USDA Northern Plains Regional Climate Hub Assessment of Climate Change Vulnerability and Adaptation and Mitigation Strategies

Photo Credit: David Augustine, ARS

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Letter from the Regional Lead

The States of Colorado, Montana, Nebraska, North Dakota, South Dakota, and Wyoming are the geographic area represented by the USDA Northern Plains Regional Climate Hub. Extensive precipitation and temperature gradients provide a diverse array of environmental conditions for agriculture in these States. Agricultural producers are responsible for making decisions on 1) the largest remaining tract of native rangeland in North America, 2) substantial areas of both dryland and irrigated cropland with diverse primary and specialty crops and pasture, 3) livestock production systems, and 4) private forests and agroforestry plantings.

One-quarter of the U.S. irrigated lands occurs in these States. Irrigation water is derived from both underground aquifers and surface water held in reservoirs. Earlier snowmelt due to warmer temperatures and earlier onset of spring, combined with less snow (more rain instead during the winter) present operational challenges for reservoir storage of water and efficient matching of water demand and availability for crop production. Furthermore, transfer of water from agricultural to urban use has transformational consequences for croplands as these lands transfer from irrigated to dryland crop production, or to permanent vegetation cover. Recent trends showcase increasing corn and soybean acreage (via displacement of wheat, hay, and pasture/rangeland) in the eastern part of the Northern Plains. Predicted increases in temperatures and longer growing seasons can increase crop yields due to earlier planting dates, or decrease yields due to negative effects during crucial grain-filling periods as a result of higher summer nighttime temperatures and dry/drought conditions. Adaptation strategies for farmers are diverse, including selection of genetics (varieties) specifically adapted to localized conditions, using cover crops, precision planting of populations of crops, precision fertilization, precision watering/irrigation, crop sequencing within crop rotations, direct seeding into stubble, and enhancement of soil health.

More than one-third of the U.S. pasture/rangeland acreage is located in the Northern Plains (>140 million acres) and a similar percentage (37 percent) of the lands enrolled in conservation programs (Conservation Reserve, Wetlands Reserve, and Conservation Reserve Enhancement Program) occur in these six States. Recent trends showcase cattle movement patterns from the Southern Plains and California to the Northern Plains due to extreme drought in those regions. Livestock producers are dealing with risks associated with longer, hotter growing seasons that include an earlier arrival of spring, an increased frequency of extreme weather events (droughts, heat waves, downpours), and altered distribution of seasonal precipitation (more winter/spring, but less predicted for summer). As a result, livestock producers are vulnerable to the following:

- Reductions in livestock performance due to higher temperatures
- Water quality issues with confined feeding operations due to predicted increases in downpours
- Increases in non-native invasive plants
- Greater occurrence of summer wildfires
- Soil erosion from wind/water on lands with low plant cover
- Reduced forage due to higher incidence of drought
- Greater pest abundance on livestock
- Enhanced woody plant expansion
- Other vegetation shifts that may negatively affect threatened/endangers species and other species of concern.

Adaptation strategies for ranchers include greater flexibility in the operation structure of their livestock enterprise, adaptive grazing management to match forage availability and forage demand, grass-banking to provide forage during dry/drought periods, increasing plant cover to improve soil health, utilization of seasonal temperature/precipitation and drought forecasting resources, and providing shelter to reduce thermal environmental effects associated with heat waves.

Agroforestry (e.g., windbreaks, silvopasture, riparian buffers, alley cropping, and forest farms) capitalizes on the interactive benefits of combining trees/shrubs with crops, livestock, or both to created integrated land use systems in the Northern Plains. Predicted increases in pests, water stress, and invasive species will increase the susceptibility of woody plants to disease and mortality. Adaptation strategies for agroforestry managers include planting a more diverse set of species, selecting species that will be better adapted to predicted, future climate conditions given their long-lived nature, and strategic use of woody plants for multiple ecosystem service benefits (e.g., shading) in urban environments.

Only 17 percent of the entire Northern Plains region is covered by natural forests or woodlands and plantations. Most of this forested land is public and contributes clean water, recreation, wildlife habitat, and wood products. Private forestland comprises 26 percent of the forestland in the Northern Plains region. Wood products, forestry, and logging contribute to the local economies across this region. Forested land owners will be challenged by longer, hotter growing seasons, greater wildfire risk, and more outbreaks of native insects. Adaptation strategies include thinning coniferous forests to reduce competition for water, and in some cases prescribed fire may have a role in enhancing the resilience of forests. Natural and planted forests are also found in the urban areas of the Northern Plains region. These forests will face the same challenges as rural forests, and in some cases, more stress related to heat generated in the urban environment. Adaptation strategies here include expanding species and seed source diversity in the urban forests, and planting pest-tolerant, drought-resistant trees. A regular cycle of maintenance can help protect city trees from extreme weather events.

The Northern Plains Regional Climate Hub is collaboratively engaged with other entities to assemble available information into tools and practices that can increase the resilience of agricultural systems to increased weather variability and a changing climate.

Justin D. Derner

Northern Plains Regional Climate Hub Lead

1. Introduction

The Northern Plains region (Colorado, Montana, Nebraska, North Dakota, South Dakota, and Wyoming) has a high diversity of land, including the largest remaining tracts of native rangeland in North America, substantial areas of both dryland and irrigated cropland and pasture, mosaics of cropland and grassland, and forested lands. Livestock production includes beef (cow-calf and yearling operations, feedlots), sheep, hogs, and dairy. Crop production is dominated by corn, soybeans, wheat, barley, alfalfa, and hay, but it also includes an array of other crops such as potatoes, sugar beets, dry beans, sunflowers, millet, canola, and barley. Agroforestry includes windbreaks, silvopasture, riparian forest buffers, alley cropping, and forest farms.

1.1. Description of the Region and Key Resources

The Northern Plains region is characterized by a northwest (dry) to southeast (wet) precipitation gradient, and a north (cool) to south (warm) temperature gradient. This region has many land uses, including the largest remaining tracts of native rangeland in North America, substantial areas of both dryland and irrigated cropland and pasture, mosaics of cropland and grassland, and forested lands (Figure 1). This region receives the majority of precipitation during the spring months (April, May, and June), and is dominated by livestock production [cattle (cow-calf, yearlings) and feedlots; hogs; dairy], crops (corn, soybeans, wheat, barley, alfalfa, hay, and a diversity of other crops such as potatoes, sugar beets, dry beans, sunflowers, millet, canola, barley, etc.) (see Table 1) (National Agricultural Statistics Service, 2012), and forest [<17% of the entire land area (Smith, Miles, Perry, & Pugh, 2009)]. Producers have adapted management and conservation practices in response to the existing precipitation and temperature gradients, and the high degree of interannual variability (Knapp & Smith, 2001). A key question for the region is how producers will be able to adapt to novel, future climatic conditions outside the ranges they have dealt with in the past. Most counties have small, rural communities that are experiencing declining populations (U.S. Census Bureau, 2009), although a few large, metropolitan cities exist (e.g., Denver, CO; Rapid City, SD; Sioux Falls, SD; Billings, MT; Omaha, NE; Lincoln, NE).

Table 1: Percent of U.S. total for agricultural commodities produced by states within the Northern Plains region 2012 (number of head, bushels, short hundredweight, tons, pounds)

	Beef cows /calves sold	Hogs/pigs sold	Sheep and Lambs sold	Corn	Corn silage	Dry Edible Beans	Forage	Oats	Wheat	Barley	Sorghum for Grain	Soybean	Sugar Beets	Sunflowers
	Percent													
Acres				22	20	57	21	21	39	59	7	19	31	85
Production	24	10	31	21	14	56	16	21	34	51	5	16	30	85

Source: US Agricultural Census (2012)

1.2. Demographics and Land Uses

The Northern Plains region is currently experiencing an unprecedented transition in agricultural land use involving the conversion of grassland to annual crops (Wright & Wimberly, 2013), and increased prevalence of monoculture cropping (Plourde, Pijanowski, & Pekin, 2013). Such trends underscore the value of understanding changes in ecosystem goods and services derived from the Northern Plains region amid a changing climate.

Increasing concentrations of greenhouse gases are anticipated to increase temperatures 2–4°F by 2050 for the Northern Plains region (IPCC, 2007). This warming is projected to modify the amount, distribution, and variability of annual precipitation, with projections of precipitation patterns in the Northern Plains indicating:

1) An increase in spring precipitation of 10–30% by the end of this century,
2) A decrease in the amount of precipitation falling as snow (USGCRP, 2009), and
3) An increase in the occurrence of both drought and heat waves.

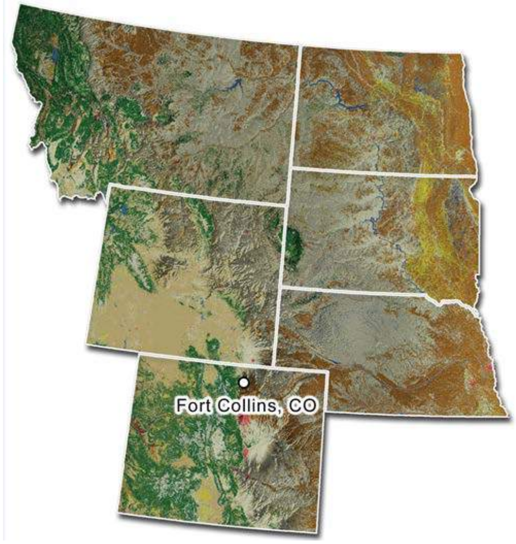

Figure 1: Northern Plains Climate Hub

Implications of this forecasted climate change include:

- Increased agricultural production (Ko et al., 2012; Morgan et al., 2011),
- Increased abundance and competitive ability of weeds and invasives (D.M. Blumenthal, Chimner, Welker, & Morgan, 2008; D. M. Blumenthal et al., 2013; Runyon, Butler, Friggens, Meyer, & Sing, 2012),
- Altered plant phenology (e.g., earlier onset of spring (Parmesan & Yohe, 2003)), and
- Advanced reproduction of plants (Zavaleta et al., 2003) and longer growing seasons in mid- and high-latitudes (Badeck et al., 2004; Menzel, Sparks, & Estrella, 2006).

1.3. General Climate Conditions, Extremes, and Past Effects

Drought is already common in this region (Soule, 1992) and was widespread and severe across most of the Northern Plains in 2012 (ERS, 2013). A new record for the hottest year ever recorded for the contiguous United States was established in 2014—surpassing the previous year's record and joining the lineup for the hottest 3 years on record (NOAA, 2013c, 2014). Increasing severity and duration of drought will require increasing flexibility in resource management (Joyce et al., 2013; Kachergis et al., 2014). Elevated atmospheric CO_2 directly stimulates plant growth and reduces negative effects of drying in a warmer climate by increasing plant water-use efficiency (Polley et al., 2013). Projected warmer and generally wetter conditions in the Northern Plains are anticipated to enhance soil water availability, net primary productivity, and crop production (Ko et al., 2012), and potentially increase forage quality, in contrast to forecasted warmer and drier conditions in many other regions [e.g., Southern Plains, Southwest (Polley et al., 2013)]. Livestock production and efficiency of production is predicted to increase due to greater net primary productivity and longer growing seasons (CCSP, 2008; Polley et al., 2013). However, more information is needed to make predictions for other agricultural systems (Haro von Mogel, 2013; IPCC, 2012).

In contrast to rangeland, little information is available on the effects of climate change on trees (natural forests, planted forests, riparian forest buffers, windbreaks, and urban trees) that occur in the Northern Plains (Joyce, 2012). Warmer temperatures are expected to reduce aboveground tree biomass and spatial variation in biomass at lower elevations, but may increase biomass on upland habitats (Guo, Brandle, Schoeneberger, & Buettner, 2004). The eastern prairie-forest boundary will likely shift under climate change (Frelich & Reich, 2010). Current stressors such as insects may be exacerbated by climate change. Eastern red cedar (*Juniperus virginiana L.*) is expanding as a result of fire exclusion and prolonged drought conditions (Meneguzzo, Butler, & Crocker, 2008), and is altering wildlife habitat (Moser, Hansen, & Atchison, 2008). Agroforestry has been suggested as a potential mitigation and adaptation strategy for producers and managers in response to a changing climate (Morgan et al., 2010; M. Schoeneberger et al., 2012).

The snow-dominated high elevations of the Rocky Mountains serve as natural reservoirs for water storage and supply irrigation water to Northern Plains croplands (in addition to the High Plains Aquifer System for the southern portion of the region). Climate change is projected to result in earlier snowmelt and stream flow runoff (Stewart, Cayan, & Dettinger, 2004), precipitation shifting to more rain than snow (Knowles, Dettinger, & Cayan, 2006), and snowpack declines (Regonda, Rajagopalan, Clark, & Pitlick, 2005) leading to less water being available for irrigation during the cropping season. Tree species are expected to move to higher elevation with projections of a warmer climate (Bartlein, Whitlock, & Shafer, 1997; Koteen, 2002; Whitlock, Shafer, & Marlon, 2003). A warmer climate may also increase the frequency and spatial extent of wildfire (Westerling, Turner, Smithwick, Romme, & Ryan, 2011), which would exacerbate existing management concerns including densely stocked stands, high fuel loads and fire hazard, mountain pine beetle (*Dendroctonus ponderosae Hopkins*) outbreaks, and potential loss of ecosystem services (Edburg et al., 2012; Mikkelson et al., 2013). Furthermore, climate change effects on stream flow in semiarid riparian ecosystems on the Northern Plains are expected to reduce the abundance of dominant, native, early successional tree species and favor increases in herbaceous species and drought-tolerant species (including many introduced species), leading to reduced habitat quality for riparian fauna (Perry, Andersen, Reynolds, Nelson, & Shafroth, 2012).

1.4. Summary of NCA Regional Climate Scenarios

Temperatures, and the freeze-free season are on the rise in the Northern Plains. Extreme variability in year-to-year hot and cold periods has been observed in the Northern Plains as well as fewer cold spells in recent years. Increased temperatures, hot days, and precipitation are expected in the Northern Plains, as well as longer freeze-free seasons.

Temperature

Annual temperatures in the Great Plains have been higher than the 1901–1960 average for the past 20 years for all seasons. The Northern Plains have seen the most change in long-term average temperatures. The annual average temperature in North Dakota rose 0.26°F per decade for the past 130 years, making it the fastest rate in the Nation (NOAA, 2013a).

The freeze-free season has been on the rise since the early 20th century (see Figure 2) with the last occurrence of 32°F in the spring occurring earlier and the first occurrence in the fall occurring later (NOAA, 2013a). Table 2 provides the trends in temperature increase/anomaly[1] in the Northern Plains for the time period 1895–2011. The most significant anomaly is in the winter season, with a 0.33°F/decade increase.

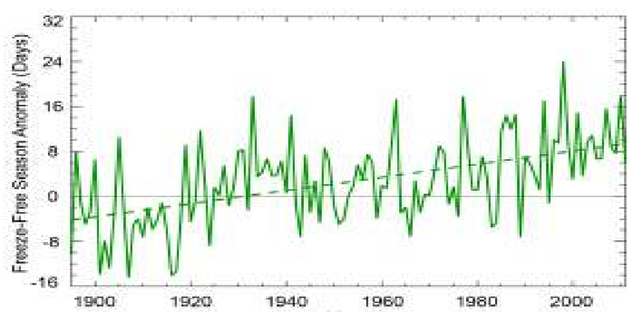

Figure 2: Difference in mean annual freeze-free season length for the U.S. Great Plains (deviations from the 1901–1960 average) (NOAA, 2013a)

[1] A temperature anomaly is a departure from a reference value over a long-term average. Positive anomalies demonstrate that the observed temperature was warmer than the reference value, and negative anomalies indicate the observed temperatures were cooler than the reference value (NOAA, 2015).

Precipitation

Annual precipitation for the Great Plains during the 1990s was greater than the 1901–1960 average, less than the average during the early 2000s, and with the exception of 2012, greater than average in recent years. The driest decades in the Great Plains were the 1950s and 1930s, with 1956 recorded as the driest year on record (NOAA, 2013a).[2]

Table 2: 1895–2011 trends in temperature anomaly (°F/decade) in the Northern Plains

Season	Temperature (°F/decade)
Winter	+0.33
Spring	+0.20
Summer	+0.14
Fall	+0.13
Annual	+0.20
Source: (NOAA, 2013a)	

Extremes

Hot and cold periods in the Great Plains are extremely variable, with a trend toward fewer cold waves. Since 1990, more extreme precipitation events have been observed with the greatest single-day downpours occurring in 2007 (NOAA, 2013a). During the 1930s, heat waves averaged more than four times the long-term mean temperature value. The highest number of heat waves since the 1930s occurred in 1954 and 2012. The frequency of cold periods in the Northern Plains has been low since the 1990s. The 1950s had the fewest severe cold waves, averaging 60 percent below the long-term mean (NOAA, 2013a).

