August 2017
August provided some drought relief to the Dakotas, but conditions continued to worsen in Montana.

August 7, 2017
North Dakota Governor Burgum requested a presidential major disaster declaration for drought-affected areas of the state.

August 31, 2017
The historic Sperry Chalet within Glacier National Park was consumed by the Sprague Fire.

DROUGHT IMPACTS

- The U.S. agricultural sector experienced impacts early on in the year, including many spring-planted crops that failed to germinate, resulting in a total loss. Agricultural impacts persisted and worsened over the duration of the 2017 drought.
- Agriculture in the southern Canadian Prairies experienced poor spring germination, stunted crop development, heat stress, accelerated crop maturity, poor grain fill, below-normal yields, water supply shortages, poor pasture conditions, feed shortages, and wildfires. Livestock production was especially hard-hit due to the widespread scarcity of feed and water.
- Tribes in the region reported similar impacts to agriculture, livestock, and, in some areas, human health and domestic water supplies. Tribal cultural resources were also impacted, putting these resources at risk for future generations.
- Cool season grass species, which dominate much of the region, suffered from the lack of spring precipitation. This led to a decline in pasture and range conditions, and reduced forage production for summer grazing.
- Lower forage production for grazing forced ranchers to significantly reduce their herds by selling cattle earlier than usual. In the U.S., producers started selling cattle in May and June (early-season); in Canada, producers started to reduce and relocate herds in July (mid-season).

▲ **Red cattle. Credit: Alf Manciagli**

- Stock ponds for livestock water were depleted, and surface water samples showed signs of poor water quality (containing higher levels of salts, nitrates, and total dissolved solids). Some livestock perished or exhibited symptoms of poisoning due to poor water quality across the region.
- A shortage of pasture and forage, along with poorly-performing crops, caused many producers to harvest grain crops as forage to feed hungry livestock.
- Despite near-normal stream flows for the entire 2017 season, water supply to rural water

September 2017
September still showed large areas of D4 (Exceptional) drought across the region.

September 6, 2017
State, tribal, and federal leaders gathered at the University of Montana to discuss climate services and needs, address communication barriers, and share knowledge about drought response.

Mid-September 2017
All seven of Montana's Indian reservations were experiencing D2 (Severe) to D4 (Exceptional) drought conditions.

Early October 2017
All seven Indian reservations in the Missouri River Basin in North and South Dakota were experiencing D2 (Severe) to D3 (Extreme) drought.

October 23, 2017
The Saskatchewan Stock Growers Association launched a wildfire relief fund for affected producers.

December 11, 2017
A rare December fire, Legion Lake, burned over 54,000 acres in the Black Hills of South Dakota. It was the largest wildfire in the state that year.

◄ Timeline of key events leading up to and during the 2017 flash drought across the U.S. Northern Plains and Canadian Prairies.

providers was reduced in some areas. Rural water systems were restricted by their infrastructure and some providers were not able to keep up with increased water demand, leading to enforcement restrictions.

- The combination of below-normal precipitation and abnormally-high temperatures in July and August contributed to near-record levels of severely-low fuel moisture in the region's forests and grasslands. These conditions worsened the fire season in 2017, setting records and contributing to large wildfires that exhibited erratic behavior and rapid growth.

▲ A Montana Fish, Wildlife, and Parks Department biologist and a local rancher discuss water management in the Big Hole Valley, Montana. Credit: USDA

DROUGHT RESPONSES

- Montana, North Dakota, and South Dakota activated their state drought task forces. These multi-agency groups considered drought conditions, reviewed impacts, and facilitated drought relief. State response varied depending on impacts, resource availability, and the authority of each state drought task force.
- Governors signed 19 drought-related executive orders between March and October 2017, including 8 in Montana, 2 in South Dakota, and 9 in North Dakota.
- State drought task forces collected data on local climate and hydrologic conditions, as well as impact reports. These were used to inform local decisions and to provide input to the USDM.
- On August 7, 2017, North Dakota Governor Burgum requested a presidential major disaster declaration for drought-affected areas of the state, based on the severity of drought conditions impacting producers and other residents.
- A "fast track" U.S. Department of Agriculture (USDA) Secretarial Drought Declaration policy came into effect for counties when drought was elevated to D2 (Severe Drought) and higher on the USDM. Programs such as the Livestock Forage Program, Livestock Indemnity Program, Small Business Loan assistance, cost-share for infrastructure, and others were also available through USDA.

- On July 31st, 2017, U.S. Dept of Interior allowed emergency grazing relief on the Charles M. Russell Wildlife Refuge in Montana for ranchers who lost grazing land due to the Lodgepole Fire Complex.
- Regional, federal, and academic partners coordinated to provide pertinent drought-related data, impact and outlook briefings, and early warning information to the region. These included the National Oceanic and Atmospheric Administration (NOAA), National Integrated Drought Information System (NIDIS), Regional Climate Services and National Weather Service (NWS), High Plains Climate Center (HPRCC), Western Regional Climate Centers (WRCC), USDA Northern Plains Climate Hub, and National Drought Mitigation Center (NDMC). In addition, federal staff from many other agencies in the region were also engaged during the drought.
- In coordination with the Great Plains Tribal Water Alliance—NOAA, NIDIS, and partners provided specific tribal webinars focused on tribal needs.
- Agriculture and Agri-Food Canada (AAFC) designated producers in drought regions as eligible for Livestock Tax Deferral to help offset the impact of selling cows to reduce herd sizes.
- Canadian provincial governments in the region provided targeted educational sessions and encouraged producers to test livestock water sources.
- Provincial groups used the Canadian Drought Monitor (CDM) as an input into drought response initiatives, including opening up grazing areas, performing additional water testing, and organizing educational sessions.

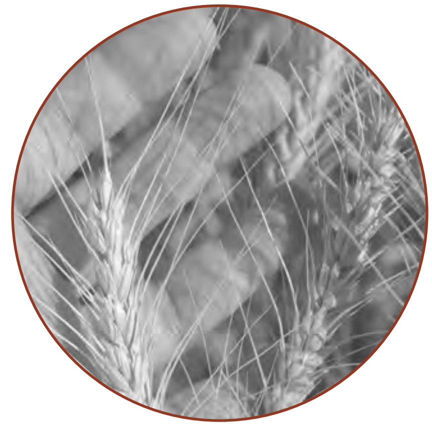
▲ **An area burned by the Lodgepole Complex Fire near Sand Springs, Montana, on July 24, 2017. Credit: YPR**

LESSONS LEARNED

- Regional Drought Early Warning Systems provide important networks through which partners convene across boundaries and exchange information before, during, and after droughts to improve our drought preparedness and response.
- Monitoring to provide early warning of potential drought conditions is vital for regional climatologists as well as federal, state/province, local, and tribal agencies in order to trigger timely and adequate drought response.
- Soil moisture conditions can change quickly, and soil moisture monitoring is a critical indicator in this dryland agriculture environment as well as for many other sectors. There are regional and national efforts to strengthen soil moisture monitoring.
- Snowpack on the plains/prairies is important for early spring moisture. An early melt is detrimental to spring growth of grass and wheat.
- Drought information providers must improve their understanding of the annual decision cycles of all sectors, including agriculture, tourism and recreation, and water supply to determine the most effective formats and timelines for delivering information to decision-makers.
- The scientific community needs to demonstrate the value of improved data collection and early drought indicators to policymakers, producers, and the general public.
- Building partnerships during non-drought periods facilitates information exchange and is critical to ensure proper relationships are in place for a coordinated, rapid response during drought. This includes strengthening coordination within and among federal,

state/provincial, local, and tribal governments for achieving an effective drought response.

- It is difficult to plan for drought when you are in drought, and while short-term response plans provide support during the event, states can benefit from longer-term planning that includes mitigation and adaptation strategies. Many states have recognized the need to plan holistically across sectors. Approaching the whole of an ecosystem allows for consideration of building soil and plant health into water management strategies.
- Maintaining outreach to stakeholders and producers during non-drought periods is key to maintaining these relationships. State climate offices and local extension services are key conduits of information to those on the ground, and setting local information in the statewide context is helpful when delivering information. During non-drought periods, activities can be undertaken to improve resilience that will help mitigate impacts in times of drought.
- The reporting of year-round conditions and drought impacts should be encouraged. Impact reports can serve as alerts for climate and hydrologic indicators, and can reveal changing conditions in areas lacking data.



▲ **Winter wheat in Beach, North Dakota. Credit: USDA NRCS**

NEEDS AND GAPS

- Drought monitoring infrastructure requires improvements in the collection, assessment, and integration of drought indicators and impacts necessary to produce applicable, reliable, and timely drought forecasts.
- Investments in existing and new monitoring and observation networks are necessary to support and improve drought research, assessment, and prediction across the region.
- Producers have their own "early warning indicators" that can help inform the science of early warning. Better cooperation between drought information providers and resource professionals would enhance this information exchange.
- Improvements in seasonal forecasts will continue to enhance drought preparedness.
- Increased technical capacity of local drought task forces through the development, sharing, and evaluation of drought monitoring tools and triggers will improve drought response and management.
- Better cooperation and coordination with university Extension professionals in each county or region of a state is essential for assistance with the documentation of drought impacts and the distribution of information to individuals on the ground.
- Improved communication between producers and USDA professionals will facilitate awareness of drought-related programs, program deadlines, and enrollment or reporting requirements.
- Better communication between federal, state, tribal, local, and private entities engaged in drought planning and preparedness will improve information transfer and decision making. This reciprocation includes continuing coordination and partnership across the U.S.–Canadian border.
- While many lines of communication performed well in 2017, there is a need to better understand communication centers and pathways in the region, and the way drought is communicated—especially in rural areas.

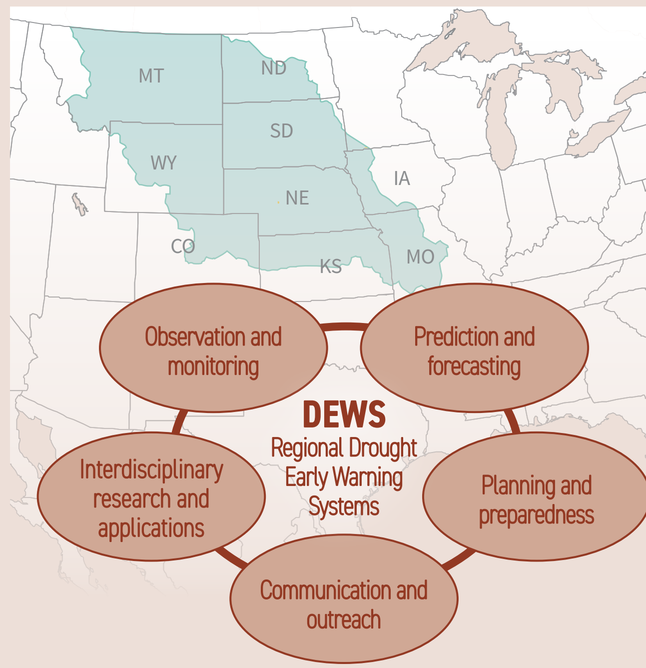
The Alice Creek Fire started by lightning strike on July 22, 2017, near Lincoln, Montana. Because of extremely low humidity, above-average temperatures, and windy conditions, fire fighters struggled to contain the blaze. It eventually burned a total of 29,252 acres and four buildings. Credit: U.S. Forest Service

INTRODUCTION

In the summer of 2017, much of the United States' attention was on an unprecedented series of hurricanes that had struck southern Texas and the Caribbean. At the same time, a less-recognized, record-breaking natural disaster was evolving over the Northern Plains region of the United States and the Canadian Prairies, impacting the region in a unique way.

Large swaths of Montana, the Dakotas, and the southern Canadian Prairies experienced a "flash drought" characterized by a rapid decline in soil moisture, brought on by record-low spring rainfall, with contributions from high temperatures and above-average wind speeds.[11,19] According to the U.S. Drought Monitor (USDM), in early May 2017, one area of western South Dakota was experiencing drought conditions, but there was no other drought identified in the region. In fact, the USDM map for May 23, 2017, featured a record-low 21st-century drought coverage of 4.52% for the contiguous United States. By July, all three states and the Canadian Prairies were experiencing areas of severe-to-extreme drought, which contributed to wildland and rangeland fires that burned 4,837,599 acres across both countries and led to agricultural losses in the U.S. in excess of $2.6 billion dollars [National Interagency Fire Center and the Canadian Forest Service; NOAA/National Centers for Environmental Information].[16]

The conditions that led to the economic and environmental impacts of this drought were historic. Montana and the Dakotas received 60% of normal precipitation in May–July 2017, ranking as the second driest interval since 1901.[22] As this region becomes more arid due to climate change, the potential for economic and cultural impacts will increase.[5,11] These changes have made communities, agencies, and businesses more dependent than ever on timely and actionable early warning information. The purpose of this report is to examine the historic 2017 drought and its impacts, identify opportunities to improve timeliness and accessibility of early warning information, and identify applied research questions and opportunities to improve drought-related coordination and management in the region.



NIDIS and the Missouri River Basin

The 2017 U.S. Northern Plains and Canadian Prairies drought significantly impacted the region and was devastating for many, creating an urgent need to evaluate and improve the efficacy of drought-related information services and management across the region. The National Oceanic and Atmospheric Administration's interagency National Integrated Drought Information System (NIDIS) was authorized by Congress in 2006 (***Public Law 109-430***) and reauthorized in 2014 (***Public Law 113-86***) and 2018 (Public Law 115-423) with a mandate to coordinate and integrate drought research, building upon existing federal, tribal, state, and local partnerships in support of creating a national drought early warning information system. NIDIS responded to its mission through the development of Regional Drought Early Warning Information Systems (DEWS). DEWS utilize new and existing networks of federal, tribal, state, local, and academic partners to make climate and drought science accessible and useful for decision-makers. They also improve the capacity of stakeholders to monitor, forecast, plan for, and cope with the impacts of drought. In 2014, NIDIS began developing a DEWS specifically focused on the Missouri River Basin. Using this network, NIDIS worked with its partners and the public to evaluate the causes and collective response to the drought, with the goal of ensuring the region is better prepared in the future.

DROUGHT EVOLUTION AND CLIMATE SUMMARY

The Northern Plains and Southern Canadian Prairies are a region of extremes. Between blizzards, tornadoes, droughts, floods, heat waves, and extreme cold, this region experiences a wide range of weather and climate conditions.

HISTORICAL CLIMATE IN THE REGION

Situated in the interior of the continent, the Northern Plains and Southern Canadian Prairies lie far away from the moderating effects of the oceans and is subject to the impacts of competing air masses from the north and south. Moving north in the U.S. and into Canada, temperatures typically decrease, with northern North Dakota, eastern Montana, and the southern prairies of Canada experiencing some of the region's greatest thermal extremes. Precipitation decreases dramatically from east to west, with areas of eastern South Dakota receiving two to three times more annual precipitation as areas in central Montana, and Manitoba normally receiving much more precipitation than southern Alberta.

Often incorrectly characterized as "flat," the plains slope upward from the east towards the Rocky Mountains in the west. The Rockies in Montana and Canada play an important role in the region, providing the source of headwaters to several rivers flowing out across the plains as well as a rain shadow effect for areas to the east. These rivers are a major source of water for the region, providing drinking water for communities and serving as a water supply for ecosystems and agriculture.

During a typical winter, heavy snows accumulate in the Rockies, subsequently melting and flowing through the rivers during the warm season. When snowpack is too low or too high, or when rapid melting occurs, impacts often develop downstream. Winter is the driest time of the year in the plains and total precipitation amounts to approximately 10% of the annual total. This precipitation normally accumulates as plains snowpack, and depending on the depth of frost in the soils, the melting snowpack recharges soil moisture and runs off to replenish ponds, wetlands, and streams. Changes in snowpack and the timing of melt is an important component of the fire seasons onset. Snowpack is also important for insulating the winter wheat crop from cold air temperatures.

Precipitation generally increases in the spring, with the wettest months occurring during the May–July time frame. June is typically the wettest month, with nearly 20% of the annual precipitation falling in that one month alone. This distribution of precipitation from late spring through early summer is crucial for the region, especially for those with agricultural interests. Precipitation usually diminishes in the fall making it increasingly difficult to overcome any deficits in precipitation from earlier in the year. Although precipitation amounts are smaller in the fall, this season is important for soil moisture recharge in the region. As the growing season comes to an end, precipitation

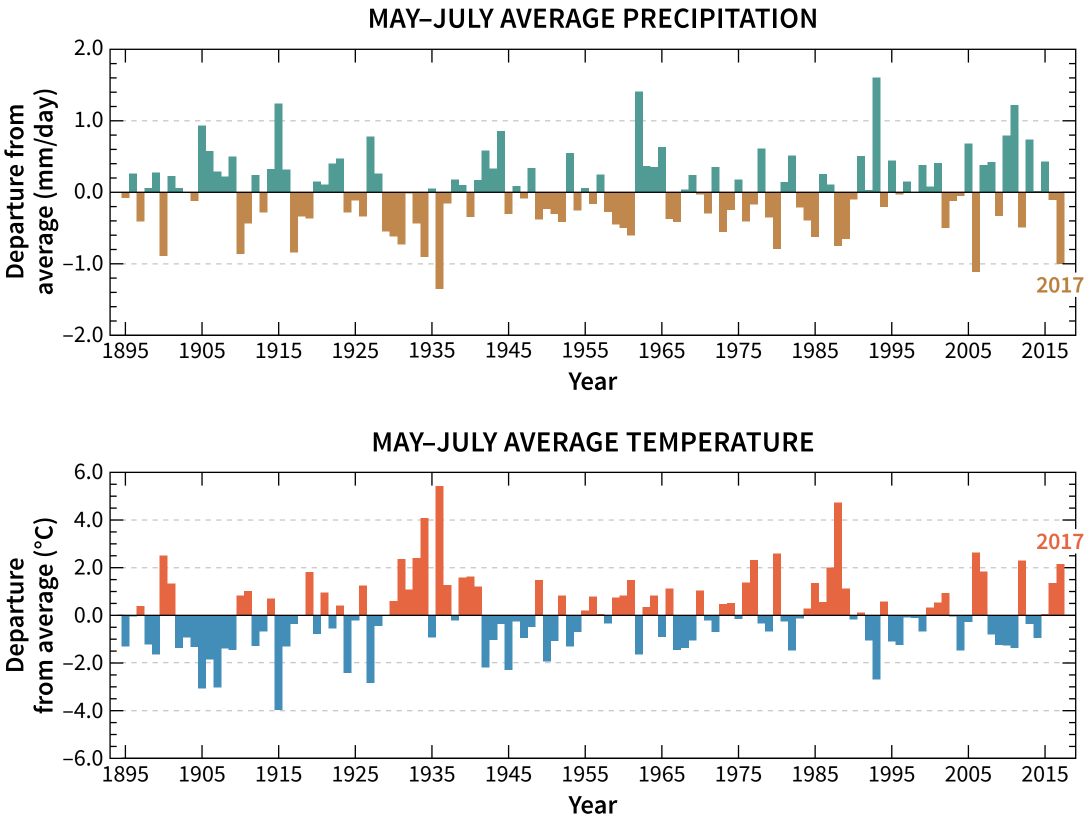


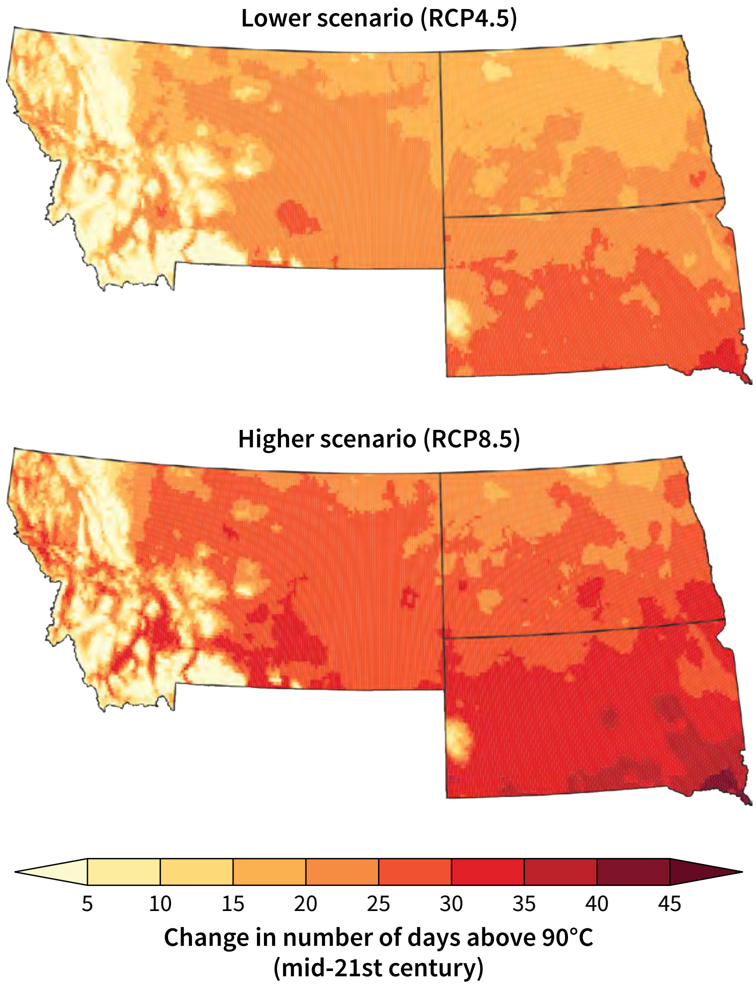
Figure 1: Time series of May-July (*a*) precipitation and (*b*) daily average temperature departures averaged over Montana, North Dakota and South Dakota east of the 109°W meridian. Precipitation and daily average temperature are based on the National Centers for Environmental Information five-km gridded data.

during fall and early winter helps to rebuild the soil moisture that is vital for crops and forage production in the spring. Once the soils freeze, the majority of moisture in the soil is retained over the winter. Soils that are too wet or too dry can impact the next growing season.

The climate indicators described above are based on averages over long periods of time. Like many places, most years in the region are not average with high variability in precipitation and temperature common from year to year (*Figure 1*). For example, in South Dakota during a four-year time frame, three years ranked in the top ten wettest or driest years on record. The years 2010 and 2013 ranked ninth and seventh, respectively, for wettest years on record, while 2012 came in as the tenth driest *(NCEI Climate at a Glance).*[15] Regionally, the back-to-back flood and drought years of 2011 and 2012 provide another example of this variability in the Missouri River Basin.

Due to these fluctuations in precipitation, droughts are a recurring feature in the Northern Plains and Canadian Prairies. Some droughts can last several years, like those of the 1930s and 1950s, while others can last for shorter amounts of time, like the drought of 1988. Although droughts are not uncommon in this region, the drought of 2017 was unusual due to its rapid onset and unique impacts.

