The environmental impact of agricultural trade liberalization in Canada

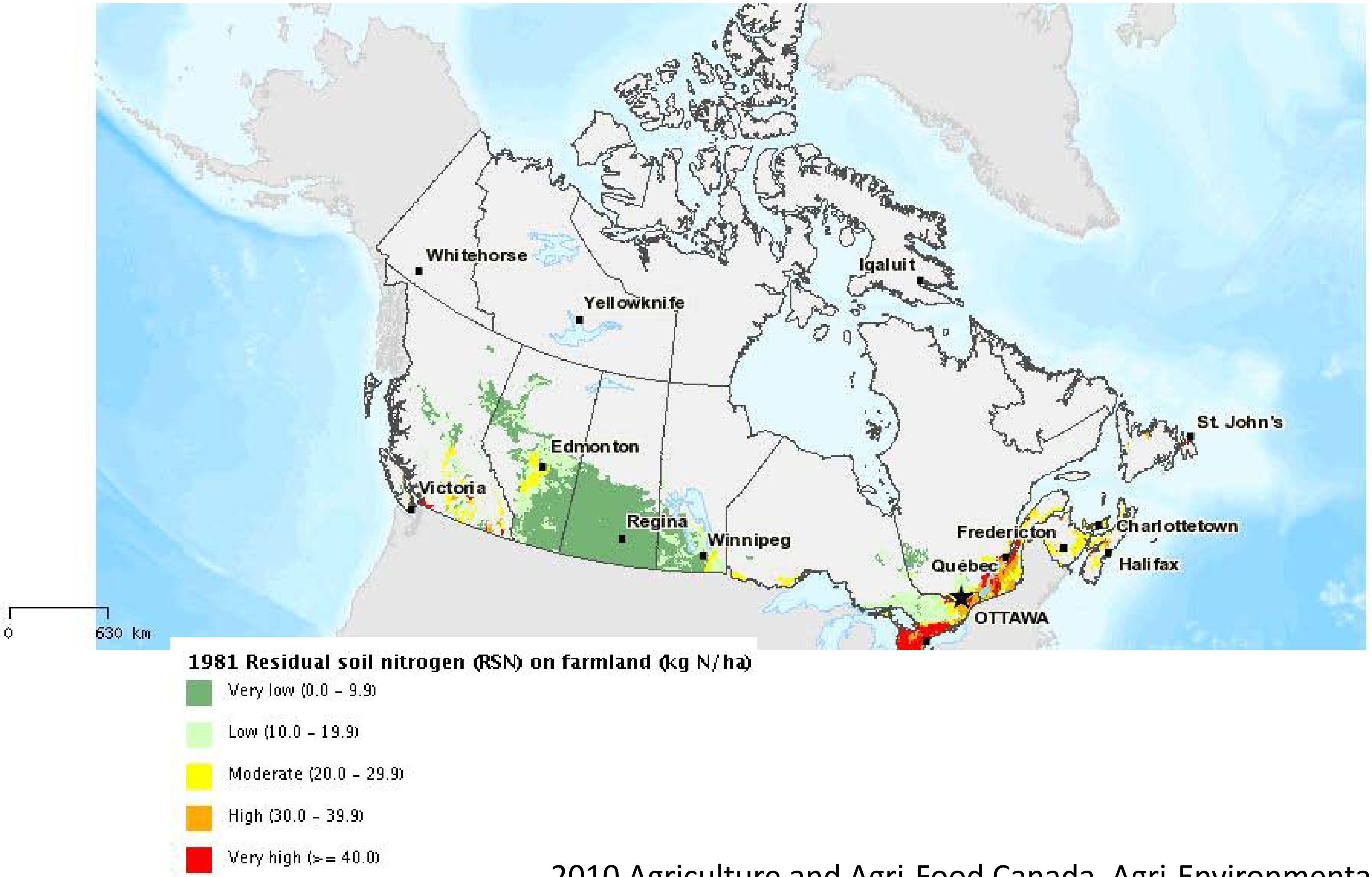
Valeria C. Castellanos-Hurtado
Faculty of Land and Food Systems
The University of British Columbia

1. Motivation
2. Risk of nitrogen water contamination from farmland
3. Trade liberalization and environmental externalities from agriculture
4. Data sources and Estimations
5. Results and final remarks

Agriculture and the environment in Canada

- Environmental degradation from agriculture
- Degradation of downstream water courses:
  - Nitrogen, phosphorus (fertilizer), coliforms (manure)
  - Pesticides, herbicides and insecticides
- Focus on nitrogen
  - More data available
  - Most of it, in the form of nitrate, is soluble in water and can move into groundwater or surface water
  - Harm to aquatic life, human health (drinking water), greenhouse gases

Residual soil nitrogen on farmland



2010 Agriculture and Agri-Food Canada, Agri-Environmental Indicators

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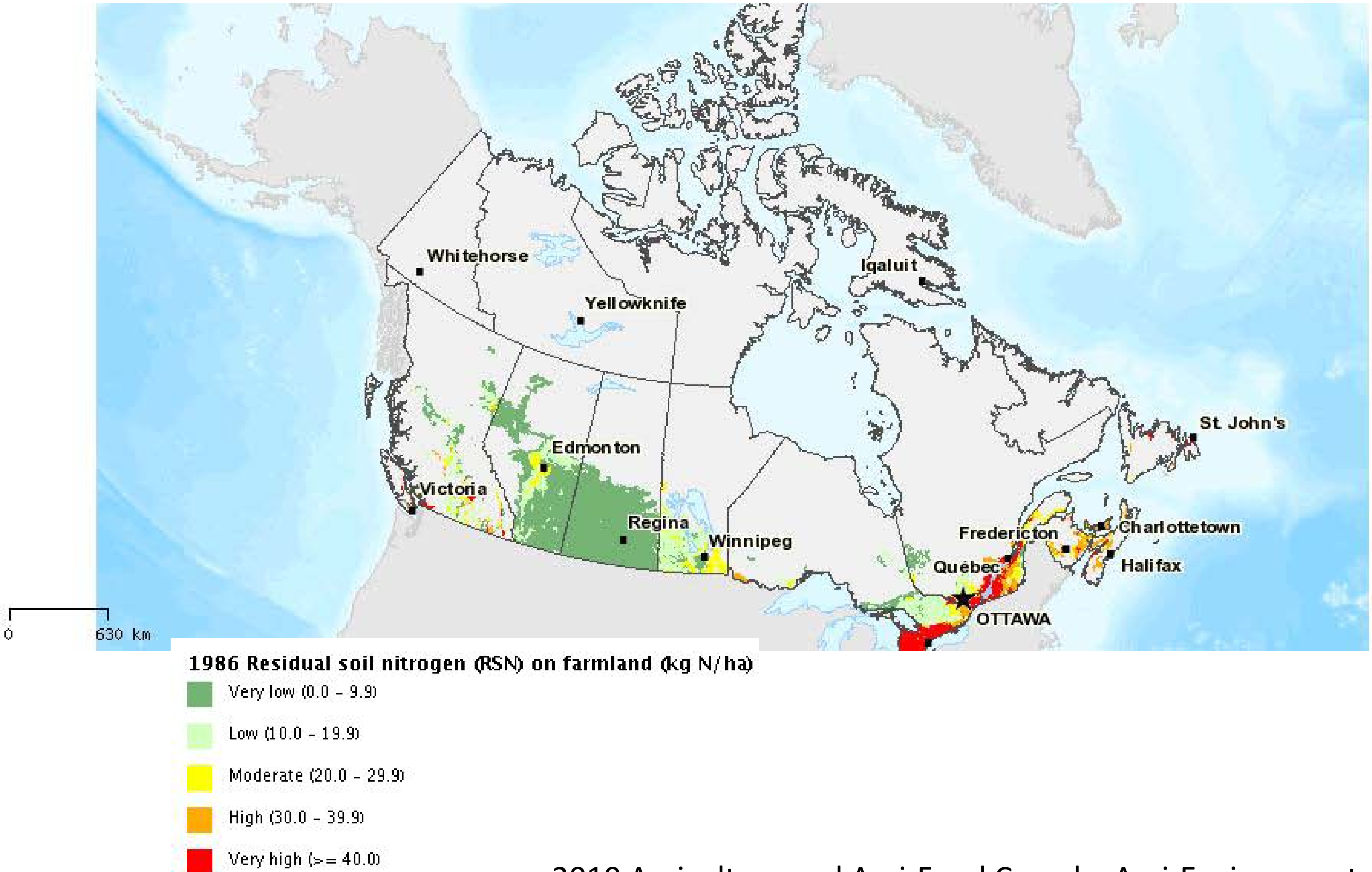

