

# Research Brief

From the Southwest BC Bioregion Food System Design Project

2016



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## The Ecological Footprint of Food Consumption in a Regionalized Food System

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### Abstract

This research brief presents findings from our investigation into the ecological footprint implications of regionalizing the food system in the Southwest BC bioregion, an area comprising five regional districts in the southwest mainland corner of British Columbia, Canada (Harris et al., 2016). We include a short description of our methods, provide highlights from our findings and a discussion of the relationship between food consumption habits, food production systems, the location of food production relative to consumption, and the ecological footprint of food consumption. When we compared the ecological footprint of food consumption across all of our modelled scenarios, we found very little difference between scenarios with higher levels of food self-reliance (resulting when more food consumed locally is grown locally) and those with lower food self-reliance (resulting when more food consumed locally is imported). However, when we modeled for reduced red meat and vegetarian diets, we saw dramatic decreases in the total ecological footprint of food consumption. These results yield two critical insights. First, increasing food self-reliance in Southwest BC has little effect on the size of the ecological footprint of food consumption. Second, the overall size of the ecological footprint of food consumption is influenced more heavily by the kinds of foods consumed (fruit, vegetables, grains, meat etc.) than whether they are produced locally or imported. Therefore the most impactful way to reduce the ecological footprint of food consumption in Southwest BC is to change diets.



*If everyone on earth adopted Canadian lifestyle habits, an additional 2.5 planet earths would be required to meet the increased resource demand and waste assimilation capacity.*

## What is an ecological footprint and why should we measure it?

The ecological footprint is an accounting tool that tracks the area of biologically productive land and sea needed to produce the renewable resources consumed by a given population and to absorb its carbon emission wastes each year. The footprint is reported in “global hectares” (gha), which represent hectares of land with global average biological productivity. In 2011, the total bio-productive area available to each person on the planet to meet all their lifestyle needs was 1.7 global hectares (gha). The average Canadian’s ecological footprint is over 6.0 gha (World Wide Fund 2014). Therefore if everyone on Earth adopted Canadian lifestyle habits, an additional 2.5 planet Earths would be required to meet the increased resource demand and waste assimilation capacity.

Studies have shown that the food Canadians eat makes up anywhere from 20% to 35% of our per capita ecological footprints (Kissinger 2013; Moore 2013). If Canadians want to live sustainably, that is, within the limits of the earth’s biological carrying capacity, we must find ways to significantly reduce our ecological footprints. In the Southwest BC Bioregion Food System Design Project, to find out if regionalizing our food system by increasing food self-reliance (the degree to which food need is satisfied by food produced locally) can help, we measured the ecological footprint of baseline (2011) food consumption in Southwest BC and compared that with the ecological footprint of food consumption in the future under various scenarios of food system regionalization.

## Methods

### Food System Scenarios and Modeling

To explore the outcome of various future scenarios of food system regionalization in Southwest BC, 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 (Dorward, Smukler, and Mullinix 2016a, 2016b). The models employed two different calculation techniques based on agricultural land use allocation. In the first model (a spreadsheet model), future agricultural land use allocation followed 2011 agricultural land use patterns. In the second model (optimization model), future agricultural land use was reallocated and prioritized to meet food need in Southwest BC, with the goal of maximizing Southwest BC food self-reliance (see Dorward, Smukler, and Mullinix 2016a for details on method of determining food consumption or food need and a list of all foods considered in the models). Therefore a key feature of the optimization model is 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.

With these computational models, 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. In this research brief we report on ecological footprint outcomes for the first three scenarios (Table 1).

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

Table 1: Summary of 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	None
2050 BUSINESS-AS-USUAL FOOD PRODUCTION	Spread-sheet	As in Baseline Scenario	4.3	4.2	101,000	None
2050 INCREASE FOOD SELF-RELIANCE	Optimization	Reallocated according to regional food need	4.3	4.2	101,000	None

that the bioregion’s population chooses to consume local products over imported products whenever possible. Therefore the amount of food production for local consumption modeled in the Baseline is likely to be greater than what actually occurred, and the amount of food import 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.

While the Baseline 2011 scenario represents the current food system, the other 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.

### Calculating the Ecological Footprint of Food Consumption

The EF of food consumption accounts for all of the food consumed in the Southwest BC bioregion (foods grown locally plus food imported from outside the bioregion). Foods grown in Southwest BC for export are not included in the EF of bioregional food consumption; these products should be accounted for in the ecological footprints of the populations that consume them.

Food consumption was assumed to be the total quantity of food required to feed the Southwest BC population a nutritionally complete diet that aligns with food preferences. Food preferences were determined from the Canadian Food Availability dataset (Statistics Canada 2011) and nutrition requirements were



*To satisfy demand for livestock products, it is possible to raise livestock locally on local feed, raise livestock locally with imported feed, or to import livestock products produced elsewhere.*

identified using Canada's Food Guide (Health Canada 2011). Total food need for the population reflects demographic composition. Note that fish and seafood are included in the account of total food consumption, but because they were not modeled in the project they are not included in the EF calculations. See Dorward, Smukler and Mullinix (2016a) for details on the method of determining food consumption.

