Institute for Sustainable Food Systems

Research Brief

From the Okanagan Bioregion Food System Project 2020

Modelling Current and Future Food Self-reliance of the Okanagan Bioregion

Authors

Wallapak Polsub[1]*
Caitlin Dorward[2]
Kent Mullinix[1]

[1] Institute for Sustainable Food Systems, Kwantlen Polytechnic University, Richmond, BC Canada

[2] Caitlin Dorward, Research Consultant, Vancouver, BC Canada

* corresponding author: wallapak.polasub@kpu.ca

Abstract

This technical report provides a summary of the Institute for Sustainable Food Systems' food self-reliance computational models and their application to the Okanagan bioregion, British Columbia (BC). The current food system and seven other future scenarios were selected and compared. These future scenarios reflect 'what-ifs' scenarios under different food system attributes. Results suggest that bioregional food self-reliance capacity can be affected by several key parameters such as a mix of crops and livestock produced, amount of agricultural land, diets and population size. The Okanagan bioregion's food self-reliance capacity could be substantially increased if agricultural land was allocated to produce food that is consumed by people in the bioregion. There was a small trade-off between food self-reliance capacity and excess production of tree fruits (such as apples and cherries) and wine grapes. This was due to the relatively small population size compared the total agricultural land area. Such theoretical exercises demonstrated in this study provide information about the implications and opportunities of food system regionalization and future food policy development.

Introduction

The Institute for Sustainable Food Systems (ISFS) developed a computational model to estimate regional food self-reliance through their work in the Southwest British Columbia Bioregion Food System Design Project (Southwest BC project) in 2016 (Mullinix et al., 2016; Dorward, Smukler & Mullinix, 2016). Upon the completion of the Southwest BC project, the ISFS furthered study of food system regionalization by working with stakeholders to conduct the Okanagan Bioregion Food System Project. The Okanagan bioregion was delineated as the regional district of North Okanagan, Regional District of Central Okanagan and Regional District of Okanagan-Similkameen (Robert et al., 2019). The project aimed to provide data-driven information on potential for increasing food production and processing for local markets, accrue economic benefits and reduce environmental impacts from food production in this region.

The optimization model calculates how much agricultural land should be allocated to produce different crop and livestock products to maximize Okanagan's bioregional food self-reliance.

This technical report summarizes and compares Okanagan bioregion's food self-reliance capacity in current food system (based on 2016 Census of Agriculture data) to that for seven 2050 future food system scenarios. Food self-reliance is one of many key indicators used to assess food system outcomes. It provides information about the capacity of the Okanagan to feed its population with food grown within the bioregion. The results illustrate how regional food self-reliance may be affected when other food system attributes change or other objectives are pursued. Measuring food self-reliance can help planners, policy makers, and food system advocates understand the relationship between local food supply capacity and amount of food demanded, and communicate effectively with the public the importance of local production and the regional agricultural land base.

Optimization modeling was employed in this study to determine how agricultural lands can be allocated to maximize Okanagan bioregion's food self-reliance. Optimization modelling is a common decision making tool used for identifying and evaluating preferred choices in complex systems such as water resource use and management, nutrition intervention programs, emissions reduction schemes and business production strategies (Sanders, Fadel & Wade, 2003; Lee & Haslenda, 2014; Vosti et al., 2015; Loucks & van Beek, 2017). In the context of food system analysis, several other studies have employed optimization technique to shed light on food supply and demand problems. A few of these studies are discussed below.

Monaco et al. (2016) used an optimization method to illustrate how different agricultural land use systems could satisfy staple food demand in Milan, Italy. In this study, food demand referred to the total amount of each staple food consumed (based on total calories needed) while food supply referred to production capacity given the amount of land available. The results suggested that the current agricultural system, which was focused on production of a few crops, could not meet the demand of other staple foods. However, agricultural land could be reallocated to satisfy food demand according to different "objectives". For example, to minimize the food demand and supply gap, areas in rice and fodder crops would have to be allocated to other crops such as fruit, vegetables and wheat. In vegetarian and vegan diet scenarios, the production of pulses would have had to increase 90 and 250 fold, respectively.

Dundar, Costello, & McGarvey (2017) used optimization modelling to identify the minimum amount of land required to satisfy population nutritional requirement in Boone County, Missouri, USA. The basic model suggested producing four food types (corn, eggs, milk and broccoli) to meet nutritional requirements. When a constraint was implemented such that the production of any single food could not exceed a specific portion of total production, the number of food types produced increased – and food with the highest yield per hectare was selected to be produced first. The study was a theoretical exercise and not meant to represent population' diets. Theoretical results suggested that given a relatively small population size, Boone County would be able to satisfy its population's nutritional requirement given the available land.

Põldaru, Viira, & Roots (2018) modelled Estonia's self-sufficiency in producing nine major food items (beef, pork, poultry meat, eggs, milk, cheese, butter, cereal products and potatoes). The model identified the minimal amount of arable land required to produce enough food to satisfy the population's daily food energy consumption and enough feed for livestock. In addition to modeling land use to achieve the self-sufficiency goal, the study sought to understand if the total arable land would allow Estonia to maintain their exportation of milk and increase exportation of dairy products. The results suggested that for Estonia to be self-sufficient in those nine food items about 70% of total arable land had to be in production. To increase exportation of dairy products and be self-sufficient in those food items, 90% of all arable land had to be in production.

Buschbeck et al. (2020) assessed regional food supply potential for the German Federal State of Baden-Württemberg. Using the multi-objective optimization technique, the model aimed to maximize food self-sufficiency level while simultaneously minimizing the environmental impacts under three different diet patterns – base (contemporary), vegetarian and vegan. The results showed the level of regional food self-sufficiency declined as additional environmental goals were met, illustrating the trade-off between food self-sufficiency and environmental impacts from food production. Comparing the three patterns, the vegan diet resulted in the highest level of self-sufficiency and lowest level of environmental impacts. Finally, the study also found that organic production practice could further minimize environmental impacts compared to conventional practice.