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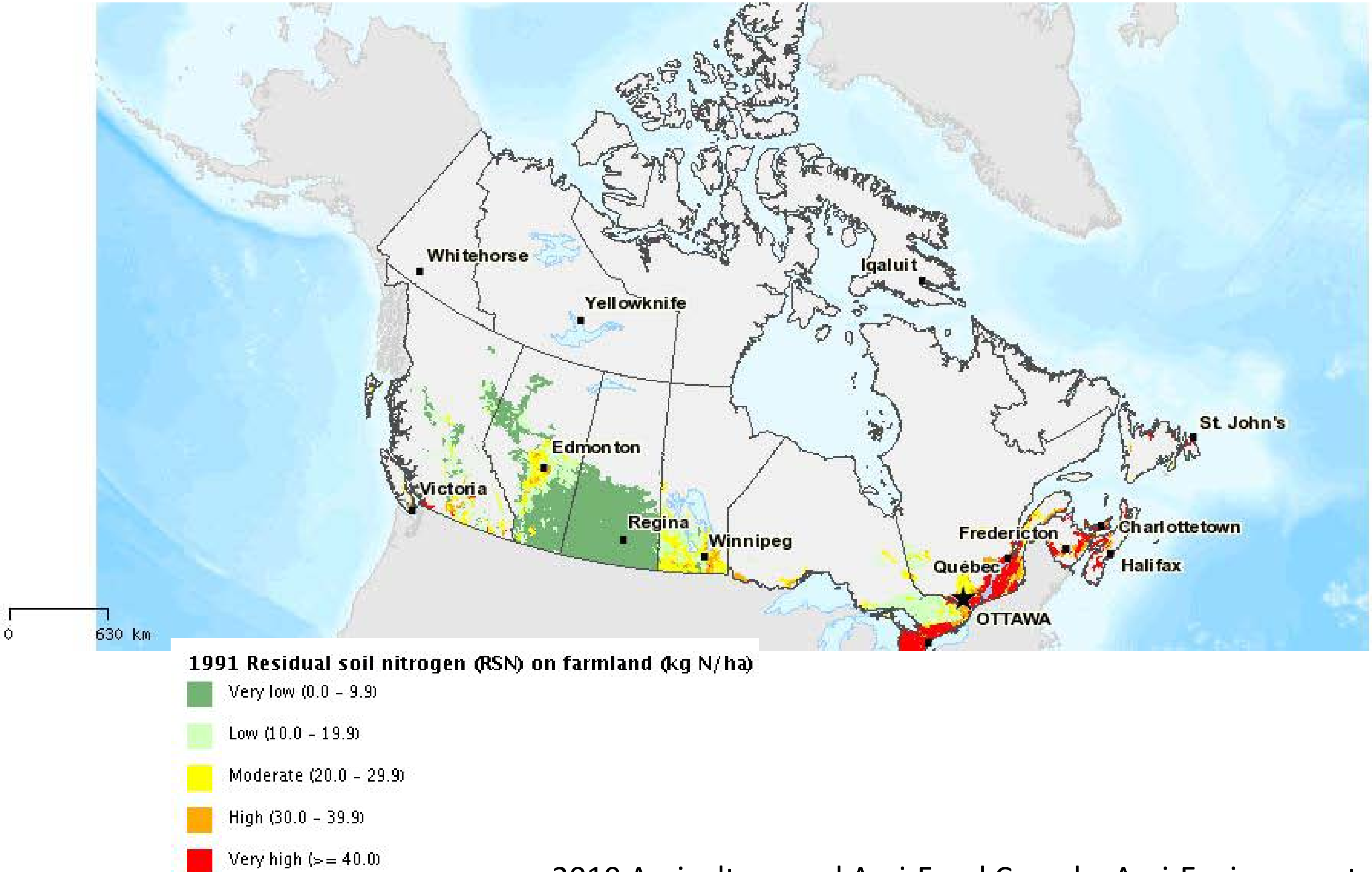

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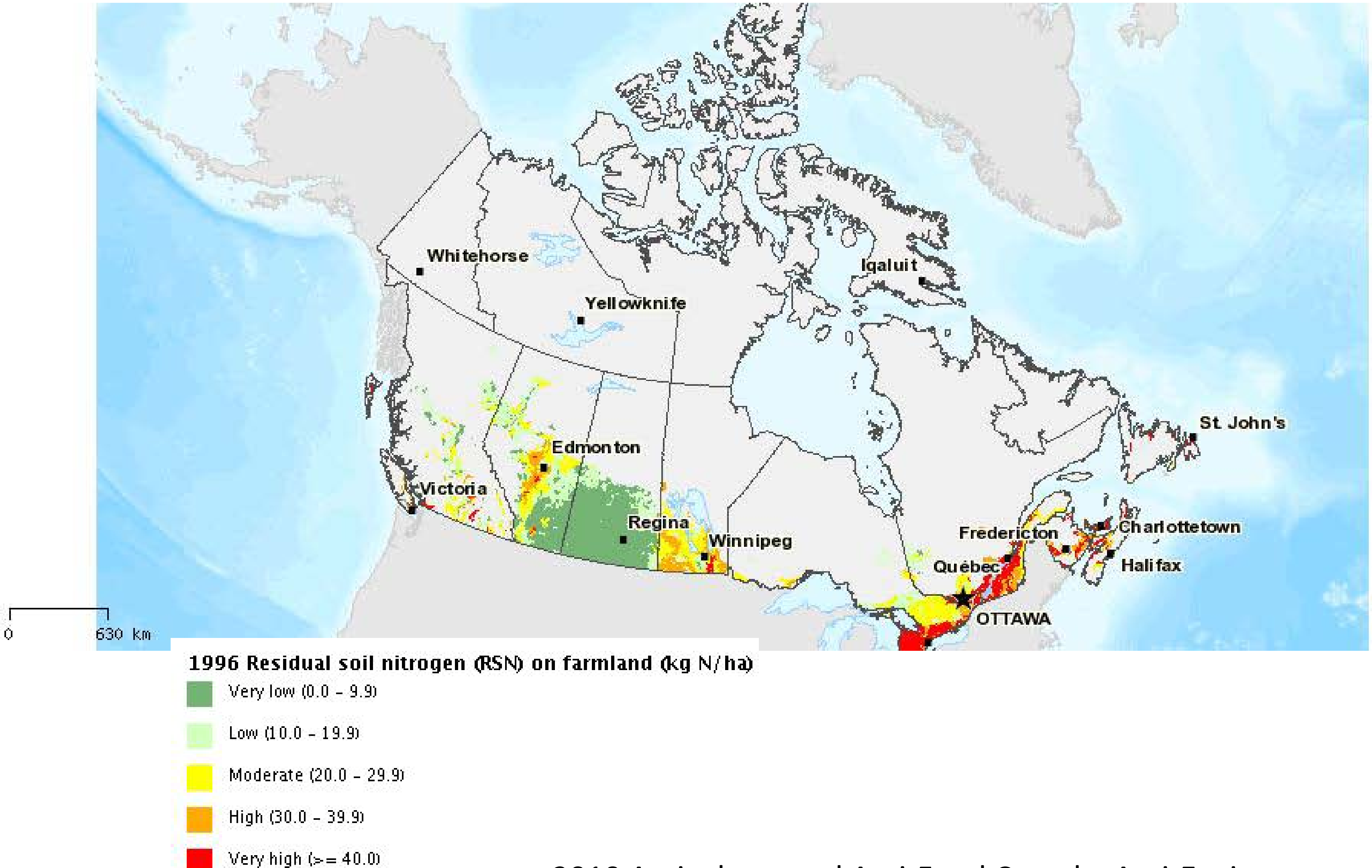