Understanding the potential for extreme precipitation is important in making infrastructure decisions and planning for potential effects on crop and rangeland. These events can be quantified in different ways; here we use the frequency of an extreme precipitation occurring in a 5-year period. Over the 1895–2011 period, extreme precipitation events demonstrate substantial interannual and decadal-scale variability, with an upward trend (Figure 3). There have been a number of years since 1990 with a high number of extreme events (NOAA, 2013a).

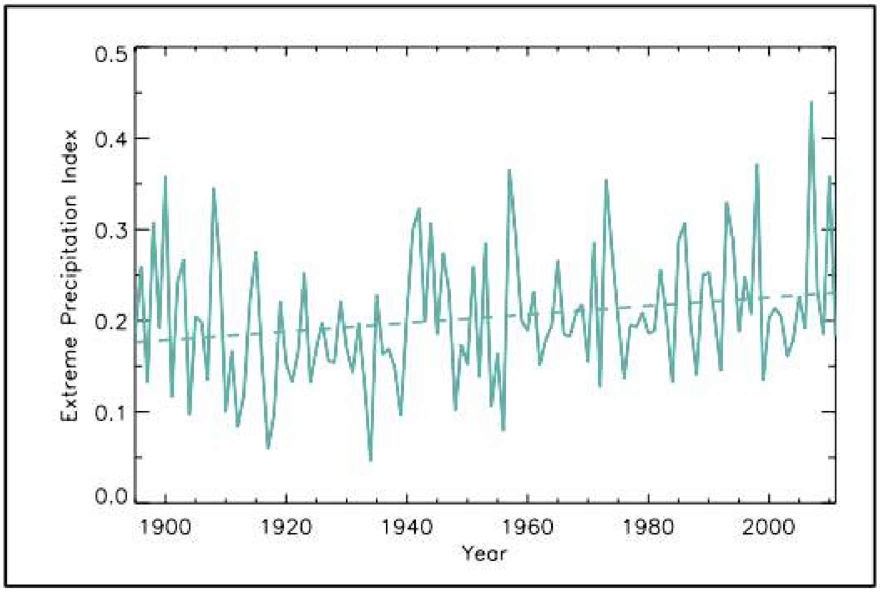

Figure 3: Time series of extreme precipitation index for the occurrence of 1-day, 1-in-5-year extreme precipitation, for the Great Plains region. The dashed line is a linear fit. Based on daily COOP data from long-term stations in the National Climatic Data Center's Global Historical Climate Network data set. Source: (NOAA, 2013a).

Expected Changes

Annual mean temperatures and number of hot days (maximum temperature of more than 95°F) are expected to increase in the Northern Plains. The freeze-free season is predicted to increase by between 20–30 days throughout the region. There is potential for more precipitation across the region in all seasons except for summer, and the number of wet days (precipitation exceeding 1 inch) is expected to increase except in the far western portions of the Great Plains (NOAA, 2013a) .

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[2] For state-level comparative seasonal or annual climate trend analysis data from the National Climate Data Center monthly and annual temperature and precipitation datasets see http://charts.srcc.lsu.edu/trends/.

2. Regional Agriculture's Sensitivity to Climate Change and Adaptation Strategies

Land managers in the Northern Plains are experiencing changing climate and weather variability on the ground that is outside of the ranges they have dealt with in the past. These changes are affecting producers' day-to-day decisions, and some of these changes are expected to intensify. Examples follow.

Extreme weather events: Extreme events have dramatically influenced farmer and rancher livelihoods and enterprises in this region. The early October 2013 snowstorm resulted in tens of thousands of livestock deaths in western South Dakota and northwestern Nebraska with ripple economic effects to the businesses and local economies of these agricultural communities (Knutson, 2013; NOAA, 2013b). Excessive rainfall in September 2013 in Colorado flooded crops and farmland, damaged houses and agricultural structures, and impaired water quality of rivers downstream in neighboring States.

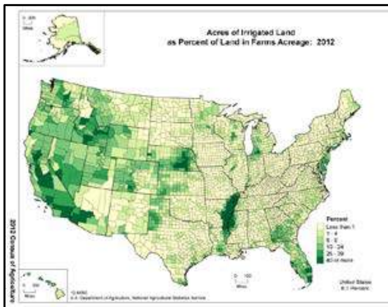
Drought: The extreme drought conditions of 2012 had substantial negative economic results for land managers and local rural economies. Forage and hay production was less than half of average values resulting in low stocks of hay and much higher prices. Many livestock producers sold their herds, or markedly reduced their numbers, with the U.S. beef cow herd now at its lowest level since 1952. More than 2,000 counties nationwide were designated as disaster areas in 2012 due to drought.

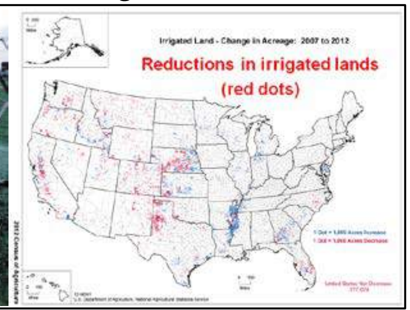
Longer, hotter growing seasons: Earlier arrival of spring is resulting in longer growing seasons; coupled with prolonged hot periods during the growing season, this is altering the selection of crops and crop varieties. It is also enhancing the growth of non-native weeds (e.g., cheatgrass, *Bromus tectorum*; smooth brome, *Bromus inermis*; Kentucky bluegrass, *Poa pratensis*; and Dalmatian toadflax, *Linaria dalmatica*) and increasing the risk of late-spring freeze damage to crops and forage production. Extended and hotter growing seasons are resulting in longer and more intense fire seasons that pose a risk of reducing forage available for livestock, altering critical wildlife habitat and affecting water quantity and quality from forest watersheds. The fire danger is especially acute for forested areas that had large diebacks of trees associated with the mountain pine beetle outbreak.

2.1. Cropping Systems Overview of Risks, Vulnerabilities, and General Adaptation Strategies

Irrigated Crops

Characteristics: Parts of the Northern Plains States (Colorado, Montana, Nebraska, North Dakota, South Dakota, and Wyoming) are reliant on irrigation (both from aquifers and surface water) for crop production. For example, Nebraska has a high proportion of irrigated crops (primarily corn and soybeans) that use groundwater from the Ogallala aquifer. In contrast, most irrigated crop production in Wyoming and western Colorado is from surface water held in reservoir storage following snowmelt runoff.





Risks:

1. Longer, hotter growing seasons with earlier arrival of spring.
2. More extreme weather events (e.g., downpours and droughts, snowstorms).
3. Altered distribution of seasonal precipitation (more winter and spring precipitation, but less summer precipitation).

Vulnerabilities:

1. Altered snowpack levels with earlier snow melt and runoff to reservoirs.
2. Dropping levels in groundwater aquifers limits water availability and increases drilling and pumping costs.
3. Reservoir management timing to accommodate the earlier snow melt and runoff.
4. Excess seasonal soil water in eastern parts of the Northern Great Plains.
5. Predicted higher frequency of downpours could present water runoff and quality issues for lands with erosion risk and/or drainage issues.
6. Greater frequency, duration, and intensity of drought can increase reliance on groundwater/surface irrigation water for crop production.
7. Longer and warmer growing seasons and altered distribution of seasonal precipitation can increase pest and weed pressure for crops.
8. Greater spring precipitation decreases the number of workable field days in the eastern portion of the Northern Plains and will place a constraint on producers being able to accomplish all of their spring operations in a timely manner.

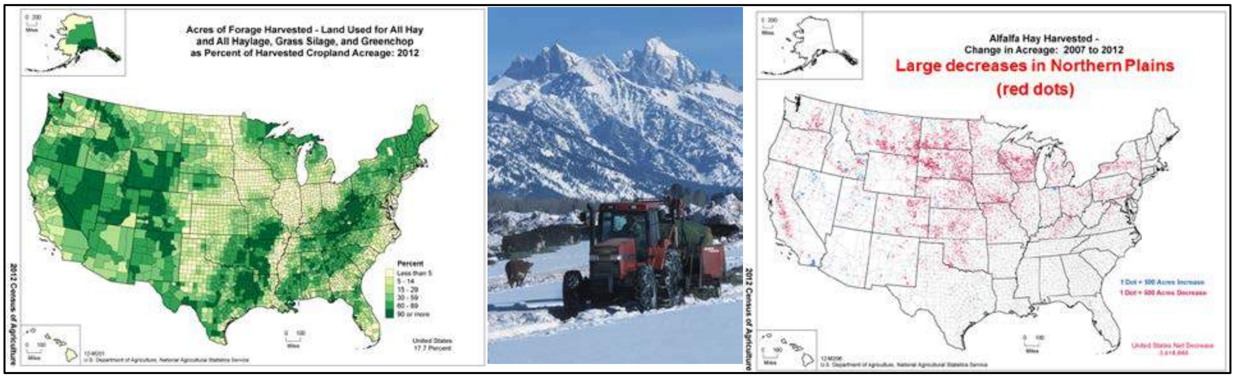
Adaptation Strategies:

1. Increase irrigation efficiency (i.e., more crop per drop).
2. Use new technology for subsurface irrigation, and irrigation with gray or reclaimed water to reduce water use.
3. Shift to more water-efficient crops.
4. “Water-bank” by using less irrigation in non-drought years, saving water for use in drought years, and creating markets to lease conserved water to municipalities to balance agricultural and municipal water needs.

References: Shafer et al. (2014), Marshall et al. (2014)

Alfalfa/Hay

Characteristics: Alfalfa/hay production in the Northern Plains occurs on about 13.7 million acres, representing 24 percent of the hay acreage in the United States. Hay production, as a percentage of the harvested cropland acreage, is more prominent in the western part of the Northern Plains, with a high reliance on irrigation from snowmelt runoff. Alfalfa/hay production contributes about $3.3 billion to the value of agricultural commodities of the Nation. From 2007 to 2012, large acreage reductions were observed across the Northern Plains for alfalfa hay due to expansion of more profitable corn/soybean, and reductions in water for irrigation.



Risks:

1. Longer, hotter growing seasons with earlier arrival of spring.
2. More extreme weather events (e.g., downpours and droughts, snowstorms).
3. Altered distribution of seasonal precipitation (more winter and spring precipitation, but less summer precipitation).

Vulnerabilities:

1. Greater frequency, duration, and intensity of drought can reduce production and economic viability of enterprises, and increase reliance on irrigation.
2. Predicted higher frequency of downpours could present water runoff and quality issues for lands with erosion risk and/or drainage issues.
3. Longer and warmer growing seasons, and altered distribution of seasonal precipitation, can increase pest and weed pressure for crops.
4. Altered snowpack levels with earlier snow melt and runoff to reservoirs influences availability of irrigation water in reservoirs.
5. Dropping groundwater aquifer levels are reducing irrigation water, and increasing costs.
6. Increased soil salinity.

Adaptation Strategies:

1. Genetic development of cultivars through breeding programs can help offset negative effects of rising temperatures, drought, and soil salinity.
2. Increase soil health through enhanced soil management and residue management.[3]
3. Increase irrigation efficiency (i.e., more crop per drop) and utilize new technology for subsurface irrigation to reduce water use.

References: Shafer et al. (2014), Johnston (2014), Russelle (2014)

[3] See http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/mgnt/.

Corn

Characteristics: Corn is a key crop of the eastern part of the Northern Plains, with substantial acreages in Nebraska, North Dakota, and South Dakota. From 2007 to 2012, large acreage expansion for corn has occurred in North Dakota and South Dakota, displacing wheat and small grains). Almost 18 million acres of corn for grain, representing 21 percent of the U.S. corn acreage, is grown in the Northern Plains. The value of this corn grain is about $13.3 billion (average from 2009 to 2013 crop years). Substantial development of ethanol facilities in the region provides by-products (e.g., distiller's grains) for cattle, and livestock also graze residues in corn fields following harvest.

Risks:

1. Longer, hotter growing seasons with earlier arrival of spring.
2. More extreme weather events (e.g., downpours and droughts, snowstorms).
3. Altered distribution of seasonal precipitation (more winter and spring precipitation, but less summer precipitation).

Vulnerabilities:

1. Warming temperatures and longer growing season has led to expansion of corn (and displacement of wheat/small grains/pastures) in the eastern part of North Dakota and South Dakota.
2. Increasing use of corn for ethanol creates greater land use change.
3. Greater frequency, duration, and intensity of drought can reduce production and economic viability of enterprises, and increase reliance on irrigation.
4. Excess seasonal soil water in eastern parts of the northern Great Plains.
5. Predicted higher frequency of downpours could present water runoff and quality issues for lands with erosion risk and/or drainage issues.
6. Longer and warmer growing seasons, and altered distribution of seasonal precipitation can increase pest and weed pressure for crops.

Adaptation Strategies:

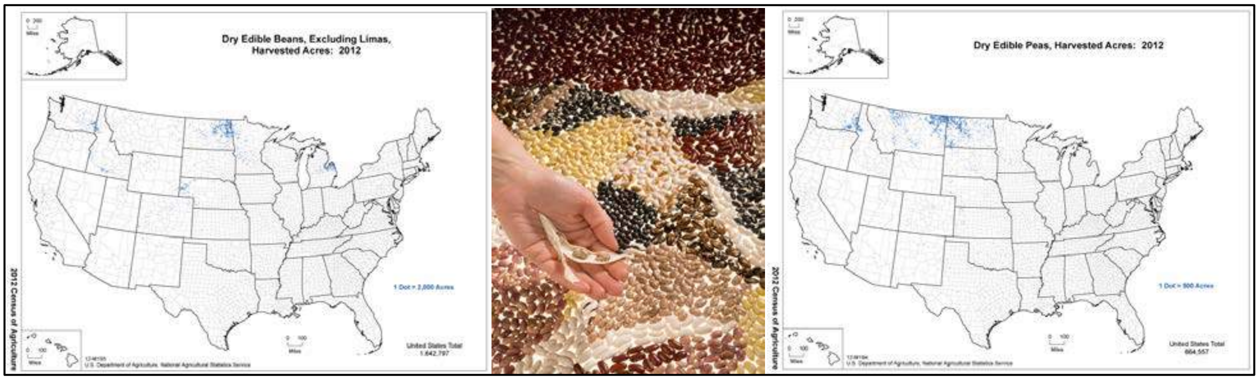
1. Genetic development of cultivars through breeding programs can help offset negative effects of rising temperatures.
2. Increase soil health through enhanced soil management and residue management.[4]
3. Use tile drainage practices to reduce excess seasonal soil water conditions.
4. Increase irrigation efficiency (i.e., more crop per drop), and new technology for subsurface irrigation to reduce water use.

References: Shafer et al. (2014), Wright & Wimberly (2013), Islam (2012)

[4] See http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/mgnt/.

Dry Edible Beans/Peas

Characteristics: Dry edible beans and peas are grown throughout Colorado, Montana, Nebraska, North Dakota, South Dakota, and Wyoming. Dry edible beans are grown on about 810,000 acres in the Northern Plains, representing 54 percent of the U.S. acreage, with a value of $450 million.



Risks:

1. Longer, hotter growing seasons with earlier arrival of spring.
2. More extreme weather events (e.g., downpours and droughts, snowstorms).
3. Altered distribution of seasonal precipitation (more winter and spring precipitation, but less summer precipitation).

Vulnerabilities:

1. Warming temperatures and longer growing seasons, which has resulted in corn and soybeans being planted farther northwest (into eastern parts of the Great Plains) can lead to displacement of acreage planted to dry edible beans and peas.
2. Greater frequency, duration, and intensity of drought can reduce production and economic viability of enterprises.
3. Predicted higher frequency of downpours could present water runoff and quality issues for lands with erosion risk and/or drainage issues.
4. Longer and warmer growing seasons, and altered distribution of seasonal precipitation, can increase pest and weed pressure for crops.

Adaptation Strategies:

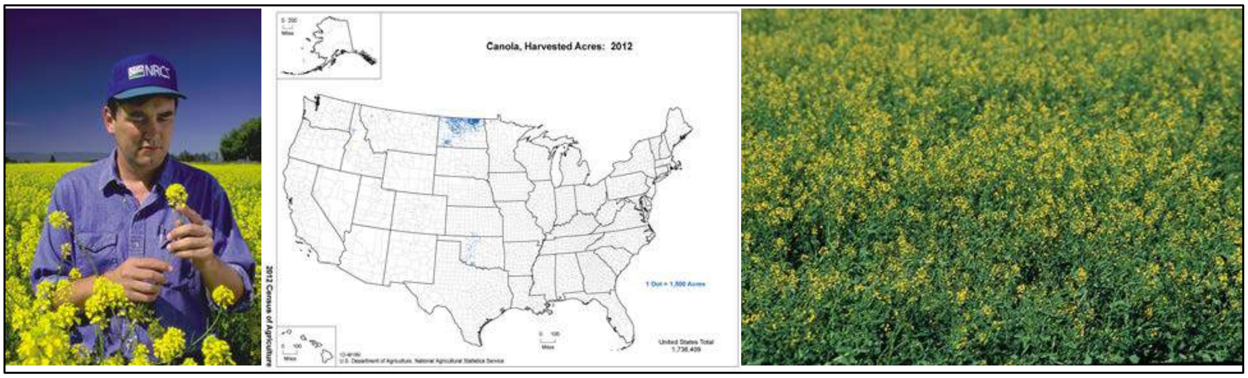
1. Increase soil health through enhanced soil management and residue management.[5]
2. Dry edible beans and peas can be used for double cropping or pulse crops to provide nearly year-round ground cover to reduce soil exposure to water and wind erosion.
3. Genetic development of cultivars through breeding programs can help offset negative effects of rising temperatures and drought.

