Northwest Regional Climate Hub Assessment of Climate Change Vulnerability and Adaptation and Mitigation Strategies

Photo credit: Gary Wilson, NRCS (2000)

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Letter from the Regional Lead

The USDA Regional Climate Hubs were established to maximise opportunities for sharing scientific findings about current and future risks from changing climate with people who manage working landscapes. There is an opportunity for Hubs and scientists to work with extension agents and others to develop effective and affordable ways of adapting to climate changes and mitigating greenhouse gas emissions, and to develop accessible formats for disseminating these materials. The Hubs can help develop and share tools and information that support these efforts. We think this effort will help farmers, ranchers, and private forest owners anticipate future conditions, rather than simply react to changes, as well as help them make more effective decisions about how to invest their time and resources.

Success in achieving this vision for the Hubs requires that we build much stronger bridges of communication between scientists, extension agents, and stakeholders. This assessment is intended to provide a foundation for these communication goals by describing what we currently know and what we understand are priority needs. We hope this will stimulate reaction and discussion among the people working to improve and protect the resources and assets of the great Northwest landscapes in the face of environmental changes that have already begun. We owe this much and more to future generations.

This assessment draws from a large bank of information developed by scientists and extension specialists in the Northwest to describe where we need to focus when dealing with climate risks to working landscapes. The changing climate has many secondary effects, such as irrigation water loss, increases in wildfire frequency, and increases in diseases and insect pest populations. Melting Arctic ice could lead to the increased prevalence of invasive species as well as more regional trade and shipping. This assessment sorts through these effects to highlight what we value, explore how those assets are at risk, and identify viable options for minimizing negative effects. It also seeks to identify where additional research or tools and outreach development is needed.

Beatrice Van Horne,

Northwest Climate Hub Lead

1 Introduction

Landscapes are integral to the culture and economies of the Northwest region. Natural and managed lands and their resources are valued locally, regionally, and nationally. The importance of agriculture to the region is reflected in efforts to conserve productive lands; over the past 30 years, less land has been converted from agriculture here than elsewhere in the United States. Producers and landowners in the Northwestern United States are already facing challenges from a changing climate and increased weather variability, and are altering their management decisions as a result.

Cropping, timber harvest, and livestock are strong contributors to the regional economy. Nearly a quarter of the land area in these states is used for agricultural production. Agriculture in Oregon, Washington, and Idaho produces 3 percent of the region's gross domestic product, over half of the Nation's potato crop, around 17 percent of the Nation's wheat and 11 percent of the Nation's milk (National Agricultural Statistics Service, 2014). According to the Agricultural Marketing Resource Center[1], Washington produces 70 percent of the apples in the United States, Washington and Oregon produce 75 percent of the pears, and Washington/California/Oregon produce 97 percent of the sweet cherries. In Alaska, farming is largely confined to the Matanuska-Susitna ("Mat-Su") Valley (24,000 sq. mi) and an area east of Fairbanks. Timber, fish, game, and other biological resources are important throughout the cash economy and essential for many subsistence users, especially in rural areas. Timber remains a substantial contributor to the economies of all four states.

Examples of climate and weather effects include:

Reduced snow water storage: Winter snowpack is essential for meeting irrigation needs in the spring. Reduced precipitation falling as snow results in reductions in snow water storage. In the mountains, higher temperatures can result in earlier snowmelt, an increase in rain events, and a decrease in snow events. This, in turn, results in lower surface water availability during the growing season and high stream flows at other times. This trend began in the 1980s, and researchers predict that it will continue.

More frequent fires: The number of wildfires has increased in the last decade and is predicted to increase even more. These fires reduce timber yields, alter wildlife and fish habitats, increase the risk of soil erosion, and expand the range of invasive annual weeds on public and private rangelands.

Higher temperatures and drought: Temperature and precipitation changes can result in drought; heat stress in crops and livestock; and increases in plant diseases, pests, insects, and weeds. Drought in the Northwest can stress forest vegetation and create conditions condusive for outbreaks of bark beetles and other pests. After these outbreaks, broad swaths of dead trees remain.

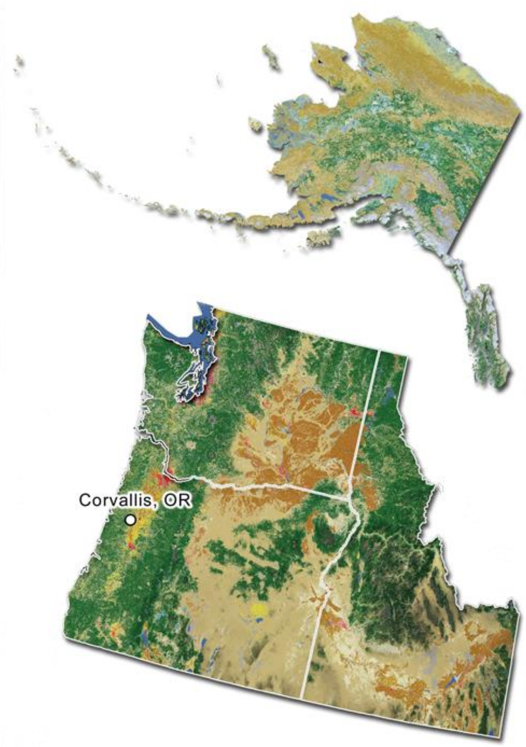

Figure 1: Northwest Climate Hub Region (Headquarters in Corvallis, OR). Legend: Cultivated (brown), Grassland (tan), Forest (green), Developed (red), Water (blue). Area represented: Alaska=656,424 sq miles, Washington=71,303 sq miles, Oregon=98,386 sq miles, and Idaho=83,574 sq miles.

[1] http://www.agmrc.org/

1.1 Description of the Region and Key Concerns

In approaching this analysis we recognize three regions that have shared geography and concerns:

Western Washington and Oregon: This subregion is west of the Cascade Mountains range crest and includes moist forests and farmlands. It has a higher human population density than the other subregions. Anticipated climate-induced changes include:

- altering available crop selections;
- an increase in insect and pathogen outbreaks in farmland, as well as an increase in insect outbreaks in forest land;
- an increase in energy-limited coastal temperate rain forest production and carbon sequestration; changes in fish habitat, population dynamics, and parasite infestations resulting from temperature increase, and downstream effects resulting from upstream nutrient dynamics changes;
- changes in the timing and quantity of water delivery from streamflow dominated by snowmelt;
- changes in human behaviors, choices, and mitigation activities;
- increased air temperatures, decreased relative humidity, and associated increases in evapotranspiration rates;
- increased human population pressures on urban systems as a result of climate migration (i.e., when climate change forces people to leave their homes); and
- reduced water availability for agronomic, natural, and urban systems during the summer dry season.

Idaho and Central/Eastern Washington and Oregon: This subregion has chronically low rainfall. Climate change will exacerbate drought stress by increasing the length of the dry season, and snowpack loss will reduce streamflows. Expected effects include:

- reduced production for some crops, especially specialty crops with specific requirements, including changes in available crop choices, increased insect and pathogen outbreaks in farmlands, and increased and insect outbreaks in forest land;
- changes in the timing and amount of available water from streamflow dominated by snowmelt;
- increased drought stress and wildfire risk in forests and rangelands;
- degraded fish habitat resulting from drought stress and increased temperature;
- changes to forest stand composition resulting from drought and the effects of increased temperature on tree production and survival;
- changes in ecosystem carbon sequestration and hydrologic cycles;
- changes to urban tree health resulting from the effects of increased temperature and air pollution;
- increases in air temperature and relative humidity, leading to increased evapotranspiration rates;
- decreased soil moisture levels;
- reduced water availability for agronomic, natural, and urban systems;
- increased water demand for livestock and crops stressed by high temperatures;
- reduced surface water quality resulting from increased agricultural runoff; and
- changes in natural environmental flows resulting from diversions of surface water for irrigation.

Alaska: Many Alaskan ecosystems are signficantly influenced by the presence of frozen water within glaciers, snowpack, and permafrost. Compared to other parts of the globe, climate change acceleration near the poles greatly accentuates the effects of climate change in Alaskan environments, particularly in the Southeast region. Increased temperatures and decreased soil moisture have already or will produce:

- carbon loss from permafrost degradation and riparian system disruptions—both of which dominate regional carbon and nitrogen cycling dynamics—as well carbon loss from river and coastal marine systems;

- increased insect and pathogen outbreaks in interior Alaska;
- drought and increased wildfire risk in interior Alaska, and increased fire frequency and intensity throughout the state;
- increased challenges to forest regeneration;
- increased challenges to southeast Alaska wood production;
- reduced agricultural production in southern and interior Alaska;
- increased challenges to southeast Alaska fisheries;
- increased species invasion events, which may be further exacerbated by emerging trade routes that result from Arctic sea ice reductions;
- disruptions to northern and interior Alaska ungulate migration and populations dynamics;
- shifts in species occupancy patterns across the landscape;
- increased sea level rise and loss of arctic sea ice that in turn affect coastal communities and animal habitats;
- reduced sea ice that increases transportation/economic opportunities; and
- reduced success in subsistence hunting and gathering.

1.2 Demographics and Land Use

Family forest landowners control about half the private forest land in the Northwest. Much of this land is located in lower elevations, along stream corridors, and near population centers. Vulnerabilities in these three regions affect both natural ecosystems and more intensively managed lands. Plants and animals are affected by even small changes in climate, and changes in habitat are leading to local extinctions of range-restricted species. The types of landscapes likely to be affected by these changes include:

Natural or semi-natural ecosystems:

Ecosystems that are particularly threatened include:

- low arctic tundra
- low arctic alpine
- coastal tundra
- boreal forest
- coastal temperate rain forest
- mixed conifer forests on the west side of the Cascade Range
- pine-dominated mixed conifer forests in the Cascade Range and northern Idaho
- pine-dominated forests of Oregon, eastern Washington, and southern Idaho

Highly managed agronomic lands:

The region contains some of the country's most productive agricultural lands. These are found in the Willamette River Valley in northwest Oregon, the Columbia River Valley in eastern Washington and north-central Oregon, and the Sanke River Plain of central and southern Idaho. Smaller areas include the Matanuska-Susitna Valley of Alaska, the Palouse region of southeast Washington and northeast Idaho, and patches of eastern Oregon, southwest Washington, and the east side of Puget Sound. Crops may be directly affected by climate changes, but so will techniques for soil enhancement, tillage, irrigation, land conservation, and the management of surface water and groundwater. Some of the biggest water challenges will be around supply, infrastructure, quality, and allocation. Changes will be needed in water conservation, water restrictions and ordinances, and policy.

Rangelands:

These are mostly found in central and eastern Washington and Oregon, and central and southern Idaho. Climate changes resulting in more drought and extreme weather events is expected to support the spread of invasive weeds through grasslands, shrub-steppe, and mixed conifer forests. This increase will be exacerbated by increases in wildfire size, frequency, and intensity.

Managed commercial forests:

These are mainly found in western Oregon and Washington and northern Idaho. Droughts and extreme weather events associated with climate change are expected to exacerbate fire risk and could quickly affect wood and biomass production economies. The development of resources that could help commercial foresters adapt to a changing climate include suggestions about soil and hydrology management, as well as the identification of suitable alternative varieties of trees for reforestation stock. It will also be necessary to understand and address how associated economic changes will impact affected regions and communities.

Alaska:

Vulnerabilities in Alaska differ from those in the other three northwestern states because of the higher rate of climate change, the larger number of people economically and culturally dependent on natural resources, and the significant role of frozen moisture in the physical environment. Climate change effects in Alaska are so rapid that they are difficult to anticipate, even with the best models. Native villages and other rural residents are among the populations most heavily affected. Subsistence hunting and fishing practices, access to traditional foods, and traditional lifestyles are threatened by these environmental changes, and in some cases have already been lost. Climate warming has already substantially reduced glaciers, ice fields, and permafrost. Some of the most vulnerable resources include:

- Fish: Salmonids are sensitive to stream temperature and cannot spawn successfully in warmer stream temperatures associated with climate change. In addition, glacial melt along the southeastern coast has increased the volume of cold water flowing into the ocean, which is affecting marine and freshwater fisheries. Fish could also be at risk from increased shipping and trade that might result from Arctic sea ice loss.

- Forests: The size, intensity, and frequency of wildfires in interior Alaska have increased significantly, and will likely double by the year 2050. These changes, in combination with changes in permafrost, river flows, and temperatures, have led to boreal forest losses. Forest landowners throughout the state are concerned with increased fire frequency and intensity, temperature changes, water supply issues, pests and disease, invasive species, species shifts, and forest regeneration problems.

- Agriculture: Alaska has about 30,000 acres in crop production. Of this total, 74 percent is in perennial hay crops, 22 percent is in grain crops, and 4 percent is in potatoes and vegetables. More than 90 percent of crop production is located in the Tanana and Matanuska-Susitna Valleys, although a much larger area of Alaska is probably suitable for cropping. It is possible that the areas suitable for crop production could expand under climate change, depending on water availability, extreme storms, and energy and transportation costs.
- Rural communities: People living in rural communities are among the populations most heavily affected by climate change. Subsistence hunting and fishing patterns have already been altered in response to environmental changes associated with climate change; traditional foods and ways of life are threatened and in some cases have already disappeared. Thawing permafrost and increased evaporation have caused a substantial decline in the number of closed-basin lakes and wetlands, which provide breeding habitat for millions of waterfowl and shorebirds that winter in the lower 48 states. These wetland ecosystems and wildlife resources provide hunting and fishing opportunities and are significant components in Alaska Native cultural practices and identity. Poor health in village residents has been linked to the loss of Native foods such as fish, seals,

waterfowl, and caribou. Melting permafrost can cause substantial damage to infrastructure such as transportation, sewage systems, and buildings.

Practical Applications to Consider:

- Improve protection of spawning streams, especially in southeast Alaska.
- Reduce fuels in vulnerable areas of the boreal forest.
- Review current regulations for protecting subsistence uses to accommodate changes in the availability and sustainability of traditional indigenous foods or "first foods."

