PACIFIC CLIMATE IMPACTS CONSORTIUM

PCIC SCIENCE BRIEF: CLIMATE IMPACTS ON SPECIALTY FRUIT AND GRAZING IN THE PACIFIC NORTHWEST

Two recent articles in the journal *Climatic Change* examine some of the effects that climate change may have on agriculture in the Pacific Northwest.

Focusing on specialty fruit production, Houston et al. (2018) find that overall warmer conditions and reduced water availability may reduce net returns on crops due to increasing farming costs, affecting yields and altering product quality. They suggest that management strategies currently employed in marginal production areas that moderate temperatures and offset mismatches between the needs of the plant at various growth stages and seasonal weather conditions may be useful adaptation strategies.

Neibergs and colleagues (2018) review the impacts of climate change on beef cattle production. They find that changes to seasonal temperature and precipitation may affect the availability of the plants on which cattle forage. This in turn could affect the number of cattle that an area can support, and the dates at which cattle are "turned-out" to pasture and taken in from pasture.

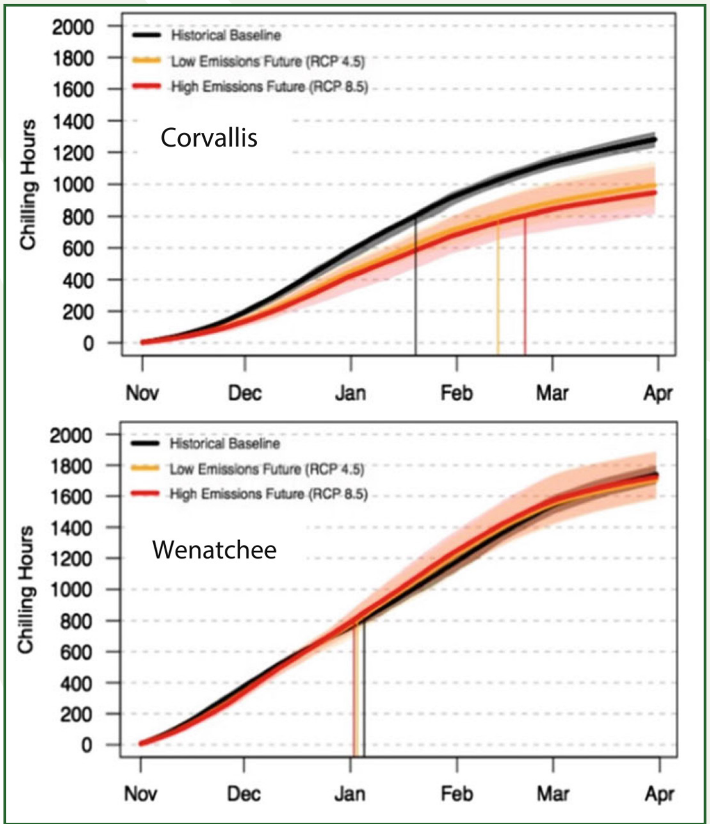

Figure 1: Simulated accumulated chill hours for Corvallis and Wenatchee for the 1976-2005 and 2020-2049 periods, from Houston et al. (2018).
This figure shows the accumulated chill hours between 0 °C and 7.2 °C (from November 1st through March 31st) for Corvallis (top panel) and Wenatchee (bottom panel) from statistically downscaled global climate model output for a historical run (1976–2005; black line) and projections for the 2020-2049 period assuming both a low emissions scenario (RCP[3] 4.5; orange line) and a high or business-as-usual emissions scenario (RCP[3] 8.5; red line). Solid lines show the ensemble mean and shading shows the ensemble range.

British Columbia's agricultural sector[1], comprised of about 17,500 farms, contributes about $1.5 billion dollars to the province's gross domestic product[2] (GDP), just over half a percent of the province's total GDP. The sector produces over 200 products, ranging from blueberries, cereal, vegetables and animal products, to wine and nutraceuticals. It is the livelihood of 70,000 people in the province and spans about 26,000 square kilometres. Specialty fruit production is especially important to southern BC and the Okanagan region, where most of the province's tree fruit production takes place. BC is also home to over 4000 cattle ranches, which span from the southwest to north-

1. For more information on agriculture in BC, see the resources available from the BC Ministry of Agriculture, here: https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood.
2. The gross domestic product (GDP) is the value in dollars of all of the goods and services produced in a region or sector over a given period of time.
3. The Intergovernmental Panel on Climate Change uses four trajectories of atmospheric greenhouse gas concentration, known as Representative Concentration Pathways (RCP) for its Fifth Assessment Report. The four trajectories are denoted by the change to radiative forcings that would result from each concentration, e.g. RCP 4.5 would result in an increase of 4.5 Watts per square meter as compared to the preindustrial period (taken to be the year 1750). For more information on the RCPs, see: van Vuuren et al. (2011).

