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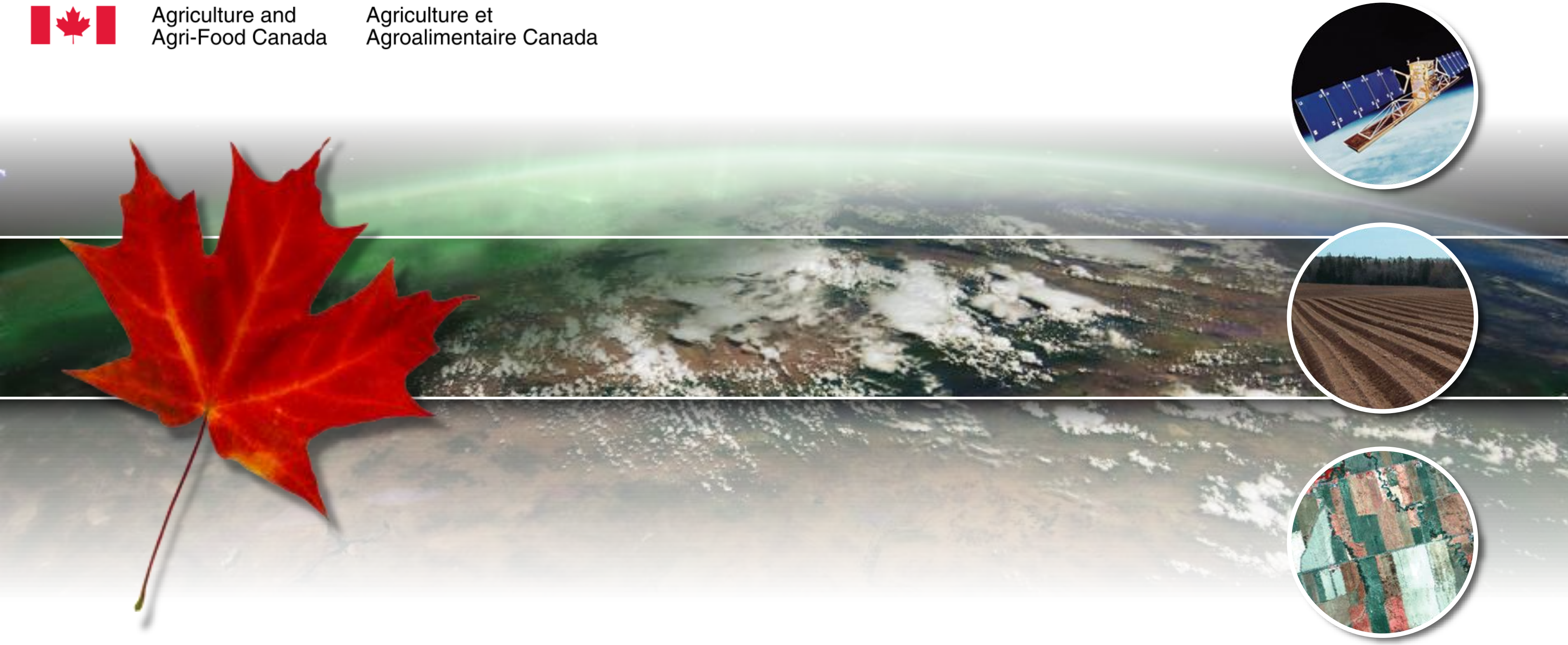


The AAFC Annual Crop Inventory

T. Fisette, L. Campbell, A.M. Davidson
Agriculture and Agri-Food Canada

August 16, 2019

Canada

Agriculture in Canada and Globally

- Canada's agricultural landscape is large and complex
  - 230,000 farms
  - Total farm area: 67.6 million hectares
  - 8.1% of total GDP
  - 5th largest exporter of agricultural products
  - Employs 2.2% of Canada's total population
- National, regional and global challenges in food supply and demand
  - UN Food and Agriculture Organization (FAO) estimates that food production must double in the next 40 years to meet global needs
  - Competing land uses and other uncertainties introduce risk
- Need sound policies and risk management strategies based on accurate, timely and cost effective information
- AAFC strives to harness the power of EO, which has become increasingly essential to address these challenges, both within Canada and globally

Earth Observation at AAFC

- AAFC has been conducting research on EO applications of space science for well over 30 years
    - World leader in agricultural monitoring and mapping, especially related to SAR applications.
    - Focus on research to support existing and future operations, followed by operational implementation
    - Sharing SAR methodology with scientists in other countries and international organizations to support agriculture monitoring

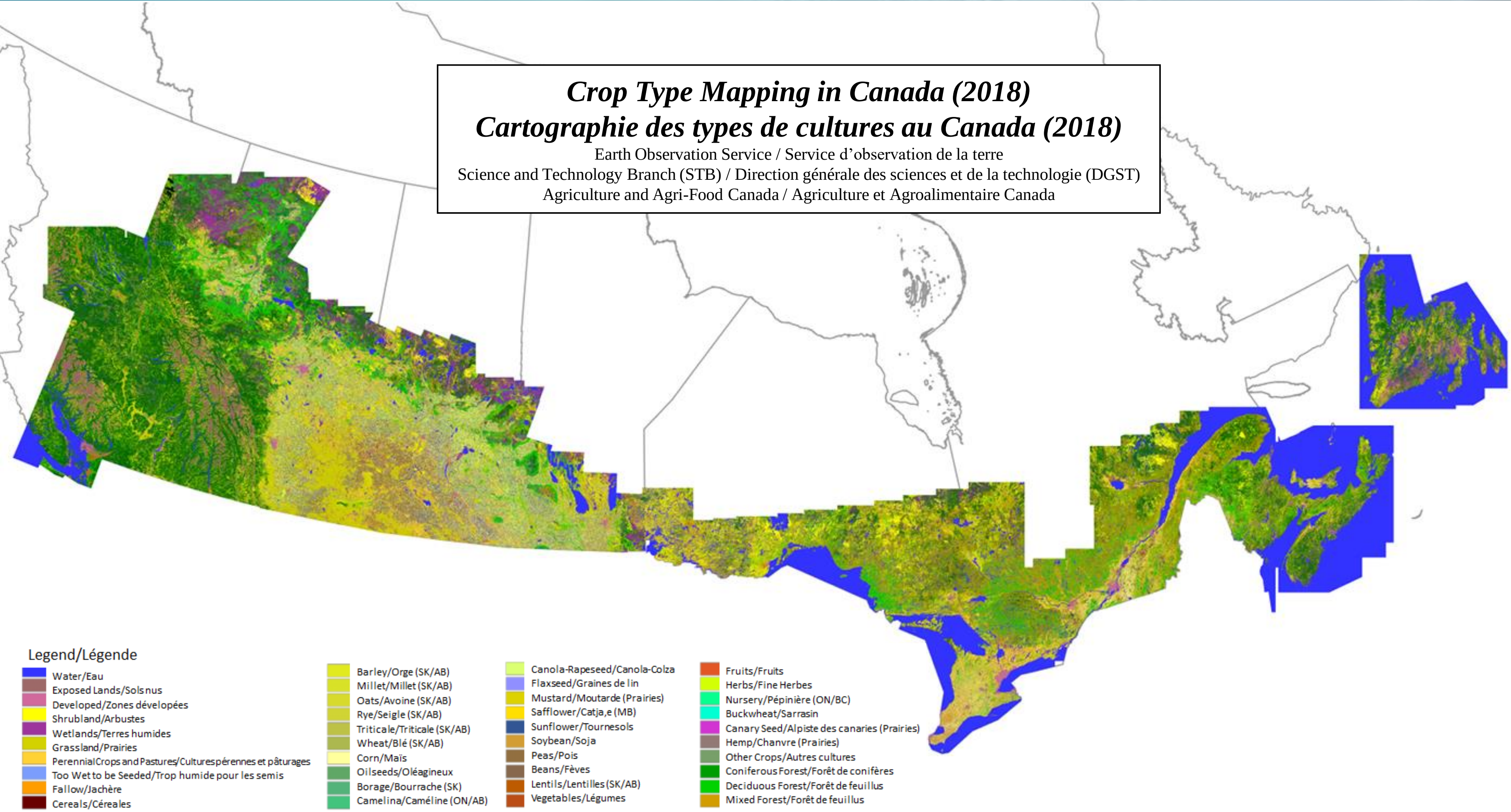
- Recent convergence of technologies (satellite imagery, software tools and hardware) allowed for operational solutions to support gov't policy development, program implementation and performance measurement

- AAFC can leverage Canadian space assets like RADARSAT-2 and the RADARSAT Constellation Mission (RCM)

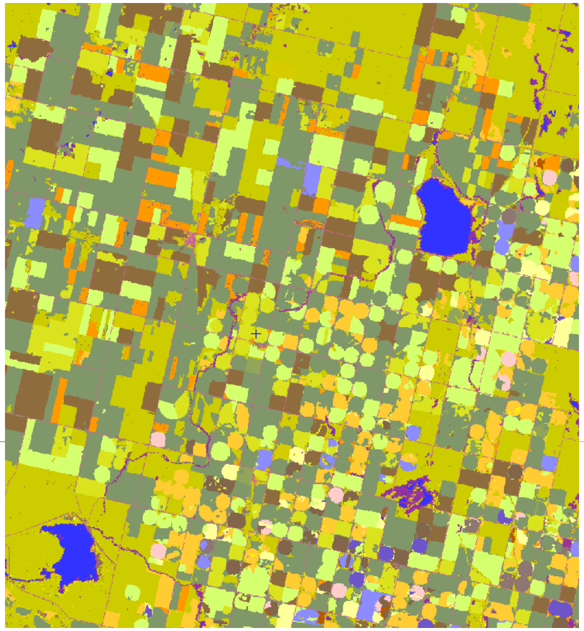
AAFC Annual Crop Inventory

- In 2009, AAFC began generating annual crop type digital maps using satellite imagery
- Mapping focused on Prairie Provinces in 2009 and 2010, expanded to entire agricultural extent of Canada in 2011
- Crop Inventory used by internal (AAFC) and external users
    - Yield prediction, rotation patterns, crop acreages
    - Landscape fragmentation, habitat pressures
    - Crop marketing / business planning
    - Many “unexpected’ uses, beyond agriculture
- Operational program, mostly automated workflow
- Crop inventories published on GoC Open Data Portal and AAFC Geospatial viewer
    - GeoTiff
    - WMS

