Earth Observation for Official Statistics at Statistics Canada

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Environmental-economic accounts with Earth observation data
Australian National University
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Statistics Canada Statistique Canada
Canada

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Canadian EO context

Earth observation in Canada

Canada is a leader in Earth observation, space robotics, space science, exploration (including a thriving astronaut program), and satellite communications

The Canadian space industry

- Contributes to $2.7B to GDP,
- Creates 10,000 jobs,
- Adds more than $146M in research and development activities.

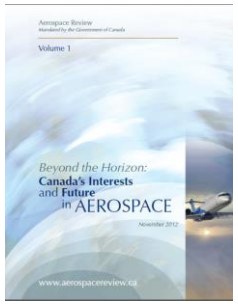
Earth observation technologies generate

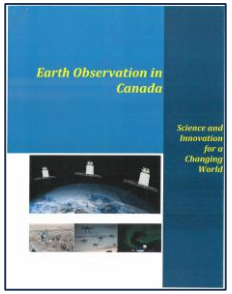
- Over 2,450 private sector geomatics firms contributed $2.3 billion to the Canadian economy;
- The use and re-use of geospatial information contributed $20.7 billion (1.1%) of national gross domestic product (GDP).
- Geospatial information also contributed $19 billion to real income and generated approximately 19,000 jobs
- Open geospatial data contributed over $600 million annually in terms of productivity and innovation enhancement to GDP

The Canadian Government is the largest user in Canada of data, products, and services derived from Earth observation (EO) systems

Earth observation in Canada: Programs and policies

- Space Policy Framework (2014)
  - National goals for the Space Program
- Space Program (2016)
  - Space Advisory Board:
    - Advise the Government of Canada on long term objectives for space and engages with Canadians
- Federal Earth Observation Strategy (2017)
  - Increase the use of EO technologies and applications
  - Competitive Canadian EO sector
  - Federal departments to define their own departmental EO strategy





Earth Observation lead agencies in Canada

Canadian Space Agency (CSA)

- The CSA is the government's lead agency for space, through collaboration with other government departments (OGDs), private organizations, universities and international partners, and is responsible for assisting the Minister of Industry in coordinating all federal space-related policies and programs

Canada Centre for Mapping and Earth Observation (CCMEO)

- CCMEO is the Government of Canada's centre of excellence for geomatics, mapping and earth observations
- The Remote Sensing Science (RSS) program provides a foundation of scientific expertise that is key to rendering satellite data useful to the Government of Canada.

EO products from Government of Canada departments

EO technologies integrated in Government of Canada business processes

Supporting Key Government Operations

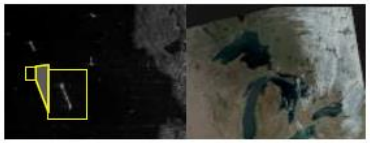
ECCC

- Weather Services
- Ice Monitoring
- Pollution / Oil Spills

National Defence

- Ship Detection
- CF Operations
- Search & Rescue

Fisheries & Oceans



- Monitor Coasts
- Illegal Fishing
- Oceans Science

AAFC

- Crop Monitoring
- Manage Irrigation
- Land-use

NRCan

- Resource Extraction
- Flood/Forest Fires

PS, Parks, TC & Others

- Emergency Management
- Environmental Monitoring

Key Benefits:

- Productivity gains in ice monitoring, agriculture, forest management, fisheries, etc
- Contributing to national sovereignty and security
- Ability to respond to emergencies and natural disasters in support of public safety

Source: Canadian Space Agency

Agriculture and Agri-Food Canada (AAFC) - Crop inventory

Starting in 2009, the Earth Observation Team of the Science and Technology Branch (STB) at Agriculture and Agri-Food Canada (AAFC) began the process of generating annual crop type digital maps at spatial resolution of 30m.

Land use maps of Canada 1990, 2000 and 2010, South of 60, produced by AAFC

AAFC integrates a variety of raster and vector spatial products to generate a series of land use maps

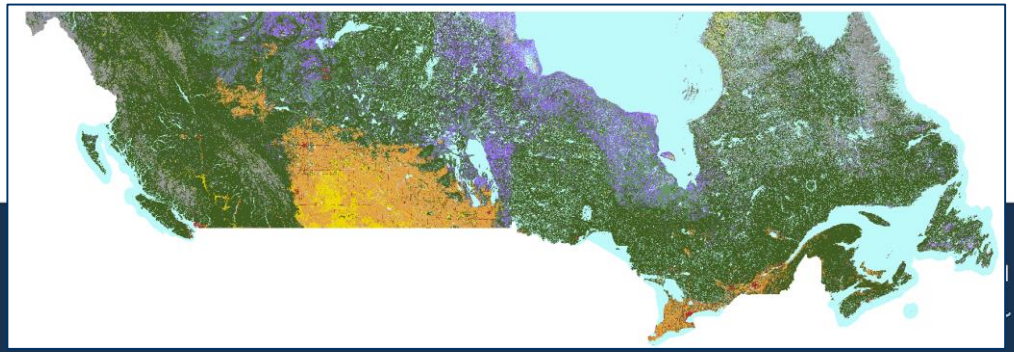
Land Use 1990, 2000, 2010 (30 m)

Integration of datasets using decision rules:

- AAFC Crop Inventory 2011, 2012, 2013
- Land Cover for Agricultural regions of Canada,
- Canadian Forest Service (CFS): Earth Observation for Sustainable Development of Forests Land Cover, c.2000
- Rasterized CanVec base features
- National Road Network (NRN) Roads

