Direction des inventaires forestiers

Interpretation Guide :
Québec Landsat Satellite Image Mosaics

Ministère des Forêts, de la Faune et des Parcs
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Introduction

The *Direction des inventaires forestiers* develops and distributes an annual Landsat satellite image mosaic. An example is the 2012 Landsat mosaic of Quebec, derived from a combination of adjacent Landsat satellite image tiles acquired mostly during the summer of 2012. The area covered by the mosaic includes all land in Quebec located south of the 53rd parallel. These images provide an overview of vegetation, land use and different natural disturbances occurring in the territory (insect outbreaks, forest fires, windfalls). The mosaic also provides support for planning, monitoring and management associated to these features.

Figure 1. 2012 Landsat Mosaic produced by the MFFP's *Direction des inventaires forestiers*

On some parts of the 2012 mosaic, lines appear on the image. This linear effect is due to the failure of one of the Landsat-7 satellite's mirrors in 2003. Only the central portion (roughly 30 kilometres across) of the Landsat-7 tiles is free of this effect. To correct this problem and minimize information loss, images from different years have been superimposed onto the original images from the Landsat-7 satellite. In some places, this results in subtle differences in the homogeneity of the resulting Landsat mosaic.

This paper describes the method used to create the Landsat mosaics and presents interpretive guidelines for their use.

General Principals

The Earth observation satellites offer an incomparable view of the Earth's surface. Equipped with multispectral sensors, they capture images that provide rich and accurate geographic information. The LANDSAT series is part of a group of medium-resolution satellites, adapted to the observation of resources and the environment.

Each spectral band of the Landsat images appears in shades of gray corresponding to a portion of the electromagnetic spectrum. To produce a coloured image composite (natural colour image), three spectral bands must simply be superimposed with red, green and blue filters. For a rich and contrasting coloured compound, each spectral band must also be accentuated by spreading the values over the full range of possible gray tones (256 tones).

The Landsat-5 and Landsat-7 images used to create a mosaic were produced using the following spectral bands and filters:
- Band 5: mid infrared applied to the red filter
- Band 4: near infrared applied to the green filter
- Band 3: red applied to the blue filter

The Landsat-8 images are produced from the following spectral bands and filters:
- Band 6: short-wave infrared applied to the red filter
- Band 5: near infrared applied to the green filter
- Band 4: red applied to the blue filter

The visible and near infrared spectral bands are widely used in remote sensing, since they each provide different and complementary information:

- Band 5 (mid infrared, 1.55 microns to 1.75 microns) from Landsat-5 and Landsat-7 images / Band 6 (short-wave infrared 1.57 microns to 1.65 microns) from Landsat-8 images – Sensitive to soil and vegetation moisture, detects chlorophyll; highly contrasted optical bands, less sensitive to atmospheric effects.

- Band 4 (near infrared, 0.76 microns to 0.90 microns) from Landsat-5 and Landsat-7 images / Band 5 (near infrared, 0.85 microns to 0.88 microns) from Landsat-8 images – Sensitive to the structure of vegetation cover, effectively distinguishes coniferous from deciduous vegetation, areas affected by fire and even clover from corn in agricultural fields.

- Band 3 (red, 0.63 microns to 0.69 microns) from Landsat-5 and Landsat-7 images / Band 4 (red, 0.64 microns to 0.67 microns) from Landsat-8 images – Portion of light used to detect plant chlorophyll activity; provides clear distinctions between vegetation and non-vegetation zones. Partial penetration in water results in different shades allowing for the detection of areas with particle suspension or shallow areas.

The contrasting coloured composite of the Québec mosaic distinguishes all types of land use: forests, fields, bogs and anthropogenic elements.

The colours of an image correspond to the reflection of light by objects at the Earth's surface. There is little or no penetration within the soil by visible and infrared wavelengths. However, shorter wavelengths from the visible spectrum can penetrate water to a certain degree.

Each pixel within an image has a uniform colour, but may represent more than one element of the Earth's surface. The colour of a pixel results from the average reflectivity of objects on the surface corresponding to the ground resolution of the image used. For example, if a pixel from a coniferous forest includes some dead trees, the colour of this pixel will be affected by those trees, which will give it a reddish green colour.

Method used to create the Landsat mosaic

The steps required to obtain a homogeneous Landsat mosaic are: (i) downloading of satellite images; (ii) merging of the images (Landsat-8) (iii) enhancement of individual images, (iv) delimitation of usable zones, (v) creation of the mosaic and (vi) creation of an index of the images used.

The satellite images are downloaded in raw format from the USGS (U.S. Geological Survey) website. Images are produced using the visible and infrared spectral bands from the Landsat-5, Landsat-7 (bands 5-4-3) or, since 2013, Landsat-8 (bands 6-5-4) satellites which all have a 30-metre resolution. The favoured image acquisition period is during maximum vegetation (late May to late August). The Internet address for downloading the images is: http://glovis.usgs.gov/.

