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ASSESSING CLIMATE VULNERABILITIES OF BRITISH COLUMBIA AND CALIFORNIA FOOD SYSTEMS THROUGH SPATIAL ANALYSIS

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ACKNOWLEDGEMENTS

The Food and Agriculture Institute at the University of the Fraser Valley is situated on the sacred lands of the Stó:lō peoples.
The Stó:lō have an intrinsic relationship with S'ólh Tém:éxw (Our Sacred Land), and we express our gratitude and respect for the honour of living and working in this territory.

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BACKGROUND OF THE FOOD SYSTEMS IN CANADA

Canada plays a crucial role in the global food market, serving as a dominant producer and exporter of various agricultural products. Domestically, the agri-food sector generates billions of dollars and contributes roughly seven percent (7%) to Canada's overall gross domestic product (Agriculture and Agri-Food Canada, 2024). British Columbia plays a key role in Canada's agri-food system; however, changes in climate and increased adverse weather events have highlighted the province's vulnerability (BC Food Security Task Force, 2020). These adverse impacts stem from a variety of environmental threats including climate change, water scarcity, changing weather patterns, and increased pests and diseases, even with adaptation measures put in place.

Adding to these complexities is British Columbia's heavy reliance on food imports from California. This state is similarly facing some of the same environmental challenges such as droughts and changing precipitation patterns along with other climate-related events, jeopardizing the United States' ability to steadily supply British Columbia with the necessary food resources in the long-term. Canada relies on the U.S. for 70 percent of its vegetable supply and 60 percent of its fruit supply (Agriculture and Agri-Food Canada, 2021). The combined pressure of climate change on Canada's food imports and exports are placing significant demands on the food system. This situation is forcing us to consider novel ways to produce more food for hyper-local consumption, especially of fruits and vegetables (Newman et al., 2023).

This research explores the crop and climate vulnerabilities facing British Columbia's food system. Specifically, it fills a research gap by undertaking both an economic and spatial analysis to identify specific crops at a high risk of climate-related disruptions.

THREATS TO THE BRITISH COLUMBIA FOOD SYSTEM

Climate change is known as both a global and local phenomenon and current statistics show BC temperatures are slowly increasing, with milder winters and higher volumes of rainfall between intermittent periods of drought (Clean BC, 2024). Climate change is altering the hydrological cycle evident in the earlier onset of spring run-off, generating concerns over water quantity throughout the grow season from the interior of British Columbia through to the coast. BC is experiencing increased weather events that are more extreme, unpredictable, and devastating.

Natural disasters in the early 2000s such as droughts and floods cost the province an average of $10 million per year, which has increased to $17.1 billion in 2021, according to a study done by the Canadian Centre for Policy Alternatives, BC Office (CCPA, 2022). The year 2021 was BC's costliest and most extreme year for climate disasters, mostly due to flooding. The atmospheric river that landed in BC in 2021 lasted for two days resulting in extreme flooding and landslides, and even cost five lives (Gillett et al, 2022). Events at this level are 60% more likely to occur due to climate change caused by humans which ultimately leads us to expect more of these events and for them to become more extreme (Gillett et al, 2022). According to the BC Government, more than 1100 farms were negatively affected by the floods and incurred severe losses: the biggest agricultural disaster in BC's history (BC Agriculture and Food, 2023).

THREATS TO THE CALIFORNIA FOOD SYSTEM

British Columbia heavily relies on the imports of fruit and vegetables from the United States, with California being a top exporter to Canada. For example, California supplies British Columbia with much of the province's lettuce grown mainly across 5 counties/regions, such as the Salinas Valley. With California experiencing its own climate threats such as prolonged drought, wildfires and climate change, these global shifts are jeopardizing the availability of imports for Canada. California is home to a multi-billion-dollar agricultural industry and is "America's most productive agricultural state in the country" due to its mild winter and hot dry summer climate (USDA California Climate Hub, n.d). California is facing milder winters, which is a challenge since many of the crops require exposure to a cold winter to develop properly come spring (USDA California Climate Hub, n.d). California experienced the most destructive wildfire season in 2020, resulting in "catastrophic and unprecedented" impacts on agricultural land (California State Assembly, 2020). Events like this continue to negatively impact the agricultural economy which is predicting an unsustainable future for BC's food security.