Inputs				Outputs	
GeoCover1990	AAFC LC2000)	EOSD2000	CANVEC (c.2000)	LU90	LU00
Cropland	Cropland	Unclassified	Unclassified	Cropland	Cropland
Unclassified	Unclassified	Unclassified	Unclassified	Unclassified	Unclassified
Shrubland	Unclassified	Forest	Unclassified	Forest	Forest
Cropland	Cropland	Herbs	Unclassified	Cropland	Cropland
Forest	Unclassified	Forest	Unclassified	Forest	Forest
Water	Unclassified	Water	Water	Water	Water
Shrubland	Unclassified	Shrubland	Unclassified	Shrubland	Shrubland
Water	Water	Water	Water	Water	Water
Shrubland	Forest	Forest	Unclassified	Forest	Forest
Grassland	Grassland	Unclassified	Unclassified	Grassland	Grassland
Forest	Unclassified	Shrubland	Unclassified	Forest	Forest
Shrubland	Cropland	Unclassified	Unclassified	Cropland	Cropland
Grassland	Cropland	Unclassified	Unclassified	Cropland	Cropland
Shrubland	Unclassified	Wetland	Unclassified	Wetland	Wetland
Shrubland	Unclassified	Forest	Wetland	Wetland	Wetland
Water	Unclassified	Water	Unclassified	Water	Water
Shrubland	Cropland	Herbs	Unclassified	Cropland	Cropland
Shrubland	Grassland	Unclassified	Unclassified	Grassland	Grassland
Forest	Cropland	Herbs	Unclassified	Forest	Cropland
Water	Unclassified	Forest	Unclassified	Water	Water
Shrubland	Wetland	Wetland	Wetland	Wetland	Wetland
Forest	Shrubland	Forest	Unclassified	Forest	Forest
Cropland	Grassland	Unclassified	Unclassified	Cropland	Cropland
Shrubland	Shrubland	Forest	Unclassified	Forest	Forest
Forest	Forest	Unclassified	Unclassified	Forest	Forest
Wetland	Unclassified	Forest	Unclassified	Forest	Forest
Forest	Unclassified	Forest	Wetland	Forest	Forest
Forest	Forest	Forest	Wetland	Forest	Forest
...	...	...	...	...	...

Category	Definition
Forest Land	A minimum land area of 1 hectare with a minimum width of 20m, with woody vegetation with a minimum crown cover of 25 percent and a minimum height of 5 metres. Forests also include systems with a vegetation structure that currently falls below, but could reach the threshold values (such as regrowth in harvested areas).
Cropland	Cropped land, including orchards, vineyards and agro-forestry systems where the vegetation falls below the thresholds of Forest Land.
Grassland	Rangeland and pasture land that is not considered Cropland, including systems with woody vegetation that falls below the threshold of Forest Land. Subdivided into Grassland Managed (grazing land) and Grassland Unmanaged (alpine meadows, tundra).
Wetland	Areas covered or saturated by water for all or part of the year. Subdivided into Wetlands (swamps, marshes, bogs, peatlands) and Water (permanent open water, including reservoirs).
Settlement	All developed or 'built-up' land, including transportation infrastructure.
Otherland	Bare soil, rock, ice and all land areas that do not fall into any of the other five categories.



Contribution of EO for official statistics

Contribution of EO for official statistics in Statistics Canada

- As a support tool (validation, analysis, research)
- As a main generator and single source of data for official statistics (e.g., treed area)
- As one of several datasets, integrated with administrative or other spatial datasets to generate official statistics

Process steps for the extraction of the information from EO and integration in Official Statistics

Federal partner	Data	• Earth observation (satellite and airborne) • Geospatial data layers • Field data
	Preprocessing (data preparation)	• Geographical registration, correction of the effect of elevation (orthorectification) • Corrections and calibrations • Mathematical transformation to enhance images to make them more suitable to meet requirements
	Digital image processing for information extraction	• Use of computer's decision-making capability to identify and extract specific pieces of information • Human operators instruct the computer and evaluate the significance of the extracted information
	Quality control	• Accuracy assessment • Document uncertainties and limitations associated with the approach
Statistics Canada	Integration	• Horizontal and vertical integration with other data layers • Document data sources and accuracies
	Results	• Baseline • Change detection/ • Documentation • Etc.

Data quality assessment

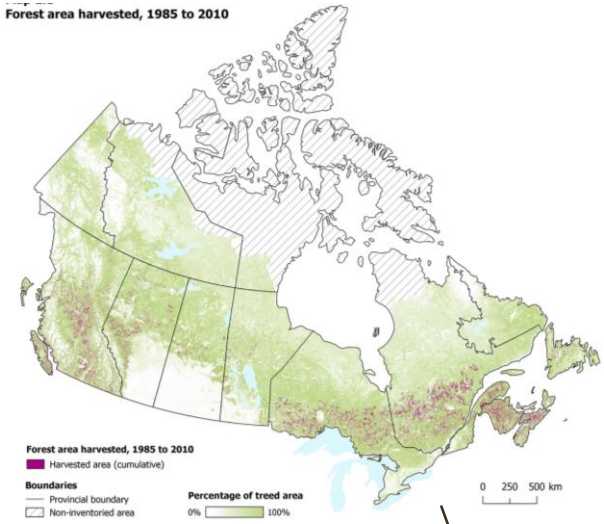
Fitness for use - Was the dataset intended or designed for the policy question for which it is being used?