References: Shafer et al. (2014), Borchers et al. (2014)

[5] See http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/mgnt/

Oilseed Crops

Characteristics: Oilseed crops (e.g., canola, safflower, camelina, mustard) are specialty crops in parts of the Northern Plains, with acreage primarily in North Dakota. Canola is grown on about 1.1 million acres annually, representing 86 percent of the U.S. acreage. The total value of canola is about $370 million (average from 2009 to 2013 crop years). Safflower is grown on about 36,000 acres in the Northern Plains (23% of the U.S. acreage), and contributes $8.6 million of commodity value. Mustard is grown on 37,000 acres in Montana and North Dakota (85% of U.S. acreage).



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2. More extreme weather events (e.g., downpours and droughts, snowstorms).
3. Altered distribution of seasonal precipitation (more winter and spring precipitation, but less summer precipitation).

Vulnerabilities:

1. Warming temperatures and a longer growing season have led to expansion of corn and soybeans and displacement of small grains and oil seed crops, leading to greater land use change and crop competition for land.
2. Greater frequency, duration, and intensity of drought can reduce production and economic viability of enterprises.
3. Predicted higher frequency of downpours could present water runoff and quality issues for lands with erosion risk and/or drainage issues.
4. Longer and warmer growing seasons, and altered distribution of seasonal precipitation, can increase pest and weed pressure for crops.

Adaptation Strategies:

1. Genetic development of cultivars through breeding programs can help offset negative effects of rising temperatures and drought.
2. Increase soil health through enhanced soil management and residue management.[6]
3. Oilseed crops being used for double cropping or pulse crops to provide nearly year-round ground cover to reduce soil exposure to water and wind erosion.

References: Shafer et al. (2014), Moore & Karlen (2013), Gesch & Archer (2013)

[6] See http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/mgnt/

Soybeans

Characteristics: Soybeans are a key crop of the eastern part of the Northern Plains, with substantial acreages in Nebraska, North Dakota, and South Dakota. From 2007 to 2012, large acreage expansion for soybeans has occurred in North Dakota and South Dakota (replacement of wheat and small grains). Soybeans are grown on almost 13.5 million acres in the Northern Plains, representing 18 percent of the U.S. soybean acreage. The value of soybeans is about $6.4 billion (average from 2009 to 2013 crop years).

Risks:

1. Longer, hotter growing seasons with earlier arrival of spring.
2. More extreme weather events (e.g., downpours and droughts, snowstorms).
3. Altered distribution of seasonal precipitation (more winter and spring precipitation, but less summer precipitation).

Vulnerabilities:

1. Warming temperatures and longer growing season has led to expansion of soybeans (and displacement of wheat/small grains/pastures) in the eastern part of North and South Dakota.
2. Greater frequency, duration, and intensity of drought can reduce production and economic viability of enterprises, and increase reliance on irrigation.
3. Excess seasonal soil water in eastern parts of the Northern Great Plains can jeopardize early season crop establishment.
4. Predicted higher frequency of downpours could present water runoff and quality issues for lands with erosion risk and/or drainage issues.
5. Longer and warmer growing seasons, and altered distribution of seasonal precipitation, can increase pest and weed pressure on crops.

Adaptation Strategies:

1. Genetic development of cultivars through breeding programs can help offset negative effects of rising temperatures and drought.
2. Increase soil health through enhanced soil management and residue management to improve water and nutrient availability.[7]
3. Use tile drainage practices and/or cover crops to manage seasonal soil water conditions.
4. Increase irrigation efficiency (i.e., more crop per drop) and new technology for subsurface irrigation to reduce water use.

References: Shafer et al. (2014), Johnston (2014), Malcolm et al. (2012)

[7] See http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/mgnt/

Sugar Beets

Characteristics: Sugar beets are grown in four primary areas with the Northern Plains States (eastern North Dakota; border of Montana and North Dakota; south central Montana and north central Wyoming; and the area where Wyoming, Nebraska, and Colorado intersect). Sugar beets are planted on about 370,000 acres annually in the Northern Plains, representing about 31 percent of the U.S. acreage. The total commodity value of sugar beets (average 2009 to 2013) is about $600 million.

Risks:

1. Longer, hotter growing seasons with earlier arrival of spring.
2. More extreme weather events (e.g., downpours and droughts, snowstorms).
3. Altered distribution of seasonal precipitation (more winter and spring precipitation, but less summer precipitation).

Vulnerabilities:

1. Altered snowpack levels with earlier snow melt and runoff to reservoirs influences availability of irrigation water.
2. Dropping levels in groundwater aquifers.
3. Increasing soil salinity issues in areas of the Northern Plains with excessive seasonal soil water.
4. Predicted higher frequency of downpours could present water runoff and quality issues for lands with erosion risk and/or drainage issues.
5. Greater frequency, duration, and intensity of drought can increase reliance on groundwater/surface irrigation water for crop production.
6. Longer and warmer growing seasons, and altered distribution of seasonal precipitation, can increase pest and weed pressure for crops.

Adaptation Strategies:

1. Increase soil health through enhanced soil management, residue management, cover crops, and rotations.[8]
2. Genetic development of cultivars through breeding programs can help offset negative effects of rising temperatures and drought.
3. Increase irrigation efficiency (i.e., more crop per drop).

References: Shafer et al.(2014), Panella et al. (2014)

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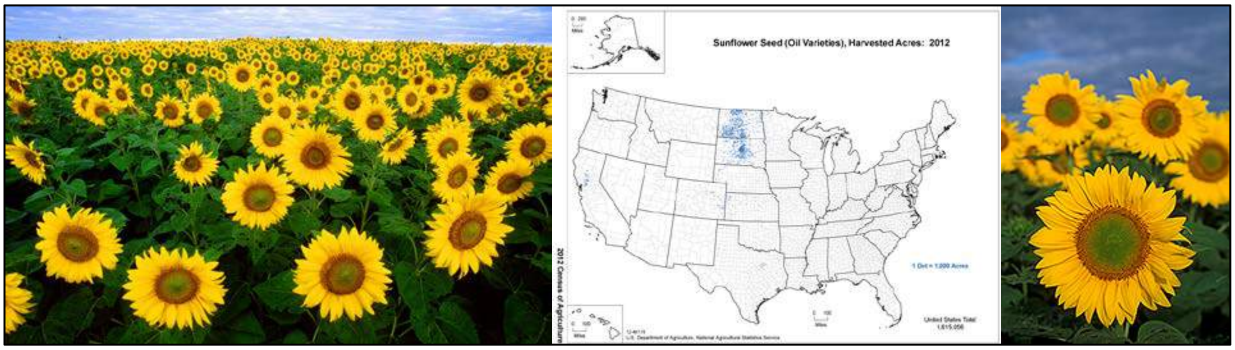
[8] See http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/mgnt/.

Sunflowers

Characteristics: Sunflower acreage is predominately in the Northern Plains States, with a majority of these acres in North Dakota and South Dakota. Sunflowers are planted on about 1.4 million acres annually in the Northern Plains, representing about 82 percent of the U.S. acreage. The total commodity value of sunflowers (average 2009 to 2013) is about $470 million.



Risks:

1. Longer, hotter growing seasons with earlier arrival of spring.
2. More extreme weather events (e.g., downpours and droughts, snowstorms).
3. Altered distribution of seasonal precipitation (more winter and spring precipitation, but less summer precipitation).

Vulnerabilities:

1. Warming in the fall through early spring can result in longer emergence periods for seedlings, thereby increasing their vulnerability to environmental conditions (e.g., frost damage).
2. Greater frequency, duration, and intensity of drought can reduce production and economic viability of enterprises.
3. Predicted higher frequency of downpours could present water runoff and quality issues for lands with erosion risk and/or drainage issues.
4. Longer and warmer growing seasons, and altered distribution of seasonal precipitation, can increase pest and weed pressure for crops.

Adaptation Strategies:

1. Increase soil health through enhanced soil management and residue management.[9]
2. Sunflowers can be used in a double cropping system to provide nearly year-round ground cover to reduce soil exposure to water and wind erosion.
3. Genetic development of cultivars through breeding programs can help offset negative effects of rising temperatures and drought.

References: Shafer et al. (2014), Thomson et al. (2014), Clay et al. (2014), Gesch & Archer (2013)

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[9] See http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/mgnt/.

Wheat

Characteristics: Wheat is a primary crop in the Northern Plains with substantial acreage in Montana, North Dakota, western Dakota and Nebraska, southeastern Wyoming, and eastern Colorado. Spring wheat (excluding durum wheat) is grown on about 9.6 million acres, representing 78 percent of the U.S. acreage. This contributes $2.7 billion value of agricultural commodity. Durum spring wheat is grown on 1.7 million acres, or 90 percent of the U.S. acreage, and contributes $400 million of commodity value. Winter wheat is grown on 7.5 million acres, or 23 percent of the U.S. acreage. Winter wheat contributes $1.9 billion value of agricultural commodity. From 2007 to 2012, large acreage reductions were observed across the Northern Plains.

Risks:

1. Longer, hotter growing seasons with earlier arrival of spring.
2. More extreme weather events (e.g., downpours and droughts, snowstorms).
3. Altered distribution of seasonal precipitation (more winter and spring precipitation, but less summer precipitation).

Vulnerabilities:

1. Warming temperatures and longer growing season has led to displacement of wheat due to expansion of corn and soybeans.
2. Greater frequency, duration, and intensity of drought can reduce production and economic viability of enterprises.
3. Predicted higher frequency of downpours could present water runoff and quality issues for lands with erosion risk and/or drainage issues.
4. Longer and warmer gr owing seasons, and altered distribution of seasonal precipitation, can increase pest and weed pressure for crops.

Adaptation Strategies:

1. Alter the dryland wheat-fallow system by adding summer crops (e.g., forages) which provides nearly year-round ground cover to reduce soil exposure to water and wind erosion. Both winter and spring wheat can add diversity to corn-soybean rotation with cover crops.
2. Genetic development of cultivars through breeding programs can help offset negative effects of rising temperatures and drought.
3. Increase soil health through enhanced soil management and residue management.[10]

References: Shafer et al. (2014), Johnston (2014), Wilcox and Makowski (2013); Saseendran et al. (2012)

[10] See http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/mgnt/.

2.2. Livestock Systems Overview of Risks, Vulnerabilities and General Adaptation Strategies

USDA Agricultural Research Service (ARS) leading novel co-production Adaptive Grazing Management experiment

Photo Credit: Matt Mortenson (2015)

Adaptive grazing management is proactively matching forage availability with forage demand, within variable (both spatial and temporal) environments to achieve desirable and sustainable production of ecosystem goods and services. Inherent to adaptive grazing management is planning, monitoring of key indicators, and using this monitoring data to make science-based management changes within and between grazing seasons. For example, adaptive grazing incorporates flexibility in stocking rates across types of grazing animals in the livestock enterprise, altering timing and season of grazing (and correspondingly rest) within a pasture among years, along with a fundamental knowledge of the distribution of precipitation that affects forage and livestock production to enhance decision-making for ranchers. Incorporation of shorter-term seasonal (1- to 3-month) weather forecasts of temperature and precipitation assist in determinations of available soil moisture through decision tools and triggers (Derner, Augustine, Ascough II, & Ahuja, 2012) to reduce risk related to forage and livestock production (Fang et al., 2014) and increase resiliency of rangelands to natural disturbances, including drought (Kachergis et al., 2014).

The Rangeland Resources Research Unit of the USDA-Agricultural Research Service is leading a novel co-production experiment in the shortgrass steppe rangeland ecosystem at the Central Plains Experimental Range (a Long Term Agro-ecosystem Research, LTAR network site) (see http://www.ars.usda.gov/Main/Docs.htm?docid=24218 for the Adaptive Grazing Management Experiment). In collaboration with scientists from Texas A&M University, UC-Davis, and Colorado State University, ARS scientists are evaluating livestock, vegetation, wildlife, soils, and ecosystem-level responses from adaptive grazing management decisions determined by a 10-member stakeholder group, with representatives from the ranching community, conservation and environmental groups, and private and public land managers. This 10-year experiment, initiated in 2012 with the first organizational meeting, was implemented beginning with the 2014 grazing season. The stakeholder group chose and prioritized outcomes desired from this experiment, determined criteria and/or triggers for movement of livestock among pastures in an adaptive manner, and selected appropriate monitoring data requirements needed for feedback to determine whether management had been achieving the desired outcomes. Replicated experimental design plans, decision-making frameworks including criteria for livestock movement among pastures, monitoring approaches, and summary data results are available through a project website. Weekly e-mail updates, and three to four project meetings annually with pasture visits included to observe on-the-ground conditions and discuss management strategies, facilitate participatory approaches, and communications among the stakeholder group members for this Adaptive Grazing Management experiment.

Grazing Lands

Characteristics: Grazing land (i.e., rangeland and pastureland) constitutes approximately 140 million acres in the Northern Plains States, which represents 34 percent of the total grazing land in the United States (National Agricultural Statistics Service, 2014a).

Risks:

1. Longer, hotter growing seasons with earlier arrival of spring.
2. More extreme weather events (e.g., downpours, droughts, heat waves).
3. Altered distribution of seasonal precipitation (more winter and spring precipitation, but less summer precipitation).

Vulnerabilities:

1. Enhanced competitive ability of non-native invasive plants (e.g., cheatgrass, smooth brome, Kentucky bluegrass, Dalmatian toadflax, Russian thistle).
2. Warmer and expected drier summers increase risk of wildfires.
3. Greater potential of soil erosion from higher frequency of downpours on grazing lands with low plant cover.
4. Reduced forage production and livestock gains with higher incidence of drought occurrence.
5. Higher pest abundance on livestock due to longer and warmer growing seasons.
6. Expansion of woody plants (e.g., eastern red cedar), which reduces productivity and livestock carrying capacity, as well as increases risks of wildfire.
7. Vegetation shifts may negatively affect threatened/endangered species/species of concern.

Adaptation Strategies:

1. Adaptive grazing management providing flexibility to match forage availability/demand [flexibility in stocking rates, time and season of grazing (and rest) across ranches/watersheds/landscapes (see textbox above)].
2. Grass-banking (resting of pastures for >1 year) to provide forage during dry periods.
3. Proactive management strategies to reduce invasive species, reduce the risk of wildfires, and promote resiliency of native plant communities.
4. Emphasis on increasing plant cover to improve soil health (e.g., beneficial for soil water holding capacity and nutrient cycling) and ecosystem resilience to drought and downpours.[11]
5. Increased attention to seasonal precipitation/temperature and drought forecasting resources (e.g., http://drought.gov/drought/).

References: Shafer et al. (2014), Polley et al. (2013), Joyce et al. (2013)

[11] See http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/mgnt/

Livestock Grazing

Characteristics: About 25 percent of the Nation's beef cows/calves (19 million head) and sheep/lambs (1.4 million head) graze on the 140 million acres of grazing land (i.e., rangeland and pastureland) in the Northern Plains States (National Agricultural Statistics Service, 2012). Livestock also graze crop residues (e.g., cornstalks) in these States.

Risks:

1. Longer, hotter growing seasons with earlier arrival of spring.
2. More extreme weather events (e.g., downpours and droughts).
3. Altered distribution of seasonal precipitation (more winter and spring precipitation, but less summer precipitation).

Vulnerabilities:

1. Expansion of non-native, invasive plants (e.g., cheatgrass, smooth brome, Kentucky bluegrass, Dalmatian toadflax, Russian thistle), and woody plants (e.g., eastern red cedar) can shift plant community composition. This shift could negatively affect forage quantity and quality, and habitat for threatened/endangered species and species of concern.
2. Predicted higher frequency of downpours on grazing lands with low plant cover can increase potential for soil erosion, resulting in reduced productivity into the future.
3. Greater frequency, duration, and intensity of drought can reduce forage production, livestock performance, and economic viability of enterprises.
4. Longer and warmer growing seasons, and altered distribution of seasonal precipitation, can increase pest abundance on livestock.