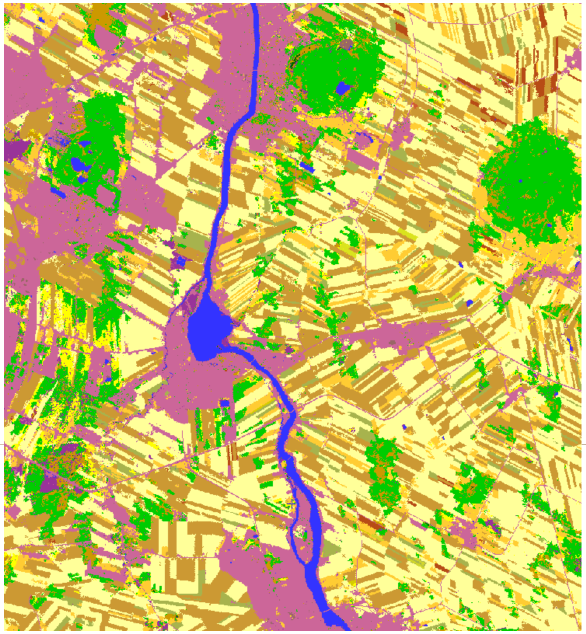
2018 Annual Crop Inventory



AAFC 2018 Annual Crop Inventory



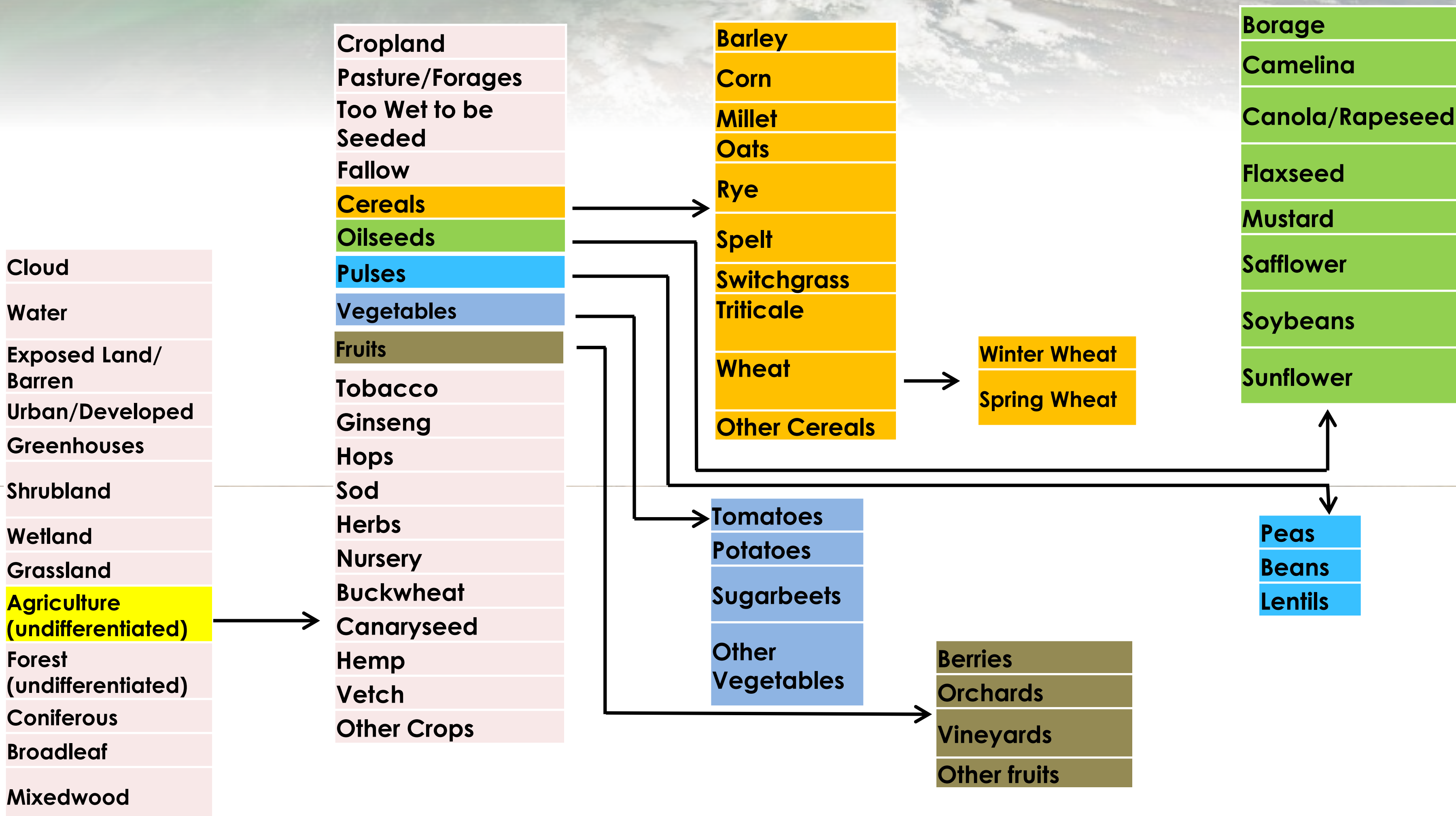
Near Taber, Alberta



Richelieu River, Quebec

Central Prince Edward Island

AAFC Annual Crop Inventory Legend



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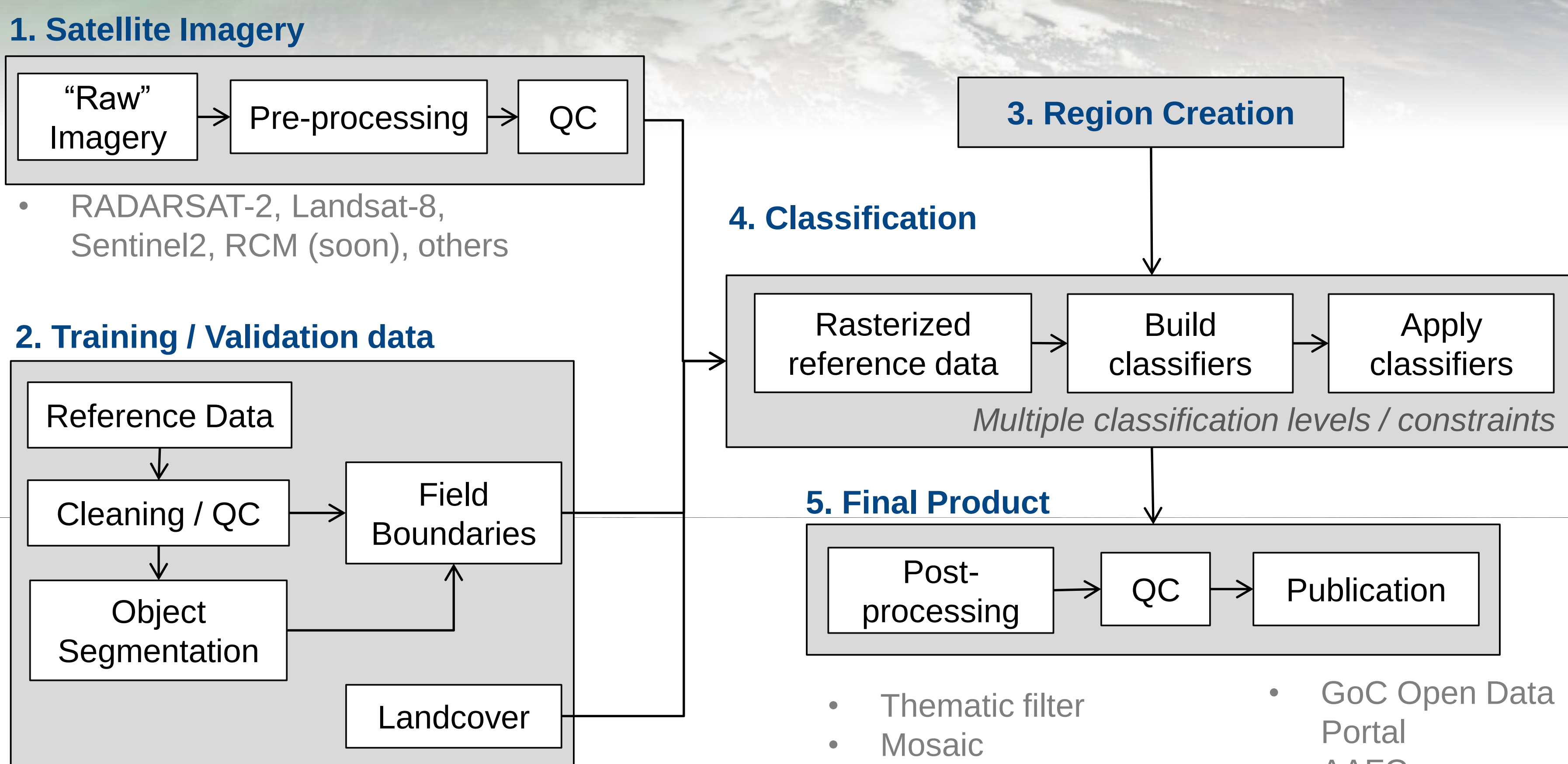
Canada

Crop Inventory Operational Methodology



1. Satellite Imagery

- RADARSAT-2, Landsat-8, Sentinel2, RCM (soon), others

2. Training / Validation data

- Crop Insurance
- Field Surveys
- Provincial and institutional partnerships

5. Final Product

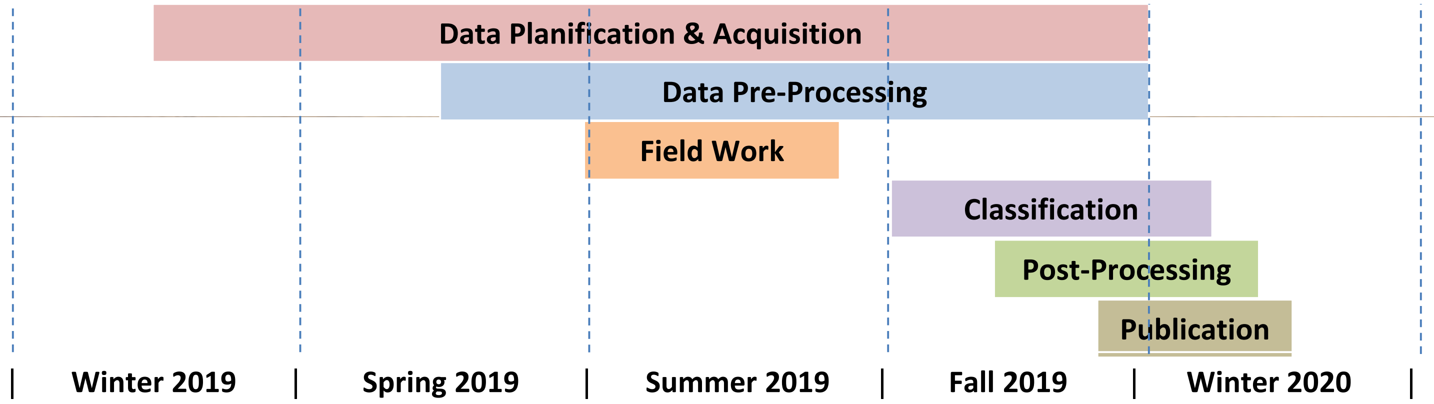
- Thematic filter
- Mosaic

- GoC Open Data Portal
- AAFC Geospatial Viewer

2019 Crop Inventory Production Schedule

- Current AAFC inventory is considered "end of season" or after harvest product

- The 2019 crop inventory production schedule:



Input EO Data

1- Optical data

- Multi-temporal optical EO data are the primary data source for crop classification.
- Over a growing season, at least three optical images are required to successfully identify crops.

