Institute for Sustainable Food Systems

Research Brief

From the Southwest BC Bioregion Food System Design Project

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Modeling Future Capacity for Food Self-Reliance in a Regionalized Food System

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Abstract

In this research brief we describe the methodology and model developed in the Southwest BC Bioregion Food System Design Project to assess the food self-reliance, economic, and environmental potentials of regionalized food systems. We describe the model's input datasets and present the results of modeling food self-reliance capacity in the year 2050 under changing agricultural land availability and crop yield and with "environmental enhancements" imposed to mitigate some negative environmental impacts of agriculture. Model results demonstrate that there is capacity to increase food self-reliance in the Southwest BC Bioregion (Southwest BC) even with population growth and the imposition of environmental enhancements, and that land availability has a greater impact on food self-reliance capacity than does crop yield change.

Food security experts have suggested that increasing food self-reliance is a key climate change adaptation strategy for British Columbia

Background

In response to concerns regarding the capacity of the global food system to meet human nutrition needs in the future, the research community has developed a variety of models and scenario analyses to assess current and future food system capacity (McCalla & Revoredo, 2001; Reilly & Willenbockel, 2010). Such studies have fostered widespread recognition that food systems must evolve in the face of threats such as climate change, population growth, changing diet, and loss of agricultural lands. Some advocate that this evolution should focus on food system regionalization and increased regional food self-reliance (the ability to satisfy food needs with food grown locally) (Dorward, Smukler, & Mullinix, 2016).

In the area known as the Southwest British Columbia Bioregion (located in the southwest mainland corner of British Columbia, Canada) (Harris, Nixon, Newman, & Mullinix, 2016), a growing segment of the population ascribes to this notion (Dorward et al., 2016). Food security experts have suggested that increasing food self-reliance here is a key climate change adaptation strategy (Mansfield, 2014; Ostry, Miewald, & Beveridge, 2011) and others have suggested that the region's extensive underutilized agricultural land could contribute greatly to improved food self-reliance (Mullinix et al., 2013). Despite this, the capacity to increase food self-reliance in this region has never been documented and the potential environmental and economic impacts of doing so are not understood.

Given this context, it was the objective of the Southwest BC Bioregion Food System Design Project to model a regionalized food system in Southwest BC under potential changes in yield (as influenced by climate change), increases to the amount of land farmed, and with various measures to reduce the negative environmental impacts of food production. Using this model, we measured the food self-reliance, economic, and environmental potentials of such a regionalized system in the year 2050. In this research brief we report on the model developed and results, with a particular focus on food self-reliance. The 2011 food self-reliance status of Southwest BC, reported on in (Dorward et al., 2016) provide a suitable baseline against which the 2050 model results are compared. Other research briefs report on the environmental and economic outcomes modeled in this study.

Methods

We wanted to determine our capacity for food self-reliance in 2050 and estimate the level of food self-reliance that could achieved if we shifted from using our agricultural land from the crop and livestock mix that we grow today, to a regionalized system in which we prioritize the production of crop and livestock products that meet food need in the bioregion.

Measuring Food Self-Reliance

At its simplest, food self-reliance measures the amount of a population's diet that could theoretically be satisfied by locally produced food by comparing the quantity and types of food consumed in a region to that is produced there. This comparison is done by food type and the results summed to determine food self-reliance for the total diet (Equation 1).

Equation 1

$$Total\ Dietary\ Food\ Self\ Reliance = \sum_{all\ consumed\ foods} \frac{Tonnes\ Produced}{Tonnes\ Consumed}$$

Modeling Land Use

To explore the outcome of and options for regionalizing the Southwest BC food system in the future, we developed two computational models to estimate current (2011) and future (2050) food production, food self-reliance, environmental impacts, and economic outcomes of various scenarios. The models employed two different calculation techniques based on agricultural land use allocation. In the first model (a spreadsheet model created in Microsoft Excel (Microsoft Corporation 2014)), future agricultural land use allocation followed 2011 agricultural land use patterns. In the second model (optimization model created with Microsoft Excel (Microsoft Corporation 2014) and OpenSolver (Mason 2012, 2014)), future agricultural land use was reallocated and prioritized to meet food need in Southwest BC, with maximizing Southwest BC food self-reliance as a 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 is for exportation). When regional production cannot satisfy regional demand, importation of that food is necessary.