Climate model projections from the *Fourth National Climate Assessment* indicate a warmer future in the U.S. Northern Plains and more variability in moisture conditions. The number of days above 90°F are expected to increase by 10–35 days by the middle of the 21st century (2036–2065) across the region under the lower emissions climate scenario (RCP4.5) (*see Figure 2 on page 12*). There is high model agreement and certainty for the direction of this temperature trend. This warming is projected to occur in conjunction with less snowpack and a mix of increases and decreases in the average annual water availability (*see Figure 3 on page 13*).[5] The U.S. Northern Plains experience high interannual variability in precipitation, which contributes



◀ **Figure 2:** **Climate model projections paint a clear picture of a warmer future in the Northern Great Plains, with conditions becoming consistently warmer in two to three decades and temperatures rising steadily towards the middle of the century, irrespective of the scenario selected. Projected changes are shown for the annual number of very hot days (days with maximum temperatures above 90°F, an indicator of crop stress and impacts on human health). Projections are shown for the middle of the 21st century (2036–2065) as compared to the 1976–2005 average under the lower and higher scenarios (RCP4.5 and RCP8.5). Source: NOAA NCEI, CICS-NC**

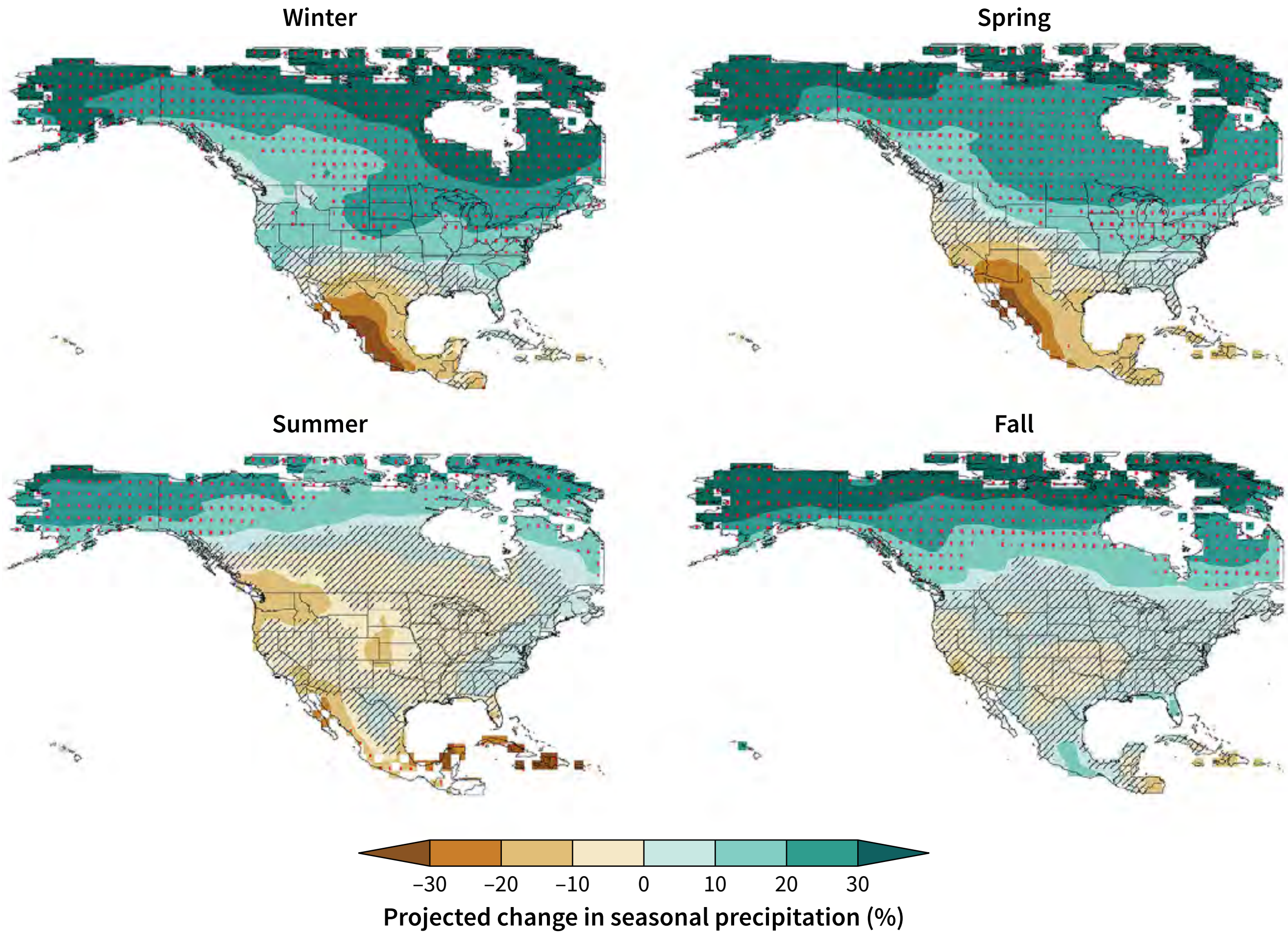
to greater uncertainty about what the future might hold in terms of dry spells. In spite of these variations, generally wetter conditions are expected in winter and spring under a higher emissions scenario (RCP8.5). In the early to middle parts of this century, this will likely be seen as snowfall but as temperatures continue to rise, precipitation will trend towards rainfall.[7] Models indicate the potential for drier summers though depending on location in the region, these changes may be small compared to natural variation. Finally, fall could be slightly wetter but natural variation will be larger than the modeled changes (*Figure 3*).[5] In all cases the projected future changes in precipitation are somewhat uncertain with many models disagreeing on the direction of the precipitation trend. Even with annual precipitation increases in the future, warmer temperatures will enhance the rate of soil moisture loss during dry spells in the summer. Thus, future summer droughts are likely to become more intense during times of reduced precipitation.[23] Similar to the historical climate of the region, there will be a high degree of year-to-year and season-to-season variability that make it difficult to predict drought in any given year.

FORMS AND DEFINITION OF DROUGHT

Drought always starts with a lack of precipitation, but warmer temperatures that contribute to dryness intensify impacts to soil moisture, groundwater, streamflow, ecosystems, and communities. This variation leads to the identification of different types of drought—meteorological, agricultural, hydrological, socioeconomic, ecological, which reflect the perspectives of different sectors on water shortages.[4,25] The different types of drought are all essentially different stages of the same natural, recurring process that occurs over periods of weeks to many years (*see "Types of Drought" on the following page*).

It should be noted that more than one drought type can occur at the same time at a given location and that droughts can transition from one type to another as conditions and impacts evolve with time. Conditions may also transition back and forth between the various types of drought. Ecological drought has been called out separately because in spite of the high cost to nature and people, current drought research, management, and policy often fail to evaluate how drought affects ecosystems and the services that they provide.[4]

The speed at which drought develops and its ultimate severity are also influenced by other environmental conditions. For example, if normal to below-normal precipitation



▶ **Figure 3: Projected change (%) in total seasonal precipitation from CMIP5 simulations for 2070–2099. The values are weighted multimodel means and expressed as the percent change relative to the 1976–2005 average. These are results for the higher scenario (RCP8.5). Stippling indicates that changes are assessed to be large compared to natural variations. Hatching indicates that changes are assessed to be small compared to natural variations. Blank regions (if any) are where projections are assessed to be inconclusive. Data source: World Climate Research Program's (WCRP's) Coupled Model Intercomparison Project. Source: NOAA NCEI**

Types of drought

Meteorological drought refers to a deficit compared to average precipitation over a period of time for a given location.

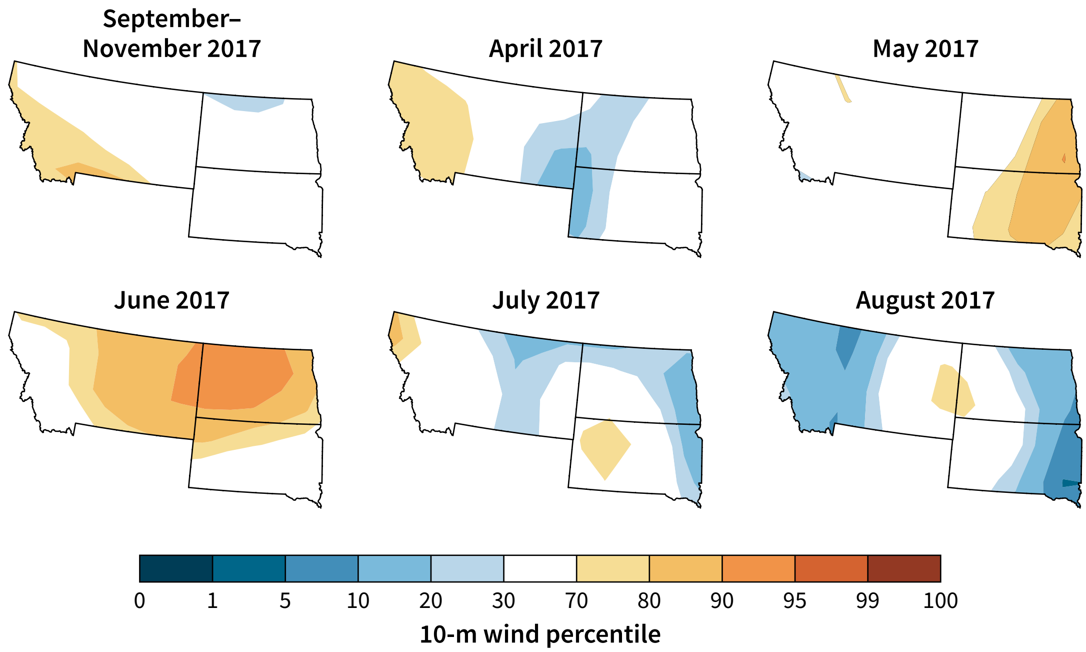
Agricultural drought occurs when plant water requirements are unmet during the growing season, especially during certain periods critical for yield development.

Hydrological drought develops if deficits in net surface water supply become large enough to reduce river, reservoir, or groundwater levels.

Socioeconomic drought considers the impact of drought conditions on the supply and demand of economic goods and services.

Ecological drought has been proposed by Crausbay et al. 2017, referring to an episodic deficit in water availability that leads to ecosystem declines and affects ecosystem services.

▶ **Figure 4:** **Monthly ranked percentiles of wind speed at 10 meters above the surface from the ERA-interim atmospheric reanalysis relative to 1979–2017. Warm colors denote higher wind speeds and cool colors denote lower wind speeds. Adapted with permission from Reference 6.**



is accompanied by above-normal evaporative demand due to high temperatures, low humidity, and strong winds, agricultural and ecological drought conditions can occur rapidly. This scenario and the development of "flash drought" has occurred several times across the United States in recent years.[19] For example, in 2012, large precipitation deficits combined with record-high temperatures led to rapid drought development across the central United States. According to the USDM, widespread areas experienced a three-, four-, or even a five-category increase in drought severity over a two-month period. Similarly, the 2017 drought was characterized by near-record-dry weather during the early summer in conjunction with above-normal temperatures and above-normal winds from mid-May to mid-June (based on the ERA-Interim reanalysis). These factors ultimately contributed to a four-category increase in drought severity over a two-month period according to the USDM.

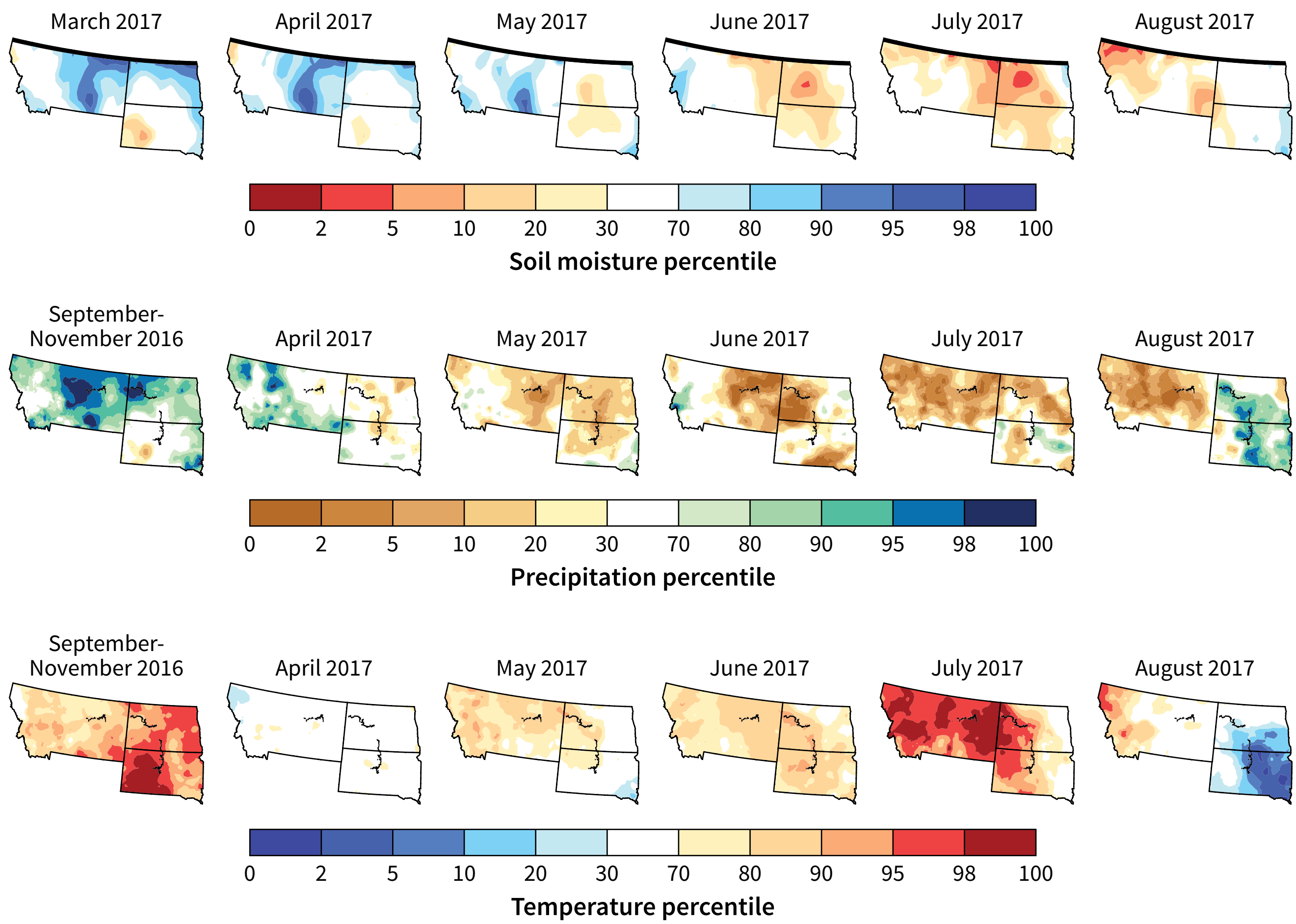
U.S. and North American Drought Monitors

The U.S. Drought Monitor (USDM) is a map that is updated each Thursday to show the location and intensity of drought across the country. The USDM uses a five-category system, labeled D0 (Abnormally Dry, a precursor to drought or when there are lingering issues/impacts/data that are still showing a dry signal, not actually drought) to D1 (Moderate Drought), D2 (Severe Drought), D3 (Extreme Drought), and D4 (Exceptional Drought). The USDM process uses a percentile ranking methodology in which several dozen indicators are analyzed each week, comparing current conditions to historical values for all variables. The convergence of these indicators dictates the severity of drought depiction on the map. The North American Drought Monitor (NADM) is a cooperative effort between drought experts in Canada, Mexico, and the United States to monitor drought on a monthly basis across the continent. It is based on the USDM methodology of using percentiles and a five-class system.

PROGRESSION OF THE 2017 U.S. NORTHERN PLAINS AND CANADIAN PRAIRIES FLASH DROUGHT

Although droughts are not uncommon in the region (*see Figure 1 on page 11*), the drought of 2017 was especially noteworthy due to its rapid onset. A defining characteristic of the onset of this drought was the rapid decline in soil moisture, caused principally by record-low precipitation during what is typically the rainiest time of year over the region. Other factors, including stronger-than-normal winds from mid-May to mid-June (*Figure 4*) and warmer-than-normal temperatures (*Figure 5*), played a secondary role in the rapid drought onset.

In the spring months prior to drought onset, soils with adequate soil moisture were observed throughout much of the area. Soils



▲ **Figure 5: Soil moisture, precipitation, and maximum temperature percentiles preceding and during the 2017 drought. Soil moisture percentiles are relative to 1916–2016 and are based on the University of Washington Surface Water Monitor. Precipitation and maximum temperature percentiles are relative to 1895–2016 and are based on NCEI 5-km gridded data.**

were especially wet over Montana during March and April of 2017 (*Figure 5*), where much of the eastern half of the state experienced soil moisture values above the 90th percentile (higher than 90% of measurements from 1916–2016). Additionally, soil moisture in the Dakotas and Canada was at or above the historical average. According to the NADM, no drought was recorded in the U.S. Northern Plains or Canadian Prairies in April with only a very small area registering as abnormally dry (*see Figure 6 on page 16*). The wet soils were the result of copious precipitation during the preceding autumn (*Figure 5*). Above-normal precipitation during September through November of 2016 and in April of 2017 was due to an increased frequency of moisture-bearing storms moving through much of the region.

Soil moisture rapidly declined during May 2017 in conjunction with near-record-low precipitation (*Figure 5*). Above-average evapotranspiration (*see "Evapotranspiration" on page 17*), due to daily high temperatures in the 80th percentile (higher than 80% of temperatures between 1895–2016) (*Figure 5*) and windy conditions (*Figure 4*), also contributed to the dry-down during May. According to the NADM, D1 (Moderate Drought) coverage increased during May, as did the amount of area covered by D0 (Abnormally Dry) conditions. A persistent high-pressure ridge was the main driver of environmental conditions that led to this drought. The high-pressure ridge deflected or prevented development of numerous moisture-bearing storms that typically move through the region at this time of year.

Rapid deterioration of soil moisture conditions continued during June and July 2017, pushing the region into severe and exceptional drought according to the NADM. By July, soil moisture fell into the 10th percentile (in the lowest 10%

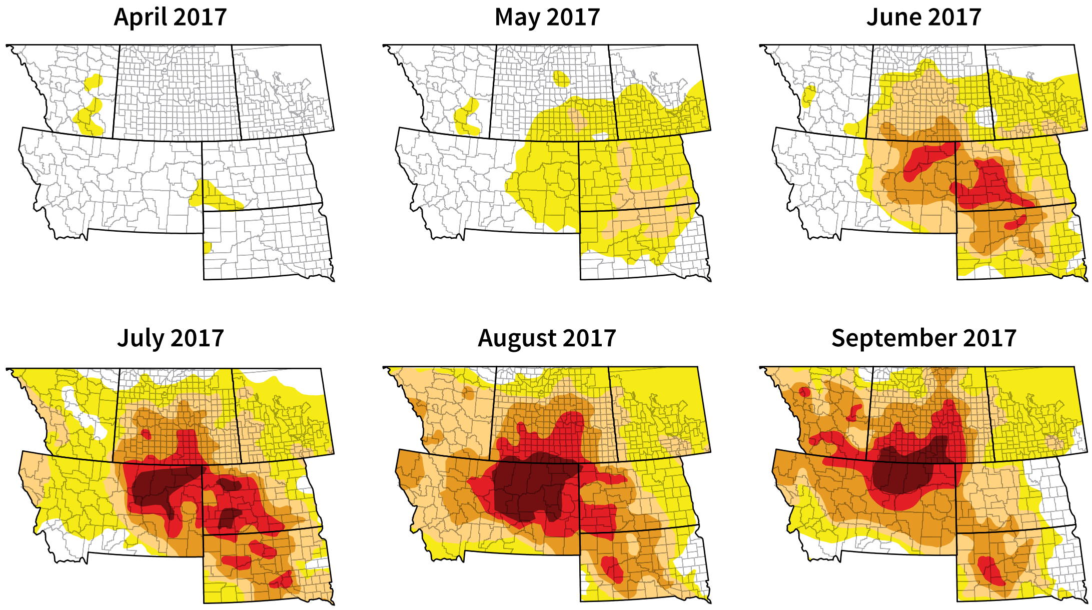


Figure 6: The North American Drought Monitor (NADM) from April to September 2017 showing the progression and intensity of drought across the U.S. Northern Plains. The NADM reflects the drought categories of the U.S. Drought Monitor across the U.S. States and Territories.

of measurements from 1916–2016) over the majority of the region. The desiccation of soils was due to exceptionally dry and warm conditions produced by the persistent high-pressure ridge that first developed during May. By the end of June, D3 (Extreme Drought) and D2 (Severe Drought) areas had developed, with D1 (Moderate Drought) and D0 (Abnormally Dry) conditions expanding as well (*Figure 6*). In July, D4 (Exceptional Drought) and D3 (Extreme Drought) conditions were evident in Montana and North Dakota with increases in the other drought categories across the entire region. For much of the region, both June and July were the driest on record, dating back to at least 1895. In fact, 2017 was the driest year on record at the NWS Glasgow Office in Montana (data going back over 100 years). July also saw the greatest maximum daily temperatures dating back to at least 1895 across almost all of Montana and western North and South Dakota.

August provided some drought relief to the Dakotas, but conditions continued to worsen in Montana. Much of the Dakotas saw cooler and wetter conditions that helped to increase soil moisture (*see Figure 5 on previous page*). By contrast, weather patterns continued to prevent moisture-bearing storms from passing through Montana resulting in historically-low precipitation across much of the state. September still showed large areas of D4 (Exceptional Drought) across the region. As the growing season ended, fall precipitation was not enough to recharge soil moisture or alleviate drought concerns prior to the winter freeze.

ATTRIBUTION OF THE 2017 U.S. NORTHERN PLAINS DROUGHT

Two recent studies—one from the NOAA Earth System Research Laboratory[11,12] and the other from the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center[22]—examined the effect of climate change on the 2017 U.S. Northern Plains drought. The studies reached similar conclusions despite using different methodologies and tools. First, the studies found that the principal driver of the drought was record low precipitation from May through July, and the cause of the low precipitation was natural variations of the atmosphere. Second, the studies based on model simulations of historical climate found that climate change increases the likelihood of agricultural droughts over the region through aridification of soils associated with warming near-surface temperatures.

