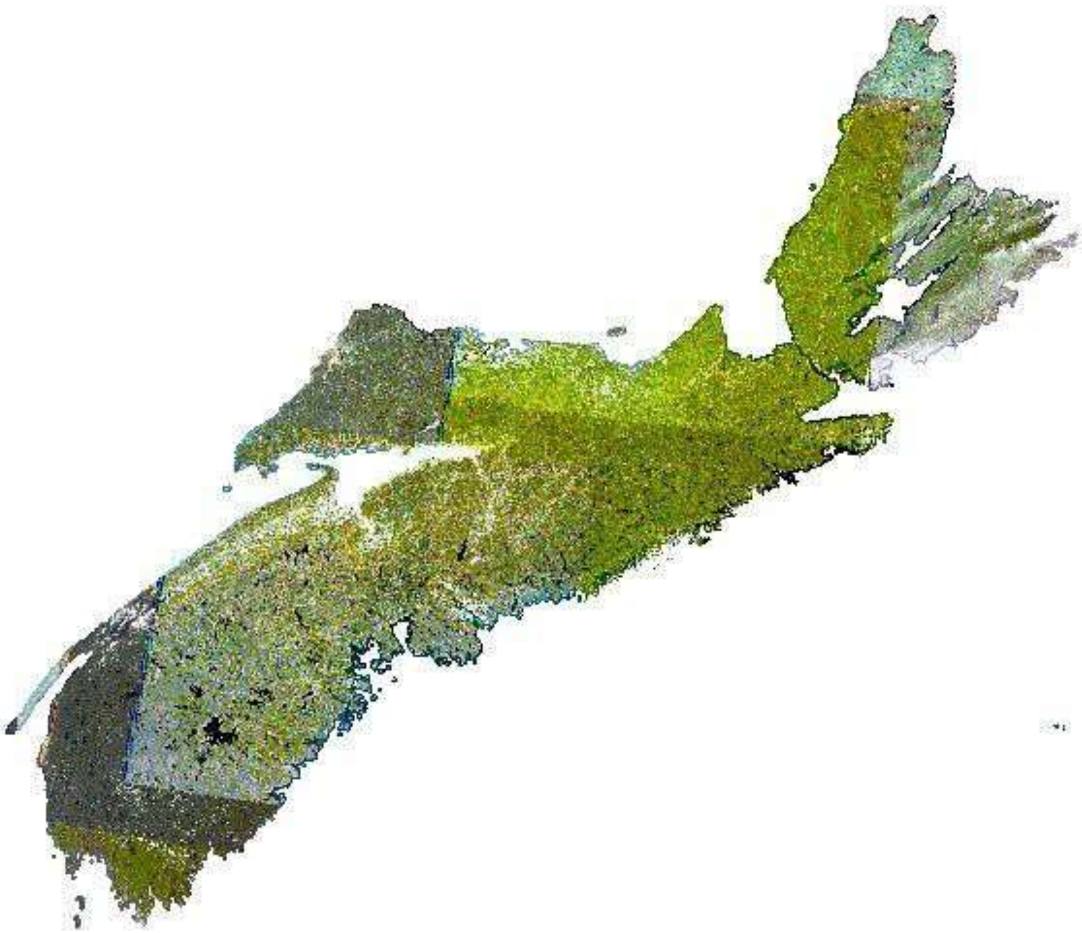
Temporal Change Detection

Identifying Forest Cover Change in Nova Scotia



Submitted to: **April 2013**
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Introduction

This work was undertaken as part of the species recovery program for the endangered mainland moose. Specifically, there is a need to understand the temporal and spatial use of the landscape by moose. Since moose observations are collected annually, it is important to have as accurate a landcover map as possible to examine how landscape conditions (including forest cover) may be influencing moose distribution.

This required the enhancement of the information content within the Department of Natural Resources (DNR) Forest Inventory between aerial photo collections dates with satellite imagery to annually delineate newly harvested stands. Optimally, this analysis was to be for the full province and to present day conditions, but could be a reduced area and/or date if suitable cloud-free satellite imagery was not available.

DNR has previously developed protocols for using Landsat imagery to conduct forest update mapping (Bruce, 2007). These protocols have been used to update the Forest Inventory up to 2005. The focus of this Forest Cover Mapping project was to implement these protocols (or protocols that produce equally suitable results) to complete the updates for 2005 forward to the present for Nova Scotia. The focus was to be on mapping the dominant change occurring on forested landscapes, which typically includes clearcuts and some other treatments that are large enough to be identified by Landsat imagery.

Objective

The purpose of this project was to identify areas of dominant change, focusing on clear cuts, in Nova Scotia. This information would then be available for use by the Department of Natural Resources when updating their Forest Inventory GIS layers. While identifying and classifying all change would have been ideal, the decision to focus on the dominant change was made due to the length of the project and the interest to provide the most useful information for the project needs. There were three main project objectives. The first objective involved image acquisition. Annual satellite imagery with minimal cloud cover needed to be obtained with coverage across Nova Scotia over the period of 2005-2012. Secondly, the imagery needed to be prepared for analysis. Imagery was selected and clipped so as to maximize cloud free landcover for each year. Imagery was then atmospherically corrected to remove anomalies resulting from atmospheric conditions. Considerations included in this process are sun angle, satellite azimuth, and visibility. The final objective was to perform a change detection through band 5 image subtraction and thresholding to define the dominant change. This change is then converted to shapefile for each image pair.

All image processing and analysis was completed in PCI Geomatica using manual techniques and EASI scripting, and shapefiles were created for the Esri ArcGIS environment.

Methods

Image Acquisition

Annual orthorectified Landsat 5 TM+ imagery (2005-2011) was obtained from USGS Global Visualization Viewer website (glovis.usgs.gov). All imagery is available free of charge to the public and at 30m resolution. Effort was made to obtain leaf-on (i.e., between the dates of June 15 – October 1) imagery with minimal cloud coverage for all of Nova Scotia. See Appendix A for an overview of imagery used as well as cloud coverage percentages and dates.

Image Preparation

Image bands were imported into PIX files using FIMPORT command while omitting band 6. Band 6, being a thermal band, was not necessary for this analysis and thus was left out of the combined PIX file. Each image was then clipped to a buffered 1km coastline to eliminate ocean data which was unnecessary for this analysis.

Imagery was atmospherically corrected using the ATCOR2 function in EASI. This function was chosen to correlate with previous analyses completed by DNR by not taking into account DEM elevation. ATCOR2 accounts for sun angle, satellite azimuth and visibility. The following is an example of the parameters used for atmospheric correction (exact values vary between imagery):

```
FILE = "D:\LandsatImagery\2011\Clipped\BLT50060292011283GNC.pix
FILO = "D:\LandsatImagery\2011\Clipped\BLT50060292011283GNC.pix
DBIC = 1,2,3,4,5,6
DBOC = 1,2,3,4,5,6
ASENSOR = "Landsat-4/5 TM'
ISBAND = 1,2,3,4,5,7
OSBAND = 1,2,3,4,5,7
ATYPE = "CONSTANT"
ATMDEF = "rura_ms"
CFILE = "C:\PCI Geomatics\Geomatica
2012\atcor\cal\landsat4_5\tm_standard_1999.cal
GELEV = 0.111
SAZANGL = 53.913, 157.00
VISIBIL = 16.1
DATE = 10,10,2011

r ATCOR 2
```

The values for SAZANGL can be found in the metadata file accompanying the imagery when downloaded. The first value is the solar zenith angle (90- solar elevation angle) and the second value, separated by a comma, is the solar azimuth angle. ATMDEF refers to a landcover description. These values are relatively subjective and the various options are listed in the ATCOR2 help section in PCI. CFILE is the calibration file for the sensor which accompanies the PCI Geomatica software. GELEV is the average ground elevation for the study area. VISIBIL refers to the visibility on that day. This value is obtained from historic weather data found at http://www.weatheroffice.ec.gc.ca/canada_e.html as specified in the ATCOR2 help section in PCI.

With imagery containing heavy cloud cover in a particular area, but not present throughout the image, a polygon was created in ArcGIS by digitizing the desired boundary (Figure 1). This polygon was then used to clip the imagery for analysis. This polygon was later merged into the resulting shapefile to define the extents.

Figure 1: The outline in orange represents the polygon digitized for clipping.

The change detection process compares spectral values from the same pixel locations in different years. For this reason, bands from corresponding imagery are incorporated into the same PIX file using the REGPRO function in EASI.

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
! REGPRO one file into another!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

FILI = "D:\LandsatImagery\Change\20102011\BLT50060292010248GNC.pix
FILO = "D:\LandsatImagery\Change\20102011\BLT50060292011283GNC.pix
DBIC = 1,2,3,4,5,6
DBOC = 7,8,9,10,11,12
RESAMPLE = "NEAR"
r REGPRO
```

Where possible, comparisons were made in one year intervals. Where cloud cover made this unsuitable, an interval of two years was analyzed. An interval of two years proved useful and significant change was accounted for. Two-year intervals provide a useful view of the landscape since vegetation rejuvenation is typically not significant in the first year. Also, a one-year interval analysis is limited to what is visible between the specific image dates which do not necessarily represent a full year of change. For example, if imagery from year one was collected in September and imagery from year two was collected in June, forest change after June of year two will not be accounted for in this interval.

Change Detection

After incorporating bands from two image dates into one PIX file, band 5 images were subtracted to determine the change (Figure 2). This subtraction was completed with EASI Modeling. The following is an example of the syntax used:

```
%14 = %5-%11
```

Where %14 is a 16bit signed band used to store the subtraction result.
%5 = Channel containing band 5 from date 1
%11= Channel containing band 5 from date 2

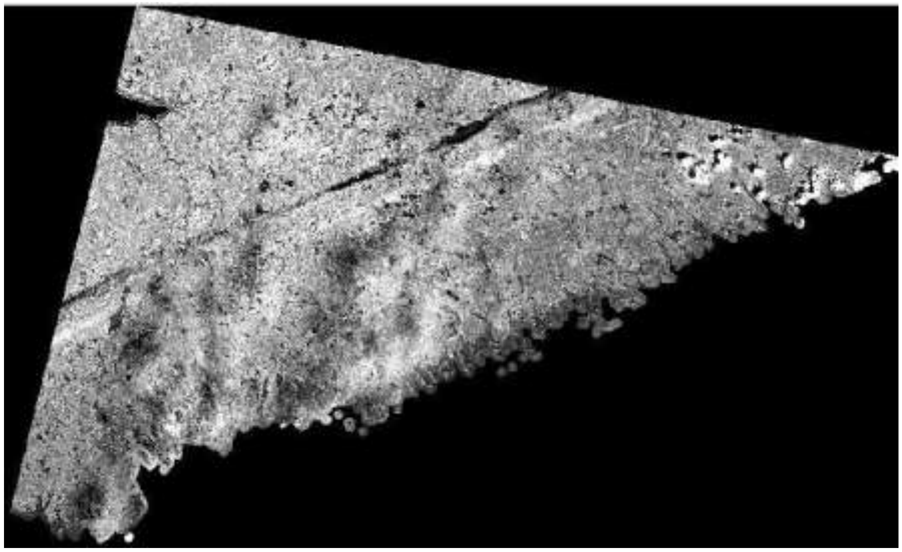


Figure 2: Image result from subtracting a 2008 image from a 2007 image.

The resulting image shows the magnitude of the change as well as whether it can be considered a loss or gain of DN values. These values can be both positive and negative so the result is written to a 16 bit signed channel. Because the focus was on dominant change, a threshold was applied to eliminate minor to mid-level change indicative of noise in data, and focus on those areas experiencing a more significant change such as changes to vegetation (Figure 3).

The threshold applied was greater or less than two standard deviations from the mean of the pixels. This resulted in the dominant positive and negative change to be written to a new image channel (Figure 4). The mean and standard deviation values were determined using the HISTOGRAM command in EASI. Those values were then put into the thresholding model:

```
if (%13 > 0.324+ (2 * 3.091) ) then;
   %14 = 10;
else;
  if (%13 < 0.324- (2 * 3.091)) then;
     %14 = 5;
  else;
     %14 = 0;
  endif;
endif;