In both models, the food self-reliance achieved was calculated using Equation 1. The models shared input datasets on food need, population, farmland availability and quality, crop yield, and land requirements for livestock, all of which are described in this research brief. They also shared datasets related to the environmental and economic impacts of food production. These datasets and associated results are described in other reports from the Southwest BC Bioregion Food System Design Project (Mullinix et al. 2016; Polasub, Chiu, and Mullinix 2016; Smukler 2016; Sussmann, Kissinger, and Mullinix 2016; Sussmann, Kissinger, et al. 2016).

Food Need

We estimated capacity for self-reliance in a diet that satisfies nutritional recommendations (according to Canada's Food Guide (Health Canada 2011)) and food preferences (according to a Statistics Canada dataset (Statistics Canada 2011)). It includes foods that are or can be produced in Southwest BC (e.g., apples, carrots) and those that must be imported (e.g., bananas, mangoes). We assumed that all crops and livestock products in the diet are consumed year round.

Population

Southwest BC is comprised of a densely populated urban zone (Greater Vancouver Regional District) surrounded by more sparsely populated peri-urban and rural areas (Fraser Valley, Squamish Lillooet, Sunshine Coast, and Powell River Regional Districts). Cumulatively, the region is expected to experience significant population growth over the coming decades. We used the geometric extrapolation method (GOE) (Smith, Tayman, and Swanson 2013) and data from BC Stats to project that the population will grow from 2.7 million (2011) to about 4.3 million people in 2050, and modeled future food self-reliance capacity for a population of this size.

Farmland Availability

Although the majority of the region's farmland is currently protected by the Agricultural Land Reserve (ALR), a provincial zone in which agriculture is recognized as the priority use (Government of British Columbia - Provincial Agricultural Land Commission 2013), threats of urban, industrial, or other non-farm development of this land persist (BC Food Systems Network 2015; Johnston 2014). Southwest BC has also been identified as an area where existing ALR land is underutilized for farming (Government of British Columbia - Ministry of Agriculture Food and Fisheries (Prepared by Anthony Jjumba) 2005; Government of British Columbia - Ministry of Agriculture Food and Fisheries 2004, 2005; Government of British Columbia - Ministry of Agriculture 2011, 2014; Mullinix et al. 2013). Almost 25% (18,000 hectares) of ALR in Southwest BC's Greater Vancouver Regional District, for example, was classified as having potential for farming but not farmed in 2014 (Government of British Columbia - Ministry of Agriculture 2014). Furthermore, recent attention to the price of farmland in Southwest BC has raised concerns that new entrants to farming, or those wishing to expand their farm businesses, might be priced out of the market (Sussmann, Dorward, et al. 2016). Given these factors, the future availability and utilization of farmland in Southwest BC is uncertain. To account for this, we modeled food self-reliance potential under two hypothetical levels of 2050 farmland availability: stable and expanded.

Stable farmland availability was equal to the amount of farmland used for agricultural production in 2011 according to Statistics Canada. Expanded farmland availability included all farmable ALR land in SWBC; an increase of about 50% over stable farmland availability. A variety of spatial datasets were used to determine the quality of SWBC's ALR land for farming per the Land Capability Classification for Agriculture in British Columbia, a classification system that groups mineral and organic soils into seven classes according to their potentials and limitations for agriculture (Government of British Columbia - Ministry of Agriculture and Food and Government of British Columbia - Ministry of Environment 1983). Based on this system, we assumed that Class 5-6 land is suitable for structure-based agriculture (greenhouse vegetables and mushrooms), pasture and barn. Other crops (fruit, vegetables, hay and grain) can be grown on Class 1-4 land (Table 1).

Crop and livestock yield

The impacts that climate change may have on crop yield are difficult to predict. The Intergovernmental Panel on Climate Change (IPCC) points to changing inter-annual yield variability as a likely global impact of climate change (Porter et al. 2014). In BC it is expected climate change will increase BC's growing degree days (Agriculture and Agri-Food Canada 2014), which could positively impact yield but could also result in increased pest and disease pressure. Additionally, excess precipitation in spring (planting season) and fall (harvest season) as well summer drought are expected to adversely affect crop production intermittently. The degree to which climate change adaptation initiatives such as adaptive breeding and technology improvements will reduce the impact of climate change is yet to be seen. Given this uncertainty, this study aimed to account for potential extremes by modeling food self-reliance potential in both models under three crop yield levels: average, decreased, and increased.

