ECONOMY WIDE AND EMERGING ISSUES

Growing Risk:
The impact of changes in agricultural production on consumer expenditures in Canada Appendices

Appendix 1

QUESTIONS AND ANSWERS ABOUT THE ECONOMIC MODEL

What was the model used?

The model used is a custom-built Computable general equilibrium (CGE) model representing Canada as a small open economy. It is based on input/output data tables from Statistics Canada and defines key parameters like price elasticities based on literature and other similar models. For details on a similar model see: http://web.mit.edu/globalchange/www/MITJPSPGC_TechNote6.pdf.

What parameters were altered?

The alternative scenarios were created by adjusting the productivity of the agriculture sector -- that is, how much output agriculture is able to produce (i.e., food crops) relative to inputs (including labour, land, capital, materials, etc.). The scenarios explore implications of decreased agricultural productivity; essentially these scenarios assess outcomes if producing agriculture becomes more expensive.

What are the data sources and dates for the unaltered parameters in the CGE model?

Main data sources are the Canadian input/output tables provided from Statistics Canada (http://www.statcan.gc.ca/nea-cen/list-liste/io-es-eng.htm). Agricultural productivity emerges from the tables that explore expenditure flows between sectors. That is, the base-case productivity is defined by the level of production in agricultural and the level of consumption of intermediate goods and factors of production.

Could the sectors be drilled down to more micro levels? How far? Is the data available, from where, and for what time periods? What is involved in gathering it?

Not really possible; more detailed data are not really available, and significant effort required to adjust model to provide more resolution. The essential data required is the Input/Output table collected by Stats Can, disaggregated by sub-sector.

Modelling Results

Table 2: Impact on Consumer Prices

SCENARIO	DECREASE AGRICULTURAL PRODUCTIVITY BY 10%	INCREASE AGRICULTURAL PRODUCTIVITY BY 10%
OTHER SEMI-DURABLES	-0.3%	0.3%
FOOD & NON-ALCOHOLIC BEVERAGES	4.4%	-3.6%
OTHER NON-DURABLES	0.3%	-0.4%
OTHER SERVICES	-0.3%	0.3%
HEATING FUEL	-0.6%	0.5%
NATURAL GAS	-0.5%	0.4%
NET EXPENDITURES ABROAD	-0.2%	0.2%
ALCOHOL & TOBACCO	0.3%	-0.2%
RESTAURANTS & ACCOMMODATION SERVICES	1.2%	-0.9%
MOTOR VEHICLES & PARTS	-0.7%	0.6%
CLOTHING	-0.6%	0.5%
FURNITURE & HOUSEHOLD APPLIANCES	-0.6%	0.5%
OTHER DURABLE GOODS	-0.6%	0.5%
MOTOR VEHICLE FUELS & LUBRICANTS	-0.5%	0.5%
OTHER TRANSPORT	-0.6%	0.5%
ELECTRICITY	-0.6%	0.5%
OWNED LIVING QUARTERS	-1.4%	1.2%
RENTED LIVING QUARTERS	-0.3%	0.2%
RECREATION, READING & ENTERTAINMENT	-1.1%	0.9%
HEALTH	-0.6%	0.5%

Source: Sustainable Prosperity

Table 3: Impact on Consumption (Quantity, not value)

SCENARIO	DECREASE AGRICULTURAL PRODUCTIVITY BY 10%	INCREASE AGRICULTURAL PRODUCTIVITY BY 10%
OTHER SEMI-DURABLES	-0.6%	0.5%
FOOD & NON-ALCOHOLIC BEVERAGES	-1.8%	1.5%
OTHER NON-DURABLES	-0.8%	0.7%
OTHER SERVICES	-0.6%	0.5%
HEATING FUEL	-0.5%	0.5%
NATURAL GAS	-0.6%	0.5%
NET EXPENDITURES ABROAD	-0.7%	0.5%
ALCOHOL & TOBACCO	-0.8%	0.6%
RESTAURANTS & ACCOMMODATION SERVICES	-1.0%	0.8%
MOTOR VEHICLES & PARTS	-0.5%	0.5%
CLOTHING	-0.6%	0.5%
FURNITURE & HOUSEHOLD APPLIANCES	-0.5%	0.5%
OTHER DURABLE GOODS	-0.5%	0.5%
MOTOR VEHICLE FUELS & LUBRICANTS	-0.6%	0.5%
OTHER TRANSPORT	-0.6%	0.5%
ELECTRICITY	-0.6%	0.5%
OWNED LIVING QUARTERS	-0.4%	0.3%
RENTED LIVING QUARTERS	-0.6%	0.5%
RECREATION, READING & ENTERTAINMENT	-0.4%	0.4%
HEALTH	-0.5%	0.5%