After the download is complete, a *pansharp* treatment is performed in the case of Landsat-8 images (for mosaics created in 2014 and later) to increase their spatial resolution to 15 metres. To do this, the optical band 8, a panchromatic band with a 15-metre resolution and covering a wider spectrum (wavelengths), is used. This treatment was not performed in the case of Landsat-5 images, due to the unavailability of this panchromatic band, or in the case of Landsat-7 images, due to the ongoing sensor malfunction since 2003. In the case of the 2013 mosaic, the treatment performed was the IHS (Intensity-Hue-Saturation) treatment, an image fusion treatment not applied to mosaics created before 2013.

Following these treatments, images are enhanced to standardize the colours of the three spectral bands within the images selected to create the Landsat mosaic. The enhancement also greatly increases the colour contrasts of these images, making them easier to process and interpret. This step is performed using all possible gray tone values or hues (i.e. from 0 to 255 for an 8-bit image) and is carried out using the image's pixel distribution histogram according to the gray tone values associated with each band. An image with pixels distributed over a range of 100 gray tones will be much less contrasted than an image with pixels distributed over a range of 255 gray tones, and will not allow for optimal differentiation of the image's elements.

When all the images have been enhanced, the unusable areas within these images are digitally removed from the mosaic by applying a manual process. These areas generally correspond to clouds, cloud shadows or atmospheric veils.

All the usable image parts are then laid out and superposed to generate the mosaic. The software generally used for this process is PCI Geomatica, although Imagine and ArcGIS software also can produce mosaics.

Lastly, the outlines of all the images used to create the mosaic are pooled to produce an index shapefile of the images. This file (e.g. index_landsat_qc_2012_lcc_MRN.shp) includes vector information from the different tiles making up the Landsat mosaic, for example the type of sensor used (Landsat-5 / Landsat-7 / Landsat-8), the image centre number (orbit / row) and the image acquisition date.

General interpretation guidelines

A satellite image can be interpreted the same way as an aerial photo, i.e. from its colours, but also from shapes, texture and context. Knowledge of the image's surroundings and of the chosen theme also helps with interpretation.

In a coloured composite such as that selected for the mosaics, hues and colours are always fairly similar. Their dominance, however, varies according to the image acquisition dates (spring, summer, fall), the size of the areas (boreal forest, agricultural area, tundra, etc.) and weather conditions during image capture.

Colours associated with forested areas

Areas where vegetation is present are characterized by high reflectance of near infrared (NIR) wavelengths. NIR is sensitive to the nature of plants, thereby making it easier to distinguish deciduous from coniferous trees. Another feature of these areas is the low reflectance of red wavelengths; this part of the visible spectrum marks the presence of chlorophyll in different plants.

-Deciduous forests:

- ✓ Mature deciduous forests are characterized by a yellowish-green colour.
- ✓ Depending on deciduous tree density, the yellowish hue will be more or less pronounced. For example, regeneration stage deciduous forests appear a lighter yellow-green.

Figure 2. Example of colours associated with deciduous forests

-Coniferous forests:

- ✓ Mature coniferous forests are characterized by a dark green colour. Young coniferous forests appear in light green. Young balsam fir forests may even appear in a shade similar to deciduous stands.
- ✓ Depending on conifer tree density, the shade of green will be more or less pronounced. For example, areas dominated by coniferous regeneration appear in a lighter green.

Figure 3. Example of colours associated with young coniferous forests (regeneration stage)

-Coniferous forests with a moss or lichen understory:

- ✓ RmC for dense coniferous forests (41% to 60 %) with moss understory
- ✓ RmL for sparse coniferous forests (10% to 25 %) with moss understory
- ✓ RcD pour dense coniferous forests (10% to 25 %) with lichen understory
- ✓ RcL for spars coniferous forests (10% to 25 %) with lichen understory

