Section 2

Agricultural climate risks and adaptation opportunities

This section summarizes lessons learned from a review of climate resilience plans, reports, and laws in Washington state and elsewhere (Appendix A), the most up-to-date science (Appendix B), and the perceptions and priorities of the state's producers (Appendix C) and farmworkers (Appendix D) described during extensive statewide stakeholder engagement. For a complete list of sources used to inform this work, see the appendices and the associated reference list at the end of the Climate Resilience Plan for Washington Agriculture.

Climate change-related risks and opportunities for agricultural production

This section is organized into on-farm risks and off-farm risks. **Figure 1** details the pathway through which climate change leads to risks for on-farm agriculture in Washington state. Climate changes (#1), like shifts in precipitation patterns, can cause climate hazards (#2), such as reduced or inconsistent water availability. These hazards can result in on-farm impacts (#3), including lower crop yields, more frequent fallowing, and/or the need for greater investment in irrigation infrastructure. Off-farm risks refer to those that affect systems that producers rely on, such as regional irrigation infrastructure, electrical grids, dependable transportation networks, and university and government research programs that help producers adapt to climate change.

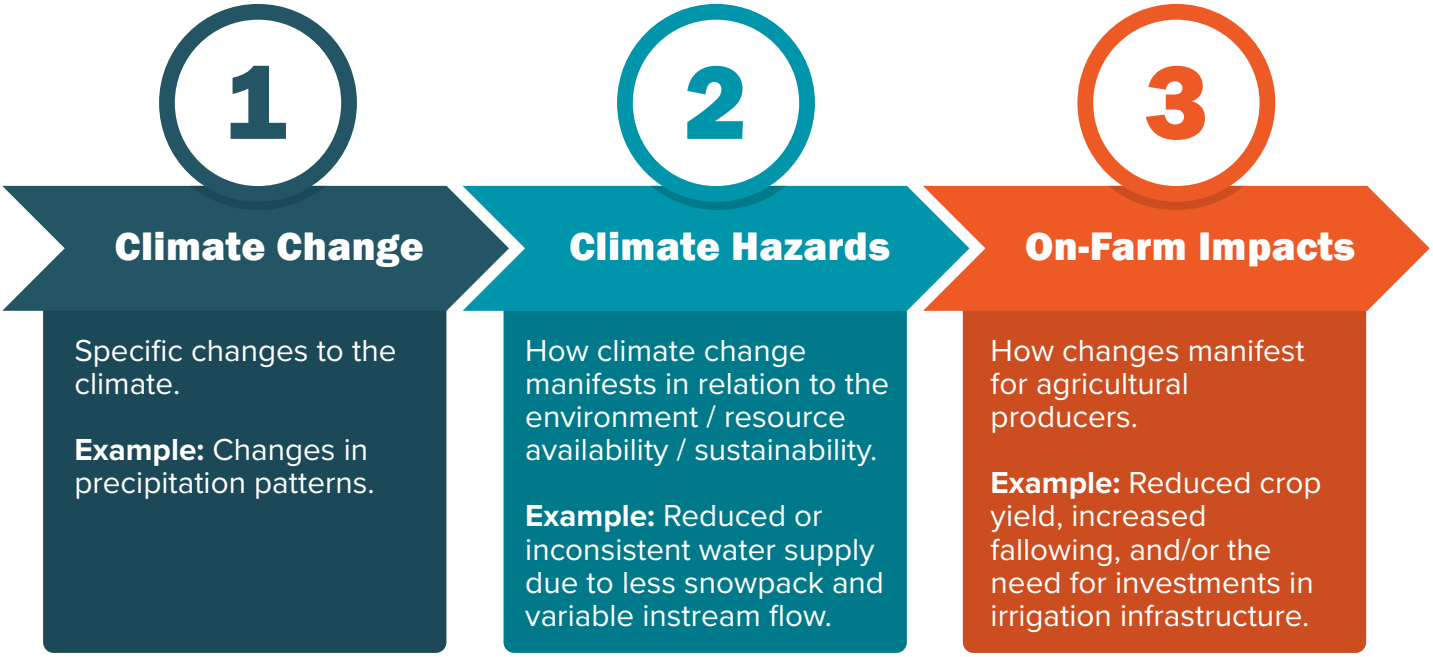

Figure 1. How climate change leads to on-farm impacts, with examples for Washington state.

On-farm climate-related risks

While the diversity in production systems across Washington state creates significant complexity in current and anticipated climate impacts, over-arching risks are described below and summarized in Figures 2 and 3.