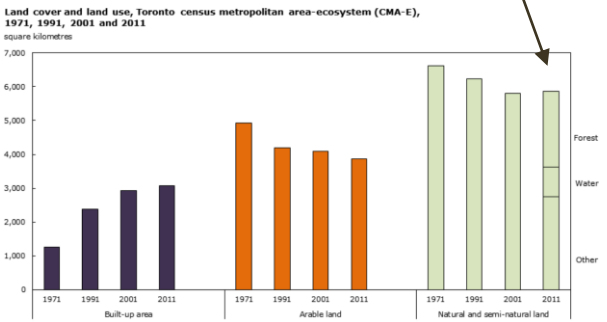
Statistics Canada Data Quality Framework:

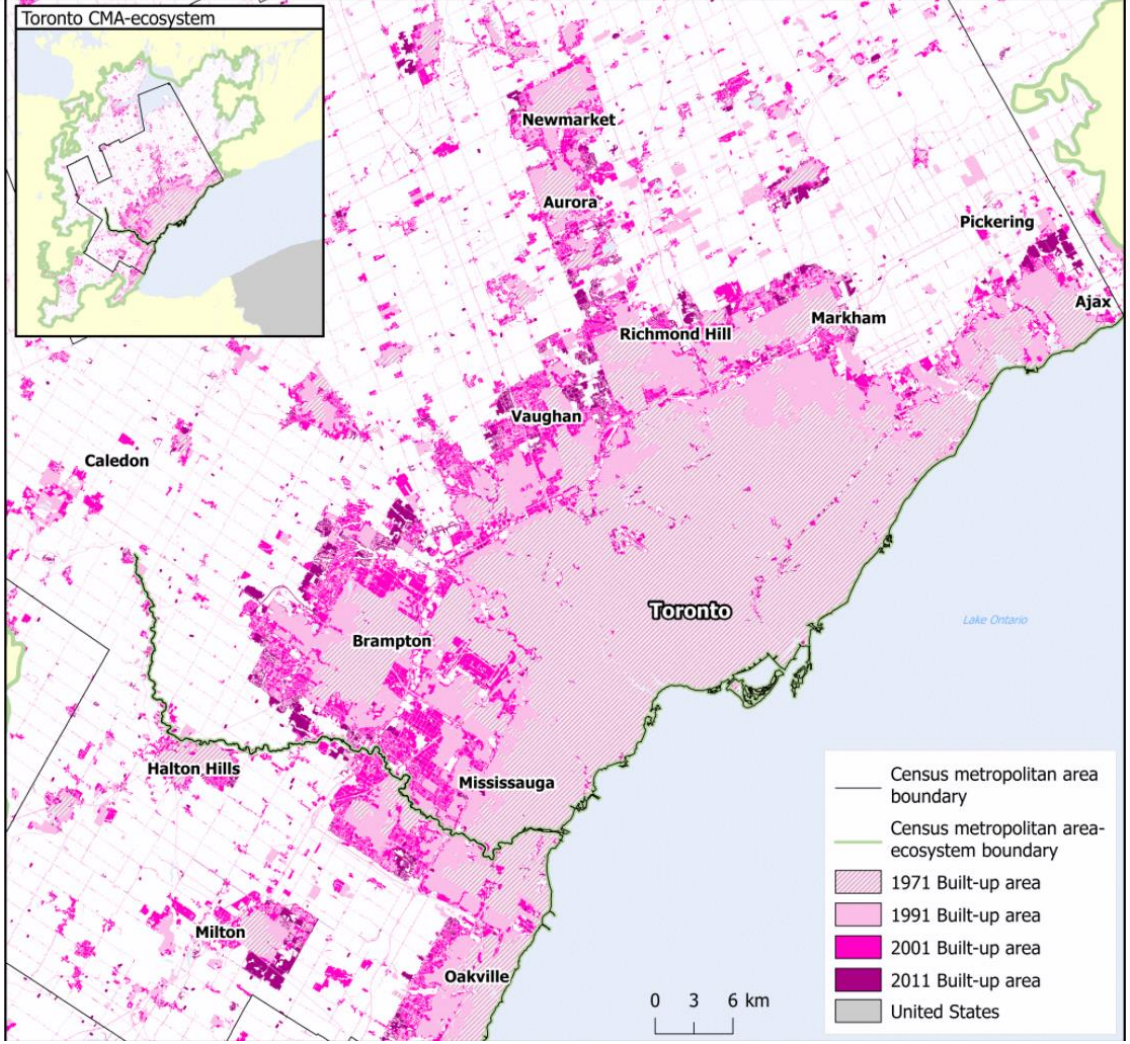
6 dimensions:

- relevance
- accuracy
- timeliness
- accessibility
- interpretability
- coherence

Land accounts







	Total built-up area [1]		Arable [2]	Natural and semi-natural [3]
	Settled	Roads		
	square kilometres			
Opening stock 1971	850	418	4,930	6,615
Land lost to settled area	...	...	-961	-448
Balance of change [4]	1,409	403	-102	-300
Closing stock 2011	2,260	821	3,867	5,866