The study of food self-reliance potential presented in this technical report will contribute to the existing literature on agricultural land use modelling. Our study takes into account all food types consumed by the population in the Okanagan bioregion. However, self-reliance in livestock feed grain is not the focus of this study; and we allow for feed grain to be imported for livestock production.

Methods

This report compares the Okanagan bioregion's food self-reliance in 2016 to its potential capacity in 2050 if the bioregion's food system is regionalized and the projected population increase is realized. Regionalization refers to shifting regional production to prioritize satisfying bioregional food demand rather than serving export markets. Methodology and data used in this study follow those of the Southwest BC project and are summarized below.

Measuring food self-reliance

Food self-reliance measures the proportion of the population's diet that could be theoretically satisfied by locally produced food (see equation 1).

To explore food-self-reliance outcomes for the Okanagan bioregional food system, two

Equation 1:

$$\text{Food self-reliance (\%)} = \frac{\text{Total food production within the region (tonnes)}}{\text{Total food required by population (tonnes)}} \times 100$$

computational techniques were used to estimate current (2016) and future (2050) scenarios. In the first technique (a spreadsheet model created in Microsoft Excel [Microsoft Corporation, 2014]), future agricultural land use allocation followed 2016 agricultural land use patterns. In the second technique (optimization model created with Microsoft Excel (Microsoft Corporation, 2016) and OpenSolver (Mason, 2012, 2014), future agricultural land use was reallocated and prioritized to meet food need in the Okanagan bioregion, with maximizing regional food self-reliance as the optimization objective (goal).

A key feature of the optimization model is therefore that land is allocated to crops that satisfy the highest level of local food need possible. The underlying assumption in both models was that bioregional consumers choose to purchase locally produced food whenever available (that is, locally produced food is first sold to the local market, excess food produced above and beyond local food need is exported). When regional production cannot satisfy regional demand, importation of that food is necessary.

The optimization model calculates how much agricultural land should be allocated to produce different crop and livestock products to maximize Okanagan's bioregional food self-reliance. A more detailed explanation of our methodology for assessing food self-reliance can be found in Dorward, Smukler, and Mullinix (2016).

Data and assumptions

The total amount of each type of food produced in the Okanagan bioregion in 2016 was estimated using data from the 2016 Census of Agriculture (Statistics Canada, 2017). We assumed that these foods would still be produced in the bioregion at the same yields in 2050. For crop production, yield was calculated using 10-year average of BC yield, wherever possible, or of Canadian yield. For livestock production (meat, milk and egg), yield was calculated based on the total area required to house and produce feed for livestock from birth to slaughter and to house and produce feed for the breeding stock and/or replacement herds (Dorward, Smukler, & Mullinix 2016). We assumed typical livestock feeding regimes and that only hay, pasture, and barn requirements for livestock would be provided in the bioregion while feed grain and silage would be imported.

Total currently farmed area for food production in 2016 was assumed to be equal to the area used for agricultural production according to the 2016 Census of Agriculture (Statistics Canada, 2017). In 2050 scenarios where area for food production expanded, several spatial databases were used to identify the total arable land not currently used for farming but hypothetically available for future food production. The Agricultural Land Use Inventory database (Ministry of Agriculture, 2016) and the Provincial Agricultural Water Demand Model (van der Gulik, Nielsen, & Fretwell, 2010) were used to evaluate the maximum amount of arable land that can be expanded while taking into account irrigation access points. The Land Capability Classification for Agriculture in British Columbia database was also employed to estimate the proportion of lands in soil classes one to six, which are generally suitable for crop and livestock production (Government of British Columbia - Ministry of Agriculture and Food and Government of British Columbia - Ministry of Environment, 1983). Finally, the Okanagan Conservation Ranking Polygons database was utilized to assess critical wildlife habitats that should be kept as natural areas and not be cleared for any agricultural activities in order to maintain critical wildlife habitat necessary to achieve biodiversity and wildlife conservation objectives.

Population of the Okanagan bioregion in 2016, by gender and age groups, were extracted from the 2016 Census of Population (Statistics Canada, 2016). We used the geometric extrapolation method (Smith, Tayman, & Swanson 2013) and data from BC Stats to project that the population will grow from 360,000 people in 2016 to about 520,000 people in 2050, and modeled future food self-reliance capacity for a population of this size.

The total amount of food required by the Okanagan bioregional population (food need) is based on a diet that satisfies both nutritional recommendations and food preferences. This study utilizes the same methods as the Southwest BC Project to estimate food need by combining two datasets. The first is the Food Available in Canada database which tracks the stocks and flows of food commodities throughout the country (Statistics Canada, 2020). The second is Canada's Food Guide which provides nutrition recommendations for Canadians by age and gender (Health Canada, 2011)[1]. With these databases, we estimated the amount of the preferred diet consumed by an average Canadian for each age and gender group.

Trade data for agricultural products are not tracked at the bioregional scale, or in units pertinent to the study of food self-reliance (commodity weight). As such we had to assume that all food produced in Okanagan bioregion is first consumed within the bioregion. The list of all 121 food items modelled in this study is shown in Table 1.

Scenarios

Eight scenarios were modelled to explore food self-reliance potential in the Okanagan bioregion. These scenarios aim to facilitate "what-if" analyses of the Okanagan bioregional food system in 2050. They elucidate outcomes of different food system options, illustrate how different production and consumption choices can impact the region's food self-reliance, and are meant for illustrative, rather than predictive, purposes.