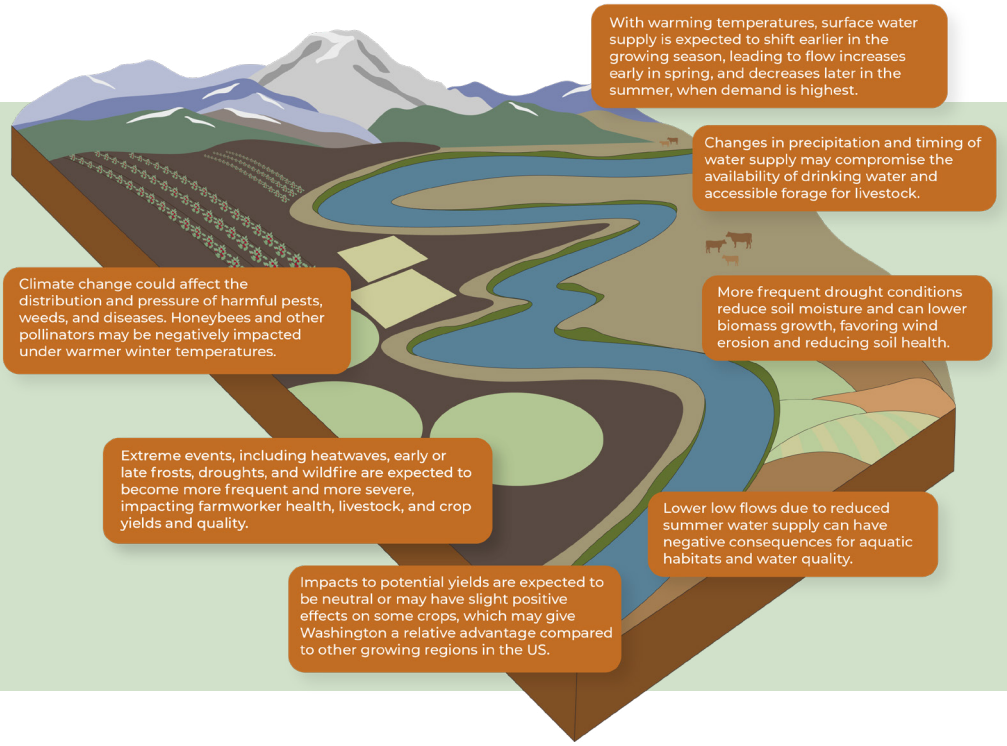

Figure 2. Major expected impacts of climate change to agricultural systems east of the Cascades in Washington state.

Credit: Katie Doonan, Washington State University.