... not applicable

Map 2.8
Forest area harvested, 1985 to 2010

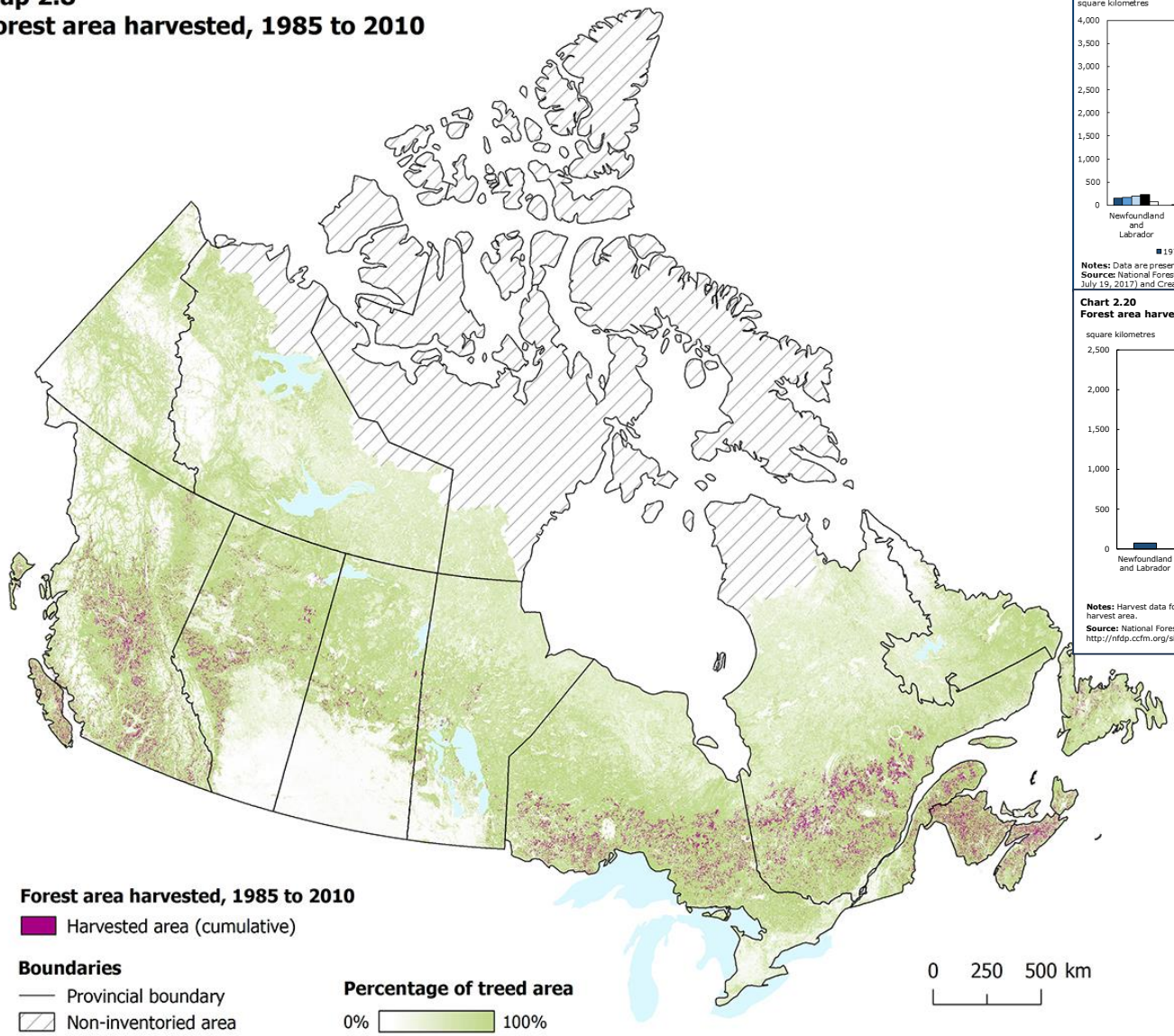
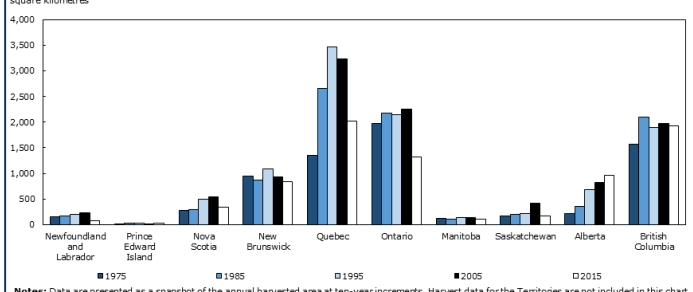
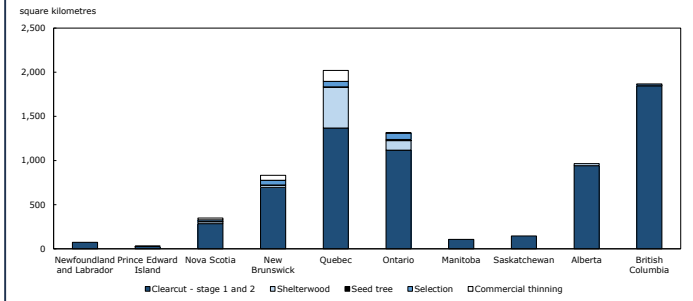


Chart 2.19
Forest area harvested by province at ten year increments, 1975 to 2015



Notes: Data are presented as a snapshot of the annual harvested area at ten-year increments. Harvest data for the Territories are not included in this chart.
Source: National Forestry Database, 2017, Table 6.1 Silvicultural Statistics by Province/Territory, http://nfdp.ccfm.org/silviculture/national_e.php (accessed July 19, 2017) and Create Your Own Report, http://nfdp.ccfm.org/dynamic_report/dynamic_report_ui_e.php (accessed July 19, 2017).

Chart 2.20
Forest area harvested by method and by province, 2015



Notes: Harvest data for the Territories are not included in this chart. The type of harvesting method is unspecified for a small amount of the harvest area.
Source: National Forestry Database, 2017, Table 6.2 Area harvested by ownership, harvesting method, and province/territory, http://nfdp.ccfm.org/silviculture/national_e.php (accessed July 19, 2017).

Notes: This map displays the cumulative forest area harvested between 1985 and 2010. Harvested areas are normally replanted or allowed to regenerate naturally and will therefore be in varying phases of succession. Data are derived from time series Landsat data with a 30 metre spatial resolution. The map also provides a visual representation of the distribution of treed area.

Sources: White, J.C., et al., 2017, "A nationwide annual characterization of 25 years of forest disturbance and recovery for Canada using Landsat time series," *Remote Sensing of Environment*, Vol. 192, p. 303–321, https://doi.org/10.1016/j.rse.2017.03.035, Data downloaded from https://opendata.nfis.org/mapserver/nfis-change_eng.html (accessed July 22, 2017); Canada's National Forest Inventory, 2016, Grouped *k*NN Map layers, http://tree.pfc.forestry.ca (accessed April 7, 2017); Statistics Canada, Environment, Energy and Transportation Division, 2018.