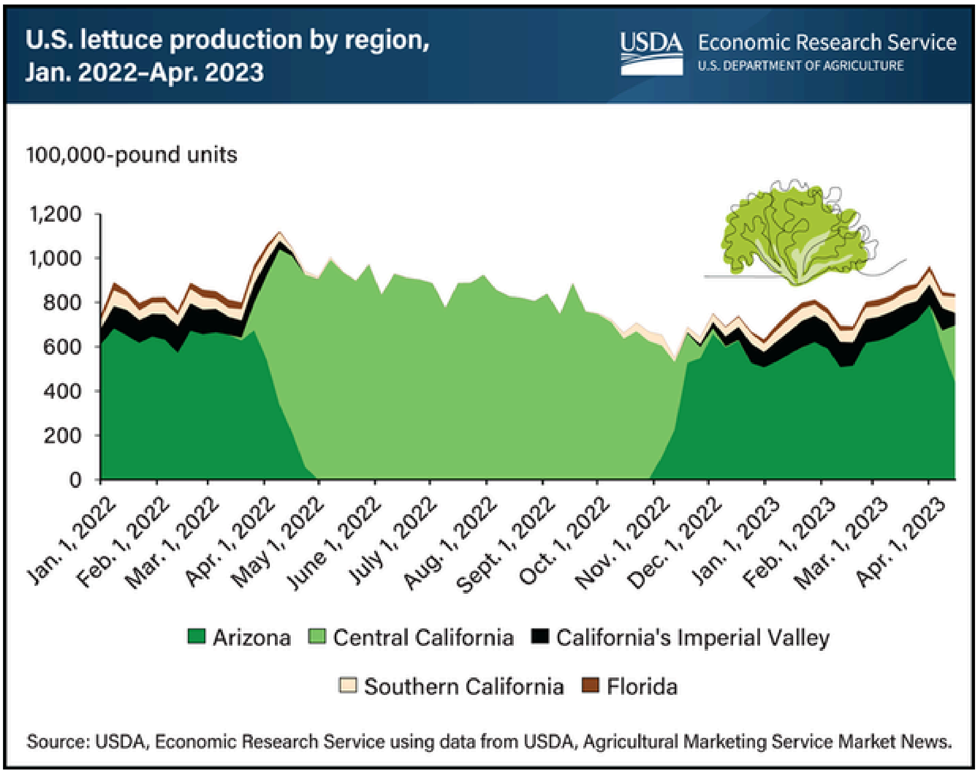

Figure 1. Lettuce is a significant export commodity from California and other major lettuce producing regions, representing roughly one fifth of total country-wide vegetable and melon cash receipts (USDA, 2023).

STUDY CONTEXT

Given the vulnerabilities facing British Columbia’s food system as well as its major trading partners, it is crucial to determine specifically what crops are most at risk. This research asks the question: what crops are most at risk of supply disruption in British Columbia? The objective is to determine and model which fruit and vegetable crops are most vulnerable to higher levels of climate change-related changes (in soil moisture, precipitation, and temperature, specifically) across the Province of British Columbia.

Enhancing British Columbia's domestic food security could help relieve the pressures of imports from the United States while protecting local agricultural production. In what follows, we describe data collection and analysis procedures, as well as key results from this research pertaining to climate-related vulnerabilities facing BC’s food system. We conclude by discussing opportunities for bolstering local production fruit and vegetable crops.

METHODS

The research project began with a literature review to identify key climate threats facing British Columbia's and California's food systems. This literature review focused on Statistics Canada documents related to the import and export of vegetable commodities between British Columbia and California to further understand the relationship between Canada and the US food systems. Simultaneously, data was gathered using online listservs and directories to create a table of farms that are currently producing these vulnerable crops in the Lower Mainland. These farms are a mixture of greenhouse farms and open-field farms.

Next, climate projection data was gathered using the Government of Canada's website, and this data was used to make a climate vulnerability assessment. The three types of climate projection raster files used in this research are three different types of climate data sourced from the Government of Canada website that provide a measure of near and long-term vulnerability. The three data layers consist of the Standardized Precipitation Evapotranspiration Index (SPEI), mean temperature and total precipitation, which were then clipped down to the scope of study in the Lower Mainland region. Temperature and precipitation models were developed by the Government of Canada, following CMIP5 IPCC statistically downscaled climate models (Government of Canada, 2024), and are presented at a 10km resolution for the 2021-2040 period, with a 'middle of the road' climate scenario of RCP 4.5. Future work could compare if and how results vary by RCP scenario or across longer time horizons, depending on available data. The SPEI index is a measure of relative soil moisture deficit – in this case, of soil measure in February 2024 with respect to the average soil moisture over the past 5 years at any given location – the raster layer is measured at a 5km resolution.

Once the data was gathered in ArcGIS, it was normalized using equal interval breaks to define a 5-point relative ranking of measure of vulnerability and then interpolated using an Inverse Distance Weighted (IDW) process to refine the raster data further. This process involved converting the raster cells to points with the aggregated points tool in ArcGIS and then carrying out a spatial autocorrelation analysis. A hotspot analysis was performed based on a cluster and outlier analysis, which then allowed for the interpolation with the IDW application.

Each map is ranked such that 1 represents the highest vulnerability, and 5 the lowest. For the first map of the precipitation projection over the next 20 years (see Figure 3), areas with higher projected percent changes in total precipitation are labelled as higher vulnerability. For SPEI over the last five years (see Figure 5), greater moisture deficits (i.e. lower negative values on the SPEI scale) indicate higher short-term vulnerability. Finally, for mean temperature projections, greater projected mean temperature changes are labelled as higher in possible vulnerability. Maps also include point data of farms that produce one or more of the sensitive crops identified through the economics analysis. These farms were found through the BC Greenhouse Growers Association and BC Farm Fresh website directories.