Source: Sustainable Prosperity

Appendix 2: Agriculture and Climate Change

Agricultural Production

Agriculture in this paper refers to food crops grown on annual and multi-cropping cultivated lands. It excludes forests, fish and livestock.

Although agriculture is a large industry in Canada, only 7% of Canadian land is suitable for agricultural production, under current climatic conditions.[1] Primary agriculture accounts for only 1.7% of Canada's gross domestic product (GDP), though when all agri-food industries (including animal production) are combined, they account for 8.1% of GDP and 2 million jobs (2010 figures).[2] More than a third (38%) of agricultural production in Canada is used as a direct input for the food processing industry.[3]

Canada's main grain crops are barley, corn, oats, rye and wheat; its main oilseeds are canola, soybean and flaxseed; and main pulses include peas, beans, chickpeas and lentils.[4] Agricultural production is spread across the country, with the main growing regions grouped into five major zones, as shown in Table 4 below.

Table 4: Characteristics of key growing regions in Canada[5,6,7,8]

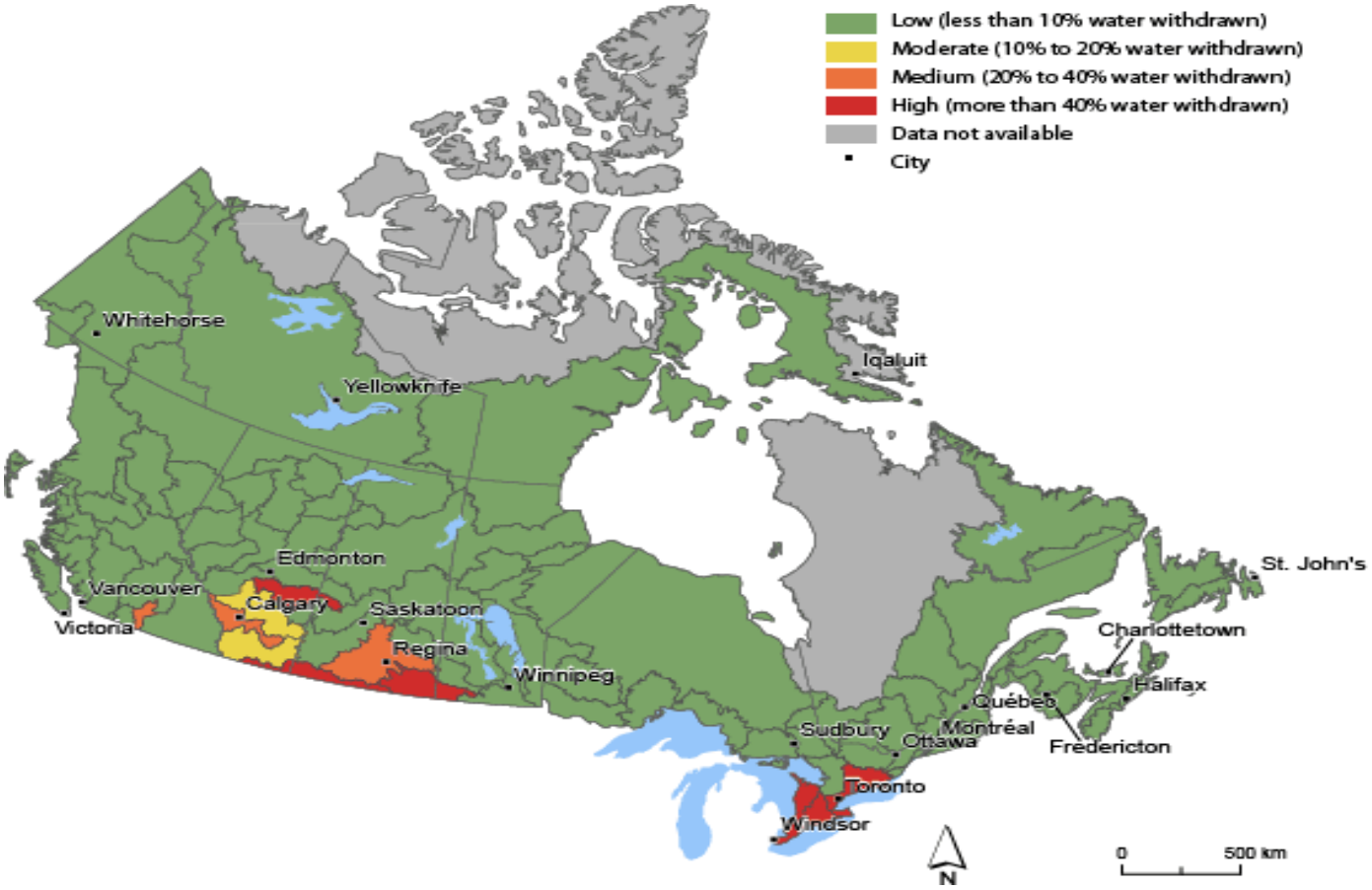
REGION	CLIMATE CHARACTERISTICS	% OF CANADIAN AGRICULTURAL LAND (INCLUDES RANGELAND & PASTURE)	% OF CANADIAN AGRICULTURAL GDP
BRITISH COLUMBIA	Low variation in Summer temperatures, humid, infrequent Winter frost, varied elevation.	3.5	7
PRAIRIES	Flat, short hot summers, very cold winters, low precipitation, strong winds.	81	46
ONTARIO	High, uniformly distributed precipitation, warmer temperatures, few early Spring and Fall frosts.	8.3	25
QUEBEC		5.1	17
ATLANTIC	Cold Winters, late Springs, cool Summers, frequent storms.	1.6	4

