SECTION 8

How Will Climate Change Affect Agriculture?

Agriculture in the Puget Sound region is projected to experience a lengthening of the growing season, shifts in crop production, increasing water supply challenges, changing risks from pests, increasing winter flood risk, and an increasing risk of saltwater intrusion. While these changes will leave some crops and locations more vulnerable than others, Puget Sound's agricultural system as a whole is expected to be able to adapt to these changes. Impacts on Puget Sound agriculture will vary by production type but generally point to increasing suitability of some crops (e.g., grapes) and declining suitability of others (e.g., berries). In addition, increasing flood risk is likely to damage farm infrastructure, and rising sea levels coupled with increased flooding could negatively affect crops, prevent planting, and affect water quality, especially near the coast. Efforts to address agricultural impacts are increasing, particularly in the areas of flood risk reduction and water management.

Climate Drivers of Change

CLIMATE DRIVERS ***Increasing air temperatures, decreasing summer precipitation, shifting types of winter precipitation, CO_2 fertilization, and sea level rise are all projected to affect agriculture in the Puget Sound region.***[A]

- *Observations show a clear warming trend, and all scenarios project continued warming during this century*. Most scenarios project that this warming will be outside of the range of historical variations by mid-century (see Section 2).[1,2] Increasing air temperatures will result in a longer growing season, but may also lead to decreased summer water availability, increased winter flood risk (see Section 3),[3,4] and an increased prevalence of pests.
- *Heavy rain events are projected to become more intense.* Current research is consistent in projecting an increase in the frequency and intensity of heavy rain events.[5] This could lead to increased damage and flood risk to farms, particularly those located in floodplains.
- *Most models are consistent in projecting a substantial decline in summer precipitation.* Projected changes in other seasons and for annual precipitation are not consistent among models, and trends are generally much smaller than natural year-to-year

[A] Throughout this report, the term "Puget Sound" is used to describe the marine waters of Puget Sound and the Strait of Juan de Fuca, extending to its outlet near Neah Bay. The term "Puget Sound region" is used to describe the entire watershed, including all land areas that ultimately drain into the waters of Puget Sound (see "How to Read this Report").

variability.[2] Declining precipitation in summer would exacerbate temperature-driven declines in summer water availability.

- *CO_2 concentrations will continue to increase.* Increasing levels of atmospheric CO_2 may result in increased productivity in some crops (referred to as "CO_2 fertilization"). In the near term, if sufficient water is available, these benefits can outweigh the negative effects of warming. Invasive species may benefit as well; some as a result may gain a competitive advantage over native species and crops.[6,7]
- *Nearly all scenarios project a rise in sea level.* Sea level rise is projected for all locations except Neah Bay, where a decline in sea level cannot be ruled out due to the rapid rates of uplift in that area.[8,9,10] Sea level rise is likely to render existing dikes insufficient to prevent flooding of agricultural lands in cultivated Puget Sound deltas.[11] Higher sea level may also affect the ability to drain farmland in these floodplains.[12]

Crops

CROPS ***Projections are imited to a small selection of species and locations, and do not include the combined effects of changing crops, predators, and other factors.*** To date, very little research has been conducted that is specific to Puget Sound agriculture. Only one of the following examples discusses Puget Sound-specific agriculture, and the remaining examples reflect a general understanding of crop requirements, and do not exclusively address Puget Sound-specific conditions and crops, which could shift as a result of climate change.[B]

CROPS ***Increasing carbon dioxide (CO_2) concentrations and increasing air temperatures are expected to cause production increases in some crops grown in the Puget Sound region.***

- *Increasing air temperatures could increase the number of grape varieties best suited to growing in Washington's temperate regions, including the Puget Sound region.*[13] The warmer climate projected west of the Cascades would make it easier to grow grapes in areas that are currently unsuitable due to low growing season temperatures.[14] Projections suggest that the Puget Sound lowlands may become newly suitable for viticulture by 2050 (2041-2060), under both a low and a high greenhouse gas scenario (Figure 8-1).[C,D,15]

[B] Many characteristics of Puget Sound's climate and climate vulnerabilities are similar to those of the broader Pacific Northwest region. Results for Puget Sound are expected to generally align with those for western Oregon and Washington, and in some instances the greater Pacific Northwest, with potential for some variation at any specific location.