To determine the EF of food consumption in Southwest BC we first calculated the EF per unit of production for each food in the nutritionally complete diet. The data included in our calculation of the EF per unit of production of each food were:

- Area of crop and grazing land required per unit of food produced;
- Quantities of synthetic fertilizer used per unit of food produced;
- On-farm fossil fuel energy used per unit of food produced; and,
- Shipping-related fossil fuel energy used per unit of food production, if applicable (i.e., fossil fuels used to transport an imported food or livestock feed product from its production location to Southwest BC).

Areas of cropland and grazing land were multiplied by equivalence factors to arrive at global hectares. Carbon emissions associated with fossil fuel use on farm and manufacture of synthetic fertilizer were multiplied by conversion factors to arrive at global hectares required to sequester the emissions (Ewing et al. 2009).

Among the crop foods in the diet (fruit, vegetables, grain, legumes, and oilseeds), some can be grown in Southwest BC or elsewhere (imported) while others can only be imported. For the former, we calculated an EF to be applied if the crop was grown locally, and an alternative EF

to be applied if the crop was imported. For crops that can only be imported, only an EF for the imported crop was calculated<sup>1</sup>. Data used to calculate the EF for imported foods were from the U.N Food and Agriculture organization (crop yield); the U.S Department of Agriculture for crops imported from specific U.S states (crop yield); fertilizer recommendations are from crop production guides specific to U. S. states and counties, and other import regions as available; on farm fossil fuel data for all imports are North American averages. The data used to calculate the ecological footprint of crops grown in Southwest BC are from Statistics Canada's CANSIM database (Statistics Canada 2013), BC Crop Production Guides (BC Ministry of Agriculture 2014), Yang (2007), and a range of North American sources for on-farm fossil fuel use data (Kissinger 2013).

For livestock products, a different approach was used. It is possible to:

- Raise livestock in Southwest BC on local pasture, hay and feed grain (termed "all local");
- Raise livestock in Southwest BC on local pasture and hay but imported feed grain (termed "imported grain"); or
- Import livestock products produced outside of Southwest BC (termed "imported product").

As such, we calculated an EF per unit of livestock product for each of these three "production methods". The livestock product EF accounted for the land area, synthetic fertilizer and fossil fuel used in production of feed for and housing of the livestock (including breeders and offspring) required per unit of production<sup>2</sup>. Table 2 outlines the assumptions behind and data sources for each livestock production method assessed.

<sup>1</sup>Most imported crops are imported to Canada (and Southwest BC) from more than one country. Therefore the EF for each imported crop is calculated as a weighted average based on the major import sources, and on production in other parts of Canada. See Kissinger (2012) for method of calculating average shipping distance and mode (rail, sea, or truck) per crop type from major production centres outside of the bioregion to the bioregion.

<sup>2</sup>See Dorward, et al. (2016) for method of determining livestock feed requirements.



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Table 2: Assumptions behind and data sources for each livestock product production method assessed

PRODUCTION METHOD	ALL LOCAL	IMPORTED GRAIN	IMPORTED PRODUCT
<b>FEED REQUIREMENTS</b>	BC average (Statistics Canada 2003)	BC average for all livestock except layer and turkey, which are Canadian averages (Statistics Canada 2003)	Canadian average (Statistics Canada 2003)
<b>FEED CROP YIELD</b>	Southwest BC for pasture; BC average for feed grain and hay	Southwest BC for pasture; BC average for hay; Canadian average for feed grain	Southwest BC for pasture; Canadian average for feed grain and hay
<b>FEED CROP FERTILIZER REQUIREMENT</b>	BC recommendations for hay and feed grain	BC recommendations for hay; Canadian recommendations for feed grain	Canadian recommendations for hay and feed grain
<b>ON-FARM FOSSIL FUEL USE</b>	North American Average	North American Average	North American Average
<b>SHIPPING-RELATED FOSSIL FUEL ENERGY</b>	N/A	Assumed feed grain imported from Alberta by rail to determine shipping emissions	Assumed products imported from Alberta by rail to determine shipping emissions

Having determined the EF per unit of production for each of the foods in the diet, we used this data in two ways.

First, we compared the ecological footprints of foods produced in the bioregion to those imported from elsewhere. Food consumed in the bioregion is comprised of foods we grow in the bioregion and foods we import. While some of the foods in our diet (e.g. rice, tropical fruit) cannot be grown in the bioregion and must be imported, about 86% of total food consumption by weight is comprised of 45 foods we can either grow in the bioregion or import from other parts of Canada, the U.S. and further abroad (e.g.: carrots, potatoes, strawberries, beef). For each of these 45 foods, we compared the ecological footprint per tonne produced in the bioregion, to the ecological footprint per tonne imported.