1.3 General Climate Conditions, Extremes, and Past Effects

Northwest weather is highly variable over space and time due to complex topography and the orographic effects of the Olympic, Coast, Cascade, and Rocky Mountain ranges. West of the Cascades, the weather is dominated by maritime influences and is characterized by mild temperatures, winter rain, and drier summers. A significantly more arid continental climate is found east of the Cascades, with colder winters and warmer summers. Seasonal weather variability is influenced by the El Niño/Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO). El Niño cycles increase the probability of drier than average winter conditions and warmer than average winter and spring conditions. La Niña conditions increase the probability of cooler and wetter than average conditions in winter (Mote et al., 2013; Ropelewski, 1986). Inherent annual weather variability has a major effect on agricultural productivity in this region and land managers are as interested in current weather as well as potential climate change effects. Potential forecasting opportunities from ENSO relationships would significantly enhance current management in addition to providing tools for mitigating the potential effects of longer-term climate change.

The Northwest climate is expected to become warmer, particularly in the summer, but with no net change in total annual precipitation. The seasonal precipitation pattern, however, is expected to shift, resulting in drier summers and wetter fall and winter periods. Overall variability in precipitation and temperature is expected to increase but with fewer cold temperature extremes (Mote & Salathe, 2010). For agricultural production, a general increase in water stress due to warmer conditions, with no net increase in precipitation, could be offset somewhat by enhanced plant productivity due to increasing atmospheric CO_2 concentrations (Eigenbrode et al., 2013; Mote et al., 2013; Snover et al., 2013). Seasonal changes in precipitation and temperature may have as much effect as mean shifts in regional temperature and increased weather variability. Eigenbrode et al. (2013) list drivers of climate change effects in this region that have different effects on crop and animal production systems, depending on the timing of management practices and plant phenology. These include, increases in average temperature for all seasons, changes in growing season length, a shift in precipitation from summer to winter, increased water stress (particularly in the summer), and a persistent annual increase in atmospheric CO_2 concentrations.

1.4 Summary of National Climate Assessment Regional Climate Scenarios

The Northwest Region's climate is highly diverse with large spatial variability. The western region of Oregon and Washington receives considerably more precipitation than the eastern region and Idaho. The regional coastal areas are the wettest in the conterminous United States, and the Cascade Range has had historically large snowfalls. Summers are typically dry and Washington, Oregon, and Idaho have the lowest frequency of convective storms in the conterminous United States. Temperatures are typically moderate and annual precipitation has a wide range due to the western mountain ranges (Kunkel et al., 2013). Alaska's climate is affected by latitude, altitude, proximity to the ocean versus the continental interior, and the seasonal distribution of sea ice. Average annual temperatures and precipitation vary widely across Alaska. Alaska also is subject to extreme weather and climate events affecting ecosystems, human society, and infrastructure (Stewart et al., 2013).

Temperature

Temperatures in the Northwest have been above average for the last 25 years both annually and seasonally[2]. Five of the nine warmest summers have occurred since 1998. Table 1 provides the trends in temperature increase/anomaly[3] in the Northwest for the time period 1895–2011. The most significant anomaly is in the winter season, with a 0.20°F/decade increase (Kunkel et al., 2013).

Table 1: 1895–2011 trends in temperature anomaly (°F/decade) in the Northwest U.S. (not including Alaska)

Season	Temperature (°F/decade)
Winter	+0.20
Spring	---
Summer	+0.12
Fall	+0.10
Annual	+0.13
Source: (Kunkel et al., 2013)	

Because average annual temperatures in Alaska are near freezing, any increase in temperature has a profound effect. Warmer temperatures increase forest vulnerability to bark beetle infestation, which in turn leads to more deadwood accumulation and increases wildfire risk. On Alaska's Kenai Peninsula, a spruce beetle outbreak caused massive tree mortality that started in the 1980s and continued for the next 20 years. Models predict that as temperatures increase, Alaskan spruce forests will be at greater risk due to continued beetle outbreaks.

During the decade of the 2000s, wildfire burned an average of 1.8 million acres in Alaska's interior, which was 50 percent higher than any previous decade since the 1940s (Stewart et al., 2013). Drivers include warmer springs, earlier spring melt, longer growing seasons, and increased pest pressure. Permafrost underlies much of Alaska. Higher temperatures increase permafrost thawing, which then activates even deeper soil layers and allows fires to persist in the organic soil horizons of some forests. Permafrost thawing can also create various types of infrastructure challenges. Roads, runways, and buildings may shift, break, or collapse as the ground beneath them thaws, softens, and sinks (Stewart et al., 2013).

Precipitation

Annual precipitation in the Northwest has been highly variable since 1976, compared to the previous 75 years. Precipitation in the majority of recent years has been below the 1901-1960 precipitation average, and winter precipitation has highly variable (Kunkel et al., 2013). In recent decades, Alaska has shown an increase in precipitation (Stewart et al., 2013).

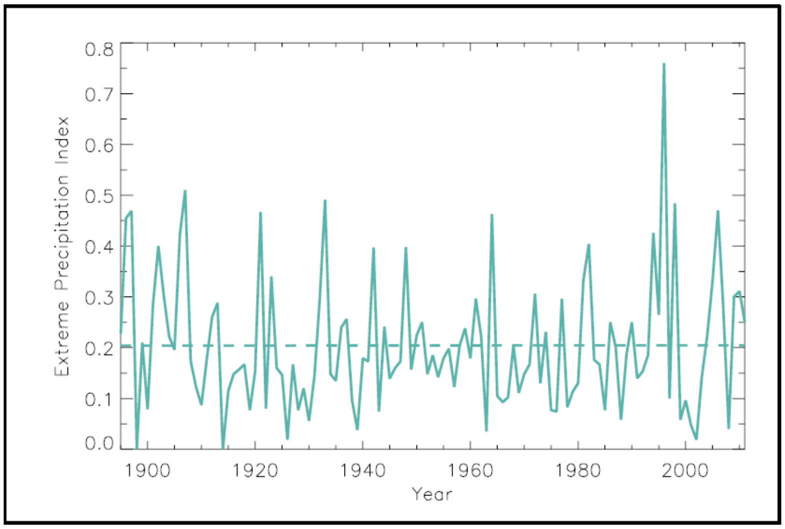

Figure 2: Time series of extreme precipitation index for the occurrence of 1-day, 1-in-5-year extreme precipitation, for the Northwest region. The dashed line is a linear fit. Based on daily COOP data from long-term stations in the National Climatic Data Center's Global Historical Climate Network data set. Source:(Kunkel et al., 2013)

Extremes

An increased interannual variability in extreme cold and hot periods has been observed in the Northwest. Heat

[2] See http://charts.srcc.lsu.edu/trends/ (LSU 2012) for a comparative seasonal or annual climate trend analysis of a specified from the Northwest, using National Climate Data Center (NCDC) monthly and annual temperature and precipitation datasets (Kunkel et al., 2013).

[3] 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 (Kunkel et al., 2013).

waves have occurred more frequently over the last 20 years, along with an increase in the number of intense heat episodes, which were 70 percent above the long-term average during the last 20 years. The frequency of cold periods, on the other hand, has been low since 1990. All of the top ten years for intense cold occurred prior to 1991. The increasing length of Northwest freeze-free seasons has been trending upward over the entire period (1895-2011); during the 1991-2010 interval, they are 11 days longer on average than during the 1961-1990 time period (Kunkel et al., 2013).

In Alaska, extreme precipitation events are highly variable and seasonal. Along the northern and northwestern coasts of Alaska, an increased number of strong storms have been observed during the absence of protective sea ice cover in the summer and autumn months. A longer ice-free season amplifies the effect of these strong storms (Stewart et al., 2013). The extent of sea ice along Alaska coastlines has changed significantly due to recent climate variability (see Figure 3), and the changes are most pronounced in the summer and fall seasons. The most extreme minimum was observed in September 2012 and was 0.7 million km^2 lower than the previous minimum record set in 2007 (Stewart et al., 2013).

Expected Changes

According to model simulations, annual mean temperature increases across the Northwest are unequivocal and large compared to historical temperature variations. The frost-free season is expected to increase by 25-35 days across much of the region, with larger increases occurring west of the Cascade Mountains. Increases in the number of hot days (maximum temperature more than 95°F) are expected to increase by up to 10 days per year, particularly in the southeastern region.

Mean annual precipitation is also predicted to increase, but is expected to vary significantly by season and location. Furthermore, model simulations indicate an increase in the number of wet days (precipitation greater than 2.5 cm) across the region, particularly east of the Cascade Range. Because winter temperatures nearer the coast can hover near freezing throughout the winter, the risk of early fall and spring freezes is greatest near the coast (Kunkel et al., 2013).

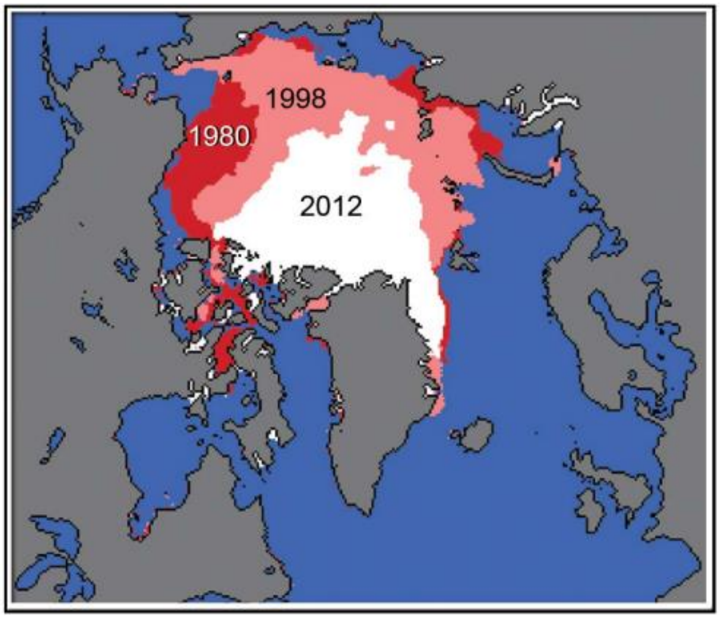

Figure 3: Extent of sea ice in September of 1980 (outer red boundary), 1998 (outer pink boundary) and 2012 (outer white boundary). Source: (Stewart et al., 2013)

Average annual temperatures and precipitation in Alaska are expected to continue to increase, with the greatest increases occurring in the northwestern portions of the state. The growing season is also expected to increase by as much as 25 days in the southwestern and south central parts of the states. Permafrost degradation is expected to continue and large declines in sea ice extent are also expected (Stewart et al., 2013).

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

Climate change is predicted to increase the frequency of extreme weather patterns in the Northwest, such as summer drought and winter flooding. Effects of these extremes will vary among subregions and resources. In moist and fertile valleys, such as the Columbia, Willamette, and Klamath River basins, most of the rain falls in winter outside the growing season. Because the Coastal Range, Cascades and other mountain ranges in the Northwest are lower in elevation compared to the Rockies, they are strongly influenced by oceanic moisture, and annual air temperatures are generally closer to the freezing point than air temperatures typical of more continental mountain ranges. In these regions, even small changes in annual temperatures can result in significant changes in rain-snow transition zones and the timing of spring snowmelt. Dams and reservoirs are used extensively to store water for irrigation and other uses, and the reservoirs are largely replenished by snowmelt runoff from the Cascades, Rocky Mountains and other ranges. Winter warming can reduce snowfall amounts and increase rainfall amounts, which could lead to summer water shortages for agriculture and hydroelectric power unless water management in storage reservoirs is adjusted accordingly. Groundwater is also used for irrigation, but in many areas groundwater levels have dropped precipitously and deeper wells are needed to pump even low-quality water laden with minerals. Individual farmers can quickly lose access to water needed for irrigation. Additional winter rain can also result in floods and saturated soils, which leads to increased topsoil loss and harms soil structure and fertility.

The effects of climate change on drylands and rangelands raises different concerns. There are large areas of non-irrigated agricultural lands in the arid portions of central Washington, southern Idaho, eastern Oregon, and the Columbia Plateau in Washington, Oregon, and Idaho that supports cereal-based cropping systems. In these areas, increasing temperatures can lead to summer drying and wind-driven soil erosion; climate change may also create conditions that support the increased survival and spread of plant diseases and pests such as cereal aphids.

American Indian tribes are greatly concerned about the effects of climate change on traditional hunting, fishing, and gathering activities. Reservation lands and ceded lands provide resources and habitats essential for community cohesion, including cultural, medicinal, and economic uses. The tribes have longstanding ties to these lands and cannot migrate as environmental conditions and faunal populations shift or change altogether. The potential effects of climate change were not included as factors when water and other treaty rights were established, and these agreements may need to be modified to ensure that access to key tribal resources is retained as the landscape changes.

Increasing climate variability and new temperature and precipitation trends directly affect agriculture and add to uncertainties about ensuring food security and identifying cost-effective practices for profitable agricultural production. Maintaining agricultural production with an increasingly variable climate requires maintaining consistent energy and water supplies and remaining flexible in adapting crop choices and crop management to future climate conditions. Table 2 provides a summary of the Northwest's regional climate risks, effects, adaptation, and information needed.