ENDMODEL

!%13 = channel representing change between 2007 and 2008
!0.324 = mean difference between 2007 and 2008 determined from histogram
!3.091 = standard deviation of change values between 2007 and 2008 determined
!                from histogram
!%14 = empty 8-bit channel, 10 = increase in brightness (forest gain)
!                            5 = decrease in brightness (forest loss)
```

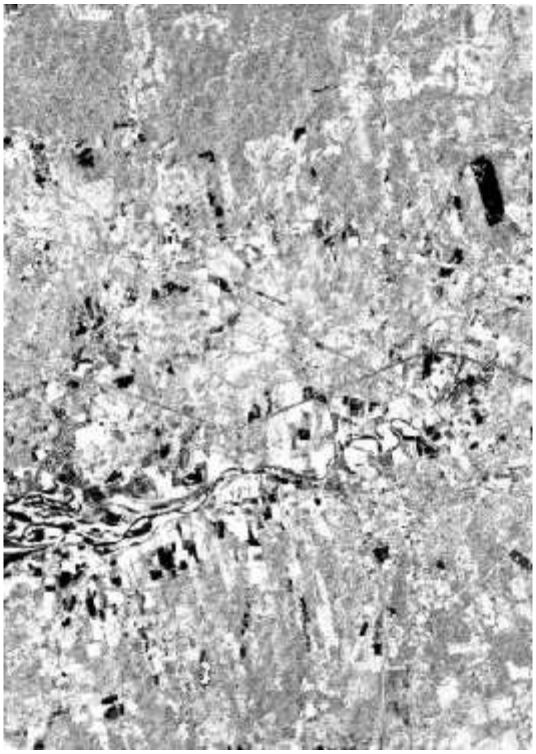


Figure 3: Result of 2007/2008 image subtraction.

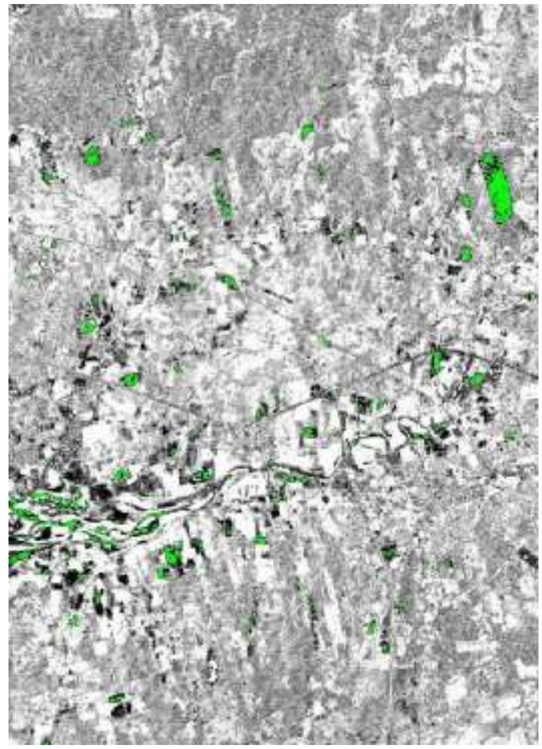


Figure 4: Subtraction with bitmap overlay representing negative change.

Those results relating to a negative change were selected out and saved as a bitmap layer with the following statement:

```
IF %14 = 5 THEN
%%2 = 1
ELSE
%%2 = 0
ENDIF
```

Where %14 was the 8bit channel containing the change standard deviation result and %%2 was the bitmap channel to which the negative change was written.
In some instances further thresholding was used to segregate the desired change. In most cases this was not necessary. This was determined on an image by image basis by observing the change values delineated by the bitmap. The following is an example of the syntax used in EASI Modeling to the new bitmap channel:

```
IF (%14 <-20) THEN
%%3 = 1
ELSE %%3 =0
ENDIF
```

Forest Mask

Change detection results were limited to only those areas occurring in forested conditions in order to exclude change due to difference in water level, urban development, wetland, etc. To accomplish this, a forest mask is created based on the FOR_NON attribute field of Forest Inventory GIS layers. ArcGIS was used to select polygons where the FOR_NON attribute represents forested areas (<=60). These polygons were then exported to create the forest mask. This mask was used to clip the PIX file bitmap with the results saved into a TIFF file.

Shapefile Creation

The TIFF files were converted to polygons using the 'Raster to Polygon' tool in ArcGIS. The area of each polygon was calculated in hectares and saved as a new attribute field using 'Calculate Geometry' tool. Polygons less than 0.25 hectares were then selected and removed from the file. Polygons less than 1 hectare have been typically excluded by DNR, however the decision was made to keep those 0.25 hectares and greater for this analysis to maintain the areas that most likely represent real change. The remaining polygons were then reviewed manually along with the satellite imagery to verify that they were representative of forest change. Those polygons resulting from cloud cover, changes in water level not accounted for with the forest mask, or resulting from image noise and seasonal differences were eliminated from the shapefile. These decisions were made based on visual assessment of imagery for DN values, spectral curves, feature geometry and various band combinations. The accuracy of detecting anomalies improved as additional imagery was processed and therefore the initial shapefiles were reassessed at the end of the project. Familiarity with the dataset and landcover conditions therefore affects the accuracy of the change detection, and this should be taken into consideration when validating the dataset. Finally, an attribute field 'DateRange' was added to the shapefile and populated with the date range used for that analysis. A polygon outlining the extents of the analysis was also incorporated into each shapefile using the 'Merge' tool.