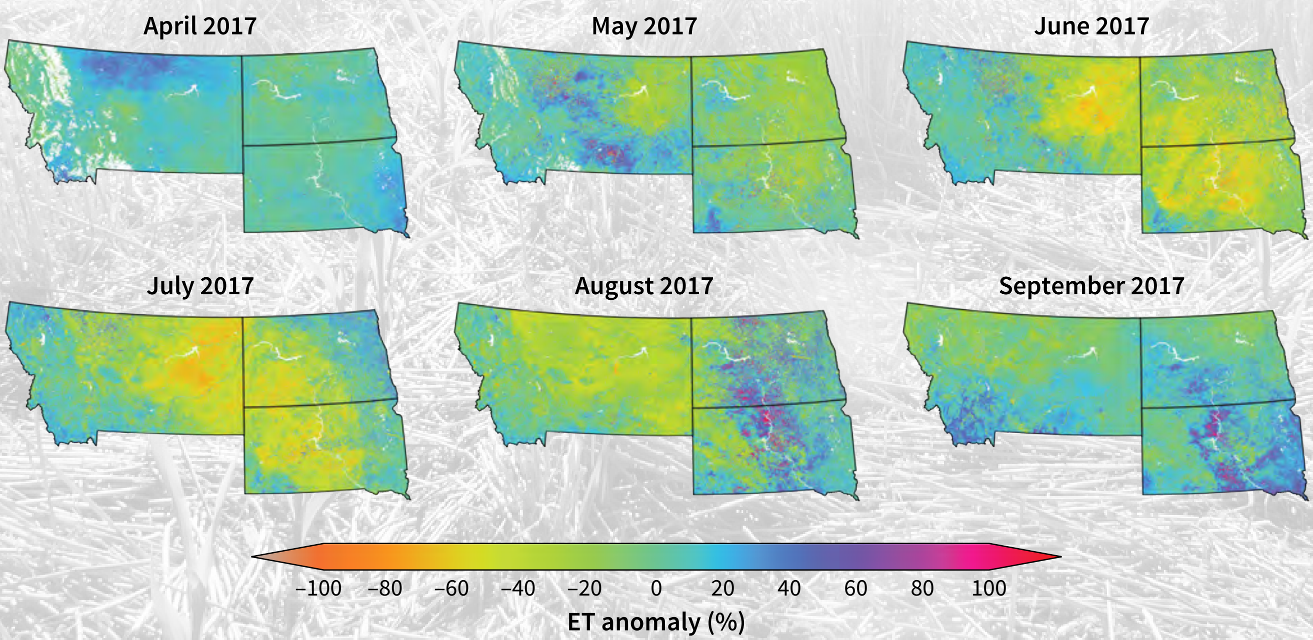
Evapotranspiration

Apart from precipitation, evapotranspiration is often the most significant component of the hydrologic budget in semi-arid settings and a major contributor to the rapid onset of drought. Evapotranspiration represents the water lost to the atmosphere by two processes: evaporation and transpiration. Evaporation is the loss of water from open bodies of water such as lakes, reservoirs, and from wetlands, bare soil, and snow cover. Transpiration is a process by which water is removed from the soil through plant roots and then released to the air through the plant leaves.

Evapotranspiration varies regionally and seasonally, and depends on a number of factors including the availability of water, temperature, humidity, and wind speed. If sufficient soil moisture is available, evapotranspiration will increase during warm and windy atmospheric conditions. However, if soil moisture supplies are depleted, evapotranspiration may decrease, as plants will limit transpiration in order to conserve water. As transpiration decreases, plants decrease their growth to limit the potential for mortality resulting in declines in agriculture production as well as range and forest ecosystem health.

Weather conditions were optimal for enhanced loss of moisture from evapotranspiration during the 2017 drought. The National Aeronautics and Space Administration (NASA) Numerical Terradynamic Simulation Group performed an analysis of the 2017 evapotranspiration anomalies relative to the period from 2002–2017 using the MODIS Global Evapo-transpiration (ET) satellite data product. In April to mid-May, moist soils in conjunction with warmer temperatures and windy conditions contributed to average to above-average evapotranspiration rates across the region (*Figure 7*).

These conditions were especially apparent in central to eastern Montana during May 2017 (*Figure 7*), where much of the area experienced abnormally high evapotranspiration rates. As May progressed to June, the lack of precipitation and depleted soil moisture led to a rapid decline in evapotranspiration amounts. Large areas of central to eastern Montana and the entirety of both North and South Dakota experienced exceptionally low evapotranspiration rates (*Figure 7*). These conditions reflected the limitation of water in soils as well as the rapid decline in plant health. Evapotranspiration rates increased across portions of North and South Dakota in response to the precipitation that fell in late July and August (*Figure 7*). Across Montana, evapotranspiration rates remained far below average from August to September due to the ongoing lack of rainfall.



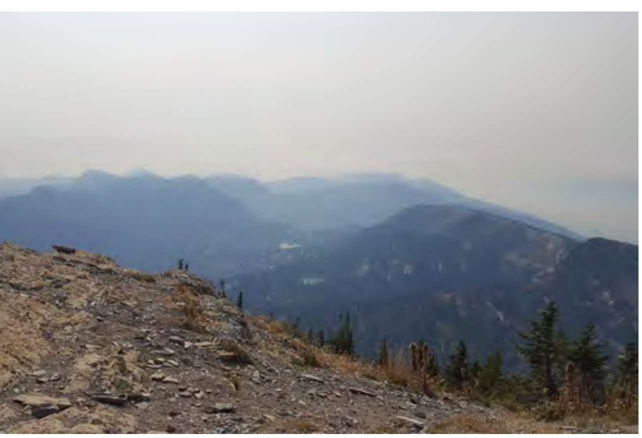
▲ **Figure 7: 2017 monthly evapotranspiration percentiles relative to the period from 2002–2017 using satellite data from the NASA MOD16A2 global operational ET product. Analysis was performed at 500 m and 8-day intervals across the region for Montana, North Dakota, and South Dakota. Blue-to-purple shading represents locations of higher-than-normal evapotranspiration. Yellow-to-orange shading represents locations of lower-than-normal evapotranspiration. As May progressed to June, the lack of precipitation and depleted soil moisture led to a rapid decline in evapotranspiration amounts. Large areas of central to eastern Montana and the entirety of both North and South Dakota experienced exceptionally low evapotranspiration rates.**

DROUGHT IMPACTS TO U.S. TOURISM AND RECREATION

The growing tourism and recreation industry often suffers under socioeconomic drought. From lack of snow for winter sports, to low river flows for rafting, to impacts to hunting and fishing, drought can result in large revenue losses to this industry.

The outdoor recreation economy across Montana and the Dakotas is responsible for approximately 149,000 jobs and $14.9 billion in annual consumer spending. According to the Outdoor Industry Association, large majorities of residents in each state participate in outdoor recreation activities every year: 81% in Montana, 76% in North Dakota, and 69% in South Dakota.[18] Beyond recreation opportunities for local residents, the region's tourism and recreational activities attract visitors from around the country and the world.

The summer drought in 2017 across the region caused notable impacts to tourism and recreation. Many of the examples presented below are from Montana, but similar impacts were also reported in the Dakotas.



▲ **Wildfire smoke from Mount Aneas in the Whitefish Range, Montana. Credit: Megan Syner, NWS**

NONRESIDENT IMPACTS

In 2017, wildfires consumed over 1.2 million acres of Montana lands. Over 54,000 acres in the Black Hills of South Dakota also burned in a rare December fire.[8] Wildfires and the resultant smoke impair travelers and outdoor recreationists well beyond the immediate boundaries of the fires. Studies by University of Montana Institute for Tourism and Recreation Research (ITRR) (nonresident survey related to tourism and recreation) found that 7% of nonresident visitors in July, August, and September shortened their stay in Montana due to smoke or fires, and 10% were not able to participate in their desired activities. Another 7% canceled additional trips to Montana. Of individuals who did not travel to Montana during the summer of 2017, 9% indicated they had planned to visit the state but canceled due to the smoke or fire. In total, Montana lost roughly 800,000 visitors in the third quarter of 2017. This decrease in visitation resulted in an estimated $240.5 million loss in visitor spending, or 12.4% for the quarter, translating to a 6.8% loss in expected annual spending.[20]

RESIDENT IMPACTS

Smoke and fires, wherever they occur, have the potential to affect resident recreation and travel as well. As many as 76% of all Montana residents indicated they experienced decreased air quality during the 2017 wildfire season. Of the adults surveyed in Montana, 69% said the smoke affected their outdoor activities. Extrapolating to the whole Montana population of 813,165 residents 18 and older, the 2017 wildfire season impacted the outdoor activities of approximately 561,084 Montana residents, which included running/jogging, hiking/walking, fishing, sports, and outdoor events. Hunting and fishing in each state contributes to the overall U.S. Northern Plains economy, with hunters in North Dakota

◀ **Pheasant hunting in the Montana grasslands. Credit: Outdoor Media**

◀ **(*Left*) Flathead River above Kerr Dam, Montana. Credit: Girl Grace. (*Right*) Smokey the bear and a fire danger sign in Custer, South Dakota. Credit: CrackerClips.**

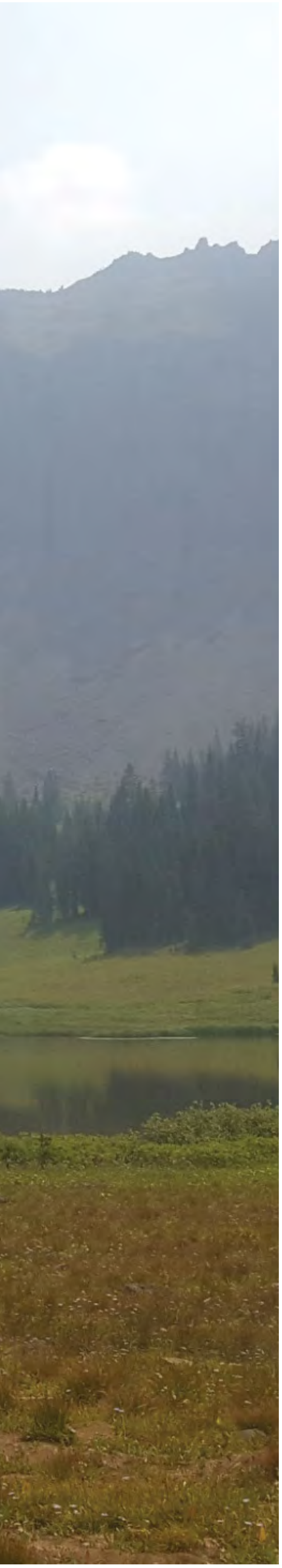
spending approximately $148 million annually, big game hunters and fishers in Montana spending $1.26 million annually, and the average hunter in South Dakota spending $2,200 annually.[3,13,17]

FISHING AND HUNTING

Droughts impact the availability of fish and game, and reduce the quality of fishing and hunting. The 2017 drought led to a downturn in bird hunting across the region, which had a significant impact on each state's economy. In South Dakota, the statewide Pheasants Per Mile Index for the 2017 pheasant brood survey decreased 45% (3.05 to 1.68) as compared to the 2016 statewide index.[2] This reduction in the number of pheasants and the impacts to brood size resulted in losses to local businesses and a reduction in tax revenues.

The total economic loss from drought to all the affected recreational activities is potentially significant and necessitates appropriate action from government and industry. For example, in Montana, the Office of Tourism and Business Development responded to the smoke and fires by sending daily updates to regional and local community visitor centers, explaining where travelers could still enjoy Montana. These daily updates were also sent to lodging facilities and campgrounds to keep their guests informed. Other responses included suggesting more indoor activities like visiting museums, restaurants, shopping malls, and indoor activity centers.

Wildfire smoke from Upper Hyalite Lake in the Gallatin Range, Montana. Credit: Megan Syner, NWS



DROUGHT OF 2017: MONTANA

Summer 2017 was full of extremes across Montana. The weather was consistently warm and dry, with the state having its second-driest and eighth-warmest summer on record (since 1895).

Events of this kind are increasingly more frequent in the last 30 years due to climate change.[24] Some areas of Montana received less than an inch of rain during the summer, and others went for long stretches without any measurable rainfall. Drought impacted nearly all of Montana in a variety of ways, including impacts to agriculture, recreation, tourism, fisheries, wildlife, water supply, energy, and human health.

The persistently dry and warm conditions and observed impacts to agriculture, wildland fire, and human health led to the activation of drought and emergency management plans. The Montana Governor's Drought and Water Advisory Committee worked closely with Disaster and Emergency Services to help ensure public safety by working with local, state, federal, and tribal partners. The Montana Department of Agriculture (MDA) followed North Dakota's lead and established the Montana Hay Hotline to assist producers suffering forage losses with locating available resources such as crops and pastures for lease.

Montana's 2017 fire season was the largest in the last 100 years. Fires across the state burned approximately 1.4 million acres and destroyed 141 structures.

MONTANA DROUGHT ASSESSMENT METHODS

The Montana Department of Natural Resources and Conservation (DNRC) convenes and staffs the Governor's Drought and Water Supply Advisory Committee (DWSAC). Chaired by the Lieutenant Governor with representatives from each of the executive branch agencies, the committee serves as the platform for the administration of drought policy and response in Montana. DWSAC advises executive natural resource agencies regarding the state's drought response, circulation of information to the public, and coordination of requests for use of state resources necessary to minimize impacts from a drought emergency. The committee also works closely with Disaster and Emergency Services for the promulgation of drought disaster declarations. A technical Drought Monitoring Sub-Committee (DMSC) performs weekly assessments of drought conditions across the state and serves as the primary liaison to the USDM authors. The DMSC consists of local, state, tribal, federal, and private partners.

The DWSAC convened monthly public meetings during the 2017 drought to assess current conditions, based upon input from the DMSC. Information gathered and presented at each meeting was distributed widely through media outlets, the DRNC's *Drought Management* website, *Basin Water Supply* newsletters, and by state and federal agencies represented at the DWSAC meetings. As conditions worsened, the DMSC convened bimonthly conference calls to evaluate conditions across the state. In addition, weekly input for the USDM was collected and shared through emails, based upon the analysis of drought indices, data collection, and on-the-ground observations by DMSC partners and other private individuals. The team leveraged tools and analyses provided by data from existing sources [including NOAA, U.S. Geological Survey (USGS), U.S. Bureau of Reclamation (USBR), the Bureau of Land Management (BLM), and the USDA) as well as new automated drought toolsets. Results of these weekly assessments were reported to the USDM, the Montana Governor's office, and other executive branch agencies.

▲ Red cattle. Credit: Alf Manciagli

Updates on drought conditions were posted regularly on the *Drought Management* website throughout the season. The site included monthly presentations of current drought conditions, historical perspectives, weekly maps containing statewide data on range/pasture conditions and use, and a web-based survey tool that enabled the public to report drought impacts—including changes to surface and groundwater availability (similar to the NDMC *Drought Impact Reporter*). The website also provided links to drought management resources related to emergency services, crop production, farm and range management, livestock production, feeds and grazing, and others.

MONTANA DROUGHT IMPACTS

Drought impacted nearly all of Montana in a variety of ways, including impacts to agriculture, recreation, tourism (*see page 14*), fisheries, wildlife, water supply, energy, and human health.

Agriculture: Early in 2017, signs pointed towards a productive season for Montana agriculture. The spring was warm and moist through April and into early May. At the end of April, soil moisture conditions were well above the five-year average, with 92% of topsoil and 89% of subsoil rated as adequate to surplus in terms of soil moisture. Spring seeding was underway for all crops, though most were behind the five-year average due to cooler-than-normal temperatures. At the same time, livestock producers were nearing the completion of the calving season and preparing to move their animals to summer ranges, 51% of which were rated good to excellent (compared with a five-year average of 31%) on crop progress and condition [USDA National Agricultural Statistics Service (NASS)].

In May, agricultural conditions in eastern and north-central Montana deteriorated rapidly.

Drought Response: Montana Case Study

In the spring of 2017, retirements and other personnel changes at the state and federal level left Montana challenged to deal with the ensuing onslaught delivered by the swift and severe drought. With the help of the Montana Climate Office (MCO), National Weather Service (NWS), and others, the state quickly restructured their Drought Monitoring Committee to provide more comprehensive, timely, and accurate input to federal, tribal, state, and local partners, the U.S. Drought Monitor, and the Governor's office.

On September 6 and 7, 2017, with air quality alerts from wildfires in effect across western Montana, the MCO and NWS offices in Montana hosted a gathering at the University of Montana that included university, state, tribal, and federal experts and officials to discuss climate services and needs, address communication barriers, and share knowledge on drought response and communication. The meeting enabled professionals to share and in some cases resolve ongoing communication barriers and technical hurdles during the height of this drought emergency. The gathering also gave all involved a much better understanding of the climate services offered by the groups represented along with associated climate and weather information needs.

◀ **Failed grain crop near Wolf Point, Montana. Credit: Michael Downey, MT DNRC**

Lack of rainfall, above-normal temperatures, and above-normal winds from mid-May to mid-July led to a quick decrease soil moisture. Crops in these areas began to suffer from the lack of water. Wheat stripe rust appeared in the central part of the state and winds further dried out crops and pastures in the northeast. By this time, winter wheat was rated at 48% good to excellent, compared to the five-year average of 60%. Pasture and range conditions declined from previous weeks to 49% good to excellent. By early June, producers in eastern Montana reported that the dry conditions had prompted them to sell cow and calf pairs due to poor grazing conditions. This trend continued as drought conditions worsened across the state.

Barley and spring wheat in poor condition was harvested for hay or grazed to make up for poor quality and low-production rangeland.

Through July, crop conditions deteriorated significantly due to hot, dry weather. Soil moisture conditions declined until 88% of topsoil was rated short to very short, and 80% of subsoil was rated short to very short (compared to 30% and 36%, respectively, in 2016). Winter wheat, for the state as a whole, was rated at 69% fair, compared to 2016 when 61% was rated as good to excellent. Across the state, the hay harvest was running at least two weeks ahead of schedule. Many producers have both cattle and hay, and in a typical year some hay is held and some is sold. But in 2017, very little hay was actually put on the market, worsening an already diminished market for livestock forage. Barley and spring wheat in poor condition was harvested for hay and/or grazed to make up for poor-quality and low- production rangeland. Low yields from grain and pulse crops became increasingly widespread and some areas exceeded the maximum claims for crop insurance.

Major impacts to livestock production occurred in August to early September with continued dry, hot, and smoky conditions. Stock water shortages were increasing and unirrigated pastures were in poor condition. Many operations were culling and shipping cattle to market early, and livestock sales across the state were three to four weeks ahead of normal. In addition, warmer temperatures and

▶ Aftermath of the Lodgepole Complex Fire near Roundup, Montana. Credit: Michael Downey, MT DNRC

▶ **Table 1:** Syndromic surveillance of respiratory-related Emergency Room visits during 2017 wildfires compared to the same period for 2016 in key wildfire-affected areas of Montana (Montana Department of Public Health and Human Services Communicable Disease Bureau, Epidemiology Program)

Name of fire	Timeframe of Report	Counties Examined	Respiratory-related ED visits in 2017 vs 2016
Alice Creek *Rice Ridge, Park Creek, Arrastra	July 22–Sept 10, 2017	Lewis and Clark; Powell	Not higher
Highway 200 Complex Fire *Moose Peak, Sunrise, Burdette	Aug 28–Sept 11, 2017	Lake, Mineral, and Sanders	1.3 times higher
Moose Park *West Fork, Highway 200 Complex	Aug 30–Sept 11, 2017	Lake, Lincoln, and Flathead	1.9 times higher
Rice Ridge Fire *Liberty, Park Creek, Alice Creek	July 24–Sept 7, 2017	Missoula and Powell	2.3 times higher

*Other fires within 100 miles

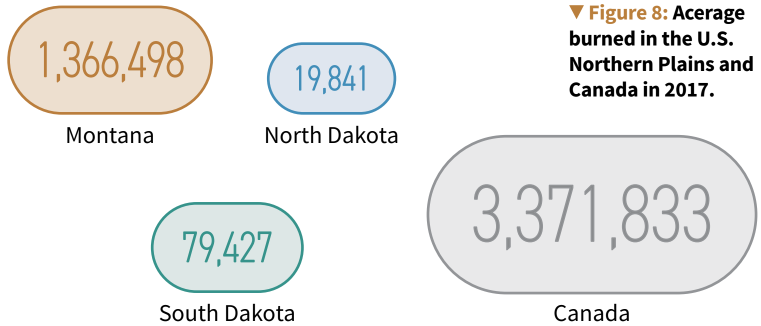
significant smoke associated with forest and grassland fires contributed to poor air quality, leading to stress and weight loss among the cattle. In general, low yields were reported on winter wheat and harvest was completed in early September. Sustained rainfall occurred across most of the state in mid-September. It was a welcome reprieve from the summer's record-setting dryness. Still, many producers continued to hold off planting for the next season and waited to see if conditions would continue to improve.

Wildfire: Montana's 2017 fire season was the largest in the last 100 years. The impacts associated with burned areas cascaded into loss of forage for wildlife and livestock, loss of crops, injury to human health, and loss of tourism revenue. Approximately 1.4 million acres burned in Montana with 2,420 individual fires recorded across the state during the fire season. Many of these fires were especially large and set records for amount of area burned. Early in the season, the Lodgepole Complex Fire burned 270,000 acres in eastern Montana, tied for the largest wildfire in the U.S that year. It destroyed 16 structures, utilities, and power lines, and burned significant amounts of hay and feed reserves intended for livestock. The Rice Ridge Fire occurred later in the season and was the second-largest fire in the western portion of the state. It burned 160,000 acres and resulted in significant impacts on air quality and public health for the nearby town of Seeley Lake. In late August, the historic Sperry Chalet within Glacier National Park was consumed by the Sprague Fire.

In total, the fires across the state destroyed 141 structures, with firefighting costs totaling $400 million (Northern Rockies Coordination Center). The 2017 fire season cost Montana $86 million in fire suppression costs (DNRC).

Human health: Smoke from wildfires in Montana and the Western U.S. caused poor air quality and health effects across the state. The pooling of air and inversions across western Montana valleys exacerbated the impacts of smoke for many mountain communities. The Department of Public Health and Human Services (DPHHS) Communicable Disease Bureau provided information on the potential health impacts from smoke, and used their Syndromic Surveillance System to pull data related to respiratory-related Emergency Department (ED) visits. Total respiratory visits during the 2017 fire season were compared to the same time period for 2016 in key areas of the state. Table 1 compares the number of respiratory-related ED visits in 2017 to the same time period in 2016.

Staff at the Centers for Disease Control Control and Prevention (CDC) compiled data on daily air quality recorded at monitoring stations in Montana from August 1st to September 12th, 2017. In the month of August, there was no single day when all of the monitoring stations in Montana reported good air quality. The town of Sidney experienced the most "healthy" days (22 days) whereas Seeley Lake had the most "very unhealthy" and "hazardous" days (14 and 11 days, respectively) during August.



▼ **Figure 8: Acerage burned in the U.S. Northern Plains and Canada in 2017.**

Drought and Wildland Fire

Drought is a common climate phenomenon that impacts wildland fire planning, fire behavior, and fire management before, during, and after fire events. Across the U.S. Northern Plains and Canadian Prairies, drought exacerbates the fire season and fires are often larger, burning longer and more intensely. Drought can lead to early curing of fine fuels and the desiccation of the larger logs and downed timber, while short-term precipitation deficits are responsible for the drying of the fine fuels which typically allow a wildfire to ignite and expand. In late July 2017, the location of the Lodgepole Complex Fire in east-central Montana saw D3 (Extreme Drought) to D4 (Exceptional Drought) and 60-day stretch of precipitation that was less than 50% of normal—a perfect recipe for a large wildfire. Drought conditions further deteriorated across western Montana from August to September, fueling a number of wildfires along the Great Divide. D2 (Severe Drought) to D4 (Exceptional Drought) was also noted for much of North and South Dakota through the summer and fall months. Large wildfires, including the Magpie Fire in North Dakota (5,100 acres) and the Wanblee Timber Fire in South Dakota (5,305 acres), burned during July. The record-breaking Legion Lake Fire (54,000 acres) in South Dakota was the largest December fire and third-largest fire of any month on record within the state. It burned under D1 (Moderate Drought) conditions during the second week of December, but was likely impacted by a lack of snow cover and short-term snow deficits in combination with warm temperatures and high winds. NOAA National Weather Service offices in eastern Montana were still issuing Red Flag Warnings into December when normally the fire season ends in early October.

