Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Space for Agriculture: Supporting a Competitive and Sustainable Canadian Agricultural sector through Earth Observation

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Canada

The Importance of Agriculture to the Canadian Economy

- Canada's Agricultural landscape is **large and complex**:
  - o 229,000 farms;
  - o 67.6 million hectares of total farm area;
  - o 35.9 million hectares of land in crops;
  - o 8.1% of total GDP;
  - o 5th largest exporter of agricultural products; and
  - o Employs 2.2% of Canada's total population.
- **Importance of the sector varies across the provinces**, with food processing being more important in Central and Eastern Canada, and primary agriculture more important in the Prairies.
- **Impacts of weather, climatic variability and extreme can have a significant impact on the Canadian economy** (2001-02 Prairie drought, production losses of $3.6b and a GDP loss of $5.8b; 2011 prairie flooding, $15m in federal government compensation).

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Challenges for the Canadian Ag Sector

- Food Security:
  - How to feed a growing population in a sustainable way?
  - Market price volatility: food prices are increasing worldwide due to changes in energy and water availability, climate risk.
- Environmentally Sustainable Food Production:
  - Energy, water, fertilizer/pesticide usage by agriculture.
  - Greenhouse gas emissions from agricultural activities.
  - Land conversion, loss of ecosystem goods and services.
  - Consumer demands for sustainably grown foods, certification.
- Economic Sustainability of Agriculture:
  - Need to expand markets, develop new products.
  - Costs of water, energy, fertilizers/pesticides against food prices.
  - Impact of climate variability, disease.

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Emerging Science & Policy Trends: Why AAFC Monitors

- To meet these challenges sound policies and programs require **appropriate**, **timely** and **cost effective** information.
- Effectiveness of policies and programs to achieve management goals depends on the **quality of information** upon which they are based.
- There is a growing need to **measure and report on performance** as expectations about accountability and value for money grow.
- Participation in international fora (e.g. GEO, OECD) demands the **capacity to monitor and report** on agri-environmental conditions.
- As government resources decline and as new funding pressures arise, there is greater **pressure to do more with less.**
- There is a growing realization of the value of moving from **reactive** strategies to more **proactive** approaches.

We must measure in order to manage effectively.

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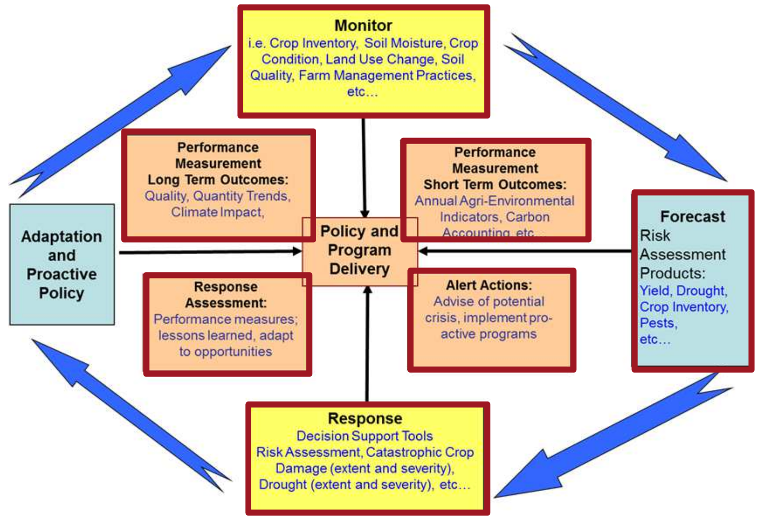
Monitoring, Forecasting and Risk Assessment: From Reactive to Proactive



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Looking Forward

- In light of these policy trends, it is critical that AAFC geospatial science development be quickly **moved outside of the research domain in to operational application** for targeting and implementing policy.
- As AAFC moves forward with this new capacity it needs to **better align monitoring activities** and **strengthen interaction with policy / programs**.
- New geospatial technology offer opportunities to improve the timeliness, scope, accuracy and integration of science, bringing **more relevance to AAFC science** and **more science to AAFC's policies and programs**.
- **Earth observation-based decision support** that integrates airborne, satellite, in situ, and ground data collection networks are some of the **geospatial technological keys** to this future.

Earth Observation (EO) has potential to provide timely "wall-to-wall" information to support AAFC programs and activities.