Average crop yields (tonnes/hectare) were derived from ten year (2002 – 2011) averages of BC crop yield wherever possible, or of Canadian crop yield

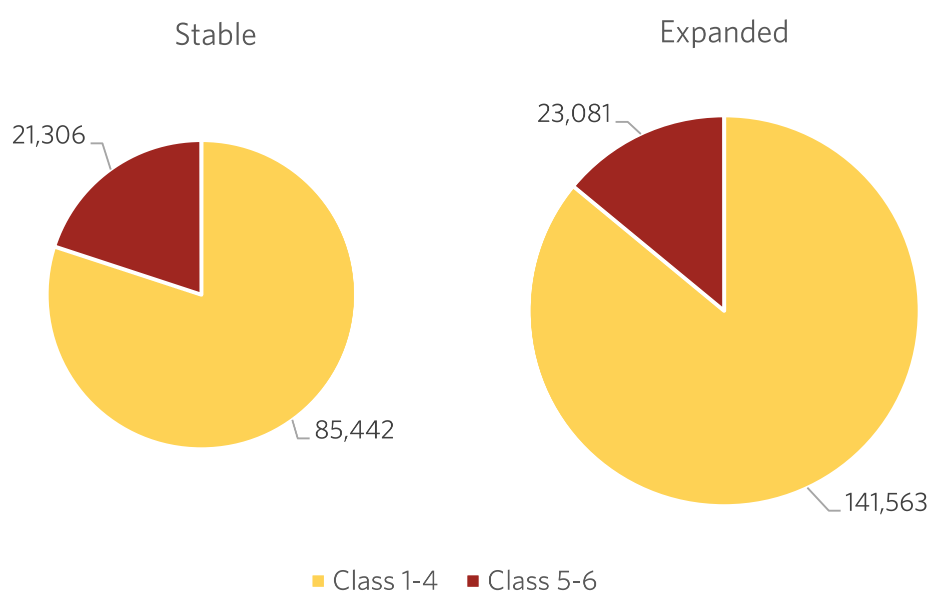

Figure 1: Agricultural land availability in Southwest BC by land capability classification and scenario (hectares)

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We measured the impact of planting hedgerows along all parcel boundaries and riparian buffers along all waterways in Southwest BC.

secondarily. A 25% reduction in tree fruit yield was applied to account for likely reduction in production potential in SWBC compared to the south-central fruit producing regions of the province (K Mullinix 2014, pers. comm., 14 Jan). Decreased crop yield was 25% lower than average and increased crop yield was 25% higher than average. These yield changes were applied across all crops.

Livestock product (meat, milk, and eggs) yields used in this study take into account 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 herd (Dorward, Smukler, and Mullinix 2016a). 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. Regionally-specific data were used wherever possible and Canadian data secondarily. For further discussion of the impact of a definition of local livestock on capacity for food self-reliance, see Dorward et al. (Dorward, Smukler, and Mullinix 2016a, 2016c).

Environmental enhancements

We modeled the impact of implementing two measures to curb environmental impacts of agriculture: “nitrogen balance” and “habitat enhancements”. With the nitrogen balance implemented, in any given scenario the quantity of nitrogen (N) and produced by livestock never exceeds the quantity required to satisfy crop requirements. With the habitat enhancements implemented, some farmland is used for hedgerows along parcel boundaries and riparian buffers along all waterways. Further description of the method and data used in the nutrient balance and habitat enhancements can be found in Smukler, Dorward and Mullinix (2016) and Rallings et al. (2017a, 2017b).

Scenarios

Using the input data on population size, food need, farmland availability, and crop and livestock yield, and environmental enhancements allowed us to model many different scenarios of future food systems to explore what they might look like and their impacts might be. Numerous food system scenarios were generated and five

selected for comparison. Each scenario selected is predicated upon an incremental change from the previous scenario, and highlights outcomes of different approaches to the regionalization of the food system by increasing food self-reliance.
The first is the 2011 Baseline scenario (Baseline) which draws upon 2011 statistical data regarding amount of land farmed, land use for crop and animal production, population, and food need (Dorward, Smukler, and Mullinix 2016a). The Baseline scenario represents our contemporary regionalized food system situation in Southwest BC as we assume that the bioregion's population chooses to consume local products over imported products whenever possible. Therefore the amount of food production modeled in the Baseline is likely to be greater than what actually occurred, and the amount of food import to be smaller.

