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Climate Change and *Food Security* in British Columbia

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EXECUTIVE SUMMARY

Most predictions of the effects of climate change on agricultural productivity are based on studies undertaken in developing nations with few conducted on temperate regions such as British Columbia (BC). This lack of attention, along with uncertainty about how climate change will unfold in different regions of the province, makes it difficult to predict future impacts on food security.

To gauge such impacts, we must first understand the province's current system of food production, import and export and identify the future non-climatic demands on this system. BC produces about three billion dollars worth of food each year, about half of which is exported. Its largest export "crops" by value are fish and meat (mainly cattle). Also exported are most of the vegetables grown in the province's rapidly expanding greenhouse sector. BC currently imports about two billion dollars worth of food each year including most of its fruit and vegetables, and is highly dependent on the state of California for most of this produce.

Despite the lack of attention on the impact of climate change on food crops commonly grown in BC, we do know that BC's agricultural regions will face, in future, new biological, physical and socio-economic threats, especially on their periphery, and these may evolve in unpredictable fashions. The evidence that a carbon dioxide fertilization effect might increase yields of important crops in BC is limited and indirect and must be evaluated against the likelihood of physical and biological degradation of agri-ecosystems as these face a difficult-to-predict mix of long term climate change and extreme weather events. Moreover, rural areas on the periphery of BC's three main agricultural regions, especially those on the coast, may be the "canaries in the mine" for climate change in terms of impacts on food production. Finally, California is suffering from long-term drought and is likely to suffer further as climate change evolves. Given that this state is BC's main source for fruit and vegetables, diversification away from this region should be a priority for BC food security policy.

BC's agricultural sector also has an impact on greenhouse gas (GHG) emissions. Although the small agricultural sector in BC is a low emitter of GHGs overall, carbon dioxide, methane and nitrous oxide are released to the atmosphere, primarily through the production of meat (mainly cattle). While the government has developed programs to reduce meat and manure-based (methane) emissions their success is unclear given the relatively major expansion of this sub-sector in BC over the past quarter century.

If the objective of future food security is to enhance access to nutritious foods and improve population health while simultaneously reducing agricultural GHG emissions, new types of evidence are required to guide policy. More accurate and detailed descriptions of existing and potential food chains and determinations of GHG emissions at each link are particularly needed. A better framing of such descriptions would reduce the current focus on emissions that arise from food miles travelled. Moreover, a focus on health should cast the spotlight toward improved sustainability, which would add the advantage of making our agricultural sector more resilient to changes in climate.

The report makes seven recommendations:

1. Facilitate more agricultural and health sector partnerships to ensure more effective food policies.
2. Encourage people to choose healthier and more environmentally sustainable diets.Promote local agriculture to reduce BC's dependence on imports.
3. Develop a better policy evidence base, especially for analyzing GHG emissions at each stage in food supply chains and for assessing the economic implications of different production, import and export strategies.
4. Determine the likely impacts of different climactic scenarios on crops that are important to BC to maximize limited land production capacity.
5. Ensure that current initiatives underway in BC to manage GHG emissions from the meat industry and from manure are effective, as these are the agricultural sector's biggest emitters.
6. In a world of rising food prices, develop policies to cushion the impact of reduced food availability and access for those with low income.

1. INTRODUCTION

Food security represents "a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (Food and Agricultural Organization, 1996). Canada is not immune from these concerns: approximately one in ten Canadians is food insecure. Food insecurity is associated with higher prevalence of chronic diet-related illnesses, including diabetes and coronary heart disease.[1] As the prevalence of diet-related illness escalates, improvements in food security are increasingly recognized as key to reducing the future burden of poor health due to diet-related illness.[2]

Food insecurity is more common among the poor because lack of income is the key barrier restricting access to a nutritious diet. In British Columbia, approximately one quarter of those in the lowest decile of household income are food insecure.[3]

Many people in BC with adequate incomes also do not eat healthy diets, however, due to high fat intake and low consumption rates of fruit and vegetables. To ensure the health of BC's population, access to more fruit and vegetables is particularly important. While many investigations on food insecurity (rightly) focus on vulnerable and poor populations there is increasing focus on broader questions of availability of such foods through, for example, import supply chains and local production. This focus is strengthened by growing concerns over the potential impact of climate change on food import patterns and on local production.

Governments and industry are waking to the need for a more coherent health-focused approach to food policy to ensure food security. For example, the Canadian Agri-Food Policy Institute (2011) recently called for a national food policy that positions the dietary health of the Canadian population and the environmental sustainability of Canadian agriculture at the center of an innovative, safe and competitive national food system. The report notes that there is no consolidated "atlas" of climate change impacts on Canadian agriculture that can help guide policy development at a regional level,[4] a need that clearly requires attention.

Predictions of the effects of climate change on agricultural productivity tend to be based on studies undertaken in developing nations located near the equator. Most of these indicate that adverse effects on the yields of many staple crops are already evident and that yields in the future will likely decline.[5] Under the most pessimistic scenarios, parts of Africa and Asia face reductions in agricultural output of up to 30% of 1990 levels by 2080.[6] However, relatively few investigations have been undertaken on the impact of climate change on the yields of crops grown in temperate regions or on food security in relatively healthy populations in developed temperate-region nations.

Uncertainty about the impacts of climate change on food security in different regions of BC is compounded by difficulty in prediciting future shifts in demographic, market and technological factors. For example, changes in the size and structure of BC's population will impact the demand for food grown in BC as will changes in demand from overseas and the development of new technologies for food production and transport. Thus, prediction of future food security requires understanding better the basic structure of our current system of food production, import and export, as well as the character and momentum of long term background trends, including external and internal demands for food.

This paper considers just a part of this complex matrix, focusing on food availability via imports, production within the province, and potential impacts on these due to climate change. The focus is high level and does not consider adaptation and mitigation efforts conducted at the level of the farm.

This paper is divided into seven sections. Section 2 describes the basic structure of BC's food system and identifies the major non-climactic drivers of food demand. Evidence of climate change in BC and potential impacts on agriculture in BC and California are discussed in Section 3. Section 4 considers greenhouse gas emissions from the BC agricultural sector. Section 5 considers how BC might adapt food and agricultural policy to both reduce GHG emissions and improve the health of the population, as well as examines the food miles issue, Section 6 summarizes and synthesizes the results, and Section 7 offers recommendations.