Table 2: Summary of Northwest Climate Risks, Effects, Adaptation, and Tools by Sector

Sector	Climate Risk	Effect	Adaptation	Information Needed
Milk Production	Increased heat stress	Decreased fertility	Genetic selection for more heat-tolerant livestock breeds	Breed information
		Increased infections	Provide heat abatement strategies for animals (e.g., shade structures)	Cost/benefit information, given climate projections
		Decreased growth	Adjust timing of livestock rotation to reduce erosion and exposure to solar radiant energy.	Seasonal temperature projections
		Decreased milk production	Conduct selective plant breeding	Seed availability information
	Decreased snowpack/ decreased summer rainfall	Decreased foliage productivity	Adjust foliage management	Seasonal forage condition projections
		Decreased soil moisture	Reduce soil erosion using accepted practices.	NRCS information
		Increased erosion	Work with municipalities to maintain consistent energy and water supplies	Water availability and demand projections, NRCS tools (such as RUSL2[4])
	Increased temperatures	Increased coverage of woody conifers	Irrigate pastures; reduce animals/acre	Seasonal heat and rainfall projections
		Decreased forage productivity	Adjust timing of livestock rotation	Seasonal forage condition projections
		Decreased nutritional value of forage	Adjust forage management	Forage nutritional information
Cattle and Calf Production	Decreased summer rainfall	Decreased nutritional value of forage	Adjust timing and spatial distribution of grazing	Seasonal rainfall projections
		Increased coverage of woody conifers	Shifts in grazing areas	
	Increased temperatures	Increased invasive weeds	Alternative livestock breeds	Information about breeds
		Increased coverage of woody conifers	Shifts in grazing areas	Monitor and manage invasive plants
Grains, oilseed, dried beans, dried peas	Changes in timing and amount of precipitation	Advanced growing degree days	Earlier applications of fertilizers, pest controls; earlier harvest, changed crops and rotations	Cost/benefit analysis of alternatives, given climate projections
		Decreased water availability for irrigated farming operations	Adjust timing of farm operations	
	Increased CO_2 concentrations	Decreased water demands	Alternative varieties and crop systems	
	Heat stress	Decreased grain filling	Alternative varieties	

[4] RUSLE2 refers to the Revised Universal Soil Loss Equation, Version 2

Sector	Climate Risk	Effect	Adaptation	Information Needed
		Increased water demands	Improve irrigation efficiency	
Fruits, tree nuts, and berries	Increased heat and drought stress	Advanced bud break	Alternative vine and tree varieties	Cost/benefit analysis of cropping systems, given climate projections and varieties available
		Increased water demands	Increased irrigation	
		Increased pests	Increased monitoring and reporting of local and regional outbreaks	
	Increased winter rainfall	Increased fungal pathogens, rain-cracking.[5]	Increased spraying especially grape, cherry and apple; alternative varieties	
	Decreased cold temperature and chilling	Decreased fruit production	Alternative vine and tree varieties	
		Delayed bud break		
	Decreased water availability for irrigation	Decreased fruit production		
	Increased CO_2 concentrations	Increased yields		
Vegetables, melons, potatoes and sweet potatoes	Decreased snowpack	Decreased availability of irrigation water	Adjust cropping systems	Cost/benefit analysis of cropping systems, given climate projections and varieties available
	Earlier rainfall	Increased water demand	Increased irrigation	Seasonal rainfall projections
	Increased temperature	Increased water demand	Increased irrigation	Seasonal temperature projections
	Shifting growing season	Decreased potato yield	Develop and use later-maturing varieties (delayed leaf senescence)	Information on potato varieties
	Increased CO_2	Increased potato yield		

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

Higher temperatures: Higher temperatures directly affect crop and livestock production, with secondary effects resulting from reduced snowpack, drier soils, increased erosion, and the migration and spread of pests and disease further north and to higher elevations. On average, the frost-free period is expected to lengthen, especially into the fall. The longer growing season may influence the selection of crops and varieties. Slower growth in beef cattle and lower milk production in dairy cattle are also associated with higher temperatures.

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[5] Sweet cherries crack because of rain near harvest causing major losses in the cherry industry. This disorder is characterized by a splitting of the outside layer of the cherry skin called the cuticle. The splitting most commonly appears around the stem bowl, where water can accumulate, but is also seen on other areas of the cherry cuticle (Jedlow & Schrader, 2005).

Decreased chilling hours: Some tree fruits require cold temperatures to produce the best yield and quality. Idaho's Payette County, the Willamette Valley in Oregon, and central Washington are major producers of tree fruits, whereas western Oregon and the Columbia River Basin are increasingly important grape-producing areas. Production of some fruit varieties and crops may shift northward or to higher altitudes, although often these specialty crops are dependent on irrigation systems, which could complicate spatial shifts.

Drought and floods: Warming in the Northwest is significantly reducing the amount of water held in the snowpack, so that on average streamflows increase during the winter and early spring but decrease in late spring through summer and early fall. Changing water availability patterns will require improved water management strategies—to respond to both water shortages as well as increased intensity of precipitation events. In addition to local flood control measures, adaptations to flooding will need to include management to increase soil organic content, as well as to reduce soil erosion, compaction, acidification, and salinization. Irrigation water will need to be managed for the longer growing season.

Grains, oilseeds, dried beans, and dried peas

The 2012 Agricultural Census (2014)lists 11,611 farm operations in the Northwest that generated $3.5 billion in sales for grains, oilseeds, dried beans, and dried peas. Climate change in the Northwest is expected to affect these crops via heat and drought stress, the need to adjust production management for changes in precipitation timing and amounts, reduced water availability for irrigation, and potential positive effects of increased CO_2 concentrations (Snover et al., 2013).

Heat stress affects wheat production by accelerating leaf senescence and reducing photosynthesis and subsequent grain filling (Ferris et al., 1998; Ortiz et al., 2008). While increasing temperatures in the short term may result in earlier crop maturity and increased dryland winter wheat yields, these same temperatures may eventually harm flowering and subsequent grain formation (Stockle et al., 2010). However, increased atmospheric CO_2 concentrations are also expected to result in greater fertilization and water-use efficiency. The combined effect of warming air temperatures and increased CO_2 concentration are expected to increase grain yields by 12 to 15 percent in the short term and from 23 to 35 percent by the end of this century (Stockle et al., 2010). Under some future climate scenarios, yield projections could be further enhanced by planting as much as two weeks earlier (Stockle et al., 2010).

Fruits, tree nuts, and berries

The 2012 Agricultural Census (2014) listed 9,854 farm operations in the Northwest that netted $3.4 billion in agricultural sales for fruits, nuts, and berries. Climate change in the Northwest is expected to affect these crops via increased heat and drought stress, changes in cold temperature-chilling requirements for fruit production, reduced water availability for irrigation, and potential positive effects of increased CO_2 concentrations (Snover et al., 2013).

General warming can interfere with fruit and berry production due to chilling effects on bud-break, flowering, and fruit production, and may support more rapid phenological development that will reduce the amount of time for fruit development (Duchene & Schneider, 2005; Snover et al., 2013; Stockle et al., 2010). Cool-climate wine grape varieties currently grown in the Northwest require significant chilling conditions to produce high-quality fruit and under future warming scenarios it may be necessary to shift production to warmer grape varieties (Diffenbaugh et al., 2011; Jones, 2007; Snover et al., 2013). Rising air temperatures may also alter typical weather conditions so significantly that the colder temperatures needed by current fruit and nut tree crops for winter chilling requirements no longer occur. As a result, producers may need to switch to alternative warm-climate crop varieties that are currently grown at lower latitutdes (Eigenbrode et al., 2013; Luedeling et al., 2011).

Increased CO_2 levels will have a fertilization effect on these crops if sufficient water is available (Stockle et al., 2010). When CO_2 effects are factored in, overall climate change projections for this class of crops predict an increase in wine grape yields of as much as 16 percent in the next century (Stockle et al., 2010). The introduction of new apple varieties adapted to a longer growing season could increase net regional yields in the next century as much as 19 percent, (Stockle et al., 2010). Fruit, nut, and berry production may require more irrigation to meet the increased water demands associated with warmer air temperatures (Snover et al., 2013).

For irrigated grape, cherry, and apple crops, increased winter precipitation associated with climate change may increase the risk from fungal pathogens, while higher temperatures may increase the risk from insect pests (Stockle et al., 2010).

Vegetables, melons, potatoes, and sweet potatoes

The 2012 Agricultural Census listed 6,407 farm and ranch operations in the Northwest yielding $2.5 billion in agricultural sales. Principal climate change effects on vegetables, melons, potatoes and sweet potatoes include reduced availability of irrigation water, and potential positive effects of increased CO_2 concentrations (Snover et al., 2013).

Annual cropping systems throughout the Northwest are dependent on irrigation to compensate for extremely low summer precipitation (Eigenbrode et al., 2013). Air temperature increases associated with climate change will also increase crop demand for water, which will necessitate increased levels of irrigation for successful production (Fischer et al., 2002). However, the amount of water stored in reservoirs and tapped for irrigation use will likely be reduced because of reduced snowpack and earlier spring snowmelt (Fritz et al., 2011; Mote, 2006; Nayak et al., 2010; Stewart et al., 2005).

Potato crops in this region are projected to exhibit significant yield declines due to the effects of warming temperatures, with as much as a 22 percent decline by 2080 (Rosenzweig et al., 1996; Stockle et al., 2010; Tubiello et al., 2002). This reduction is primarily due to a shortened growing season that will accelerate leaf senescence and increase plant stress levels, which will reduce tuber growth and tuber quality (Alva et al., 2002; Stockle et al., 2010; Timlin et al., 2006). In grain production systems, these effects can be mitigated with earlier planting, but this strategy will not work in potato production systems (Rosenzweig et al., 1996; Stockle et al., 2010).

Increased atmospheric CO_2 concentrations will have a positive effect on potato production that will help mitigate the effects of increased temperatures. But the most effective adaptation strategy may require development and utilization of later-maturing plant materials that delay leaf senescence until later in the growing season (Snover et al., 2013; Stockle et al., 2010).

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

Some of the most productive and diverse rangelands are found in Northwest shrub steppe areas and depend on rainfall for productivity and sustainability. These lands support a wide diversity of plants and animals and are used to support livestock grazing. Areas of bare ground throughout rangelands contribute to the relative fragility of these ecosystems, leaving them especially sensitive to local rainfall events, drought, extreme heat, and lack of snow pack. Rangeland restoration can improve the resilience of rangeland ecosystems under potential climate change scenarios.

Dairy Production

Oregon, Washington, and Idaho produce 11 percent of the Nation's milk. In 2012, Oregon, Washington, and Idaho had 1,424 dairy farms that generated $4,326,728, or 19.8 percent of total agricultural products sold (National Agricultural Statistics Service, 2014).

Dairy production in the Northwest is vulnerable to risks associated with climate change, including increased temperature. Heat stress in dairy animals can be attributed to high temperatures, high humidity, and radiant energy. Heat stress reduces milk production in dairy cows and also lowers successful reproduction rates, which in turn affects dairy production and results in U.S. dairy losses of $897 million annually (St-Pierre et al., 2003).

Even periods of heat stress as short as 3 hours can have long-term effects on fertility in male and female cattle, resulting in reduced reproductive performance. Heat stress can lower resistance to the onset of new infections such as mastitis. Higher temperatures are also associated with slower growth in calves and heifers, as well as lower milk production in lactating dairy cattle. Current breeding practices that favor dairy cattle traits such as increased milk production and larger animals have also resulted in lowering heat tolerance, which in turn increases livestock energy expenditures needed to offset the physical effects of heat stress. Heat abatement strategies, such as shade structures, fans, and ventilated barns are cost-effective strategies that producers in all three states can use to reduce heat stress in their herds.

Indirect or secondary effects of climate change may also reduce milk production. Dairy farms require water to grow grains and forages to feed and water cows and to wash and clean parlors and other facilities. Reduced snowpacks, drier soils, and increased erosion may reduce the availability of high-producing lands. Decreased summer rainfall and increased temperatures are predicted to increase the spread of woody conifers, as well as reduce forage productivity and nutritional value.

Adaptation to these changes may include:

- Genetic selection for more heat-tolerant breeds of livestock (e.g. smaller cattle with reduced feed and water requirements);
- Providing heat abatement strategies for animals (e.g. shade structures);
- Adjusting timing of livestock rotation to reduce erosion and exposure to solar radiant energy;
- Conducting selective plant breeding to produce varieties with increased tolerance to higher temperatures and drier conditions;
- Reducing soil erosion with accepted practices;
- Working with municipalities to maintain consistent energy and water supplies, including plans that account for reduced overall hydroelectric production from a changed climate.

Mitigation Opportunities:

The Northwest is a leader in adopting anaerobic digestion (AD) as a manure management technology on dairy farms. Anaerobic digesters process manure to produce biogas used to generate electricity. In addition to being a source of renewable energy, AD manure treatment prevents loss of methane, a potent greenhouse gas, to the atmosphere. Washington, Oregon, and Idaho host a total of 13 manure-based digesters. Two digesters in Oregon are currently producing 1.5-1.6MW of power, and other digester projects are in development (Sullivan, 2012).

Cattle and calf production

The 2012 Agricultural Census listed 29,215 farm and ranch operations in the Northwest that netted $3.7 billion in agricultural sales (National Agricultural Statistics Service, 2014) . Principal climate change effects on cattle and calf production in the Northwest include potential changes in forage quality, as well as changes in forage availability from the proliferation and expansion of invasive weeds (Polley et al., 2013; Snover et al., 2013).

Warming effects on rangeland productivity will vary across existing precipitation gradients within the Northwest (Eigenbrode et al., 2013). Warming temperatures will have a greater positive effect on plant biomass production where water is less limiting, but will exacerbate drought stress in areas of lower precipitation, particularly in the summer (Abatzoglou & Kolden, 2011). Rangeland species in this region principally regenerate from seed, and an increase in water stress during the summer will lower reproductive viability of native perennials (Svejcar et al., 2014). In the absence of physical barriers, warming micro-climatic conditions will result in net migration of rangeland plant communities to higher elevations (Chambers et al., 2014).

Studies in the short and tall-grass prairies of the Great Plains have shown increased productivity and decreased forage quality under increased temperature and atmospheric CO_2 concentrations (Morgan et al., 2004; Wan et al., 2005). Previous research on seasonal precipitation and temperature effects on perennial forage grasses in the Northwest indicate that warmer and wetter winter and spring periods will increase overall biomass production but reduce forage quality (Ganskopp & Bohnert, 2001). Increased growth rates and productivity from higher CO_2 concentrations would also be offset by soil nutrient limitations and a resulting reduction in forage quality (Izaurralde et al., 2011; Polley et al., 2013).

Invasive annual weeds expand their coverage and range in response to most types of disturbance, including climate change (Chambers et al., 2014; Chambers et al., 2007; Polley et al., 2013). Cheatgrass (*Bromus tectorum* L.) currently dominates millions of hectares of rangeland in the Intermountain west and is expected to continue range expansion under both current and potential future climate regimes (Abatzoglou & Kolden, 2011; Bradley, 2010; Chambers et al., 2007; D'Antonio & Vitousek, 1992; DiTomaso, 2001; Knapp, 1996). Cheatgrass is expected to shift its range northward as regional temperatures increase and summer precipitation decreases (Bradley, 2009; Bradley et al., 2009). Elevated CO_2 will exacerbate this effect, as cheatgrass and other important rangeland weeds in this region are C3 species (Dukes et al., 2011; Polley et al., 2013; Smith et al., 2000; Ziska et al., 2005).