Results and Discussion

Image Selection

The analysis focused on 'leaf-on' conditions, which for this study area translates to June 15-October 15. See Figure 5 for an example for image coverage. In a few cases imagery outside of these parameters is used due to cloud free availability, however, image dates did not exceed October 31st. Maintaining similar dates between image pairs is ideal to most accurately gauge and limit seasonal factors as much as possible (Figure 6). This was not possible in all pairs due to image availability. Available and useful imagery is sparse for 2011 so minimal analysis is complete for the 2010-2011 interval. No imagery is currently available for 2012 due to an inoperable satellite.

Figure 5: Example of satellite imagery coverage for 2005. See Appendix A for annual coverage.

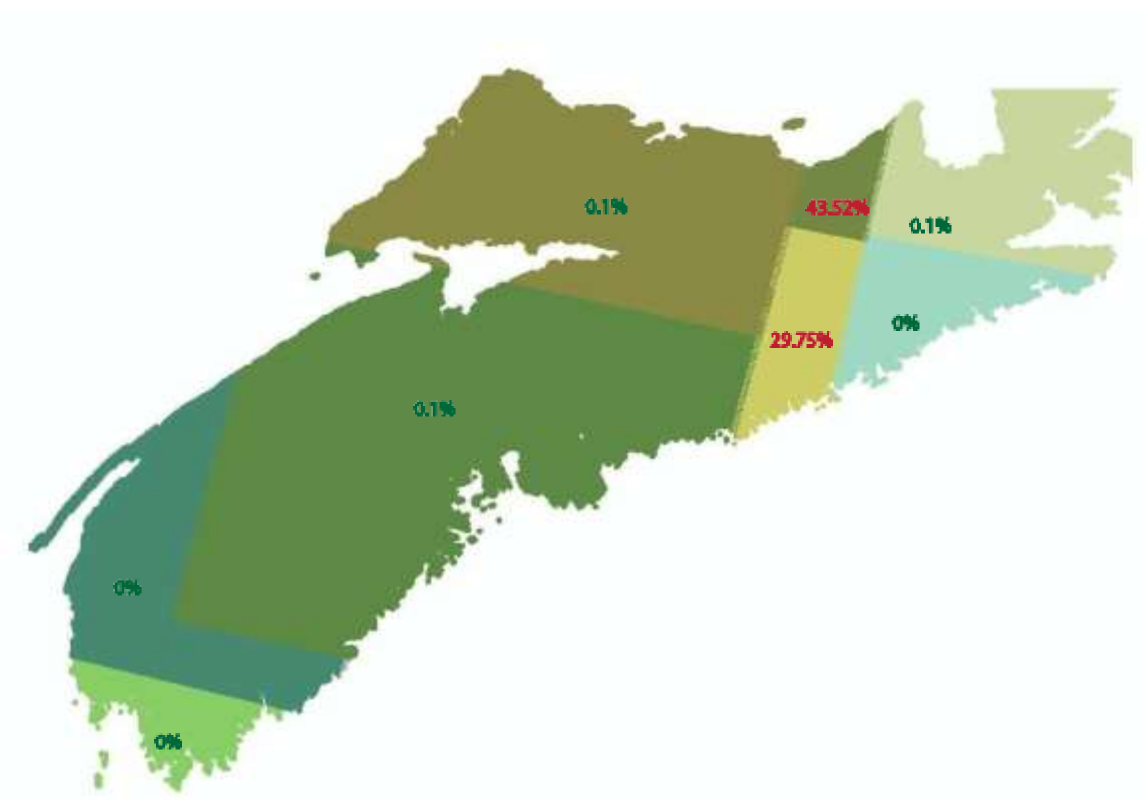


Figure 6: 2005 satellite imagery coverage with cloud cover percentages. See Appendix A for annual data.

Image Preparation

ATCOR2 produced a positive result for atmospheric correction. Although elevation is not accounted for, given a relatively uniform study area with only minor topographic fluxes, this does not appear to have been a hindrance in the analysis. All bands were corrected even though only band 5 was used for subtraction. The result was an adjustment in brightness values that better represented reflectance values without atmospheric influences.

Imagery for this analysis has not been radiometrically corrected, however, a test was completed to gauge whether the results of this correction would be more effective. Radiometric correction will account for sensor calibration from one year to the next and limit change attributed to those differences. With the radiometric correction followed by subtraction, there was a wider variety of grey values relating to mid-range change. However, dominant change proved most distinguishable without radiometric correction. See Figure 7 and Figure 8 for a comparison.

Figure 7: Result of image subtraction of non-radiometrically corrected imagery. Very dark and very light pixels represent drastic change. This dominant change is more distinguishable from moderate change.

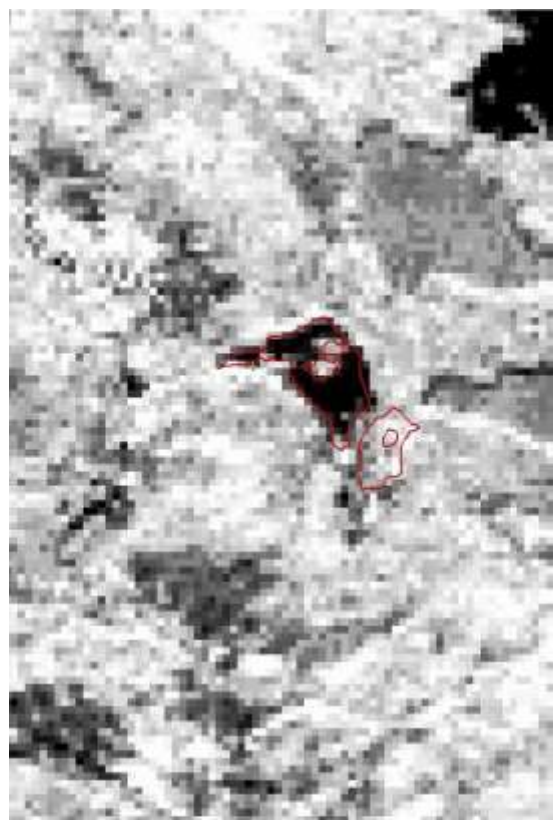