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What is Earth Observation (EO)?

Earth Observation is the art, science, and technology of obtaining reliable information about physical objects and the environment, through the process of recording, measuring and interpreting imagery and digital representations of energy patterns derived from non-contact sensor systems.

-- ASPRS (1988)

EO is Attractive to AAFC Because…

… it can provide:

- Spatially complete information over very large and inaccessible regions;
- Well calibrated data over time;
- Information at wavelengths sensitive to vegetation and soil properties.

… it can support AAFC activities and programs:

- EO data at various spatial and temporal scales can support agricultural land use management, biomass estimation, modeling and monitoring.

… it will continue to provide observations well into the future:

- In the next 5 years, new sensors planned for launch by Canada, U.S., European Space Agency, India, Japan, Argentina.

AAFC has the experience and expertise to take advantage of new opportunities in EO to develop state-of-the-art methods to extract meaningful information from new platforms and sensors.

What are these Opportunities?

Advances in Satellite and Sensor Engineering…

- New technology trends:
  - Miniaturization of electronics.
  - Large light-weight structures.
  - Compact optics.
  - Improved cooling.
  - High-performance onboard computing.
  - More efficient transmitters.
  - Increased power efficiencies.
  - Reduced noise.
  - Tunable systems.
- Progression to large numbers of small satellites will depend on increases in launch opportunities and decreasing launch cost.
- Progression to very large satellites will depend on the progress of the enabling large structure technology.

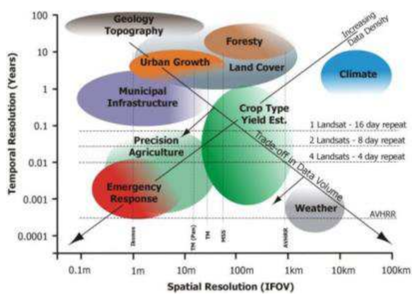
What are these Opportunities?

… Will Lead to the Launch of New EO Instruments...

- New sensors have enhanced capabilities:
  - Improved spectral, spatial and temporal capabilities.
  - Enhanced monitoring capabilities.
  - More detail, more frequently.
  - Allows mapping of new variables.
- New missions include:
  - Landsat-8.
  - Visible/Infrared Imager Radiometer Suite (VIIRS).
  - Soil Moisture Active Passive (SMAP).
  - Global Precipitation Mission (GPM).
  - Radarsat Constellation Mission (RCM)
  - Sentinel-1, -2 and -3.
  - Others …

What are these Opportunities?

… That Will Increase the Availability of EO Data at Fine Spatial AND Fine Temporal Resolutions, ...



- Sensors usually provide EO data at fine temporal OR spatial resolutions.
- Fine spatial resolution EO data needed to map at local-scales…
- … BUT often cannot meet temporal revisit needed for timely monitoring.
- Fine (but costly) temporal resolution data needed to map frequently…
- … BUT often cannot provide spatial resolution for fine-detailed studies.
- Planned satellite constellations will provide more frequent EO data at required fine spatial resolutions.

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Graphic Source: Goward and Williams (1997)

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What are these Opportunities?

… Provide Data Continuity & Long Term Data Records, …

- Long term data continuity is essential for operational agricultural monitoring.
- LTDC is vital to create the historical records necessary for anomaly detection and a consistent and reliable data record.
- Involves sensor inter-calibration (same sensor, different satellites) or calibration (different sensors, different satellites).
- Users want ready-to-use data from sensors whose calibration transparent to them.
- Future calibration of new sensors vital for seamless long term data streams for monitoring efforts are to be maintained.

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Graphic Source: www.nasa.org

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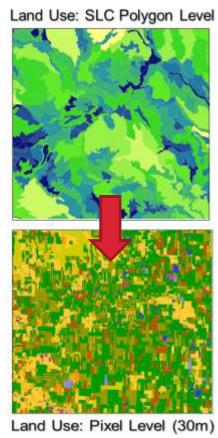
What are these Opportunities?