Cheatgrass grows primarily in the spring when water is available and senesces in late spring when water becomes limiting (Rice et al., 1992). Sagebrush species in the shrub-steppe of Idaho and eastern Oregon start growth in mid to late spring and continue growing through the summer if water is available. Anticipated climate change will have a relatively higher effect on these shrubs, since they are more dependent on summer precipitation (Loik, 2007; Rice et al., 1992). The growth and expansion of cheatgrass will be magnified by feedbacks between cheatgrass coverage and fire frequency, as well as direct effects of climate change on the length and severity of the wildfire season (Abatzoglou & Kolden, 2011; Miller et al., 2011). Elevated levels of CO_2 may support increased cheatgrass growth and lower its nutritional value as a forage (Ziska et al., 2005). Livestock that prefer to graze on more nutritious forage will increase the likelihood that cheatgrass will be available to help fuel rangeland wildfires, which will increase fire risks associated with climate change.

One way to mitigate the effects of climate change is by altering grazing management to increase carbon sequestration, but using this approach on arid and semi-arid rangelands is currently not cost-effective. (Joyce et al., 2013; Svejcar et al., 2008). Adapting to climate change may require adjusting grazing management schedules and locations, introducing livestock breeds that are more adapted to warmer temperatures, and probably shifting grazing land distributions as plant communities migrate and adjust to new climatic regimes (Joyce et al., 2013).

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

In Oregon, forestry directly employs 76,000 employees and generates $5.2 billion in total income (Oregon Forest Resources Institute, 2015). In Washington, the forest industry provides over 100,000 jobs and $4.5 billion in income (Washington Forest Protection Association, 2015), while in Idaho, it generates $4.2 billion dollars annually and employs over 20,000 people (Idaho Forest Production Commission, 2015). In addition to timber and other forest products, forests provide wildlife habitat, clean air and water, and recreation opportunities, so indirect contributions to the economy are also substantial.

Some of the most significant risks to forests in the Northwest, including family-owned forests and woodlands, include drought, increased wildfire events, increased insect infestations, extreme weather events, and potential species shifts.

Drought: Weather variability raises the probability of severe drought, high winds, ice storms, and landslides in any single year, as well as a decreased snowpack in the mountains.

Wildfire: The predicted changes in temperature and rainfall patterns and extremes will continue to increase the forest area burned each year, which in turn will increase soil erosion, flooding, and weed invasion.

Insect infestations: The survival and spread of forest pests and diseases will also be favored, exacerbating tree mortality in cycles of fire, pests, and invasive vegetation.

Species shift: Some models predict a shift in species and habitat types in response to environmental changes, especially in areas with a projected decreases in annual precipitation and increased temperatures, such as subalpine and alpine forests.

Family forests and woodlands

Family forest landowners control over 60 percent of the private forest land in the United States (Butler, 2008). In the Northwest, family-owned forests make up more than 6,900,000 acres; it is estimated that more than 200,000 families each own between 5 and 10,000 acres in Oregon, Washington, Idaho and Alaska (U.S. Forest Service, 2006).

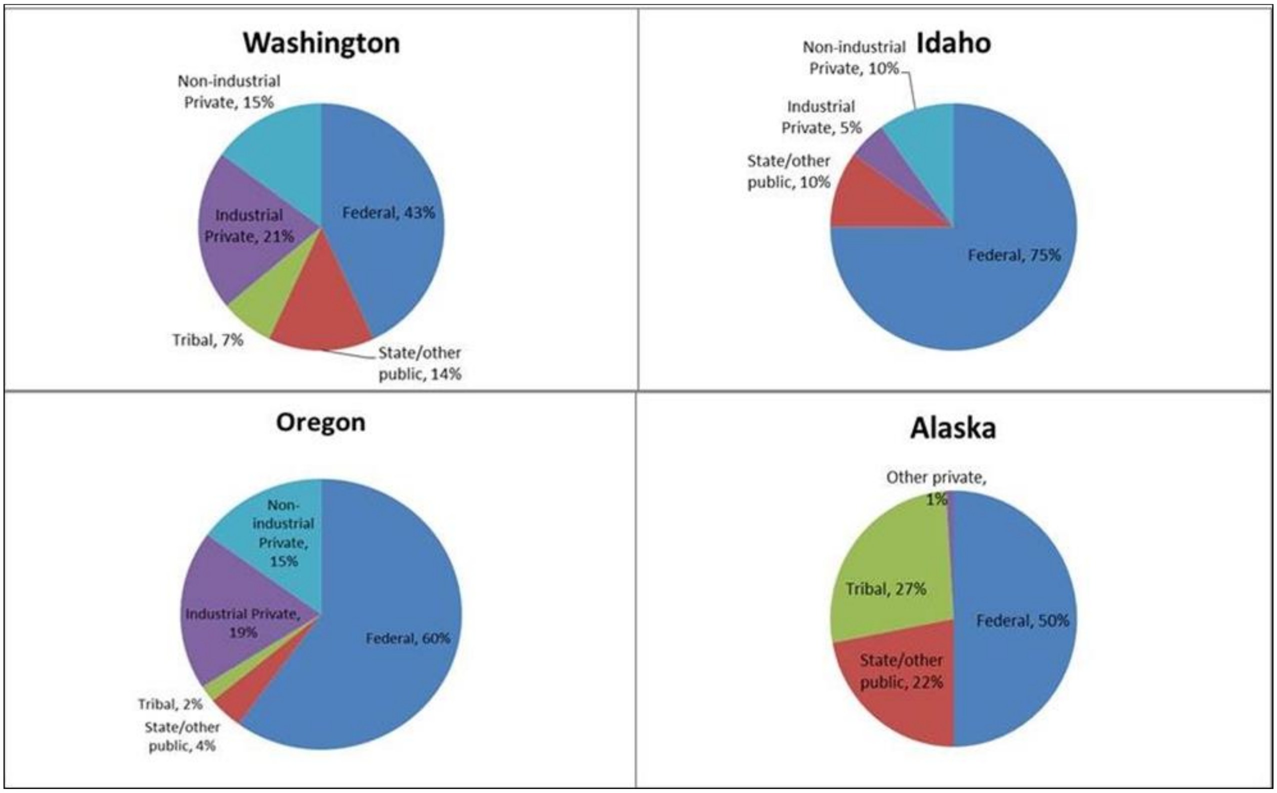


Figure 4: Forest Ownership in the Northwest Region
Source: Washington Forest Protection Association; Idaho Forest Production Commission; Alaska Resource Development Council; (Oregon Forest Resources Institute, 2015).

Table 3: Major Forest Types in the Northwest

Alaska	Washington	Oregon	Idaho
▪ Coastal Sitka spruce, western hemlock	▪ Spruce, western hemlock	▪ Spruce, western hemlock	▪ Dry Limber Pine
▪ Interior spruce, hardwood (south of Alaska range)	▪ Douglas fir	▪ Douglas fir, Douglas fir-mixed	▪ Ponderosa Pine
▪ Interior spruce, hardwood (west of Alaska range)	▪ True fir, spruce, mountain hemlock	▪ True fir, mountain hemlock	▪ Douglas fir-Dry
	▪ Ponderosa Pine	▪ Ponderosa Pine	▪ Douglas fir - Moist
	▪ Lodgepole Pine	▪ Northeast Oregon mixed conifer	▪ Grand fir
	▪ Western Larch	▪ Western Oregon mixed conifer	▪ Lodgepole Pine
			▪ True fir, spruce

Source: (Alaska Resource Development Council, 2015; Idaho Forest Production Commission, 2015; Oregon Forest Resources Institute, 2015; Washington Forest Protection Association, 2015)

Vulnerabilities of Northwest Forests

Vulnerabilities by forest type are provided below. Different forest types are vulnerable to climate change in different ways, so, adaptation strategies will vary by region and forest type. Vulnerabilities will be more severe in 2100 than in 2050.

- ***Coastal forests (spruce, western hemlock)***
  Maritime climate is becoming more like a temperature forest. Douglas-fir may become more dominant but will also be at higher risk for diseases such as Swiss needle cast and Armillaria root rot.
- ***Lowland forests (Douglas-fir, Douglas-fir-mixed)***
  Forests will experience more severe and possibly longer periods of water limitation during the growing season, primarily due to reduced snowpack and lower soil moisture levels. Consequences include reduced seedling regeneration and tree growth and increased mortality from insects and more frequent fires. With warming temperatures, insect population cycles may be altered and result in greater survival and expansion into higher elevations. The number of Douglas-fir trees is expected to decline in the drier parts of its range.
- ***Sub-alpine/Mountain forests (true fir, mountain hemlock, grand fir, western larch)***
  Evidence suggests higher elevation forests may experience increased tree growth, especially for species that are energy-limited as opposed to water-limited. However, the extent of subalpine forests is expected to decline with increasing temperatures and may become more suseptible to damage from of insects, disease and fire.
- ***Eastside forests (ponderosa pine, lodgepole pine, Juniper)***
  In fire-adapted ecosystems, forests may experience more indirect effects of climate change from changes in the disruptive agents. For example, more intense fires may occur more frequently as drought conditions persist. Forests are expected to become less resistant to insect outbreaks such as mountain pine beetle and diseases. Fuel treatments, such as thinning and prescribed fire, will cause a small overall reduction in carbon storage over long time scales and large landscapes, but allows one to control carbon release in pulses (Restaino & Peterson, 2013).

Additional considerations

- Suitable climate for many ecologically and economically important tree species in the Northwest may change considerably by the end of the 21st century, and some vegetation types, such as subalpine forests, may become very limited in their ranges.
- Changes in forest structure and composition will be driven primarily by disturbances.
- Climate change may affect the productivity of northwest forests.
- Forests will likely become increasingly water-limited; droughts will occur over larger areas and become more severe.
- Drier, warmer conditions are likely to increase the area burned annually by forest fires.
- The frequency and location of insect outbreaks are likely to change as forests become more susceptible due to climatic stressors (e.g., drought), and as climate conditions that favor outbreaks shift.
- Climate change will probably affect forest disease outbreaks, but generalizations are difficult to make because climatic influences will probably be species- and host-specific.
- Climate change may increase disturbances such as fire, which may alter carbon levels stored in soils and vegetation and reduce the ability of forest ecosystems to sequester carbon.

3.1 Adapting Forest Management to Climate Change

A recent study of family forest owners in Washington, Oregon, Idaho, and Alaska found that although study participants had varying degrees of skepticism, beliefs, and concerns regarding climate change, most were interested in learning about potential climate change effects to their forests (Grotta et al., 2013). The study results indicate that transparency, local context, uncertainty, risk analysis, and forest management and policy implications are key considerations for developing extension outreach to address climate change.

- *Transparency*: Extension and research can support transparency by understanding family forest owners' concerns and attitudes regarding climate science. Possible approaches to improving transparency include clarifying how grant funding affects research focus and results, and clearly outlining peer review processes and other research quality controls, and developing meaningful stakeholder participation.
- *Local frame of reference*: Rural residents' views of global environmental issues are often framed by local conditions (Hamilton et al., 2012). Many show that information sources that reflect an individual's cultural context or sense of place are influential in shaping perceptions studies (Gootee et al., 2010; Grotta et al., 2013; Kahan et al., 2007).
- *Understanding modelling and uncertainty*: Modeling is a key tool for understanding climate change projections, yet skepticism towards models is common across the general public and in the media (Akerlof et al., 2012). Extension can help landowners use models as decision making tools. Programming to increase understanding of how models are developed and used (e.g., predictions vs. projections), how model quality is evaluated, and sources of model uncertainties can help landowners navigate climate science. Discussing model projections many people use every day (e.g., weather and economic forecasts), and models that have long been used within forestry (e.g., forest growth and yield models) may be helpful. Given their interest in local information on temperature, precipitation, and potential effects, landowners need to understand the risk of applying larger scale model projections to finer local scales. An understanding of model outputs and their associated uncertainties is important in analyzing the risks and benefits of adaptation strategies.
- *Mitigation*: Many participants wanted to learn about potential markets associated with climate mitigation tools, such as carbon markets or biofuels. At the time of our study, cap and trade was being debated nationally, which may explain the extent to which participants discussed carbon markets. Currently, few U.S. family forest owners are participating in carbon markets (Wade & Moseley, 2011) or showing interest in doing so (Thompson & Hansen, 2012). If cap and trade re-emerges, programming on the details of carbon markets may be of interest to forest landowners. Additionally, some forest owners are interested in learning more about carbon sequestration practices, regardless of whether they receive payments for carbon offsets.

Adaptation strategies

- *Monitoring***:** Most climate change effects will manifest themselves as forest health problems such as stress and the inability to successfully fend off insects and pathogens. Keeping an eye on forest conditions is important, especially for signs of insect and disease outbreaks, increased populations of invasive species, weak and dying trees, reduced growth, and crown dieback.
- *Increase resilience*[6]: Thinning stands of trees to promote growth and the release of suppressed trees will support the development of more resilient forests over time. A diversity of tree genotypes, species, and ages will add to forest resilience, as some trees will respond differently to changing conditions. Specific management activities could include thinning overstocked stands and building seed banks.
- *Assisted species migration***:** Although still a topic of debate, planting new native or near-native species is another approach to adaptation. Considerations include finding species that are adapted to current conditions, finding varieties with desirable initial survival rates, and types that are able to adapt to changing conditions or predicted future conditions.