Population Growth in the Okanagan

Population of the Okanagan bioregion in 2016, by gender and age groups, were extracted from the 2016 Census of Population (Statistics Canada, 2016). We used the geometric extrapolation method (Smith, Tayman, & Swanson 2013) and data from BC Stats to project that the population will grow from 360,000 people in 2016 to about 520,000 people in 2050, and modeled future food self-reliance capacity for a population of this size.

1 *At the time of this report, detailed serving size recommendations base on the most recent Canada's food guide were not yet published*

Table 1: Modelled food items in this study, by food group

Fruits and Vegetables		
Apple, canned	Cauliflower, fresh	Pea, fresh
Apple, dried	Celery, fresh	Pea, frozen
Apple, fresh	Cherry, fresh	Peach, canned
Apple, frozen	Cherry, frozen	Peach, fresh
Apple, juice	Coconut, fresh	Pear, canned
Apple, pie filling	Corn, canned	Pear, canned
Apple, sauce	Corn, fresh	Pear, fresh
Apricot, canned	Corn, frozen	Pear, fresh
Apricot, fresh	Cranberry, fresh	Pepper, fresh
Asparagus, canned	Cucumber, fresh	Pineapple, canned
Asparagus, fresh	Date, fresh	Pineapple, fresh
Avocado, fresh	Fig, fresh	Pineapple, juice
Banana, fresh	Grape, fresh	Plum, fresh
Beans green & wax, canned	Grape, juice	Potato, frozen
Beans green & wax, fresh	Grapefruit, fresh	Potato, sweet, fresh
Beans green & wax, frozen	Grapefruit, juice	Potato, white, fresh
Beet, canned	Guava and Mango, fresh	Pumpkin and squash, fresh
Beet, fresh	Lemon, fresh	Radish, fresh
Blueberry, canned	Lemon, juice	Raspberry, frozen
Blueberry, fresh	Lettuce, fresh	Rutabaga & turnip, fresh
Blueberry, frozen	Lime, fresh	Spinach, fresh
Broccoli & Cauliflower, frozen	Manioc, fresh	Spinach, frozen
Broccoli, fresh	Mushroom, canned	Strawberry, canned
Brussels sprout, fresh	Mushroom, fresh	Strawberry, fresh
Brussels sprout, frozen	Onions and shallot, fresh	Strawberry, frozen
Cabbage, fresh	Orange, fresh	Tomato, canned
Carrot, canned	Orange, juice	Tomato, fresh
Carrot, fresh	Papaya, fresh	Tomato, juice
Carrot, frozen	Pea, canned	Tomato, pulp, paste, purée
Meat and Alternatives		
Baked and canned bean	Peanut	Egg
Chicken and Stewing hen	Turkey	Mutton and lamb
Lima bean	Beef and veal	Pork
Milk and Alternatives		
Buttermilk	Cheddar cheese	Chocolate drink
Concentrated skim milk	Concentrated whole milk	Cottage cheese
Partly skimmed milk 1%	Partly skimmed milk 2%	Processed cheese
Skim milk	Powder buttermilk	Powder skim milk
Standard milk 3.25%	Variety cheese	
Fats and Oils		
Butter	Oatmeal and rolled oat	Margarine
Shortening, shortening oil	Salad oils	
Grains		
Rye flour	Rice	Wheat flour
Corn flour and meal	Pot and pearl barley	

The first scenario (Food System 2016) was the only scenario modelling current food system capacity. All other scenarios modelled a hypothetical future in 2050, when population is assumed to increase by about 40%. In the 2050 scenarios, crop and livestock yields, land available for food production and dietary preferences are assumed to remain at 2016 levels unless otherwise noted.

- **Food System 2016**: Represents the current food self-reliance capacity of the contemporary food system in the Okanagan bioregion.
- **Business as Usual (BAU)**: Models a future in which the Okanagan food system continues to operate under the current dominant global food system, and therefore there are no changes from the Food System 2016 except for an increase in population.
- **Farmland Loss**: models a future in which the Okanagan food system continues to operate under the current dominant global food system, and 20% of currently farmed area is no longer available for food production. There are no changes in the types of food produced in the bioregion compared to the Food System 2016.

The final five scenarios present a different food system future in which the bioregional food system is regionalized. Food production is guided by the type and amount of food that the bioregion's population consumes. Regional markets are the food systems economic driver rather than export markets. The food system scenarios and their assumptions are summarized in Table 2

- **Regionalized Food Production**: models a future in which all available land is used to produce food that satisfies the bioregional population's food need – no exportation of food to other regions occurs.
- **Maintain Export Production (Maintain Exports)**: models a future in which land that was allocated to tree fruit and wine grape production in the Food System 2016 scenario is maintained to produce these crops for export markets and wine production. All remaining land is used to produced food that satisfies bioregional population's food need.
- **Change Diets**: models a future in which the population's consumption pattern is changed to follow the "planetary health" diet guidelines developed by the EAT Lancet Commission (Willett et al., 2019). Meat protein consumption is drastically reduced from the Food System 2016 diet and substituted with plant-based foods such as legumes, nuts and seeds. Whole grain, fruit and vegetable are the main sources of daily caloric requirements. Lands are only used to produce food that satisfies the bioregional population's food need – there is no exportation of food to other regions.
- **Expand Land in Food Production (Expand Land)**: models a future in which the area for food production can be expanded by clearing all natural areas where it is theoretically possible to irrigate. Lands are only used to produce food that satisfies the bioregional population's food need – there is no exportation of food to other regions.
- **Mitigate Habitat Impacts**: models a future in which the area for food production can be expanded by clearing some natural areas while maintaining critical wildlife habitats. Lands are only used to produce food that satisfies the bioregional population's food need – there is no exportation of food to other regions.

The food system scenarios and their assumptions are summarized in Table 2.