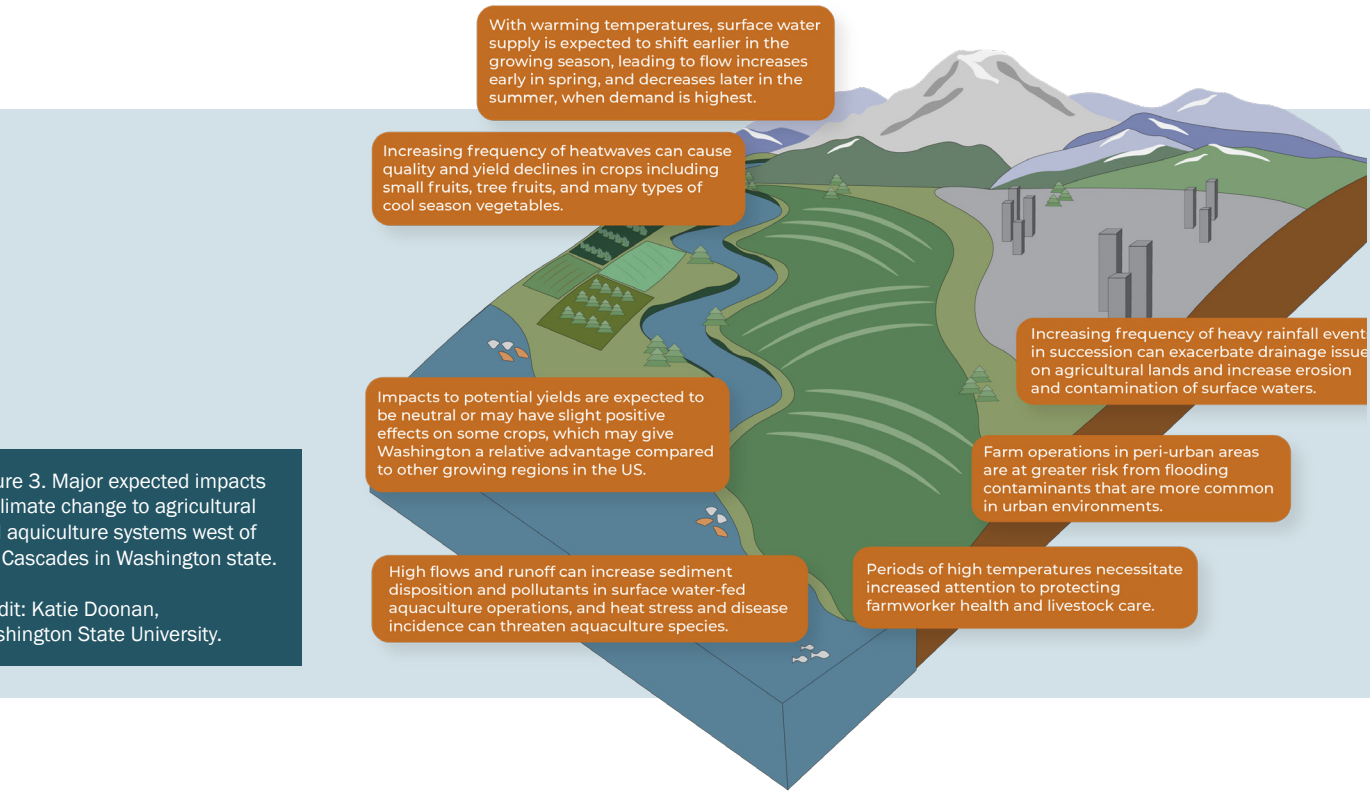

Figure 3. Major expected impacts of climate change to agricultural and aquiculture systems west of the Cascades in Washington state.

Credit: Katie Doonan, Washington State University.

Changes to the water supply

Successful crop production relies on water being available at specific times and in anticipated amounts. Warming temperatures and shifts in precipitation patterns will significantly alter the timing and volume of water supply available in many Washington watersheds. Water supply is expected to increase early in the growing season and decrease later in the growing season when demands are highest. This shift will occur in many watersheds in the state, especially those where precipitation is stored in higher elevations as winter snow and snowmelt provide flows to rivers in the spring and through the summer. Junior water rights holders will be disproportionately impacted and may lose partial or full access to water more frequently than they do currently.

It may be more challenging than in the past to ensure that water is adequately stored, distributed, and delivered to irrigated cropping and livestock systems. Changing temperatures that change crop growth patterns are also likely to change the timing and quantity of water demand. Flooding, and increased challenges managing stormwater, are more likely west of the Cascades. Cropping systems that utilize irrigation water from reservoirs and other water storage systems will be more resilient to changing water availability. Both crop and livestock producers, especially those located east of the Cascades where the impacts of drought may be more severe, may need to invest in upgrading water-related infrastructure.