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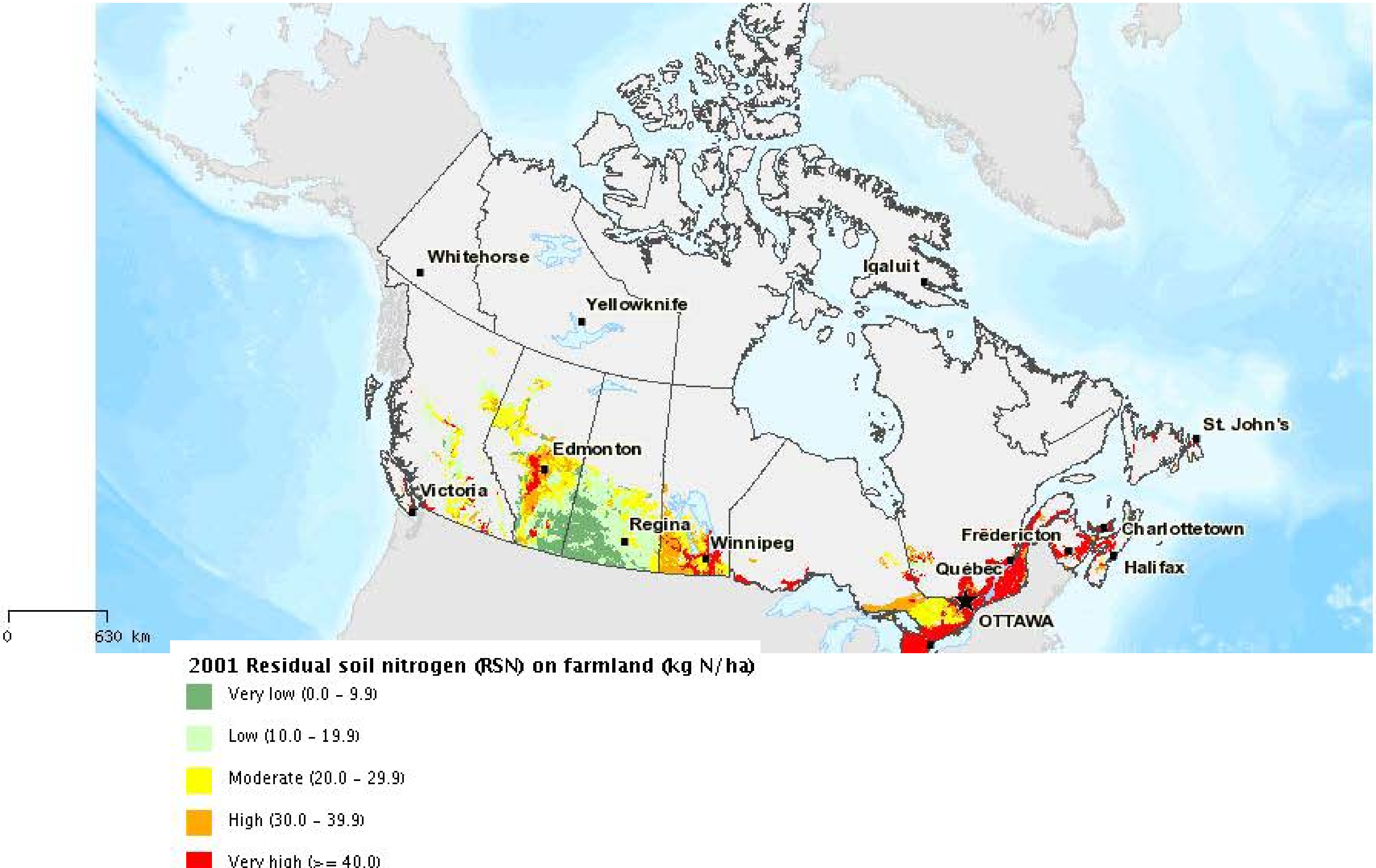