Figure 8: Result of image subtraction of radiometrically corrected imagery. More mid-range grey values represented making dominant change distinction more difficult.

As stated previously, where cloud cover and image availability proved to be a hindrance for analysis a two-year interval was used. Table 2 outlines the date ranges for various image tiles that were processed. Note that this only illustrates the variety of dates used and does not indicate that a full analysis of each range was completed for the entire study area. The two year range was only used for those tiles where annual image coverage for a given location was not available.

Table 1: Number of image tiles acquired for temporal analysis.

Year	# Image Tiles
2005	10
2006	11
2007	11
2008	11
2009	12
2010	8
2011	5
2012	N/A
Total	68

Table 2: List of Image Pairs Comparisons

Consecutive Image Pairs
2005-2006
2005-2007
2006-2007
2006-2008
2007-2008
2008-2009
2008-2010
2009-2010
2009-2011
2010-2011

Change Detection

The process of image subtraction along with subsequent thresholding was successful in identifying the dominant change, which most often was the result of forest clear cutting. By subtracting the recent date from the oldest date, the dominant change relating to clear cutting appears as very dark in the result. In some cases the change detection and thresholding was able to pick up on new roads; however, several were eliminated or fragmented if pixel groups were less than 0.25ha. Shapefiles supplied by DNR were used for validation purposes when verifying that the process was successful in delineating identified clearcuts. These polygons included Bowater reported clearcuts as well as the results of previous DNR change analysis (Figure 9)

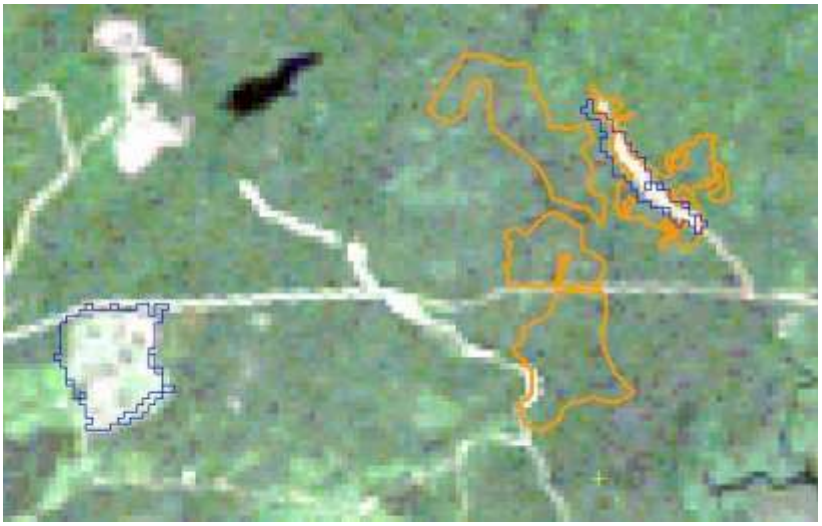


Figure 9: 2005 Landsat imagery. Bowater cut polygons in orange. DNR 1997-2005 polygons in blue.

Figure 9 Shows a true colour (3,2,1) composite of 2005 imagery. The orange polygons were provided by Bowater and outline areas of reported clear cutting. Blue polygons were provided by DNR and represent previous change detection analysis. In this image the DNR polygon delineates change between 1997 and 2005. The DNR polygon outlines an area of previous clear cutting. Because this area is showing brightly in the imagery it has likely been cleared relatively recent to the date of the image. The Bowater polygon outlines an area that has yet to be cleared, however, in the 2007 image, that same area has been affected (Figure 10)