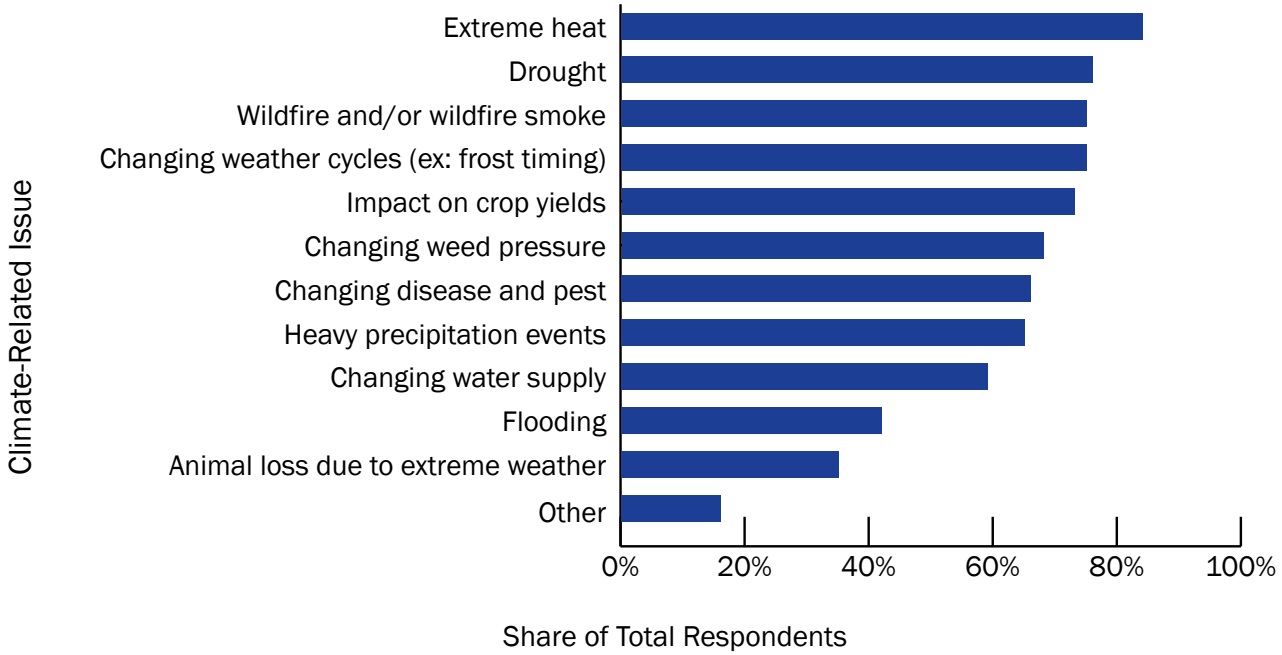

Figure 4. Responses to "Over the last five years, how impactful have the following climate-related issues been to your agricultural operation or the operations you support?" during a survey of producers and other agricultural stakeholders. Bars represent respondents who selected *Extremely Impactful*, *Impactful*, or *Somewhat Impactful* (n=292).

Increased threat to water quality

Flooding and heavy rainfall can cause erosion and soil runoff that increases nutrient loads and sediment in waterways and impacts drinking water quality, aquatic species habitat, and aquaculture production in coastal waters. Runoff can make filter-feeding bivalves, an important part of aquaculture production, unsafe to eat due to the bioaccumulation of toxins or fecal bacteria. Elevated nutrient loads in the water can also promote the growth of harmful algal blooms, which prevent shellfish harvesting. The optimal size of shellfish at the time of harvest is critical for the aquaculture industry and delays in harvesting, caused by water quality issues, can negatively impact economics. Heavy rainfall can also exacerbate existing drainage issues on agricultural lands. Additional runoff from hardscapes in peri-urban areas may contaminate soils with pollutants that are more common in urban environments. Projected increases in winter and spring precipitation have the potential to increase lagoon storage challenges for dairies in Western Washington.

Conditions that reduce river flows, including drought, can concentrate pollutants in waterways and increase water temperatures, negatively impacting water quality. Salmon and trout in the state are highly susceptible to increases in water temperature as it alters their metabolic rate, reduces oxygen availability, and can increase disease susceptibility. Summer high water temperatures in areas with high aquaculture production, such as the Lower Columbia River, are already in the upper tolerance range of native salmon and trout species, and future temperature increases could negatively impact aquaculture production. Drought conditions can also lead to an increase in fallowing, erosion from fallowed fields, and associated air and water quality issues.

Increased impacts and losses from extreme events

Extreme heat and cold events, as well as rain and windstorms during critical developmental periods, can result in significant or complete agricultural losses. Early spring freeze and frost are particularly harmful to perennial fruit crops such as tree fruits, grapes, and berries. Many crops, including small fruits, tree fruits, and various brassicas, experience declines in quality and yield when temperatures exceed certain heat thresholds. Extreme summer heat can also increase irrigation water demand when water availability may already be scarce. For shellfish, extreme heat events that occur during seasonal ultralow tides can result in mass mortality events on aquaculture farms when the shellfish are exposed to an extended period of elevated air temperature. Future increases in the number of high-temperature days per year could make these mortality events more common. Wind and waves from extreme weather events can also damage finfish and shellfish infrastructure or cause coastal erosion that may threaten shellfish operations.

Livestock also suffers when temperature and humidity thresholds are exceeded, with the potential for both short- and long-term health impacts, increased mortalities, and production losses. Dairy cows are among the most susceptible. While higher temperatures and humidity are expected to impact dairy cows, feeder cattle, and cattle on rangeland in the state (as well as other livestock and poultry), the impact may be less than in other regions across the country where thresholds are expected to be exceeded more frequently. Nevertheless, these events can increase mortality rates in the state's livestock systems. Mortality management for both routine and mass mortality events requires rapid response capacity and access to environmentally safe carcass disposal methods.

Flooding and fire can cause significant or total loss of crops, livestock, buildings, and equipment. Rangeland and the livestock they support are at particular risk from wildfire, as systems are extensive, livestock are dispersed, and it can take up to 15 years for rangeland to recover. Moving livestock to other locations or importing feed is expensive. For all types of extreme events, insurance programs may need to evolve to protect against damages, but will likely become more expensive, increasing financial stress on producers.