2- Radar data

- RADARSAT2 (RCM very soon!)

- Currently AAFC uses **Landsat-8, Sentinel-2, and RADARSAT-2** EO imagery
- It is an **annual** crop inventory with the overall target accuracy of at least 85% at a final **spatial resolution of 30 m** and at the **national scale**.
- More than 1500 satellite images, each linked to thousands of ground data points, are required to map the entire agricultural extent of Canada annually and validate the resulting product.
- Hundreds of hours of computer processing time are required to do all the calculations to produce the provincial classification results.

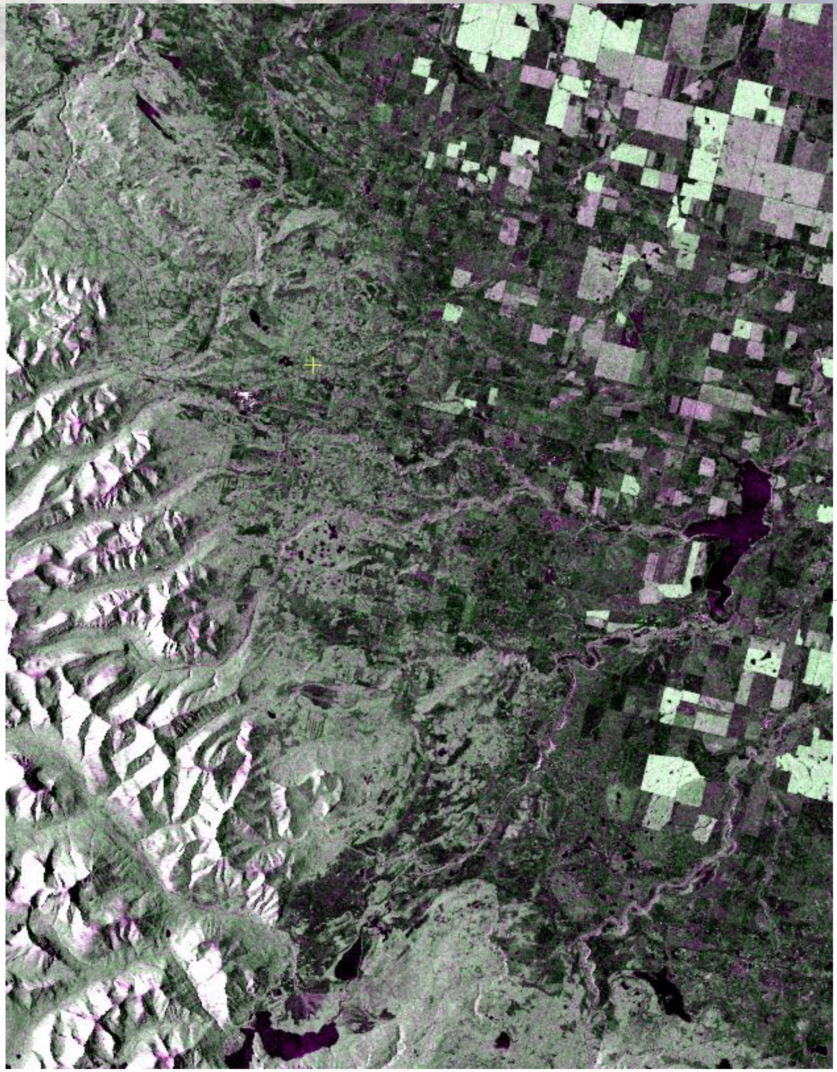
Radarsat-2 Pre-Processing

Automated open-source workflow for RS-2:
- Sigma-nought calibration
- Speckle filter
- Ortho-rectification / re-projection

Directly transferable to RCM data
- “Plug-in” architecture
- Standard structure for specifying processing parameters

Process “raw” RS-2 image (SGX Dual Pol Wide mode) in < 2 min
- Including copy from repository, archive extraction

Output: individual bands, 32-bit GeoTiff, georeferenced, aligned grid

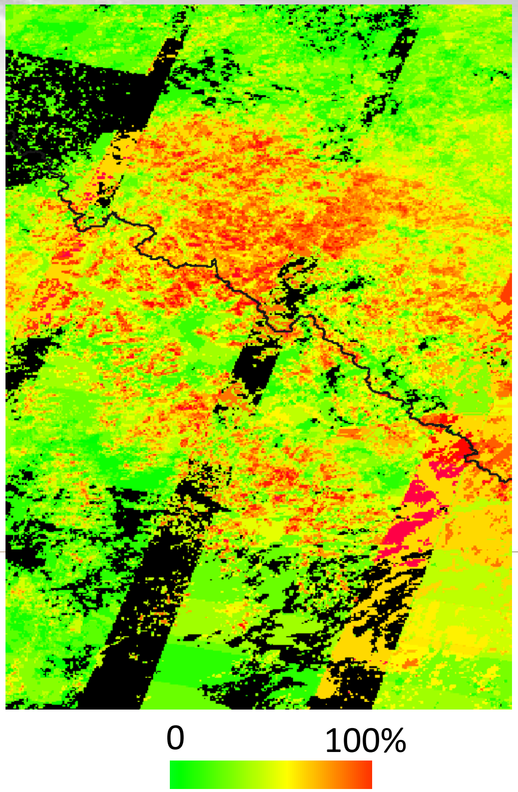


RCM – Launched mid-June 2019

Constellation
RADARSAT

Importance of SAR Imagery for the Inventory

- Optical multi-spectral data (Landsat-8, Sentinel-2) adequate to classify crops **if** data are available during critical periods of the growing season
- Accuracies greater than 85% have been achieved (overall and for individual crops), but can be significantly degraded by gaps in optical data collection
- Main issue is presence of clouds in multiple (or all) images
- The use of single-frequency, dual polarization (VV and VH) SAR imagery has been shown to increase the overall accuracies
- Current practice is to build regions from ~3-5 optical images and ~1-3 SAR images (non-optimal, due to system limitations)
- **Overall, integrating SAR data with an adequate national optical coverage significantly improves the accuracy of AAFC's annual crop inventory**



Percentage of available optical images with cloud cover, AB-BC border, 2015 Inventory

Intended Use / Utilisation of RCM Imagery

- RCM imagery expected to replace use of RADARSAT-2 imagery
  - Possible that both will be used in tandem while availability persists

- Ideal case would be complete coverage of the agricultural extents on a monthly repeat cycle

Image: MDA

- Main requirement continues to be for dual-pol VH+VV imagery with large swath and medium resolution:
  - RCM Medium resolution 30m mode, 125 km nominal swath width

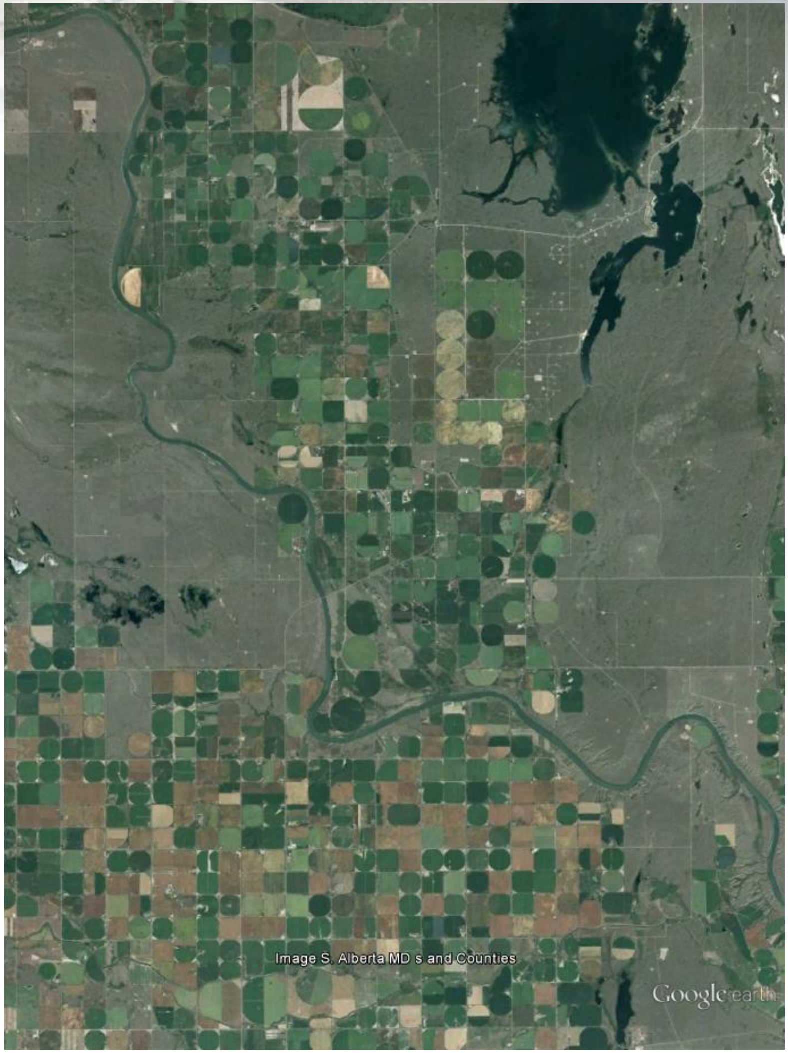
- Depending on early availability of reference data, frequent RCM data takes could enable the creation of in-season crop maps, rather than end-of-season