Results and discussions

Food System 2016

We estimated that food self-reliance in the Okanagan bioregion was 38%. That is, 38% of food that the Okanagan population consumed came from within the Okanagan bioregion, while the rest was imported. This estimate is likely to be an optimistic representation of the region's true food self-reliance. This is because accurate data on how much food is produced and consumed locally do not exist. The model, therefore, assumed that food produced in the Okanagan first served the local population. The amount exceeding the population's food need was then sold outside of the bioregion. As a result, modelled importation of food is likely smaller than what actually occurred.

Scenario	Modelling Technique	Regional Focus	Farmland Modelled (ha)	Proportion of Land Suitable for Crop vs Livestock Production (%)	Population (# of people)	Food Need (tonnes)
Food System 2016	Spreadsheet	No	40,000	85% : 15%	360,000	330,000
Business as Usual (BAU)	Spreadsheet	No	40,000	85% : 15%	520,000	480,000
Farmland loss	Spreadsheet	No	32,000	85% : 15%	520,000	480,000
Regionalized Food Production	Optimization	Yes	40,000	85% : 15%	520,000	480,000
Maintain Export Production	Optimization	Yes	40,000	85% : 15%	520,000	480,000
Change Diets	Optimization	Yes	40,000	85% : 15%	520,000	440,000
Expand Land in Food Production	Optimization	Yes	70,000	85% : 15%	520,000	480,000
Mitigate Habitat Impacts	Optimization	Yes	57,000	85% : 15%	520,000	480,000

Table 2: Summary of theoretical food system scenarios modelled in the Okanagan Bioregion Food System Project and select food system parameters.

Food self-reliance can also be calculated by food group: dairy, egg, fat and oil, fruit, grain, legume, poultry, red meat and vegetable (Figure 1). Results suggested that under the Food System 2016 scenario, the highest food self-reliance was in dairy (88%) and poultry (60%). Food self-reliance for fruits and vegetables was comparatively low (34% and 14% respectively) in part because the population's diet consists of foods that cannot be grown locally (e.g. bananas) and those that are eaten out of season (e.g. fresh strawberries in January). Based on the number of animals in the bioregion, area in grain production and dietary preference, the Okanagan had low food self-reliance in red meat (9%), egg (7%) and grain (5%). Finally, the bioregion did not have significant production in fat and oil crops and legume, as reflected in very small food self-reliance levels of 2% and 0.2% respectively.

Results in this scenario serve as a point of reference to help us understand the future capacity of the bioregion if and when the food system is configured differently.

Future Scenarios

The first two future scenarios (BAU and Farmland Loss) present a future where we continued to operate under the dominance of the global food supply chain while our population increased. The food self-reliance capacity of the Okanagan bioregion decreased from 38% to 33% in the BAU scenario (Figure 2). The bioregional food self-reliance capacity further declined to 28% if 8,000 hectares (20%) of current food land was lost to other competing activities (Farmland Loss scenario). Dependency on food imports is not uncommon and some level can be expected, necessary. However, reduced food self-reliance capacity implies that more food imports are required. The Okanagan bioregional food system would be at risk from several exogenous factors such as foreign trade policies, world energy price volatility, climate change impacts in exporting countries and global epidemics for example. With limited farmland, competing interest in farmland usage, concerns for local economic development and environmental stewardship, it is important to reimagine a different path for the Okanagan food system and evaluate its food self-reliance capacity. Such information could assist food system actors plan for a preferred future.

The next five scenarios illustrate different paths in a regionalized food system in which as much food as possible is produced to satisfy local demand.

The Regionalized Food Production scenario revealed that without expanding farmed area, the bioregion would still be able to increase its food self-reliance to 69% if crop and livestock land areas were allocated per a regional food satisfaction focus. In this scenario, there were no lands allocated to produce crop/livestock products to supply markets outside of the bioregion.

Food Self-reliance for the Okanagan Bioregion, 2016

Percentage of local diet satisfied by locally produced food for the population in 2016

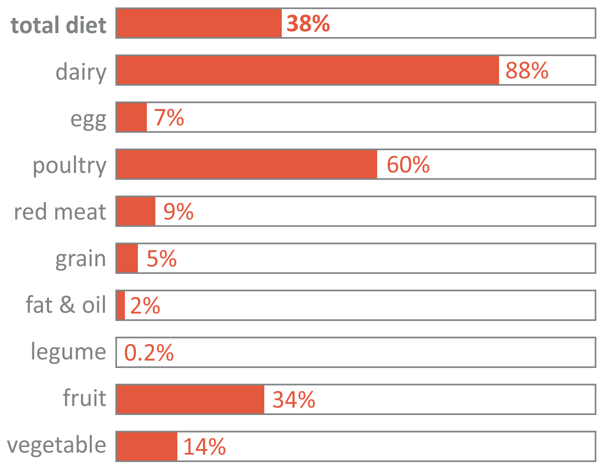


Figure 1: Food self-reliance by food group and total diet for the Okanagan bioregion, 2016