Secondly, for each modeled scenario (described above) we multiplied this by the tonnes of each food consumed and summed the EF of all foods to determine the total ecological footprint of consumption associated with regionalized food system futures in Southwest BC.

## Results and Discussion

### Comparing the Ecological Footprints of Regionally Produced and Imported Foods

Of 45 fruit, vegetable, and field crops that we can grow in Southwest BC or import to meet our food consumption needs, we found a local ecological footprint advantage for 16 crops, an import advantage for 16, and the remaining 13 crops have ecological footprints that are similar whether grown regionally or imported (less than 15% difference in ecological footprint per tonne). The reason some import crops have a lower EF than their Southwest BC counterparts is that they have significantly higher production yields. A higher yield means a smaller land area is required per unit of crop produced. In the case of crops like apricots import crop yields are so high that despite the addition of shipping emissions, imported apricots have lower per tonne ecological footprints than apricots grown in Southwest BC (Figure 1).

Figure 2 (following page) compares the ecological footprint of crops grown in Southwest BC to those imported.

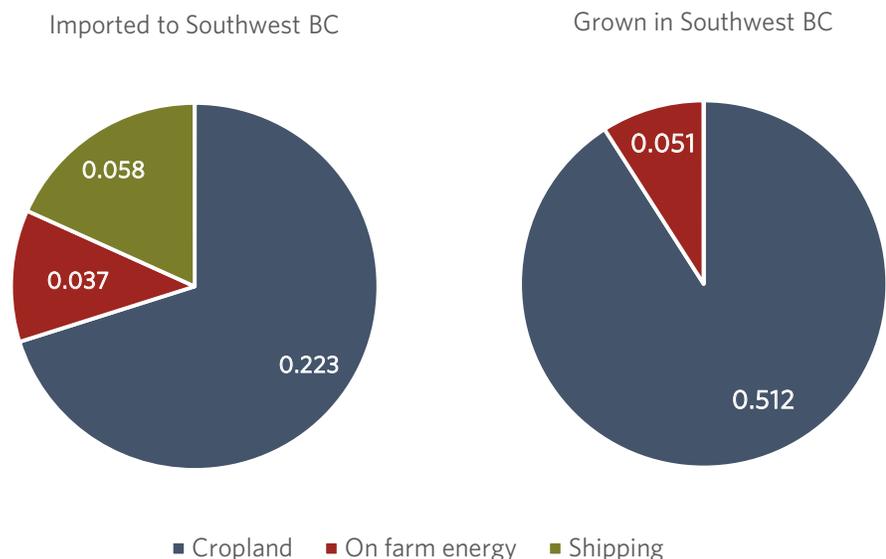


Figure 1: Ecological footprint of apricots imported to and grown in Southwest BC (global hectares/tonne)