Figure 4. Example of colours associated with coniferous forests with a moss or lichen understory
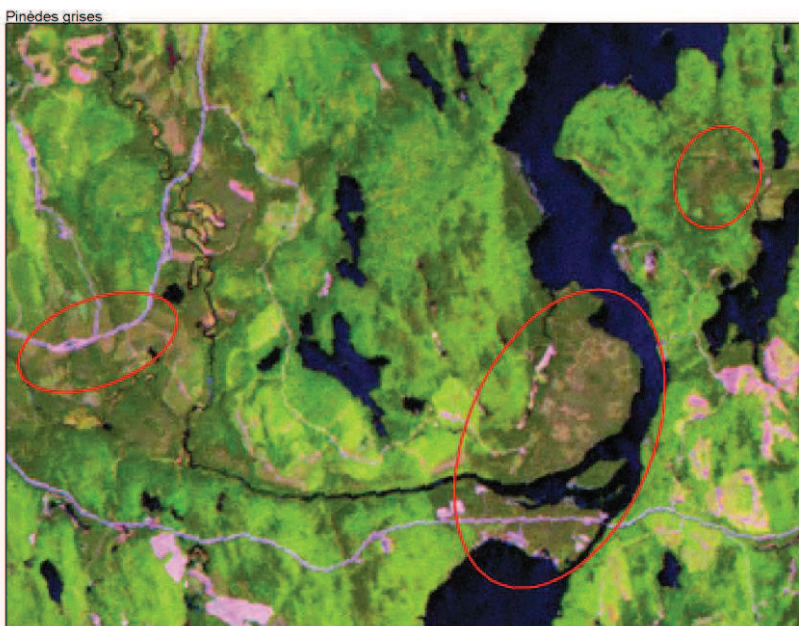
-Jack pine stands

Figure 5. Example of colours associated with jack pine stands

-Old growth forests:

- ✓ Old growth forests are defined as stands that have reached maturity. These forests have a decreasing growth rate and the trees present are senescent. [1]
- ✓ In the following example, old growth stands are about 90 years old (year of origin 1923).
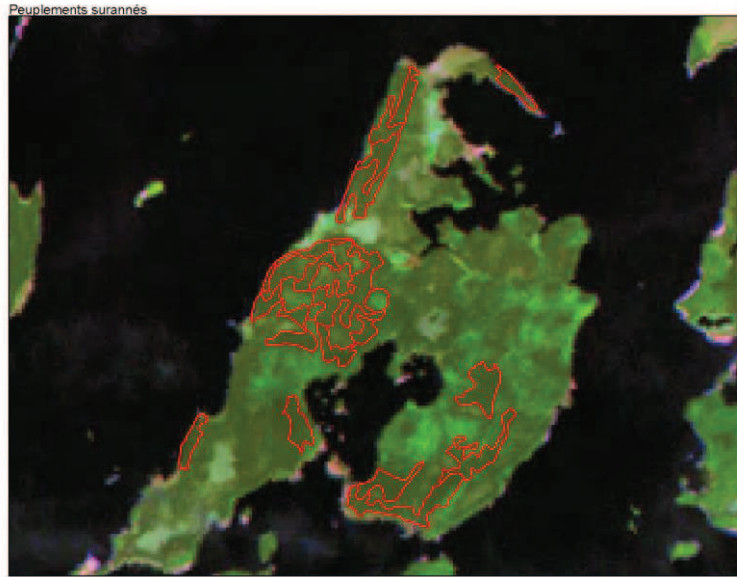

Figure 6. Example of colours associated with old growth forests

-Windfall

Windfalls are areas where trees have been uprooted by the wind. Vegetation in these areas is dead; they therefore have a pinkish hue.

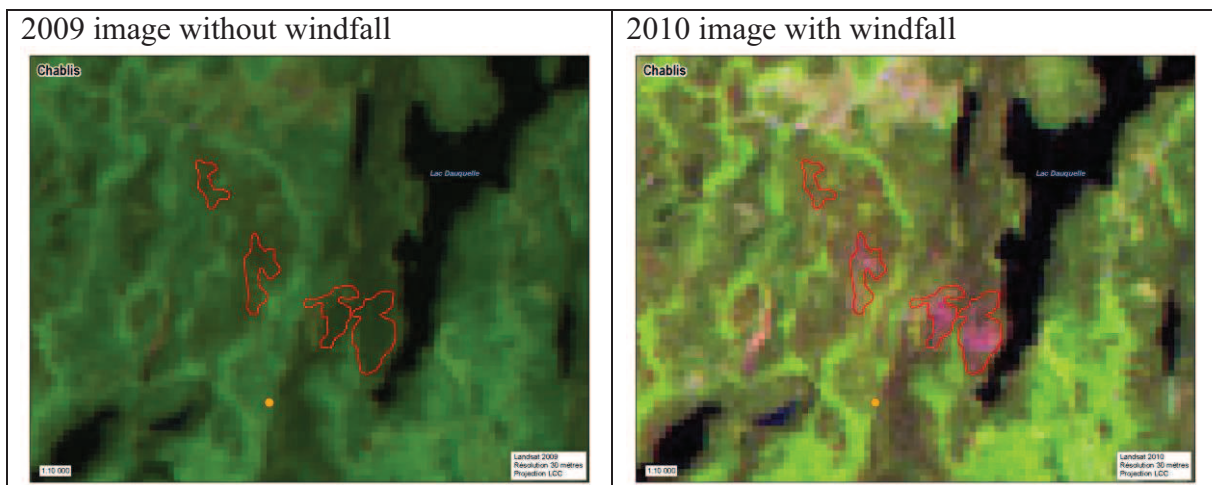| 2009 image without windfall	2010 image with windfall

Figure 7. Examples of colours associated with areas affected by windfall

-Lichen:

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[1] National Forest Database, *Official site* [online], Glossary, last updated in 2011, http://nfdp.ccfm.org/glossary_f.php, consulted on February 12, 2013.