Optical Data Pre-Processing

Automated open-source workflow for optical data (Ldsat-8 and S2):

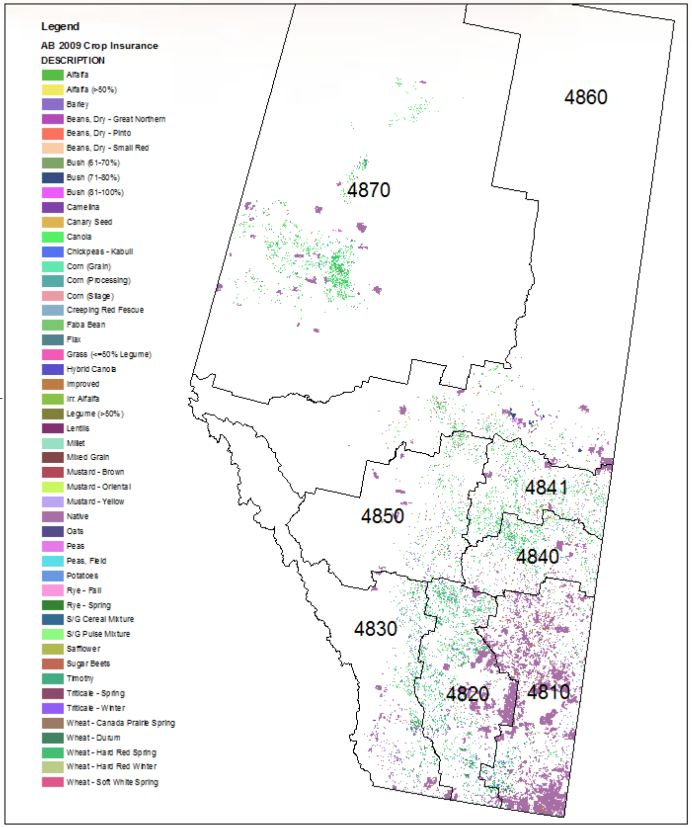
- Bottom of atmosphere reflectance
- Reprojection
- PCA (S2)

Output: individual bands, 16-bit GeoTiff, georeferenced, aligned grid

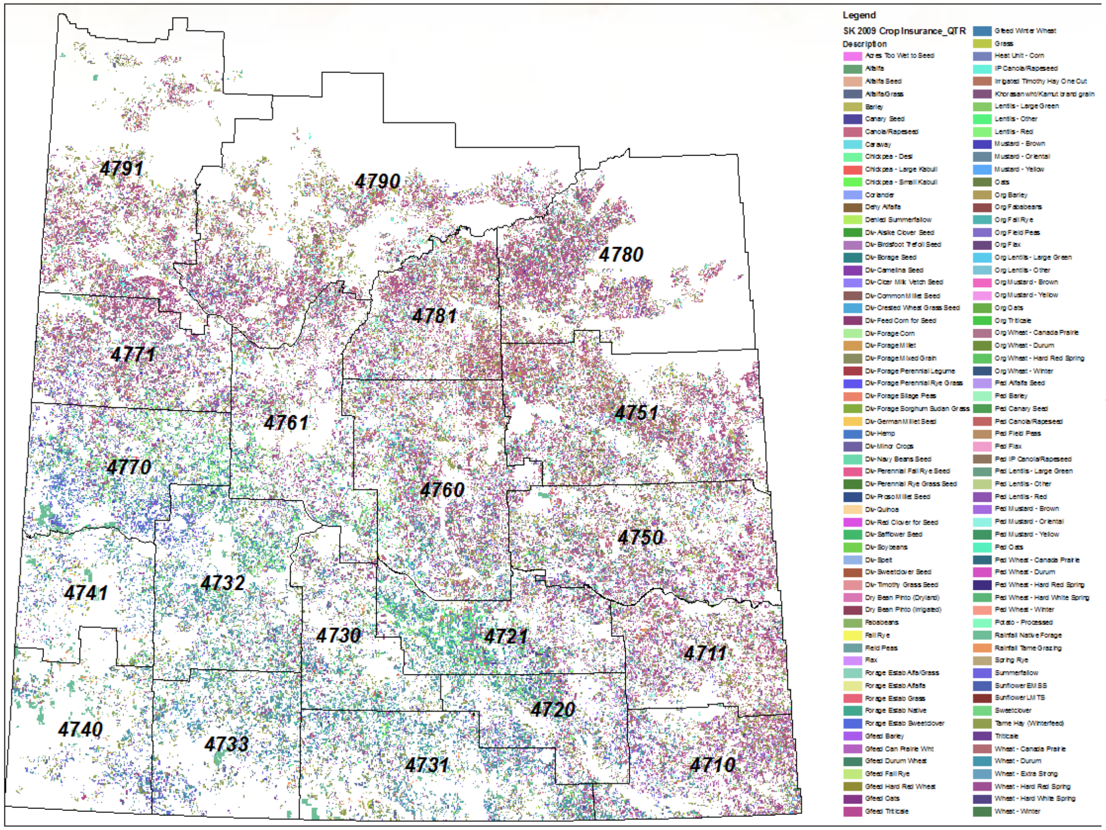


Ground Data Pre-Processing (Crop Insurance)

Alberta



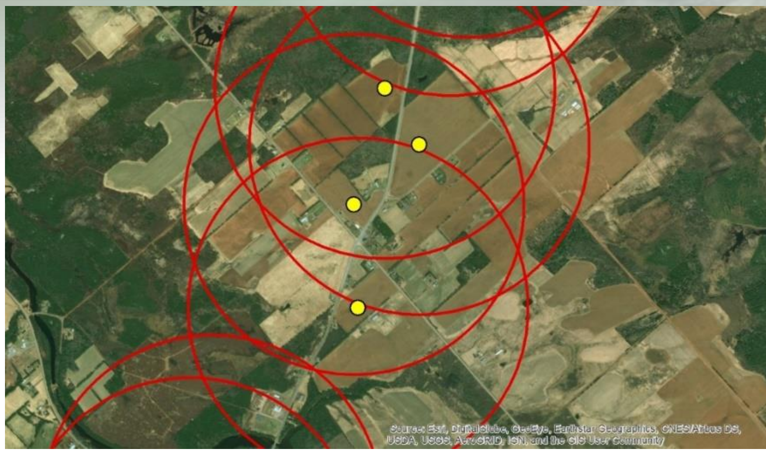
Saskatchewan



Ground Data Pre-Processing (Collected by AAFC)