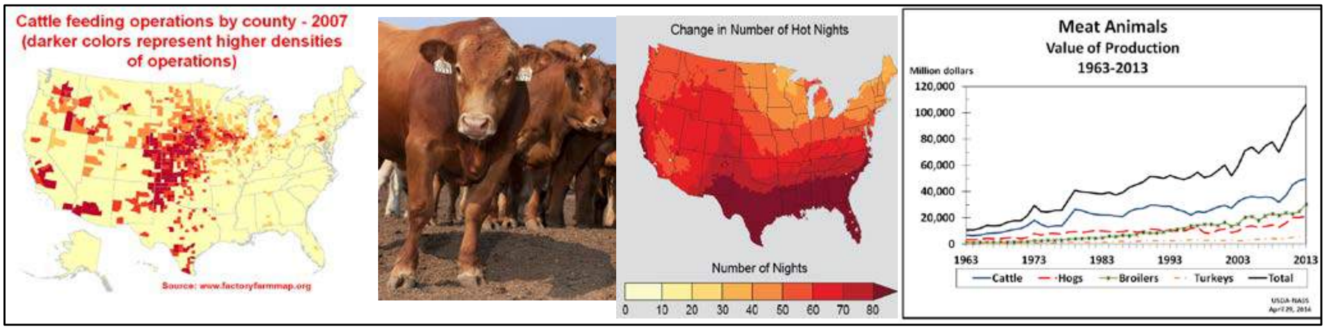
Adaptation Strategies:

1. Flexibility in operation structure to include both cow-calves and yearlings, along with incorporation of high-quality precipitation forecasts could potentially double economic returns.
2. Flexible and adaptive grazing management to match forage availability with forage demand [flexibility in stocking rates, timing and season of grazing, and rest (see textbox above)].
3. Alternative livestock breeds, class, or species, especially those with a higher heat, drought, and parasite tolerance.
4. Geographic relocation and grass-banking (resting of pastures for >1 year) to provide forage during dry periods.

References: Shafer et al. (2014), Polley et al. (2013), Joyce et al. (2013), Torell et al. (2010), Ritten et al. (2010)

Confined Livestock

Characteristics: The Northern Plains States produce about 23 percent of the Nation's commercial red meat production. About 31 percent of the commercial cattle slaughter, 11 percent of hog slaughter, and 40 percent of sheep and lamb slaughter occurs in the Northern Plains States. Nationally, about 74 billion pounds of meat is produced with a value of more than $100,000 million. Approximately 11.6 million head of cattle were on feed (July 25, 2014), with this value down 6 percent from a year earlier (National Agricultural Statistics Service, 2014b).



Risks:

1. Longer, hotter growing seasons with earlier arrival of spring.
2. More extreme weather events (e.g., downpours and droughts, snowstorms).
3. Altered distribution of seasonal precipitation (more winter and spring precipitation, but less summer precipitation).

Vulnerabilities:

1. Higher temperature-humidity indexes are predicted, and can reduce livestock performance and possibly increase livestock mortality.
2. Increases in cattle on feed in Northern Plains States provides potential for land use competition for grain production to meet demand for livestock feed.
3. Predicted higher frequency of downpours could present water runoff and quality issues for confined animal feeding operations.
4. Greater frequency, duration, and intensity of drought can reduce crop production, which could reduce the economic viability of enterprises.
5. Longer and warmer growing seasons, and altered distribution of seasonal precipitation, can increase pest pressure (e.g., ectoparasites) on livestock.

Adaptation Strategies:

1. Provide partial to total shelter to reduce heat stress associated with extreme heat.
2. Housing systems may need to be modified to provide increased temperature regulation.
3. Integrate livestock and cropping enterprises to utilize aftermath grazing on crop residues and cover crop grazing.
4. Alteration of timing of placement of feeder animals and subsequent finishing time of these animals to reduce stress associated with heat waves.
5. Alternative livestock breeds, class or species.

References: Shafer et al. (2014), Polley et al. (2013), Karl et al.(2009)

3. Forest Systems Overview of Risks, Vulnerabilities, and General Adaptation Strategies

Agroforestry

Characteristics: Agriculture has used a variety of agroforestry practices to capitalize on the interactive benefits of combining trees and shrubs with crops and/or livestock to create integrated and sustainable land-use systems in the Northern Plains. These tree-based practices can provide effective adaptation strategies for climate change and extreme weather events. These practices, however, are also susceptible to climate change as described in this vulnerability assessment. See the Agroforestry and Climate report (cited below) for more information on how to use agroforestry for building climate-smart agricultural landscapes.

Kansas wheat field protected by agroforestry practices

	Shelter Belts	Living Snow Fences
States	Total Acres (put under contract 2013)	
Colorado	4508.3	35.4
Montana	242.8	41.4
Nebraska	2243.3	114.4
North Dakota	5288.4	678
South Dakota	15876	607.6
Wyoming	58.9	3.4

Riparian forest buffer

Risks to Agroforestry Practices:

1. Longer, hotter growing seasons with earlier arrival of spring; declining snowpack.
2. More extreme weather events (e.g., downpours, droughts, snowstorms).
3. Greater wildfire risk from warmer and expected drier summers.
4. More outbreaks of pests and pathogens.

Vulnerabilities of Agroforestry Practices:

1. Greater water stress will increase susceptibility of woody plants to disease, pest, and insects.
2. Potential for invasive species with stressed forests.
3. Stress-related mortality of woody plants will delay the time required for agroforestry practices to become fully functional.

Adaptation Strategies:

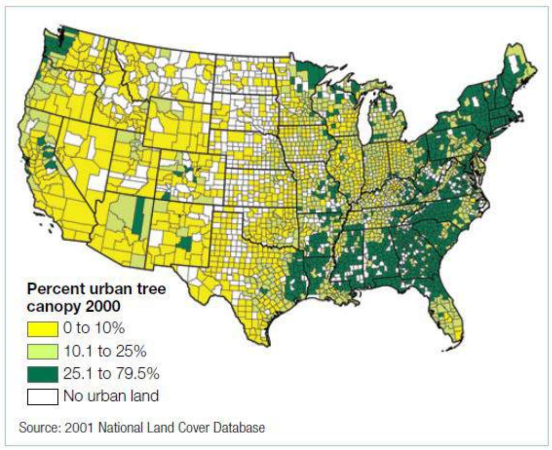
1. Plant diverse species to hedge bets under the many conditions created by shifting weather patterns and climate change.
2. Select woody species that will be better adapted to the future climate recognizing that woody plants may be expected to live 60 years or more.
3. Use good silviculture management practices such as pruning to maintain tree health.
4. Plant cultivars bred with better resistance to stressors.
5. Use seed from a different location where current conditions are similar to those expected locally under climate change.

References: Schoenberger et al. (2012), Agroforestry and Climate (in review)

Urban Forests

Characteristics: Urban forest cover in the Northern Plains States ranges from 21 percent of the urban areas in South Dakota and to 9 percent in Montana and Wyoming. Urban trees and forests provide many benefits and values to society because they improve quality of life, raise property values, save energy, reduce air and noise pollution, improve water quality, reduce erosion, improve business districts and tourism, and provide recreation opportunities. Tree cover tends to decrease as urban population density increases, and may vary with land uses in urban area (e.g., trees may grow on vacant lots in forested regions, but not in grassland or desert regions).

Figure 89. Percent tree cover in urban areas by county in the conterminous United States, 2000.



Urban Trees and Building Energy Reduction Value in the Great Plains

Number of urban trees
Kansas: 33,141,000
Nebraska: 13,317,000
North Dakota: 975,000
South Dakota: 5,414,000

Building energy reduction value per year
Kansas: $19,700,000
Nebraska: $28,200,000
North Dakota: $3,300,000
South Dakota: $519,000

Risks:

1. Urban heat island-effect coupled with longer, hotter growing seasons, and potential for more drought.
2. Expansive impervious surfaces coupled with increased extreme events (e.g., downpours).
3. Air pollution sources interacting with changes in climate.
4. Low tree species diversity increases susceptibility to invasive and non-native plants and animals.

Vulnerabilities:

1. Warm temperatures trigger early vegetative growth and increases the likelihood of winter kill.
2. Spring and fall damage from weather extremes when trees have leafed out or are not yet dormant.
3. Reduced vigor and increased mortality of trees will further decrease the capacity of urban forests to mitigate higher urban temperatures, compromising human health.

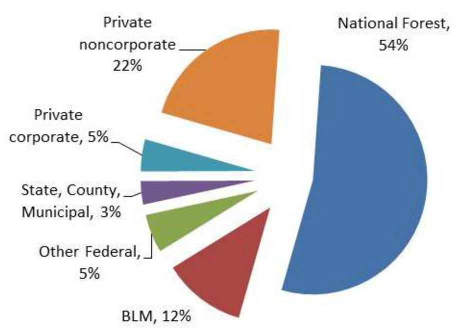
Adaptation Strategies:

1. Increasing species and seed source diversity, and planting pest-tolerant, drought-resistant trees enhances resilience of urban and conservation plantings.
2. Adhering to a regular maintenance cycle can help protect urban trees and forests from extreme weather events.
3. Strategic tree plantings to maximize benefits (i.e., aspect, proximity to pavement and buildings).

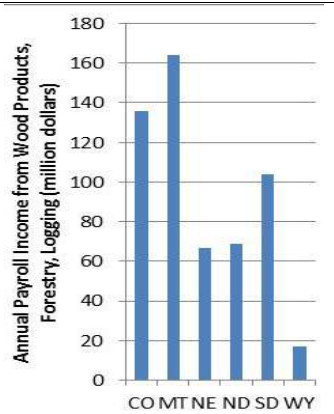
References: Greenfield and Nowak (2013), USFS (2012a), Nowak et al. (2012), Safford (2013)

Wood Products and Bioenergy

Characteristics: Trees in the Northern Plains occur along streams and rivers, on planted woodlots, isolated forests such as the Black Hills of South Dakota, and on the western and eastern fringes where the Northern Plains meets the Rocky Mountains and the eastern deciduous forests, respectively. Only 17 percent of the Northern Plains area is in forested vegetation. Private landowners manage 27 percent of forest land in the Northern Plains. The annual payroll income associated with wood products, forestry, and logging in the Northern Plains region is $557 million.



Forestland in the Northern Plains by ownership category (percent)



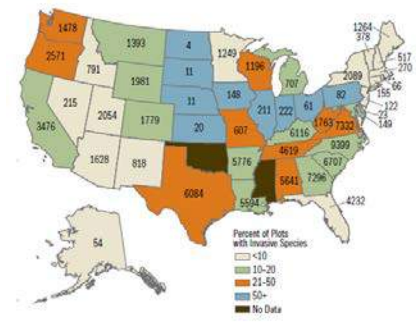


Figure 4c.1. Percent of forested plots containing at least one invasive species. Note: Total sample size is indicated on each State.

Source: Forest Inventory and Analysis plot data.

Risks:

1. Longer, hotter growing seasons with earlier arrival of spring; declining snowpack.
2. More extreme weather events (e.g., downpours and droughts).
3. Greater wildfire risk from warmer and expected drier summers.
4. More outbreaks of native insects such as mountain pine beetle and spruce beetle.

Vulnerabilities:

1. Ecosystem changes and tree mortality through fire, drought, insect, and disease outbreaks.
2. Potential for invasive species with stressed forests.

Adaptation Strategies:

1. Thinning coniferous forests reduces competition for water, improves tree vigor, and protects remaining islands of live forest stands isolated by previous wildfires.
2. Prescribed fire may have a role in enhancing the resilience of forests.
3. Carbon sequestration could be a future management options.
4. Bioenergy could emerge as a new market for wood and could aid in the restoration of forests killed by drought, insects, and fire.
5. Large-scale tree planting campaigns may increasingly be needed to replace trees and forests damaged or killed by severe weather events and more stressful climate conditions aggravated by climate change.

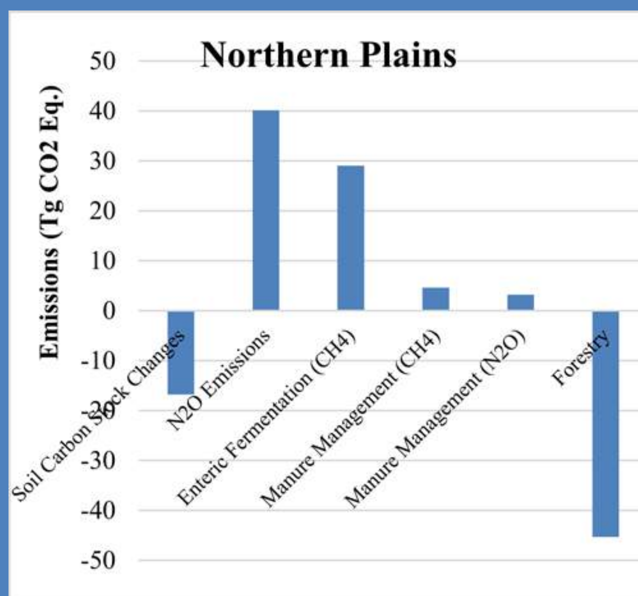
References: Melillo (2014), Smith et al. (2009), Bathke et al. (2014), American Wood Council (2013a, 2013b, 2013c, 2013d, 2013e, 2013f)

4. Greenhouse Gas Emissions Profile and Mitigation Opportunities

Agriculture in the Northern Plains region (including crop, animal, and forestry production) has net annual greenhouse gas (GHG) emissions of approximately 14.8 teragrams[12] of carbon dioxide equivalent (Tg CO_2 eq.). In the region, crop-related nitrous oxide (N_2O) emissions are the largest contributor to GHGs at 40 Tg CO_2 eq., followed by methane (CH_4) from enteric fermentation (29 Tg CO_2 eq.) and CH_4 and N_2O from manure management (8 Tg CO_2 eq.). Forestry is the largest contributor to net carbon storage at −45 Tg CO_2 eq. followed by soil carbon stock changes at −17 Tg CO_2 eq.[13]

Northern Plains Region Highlights

- Corn, soybeans, wheat, beef cattle, and swine are the primary agricultural commodities produced in the Northern Plains.
- The highest source of GHG emissions is N_2O from croplands.
- Changes in carbon storage in 2008 did not offset GHG emissions resulting in GHG net emissions.
- The greatest mitigation potential is available from changes in field tillage management practices (e.g., adoption of long term no-till).
- Retiring soils from cultivation and establishing conservation cover provides a good opportunity for additional carbon sequestration in the region.



4.1. Soil Carbon Stock Changes

Carbon stock changes of major land use and management type for both soil types resulted in a net sequestration of −16.83 Tg CO_2 eq. in 2008. Specifically, cropland production changes on mineral soils sequestered 5.14 Tg CO_2 eq., changes in hay production sequestered 5.96 Tg CO_2 eq., and land removed from agricultural management and enrolled in the Conservation Reserve Program sequestered 5.86 Tg CO_2 eq. (Table 3). In contrast, agricultural production on organic soils (which have a much higher organic carbon content than mineral soils) resulted in emissions of 0.13 Tg CO_2 eq.

Tillage practices contribute to soil carbon stock changes. Table 4 provides the tillage practices by type of crop for the Northern Plains Climate region. Management practices that utilize reduced till or long-term no-till can contribute to increased carbon storage over time depending on site-specific conditions.

[12] A teragram (Tg) is 10^{12} grams, which is equivalent to 10^9 kilograms and 1 million metric tons.
[13] Net carbon storage is the balance between the release and uptake of carbon by an ecosystem. A negative sign indicates that more carbon was sequestered than greenhouse gases emitted.

Table 3: Northern Plains estimates of annual soil carbon stock changes by major land use and management type, 2008

Land Uses	Emissions (Tg CO_2 eq.)
Net change, cropland[a]	−5.14
Net change, Hay	−5.96
CRP	−5.86
Ag. land on organic soils	0.13
Total[b]	−16.83

Source: USDA (2011)
[a] Annual cropping systems on mineral soils (e.g., corn, soybean, and wheat).
[b] Total does not include change in soil organic carbon storage on Federal lands, including those that were previously under private ownership, and does not include carbon storage due to sewage sludge applications.

Table 4: Tillage practices in the Northern Plains region by crop type (percent of acres utilizing tillage practice)

Crop Type	Acres[a]	No Till[b]	Reduced Till[b]	Conventional Till[b]	Other Conservation Tillage[b]
Corn	17,867,953	34.8%	15.7%	14.0%	35.5%
Sorghum	310,140	45.1%	15.2%	14.1%	25.6%
Soybeans	12,664,919	34.4%	16.8%	4.5%	44.3%
Wheat	19,246,122	33.9%	20.1%	14.6%	31.4%
Total	50,089,135				

[a] Source: USDA (2011)
[b] Source: USDA ERS (2011)

4.2. Nitrous Oxide (N_2O) Emissions

In 2008, N_2O emissions in the Northern Plains region were approximately 40 Tg CO_2 eq. Of these emissions, 25 Tg CO_2 eq. was emitted from croplands and 15 Tg CO_2 eq. was emitted from grasslands.[14] Because the majority of arable land in the Northern Plains region is planted with corn, wheat, and soybean, the majority of crop-related N_2O emissions in the region (more than 70 percent) are from the production of these three crops (National Agricultural Statistics Service, 2014a).