- ✓ Lichen is a symbiosis between fungi and algae. It contains very little chlorophyll and appears in shades of blue or purple, or sometimes nearly white. Lichen produces a strong reflection of the red band (applied to the blue filter) due to the low presence of chlorophyll.
- ✓ The lichen heathlands highlighted in the following example are open areas with a lichen coverage greater than 30%.
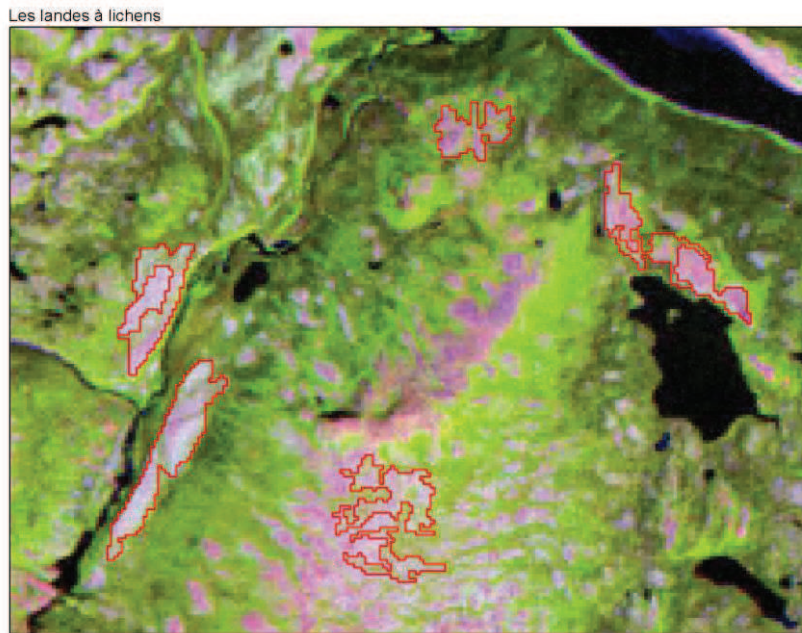

Figure 8. Example of colours associated with lichen heathlands

Colours associated with logged areas

Logged sites are easily recognizable from their particular shapes (checkerboard forms or stripes) and the adjacent presence of forest roads.