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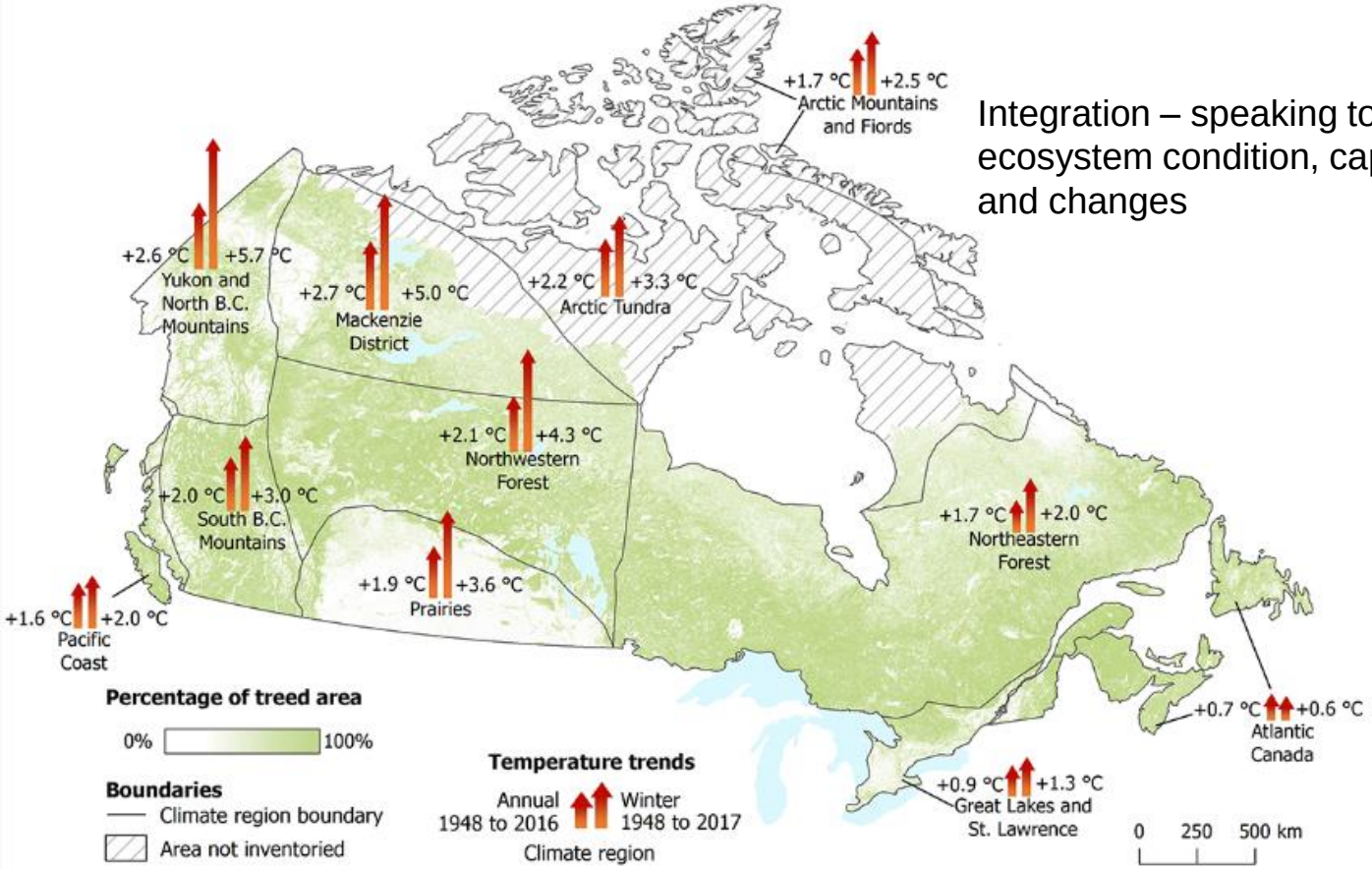
Map 2.5
Treed area and long-term temperature trends by climate region



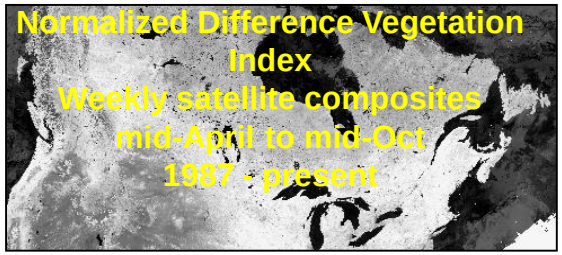
Integration – speaking to ecosystem condition, capacity and changes

Temperature increases were observed in every climate region during every season over the 1948 to 2016 time period.

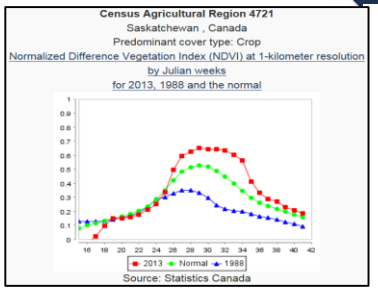
Nationally, winter temperatures increased by 3.4 °C on average.