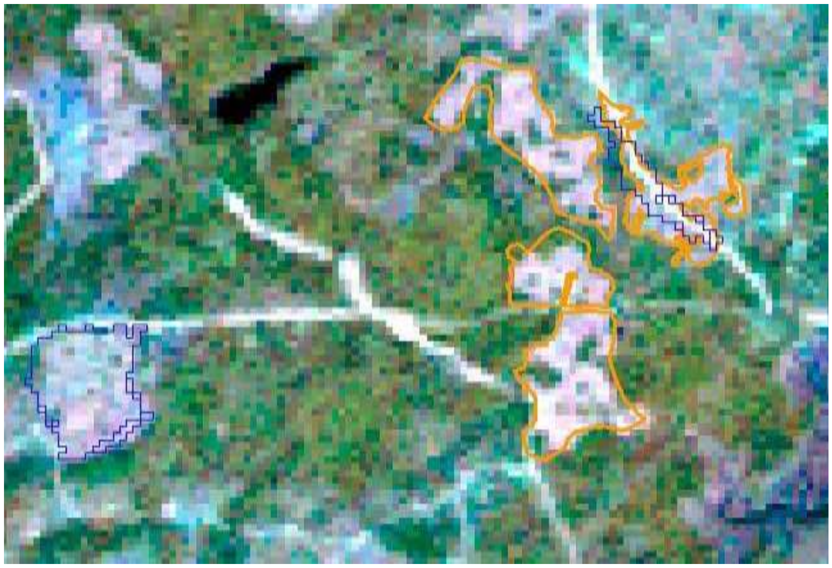


Figure 10: 2006 Landsat imagery. Bowater cut polygons in orange. DNR 1997-2005 polygon in blue.

Figure 11 is the result of image subtraction of 2005 and 2006 imagery above. Using the Bowater polygons as validation, it is clear that the process was able to capture the clear cuts while omitting other more moderate change. The blue DNR polygon delineates an area without dominant change, and that is likely due to the fact that the clear cutting occurred at an earlier date. Figure 12 highlights the result of standard deviation thresholding in red. These results are then clipped with the forest mask and ultimately converted to a shapefile. The standard deviation method of defining clear cuts and similar change proved to be successful in capturing those areas identified by Bowater and DNR.

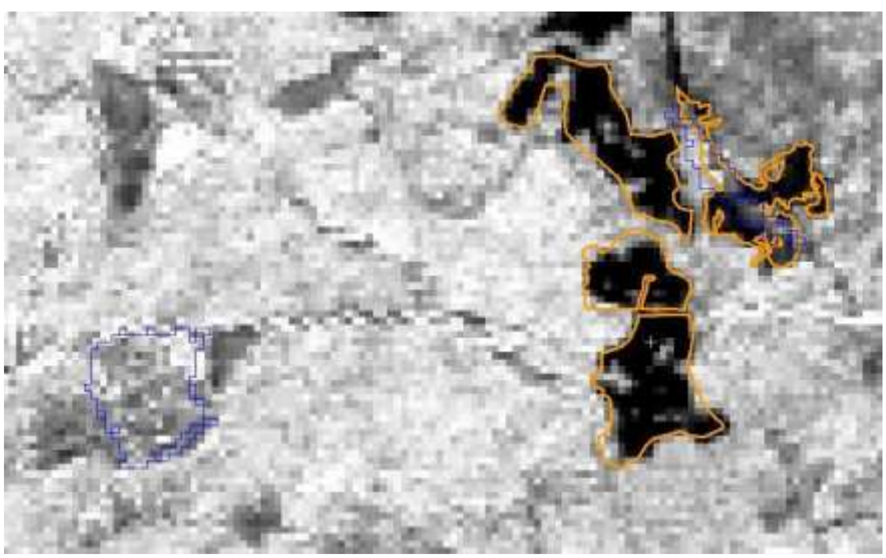


Figure 11: Result of image subtraction (change). Clear cuts showing dominant loss appear dark. Bowater cut polygons in orange. DNR 1997-2005 polygon in blue.

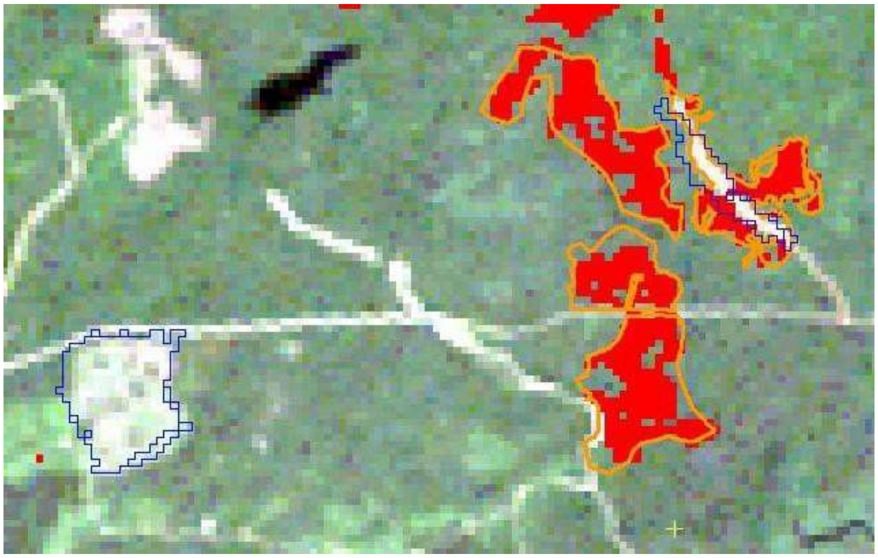


Figure 12: Result of standard deviation thresholding in red. Bowater cut polygons in orange. DNR 1997-2005 polygon in blue.

Forest Mask

The purpose of the forest mask was to eliminate those areas of change unrelated to forested locations (i.e., urban, water bodies, wetland, etc.) see Figure 13. The method of creating this mask using forest inventory polygons was successful in eliminating most extraneous change (Figure 14).

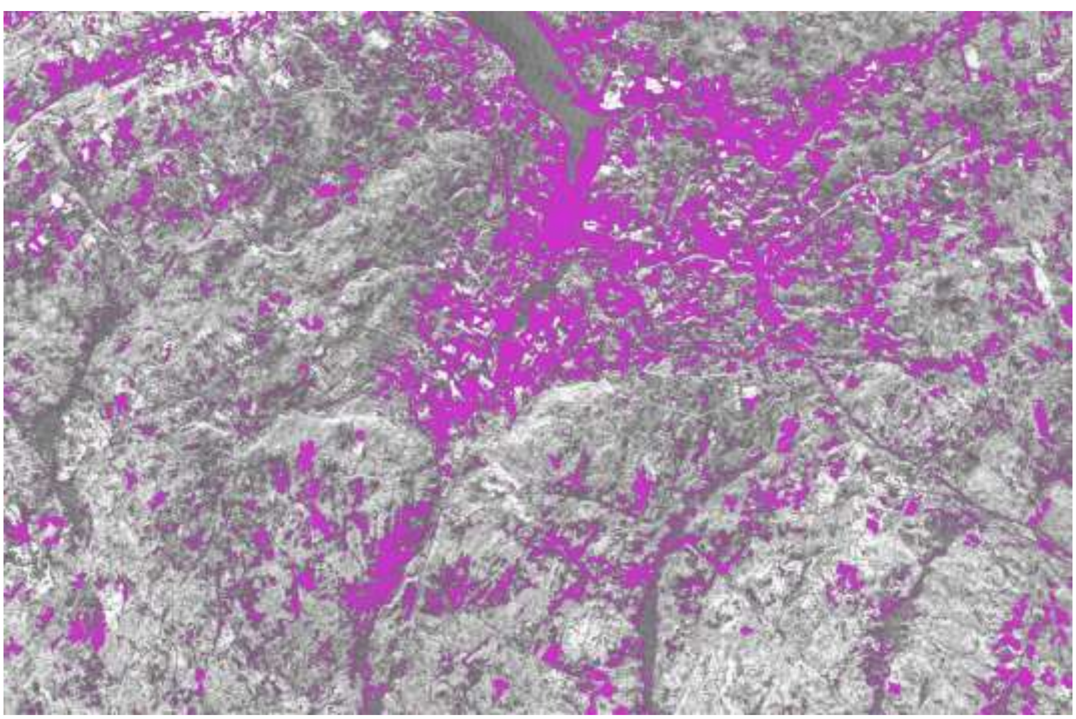


Figure 13: Result of standard deviation method before clipping to forest mask.

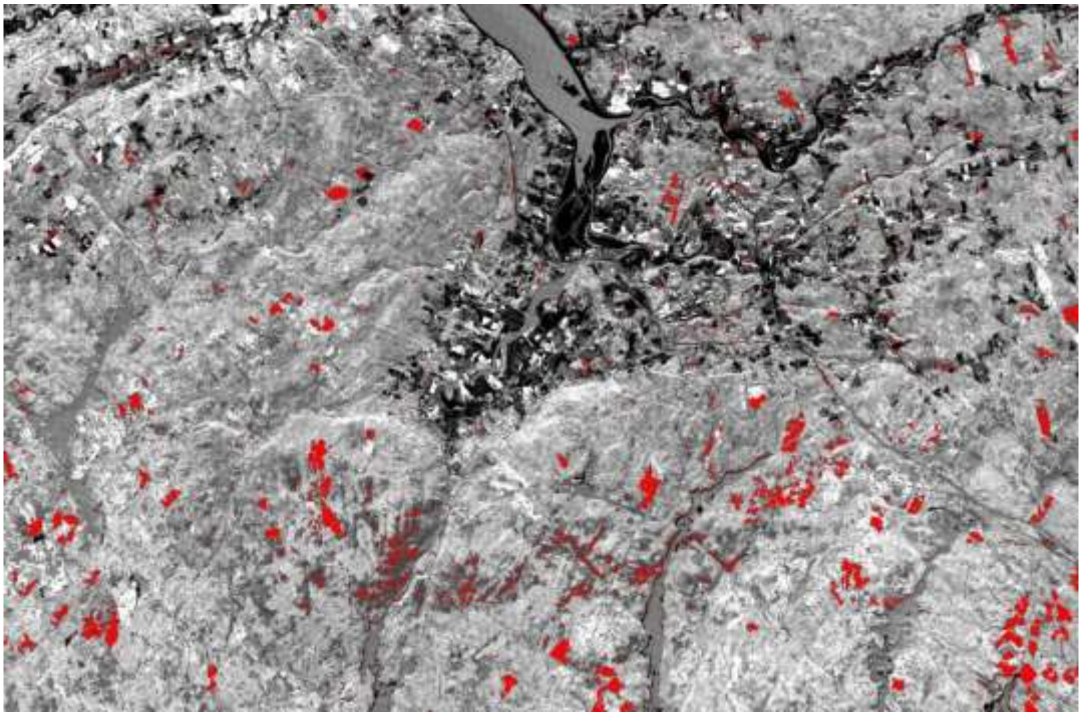


Figure 14: Red polygons clipped to the forest mask. Urban areas and water body shoreline have been eliminated from results.

Shapefiles