> *"The really low [temperature] drops in the wintertime—we had minus 24 to minus 26 degrees [Fahrenheit]—have caused a lot of winter damage and have hit us hard the last few years."*
> *— Washington Tree Fruit Research Commission listening session participant*

> *"As a producer from Southeast Washington that grazes strictly on dryland pasture, our pastures won't continue to grow into summer like they used to. Our total amount of moisture is staying close to historical normals, but now we don't get our late spring and early summer rains…that bring those pasture green-ups; that is a concern since we will need to change how we rotate and feed the cattle and must buy more hay in the winter beforehand."*
> *— Washington Cattlemen's Association listening session participant*

Risks to crop and forage quality

Climate change may negatively impact important aspects of crop and forage quality. For example, high nighttime temperatures in the fall can reduce the development of red color in apples—a key marketing trait. In listening sessions and surveys, agricultural producers across the state also emphasized that extreme events related to heat, cold, flooding, and wildfire are, and will continue to, impact crop and forage quality. Wildfires and smoke are impacting forage crop harvests and hay storage for livestock producers, as well as the quality of wine, especially in Central and Eastern Washington. Limited evidence also suggests that climate change may decrease certain nutrients and proteins in some plants, as accelerating maturation affects nutrient accumulation. While producers are concerned, more research is needed.

Increased impacts from pests, weeds, and disease

Climate change is likely to affect distributions and pressures from pests, weeds, and disease, threatening agricultural yields and quality. Many pests and weeds also benefit from warmer temperatures and increased carbon dioxide (CO_2). Certain insect pests can emerge earlier and produce additional generations within each growing season. Simultaneously, climate change will also impact beneficial insects and pollinators, creating complex ecosystem impacts. Warmer winter temperatures can cause premature physiological aging of pollinators, weakening managed beehives before critical spring pollination windows. Increased weed pressure may compound existing challenges with herbicide resistance, as noted by representatives from the Washington Grain Commission. Collectively, these challenges can significantly reduce crop yields. Unfortunately, pest management may also be adversely impacted by higher temperatures and wind, by potentially reducing pesticide application windows and increasing spray drift. However, the research is limited, and additional studies are needed to better understand the risks and identify new or updated management practices that reduce risks.

Increased health risks to the agricultural workforce

Climate change is expected to increase the exposure of agricultural workers to heat stress, poor air quality from wildfire smoke and wind erosion, animal-to-human disease transmission, and related health impacts. By mid-century, workers in Eastern Washington, including Yakima, Okanogan, and Benton counties, may experience an additional ~35 days with a heat index over 90 degrees, conditions which are dangerous for workers. In 2023 L&I updated the state's requirements for farmworker safety, requiring additional shade, rest, and acclimatization. However, there is an ongoing need to support implementation, especially in the development of strategies that simultaneously protect workers without reducing farm productivity and worker earnings.

> *"From experience, I have never seen heat as intense as this year [2024]. It reached up to 113°F for three days, and now it has been three consecutive weeks. Now my blood pressure is higher due to the heat." — Farmworker survey respondent*

> *"During wildfire season, the smoke damages the eyes and lungs. You can't wear a mask and glasses at the same time because the glasses fog up, and you can't remove the face covering because you end up breathing in the smoke." — Farmworker survey respondent*

Threat of ocean acidification to aquaculture operations

There is growing concern in the shellfish industry over the full impact that increasingly corrosive water will have on production. Oceans absorb CO_2 from the atmosphere, which reduces the pH of surface water (i.e., ocean acidification). Similarly, the upwelling of deep acidic ocean water and coastal nutrient runoff makes waters more corrosive. This changing ocean chemistry reduces carbonate ion concentration in the water, which is essential for the production and maintenance of bivalve (clams, mussels, oysters, etc.) shells and affects the behaviors of other animals such as salmon. The shellfish industry now commonly employs hatcheries over natural recruitment to have better control over water quality parameters during the sensitive larval life stage. However, ocean acidification is projected to worsen in the future.

Increased financial risk for farmworkers and small, under-resourced, and socially disadvantaged operators

Farmworkers and small, under-resourced, and socially disadvantaged operators may be more vulnerable to climate change impacts, with fewer financial and social resources to invest in climate adaptation infrastructure and practices. Furthermore, these groups have long been excluded from conservation programs and grants that help them cope with extreme events. Small-scale producers may also face challenges specific to diversified production and marketing strategies. For example, many diversified direct market farms rely on crops such as cabbages, broccoli, kale, and spinach that prefer cooler temperatures, and may have reduced season length in a changed climate.