As indicated in Table 5, the majority of N_2O direct emissions is from corn. The quantity and timing of nitrogen-based fertilizer affects the rate of both direct and indirect N_2O emissions.[15] Table 6 indicates the percent of national acres that did not meet the rate or timing criteria as defined by Ribaudo et al. (2011). Timing criteria is defined in terms of best practices for quantity and timing of fertilizer application. Meeting the best practice rate criterion is defined as applying no more than 40 percent of the nitrogen (commercial and manure) that was removed with the crop at harvest, based on the stated yield goal, including any carryover from the previous crop. Meeting the best practice timing criterion is defined as not applying nitrogen in the fall for a crop planted in the spring (Ribaudo et al., 2011). Acreages not meeting the criteria represent opportunities for GHG mitigation.

[14] Including both direct and indirect emissions; Table 5 includes only direct emissions from crops.
[15] Direct N_2O emissions are emitted directly from agricultural fields and indirect N_2O emissions are emissions associated with nitrogen losses from volatilization of nitrogen as ammonia (NH_3), nitrogen oxides (NOx), and leaching and runoff.

Table 5: Direct Nitrous Oxide (N_2O) Emissions by Crop

Crop Type	Direct N_2O Emissions (Tg CO_2 eq.)	% of Region's Cropland N_2O Emissions
Corn	8.56	41.6%
Soybean	3.45	16.8%
Hay	3.20	15.5%
Wheat	2.43	11.8%
Barley	0.32	1.5%
Sorghum	0.05	0.3%
Non-major Crops	2.57	12.5%
Total	20.58	100%

Source: USDA (2011)

Table 6: National Percent of Acres Not Meeting Rate and Timing Criteria (Percent of Acres)

Crop	Not Meeting Rate[a]	Not Meeting Timing[b]
Corn	35%	34%
Sorghum	24%	16%
Soybeans	3%	28%
Wheat	34%	11%

[a] "Did not meet rate" indicates that managers applied nitrogen (commercial and manure) at a rate of 40 percent more than that removed with the crop at harvest based on the stated yield goal, including any carryover from the previous crop.
[b] "Did not meet timing" indicates that managers applied nitrogen in the fall for a crop planted in the spring.
Source: Ribaudo et al. (2011)

4.3. Livestock GHG Profile

Livestock systems in the Northern Plains focus primarily on the production of poultry, beef and dairy cattle, swine, sheep, goats, and horses. There were more than 25 million head of poultry in the region in 2008. Cattle are second (beef and dairy) with close to 21 million head, followed by swine with more than 5 million animals (USDA, 2011). Nearly 94 percent of the cattle in the region is beef cattle. As with patterns in livestock production across the country, the primary source of GHGs from livestock is from enteric fermentation, digestive processes that result in the production of methane (CH_4) (referred to as enteric CH_4). In 2008, livestock in the Northern Plains produced 26.19 Tg CO_2 eq. of enteric CH_4.[16] Most of the remaining livestock-related GHG emissions are from manure management practices—which produce both CH_4 and N_2O.[17] In 2008, manure management in the Northern Plains region resulted in 7.8 Tg CO_2 eq., considering both CH_4 and N_2O, with the majority attributed to CH_4 (USDA, 2011).

4.4. Enteric Fermentation

The primary emitters of enteric CH_4 are ruminants (e.g., cattle and sheep). Emissions are produced in smaller quantities by other livestock, such as swine, horses, and goats.

The per-head emissions of enteric CH_4 for dairy cattle are 40 to 50 percent greater than for beef cattle [e.g., 2.2 metric tons CO_2 eq. per head per year for dairy vs. 1.6 metric tons for beef in 2008 due primarily to their greater body weight and increased energy

Table 7: Emissions from enteric fermentation in the Northern Plains, in Tg of CO_2 eq. and as a percent of regional emissions

Animal Category	Tg CO_2 eq.	% of Region's CH_4 Enteric Emissions
Beef cattle[a]	25.77	88.3%
Dairy cattle[a]	3.13	10.7%
Goats[b]	0.00	0.0%
Horses[b]	0.04	0.1%
Sheep[b]	0.06	0.2%
Swine[b]	0.19	0.6%
Total	29.19	100.0%

[a] Source: USDA (2011)
[b] Source: Based on animal population from USDA (2011) and emission factors as provided in IPCC (2006)

[16] The enteric CH_4 emissions total for the region includes cattle and non-cattle.
[17] Livestock respiration also produces carbon dioxide (CO_2), but the effects of ingesting carbon-based plants and expelling CO_2 result in zero-net emissions.

requirements for extended periods of lactation (EPA, 2014)]. However, in the Northern Plains region, because 94 percent of all cattle is beef cattle, the overall contribution to enteric CH_4 emissions from beef cattle of enteric fermentation is much higher than for dairy cattle (USDA, 2011). Table 7 provides CH_4 emissions by animal types for 2008. As indicated, the majority of emissions are from beef and dairy cattle.

4.5. Emissions from Manure Management Systems

Manure management in the Northern Plains resulted in 4.6 Tg CO_2 eq. of CH_4 and 3.2 Tg CO_2 eq. of N_2O in 2008. Table 8 provides a summary of CH_4 and N_2O emissions by animal category. Swine and dairy and beef cattle waste account for the majority of manure emissions, with swine waste accounting for 28 percent of CH_4 and 5 percent of N_2O, dairy waste accounting for 56 percent and 21 percent, and beef cattle accounting for 12 and 74 percent, respectively.

Table 8: 2008 Emissions from manure management in the Northern Plains, in Tg of CO_2 eq. and as a percent of regional emissions

Animal		Methane		Nitrous Oxide	
Category	Population	Tg CO_2 eq.	Percent	Tg CO_2 eq.	Percent
Swine	5,935,500	1.3	28%	0.2	5%
Dairy cattle	1,309,540	2.6	56%	0.7	21%
Beef cattle	19,700,969	0.5	12%	2.3	74%
Poultry	25,876,263	0.1	2%	0.0	1%
Horses[a]	1,354,340	0.1	2%		
Sheep[a]	1,863,000	0.0	0%		
Goats[a]	65,336	0.0	0%		
Total	48,859,908	4.6	17%	3.2	75%

Source: USDA (2011)

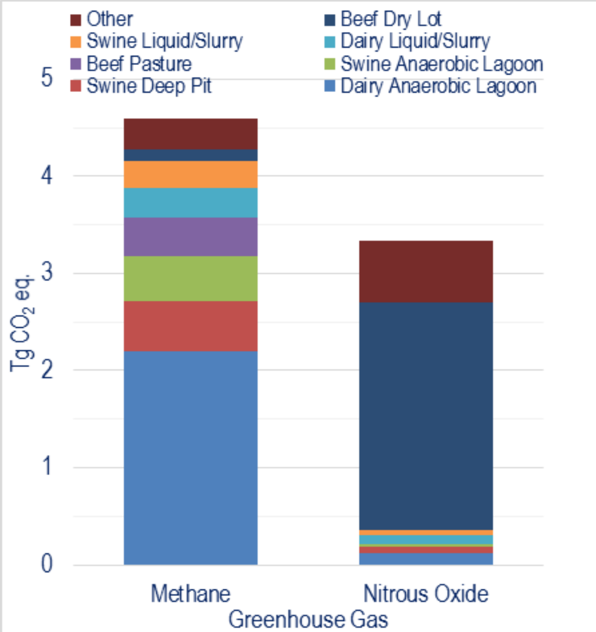
[a] N_2O emissions are minimal and not included in this total.

The distribution of animal population among different farm sizes varies across animal categories. Forty-two percent of dairy cattle is raised on operations with more than 2,500 head and 65 percent of swine exist on operations with more than 5,000 head; mitigation technologies such as anaerobic digesters[18] are more economically feasible on large farm operations due to economies of scale. Figure 4 provides a summary of CH_4 and N_2O emissions by animal category and baseline manure management practices.[19] The largest sources of CH_4 are anaerobic lagoons, deep pits, and liquid/slurry systems, primarily with dairy and swine waste. The largest sources of N_2O are beef dry lots. Figure 5 describes the proportion of beef cattle, dairy cattle, and swine that are managed using various manure management systems. The majority of beef waste is deposited on pasture, whereas dairy and swine waste is managed using a variety of systems, including anaerobic lagoons, deep pits, dry lots, and liquid/slurry systems.

[18] Anaerobic digesters are lagoons and tanks that maintain anaerobic conditions and can produce and capture methane-containing biogas. This biogas can be used for electricity, heat, or both, or can be flared. In general, anaerobic digesters are categorized into three types: covered lagoon, complete mix, and plug flow digesters.

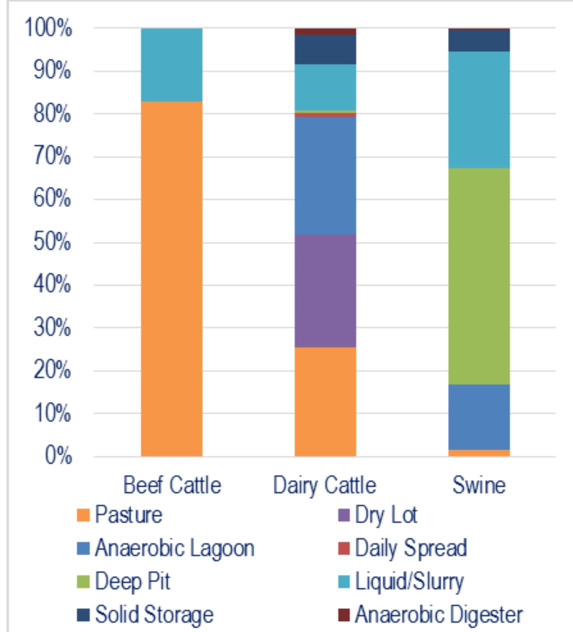
[19] Definitions for manure management practices can be found in Appendix 3-B of (ICF International, 2013).

Figure 4: 2008 CH_4 and N_2O emissions from the Northern Plains by animal category and management system (Tg of CO_2 eq.)



Source: EPA (2010)

Figure 5: Proportion of beef cattle, dairy cattle, and swine managed with each manure management system in the Northern Plains



Source: EPA (2010)

4.6. Forest Carbon Stocks and Stock Changes

In the annual GHG inventory reported by the USDA, forests and harvested wood products from forests sequester 45 Tg CO_2 eq. per year in the Northern Plains; in addition, the 85 million acres of forest land in the Northern Plains maintain 18,216 Tg CO_2 eq. in forest carbon stocks.[20]

Table 9: Northern Plains Forest Carbon Stock and Stock Changes

Source	Units	Northern Plains
Net Area Change	1000 ha./yr	150
Non-Soil Stocks	Tg CO_2 eq.	13,523
SOC	Tg CO_2 eq.	4,623
Non-Soil Change	Tg CO_2 eq./yr	−42[a]
Harvested Wood Products Change	Tg CO_2 eq./yr	−3[a]
Forest carbon stock summary (Tg CO_2 eq.)		
Non-soil stocks + SOC		18,216
Forest carbon stock change summary (Tg CO_2 eq./yr)		
Forest carbon stock change		−45[a]

Source: USDA (2011)
[a] Negative values indicate a net removal of carbon from the atmosphere.

Managed forest systems in the Northern Plains focus primarily on the production of softwood timber, in addition to serving as riparian buffers and wind breaks. Forestry activities represent significant opportunities for managing GHGs. Forest managers in the Northern Plains use a wide variety of silvicultural techniques to achieve management objectives, most of which will have effects on the carbon dynamics. The primary effects of silvicultural practices on forest carbon include enhancement of forest growth (which increases the rate of carbon sequestration) and forest harvesting practices (which transfers carbon from standing trees into harvested wood products and

[20] Other GHGs such as N_2O and CH_4 are also exchanged by forest ecosystems. N_2O may be emitted from soils under wet conditions or after nitrogen fertilization; it is also released when forest biomass is burned. CH_4 is often absorbed by the microbial community in forest soils but may also be emitted by wetland forest soils. When biomass is burned in either a prescribed fire/control burn or in a wildfire, precursor pollutants that can contribute to ozone and other short-lived climate forcers as well as CH_4 are emitted (USDA, 2014).

residues, which eventually decay or are burned as firewood or pellets). Other forest management activities will result in accelerated loss of forest carbon, such as when soil disturbance increases the oxidation of soil organic matter, or when prescribed burning releases CO_2 (N_2O and CH_4).

Forest management activities and their effects on carbon storage vary widely across the Northern Plains with different forest types, ownership objectives, and forest stand conditions. However, there are commonly used silvicultural prescriptions for common forest types in the Northern Plains. For example, the USDA's *Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory* Technical Bulletin (2014) provides information for regions overlapping with the Northern Plains (i.e., the Rocky Mountain North, Rocky Mountain South, and Great Plains regions; see Table 6-6 on page 6-59 in the technical bulletin).

The USDA's *Forest Service 2010 Resources Planning Act Assessment* General Technical Report (2012b) describes future projections of forest carbon stocks in the United States resulting from various vulnerabilities (e.g., less-than-normal precipitation, above-normal temperature) and other stressors (e.g., urbanization, other land development, demand for forest fuel and fiber). The Resource Planning Act Assessment projects that "declining forest area, coupled with climate change and harvesting, will alter forest-type composition in all regions." For example, the report notes that for a larger region (i.e., the Rocky Mountains), which includes the Northern Plains region, the rate of urban growth is highest, and Douglas fir and lodgepole pine are projected to decline, whereas fir-spruce-hemlock and ponderosa pine area increases.

4.7. Mitigation Opportunities

Figure 6 presents the mitigation potential by sector for the Northern Plains region. Each bar represents the GHG potential below a break-even price of \$100/metric ton CO_2 eq.[21] A break-even price is the payment level (or carbon price) at which a farm will view the economic benefits and the economic costs associated with adoption as exactly equal. Conceptually, a positive break-even price represents the minimum incentive level needed to make adoption economically rational. A negative break-even price suggests the following: 1) no additional incentive should be required to make adoption cost-effective; or 2) there are non-pecuniary factors (such as risk or a required learning curve) that discourage adoption. The break-even price is determined through a discounted cash-flow analysis such that the revenues or cost savings are equal to the costs.[22] The left two bars represent reductions from changes in management practices that mitigate GHGs. The right three bars represent increased carbon storage from changes in management practices. As indicated in the left two bars, approximately 3 Tg CO_2 eq. can be mitigated at a break-even price below \$100/metric tons CO_2 eq. Changes in land management practices can increase C storage by 16 Tg CO_2 eq. at a break-even price below \$100/metric tons CO_2 eq. The color shading within a bar represents the mitigation potential or the potential increased C storage below different break-even prices indicated in the legend. For example, changes in tillage practices have the potential to contribute to almost 3 Tg CO_2 eq. of increased C storage for less than \$20/metric ton CO_2 eq. (i.e., light blue and light green bar).

[21] Break-even prices are typically expressed in dollars per metric ton of CO_2 eq. This value is equivalent to \$100,000,000 per Tg of CO_2 eq. or \$100,000,000 per million metric tons of CO_2 eq.
[22] See ICF International (2013) for additional details.