Southern Ontario Data Collection

Ground Data Pre-Processing



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Optical Data

Name

- LC8_001_2018139_027_B2_sr_none_reproj_F32.tif
- LC8_001_2018139_027_B3_sr_none_reproj_F32.tif
- LC8_001_2018139_027_B4_sr_none_reproj_F32.tif
- LC8_001_2018139_027_B5_sr_none_reproj_F32.tif
- LC8_001_2018139_027_B6_sr_none_reproj_F32.tif
- LC8_001_2018139_027_B7_sr_none_reproj_F32.tif
- LC8_001_2018139_027_clouds_none_reproj_Bool.tif
- LC8_002_2018130_026_B2_sr_none_reproj_F32.tif
- LC8_002_2018130_026_B3_sr_none_reproj_F32.tif
- LC8_002_2018130_026_B4_sr_none_reproj_F32.tif
- LC8_002_2018130_026_B5_sr_none_reproj_F32.tif
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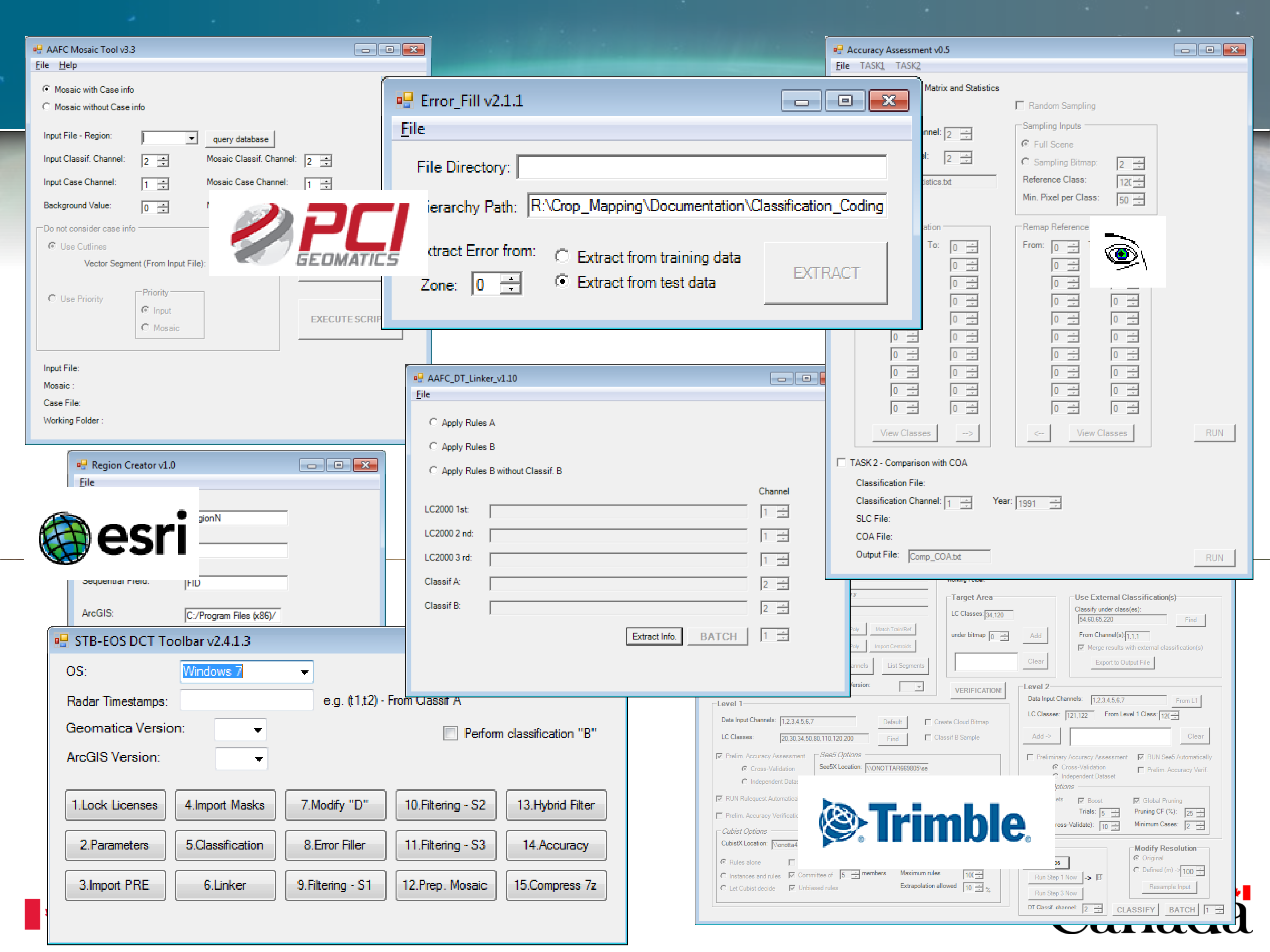
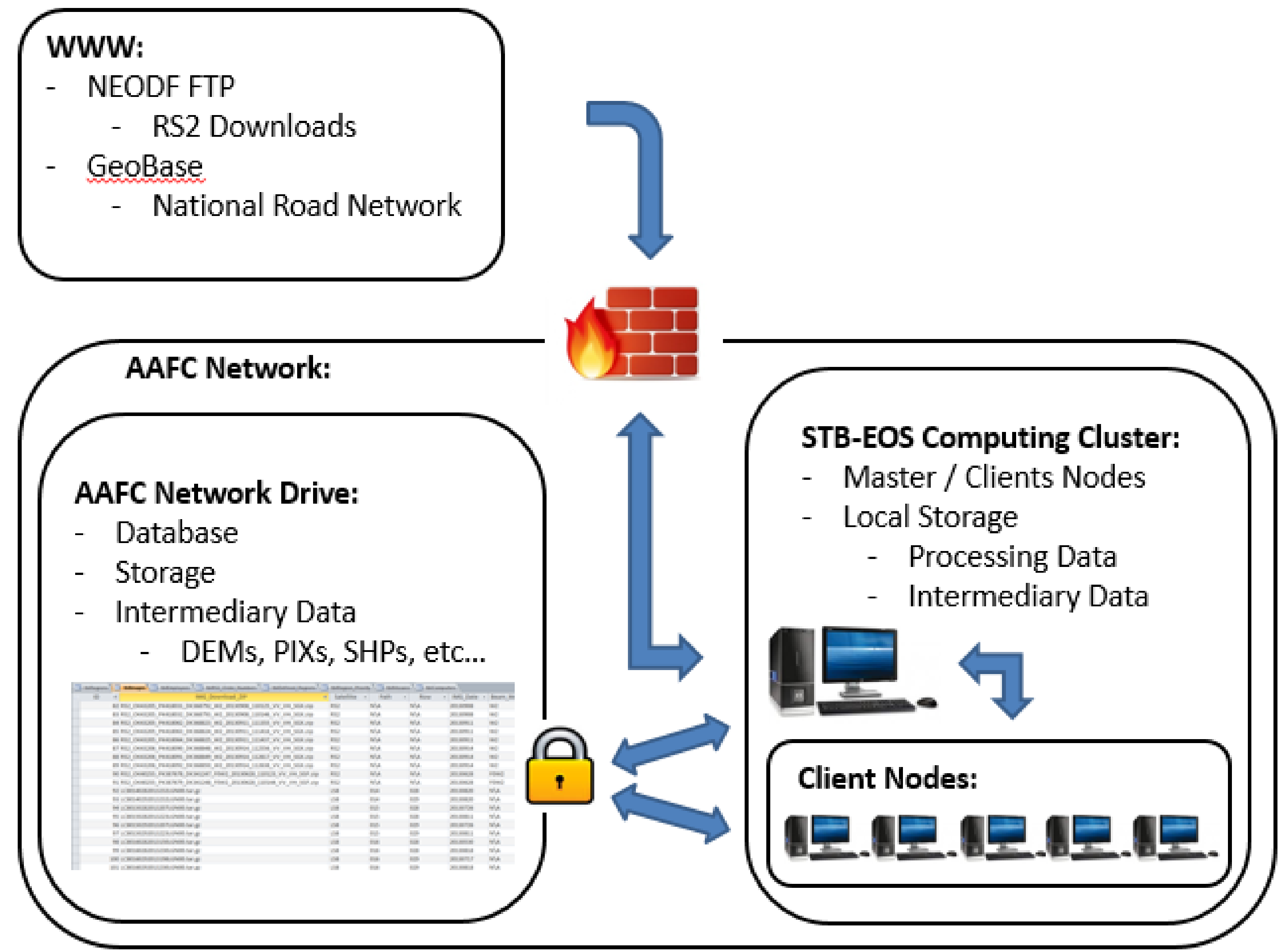
- LC8_002_2018130_026_B7_sr_none_reproj_F32.tif
- LC8_002_2018130_026_clouds_none_reproj_Bool.tif
- LC8_002_2018130_027_B2_sr_none_reproj_F32.tif
- LC8_002_2018130_027_B3_sr_none_reproj_F32.tif
- LC8_002_2018130_027_B4_sr_none_reproj_F32.tif
- LC8_002_2018130_027_B5_sr_none_reproj_F32.tif
- LC8_002_2018130_027_B6_sr_none_reproj_F32.tif
- LC8_002_2018130_027_B7_sr_none_reproj_F32.tif
- LC8_002_2018130_027_clouds_none_reproj_Bool.tif
- LC8_002_2018194_026_B2_sr_none_reproj_F32.tif

SEGMENTATION

- eCognition or
- Open Source

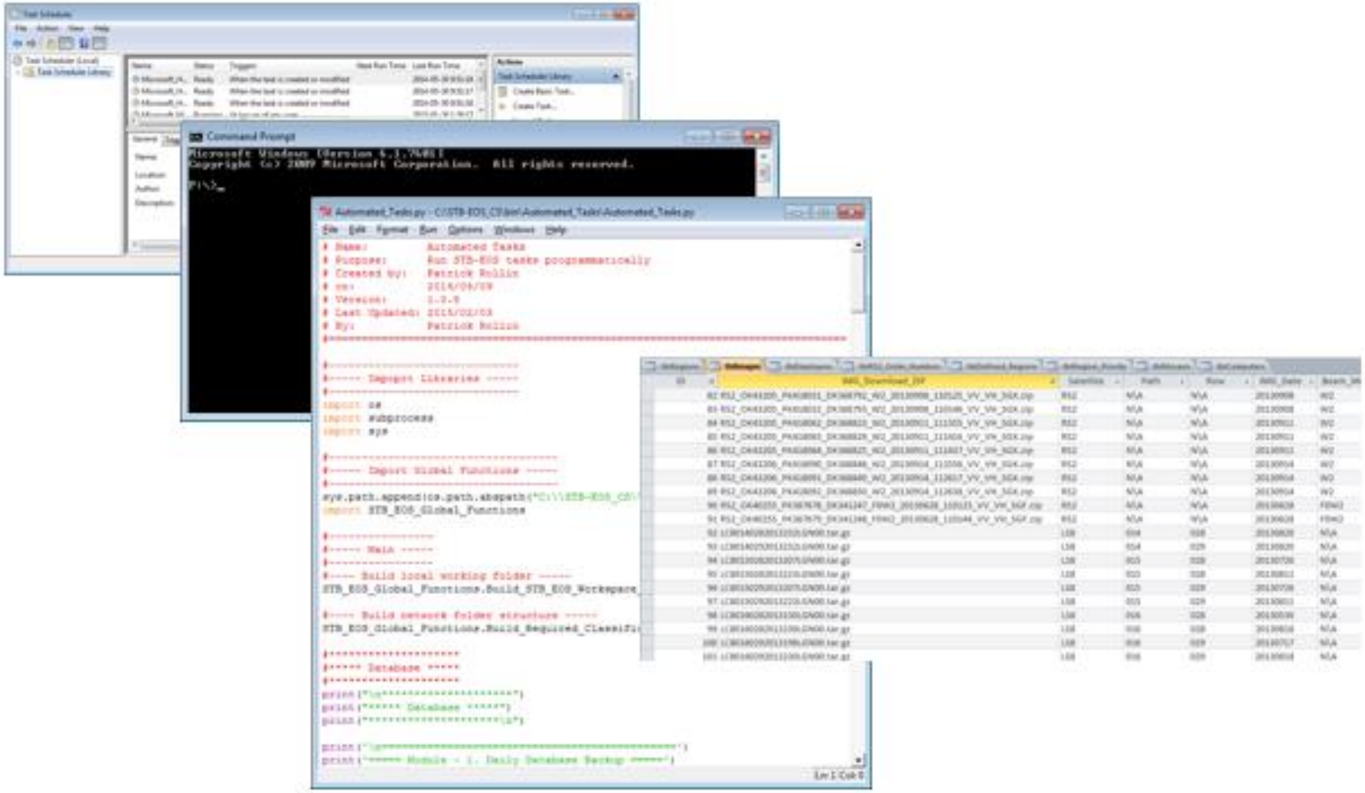

AAFC Mosaic Tool v3.3
File Help
Mosaic with Case info
Mosaic without Case info
Input File - Region:
query database
Input Classif. Channel:
Mosaic Classif. Channel:
Input Case Channel:
Mosaic Case Channel:
Background Value:
Do not consider case info
Use Cutlines
Vector Segment (From Input File):
Use Priority
Priority
Input
Mosaic
EXECUTE SCRIP
Input File:
Mosaic :
Case File:
Working Folder :
PCI GEOMATICS
Error_Fill v2.1.1
File
File Directory:
ierarchy Path:
R:\Crop_Mapping\Documentation\Classification_Coding
xtract Error from:
Extract from training data
Extract from test data
Zone:
EXTRACT
Accuracy Assessment v0.5
File TASK1 TASK2
Matrix and Statistics
Random Sampling
Sampling Inputs
Full Scene
Sampling Bitmap:
Reference Class:
Min. Pixel per Class:
Remap Reference
From:
To:
View Classes
RUN
TASK 2 - Comparison with COA
Classification File:
Classification Channel:
Year:
1991
SLC File:
COA File:
Output File:
Comp_COA.txt
AAFC_DT_Linker_v1.10
File
Apply Rules A
Apply Rules B
Apply Rules B without Classif. B
Channel
LC2000 1st:
LC2000 2 nd:
LC2000 3 rd:
Classif A:
Classif B:
Extract Info.
BATCH
Region Creator v1.0
File
esri
Sequential Field:
FID
ArcGIS:
C:/Program Files (x86)/
STB-EOS DCT Toolbar v2.4.1.3
OS:
Windows 7
Radar Timestamps:
e.g. (t1,t2) - From Classif A
Geomatica Version:
Perform classification "B"
ArcGIS Version:
1.Lock Licenses
4.Import Masks
7.Modify "D"
10.Filtering - S2
13.Hybrid Filter
2.Parameters
5.Classification
8.Error Filler
11.Filtering - S3
14.Accuracy
3.Import PRE
6.Linker
9.Filtering - S1
12.Prep. Mosaic
15.Compress 7z
Target Area
Use External Classification(s)
VERIFICATION!
Level 1
Level 2
See5 Options
Cubist Options
Modify Resolution
Trimble
CLASSIFY
BATCH