During surveys and listening sessions, Washington farmworkers described how the impacts of climate change extend beyond health (Figure 5). Extreme weather can lead to work disruptions, changes in produce quality, and new challenges in working conditions. Collectively, these impacts can reduce farmworker earnings. Respondents also reported climate-related financial impacts at home, including rising costs due to increased demand for air conditioning or heating, and the cost of daycares that can care for children while workers begin harvest as early as 3 a.m. to avoid peak heat.

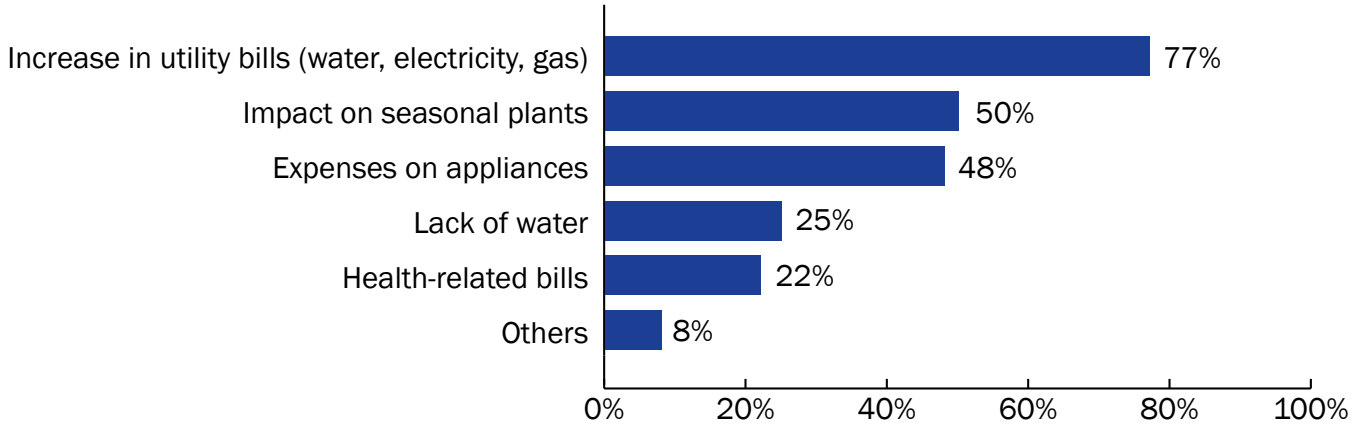

Figure 5: Farmworker survey responses to the question, “In your home, what are the effects of climate change?” (n=211)

Changing crop suitability

Long-term changes in crop suitability are anticipated due to water availability constraints, increased temperatures, and changing weather patterns. Producers indicated a need for information about crops and practices that are resilient to multiple climate stressors, including drought and extreme temperatures.

Off-farm climate-related risks

Increased threats to transportation and utility infrastructure

Multiple producer groups and WSDA staff noted increasing risks of climate change-related disruptions to transportation and power that can raise input and production costs for producers, put harvested products at risk, and reduce income for farmers and farmworkers. Climate change-related impacts can compound other existing infrastructure issues or disturbances. For example, oyster broodstock raised in Hawai'i can die in transit to Washington state during heat waves or transportation system delays. Wildfires, windstorms, and flooding events can damage or shut down roads, requiring lengthy detours or delays in shipments that can impact quality and scheduled delivery of perishable products such as dairy or produce. Similarly, port disruptions can affect produce quality if shipments are delayed. Both the Washington Grain Commission and the Washington Tree Fruit Research Commission listening session participants described transportation volatility as a major concern.

Extreme events, or the threat of such events, can disrupt agricultural processes, particularly through the loss of electric power. Due to wildfire-related liability, many electric companies across the West proactively shut down power when conditions are conducive to wildfires. Loss of power disrupts automated feeding machinery, irrigation systems, and farm office operations, and can result in the loss of agricultural products that require cooling or freezing.

> *"There are days when I drop my children off at daycare early morning, only to arrive at work and be sent home due to the rain or cold weather. Regardless of whether I work or not, I still have to pay for a full day of daycare, even if I don't get paid myself"*
> *— Farmworker listening session participant*

Increased regulatory costs, risks, and market volatility

The global effects of climate change can lead to local consequences, with fluctuations in food and agricultural input costs, as well as commodity prices, driven by extreme events and other worldwide disruptions. Producers also view current and potential greenhouse gas emissions regulations, along with heightened environmental rules, as risks, since they could raise both costs and the administrative workload of farming. During listening sessions, producers were critical of government regulations, lack of support funding, and the disconnect between policymakers and producers in addressing climate change.