- ✓ In areas of recent logging, clearcuts and logging roads are represented by a very light pink colour. This colour can be explained by the presence of bare soil, which produces a lower reflection of the near infrared and a stronger reflection of the red and mid infrared range, the latter being sensitive to soil moisture.
- ✓ In older logged areas, greener hues appear because of the presence of regeneration; there is a higher percentage of chlorophyll which absorbs a greater proportion of the red wavelengths, and the vegetation structure increases the reflection of the near infrared spectrum.
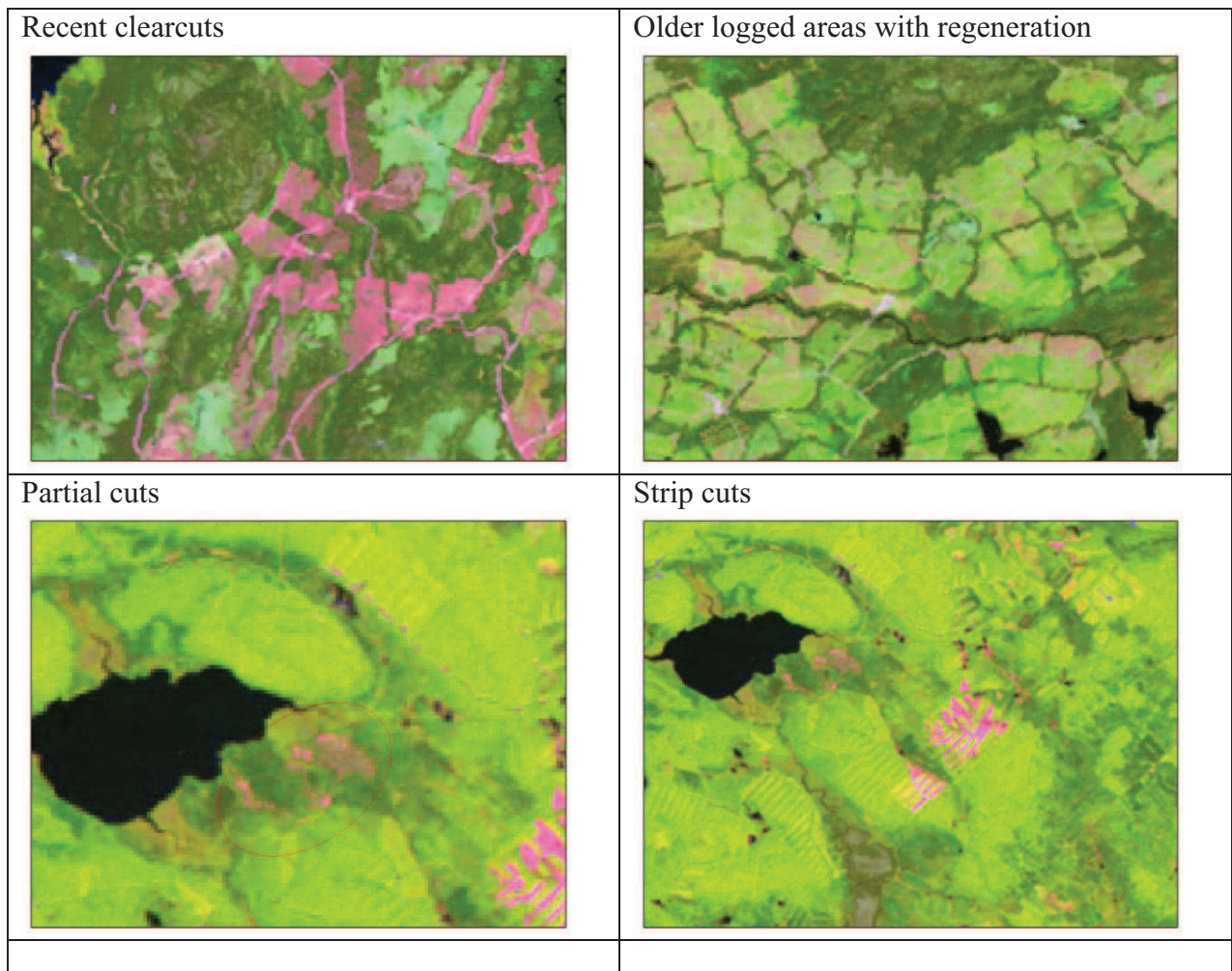
Recent clearcuts	Older logged areas with regeneration
Partial cuts	Strip cuts

Figure 9. Examples of colours associated with logged areas

Colours associated with insect defoliation

 - Spruce budworm
 ✓ Sites affected by spruce budworm outbreaks exhibit gradual defoliation of coniferous trees (increasing defoliation from bottom to top of image below). Defoliation is caused by spruce budworms that feed on new tree growth. Tree death occurs only after several years of defoliation.[2] Outbreak areas appear in a reddish hue where there is a large percentage of dead trees, and in a brownish hue where there is a smaller percentage of dead trees.

 - Hemlock looper
 ✓ The hemlock looper feeds on foliage from previous years, and defoliation occurs over a short period of time, roughly three years. Thus, the speed of defoliation can be observed throughout the entire tree. Forest areas affected by the hemlock looper will have a reddish hue, and are easily distinguishable from other elements in the region by their disparate distribution.
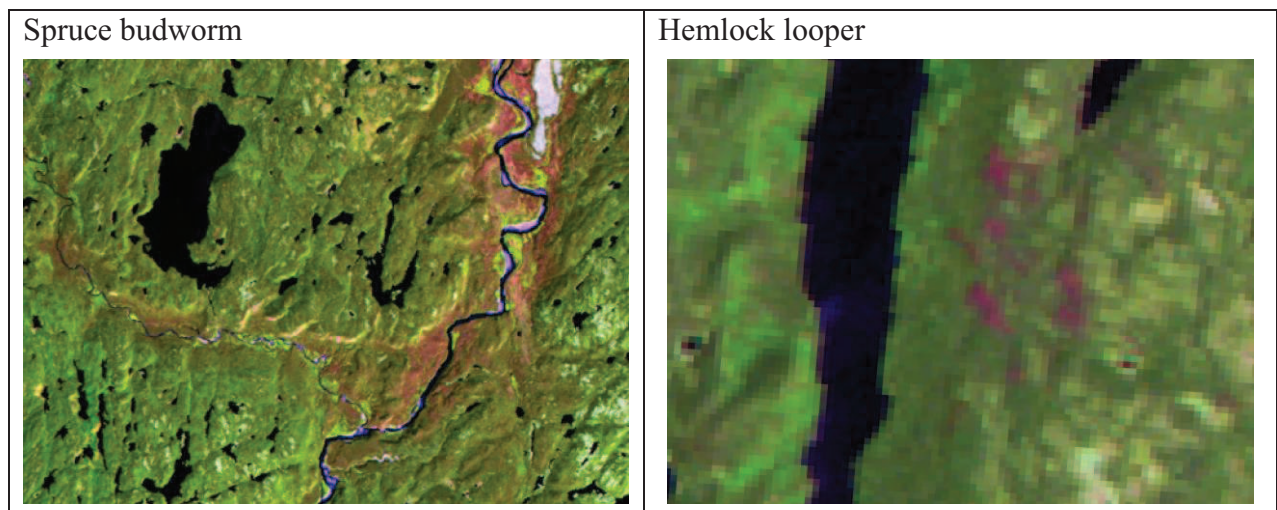
Spruce budworm	Hemlock looper