… Drive A New Generation of Scalable and Spatially Explicit Agro-Environmental Indicators, and …

- Input data to create current agro-environmental (AE) metrics limited on number of counts.
- Inconsistent data collection requires re-allocation of variables measured using different spatial f'works.
- If data are missing or unreliable, metrics often use missing, interpolated or out-of-date historic data.
- Data is inappropriate if mis-matched to temporal or spatial resolutions required to generate metrics with detail necessary to inform decision making.
- The new generation of spatially explicit and scalable indicators will use new EO data to provide national-scale, cost-effective, timely, accurate and scalable information at the producer level.



Graphic Source: AAFC (2012)

What are these Opportunities?

… Improve The Output of Process-Based Models.

- P-B models try to represent physical processes observed in real world.
- System behaviour derived from set of functional components and their interactions with each other and the system environment, through physical and mechanistic processes occurring over time.
- Process-based models include many uncertainties and often use poorly known parameters to make their projections.
- Limitations can be addressed using EO data to provide spatially and temporally comprehensive information on environmental surfaces.
- Spatially distributed process models use EO data to define initial conditions, drivers of processes, state variables and crop phenology.
- Rapidly increasing volume of EO-based spatial data creates challenges for assimilation and integration of these data into useful information.

What are these Opportunities?

Open Data Archives in Canada and Elsewhere…

B. Open Data - Open Data Without Borders

In its June 2014 report entitled *Open Data: The Way of the Future*, the House of Commons Standing Committee on Government Operations and Estimates indicated that open data has become the "raw material for the digital age," and encouraged the federal government to continue to "innovate and develop its vision for open data in Canada."

Building on the strong foundation of open data efforts to date, Canada's Action Plan on Open Government includes four specific commitments to unlock the innovation potential of open data over the next two years.

The first two open data commitments focus on deepening the collaboration on open data between Canadian governments at all levels, and with the private sector. The objective of these commitments is to harmonize open data services in Canada and encourage the reuse and commercialization of open data. The third commitment supports open data activities internationally in order to encourage the continued growth of the global open data movement, and reinforce Canada's role as an international leader for open government. Finally, the fourth commitment lays out improvements to be made to ongoing core open data activities.

What We Heard From Canadians

"Ensure portals are easy to use, data is easy to discover, and datasets are readable for all individuals, not just those with an extremely high level of data literacy."

"Work to integrate Open Government accountability mechanisms and Open Data access across federal, provincial, territorial and municipal jurisdictions."

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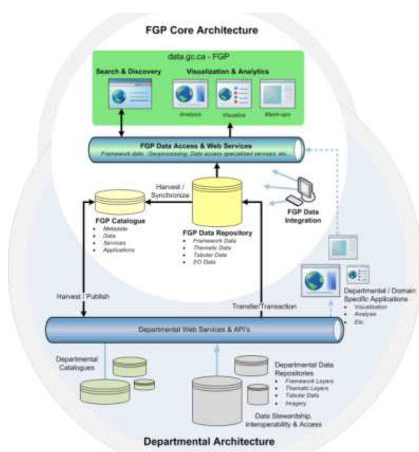
What are these Opportunities?

… Will Improve Access to Data, Products and Services, …

- Products not useful if end users cannot readily access or use them.
- Use of products often limited by cost, software dependencies, know-how,
- Increased push for easy discovery, access and use of data / information.
- Desire to let end users use information in 'their way for their own purposes'.
- Though different GoC Departments now serve geospatial data in different ways…
- … a proposed Federal Geospatial Platform will host key Canadian geospatial data and deliver it through various formats and applications.



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Graphic Source: AAFC (2014)

What are these Opportunities?

… Increase International Collaboration, …

- The GEO Agricultural Community of Practice Established Joint Experiment for Crop Assessment and Monitoring (JECAM) to:
  - Enhance international collaboration around agricultural monitoring towards the development of a "systems of systems" to address issues associated with food security and a sustainable and a profitable agricultural sector worldwide
- JECAM will achieve this by:
  - Network distributed regional research sites.
  - Share time series datasets from earth observing satellites and in-situ data.
  - Facilitating the inter-comparison of monitoring and modeling .
- The Approach:
  - Collect and share time-series datasets from a variety of Earth observing satellites and in-situ crop and meteorological measurements for each site.
- The Committee on Earth Observing Satellites (CEOS) and member support this activity with the acquisition and timely provision of data for JECAM.

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What are these Opportunities?

… And Lead to Globally Consistent Methods for Data Product Validation.