Lack of climate data, research, technical support, and equipment

During climate resilience listening sessions with Washington commodity groups, producers stressed the need for science-based information and technical assistance. Producers also discussed the need for region-specific climate resilience research, and local support to access and understand findings, and to implement solutions on their farms.

While many agree that climate change has made an already unpredictable industry even more challenging, there is a shortage of reliable solutions and local experts to assist. Producers expressed concern about the decline in available services over the years and emphasized the need for more basic and applied research, as well as additional staff for outreach, education, and technical support. Multiple listening session participants and survey respondents asked for additional WSU Extension resources. They also pointed out the disparities in access to these resources across different regions.

Much of the scientific research on climate change impacts on agriculture has been conducted in the last 15 years. Although research continues, there are still significant gaps in knowledge specific to Washington state. Producers and farmworkers particularly pointed out the need for better forecasting to help them prepare for extreme events. They also emphasized the need for more information and support on best management practices to help them adapt to climate change and sustain their resilience in evolving conditions.

> *"[We have a] lack of adequate research to implement climate solutions, for example, cover crops sound great, but in this [Eastern Washington] water-limited environment, cover crops aren't possible. There are lots of programs for it, but it just doesn't work here, and we don't have university research to prove it. A lot of times we get our desires and funding ahead of our knowledge. — Washington Grain Commission listening session participant*

> *"Flood warning system is not accurate and [provides] late information. We rely on the system for livestock evacuation, it needs to [be] updated to reflect real-time data and more accurate predicted crests. " — Producer survey respondent*

> *"It's always good to know what to do [to] improve the conditions of climate since it affects our lives in every way" — Farmworker survey respondent*

Opportunities and strategies to mitigate risk

Climate change poses significant risks to Washington state's agriculture industry. However, due to its agricultural variety, unique landscapes, and location, climate change is anticipated to provide opportunities as well, especially compared to other states across the country. Strategic funding and focus can position the state to take advantage of these opportunities.

Geographic advantages

Negative climate-related impacts on Washington state's agriculture may be less severe than on other production regions in the US, making the state relatively more important in terms of its contributions to the national agricultural economy and food security. The state's relatively temperate climate, surface water availability, extensive irrigation systems, and variety of crops bolster its potential to become an even more agriculturally important region in a climate-changed future. For example, compared to the northwest region, the southwest may be experiencing an increasing trend in meteorological drought severity.

Other influences are also contributing factors. For example, California's San Joaquin Valley could face up to a 20 percent reduction in irrigation water supply by 2040 due to the combination of climate change and policy changes that drastically reduce groundwater withdrawals. Washington is not expected to see comparable reductions.

There remain many consequential impacts from climate change that will affect agriculture in the state. However, strategic investment and management at every scale will support the state's agricultural economy to realize the potential resulting from geographic advantages. Investments in a variety of trials, processing infrastructure, and water storage infrastructure may be key, especially through multi-benefit projects that support people, farms, and aquatic ecosystems.

Increased funding for on-farm climate resilience practices

Federal, Tribal, state, regional, and local governments have increasingly recognized the need to reduce emissions from agricultural production and enhance the resilience of agricultural operations to climate change. According to the USDA, the federal government invested $3 billion in conservation and climate-smart practices nationwide in 2024. Revenue from Washington State's CCA has also supported the state's agriculture, including through WSDA's Compost Reimbursement and Saving Tomorrow's Agricultural Resources (STAR) programs and the State Conservation Commission's (SCC) Sustainable Farms and Fields (SFF) Program. Along with the Natural Resources Conservation Service's (NRCS) Environmental Quality Incentives Program (EQIP), SFF was one of the top-ranked resources used by survey respondents. While there is an ongoing need for more CCA investment into agriculture, future eligible activities include incentives for dairy anaerobic digesters, on-farm renewable energy, farmworker housing weatherization, and farm fleet electrification. It is critical for these potential projects to be realized and implemented through the CCA and other funding sources.

Importantly, there is growing recognition that the most effective funding programs should be implemented before a crisis occurs. For example, Washington State's HB 2147 passed in 2024 to establish the Agricultural Pest and Disease Response Account that can rapidly distribute funds during an invasive species crisis. This will help the state be more resilient through climate change by bolstering early pest detection and rapid response. To better plan and prepare for drought, HB 1138 established a Drought Preparedness Account in 2023. In response to low snowpack and forecasted warm and dry conditions, Washington State made an early drought declaration in April 2024, to ensure emergency funds could be distributed early enough to mitigate existing and anticipated impacts.