Agricultural statistics: crop yields

2017 Yield Model – 3 data sources



Census Agriculture Region	Year	NDVI
4601	1987	0.786
4601	1988	0.655
4601	1989	0.699
4601	...	...
4601	**Current year**	**0.776**



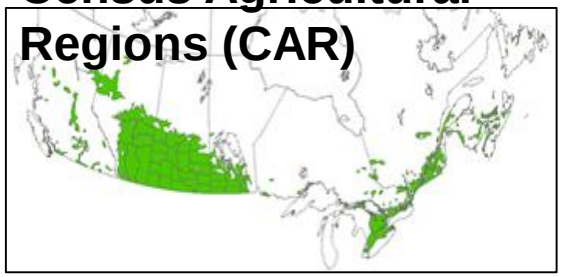
Small Area Data
Spring Wheat Yield – Regina, SK

2013: 56.5 bu/ac (record yield)
Normal: 30.8 bu/ac
1988: 14.4 bu/ac (severe drought)

Agroclimatic data

	Example of top 5 predictors used						Max 80 predictors
Census Agricultural Region	Year	Total Precip (mm)	Total GDD	Average Stress Index	SD of Daily SI	SD of Daily GDD	Top 5 used
4601	1987	340	1,125	0.45	0.063	2.60	…
4601	1988	255	1,087	0.56	0.101	2.78	…
4601	1989	312	1,200	0.48	0.084	2.36	…
4601	...	...	...	...	...	...	…
4601	**Curren**	**355**	**1.211**	**0.34**	**0.079**	**2.49**	**…**

Census Agricultural Regions (CAR)



Historical and current yield estimates by crop

Census Agricultural Region	Year	Survey Yield (bu/ac)
4601	1987	34.2
4601	1988	28.8
4601	1989	30.6
4601	...	...
4601	**Current year**	**???**

September yield model versus November survey yield, 2017

Crop	Sept. yield model[1] 2017	Nov. yield survey [2] 2017	Sept. vs Nov Difference
	(bu/ac)	(bu/ac)	(%)
Barley	64.0	69.4	-8.4
Canola	38.1	41.0	-7.6
Corn for grain	160.9	159.7	0.7
Flaxseed	19.4	21.0	-8.2
Mixed grains	58.4	58.3	0.2
Oats	93.2	93.1	0.1
Peas, dry	35.0	37.2	-6.3
Rye, fall	51.9	53.2	-2.5
Soybeans	42.2	39.1	7.3
Wheat, durum	31.0	35.3	-13.9
Wheat, spring	47.2	52.0	-10.2
Wheat, winter	73.9	75.9	-2.7
	(pounds/ac)	(kg/ha)	
Canary seed	1,026	1,187	-15.7
Lentils	1,239	1,287	-3.9
Mustard seed	676	709	-4.9

[1] CANSIM Table 001-0075 (Retired Dec 6, 2017)
[2] CANSIM Table 001-0017 (Dec 6, 2017)

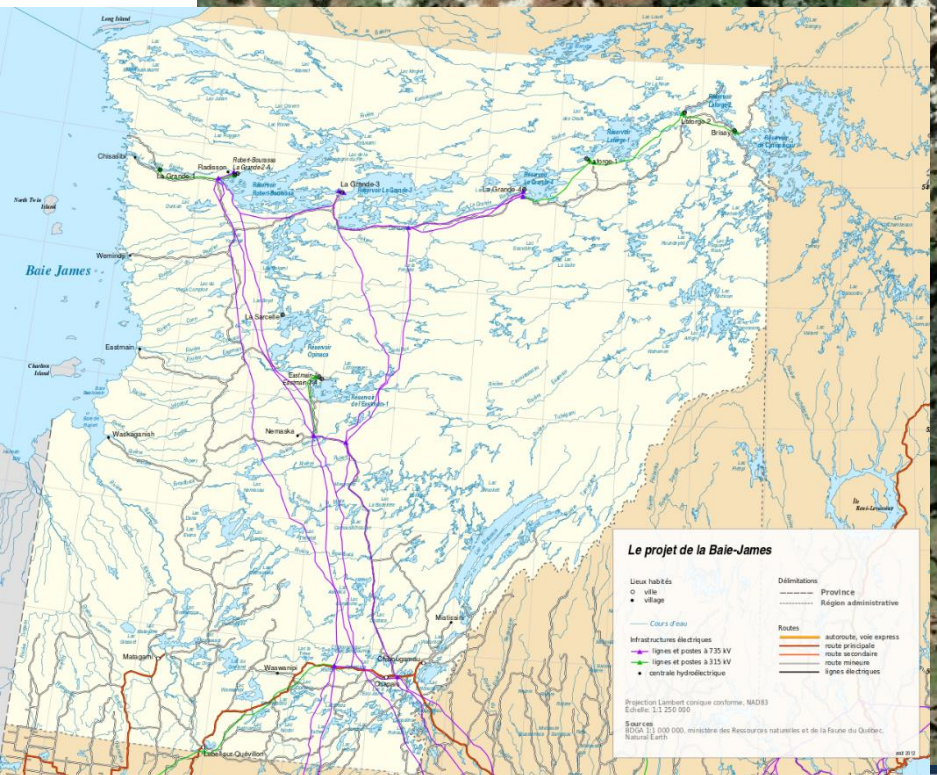
Assessment of global datasets

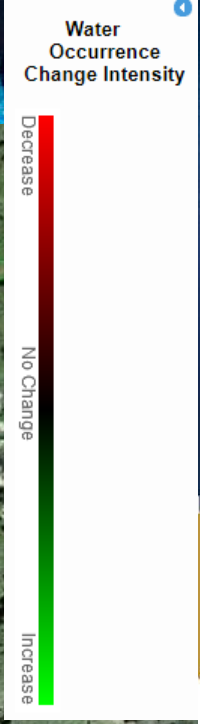
Qualitative assessment of Global Surface Water

Global Surface Water (GSW)