[C] Greenhouse gas scenarios were developed by climate modeling centers for use in modeling global and regional climate impacts. These are described in the text as follows: "very low" refers to the RCP 2.6 scenario; "low" refers to RCP 4.5 or SRES B1; "moderate" refers to RCP 6.0 or SRES A1B; and "high" refers to RCP 8.5, SRES A2, or SRES A1FI – descriptors are based on cumulative emissions by 2100 for each scenario. See Section 1 for details.

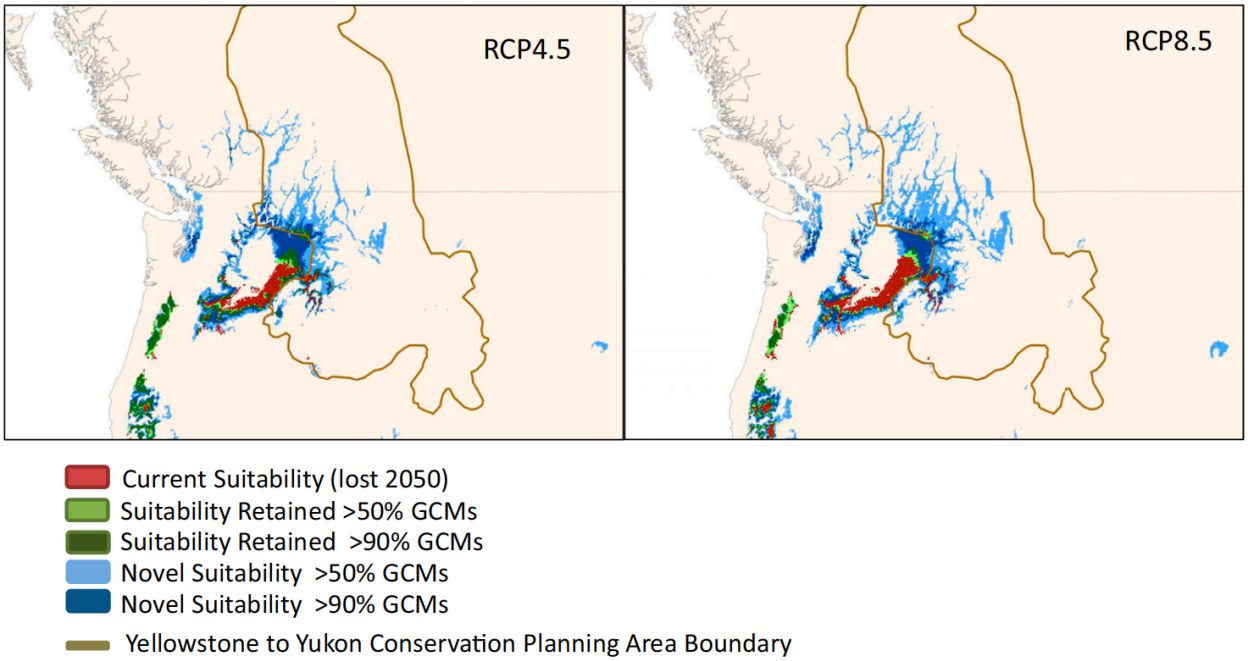

Figure 8-1. New areas becoming suitable for cultivating wine grapes. Projected changes in areas of climatic suitability for grapes for 2050 (2041-2060, relative to 1971-2000), under a low (RCP 4.5, left) and high (RCP 8.5, right) greenhouse gas scenario (see Section 1). Area suitable for viticulture is projected to increase from ~1.7 million acres to >+ 22 million acres under RCP 4.5 and to >+ 29 million acres under RCP 8.5 (increasing by a factor of 13 and 19, respectively). Results for both greenhouse gas scenarios indicate that the lowlands of Puget Sound will become newly suitable for grape production. *Figure source: Hannah et al. 2013* [D,15]