While increased funding is important, listening sessions and surveys revealed the following challenges in accessing those funds:

- The administrative burden of applying for, managing, and reporting on grant funds can be prohibitive, even for large farms with advanced administrative capacity. This makes it especially challenging for small or low-income farms to apply for and use grant funds, especially when language, literacy, or technology barriers exist.
- Producers must have significant upfront capital to meet the matching or reimbursement requirements of many grants. This brings further disadvantages to small or low-income farmers.
- Many grant programs that fund on-farm conservation practices have strict implementation requirements. Farmers with unique production practices, geographies, or diversified systems cannot always meet these requirements.
- Tenant farmers and farmworkers are ineligible for many grant programs that may require applicants be landowners or US citizens. There are few programs available to these communities.

> *"Farmers are on the frontlines of the climate crisis and we're being asked to bear the brunt of investment while prices stagnate and inflation makes the cost of production almost impossible to make a living!" — Producer survey respondent*

Advances in climate science, data collection, and research funding

There has been increased focus and funding for developing on-farm management practices that can increase farm resilience. Federal funding for climate science and resilient management strategies could help shape practices in the state. For example, the NRCS used Inflation Reduction Act funds to expand climate-smart agriculture and forestry activities in 2024. In July 2024, the USDA announced $90 million for Conservation Innovation Grants (CIG), including a $1.2 million grant to the Whatcom Conservation District to research soil moisture and evapotranspiration-based precision irrigation technologies, and a multistate award that includes

Washington state, to assess 88 new trials of compost application. CCA funds may make similar advances for Washington state researchers and agricultural stakeholders going forward.

In Washington state, SCC, WSDA, and WSU work together to improve soil health through the Washington Soil Health Initiative. This effort works to ensure the adoption of on-farm conservation practices through outreach and education, policy support, research, and diverse economic incentives. Soil health practices were one of the most cited climate resilience practices mentioned by survey respondents in all regions of the state. State funding has also supported an expansion of WSU's Agricultural Weather Sensing Network (AgWeatherNet), which collects and delivers quality spatiotemporal weather data in the state to drive forecasts, models, and decision-support tools.

These are just a few scientific advances supported at the federal and state levels. Additional research and experimentation will help producers implement practices that work best on their farms.

Increased climate investments in infrastructure, energy, buildings, and transportation

Through the Inflation Reduction Act, the federal government and Washington State are investing in climate-resilient roads and utilities, electric vehicles, decarbonized buildings, and other strategies that could benefit agriculture. While some types of on-farm renewable energy are tried and true, others are still relatively new and should be deployed with care. Electric vehicles, for example, must be reliable and "fit-to-purpose" for long and sometimes unpredictable harvest schedules. The production of energy from anaerobic digesters on livestock operations could greatly benefit from significant advancements to overcome issues with scale and economic accessibility. Agrivoltaics—a system in which land is used for both agriculture and solar energy production—has shown promise in academic studies, though field scale implementation has not yet been realized in the state. With appropriate research, careful land use planning, and inclusive stakeholder involvement, this technology may provide additional farm income, support the state in achieving its energy goals, and simultaneously conserve agricultural land and heritage without undermining agricultural production.

Emerging technologies

Many emerging technologies support data-driven precision management on agricultural fields. These technologies may provide opportunities to optimize production, protect worker health, and achieve environmental goals. While some technologies such as autonomous tractors, precision sprayers, and robotic harvest machines require more research and development to overcome challenges of scale and accessibility, other technologies such as soil moisture monitor sensors are increasingly affordable and may be subsidized by public grants. Collectively, these technologies can support the efficient use of fuel, water, and farm inputs, which can reduce GHG emissions, off-target drift of pesticides and nutrients, and farmer input costs.

Expanded climate planning

Increased awareness of climate risks has led to the adoption of new policies and plans related to climate at the state and local levels. Governments are including climate risks in natural hazard mitigation and resilience plans and are factoring in the anticipated future climate (rather than historical climate) into their plans. WSDA has an opportunity to work with counties across the state as they create or update climate action plans to ensure that: agricultural risks and opportunities are included, diverse agricultural stakeholders are part of the planning processes, and planned actions are coordinated and complementary across the state.

> *"Fighting climate change is expensive, not doing something will be even more expensive"*
> *— Farmworker survey respondent*