In the second scenario, 2050 Business-as-Usual Food Production (BAU), future land use levels and the food production mix is the same as in 2011 while population increases by about 60% (Dorward, Smukler, and Mullinix 2016b). This scenario portrays the degree to which regional food need can be satisfied by land based food production in Southwest BC under the pressure of population increases given no changes in land use, production method, and yields. The 2011 Baseline and the 2050 Business as Usual scenarios were both generated by the spreadsheet model, whereas the following scenarios were generated by the optimization model.

The third scenario is the 2050 Increase Food Self-Reliance (Increase FSR) scenario, representing a future in which farmable land is allocated differently; to the production of crops and livestock that satisfy regional food need and maximize food self-reliance. In this scenario, our theoretical food system becomes increasingly regionalized. Not only do consumers choose to purchase local products over imported products, the producers also aim to produce and process the types of food that would satisfy the local food need.

The fourth is the 2050 Mitigate Environmental Impacts from Agriculture (Mitigate Impacts) scenario. This scenario builds upon the Increase FSR scenario. It represents a future in which we attempt to alleviate some of the negative environmental impacts from agriculture; specifically reducing nitrogen and surpluses from animal manure and enhancing wildlife habitat quantity, quality, and connectivity (via hedgerows and riparian buffers).

Finally, the 2050 Expand Agricultural Land in Production (Expand Land) scenario represents a future where food self-reliance is increased through reallocating production foods that satisfy local food need, and by increasing the amount of agricultural land in production. This scenario builds upon the Mitigate Impacts scenario. It shows the gain when we put currently unfarmed agricultural land into production to serve our regional food need, while maintaining our efforts to alleviate some of the negative environmental impacts from agriculture.

While the Baseline 2011 scenario represents the current food system strategy, the other four scenarios offer a glimpse into different food system options for our 2050 future. This, however, does not mean that these are our only options. The scenarios are meant for illustrative purpose and to stimulate discussion about our preferred food system future.

In this research brief we also discuss a scenario in which crop yield changes (increases or decreases by 25%) due to the impact of climate change.

As a summary, the five main food system scenarios and their assumptions are outlined in Table 1.

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Table 1: Summary of five theoretical food system scenarios modeled in the Southwest BC Bioregion Food System Design Project and reported in this brief

SCENARIO	TYPE OF MODEL	FARMLAND USE	POPULATION (MILLION)	FOOD NEED (MILLION TONNES)	FARMLAND MODELED (MILLION HECTARES)	ENVIRONMENTAL ENHANCEMENTS
2011 BASELINE	Spread-sheet	As Statistics Canada reported for 2011	2.7	2.6	101,000	No enhancements
2050 BUSINESS-AS-USUAL FOOD PRODUCTION	Spread-sheet	As in Baseline Scenario	4.3	4.2	101,000	No enhancements
2050 INCREASE FOOD SELF-RELIANCE	Optimization	Reallocated according to regional food need	4.3	4.2	101,000	No enhancements
2050 MITIGATE ENVIRONMENTAL IMPACTS FROM AGRICULTURE	Optimization	Reallocated according to regional food need	4.3	4.2	101,000	Nitrogen balance and habitat enhancements
2050 EXPAND AGRICULTURAL LAND IN PRODUCTION	Optimization	Reallocated according to regional food need	4.3	4.2	165,000	Nitrogen balance and habitat enhancements

Results and Discussion

In previous research we reported that, including livestock raised with imported feed, Southwest BC was 40% food self-reliant in 2011 (Dorward, Smukler, and Mullinix 2016a). In 2050, if land continued to be allocated to crops and livestock as it was in 2011 (the "Business as Usual" scenario), food self-reliance would decrease to about 28% (Figure 2). Decreases would be seen across all food groups with the exception of poultry, which was produced in excess of food need in 2011; it would remain at 100% in 2050.