As a whole, the summer and fall of 2017 brought significant and record-breaking wildfire activity to the U.S. Northern Plains region, with fires burning 4,837,599 acres in both countries (*Figure 8*). Montana witnessed historic wildfire conditions starting in early summer and continuing through the early fall. Although wildfire starts were close to decadal averages, the number of acres burned on state lands was over 400% of average. These events highlight the relationship between drought and fire, and the pressing need to better understand how drought and water cycle indicators can guide fire management. Beyond property damage, wildfire smoke also causes human health impacts. Record-breaking fire activity can create situations where ranchers, farmers, community members, and rural volunteer fire departments put their personal safety at risk to help protect their homes and buildings.

Water supply: Montana's surface and groundwater supplies remained relatively stable and the effects of the drought appeared only locally. The water supply response reflects the different time frames of drought, with hydrological drought taking longer to develop than other forms of drought. During early 2017, there was above-normal runoff in the majority of Montana's river basins due to mountain snowpack. Though the rest of the year brought dry terrestrial conditions, significant impacts were not observed in the main stem of the Missouri River or in the reservoir system. Across the region, minimal impacts to the energy sector were observed because flows to the major rivers were not generally reduced and reservoirs were full going into the dry season. There were some reported impacts related to stock ponds in Eastern Montana but this was not widespread.

▲ Sperry Chalet in Glacier National Park burned down on August 31, 2017, in the Sprague Fire that burned 2,000 acres west of Lake McDonald. Credit: NPS

MONTANA DROUGHT RESPONSE

The Montana Governor's Office issued a series of executive orders (*Figure 9*) to address the worsening drought and fire conditions over the course of the summer of 2017. Full text of these executive orders can be found on the Montana *Governor's website*.

Agriculture response: The USDA Farm Service Agency (FSA) provided federal farm program benefits to farmers and ranchers to support producers with drought and fire recovery. Key federal programs that provided benefits during the 2017 drought include the Noninsured Crop Disaster Assistance Program (NAP), Livestock Indemnity Program (LIP), Livestock Forage Program (LFP), Tree Assistance Program (TAP), Emergency Livestock Assistance Program (ELAP), Emergency Loan Program, and Emergency Conservation Program (*for details, see Tables 4 and 5 later in this document*). The Montana Department of Agriculture (MDA) conducted multiple hay lotteries for donated hay (a lottery to match producers in need with available hay when demand is greater than supply). The Montana Stockgrowers Association helped coordinate cash donations for the transportation costs of the donated hay.

▶ On September 10, 2017, the Montana Department of Agriculture (MDA) expanded its hay lottery due to worsening drought conditions and fires. Credit: MDA

State agencies: Many of the state agencies in Montana have drought response capabilities and responsibilities. Montana DNRC coordinates the technical DMSC and staffs the Governor's DWSAC, which transfers information between the Governor's Office and the Executive Branch agencies with respect to statewide drought and water supply conditions. The Committee also advises the Governor's Office on the need for drought declarations.

DNRC Forestry Division oversees fire suppression activities on all state and privately-owned lands in Montana. The division works closely with federal, tribal, and local partners to coordinate timely and efficient fire suppression activities, irrespective of land ownership.

The Montana Department of Military Affairs oversees the department of Disaster and Emergency Services, which coordinates with the Governor's Office to develop and distribute state drought and other emergency declarations with input from other executive branch agencies.

Montana Department of Environmental Quality actively monitors air quality impacts from wildfire smoke and provides regular smoke updates during the wildfire season. They maintain a website called *Today's Air* that enables Montanans to evaluate their local air quality. The website also offers guidance to impacted areas on how to minimize their exposure to smoke.

The MDA assists producers who are suffering from drought impacts with securing available state and federal drought relief. In 2017, MDA followed North Dakota's lead and established the Montana Hay Hotline to assist producers suffering forage losses with locating available resources such as crops and pastures for lease.

Executive Order No. 5-2017 (June 23)	Drought Emergency	18 Counties and 2 Indian Reservations
Executive Order No. 6-2017 (July 19)	Drought Disaster Declaration	D3: 14 Counties/ 2 Reservations; D2: 14 Counties/3 Reservations
Executive Order No. 7-2017 (July 23)	Fire Emergency	Numerous fires; firefighters and resources expected to reach critical shortages
Executive Order No. 7-2017 (August 13)	Fire Emergency	Current and new wildland fires warranted aggressive attacks
Executive Order No. 9-2017 (August 18)	Drought Disaster Declaration	Drought conditions worsened; MDT and MDOL eased restrictions
Executive Order No. 10-2017 (September 1)	Disaster Declaration	State of Disaster declared for Montana due to wildfires
Executive Order No. 11-2017 (September 18)	Drought Measures	Waived restrictions and permits for hauling of baled livestock feed
Executive Order No. 13-2017 (October 25)	Drought Measures Extension	Extended previous measures for hauling of baled livestock feed

▲ **Figure 9: Executive orders issued by Governor Steve Bullock of Montana during the 2017 drought. Abbreviations: D2, Severe Drought; D3, Extreme Drought.**

Late summer watering hole along Hwy 20 near Camp Crook, Harding County, South Dakota. Credit: Kevin Hyde, Montana Climate Office

DROUGHT OF 2017: SOUTH DAKOTA

In May 2017, drought impacts were noted in the north-central region of South Dakota. Early impacts affected the state's agricultural industry and continued through the duration of the drought. These early reports were surprising to many since the area received ample snowpack during the winter season.

Impacts of drought were first noted in the north-central region of South Dakota affecting the state's agricultural industry and initial reports included poor wheat crop establishment and growth, reduced water supply for livestock, and poor forage and pasture growth in the spring season.

The South Dakota State Drought Task Force was activated on June 8, 2017, to address the increasing drought severity and coordinate response.

South Dakota State University Extension and USDA partners held a series of drought management meetings across the drought-stricken region. Topics of these meetings focused on the agricultural sector, primarily feed and livestock herd management. USDA Natural Resources Conservation Service (NRCS) and FSA offices provided information on their drought disaster programs for agricultural producers.

Many fields were cut for feed or silage, since crop insurance deemed them as total losses.

SOUTH DAKOTA DROUGHT ASSESSMENT METHODS

The State Climatologist, housed within South Dakota State University (SDSU) Extension, leads a weekly discussion with partners across the state for the purpose of informing the USDM authors of local conditions. As the USDM reflected the increasing drought severity in the region based on this input, the co-chairs of the South Dakota State Drought Task Force (DTF) and Governor's office took notice. The SD DTF is co-chaired by the South Dakota Department of Agriculture and the Office of Emergency Management. D2 (Severe Drought) on the USDM is often utilized as a "soft trigger" for the DTF. After discussion with the DTF Co-Chairs, the South Dakota State Climatologist, and the State Fire Meteorologist on the current conditions and outlook for continuing drought, then-Governor Daugaard activated the DTF on June 8, 2017.

The South Dakota DTF met via conference call on a weekly or biweekly basis throughout the summer season to communicate with state agencies. Information shared via these calls included weather and climate updates, impacts, needs, and drought-related activities that agencies or partners were undertaking. This process follows the state's drought plan and the Drought Incident Annex, which is the document that describes the duties of the DTF and its members during times of drought. Later in the summer, the FSA and NRCS were invited to participate in the conference calls, as they also provide critical drought disaster assistance in the agricultural sector.

SOUTH DAKOTA DROUGHT IMPACTS

Agriculture: Early impacts affected small

▶ Rows of corn near Harrold, South Dakota. May 24, 2017. Credit: Laura Edwards, SDSU

grain crops, such as winter wheat and spring wheat. This was indicated by poor stands, short growth, low or no grain fill, and very low expected yields. Many fields were cut for feed or silage, since crop insurance deemed them as total losses.

Significant impacts were noted in late May and early June as large sales of cattle were reported in Aberdeen sales barns, the largest market in the region. These sales are an indicator of insufficient feed and/or water necessary to maintain herds. The culling or selling of livestock is a common, effective drought management strategy.

▲ Corn showing drought stress. May 18, 2017. Credit: Wade Jones

As the spring season progressed into summer, the drought area expanded westward and southward and increased to a maximum severity of D3 (Extreme Drought) on the USDM. Later-planted crops (such as corn, soybeans, and sunflower) suffered due to ongoing hot and dry conditions. Eventually, around mid-to-late July, corn and other crops were cut for silage instead of growing full season for grain harvest in the fall. These measures were dependent upon crop insurance and the determination of total losses sustained in many farm fields.

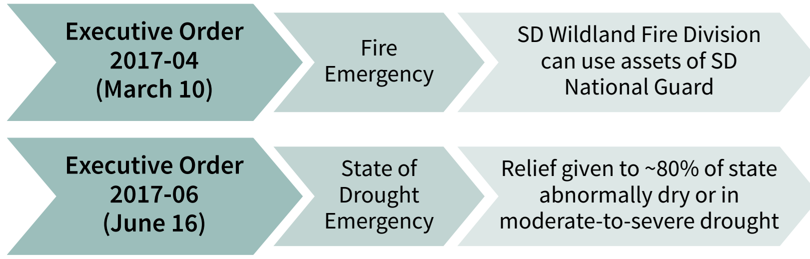
Wildfire: The 2017 wildfire season in South Dakota had over 1,600 wildfires, burning nearly 80,000 acres. This amount is twice the average number of wildfire starts and is 40% higher than the average yearly acreage burned. The Legion Lake Fire was the largest fire in 2017 and burned over 54,000 acres during the second week of December. The early onset of the drought and poor pasture growth led to very little wheat harvested and grass hay baled, resulting in a reduction in fires ignited by combines and hay balers.

Tourism: In 2017, the growth rate of South Dakota's tourism industry was down from previous years, and some of this reduction was a direct result of the drought. Pheasant hunting is a significant contributor to the state's tourism industry. Following the difficult winter of 2016, widespread and intense drought developed and persisted throughout the nesting and brood-rearing season. Extremely dry conditions during the primary nesting and brood-rearing season are believed to be the main contributor to the significant statewide decline in pheasant abundance. This impact reduced the numbers of both in- and out-of-state hunters who participated in pheasant hunting in 2017.

Water Supply and Quality: South Dakota did not experience any widespread significant impacts to water supply or water quality for human consumption. Due to collaboration between the South Dakota Department of Environment and Natural Resources and irrigators across the state, there were no shut-off orders issued.

SOUTH DAKOTA DROUGHT RESPONSE

Governor Daugaard activated the State DTF on June 8, 2017. Task Force members are charged with coordinating the exchange of drought information among government agencies as well as agriculture, fire, and water supply organizations. This exchange of information enabled the task force to better monitor the development and intensity of the drought and to evaluate the impact of drought on economic sectors of the state.



▲ **Figure 10: Executive orders issued by then-Governor Dennis Daugaard of South Dakota during the 2017 drought.**

State government agencies represented on the DTF include: the Governor's Office; Department of Agriculture; Department of Public Safety; Department of Environment and Natural Resources; Department of Game, Fish and Parks; South Dakota National Guard; and the Bureau of Information and Telecommunications. The State DTF met biweekly through the growing season, and every one to two months in the winter season as drought conditions lingered.

The South Dakota Governor's Office issued a series of executive orders (*Figure 10*) to address the worsening drought and fire conditions over the course of the summer of 2017. Full text of these executive orders are available on the official *South Dakota Secretary of State* website.

◀ **Aerial view of the Hilltop Fire in South Dakota on July 9, 2017. Credit: Laura Edwards, SDSU**

According to NASS, North Dakota farmers saw a 41% decline in oil sunflower production in 2017 compared to 2016. Credit: Dancsomarci

DROUGHT OF 2017: NORTH DAKOTA

During the growing season of 2017, North Dakota experienced its worst drought since 2006 based on the state Drought Severity and Coverage Index.[1] At its peak, more than 80% of the state was experiencing drought conditions, of which close to 8% was in the D4 (Exceptional Drought) designation.

On August 7, 2017, North Dakota Governor Doug Burgum requested a presidential disaster declaration based on the exceptional drought that has adversely impacted the state's agribusiness and producers, residents, and overall economy. The North Dakota Department of Emergency Services (NDDES) hosted periodic Drought and Wildfire Unified Command Team meetings to review drought status and impacts, and evaluate drought responses and potential measures for mitigation against further impacts. North Dakota State University (NDSU) maintained a Drought Information website that provided drought resources and best practices for crop production; farm and range management; livestock production; forage; avoiding livestock poisoning; maintaining lawns, gardens, and trees; as well as mental health resources.

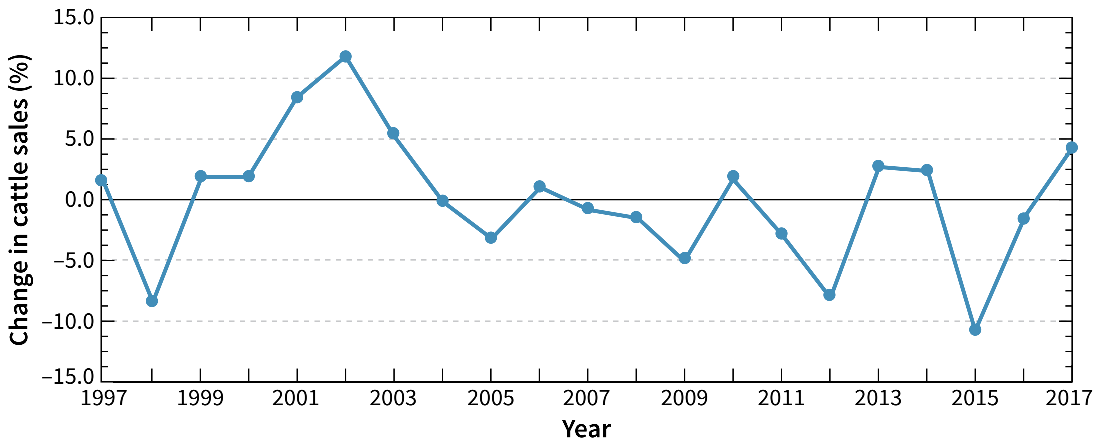
The 2017 drought in North Dakota not only hindered crop production, but also negatively impacted feeding and grazing statewide.

NORTH DAKOTA DROUGHT ASSESSMENT METHODS

The NDDES hosted periodic Drought and Wildfire Unified Command Team meetings, with leadership representation from the NDDES Division of Homeland Security, North Dakota State Water Commission, Forest Service (NDFS) and Department of Agriculture (NDDA). Meetings during the growing and fire seasons collected intelligence from various sources including, but not limited to, the ND State Climate Office, NDDA, NDFS, and the NOAA NWS and other federal agencies. These participants reviewed the current status, and long-term trends of the drought, and its impact on various resources. Further, they evaluated the current drought response and investigated potential additional response measures for mitigation against further impacts. The groups also monitored the current status and trends for wildfire conditions in North Dakota and nationwide.

NDSU hosted weekly calls among Extension offices in each county. Key personnel from the NDDA, FSA, and State Climate Office attended these conference calls to evaluate conditions across the state. Agents from each county were encouraged to participate in a weekly drought survey using a Google form. These surveys were evaluated by the state climatologist and communicated to the USDM each week following consultation with key NWS personnel and neighboring experts in South Dakota, Montana, Minnesota, and Canada. Drought conditions were updated weekly on an *NDSU Drought* information page throughout the season. The website included weekly PowerPoint presentations containing current drought conditions, historical perspectives, and weekly maps containing statewide data

▶ **Figure 11: Change in cattle sales (cattle and calves) compared to the 20-year average (1997–2017) for the three-state area of North Dakota, South Dakota, and Montana. Source: USDA, NASS**



on range and pasture conditions provided by county agents. The website also contained drought resources and best practices for crop production; farm and range management; livestock production; forage; avoiding livestock poisoning; maintaining lawns, gardens and trees; as well as mental health resources.

NORTH DAKOTA DROUGHT IMPACTS

The 2017 drought in North Dakota not only hindered crop production, but also negatively impacted feeding and grazing statewide. According to the NASS, there was a 41% decline in oil sunflowers, a 13% decrease in corn production, and a 4% decline in soybean production from the previous year. The report also indicated declines in other crops including canola, non-oil sunflowers, flaxseed, dry peas, lentils, safflowers, and alfalfa hay. The following impacts are summarized from assessments of reported drought impacts.

▲ **An abandoned granary in Dodge, North Dakota. Credit: Traveller70**

Water quality: County agents from the western part of the state reported declines in water quality throughout the drought season. Drought conditions compromised water quality in ponds and dugouts, and caused elevated levels of salts, minerals, bacteria, and total dissolved solids (TDS). Livestock were at higher risk of nitrate poisoning during the drought. In mid-July, high temperatures increased the evaporation rate which, when paired with lack of precipitation, facilitated toxic *Cyanobacteria* algal blooms in stagnant ponds and dugouts designated for cattle, making the water unfit for animal consumption. Despite an increase in pipelines for livestock water in recent years, many livestock producers hauled water to overcome the demand for water, which increased the cost for livestock maintenance.

Agriculture: The drought caused hay shortages in drought-stricken areas and forced growers to reduce herd size at a reduced market price. Some growers relocated livestock to rented pastures as an alternative to culling. This pattern can be seen across the region (*Figure 11*) in 2017 USDA NASS cattle sales data for Montana, North Dakota, and South Dakota compared to the 20-year average for cattle sold in the three states between 1997 and 2017. Cattle sales are a complex function of many factors other than drought (namely price) and "average sales" in livestock over a short period are dependent on many factors including weather, market prices, availability of grazing/feed, demand from other parts of the country, and food supply demand. But this simple analysis does indicate that 2017 cattle sales were 4.2% higher than average which is a similar magnitude as the increase in sales triggered during the 2013–2014 drought, and the 2003 drought.

◀ **The 2017 drought compromised water quality in ponds and dugouts. Producers hauled water to overcome the demand for clean water, increasing the cost of livestock maintenance. Credit: Laura Edwards, SDSU**

Based on the weekly NASS reports, crop and pasture conditions declined in July. Many pastures were heavily grazed, forcing producers to pull cattle off of the pastures early and start feeding them with the hay that was intended for winter feed. This resulted in the need for even more hay. The drought encouraged the growth of weeds, primarily Kochia spp., where row crops could not compete for survival. Rabbits and pheasants also caused considerable damage to gardens while looking for alternative food sources.

Wildfire: North Dakota saw above-average wildfire activity with an area burned that was 35% larger than the 5-year average. In total, 639 wildfires were reported to NDDES during the 2017 fire season. The state of North Dakota has no formal, centralized wildfire reporting system, so this number is not indicative of the total number of wildfires which likely occurred in 2017—which is assumed to be much higher. Air quality also declined due to fires in North Dakota and Montana.

NORTH DAKOTA DROUGHT RESPONSE

Several different state and federal agencies provided drought and wildfire resource information via outreach activities and through the *ND Response* website. In 2017, Drought Declarations were issued by 36 counties and one tribal nation. A Drought and Wildfire Unified Command Team was created by NDDES. North Dakota's Department of Human Services provided outreach to nongovernmental organizations regarding drought and wildfire concerns and facilitated the support of impacted communities.

▼ **On Sunday, September 3, 2017, tractor trailers hauled hay along Interstate 94 to drought-stricken farmers and ranchers in Western North Dakota and Montana. Credit: Northlight**

Agricultural response: North Dakota State Water Commission authorized and managed the Drought Disaster Livestock Water Supply Program. The NDSU held weekly conference calls throughout the growing season to collect drought information in each county from the NDSU Extension personnel scattered across the state. Extension Services supported communities and producers impacted by drought via a series of outreach and information sharing brochures and webinars. This effort included

▶ One of the "hay haulers" producers can access using North Dakota's Drought Hotline Map. Credit: North Dakota Department of Agriculture

▶ (*Left*) North Dakota bison herd. Credit: Anh Luu. (*Right*) Drought-damaged cornfield. Credit: Somchaip.

North Dakota Request for Presidential Major Disaster Declaration

On August 7, 2017, North Dakota Governor Burgum requested a presidential major disaster declaration for drought-affected areas of the state, based on severity of drought conditions impacting producers and other residents. The request was sent through the Federal Emergency Management Agency (FEMA) Region VIII office, and sought to activate the Individual Assistance Program as well as authorization for Direct Federal Assistance. The governor also requested additional staff from the U.S. Department of Agriculture and other federal agencies to provide expertise to those impacted by the drought.

FEMA Region VIII organized an interagency drought task force and examined drought resources across the government for states impacted by drought. FEMA determined "that supplemental federal assistance under the Stafford Act was not appropriate for the event" and that furthermore, "drought relief was available through other federal programs and sources." The request was denied on October 7, 2017 in a letter from FEMA Administrator Brock Long. While Stafford Act declarations are most often granted for natural disasters, the guidelines established in the Code of Federal Regulations and other guidance do not address the unique effects of widespread drought. Specifically, the Stafford Act defines major disasters as any natural catastrophe or fire, flood, or explosion, regardless of cause, which is of sufficient severity to warrant assistance under the act to alleviate the damage, loss, or hardship caused by the event.

opening an online FeedList that connected ranchers in need of hay with ranchers willing to offer spare hay. North Dakota Department of Agriculture opened a Hay Hotline which initially started as a phone-in service, but later transitioned into an interactive *online map* where hay shortages and surplus were identified along with hay haulers willing to transport the hay. Hay donations were offered through a lottery-style system, in addition to the NDDA and the NDSU efforts to provide relief to livestock producers affected by drought. Winners of the lottery received two semi loads of hay from donors across the nation. The lottery system soon was extended into South Dakota and Montana. The NDDA Emergency Hay Transportation Assistance Program provided $1.5 million in aid to nearly 500 successful applicants for about one-third of their hay-hauling costs. NDDA provided drought information for crop and livestock producers via a *Drought Resources* website. Finally, the *North Dakota FSA eNews* listed mental health resources for farmers and ranchers who might be feeling mental health impacts due to the financial stress resulting from the drought.