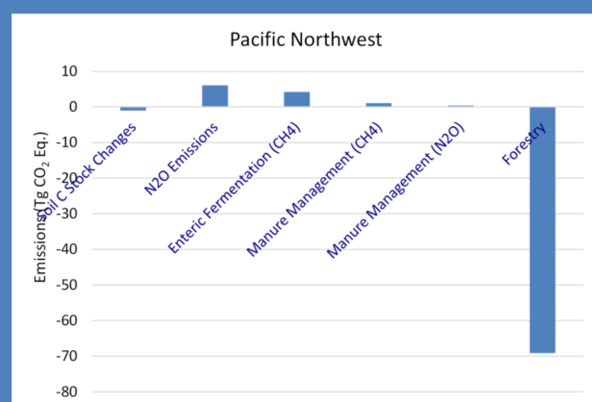
[6] The U.S. Forest Service defines resilience as, "the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change" (U.S. Forest Service, 2011).

4 Greenhouse Gas (GHG) Emissions Profile from Agriculture and Forests within the Northwest Region and Mitigation Opportunities

Agriculture in the Northwest region, including crop, animal, and forestry production, results in net greenhouse gas (GHG) emissions of approximately -58 teragrams[7] carbon dioxide equivalent (Tg CO_2 eq.), which represents a net storage of GHG emissions (U.S. Department of Agriculture, 2011). In the region, crop-related nitrous oxide (N_2O) emissions are the largest contributor to GHGs at about 6 Tg CO_2 eq., followed by methane (CH_4) from enteric fermentation (4 Tg CO_2 eq.), CH_4 and N_2O from manure management (1 Tg CO_2 eq.), and rice cultivation (1 Tg CO_2 eq.). Forestry is the largest contributor to net carbon storage at -69 Tg CO_2 eq., followed by soil carbon stock changes at -1 Tg CO_2 eq.[8]

Northwest Region Highlights

- Wheat, beef cattle, and poultry are the primary agricultural commodities produced in the Northwest.
- The largest source of GHG emissions in the region is N_2O from croplands.
- Increases in carbon storage in 2008 offset GHG emissions, resulting in GHG net storage.
- The greatest mitigation potential is available from adopting land retirement management practices.
- Incorporating long-term reduced and no-till management practices provides a good opportunity for additional regional carbon sequestration.



4.1 Soil Carbon Stock Changes

In both agricultural and forested soils, land use and management changes resulted in net carbon sequestration of 1.0 Tg CO_2 eq. in 2008. Specifically, cropland production changes on mineral soils resulted in net positive emissions of 0.5 Tg CO_2 eq., while changes in hay production sequestered 0.7 Tg CO_2 eq. and land removed from agriculture and enrolled in the Conservation Reserve Program sequestered 0.9 Tg CO_2 eq. In contrast, agricultural production on organic soils, which have a much higher organic carbon content than mineral soils, resulted in net positive emissions of 0.1 Tg CO_2 eq.

Tillage practices contribute to soil carbon stock changes. Table 5 provides the tillage practices for different crops in the Northwest Hub. Management practices that utilize reduced till or no till can contribute to increased carbon storage over time, depending on site specific conditions.

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[7] A teragram (Tg) is 10^{12} grams, which is equivalent to 10^9 kilograms and 1 million metric tons.
[8] 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 4: Northwest 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]	0.49
Net Change, Hay	-0.69
CRP	-0.94
Agricultural Land on Organic Soils	0.14
Total[b]	**-1.00**

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 5: Tillage Practices in the Northwest 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	242,288	N/A	N/A	N/A	N/A
Wheat	2,026,071	10.2%	26.6%	35.5%	27.7%
Total	2,268,959	-	-	-	-

[a] Source: USDA (2011)
[b] Source: USDA ERS (2011)
N/A: Not available

4.2 Nitrous Oxide (N_2O) Emissions

In 2008, N_2O emissions in the Northwest Region were 6.0 Tg CO_2 eq. Of these emissions, approximately 3.3 Tg CO_2 eq. were emitted from croplands and 2.7 Tg CO_2 eq. were emitted from grasslands.[9] The majority of crop-related N_2O emissions in the region are from the minor crops.

As indicated in Table 6, the majority of N_2O direct emissions are from corn crops. The rate of both direct and indirect N_2O emissions resulting from the use of nitrogen-based fertilizers is affected by how much fertilizer is used to amend the soils and the time of year that soils are amended.[10] Table 7 indicates the percentage of national acres that did not meet fertilizer application rate or application schedule criteria as defined by Ribaudo et al. (2011). These criteria are defined by best management practices for application rates and times. The best practice rate for both commercial fertilizer and manure is defined as applying no more than 40 percent of nitrogen that was removed with the crop at harvest (determined by the stated yield goal), including any carryover from the previous crop. The best practice for schedule application criterion is defined as not amending soils with nitrogen in the fall for a crop planted in the following spring (Ribaudo et al., 2011). Acreages that do not meet the criteria represent opportunities for GHG mitigation.

[9] Including both direct and indirect emissions; Table 6 includes only *direct* emissions from crops.
[10] Direct N_2O emissions are emitted directly from agricultural fields and indirect N_2O emissions are emissions associated with N losses from volatilization of N as ammonia (NH_3), nitrogen oxides (NOx), and leaching and runoff.

Table 6: Direct Nitrous Oxide (N_2O) Emissions by Crop Type

Crop Type	Direct N_2O Emissions (Tg CO_2 eq.)	Percent of Region's Cropland N_2O Emissions
Hay	0.51	20.2%
Corn	0.38	14.9%
Wheat	0.37	14.7%
Barley	0.03	1.1%
Non-Major Crops	1.24	49.1%
Total	**2.53**	**100.0%**

Source: (U.S. Department of Agriculture, 2011)

Table 7: National Percent of Acres Not Meeting Rate and Timing Criteria (Percent of Acres)

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

Source: (Ribaudo et al., 2011)

4.3 Livestock GHG Profile

Livestock systems in the Northwest focus primarily on the production of swine, beef and dairy cattle, sheep, poultry, goats, and horses. There were over 42 million head of poultry in the region in 2008. Cattle (beef and dairy) have a population of over 2.5 million head in the Northwest (U.S. Department of Agriculture, 2011). Nearly 79 percent of the cattle in the region are beef cattle. As with patterns in livestock production across the country, the primary source of GHGs from livestock is from enteric fermentation, which is the digestive process that produce methane (referred to as enteric CH_4). In 2008, Northwest livestock produced about 4.2 Tg CO_2 eq. of enteric CH_4.[11] Most of the remaining livestock-related GHG emissions are from manure management practices, which produce both CH_4 and N_2O.[12] In 2008, CH_4 and N_2O emissions from manure management in the Northwest resulted in about 1.4 Tg CO_2 eq., with the majority attributed to CH_4 (U.S. Department of Agriculture, 2011).

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.

Because of their greater body weight and increased energy requirements for extended periods of lactation, the per-head emissions of enteric CH_4 for dairy cattle are 40 to 50 percent greater than for beef cattle; dairy cattle average 2.2 metric tons CO_2 eq. /head/year, while beef cattle average 1.6 metric tons for beef in 2008 (U.S. Environmental Protection Agency, 2014). However, in the Northwest region, 79 percent of all cattle are beef cattle, so their overall contribution to enteric CH_4 emissions is much higher than for dairy cattle (U.S. Department of Agriculture, 2011). Table 8 provides CH_4 emissions by animal types for 2008. As indicated, the majority of emissions are from beef and dairy cattle.

Table 8: Emissions from Enteric Fermentation in the Northwest, in Tg of CO_2 eq. and as a Percent of Regional Emissions

Animal Category	Tg CO_2 eq.	Percent of Region's CH_4 Enteric Emissions
Beef Cattle[a]	2.84	67.6%
Dairy Cattle[a]	1.33	31.7%
Goats[b]	0.00	0.0%
Horses[b]	0.01	0.3%
Sheep[b]	0.01	0.2%
Swine[b]	0.00	0.0%
Total	4.19	100.0%

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

[11] The enteric CH_4 emissions total for the region includes cattle and other animals.
[12] Livestock respiration also produces carbon dioxide (CO_2), but the impacts of ingesting carbon-based plants and expelling CO_2 result in zero-net emissions.

Emissions from Manure Management Systems

Manure management in the Northwest resulted in 1.0 Tg CO_2 eq. of CH_4 and 0.4 Tg CO_2 eq. of N_2O in 2008. Table 9 provides a summary of CH_4 and N_2O emissions by animal category. Dairy waste accounts for the majority of manure emissions, contributing 84 percent of CH_4 and 58 percent of N_2O.

Table 9: 2008 Emissions from Manure Management in the Northwest, in Tg of CO_2 eq. and as a Percent of Regional Emissions

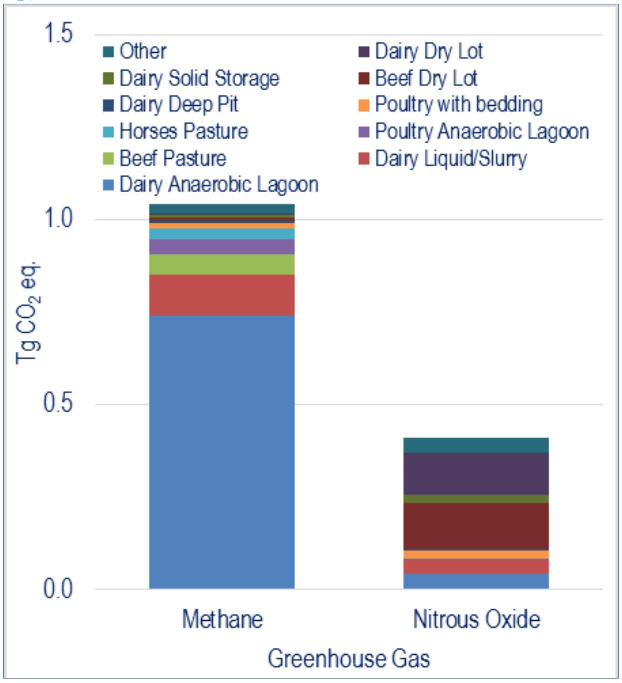
Livestock	Population	Methane Tg CO_2 eq.	Methane Percent	Nitrous Oxide Tg CO_2 eq.	Nitrous Oxide Percent
Beef Cattle	1,993,661	0.06	6%	0.13	33%
Dairy Cattle	528,262	0.88	84%	0.22	58%
Goats[a]	54,122	0.00	0%	-	-
Horses[a]	443,934	0.03	3%	-	-
Sheep[a]	283,091	0.00	0%	-	-
Swine	45,900	0.01	1%	0.00	0%
Poultry	42,609,720	0.06	5%	0.03	9%
Total	45,958,690	1.04	100%	0.38	100%

Source: USDA(2011)
[a] N_2O emissions are minimal and not included in this total.

Livestock numbers vary from farm to farm, depending on the size of the farm and its livestock production practices, and 25 percent of dairy cattle are on operations with more than 2,500 head. Mitigation technologies such as anaerobic digesters[13] are more economically feasible on large farm operations due to economies of scale. Conversely, 75 percent of swine exist on operations with fewer than 1,000 animals, and there are fewer lower-cost mitigation options for these small operations. Figure 4 provides a summary of CH_4 and N_2O emissions by animal category and baseline manure management practices.[14] The largest sources of CH_4 are anaerobic lagoons, deep pits, and liquid/slurry systems, which are primarily used for 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, while dairy and swine waste is managed using a variety of systems, including anaerobic lagoons, deep pits, dry lots, liquid/slurry systems, and anaerobic digesters.

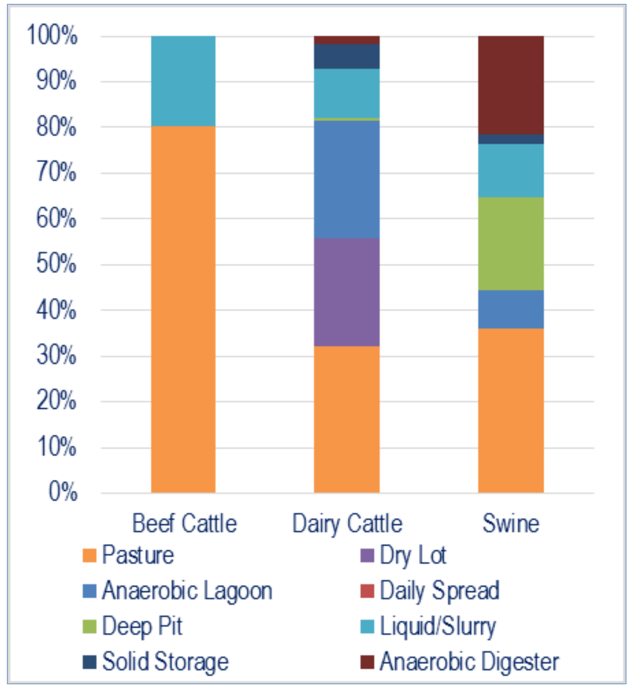
[13] Anaerobic digesters are lagoons and tanks that maintain anaerobic conditions and can produce and capture methane-containing biogas. This biogas can be used for electricity and/or heat, or can be flared. In general, anaerobic digesters are categorized into three types: covered lagoon, complete mix,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



Source: EPA (2010)

4.4 Forest Carbon Stocks and Stock Changes

In the annual GHG inventory reported by the USDA, forests and harvested wood products from forests sequester 69 Tg CO_2 eq. per year in the Northwest. In addition, 67,778,000 acres of forest land in the Northwest sequester 26,428 Tg CO_2 eq. in forest carbon stocks.[15]

Managed forest systems in the Northwest focus primarily on the production of softwood timber, as well as serving as reserved forest land. Forestry activities represent significant opportunities to manage GHGs. Forest managers in the Northwest use a wide variety of silvicultural techniques to achieve management objectives, most of which will affect carbon cycles in these systems. Silvicultural practices on forest carbon enhance forest growth that increases carbon sequestration rates, while forest harvesting practices transfer carbon from standing trees into harvested wood products and residues that 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 Northwest, depending on forest type, ownership objectives, and forest stand conditions. However, silvicultural prescriptions are often used for common forest types in the Northwest. For example, the USDA's *Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory*

[15] 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 (U.S. Department of Agriculture, 2014).

Technical Bulletin (2014) provides this information for two regions in the Northwest: the Northwest, West and Northwest, East regions (see Table 6-6 on page 6-59).

