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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Table of contents

1. Canadian EO context
2. EO products from Government of Canada departments
3. Contribution of EO for official statistics
   1. Processes/workflows for the use of EO products for official statistics
   2. Canadian statistical context
      1. Quality framework
      2. Visualization
      3. Official account statistics (tables/stocks/flows)
4. Assessment of global datasets
5. Challenges
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

**AAFC**
- Crop Monitoring
- Manage Irrigation
- Land-use

**National Defence**
- Ship Detection
- CF Operations
- Search & Rescue

**NRCan**
- Resource Extraction
- Flood/Forest Fires

**Fisheries & Oceans**
- Monitor Coasts
- Illegal Fishing
- Oceans Science

**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
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:
- 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

#### 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

<table>
<thead>
<tr>
<th>Federal partner</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Earth observation (satellite and airborne)&lt;br&gt;• Geospatial data layers&lt;br&gt;• Field data</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Preprocessing (data preparation)</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Geographical registration, correction of the effect of elevation (orthorectification)&lt;br&gt;• Corrections and calibrations&lt;br&gt;• Mathematical transformation to enhance images to make them more suitable to meet requirements</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Digital image processing for information extraction</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Use of computer's decision-making capability to identify and extract specific pieces of information&lt;br&gt;• Human operators instruct the computer and evaluate the significance of the extracted information</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Quality control</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Accuracy assessment&lt;br&gt;• Document uncertainties and limitations associated with the approach</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Integration</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Horizontal and vertical integration with other data layers&lt;br&gt;• Document data sources and accuracies</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Results</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Baseline&lt;br&gt;• Change detection/&lt;br&gt;• Documentation&lt;br&gt;• Etc.</td>
</tr>
</tbody>
</table>
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

Forest area harvested, 1985 to 2010


<table>
<thead>
<tr>
<th>Year</th>
<th>Total built-up area</th>
<th>Arable</th>
<th>Natural and semi-natural</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Settled</td>
<td>Roads</td>
<td>square kilometres</td>
</tr>
<tr>
<td>1971</td>
<td>850</td>
<td>418</td>
<td>4,930</td>
</tr>
<tr>
<td></td>
<td>...</td>
<td>...</td>
<td>-961</td>
</tr>
<tr>
<td></td>
<td>1,409</td>
<td>403</td>
<td>-102</td>
</tr>
<tr>
<td>2011</td>
<td>2,260</td>
<td>821</td>
<td>3,867</td>
</tr>
</tbody>
</table>

... not applicable
Map 2.8
Forest area harvested, 1985 to 2010

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.

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

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)

Normalized Difference Vegetation Index
Weekly satellite composites mid-April to mid-Oct 1987 - present

Agroclimatic data
Example of top 5 predictors used
Max 80 predictors

Census Agricultural Regions (CAR)

Historical and current yield estimates by crop

Survey Yield (bu/ac)

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

Census Agriculture 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                      | Current year | 355          | 1,211     | 0.34                 | 0.079          | 2.49           | ...            

Source: AAFC

2017 Yield Model – 3 data sources
Agricultural statistics: crop yields
<table>
<thead>
<tr>
<th>Crop</th>
<th>Sept. yield model(^1)</th>
<th>Nov. yield survey (^2)</th>
<th>Sept. vs Nov Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>64.0</td>
<td>69.4</td>
<td>-8.4</td>
</tr>
<tr>
<td>Canola</td>
<td>38.1</td>
<td>41.0</td>
<td>-7.6</td>
</tr>
<tr>
<td>Corn for grain</td>
<td>160.9</td>
<td>159.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Flaxseed</td>
<td>19.4</td>
<td>21.0</td>
<td>-8.2</td>
</tr>
<tr>
<td>Mixed grains</td>
<td>58.4</td>
<td>58.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Oats</td>
<td>93.2</td>
<td>93.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Peas, dry</td>
<td>35.0</td>
<td>37.2</td>
<td>-6.3</td>
</tr>
<tr>
<td>Rye, fall</td>
<td>51.9</td>
<td>53.2</td>
<td>-2.5</td>
</tr>
<tr>
<td>Soybeans</td>
<td>42.2</td>
<td>39.1</td>
<td>7.3</td>
</tr>
<tr>
<td>Wheat, durum</td>
<td>31.0</td>
<td>35.3</td>
<td>-13.9</td>
</tr>
<tr>
<td>Wheat, spring</td>
<td>47.2</td>
<td>52.0</td>
<td>-10.2</td>
</tr>
<tr>
<td>Wheat, winter</td>
<td>73.9</td>
<td>75.9</td>
<td>-2.7</td>
</tr>
<tr>
<td>Canary seed</td>
<td>1,026</td>
<td>1,187</td>
<td>-15.7</td>
</tr>
<tr>
<td>Lentils</td>
<td>1,239</td>
<td>1,287</td>
<td>-3.9</td>
</tr>
<tr>
<td>Mustard seed</td>
<td>676</td>
<td>709</td>
<td>-4.9</td>
</tr>
</tbody>
</table>

\(^1\) CANSIM Table 001-0075 (Retired Dec 6, 2017)  
\(^2\) CANSIM Table 001-0017 (Dec 6, 2017)
Assessment of global datasets
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 Transitions (First year to Last Year)
Global Surface Water – JRC - Reservoirs
Cranberries
Macrophytes
Emergent vegetation

2010 and 2012 abnormally dry years
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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