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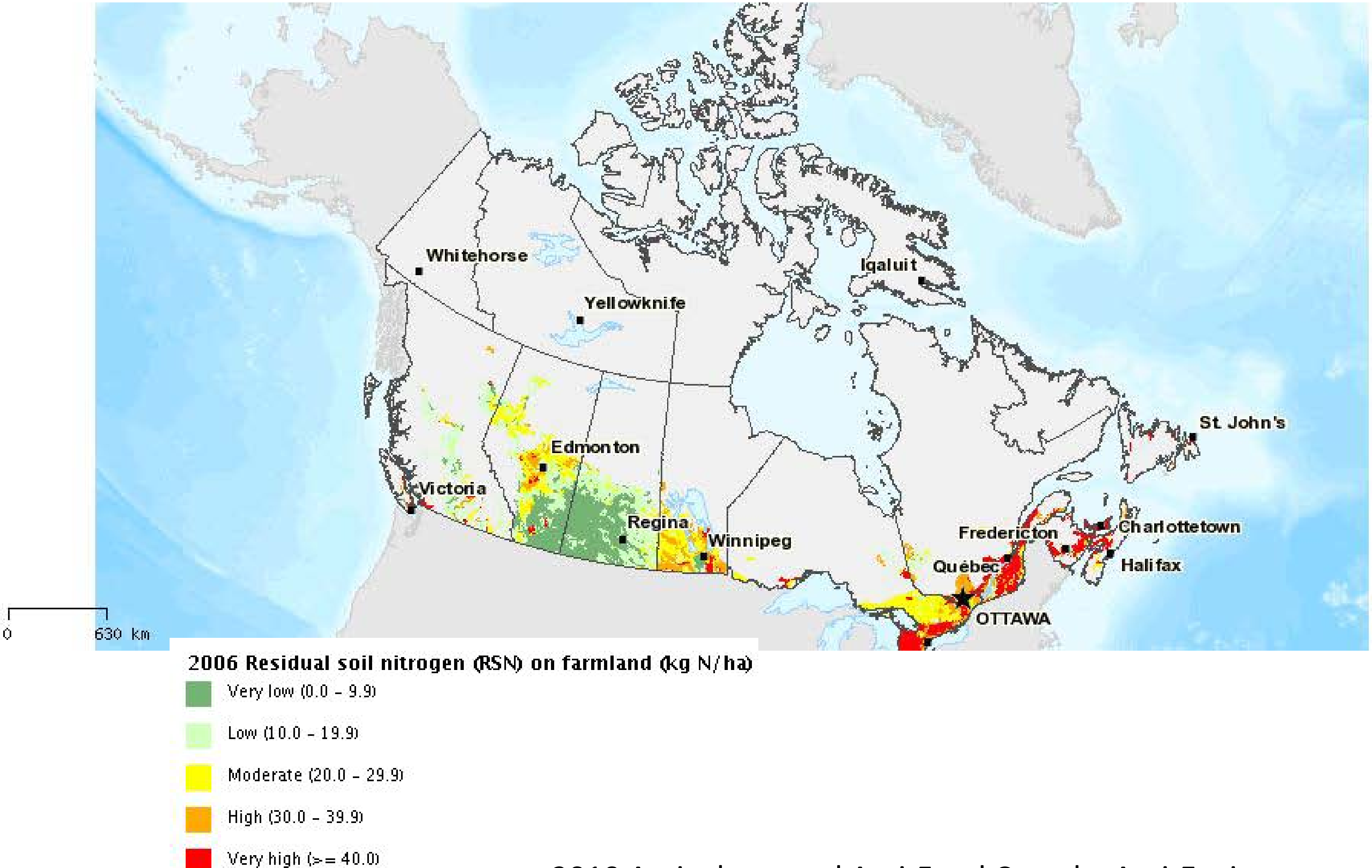
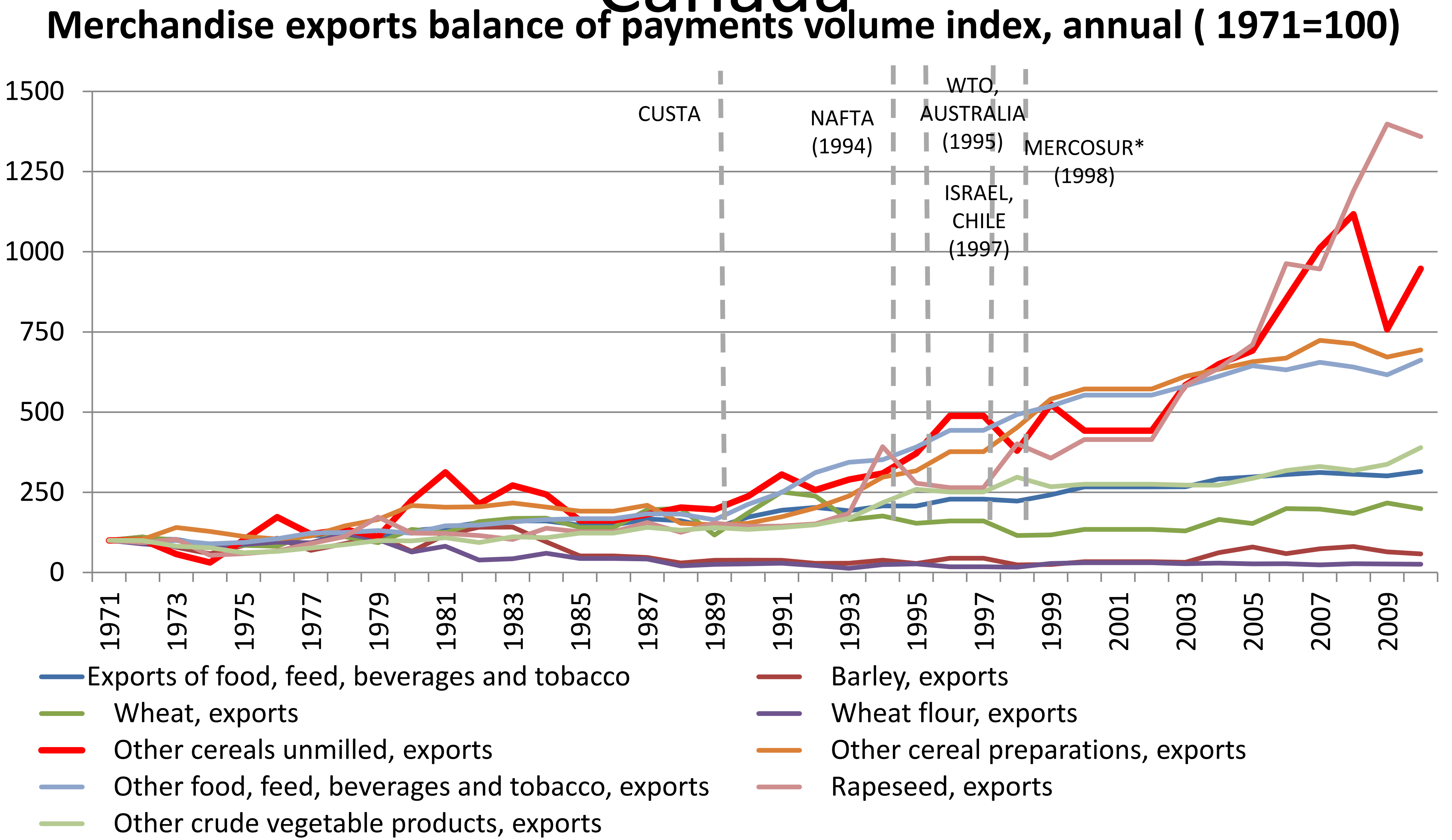


2010 Agriculture and Agri-Food Canada, Agri-Environmental Indicators

Environmental issues and agricultural trade

- Increased pollution around 1996, 2001, coinciding with Canadian major trade liberalization
  - CUSTA in 1989, WTO 1995
- How does increased pollution relate to agric. trade liberalization?
  - Crop choices depend mainly on crop demand (i.e. prices), factor costs, soil type, weather type
- Assuming full trade liberalization, producers will switch to those crops for which they have a comparative advantage and that result in greater profit
  - Different N requirements per crop