Executive Order 2017-06 (June 22)	Drought Emergency	ND State Water Commission water supply assistance program in 26 counties
Executive Order 2017-07 (June 26)	Statewide Fire and Drought Emergency	ND State Emergency Operations Plan activated
Executive Order 2017-06.1 (June 30)	Drought Emergency	For counties in Extreme Drought and adjacent counties
Executive Order 2017-08 (July 10)	Drought Declaration of Emergency	Waives restrictions pertaining to hauling of hay, water and livestock
Executive Order 2017-09 (Jul 12)	Drought Declaration of Emergency	Suspends NDCC 39-06.2-06 (3)(d) to remove 150-mile limit on distance for farm licensed vehicles
Executive Order 2017-11 (July 22)	Drought Declaration of Emergency	Waiving restrictions pertaining to the transport of hay, water and livestock
Executive Order 2017-12 (July 26)	Drought Disaster Declaration	For Counties and Tribal Nations experiencing extreme and longterm drought
Executive Order 2017-11.1 (July 28)	Drought Measures Extension	Extends previous previous executive order
Executive Order 2017-11.2 (August 26)	Drought Measures Extension	Extends previous previous executive order

▲ **Figure 12: Executive orders issued by Governor Doug Burgum of North Dakota during the 2017 Drought.**

Wildfire response: the North Dakota Forest Service provided expert fire conditions and behavior analysis to the Information and Intelligence Unit, directly supporting local and federal response efforts. The North Dakota National Guard, Department of Game and Fish, and Department of Parks and Recreation maintained readiness to provide fire response assistance to local and tribal authorities. The North Dakota State Fire Marshal provided fire management planning and outreach to the statewide fire community. Fire Emergency/Burn Ban Declarations were issued by 34 counties and two tribal nations during the fire season. Open fires were banned on the Oahe Wildlife Management Area in Emmons and Burleigh Counties.

The North Dakota Governor's Office issued a series of executive orders (*Figure 12*) to address the worsening drought and fire conditions over the course of the summer of 2017. Full text of these executive orders can be found on the official North Dakota state website.

Timpsula, or prairie turnip (*Pediomelum esculenta*), growing in Montana's Charles M. Russell National Wildlife Refuge. Linda Black Elk, an herbalist at Standing Rock,observed an early growth cycle in 2017. By harvest, it had already dried out due to the warm weather. Credit: Matt Lavin

DROUGHT OF 2017: TRIBAL NATIONS

Tribes throughout the U.S. Northern Plains continue to experience impacts from the 2017 drought on their communities, land, and natural and cultural resources.

Drought has impacted vegetation and local water resources in ways that threaten agricultural systems and ecosystems that are critical to supporting the tribes. The challenge for tribal environmental and natural resource managers is to understand these impacts and incorporate actions into their adaptation planning initiatives to reduce the impacts of future droughts.

By early June 2017, the Fort Peck Indian Reservation in Montana was in moderate drought and experiencing a variety of terrestrial impacts to native and cultivated plant communities. Conditions deteriorated rapidly from that point, with D3 (Extreme Drought) and D4 (Exceptional Drought) conditions emerging by mid-July. By mid-September, all seven of Montana's Indian reservations across the state were experiencing D2 (Severe Drought) to D4 (Exceptional Drought) conditions. The seven Indian reservations of the Missouri River Basin in North and South Dakota also experienced D2 (Severe Drought) to D3 (Extreme Drought) through early October.

The drought of 2017, along with high temperatures, overtaxed the Mni Wiconi water delivery system in South Dakota so much that the tribes were asked to reduce their water use for the first time ever.

DROUGHT IMPACTS TO TRIBAL NATIONS

Due to the mostly terrestrial nature of the drought, impacts differed greatly within local regions depending upon the availability of surface water supplies as well as the condition and extent of the infrastructure required to deliver surface and groundwater. Some farmers on the Fort Belknap and Fort Peck Reservations in Montana, with properties serviced by their respective irrigation projects, came through the drought in much better condition than neighbors without access to water supplies from other on-and-off-stream storage projects. In times of drought, many sectors experience economic hardship, especially on Indian Reservations where a lack of support resources like social services and agricultural outreach support is well-documented.

Agriculture and farming: Drought impact reports, gleaned through conversations with tribal leaders and tribal resource managers, emphasized numerous challenges—mostly related to agricultural production. Impacts to agriculture, livestock, and subsistence farming on reservations are further complicated by land tenure. Producers on the reservation lease the land, unlike off-reservation producers who tend to own their land. This distinction makes on-reservation producers more dependent on short-term forage production and increases their drought vulnerability. Reduced forage production can also force livestock producers to either purchase feed or reduce herd size. Changes in livestock production impact both individual producers as well as the tribe's revenue from pasture leases.

In Montana, inadequate stock water from depleted ponds and reservoirs prevented full utilization of upland forage. Spring plantings on the Fort Peck, Fort Belknap, and Rocky Boy's Agency in Montana were generally insufficient to produce even a hay crop, although some fields did provide sufficient forage for fall grazing. Across northeast Montana, tribal cattle producers were severely challenged with inadequate forage for grazing and hay production. As a result, what little hay that was produced sold quickly, and many producers were forced to cull herds due to the absence of available forage. Drought impacts related to forage availability continued into the spring and summer of 2018 for all reservations east of the Continental Divide. A long 2016–2017 winter depleted hay stocks and a late spring delayed the growth of new forage. Resource managers on the Fort Peck, Fort Belknap, and Blackfeet Reservations expressed frustration resulting from pressure to open access to grazing leases on tribal lands earlier than usual to accommodate producers with depleted forage reserves. Forage demands were exacerbated by land managers' decisions to limit access to grazing on lands overstressed from severe drought conditions through late 2017.

The Crow Creek Tribe in South Dakota reported that winter wheat production suffered as a result of low soil moisture. Corn and soybeans for dry land crops also fared poorly in 2017. Crops like sunflowers and milo were not affected as badly. In Montana, fall-planted crops like winter wheat performed substantially better than spring-planted crops such as barley, spring wheat, peas, and lentils—which, in many fields, failed to germinate.

Water quality: Another issue for livestock is water availability. According to Mary Scott (NRCS Tribal Liaison), one of the main impacts with the drought the NRCS program responds to is blue-green algae blooms. Animal deaths due to algae blooms on reservations were reported in 2017. Drought also reduces plant growth, commonly thought of as reducing forage production available to wildlife, buffalo, and livestock. Lower forage production often leads to buffalo and cattle sales.

Ecosystems and wildlife: The 2017 drought reduced the amount of vegetation that grows in a given year and impacted the amount of food available for wildlife on several reservations. Reductions in wildlife can impact subsistence hunting and tribal-guided hunting opportunities. The drought also increased production of invasive plant species and dried-out trees, making them more susceptible to wind damage and bug infestation. On the Rosebud Sioux Reservation, primary and secondary drought impacts included epizootic hemorrhagic disease and bluetongue virus in wildlife. An increased abundance of non-native plants reduced forage production, impacted wildlife, buffalo, and wildland fire. Tribal land managers also observed increased plague in prairie dog towns and degraded water quality leading to reduced fish populations. There is concern that the increased competition from non-native and invasive plant species during the drought detrimentally affected environmentally- and culturally-significant plants.

Other tribes who manage big game animals stated that disease and the drought decreased the population of big game, limiting the number of hunting licenses available. Harvest numbers for big game are set in February and March, so an unforeseen drought, like in 2017, can lead to overharvest and negative impacts to the overall animal populations.

The Crow Creek Tribe in South Dakota reported a decrease in upland birds due to lack of water and additional haying. Waterfowl nesting habitat in fall migration rest areas was also limited by the depletion of surface waters.

Water supply: Drought impacts on water supply are often localized, depending on how freshwater is supplied—whether via aquifers, wells, springs, reservoirs, or water delivery systems. The drought of 2017, along with high temperatures, overtaxed the Mni Wiconi water delivery system in South Dakota so much that the tribes were asked to reduce their water use for the first time ever. These limits impacted residential water users and livestock producers who rely upon the Mni Wiconi system for water. While there are many municipal wells on the reservation, they are not necessarily hooked up to the water system and are therefore not broadly useable in the event of water shortages. In 2017, the USBR restricted water use on the Pine Ridge and Rosebud Sioux Tribes. The water use restrictions appeared effective, as the overall usage went down during the drought.

On the Standing Rock Reservation, tribal leadership issued a water restriction and enforced a burn ban. During that time, restrictions included lawn watering, the use of personal swimming pools, and a ban on fireworks. Other tribes, such as the Rosebud Sioux of the Dakotas, rely on groundwater aquifers for their water supplies. The Rosebud Sioux monitored and collected data on their aquifers during the 2017 drought. There are usually delays between conditions on the surface and impact to groundwater; typically, it takes 25–30 days for the aquifers underneath the reservation to show the effects of drought. Drought vulnerabilities of aquifers on the Rosebud Sioux Reservation include irrigation overdraft and contamination, but near-term well production was not affected by the 2017 drought.

In Montana, residents of Rocky Boy's Agency and the nearby town of Box Elder faced severe domestic water shortages in early July as a result of the drought coupled with the failure of a major water storage tank. Chippewa Cree Tribal officials implemented water restrictions, prohibiting residents of the Box Elder area from watering their lawns, filling swimming pools, or washing their vehicles. Despite these restrictions, the demand for water continued to significantly outpace inflow from the system's four drinking water wells. The domestic water crisis was finally stemmed by the development of a new groundwater well and repairs to the damaged storage facility. Domestic water supply shortages on the Rocky Boy's Agency are chronic. The completion of a pipeline from Tiber Dam to the Reservation and other communities in the area will greatly improve water security in the area. Dam maintenance is another issue that is complicated by drought. Reservoir levels on some reservations were extremely low, and it was important to take care of the embankments.

▲ **Chokecherry tree in Alberta. A rise in pests and other changes in growing conditions have led chokecherries—which used to be a main source of food for the Lakota people—to develop undesirable characteristics. Credit: Amanda TQ**

Cultural resources and cultural lifeways: All tribes who participated in the 2017 Drought Impact Assessment clearly understood the need to protect, preserve, and enhance their cultural resources for current and future generations—especially in a changing climate.

According to Russell Eagle Bear, Lakota Leader in Traditional Knowledge and Historical Preservation programs, it is getting harder to be an Indian during drought. He observed that, generally "in the past, reservations would experience a few hot days in a row and then it would cool down. Now, the hot days have turned into hot weeks that never seem to go away, and the temperatures of those times seem to be getting hotter and hotter. Creeks and streams on the reservation all used to run year-round with drinkable water and trout. Now, no creek is potable and the fish are gone. Tribal members used to have large gardens to supply their families with food, now there are hardly any gardens."

After the 2017 drought, the Tribal Historic Preservation Office programs initiated a plant study to better understand the viability of 415 plants that grow on the Rosebud Sioux Reservation; 405 of the species were identified as culturally significant. Initial findings from the plant study indicate that timpsula (prairie turnip), plums, and chokecherries, which used to be the main sources of food for the Lakota people, have developed undesirable characteristics. The study also found that plums are being killed by late spring freezes, and poison ivy is encroaching on chokecherry plants and preventing harvest. At the same time, there are also culturally-significant, medicinal plants that have not been seen for years but are coming back.

Another cultural leader, Linda Black Elk, Standing Rock Sioux Herbalist, believes that invasive species are increasing, natural species are decreasing, natural plants are moving northward, and that the dry climate is favoring invasive species. She noted, "The traditional plant timpsula (prairie turnip) was available earlier this year, around the end of May, and is usually unavailable until around June 19". When she came to harvest them, they were already dried out by the warm weather. She also noted that Chiyaka (wild mint tea)—which requires more rainfall and standing water—was limited by the hot and dry conditions. A rise in pests affected the production of chokecherries and buffalo berries, resulting in diminished availability of these important fruits.

While the wet conditions in the fall of 2016 and above-normal snowpack in the western half of Montana benefited the production of berries and medicinal plants, the eastern two-thirds of the state saw diminished yields due to the hot and dry conditions beginning in late spring and persisting through the summer. Warmer-than-usual temperatures in the late summer and fall resulted in a longer-than-normal growing season and affected some cultural activities by delaying the harvest of berries and medicinal plants.

Human health: The 2017 drought caused tribal health officials to express concern regarding the effects of excessive heat stress on children, particularly in homes without air conditioners. Tribal community members were also concerned about the heavy toll of natural disasters on the health of residents on the reservations, which is exacerbated by the high poverty levels. Natural disasters that commonly occur on the reservation and affect human health are: hail storms, snow storms, floods, fires, and drought. Many families on the reservations cannot afford air conditioning and are vulnerable to heat stress during hot and dry periods. Finally, excessive heat and drought conditions, like those in 2017, gives rise to concern that tribal war veterans who experience PTSD might be vulnerable to flashbacks and other related challenges when temperatures increase. Tribal members on the Flathead, Blackfeet, Rocky Boy's, and Fort Belknap Indian Reservations also reported health impacts as a result of excessive smoke from wildland fires beginning in late July through early October 2017. Tribal leaders expressed concern that drought may be partially responsible for a long-term trend in decreased life expectancy on the reservations and noted the need for further investigation into this trend.

Wildfire: About 200 fires were reported on the reservations during the 2017 fire season. A fireworks ban was put in place to try to reduce fire starts. Tribal fire managers believe that fires are getting harder to put out, and that the fires are staying hot during the night. In the past, cooler night time temperatures suppressed fire starts. The warmer temperatures also appear to result in longer and more intense fire seasons. They also noted that in recent years bad fire seasons occur every 5 to 6 years. Burn bans were helpful in reducing the number of fires. According to the Crow Creek Tribe, the 5-year fire occurrence average from 2013 to 2017 is 47 fires per year. In 2017, Crow Creek Agency has 67 wildland fires. The largest, Numpa, was 51 acres.

TRIBAL NATIONS' RESPONSE AND NEXT STEPS

Many of the U.S. Northern Plains tribes are involved in completing climate and drought vulnerability assessments and adaptation plans to build resilience to climate-related events. During the 2017 drought, many steps were taken to try to lessen the impacts on tribal communities. In light of lessons learned, tribal water managers are concerned that uncontrolled water use could lead to greater vulnerability. Current tribal policy of water use on the reservation is not effective at identifying or penalizing the abuse of water supplies. According to Young Colombe, the Rosebud Sioux Tribe Water and Sewer Manager, there are problems with perception and behavior that present major obstacles to improvements in water conservation on the reservation such as people leaving their outdoor faucets running nonstop or refilling their swimming pools weekly, instead of using chemicals to treat the water to prevent the development of algae. During the 2017 drought, cattle often congregated by the water tanks drinking all day. There is concern that this behavior further stresses the water system. This problem raises the question of whether or not existing livestock water systems are large enough to provide adequate supply during the hottest and driest parts of the season. The Mni Wiconi water project brought a guarantee of water, but there is still a need to balance water availability while promoting smart water use.

Tribal leaders and resource managers generally offered positive reviews of outreach efforts by the USDA farm programs and drought response coordination efforts by local, state, and federal partners. The Montana Governor's Office of Indian Affairs hosted a conference call between the Blackfeet Tribal Council and the Montana DNRC to address questions regarding the development of the USDM maps. Blackfeet Tribal Leaders and resource managers expressed frustration with the slow transition from D2 (Severe Drought) to D3 (Extreme Drought) drought designations. The USDA uses the USDM as a trigger for drought relief programs. Despite the use of objective metrics like the Standardized Precipitation Index, Standardized Precipitation Evapotranspiration Index, Evaporative Demand Drought Index, and others, the observed impacts in areas on the Blackfeet Reservation and on other private land identified by the USDM as D2 (Severe Drought)—such as crop failures, depleted stock water resources, and diminished forage—appeared strikingly similar to impacts classified under D3 (Extreme Drought).

Today, the NRCS is taking drought mitigation steps to assist livestock producers such as offering cost share programs to construct and improve water systems for livestock. Water conservation and proper range management practices are most effective through a combination of planning, education, outreach, and policy changes as necessary.

The Rosebud Sioux Tribe Wildlife department has already implemented drought mitigation strategies for ecosystems and wildlife. One strategy is to use money from the sales of hunting licenses to purchase and supply hay for supplemental winter feed to buffalo and elk herds. They have also started planting feeding plots for wildlife, such as a 180-acre cornfield.

To help reduce tribes' vulnerability to drought, tribal leaders in Montana and the Dakotas have identified the need for increased and improved local weather data. There is a perception among the tribes that the USDM is inaccurate at local scales. Tribes want to get more involved in drought management planning to better prepare for the response to future droughts. Because monitoring of precipitation, temperature, and streamflow is often limited on reservations, there is a desire to strengthen these networks to support better-informed, more timely decision-making on reservations.

In terms of drought early warning information, tribes stated that they do not receive much advanced warning and that the short-term updates provided through drought webinars offered by NOAA, NIDIS, State Climatologists, USDA, and others in the region are inadequate for effective tribal decision-making. The tribes understand that it is difficult to predict long-range precipitation, especially in light of the extreme weather and climate variability common to the region. The tribes encourage the development of consistent communication and collaboration between tribes, NIDIS, and other local, state, and federal entities to ensure the sharing of information and resources necessary for drought planning, management and response.

Forest fire near Roger's Pass in Glacier National Park, British Columbia, Canada. Taken from the Trans Canada Highway on August 17, 2017. Credit: Moore Media

DROUGHT OF 2017: CANADIAN PRAIRIES

The southern Canadian Prairies, especially southern Saskatchewan, experienced a wide range of drought impacts, including poor spring germination, stunted crop development, heat stress, accelerated crop maturity, poor grain fill, below normal yields, water supply shortages, poor pasture conditions, feed shortages, and wildfires.

DROUGHT ASSESSMENT METHODS

In Canada, Agriculture and Agri-Food Canada (AAFC) maintains the National Agroclimate Information Service, which assesses drought across the country monthly via the Canadian Drought Monitor (CDM). Initial assessments are completed during the last week of each month using various indices, indicators, and impact information. The assessment begins with an evaluation of meteorological conditions, including precipitation and temperature departures from average and precipitation percentiles at various time scales produced from station and modeled data. This is followed by the incorporation of various drought indices, models, and satellite data, including the Standardized Precipitation Index, the Palmer Drought Severity Index, soil moisture models, vegetation health index, and satellite soil moisture. The CDM authors participate in various provincial drought committee and information conference calls throughout the year to gather regional and local input for the assessment. To understand the impacts of drought to the agricultural sector, AAFC conducts biweekly climate-related production risk meetings with representatives from all regions of the country. In addition to these meetings, AAFC surveys producers on a monthly basis to gather farm-level information regarding weather and climate impacts to producers.

The authors at AAFC maintain strong lines of communication with USDM colleagues to compare assessments and collaborate on U.S.–Canada border regions. Once the end-of-month data are collected, a small team at AAFC identifies regions of improvement or degradation from the previous month's assessment. A draft assessment is sent out for comments to the CDM Review Team, which consists of regional authorities within the provinces and nongovernmental organizations. The assessments, along with additional material, are posted on the department's *Drought Watch* website early each month. The CDM portion of the website includes the monthly CDM map, an interactive mapping application describing conditions across the country, and a variety of tools to analyze the drought—including agricultural statistics. The Drought Watch website itself provides additional information on current conditions, including many of the key drought indicators used in the assessment, information on agricultural programs related to climate-related risks, and information for producers to better manage the risks associated with droughts and other natural hazards.

DROUGHT IMPACTS

Agriculture: Livestock production was especially hard-hit due to the widespread scarcity of feed and water; some herds were reduced in response to drought conditions. Reliable water sources were negatively affected, and several failed to meet producers' requirements. Crop production losses were also significant for a wide variety of crops across the region. In parts of the Southern Prairies, spring seeding was completed well ahead of the 5-year average due to limited snowpack, an early melt, above-normal spring temperatures, and dry conditions. However, dry conditions in some areas led to uneven germination, which resulted in crops developing and maturing at different stages within the same field. This variability made for challenging field management decisions, such as the timing of herbicide and fungicide application.

Early in the growing season, producers reported very dry pastures with low productivity and below-normal first cut hay yields, which gave rise to concerns about feed availability. Low hay yields and poor pasture conditions resulted in some producers selling off a portion of their cow-calf pairs to reduce the risk of running short of hay and feed later in the year. Drought also negatively impacted the nutritional value of pasture and forage crops, which necessitated supplemental feeding to increase nutrition intake.

Due to drought, livestock production was impacted by water scarcity and salinization concerns, feed shortages, and heat stress across the region. On July 7, more than 200 cows and calves were found dead in a pasture in southwestern Saskatchewan due to salt poisoning, heat stress, and dehydration. Sulphate levels in the water were reported to be more than three times the lethal concentration. The rancher in this case faced over $300,000 in losses and Saskatchewan's Chief Veterinary Officer investigated the incident. Following this discovery, the province recommended producers have

▶ **Table 2:** **2017 crop yields for the southern regions of Saskatchewan compared to the 10 year Provincial Average (source: Agriculture and Agri-Food Canada).**

SASKATCHEWAN 2017 CROP YIELDS

Crops	Estimated Yield			
	Southeast	Southwest	Provincial	10-year provincial average (2007–2016)
Winter wheat (bushel/acre)	43	33	43	42
Fall rye (bushel/acre)	41	27	38	37
Hard red spring wheat (bushel/acre)	41	33	43	36
Durum (bushel/acre)	34	33	36	35
Oat (bushel/acre)	66	51	89	75
Barley (bushel/acre)	58	43	63	57
Canary seed (lbs/acre)	949	873	1,123	1,211
Flax (bushel/acre)	19	17	21	22
Canola (bushel/acre)	29	25	34	31
Mustard (lbs/acre)	621	633	746	1,010
Soybean (bushel/acre)	16	13	18	N/A
Pea (bushel/acre)	32	25	33	34

their stock ponds tested, which increased demand on water testing labs.

Across the southern Prairies, the warm dry weather advanced the harvest well ahead of the five-year average. Throughout western Canada, national agricultural production fared better than initially expected considering the severity and extent of the drought. Abnormally-high precipitation in the fall of 2016 played a critical part in partially mitigating crop impacts. Crops that were established early fared better than expected due to timely rains that are critical for root development down to the subsoil moisture reserves. In southern regions of Saskatchewan and Alberta (*Table 2 and Table 3*), drought resulted in below-average yields, but the dry heat did keep crop quality high and disease incidence low. Additionally, the dry conditions in 2017 reduced hail claims in Alberta to the lowest level since 2009.