Source: Sustainable Prosperity, see footnotes

Water availability may not be an issue in much of Canada, but it can be in some of the country's main agricultural regions, as shown below in Figure 4.

[1] Government of Canada, 2004. *Climate Change Impacts and Adaptation: A Canadian Perspective*, http://www.nrcan.gc.ca/earth-sciences/products-services/publications/climate-change/climate-change-impacts-adaptation/356.
[2] Agriculture and Agri-Food Canada, 2012. "An Overview of the Canadian Agriculture and Agri−Food System 2012," http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1331319696826&lang=eng&src=hp.
[3] Agriculture and Agri-Food Canada, 2012. "An Overview of the Canadian Agriculture and Agri−Food System 2012," http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1331319696826&lang=eng&src=hp.
[4] Agriculture and Agri-Food Canada, 2012. "Crop Production," http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1183742189093&lang=eng.
[5] Weber, Marian and Hauer, Grant, 2003. A Regional Analysis of Climate Change Impacts on Canadian Agriculture. *Canadian Public Policy*, Vol. XXIX, No. 2.
[6] Agriculture and Agri-Food Canada, 2012. "Appendix C: Description of the Ecozones of Canada with Significant Agricultural Activity," http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1178820186667&lang=eng.
[7] Weber, Marian and Hauer, Grant, 2003. A Regional Analysis of Climate Change Impacts on Canadian Agriculture. *Canadian Public Policy*, Vol. XXIX, No. 2.
[8] Weber, Marian and Hauer, Grant, 2003. A Regional Analysis of Climate Change Impacts on Canadian Agriculture. *Canadian Public Policy*, Vol. XXIX, No. 2.

Figure 4: Threats to water availability in Canada (2007)



Source: Environment Canada, 2011. *Water Availability in Canada*, http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=1B1433B4-1.