Figure 10. Examples of colours associated with insect defoliation

Colours associated with forest fires

The zones affected by forest fires are irregular and elongated in shape. Prevailing winds during fires can create an elongated arrow shape on certain sites.

 ✓ Recent forest fires are characterized by a dark burgundy colour due to the lack of vegetation. The various shades of burnt areas can be characterized according to the degree or type of burning of the vegetation:

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[2] Natural Resources Canada, *Official Site* [online], spruce budworm, last updated in 2012, http://scf.rncan.gc.ca/pages/50, consulted on February 12, 2013.

- Carbonized: when everything has been burned by fire and there is nothing left: **dark burgundy**.
- Scorched: when the needles of the trees have been burned by fire: **light burgundy**.
- Affected: when low vegetation has been damaged by fire but the crowns are still alive; this vegetation will die in the short term. Land or aerial surveys are conducted to confirm the presence of fire under cover:
  mix of green and burgundy.
- Green: when vegetation has been unaffected by fire:**green**

✓ Regeneration following forest fires turns light green over the years, but will retain the shape of the fire. It is therefore possible to characterize the regeneration of different fires over time.
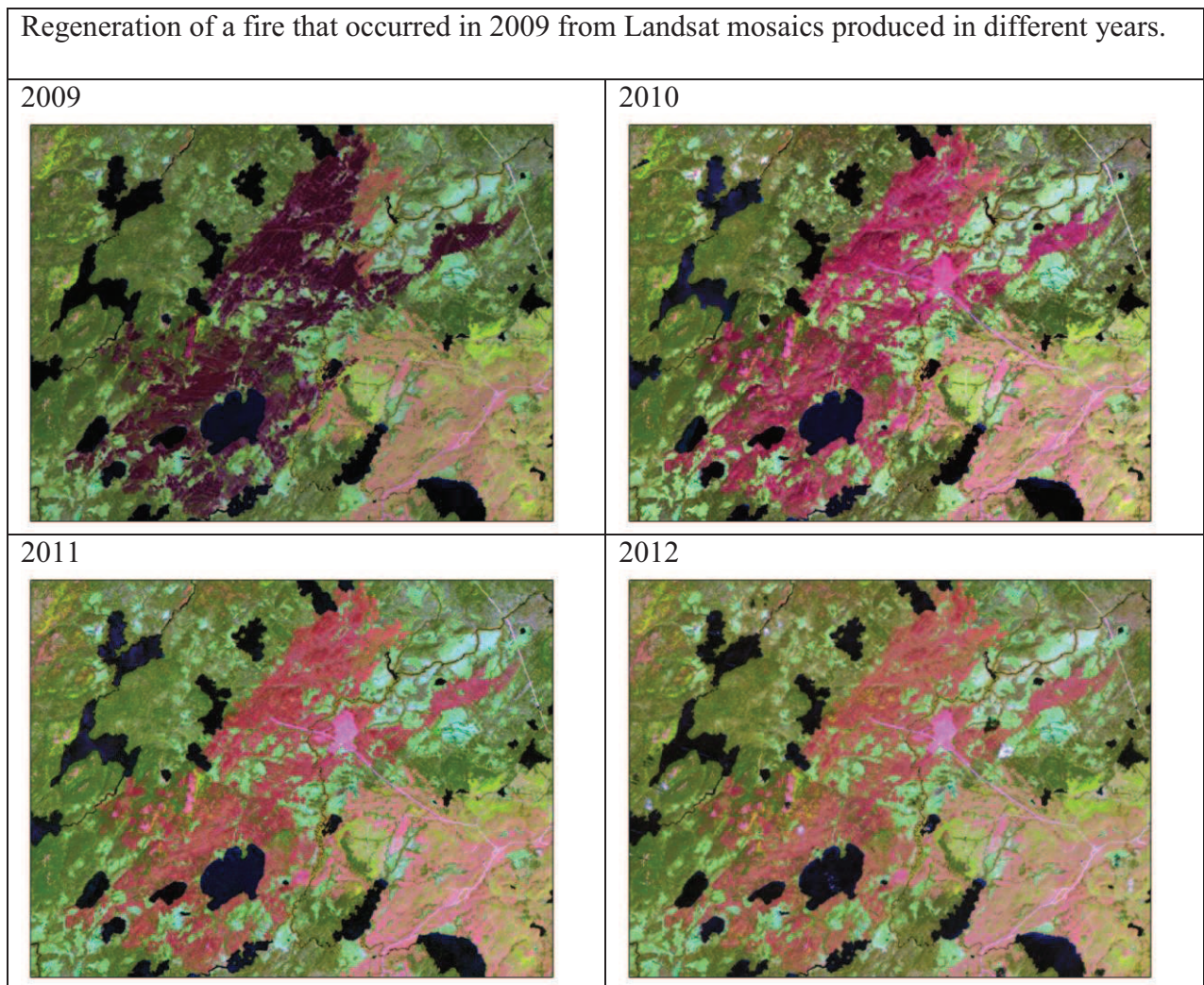
Regeneration of a fire that occurred in 2009 from Landsat mosaics produced in different years.	
2009 	2010
2011 	2012