CROPS ***Increasing air temperatures and increasing water stress are expected to cause production declines in some crops grown in the Puget Sound region.***

- *Increasing air temperatures may negatively affect the production of some berries and tree fruit due to an insufficient chilling period – winter periods with low air temperatures necessary for fruiting and flowering.*[16,17] Extended periods between 32 °F and 45 °F are ideal for raspberry chilling, and warm air temperatures during winter may result in lower yields.[18]

- *Projected declines in summer water availability may adversely affect tuber production and quality.* Although not focused on the Puget Sound region, one study found that tuber production in Benton County, WA decreased by –8% to –17% in response to relatively modest decreases in irrigation.[19]

[D] The study defined the current climate by using a reference period from 1971-2000 and all parameters used were monthly or annual means. Future global climatologies, representing monthly 20-year normals for 2041-2060, were downscaled from 17 global climate model simulations (see Section 1), based on the RCP 4.5 and RCP 8.5 greenhouse gas scenarios.

CROPS ***Increased CO_2 concentrations are projected to reduce nutritional quality of forage and pasture, and can reduce the digestibility of forage.***[E,6] Experiments indicate that CO_2 fertilization will result in reduced nutritional value in forage and pasture land. For instance, up to a −14% reduction in forage digestibility for livestock was observed in response to a doubling of CO_2.[20]

Water Resources Impacts

WATER RESOURCES ***Elevated sea levels and declines in summer water availability could increase the risk of saltwater intrusion into Puget Sound groundwater; reduced summer water availability could also result in water supply challenges.*** Limited summer water supply can lead to an increase in groundwater extraction. When extraction outpaces recharge, the risk of saltwater intrusion grows.[21]

- *Several coastal regions of Washington have documented cases of saltwater intrusion*.[21] The most widespread occurrences of saltwater intrusion have been documented on San Juan and Island Counties.[22] Although climate change will likely increase the risk of saltwater intrusion, there are no published projections that quantify the anticipated change.

- *As water availability declines, it could be increasingly challenging to supply water to all consumers.* Projected increases in air temperatures and declines in summer precipitation could reduce summer water availability in the region (see Section 3). Increasing water scarcity could result in increased conflict over water rights.

WATER RESOURCES ***Increasing flood risk may negatively affect Puget Sound farms, a significant proportion of which lie in susceptible valleys and floodplains.*** For example, farms in the Snoqualmie Valley Agriculture Production District are already very vulnerable to flooding, and have experienced several major floods since 1990.[23]

- *Rising sea levels could inundate farmland in the Skagit River delta, adversely affecting crops already in the ground and preventing planting.*[11] On the Swinomish Reservation in southwestern Skagit County, sea level rise (see Section 4) could inundate over 1,100 acres of reservation land, including the only agricultural lands in the Reservation.[F,24] Sea level rise is also likely to increase inundation risk and slow drainage of cropland elsewhere in Skagit County.[12]

E When yield is increased (e.g., as a result of CO_2 fertilization) without a concurrent increase in nitrogen supply, protein levels (and thus quality) of the plant are reduced. If nitrogen levels are adjusted based on increasing yields, the issue of reduced plant quality is eliminated. Therefore, it is likely that this is a manageable agricultural concern.

F This study incorporated approximate local sea level rise in in the Puget Sound by applying the contributions of regional atmospheric dynamics and vertical land movement to the average of 18 IPCC global model projections of sea level rise. These estimates range from very low, 8 cm (3 inches), by 2050 to very high, 128 cm (50 inches), by 2100.