It is important to note that the term ‘vulnerability’ does not refer to the vulnerability of the individual farm or area to fail or collapse, etc. Rather, vulnerability here refers to the potential for that area or individual farm to experience greater current soil moisture deficits, as well as experience greater changes in precipitation and temperature, respectively.

AGRICULTURAL CLIMATIC MONITORING AND ASSESSMENT

Agricultural drought is notoriously difficult to predict in the long-term. Agricultural drought occurs when the root zone of a crop does not have access to water. Inherently, these droughts are observed and felt at a highly local level (i.e. the level of individual fields or operations), occurring when larger scale (i.e. regional or continental) meteorological droughts are present (Mardian, 2024). In this research, we used the SPEI as well as temperature and precipitation changes as indicators of vulnerability. Alternative options for drought measurement and assessment include the modified Palmer Drought Severity Index, satellite vegetation image-based assessments, as well as remote sensing tools (Mardian, 2024; Xue & Su, 2017).

For the reasons mentioned above, using SPEI and climate change precipitation as well as temperature changes as measures of vulnerability poses a key limitation to the analysis. While these measures are useful indicators of regional water variance now and in the future, they may not capture the localized terrain and waterflow dynamics of individual fields. For the purpose of this exploratory research, however, SPEI and climate change projection data provide a useful approximation of water stress. Further research that applies alternative indices and takes stock of local irrigation norms in the region is required.

Canada continues to be a top export market for the United States agricultural exports, reaching close to 15 percent of all U.S. agricultural exports (International Trade Administration, 2023). Due to a decrease in domestic production, lettuce remained Canada's top vegetable import in 2020, even with increased import requirements for romaine lettuce (see Figure 2.) (Agriculture and Agri-Food Canada, 2021). Following lettuce as a second imported vegetable were cabbages, tomatoes, peppers, onions, and shallots. Though Canada produces a significant number of cabbages for export, they hold a high value and are important in terms of an imported crop. In 2020, Canada spent close to $553 million CAD on lettuce imports, $311 CAD million on cabbage imports and $101 million CAD on tomato imports, all originating from the United States alone (Agriculture and Agri-Food Canada, 2021). Though Canada is the fifth top importer of fresh vegetables globally, Canada is the sixth top exporter of fresh vegetables worldwide, exporting just over $2 billion CAD in fresh vegetables in 2020, which was a 15.7% increase from 2019 (*ibid*).

BC is the top producer of fruit in Canada and is ranked second nationally in the production of grapes according to the British Columbia Agriculture and Food (BC Agriculture and Food, 2018). Due to the changing climate bringing increased temperatures and lack of precipitation, there are anticipated changes surrounding what crops BC imports and exports are at risk of supply disruption. Lettuce is BCs largest imported crop which comes primarily from the State of California (see Figure 1.) The overall escalation of extreme weather events due to the changing climate presents significant risks, leading to severe events such as widespread flooding, prolonged droughts, and devastating wildfires. These adverse conditions pose a threat to crucial imported crops that BC heavily relies on, ultimately resulting in supply disruption between California and British Columbia within the current food systems.

Sources of top five Canadian Vegetable Imports (CAN$ '000)

		2016	2017	2018	2019	2020
Lettuce[2]	United States	503,543	538,905	524,049	559,489	552,891
	Mexico	5,516	9,702	13,376	19,638	20,262
	China	531	614	684	1,128	1,038
	Guatemala	11	6	213	323	271
	Spain	194	1,126	379	366	157
Cabbages[3]	United States	323,162	314,193	314,624	329,379	311,777
	Mexico	55,024	55,540	58,571	76,173	84,215
	Guatemala	242	59	16	957	4,940
	China	3,569	2,551	2,802	3,185	3,078
	Spain	905	1,530	3,185	5,206	1,745
Tomatoes	Mexico	125,838	133,111	171,119	172,055	160,516
	United States	93,418	98,134	93,246	94,447	101,212
	Guatemala	209	554	857	2,522	2,869
	New Zealand	796	518	450	484	746
	Dominican Republic	571	526	255	27	56
Peppers	Mexico	92,336	85,148	104,384	119,593	113,021
	United States	72,839	71,818	72,077	73,880	78,540
	Spain	14,970	7,888	10,356	16,844	12,311
	Honduras	8,231	7,331	7,159	10,313	11,551
	Dominican Republic	4,008	5,457	4,546	4,094	5,785
Onions and shallots	United States	137,552	117,023	122,495	157,970	140,271
	Mexico	50,688	49,095	55,506	63,150	57,825
	Peru	7,346	6,699	7,060	7,596	9,601
	Netherlands	2,268	1,326	2,377	959	1,732
	China	1,224	1,138	1,517	1,629	1,618