Impacts of environmental trends

Agricultural growing conditions have evolved over thousands of years, and food crops have adjusted to the current climate. Agriculture is inherently sensitive to climatic changes given its dependence on a stable and predictable climate. According to the United States Environmental Protection Agency, "climate change could make it more difficult to grow crops, raise animals, and catch fish in the same ways and same places as we have done in the past".[9]

The key climatic determinants of agricultural production are temperature, soil moisture and fertility, length of growing seasons and severity of winter conditions, all of which will be impacted by climate change.[10] For example, research has shown that low soil moisture is the main limiting factors on wheat yields in the Canadian prairies.[11] Table 5 shows some of the predicted climate changes for Canada.

[9] United States Environmental Protection Agency, June 14, 2012. *Agriculture and Food Supply Impacts & Adaptation,* http://www.epa.gov/climatechange/impacts-adaptation/agriculture.html.

[10] Bootsma, A., 1997. A *review of impacts of climate variability and change on agriculture in Atlantic Canada*. Environment Canada.

[11] Qian, Budong, De Jong, Reinder and Gameda, Samuel, 2009. Multivariate analysis of water-related agroclimatic factors limiting spring wheat yields on the Canadian prairies. *European Journal of Agronomy* 30: 140–150.

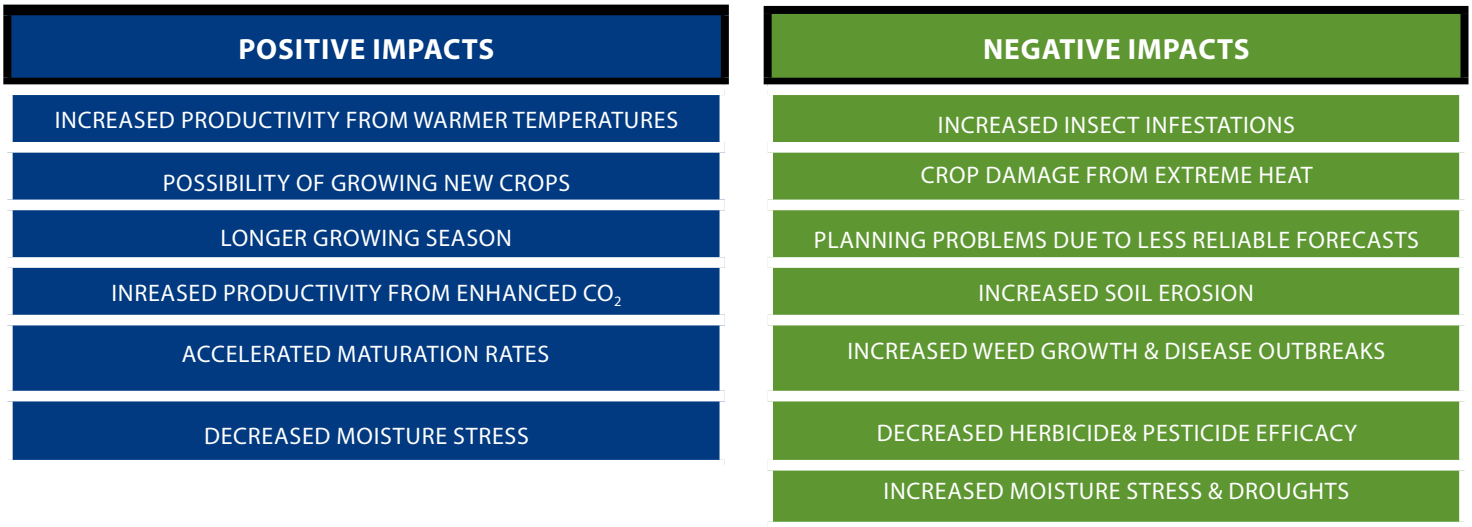
Table 5: Select Predicted Climatic Changes in Canada[12],[13],[14]

REGION	PREDICTED CLIMATIC CHANGES
PRAIRIES	Increase in temperature and reductions in soil moisture with a doubling of atmospheric carbon dioxide.
EASTERN CANADA	Extension of growing season by 5-7 weeks.
CENTRAL CANADA	Increase in average annual temperature of 5.88 C and in precipitation of 0.20mm (both per day) by 2099.