2. FOOD PRODUCTION, IMPORTS AND EXPORTS IN BC

2.1 Introduction

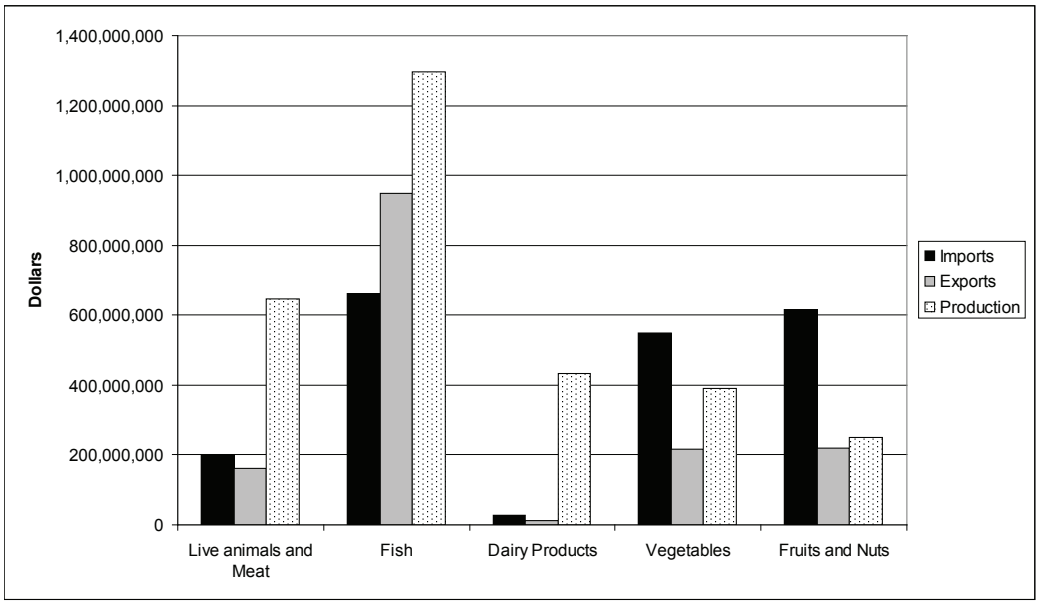
Approximately half the province's food is imported from other regions of Canada or from other nations.[7] It is important to note that while statistics are available for BC's imports and exports from other nations, these data are largely unavailable for imports and exports with other Canadian provinces and territories. Notwithstanding this limitation, in this section we show, for each major food category, the dollar value of production within BC, and the dollar value of imports and of exports from other nations. This exercise allows us to identify and compare those foods that are mainly produced and consumed in BC versus foods which are produced in BC but mainly for export to other nations, and finally, foods which are mainly imported from other nations.

Adaptive climate change and food policies for foods produced within BC, whether for local consumption or export, will be more directly under the jurisdiction and control of BC's policy makers, regulators and businesses. For foods that are mainly imported from other nations or other parts of Canada, clearly BC-based stakeholders and businesses will have limited direct policy making power. Nonetheless, it is important for the food security of British Columbians to more clearly know where our major food imports come from and the potential that climate change poses to their future availability.

2.2 Food imports, exports and food production in BC

At present, BC imports about half its food but the extent of reliance varies dramatically for different foods. Using 2007 import and export data obtained from Industry Canada and production data from Statistics Canada, we can determine the relative reliance on imports compared to within-province production for the major food categories fruit, vegetables, fish, dairy products and meat (Figure 1). BC produced about 3.0, imported about 2.0, and exported about 1.6 billion dollars worth of food in 2007. And, approximately half the value of the food we produce in BC (i.e., 1.6 billion dollars out of the total value of food produced in BC of 3 billion dollars) is exported. The largest sub-component, by value, of the agriculture production sector in BC is fish and livestock. In 2007, about 1.3 billion dollars of fish and 600 million dollars of livestock and meat products were produced in BC.

Figure 1: Approximate value in Canadian dollars of foods imported into, exported from, and produced in British Columbia in 2007.



Note: Industry Canada has data on the Canadian dollar value of foods imported into BC and exported from BC and, Statistics Canada has data on the value of foods produced in BC. Because Industry Canada and Statistics Canada classify foods in different ways, it is difficult to accurately compare the volume or value of imported and BC produced foods to determine the relative import dependence for different types of foods. By aggregating Statistics Canada food categories it is possible to arrive at a rough estimation of value of foods, by basic food category, that are both imported and produced in BC.

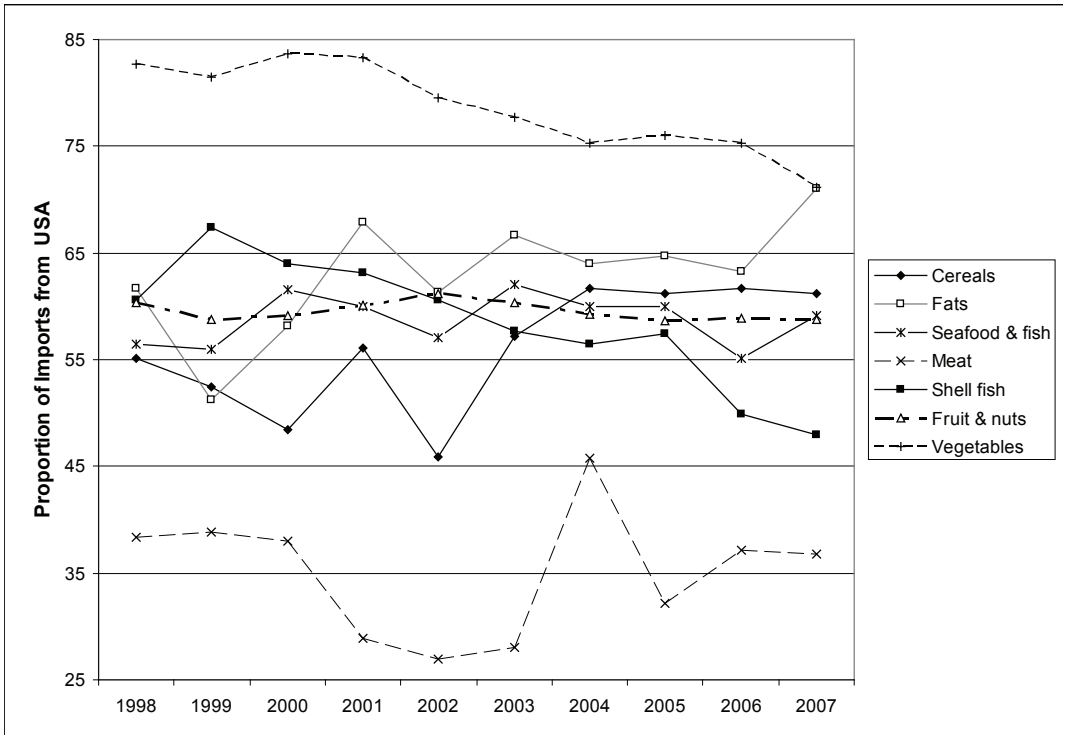
It is clear from Figure 1 that dairy products are the most "local" category of food in the province as most is produced for consumption in BC, and import and export markets are limited. There is a somewhat similar pattern for live animals and meat, although it is much less pronounced. It should be noted that almost all dairy and many meat products are heavily protected with tariffs and production within BC is regulated using supply quotas. Fish farmed and wild in BC (and either consumed in the province or exported) is by far the largest single "crop" (at least in terms of dollar value). (Note – the value of farmed relative to wild fish has been rapidly accelerating in BC). Figure 1 also demonstrates very different import, export and production patterns for fruit and vegetables as BC is clearly much more dependent on imports for these two categories of foods.