THE ECOLOGICAL FOOTPRINT OF FOOD CONSUMPTION IN A REGIONALIZED FOOD SYSTEM

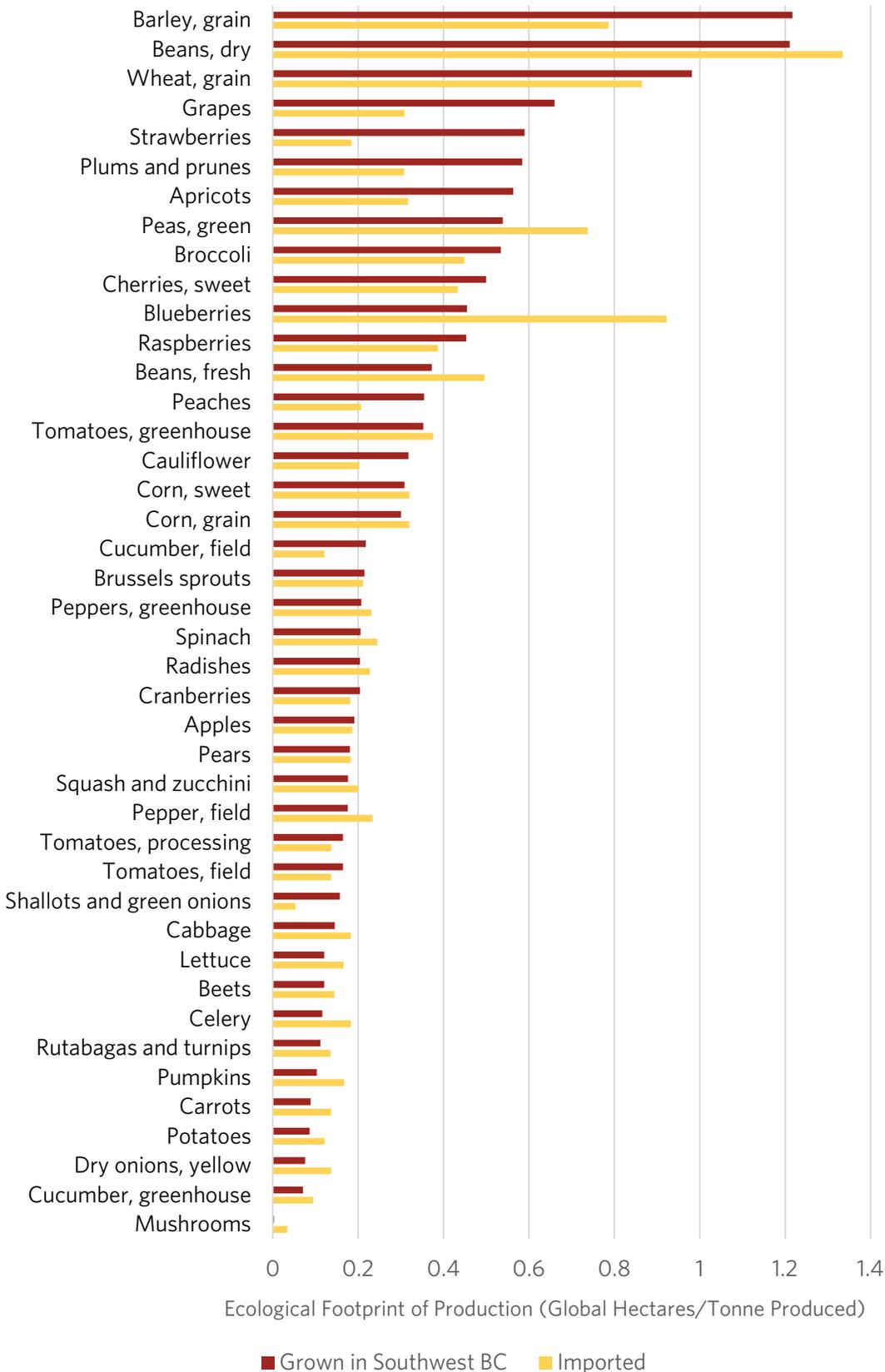


Figure 2: Comparison of ecological footprints for crops grown in Southwest BC and imported

Other crops (eg, carrots) achieve higher yields in the US and Mexico than in Southwest BC but the advantage is not high enough to overcome the addition of shipping emissions to the footprint.

Overall, we found that no general statement can be made about whether local or imported crop foods have an ecological footprint advantage. Each crop must be assessed individually. Crop yield is the most significant factor in determining the total ecological footprint of a crop. On farm energy use is responsible for, on average, 9-10 % of the EF per tonne crop for both Southwest BC and imported crops, excluding greenhouse crops. The EF associated with shipping import crops ranges from 0.023 – 0.074 gha/t depending on distance and mode of shipping (truck, rail or sea). Depending on the crop and its yield, addition of the shipping gha can increase the total EF by anywhere from 3% (e.g. imported wheat) to 157% (e.g. imported carrots).

**Ecological Footprint of Livestock Products**

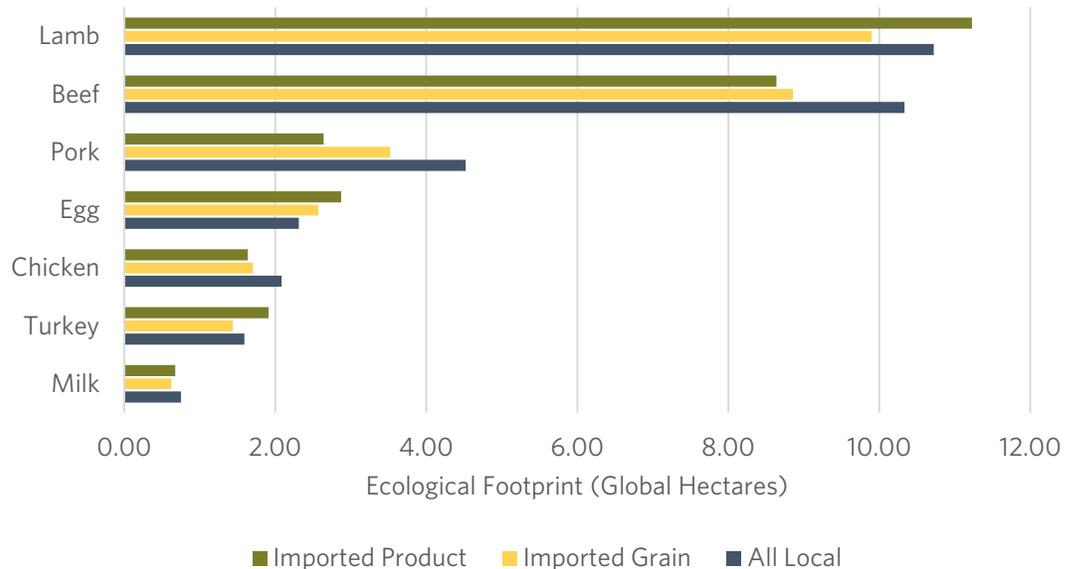
Like crops, the ecological footprints of livestock products produced in the bioregion must be assessed product by product, and compared to the footprints of

their import counterparts.