Notes:
1. Includes field vegetables and mushrooms, excludes greenhouse vegetables and potatoes.
2. Includes cabbage lettuce (head lettuce).
3. Includes kohlrabi and kale and similar edible brassicas.
Source: Statistics Canada. (CATSNET, May 2021)

Figure 2. Sources of Canada's top 5 imported foods. This figure lists the top five imported vegetables into Canada by value in millions of dollars CAD. It clearly outlines how lettuce is the leading imported crop from the United States, followed by cabbages, tomatoes, onions and shallots. The United States primarily grows the crops listed, with Mexico being the largest exporter of tomatoes for Canada. Supporting exporting countries include China, Guatemala, Spain, New Zealand, The Dominican Republic, Honduras, Peru, and the Netherlands (Agriculture and Agri-Food Canada, 2021).

SPATIAL ANALYSIS

The first map depicting the Standardized Precipitation Evapotranspiration Index (SPEI) shows many of the farms that produce the Lower Mainland's most sensitive crops are found in the high-vulnerability zone where there is the highest moisture deficit and, therefore, are at a higher potential vulnerability. The second map depicts the mean temperature, which shows that 38% of farms are in moderate through to high (ranks 1-3) vulnerability areas and 61% are in low (ranks 4-5) vulnerability areas. The last map representing precipitation projections for the next 20 years shows that most farms are in the highest vulnerability areas (ranks 1-2). This is expected due to the increased extreme weather events that are occurring due to the changing climate. Too much precipitation puts these vulnerable crops at risk, potentially making it harder to grow them at these sites.

The results show a clear indication that there are challenges of increased term drought and challenges with increased precipitation. This increased drought may cause instability and lack of moisture which is a concern for most of the vulnerable crops produced on these farms. Increased precipitation is expected to cause increased erosion, especially in hand with the drought, as well as elevated runoff (Nearing et al, 2005). The unstable, dry ground will be unable to absorb water quickly enough since this increased precipitation is an abundance of rain within a short period.

IDW Crop Vulnerability Considering Precipitation Projections Between 2021-2040 in the Lower Mainland

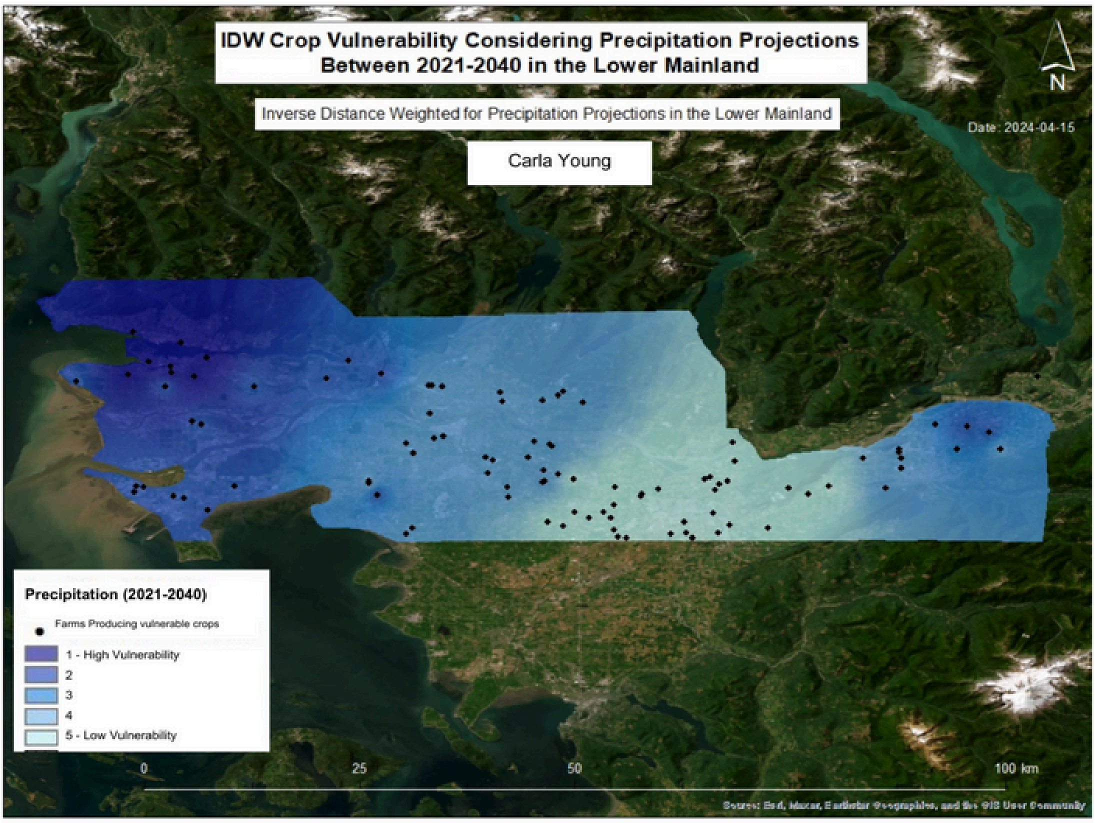

Figure 3. Map of % change for precipitation projections between 2021-2040 in the Lower Mainland.