Even with population growth and without expanding farmed area, there is potential to increase Southwest BC's food self-reliance in 2050 if crops were to be reallocated to agricultural land in a manner that maximizes food self-reliance. Even if only half of the farmed land were reallocated to satisfaction of local food need, food self-reliance could still increase to 49%. However, by reallocating all farmed land to production for local consumption, food self-reliance could be increased to 56%. Under both of these scenarios, food self-reliance gains would be seen across all food types except grains & legumes and fats & oils (Figure 2)
Land use data from these scenarios reveals the "efficiency" of livestock production when grain feed imports to the region are allowed. 100% self-reliance in eggs and poultry is achieved on less than 1% of the total land due to the fact that barn space is the only regional agricultural land needed to raise them locally. Dairy production is slightly more land intensive due to its requirement for locally produced hay and access to local pasture (Figure 3).

As expected, implementing environmental enhancements in the "Mitigate Impacts" scenario causes a modest reduction in total dietary food self-reliance potential (from 56% to 49%). This reduction is driven by decreases in livestock production (primarily egg and red meat – pork) necessary to achieve a nutrient balance. There is negligible decrease in fruit and vegetable self-reliance in this scenario. With the nutrient balance enacted, in any given scenario the quantity of nitrogen (N) and phosphorous (P) produced by livestock never exceeds the N and P required for crop fertility, thus avoiding environmental contamination. The imposition of habitat enhancements also contributes to the reduction in total dietary food self-reliance because it reduces the total area of land available for farming, however this impact is nominal compared of that of the nutrient balance.

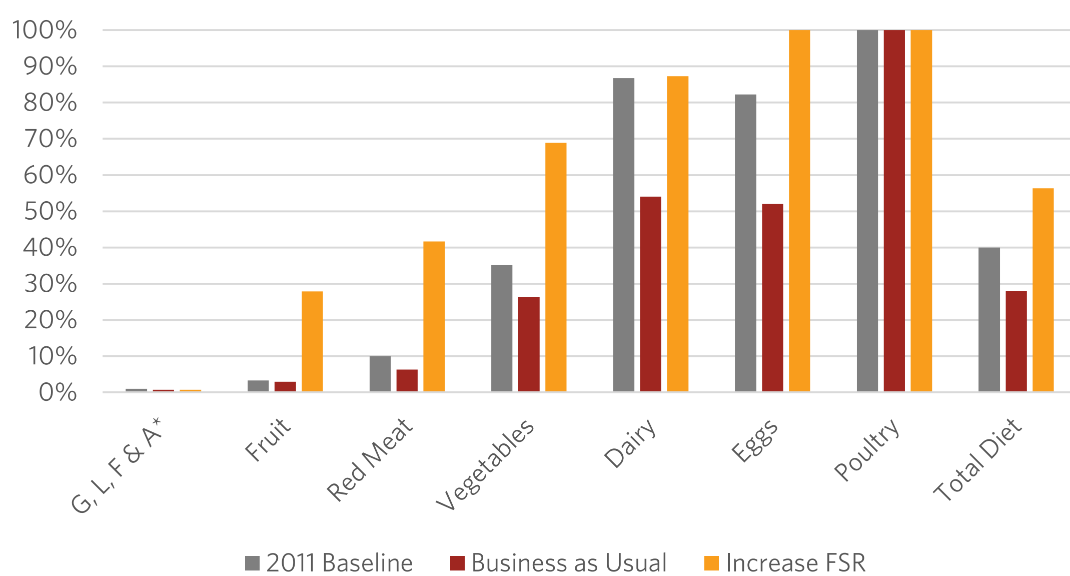
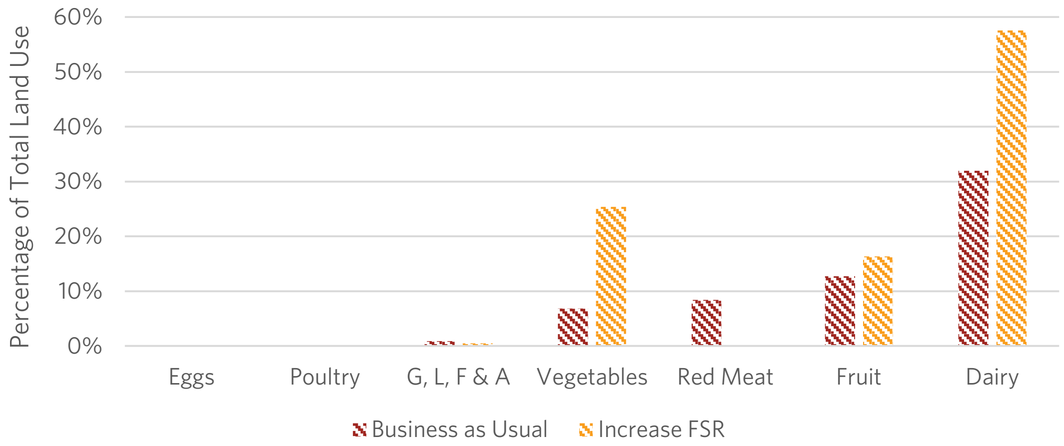