Figure 3 reveals differences in the size of the ecological footprint between livestock products from animals raised in Southwest BC on local feed, products from animals raised in the bioregion on local pasture and hay but with imported grain feed, and products from livestock raised outside of the bioregion on a slightly different diet than Southwest BC animals and imported to the bioregion for consumption.

In the cases of beef, pork, chicken, and milk we find that when these products are produced in the bioregion with feed grown in the bioregion, they have larger ecological footprints per tonne than both product imports, and products grown in the bioregion with feed imports (Figure 3). The main reason for the larger footprints is the higher livestock feed yields that are achieved outside of the bioregion.

In the case of egg, turkey, and lamb, those produced in Southwest BC with imported feed have a smaller ecological footprint per tonne than their imported counterparts. For turkey and egg, the ecological footprints associated with shipping livestock feed to Southwest BC are smaller than the ecological footprints of shipping imported product.



*Figure 3: Ecological footprint of livestock products in Southwest BC, by production method*

In the case of lamb, a combination of diet, feed crop yield, and shipping footprint results in lower ecological footprint per tonne for livestock raised in Southwest BC with imported feed grain.

Despite the ecological footprint differences identified between livestock products from livestock raised in Southwest BC, livestock raised in Southwest BC with imported feed grain, and those imported to the bioregion, it should be noted that from a global ecological perspective, the more important differences are the magnitude of ecological footprints between types of livestock products. Dairy products, poultry and egg have relatively lower ecological footprints per unit of production than pork, beef and lamb. Substituting a unit of poultry consumption for a unit of beef consumption will be more effective in reducing the ecological footprint than choosing between local or imported livestock products.

**Baseline 2011 ecological footprint of Southwest BC food consumption**

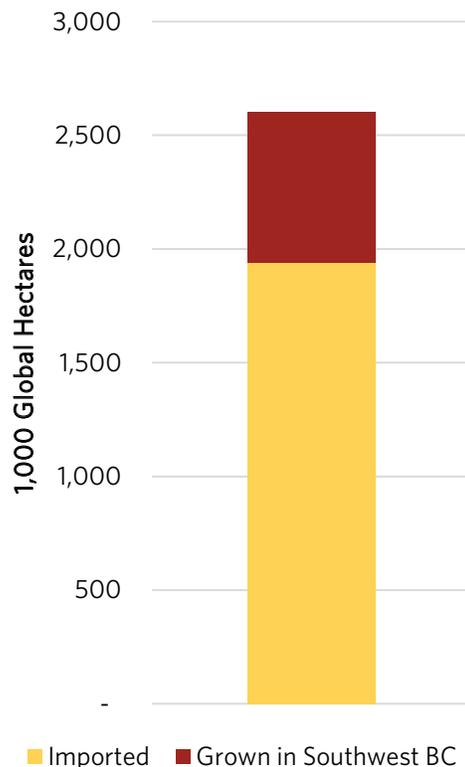
The ecological footprint of food consumption, given the diet we have modeled, is 0.97 global hectares per capita for the 2011 population of Southwest BC. This ecological footprint is over half of the 1.7 global hectares per capita available to each person to meet all of their lifestyle needs (food, shelter, clothing, transportation and services) in one year (World Wide Fund 2014).

The total ecological footprint of Southwest BC food consumption is 2.6 million global hectares. That means 2.6 million hectares of biologically productive land and sea, in Southwest BC and in other parts of the world, are required to meet food consumption needs. Figure 4 shows the size of the bioregion’s food consumption footprint; it also shows how much of the food footprint is associated with locally produced foods and how much with foods imported to the bioregion.

The majority of the EF (74%) is associated with foods produced outside of the bioregion because approximately 68%

of total food need by weight is imported. Figure 4 slightly under-represents the size of the import footprint because we assumed that in 2011, livestock products produced in the bioregion (dairy, egg, poultry, meat) were fed imported grain; the ecological footprint of that grain is counted here as part of the Southwest BC EF, rather than as part of the EF of imported foods.

Figure 5 shows the EF by food commodity group, and identifies the amount of each footprint associated with locally produced and imported foods. In each case the portion of the footprint associated with food produced in Southwest BC equates roughly to the portion of the total food consumed that is produced in the bioregion. For example, the footprint of Southwest BC eggs consumed is far larger than the ecological footprint of imported eggs consumed because very few eggs are imported to the bioregion. On the other hand, the ecological footprints of red meat, fruit, grains and oils is almost exclusively associated with imports because only small amounts of these commodities are produced in the bioregion.