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ern BC, comprising about 5% of Canada's total cattle herd and contribute about 0.25% of BC's GDP. Understanding how climate change could affect agriculture in the Pacific Northwest may help farmers in their adaptation planning.

In their recent article in *Climatic Change*, Houston et al. (2018) examine the potential impacts of climate change on specialty fruit production in Washington and Oregon and suggest some adaptation strategies to mitigate these effects. They begin by noting how the climate of the region has changed and how projections suggest that it may change in the future. In brief, the Pacific Northwest has warmed by about 0.7 °C over the 1895-2011 period. Both the growing season and the seasonal frost-free period have increased in length over the 1991-2012 period, relative to the 1901-1960 period. Heat waves have become more intense over the 1990s and 2000s than they were in any decade between 1901-1990 and spring runoff is peaking 10-30 days earlier in the year than in the mid-1900s in many locations. Also, snowpack has decreased by about 20% on average, both in the Cascades and across western North America in general, since 1915. Future projections suggest that these trends will continue, with temperatures in the region increasing by between 1.8 °C and 5.4 °C by the 2080s relative to the 1970-1999 period. Growing seasons are expected to lengthen, heat waves are projected to become more intense, spring snowmelt is projected to occur earlier and summer streamflows are projected to decline. While summers are projected to become dryer and cool seasons wetter, with an increase in the frequency and intensity of extreme precipitation events.

The authors find that these shifts in climate will have multiple effects. The warming climate is already affecting the areas in which plants can be grown, known as hardiness zones. These hardiness zones are shifting northward and are projected to continue to do so, forcing producers, processors and distributors to adapt. The warming climate has reduced, and is projected to continue to reduce the number of chill hours[4] (Figure 1) that fruit-bearing plants need as a part of their life cycle. This can affect fruit yields and quality. While some fruit crops will be negatively impacted, those types of blueberries that have no chilling requirements may be less affected, and grape production may benefit. Warming temperatures may also cause more "false springs," periods of warm temperatures early in the year that lure plants out of dormancy, followed by freezing temperatures that can damage fruits. Changes in spring temperatures can also affect pest management, with some insects hatching and multiplying earlier. As the rates at which plants and insects respond to climate change may differ, pollination rates may be affected, potentially reducing yields. In addition, reduced water supply from declines in snowpack, combined with warmer weather may increase the heat stress of crops. Finally, extreme heat can cause damage to the texture and skin of fruits, and affect their biochemistry, affecting firmness, sweetness and antioxident concentrations.

Houston and colleagues then examine some potential adaptation strategies. These include measures already being used in some regions, such as marginal production areas. The strategies include moderating the temperature of the crops and changing the variety of fruit being planted. Temperature control measures include creating shade with nets to protect crops from high temperatures. These can be expensive, but still viable for some crops. Another strategy is to plant fruit varieties more suitable for the changing regional climate. For example, apples with lower requirements for chill hours, such as Fujis and Pink Ladies may be substituted for apples with higher chill hour requirements. This strategy also requires monitoring the climatic conditions of the region to ensure that the new varieties are well matched for both the current and projected climates. Other options to manage heat and heat stress currently used include pruning, applying clay, wax or calcium carbonate, and sprinkler cooling. Frost is being managed through the use of wind machines, heaters, sprinklers and management methods, such as adjusting the height of cover crops[5]. The authors also suggest that orchards could be planted where temperatures are cooler, at higher elevations or latitudes.

Moving from individual adaptation methods to the larger picture of adaptation planning and management strategy, the authors suggest identifying relevant climate variables, both observations and projections, and accessing them in useful formats, such as maps, and through the use of online tools, at a suitable scale. From these, relevant thresholds for things such as growing season temperatures can be determined for planning and decision making. The authors provide the Northwest Climate Toolbox[6] as an example of such a tool. The authors also suggest that farm-level decision support tools such as AgBiz Logic™ that take into account climate, finance and lease considerations for farm adaptation and management may be of use.