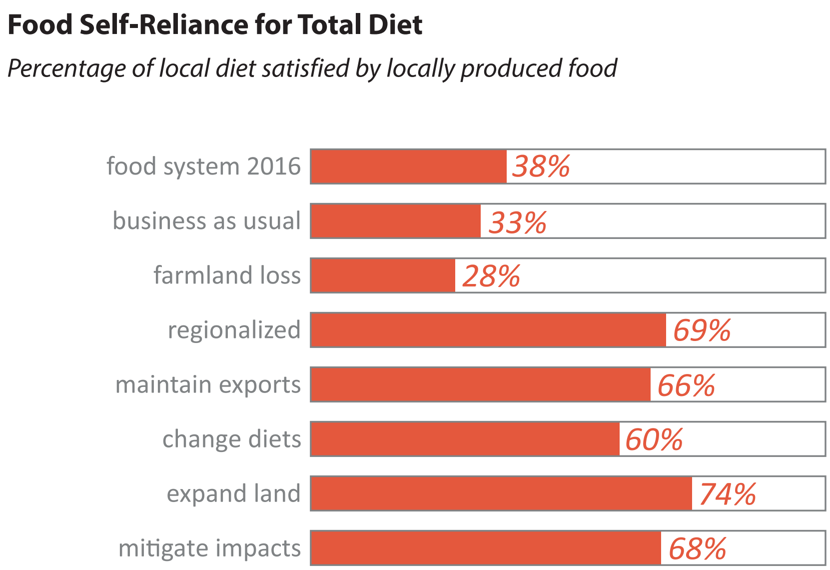
In the Maintain Exports scenario, about 8,500 hectares (21% of currently farmed area) of land were maintained for the production of apple, sweet cherry and wine grape – important crops for export markets and wine production (non-food product). When the food system had a regional focus, even with 21% of farmed area devoted as such, the food self-reliance capacity in this scenario was still estimated at 66%. Compared to the Regionalized Food Production scenario, results imply that when lands were used to produced crops which did not serve the local population's food need (apple and sweet cherry for exports and grape for wine production), the bioregional food self-reliance capacity declined somewhat (3%). However, positive economic tradeoffs can be realized in this scenario. Detailed analysis of economic impacts from different food system scenarios can be found in Wijekoon et al. (2021).

The Change Diets scenario assumed that the bioregional population switched from the current preferred diet to a diet outlined in Willett et al. (2019) which was designed to benefit both human and environmental health. In this scenario, food production focused on serving the population's 'sustainable' food need. There was no exportation of food, and the amount of farmed area remained the same as the Food System 2016 year. Food self-reliance was estimated at 60%. The main reason why the level of food self-reliance in this scenario was lower compared to the Regionalized Food Production scenario was because currently the Okanagan bioregion does not have much capacity to produce plant based protein (partly due to the lower level of yield per hectare). As such if the bioregion's population consumes more plant-based protein and less animal protein, the bioregion will have to import those products. As a result, food self-reliance became smaller. Of course in all scenarios we assume animal feed is imported.

Finally, the Expand Land and Mitigate Habitat Impacts scenarios presented futures in which additional lands were put into food production. In the Expand Land scenario, an additional 30,000 hectares of natural land would be cleared and prepared to use for food production, bringing the total area to about 70,000 hectares. Bioregional food self-reliance was estimated at 74% with all additional areas were used for food production. Compared to other scenarios, this scenario presented the highest level food self-reliance capacity given food system parameters as discussed in this report.

Mitigate Habitat Impacts scenario presented a future in which food production coexisted with natural areas which are important wildlife habitats and provide other ecosystem services such as carbon storage, nutrient cycling, and recreational opportunity. In this scenario, some natural areas would be cleared and prepared for food production while critical wildlife habitat areas are identified and conserved. Parts of existing farmed areas would also be dedicated to hedgerows and riparian buffers along all waterways. Detailed description of the method and data can be

Figure 2: Food self-reliance capacity for the Okanagan bioregion in 2050 comparing across all scenarios



found in Rallings (2021). As a result, about 57,000 hectares of lands would be utilized for food production. Food self-reliance was estimated at 72%.

Theoretical future food self-reliance by food groups

In addition to food self-reliance calculated based on the total diet, we can also estimate food self-reliance for each food group using equation 1. In the BAU and Farmland Loss scenarios, the amount of food produced in the bioregion was determined based on what was actually grown in the Food System 2016. In contrast, in a future where the Okanagan bioregional food system was regionalized, land would be allocated differently from the Food System 2016. Mathematically, the optimization modelling technique (employed in Regionalized food production, Maintain Exports, Change Diets, Expand Land and Mitigate Habitat impacts scenarios) identified the best possible way to achieve the best outcome under given constraints. In our case, the model allocated land to grow and raise different crops and livestock in such a way that returned the highest level of food self-reliance given various food system parameters such as crop and livestock yield, land area and population size. Theoretically, the land allocation strategy is predicated upon yield (tonnes per hectare of crop/livestock products). Those crop or livestock products with higher yields were selected to be produced first to satisfy the population's food need, reflecting efficiency in land use decisions. In this way, the model illustrates the bioregion's potential rather than real world decision making.

Table 3 illustrates food self-reliance by food group in each food system scenario. If we do not change the way that our food system operates, the bioregion's food self-reliance capacity decreases in the BAU scenario for every food group due to the pressure of an increased population's food demand. Future food self-reliance capacity declines even further when agricultural land availability is reduced. When the food system was regionalized, given the same amount of land (Regionalized Food Production scenario), poultry and egg productions have the highest potential in term of satisfying the population's need. The main reason for this is because the land requirements for the production of poultry meat and eggs is minimal as it does not require grazing land, and takes advantage of imported grain feed. Increased food self-reliance of red meat was predicated upon the production of pork which shares these same production characteristics. Theoretically, food self-reliance capacity in grain and vegetable could be increased significantly were land reallocated away from other products such as hay and fruits grown for export markets.

In all regionalized food system scenarios, food self-reliance for all food groups was higher than the BAU scenario, emphasizing that the bioregion has the theoretical capacity to feed its own population to a greater degree than it does currently. For certain food groups, food self-reliance would never reach 100% (self-sufficient level) due to dietary preference and growing season. This topic is explained further in the next section.

Theoretical maximal food self-reliance

Given the Okanagan bioregion's agricultural climate and soils, and the population's dietary preferences, the hypothetical maximum level of food self-reliance that the Okanagan bioregion could ever achieve is 77%. The total amount of land needed for this level of food production is 115,000 hectares.