TIFF files were converted to shapefiles using the Raster to Polygon tool in ArcGIS. Polygons were simplified to avoid the staircase effect, however they were not smoothed. The result of this was a more jagged and angular shapefile (Figure 15). Although smoothing polygons would create a more aesthetically pleasing look, the integrity of the data would have been compromised.

Figure 15: Forest change shapefiles

Shapefiles with an area less than 0.25ha were eliminated as they did not indicate areas of significant change and were likely the result of an anomaly in the data such as satellite noise or a mixed pixel.

Polygons indicative of cloud cover and shadow change that had not been eliminated from clipping were manually selected and removed. This process was made more efficient by toggling various band combinations to verify the change was not representative of clear cutting. See Figure 16 and Figure 17.

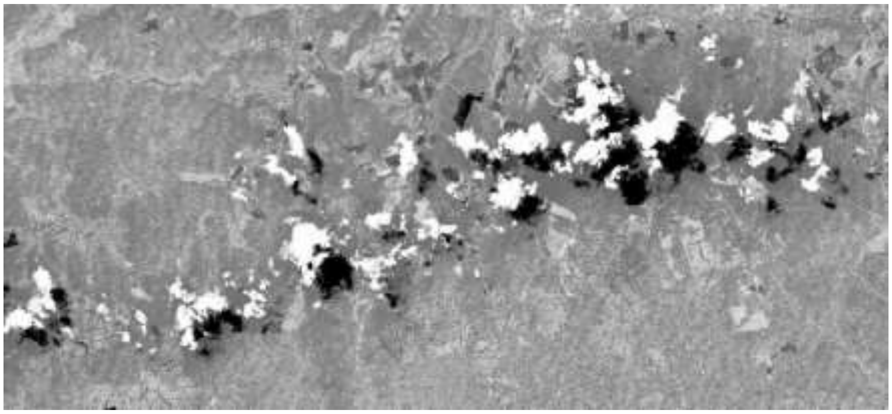


Figure 16: Image subtraction showing cloud and shadow.

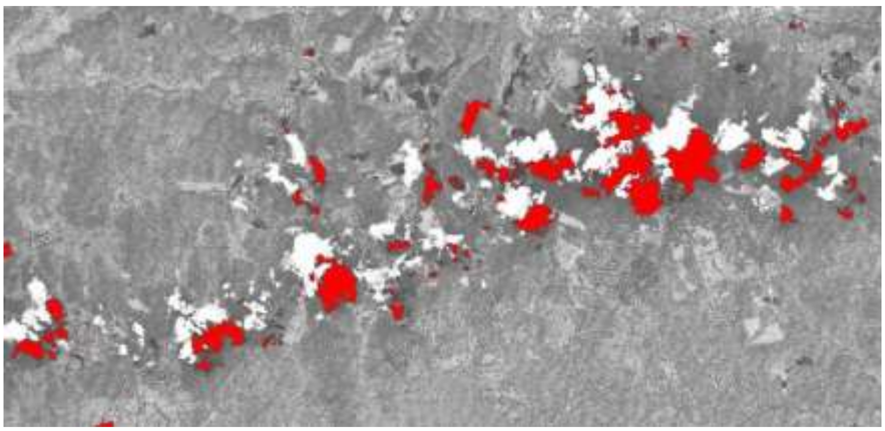


Figure 17: Standard deviation thresholding defining shadow as change.

Submission

Included in the submission for this project are all shapefiles containing change polygons as generated by the aforementioned process. Shapefiles are labeled according to years analyzed. All imagery used for processing is included in TIFF format. Scripts used for processing as well as this report are also included on DVDs.

Summary

The completed project result illustrates the extents of negative change throughout Nova Scotia, much of which can be attributed to clear cutting (**Error! Reference source not found.**). The majority of the province is affected by this change with few exceptions such as the vicinity of Kejimkujik National Park and National Historic Site. It cannot be concluded that all change during this time frame has been captured because of the limitations of image availability, cloud cover and date ranges. This process is however easily reproduced and updated as new imagery becomes available.

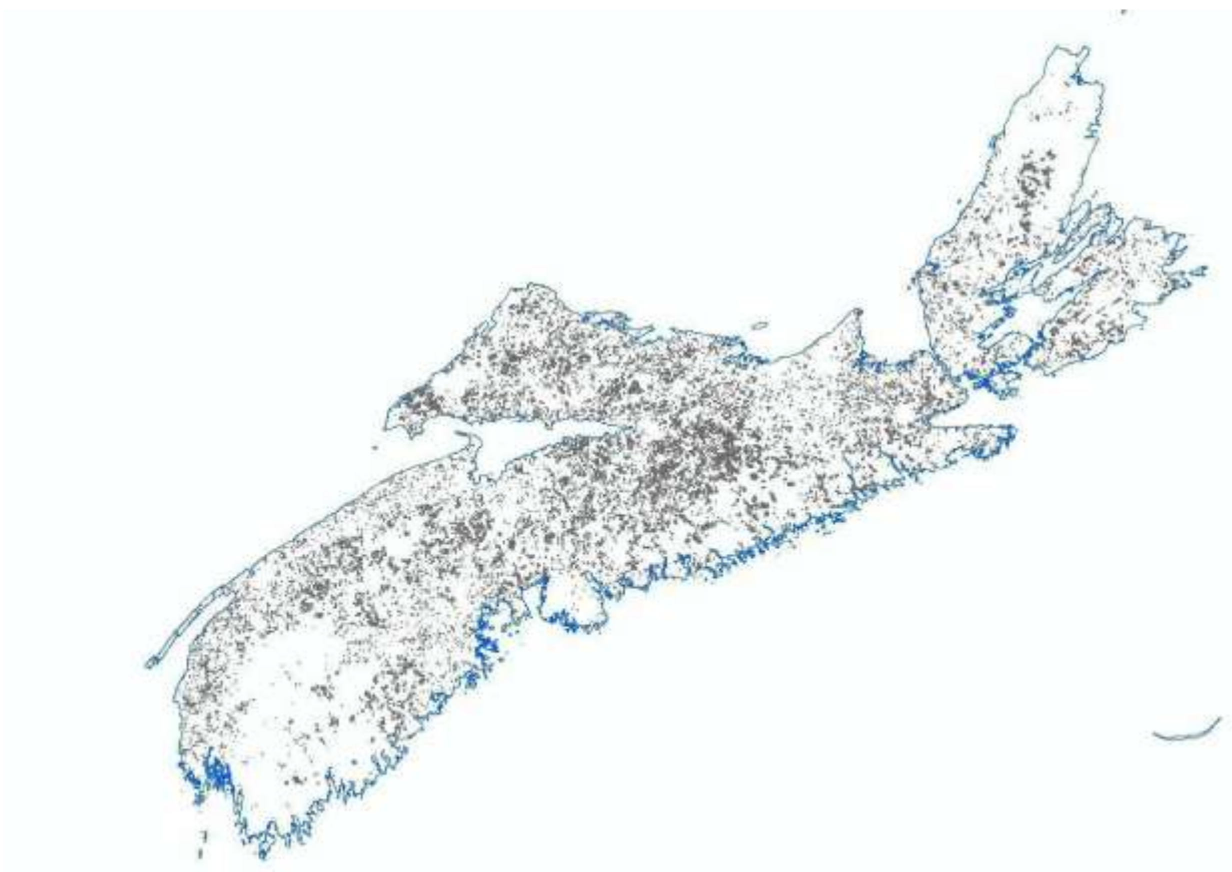


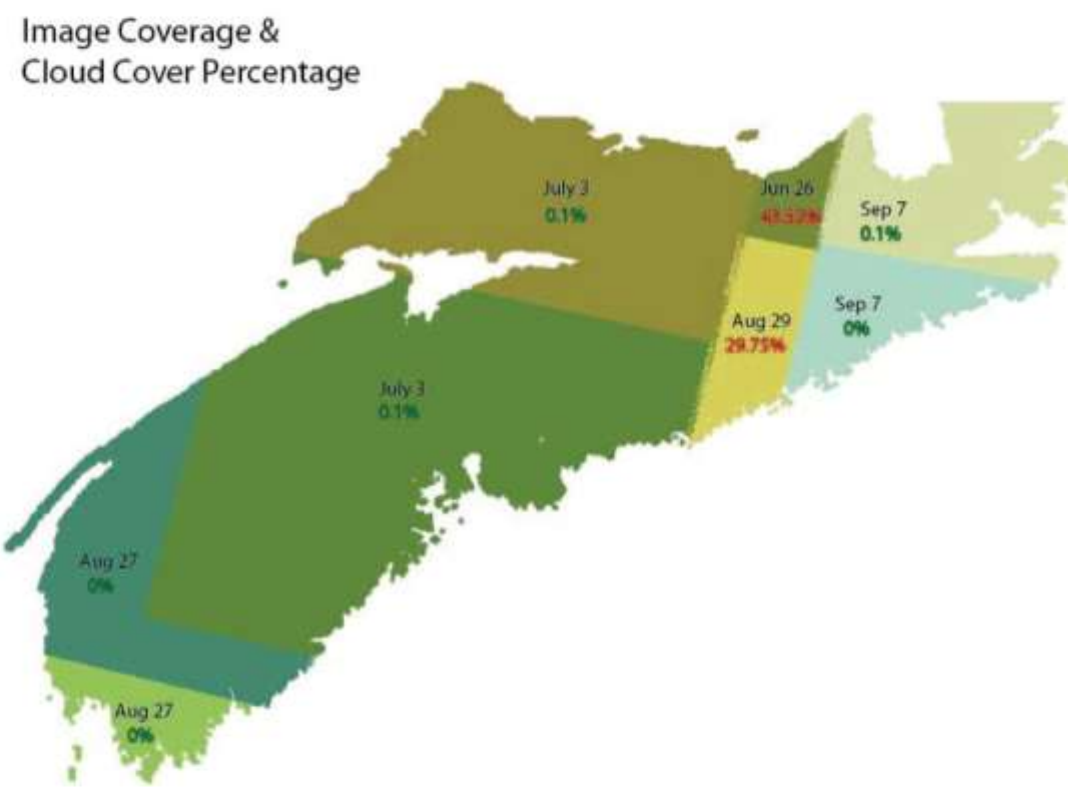
Figure 18: Distribution of all change polygons from 2005-2011

Bibliography

Bruce, J. (2007, April 15). Identifying Forest Wind Throw in Nova Scotia due to Hurricane Juan using Landsat Satellite Imagery.