Classification System

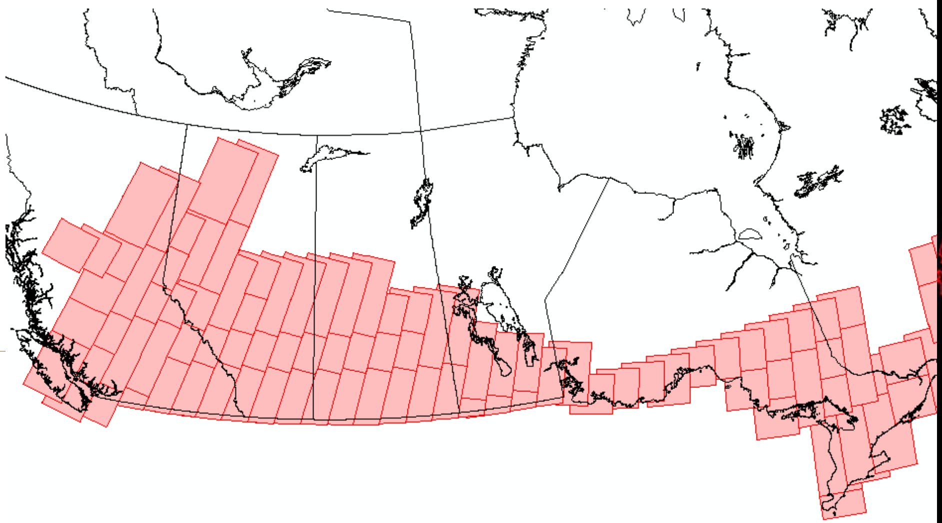


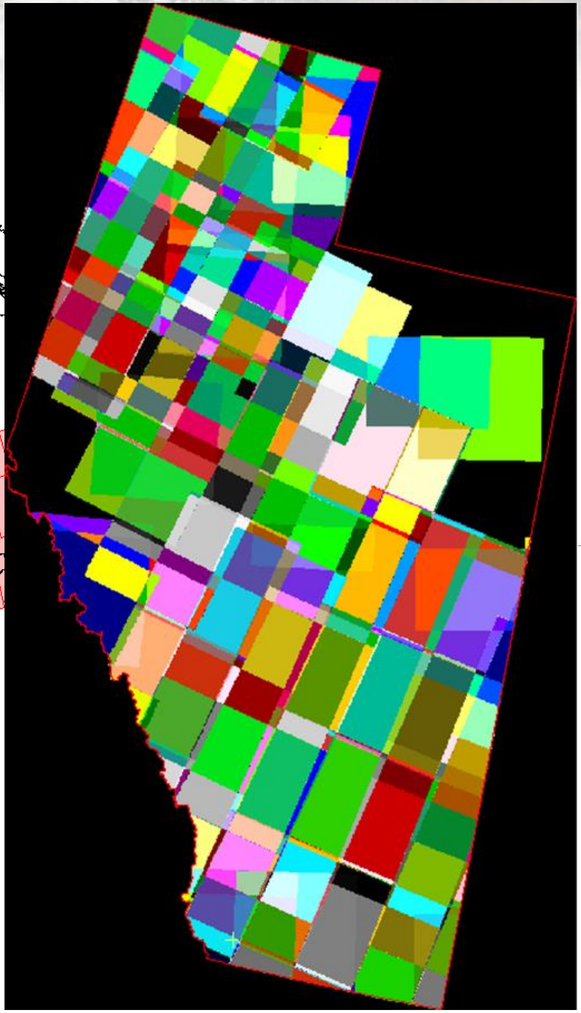
Classification System

- Task Scheduler launches a python script via Command / Console window. The script looks to the database for tasks to execute.



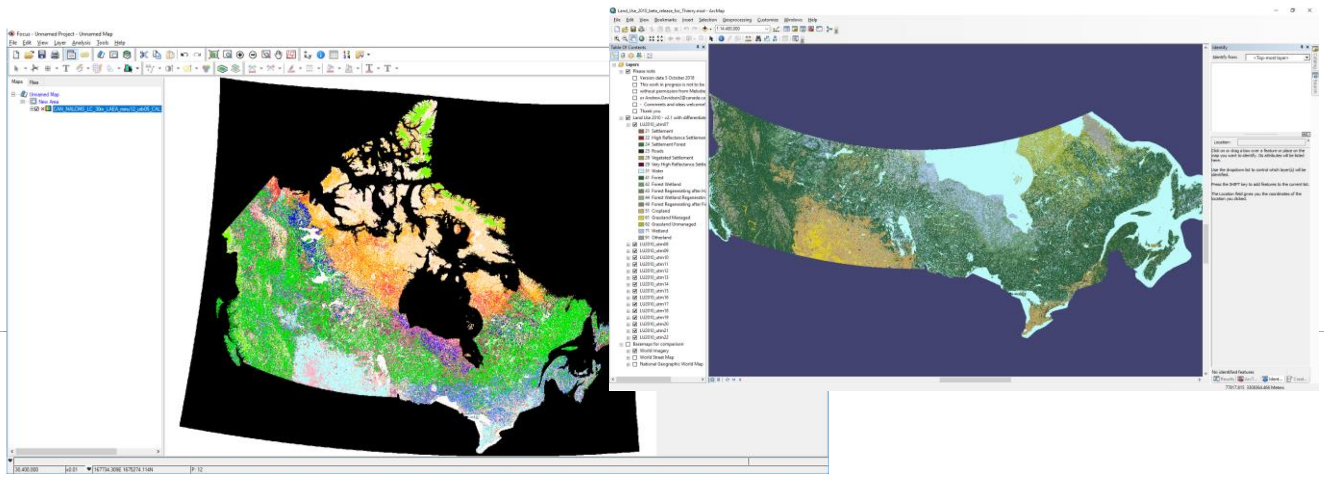
Classification regions





Land Cover & Land Use Classifications

1. Land Cover Mapping
   - Integration of independent datasets
   - Training sites from random sampling
   - Classification (mostly optical data from current year)



2. Land Use (Crop) Mapping
   - Training sites from insurance data & field work
   - Mask non-agr area from land cover mapping
   - Classification (current year radar & optical)

Classification System

The DT method, as implemented in see5 software, is a multivariate model based on a set of decision rules.

The decision tree is built empirically from training data.

The DT method was chosen because of its ability to handle discrete data, processing speed and independence of the distribution of class signatures.

Advanced options such as pruning and boosting have also been incorporated into the decision tree classification process to improve the accuracy of the algorithm.

Classification System

Current classification system developed, refined and modified over the last 10 years.

Beginning to experience limitations

- Increases in data volume
- New classification methods
- New sensors
- No 32-bit support
- Long processing times and inefficiencies

Desire to move away from commercial software, distribute classification software to other internal groups, external partners (and public?).

Opportunity to implement new system in preparation for RCM imagery.

Classification System

- AAFC is adapting current technologies to RCM
- This will help AAFC significantly reduce image processing time so that the annual crop inventory product can be delivered in a more timely manner
- These efforts are well underway:
  - Open source workflow (see5 or Random Forest)
  - Up to 20 times faster

Classification Filtering

AG groups connected to larger AG groups

1. Mask non-ag and "0" classes

2. Find groups of AG pixels smaller than threshold (in individual classes)

3. Replace those pixels with the 3x3 mode

Repeat until the mode is "stable" (no longer changes)

4. Re-insert LCV classes to filtered map

Isolated Ag groups within LCV

5. Find groups of AG pixels smaller than the threshold and disconnected from other AG

6. Replace those pixels with the 3x3 mode

Repeat until the mode is "stable" (no longer changes)

7. (Optional) Apply a final sieve filter to deal with remaining "stable" patches.