Closing by considering future research, Houston et al. highlight the need for greater understanding of the microclimates in these agricultural regions. They suggest

4. Chill hours are hours that the fruit spends in temperatures between zero and seven degrees Celsius, triggering dormant periods necessary for fruit production.
5. Cover crops are crops that are used to add nutrients, reduce weeds and pests, prevent erosion and manage biodiversity in a region.
6. The Northwest Climate Toolbox can be accessed at: https://climatetoolbox.org/.

continued field trials that examine the usefulness of new crops and technology, further research on technologies and crops that address specific challenges and the further development of decision support tools.

Neibergs et al. (2018) explore how the changing climate may affect beef cattle production in the Pacific Northwest (here, Oregon, Washington and Idaho). They explain that rangeland[7] and pasture[8] are vulnerable to climate change impacts because of their vast extent, sensitive ecological communities, inaccessibility and comparatively low economic value. The authors provide an overview of the changing climate that matches that of Houston et al., with warming during all seasons, decreased snowpack, earlier spring melt, drier summers and wetter winters and autumns. Earlier spring warming would cause spring grass to appear earlier in the year and be gone earlier. Hotter, drier summers would increase wildfire risk and damage. See Figure 2 for a sample of the historical distribution of cattle and wildfires.

The cattle themselves are affected by climate change. They suffer from temperature-related morbidity and can die during extreme weather events. In addition, they are vulnerable to shortages of food and water, and climate change may affect the distribution of diseases, both insect- and food-borne. Heat stress also reduces fertility and lactation, and reduces carcass quality. In addition to impacts directly on the cattle, increased wildfire risk can reduce grazing land and damage farm fencing.

While the Pacific Northwest is projected to be exposed to climate impacts, the authors find that, compared to the Southwest, it has several regional advantages, notably that it has lower projected risk of both drought and declines in plant biomass. The area also has greater ability to withstand those droughts that do happen, owing to its irrigation supply, and it is capable of producing more cattle feed, if demand were to increase.

In order to address the challenges that climate change may bring, the authors suggest several strategies. One of these is dynamic grazing, in which cattle are moved through their grazing program according to the conditions and grazing resources of the land on which they graze. This may entail changing the timing of grazing, moving the cattle between locations, lowering herd sizes and doing supplemental feeding. In addition, the dates for grazing permits may be made more flexible by monitoring pastures and rangelands with drones and remote sensing data to evaluate the condition of the land. The need for alternative grazing and feed may increase due to wildfire

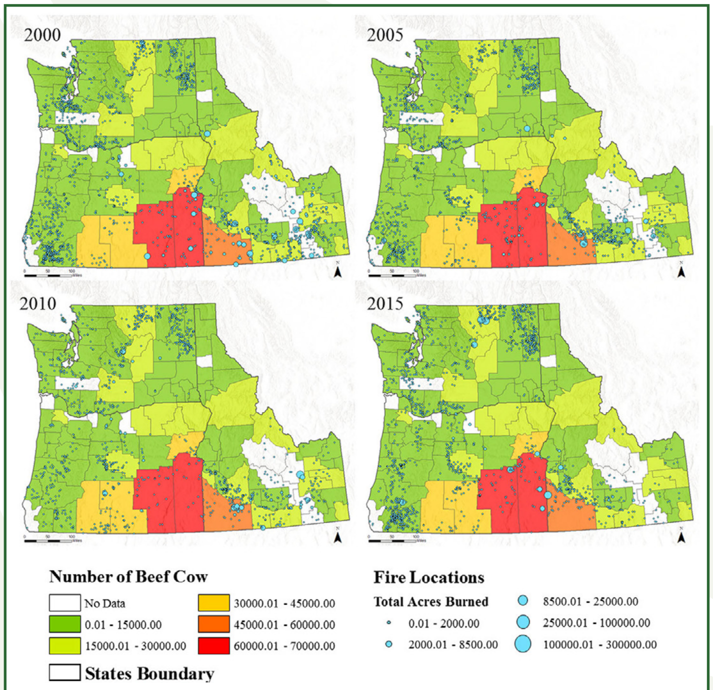

Figure 2: Cattle used for beef production and fire incidents in the Pacific Northwest, from Neibergs et al. (2018). This figure shows the number cattle (here, "beef cow") used for beef production in the Pacific Northwest (coded by colour) and the locations and magnitudes (size of blue circles, as given by scale) of fire incidents. Thin outlines indicate county boundaries, thick outlines indicate state boundaries.