Figure 2: Food Self-Reliance in Southwest BC in the 2011 Baseline, Business as Usual Scenario, and Increase FSR Scenario

* "G, L, F & A" denotes "Grains, Legumes, Fats & Oils"



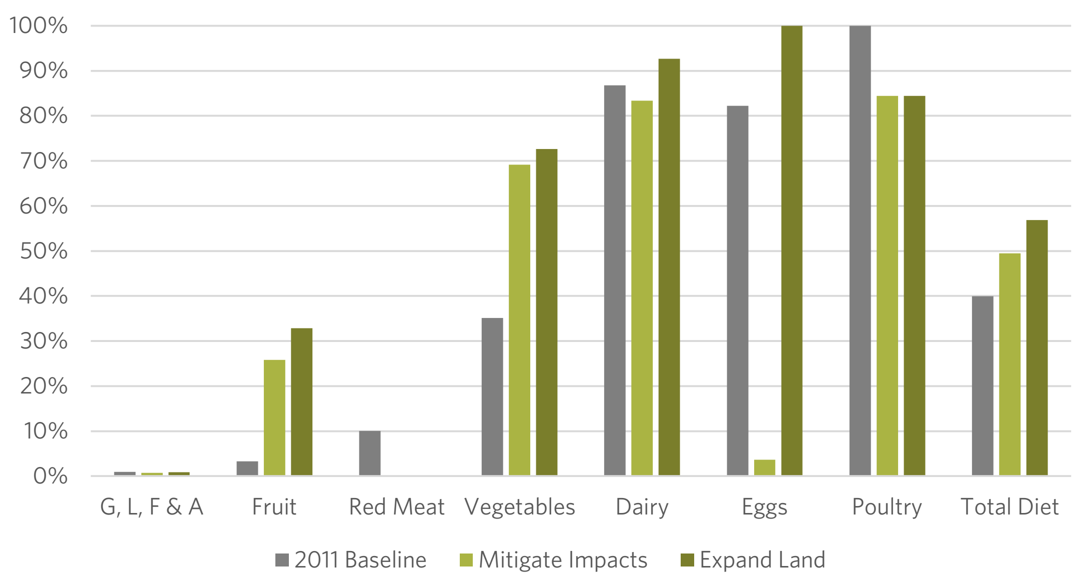
*"G, L, F & A" denotes "Grains, Legumes, Fats & Oils"

Figure 3: Percentage of total land use by crop type, Business as Usual and Increase Food Self-Reliance Scenarios

Given the negative impacts associated with excess production of nutrients (Smukler 2016) the reduction in food self-reliance caused by imposing a nutrient balance may well be an appropriate trade-off to bring this environmental issue in check. Particularly because the 49% food self-reliance possible while achieving a nutrient balance still represents a substantial increase over that possible in the Business as Usual scenario (in which a nutrient balance is not achieved).

The "Expand Land in Production" scenario demonstrated that, even with environmental enhancements implemented, there is opportunity to further increase food self-reliance by expanding farming onto some of the currently underutilized land in Southwest BC. In this scenario, food self-reliance for the total diet reached 57% (Figure 4).