- Validation assesses uncertainty of AAFC EO-derived products.
- Involves comparison to reference data assumed to represent target values.
- Independent validation data required to determine product accuracy (in situ other data, imagery, maps, etc…).
- Methods often variable-dependent and determined by data availability.
- Validation standards for higher-order EO products yet to be fully developed.
- Product validation using common standards vital for meeting future needs of end users in ag sector.

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Graphic Source: calvalportal.ceos.org

What are these Opportunities?

Government Data Center Centralization...

- New EO sensors with finer spatial and temporal resolutions mean even more data needs to be processed.
- Gvt of Canada Departments have variable capacity to deal with this growing volume of information.
- Movement to centralized data centers -- where organizations operate and manage their data processing and data storage -- will allow more efficient data processing under a Government of Canada wide solution.
- New modern and efficient facilities will be designed to evolve to meet the ever-changing needs of citizens, government and technology.

What are these Opportunities?

… Will Allow Increased Data Volumes to be More Quickly and Efficiently Acquired, Processed and Stored.

- Data Centers planned to meet the government's current and future requirements, including those relating to geospatial and EO data.
- Non-production data centres will allow applications and systems to be developed and tested before going live.
- Production data centres will support live systems and applications.
- A single data centre will house supercomputing services for departments requiring scientific computing. Will have capacity to process and store large volumes of complex data.
- Moving applications to the data, rather than data to the applications will become the norm.

The Application of EO at AAFC

- The recent convergence of technologies (data, software, hardware) and policies (cheaper, open data) offer operational solutions for AAFC policy development, program implementation and performance measurement.
- EO work at AAFC spans full research, development and transfer (RDT) continuum. Involves development of… :
  - o Acquisition and pre-processing methods.
  - o Models and their validation.
  - o Applications and their operationalization.
  - o Data and information delivery platforms and tools.
- … and uses satellites and sensors with :
  - o Orbits (geostationary; sun-synchronous).
  - o Spectral resolution (wavelengths used; optical vs microwave).
  - o Spatial resolution (< 1 metre to 50 km).
  - o Temporal resolution(daily to every few weeks).
  - o Radiometric resolution (sensitivity to changes on the landscape).
  - o Swaths that single image covers (10s km to 1000 km).

How is EO Currently Used at AAFC?

EO-Based Information Products

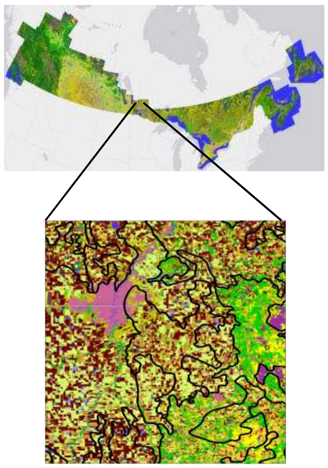
- o Circa 2000 National Land Cover Monitoring;
- o Annual National Crop Inventory Monitoring (2009-);
- o Agricultural Land Use Change Indicators;
- o Passive and Active Microwave Soil Moisture Estimation;
- o Near Real Time Weekly Crop Condition Assessment (250m);

EO-Integrated Information Products

- o Canadian Crop Yield Forecaster (CCYF);
- o Agroclimate Impact Reporter (AIR);
- o North American Drought Monitor (NADM);
- o Drought Watch;
- o Crop Specific Soil Suitability Ratings (LSRS);
- o National Soil Database.

AAFC EO-Based Activities

2013 Canadian Crop Inventory



Winnipeg Manitoba Area

Circa 2000 National Land Cover of Canada

- Land cover classification representing agricultural regions of Canada, circa 2000.
- Based on Landsat-5 and -7 data (30m).

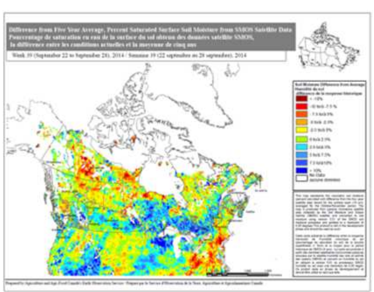
Annual Canadian Space-Based Crop Inventory

- Annual crop inventories for all agricultural lands at high resolution (i.e. field level).
- Analysis is based on Radarsat-2 and optical (AWiFS, SPOT, DMC, Landsat-8) imagery.