BC agriculture has shifted markedly in the past 50 years from a fairly balanced production of meat, fish, dairy, grain, fruit and vegetables to one that is now more heavily focused on production of grains grown for livestock, meat, fish and dairy, with less local and more import reliance on cereals for human consumption, fruit and vegetables.[8] While most of our vegetables and fruit are imported there is an important vegetable and fruit sector in BC. However, there has been a marked decline in the quantities of field grown vegetables in BC (except for potatoes) over the past quarter century and a stunningly rapid growth in greenhouse vegetable production.[9] The greenhouse vegetable industry in BC is mainly located in the Lower Mainland and is almost entirely geared to the production, for export, of tomatoes, cucumbers and bell peppers. As in the case of field vegetables, there has been a major decline in the production of tree fruit in BC over the past quarter century mainly because many Okanagan orchards have switched to intensive grape production for wine.[10]

2.3 From where does BC import its food?

In 2007, approximately 70 % of fats and vegetables, 60% of cereals, fruit and nuts and fish, 50% of shellfish, and 40 % of meat imported into BC came from the United States (Figure 2). Also, shown in Figure 2, the pattern of food import dependence on US sources has remained largely unchanged for the past decade, except in the case of vegetable imports which decreased by about 10 percent over the decade. By 2007, BC imported about three quarters of its vegetables from the United States.

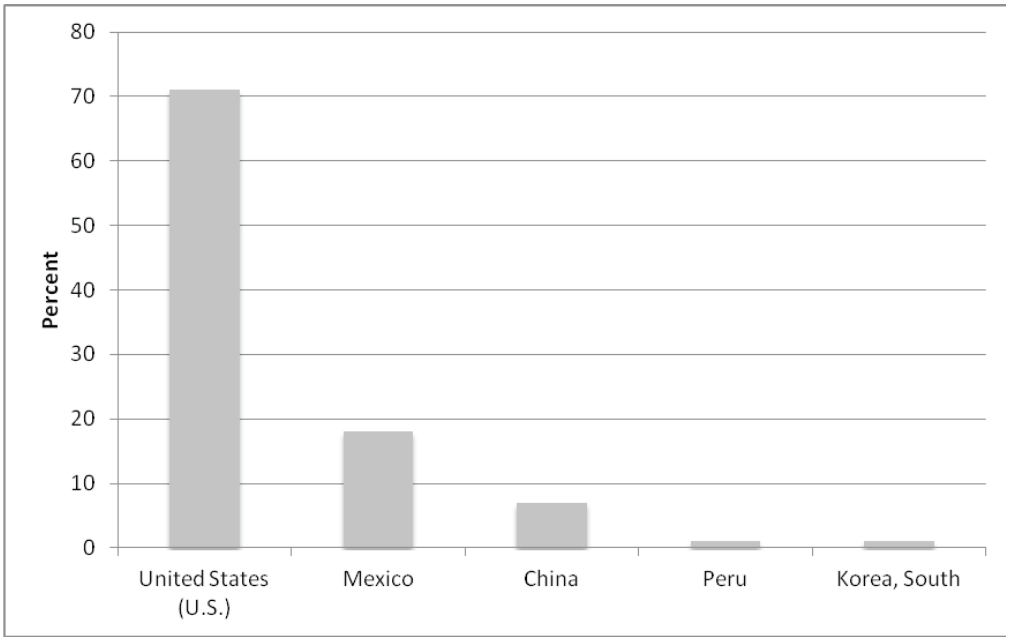
Figure 2: Proportion of imports from the USA into BC by major food categories from 1998 to 2007.



Source: Industry Canada, 2009.

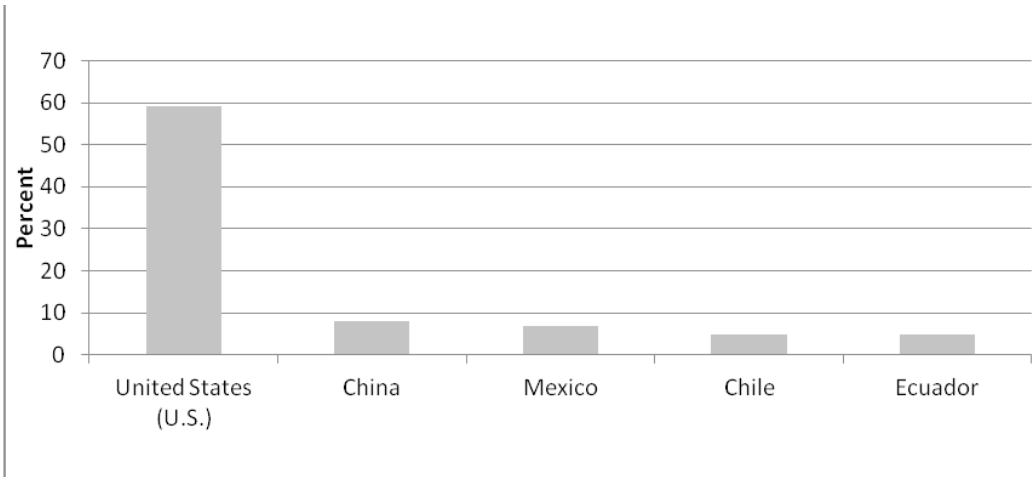
BC is more reliant on imports of fruits and vegetables than other foods. In 2007, approximately 70% of our imported vegetables came from the United States and about 17% came from Mexico with China also supplying 7% (Figure 3). Figure 4 shows that 55% of BC's imported fruit came from the United States (primarily California), about 8% came from Mexico and Ecuador respectively, 7% from China and 6% from Chile, and the remaining 13% came from 30 other nations. Thus, for fruits and vegetables, the United States is the most important source while Mexico and China play a lesser role in BC's fruit and vegetable security.

Figure 3: Top 5 source nations for imports of vegetables to BC and proportion imported into BC in 2007.



Source: Industry Canada, 2009.

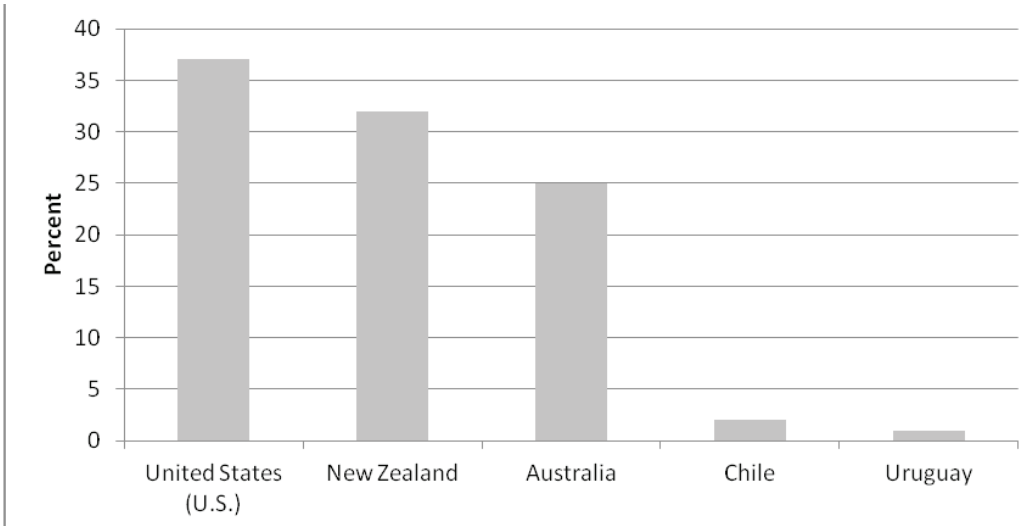
Figure 4: Top 5 source nations for imports of fruit to BC and proportion imported into BC in 2007.