Source: Sustainable Prosperity, see footnotes

Agriculture in Canada could benefit from climate change due to longer growing seasons and, to a certain point and with sufficient water availability and appropriate soil conditions, warmer temperatures.[15] However recent research shows that above temperature increases to 30C, yields of crops such as cotton, soybeans and corn would significantly decline.[16] The interaction of the varied effects of climate change has an unclear impact on agricultural yields. Figure 5 shows the varying positive and negative effects.

Figure 5: Positive and negative impacts of climate change on agriculture in Canada



Source: Adapted from Natural Resources Canada. *Potential impacts of climate change on agricultural crops in Canada*, http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca.earth-sciences/files/jpg/perspective/images/figure1_potential_impacts_e.jpg.

Table 6 shows the likely impacts of select effects of climate change on crop yields, with details about how various aspects of climate change affect agricultural conditions and plants. It is important to keep in mind that these are general predictions, which will vary by location, type of plant, and other factors. In addition, the yield impacts do not account specifically for adaptation actions, which could potentially offset some of the effects of climate change, including changing planting dates, and irrigation and fertilizer levels.[17]

[12] International Institute for Sustainable Development, 1997. *Agriculture and Climate Change: A Prairie Perspective*, http://www.iisd.org/pdf/agriculture_climate.pdf.

[13] Pearson, Craig J., Bucknell, Delia and Laughlin, Gregory P., 2008. Modelling crop productivity and variability for policy and impacts of climate change in eastern Canada. *Environmental Modelling & Software* 23:1345–1355.

[14] William R. Cline. July 2007. *Global Warming and Agriculture: Impact Estimates by Country*. Center for Global Development and the Peterson Institute for International Economics.

[15] National Round Table on the Environment and the Economy, 2010. *Degrees of Change: Climate Warming and the Stakes for Canada*, http://nrtee-trnee.ca/climate/climate-prosperity/degrees-of-change.

[16] Schlenkera, Wolfram and Roberts, Michael J., September 2009. Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change. *Proceedings of the National Academy of Sciences (PNAS) vol 106 (37)*, 15594–15598.

[17] Weber, Marian and Hauer, Grant, 2003. A Regional Analysis of Climate Change Impacts on Canadian Agriculture. *Canadian Public Policy*, Vol. XXIX, No. 2.

Table 6: Select impacts of climate change on crop yields[18],[19],[20],[21],[22],[23],[24],[25]

ASPECT OF CLIMATE CHANGE	EFFECT ON AGRICULTURAL CONDITIONS	EFFECT ON PLANTS	LIKELY EFFECT ON YIELDS
HIGHER MAXIMUM TEMPERATURE	Increased weeds, insects and diseases. Longer growing season.	Growth rate accelerated due to increased plant temperature, which reduces the window of opportunity for photosynthesis.	Increase/Decline.
TEMPERATURE- SHOCK		Heat stress may inhibit growth, by accelerating plant life cycles, reducing photosynthetic capacity via restricted leaf area and duration, and inhibiting metabolism and reproduction.	Decline.
HIGHER CONCENTRATIONS OF CO_2		Stimulates plant growth, via increased photosynthesis and reduced plant water loss.	Increase - could offset yield declines ("carbon fertilization effect").
INCREASE IN SEA LEVEL	Salinization of soil and subsurface water in coastal regions. Loss of agricultural land.		Decline.
INCREASED RISK & DURATION OF DROUGHT	Soil erosion. Change in soil moisture availability.	Drought stress may inhibit growth by accelerating plant life cycles, reducing photosynthetic capacity via restricted leaf area and duration, and inhibiting metabolism and reproduction.	Decline.
INCREASED PESTS AND DISEASES	The range of pests will expand or change. New and more powerful diseases. Increased rate of development and number of pests.	Can kill or damage plants.	Decline.