ALBERTA 2017 CROP YIELDS

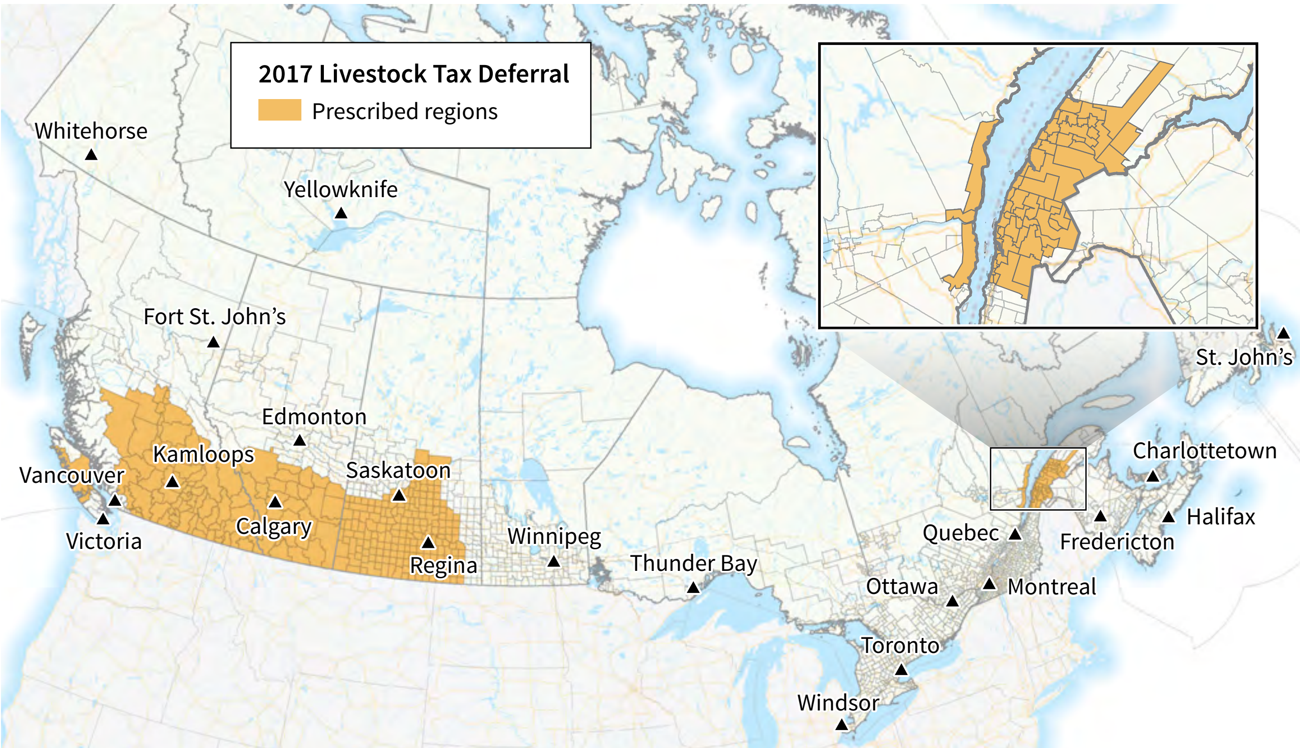
Crops	Estimated Yield (bushel/acre)	
	South	All Alberta
Spring wheat	35.2	47.8
Durham wheat	34.3	35.8
Barley	41.8	60.4
Oats	41.1	77
Canola	26.8	39.2
Dry peas	30.2	39.3
Yield Index 2017	73.4%	97.4%
2016 Yield	106.3%	114.1%

◀ Table 3: **2017 crop yields for southern Alberta compared to yield in 2016 (source: Agriculture and Agri-Food Canada).**

Fall precipitation events in October did little to alleviate drought conditions. Much of the southern Prairie region ended the growing season and entered winter with significant soil moisture deficits. Fall soil moisture deficits reduced seeded acreage for winter cereal crops. October rain helped winter wheat seeding in some areas. However, winter wheat kill was a concern if drought in the Southern Prairies were to persist into the winter, with below-average precipitation and no snow to insulate against cold temperatures. There were also concerns over livestock feed supplies and soil moisture going into the 2018 growing season. Long-term agricultural impacts include damage to soils, soil loss through wind erosion, deterioration of grasslands, and herd reductions. Recovery from some of these impacts can take a much longer time.

Wildfire: Late in the summer, wildfires in southern Alberta and Saskatchewan destroyed rangeland forage, agricultural machinery, and infrastructure; damaged crops; reduced feed supplies; and resulted in significant livestock loss. Wildfires across southern Alberta and Saskatchewan, fanned by strong winds, burned more than 85,000 acres, destroying farmyards, cropland, and homes. Hundreds of evacuees were temporarily homeless, and smoke inhalation and disorientation resulted in the death of one firefighter.

Infrastructure: The 2017 drought also affected urban areas in addition to impacting farms and agricultural land. In some regions, groundwater sources were severely depleted, causing clay-rich soils to contract and crack. This ground shifting damaged building foundations and caused significant structural damage. The drought in southern Saskatchewan—and subsequent shifting in the ground—caused damage to over 1,200 homes and pulled underground electricity wires from their boxes, causing several home fires. Regina and Moose Jaw also reported record-breaking numbers of water main breaks caused, in part, by drought-induced ground shifting in 2017.



▲ **Figure 13: Map showing the prescribed areas for the Livestock Tax Deferral in drought- and flood-stricken regions in 2017. Adapted with permission from Agriculture and Agri-Food, Canada's National Agroclimate Information Service.**

Tourism: The 2017 drought reduced tourism in the Southern Prairies. Provincial fire bans prohibited camp fires for most of the summer at federal and provincial parks, and often resulted in trail closures and other outdoor restrictions. Hunting was also affected by off-highway vehicle bans, which limited backcountry access. Full public-access bans in some public areas had a similar effect.

Extreme hot and dry conditions led to the Kenow Wildfire in southern Alberta burning through Waterton Lakes National Park (adjacent to Glacier National Park in Montana) in September, resulting in an evacuation that lasted two weeks and over 80% of the hiking trail network being closed for the season. Tourism saw a 14.1% decrease from the previous year in the month following the wildfire. The western part of the park remained closed through the 2018 season. Increased temperatures and smoke from neighboring wildfires led to several backcountry campground closures in Banff and Kootenay National Parks in September. The actual visitor numbers are somewhat masked by the fact that in 2017 all national parks had free entry as part of Canada's 150th anniversary celebrations. Most parks across the country saw huge increases in visitation. Saskatchewan's provincial parks visitation was down 1.8% in 2017 compared to 2016. The slight drop in visitation in 2017 was due, in part, to the large number of fire restrictions and bans throughout the province. In British Columbia, the impacts were much greater as fires covered a larger region and for a longer period. Businesses in Kootenay-Rockies anticipated a loss of 32%. One business in this region lost $100,000 due to cancellations. 47% of businesses in the Thompson-Okanagan are reported a loss in tourism revenue. The Barkerville Historic Town reported a 54% decrease in visitors in July 2017 compared to 2016. The Province provided the Cariboo Chilcotin Coast Tourism Association with financial support of up to $200,000 to help with tourism-related impacts from the British Columbia wildfires.

CANADIAN FEDERAL AND PROVINCIAL RESPONSE AND SERVICES

Federal Livestock Tax Deferral: This provision allows farmers who sell part of their breeding herd due to drought or flood conditions to defer a portion of the sale proceeds to the following year. Each year, a list of designated regions prescribed as drought and/or excess moisture and flood regions is announced. The 2017 designations included 27 rural municipalities in Alberta and 201 rural municipalities in Saskatchewan located across southern portions of both provinces (*Figure 13*).

Provincial water: Surface water shortage advisories and outdoor water bans were issued in southern portions of both Alberta and Saskatchewan due to extremely low surface water flows. Impacted communities included those south of Calgary and along the U.S. border in Alberta and southwestern communities in Saskatchewan.

Provincial wildfire: The combination of drought conditions and high winds prompted a number of fire ban advisories across the southern Prairies. In Saskatchewan, fire bans began in July 2017 for southern areas and were extended to everywhere south of Churchill River to the U.S. border by the end of August. Fire bans were lifted for a short time in September, only to be re-implemented in October. Fire bans in Saskatchewan were not lifted for the entire province until early November.

In Alberta, fire bans began in July for southern areas east of the Rocky Mountains. From April 1 to October 31, there were 1,230 wildfires that burned just over 49,000 hectares of Alberta's forests. The five-year average is 1,486 fires burning approximately 301,000 hectares. A forest area closure was put in place in southern portions of Alberta's forests September 4–19. In preparation for the 2017 wildfire season, the Alberta government set aside $133 million for wildfire relief—part of which comes from the provincial disaster relief fund. While the provincial fire ban was in effect, a wildfire started on a military base during the process of destroying ordinance. This fire, fueled by wind and drought conditions, caused the loss of more than 100 cattle and sheep, rangeland, and homes. The Department of National Defense made full compensation available.

On October 23, 2017, the Saskatchewan Stock Growers Association (SSGA) launched a wildfire relief fund for affected producers. The Saskatchewan government matched up to $100,000 cash donations to this fund and provided the following additional support:

- Non-permit harvested hay from the Qu'Appelle Coulee Ecological Reserve was donated to help ranchers feed their livestock (Ministry of Environment)
- Grants of up to $10,000 for each of the five affected rural municipalities to support the disposal and burial of deadstock (Ministry of Agriculture)
- The Agriculture Operations Unit worked with rural municipalities to locate suitable deadstock burial sites (Ministry of Agriculture)
- Provided assistance to producers with range health assessments and grazing management plans; relief extended into the spring of 2018 for further assessments as pastures recovered (Ministry of Agriculture)
- Eligible producers that wanted earlier access to their AgriStability benefit could file a 2017 interim application (Saskatchewan Crop Insurance Corporation)
- People who volunteered to haul hay donated through the SSGA were allowed to use their farm license plates (Saskatchewan Government Insurance)
- The Cypress Health Region offered mental health support to those impacted by the fires (Ministry of Health).

The Agriculture Financial Services Corporation (AFSC) administers the Hilda Wildfire Support Loan Program to support eligible agricultural producers impacted by the September 2017 Hilda Wildfire; AFSC will provide interest-free loans to enable producers to rebuild, recover, and/or regain viability.

FEDERAL PREPAREDNESS AND RESPONSE SERVICES

The 2017 drought impacts gained notice throughout the month of May in Montana and the Dakotas. By June, federal experts recognized the severity of the drought and expanded the breadth of activities they engaged in to provide drought and climate information.

DISSEMINATION OF REGIONAL CLIMATE AND DROUGHT INFORMATION

Across the U.S. Northern Plains, regional partners coordinate to provide climate information and drought early warning for the region. These include NOAA NIDIS, Regional Climate Services and NWS, both the HPRCC and WRCC, the USDA Northern Plains Climate Hub, and the NDMC. In addition, there are Federal staff in the region from the U.S. Army Corps of Engineers (USACE), USDA [NRCS, FSA, Risk Management Agency (RMA), Agricultural Research Service (ARS), etc.], FEMA, USBR, Bureau of Indian Affairs (BIA) and USGS who also engage during times of drought. These agencies interact through key personnel in each state, including state climatologists, state drought coordinators, other state agencies, and university extension professionals who deal with drought and drought impacts. This group engages stakeholders regularly through monthly conference calls and webinars that provide information on current and developing drought conditions, as well as a host of other climate-related impacts including the seasonal drought outlook. In addition, the HPRCC produces a quarterly, two-page briefing paper focused on the Missouri River Basin that gathers current and projected future impact information combined with outlooks for the next season.

▲ **A Montana Fish, Wildlife, and Parks Department biologist and a local rancher discuss water management in the Big Hole Valley, Montana. Credit: USDA**

In late June, 2017, the first action taken in response to the drought was to develop a briefing paper focused on the areas experiencing the worst effects. The High Plains Regional Climate Center (HPRCC) organized pertinent data, impacts, and outlooks, and summarized them as part of their *Climate Summary* series. These briefs were designed for decision-makers and were purposefully non-technical and short. They were distributed widely to a variety of stakeholders and partners throughout the Missouri River Basin. A similar briefing was issued again in July as conditions worsened across the three states. In addition to these special briefs, HPRCC hosted monthly *Climate and Drought Outlook Webinars* that summarized past and current conditions as well as short-term and seasonal climate outlooks. Due to the severity of the drought, three additional

◀ **On August 2 4, 2017, local officials brief Secretary of Agriculture Sonny Perdue and Secretary of Interior Ryan Zinke, U.S. Senator Steve Daines, and U.S. Congressman Greg Gianforte, on the wildland fires in Montana on August 24, 2017. Credit: USDA, Lance Cheung**

geographically-focused webinars were held for decision-makers in the affected areas. These included a presentation in June by the South Dakota State Climatologist and a North Dakota Extension specialist, who detailed impacts to the agricultural community. The North Dakota State Climatologist held a webinar in July detailing impacts across the three-state area as well as short-term forecasts. A final webinar in August focused on tribal land impacts and ecosystems with contribution from the South Dakota State Climatologist and input from several tribes and the U.S. Fish and Wildlife Service. These webinars drew participation from across federal, state, local, and tribal governments, universities, private sectors (insurance industry, commodities, agricultural cooperatives, utilities, trade associations, etc.), non-governmental organizations, private citizens, and the press.

AGRICULTURAL AND FORESTED LANDS PREPAREDNESS AND RESPONSE

The state sections cover much of the on-the-ground efforts of the USDA to assist producers affected by the 2017 drought. The long-term impacts to agriculture and forested lands are still being evaluated. There are many programs that producers can access before, during, and after drought; they are briefly summarized here.

Dozens of drought-relevant programs focused on preparedness, response, and recovery are administered through the following USDA agencies: NRCS, FSA, ARS, Forest Service (USFS), Rural Development (RD), RMA, and Animal and Plant Health Inspection Service (APHIS). The programs administered by these agencies play a vital role in sustaining agricultural and forested lands in an increasingly variable climate. NRCS, FSA, and RD are often co-located in county-level offices throughout the country—known as USDA Service Centers. These agency staff are well-positioned to provide outreach and support before, during, and after a drought. When disaster strikes on a large scale, however the number of producers filing for assistance may overwhelm local staff. In such cases, USDA dispatches additional staff to the affected area, drawing upon personnel from more than 2,100 county and state offices.

Some programs—such as the Emergency Haying and Grazing of Conservation Reserve Program, and many FSA programs—can be implemented quickly to provide immediate

USDA NATURAL RESOURCES CONSERVATION SERVICE (NRCS)
CONSERVATION PROGRAMS FOR DROUGHT PREPAREDNESS, RESILIENCE, AND RESPONSE

Program	Mechanism	Trigger	Description
Emergency Watershed Protection Program (EWPP)	Financial and Technical Assistance	Application at local NRCS Office	Helps communities address hazardous watershed impairments, including re-seed drought stricken areas prone to erosion that could pose threat to life or property
Environmental Quality Incentives Program (EQIP)	Financial and Technical Assistance	Application at local NRCS Office	Assists agricultural producers to plan and implement conservation practices that can lead to water conservation and recharge, cleaner water and air, healthier soil, and better wildlife habitats, all while improving agricultural operations.
Conservation Technical Assistance (CTA)	Technical Assistance	Application at local NRCS Office	Identifies measures to reduce soil loss from erosion; solve soil, water quality, and water conservation problems; reduce potential damage caused by excess water and sedimentation or drought; enhance the quality of fish and wildlife habitat; improve the long- term sustainability of all lands; and assist others in facilitating changes in land use for natural resource protection and sustainability
Conservation Stewardship Program (CSP)	Financial and Technical Assistance	Application at local NRCS Office	Helps build conservation efforts while strengthening operations through activities such as scheduling timely planting of cover crops, developing a grazing plan that will improve forage base, implementing no-till to reduce erosion, and increase water infiltration, or managing forested areas in a way that benefits wildlife habitat.
Watershed and Flood Prevention Operations (WFPO)	Financial and Technical Assistance	Application at local NRCS Office	Provides for cooperation between Federal government and states and their political subdivisions to prevent erosion; floodwater and sediment damage; to further the conservation development, use and disposal of water; and to further the conservation and proper use of land in authorized watersheds.
Regional Conservation Partnership Program (RCPP)	Financial and Technical Assistance	Application at local NRCS Office	Encourages partners to join efforts with producers to increase restoration and sustainable use of soil, water, wildlife, and related natural resources on regional or watershed scales

▲ **Table 4: Conservation programs for drought preparedness, resilience, and response administered by the USDA Natural Resource Conservation Service (NRCS).**

relief to affected agricultural producers. Others, such as Agricultural Risk Coverage (ARC), might take several months to more than a year between the date of loss and the date assistance is received. To raise awareness and connect stakeholders to these and other relevant federal programs and resources, NRCS and FSA staff members often participate in land-grant university or state drought task forces.

PREPAREDNESS

The 2017 drought was a flash drought that developed quickly across the region. While it is tough to prepare as drought evolves, especially a quickly progressing flash drought, there are many programs that provide technical and financial assistance to build resilience such that producers are better prepared when drought hits. NRCS is the primary federal agency that provides conservation assistance to private citizens in close partnership with local Conservation Districts. Together, they help implement voluntary conservation programs and efforts such as the Regional Conservation Partnership Program (RCPP), Conservation Stewardship Program (CSP), Environmental Quality Incentives Program (EQIP), Emergency Watershed

USDA FARM SERVICE AGENCY DROUGHT-RELATED DISASTER ASSISTANCE PROGRAMS*

Program	Agency	Mechanism	Trigger	Description
Emergency Farm Loan Program	Farm Service Agency	Low Interest Loan	USDA Secretarial Disaster Designation; Fast-track process based on USDM	The Emergency Loan Program offers low-interest emergency loans to qualifying producers in eligible counties to restore or replace essential property, pay production costs incurred during the affected year, pay essential family living expenses, or refinance certain debts.
Emergency Conservation Program	Farm Service Agency	Emergency Funding	Application to local FSA Office	Provides emergency funding for farmers and ranchers to rehabilitate land severely damaged by a natural disaster or to implement emergency water conservation measures during severe drought.
Livestock Indemnity Program (LIP)	Farm Service Agency	Financial Assistance	Application at local NRCS Office	Compensates eligible livestock owners and contract growers for excess livestock deaths due to an eligible disaster. Drought is not an eligible disaster, except when drought-driven diseases such as blue-green algae poisoning or anthrax occur.
Livestock Forage Disaster Program (LFP)	Farm Service Agency	Financial Assistance	Application to local FSA Office; payments based partly on USDM	Compensates eligible livestock owners for grazing losses on eligible pastures (e.g., native pasture, improved pasture, long-season small grains, federal grazing allotments) due to drought, and producers who lose access to federal grazing allotments due to wildfire.
Emergency Livestock Assistance Program (ELAP	Farm Service Agency	Financial Assistance	Application to local FSA Office	Compensates any remaining feed or water shortages not adequately addressed by LIP or LFP, including the cost of hauling water to eligible affected livestock.
Tree Assistance Program (TAP)	Farm Service Agency	Financial Assistance	Application to local FSA Office	Provides assistance to eligible orchardists and nursery tree growers for qualifying tree, shrub, and vine losses due to drought.

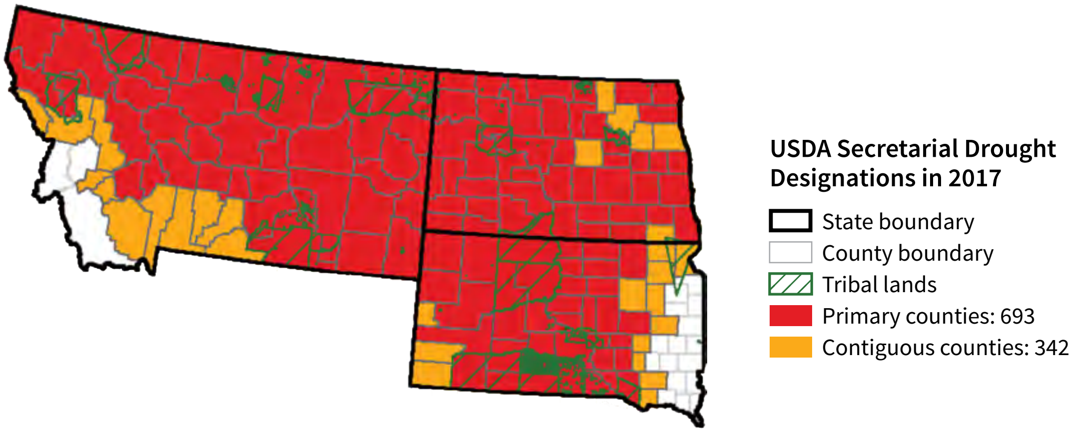
*These do NOT require enrollment before disaster, but post-disaster application deadlines must be met.

▲ Table 5: Drought-related disaster assistance programs administered by the USDA Farm Service Agency (source: USDA website).

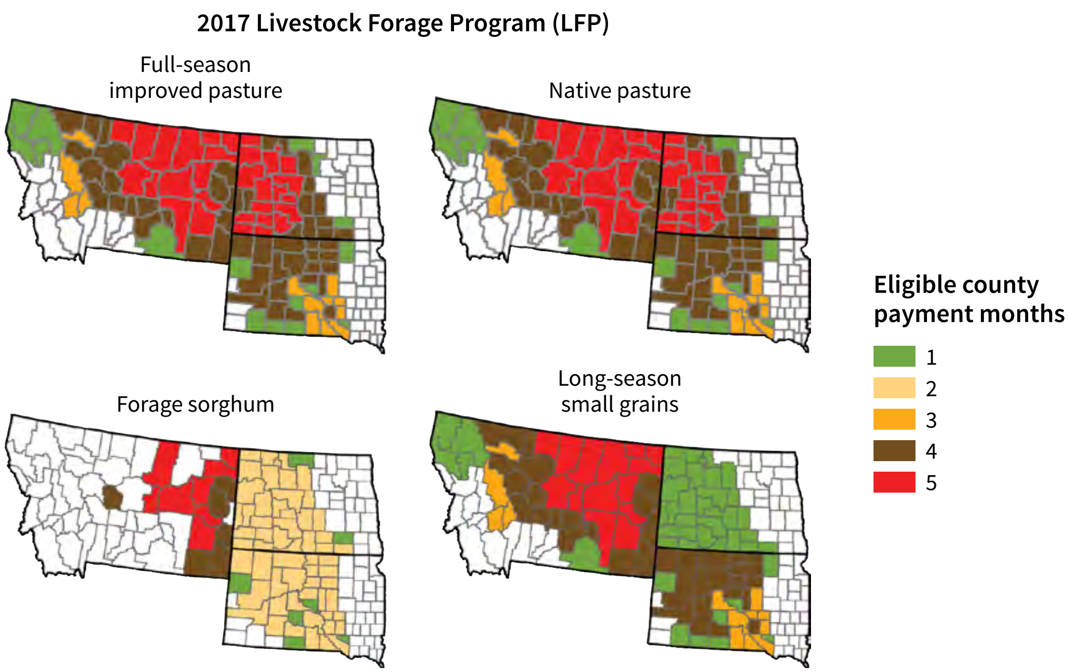
Protection Program (EWPP), Conservation Technical Assistance (CTA), and Watershed and Flood Prevention Operations (WFPO) (*Table 4*). Through these programs, NRCS helps farmers and ranchers implement management strategies that enhance drought preparedness and resilience, such as:

- Installing pipelines and water tanks to ensure adequate water quantity and quality for livestock
- Writing grazing management plans that include drought triggers and contingencies
- Building cross-fences to improve livestock distribution and avoid overgrazing
- Designing and cost-sharing the installation of shelterbelts, windbreaks, or riparian buffers
- Providing educational and cost-share resources in support of reduced-tillage, cover crops and rotations to help capture and hold more soil moisture in crop fields
- Addressing hazardous watershed impairments, including re-seeding drought-stricken areas to stabilize shorelines

▶ Figure 14: USDA Secretarial Drought Designations in 2017 for primary and contiguous counties covered all three states except for a few counties in southwestern Montana and eastern South Dakota. This designation triggers access to federal assistance through the USDA Farm Service Agency.