- *Floods allow pollution from roads, including oil and hazardous material, to wash into rivers and streams.* During a flood, these pollutants can settle on dry soils, which can negatively affect crops and livestock.[25]

- *The majority of the crop and pastureland in Skagit County is in the floodplain-delta area and is vulnerable to repeated flooding*. Increased peak river flows (see Section 3) and sea level rise (see Section 4) are projected to substantially increase flood risk for agriculture in these floodplains. Flower (tulips) and vegetable crops (including seed crops) are especially vulnerable to floods, as they may still be in the ground during fall floods, or may need to be planted in spring, before spring floods have receded.[23]

- *Increasing flood risk is likely to result in direct damage to farm infrastructure.*[25,26] An analysis evaluating the expected annual flood damages of a Skagit River flood estimated that farm buildings will incur just under $1.5 million dollars worth of damage annually.[G,26] The total value of existing at risk farm property (structures and contents) in the Skagit River basin is estimated at a little more than $86 million.[H,26]

Agricultural Pests

PESTS ***Increasing air temperatures are associated with changes in the geographic distribution of insect pests, spring arrival dates, and life-cycle durations.*** Although specific projections of changes in Puget Sound agricultural pests are not currently available, studies have identified links between pests and air temperature. However, making generalizations about how pathogens will respond to climate change is difficult because responses are likely to be species- and host-specific.

- *Increasing winter air temperatures will likely drive a mixture of increases and decreases in the damages caused by pests.* As geographic ranges for agricultural pests shift, some new pests will arrive in the region, while others will no longer be suited to the new climate. Some pests will survive winters when they previously had not, and longer growing seasons may allow for more successful reproductive cycles within a given year, resulting in exponentially faster population growth. Conversely, some pests that have historically emerged in tandem with specific crop life stages (e.g., flowering) may no longer emerge at the correct time, resulting in a decrease in economic damage.[27,28,29]

G A Monte-Carlo analysis of flood damages was conducted using the HEC-FDA model (Flood Damage Analysis), which considers uncertainties related to hydraulics, hydrology, levee performance, and economics. Expected annual damages for the lower floodplain is based on the current 500-year flood event.

H Value of damageable property is based on October 2012 prices, and is based on the current 500-year flood event.

Livestock

LIVESTOCK ***Livestock production may be adversely affected by increasing air temperatures and flood risk.***

- *Heat stress may lead to reduced milk production in dairy cattle, due to the high metabolic costs of lactation.*[30,31,32] Beef cattle are generally considered to be less vulnerable to heat stress, however, they do display similar physiological responses to heat stress as dairy cattle.[31,33] While the effects of heat stress on milk production are not negligible, they are small: nationally, climate change is projected to reduce dairy production by –6.3% by the 2080s.[32]

- *Livestock production may be adversely affected by increased flooding.* While livestock may be managed in emergency conditions for a few days, flood emergency operations typically cannot be sustained for more than one to two weeks.[23] One King County dairy farmer stated that he was unable to milk 47 dairy cows for over 50 hours during flooding of the farm's milking parlor. As a result, the cows became sick and the milk could no longer be sold.[34]

Capacity for Accommodating Climate Change

CAPACITY ***Agriculture is expected to be very adaptable to changing circumstances, although some crops and locations are more vulnerable than others.***

- *Farming and ranching are inherently flexible.* Agricultural production already involves adapting to changing weather and climate conditions. This flexibility will facilitate adaptation to climate change.

- *Agriculture in the Puget Sound region is very diverse.* This will likely facilitate adaptation, as some crops fare better than others.

- *Shifts in irrigation and improved management practices could outpace climate-related effects.* For instance, the pace of recent changes in livestock production – in response to changes in management and breeding – is much larger than existing projections of climate-related changes.[32] Although increased competition for water is likely to become a key challenge, shifts from dryland (non-irrigated) to irrigation could reduce the impact of declining in summer water availability on Puget Sound crops.

- *Western Washington agriculture is likely less vulnerable than central and eastern Washington.* Greater water availability, access to urban markets, and the milder climate of coastal Washington will likely make it easier for agriculture to adapt in this region.