If we assume that the Okanagan bioregion had a 12-month growing season, the theoretical maximum food self-reliance would reach 85% with about 118,000 hectares needed for food production. Finally, if we further assumed that bioregional population did not consume food that could not be produced within the bioregion and only consumed food which were available in their seasons of production (i.e. no strawberries in January), the bioregion would be completely self-sufficient (100% food self-reliant) if 118,000 hectares of land were used for food production. This theoretical exercise aims only to illustrate the maximum capacity of the Okanagan bioregion and how food self-reliance may change if various food system parameters change. It is not intended to suggest best dietary choices for the population.

Theoretical relationship between food self-reliance and land availability

Based on the optimization model developed by the ISFS and used for this study, we found that the Okanagan bioregion could be 69% food self-reliant in 2050 even if no additional land was utilized. This could be achieved if, and only if, food was produced to satisfy the local population's dietary need first. Land would have to be allocated differently from how it was in 2016. Exportation of food outside of the bioregion contracts. Assuming that these conditions hold true, this section discusses the theoretical relationship between the amount of land available for food production and food self-reliance capacity of the study region.

Given the same population level, the more land there is the higher level of food self-reliance can be achieved but at a diminishing rate as shown in Figure 3. The relationship between food self-reliance and land used in food production is not linear. The slope of the curve representing this relationship is steepest closest to the Y axis when there is a smaller amount of land in production. That is, an additional increase in land would contribute to a higher level of food self-reliance if the bioregion has not utilized much land for food production. However, when the bioregion has utilized the majority of its land for food production, an additional increase in land would result in

Table 3: Food self-reliance by food groups for all scenarios

	Food System 2016	BAU	Farmland Loss	Regionalized Food Production	Maintain Exports	Change Diets	Expand Land	Mitigate Habitat Impacts
Dairy	88%	76%	62%	92%	82%	85%	100%	100%
Egg	7%	5%	4%	100%	100%	100%	100%	100%
Fat and oil	2%	2%	1%	0%	0%	0%	100%	55%
Fruit	34%	33%	33%	37%	37%	37%	37%	37%
Grain	5%	4%	3%	87%	87%	87%	90%	90%
Legume	0.2%	0.1%	0.1%	19%	19%	19%	19%	19%
Red meat	9%	6%	5%	43%	43%	43%	52%	43%
Poultry	60%	41%	33%	100%	100%	100%	100%	100%
Vegetable	14%	10%	9%	68%	68%	57%	68%	68%

a smaller proportional increase in food self-reliance. Eventually, no amount of land would be able to increase food self-reliance capacity as the bioregion reaches its food self-reliance maximum (unless other parameters change as explained in the previous section). As shown in Figure 3, the first 10,000 hectares increase food self-reliance from 0 to 43%. However, when the bioregion utilized 40,000 hectares for food production, an additional 10,000 hectares would only increase food self-reliance by 2%, from 69% to 71%.

This relationship presents an important implication on food land conservation. If land that is currently utilized for food production slowly gets converted to non-food crop or non-agricultural purposes, we may see negligible impacts on food production at the beginning. This may lead us to support of such conversion for greater, immediate economic gains. However, if we let the conversion continue, we may reach a critical level where bioregional food supply capacity will be substantially threatened.

Theoretical relationship between food self-reliance and population size

The size of the population can impact the bioregional food self-reliance capacity. Up until now we have assumed that the population of the Okanagan bioregion in 2050 increases by about 40% from the 2016 level. Table 4 illustrates two examples of food self-reliance level if the population increased at a different rate than what was forecast.

In the third column (Regionalized Food Production scenario), population was assumed to increase by 40% from 360,000 to 520,000. Food self-reliance capacity of the total diet was estimated at 69%. In the second column, the increase in population was smaller (20% increase). In this scenario, food self-reliance capacity was estimated at 71%. In the forth column, population was assumed to increase by about 80%. In this scenario, food self-reliance capacity was estimated at 57%. The results suggest that, given the same amount of land available for food production, smaller population size implies that the region will be able to serve more of the population's food need. While this relationship seems intuitive it does serve to illustrate the often forgotten relationship between population, demand and resource capacity. For our sustainable future all three must be in balance.

Theoretical Relationship between Food Self-reliance and Land Availability in the Okanagan Bioregion