Agricultural trade liberalization in Canada

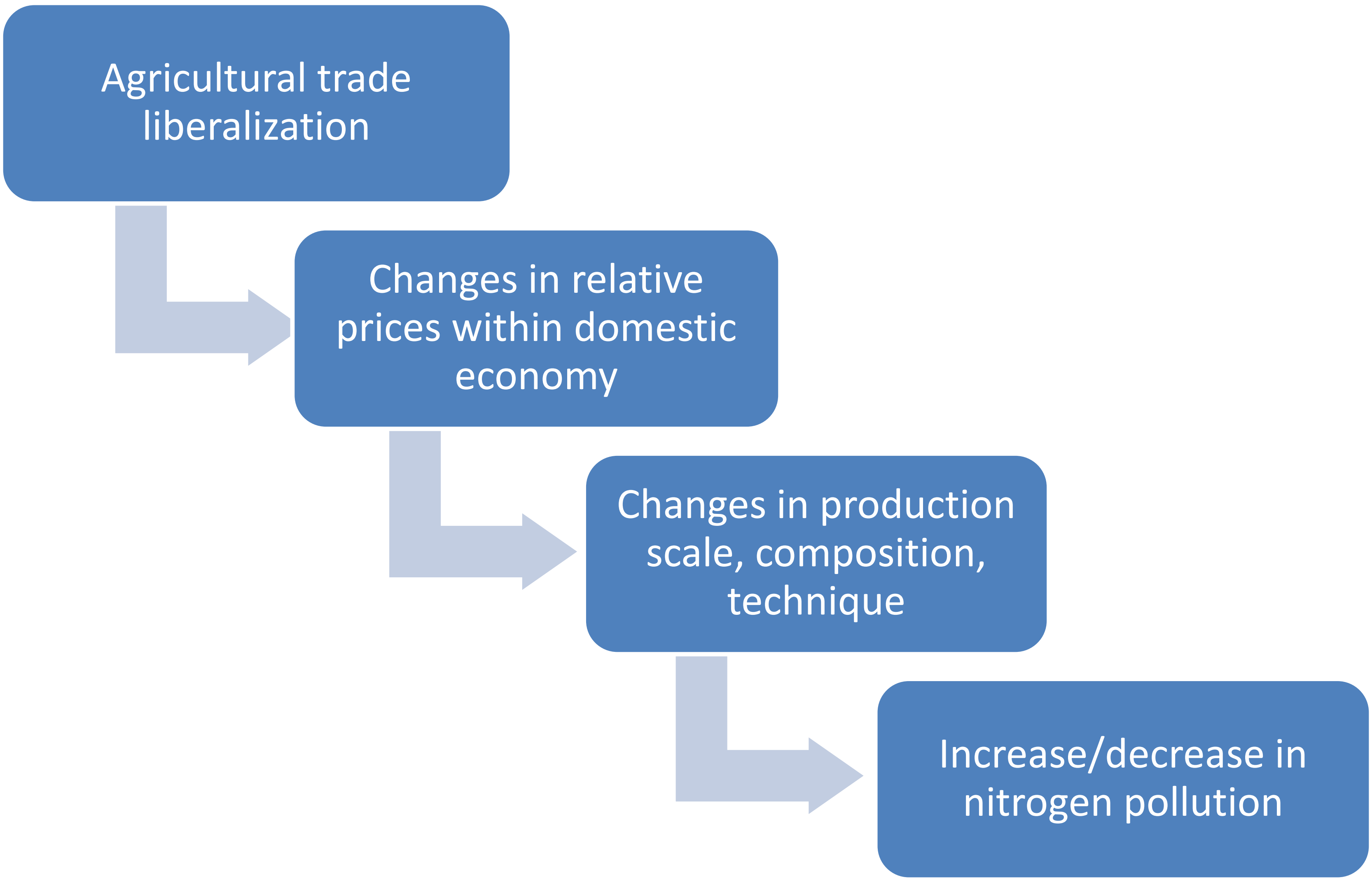


Source: Statistics Canada. Tables 228-0006,0012,0018,0049, CANSIM (database).

Agricultural trade liberalization in Canada

- As predicted by most international trade models, Canadian agricultural exports increased considerably after trade liberalization
  - Production volumes for most of the main crops increased as well
- The net effect on the environment, however, will not only depend on the scale of production, but also on the resulting crop composition
  - Increase in the proportion of rapeseed (canola), maize, soybeans and peas
  - Decrease in the proportion of barley and oats
  - Proportion of wheat increased, then decreased
  - Composition of maize for forage and silage decreased, then increased

Environmental issues and agricultural trade



Impact of trade liberalization on RSN in Canada

1. Econometric analysis of:
   - Fertilizer use as a function of crops, to reflect crop N intake
   - RSN as a function of commercial fertilizer, manure, agricultural techniques (summerfallow, tillage, irrigation) and farm/farm owner characteristics

   To determine which crops and farm/production characteristics are relevant to RSN levels; then:

2. Econometric analysis of trade liberalization as a determinant of crop production and fertilizer usage (still under work)

Estimations: Data

1. AAFC: Residual Soil Nitrogen indicator (kg N/ha)
   – Estimates the residual N in the top 60 cm of soil at the end of the cropping season using Census of Agriculture data
   – Census years: 1981 – 2006 every five years
   – Using GIS, superimposed the boundaries of CD to calculate RSN per CD. In areas where different levels arose, calculated weighted averages of RSN per polygon area

Estimations: Data

2. Census of Agriculture, 1971 - 2006
   – Crop area (ha), fertilizer use, irrigation use, summerfallow area, livestock numbers (farms, head), farm characteristics
   – Significant variation in Census Divisions (CD) across years, especially 1971-1991.
     - Adjusted with GIS software through aggregation of Census Consolidated Subdivisions to generate CD comparable across years

Estimations - Fertilizer use as a function of crops

- $Fertilizer_{it} = \phi_1 + \phi_2 crop\ area\ (\%)_{ijt} + u_{it}$; i: CD, j: crop, t: year
- This estimation will show the relationship between the percentage of each aggregate crop group (i.e. crop composition), and the use of fertilizer
- Higher oilseed/beans/grains compositions should represent higher fertilizer use
- Low N-requiring crops such as pasture or fruit trees should have a negative relationship with fertilizer use
- Estimated first as a panel-level OLS regression
  - No autocorrelation or multicollinearity
  - Some heteroskedasticity, corrected through GLS panel estimation with no changes in equation/var efficiency

Fertilizer	**OLS, random effects**	**OLS, fixed effects**	**GLS w/heterosk. Correct.**
Grains	**0.7695092**	**2.495207**	**0.7695092**
(std err)	**(0.0151473)**	**(0.1178066)**	**(0.0151101)**
(p-val)	**(0.000)**	**(0.000)**	**(0.000)**
Forage	**-0.2917914**	**-0.3937564**	**-0.2917914**
(std err)	**(0.0519979)**	**(0.0611724)**	**(0.0518704)**
(p-val)	**(0.000)**	**(0.000)**	**(0.000)**
Pea/beans/ oilseeds	**0.3477418**	**1.294687**	**0.3477418**
(std err)	**(0.0543707)**	**(0.084716)**	**(0.0542373)**
(p-val)	**(0.000)**	**(0.000)**	**(0.000)**
Vegetables	**6.006723**	*-3.253242*	**6.006723**
(std err)	**(1.438739)**	*(3.097454)*	**(1.435211)**
(p-val)	**(0.000)**	*(0.294)*	**(0.000)**

Fertilizer	OLS, random effects	OLS, fixed effects	GLS w/heterosk. Correct.
Fruits and berries	**-12.25187**	*-4.054639*	**-12.25187**
(std err)	**(5.43249)**	*(11.55231)*	**(5.419167)**
(p-val)	**(0.024)**	*(0.726)*	**(0.024)**
Greenhouse veg. and sod	**0.1219723**	**0.1774355**	**0.1219723**
(std err)	**(0.0190596)**	**(0.0252851)**	**(0.0190129)**
(p-val)	**(0.000)**	**(0.000)**	**(0.000)**
Potatoes, sugarbeets, other field cr.	**20.32295**	**31.72801**	**20.32295**
(std err)	**(1.702703)**	**(5.927008)**	**(1.698527)**
(p-val)	**(0.000)**	**(0.000)**	**(0.000)**
R2 within	0.2745	0.3624	-
R2 between	0.9916	0.9858	-
R2 overall	0.9627	0.9565	-
Observations	1633	1633	1633
Groups	275	275	275

Estimations – RSN as a function of fertilizer use and crop production tech.

- As expected, more nitrogen-demanding crops have a direct relationship with fertilizer use, while less nitrogen-demanding crops are either non-significant or have a negative relationship with the level of fertilizer in the period

Estimations – RSN as a function of fertilizer use and crop production tech.

Ideally, explain RSN in terms of fertilizer and manure inputs *per crop* since RSN depends on N input and crop N intake

- No time series on fertilizer/manure application per crop.
- Furthermore, total manure appl. not available in some census years

Instead, analyze RSN in terms of predicted fertilizer use (from previous estimation) that reflects per-crop N intake, and cattle head per farm as a proxy for likelihood of manure use:

- $RSN_{it} = \beta_1 + \beta_2 fertilizerHAT_{it} + \beta_3 manureproxy_{it} + \beta_4 irrigation_{it} + \beta_5 summerfallow_{it} + \beta_5 farm\ character_{it} + \varepsilon_{it}$
  - I expect a direct effect of fertilizer and manure (proxy) on RSN
  - Uncertain effect from irrigation: improves N uptake in dry areas; over-irrigation could lead to N leaching
  - Summerfallow would have an inverse relationship with RSN as no fertilizer is needed

RSN	OLS panel, fixed effects	GLS, correct. Heterosk, autocorr
Fertilizer (hat)	*0.622*	**1.214**
(std err)	*(0.392)*	**(0.242)**
(p-val)	*(0.114)*	**(0.000)**
Cattle x farm	**18.87**	**41.69**
(std err)	**(4.385)**	**(1.891)**
(p-val)	**(0.000)**	**(0.000)**
Irrigated ha as a percentage of total farmland	*-20.9*	**-35.2**
	(34.91)	**(8.199)**
	(0.55)	**(0.000)**
Pasture (converted) ha as %of total farmland	**-93.3**	**-161**
	(15.12)	**(7.824)**
	(0.000)	**(0.000)**

RSN	OLS panel, fixed effects	GLS, correct. Heterosk, autocorr
Pasture (natural)	**-53.6**	**-43**
ha as % of total farmland	**(9.225)**	**(1.622)**
	(0.000)	**(0.000)**
Summerfallow ha	**-163**	**-142**
as % of total farmland	**(17.56)**	**(3.760)**
	(0.000)	**(0.000)**
Observations	966	966
Groups	263	263
R2 within	0.201	
R2 between	0.619	
R2 overall	0.578	Wald chi2(6)
F(6,697)	29.19	5771
	(0.000)	(0.000)
F test that all u_i=0:		
F(262, 697)	6.04	

Estimations – RSN as a function of fertilizer use and crop production tech.