Source: Industry Canada, 2009.

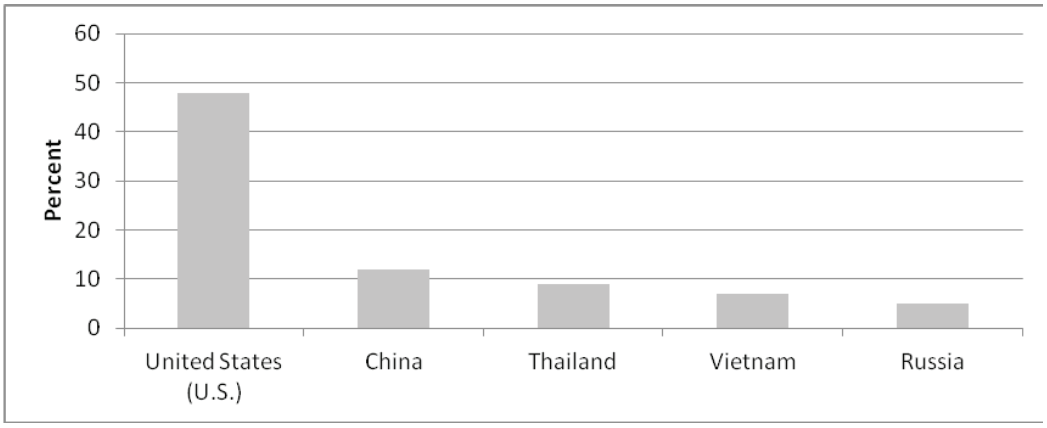
Other than the USA, which in 2007 provided 35% of BC imported meat, the nations that supply a significant proportion (58%) of meat to British Columbians are Australia and New Zealand (Figure 5). Given that meat imports form a relatively small proportion of total meats consumed in BC, if these supplies were eliminated due to adverse climate events in these two nations the impact would be relatively small on food security in BC. Despite producing a significant amount of fish in the province, fish are imported from the US as well as China, Vietnam, Thailand and Russia (Figure 6).

Figure 5: Top 5 source nations for imports of meat to BC and proportion imported into BC in 2007.



Source: Industry Canada, 2009.

Figure 6: Top 5 source nations for imports of Fish to BC and proportion imported into BC in 2007.



Source: Industry Canada, 2009.

We have sketched the basic outlines of BC's current food system, in terms of production and import and export flows. With this information in place it is easier to assess how future non-climactic factors might impact the food security of British Columbians.

2.4 Non-climactic influences on BC's food system

Even if climate change was not occurring, demand for food is rapidly accelerating driven by a growing human population that is increasingly wealthy.[11] As developing nations become developed ones, diets tend to shift towards increased meat, dairy and fat intakes. Because the quantity of arable land is limited, demand for "western" diets, will result in the intensification of agriculture on existing lands in order to increase current yields. These intense methods usually require greater application of fertilizer, which will generate more nitrous oxide (N_2O). In other words, current global demographic, economic and dietary trends point to both future increases in the demand for food as well as future increases in GHG emissions from a more energy-intense agriculture.

BC's food system will also be subject to increased internal demand as the population is predicted to increase by about one third from 4.5 to 6.1 million by 2036.[12] Over the next quarter century, the quantity of food needed in BC from local production and from imports is going to increase markedly at the same time as the demand for food exports increases. This increase will occur even if BC attempts to stabilize or otherwise protect its export sector from expected increases in global food demand.

While it is difficult to predict the precise kinds and quantities of food that BC will need to produce and import, this demand will be driven by changes in demography, income levels and consumer preference. To some extent these are predictable. For example, it is clear that the long term decline in milk consumption, underway in Canada, and in most other developed European nations, over the last 40 years, has been mainly due to a steady decline in the birth rate resulting in an ever shrinking proportion of infants and young children in our population.[13] It is also clear that the concomitant rise in cheese and consumption of other dairy products is shaped, in part, by campaigns which have opened up new markets for other dairy products (e.g. pizza-driven cheese consumption). Canada's relatively high immigration rates also have a cumulative impact especially on the types of food that will be demanded in the future as immigrants (at least for the first generation or two) bring with them their own food preferences.

These demands arising from shifts in population, income and consumer preference will also be directed and mediated by developments in industry including the changing structure of corporate ownership, shifts in horizontal and vertical integration within industry and new food production technology. They may be further moderated by global, Canadian, and British Columbian agricultural, food and health policy. For example, the way in which global agricultural trade talks evolve (or not) in the next decade will shape export markets for agricultural products. And, in terms of health and nutritional policy, nutritionists are increasingly developing guidelines to encourage individuals to consume more vegetables, more fruit and nuts and more fish. The net effect of these health guidelines, especially in a more educated population, will be to increase demand for these types of food.

As climate change evolves it too will begin to exert its effects on BC's system of food production, import and export. The question that emerges is how can we manage and plan for this new pressure on our food system while improving our food security and the dietary health of the population, while reducing or, at the very least, holding GHG emissions from food production and transportation steady over the next quarter century in BC?

In summary, production in BC is particularly strong for fish, dairy and meat (i.e., for high value protein and animal fat). The ability to develop comprehensive made-in-BC climate change sensitive policies in these sub-sectors of BC agriculture is therefore fairly high. However, BC imports about half of its food. Import dependence is much greater than this for fruit, cereals for human consumption, and for vegetables. California is a key source of most vegetable and fruit imports to BC. How climate change evolves in that state in relation to food production is key for understanding future fruit and vegetable security for British.