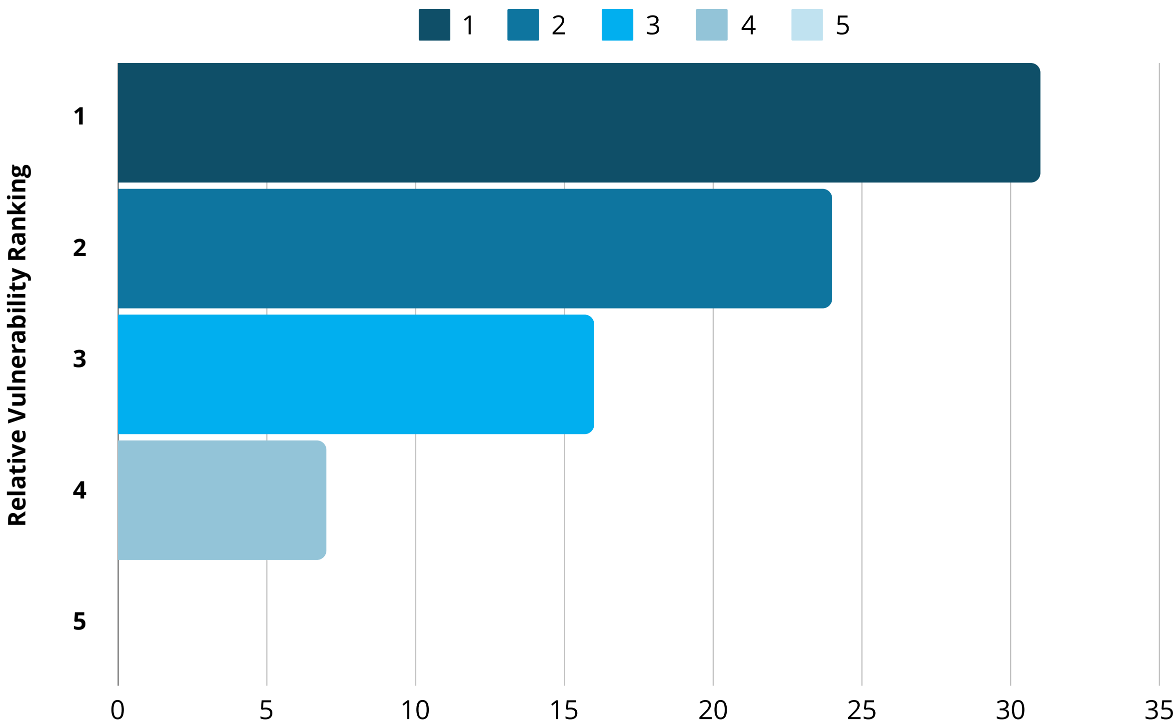

Figure 4. Graph of farms ranked 1-5 for projected precipitation changes. Rank 1 indicates that a farm was present on land with the highest relative vulnerability to increased precipitation under RCP 4.5 emissions scenarios, from 2021-2040.

IDW Crop Vulnerability Considering SPEI Projections Between 2021-2040 in the Lower Mainland