Agricultural Land Use Change Indicators

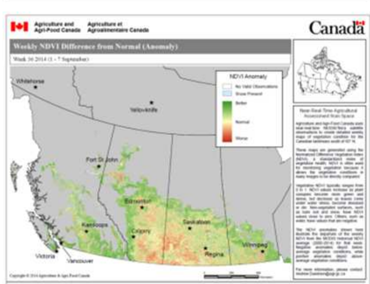
- Indicators indicate "where", "how much" and "how" agricultural land use has changed.
- Allows annual land use changes to be tracked between important cover types.
- Recent application to facilitating market access for Canadian Canola producers.

AAFC EO-Based Activities



Near-real-time Surface Soil Moisture Mapping

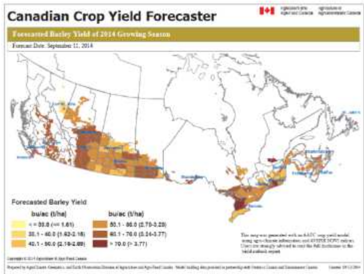
- Near-real-time weekly, bi-weekly and monthly surface soil moisture maps derived from daily passive microwave data from the Soil Moisture and Ocean Salinity (SMOS) satellite.
- Collaborating with USA (NASA and USDA) on the calibration of the Soil Moisture Active passive (SMAP) satellite.



Near-real-time Crop Condition Assessment

- Near-real-time weekly maps of crop condition and differences from normal conditions using daily Moderate Resolution Imaging Spectro-radiometer (MODIS) reflectance observations.
- Contributes to the Canadian GEOGLAM crop condition assessments for the Agricultural Market Information System (AMIS).

AAFC EO-Integrated Activities



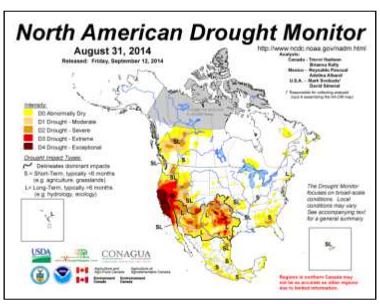
Canadian Crop Yield Forecaster (CCYF)

- Monthly crop yield forecasts during the growing season using statistical forecast models, agri-climate information and remotely sensed data.
- Currently for: Spring Wheat; Durham Wheat; Canola; Barley; Corn; and, Soybean.

Agroclimate Impact Reporter (AIR)

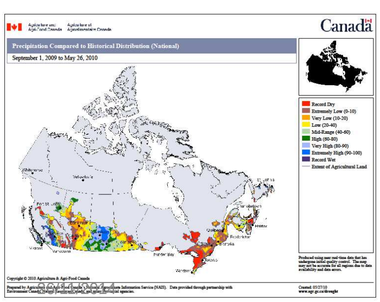
- An online tool for the collection and reporting of agro-climate impacts across Canada.
- Reports collected using a network of registered users as well as anonymous and media input.
- Information gathered plays a significant role in evaluating weather and climate-related risks to Canadian agriculture and supports policy and program decisions.

AAFC EO-Integrated Activities



North American Drought Monitor (NADM)

- Cooperative effort between drought experts in Canada, Mexico and United States with aim of monitoring ongoing drought across NA.
- AAFC has participated in the NADM since its inception in 2002 (via Canadian Drought Monitor) and reports on drought for agricultural and non agricultural regions of Canada.



Drought Watch (DW)

- Provides drought-related information, including information on weather and climate conditions, impacts throughout Canada and best management practices.
- More than 500 maps are produced daily.

Future Directions

- More active engagement of end users. Stronger linkages lead to better defined informational requirements and improve ability of users to apply EO in meaningful way (e.g. market access).
- Better integration of multi-satellite, multi-sensor, multi-resolution data for meeting monitoring needs (incl. UAVs).
- Derivation of validated biophysically meaningful parameters (e.g. yield) from EO data at multiple spatial and temporal resolutions.
- Increased incorporation of data from crowd-sourcing (incl. social media) to better inform and validate informational products.
- Implementation of new processing systems and methods (through centralized science data center) to facilitate more timely delivery of time-sensitive products.
- Closer international collaborations (e.g. JECAM) will identify best practices for data collection, processing and dissemination to ensure consistency and comparability among agricultural systems.