▶ Figure 15: Eligible counties for payments for full season improved pasture, native pasture, forage sorghum, and long season small grains through the Livestock Forage Program (LFP).



FSA also has programs that can improve soil health to help build resilience to drought, including the Conservation Reserve Program (CRP) and Conservation Reserve Enhancement Program (CREP), which are among the largest voluntary conservation programs in the world. These programs offer incentives for producers to take marginal cropland out of production for 10–15 years to improve soil health, reduce erosion, enhance water quality, and create wildlife habitat. During qualifying drought events, USDA may authorize emergency haying or grazing of CRP acres. This option was activated during the 2017 drought in many affected counties, providing a much-needed source of supplemental hay and forage for livestock in the region.

RESPONSE AND RECOVERY

Many agricultural producers turn to their local USDA Service Center for assistance in the aftermath of drought. They may participate in some of the many FSA disaster programs, those most relevant to severe drought events are covered in Table 5 (*previous page*). One in particular, the Emergency Farm Loan Program provides low-interest emergency loans to producers in eligible counties based on USDA Secretarial

USDA FARM SERVICE AGENCY/RISK MANAGEMENT AGENCY AND OTHER DROUGHT-RELATED ASSISTANCE PROGRAMS*

Program	Agency	Mechanism	Description
Disaster Set-Aside Program (DSA)	Farm Service Agency	Postpone FSA Loan Repayment	Allows FSA borrowers in disaster designated areas to postpone one FSA loan installment until the loan's final due date.
Noninsured Crop Disaster Assistance Program (NAP)	Farm Service Agency	Financial Assistance	Provides financial assistance to producers of non-insurable crops to protect against natural disasters that result in lower yields or crop losses, or prevents crop planting.
Price Loss Coverage (PLC)	Farm Service Agency	Income Support	Payments are issued when the effective price of a covered commodity is less than the respective reference price for that commodity.
Agricultural Risk Coverage (ARC)	Farm Service Agency	Income Support	Provides revenue loss coverage at the county level. ARC-CO payments are issued when the actual county crop revenue of a covered commodity is less than the ARC-CO guarantee for the covered commodity.
Multi-Peril Crop Insurance (MPCI)	Risk Management Agency	Crop Insurance Product	Covers individual crops against eligible weather-related yield losses.
Whole Farm Revenue Protection (WFRP)	Risk Management Agency	Crop Insurance Product	Covers multiple crops and/or livestock under the same policy; furthermore, it simultaneously covers yield losses and/or price-related losses.
Livestock Gross Margin (LGM)	Private Insurance	Livestock Insurance Product	Covers market value of livestock minus feed costs.
Pasture Range Forage insurance (PRF)	Private Insurance	Livestock Insurance Product	Covers price-related losses.

*These require enrollment before disaster.

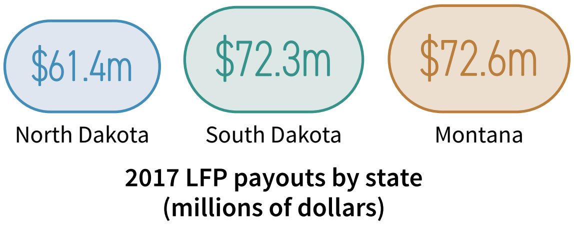
◀ **Table 6: Drought-related assistance programs, administered by the U.S. Department of Agriculture Farm Service Agency, Risk Management Agency, and crop insurance agents. *These require enrollment *before* disaster occurs. Source: USDA website**

Disaster Designations (*Figure 14*). These loans are available to restore essential property, pay production costs incurred during the affected year, pay essential family living expenses, or refinance certain debts.

The Livestock Forage Disaster Program (LFP) compensates eligible livestock owners for grazing losses on eligible pastures—including native pasture, improved pasture, long-season small grains, and federal grazing allotments—due to drought (*Figure 15*). The LFP may also be available to producers who lose access to federal grazing allotments due to wildfire. This program is triggered by the U.S. Drought Monitor status of the county in which a pasture is located, requiring a minimum of eight consecutive weeks at D2 (Severe Drought) or any amount of time at D3 (Extreme Drought) or worse. The LFP payouts for 2017 in North Dakota totaled $61.4 million, in South Dakota $72.3 million, and in Montana $72.6 million for a total of $206.3 million in payments for forage losses across the three states (*see Figure 16 on the following page*).

The FSA also administers several other relevant programs, but they require enrollment before a

▼ **Figure 16: Livestock Forage Program (LFP) payouts by state for 2017 totaled over $206.3 million in agricultural losses.**



producer would typically know of an impending drought. The RMA complements FSA disaster assistance programs with more traditional crop insurance products. These products are developed by RMA through the Federal Crop Insurance Corporation (FCIC), and then sold to agricultural producers through private crop insurance companies and agents. See Table 6 (*previous page*) for a summary of these programs.

PLANNING, PREPAREDNESS, AND BUILDING RESILIENCE

Several federal agencies have programs that support state drought resilience and response efforts. The NOAA NIDIS program was authorized by Congress in 2006 (*Public Law 109-430*) reauthorized in 2014 (*Public Law 113-86*) and 2018 (Public Law 115-423) with an interagency mandate to coordinate and integrate drought research—building upon existing federal, tribal, state, and local partnerships—in support of creating a national drought early warning information system. A Drought Early Warning System (DEWS) utilizes new and existing partner networks to optimize the expertise of a wide range of federal, tribal, state, local, and academic partners in order to make climate and drought science readily available, easily understandable, and usable for decision makers; and to improve the capacity of stakeholders to better monitor, forecast, plan for, and cope with the impacts of drought.

The Missouri River Basin DEWS launched in 2014. Since that time, a unique network has been built that has improved coordination in this region. This network has a mix of technical expertise and decision-makers from federal, tribal, state, and local agencies. The trust and relationships built through the DEWS resulted in a faster and more informed response in 2017 than in the previous 2011–2012 drought; from awareness of tools, products, and services to knowing (and trusting) contacts who can provide more in-depth insight and information. In addition, the DEWS network supports activities in this region that include working with tribes to better understand drought vulnerability to inform planning, strengthening mesonets, and monitoring in the states in the region, improving drought monitor coordination across the U.S. and Canadian border, and supporting opportunities for training of university extensions in the region on available drought tools and information. In addition,

▶ **On Sunday, September 3, 2017, tractor trailers hauled hay along Interstate 94 to drought-stricken farmers and ranchers in Western North Dakota and Montana. Credit: Northlight**

state and federal partners have worked in the upper Missouri River Basin to incorporate drought into risk estimates to improve fire management decisions.

In 2015, the Missouri Headwaters Basin in southwest Montana was selected as one of two national drought resilience projects by the National Drought Resilience Partnership (NDRP). This initiative also provides an opportunity to explore ways of preparing for drought. Montana, working with federal agencies and local partners, set a goal that amounted to a two-way proposition—to deliver government drought mitigation tools and resources to watershed stakeholders, and to collect information from local groups in direct contact with the landscape. The project produced a model for information sharing, efficient water use and storage, and community collaboration—and helped prepare communities and groups to mitigate drought impacts while preserving cultural and ecological values. As a region that will likely face drought again in the near future, lessons from this demonstration project and past planning efforts are important to future planning efforts. Key lessons included:

- Strengthening relationships between federal and state partners are important, and good relationships with local, community based working groups are not optional.
- Drought planning must be proactive—you cannot plan for drought once you are in drought.
- Short-term response plans are good, but they should be embedded in longer-term adaptation and mitigation strategies resulting in a more comprehensive approach to drought mitigation.
- Ideally, planning should be done holistically, taking an ecosystem approach.
- Soil health, plant health, and water management are all foundational pieces of successful drought planning.

Resources are available to continue to develop and build resilience through planning and preparedness. The USBR Drought Response Program supports a proactive approach to drought by providing assistance to water managers to develop and update comprehensive drought plans, and implement projects that will build long-term resilience to drought. Many states have used the USBR programs to develop drought contingency plans. In addition, the BIA Tribal Resilience Program helps tribal nations build capacity and resilience through leadership engagement, training, and sharing data and tools. While the Tribal Resilience Program is widely defined, many tribes in the region have applied those funds to drought vulnerability assessments and planning.

Lesson Learned from the 2017 Drought

Agricultural producers are not required to enroll in any of the U.S. Department of Agriculture (USDA) Farm Service Agency (FSA) disaster programs before a drought strikes, nor do they have to pay premiums to participate. If producers, and the drought event affecting them, both meet eligibility requirements, they can simply file an acreage report with FSA at their nearest USDA Service Center and, in some cases, also file a loss report in time to meet the program's deadlines.

This two-step process, though simple, presents notable hurdles to agricultural producers unacquainted with their local USDA Service Center. Participation requires awareness of the programs, knowledge of the filing deadlines (some of which are only 30 days after a loss) and the necessary records to prove the extent of their loss. The FSA communicates regularly with existing customers about programs and deadlines through an electronic newsletter. However, this newsletter does not reach agricultural producers who have never interacted with the agency. Some producers in need of help following a severe drought might be relatively unaware of the benefits available through FSA programs. Even if they learn about the programs prior to critical deadlines, they might not have the records necessary to prove their loss. These barriers present an opportunity for the USDA Climate Hubs and university Extension programs to add value by raising awareness among agricultural producers about USDA's drought preparedness and recovery programs, and the types of records producers will need to keep on a regular basis to prove any future losses.

CONTINUED EVOLUTION OF DROUGHT IN 2018

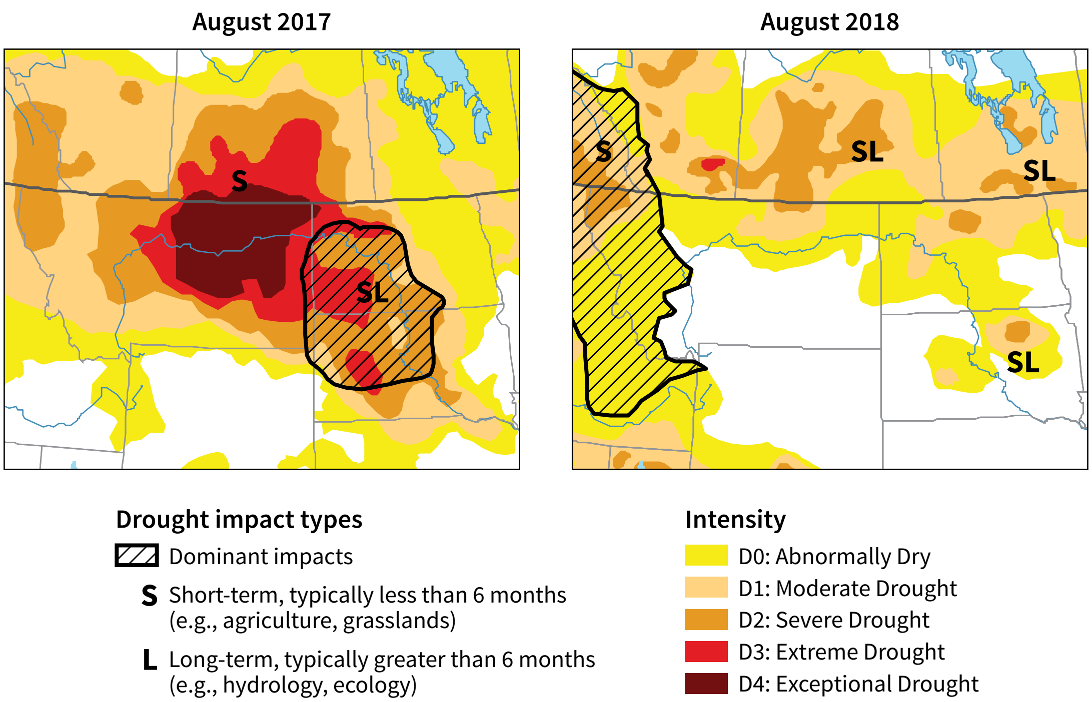
The impacts of the 2017 drought cascaded into 2018 as extreme moisture deficits continued in certain locations. A comparison of the NADM maps from August 2017 and August 2018 show a remarkably similar spatial pattern between locations, where extreme and exceptional drought occurred in 2017 and long-term locations of drought and impacts in 2018 (*Figure 17*). This relationship highlights the legacy effects of the 2017 drought on deeper soil moisture, groundwater, and streamflow during the 2018 season.

The winter of 2017 was a welcome reprieve to dry conditions experienced the preceding summer and contributed to recharge of soil moisture and decline in drought conditions by April (*Figure 18*). La Niña conditions helped to contribute to ample moisture and extreme cold to a large part of Montana. Despite the onset of winter, several fires burned into the winter months, with the ongoing drought likely a factor in what was ultimately the third-largest fire in South Dakota's history (Legion Lake Fire; 54,000 acres). Fires continued to burn into January 2018, with grass fires reported in South Dakota. Over the winter, low snowfall led to reports of low stock pond levels and low soil moisture in the Dakotas.

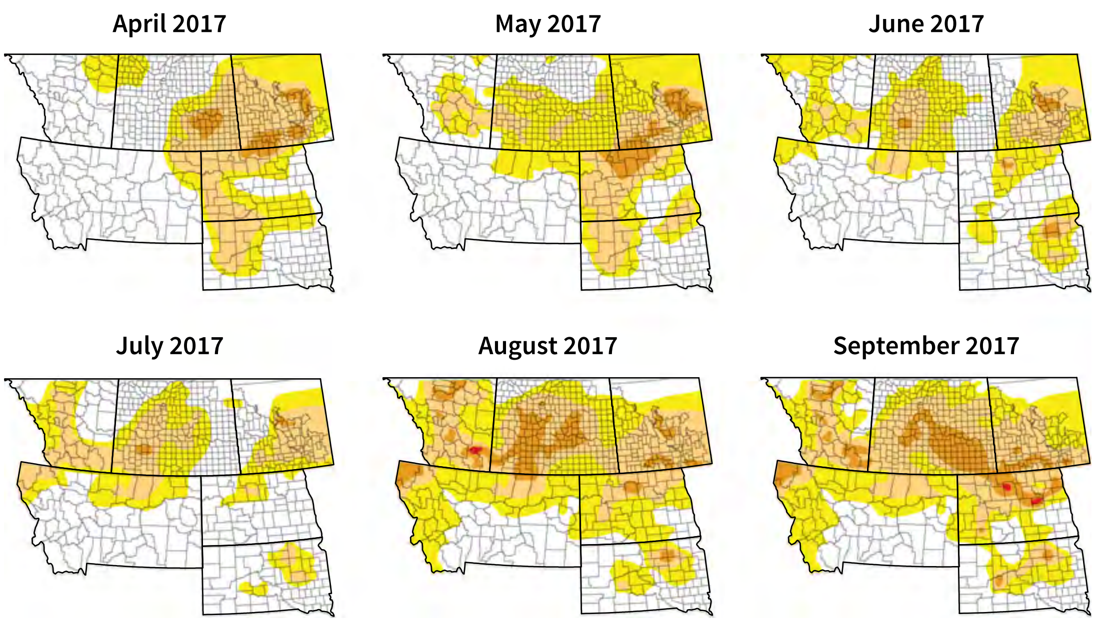
▲ **Spring-planted wheat germinating following a September rain event near Culbertson, Montana. Credit: Michael Downey, MT DNRC**

April and May of 2018 brought back-to-back temperature extremes (cold then warm), while both snowmelt flooding (Montana) and drought (Dakotas) impacted the region. The cold start to spring resulted in a slow green-up and delays in spring planting due to frozen soils. A transition to exceptionally-warm conditions in May enabled some producers to make significant planting progress, especially for corn and soybeans. Winter wheat quality declined due to high spring temperatures and drier conditions. Additionally, some cattle deaths were reported in South Dakota where unseasonably hot and humid conditions occurred (HPRCC Winter and Spring Quarterly Impacts and Outlook). During this time period, drought expanded from the Dakotas and Manitoba into Montana and Saskatchewan (*Figure 18*). Pastures and crops in central North Dakota started to show drought stress and some rivers and creeks were very low for this time of year despite the snow runoff.

While several areas of the basin had a wet summer (southeastern South Dakota had one of their wettest summers on record), drought was still an issue that impacted crops and water supply in other parts of the Dakotas and Montana. Late summer dryness resulted in the rapid spread and intensification of drought across portions of the Dakotas and Montana (*Figure 18*). In western Montana,



◀ **Figure 17:** A comparison of the late August Drought Monitor maps for 2017 and 2018. Areas of extreme to exceptional drought in 2017 set the stage for deeper soil moisture deficits and long term drought (L) in 2018. Credit: NOAA, USDA, NDMC, Conagua, Agriculture and Agri-Food Canada.



◀ **Figure 18:** The North American Drought Monitor (NADM) from April to September 2018 showing the pattern of persistent drought and impacts across the U.S. Northern Plains. The NADM reflects the drought categories of the U.S. Drought Monitor across the U.S. States and Territories.

many basins experienced hydrologic drought and extremely-low flows, which resulted in daytime river closures for fishing. Over the course of 2018, Secretarial Drought Designations were issued for 17 primary and 32 contiguous counties in Montana, South Dakota, and North Dakota with impacts to soybeans, corn, sunflowers, grazing pastures, and stock ponds. Some trees showed impacts from multiple dry years.

◀ **Grain crop left in a field to overwinter due to poor fall harvesting condition. Credit: Bruce Raynor**

LESSONS LEARNED, GAPS, AND NEEDS

The timing of federal, state, tribal, and local responses to drought in 2017 and beyond are contingent upon accurate and timely drought assessments, predictions, and coordination by partners with NIDIS and other services providers. More importantly, communication of drought information and education that supports the development of state to local drought mitigation and response plans is critical for mitigating drought impacts, and for moving away from a reactionary paradigm of drought response.

According to the Fourth National Climate Assessment—temperature increases, changes in the amount, distribution, and variability of annual precipitation, potential increases in winter and spring precipitation, and increases in extreme precipitation events are expected across the region. Even with increases in precipitation, warm temperatures are expected to increase evaporative demand, leading to more frequent and severe droughts.[5] Given the dependency on water for crops and livestock, ecosystems, the energy industry, and communities in the region, improved infrastructure and planning is crucial in preparation for these changes (*see "Gaps and Needs" on next page*).

▲ Winter wheat on a Chippewa Cree Tribal Farm. Rocky Boy Reservation, Montana. Credit: USDA NRCS

▶ *Opposite page:* rails and private rangeland along Montana Hwy 81 near Denton, Fergus County, Montana. Credit: Kevin Hyde, Montana Climate Office

Lessons learned from the 2017 drought as well as gaps and needs are explored in more detail in the following sections, organized by the five components of drought early warning: observations and monitoring, prediction and forecasting, planning and preparedness, communications and outreach, and applied research.

OBSERVATIONS AND MONITORING

Drought monitoring is a complex process and depends on a variety of atmospheric, hydrologic, vegetative, and human factors—all of which are challenging to monitor consistently and accurately across the region. In this context, improved observation and monitoring were identified by the states as important needs during the 2017 flash drought. Local and regional drought early warning systems must be well-coordinated and integrated across federal, tribal, state, and local government agencies.

The USDM was developed to track the severity and extent of drought across the nation using various triggers.[21] On a weekly basis, state drought task forces coordinate with the USDM authors and provide expert assessments of rainfall, streamflow, crop conditions, and local drought impact observations. The USDM provides a consistent and applicable drought monitoring product generated by combining information from local reports, using a measure of drought severity from D1 to D4 (Moderate to Exceptional Drought) or D0 (Abnormally Dry) conditions. This metric is based upon a combination of evidence from several dozen drought indices/indicators and observations which are provided by a variety of state and federal partners.

MONITORING

Measurements of precipitation (rain and snow), weather conditions, soil moisture, groundwater, and streamflow are critical for use in many areas of drought planning and response. This information is useful to inform policy, planning, risk assessment, and decision-making at multiple levels of government (e.g., national,

Gaps and needs

The flash drought of 2017 illustrated the value of NIDIS and the early warning system in the region. However, it also highlighted areas for continued need for improved federal to local channels of communication. The exchange of timely and accurate drought information is essential to the process of drought preparedness and response. States affected by the drought identified several important needs:

- Drought monitoring infrastructure requires improvements in the collection, assessment and integration of drought indicators and impacts necessary to produce applicable, reliable and timely drought forecasts.
- Investments in existing and new monitoring and observation networks are necessary to support and improve drought research, assessment and prediction across the region.
- Producers have their own "early warning indicators" that can help inform the science of early warning. Better cooperation between drought information providers and resource professionals would enhance this information exchange.
- Improvements in seasonal forecasts will continue to enhance drought preparedness.
- Increased technical capacity of local drought task forces through the development, sharing and evaluation of drought monitoring tools and triggers will improve drought response and management.
- Better cooperation and coordination with university extension professionals in each county or region of a state is essential for assistance with the documentation of drought impacts and the distribution of information to individuals on the ground.
- Improved communication between producers and USDA professionals will facilitate awareness of drought-related programs, program deadlines and enrollment or reporting requirements.
- Better communication between federal, state, tribal, local and private entities engaged in drought planning and preparedness will improve information transfer and decision making. This reciprocation includes continuing coordination and partnership across the U.S.-Canadian border.
- While many lines of communication performed well in 2017, there is a need to better understand communication centers and pathways in the region and the way drought is communicated especially in rural areas.

Local and regional drought early warning systems must be well-coordinated and integrated across federal, tribal, state, and local government agencies.

regional, tribal, state, county, and local), and across many time scales. Timely, accurate, and actionable observations of water availability are needed to prepare communities for drought, mitigate impacts, and enhance post-event recovery.

There is a need for increased and sustainable levels of investment for critical drought monitoring infrastructure, such as USGS stream gauging and groundwater monitoring, NRCS snow survey and soil moisture monitoring, Remote Automated Weather Station (RAWS) networks, NOAA Cooperative Observer Program (COOP), USDM, and NASA/USGS satellite platforms. Most of these programs have developed extensive data-rich observations for more than 30 years. These important records enable climatologists to place current conditions in the context of past events and help to determine the presence of absence of drought conditions for a given area. Historical observations are a key aspect of drought detection and they require support for maintenance to ensure data continuity and minimal data gaps. Additional support is needed for developing, communicating, and sharing information collected by these observational systems. Efforts to increase the integration of existing networks, address monitoring gaps, and to increase overall cost effectiveness are important to ensure the maintenance of data collection to support long-term observations.

▲ **John Wiegand, left, farmer near Shelby, Montana, talks to Ernie Haglund, NRCS soil conservationist, about the changes he has made to his farm. Toole County, Montana. June 2017. Credit: USDA NRCS**

New and expanded monitoring networks are also needed, and the 2017 drought illustrates a need to accelerate these initiatives. Efforts are currently underway to improve soil moisture, soil temperature, and snowpack observations in the region as a whole. These observations are useful for monitoring frozen soils, plains snowpack (poorly measured), and soil moisture. These data are critical for developing run-off predictions, and for assessing drought onset and vegetation water stress. These efforts are focused on establishing best practices and consistent monitoring protocols. NIDIS and its partners—including USDA, USGS, and NASA—are working on developing a strategy for a National Soil Moisture Network (NSMN). A related effort by the USACE in the Upper Missouri River Basin will strengthen water supply and drought monitoring in the region and help to inform the NSMN strategy. Additional efforts are identified in the Agriculture Improvement Act of 2018 and 2018 NIDIS Reauthorization (Public Law 115-423).