3. IMPACTS OF CLIMATE CHANGE ON FOOD SECURITY OF BRITISH COLUMBIANS

3.1 Introduction

BC's climate has warmed significantly in recent decades with changes in temperature, and with precipitation in southern BC exceeding global average changes.[14] More extreme weather events have also been documented. For example, at some locations in Metro Vancouver,[15] extreme precipitation has been increasing in both frequency and intensity during times of year that are important to agriculture. In the period 1999 to 2002, extreme climate-related natural disasters cost BC an average of 10 million dollars per year. In the period from 2003 to 2005 average yearly costs of these types of disasters rose to 86 million dollars per year in the province.[16]

The long term changes in temperature and rainfall associated with climate change are likely to significantly affect agricultural production in BC and the food security of its residents. There is a body of research that indicates an increase in carbon dioxide in the atmosphere will, in the short and medium term, lead to increased yields for some grain and other kinds of crops.[17] Little information is available for BC, although there is the suggestion that, over the short and medium term, as northern regions such as the Peace River Valley warm, the range and types of crops grown there could increase.[18] However, it is important to note that in the long term, this window of temperate crop yield improvement (to the extent that it may exist), will close and reverse rapidly reducing crops yields. Worsening climactic conditions in BC are likely to adversely impact food security directly through i) physical degradation of land and water used in agriculture, ii) biological changes such as increases in plant and animal pathogens in staple crops, iii) increased air pollution from forest fires and atmospheric ozone iv) de-stabilization of communities through degradation of local agriculture and reductions of income directly reducing the ability of British Columbians to purchase food and conduct local farming operations.[19]

3.2 Physical degradation of land and water used in agriculture

Projected sea level rise rates will vary significantly along the BC coast with climate change.[20] Sea level rise may cause groundwater and land quality degradation through salination along the coast and coastal valleys.[21] Along the coasts, high winter stream flow and increased groundwater levels coupled with increased runoff due to greater frequency of extreme events, may lead to greater erosion and contamination of agricultural land and water.[22] Such floods (as well as increased winter runoff and sedimentation of streams) may adversely affect salmon breeding habitat reducing the already stressed wild salmon fishery in BC[23] and reduce viability of salmon farms. Given that floods tend to occur more in agriculturally productive flood plains (Peace River and Fraser River Valleys) increased flooding attendant to climate change may negatively affect crop growth, particularly if contaminant and salt levels increase.[24]

While the coasts may experience more hazards related to increased water inundation due to climate change, somewhat paradoxically, in the short and medium term, earlier spring melt coupled with shifts to more precipitation in winter and less in summer, will reduce groundwater recharge rates in summer time leading to more frequent and prolonged droughts especially during peak summer demand periods, and particularly in the Okanagan and other dry regions of the province.[25]

With temperature increases, built up urban areas are prone to an "urban heat island effect". Very high temperatures in concrete urban cores may reduce the option of relying more on urban gardening,[26] as this would put strain on water supplies through projected decreases in summer rainfall and winter snowpack.[27] In regions of the province affected by forest kill due to mountain pine beetle (MPB) infestation (a direct result of climactic change) secondary impacts on agriculture due to increased fire and flood could be considerable. Dead standing trees are a fire risk and also exacerbate rapid water run-off patterns in the spring. It is therefore likely that increased fire and flood will occur, particularly in the zones of the province affected by MPB[28] with possible degradation of water and land used for agriculture in these regions of the province.

Finally, air pollution occurring with temperature increase may reduce crop yields particularly near urban regions in BC and especially due to greater exposure to ozone.[29] Air pollution/temperature interactions could be further exacerbated by increased particulate exposure due to wood smoke from more severe and frequent forest fires[30] further compromising crop yields in affected areas.

3.3 Biological changes attendant to climate change that may impact food security

As well as the physical changes outlined above, biological alterations will arise when temperatures and precipitation increase. The higher average rainfall and temperatures and earlier onset of spring predicted for BC could result in prolonged transmission cycles for vectors of human, plant and animal disease.[31] New fungal pathogens that originate in warmer and wetter climates may find the local soil ecology and climate more welcoming with climate change.

3.4 Community dislocation, climate change and impacts on food security

Rural and remote places in central and northern BC are already facing a severe climate-change related disaster, namely infestation of pine forests by the mountain pine beetle.[32] Effects of climate change on rural resource-dependent communities will likely arise through socio-economic de-stabilization directly arising from depletion of these forests. The effects will be magnified in vulnerable communities, as they are already buffeted by more adverse socio-economic winds than more diversified urban communities.[33] This double de-stabilization threat to communities could be exacerbated because many will also be exposed to increased frequency of fires and floods (as forests infested with MPB are at heightened risk for fire), which may also degrade their agricultural land.[34] Therefore, impacts of climate change may be particularly severe for local food security which is often fragile in small remote and rural communities, especially those located outside BC's main agricultural regions.

Finally, aboriginal communities, particularly those located in coastal regions, in MPB affected zones and those that are already economically and environmentally challenged, may be at risk for further adverse impacts on food security due to community dislocation exacerbated by climate change. This may be particularly true for those aboriginal communities that are highly dependent on "wild foods" such as salmon that are under direct threat due to climate change.

3.5 Impacts of climate change on agricultural productivity in California

According to the California Energy Commission: "First, the impacts of climate change, often still perceived as problems that might manifest in the distant future and in distant places, are actually evident in California at this time. Second, with only a relatively small temperature increase over the past few decades, the magnitude of impacts on physical and ecological systems is surprisingly large, especially for essential resources such as snowpack and water supplies. Moreover, in the last few decades, these changes have begun to accelerate."[35]

Given BC's high dependence on California for vegetables and fruit, it is also imperative to understand the potential impacts of climate change in that state as any reduction in agricultural productivity there could have major implications for the food security of British Columbians.

While increases in average temperatures will play a role in California's agricultural production, there are other important variables such as minimum winter temperatures and water availability. By the end of the century, the Sierra Nevada snowpack is predicted to be 30% to 70% lower than at present, due to an increase in rainfall versus snowfall, and earlier melting of the snowpack.[36] This change will be most prominent in the southern Sierra Nevada where 80% of California's snowpack storage currently occurs. The combined effects of less snow and reduced reservoir storage will make less water available in the summer for agriculture. The changing availability of river water in California will lead to heavier reliance on groundwater resources, which are currently stretched beyond capacity in many agricultural areas in the state.[37]

The impacts of these anticipated climatic changes in California include diminished yields from increased temperatures during crop and animal development,[38] shorter periods of crop development,[39] reduced product quality from unseasonal precipitation or adverse temperatures during fruit development,[40] and shifts in growing regions suitable for specialty crops.[41] Increased temperatures may adversely affect yields of tomato,[42] rice,[43] stone fruits,[44] grapes,[45] and milk.[46] Furthermore, by the end of the 21st century, orchards in California are expected to experience less than 500 chill hours per winter, which will negatively affect fruit and nut production.[47]

This paper does not consider the impact of climate change in China or Mexico or other major sources of BC's food imports. However, it is quite likely that in China especially, given the acceleration in the nutrition transition, rapidly growing incomes, and environmental degradation (including due to climate change) that local demand for increasingly scarce food supplies may limit future exports to BC.