*Figure 4: Ecological footprint of food consumption in Southwest BC, 2011*

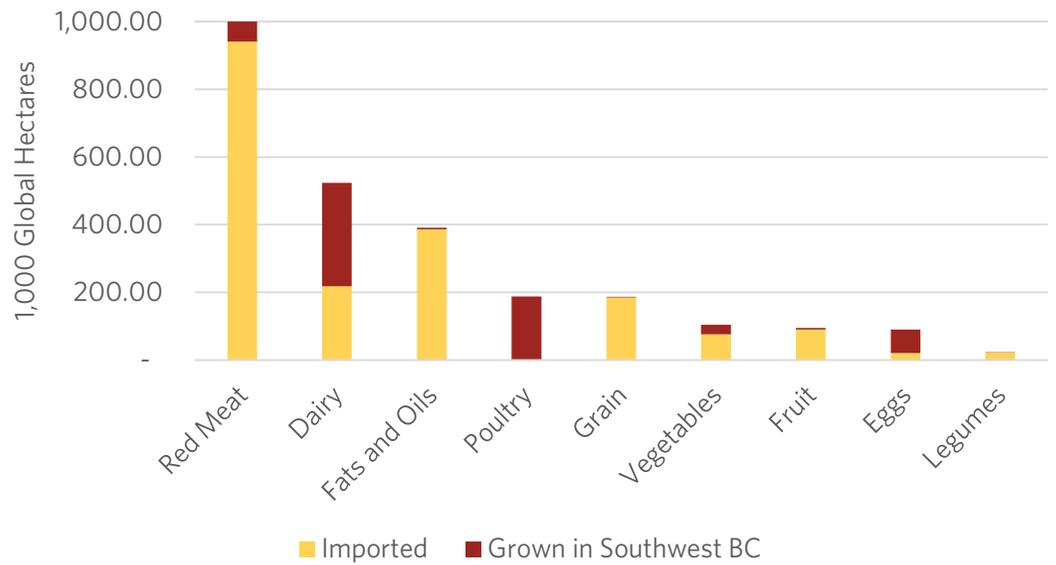


Figure 5: Ecological footprint of food consumption in Southwest BC by food commodity, 2011

Figure 5 also illustrates how the types of foods consumed significantly impact the overall size of the EF. For example, at over 1 million gha, red meat makes up the largest single component of the EF of food consumption. Yet, it represents only 6% of total food consumption by weight (Figure 6).

Contrast this with vegetables which make up 24% of total food consumption (tonnes) and only 4% of the total EF.

On a per unit production basis, red meat has a very high EF compared to other food commodities. This is because its footprint accounts for the land area and fossil fuel used to produce the feed grain and hay that supports animals including breeders and their offspring. In our calculations the average EF per tonne of beef is about 9.0 gha whether the animal is raised locally or outside of Southwest BC. Contrast this to the average ecological footprint per tonne of fruit, 0.37 gha, and per tonne of vegetables, 0.24 gha.

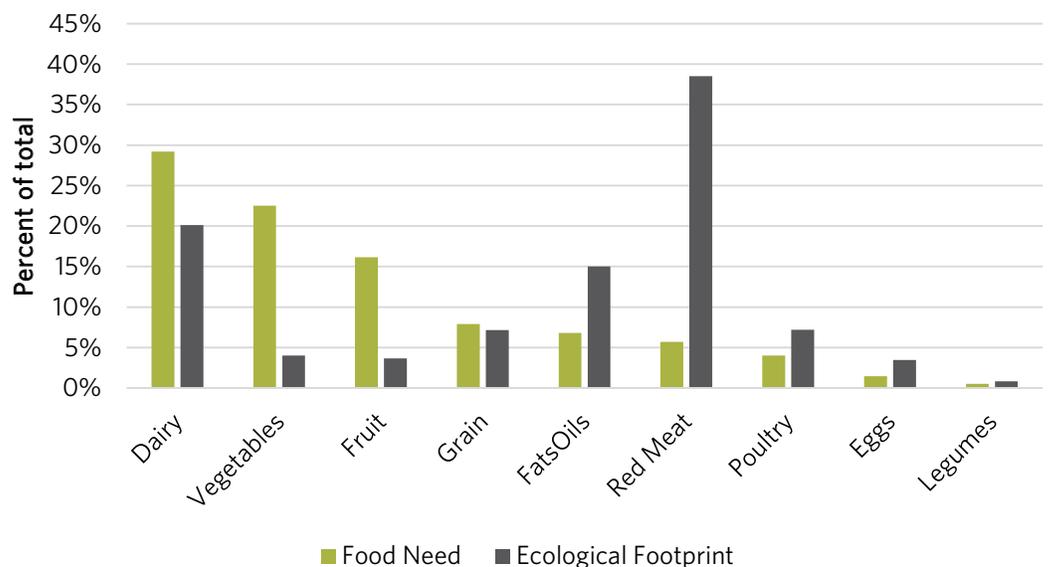


Figure 6: Percent of total Southwest BC food need and total ecological footprint by food type, 2011

**The ecological footprint of food consumption in 2050**

In 2050 the population will be about 60% larger than in 2011 and the total tonnes of food required will be 59% higher. The EF of food consumption for the Business as Usual scenario is 60% larger than in the baseline year while the Increase Food Self-Reliance scenario has an ecological footprint 61% larger than the baseline. The difference between the percent population increase and food need increase is due to demographic differences in the future population. These differences and seasonality constraints on production explain why the percent increase in the Business as Usual EF is slightly higher than the population increase.