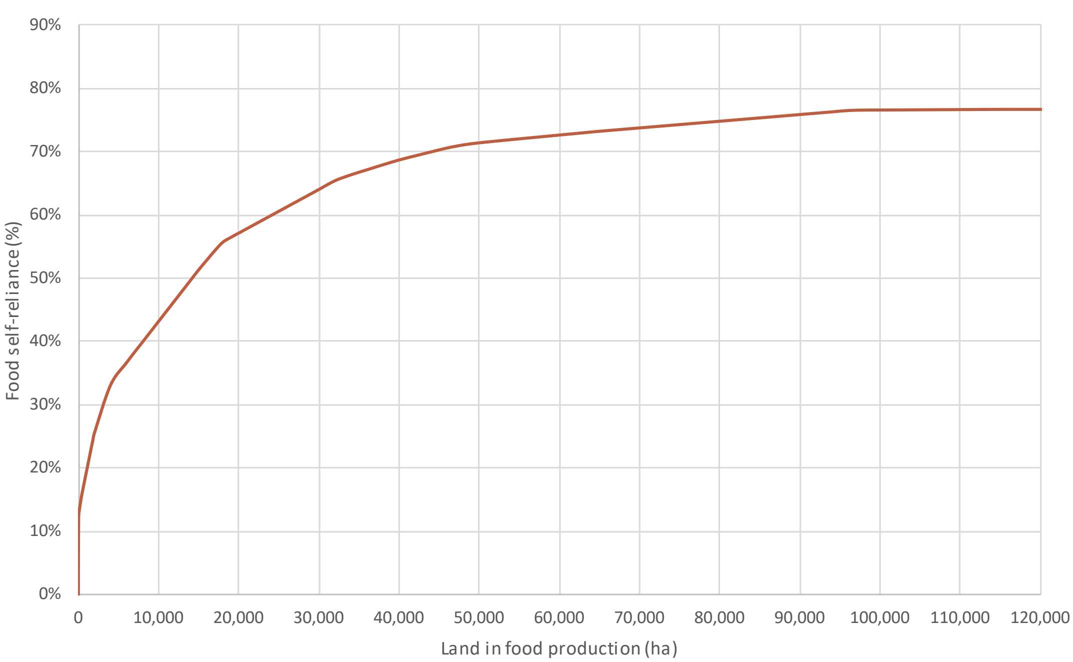


Figure 3: Theoretical relationship between food self-reliance and land availability in the Okanagan bioregion given 2050 population

	Population increased by 20%	Population increased by 40%	Population increased by 80%
Population size in 2050 (# of people)	430,000	520,000	1,000,000
Land in food production (ha)	40,000	40,000	40,000
Food self-reliance (%)	71%	69%	57%

Table 4: Theoretical food self-reliance capacity under different rate of population increase

Conclusion

This report explores food self-reliance capacity of the Okanagan bioregion under different food system scenarios. Scenarios are divided into two food system environments. The first portrays the food system in which the current global food system dominates. The second depicts an alternate food system environment in which food is largely produced, processed and consumed within the Okanagan bioregion - representing the food system regionalization concept. Food self-reliance results shown in this report are theoretical examples of food system outcomes given various food system parameters within the Okanagan bioregion context. These examples highlight the following three key points.

First, the Okanagan bioregion can increase its food self-reliance without expanding agricultural land base. To do so, agricultural land has to be allocated differently with a priority in producing food according to the population's food need. This means putting more emphasis on expanding local markets rather than export markets. As such, it may result in a trade-off between economic outcomes and bioregional food self-reliance (Wijekoon et al., 2021). The implications of land reallocation for various agricultural sectors are not discussed in this report but are important considerations for future food system planning.

Second, agricultural land availability is positively correlated with food self-reliance capacity. Reduction in agricultural land translates to decreased capacity of the bioregion to feed its own populace. Currently, given the population size and agricultural land availability, the Okanagan bioregion could nearly attain a theoretical maximum level of food self-reliance if under-utilized agricultural land were in production. Utilizing additional land (not currently in production) often implies clearing natural areas, losing critical wildlife habitat areas and reduction in ecosystem services (Rallings, 2021). This suggests a trade-off between natural area and its associated benefits and bioregional food self-reliance. Therefore, agricultural land should be managed accordingly to ensure that it is protected, used for food production and strategically conserved as natural habitats.

Third, food preference and diet choice can play an important role in limiting or expanding bioregional food self-reliance capacity. If the population chose to consume only food that cannot be produced in the bioregion it would be impossible to satisfy the population's food need no matter how much agricultural land exists. These parameters represent the demand side of the food system. Though not discussed in detail in this report, diet patterns can result in immense environmental impacts in the food systems (Harder, 2021; Sussmann, Kissinger & Mullinix, 2016). Adjustment in food preference and diets, through education and increased awareness, can potentially increase food self-reliance and simultaneously minimize negative impacts from food production.

These theoretical exercises illustrate Okanagan bioregion's production capacity and what could be possible under different conditions. This report, however, focuses on food self-reliance as a sole food system objective. To better understand trade-offs between food self-reliance, economic impacts, and environmental outcomes, further information can be found in the report Bringing our Food System Home: Report on the Okanagan Bioregion Food System Project (Mullinix et al., 2021).

Suggested Citation

Polasub, W., C. Dorward, & K. Mullinix. (2020). Modelling Current and Future Food Self-reliance of the Okanagan Bioregion. Research Brief from the Okanagan Bioregion Food System Project. Richmond, British Columbia: Institute for Sustainable Food Systems, Kwantlen Polytechnic University.

References

Buschbeck, C., Bitterich, L., Hauenstein, C., & Pualiuk, S. (2020). Multi-objective optimization identifies trade-offs between self-sufficiency and environmental impacts of regional agriculture in Baden-Württemberg, Germany. Journal of Agriculture, Food Systems, and Community Development. 10(1): 43-62.

Dorward, C., Smukler, S., & Mullinix, K. (2017). A novel methodology to assess land-based food self-reliance in the Southwest British Columbia bioregion. Renewable Agriculture and Food Systems. 32(2): 112-130.

Dundar, B., Costello, C., & McGarvey, R.G. (2017). Robust optimization evaluation of reliance on locally produced foods. Environment Systems and Decisions. 37: 34–41.

Harder, R., Smukler, S., & Mullinix, K. (2021). Nutrient Management in Okanagan Bioregion. Research brief from the Okanagan Bioregion Food System Project. Richmond, British Columbia: Institute for Sustainable Food Systems. Kwantlen Polytechnic University.

Health Canada. (2011). Eating well with Canada's food guide. Ottawa, Ontario, Canada.

Lee, M.Y., & Haslenda, H. (2014). Modelling and optimization of CO_2 abatement strategies. Journal of Cleaner Production. 71: 40-47.

Loucks D.P., & van Beek E. (2017) An Introduction to optimization models and methods. In: Water Resource Systems Planning and Management. Springer, Cham.

Mason, Andrew. (2012). "OpenSolver - An open source add-in to solve linear and integer programmes in Excel." In D, Klatte, H., Lüthi, & K. Schmedders (Eds.). Operations Research Proceedings 2011 (401-406). Springer: Berlin Heidelberg.

Mason, Andrew. (2014). "OpenSolver for Excel."