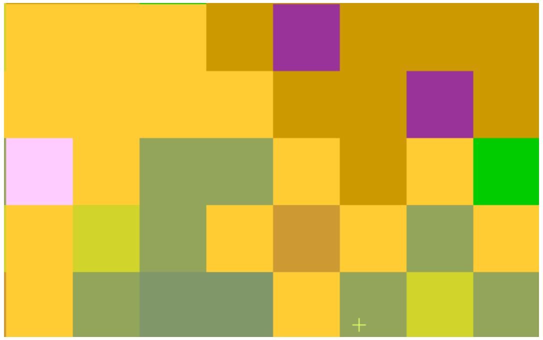
Classification filtering

In the first part (AG->AG), LCV coverage is maintained exactly

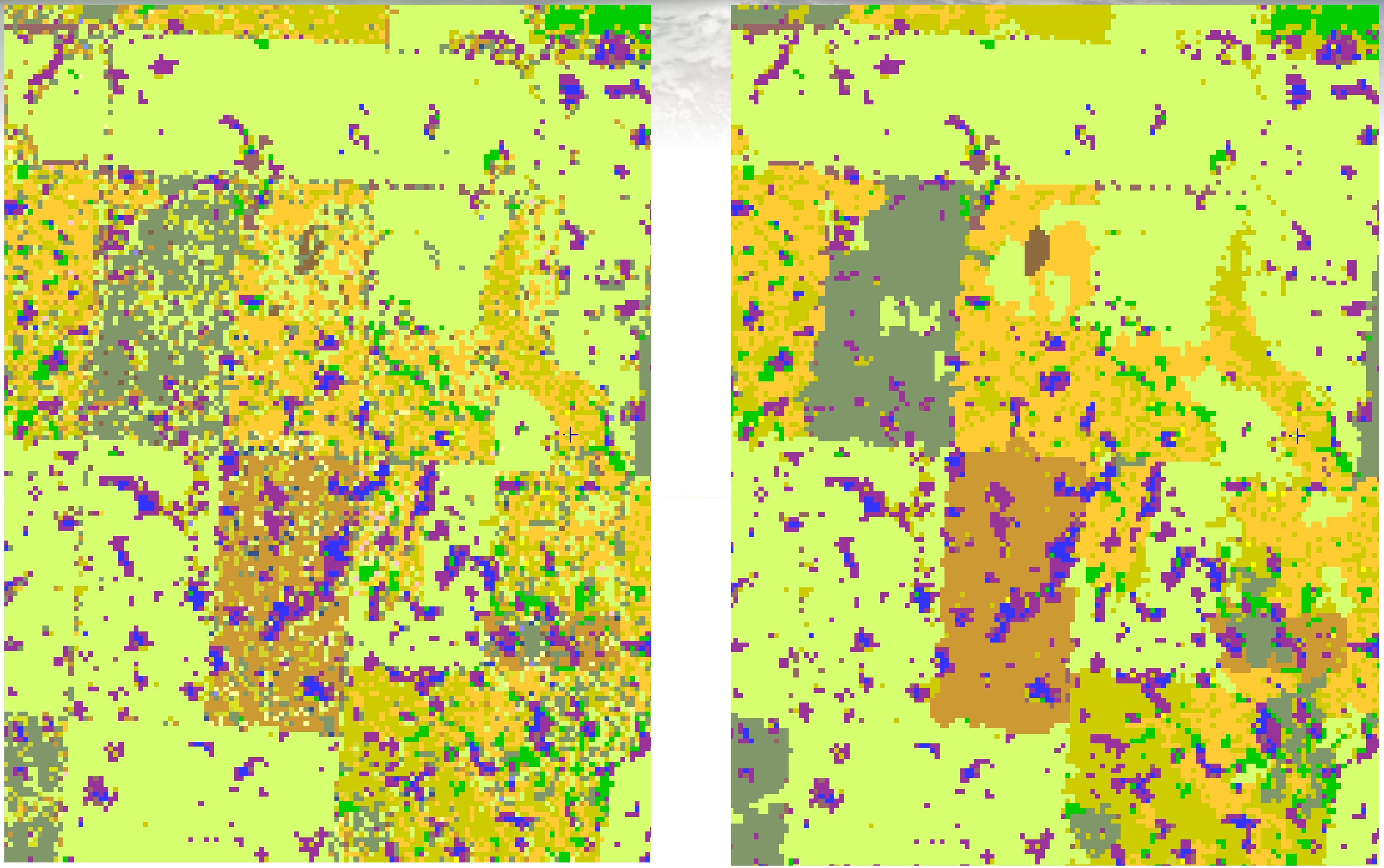
In the second part (AG->LCV), AG pixels are converted to LCV.

Why do we need an iterative filter?

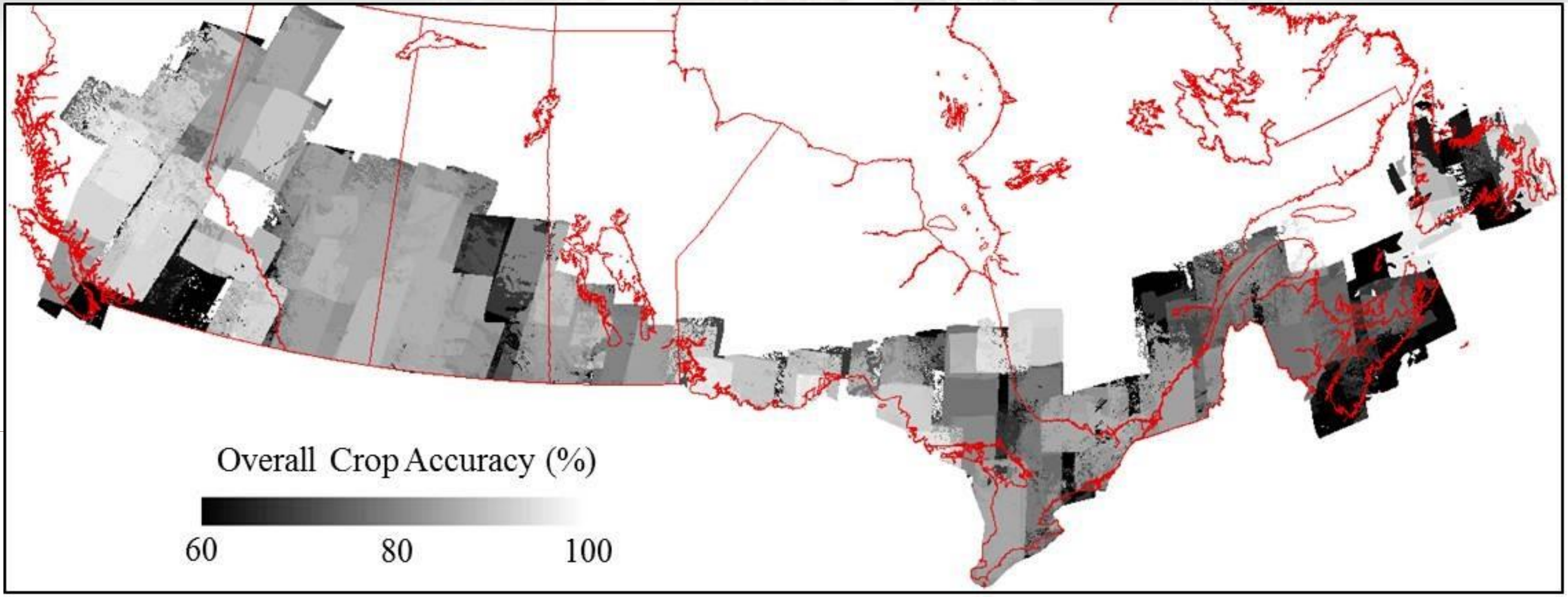
- Sieve filter cannot merge to classes smaller than threshold, problematic in noisy areas (below)
- Sieve filter can alter field boundaries significantly