In summary, there is little direct evidence to guide food and climate change policy in developed nations located in agriculturally productive temperate zones. However, the little evidence available suggests that BC's agricultural regions will face new biological, physical and socio-economic threats, especially on our agricultural periphery, and these may evolve in unpredictable fashion. The evidence that a carbon dioxide fertilization effect might increase yields of important crops in BC is limited and indirect[48] and must be evaluated against the likelihood of physical and biological degradation of agri-ecosystems as these face a difficult-to-predict mix of long term climate change and extreme weather events. Finally, rural and remote places on the periphery of BC's three main agricultural regions, especially those on the coast, may be the "canaries in the mine" for climate change in terms

of impacts on food production. (The recent unprecedented deluge in the Bella Coola Valley, is a good example of the power of an extreme weather event to disrupt the food supply and local agriculture in these kinds of vulnerable communities). Finally, California is suffering from drought and is likely to suffer further as climate change evolves. Given that this state is BC's main source for fruit and vegetables BC diversification away from this climate-change sensitive region should be a priority for BC food security policy.

4. FOOD PRODUCTION IN BC AND GHG EMISSIONS

4.1 Introduction

Because the agricultural sector itself produces GHG emissions, any policy changes that involve growing different crops or animals and/or using different methods to produce and transport food in BC must be undertaken with awareness of their potential contribution to GHG emissions. In other words, any positive policy adaptation to improve food security for British Columbians should be undertaken in such a way that GHG emissions from agriculture are minimized. This presupposes, of course, that the research evidence either exists, or can be gathered, to determine the various GHG emission scenarios arising from major shifts in the way we grow and transport our food.

4.2 The volume and character of GHG emissions from agriculture

Globally, anthropogenic GHG emissions from agricultural activity accounted for 10-12% of total emissions in 2005.[49] The most significant greenhouse gases produced by agriculture are carbon dioxide (CO_2), nitrous oxide (N_20), methane (CH_4) and nitrate (NH_3)[50] – the sector being responsible for approximately 60 % of N_2O and 50% of CH_4 global emissions. This is important because N_2O and CH_4 have a much greater radiative effects than CO_2, therefore contributing proportionately more to global warming than CO_2 emissions.[51] Therefore, while the agricultural sector is not the largest contributor to global GHG emissions, it is disproportionately responsible for producing large amounts of the worst types of GHGs.

The main sources of GHG's from agriculture arise from decomposition of organic matter (i.e. plant litter, soils, manure).[52] Carbon dioxide is released primarily from microbial decay or burning of plant litter and soil organic matter.[53] The largest sources of CH_4 in agriculture are from fermentative digestion of ruminant animals, stored manure and rice grown under flooded conditions.[54] Decomposition of organic materials under oxygen-poor conditions also produces CH_4. Nitrous oxide is emitted during the transformation of nitrogen in soil and manure by microbes, a process that is greatly enhanced by the addition of nitrogen fertilizers to agricultural lands. Emissions of N_2O are greater when vegetation is nitrogen saturated, especially under wet conditions.[55]

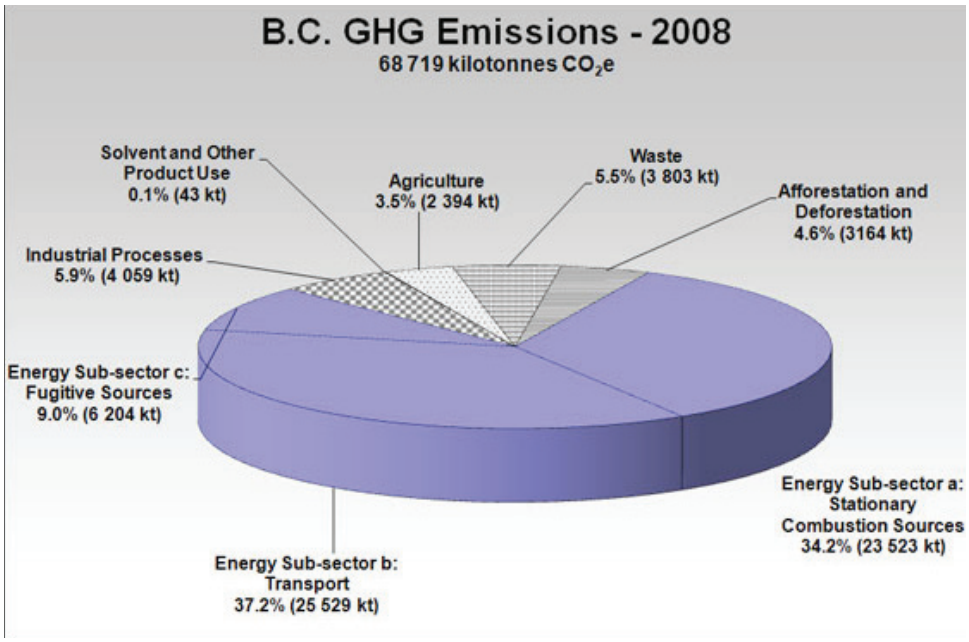
According to Environment Canada (2009), animal production is responsible for about 60% of Canada's agricultural GHG emissions. (Note - This inventory is not comprehensive, as emissions from the distribution of agricultural products and emissions from on-farm energy use are omitted). Enteric fermentation, in turn, is responsible for approximately 65% of animal emissions in Canada (24Mt in 2006). Ruminants, especially beef and dairy cattle, are mainly responsible for enteric emissions of CH_4 with a minor contribution from swine. Beef cattle are the species that produce the greatest emission of CH_4 gas in Canada.[56] Given that CH_4 is a more potent agent of global warming than carbon dioxide this is a major concern.

4.3 GHG emissions due to food production in British Columbia

On a per capita basis, BC is one of the lowest greenhouse gas emitters in North America. Within Canada, it currently ranks second lowest after Quebec in GHG emissions per person. In 2008, BC emitted 68.7 million tons (MT) of greenhouse gas emissions measured in carbon dioxide equivalent (CO_2e), representing approximately 8.9% of Canada's total GHG emissions.[57] The predominance of hydroelectricity in the provincial energy grid is the main reason for the relatively low per capita emissions along with the fact that BC's agricultural sector is, relative to other parts of Canada, quite small.

As shown in Figure 7, emissions from agriculture in BC represent 3.5 % of all emissions in the province in 2008.

Figure 7: BC GHG Emissions



Source: BC Ministry of Environment, 2010.

According to the Ministry of Environment (2010), within BC's agricultural sector, livestock production accounts for 48% of agricultural emissions, emissions from agricultural soils account for 36% and, emissions from manure account for 15%. Given these statistics, it is clear that a focus of GHG reduction strategies in the province's agricultural sector should be on livestock production and management.

The Investment Agriculture Foundation of BC and the British Columbia Agriculture Council have jointly established an industry-led Climate Action Initiative Committee, which is working on a climate action plan for agriculture. In partnership with the initiative committee, the BC Ministry of Agriculture and Lands and the BC Climate Action Secretariat are identifying various GHG reduction and adaptation strategies for the agricultural sector. These include facilitating the development of anaerobic digesters that utilize agricultural waste to produce biogas, exploring the role of agriculture in supplying carbon credits, developing programs to increase on-farm energy efficiency, and providing incentives for beneficial management practices that reduce emissions. The initiative also

develops tools and resources that provide information to agricultural producers on climate-related topics.[58]

In summary, BC agriculture is, relative to other sectors in the province and relative to other agricultural sectors in Canada, a relatively low emitter of GHGs. This is due to fairly high reliance in BC on clean hydro energy and the province's small agricultural sector. Nonetheless, the greatest contributor to GHG emissions in BC is from meat (mainly cattle) production which is responsible for most of the methane emissions in this sector. While government has developed programs to reduce these emissions it is unclear how successful they are especially given the relatively major expansion of this sub-sector relative to others over the past quarter century.