- The relationship between RSN and N inputs is strongly supported:
  - Having corrected for heteroskedasticity, there is a positive, significant relationship between (predicted) fertilizer and manure use, and RSN levels, as expected
  - The presence of low N-requiring areas (pasture, summerfallow) has a negative, significant relationship with RSN
- Irrigation has a negative sign, suggesting less likelihood of over-irrigation; more likely irrigation occurs in dry areas and thus improves N intake
- *Evidence of good land management practices*

RSN	GLS corrected heterosk, autocorr
Fertilizer (hat)	0.7801367
(std err)	(0.246)
(p-val)	(0.002)
Cattle x farm	40.80522
(std err)	(2.008)
(p-val)	(0.000)
Irrigated ha as a percentage of total farmland	-52.25196
	(8.937)
	(0.000)
Pasture (converted) ha as %of total farmland	-126.8441
	(7.484)
	(0.000)
Pasture (natural) ha as % of total farmland	-48.00979
	(1.973)
	(0.000)

RSN	GLS corrected heterosk, autocorr
Summerfallow ha as % of total farmland	**-119.4713**
	(4.747)
	(0.000)
% of farms with farm owner/main operator younger than 35	**-17.20215**
	(4.863)
	(0.000)
… between 35 and 55 years old	**12.01118**
	(4.737)
	(0.011)
Total area rented or leased from others, as a % of total farmland	**4.194916**
	(2.279)
	(0.066)
Sole proprietorship	**-16.39069**
(std err)	***(3.188)***
(p-val)	***(0.000)***
Family owned farm	**35.87645**
(std err)	***(5.205)***
(p-val)	***(0.000)***
Observations	966
Groups	263
Wald chi2(10)	6671.26

RSN	**GLS corrected heterosk, autocorr**
Fertilizer (hat)	0.5873562
(std err)	(0.239)
(p-val)	(0.014)
Bulls x farm	-862.8287
(std err)	(132.6)
(p-val)	(0.000)
Milk cows x farm	51.31265
(std err)	(7.168)
(p-val)	(0.000)
Beef cows x farm	61.75453
(std err)	(11.78)
(p-val)	(0.000)

Following Oenema, Oudendag, Velthot (2007), we'd expect dairy cows to have the strongest predictability power for manure use; in this regression, it seems as efficient as other cattle variables

RSN	**GLS corrected heterosk, autocorr**
Heifers x farm	69.0824
(std err)	(13.21)
(p-val)	(0.000)
Steers x farm	72.17481
(std err)	(8.507)
(p-val)	(0.000)
Irrigated ha as a percentage of total farmland	-32.24222
(std err)	(9.137)
(p-val)	(0.000)
Pasture (converted) ha as %of total farmland	-152.4335
(std err)	(8.702)
(p-val)	(0.000)
Pasture (natural) ha as % of total farmland	-38.71736
(std err)	(2.249)
(p-val)	(0.000)
Summerfallow ha as % of total farmland	-159.1695
(std err)	(3.911)
(p-val)	(0.000)

Findings and conclusions

- Use of fertilizer is in line with the nutrient requirements outlined by OECD, FAO and the handbooks for most provinces
  - Grains and oilseeds, which are the main crops in Canadian farmlands, are the most significative in fertilizer use
  - Pasture, forage, fruit and berry trees have an inverse (sometimes insignificant) effect in the use of fertilizer
- RSN also in line with previous literature:
  - Heavily dependant on commercial fertilizer and the proximity of (proxy for) manure production
  - Pasture and summerfallow have a negative effect on RSN
  - Positive sign for irrigation, i.e. mostly used in dry areas, therefore improving N intake by crops

Findings and conclusions

- Additionally, one of the main sources of residual nitrogen (manure) is highly correlated with intensive cattle farming; average cattle number per farm has increased in recent years
- Products such as wheat (during the sampled period, until 2006) might not have responded as much as other crops to trade liberalization, due to their respective boards
  - The important effect to measure, however, is the response of production of other goods (which would react to world prices) in the total composition of crop/livestock production

Further steps

- To complete analysis of trade liberalization impact on crop and livestock production
- To extend environmental analysis with regional proxies of soil and weather characteristics, to identify which areas might be more at risk
  - Cross these results with crop production and response to trade liberalization to identify key regions

Appendix – Data sources and acknowledgements

Data Sources and Acknowledgements:

-
- Agri-Environmental Indicators
- Soil Landscapes of Canada v3.0 Fundamental Drainage Areas of Canada
- Census of Agriculture adapted from Agriculture and Agri-Food Canada and Statistics Canada,
- customized tabulations, Census of Agriculture, CGC Base 1996, 2001, 2006, Census of Agriculture
- Regular Base 1971, 1976, 1981, 1986, 1991.
-
- Atlas of Canada 1:1,000,000 National Frameworks Data

http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1228838087110&lang=eng → click on Agri-Environmental Indicators

Appendix – RSN

- The RSN indicator is calculated as the difference between all N inputs (fertilizer and manure addition, N fixation by leguminous plants, wet and dry atmospheric deposition) and all N outputs (N removal from the soil via crop uptake, plus N losses through volatilization of ammonia, N_2O and N_2 emissions). The RSN indicator provides an estimate of the amount of unused N that remains in the soil at the end of the cropping season.
- A model was derived to estimate the RSN indicator in agricultural regions across Canada on the basis of Soil Landscape of Canada (SLC) polygons (Yang et al., 2007). RSN is estimated for each year from 1981 to 2006 using annual data where available (e.g. yields and fertilizer sales) and by interpolating the census of agriculture data between census years (e.g. crop area and livestock number).

Appendix: Data for trade estimations

3. Statistics Canada: Production
   - Special data product from Statistics Canada
   - Yearly production, seeded area, harvested area, yields from 1976 to 2011
   - Data per province and Census Agricultural Region (CAR)

Barley
Canola
Chick Peas
Corn for Grain
Dry Field Peas
Durum wheat
Fall rye
Flaxseed
Oats Soybeans
Spring rye
Summerfallow
Sunflower seed
Total Canary seed
Total lentils
Total mustard seed
Total rye
Total spring wheat
Total wheat
Triticale
Winter wheat

Appendix: Data for trade estimations

4. Statistics Canada: Prices (quarterly indexes)
   – Input price indexes, 1961 - 2011: total input index, plus general index for a) building, b) machinery, c) crop production, d) animal production, e) supplies and f) interest, and sub-indexes for elements within these six categories (53 indexes total)