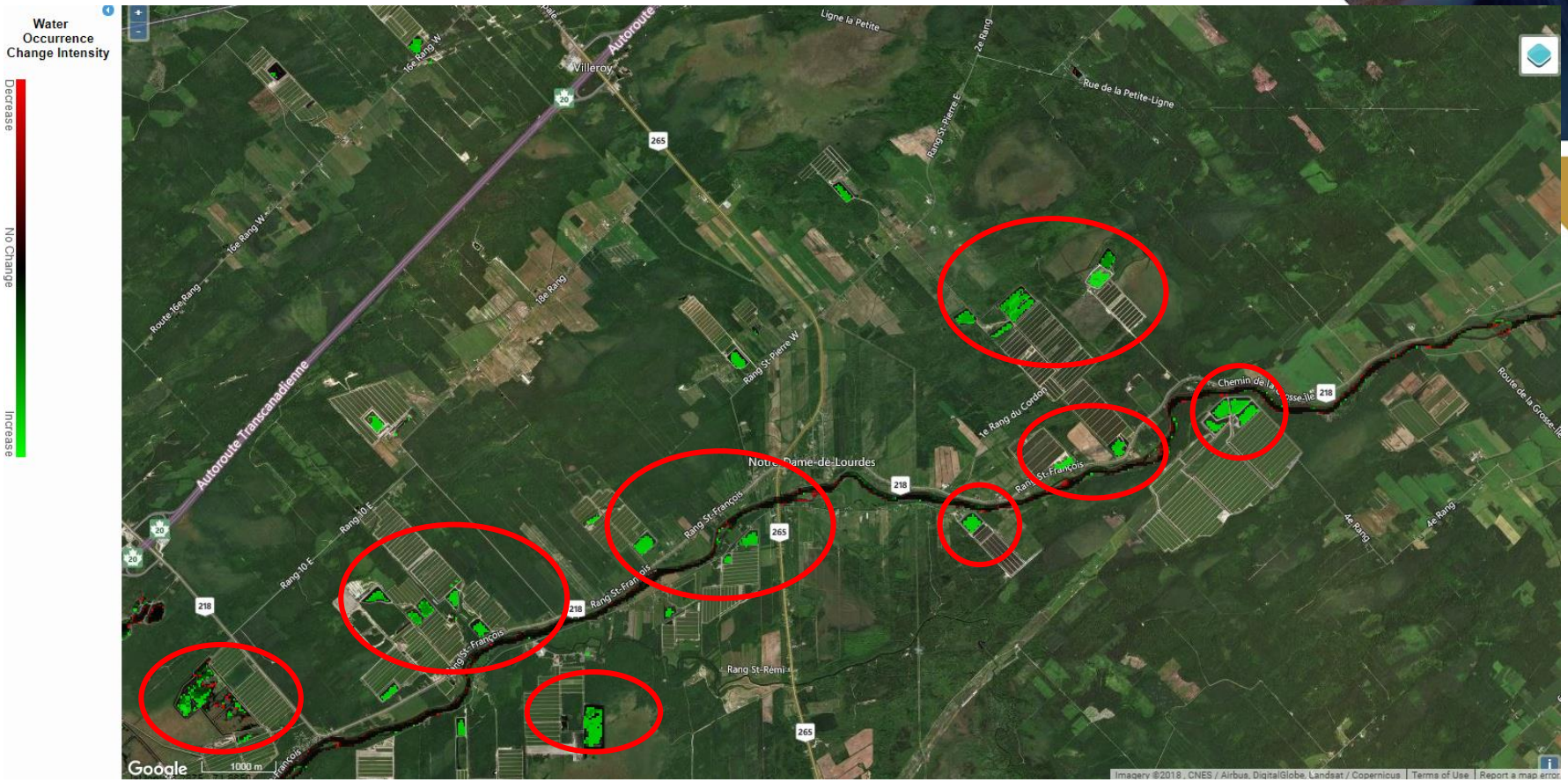
- Produced by – European Commission's Joint Research Centre
- Maps the location and temporal distribution of water surfaces at the global scale over the past 32 years and provides statistics on the extent and change of those water surfaces, 6 layers:
  - Water Occurrence (1984-2015)
  - Water Occurrence Change Intensity (1984-1999 to 2000-2015)
  - Water Seasonality (2014-2015)
  - Annual Water Recurrence (1984-2015)
  - Water Transitions (First year to Last Year)