Classification Filtering



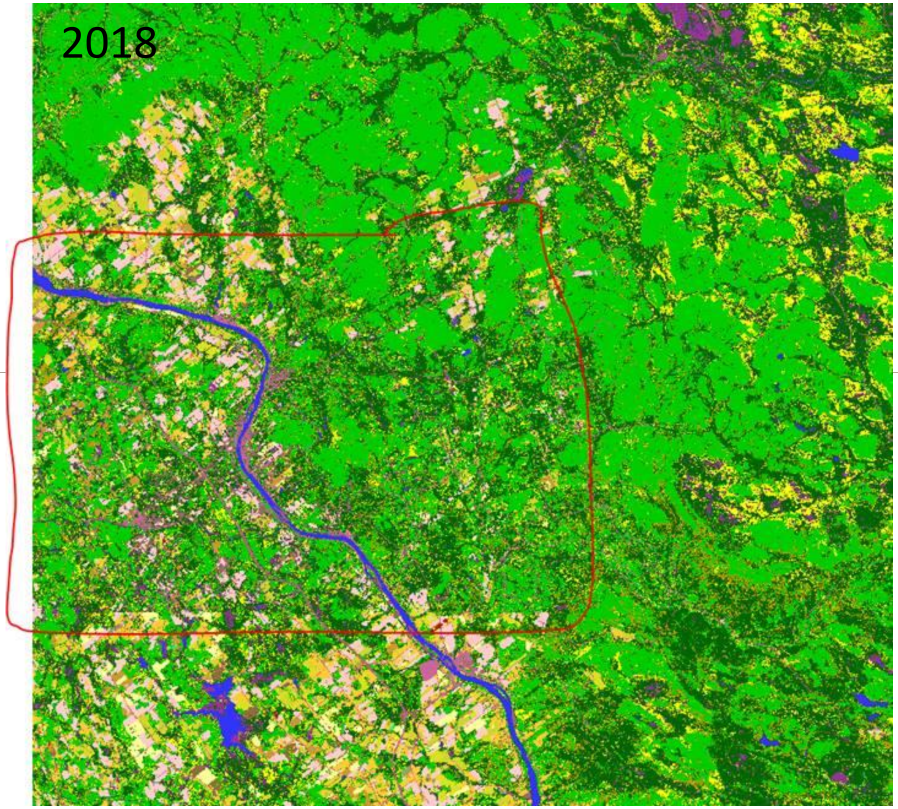
Mosaic Process

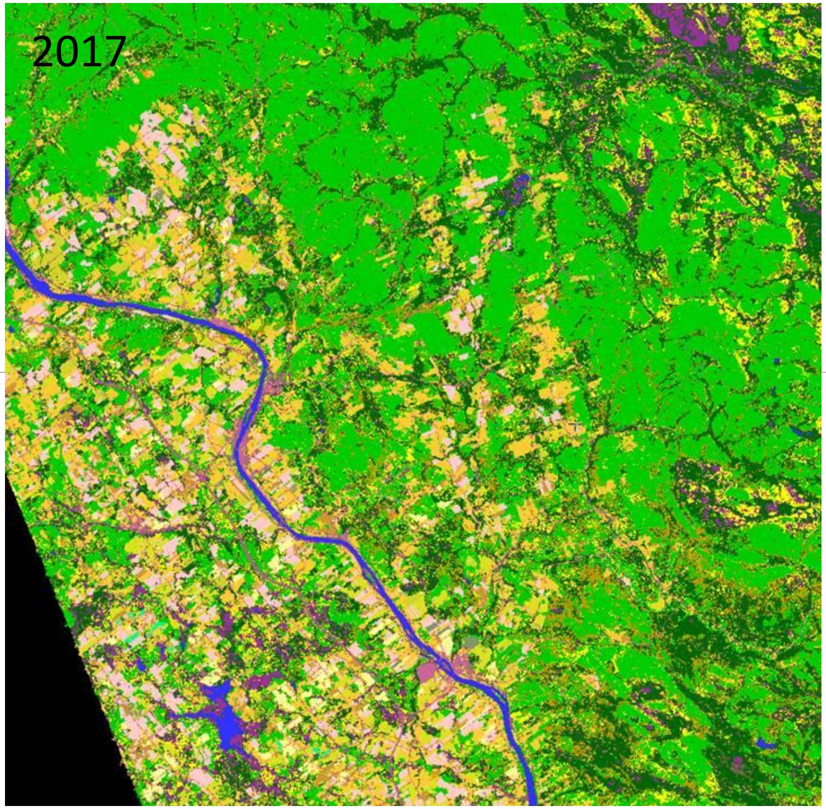


Revision

Once all areas classified: Manual revision for major errors only

Need to find balance between maps quality vs analyst time

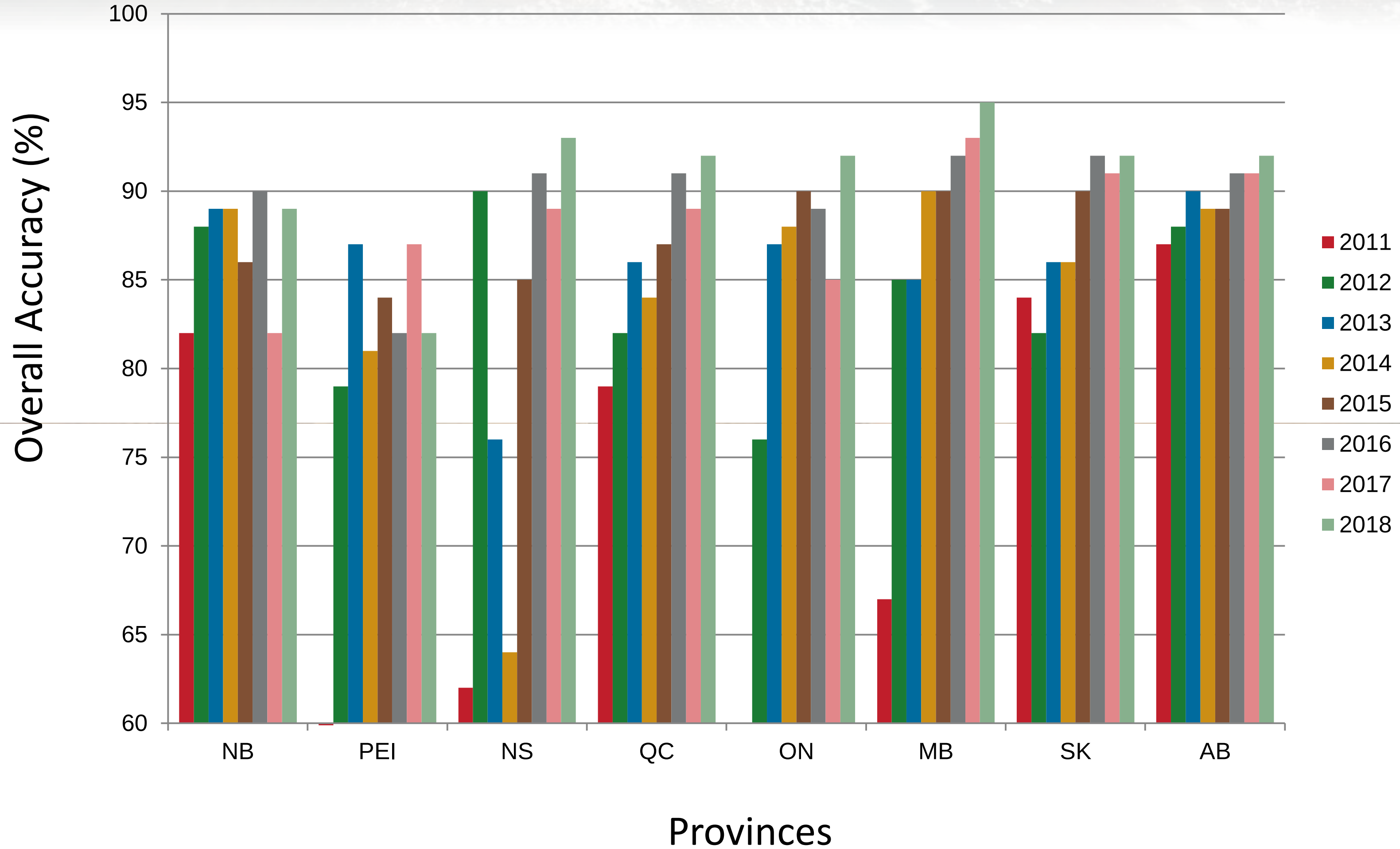




Final Steps

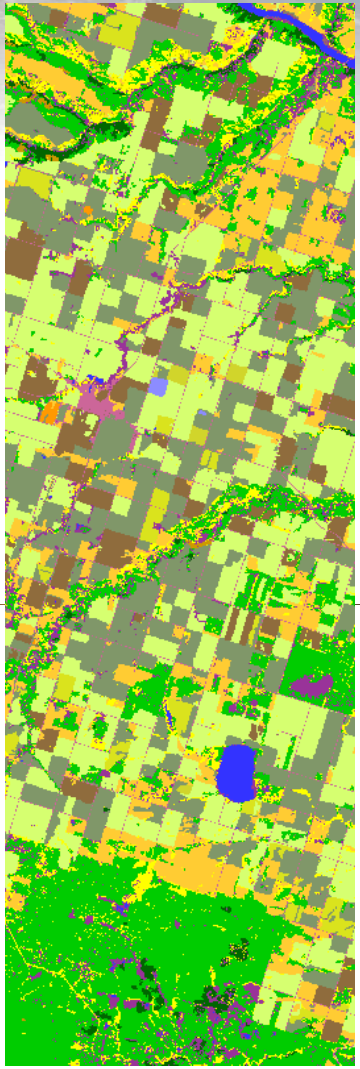
- Burn permanent classes
- Per-province accuracy assessment
- Compile metadata
- Distribute

Accuracies 2011 - 2018



Operational Challenges & Future Implementation

- Can’t assume we’ll have access to specific sensors;
- Our mapping success is link to specific staff members;
- Ground data quality not consistent;
- Ground data availability;
- Low processing speed;
- Data download over several weeks;
- Huge data storage requirement;
- Code: very high level of complexity;
- Evaluate cloud based solution – such as Google Earth Engine;
- Improve the non-agr classes



Allocated Ressources

Staff implicated in the Annual Crop Inventory – ACI (technical work, EXCLUDING field work):
- 4 permanent (75% of their time allocated to ACI)
- 2 terms (70% of their time allocated to ACI)

ACI field work:
- Budget: ~$45 000/year (Excluding salary)
- Provinces Sampled: BC, ON, NFLD, PEI, NB, NS
- Staff distribution by province:

STAFF / PROVINCE	NFLD	NB	PEI	NS	ON	BC	ALL
AAFC (Ottawa)		1(5)	1(5)	1(5)	5(37)	1(5)	6(57)
AAFC – Students (Ottawa)					3(15)		3(15)
AAFC Local	1(4)	1(5)	1(5)	1(5)	4(20)	1(5)	9(44)
Statistics Canada					4(20)		4(20)
OMAFRA					2(12)		2(12)
BC Government						2(20)*	2(20)
TOTAL	1(4)	2(10)	2(10)	2(10)	18(104)	4(30)	**26(168)**

* Crop identification combined with other field activities: Rough estimation.
First Number: Number of individuals
Second Number (in bracket): Summation of field work days for all individual
To collect ground data for the entire country: 26 people for a total of 168 days (or an average of 6.5 days per people)

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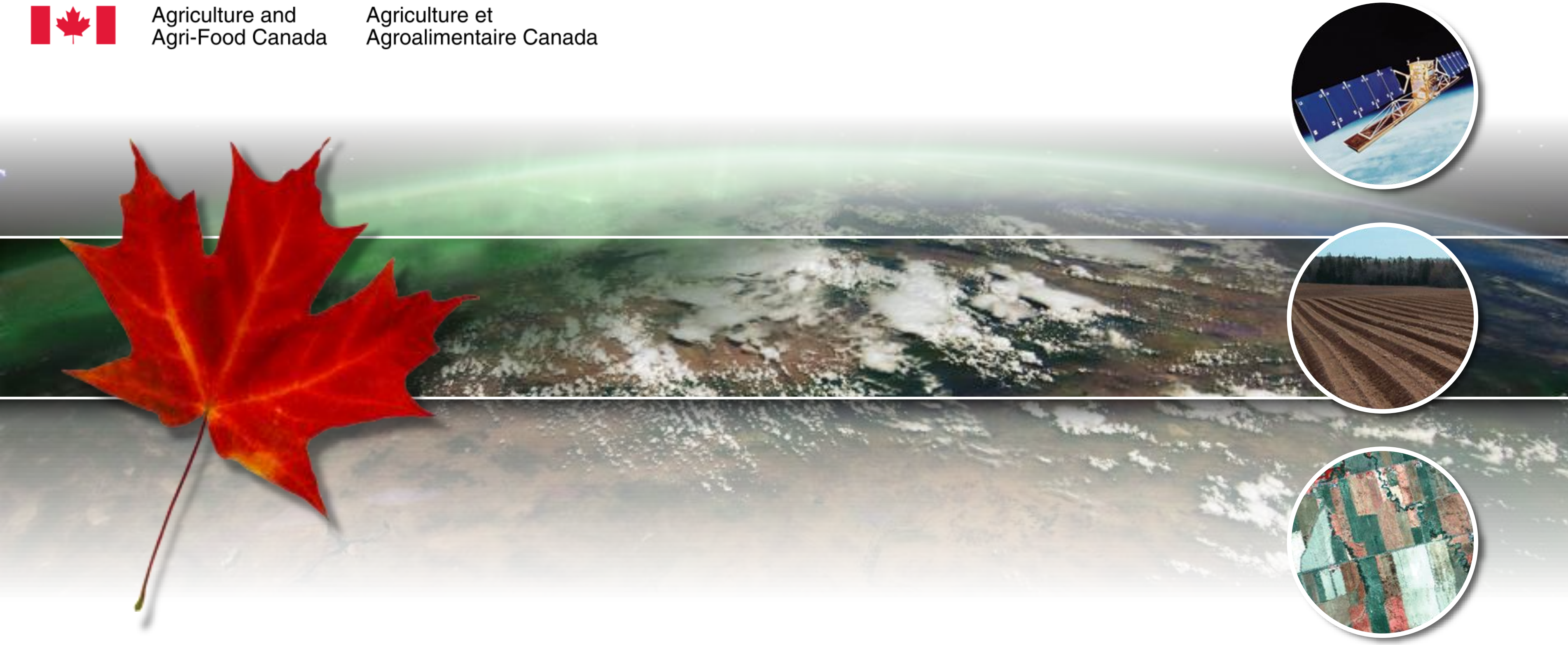

Thank You

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Canada