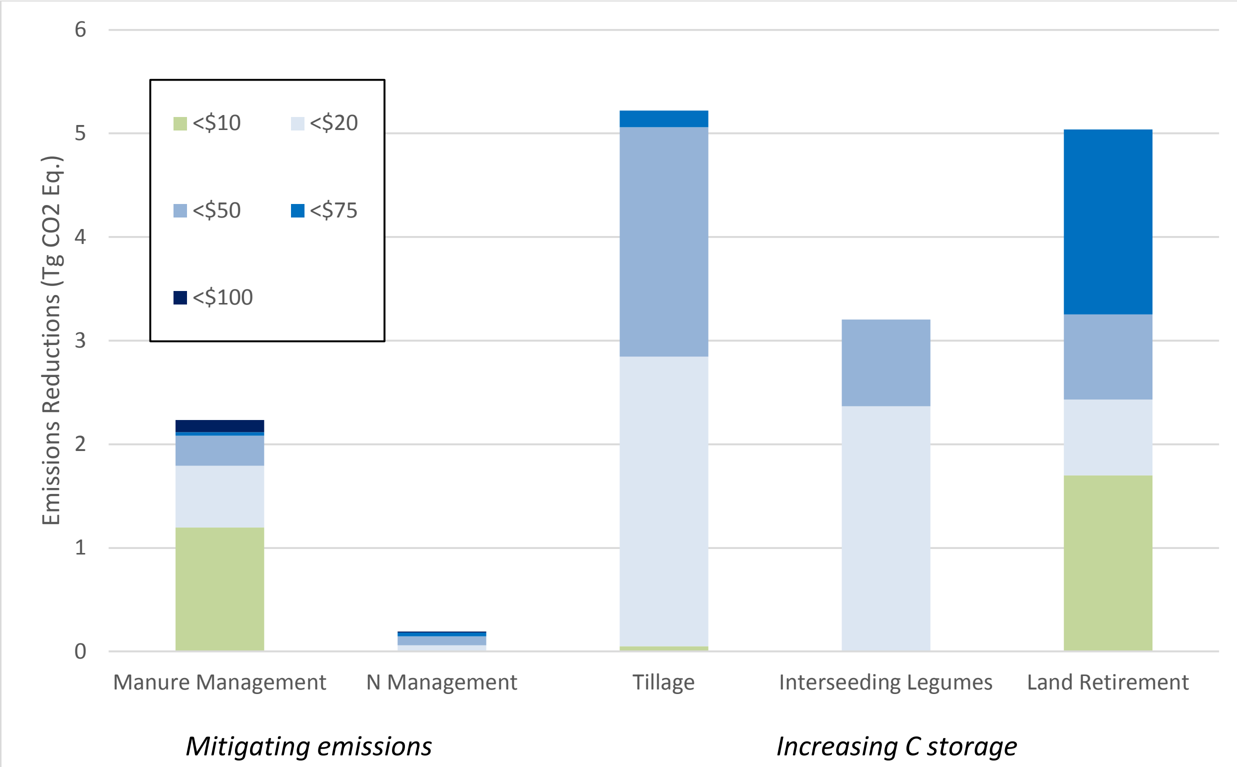


Figure 6: Mitigation potential in the Northern Plains, by sector

- Most of the opportunity for reducing net GHGs emissions is from changes in field tillage practices (i.e., adopting long-term reduced tillage practices).
- The second largest opportunity is by increasing carbon stock in land retirement practices, such as retiring organic and marginal soils.
- The relatively highest potential for emissions reduction from manure management are installing complete mix digesters with electricity generation at swine and dairy farms, and installing improved separators and lagoon digesters or covering existing anaerobic lagoons at dairy farms with anaerobic lagoons.[23]

Agricultural Soils

For farms larger than 250 acres, variable rate technology is a relatively low-cost option for reducing N_2O emissions from fertilizer application.[24] Reducing nitrogen application can be a relatively low-cost option for all farm sizes. Transitioning from conventional tillage to continuous no-tillage or reduced tillage to continuous no-tillage field management practices results in relatively large potential for carbon storage at low cost (i.e., the magnitude of the carbon storage potential is orders of magnitude higher than the potential to reduce N_2O emissions). Carbon gains can only be realized if no-till is adopted permanently, otherwise gains will be reversed.

[23] The emission reduction excludes indirect emission reductions from the reduced use of fossil fuels to supply the electricity for on farm use (i.e., the emission reductions only account for emissions within the farm boundaries).
[24] Variable rate technology (VRT), a subset of precision agriculture, allows farmers to more precisely control the rate of crop inputs to account for differing conditions within a given field. VRT uses adjustable rate controls on application equipment to apply different amounts of inputs on specific sites at specific times (Alabama Precision Ag Extension, 2011).

Land Retirement

This category includes retiring marginal croplands and establishing conservation cover, restoring wetlands, establishing windbreaks, and restoring riparian forest buffers. Retiring marginal soil and restoring forested wetlands provide the most opportunities for increasing carbon storage.

Manure Management

The total CH_4 mitigation potential for livestock waste in the Northern Plains is 2.4 Tg CO_2-eq. Lower-cost GHG mitigation opportunities for manure management are primarily for large swine and dairy operations. The greatest CH_4 reductions can be achieved on dairy operations by transitioning to improved solids separators, covering existing anaerobic lagoons, covered lagoon digesters, or complete mix digestesr. For large swine operations, the greatest and most cost-effective mitigation are complete mix digesters at large farms.

Enteric Fermentation

Emissions from enteric fermentation are highly variable and are dependent on livestock type, life stage, activity, and feeding situation (e.g., grazing, feedlot). Several practices have demonstrated the potential for efficacy in reducing emissions from enteric fermentation. Although diet modification (e.g., increasing fat and protein content, providing higher quality forage) and providing supplements (e.g., monensin, bovine somatotropin or bST) have been evaluated for mitigation potential, the effectiveness of each option is not conclusive.

5. USDA Programs

The recently published USDA Climate Change Adaptation Plan[25] presents strategies and actions to address the effects of climate change on key mission areas including agricultural production, food security, rural development, and forestry and natural resources conservation. USDA programs administered through Natural Resource Conservation Service (NRCS), U.S. Forest Service (USFS), Farm Service Agency (FSA), Rural Development (RD), Risk Management Agency (RMA), and Animal and Plant Health Inspection Service (APHIS) have been and will continue to play a vital role in sustaining working lands in a variable climate and are key partner agencies with the USDA Climate Hubs. The Northern Plains Hub partner agencies are also vulnerable to climate variability and have programs and activities in place to help stakeholders respond to climate-induced stresses.

5.1. Natural Resource Conservation Service

The anticipated effects of climate change on private lands in coming years and decades will necessitate that NRCS place additional emphasis on actions that explicitly address climate change. NRCS is already well positioned to address (via adaptive strategies) soil quality, landscape stability, extreme weather events, climate variability, natural disasters, and other issues. The point at which existing systems are transformed will vary on the basis of interaction of climate change and variability of factors such as land use, land fragmentation, water availability, and energy costs. NRCS can work with a variety of research and development partners and affected producers to identify 1) land use alternatives, 2) land management systems, and 3) conservation priorities necessary to protect natural resources.

[25] The 2014 USDA Climate Change Adaptation Plan includes input from 11 USDA agencies and offices. It provides a detailed vulnerability assessment, reviews the elements of USDA's mission that are at risk from climate change, and provides specific actions and steps being taken to build resilience to climate change. Find more here: http://www.usda.gov/oce/climate_change/adaptation/adaptation_plan.htm

The NRCS field office staff members across the Northern Plains provide the technical link between research and application for the Climate Hubs. NRCS is the primary Federal agency that supplies conservation assistance on a voluntary basis to private citizens through its Conservation Technical Assistance (CTA) Program. NRCS has staff in nearly every U.S. county, thereby well-positioning the agency to provide outreach and support, and to implement conservation measures to increase resiliency to climate change and reduce GHG emissions as a member of the regional Climate Hubs. Regional NRCS climate vulnerabilities and priorities are provided by State below.

Nebraska

In Nebraska, NRCS efforts related to water quantity, rangeland health, and wetland conversions are the most vulnerable to climate change. To address regional water concerns, NRCS developed the Ogallala Aquifer Initiative to reduce aquifer water use, improve water quality, and enhance the economic viability of croplands and rangelands in Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming (NRCS, 2015a). Additionally, the Environmental Quality Incentives Program (EQIP) promotes practices that improve irrigation efficiency and rangeland health. NRCS also provides rangeland technical assistance across the Northern Plains.

Nebraska NRCS conservationists encourage no-till management and the adoption of cover crops to preserve soil moisture. They also communicate wetland compliance rules and educate producers on the Wetland Conservation provision of the Federal farm bills (Swampbuster[26]) encouraging them not to fill or drain wetlands (even if they are dry during certain time periods).

North Dakota

North Dakota NRCS activities related to water resources—both quantity and quality—are highly susceptible to climate change. Additionally, North Dakota is undergoing significant shifts in cropping systems and production practices as the climate changes. To address these concerns, North Dakota's conservationists are focused on implementing the soil health initiative—improving the resilience of the soil to mitigate weather changes. In addition, outreach and communication to producers focuses on adapting agricultural practices and techniques to best manage water resources. NRCS in North Dakota is also leveraging area plant materials centers to develop improved and adapted plant species.

South Dakota

Every conservation practice that a producer implements is vulnerable to climate change. Whether due to drought, wind, or more frequent high-intensity storms, a changing climate affects how practices are designed and how they function. Knowing changes to precipitation amounts and frequency are critical in properly sizing erosion control practices such as holding ponds, stream bank protection, terraces, grassed waterways, and structures for controlling water.

Warmer and wetter conditions across much of South Dakota have expanded annual crop production onto more marginal soils farther and farther west where soil properties are not suited to crop production. These soils do not have the available water capacity or organic matter content needed to support the high levels of biomass production associated with modern farming practices. Due to these conditions, when drought occurs, the magnitude of crop damage may be larger than has historically occurred. With the expansion of annual crop production, the loss of wildlife habitat and native grassland has accelerated. Stream channel erosion is likely increasing due to longer duration and higher stream flows resulting from higher precipitation levels. Soil erosion increases in areas where farming practices neglect to leave the top soil armored with organic matter. This is especially damaging to soils that are prone to erosion, such as many

[26] The Highly Erodible Land Conservation and Wetland Conservation Compliance provisions (Swampbuster) were established in the 1985 Farm Bill. The provisions remove eligibility to incentives to produce crops on converted wetlands or highly erodible land (HEL) unless the HEL is protected from excessive soil erosion (NRCS, 2015b).

of the Pierre Shale–influenced soils. New insect, weed, disease, and pest populations are shifting into parts of the State where historically they have not been found.

Agency technical assistance will need to recognize, adapt, and prescribe new pest remediation techniques, new plant varieties, and new management practices that have to date mainly been applied in either nearby warmer and drier or warmer and wetter regions. Agency predictive tools such as runoff curve numbers will need continuous revisions to recognize new climatic characteristics that affect the design and performance of NRCS conservation practices. It is likely that public outreach will be needed to help stakeholders better understand the effects of NRCS practices.

There are several conservation programs in place to help producers deal with environmental risk and vulnerabilities associated with natural resource protection. These include EQIP, Conservation Stewardship Program, and Wetlands Reserve Program (WRP). NRCS staff members in South Dakota actively participate in the South Dakota Drought Task Force and have developed and support various drought prediction tools. Whereas all conservation practices are vulnerable to climate change, they are also essential to mitigating and responding to climate risks.

NRCS conservation planning expertise will become more and more important in a changing climate. Smart land-use planning can help a producer manage risk (e.g., conversion of a flood plain to row crop will likely result in flooding and severe scour erosion). Planting crops that need their highest amounts of moisture in soils with less water-holding capacity in regions that receive less rain during those periods, will likely result in more crops damaged by lack of moisture. Finally, promoting improved soil health on all land uses is essential to improving working land resilience in South Dakota.

Wyoming

Grazing land management activities are vulnerable to climate change due to existing pressures on ecosystems and natural resources. It is unclear how climate change will manifest itself on arid and semi-arid ecosystems. It is likely that climate variability will drive plant communities outside what is currently considered their natural range. Invasive species such as annual bromes have already dramatically changed ecosystems and fire regimes and will likely continue to expand their range. Dominant forage species will likely be replaced by species that are less palatable to grazing animals. Some plant species may undergo changes to their physiology making them less digestible. Extreme weather events will likely become more common and drought conditions the new norm. Diminishing water resources could limit livestock access to adequate forage.

In Wyoming, prescribed grazing is one of the best opportunities to mitigate the effects of climate change on grazing lands. NRCS is working closely with livestock producers to conserve their resources and prevent plant communities from crossing irreversible ecological thresholds. NRCS staff in Wyoming will need to include potential climate change effects within the ecological site descriptions (ESDs) and be able to explain climate change concepts to their clients. NRCS will need to help land managers increase their resiliency so they can quickly respond to drought and other climate-related effects. Furthermore, land managers will need assistance to extend the length of their grazing seasons and become less dependent on intensive forage production. In the coming years, NRCS in Wyoming will start to encourage producers to convert to smaller, more efficient animals that need minimal inputs to produce a sellable product, and help producers develop water systems that are sustainable and minimize waste.

Wildlife Concerns

In Wyoming, cold-water-associated fauna are the most vulnerable to climate change due to anticipated earlier, more erratic snowmelt runoff and lower flows later into the summer/fall, which will likely lead to higher stream temperatures and potential new invasive species. Prolonged drought will negatively affect almost all fisheries and most wildlife. However, efforts to conserve habitat-specialist species and species with strong seasonal site fidelity, such as mule deer and sage grouse, could prove to be the most challenging as plant communities move, change, or are eliminated by climate shifts and more extreme weather events. These changes could lead to catastrophic wildfire, new invasive species, and major pest outbreaks. Species that are vulnerable to West Nile virus and other similar, but currently uncommon, insect vectors and diseases will also suffer decline. Although not a major component of Wyoming, species associated with ephemeral wetlands will almost definitely decrease unless alternative water sources are identified.

NRCS efforts are primarily directed at programs and measures to promote diverse and vigorous plant communities that are capable of persisting through prolonged, adverse weather situations and fighting off invasion from less desirable species such as cheatgrass and pests such as the mountain pine beetle. Such efforts can involve grazing management, range seeding, prescribed burning, integrated pest management, brush management, herbaceous weed control, forest stand improvement, water development, and others.

Efforts to conserve fisheries generally revolve around efforts to maintain vegetative cover along stream courses to provide shade and maintain connectivity for aquatic species to migrate to more favorable stream conditions. This could include streambank stabilization, aquatic organism passage,[27] water control structure, riparian herbaceous cover, and other practices. Conservation easements and efforts to identify and maintain species migration corridors could also prove beneficial to the long-term persistence of such species as they may be forced to move to find favorable habitat conditions across the landscape.

Agronomic Concerns

All crop production enterprises are vulnerable to climate change. Farmers have always experienced extreme temperatures, droughts, and floods. Increasing the amplitude of the extremes will only exacerbate these challenges. To mitigate this, NRCS is encouraging the adoption and improvement of soil health-promoting practices. A balanced soil ecology (i.e., a diverse and active soil food web of flora, fauna, and microbes) will increase the resilience of farms and ranches by increasing soil organic matter (soil carbon), which increases soil water-holding capacity and nutrient cycling capacity. Increased microbial activity paired with reduced tillage increases soil aggregation providing a stable soil structure, which increases soil porosity, thereby increasing water infiltration from torrential rainfall events that have become more frequent in recent years.

Adding multi-species cover crops to existing rotations will increase soil organic matter and provide sufficient surface residue to protect the soil from erosion events. Producers with 3 to 6 years of experience with these practices report 75 percent or greater reduction of commercial fertilizer, herbicides, and insecticides without any reduction of yield, which improves operation profitability.

The Conservation Reserve Program takes less-productive, marginal land out of cultivation and puts it into permanent cover. Whether that land stays out of cultivation depends on the crop economics upon completion of the term. The Conservation Stewardship Program pays producers with good conservation histories to enhance their conservation practices to a higher standard, which ultimately decreases erosion and increases precipitation infiltration. The Environmental Quality Incentives Program (EQIP) offers a wide variety of conservation technical and financial assistance to producers to manage or alleviate resource constraints in their operation.

Montana

[27] Modification or removal of barriers that restrict or impede movement or migration of fish or other aquatic organisms (NRCS, 2011).

In Montana, grazing lands are vulnerable to drought and weather extremes. Land managers are experiencing more weather extremes such as flooding, resulting in damage to irrigation systems along rivers. Snow pack variability and rapid runoff is affecting base flows and late-summer irrigation supply. There is growing concern about drought across the State and vulnerability to wildfires due to trees that have been killed by the pine bark beetle.

NRCS in Montana is focused on implementing soil health improvement measures on crop and grazing lands. NRCS collaborates with the Montana Department of Natural Resources and Conservation and Montana Association of Conservation Districts to provide outreach through workshops and news releases.

NRCS, the U.S. Fish and Wildlife Service (FWS), Montana Department of Natural Resource Conservation (Water Resources), and Montana Fish Wildlife and Parks have worked on water use improvements in the Big Hole Watershed for nearly 10 years. The coalition assists landowners in voluntarily reducing water withdrawals from the Big Hole River to maintain the Fluvial Arctic grayling habitat. FWS announced in August that this effort was successful and the fish did not warrant listing as threatened or endangered under the Endangered Species Act.

NRCS implemented a State Sage Grouse Initiative in 2009 to improve grasslands and sage grouse habitat for the Greater Sage-Grouse. The threats mitigated include brood-rearing habitat in wet meadows, protected migratory corridors through easements and fence marking, and longer grazing rotations allowing improved plant health and density.

NRCS Leading National Drought Resilience Demonstration Project in Montana

NRCS is leading a partnership through the National Drought Resilience Partnership which includes the National Ocean and Atmospheric Administration, the U.S. Department of the Interior, Assistant Secretary for the Army Civil Works, Federal Emergency Management Agency, Environmental Protection Agency, and Department of Energy.

Montana NRCS is working closely with a number of Federal and State agencies to devise strategies to assist communities and landowners in the eight 6-digit HUCS above the confluence of the Madison, Jefferson, and Gallatin Rivers (Missouri River Headwaters) to prepare for drought and implement drought resiliency practices. The watersheds are: Jefferson, Gallatin, Madison, Ruby, Red Rock, Big Hole, Beaverhead, and Boulder.

Possible outcomes could include better measurement and analysis of water, snowpack, and soil moisture data; and resources to assist watershed groups to develop and implement watershed drought plans (Swartzendruber, 2014).