risk, but the authors caution that, "in many cases, low carrying capacity grazing lands do not justify the capital investment required to repair extensively damaged fencing." To address water constraints, the authors suggest that farmers may have to upgrade and expand water systems, but that trucking water may be prohibitively expensive and labour intensive. Managing for summer heat stress may require that feed lots install shade structures. However, heat stress is not likely to change the cattle breeds used in the region. Slaughter plants may see increased energy costs, but these are not anticipated to be large enough to reduce slaughter numbers.

The overviews for specialty fruit production and cattle grazing, provided by Houston et al. and Neibergs et al., respectively, paint a picture of a Pacific Northwest that is in transition, getting warmer in all seasons, with dry summers and wetter winters and autumns. As the region warms, its growing seasons and heat waves lengthen, while the amount of cold winter weather and available snowpack

7. Rangelands are areas (including wooded areas, but excluding forests without grazable undergrowth on the forest floor) generally with primarily native shrub and herbaceous (i.e. plants without persistent woody stems, such as grasses) vegetation on which domestic cattle can graze. They are also principally managed through grazing and fire rather than irrigation, fertilization and sowing seeds.

8. Pastures are tended areas of farmland that contain forage crops, such as grasses and legumes, on which domestic cattle can graze.

decline. Projections these trends continuing on into the future. This may impact fruit production through drought, damaging heat, the shrinking of needed cool periods, increasing growing seasons, plants being damaged due to false springs and mismatches arising between the timing of pollinators and flowering. Cattle may be affected both directly by the heat, due to heat stress and disease, and by the impacts of hotter, dryer summers on the availability of water and land for grazing. The changing climate might also affect where it makes sense to grow certain varieties of fruits and graze cattle.

In both instances, the recommended adaptation measures consist largely of relying on and expanding upon the use of measures currently being used to adapt to increasing temperatures. For fruit in hot weather, this includes providing shade, applying wax and clay, pruning and using sprinklers. To manage freezing weather after false spring events, heaters, wind machines, sprinklers and adjustments to cover crop height may be employed. For cattle, adaptation methods include upgrading and expanding water systems, adjusting grazing schedules, moving cattle between grazing areas and providing shade at feed lots. In both cases, new technology may be of use. For fruits, this would include the availability of projections of future climate variables and farm-level decision support tools that could aid in planning. For cattle grazing, this may include the use of drones to monitor rangeland to allow for more flexible dates on grazing permits.

While both papers focus on the American portion of the Pacific Northwest, their findings are relevant to BC, especially southern BC, which shares ecosystems and topographical features with portions of their study regions. In general, agriculture in the province is expected to face the impacts that the authors noted for the Pacific Northwest. In particular, BC faces reduced summer stream flows, with increased heat, drought and fire risk. The province also faces challenges not discussed by the authors. For example, coastal regions may suffer from both inundation and saltwater intrusion into aquifers as sea levels rise. Along with these challenges, climate change may bring new opportunities, with increased growing seasons and the possibility of planting new types of crops in the province. Similar adaptation measures as discussed by the authors are also being implemented by BC farmers, such as wind machines and evaporative cooling for plant heat stress, and expanded water storage for livestock. Because the study region shares much in common with BC, the authors' findings are useful as an overview of some of the climate related challenges that the province has ahead of it and what general adaptation measures may be of use in facing them.

Houston, L., et al., 2018: Specialty fruit production in the Pacific Northwest: adaptation strategies for a changing climate. *Climatic Change*, **146**, 159-171, doi:10.1007/s10584-017-1951-y.

Neibergs, J.S. et al., 2018: Estimating climate change effects on grazing management and beef cattle production in the Pacific Northwest. *Climatic Change*, **146**, 5-17, doi:10.1007/s10584-017-2014-0.

van Vuuren et al., 2011: The Representative Concentration Pathways: An Overview. *Climatic Change*, **109**, 1-2, 5-31 doi:10.1007/s10584-011-0148-z