The yield changes we modeled were found to impact food self-reliance potential only marginally. Across all three yield levels, the Increase Food Self-Reliance scenario performs better in terms of food self-reliance than the Business as Usual scenario. In fact, even the Increase FSR-Low Yield scenario affords a higher level of food self-reliance than that in the Business as Usual-High Yield scenario. The impact of



"G, L, F & A" denotes "Grains, Legumes, Fats & Oils"

Figure 4: Food Self-Reliance in Southwest BC in the 2011 Baseline, Mitigate Impacts Scenario, and Expand Land Scenario

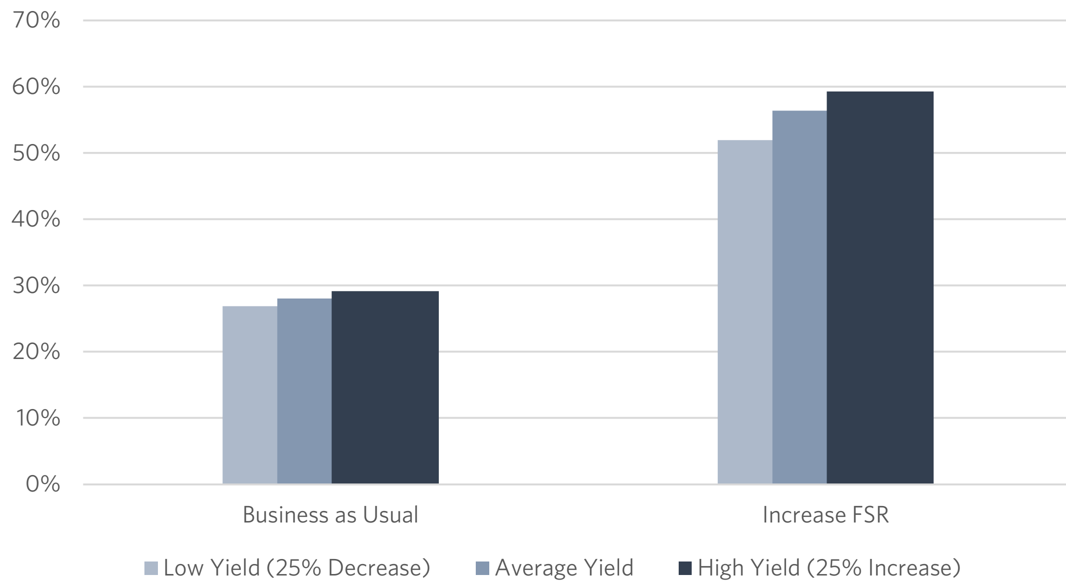


Figure 5: Effect of crop yield increases and decreases on Southwest BC Food Self-Reliance capacity in the Business as Usual and Increase Food Self-Reliance scenarios

yield changes on food self-reliance in the 2050 Business as Usual and 2050 Increase Food Self-Reliance scenarios are shown in the Figure 5. Results are similar for other scenarios. Note that the potential impact of isolated, severe climate change induced weather events (e.g. fields flooded at fall harvest, summer drought) on specific farms were not modeled in this study.

Conclusions

The study's results indicate that Southwest BC's future food self-reliance status could be increased over current (2011) levels in a regionalized food system in which crops are allocated to agricultural land in a manner that maximizes food self-reliance, but not in a Business as Usual food system in which future crop and livestock production follows 2011 patterns. Food self-reliance capacity is more affected by changes in farmland availability than to climate change-induced changes in crop yield, however other sources of crop yield variability that were not modeled could have a greater impact on food self-reliance. Horticultural crop production would dominate farmland use in a scenario of increased food self-reliance, and overall the study reaffirmed previous evidence (Dorward, Smukler, and Mullinix 2016a) that the capacity for the production of food grain or feed grain in Southwest BC is extremely limited. As such, the continued importation of livestock feed and food grain to Southwest BC is likely unavoidable in the future.

Modeling of the Localized and BAU food systems was based solely on variations of farmland availability and expected crop yield. Modeling of the economic outcomes or environmental impacts associated with either food system was beyond the scope of this study, as was crop yield and land use change modeling that incorporated climate models in a dynamic manner. Doing so would add further richness to the discussion of the merits and detriments of a local food system.

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About ISFS

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

About the Southwest BC Bioregion Food System Design Project

The Southwest BC Bioregion Food System Design project was conceptualized at ISFS in 2012 and concluded in 2016. The project was conceived as a “research project within a research project,” with the broad goals of developing a method to delineate the interconnected economic, food self-reliance, and environmental stewardship potentials of a bioregional food system and applying the method to the Southwest BC bioregion. To our knowledge, this project is the first of its kind. Project research briefs are one means used to present project findings. They are intended to report detailed, topic specific project methods and results. For other research briefs from the project, as well as the project report and summary, and peer-reviewed publications, please visit kpu.ca/isfs.

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