Colorado

In Colorado, practically all NRCS efforts can be viewed as being vulnerable to climate change. Most significant are the potential effects on wildlife habitat restoration and management issues. Management of rangelands must become more adaptive with shorter response times to onset of climate change; cropping systems, both dry and irrigated, must adapt to changes in weather and soil; and probably the largest potential impact is on water quantity and water/irrigation efficiency efforts.

NRCS programs in Colorado are being designed to promote sustainable, resilient eco-systems to decrease the risks of climate change on working lands. Planning efforts are going beyond one resource concern and considering unintended consequences of practice application. NRCS in Colorado has begun working on targeted conservation efforts so that effects of conservation can be more readily observed and possibly measured.

NRCS staff members in Colorado are working on methods to reduce water consumption on irrigated acres by promoting alternative crops, deficit irrigation, and limited irrigation (to manage moisture in top 14–18 inches). Promoting energy efficiency improvements on dairies and irrigation systems through partnerships with, among others, Colorado Department of Agriculture, Colorado Energy Office, Tri-State Power, Colorado Rural Electric Associations, and Colorado State University. Other focus areas include work on salinity and selenium management for water quality, ammonia deposition for air quality, and soil health improvements for sustainable agriculture.

5.2. U.S. Forest Service

The Forest Service approach for adapting to climate change encompasses climate-specific strategies across the agency and direct program-by-program efforts to integrate climate-related policies and guidance. Climate change is one of many drivers of change to be considered in sustaining forest and grassland ecosystems. The Forest Service is involved in research, translation, and delivery of information and technical tools for use on public and private forest and rangelands. The Research and Development branch of the Forest Service is the principal in-house forestry and natural resource research arm of USDA. The State and Private Forestry (S&PF) branch is the Federal leader in providing technical and financial assistance to landowners and resource managers to help conserve, protect, and enhance the Nation's non-Federal forests. The National Forest System comprises 193 million acres of national forests and grasslands, and is often the agency's "front line" for communicating with the public.

Research and Development

The Rocky Mountain Research Station conducts research in eight science programs: 1) air, water and aquatic environments; 2) fire, fuels, and smoke; 3) human dimensions; 4) forest and woodland ecosystems science; 5) grasslands, shrubland, and desert ecosystems; 6) inventory and monitoring; 7) science application and communication; and 7) wildlife and terrestrial ecosystems.[28] Scientists in the Grassland, Shrubland and Desert program are studying climate change in the following ways: evaluating the effect of historic climatic change on biotic communities, monitoring contemporary changes to ecosystems, evaluating the risk of potential future climate change to species and populations, investigating how climate interacts with disturbances and invasive species, and developing approaches to mitigate potential impacts to threatened communities and species (Finch, 2015). Research under the Air, Water and Aquatic Environments program aims to assess, characterize, and model ecological effects of past, present, and future climate change on physical environments, plant and animal species, ecosystems and landscapes, and biogeochemical cycles. Populations of many cold-water species are likely to decline this century with global warming, but declines will vary spatially, and some populations will persist even under extreme climate change scenarios. The Climate Shield website hosts geospatial data and related information that describes specific locations of cold-water refuge streams for native Cutthroat trout and Bull trout across the northwestern United States including Montana and Wyoming.[29] Scientists in the Inventory, Monitoring and Analysis program provide baseline carbon data at various scales to managers and provide methods to assess carbon in the forests and forest products. The Science Application and Communication Program provides leadership in knowledge transfer and the integration and use of scientific information in natural resource planning and management. Several programs (Wildlife and Terrestrial Ecosystems, Grassland Shrubland, and Desert, and Human Dimensions) are studying the effects of future climate change on wildlife species and their habitat.

State and Private Forestry

State and Private Forestry (SPF) works with States, tribes, private landowners, and other partners to promote healthy forests and livable communities throughout the United States. In partnership with State

[28] See: http://www.fs.fed.us/rmrs/research/programs/
[29] See: http://www.fs.fed.us/rm/boise/AWAE/projects/ClimateShield.html

forestry agencies, SPF implements a suite of cooperative forestry programs, including Forest Stewardship, Forest Legacy, Urban and Community Forestry, Cooperative Fire, and Forest Health. Forest Stewardship helps private forest landowners develop plans for the sustainable management of their forests. Forest Legacy protects working forests and the public benefits they provide (water quality, wildlife habitat, forest products, recreation, etc.) through acquisition and conservation easements. The Urban and Community Forestry program encourages States, Federally recognized tribes, and other partners to focus financial, educational, and technical assistance on improving the resilience of urban and community ecosystems. Cooperative Fire programs support resilient ecosystems, communities, and safe and effective response to wildland fire. Forest Health programs protect and improve the health of America's rural, wildland, and urban forests by providing funding for, monitoring of, and technical assistance on forest health-related matters, particularly those related to disturbance agents such as native and non-native insects, pathogens, and invasive plants. More than 250 specialists in the areas of forest entomology, forest pathology, invasive plants, pesticide use, survey and monitoring, suppression and control, technology development, and other forest health-related services provide expertise to forest land managers throughout the Nation.

National Agroforestry Center

The USDA National Agroforestry Center (NAC) is a partnership between the Forest Service and NRCS to accelerate the application of agroforestry through a national network of partners. NAC conducts research, develops technologies and tools, coordinates demonstrations and training, and provides useful information to natural resource professionals.[30]

The Role of National Forest Service in the Northern Plains Region

The Rocky Mountain Region of the Forest Service oversees management of 17 national forests and 7 grasslands as well as State and private forestry programs in Colorado, Kansas, Nebraska, South Dakota, and Wyoming. A diversity of ecosystems provide an array of ecosystem goods and services including clean and plentiful water, wildlife habitat, recreation opportunities, and much more. Many of these ecosystems and values are at risk as we experience the effects of climate change, such as declining snowpack and stream flow, altered weather patterns, increased risk of uncharacteristic wildfire, and expansion of invasive and destructive pests and plants.

The region is currently working with the Rocky Mountain Research Station to assess the vulnerability of key ecosystems on national forests within region. Initial assessments include the following:

- High vulnerability of alpine mountain systems because potential for upslope migration is limited and associated biota have a very high vulnerability to warming.
- High vulnerability of aquatic, riparian, and wetland ecosystems in glaciated valleys because there is often little or no potential for cold-water species to shift upward to cooler elevations and fragmented habitat.
- High vulnerability of dessert grasslands in southwestern Colorado because the area has been highly altered and faces encroachment by dry-weather shrubs.
- Moderate vulnerability of subalpine spruce-fir because they are susceptible to negative effects of climate change, but are fairly widespread and do not depend on a specific hydrologic regime.

In addition to ecosystem vulnerability, the region is also enhancing our understanding of vulnerability of infrastructure and other services owned or permitted on National Forest System lands:

- Winter recreation in the region is highly dependent on the timing and amount of snow. Smaller changes might be more pronounced at lower elevations.

[30] See http://nac.unl.edu/

- Roads, bridges, and culverts are often located in narrow valleys and are susceptible to more extreme precipitation events. Spring rain events can be magnified when warmer temperatures lead to earlier snowmelt.
- Campgrounds, trailheads, and other recreation infrastructure are often vulnerable to flooding, fire, and drought. For example, marinas and boat ramps may become ineffective during low water conditions.
- Grazing activities on Federal lands are often associated with expected timing spring and summer forage availability. Quality and availability of high-quality forage, as well as decreased water availability, could compromise grazing activities in some places.
- Water storage and provision is a critical service provided by national forests in Colorado and Wyoming. Many western municipalities rely on the snowpack to normalize flow throughout the year. Water quality is also highly variable and can be significantly affected by wildfire.

On State and private lands, many of the same social and ecological vulnerabilities exist. The region is working with State forestry agencies and many other partners to mitigate risk and support ecosystem resilience across rural and urban landscapes.

The Rocky Mountain region has modified existing programs and expanded partnerships to address climate change adaptation and mitigation.

- High-performance partnerships with Denver Water and other municipal water providers leverage funding to reduce the risk of catastrophic wildfire in key watersheds.
- Agreements with Xcel Energy facilitate maintenance and protection of energy transmission lines permitted on National Forest System lands. This work expedites the cutting of dead and dying trees that threaten power lines and could disrupt power supply and start fires.
- Our vegetation management and fuels reduction programs have shifted focus to accelerated landscape restoration for forest health and wildfire protection. Collaborative Forest Landscape Restoration Program projects and other stewardship tools, along with new woody biomass facilities, have expanded our capacity to enhance resiliency of our forests.
- Additional engagement with Rocky Mountain Research Station, the Southwest Ecological Restoration Institutes, and other partners is producing ecosystem and infrastructure vulnerability assessments and other tools that will characterize risk and inform cross-boundary priorities for the region.
- Recent forest plan revisions on the San Juan (Colorado) and Shoshone (Wyoming) national forests provide strategic direction for climate change adaptation. Other national forests and grasslands in the region will have climate change monitoring components in place by May 2016.

5.3. Farm Service Agency

With more than 284 State and county offices throughout the six-state Northern Plains region, the Farm Service Agency is the face of USDA to producers who participate in the conservation and energy, commodity crop, disaster assistance, and farm loan programs it manages. In the Northern Plains region, crop production and protection of our soil and water resources are extremely vulnerable to climate fluctuations.

- Conservation Reserve Program (CRP) land and rangeland is vulnerable to drought because these acres are not commonly irrigated. During drought, the danger of wildfires spreading over vast areas of CRP and rangeland is greatly increased. These acres, once devoid of growing cover, then become susceptible to wind erosion, and severe dust storms may result. Loss of grazing lands increases the economic risk to livestock producers resulting in herd reduction.
- The susceptibility of dry land and irrigated crops as well as CRP, rangeland, and livestock forage increase the economic risk to agricultural producers, rural communities, and to maintaining and sustaining soil and water resources.

- The productivity of the Biomass Crop Assistance program would be at risk during periods of drought and high temperatures because these crops are also highly susceptible to fire under drought conditions. The results would be similar to loss of CRP cover or rangeland. Once the biomass crop is harmed by drought, fire, or both, the soil and water resources then become extremely vulnerable to wind and water erosion.

Virtually all of FSA's programs affect producers' ability to adapt to and even mitigate the effects of climate change, as outlined below:

- The CRP is among the largest voluntary conservation programs in the world, provides incentives to producers to take marginal or vulnerable cropland out of production for 10–15 years in an effort to improve soil health, effectively eliminate erosion, enhance water quality, and create wildlife habitat. Under the Agricultural Act of 2014 (the 2014 Farm Bill), grassland can also be enrolled in and maintained under CRP.
- The Biomass Crop Assistance Program provides incentives to producers to establish, cultivate, and harvest eligible biomass for heat, power, bio-based products, research, and advanced biofuels.
- The new Price Loss Coverage and Agricultural Risk Coverage programs, along with the Marketing Assistance Loan and other existing programs, help to mitigate the price and yield risks that producers' face, which maintains farm incomes and keeps farmers on the land.
- The Noninsured Crop Disaster Assistance, Livestock Forage Disaster, Livestock Indemnity, and other programs provide emergency assistance to producers when drought and other disasters affect agricultural production.
- The Direct and Guaranteed Loan Programs provide many farmers and ranchers the opportunity to obtain the credit they need to begin and continue their operations, particularly when obtaining commercial credit is difficult. Under the 2014 Farm Bill, the ability to help beginning and socially disadvantaged producers has been enhanced.

Farm Service Agency administers the programs that Congress provides through the Farm Bill. The Food and Agriculture Act of 2014 provides the following programs that are meant to assist producers in managing the risks and vulnerabilities created by the changing climate:

- The new Price Loss Coverage and Agricultural Risk Coverage programs, along with the Marketing Assistance Loan and other existing programs, provide an economic safety net for producers of 20 covered commodities during times of economic loss that could be triggered by crop losses or price declines.
- The Noninsured Crop Disaster Assistance, Livestock Forage Disaster, Livestock Indemnity, Emergency Livestock Assistance Program, and Tree Assistance Programs provide emergency assistance to specialty crop and livestock producers when drought and other natural disasters strike.
- The Dairy Margin Protection Program provides risk management tools for dairy producers when their feed costs increase and milk prices decline (dairies are very susceptible to rapid increases in the cost of feed, which is often the result of drought, floods, fires, unseasonable freezes, and other natural events that diminish the production of feed crops).
- Farm Service Agency direct, guaranteed, and emergency loan programs are helpful to producers who have suffered economic losses. Loan guarantees through commercial agricultural lenders allow producers to obtain credit during years of poor production. This is an extremely valuable resource for producers affected by climate change scenarios.
- Farm Service Agency offers 9-month commodity loans that can be used by producers to obtain quick financial aid in times when markets could be volatile due to various climatic extremes.
- The CRP and Continuous CRP programs, such as Pollinator Habitat, SAFE projects, Farmable Wetland Program, and Duck Nesting Habitat, can also be used to reduce environmental risks and

vulnerabilities of climate change and may be used to mitigate the effects of climate change or contribute to restoration efforts after a natural disaster.

- Farm Service Agency has two emergency cost-share programs that can be implemented when the need arises. The Emergency Conservation Program (ECP) and the Emergency Forest Restoration Program (EFRP) are available to farmers and ranchers affected by natural disasters, to financially assist the restoration of conservation practices.

5.4. Rural Development

Rural Development (RD) supports rural communities through loans, loan guarantees, and grants. For some RD programs, the agency holds liens or other security interests in facilities and related infrastructure in areas that could be affected by hydrological changes and sea-level rises resulting from effects such as inundation and erosion. Additionally, many climate change models predict greater frequency and severity of weather events such as tornados and hurricanes, which can damage utility facilities and infrastructure. Climate change therefore represents a risk to these agency assets and the communities they serve.

Within the Northern Plains region the occurrence of more extreme weather events such as drought and longer, hotter growing seasons are anticipated to cause 1) disruption of electric and other energy supplies, 2) greater damage to structures/infrastructure from flooding, and 3) greater demand on the water supply.

Rural Development has services in place to administer different program areas including the Rural Housing Service, Rural Business-Cooperative Service, and Rural Utilities Service.

Rural Housing Service

The Rural Housing Service (RHS) administers programs that provide financial assistance (loans and grants) for quality housing and community facilities for rural residents within the all of the Climate Hub regions.

RHS will implement the prevention measures outlined below in an effort to reduce the effects of climate change and become more resilient to adverse effects predicted to be incurred by flooding, storm surges, hurricanes, tropical storms, and other severe weather patterns that could adversely affect structures funded through RHS programs.

1) RHS will continue to provide training to staff on proper siting of facilities/infrastructure for the life-of-structure (30 to 50 years in some cases) in locations where the effects from climate change will not adversely affect the facility or the surrounding environment.
2) RHS will also continue to consider the effects of sea-level rise, other potential flooding, and severe weather effects into long term planning.
3) RHS will continue to provide funding for the following programs, which have been designed to lessen the need for fossil fuels, promote renewable energy, and increase energy efficiency in an effort to reduce the effects of climate change:
    - Multi-family Housing Energy Efficiency Initiative
    - Multi-family Housing Portfolio Manager, Capital Needs Assessment/Utility Usage
    - Energy Independence and Security Act compliance (affects new construction of single family housing)
    - Climate Action Plan installation of 100-megawatt-capacity onsite renewable energy multi-family housing by 2020

Rural Business-Cooperative Service

The Rural Business-Cooperative Service (RBS) administers programs that lessen the need for fossil fuels, promote biomass utilization, renewable energy, and increase energy efficiency within all of the Climate Hub regions. The Rural Energy for America program lowers the demand on base plants by investing in energy efficiency and renewable energy. Lower base load demand conserves water and helps to reduce greenhouse gasses that contribute to climate change. Renewable energy investments can provide extra resiliency by distributing energy resources.

RBS is investing in alternative fuels, renewable chemicals, biogas, wastewater conservation, and harvesting combustible forest thinning's for advances biofuel.

Rural Utilities Service

The Rural Utilities Service (RUS) administers programs that provide clean and safe drinking water and sanitary water facilities, broadband, telecommunications, and electric power generation and transmission/distribution within all of the Climate Hub regions.