Source: Sustainable Prosperity, see footnotes

PREDICTIONS

A number of researchers have used modelling to predict the impact of climate change on various crops, or land values or other factors. A number of the predictions for Canada are shown in Table 7 below. The predictions for Canada are mostly positive, largely due to the extension of the growing season, though the overall global predictions are negative.

[18] Reynolds, Matthew (ed.), 2010. *Climate Change and Crop Production*. CAB International.
[19] Government of Canada, 2004. *Climate Change Impacts and Adaptation: A Canadian Perspective*, http://www.nrcan.gc.ca/earth-sciences/products-services/publications/climate-change/climate-change-impacts-adaptation/356.
[20] Agriculture and Agri-Food Canada, 2012. "Climate Change: Questions and Answers," http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1188220105158&lang=eng.
[21] Reynolds, Matthew (ed.), 2010. *Climate Change and Crop Production*. CAB International.
[22] Reynolds, Matthew (ed.), 2010. *Climate Change and Crop Production*. CAB International.
[23] Agriculture and Agri-Food Canada, 2012. "Climate Change: Questions and Answers," http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1188220105158&lang=eng.
[24] Reynolds, Matthew (ed.), 2010. *Climate Change and Crop Production*. CAB International.
[25] Reynolds, Matthew (ed.), 2010. *Climate Change and Crop Production*. CAB International.

Table 7: Select predictions of climate change for Canada[26],[27],[28],[29],[30],[31],[32],[33],[34]

REGION	CROP/ASPECT	PREDICTION
ATLANTIC CANADA	Grain corn	Increase of 3.8 tonnes/hectare.
	Soybean	Increase of 1.0 tonne/hectare.
	Barley	No change.
CANADA	Land value	Increase by 65% by 2050.
NORTH AMERICA	Potential agricultural land	Increase of between 20-50% by 2080
ALBERTA	Canola, corn and wheat yields	Increase of between 21% and 124%.
QUEBEC	Corn and sorghum yields	Increase by 20%.
QUEBEC	Wheat and soybean yields	Decrease by 20-30%.
CANADA	Overall agricultural output	Decrease of 2.2% by 2080 (without carbon fertilization effect) or Increase of 12.5% (with carbon fertilization effect).

Source: Sustainable Prosperity, see footnotes

[26] Bootsma, A., Gameda, S., McKenny, D.W., Schut, P., Hayhoe, H.N., de Jong, R. and Huffman, E.C. , 2001. *Adaptation of agricultural production to climate change in Atlantic Canada*. Final report submitted to the Climate Change Action Fund.

[27] Ibid.

[28] Ibid.

[29] Weber, Marian and Hauer, Grant, 2003. A Regional Analysis of Climate Change Impacts on Canadian Agriculture. *Canadian Public Policy*, Vol. XXIX, No. 2.

[30] Easterling, W.E., P.K. Aggarwal, P. Batima, K.M. Brander, L. Erda, S.M. Howden, A. Kirilenko, J. Morton, J.-F. Soussana, J. Schmidhuber and F.N. Tubiello, 2007. *Food, fibre and forest products. Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 273-313.

[31] McGinn, S.M., Toure, A., Akinremi, O.O., Major, D.J. and Barr, A.G., 1999. Agroclimate and crop response to climate change in Alberta, Canada. *Outlook on Agriculture* 28 (1):19-28.

[32] Singh, B., El Maayar, M., André, P., Bryant, C.R. and Thouez, J.P., 1998. Impacts of a GHG-induced climate change on crop yields: effects of acceleration in maturation, moisture stress and optimal temperature. *Climatic Change* 38 (1): 51-86.

[33] Singh, B., El Maayar, M., André, P., Bryant, C.R. and Thouez, J.P., 1998. Impacts of a GHG-induced climate change on crop yields: effects of acceleration in maturation, moisture stress and optimal temperature. *Climatic Change* 38 (1): 51-86.

[34] William R. Cline. July 2007. *Global Warming and Agriculture: Impact Estimates by Country*. Center for Global Development and the Peterson Institute for International Economics.