The USDA's *Forest Service 2010 Resources Planning Act Assessment* General Technical Report (2012) describes future projections of forest carbon stocks in the United States resulting from various vulnerabilities (e.g., less-than-normal precipitation or above-normal temperature) and other stressors (e.g., urbanization, other land development, or demand for forest fuel and fiber). The Resources 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 such as the Pacific Coast—including the Northwest--the rate of urban growth is high, Hemlock-Sitka spruce area is projected to decline, and Douglas-fir forest area is projected to increase.

Table 10: Northwest Forest Carbon Stock and Stock Changes

Source	Units	Northwest
Net Area Change	1000 ha yr^{-1}	31
Non-Soil Stocks	Tg CO_2 eq.	18,034
SOC	Tg CO_2 eq.	8,394
Non-Soil Change	Tg CO_2 eq. yr^{-1}	-57[a]
Harvested Wood Products Change	Tg CO_2 eq. yr^{-1}	-12[a]
Forest Carbon Stock Summary		
Non-Soil Stocks + SOC	Tg CO_2 eq.	26,428
Forest Carbon Stock Change Summary		
Forest Carbon Stock Change	Tg CO_2 eq. yr^{-1}	-69

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

4.5 Mitigation Opportunities

Figure 6 presents the mitigation potential for the Northwest Region by sector. Each bar represents the GHG potential below a break-even price of $100/metric ton CO_2 eq.[16] 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 required learning curves) 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.[17] The left two bars represent reductions from management practices changes that mitigate GHGs. The right three bars represent increased C storage from management practices changes. A total of 0.7 Tg CO_2 eq. can be mitigated at a break-even price below $100/metric tons CO_2 eq. Land management practice changes can increase carbon storage by 1.4 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 carbon storage below different break-even prices indicated in the legend. For example, changes in manure management practices have the potential to contribute to 0.5 Tg CO_2 eq. of mitigated emissions for less than $20/metric ton CO_2 eq. (i.e., light blue and light green bar).

[16] 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.
[17] See ICF International (2013) for additional details.

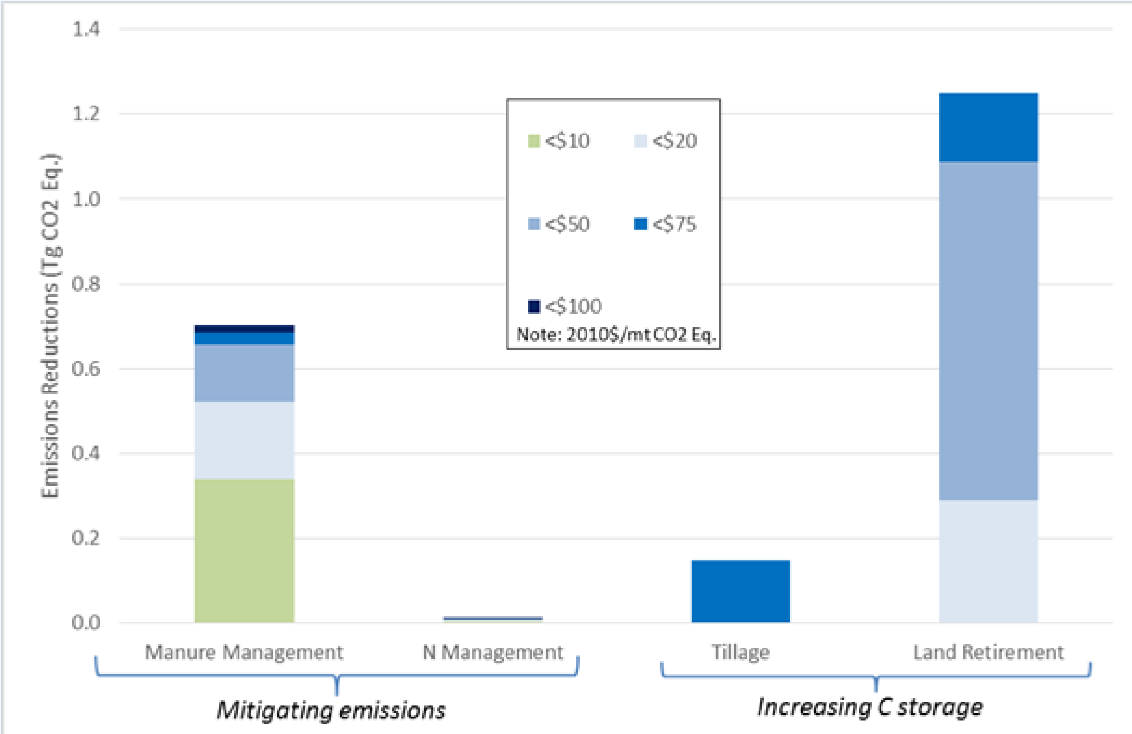


Figure 6: Mitigation Potential in the Northwest, by Sector

- Most of the opportunity for reducing net GHGs emissions is from changes in land retirement practices (i.e., retiring organic and marginal soils).
- The highest reductions in emissions from manure management are realized from installing improved separators at large dairy farms and complete mix and covered lagoon digesters with electricity generation at large swine and dairy farms.[18]
- Long-term reduced tillage intensity has the potential to increase carbon storage in the Northwest.

4.5.1 Agricultural Soils

For farms over 250 acres, variable rate technology is a relatively low cost option for reducing N_2O emissions from fertilizer application.[19] 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, or else the gains will be reversed. Other options include growing more perennial crops, thus avoiding tillage; including more fallow periods; including growth of high-biomass cover crops; and conversion of marginal agricultural lands to native ecosystems.

[18] 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).
[19] 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 Northwest is 0.7 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 from anaerobic lagoons to improved solids separators, covered anaerobic lagoons, acovered lagoon digesters, or complete mix digesters. For large swine operations, the greatest and most cost-effective mitigation measures are transitioning from anaerobic lagoons to complete mix digesters, covered lagoon digesters, or covering an existing lagoon.

Enteric Fermentation

Emissions from enteric fermentation are highly variable and depend on livestock type, life stage, activity, and feeding situation (e.g., grazing, feedlot). Several practices have demonstrated their potential efficacy for reducing enteric fermentation emissions. Although diet modifications (e.g., increasing fat content, providing higher quality forage, increasing protein content) and providing supplements (e.g., monensin or bovine somatotropin [bST]) have been evaluated for mitigation potential, their effectiveness has not been conclusively demonstrated.

5 USDA Programs

The recently published USDA Climate Change Adaptation Plan[20] presents strategies and actions for addressing 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 the Natural Resources 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 and will continue to play vital roles in sustaining working lands in a variable climate and are key partner agencies with the USDA Climate Hubs. The Northwest 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 Resources Conservation Service

The Natural Resources Conservation Service (NRCS) is the principal Federal agency that provides technical and financial assistance for conservation practices on private agricultural and forest lands. As such, NRCS has a primary role in the delivery end of the Hub network. NRCS, along with other the USDA Service Center agencies and the Cooperative Extension System, will connect farmers, ranchers, Conservation Districts, and other public sectors to advance climate change research and applications. USDA has 41 service centers in Washington, 89 in Oregon, 39 in Idaho, and 10 in Alaska.

NRCS is already addressing potential effects of climate change in the Northwest through ongoing conservation programs and technical assistance activities that take steps to conserve and improve natural resources and to assist farmers and ranchers as stewards of the land. Much of this assistance mitigates

[20] 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

climate change via reduced greenhouse gas emissions or increased carbon sequestration and builds greater resiliency to variability in climate and weather. The Soil Health Initiative includes education and training sessions for producers on methods for improving the condition and resiliency of working lands and soils. NRCS will continue to enhance delivery of conservation programs and assistance in the Northwest using advances in information and tools available through the Hub network.

In Alaska, permafrost loss is a critical NRCS issue because of concerns about associated structural changes that affect the landscape, infrastructure, biota, hydrology, and stored soil carbon. Throughout the Northwest, changes in temperature and precipitation are affecting snowpack at higher elevations and the delivery of water supplies for agricultural needs, power generation, municipal water storage, aquatic habitat, and recreation. Changing temperatures and precipitation distribution also affects agricultural land use by affecting soil moisture, growing seasons, crop type, and potential increases in erosion. Increases in temperatures and changes in the timing of water delivery from snowmelt can result in increased use of groundwater. This, in turn, lowers groundwater levels in aquifers and increases the demand for power needed to pump water for irrigation.

A NRCS regional priority is sharing information with agricultural producers and encouraging them to include climate change factors in their management decisions. Many NRCS programs specifically focus on conservation practices that could help offset effects of climate change, including programs such as CRP, no-till approaches to land management, using technology such as soil moisture monitoring to optimize water use, improvements to riparian systems, and rapid carbon assessments. NRCS can effectively address risks by helping agricultural producers in the Northwest develop land management strategies that anticipate extreme events such as floods and droughts, as well as changing trends in annual temperature and streamflow.

In addition to communicating information to land managers, NRCS continues to focus on best management practices for agriculture. Key elements of implementing programs that address climate change include taking the approach of reducing risk; improving soil and water quality; reducing costs; and increasing productivity and efficiency through better land management. Producers understand risk and how weather and climate affect their operations. They can benefit by having access to information, tools, and programs that help them adapt to and manage changing climate conditions, improve the land, and help make production systems more resilient to changes in climate and extreme events. NRCS personnel can effectively work one-on-one with producers to transfer information and implement programs, and will prioritize efforts to provide field personnel with current climate change information, tools and approaches.

NRCS's mission is to help landowners by providing assistance in improving land and soil conditions, reducing erosion, increasing soil health, improving water quality and water supplies, and offering efficient agricultural practices that reduce costs and increase natural resource conservation. Given this mission, many NRCS programs and activities are already responsive to the needs related to a changing climate and to helping people manage these challenges through adaptation and mitigation. Utilizing the large number of field offices throughout the Northwest and working with individuals, cooperatives, extension services, and other groups allows NRCS to deliver information and programs directly to the people working the lands. These activities help address, reduce, and manage the risks and vulnerabilities related to climate change. Some of the key regional initiatives that NRCS is implementing follow.

Drought Assessment: Snow Survey and Water Supply Forecasting Program and the Soil Climate Analysis Network

NRCS manages is the Snow Survey and Water Supply Forecasting Program[21], which collects high-elevation snow data in the western United States and provides managers and users with snowpack information, water supply forecasts, and other climatic data. NRCS field staff and cooperators collect and analyze data on snow depth, snow water equivalent, and other climate parameters at nearly 2,000 remote, high-elevation data collection sites. These data are used to provide estimates of annual water availability, spring snowmelt runoff, and summer streamflows. Climate change researchers are increasingly accessing the data to evaluate climate trends in the western United States. Water supply forecasts are used by individual farmers and ranchers; water resource managers; Federal, State, and local government agencies; municipal and industrial water providers; hydroelectric power generation utilities; irrigation districts; fish and wildlife management agencies; reservoir project managers; recreationists; tribal Nations; and Canada and Mexico.

The program provides water and climate information and technology support for natural resource management in 13 states: Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, South Dakota, Utah, Washington, and Wyoming. In the four states covered by the Northwest Hub, there are 309 SNOTEL (snow telemetry) and SnowLite (aerial markers with telemetry) stations and 487 manual snow courses. The National Water and Climate Center, located in Portland, Oregon, provides water supply forecasts and leadership and technology support to the states.

Snowmelt provides a majority of the water supply in the West, so the information provided by the program is critical for water managers. The demographic, physical, and political landscape of the western United States is changing rapidly, and there is increasing competition for water supplies from irrigation, municipal and industrial customers, and in-stream uses, such as river-based recreation, esthetic enjoyment, fish and wildlife habitat, and hydroelectric power generation. Increasing water demands require accurate data collection and dissemination about current conditions and trends in order to optimize management decisions for valuable water resources.

Soil moisture information is invaluable for National, State, and local government agencies concerned with weather and climate, runoff potential, flood control, soil erosion, reservoir management, and water quality. Soil moisture is an integral variable in the exchange of water and heat energy between the land surface and the atmosphere through evaporation and plant transpiration. As a result, soil moisture plays an important role in the development of weather patterns and precipitation events. Weather prediction models have shown that improving the characterization of surface soil moisture, vegetation, and temperature can lead to significant forecast improvements. Soil moisture also strongly affects the amount of precipitation that runs off into nearby streams and rivers.

The NRCS Soil Climate Analysis Network (SCAN)[22] consists of 211 stations across the United States, including 20 in the Northwest Hub region. SCAN plays a critical role in assessing the effects of climate and drought on agriculture by providing real-time soil moisture, soil temperature and other atmospheric information necessary to:

- support county, State, regional and National drought risk assessments;
- assist in agriculture production assessments and crop management;
- provide improved water supply forecasts for water managers;
- detect and manage the effects of climate extremes, and;
- support global climate change research.

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[21] http://www.wcc.nrcs.usda.gov/partnerships/links_wsfs.html
[22] http://www.wcc.nrcs.usda.gov/scan/

In addition to the present SCAN network, over 430 SNOTEL stations in the western United States, including 107 in the Northwest, have soil moisture/soil temperature sensors, and contribute to the data used in SCAN.

Ecological Site Information

The Ecological Site Information System (ESIS)[23] is the repository for forestland and rangeland plot data and for the development of ecological site descriptions. ESIS is organized into two applications and associated databases: Ecological Site Descriptions (ESD) and Ecological Site Inventory (ESI). The ESD application provides the capability to produce automated ecological site descriptions from the data stored in its database. ESD is the official repository for all data associated with forestland and rangeland ecological site descriptions by NRCS. The ESI application provides the capability to enter, edit, and retrieve rangeland, forestry, and agroforestry plot data. ESI is the official repository for all plot data collected via the Soil-Woodland Correlation Field Data Sheet (ECS-005), the Windbreak-Soil-Species Evaluation Data Sheet (ECS-004), and the Production and Composition Record for Native Grazing Lands (RANGE-417). The collection of plot data is an important activity conducted by NRCS. The data are used to develop inventories for planning, monitor ecological change, provide data for management decisions, develop ecological site descriptions, obtain data for hydrologic models, study treatment effects, and for many other purposes.