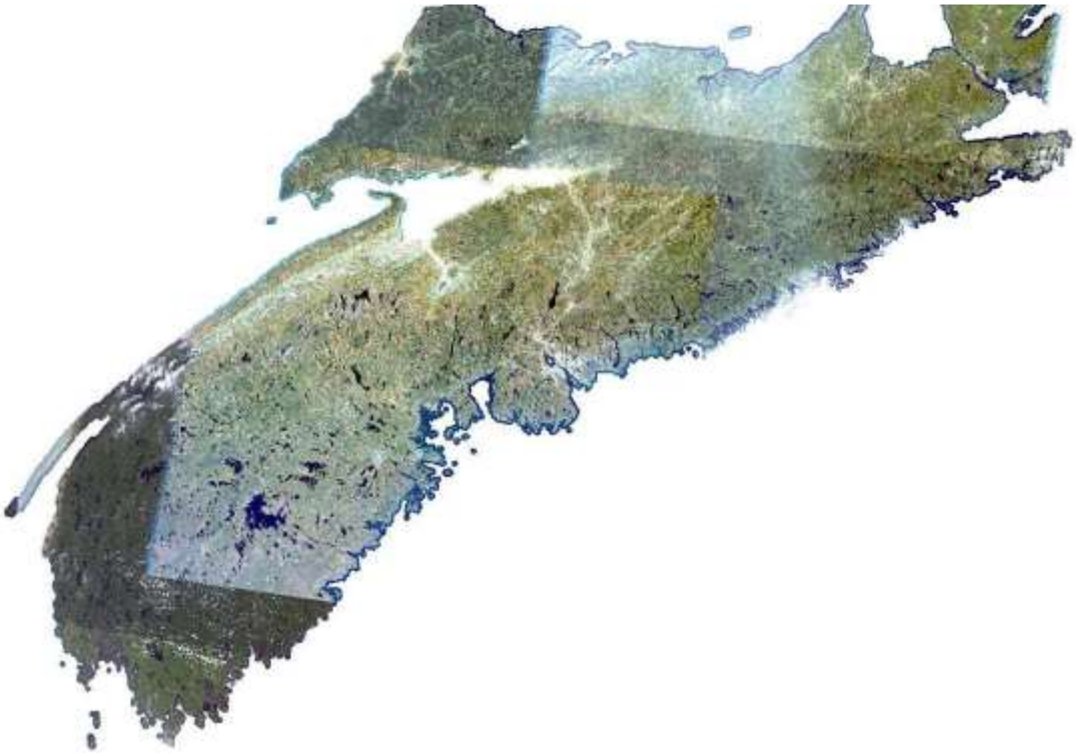
Appendix A – Imagery

2005




0.07%
0.2%

2006



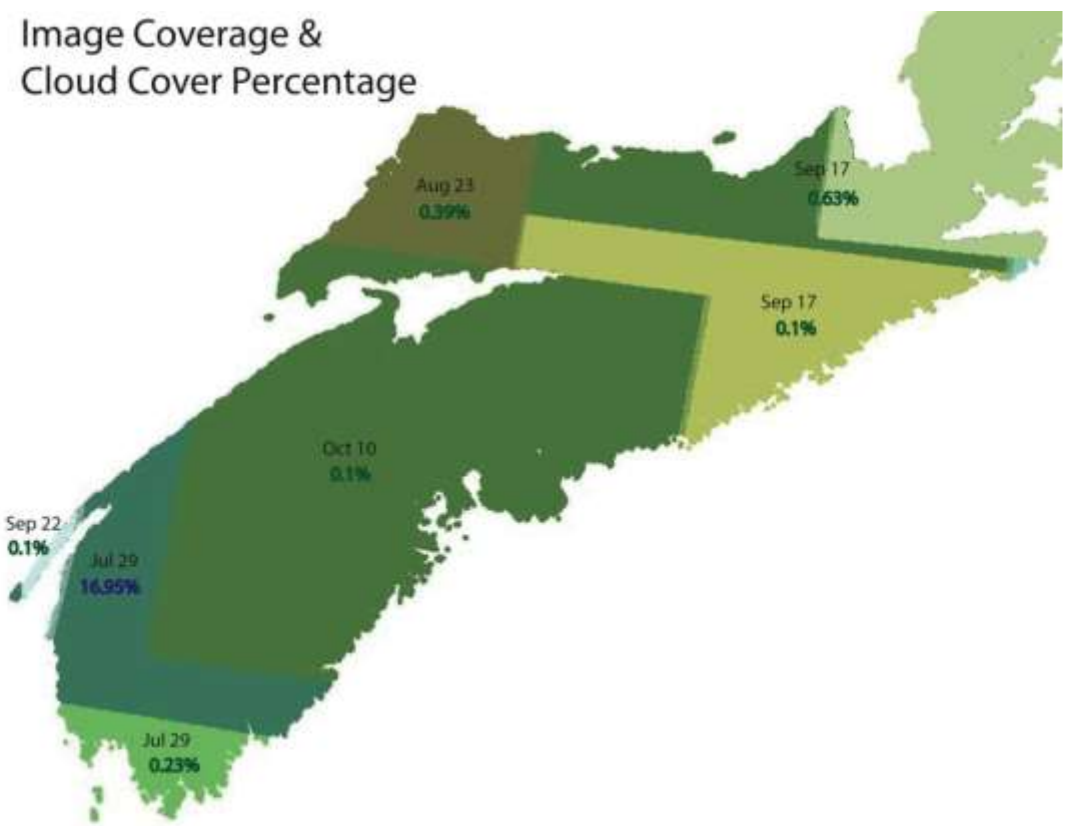
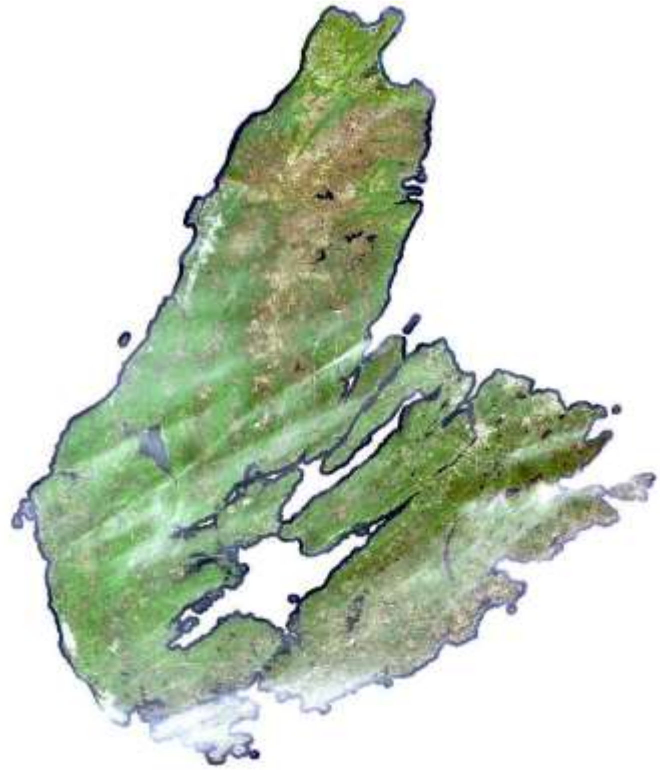


Image Coverage &
Cloud Cover Percentage
Aug 23
0.39%
Sep 17
0.63%
Sep 17
0.1%
Oct 10
0.1%
Sep 22
0.1%
Jul 29
16.95%
Jul 29
0.23%



0.05%
4.6%

2007

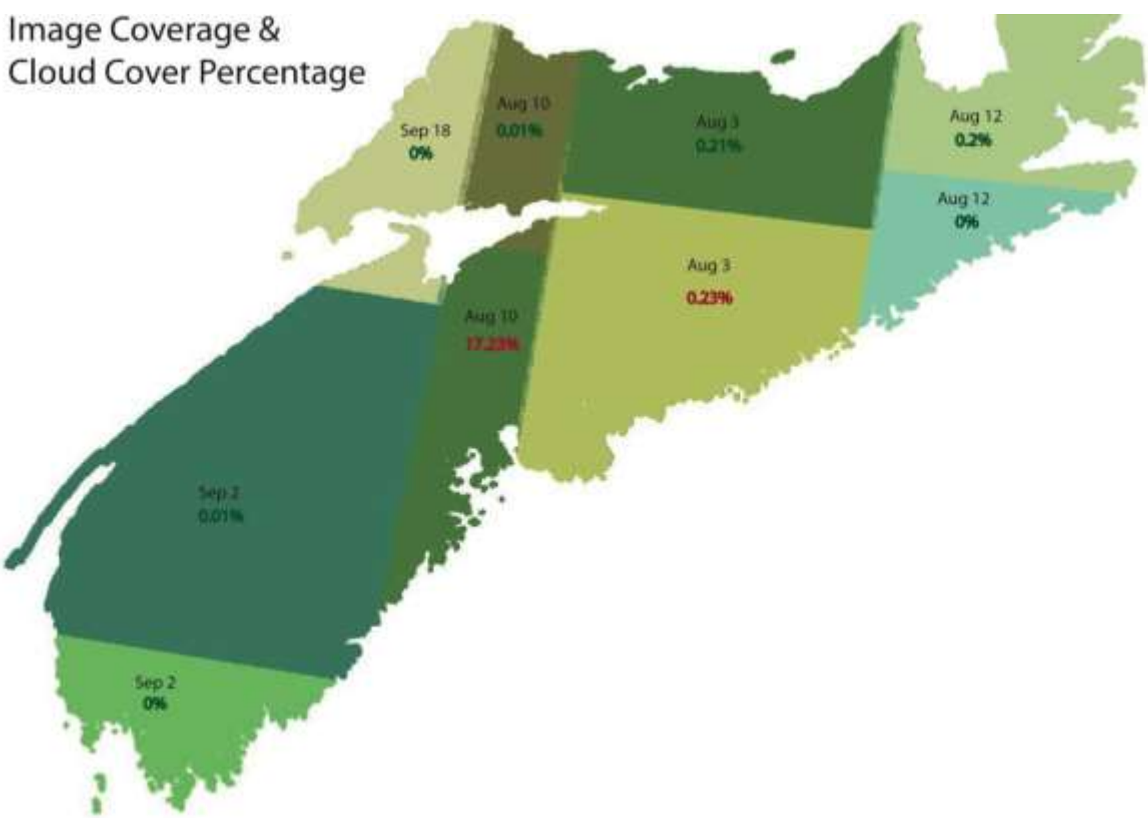


Image Coverage &
Cloud Cover Percentage
Sep 18
0%
Aug 10
0.01%
Aug 3
0.21%
Aug 12
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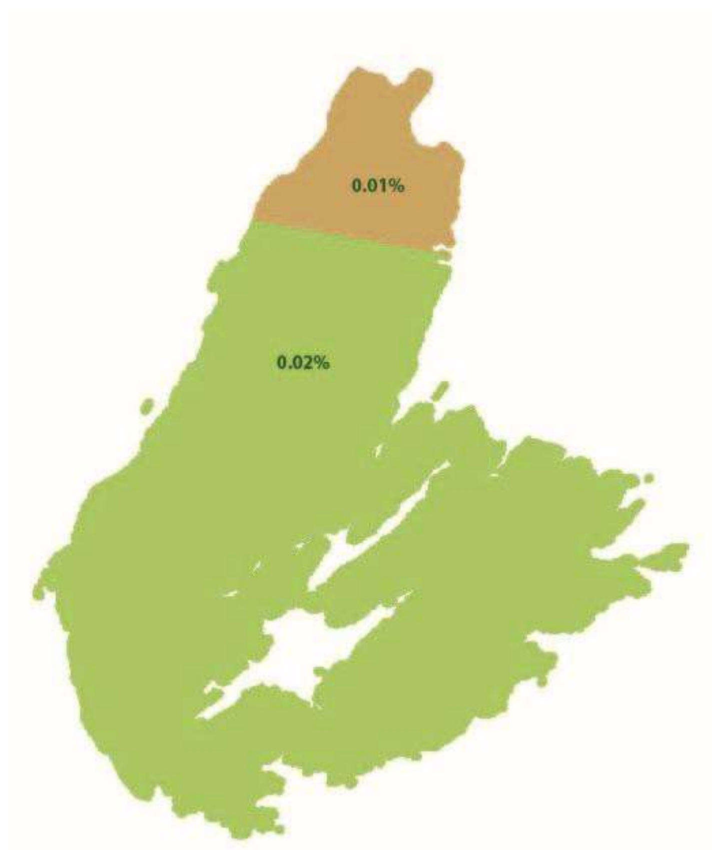
Aug 12
0%
Aug 3
0.23%
Aug 10
17.23%
Sep 2
0.01%
Sep 2
0%


0.01%
0.02%

2008

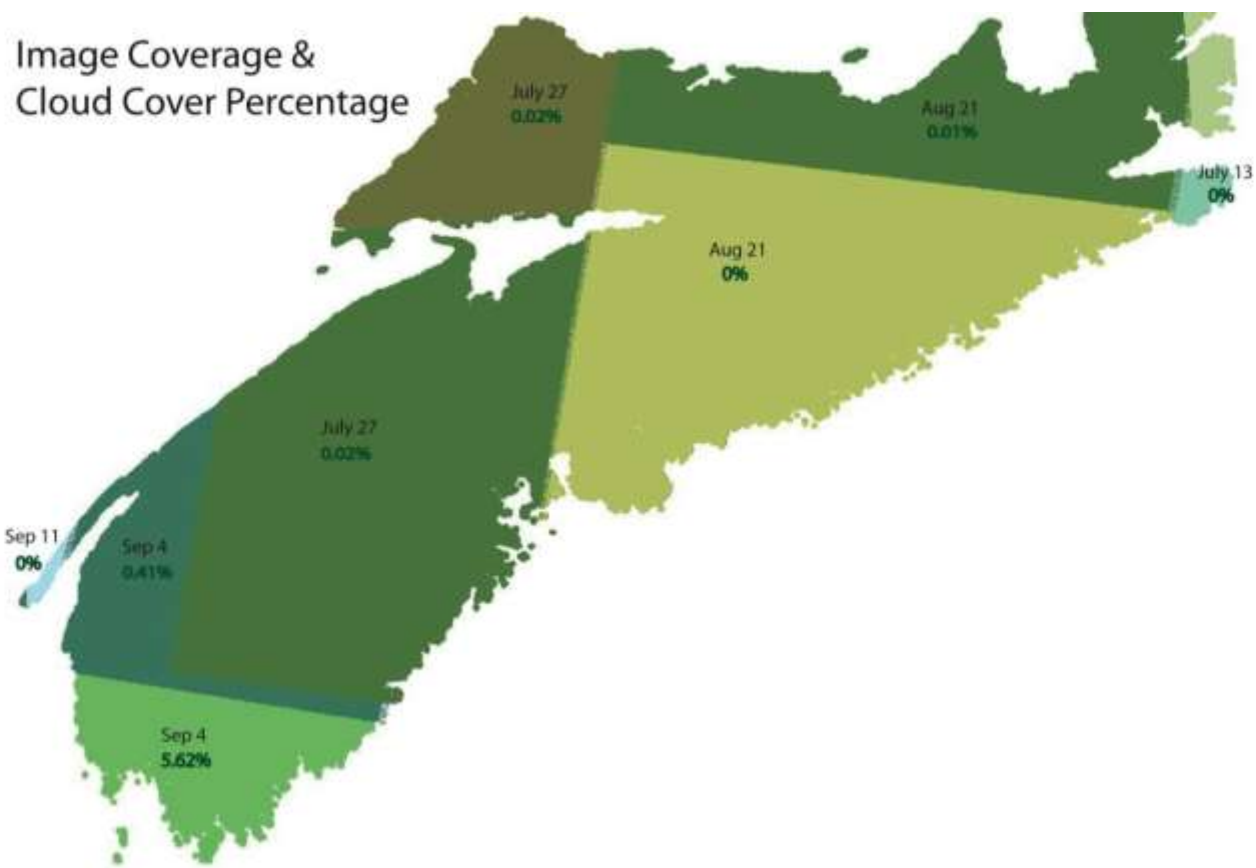


Image Coverage &
Cloud Cover Percentage
July 27
0.02%
Aug 21
0.01%
July 13
0%
Aug 21
0%
July 27
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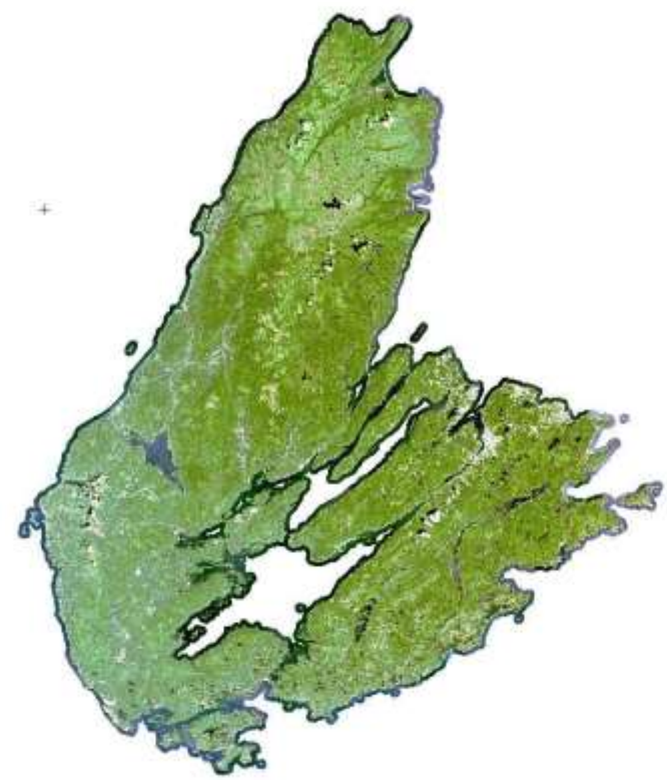
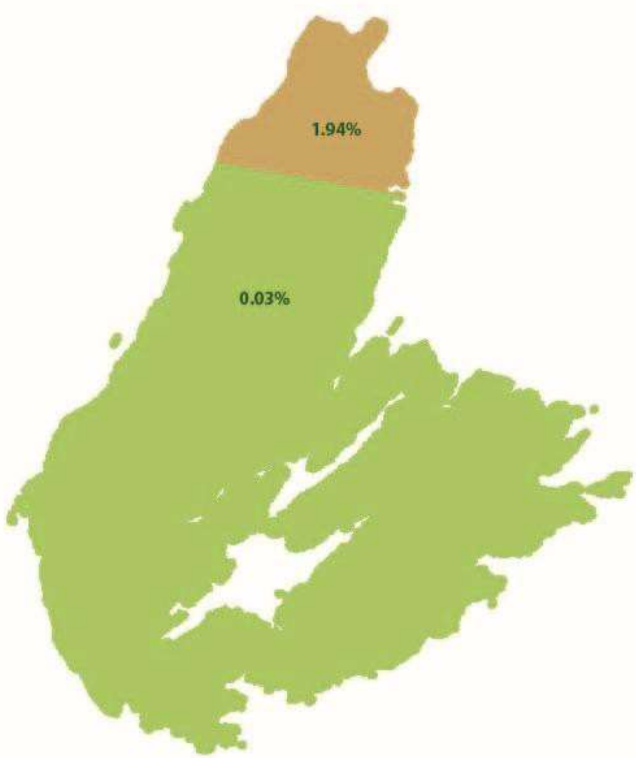
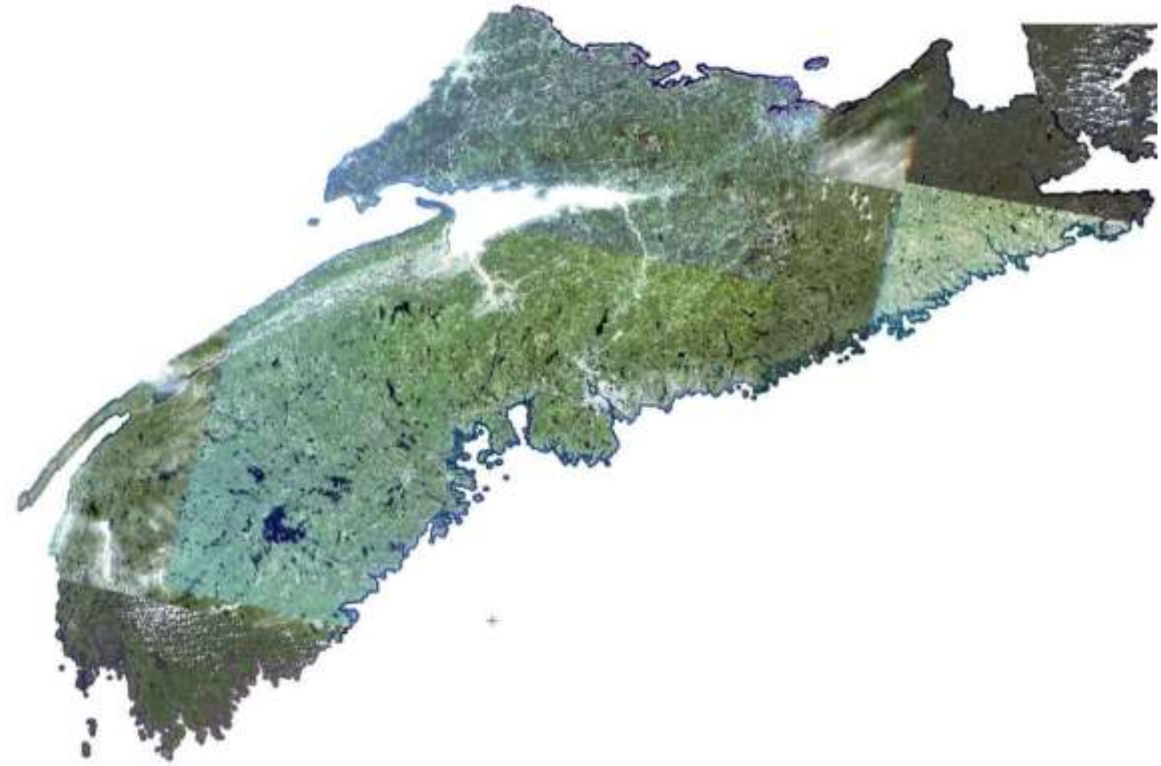
Sep 11
0%
Sep 4
0.41%
Sep 4
5.62%




1.94%
0.03%

2009



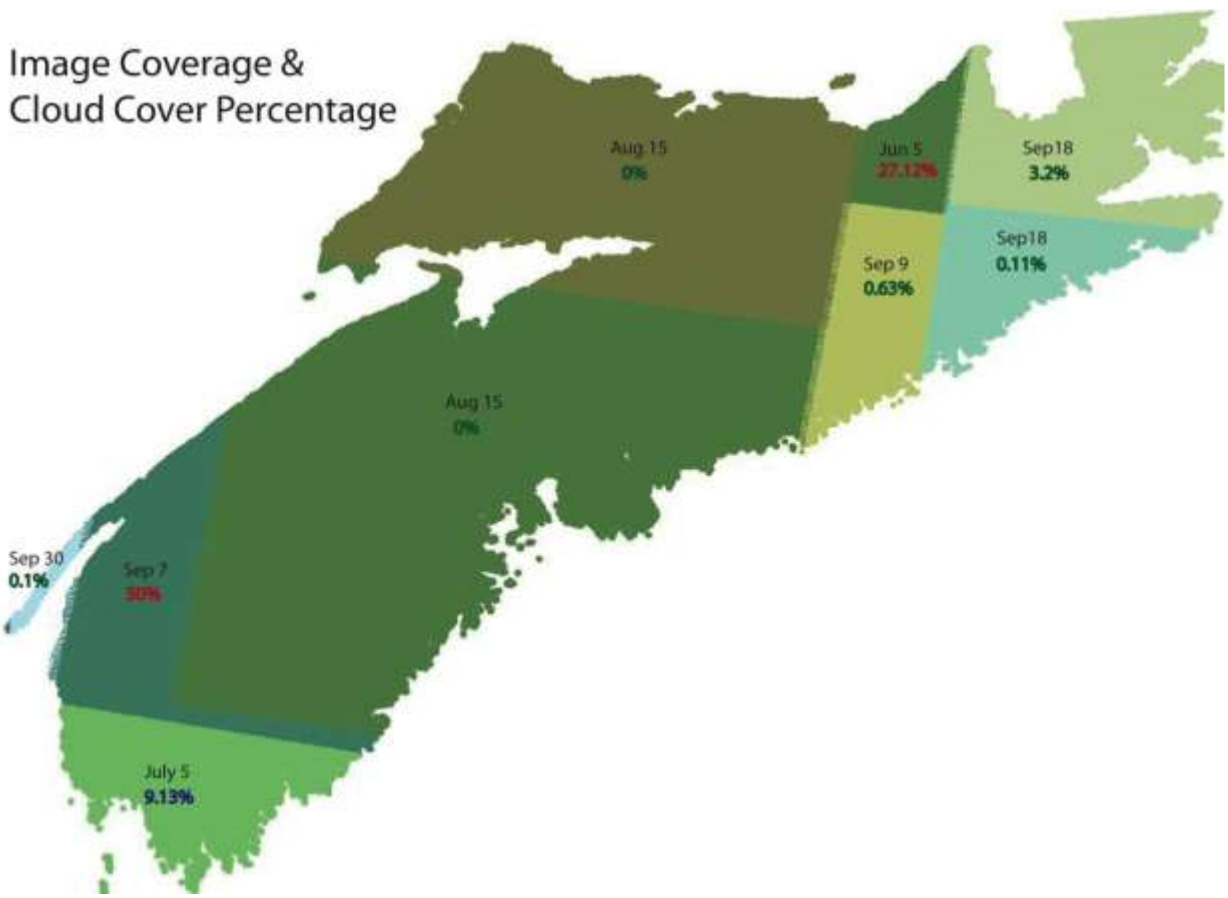
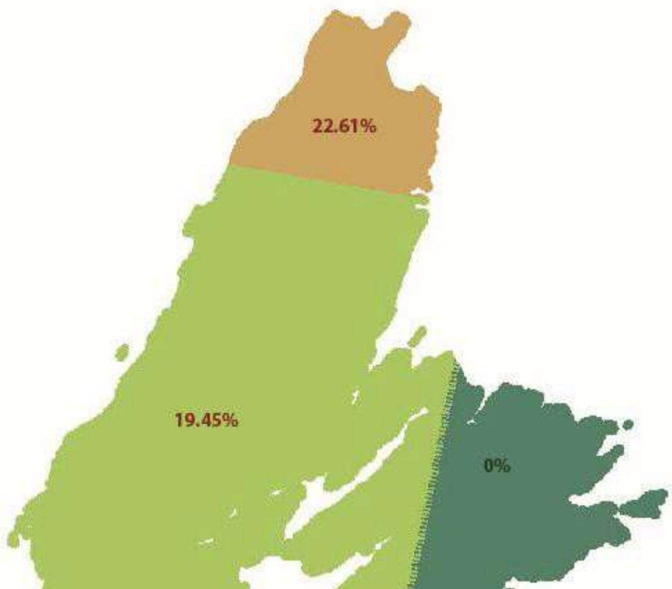


Image Coverage &
Cloud Cover Percentage
Aug 15
0%
Jun 5
27.12%
Sep18
3.2%
Sep 9
0.63%
Sep18
0.11%
Aug 15
0%
Sep 30
0.1%
Sep 7
30%
July 5
9.13%


22.61%
19.45%
0%

2010

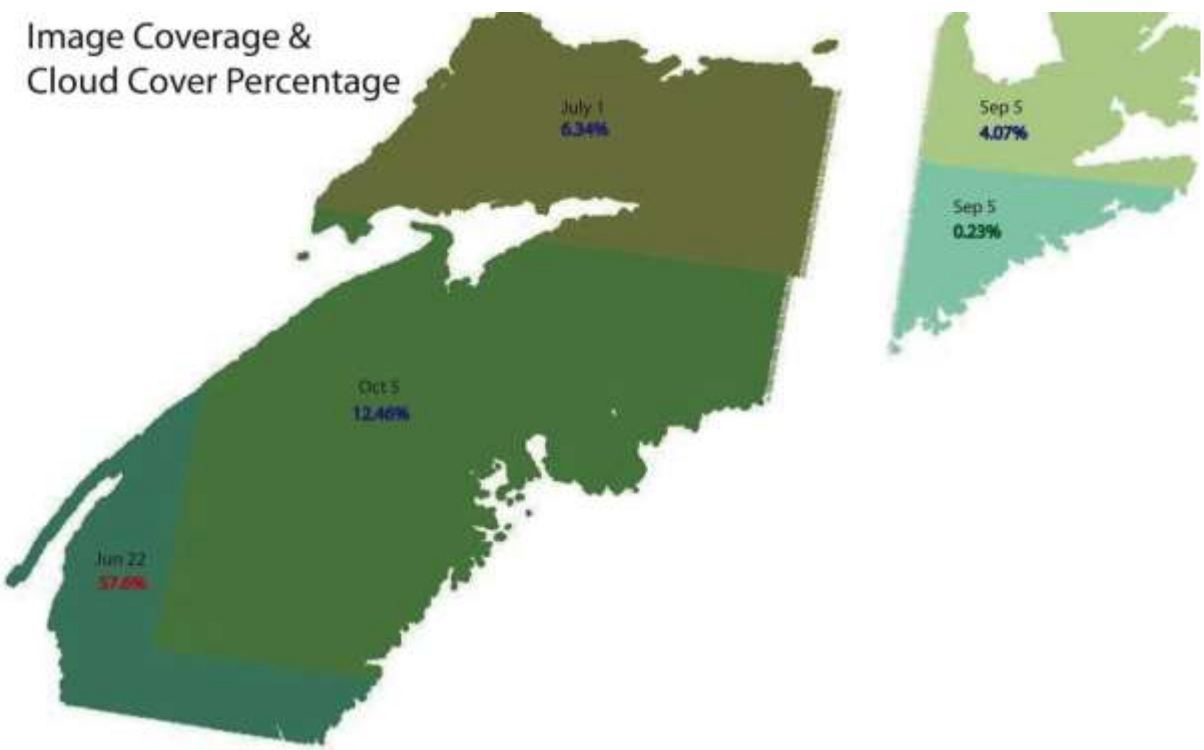
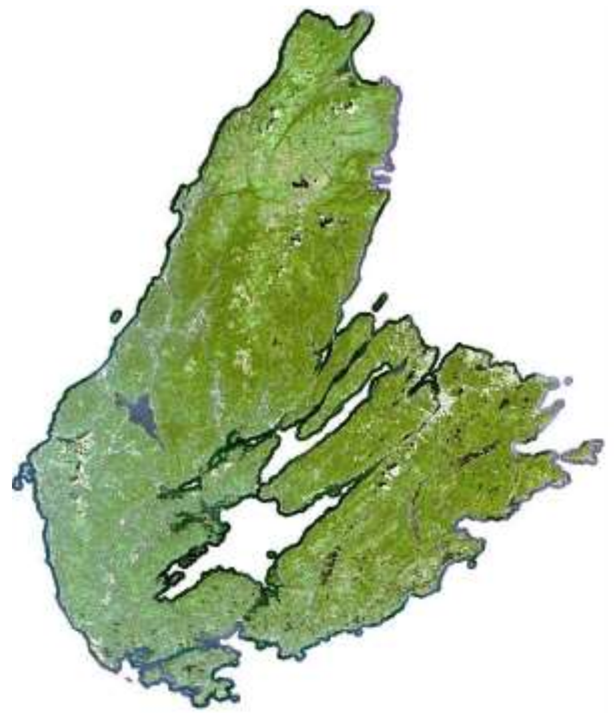


Image Coverage &
Cloud Cover Percentage
July 1
6.34%
Sep 5
4.07%
Sep 5
0.23%
Oct 5
12.46%
Jun 22
57.0%




1.64%
0.2%

2011

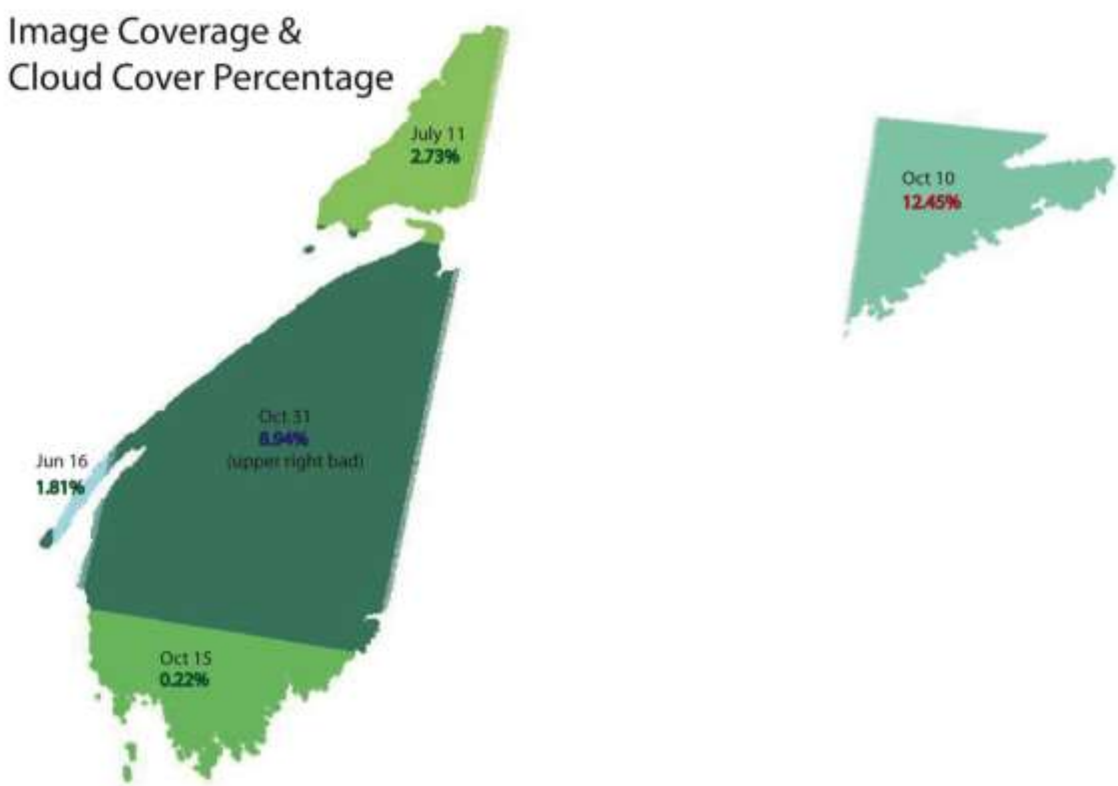
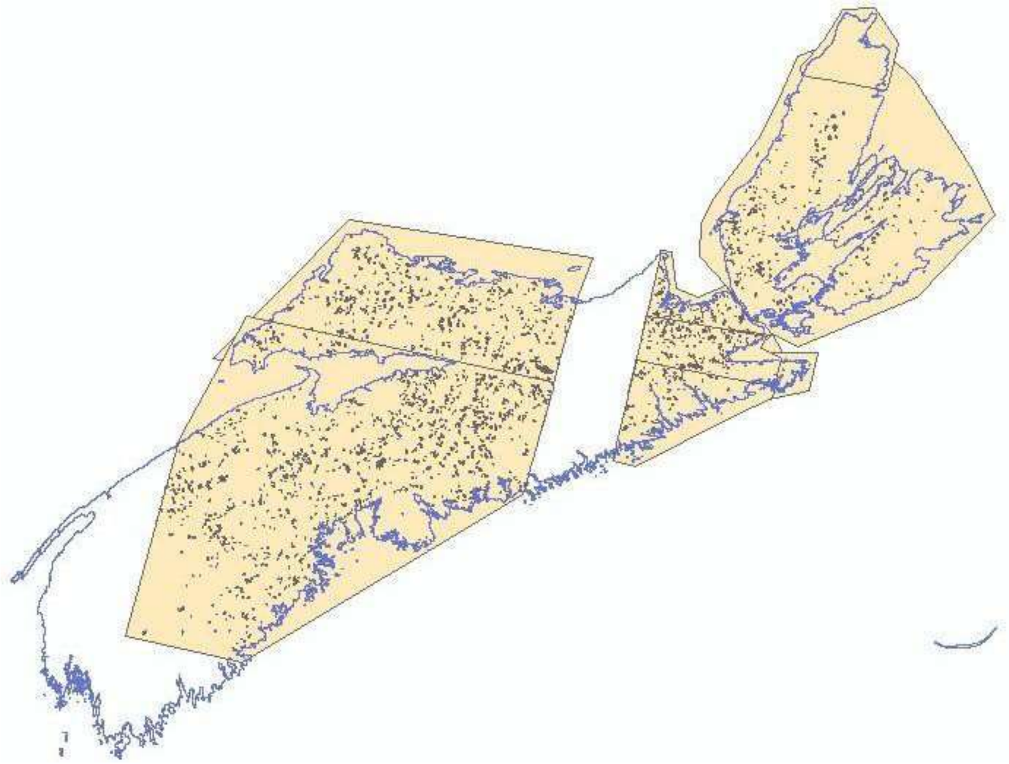


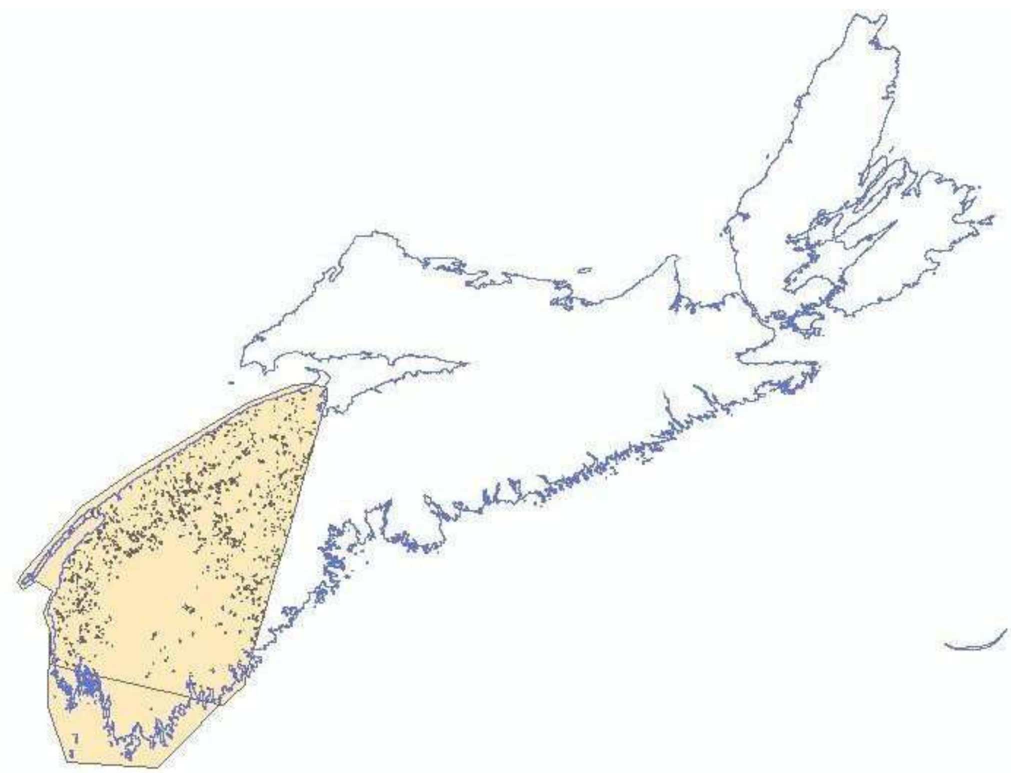
Image Coverage &
Cloud Cover Percentage
July 11
2.73%
Oct 10
12.45%
Jun 16
1.81%
Oct 31
(upper right bad)
Oct 15
0.22%

Appendix B – Shapefile Coverage

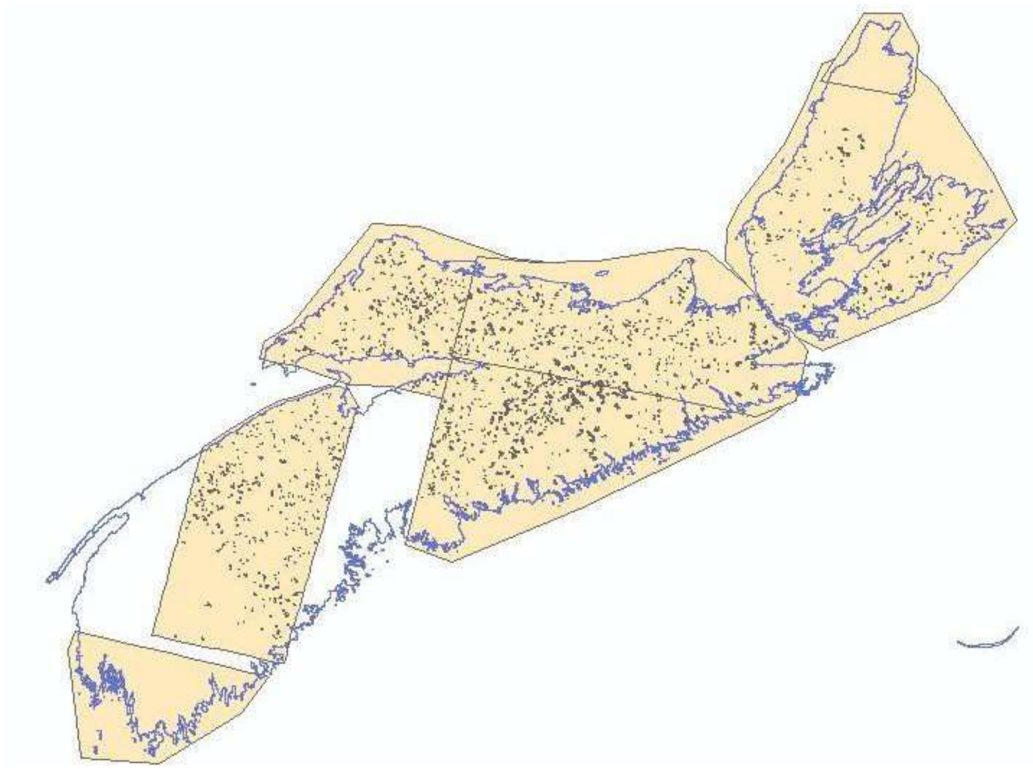
2005-2006



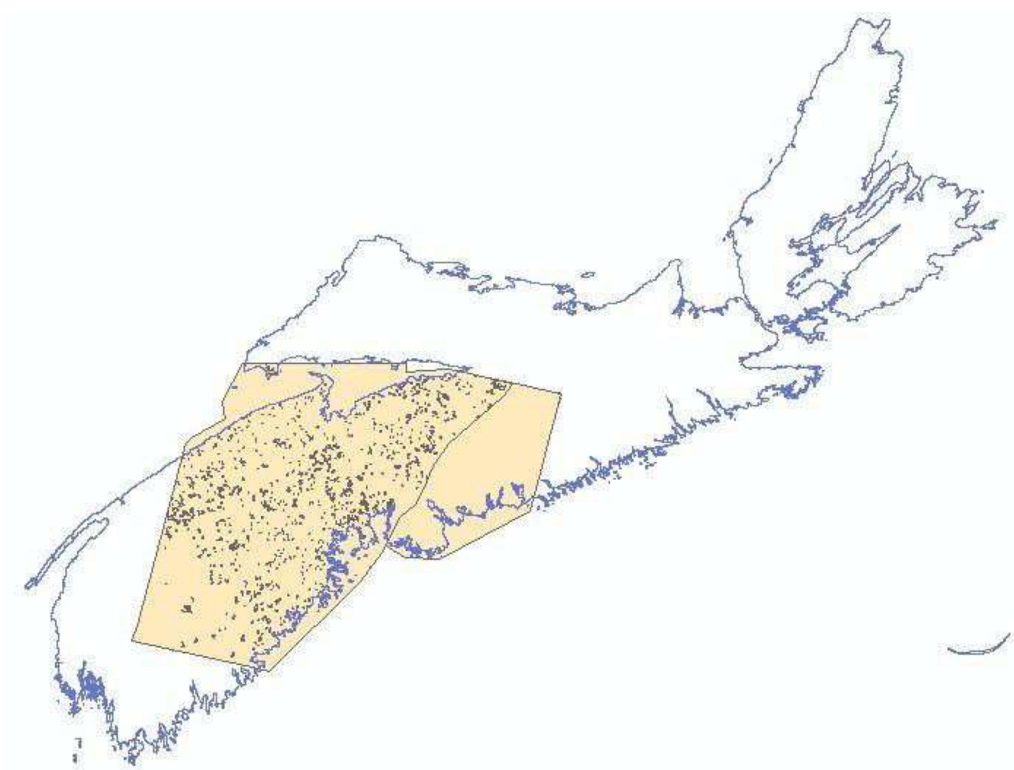
2005-2007



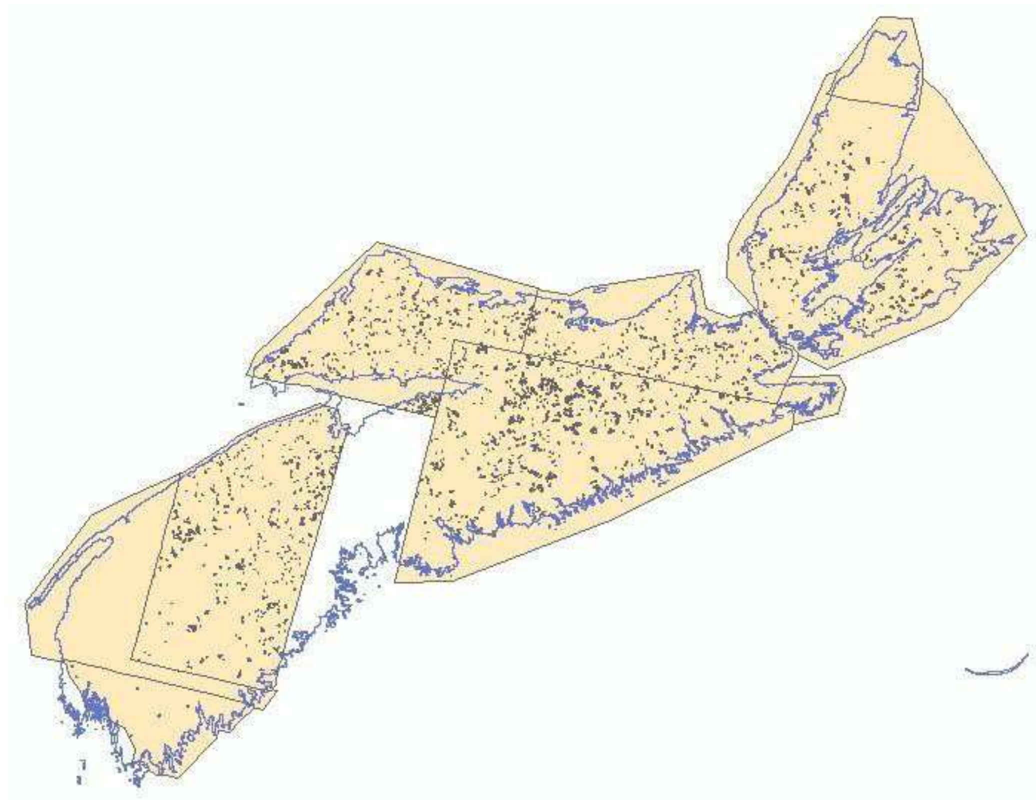
2006-2007



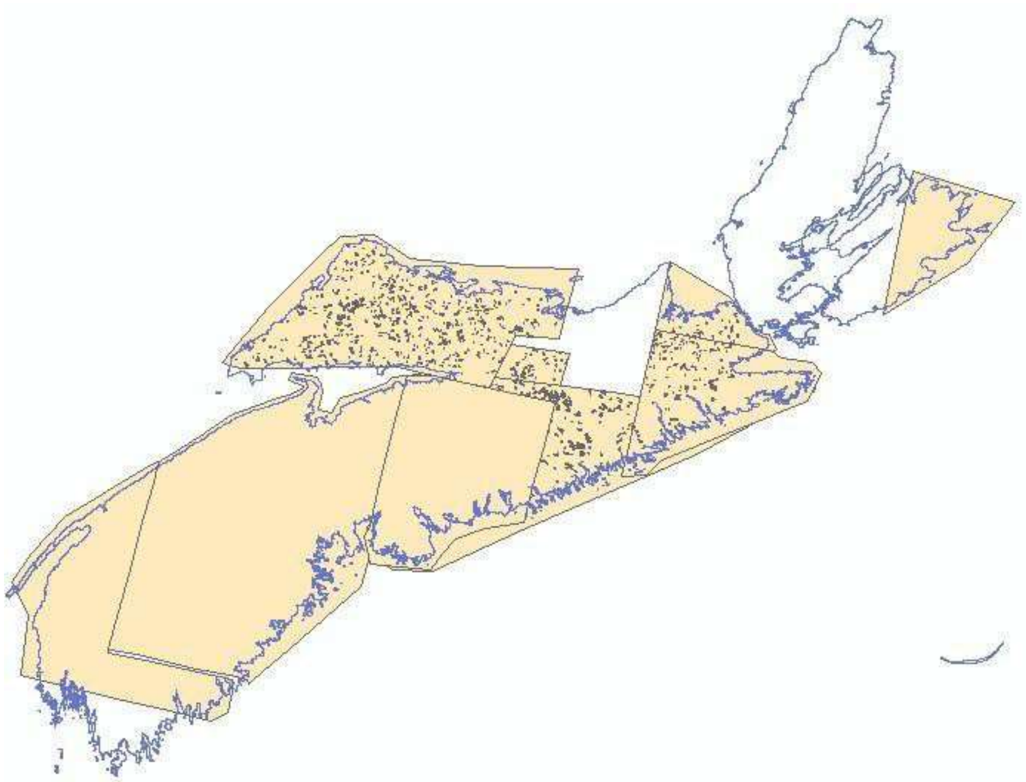
2006-2008



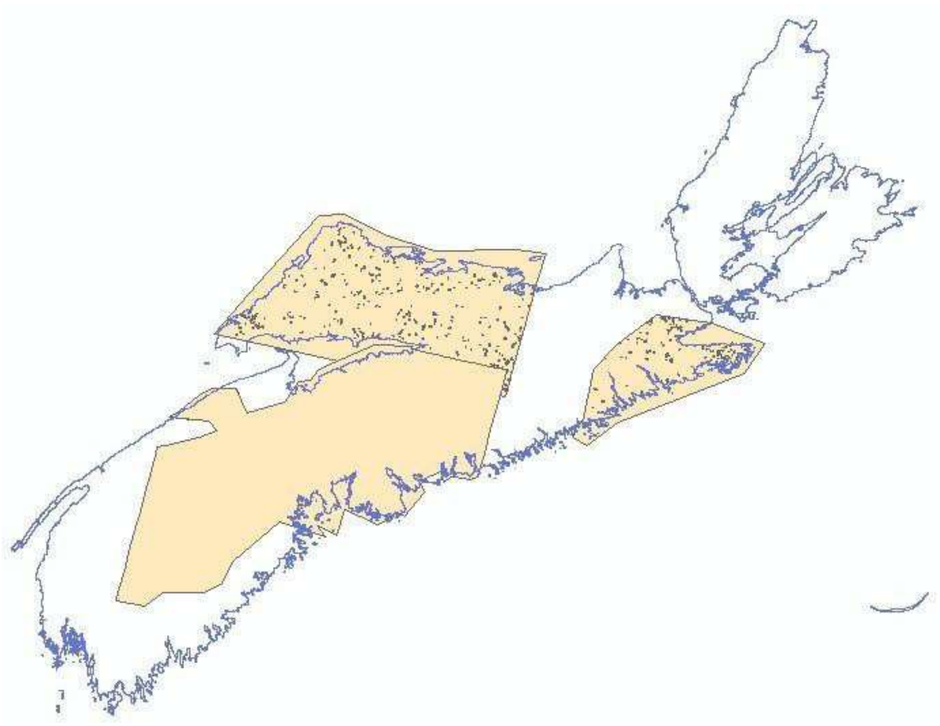
2007-2008



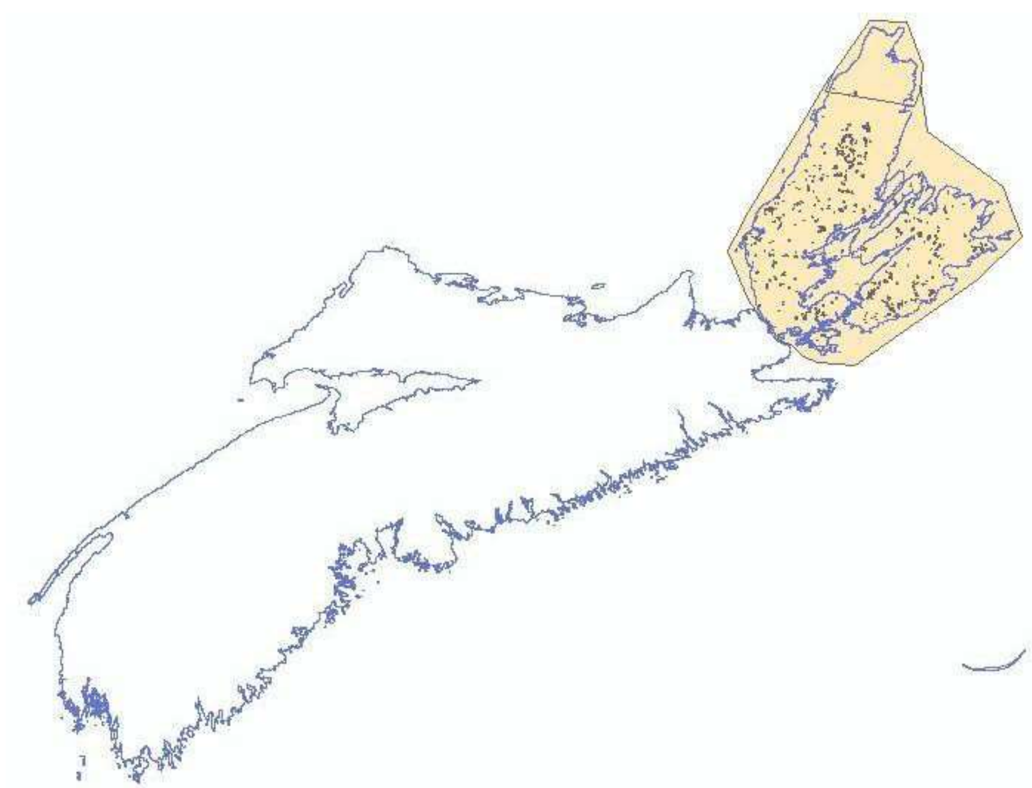
2008-2009



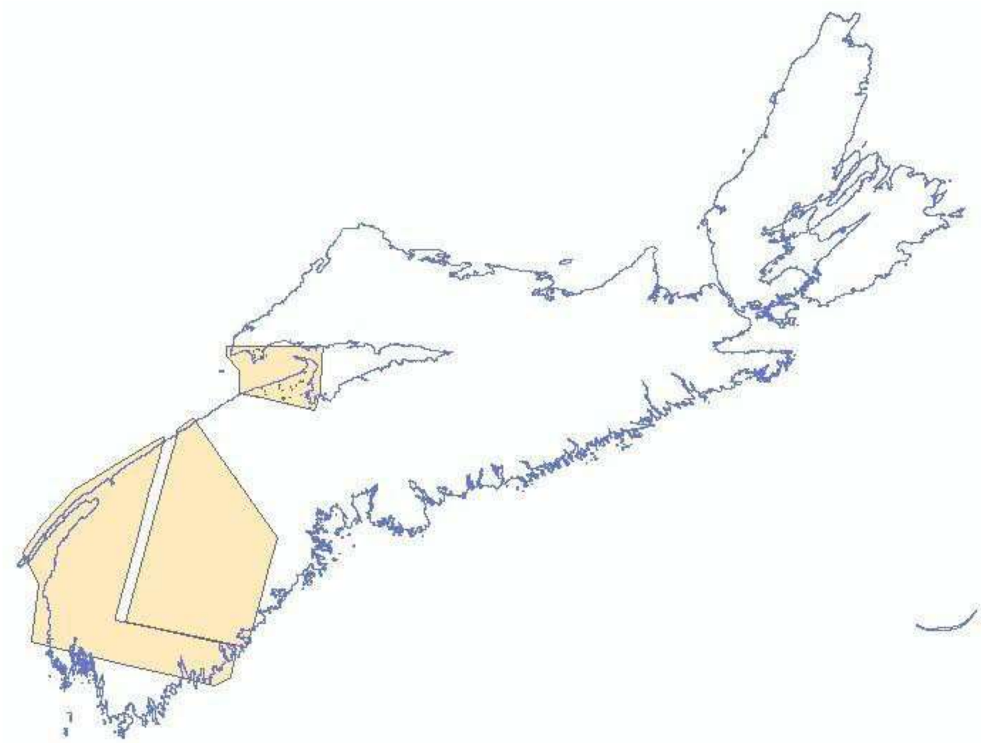
2008-2010



2009-2010



2009-2011



2010-2011