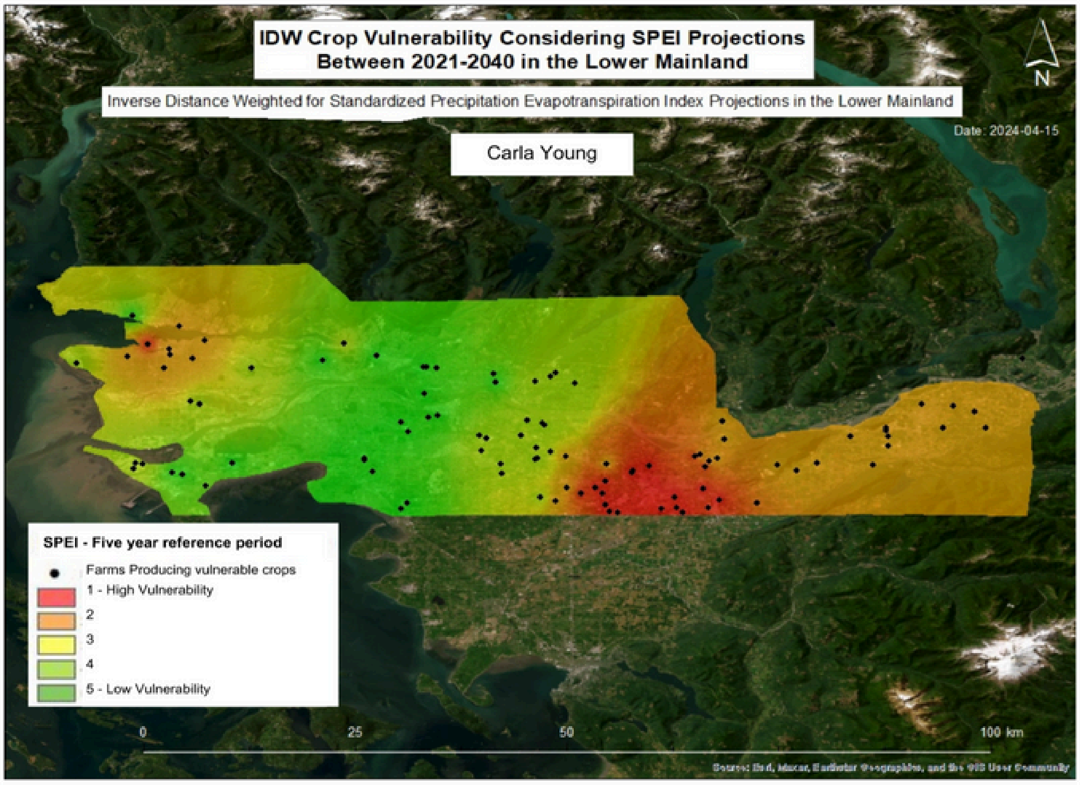

Figure 5. Map of SPEI projections between 2021-2040 in the Lower Mainland.

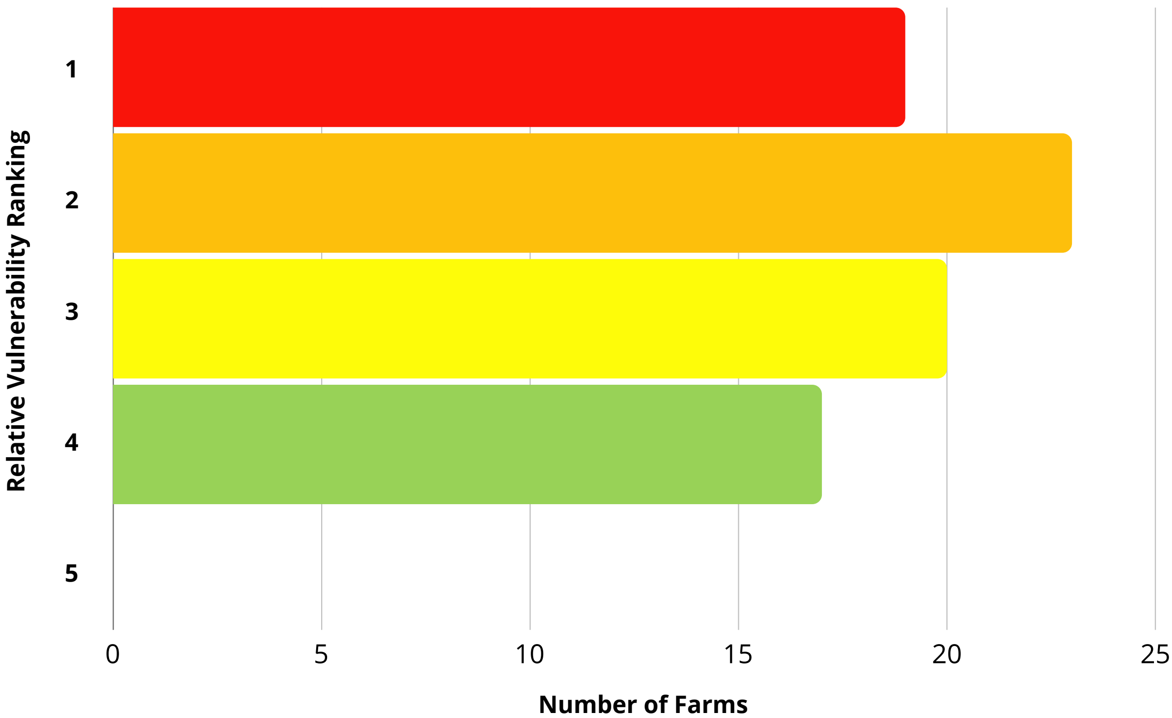

Figure 6. Graph of farms ranked 1-5 for SPEI Index. Rank 1 indicates that a farm was present on land with the highest relative vulnerability to soil moisture deficit, as of February 2024.