5. ADAPTING FOOD AND AGRICULTURAL POLICY TO REDUCE GHG EMISSIONS AND IMPROVE HEALTH

5.1 Introduction

The central challenge is how to both encourage British Columbians to eat more healthy locally produced foods while at the same time shifting the province's agricultural systems towards a foundation that is more ecologically sustainable with lowered GHG emissions. Further it is essential that advice from health professionals to individual British Columbians to eat more healthy foods is supported with policies that make these foods readily available at a reasonable price.

5.2 Improving fruit and vegetable consumption in BC

In 2007, only 40% of British Columbians consumed recommended quantities of fruit and only 35% of the population consumed recommended amounts of vegetables.[59] The large quantities of fat in the diet of British Columbians in combination with low regular intakes of fruit and vegetables are associated with an increasing prevalence of diet-related chronic illnesses like diabetes.[60] As well, people who are poor and therefore the most food insecure tend also to have even lower intakes of fruits, vegetables and milk products than the average[61] and are therefore at particularly high risk from diet-related chronic illness compared to the general population. Accordingly, the Chief Medical Health Officer in BC has recommended that British Columbians reduce their intakes of fat and increase their intakes of vegetables and fruit in order to reduce the prevalence of diet-related chronic illness.[62]

Given these health and equity considerations and that we have seen fairly dramatic (and continuing) reductions in the production of field vegetables (except potatoes) and tree fruit in BC (the same trend has occurred for soft fruits like berries except in the case of blue-berries) and, considering that our rapidly expanding greenhouse vegetable industry appears to be mainly export oriented, improving fruit and vegetable security in BC in the future is important. Climate change will make this issue even more important to the health of British Columbians. The confluence of the increased health need for BC's population to consume more vegetables with high dependence on a single likely-to-be heavily climate change affected region (California) for these foods, and deteriorating (non-potato) field vegetable growing capacity makes this a priority for policy makers as climate change unfolds. For fruit the issue is similar but perhaps more difficult, potentially, than for vegetables because most tree fruit in BC is grown in the Okanagan Valley. The Okanagan will likely face drier growing conditions on its already irrigation dependent system of fruit

production possibly at the same time that California's fruit regions become drier. This could lead to a climate-change induced reduction in the availability of fresh fruit in BC marking fruit self-sufficiency as a key issue as climate change unfolds.

Reversal of the current decline in both tree fruit and field vegetable (especially non-potato) capacity in BC is key. Eventual expansion of capacity in these sectors is also necessary. Finding ways to re-direct current greenhouse vegetable capacity from export to domestic consumers is also an important component in any attempt to directing BC's fruit and vegetable production capacity to domestic consumers.

Expansion of BC's fruit and vegetable production capacity makes sense in a future where produce from California may not be as available as it is at present nor at prices as low as they are at present. While BC importers may be able to diversify sourcing and obtain produce from places other than California, given the state's major role in global produce markets, produce obtained elsewhere under conditions of climate change induced food shortages will likely be quite expensive. Expansion of local vegetable and fruit capacity is good policy and serves as a hedge, particularly for poor and less healthy British Columbians, against higher future produce prices.

It is important in any adaption of agricultural policy in relation to climate change to grow more healthy crops for British Columbians while moving to sustainable methods of agricultural production and distribution with a focus on reducing GHG emissions. In terms of the latter it is essential to understand the role of "food miles" in the production of GHGs as there has been much public anxiety about the contribution of long food chains to both high energy inputs into modern food systems and into GHG emissions.

5.3 Food miles and GHG emissions

Several methods have been developed to measure the relative emissions arising from various part of the food production-distribution-consumption-waste food chain including energy accounting,[63] economic valuation,[64] ecological footprint analysis,[65] carbon accounting,[66] development of sustainability indicators,[67] and life-cycle assessment.[68]

While methods have become more sophisticated for estimating the GHG emissions of various food supply chains, the popular discourse on "food miles" remains fairly narrowly focused on the direct impact on the environment of transporting food from the farm gate or processing facility to the retail outlet. Because of this focus on food miles, consumers have been encouraged to purchase local food, in part, with a view to reducing GHG emissions due to transport from distant locations. However, most research on GHG emissions across the entire food production and distribution cycle for various foods show that the food miles component (even when broadly conceived) is a relatively minor contributor to emissions. The production portion of the food chain is the source of the bulk of GHG emissions for most (but not all) food supply chains. Accordingly, while the popular debate and policy response may be (at least partly) driven by rhetoric over the GHG emissions arising from long food miles, the evidence is weak. It is necessary to conduct GHG emissions analyses for all stages of the production and distribution cycle to resolve this issue.[69]

Using gross American data on household food expenditure and life cycle assessment methods, Weber and Matthews (2008) calculated the total GHG emissions due to food production and distribution in 2006 was 8.1 t CO_2 equivalent/yr per household. The transport of food accounted for 0.91 t CO_2 equivalent/yr per household (i.e., 11 %) of total GHG emissions

due to all food production and distribution. Furthermore, they demonstrated that 0.36 t CO_2 equivalent/yr per household was due to transport of food from the farm gate or production facility to retail outlets. This distance (farm gate to production facility) is the way in which food miles is usually conceptualized and indicates that in the United States food miles narrowly defined at least in this study, accounts for only four percent of total GHG emissions in the United States due to food production and distribution.

These gross food supply chain/GHG data indicate that the production link in the food supply equation contribute much more to GHG emissions than the food miles link. In addition, Wynen and Vanzetti (2008) point out that distance is only one factor in calculating the impact of the transportation of food on GHG emissions, both "the mode and scale of transport are important determinants of the quantity of energy used." Sea transport has a relatively low environmental impact, followed by rail, road and air transport. For example, sea transport of food emits approximately 15 grams per ton per kilometer (g/t/km) compared to 98 g/t/km from road transport, and 570 g/t/km for transport by airplane. There are also issues related to the number of vehicles used to transport food. A few large vehicles are more efficient than several smaller ones for transporting the same amount of food. Thus, any assessment of the impact of food miles on GHG emissions, must not only consider length but also mode and scale of transport.

6. DISCUSSION

Moving to policies that increase food security and the nutritional health of British Columbians while also reducing GHG emissions will require a more thoughtful and "joined-up" consideration of agriculture, food, health and nutrition policy along with stronger involvement of consumers and industry. Many basic decisions about where our food comes from and where it is exported are made in corporate board rooms. And yet, there appears to be insufficient research underway and relatively few partnerships with industry associations, major producers, major processors, or major distributors about the nature and character of BC's major food chains. This means that much industry thinking and plans about how these might have to shift as climate change unfolds is under articulated outside the sphere of public policy making This state of affairs is not conducive to the development of more evidence-based proactive planning to ensure we maintain and improve food security in BC as climate change unfolds.