Carbon Management Evaluation Tool (COMET)

An online tool called COMET-FARM[24] enables agricultural producers to calculate how much carbon their conservation actions can remove from the atmosphere. A collaboration between NRCS, Colorado State University and USDA's Climate Change Program Office, COMET-FARM will also help producers calculate and understand how land management decisions affect energy use and carbon emissions.

COMET-FARM allows producers to use a secure online interface to enter information about their land and its management, including location, soil

National Soil Health Initiative

NRCS has initiated a National Soil Health Initiative to increase awareness and understanding of the critical importance of soil management for improving agricultural production, decreasing erosion, and mitigating factors affecting the climate. Soil health, also referred to as soil quality, is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans. This definition speaks to the importance of managing soils so they are sustainable for future generations. Potential climate change in the Northwest can alter the capability of soils to sustain organisms and retain carbon.

Healthy soils serve a number of critical purposes, including regulating the flow of rain, snowmelt, and irrigation water; sustaining plant and animal life; filtering and buffering potential pollutants; cycling nutrients; and providing physical stability and support.

Dynamic soil quality is how soil changes, depending on how it is managed. Management choices affect levels of soil organic matter, soil structure, soil depth, and water and nutrient holding capacity. One goal of soil health research is to learn how to manage soil in a way that improves soil function. Soils respond differently to management, depending on the inherent properties of the soil and the surrounding landscape.

[23] https://esis.sc.egov.usda.gov/
[24] http://cometfarm.nrel.colostate.edu/

characteristics, land uses, tillage practices, and nutrient use. The tool then estimates carbon sequestration and greenhouse gas emission reductions associated with conservation practices for cropland, pasture, rangeland, livestock operations, and energy.

Agricultural conservation, especially soil and crop management, can contribute to removing CO_2 from the atmosphere. Historically, conversion of native lands to crop production using intensive tillage has resulted in significant releases of soil carbon. According to USDA's Agriculture and Forestry Greenhouse Gas Inventory, conservation tillage and other practices have helped reduce these losses and, in many cases, reverse them. Agricultural soils could potentially be used to sequester a significant amount of carbon. Carbon-rich soils are healthy soils, meaning they're more productive and resilient to extreme weather events, such as drought, because they hold more water and reduce soil temperature.

Conservation Innovation Grant program: a focus on greenhouse gas mitigation

NRCS provides funding opportunities for agriculturalists and others through various programs. Conservation Innovation Grants (CIG)[25] is a voluntary program designed to stimulate the development and adoption of innovative conservation approaches and technologies while leveraging Federal investment in environmental enhancement and protection, in conjunction with agricultural production. Under CIG, Environmental Quality Incentives Program funds are used to award competitive grants to non-Federal governmental or nongovernmental organizations, tribes, or individuals.

CIG enables NRCS to work with other public and private entities to accelerate technology transfer and adoption of promising technologies and approaches to address some of the nation's most pressing natural resource concerns. CIG will benefit agricultural producers by providing more options for environmental enhancement and compliance with Federal, State, and local regulations. NRCS administers CIG projects throughout the Northwest that address issues such as carbon sequestration; erosion reduction; best management practices for soil health, water-use reduction, and reduced energy consumption; and adaption of forest carbon protocols for tribal lands, to name a few.

Conservation Effects Assessment Project (CEAP)

Conservation Effects Assessment Project (CEAP)[26] is a multi-agency effort to quantify the environmental effects of conservation practices and programs and develop the science base for managing the agricultural landscape for environmental quality. Project findings will be used to guide USDA conservation policy and program development and help conservationists, farmers, and ranchers make more informed conservation decisions.

CEAP assessments are carried out at national, regional, and watershed scales on cropland, grazing lands, wetlands, and for wildlife. The three principal CEAP components—national assessments, watershed assessment studies, and bibliographies and literature reviews— contribute to building the science base for conservation. That process includes research; modeling; assessment; monitoring and data collection; outreach; and extension education. Efforts are focused on translating CEAP science into practice

The purpose and goal of CEAP is to enhance natural resources and healthier ecosystems through improved conservation effectiveness and better management of agricultural landscapes, and to improve efficacy of conservation practices and programs by quantifying conservation effects and providing the science and education base needed to enrich conservation planning, implementation, management decisions, and policy.

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[25] http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/cig/
[26] http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap/

Reassessment of Conservation Practice Standards

NRCS is presently reassessing the application and utility of the established National Conservation Practice Standards[27]. A conservation practice standard contains information on why and where a practice is applied, and it sets forth the minimum quality criteria that must be met during the application of that practice in order for it to achieve its intended purpose(s). NRCS is reassessing many of the standards to look at effectiveness and applicability, in part to address how changing climate and conditions can affect how a practice is utilized. There are five additional national templates for Statements of Work that are not directly associated with conservation practices: 1) Conservation Planning, 2) Comprehensive Nutrient Management Planning, 3) Cultural Resources Archival Research, 4) Cultural Resources Identification Surveys, and 5) Cultural Resources Evaluations.

Regional Conservation Partnership Program (RCPP)

The Regional Conservation Partnership Program (RCPP)[28] promotes coordination between NRCS and its partners to deliver conservation assistance to producers and landowners. NRCS provides assistance to producers through partnership agreements and program contracts or easement agreements.

RCPP combines the authorities of four former conservation programs: the Agricultural Water Enhancement Program, the Chesapeake Bay Watershed Program, the Cooperative Conservation Partnership Initiative, and the Great Lakes Basin Program. Assistance is delivered in accordance with the rules of EQIP, CSP, ACEP and HFRP; and, in certain areas, the Watershed Operations and Flood Prevention Program.

RCPP encourages partners to join in efforts with producers to increase the restoration and sustainable use of soil, water, wildlife, and related natural resources on regional or watershed scales. Through RCPP, NRCS and its partners help producers install and maintain conservation activities in selected project areas. Partners leverage RCPP funding in project areas and report on the resulting benefits.

Conservation program contracts and easement agreements are implemented through the Agricultural Conservation Easement Program (ACEP), Environmental Quality Incentives Program (EQIP), Conservation Stewardship Program (CSP), or the Healthy Forests Reserve Program (HFRP). NRCS may also utilize the authorities under the Watershed and Flood Prevention Program, other than the Watershed Rehabilitation Program, in designated critical conservation areas[29].

Rapid Carbon Assessment

The Rapid Carbon Assessment (RaCA)[30] is an extensive database on soil carbon. In 2012, NRCS embarked on the largest concentrated soil sampling effort in the history of soil survey to build the most extensive database on soil organic and inorganic carbon in the United States.

The Greenhouse Gas and Carbon Sequestration Tool

The GHG and Carbon Sequestration Ranking Tool[31] is a qualitative ranking of NRCS Conservation Practice Standards that can be applied effectively to the Greenhouse Gas and Carbon Sequestration Resource Concern.

[27] http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/cp/ncps/
[28] http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/farmbill/rcpp/
[29] http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/initiatives/?cid=stelprdb1254053
[30] http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_054164
[31] http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/air/?cid=stelprdb1044982

Cover Crop Termination Guidelines

Cover Crop Termination Guidelines[32] provide information on the termination of cover crops on non-irrigated cropland. They were developed by NRCS, Risk Management Agency (RMA), Farm Service Agency (FSA), and other public and private stakeholders to address concerns about cover crops' effect on crop insurance.

5.2 United States 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 (SandPF) 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.

The potential climate change effects for Forest Service Region 6 and Idaho portion of Region 1 include changes to streamflow dynamics, stream temperature, and increases in large disturbance events, wildfire, insects, disease and invasive plants and animals. As winters become warmer on average, many watersheds will experience a larger fraction of streamflow earlier in the year. Effects include increased frequency and magnitude of extreme low-flow and high-flow events, as well as higher winter soil moisture levels. The aging infrastructure and roads are vulnerable to damage and potential loss from flooding and landslides that in turn may degrade aquatic resources. Climate change coupled with riparian vegetation loss will lead to warmer streams in many locations, which could reduce habitat for trout and salmon species adapted to cold water. Region 6 contains coastlines vulnerable to sea-level rise, including the Oregon Dunes National Recreation Area, the largest coastal dune fields in the United States. Effects of storm events and wave action amplify as sea level rises, and coastal features may reconfigure more quickly due to an intensified pattern of inundation and erosion of sea cliffs, beaches, dunes, estuaries, and tidal marshlands. Rare extreme events such as massive storms may be more damaging.

The region's forest communities will be more susceptible to stressors like disease, insects, and drought. Portions of the Region have large wildfire potential and projections indicate more frequent and larger fires in the future. The predicted changes in temperature and rainfall patterns and extremes will continue to increase the amount of forest area burned each year, contributing to additional soil erosion, flooding, and weed invasion. The survival and spread of forest pests and diseases will also be favored, exacerbating tree mortality in cycles of fire, pests, and invasive plants and animals. The likelihood of increased disturbance (fire, insects, diseases, drought, and other sources of mortality) and altered forest distribution are very high and will likely lead to changes in habitat that would affect native species and ecosystems. Subalpine forests and alpine ecosystems are especially at risk.

Natural resources vulnerable to climate change can affect the economic well-being and cultural character of rural communities. Increasing water scarcity can potentially lead to greater conflicts among diverse water users on and adjacent to Federal Forests. The Native tribes in the Northwest are greatly concerned about the effects of climate change on their traditional hunting, fishing, and gathering activities. Ceded lands on the Forests provide resources and habitats essential for cultural, medicinal, and economic uses and community cohesion. In addition, recreational experiences on the Forests may be affected.

[32] http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1167871.pdf

The Forest Service recognizes that its mission to sustain forestlands for the future is threatened by climate change. The agency uses a climate change performance scorecard to maintain accountability for addressing the challenge. Current and anticipated results of its climate change-related activities include the completion of vulnerability assessments,which are conducted through partnerships between scientists and managers, to identify the vulnerabilities and potential responses for minimizing effects from climate change. Regions 1, 4 and 6, are working with the Northwest Research Station and have made good progress on completing USFS climate change performance scorecard element 6 (vulnerability assessment) and element 7 (adaptive management). Five of 17 Forests in Region 6 have vulnerability assessments in place, and staff associated with 6 Forests are in process of completing these assessments. Vulnerability assessment should be completed across all Forests by the end of FY16. In addition, a Region 6 climate change vulnerability assessment based on socioeconomic and ecosystem services is underway and will result in a peer-reviewed technical report and the development of a regional mapping tool. This tool will display and disseminate relevant ecosystem services, geo-spatial data, and socioeconomic vulnerability analyses outputs. This work will provide a regional context and will complement the more ecologically-based vulnerability assessments that have been completed or are underway in the Region.

Also by FY16, four Forests in the northern portion of Idaho (USFS - Region 1) will have published peer reviewed General Technical Report (GTR) vulnerability assessment and adaptation strategies for a full suite of resources. These resources include hydrology, forested and non-forested vegetation, vegetative disturbance, wildlife, fisheries, recreation, cultural resources, and ecosystem services (Northern Rockies Adaptation Partnership). The southern portion of Idaho (Region 4) will also have completed vulnerability assessments and adaptation strategies for a similar set of resources (Intermountain Adaptation Partnership).

Vulnerability assessments and adaption strategies are being and will be used to inform restoration work, conservation strategies, grazing allotment plans, fire management plans, short- and long-term resource program strategies, postfire management, plan revision processes, and plan oversight. Developed adaptation strategies and actions can help mitigate the potential effects climate change may have on infrastructure, aquatic resources, and terrestrial resources within the Regions.

5.3 Farm Service Agency

The Farm Service Agency (FSA) has 82 state and county offices located throughout the four-state Northwest Region. These offices are the "face" of USDA to farmers and ranchers who participate in the conservation and energy, commodity crop, disaster assistance, and farm loan programs that FSA manages. Virtually all of FSA's programs affect producers' ability to adapt to and even mitigate the effects of climate change:

- The Conservation Reserve Program (CRP), among the largest voluntary conservation programs in the world, provides incentives to take marginal or vulnerable cropland out of production for 10-15 years in order 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 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 programs, maintain farm incomes and keep farmers on the land by helping to mitigate price and yield risks.
- 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 needed to begin and continue their operations, particularly when obtaining commercial credit is difficult. Under 2014 Farm Bill, the ability to help beginning and socially disadvantaged producers has been enhanced.

In the Northwest Region of the United States, crop production, soil resources, and water resources are extremely vulnerable to climate fluctuations.

- Agricultural crop production includes dryland (non-irrigated) crops, such as wheat, barley, pulse crops, oil seeds, grass seed and forage, etc., which are extremely vulnerable to drought conditions. These crops are also vulnerable to erratic weather cycles that produce excessive heat during the wrong stage of growth or freezing temperatures during the growing season.
- Irrigated crop production, which includes corn, alfalfa hay, potatoes, orchards and vineyards, berries, and specialty seed crops, can become vulnerable to drought if/when drought conditions result in diminished water supply. Snowpack supplies 70 to 75 percent of the water used for irrigated agriculture in Washington. Fruit and vegetable crops can also be vulnerable to erratic weather cycles that produce excessive heat during the wrong stage of growth or freezing temperatures during the growing season.
- CRP and rangeland is vulnerable to drought because these areas are not typically irrigated. During drought, the risk of wildfire spreading over vast areas of CRP and rangeland is greatly increased. If these areas lose their growing cover they become susceptible to wind erosion, and severe dust storms may result. Loss of grazing lands increases the economic risk to livestock producers, who may have to reduce herd size as a result.
- The susceptibility of dry land, irrigated cropland, CRP, rangeland, and livestock forage to climate change effects increases economics risk for agricultural producers, rural communities and presents new challenges in maintaining and sustaining valuable soil and water resources.
- During periods of drought and high temperatures, the productivity of the Biomass Crop Assistance program would be at risk, as crops in this program 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 and/or fire, the soil and water resources become extremely vulnerable to wind and water erosion.