IDW Crop Vulnerability Considering Temperature Projections Between 2021-2040 in the Lower Mainland

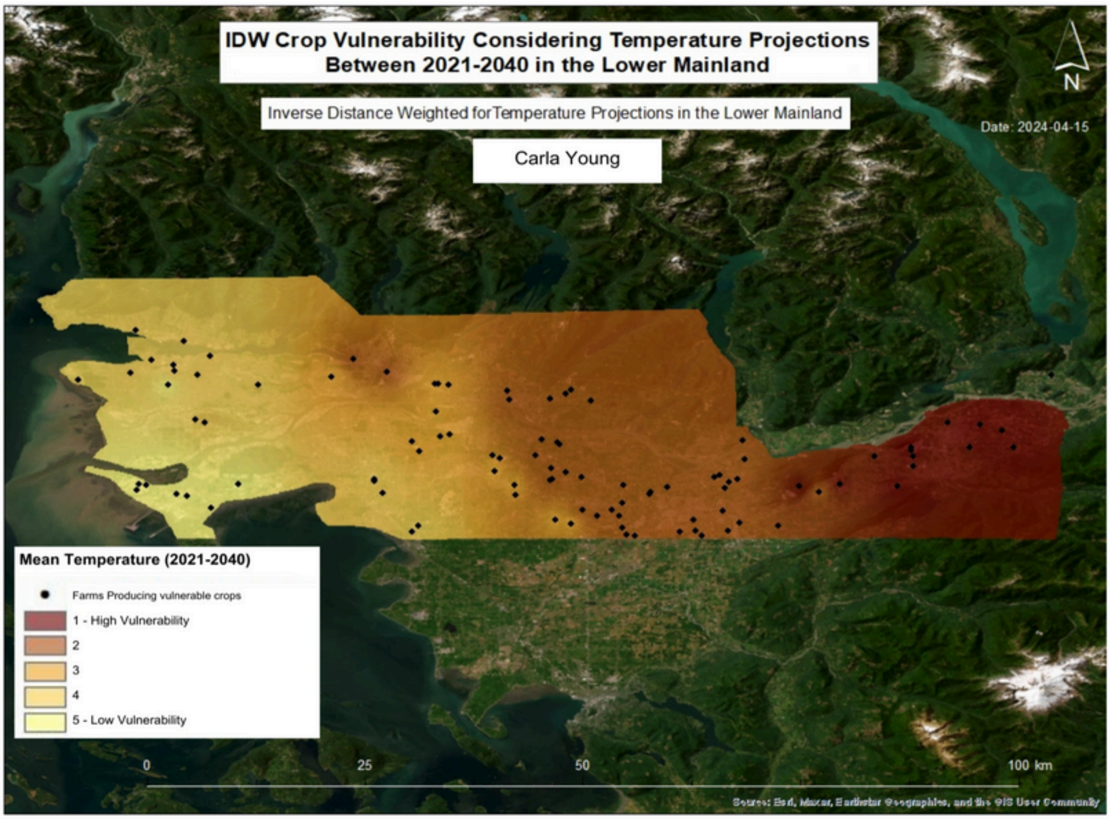

Figure 7. Map of mean temperature projections in degrees Celsius between 2021-2040 in the Lower Mainland.