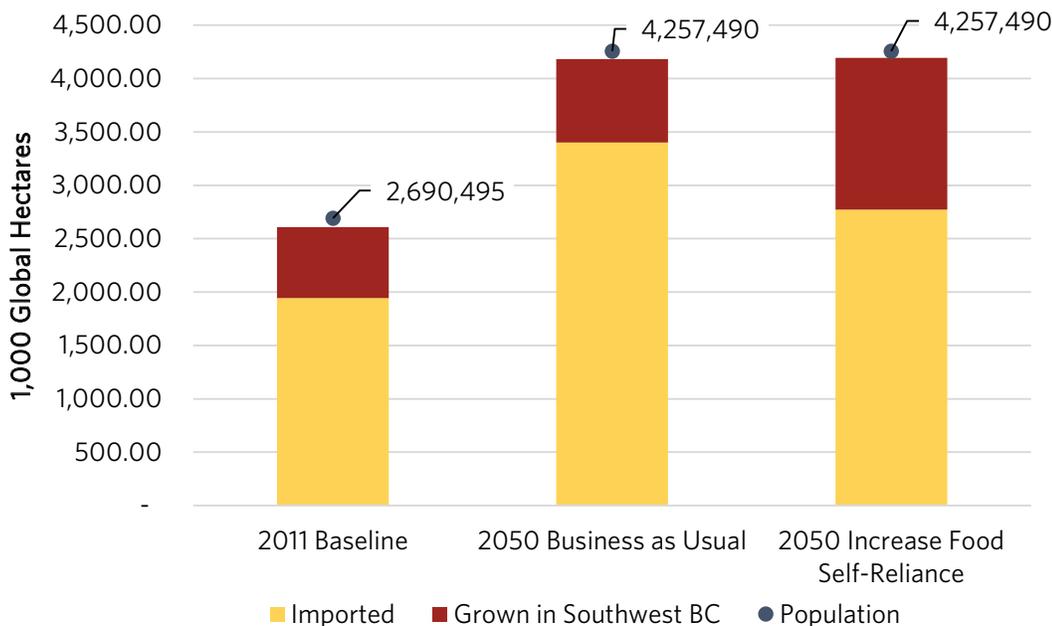
Figure 6 shows the population and ecological footprint of food consumption for 2011, the Business as Usual scenario and the Increase Food Self-Reliance scenario.

Figure 6 also shows how much of the ecological footprint is associated with food crops produced in Southwest BC and food crops imported from outside the bioregion. The ecological footprint associated with crops grown in Southwest BC is larger in the Increase Food Self-Reliance scenario than in Business as Usual because more

of the food consumed is locally grown. The ecological footprint of Southwest BC crops in the Business as Usual scenario is slightly larger than 2011 because although the same amount and type of foods are produced, in 2050 the larger population consumes larger quantities of some local products like blueberries and cranberries; quantities that were exported as excess in 2011. The total ecological footprint of the Increase Food Self-Reliance scenario is almost the same as that of the Business as Usual; it is 1% larger.

Producing more food locally to increase food self-reliance does not reduce the overall ecological footprint of consumption because not all foods grown in Southwest BC have a lower ecological footprint per tonne than their import counterparts. Some have larger footprints.

In our Increase Food Self-Reliance scenario, the model allocated land first to the Southwest BC crops with the highest yields (Dorward, Smukler, and Mullinix 2016b). In cases where those crops have a smaller ecological footprint/tonne than their imported counterparts, growing more of them locally decreases the size of the ecological footprint associated with consumption of that crop or food category.



*Figure 7: Ecological footprint of food consumption and population in Southwest BC by scenario*

This is the case for dairy, egg and most vegetables. However, the Increase Food Self-Reliance scenario also allocates land to food crops with larger ecological footprints/tonne than their imported counterparts: increased bioregional production of pork and some fruit increased the ecological footprints of those two categories compared to the Business as Usual scenario. Our calculations show that the total ecological footprint is 1% smaller in the Increase Food Self-Reliance scenario compared to the Business as Usual scenario (Figure 8).