- *While the agricultural system in western Washington is expected to be able to adapt to climate-related effects, individual farms in the region may be unable to adopt new*

management practices or switch crop varieties. For example, transitioning to new crops can require substantial investments in time and money. Wine grapes and apples, for instance, require years to establish and begin generating revenue.

- *Some subsidies and conservation programs could inhibit adaptation.* Some policies and regulations – including crop subsidies, disaster assistance, conservation programs, environmental regulations, and certain tax policies – may reduce the incentive for adaptation.

Climate Risk Reduction Efforts

CLIMATE RISK REDUCTION ***Many communities, organizations, tribes, and government and state agencies are working to adapt agricultural systems in the region to the potential effects of climate change.*** Examples include:

- *Puyallup Tribe of Indians vulnerability assessment and adaptation plan.* This assessment and plan will address priority issues within the following sectors: agriculture and first foods[1]; water resources; human health; ecosystems and habitats; species; forests; oceans and shorelines; traditional lifestyles; and infrastructure.

- *King County 2015 Farm Pad Program.* King County offers technical assistance and logistical support for the construction of farm pads in the Snoqualmie Valley Agricultural Production District. Farm pads are elevated areas where livestock, farm machinery and other agricultural equipment and supplies can be stored safely during a flood. Properly designed farm pads and other elevated flood refuges can help mitigate flood damages to farming operations. http://www.kingcounty.gov/environment/water-and-land/flooding/farm-pad.aspx

- *Ensuring adequate water supply for fish and farms.* King County Water and Land Resources and Wastewater Treatment Divisions (WLRD, WTD) will work with water purveyors and the U.S. Army Corp of Engineers to help ensure minimum viable river flows for fish and agriculture during low flow seasons, and will work with water purveyors and farmers to expand water conservation efforts and use of reclaimed water.

- *King County Agricultural Drainage Assistance Program (ADAP).* ADAP helps agricultural property owners improve drainage of agricultural lands by providing technical and financial assistance. http://www.kingcounty.gov/environment/waterandland/stormwater/agricultural-drainage-assistance.aspx

[1] "First foods" includes salmon, wild game, roots, berries, and clean water.

Additional resources for evaluating and addressing the effects of climate change on agriculture in Puget Sound.

The following tools and resources are suggested in addition to the reports and papers cited in this document.

- **U.S. Department of Agriculture (USDA) Climate Change Adaptation Plan.** This plan presents strategies and actions to address the effects of climate change on key USDA mission areas including agricultural production, food security, rural development, and forestry and natural resources conservation. http://www.usda.gov/oce/climate_change/adaptation/adaptation_plan.htm

- **The Future of Farming, a strategic plan for Washington agriculture.** This plan was developed in 2008 by the Washington State Department of Agriculture, and includes detailed recommendations and proposals for potential future agricultural actions within the state. http://agr.wa.gov/fof/

- **Regional Earth System Modeling Project (BioEarth).** This project improves the understanding of the interactions between carbon, nitrogen, in the Pacific Northwest, in the context of global change, to inform decision makers' strategies regarding natural and agricultural resource management. http://bioearth.wsu.edu/

- **Climate Friendly Farming (CFF).** Established by Washington State University's Center for Sustaining Agriculture and Natural Resources, CFF aims to better understand carbon sequestration and greenhouse gas emissions from agricultural systems and to establish long-term agricultural research projects that are focused on improving resiliency of agriculture to a changing climate. http://csanr.wsu.edu/program-areas/climate-friendly-farming/

- **Watershed Integrated Systems Dynamics Modeling (WISDM).** This program aims to improve understanding of interactions between water resources, water quality, climate change, and human behavior in agricultural and urban environments in the Columbia River Basin, including exploring how primary water users can be involved in the research process to develop scientifically sound and economically feasible public policy. http://wisdm.wsu.edu/

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