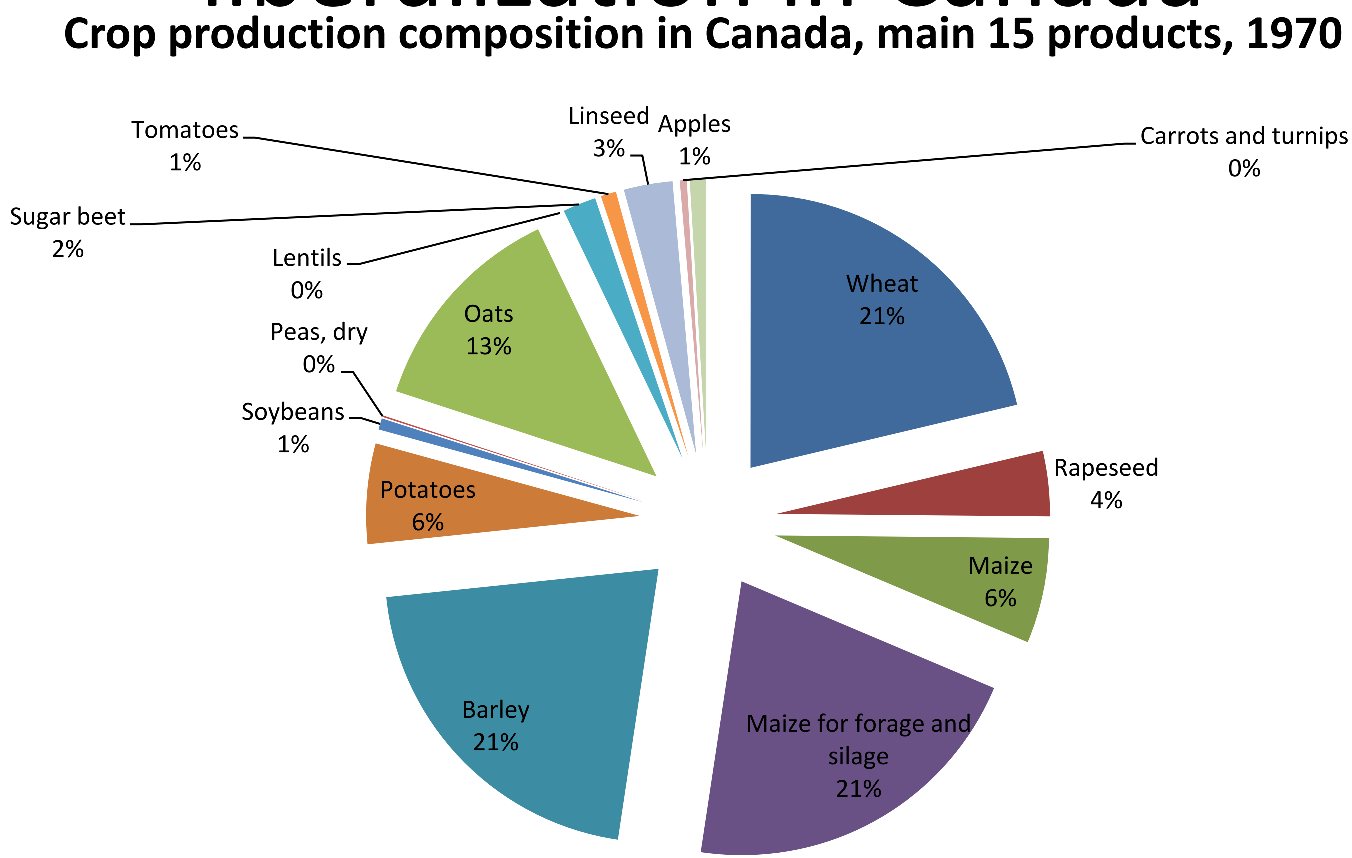
   – Agricultural production price indexes 1961– 2011: general indexes for:

- cattle and calves,
- dairy,
- eggs,
- fruit, grains,
- hogs,
- oilseeds,
- potatoes,
- poultry,
- total crops,
- total livestock and animal products,
- vegetables excluding potatoes

Appendix: Data for trade estimations

4. Statistics Canada: Prices
   - Price indexes for specific commodities:
     - Barley (1982-) and Wheat (1985-) for the Canadian Wheat Board
     - Canola (1985-)
     - Ontario Wheat Board (1985-)
     - Rye (1985-)

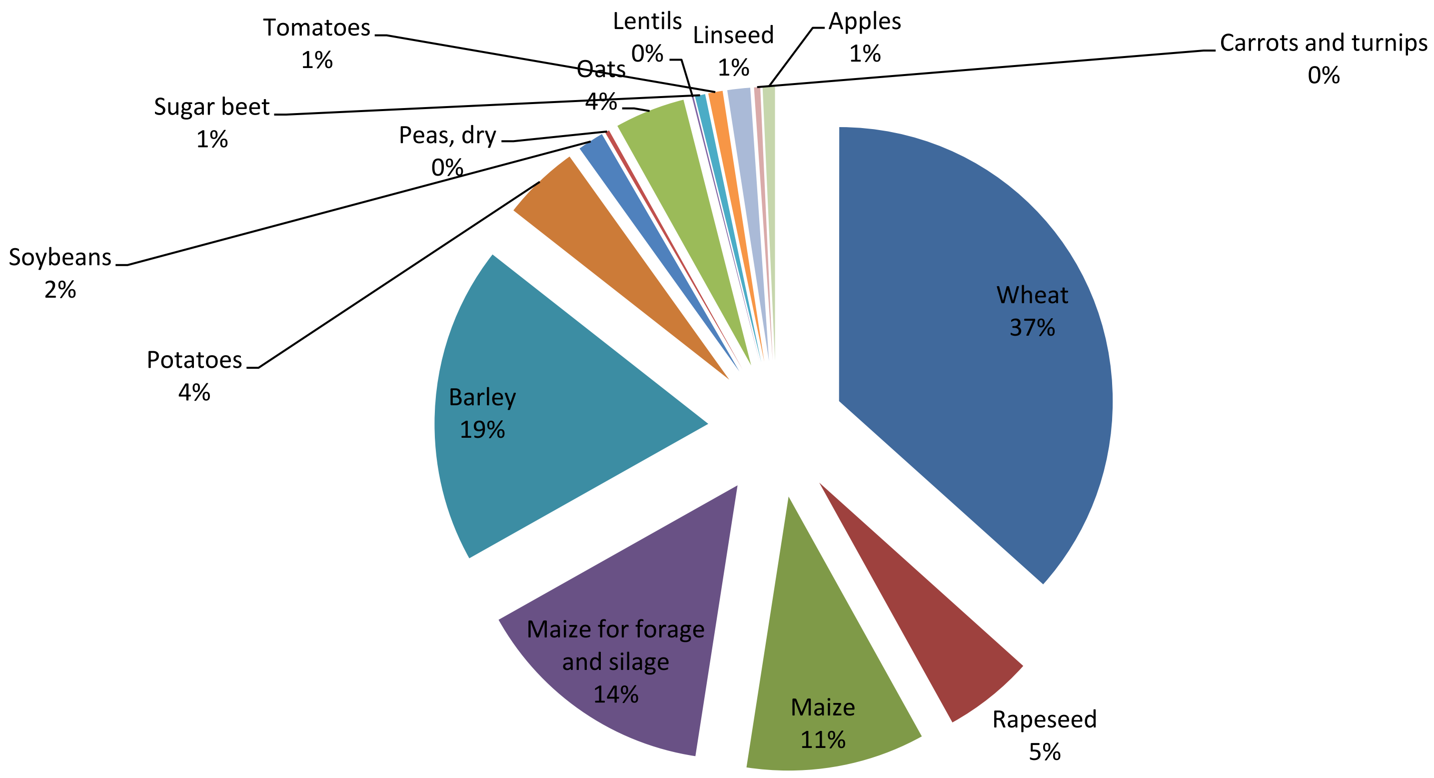
Appendix: Agricultural trade liberalization in Canada



Source: FAOSTAT, Production: Crops | © FAO Statistics Division 2012 | 26 February 2012