When we modeled Business as Usual and Increase Food Self-Reliance scenarios with changes to Southwest BC land availability (expanded by 50% and decreased by 50%) and Southwest BC crop yields (increased by 25% and decreased by 25%), we found that the overall ecological footprint of food consumption for the Business as Usual scenarios and the Increase Food Self-Reliance scenarios had ecological footprints of similar size (maximum 2% difference). We also modeled scenarios with habitat enhancements (riparian buffers and hedgerows), and found the same result (Mullinix et al. 2016). In all cases we found that optimization of land use to increase food self-reliance in Southwest BC does not demonstrably decrease the size of the

ecological footprint of food consumption over business as usual scenarios (Table 4).

**How can the Ecological Footprint of Southwest BC food consumption be reduced?**

A substantial reduction in the ecological footprint of Southwest BC food consumption can be achieved through changes to the diet consumed. We adjusted Southwest BC food consumption by substituting meat alternatives for all meat products but maintaining egg and dairy consumption (a lacto-ovo vegetarian diet). The ecological footprint of this diet in the 2050 Business as Usual Scenario is 37% smaller than that of the Business As Usual scenario for the conventional diet. When we optimized land use to maximize food self-reliance for the lacto-ovo vegetarian diet we found an overall ecological footprint that is 40% smaller than the footprint of the 2050 Business as Usual.

We also modeled a reduced red-meat diet in which 50% of red meat consumption was replaced with meat alternatives. The ecological footprint of this diet in the Business as Usual scenario is 14% smaller than that of the conventional diet in the Business as Usual scenario.

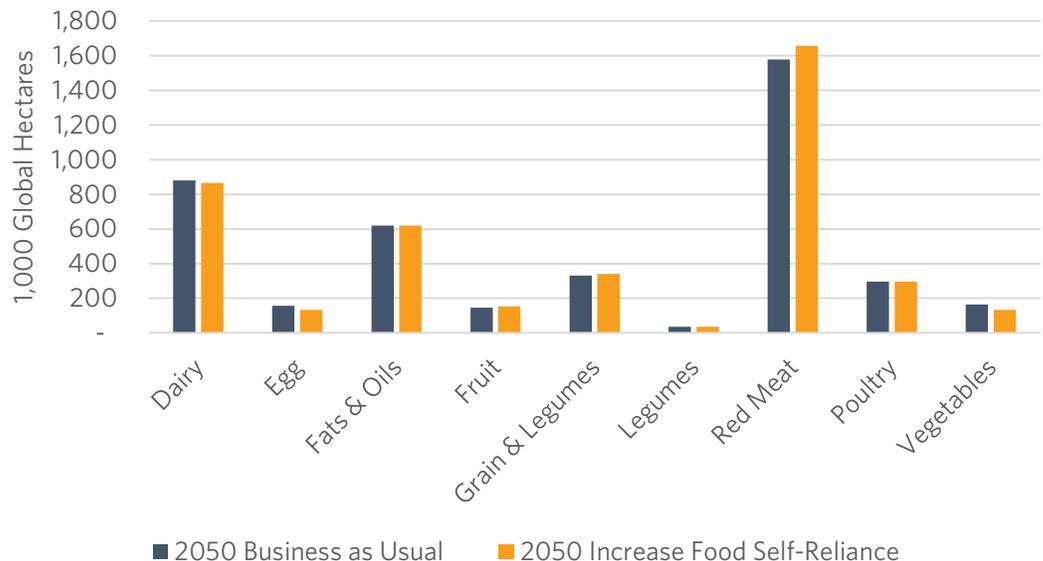


Figure 8: Ecological footprint of food consumption in Southwest BC by food category, Business as Usual and Increase Food Self-Reliance scenarios

## Conclusions

Regionalizing a food system with the goal of increasing local food self-reliance, as we have modeled it, does not result in appreciable reductions in the ecological footprint of food consumed in the Southwest BC bioregion. The reason is that growing food locally, depending on the food crop, can be more land and energy intensive than importing it from outside the bioregion. This is the case with livestock products like pork and red meat, with grains, and with many fruits consumed in the Southwest BC diet. No generalizations can be made; each food crop must be assessed against its import counterpart.

Our findings are based on current production practices. If local production practices were to increase yields of a particular crop while imports from other countries did not, then local products could gain an advantage. However, if at the same time, other countries increased their yields

and shipping became less energy intensive (for example through electrified rail or truck transport), then the ecological footprint of the imported foods might be lower than that of foods produced in Southwest BC. The most significant reduction to the ecological footprint of food consumption can be achieved through dietary change. Reducing consumption of high footprint foods like red meat will reduce the ecological footprint of food consumption more dramatically, and more quickly, than regionalizing the food system for increased food self-reliance.

Despite the limited reduction in the ecological footprint of food consumption, there are other benefits to regionalizing a food system, not the least of which is increasing food self-reliance in uncertain economic, political and climatic times (Mullinix et al. 2016). Dietary changes can occur alongside regionalization and thereby increase the number and type of benefits that accrue.



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*The most significant reduction to the ecological footprint of food consumption can be achieved through dietary change.*

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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](http://kpu.ca/isfs).

## Major Financial Support Provided by



R. Howard Webster Foundation  
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