The following programs or measures will help address resiliency and lessen the effect of droughts, floods and other natural disasters and increase energy efficiency:

- National Rural Water Association (NRWA) Grant: an energy efficiency program designed to promote energy-efficient practices in small water and wastewater systems. Performs energy assessments, recommends energy-efficient practices and technologies, and provides support in achieving recommendations.
- Rural Development Rural Utilities Service – Promoting Sustainable Rural Water and Wastewater Systems (Memorandum of Agreement between the Environmental Protection Agency and USDA: The goals of this program are to increase the sustainability of drinking water and wastewater systems nationwide to ensure the protection of public health, water quality, and sustainable communities, to ensure that rural systems have a strong foundation to address 21st century challenges, and assist rural systems in implementing innovative strategies and tools to allow them to achieve short- and long-term sustainability in management and operations.
- Emergency Community Water Assistance Grants: These grants assist rural communities that have experienced a significant decline in quantity or quality of drinking water due to an emergency, or in which such decline is considered imminent, to obtain or maintain adequate quantities of water that meets the standards set by the Safe Drinking Water Act. Emergencies are considered to include incidents such as (but not limited to) drought, earthquake, flood, tornado, hurricane, disease outbreak, or chemical spill, leakage, or seepage.
- Electric Program–Energy Efficiency and Conservation Loan Program: The program is "for the purpose of assisting electric borrowers to implement demand side management, energy efficiency and conservation programs, and on-grid and off-grid renewable energy systems." Program goals include 1) increasing energy efficiency at the end user level; 2) modifying electric load such that there is a reduction in overall system demand; 3) effecting a more efficient use of existing electric distribution, transmission and generation facilities; 4) attracting new businesses and creating jobs in rural communities by investing in energy efficiency; and 5) encouraging the use of renewable energy fuels for either demand-side management or the reduction of conventional fossil fuel use within the service territory.
- Principles, Requirements, and Guidelines (PR&G): Application of the revised PR&G in the near future to RUS water and wastewater program planning will include consideration of, among other factors, effects of climate change.
- Rural Development Climate Change Adaptation Planning Document: This document, from June 2012, would apply to all three RD agencies. The plan was prepared to in support of Departmental

efforts to respond to Executive Order 13514 (Federal Leadership in Environmental, Energy, and Economic Performance) and to USDA Departmental Regulation 1070-001. The planning document discusses greater efforts at risk assessment and identifies five specific actions related to climate change planning and adaptation.

- Engineering Design Standards and Approved Materials: The RUS electric program envisions increased incorporation of climate change-related effects as it revised its standards and materials for RUS-financed infrastructure. Some borrowers (e.g., in coastal areas and the Great Plains) have already received agency approval for “hardened” electric poles and lines.

5.5. Risk Management Agency

The Risk Management Agency (RMA) provides a variety of actuarially sound crop and livestock-related insurance products to help farmers and ranchers manage the risks related to agricultural production. Coverage is provided against agricultural production losses due to unavoidable natural perils such as drought, excessive moisture, hail, wind, hurricane, tornado, lightning, and insects. In 2014, the Federal crop insurance program provided U.S. agricultural producers with almost $109 billion in protection for agricultural commodities. These policies provide financial stability for agricultural producers and rural communities, and are frequently required by lenders.

Because climate change is an ongoing process, the risk environment for agricultural production will also be undergoing constant change (e.g., some perils may occur with greater or lesser frequency and/or severity). Climate change will also promote adaptive responses by producers, such as adopting new production practices, planting new varieties, or shifting the locations of farming operations.

RMA continually strives to improve the effectiveness of programs by refining insurance offers to recognize changes in production practices and, where appropriate, adjusting program parameters (e.g., premium rates, planting dates, etc.) within each county to recognize structural changes to the risks of growing the crop in those areas. In that regard, RMA monitors climate change research and, to the extent that climate changes emerge over time, updates these program parameters to reflect such adaptation or other changes. RMA also updates loss adjustment standards, underwriting standards, and other insurance program materials to ensure they are appropriate for prevailing production technologies.

Vulnerabilities in the Northern Plains include:

- Prevented planting in the Prairie Pothole Region
- Early/late freezes
- Flooding issues
- Prolonged drought
- Lack of irrigation water

To address these vulnerabilities, RMA issued press releases on drought relief and prevented planting “1 in 4” rule in 2012 and a response to the Devil’s Lake flooding in 2011. RMA also provided information on drought management and grazing through Risk Management Education. RMA in Montana is partnering with the University of Wyoming and the National Center for Applied Technology on a Risk Management Education project to promote the use of cover crops. RMA published Frequently Asked Questions for Colorado in 2013 and Nebraska in 2013 and 2014 to explain covered causes of loss when there irrigation supplies are reduced.[31]

[31] See: http://www.rma.usda.gov/help/faq/irrigatedppco.html; http://www.rma.usda.gov/help/faq/irrigatedppne.html; http://www.rma.usda.gov/help/faq/irrigatedpprepriver.html;http://www.rma.usda.gov/help/faq/nepp2014.html

5.6. Animal and Plant Health Inspection Service

The Animal and Plant Health Inspection Service (APHIS) is responsible for protecting and promoting U.S. agricultural and forest health, regulating certain genetically engineered organisms, enforcing the Animal Welfare Act, and carrying out wildlife damage management activities. APHIS is constantly working to defend U.S. plant and animal resources from agricultural and forest pests and diseases. Once a pest or disease is detected, APHIS works in partnership with affected regions to manage and eradicate the outbreak. In its new Strategic Plan[32] for 2015, APHIS lists seven goals:

1. Prevent the entry and spread of agricultural pests and diseases.
2. Ensure the humane treatment and care of covered vulnerable animals.
3. Protect forests, urban landscapes, rangelands and other natural resources, as well as private working lands from harmful pests and diseases.
4. Ensure the safety, purity, and effectiveness of veterinary biologics and protect plant health by optimizing our oversight of genetically engineered organisms.
5. Ensure the safe trade of agricultural products, creating export opportunities for U.S. producers.
6. Protect the health of U.S. agricultural resources, including addressing zoonotic disease issues and incidences, by implementing surveillance, preparedness and response, and control programs.
7. Create an APHIS for the 21st century that is high-performing, efficient, adaptable, and embraces civil rights.

APHIS works to achieve these goals through the actions of several mission area program staffs and support units. The text below discusses the APHIS programs and their respective responsibilities, as well as their expected vulnerabilities related to a changing climate and the measures in place to minimize risks from these vulnerabilities. As an agency with nationwide regulatory concerns, APHIS programs are typically national in scope and application.

Animal Care (AC)

The mission of the AC program is to protect animal welfare by enforcing the Animal Welfare Act and the Horse Protection Act. AC protects animals and their owners by supporting Federal Emergency Management Agency (FEMA)-led emergency pet evacuations necessitated by disasters such as hurricanes.

The APHIS Animal Care non-statutory mission to support FEMA for the well-being of household pets during disasters is vulnerable to climate change. More storms and more severe storms are predicted as the climate warms, and consequently, activities in this mission area may increase. The Animal Care statutory mission to ensure the welfare of animals used in commerce, exhibition, and research may change as well. For example, the availability of water may change the economics of these industries resulting in a decrease in activities in certain parts of the country.

Animal Care sponsors and participates in planning and exercise activities together with FEMA, Emergency Support Function (ESF) #11,[33] States, nongovernmental organizations, and other response partners to strengthen the Nation's capacity to respond to natural disasters. These efforts should help reduce the impact of disaster and help people recover more quickly.

Biotechnology Regulatory Services (BRS)

To protect plant health, BRS implements the APHIS regulations for genetically engineered (GE) organisms that may pose a risk to plant health. APHIS coordinates these responsibilities along with the

[32] http://www.aphis.usda.gov/about_aphis/downloads/APHIS_Strategic_Plan_2015.pdf
[33] http://www.fema.gov/pdf/emergency/nrf/nrf-esf-11.pdf

other designated Federal agencies as part of the Federal Coordinated Framework for the Regulation of Biotechnology.

No BRS actions are directly “vulnerable” to climate change. However, because climate change would likely affect the distribution of some agricultural crops and other plants, BRS actions related to conducting inspections of field trials for GE plants could be affected. Therefore, if growing areas for regulated GE plants shift, BRS would need to conduct inspections in those new locations.

BRS has in place a flexible staffing plan and practice—not all of its staff are centrally located; they are set up to provide mobile inspection service to wherever GE crops are growing in field trials. Additionally, BRS receives reports each year from those holding permits for conducting field trials. BRS uses this information to plan inspections throughout the life cycle of the field trials. The flexibility and regular use of new information inherent in BRS planning and practice will help minimize risks from climate change.

Plant Protection and Quarantine (PPQ)

PPQ is responsible for safeguarding and promoting U.S. agricultural health. PPQ is constantly working to defend U.S. plant and forest resources from agricultural pests and diseases. Once a quarantine plant pest or disease (one not previously found in the U.S. or if found, is under official control) is detected, PPQ works in partnership with affected regions to manage and eradicate the outbreak. PPQ has three strategic goals:

1. Strengthen PPQ’s pest exclusion system.
2. Optimize PPQ’s domestic pest management and eradication programs.
3. Increase the safety of agricultural trade to expand economic opportunities in the global marketplace.

In the face of an increasingly variable climate and more erratic weather conditions, PPQ will continue to play a central role in responding to risk and managing vulnerabilities. In this capacity, PPQ operates primarily on a national level with regional emphasis as needed to address and divert pest incursions.

PPQ is tasked with assessing risk and predicting where an invasive plant pest may be introduced, establish, and spread; these assessments are often based on climatic conditions and host availability from a national perspective. As climate changes, host distribution and landscape conditions deviate from what is considered “normal”. PPQ assessments are based on available data that often reflect past conditions. As climate changes, the actual relevance of these data may lessen our ability to accurately predict and understand risk.

Some of the challenges in predicting future risk under climate change require a shift from analyzing mean responses (e.g., an increase of 2 to 3 degrees temperature on average), and instead focus on trying to understand how pest invasiveness and establishment potential change with greater weather variability and more extreme events. For example, several years of warmer than normal weather can allow the development of invading pest populations and their spread to new areas. Once arriving in new areas, if such pest populations can secure warmer microclimates to survive the winter, they can become more prevalent earlier the following season. Anticipating global trade shifts in response to climate change is another challenge, as is the subsequent risk of new crop pests and diseases associated with them.

PPQ Science and Technology is partnering with other agencies, universities, and the Climate Hubs to increase our capacity to obtain and analyze data, and implement models that inform climate change-specific policies and pest programs. We have increased our capacity to perform pest risk modeling at regional, national, and global levels with new platforms. These platforms are designed to project climate change scenarios onto the landscape to model geographic shifts in climatic suitability and host availability. We are also applying phenological models that can be used to analyze how climate change and increased weather variability might affect temporal sequencing of pest development and subsequent population response.

Veterinary Services (VS)

VS is responsible for regulating the importation and interstate movement of animals and their products to prevent the introduction and spread of foreign animal diseases of livestock. If a foreign animal disease were to be detected in the United States, VS is responsible for responding to the outbreak in coordination with States, tribes, and producers. VS also regulates the licensing of veterinary biologics such as vaccines.

Changing Vector Distribution

- *Vulnerabilities:* Climate change could mediate changes in the dispersal and redistribution of arthropod vectors along with the ability of these vectors to transmit economically important pathogens, potentially allowing them to spread from areas where they are already established to new locations. This change in distribution could result in significant increases in morbidity and mortality to livestock, wildlife, and people, along with a reduction in market value of animals from affected areas.
- *Current measures addressing vulnerabilities:* VS conducts passive—as well as some active—surveillance for diseases spread by vectors including cattle fever (babesiosis), epizootic hemorrhagic disease virus (EHDV), vesicular stomatitis virus and blue tongue virus (BTV), and monitors reports and studies of other vector-borne diseases. This surveillance activity may help identify any changes in vector populations and inform recommended changes to disease surveillance and production practices. VS could identify other mitigations through further research in this area. Such projects may include using climate models and scenario analyses to identify geographic areas likely to undergo environmental changes that would lead to an increased risk of infection with selected pathogens, and simulating economic impacts of potential vector and pathogen range expansion to livestock and wildlife industries.

Increased Wildlife-Livestock Interaction

- *Vulnerabilities:* Increased pest infestation, fires, and expansion of the wilderness-urban interface will alter wild animal distribution, movements, and feeding patterns, thereby increasing contact and the potential for disease exchange with agricultural animal populations. For example, the current widespread epidemic of mountain pine beetles throughout the western United States and Canada may lead to widespread tree deaths and fires, followed by variable regrowth in forested and transient grassy areas as trees re-grow.
- *Current measures addressing vulnerabilities:* VS is a collaborator in a new APHIS Wildlife Services–led program to investigate and mitigate damage and disease risks from feral swine and is involved in studying and responding to wildlife-livestock interactions with regard to disease transmission.

Heat Stress on Livestock

- *Vulnerabilities:* In highly optimized, intensive livestock production systems, small changes in maximum temperatures can reduce productivity through decreases in weight gain or milk production or through losses of livestock.
- *Potential measures to address vulnerabilities:* Measures may include moving livestock facilities to cooler areas. For example, parts of the north central Plains and into central Canada may become more productive for livestock as other areas become too warm.

Aquaculture

- *Vulnerabilities:* Marine and freshwater food fish populations have already declined significantly due to warming waters and the attendant effects that include acidification, oxygen depletion, algal blooms, and increased pathogen loads. These effects exacerbate impacts of overharvesting, which has depleted many wild fish populations. Decreases in the wild fish catch places more pressure on the aquaculture industry for higher production and mitigation of health impacts.
- *Potential measures to address vulnerabilities*: As demands on the aquaculture industry for fish protein increases, we will rely more heavily on coordinated efforts targeting disease control and improved health of aquacultured species. APHIS VS partners with the commercial aquaculture industry and Federal agencies and States to work collectively to protect and certify the health of farm-raised aquatic animals and facilitate their trade, and safeguard the Nation's wild aquatic animal populations and resources.

Policy and Program Development (PPD)

PPD performs economic, environmental, and other analyses to support the actions of APHIS programs. PPD analyses would be more robust over time if they were better able to incorporate economic and environmental impacts of climate change to relevant agricultural systems and ecosystems. Validated forecasts for how a changing climate is likely to affect the distribution of production areas for various commodities, and anticipated needs for commodity movements at an international and domestic scale, can inform our economic analyses. This information, along with information on pollinators, water, and other resources, as well as effects on low-income, minority, and tribal communities, will better inform our environmental analyses.

PPD is incorporating climate change into many of its environmental compliance (e.g., National Environmental Policy Act; NEPA) documents and is leading an agency-wide effort to develop guidance for addressing climate change in our NEPA documents.

Wildlife Services (WS)

The mission of WS is to provide Federal leadership and expertise to resolve wildlife conflicts to allow people and wildlife to coexist. WS conducts program delivery, research, and other activities through its regional and State offices, the National Wildlife Research Center (NWRC) and its field stations, and through its national programs. Since the work of WS is greatly influenced by distributions of wildlife, which is expected to change under conditions of climate change, much of this work will be changing, as well. The following examples reflect some of those changes that are likely to impact the Northern Plains.

Managing diseases spread by wildlife: Climate change will likely have dramatic effects on the distribution of both agricultural diseases of concern as well of zoonotic diseases, both of which can be spread by wildlife. It is expected that some areas will see a decrease in endemic disease risks, while others may see new diseases emerge in areas where they were not previously documented. Given the sensitivity of insect vectors to changes in weather-related variables, it is likely that initial changes in disease distribution resulting from climate change will take place for those diseases that are vector-borne.

NWRC is conducting surveillance and research on diseases and vectors to gather baseline data on their distribution for use in climate change models and future studies. NWRC also maintains tissue archives of wildlife samples that are made available for retrospective research on diseases to identify changes in pathogen distribution and prevalence.

Predator management: As climate changes, so may landscapes and habitats shift along with changes in prey distribution and abundance. Changes in native vegetation, and therefore forage, will alter feeding patterns of omnivorous predators such as coyotes, mountain lions, and wolves. These shifts will influence the distribution and abundance of predators and will alter the predictive ability of models related to spatial patterns, behavior, abundance, and habitat use of predators. Such models may therefore need to better incorporate climate change. Results of such climate-informed models may be needed to inform predator management strategies in order to adapt to climate change.

NWRC researchers are gathering data on changes in species distribution and abundance, behavior, and habitat use for predators from around the country that are already affected by climate change (e.g., polar bears) and will use these studies as a foundation for incorporating climate change into studies of species found locally. NWRC is also incorporating climate change models into projections about future habitat availability for predators (e.g., models for wolverine habitat).

Wildlife management for aviation safety: As climate changes, so may the breeding and wintering ranges of birds, which may affect aviation safety. Airports and military installations should be prepared to address new challenges associated with changes in bird ranges. Also, species' migration strategies may change. As an example, we have developed migration models for osprey in relation to military aircraft movements. These very well could become outdated as climate, and therefore bird migration strategies, change. Proper habitat management is crucial to successful management of wildlife hazards to aviation. Distribution of plant species that grow on airports and military installations may change in the future. Thus, habitat management strategies may also need to adapt to a changing climate.

NWRC is gathering data on species and habitat distribution, so it should be able to detect changes in species ranges, and migration and movement patterns, and therefore adjust its habitat management strategies accordingly. NWRC is also researching alternative land covers that could be used at airports and military installations in the Northern Plains and across the United States. Thus their staff is determining which habitat types could be viable options in new areas as conditions change.

Wildlife management to protect agriculture: WS conducts research and management on wildlife species such as starlings and blackbirds that can have a significant effect on sunflower, rice, and other agricultural commodities. As climate changes, the distribution of these species as well as the agricultural crops they affect will also change. Information on population densities and distribution of target species is important for understanding how climate change will impact production of these agricultural commodities.

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