SELECTING DROUGHT INDICATORS AND INDICES

Due to the various facets of drought from region to region, there is no single drought index that is ideal for all regions. Drought always starts with a lack of precipitation, but can be exacerbated with warmer temperatures that contribute to dryness and impact soil moisture, groundwater, streamflow, ecosystems, and human systems. This variability has led to the identification of different indices to identify the different types of drought (e.g., meteorological, agricultural, hydrological, socioeconomic, ecological). These indices are used to evaluate the impacts on different sectors resulting from water shortages. The various forms of drought are identified through indices that also serve as triggers for drought response. These metrics are implemented in local, state, and regional drought plans. These indicators could include but are not limited to:

- Simple temperature- and precipitation-based indices
- Metrics that incorporate both atmosphere and land surface interactions from gridded meteorology
- Metrics that account for vegetation conditions and evapotranspiration through satellite-based vegetation indices and gridded meteorology

- Surface water supply data
- Metrics that account for atmospheric stressors and that could provide early warning to developing drought [e.g., Evaporative Demand Drought Index (EDDI)]
- Antecedent precipitation conditions [e.g., Surface Water Supply Index (SWSI)]

All of these metrics have merits individually and when combined. However, managers and decision-makers may have difficulty understanding and choosing the appropriate metrics for assessing the various forms of drought, considering the myriad of tools, differing resolutions (space and time), and differing land cover conditions. Several drought task forces highlighted the need for a more detailed evaluation of which drought indices are most appropriate as triggers of rapid onset drought. Furthermore, the merit of a particular metric depends on the geographic region. Many highlighted the need for new integrated indicators and an evaluation of accuracy relative to observed drought impacts. Research into these issues would fill a significant knowledge gap in terms of maintaining quantifiable, timely, consistent, and defensible drought assessments across the region.

INFORMATION ON DROUGHT IMPACTS

There is a need to improve efficiencies in the collection, analysis, and reporting on the full range of impacts both during drought and normal periods. In the 2017 drought, producers caught the drought development before it was really showing up widespread in the data. This occurred anecdotally due to stock ponds not filling with water early in the season (missed April moisture) and producers started hedging their bets in terms of their decisions. The NDMC created the National Drought Impact Reporter to capture these valuable local observations. The Drought Impact Reporter is a web-based information system for individuals to report drought impacts. NDMC has worked hard to improve the accessibility and ease for individuals to submit their observations of drought impacts at the national level.

It is also important for the state drought task forces to have access to these observations that help to inform state-based decisions. Improvements to this platform will help the public feel comfortable submitting reports and encourage the submission of reports in a sustainable way to capture both drought and non-drought conditions. States, working in partnership with NIDIS and the NDMC Drought Impact Reporter, are exploring ways to link state and national databases of impact reports and ensure those reports are incorporated into a more complete understanding of current conditions. As an example, the Montana DNRC and the Montana Water Information System put together a very short, web-based questionnaire for reporting local drought impacts that is used regularly during times of drought. The survey requests input on

Focus on State Mesonets

Many states and the U.S. government have recognized the need for monitoring systems to better characterize moisture conditions and the potential for local drought impacts to agriculture, rangelands, and water resources. The development of mesonet networks are a key step in this process for the Dakotas and Montana.

Mesonets are automated weather and environmental monitoring stations designed to observe phenomena such as precipitation, temperature, wind speed, relative humidity, and evapotranspiration. Most state mesonets have recently incorporated measurements of soil moisture as an additional important indicator for agricultural and rangeland vegetation conditions. Some advantages of mesonet stations include filling monitoring gaps from federal weather station networks in sparsely populated areas of the U.S. Northern Plains. They also provide data for the development of more continuous gridded weather and drought data sets, and seasonal predictive models of drought.

Because most mesonets are less than 30 years old, their observations do not allow for drought characterization relative to historical conditions yet. Also depending on each state's intended application and budgetary constraints, mesonets vary in the type of measurements that they collect, sensor configurations and calibrations, and how stations are situated across varying land covers (e.g., municipal, agricultural, rangelands). This variability makes it difficult to draw comparisons across data sets and highlights the need for agreement on best practices. Over time, and with the development of longer-term records and a standardized approach, mesonets may contribute to the ability of state drought committees to provide more accurate information for input to the USDM.

▶ **Mesonet Station above Cooney Reservoir in Stillwater County, Montana. Credit: Kevin Hyde, Montana Climate Office**

the type of impact (e.g., tourism, agriculture) and the user's knowledge of rainfall and soil moisture in their area. The information is used to investigate trends and impacts, and helps to inform potential responses in times of drought. A potential benefit of the state-level reporting is that stakeholders are more likely to provide input to a reporting system that addresses their geographic area of interest. The new addition of photo documentation of drought impacts at the county level provides visual evidence of the ongoing drought. It also provides visual comparisons across a range of scales for both time and location. Through better coordination, this local information can automatically contribute to the nationwide database.

PREDICTIONS AND FORECASTING

Uncertainty in drought prediction and short-term to seasonal forecasts present a major challenge to climatologists and hydrologists as well as decision and policymakers. This region is understudied compared to other regions of the country. The 2017 drought provided an opportunity to examine the predictability of the drought[11,12] and physical processes related to drought.[9,10] Improvements in the reliability of weather and climate forecasting is necessary to effectively anticipate and prepare for drought. Communication of the uncertainties in forecasting is essential for effective drought planning and response.

Highly complex models that incorporate important physical processes across the atmosphere, ocean, and land surfaces are used for seasonal predictions of temperature, precipitation, and ultimately drought. Forecasts of precipitation, temperature, and many other weather variables from these models are used by the NWS (Climate Prediction Center, River Forecast Centers, and National Water Center) and the NRCS Water Supply Forecast. In addition, the USACE and USBR produce important reservoir level forecasts.

Increases in the lead time of predictions represent one of the best ways to prepare in advance for oncoming drought. At present, the forecasts for precipitation are typically most accurate up to two weeks and they extend up to one month for temperature.[14,26] In 2017 the long-term forecast suggested normal to above-normal precipitation and near-normal temperatures for the affected region. Looking back, these conditions were very different from what was experienced. Improvements to these forecasts represent a difficult and critical component of drought preparedness. For example, farmers rely on forecasting to determine when to plant, irrigate, and harvest or when to shift their resources in anticipated drought years. Reservoir managers can incorporate forecasts into planning for upcoming storage and release scheduling. While making improvements to forecasts is challenging, the Missouri River Basin is an understudied region in the U.S. so there is potential for some improvement as we develop a better understanding of relevant processes and better simulate those processes in forecast models.

Beyond improvements in traditional forecasts of precipitation or temperature, the development of new products will help to translate this information into terms that stakeholders care more directly about. For example, precipitation forecasts are being translated for ranchers in the U.S. Northern Plains region into grassland productivity forecasts for the upcoming grazing season. This new *Grass-Cast* uses over 30 years of historical data on weather and vegetation growth— combined with seasonal precipitation forecasts—to predict if rangelands in individual counties are likely to produce above-normal, near-normal, or below-normal amounts of vegetation. This experimental product is a joint venture between Colorado State University, University of Arizona, USDA (ARS, NRCS, and the Climate Hubs) and NDMC. Grass-Cast will greatly benefit from future efforts to improve the skill, lead-time, and spatial resolution of seasonal-to-subseasonal forecasts. The effectiveness of this effort depends upon the accuracy of these forecasts.

PLANNING AND PREPAREDNESS

Drought management plans are key to responding to drought and coordinating efforts from community to state to regional to federal levels. Many different entities and organizations are responsible for drought preparedness and planning, including water resource agencies, water and energy utilities, farmers, land managers, community planners, city councils, emergency managers, and others. A key characteristic of drought management plans is that they identify drought stages and appropriate response actions. Drought management plans develop specific responses to each drought stage that trigger actions at both state and community levels. Some local drought plans also offer guidance and plans for farmers, ranchers, businesses, institutions, and households to take measures and prepare for the challenges associated with implementing drought preparedness and water conservation measures.

During the 2017 drought, each state enacted its drought management plan. The state drought task forces assessed drought conditions on a weekly basis in coordination with the USDM. These drought classifications were based upon expert assessment of drought indices, weather information, streamflow data, and reporting of impacts by local observers. As drought severity increased, each state triggered specific local actions to respond to worsening conditions across agricultural and water resources sectors. These task forces worked well in raising awareness and coordinating across county, state, and federal agencies. The importance of proactive drought planning and preparedness will only increase as warming, changes in precipitation patterns, and weather extremes alter the character of future droughts in the region.

It is difficult to plan for drought when you are in drought, and while short-term response plans provide support during the event, states can benefit from longer-term planning that includes mitigation and adaptation strategies.

The state drought plans worked as designed, but in many cases, these are reactionary-based plans intended to respond to an emergency rather than proactive plans. These response plans are not as effective in getting services out to the public prior to conditions reaching a high severity drought level. It is difficult to plan for drought when you are in drought, and while short-term response plans provide support during the event, states can benefit from longer-term planning that includes mitigation and adaptation strategies. Many states have recognized the need to plan holistically across sectors. A holistic, ecosystem-based approach allows for consideration of building soil and plant health into water management strategies. The need to balance human well-being with ecosystem health and services is always present. However, if the conservation community is engaged in the early planning stages for drought, there is an opportunity to develop mitigation actions to minimize ecological impact and maximize human benefit. In a reactive state, there is no time nor framework for balancing and communicating the trade-offs. These lessons align with those from the NDRP Montana Drought Demonstration Project and other recent planning efforts.

Technical and financial assistance are available from entities like USDA. In addition, there are a number of resource materials that provide guidance, mitigation, and adaptation options for farms, ranches, and forestry-related production from entities like USDA. These resources and an understanding of how producers might mitigate drought impacts in the short term is also important due to the lag between the appearance of impacts and the time it takes to receive assistance. Continued training and dissemination of these types of resources is necessary, an example list follows:

- USDA Northern Plains Regional Climate Hub Assessment of Climate Change Vulnerability and Adaptation and Mitigation Strategies 2015 (USDA Northern Plains Climate Hub)
- Strategies for Managing Drought in the Northern Plains (Rangeland) (NDSU Extension Service)
- Management Considerations for Drought Affected Livestock Producers (NRCS North Dakota)
- Protect Drought Damaged Crop Fields with Cover Crops (NRCS South Dakota)
- Cover Crops to Feed Livestock (Michigan State Extension)
- Help for Grassland Drought Planning (NRCS South Dakota)
- Symbiosis for Soil Health (NRCS Montana)
- Soil Health Systems Approach Paying Dividends During Drought (NRCS)
- Drought Calculator (NRCS North Dakota)
- South Dakota Drought Tool (NRCS South Dakota)
- Managing Drought Risk on the Ranch (NDMC)
- Special issue of *Rangelands* (Aug 2016, vol 38(4):159–232) Drought on Rangelands: Effects and Solutions
- Special issue of *Climatic Change* [Jan 2018, vol 146(1–2)] Vulnerability Assessment of U.S. Agriculture and Forests (includes the Northern Plains)
- Soil Health, Water, and Climate Change: A Pocket Guide to What You Need to Know (Land Stewardship Program)
- Cultivating Climate Resilience on Farms and Ranches (Sustainable Agriculture Research and Education)
- Farmers Employ Strategies to Reduce Risk of Drought Damages (USDA Economic Research Service)
- Rangeland Analysis Platform (NRCS/BLM)
- Building Drought Resilient Communities in Montana (Montana Department of Natural Resources and Conservation)

OUTREACH AND COMMUNICATION

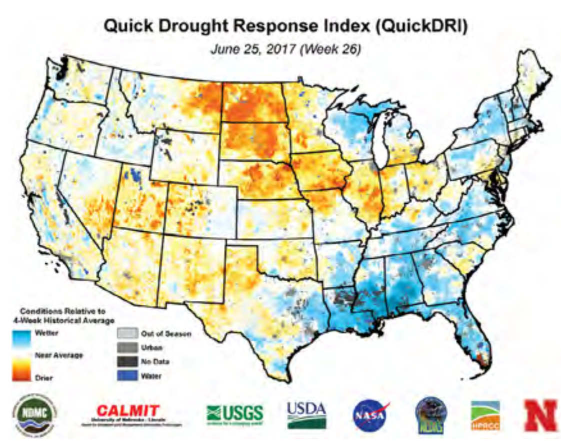
Outreach and communication are essential for effective drought early warning, planning, and preparedness—to raise awareness, to inform and warn, to share key actions that need to be taken, to understand impacts, and to evaluate actions to improve resilience moving forward. During the 2017 drought, state drought task forces, agriculture extension professionals, state climatologists, and local FSA staff played an important role in communication. While

◀ **Stef Henry, NWS Meteorologist, shared photos of smoky skies near Missoula, Montana, on Twitter.**

many lines of communication performed well, there is a need to better understand communication centers and pathways in the region and the way drought is communicated, especially in rural areas. The ability to capitalize on those networks in the future will improve both drought preparedness and response. This includes the role of social media as a tool for two-way communication to better understand the geographical spread of impacts.

Social media and other networks of communication offer efficient ways to share mental health resources in addition to traditional drought disaster assistance. During the 2017 drought there was an increased use of Twitter by the agricultural community to exchange information about the drought using specific hashtags for the 2017 drought. In the case of Montana, there was an increased public outreach over the 2012–2013 drought using more social media and getting more response from the public using avenues such as e-newsletters. In South Dakota, Twitter, radio, and TV were successful modes of communication. North Dakota also used online and call-in resources to help reach those impacted. Another lesson was that presenting local or watershed basin scales information in the context of statewide conditions worked well as local information resonated with community members. Finally, maintaining outreach to stakeholders and producers during non-drought periods is key to maintaining relationships with local extension services as conduits of information to those on the ground.

There is also a need for specific types of communication such as facilitation and training on drought-related tools, information, and mitigation and adaptation strategies for those in sectors impacted by drought. There are a number of drought web-based tools available now that were not available during the last severe drought in the region in 2011–2012; for example EDDI, Evaporative Stress Index (ESI), Quick Drought Response Index (QuickDri), Groundwater and Soil Moisture Conditions from NASA Gravity Recovery



▲ **QuickDri features short-term drought condition patterns on a weekly basis across the U.S.**

and Climate Experiment (GRACE) assimilation data, and Atmospheric Infrared Sounder (AIRS)-Based Vapor Pressure Deficit data (from NASA Jet Propulsion Laboratory). These tools are helpful, but more training is necessary to increase awareness of their existence and maximize their usefulness.

▲ **Francis "Boo Boo" Bird, rancher on the Blackfeet Indian Reservation, worked with NRCS to plan and implement a grazing management system. Glacier County, Montana. June 2017. Credit: USDA NRCS**

In terms of drought readiness, there are good examples of regional, community-based groups getting more involved, such as in the Montana Drought Demonstration Project with NDRP. In some cases, the act of drought planning itself can raise awareness, even if it is difficult to evaluate the value of a plan during drought.

A document titled *Strategies for Managing Drought in Northern Great Plains* was released in early 2017. The process of developing the plan with producers allowed for discussions about the complexities of available drought management options and the importance of looking beyond simple production numbers when determining impacts. For instance, the process and publication addressed questions like: *What are the impacts of drought to root systems of plants and soil health? How might that impact the resilience of vegetation to drought in the future?*

► ***Opposite page:*** **Solar autumn midday on fields in Montana. Credit: Kavram**

One area of communication that needs attention is the cultivation of two-way communication with the tribal nations of the U.S. Northern Plains. Information and resources necessary for drought planning, management, and response must be consistently provided and received in ways that inform decision-making for both tribal and non-tribal leaders, officials, and service providers. The need for training on tools and services applies to all communities in the region, and the tribal colleges and universities are important partners in these efforts.

INTERDISCIPLINARY RESEARCH AND APPLICATIONS

The 2017 drought underscored research questions that remain unanswered. NIDIS commissioned a drought attribution study of the 2017 U.S. Northern Plains drought to examine the causes, predictability, and the historical context of the drought for release alongside this report.[11,12] But other questions remain. For example, can the use of soil moisture observations better characterize and provide early warning for flash droughts? As more drought indicators and indices are developed, which drought indices are most appropriate as triggers of rapid onset drought? There is also a need to understand the merits of particular metrics for different geographic regions. Better seasonal forecasts for predictions, and longer lead times for drought planning and response are also needed. More timely and accurate drought forecasting includes a better understanding of the triggers used for decision-making by individuals on the ground. During the 2017 drought, the early decisions of ranchers and producers, such as destocking, provided the “early warning” of the ensuing drought for many who work on providing drought and climate information. Better communications requires a better understanding of communication networks and the way information is disseminated and travels.

In addition to these questions, there are others that were raised by this and other droughts, including the need for better predictive models for rangeland production, a better understanding of how drought and water cycle indicators can be leveraged for wildland fire management, and improvements in drought impact reporting.

CONCLUSIONS

The 2017 drought was a rapid-onset event in the spring and summer, and a major natural hazard for northeast Montana, the Dakotas, and the Canadian Prairies in which the impacts were still being felt in 2018.

Is the region prepared for future droughts, given that the frequency and intensity of future droughts will fall outside the context of our historical experience?

As a semi-arid setting with high variability, a familiar saying amongst inhabitants of the region has become, “We’re always in a drought. It just depends on how bad it is in a given year.” A pressing question after the 2017 drought was: *Is the region prepared for future droughts, given that the frequency and intensity of future droughts will fall outside the context of our historical experience?*

The purpose of this study was to examine the historic 2017 drought event and its impacts, identify opportunities to improve timeliness of and accessibility to early warning information, and identify applied research questions and opportunities to improve drought-related coordination and management within the Missouri River Basin Drought Early Warning System (DEWS). The needs that were voiced during this study repeatedly provide stepping stones to improve outcomes in future droughts for this and other regions. Identified needs include, but are not limited to, the following:

- Investing in new and existing monitoring and observation networks, which would support the development of better indicators to provide early warning.
- Improving the understanding of the relevant processes that inform forecast models in the region, which could improve seasonal forecasts to enhance drought preparedness.
- Strengthening observations and monitoring—together with forecasts—would allow decision-makers to better assess their drought risk and determine what actions to implement.
- Improving drought mitigation and response plans that consider trade-offs and actions that benefit both humans and ecosystem health and services should be in place before drought hits.
- Cultivating the relationships and networks to share information between federal, state/provincial, tribal, and local officials before, during, and after drought would improve the process of drought preparedness and response.

The challenges are large and involve uncertainties (e.g., predictions, forecasts, human behavior), trade-offs between different interests, scarce resources, and capacity, but the 2017 drought provided an opportunity to identify a path forward to a more resilient future for the region.

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ACRONYMS

AAFC	Agriculture and Agri-Food Canada
AFSC	Agriculture Financial Services Corporation (USDA)
AIRS	Atmospheric Infrared Sounder
AO	Arctic Oscillation
APHIS	Animal and Plant Health Inspection Service (USDA)
ARC	Agricultural Risk Coverage (USDA)
ARS	Agricultural Research Service (USDA)
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management (DOI)
CDC	Centers for Disease Control and Prevention
CDM	Canadian Drought Monitor
CICS-NC	Cooperative Institute for Climate and Satellites (North Carolina)
COOP	Cooperative Observer Program (NOAA)
CRP	Conservation Reserve Program (USDA)
CREP	Conservation Reserve Enhancement Program (USDA)
CSP	Conservation Stewardship Program (USDA)
CTA	Conservation Technical Assistance (USDA)
DEWS	Drought Early Warning Systems (NOAA NIDIS)
DMSC	Drought Monitoring Sub-Committee (Montana)
DNRC	Department of Natural Resources and Conservation (Montana)
DPHHS	Department of Public Health and Human Services (Montana)
DTF	Drought Task Force (South Dakota)
DWSAC	Drought and Water Supply Advisory Committee (Montana)
ED	Emergency Department
EDDI	Evaporative Demand Drought Index
ELAP	Emergency Livestock Assistance Program (USDA)
ESI	Evaporative Stress Index
ET	Evapotranspiration
EQIP	Environmental Quality Incentives Program (USDA)
EWPP	Emergency Watershed Protection Program (USDA)
FCIC	Federal Crop Insurance Corporation (USDA)
FEMA	Federal Emergency Management Agency
FSA	Farm Service Agency (USDA)
GRACE	Gravity Recovery and Climate Experiment (NASA)
HPRCC	High Plains Regional Climate Center
ITRR	Institute for Tourism and Recreation Research (University of Montana)
LFP	Livestock Forage Disaster Program (USDA)
LIP	Livestock Indemnity Program (USDA)
MDA	Montana Department of Agriculture
NADM	North American Drought Monitor
NAP	Non-Insured Crop Disaster Assistance Program (USDA)
NASA	National Aeronautics and Space Administration
NASS	National Agricultural Statistics Service (USDA)
NCEI	National Centers for Environmental Information (NOAA)
NDDA	North Dakota Department of Agriculture
NDDES	North Dakota Department of Emergency Services
NDFS	North Dakota Forest Service
NDMC	National Drought Mitigation Center
NDRP	National Drought Resilience Partnership
NDSU	North Dakota State University
NIDIS	National Integrated Drought Information System (NOAA)
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service (USDA)
NSMN	National Soil Moisture Monitoring Network (NSMN)
NWS	National Weather Service (NOAA)
QuickDRI	Quick Drought Response Index
RAWS	Remote Automated Weather Station
RCPP	Regional Conservation Partnership Program (USDA)
RD	Rural Development (USDA)
RMA	Risk Management Agency (USDA)
SDSU	South Dakota State University
SSGA	Saskatchewan Stock Growers Association
SWSI	Surface Water Supply Index
TAP	Tree Assistance Program (USDA)
TDS	Total Dissolved Solids
USACE	U.S. Army Corps of Engineers
USBR	United States Bureau of Reclamation (DOI)
USDA	U.S. Department of Agriculture
USDM	U.S. Drought Monitor
USFS	U.S. Forest Service (USDA)
USGS	U.S. Geological Survey (DOI)
WFPO	Watershed and Flood Prevention Operations (UDSA)

Partners:

Montana Climate Office

CIRES

Montana DNRC

NOAA

SDSU Extension

NCEI

National Weather Service

HPRCC

NRCS Natural Resources Conservation Service

South Dakota School of Mines & Technology

National Drought Mitigation Center, University of Nebraska

NTSG Numerical Terradynamic Simulation Group

NDDES

Institute for Tourism & Recreation Research, University of Montana

NDSU

USDA United States Department of Agriculture, Natural Resources Conservation Service

Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada

USDA Northern Plains Climate Hub, U.S. Department of Agriculture

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