Microsoft Corporation. (2016). "Microsoft Excel."

Ministry of Agriculture, Strengthening Farming Program. (2016) Agricultural land use inventory GIS files for Regional District of North Okanagan, Regional Districts of Central Okanagan and Regional Districts of Okanagan-Similkameen. British Columbia, Canada.

Ministry of Forests, Lands, Natural Resource Operations and Rural Development [FLNRORD]. (2020). Okanagan conservation ranking polygons. Thompson-Okanagan, British Columbia, Canada. https://catalogue.data.gov.bc.ca/dataset/okanagan-conservation-ranking-polygons

Monaco, F., Sali, G., Mazzocchi, C., & Corsi, S. (2016). Optimizing agricultural land use options for complying with food demand: evidence from linear programming in a metropolitan area. AESTIMUM. 68: 45-59. doi:10.13128/Aestimum-18725.

Mullinix, K., Tatebe, K., Hansen, E., Robert, N., Wijekoon, M., Polasub, W., Smukler, S., Harder, R., Rallings, A., Elton, C., Senese, D., Dorward, C. & Kissinger, M. (2021). Bringing Our Food System Home: Report on the Okanagan Bioregion Food System Project. Richmond, British Columbia: Institute for Sustainable Food Systems, Kwantlen Polytechnic University.

Oléron-Evans, T.P., & Salhab, M. (2020) Optimal land use allocation for the Heathrow Opportunity Area using multi-objective linear programming. UCL Working Papers Series. Paper 219 – April 20. University College London. UK.

Põldaru, R., Viira, A. H., & Roots, J. (2018). Optimization of arable land use to guarantee food security in Estonia. Agronomy Research. 16(4): 1837-1853.

Rallings, A. (2021). Impacts of Agricultural Production on Wildlife and Biodiversity in the Okanagan Bioregion. Research brief from the Okanagan Bioregion Food System Project. Richmond, British Columbia: Institute for Sustainable Food Systems. Kwantlen Polytechnic University.

Robert, N., Garcia, G., Tatebe, K., & Mullinix, K. (2019). Delineating the Okanagan bioregion for food system study. Research brief from the Okanagan Bioregion Food System Project. Economic Richmond, British Columbia: Institute for Sustainable Food Systems, Kwantlen Polytechnic University.

Sanders, B.J., Fadel, J.G., & Wade, E.M. (2003). Economic optimization modeling of white sturgeon (Acipenser transmontanus) caviar and meat production under different management conditions, Aquaculture. 217(1–4): 409-430,

Smith, S.K., Tayman, J., & Swanson, D.A. (2013). A practitioner's guide to state and local population projections. Springer.

Statistics Canada. (2016). Census of population. Statistics Canada Catalogue no. 98-400-X2016001.

Statistics Canada. (2017). 2016 Census of Agriculture. https://www150.statcan.gc.ca/n1/daily-quotidien/170510/dq170510a-cansim-eng.htm

Statistics Canada. (2020). Table 32-10-0054-01 Food available in Canada. https://doi.org/10.25318/3210005401-eng

Sussmann, C., Kissinger, M., & Mullinix, K. (2016). The Ecological footprint of food consumption in a regionalized food system. Research brief from the Southwest BC Bioregion Food System Design Project. Richmond, British Columbia: Institute for Sustainable Food Systems. Kwantlen Polytechnic University.

van der Gulik, T., Neilsen, D., & Fretwell, R. (2010). Agricultural Water Demand Model Report for the Okanagan Bain. https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/agricultural-land-and-environment/water/water-management/agriculture-water-demand-model

Vosti S.A., Kagin J., Engle-Stone R., & Brown K.H. (2015). An Economic Optimization Model for Improving the Efficiency of Vitamin A Interventions: An Application to Young Children in Cameroon. Food and Nutrition Bulletin. 36(3_suppl):S193-S207.

Wijekoon, M., Polasub, W., & Mullinix, K. (2021). Economic impacts of a regionalized food system in the Okanagan bioregion. Research brief from the Okanagan Bioregion Food System Project. Economic Richmond, British Columbia: Institute for Sustainable Food Systems, Kwantlen Polytechnic University.

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., ..., & Murray, C. (2019). Food in the Anthoropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. Lencet. 393:447-492.

About the Institute for Sustainable Food Systems

The Institute for Sustainable Food Systems (ISFS) is an applied research and extension unit at Kwantlen Polytechnic University that investigates and supports sustainable agriculture and regional food systems as key elements of sustainable communities. We focus predominantly on British Columbia but also extend our programming to other regions.

Our applied research focuses on the potential of regional food systems in terms of agriculture and food, economics, community health, policy, and environmental integrity. Our extension programming provides information and support for farmers, communities, business, policy makers, and others. Community collaboration is central to our approach.

About the Okanagan Bioregion Food System Project

Communities and governments are increasingly looking to strengthen regional food systems as a way to address many complex agriculture and food challenges. The Okanagan Bioregion Food System Project explores the social, economic, and ecological outcomes of a regional food system in the Okanagan. This multidisciplinary research project, initiated by ISFS and regional partners, can guide conversations among communities and decision-makers seeking to advance their regional food system.

The Okanagan Bioregion Food System Project considers and builds upon existing food system planning and other related work to support local and regional food systems in the bioregion.

For the full report and more research briefs visit: www.kpu.ca/isfs/okanagan-bioregion

Project Funders

real estate foundation BRITISH COLUMBIA

REGIONAL DISTRICT RDOS OKANAGAN-SIMILKAMEEN

CENTRAL OKANAGAN FOUNDATION empowering generations to give.

Interior Health Every person matters

Canada Green Corps | Brigade verte du Canada

REGIONAL DISTRICT NORTH OKANAGAN

KPU