Appendix: Agricultural trade liberalization in Canada

Crop production composition in Canada, main 15 products, 1985



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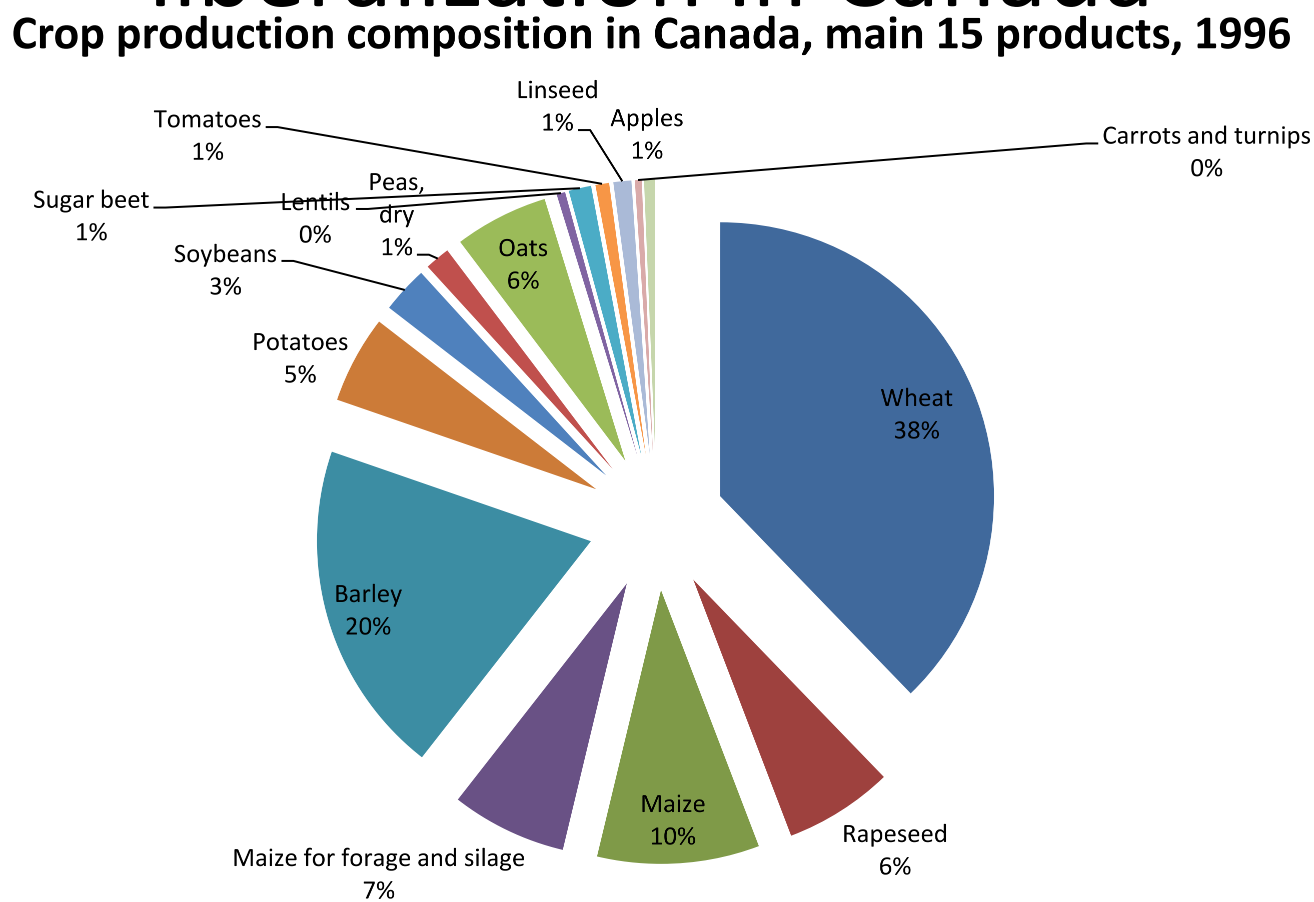

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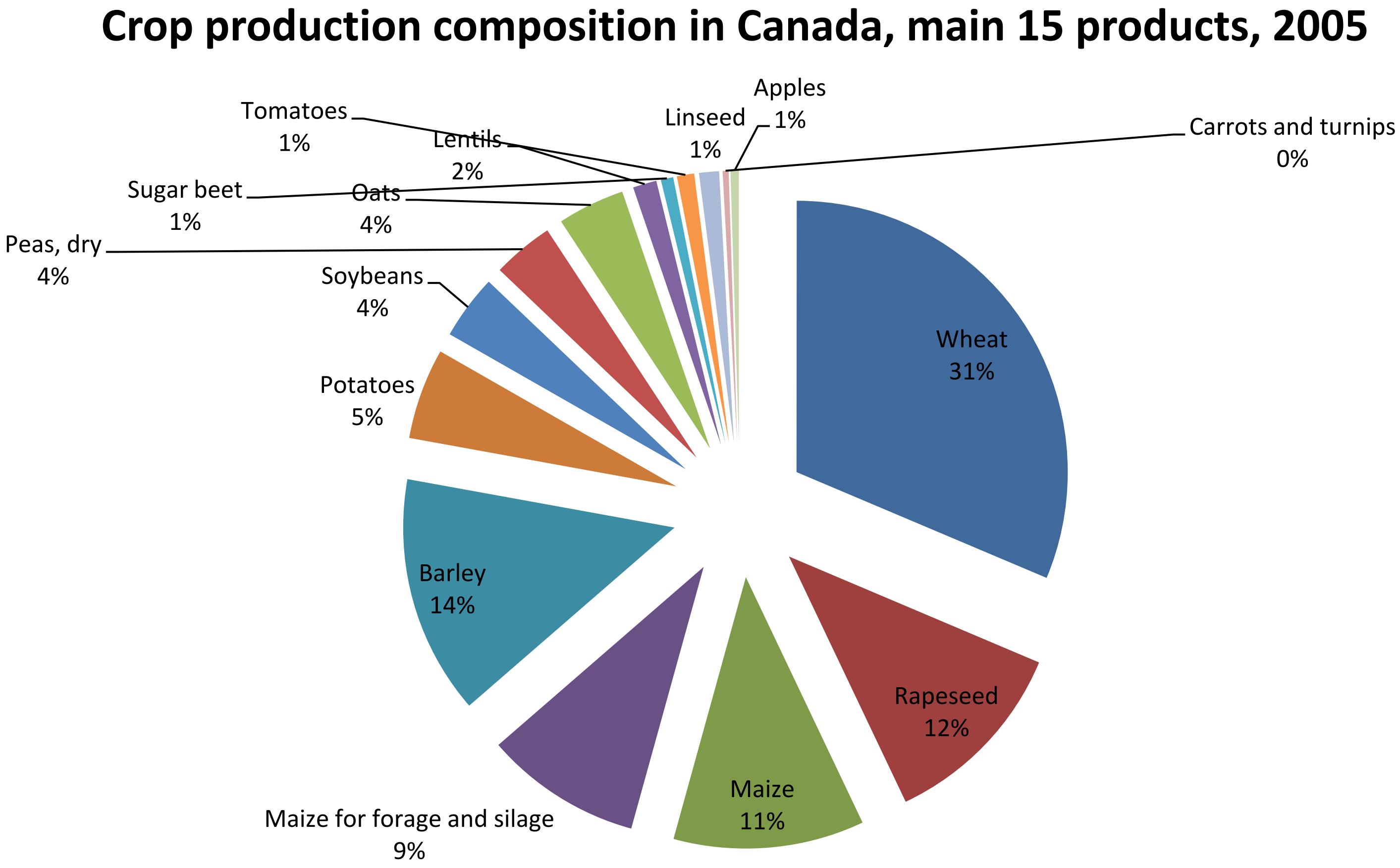

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