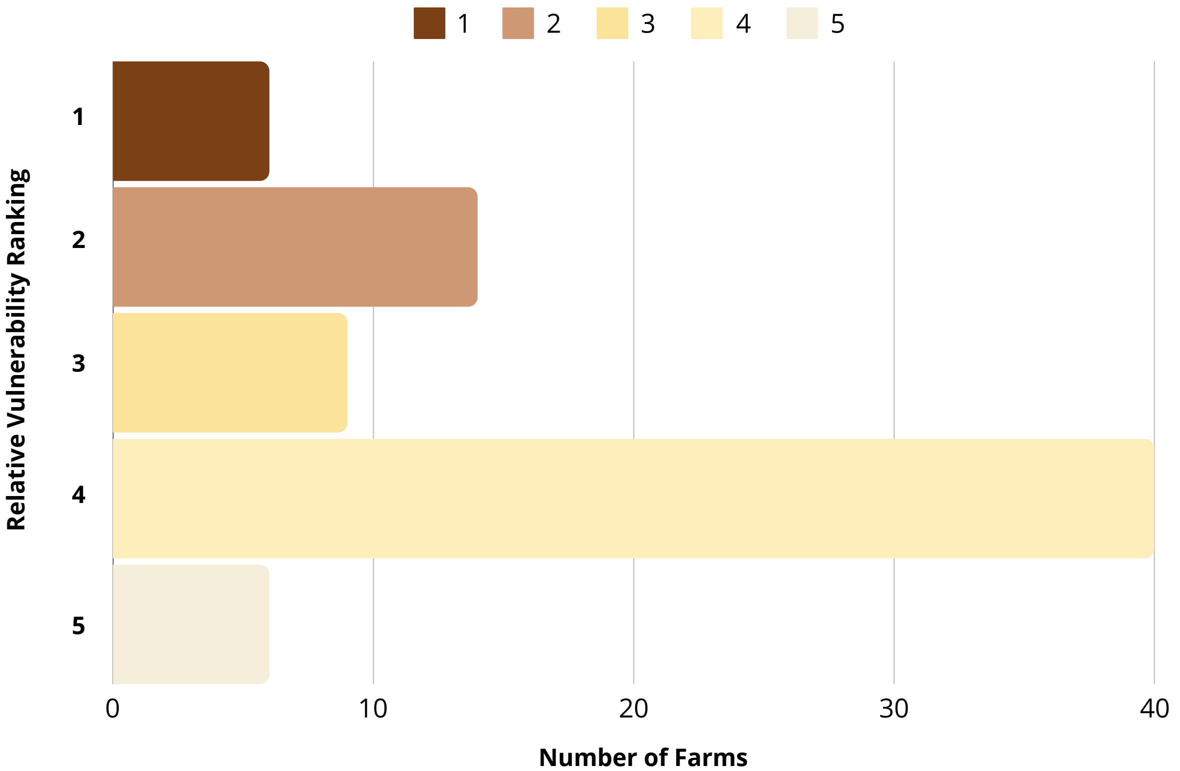

Figure 8. Graph of farms ranked 1-5 for projected mean temperature changes. Rank 1 indicates that a farm was present on land with the highest relative vulnerability to mean temperature changes under RCP 4.5 emissions scenarios, from 2021-2040.

RECCOMENDATIONS

According to the US Department of Agriculture, the adaptive capacity of lettuce surrounding temperature is considered moderate. This is measured through the analysis of Cole crops growing in California and their exposure, and sensitivity which ultimately predicts the adaptive capacity. Some suggestions to support the growth of lettuce is adjusting the planting and harvest times and using more efficient irrigation systems. Lettuce crops will not survive extreme frosts or wildfires and can withstand some pests but not all, especially if there are changes in pests including new invasives (USDA, 2015). Research suggests that warmer-than-average temperatures tended to improve lettuce crop yields between October and April, which are planting and harvesting times (USDA, 2015). Cabbage, British Columbia's second major imported crop from California is rated moderately adaptable, with suggestions to grow slightly north. Cabbage is at risk of easily being flooded; with climate change and the effects of pests are unknown, though invasive pests will likely have negative effects on the crop (USDA, 2015). Though there is some evidence that these crops are somewhat adaptable, major climate changes will alter the way they grow and potentially inhibit them from growing altogether if things become too extreme. It is key to adapt to the everchanging climate therefore discovering new growing methods will be necessary in supporting BC’s food system.

Although increased precipitation may not seem to directly impact greenhouses, it can still affect the entire region through a chain reaction within the system. Greenhouses that produce crops will feel the pressure from the farms that grow sensitive crops in open fields outdoors. In order to alleviate this pressure and ensure that essential crops are not in short supply, these greenhouses may have to increase their yields. One potential benefit of the increased precipitation for the farms located in the Lower Mainland is the use of this water for crop production. Water capture and storage systems could be built to collect the water and keep it onsite for irrigation and watering crops, indoors and outdoors. Farms that see an SPEI moisture deficit while receiving an abundance of short-term rain could benefit from this by developing a way to consistently water the crops with their stored water at a gradual rate, saving them costs by utilizing natural resources and reducing waste.

Future research could benefit from learning more about the complexity of the food systems and the relationship between Canada and the US. Additional considerations for future work include assessing risks and threats between greenhouse versus open field farms in the Lower Mainland. One limitation was the scale of the analysis since it was scoped to a small area in BC. The research would benefit from expanding to other regions rather than a single region. For example, the climate vulnerabilities that farmers are facing in the Okanagan are much different than the coastal issues farms are facing in Vancouver.

A final limitation is that this research did not quantitatively assess climate threats with respect to specific growing parameters, given that each of these crops will respond to increased rainfall, drought conditions, and temperature changes differently. Future research could assess and model the relationship between climate change threats and crop growing conditions for these specific crops in BC (similar to Mehrabi, 2023)

CONCLUSION

The results are clear that the changing climate conditions and increased extreme weather events both in British Columbia and California will pose challenges for food production in both regions. Since climate change is both a global and local concern, these changes are threatening the food supply in BC and the sustainability of the food system by impacting the capacity to cultivate and produce fruits and vegetables for import and export. The results indicate that lettuce is the top imported vegetable in BC, followed by cabbage, which is both grown and exported in California. California is currently facing environmental challenges such as extreme wildfires and droughts as well as the potential for severe flooding. These threats are anticipated to impact the lettuce and cabbage crops, which would likely lead to a supply disruption in BC.

Both lettuce and Cole crops are considered moderately adaptable, but may not withstand extreme changes in temperature, precipitation, pests, or flooding. Some studies show that changes such as planting, and harvest time can be adjusted to work with the changing temperatures and that some crops could be shifted further north. Moving towards other methods of growing such as vertical farming or adapting genomics technologies could help mitigate the pressures of the sensitive crops being affected by climate change. BC could also look at domestic growth rather than importing much of its produce or consider a new trading partner that is less affected by climate change and rising global temperatures like California. Another recommendation would be to spread awareness of BC's import and export and the food system makeup. The overall findings outline the tangible threats of climate change and how California and British Columbia are interlaced between their food systems through the import and export of food.

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