FSA administers the programs that Congress provides through the Farm Bill. The Food and Agriculture Act of 2014 provides the following programs that can assist producers in dealing with the risks and vulnerabilities created by changing climate:

- The new Price Loss Coverage and Agricultural Risk Coverage programs, along with the Marketing Assistance Loan and other programs, provide coverage for 20 agricultural commodities. These programs provide a safety net for producers during times of economic loss which could be triggered by crop losses or price declines.
- The Noninsured Crop Disaster Assistance, Livestock Forage Disaster, Livestock Indemnity, and other 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. Climate changes that exacerbate drought, floods, fires, unseasonable freezes and other natural events can diminish feed crop production, which can result in rapid increases in feed costs incurred by dairy producers.
- FSA’s direct and guaranteed loan programs are also very 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.

- The CRP and Continuous CRP programs can also be a tool to reduce environmental risks and vulnerabilities associated with climate change and may be used to mitigate the effects of or contribute to restoration efforts after a natural disaster.
- The Emergency Conservation Program (ECP) and the Emergency Forest Restoration Program (EFRP) are two FSA cost share programs that offer financial assistance with restoration costs and that are available to farmers and ranchers affected by natural disasters.

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 Northwest region the occurrence of reduced snowmelt, more frequent fires, higher temperatures, and increases in drought 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 via loans and grants for quality housing and community facilities for rural residents in all Climate Hub regions.

RHS will implement the prevention measures outlined below in an effort to reduce the effects of climate change and increase resilience to potential harm from flooding, storm surges, hurricanes, tropical storms, and other severe weather patterns that could damage structures funded through RHS programs.

- 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 harm the facility or the surrounding environment.
- RHS will also continue to consider the effects of sea-level rise, other potential flooding, and severe weather effects into long-term planning.
- 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 (this 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 within all of the Climate Hub regions that lessen the need for fossil fuels, increase energy efficiency, and promote biomass utilization and renewable energy. 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 gases 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 thinnings for advanced 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, increase energy efficiency, and lessen the effect of droughts, floods, and other natural disasters:

- National Rural Water Association (NRWA) Grant: an energy efficiency program designed to promote energy-efficient practices in small water and wastewater systems. The program 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 help them 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 drinking water quantity or quality due to an emergency, or when this decline is considered imminent. The grants help these communities obtain or maintain adequate quantities of water that meets the standards set by the Safe Drinking Water Act. Covered emergencies include incidents such as, but not limited to, drought, earthquake, flood, tornado, hurricane, disease outbreak, chemical spill, leakage, or seepage.
- Electric Program–Energy Efficiency and Conservation Loan Program: The program assists electric borrowers in implementing demand-side management, energy efficiency and conservation programs; and on-grid and off-grid renewable energy systems. Program goals include:
    - increasing energy efficiency at the end-user level;
    - modifying electric load to reduce overall system demand;
    - optimizing the use of existing electric distribution, transmission, and generation facilities;
    - attracting new businesses and creating jobs in rural communities by investing in energy efficiency; and
    - 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 (PRandG): Applying the revised PRandG in the near future to RUS water and wastewater program planning will include the consideration of climate change effects, among other factors.
- Rural Development Climate Change Adaptation Planning Document: This document, from June 2012, would apply to all three RD agencies. The plan was prepared 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 insurance products for crops and livestock to help farmers and ranchers manage risks related to agricultural production. Coverage is provided for agricultural production losses due to unavoidable natural perils such as drought, excessive moisture, hail, wind, hurricane, tornado, lightning, and insects, etc. In 2014, the Federal crop insurance program provided U.S. agricultural producers with over $109.8 billion in protection for agricultural commodities. These policies provide financial stability for agricultural producers and rural communities, and are frequently required by lenders.

As climate change is an ongoing process, the frequency and severity of environmental risks for agricultural production are also expected to undergo constant change. Producers can choose to adapt their management strategies to these challenges by incorporating new production practices, planting new crop varieties, or shifting the location of their farming operations.

RMA continually strives to improve programmatic effectiveness by refining insurance options in response to changes in production practices and adjusting program parameters as needed (e.g., premium rates, planting dates, etc.) within each county in response to changing crop production risks in those areas. To those ends, RMA monitors climate change research and updates program parameters to reflect agricultural adaptations or other changes in response to climate challenges. RMA also updates loss adjustment standards, underwriting standards, and other insurance program materials to ensure they are appropriate for prevailing production technologies.

RMA’s Spokane Regional Office (RO) manages insurance programs in the Northwest Climate Hub Region in Alaska, Idaho, Oregon, and Washington.

In 2010, RMA’s crop insurance National liability (book of business) was $78 billion. In 2014, RMA’s National liability was $109.8 billion. The four states located in the Northwest Climate Hubs Region accounted for over $3.3 billion in liability in 2010, and this increased to over $4.1 billion in liability in 2014. While the Northwest Region makes up a small book of business for the crop insurance program, it is an important risk management tool for grain, livestock, fruit, nursery, and specialty crop producers.

Over the last five years (2010-2014) participation in crop insurance has grown. Crop insurance liabilities for Alaska, Idaho, and Washington also increased.

- Washington’s Total Liability went from $1.7 billion in 2010 to over $2.5 billion in 2014;
- Idaho’s Total Liability went from $795 million in 2010 to over $1.0 billion in 2014;

- Alaska’s Total Liability went from $376,395 in 2010 to over $576,583 in 2014;
- Oregon’s Total Liability went from $765 million in 2010 and declined to $628 million in 2014.

In Alaska, Idaho, Oregon, and Washington over the last five years, the crops with the highest losses reported due to natural disasters were wheat, potatoes, sugar beets, barley, dry peas, and nursery crops. In addition, this Region has numerous speciality crops and the crops with the highest losses were apples, cherries, and grapes. Producers also received high loss payments for the Adjusted Gross Revenue (AGR) and AGR-Lite Product (which has been replaced with the new Whole Farm Revenue Product-and covered revenue produced on the whole farm).

In 2014, the crop with the most liability exposure for the top three states (Idaho, Washingon, and Oregon) was wheat, with a liability of $1.1 billion. Apples had the next highest liability with $742 million, while potatoes had a liability of $487 million. AGR and AGR-Lite product had a liability of $440 million, and cherries had a liability of $257 million. These five crops/products have the highest liability exposure for the Federal crop insurance program in the Northwest Climate Hubs Region.

RMA offices in the Northwest will continue to monitor crop disasters such as freeze, excess precipitation, and drought. RMA will respond to Approved Insurance Providers and producer inquiries during these events. In addition, RMA’s Spokane Regional Office will continue to provide RMA headquarters in Washington, D.C. with estimates of liabilities, losses, and the potential effects of natural disasters on the Federal crop insurance program.

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[33] 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 the 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 staff 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.

[33] http://www.aphis.usda.gov/about_aphis/downloads/APHIS_Strategic_Plan_2015.pdf

Animal Care (AC)

The mission of the AC program is to protect animal welfare by administering the Animal Welfare Act and the Horse Protection Act. AC also protects the safety and well-being of pet owners and their pets by supporting the Federal Emergency Management Agency (FEMA).

AC's supporting role in the safety of pet owners during disasters may be affected by climate change. An increase in storms and the severity of storms as the climate warms may increase the frequency of evacuations, and these events can be complicated when people are reluctant to evacuate threatened areas without their pets. In anticipation of the increase in emergency response activities, AC proactively organizes and participates in emergency planning with FEMA, Emergency Support Function (ESF) #11[34], and other response partners to strengthen the Nation's capacity to respond to natural disasters. These efforts will help reduce the effects of disasters and help people and their animals recover more quickly.

Biotechnology Regulatory Services (BRS)

To protect plant health, BRS implements APHIS regulations for genetically engineered (GE) organisms that may pose a risk to plant health. APHIS coordinates these responsibilities, along with the 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, climate change would likely affect the distribution of some agricultural crops and other plants, so 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 a flexible staffing plan and practice in place. Not all BRS staff is centrally located, and they are set up to provide mobile inspection services wherever GE crops are growing in field trials. Additionally, BRS receives reports each year from permit holders conducting field trials with GE crops, and 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 (either one not previously found in the United States, or one known to be present and officially under control) is detected, PPQ works in partnership with affected regions to manage and eradicate the outbreak. PPQ has three strategic goals:

- Strengthen PPQ's pest exclusion system;
- Optimize PPQ's domestic pest management and eradication programs;
- 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 invasive plant pests might be introduced, become established, 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 PPQ's ability to accurately predict and understand risk.

[34] http://www.fema.gov/pdf/emergency/nrf/nrf-esf-11.pdf

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 the potential for establishment may be altered with greater weather variability and more extreme events. For example, several years of warmer than normal weather can facilitate 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 its capacity for obtaining and analyzing data and implementing models that inform climate change-specific policies and pest programs. It is increasing capacity with new platforms for performing pest risk modeling at regional, national, and global levels. These platforms are designed to model geographic shifts in climatic suitability and host availability by projecting climate change scenarios onto the landscape. The group is also developing 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. Being able to produce robust projections of such shifts will improve the efficacy of early PPQ detection surveillance programs conducted in cooperation with States.

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 livestock diseases. If a foreign animal disease is 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, as well as the ability of these vectors to transmit economically important pathogens. This could increase their potential for spreading 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, and could reduce the market value of animals from affected areas.
- *Current measures addressing vulnerabilities:* VS conducts passive and active surveillance for arthropod-borne diseases such as vesicular stomatitis virus (VSV), equine encephalitis viruses (EEE, WEE, and VEE),[35] and hemorrhagic disease viruses (EHDV and BTV).[36] This surveillance activity may help identify changes in vector populations and inform recommended changes to disease surveillance and production practices. VS could identify other mitigation strategies through further research in this area. These projects could 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 effects 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 could alter wild animal distributions, movements, and feeding patterns, thereby increasing contact

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[35] Eastern, western, and Venezuelan equine encephalitis viruses, respectively.
[36] Epizootic hemorrhagic disease virus and blue tongue virus, respectively.

and the potential for disease exchange with agricultural animal populations. For example, the recent widespread epidemic of mountain pine beetles throughout the western United States and Canada may lead to widespread tree death and fires followed by variable regrowth in forested and transient grassy areas as trees re-grow. Habitat suitability may improve for species such as elk and feral swine, which could increase contact and subsequent disease transmission between these wild species and livestock.

- *Current measures addressing vulnerabilities:* VS is a collaborator in a new program led by APHIS Wildlife Services to investigate and mitigate agricultural and natural resource damage and disease risks from feral swine. VS is also involved in studying and responding to wildlife-livestock interactions associated with disease transmission, such as with brucellosis in the Greater Yellowstone Area.

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 livestock losses.
- *Potential measures to address vulnerabilities:* Measures may include shifting the distribution of livestock facilities to cooler areas. For example, an area that includes parts of the north central Plains and central Canada may become more productive for livestock as other areas become too warm.

Aquaculture

- *Vulnerabilities:* Marine and freshwater food fish populations have already seen significant declines due to warming waters and attendant effects that include acidification, oxygen depletion, algal blooms, and increased pathogen loads. These effects exacerbate effects of overharvesting, which has already depleted many wild fish populations. Reductions in the wild fish catch, places more pressure on the aquaculture industry to increase production and mitigate health effects on fish populations.
- *Potential measures to address vulnerabilities*: As the aquaculture industry meets increasing demands for fish protein, VS will rely more heavily on coordinated efforts that target disease control and the improved health of aquaculture species. VS works with the commercial aquaculture industry and Federal and State agencies to protect and certify the health of farm-raised aquatic animals, 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 APHIS program activities. Incorporating the economic and environmental effects of climate change on relevant agricultural systems and ecosystems would increase the robustness of PPD analyses over time. PPC economic analyses would be enhanced by robust projections of climate change and their effects on the distribution of production areas for various commodities, as well as anticipated needs for domestic and international commodity movements. These projections, along with information on pollinators, water, and other resources, as well as climate change effects on low-income, minority, and tribal communities, will better inform PPD environmental analyses. PPD is incorporating climate change into many of its environmental compliance activities, such as its National Environmental Policy Act (NEPA) documents and is leading an agency-wide effort to develop guidance for addressing climate change in NEPA documents.

Wildlife Services (WS)

The mission of WS is to provide Federal leadership and expertise to resolve wildlife conflicts and 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, as well as 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 affect the Northwest.

Managing diseases spread by wildlife: Climate change will probably have dramatic effects on the distribution of agricultural diseases of concern and 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. WS NWRC is conducting surveillance and research on diseases and vectors to gather baseline data on their distribution and will use this information in climate change models and future studies. WS NWRC also maintains tissue archives of wildlife samples that are made available for retrospective research on diseases. These studies support the documentation of changes in pathogen distribution and prevalence.

Predator management: As climate changes, shifts in landscapes and habitats may result, along with changes in prey distribution and abundance. Changes in native vegetation could include changes in forage availability and result in changing the feeding patterns of omnivorous predators such as coyotes, black bears, mountain lions, and wolves. These shifts will influence the distribution and abundance of predators and will alter the predictive ability of predator models related to spatial patterns, behavior, abundance, and habitat use. Results of such climate-informed models may be needed to inform predator management strategies in order to adapt to climate change. WS 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). These studies will provide a foundation for incorporating climate change into studies of species found locally. WS 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, these changes may alter the breeding and wintering ranges of birds that affect aviation safety. Airports and military installations need to be prepared to deal with new challenges associated with changes in bird ranges, including avian migration patterns. For example, WS has developed migration models for osprey in relation to military aircraft movements, but these could become obsolete if migration patterns change in response to climate changes. Proper habitat management is crucial to successfully managing wildlife risks associated with aviation activities. If climate changes affect the distribution of plant species that grow on airports and military installations, habitat management strategies may need to adapt to these changes. WS is gathering data on species and habitat distribution, which will faclitate the detection of changes in species ranges, migration patterns, and movement patterns, and support the adjustment of habitat management strategies accordingly. In an effort to identify potentially viable habitat types in new areas as conditions change, NWRC is also researching alternative land covers that could be used at airports and military installations in the Northwest and across the United States.

Wildlife management to protect agriculture: WS conducts research and management on coyotes, feral swine, bears, beaver, and other wildlife that can have significant effects on agricultural commodities such as livestock, timber, and crops. As climate changes, the distribution of these species and the agricultural crops they affect will also change. Information on population densities and the distribution of target species is important for understanding how climate change will affect production of agricultural commodities.

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