There is a strong need to develop new partnerships between agricultural, health and nutritional policy makers on the one hand, and industry, farmers, and academia and consumers associations on the other hand. In BC, there are some unique partnerships already in place between nutritionists working in health authorities and the Ministry of Healthy Living and Sport and community organizations concerned with food security, as well as with farming and consumer organizations. Some of these partnerships have resulted in new programs and policies (e.g., farmers' market coupon program; farm-to-school salad bar program) that have better connected the world of nutritional and health policy making with agriculture, consumers and farming. As well, within government itself, there is, because of the growing concern about diet-related chronic illness, strong inter-Ministerial cooperation broadly around the issue of food security. A current BC Agriculture Council-led climate change adaptation risk and opportunity assessment for BC agriculture - that is supported by government and PICS – is also a step in the right direction. All these positive developments within government and across nutrition, health and agricultural policy arenas and between the government and NGO sectors in the province need to be strengthened and extended to include and involve the food industry.

With these types of partnerships BC is in a better position to pro-actively build an evidence base to plan for improved food security as climate change unfolds. These partnerships need to be developed at the local, regional, and at the highest levels (e.g., government, regional health authority and industry association levels). They need to be supported by strong research funding given that the types of policies needed require new types of information and monitoring. For example, at a very basic level, if we want to move to a food system in this province that enhances food security while keeping GHG emissions to a minimum we need easily accessible information about GHG emissions from alternative food chains for major types of food. And, as shown in this report, this information has to be for all links in the chain, not just for the "food miles" link.

More information is also needed about the economic implications of changes we might make in how, where and when we source our food. This will enable us to answer questions about the trade-offs between emissions and economy that will emerge as climate change begins to alter the basic rules of food supply and demand that have underpinned our system of food production, import and export in BC. The food and agricultural sector in BC is one of the largest employers and accounts for a major share of provincial exports. The economic implications of any changes in food and agricultural policy as climate change evolves could be large.

As shown in this report, there are major changes underway as formerly under-developed nations increase in population and income. New and emerging demands for the animal fats and protein that underpin the Western diet of most North Americans and Europeans (and that underpin BC's food export sector) are exploding. These new demands are the fundamental context within which food policy must be made in the near future as constraints on food supply due to climate change come into play. This means that future policy vis-à-vis climate change and food security in BC cannot focus solely on climate change. There is a need to move to a holistic sustainability model for our province's system of food production, import and export. This model also needs to fully embrace the "health" dimension. In other words, we need policy that moves production, import and exports of food in a direction of greater food security and improved nutritional health for the population, while reducing GHG emissions.

In conclusion, a major question for policy makers concerned about health, food security and climate change is; are we going to react to changes in supply and demand for food as these are shaped by climate change or are we going to build the evidence base and partnerships required to develop intelligent, forward-thinking policies that improve BC's food security situation as these new constraints emerge?

7. RECOMMENDATIONS

1. In order to build appropriate partnerships, make the connections between food security, climate change and health more explicit.

Kearney[70] notes that "food policies will only be effective if they are developed with input from both the agricultural and health sectors, thereby enabling the development of coherent policies that will ultimately be beneficial to agriculture, human health and the environment." Historically, agriculture and health have operated in separate silos although this is beginning to change in BC with examples such as the BC Fruit and Vegetable Program. However, there is the need to create "joined up" food and agricultural policies that can address the nutritional needs of consumers as well as the economic needs of producers.

2. Make more explicit the connections between food security, climate change and health for consumers.

There are several mechanisms that governments might use to inform consumers of the linkages between a healthy diet and climate change including "food pricing, food marketing and labeling, and community-level interventions".[71] For example, Sweden produced dietary guidelines in 2009 recommending that citizens eat meat less often and in reduced quantities, to decrease greenhouse-gas emissions.[72] Carbon labeling is another strategy to inform consumers about the environmental impact of food that they purchase in an effort to encourage them to make choices that result in lower GHG emissions. Several retailers in the UK and Europe have developed carbon labels for at least some of the products they sell. However, if consumers are asked to change their food consumption habits to reduce GHG, low carbon food must be available at a price that is affordable.

3. Promote local agriculture .

The promise of the global industrial food system to supply food cheaply to large populations may be threatened as climate change evolves. One needs only to look at the events in Russia in the summer of 2010 to realize that very hot temperatures in normally cool regions with major forest ecosystems lead to fires. In the summer of 2010 an extreme heat wave and subsequent fires reduced the grain harvest to such an extent that grain exports were banned. The impact on grain prices was immediate. This "incident" however, serves as a reminder of the way in which normally reliable international supply through long well established food chains can be disrupted quite suddenly by climate-related disasters.

There is a need, in the likely more unpredictable food supply of the future, and in conjunction with increased global demand for food, to firmly "establish" local supply. This may require intervention by government. For example, in BC, the most "local" food supply chains are those in the dairy industry. As shown in figure 1 of this report, BC has a negligible dairy products food import or export sub-sector. The large dairy industry in BC is mainly for within-province consumption. This situation has evolved through supply management policies. Although attacked often by the World Trade organization and by some economists and consumers, it is likely that supply management in BC has helped to preserve the more local character of these diary food chains.

4. **Develop the evidence base required to make pro-active food security policy in BC as climate change evolves.**

   It is necessary to develop a better evidence base especially for analyzing GHG emissions from links in BC's major domestic, import and export food supply chains and in relation to the economics of choosing different kinds of food production, import and export strategies. It is only with these data in place that we can determine the climate change implications when we develop food policy which alters existing food supply chains or moves to entirely or partially new ones.

5. **Develop evidence for impacts of different climactic scenarios on crops that are important to BC to maximize limited land production capacity.**

   We need to be able to model the impact of various climate change scenarios on crop yields in BC in order to better understand future impacts on production both for within-province consumption and for export. An important question for the food security of British Columbians is "as climate change unfolds what will happen to yields especially for foods that we export"? These models should attempt to model multi-causal impacts and not just single variable impacts in isolation such as is often done in CO_2 fertilization modelling.

6. **Ensure that current initiatives underway in BC to manage GHG emissions from the meat and dairy industry and from manure are effective and if they are not, improve their effectiveness.**

   While, as pointed out in this report, a number of initiatives are underway in the meat production sector to better manage emissions, it is necessary to develop a clear and comprehensive monitoring framework to ensure that reductions in emissions are achieved.

7. **Monitor changes food prices as the climate changes in order to be able to proactively develop policy to cushion the impact of reduced availability and access for the entire population but especially those with low income.**

   This is particularly important for more nutritious foods such as vegetables, fruit, fish and grains for direct human consumption as these items are under-consumed at present.

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