Figure 11. Examples of colours associated with forest fires

Colours associated with agricultural areas

Agricultural areas are readily distinguished from other elements by their rectangular shape and their location.

- ✓ Agricultural areas with denser crops are represented by the green colour in the example below.
- ✓ Fields with mature crops have a purple hue; these crops no longer have chlorophyll, resulting in a strong reflection of red wavelengths compared to growing crops.
- ✓ Bare agricultural areas are light pink (reflection: high of red wavelengths and low of near infrared).
- ✓ An orange hue indicates the presence of forage plants, pastures or fallow fields.
- ✓ When forage plants are cut, the field takes on a yellow hue.

Figure 12. Example of colours associated with agricultural areas

Colours associated with urban areas

The different shades seen in urban infrastructures are due to their high reflectance of band 3 (part of the visible spectrum used by chlorophyll: a strong reflection of red wavelengths), low reflectance of band 4 (sensitive to plants) and low reflectance of band 5 (sensitive to soil moisture).

- ✓ Urban infrastructures such as roads, airstrips and urban areas appear in blue or purple. They have a high reflectance of red wavelengths due to their inorganic composition.
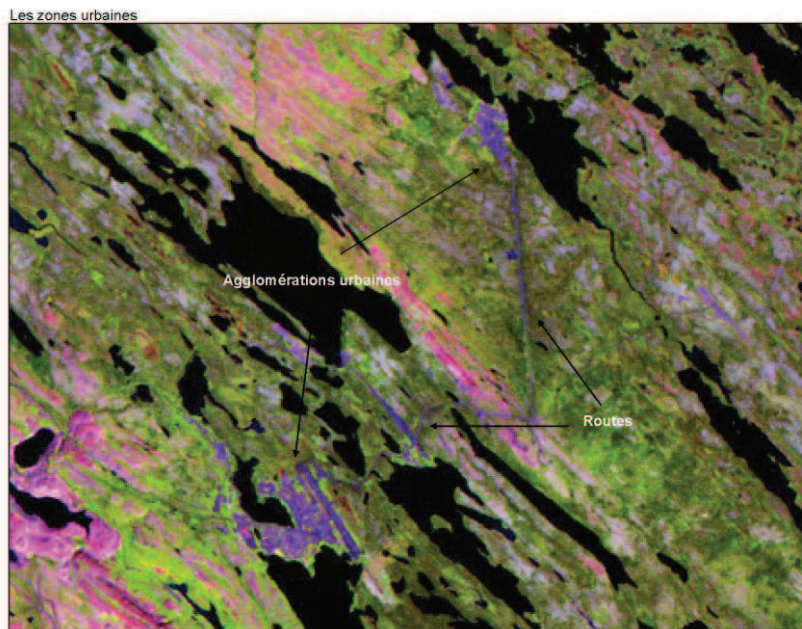- ✓ Some urban infrastructure such as oil reservoirs appear in white.

Figure 13. Example of colours associated with urban areas

Colours associated with peatlands (bogs and fens)