Global Surface Water – JRC - Reservoirs



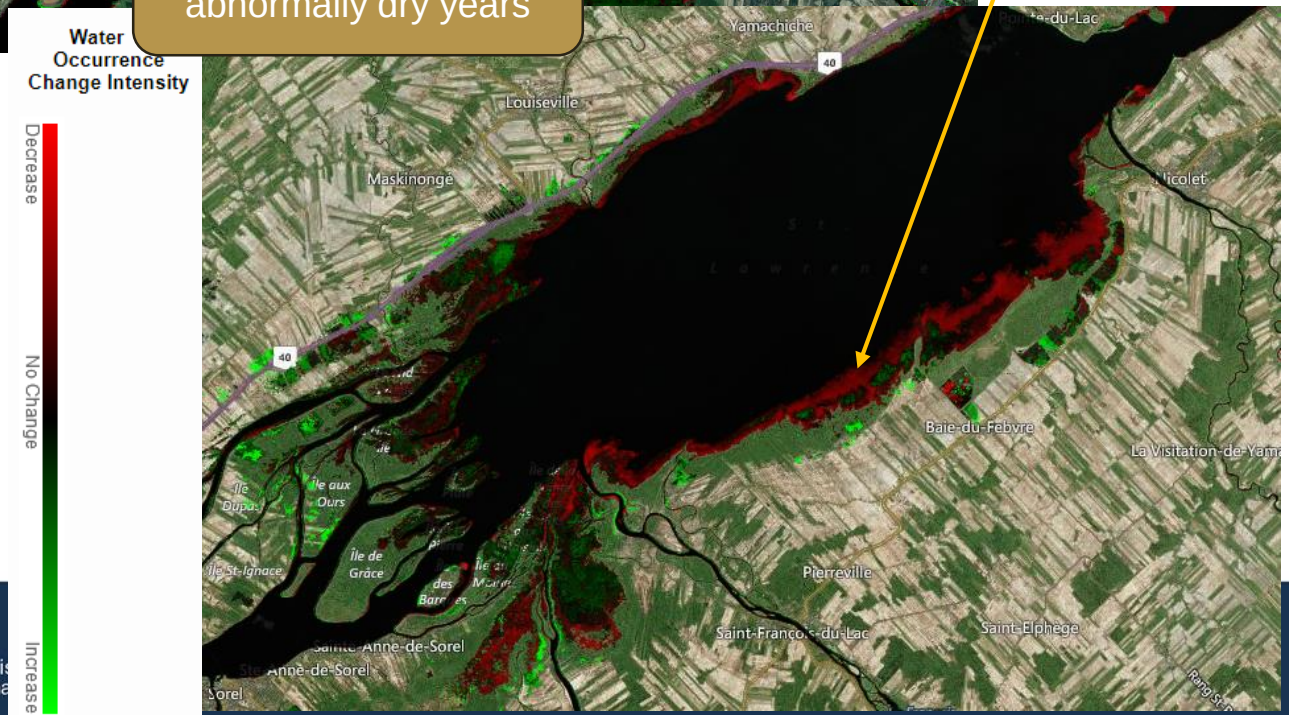


Cranberries

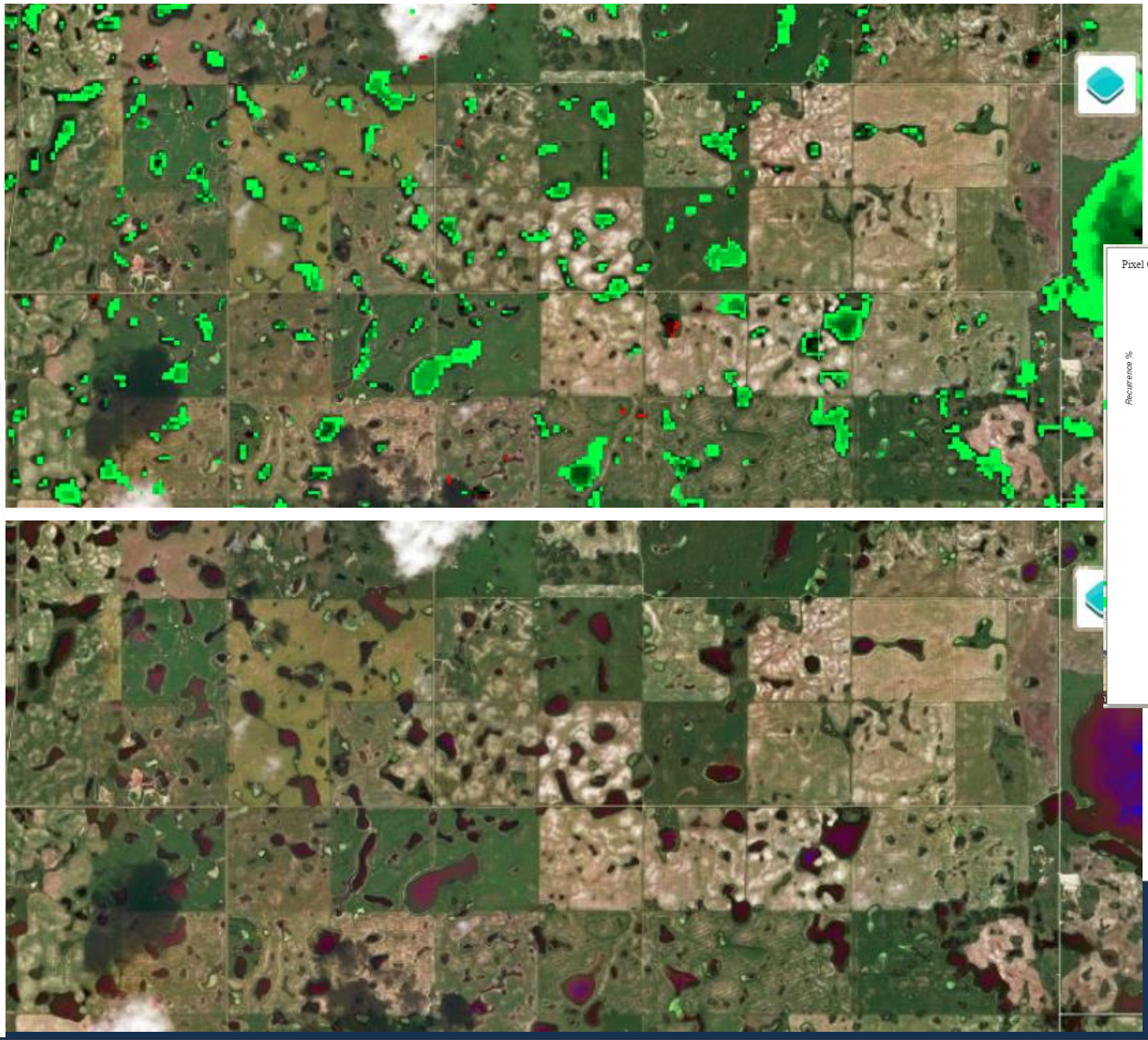


2010 and 2012
abnormally dry years

Macrophytes
Emergent vegetation



Prairie Potholes – ephemeral water/wetlands



Challenges

Challenges of using EO for Official Statistics

1. Datasets created from EO were not designed for official statistics
2. NSO workflow changes from data creation to data evaluation and integration of the EO datasets
3. NSO needs to adapt in order to:
   A. Develop methodologies to properly interpret existing datasets to estimate for official statistics
   B. Evaluate global datasets that are often designed without regional considerations
   C. Keep up with ever increasing number of EO generated datasets (risk of falling behind and loosing relevance)
   D. Adjust the national or regional data where local data of better quality highlights important shortcomings of the national or regional dataset.
   E. Evaluate EO data where other data often does not exist
   F. Influence EO producers to integrate official statistics objectives into the EO processing workflow from the beginning
   G. …

THANK YOU!

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