- ✓ The reflectance of peatlands can vary considerably, depending on the type of peatland, because they have different characteristics, including soil moisture or the presence of surface water (sensitivity to band 5), plant composition - sphagnum mosses, sedges, shrubs, etc. (sensitivity to band 4), and chlorophyll content (sensitivity to band 3).[3] Depending on how they were formed, they have either a concentric shape or appear in strips, or they include pools, which may be structured or unstructured.
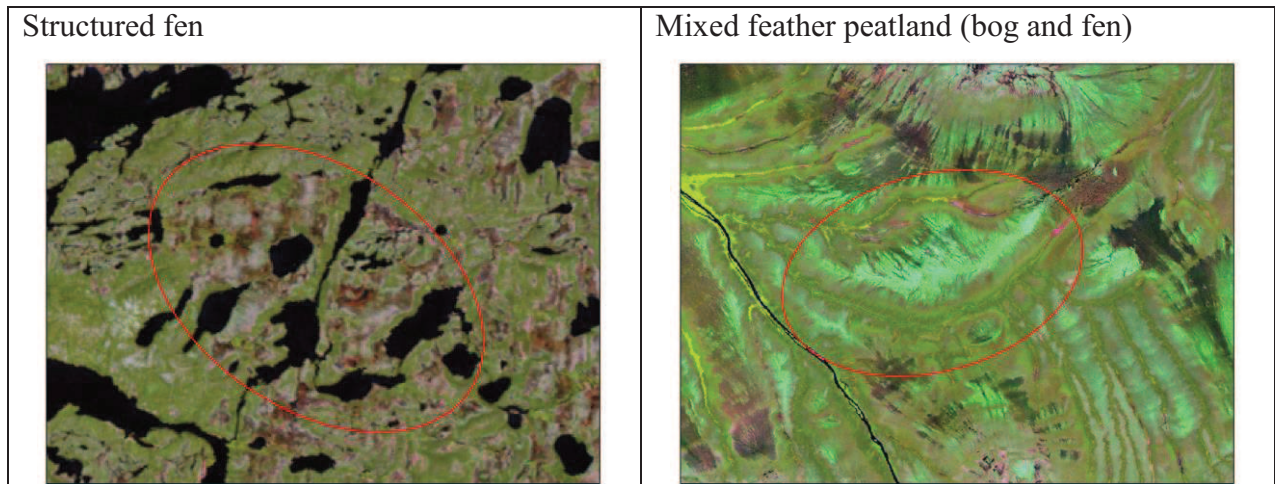
Structured fen	Mixed feather peatland (bog and fen)

Figure 14. Examples of colours associated with peatlands

Colours associated with bodies of water

- ✓ Black appears when the three bands used are absorbed without reflection. Lakes and rivers are the only features that appear in black on the mosaics because they absorb all band wavelengths. When a lake or river is shallow or contains a lot of suspended matter, the presence of sediment and suspended matter results in some reflection of the red wavelength. These bodies of water therefore appear more of a bluish colour.

- ✓ Sandy beaches along rivers and around lakes appear in pink.

Colours associated with rocky outcrops

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[3] F. BONN. *Télédétection de l'environnement dans l'espace francophone*, Sainte-Foy, Presses de l'Université Laval, 1994, p. 108.

✓ Rocky outcrops are areas where bedrock is visible. Rocky outcrops and boulder fields appear in shades of purple, which sometimes take on a pinkish hue. Quartzite outcrops appear in white. In the case of northern regions, rocky outcrops can take on reddish hues due to the presence of mosses, grasses and shrubs. Otherwise, rock composition is the main factor that influences the colour of outcrops on the mosaic images.
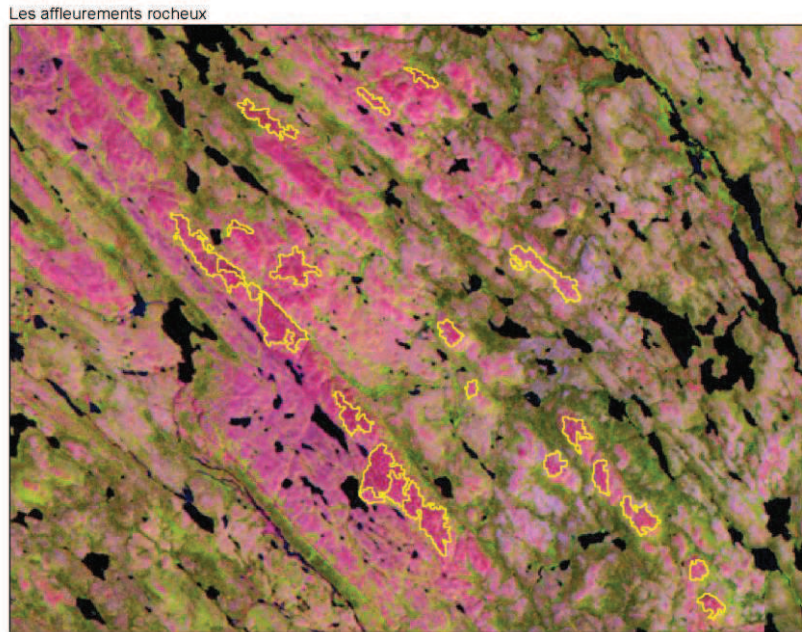

Figure 15. Example of colours associated with rocky outcrops