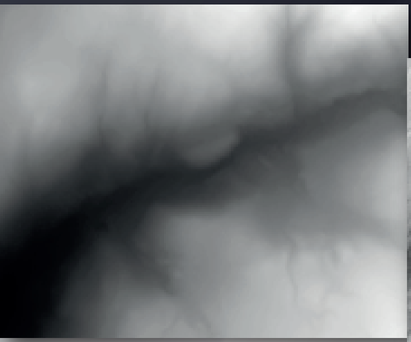
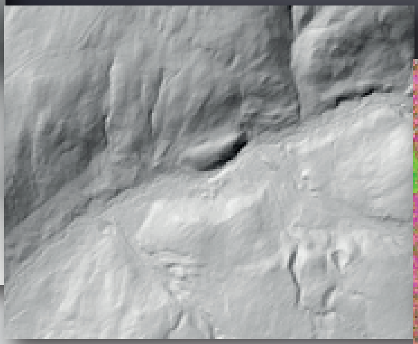
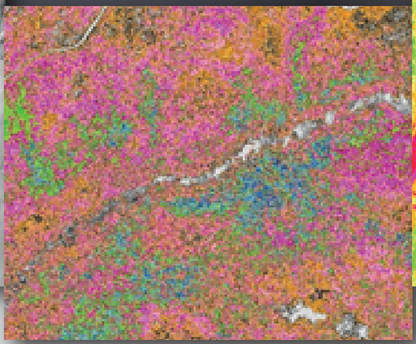
User's Guide:

The Four Derivative Products of Basic LiDAR Data







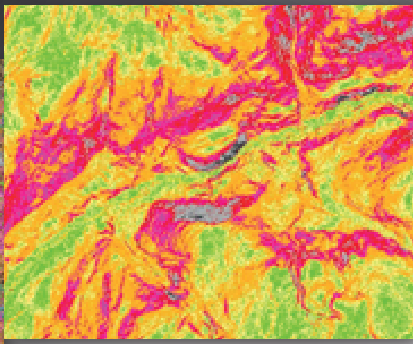


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Table of contents

Introduction

It has often been shown that the information obtained from aerial LiDAR[1] surveys generates significant economic benefits for the forest industry and for several other Québec Government activity sectors. These benefits have already been demonstrated (Leboeuf et al., 2015[2]). Nevertheless, the use of raw LiDAR data remains complex and requires extensive experience and advanced computing tools. To facilitate the use of this data and optimize the benefits of LiDAR data use, the Ministère des Forêts, de la Faune et des Parcs (MFFP) has therefore generated and made available a range of user-friendly products derived from LiDAR data.

The purpose of this document is to help clients to use these derivative LiDAR products. It presents the products, as along with techniques for their use and transformation.

[1] LiDAR : Light Detection and Ranging

[2] Accessible online : http://www.mffp.gouv.qc.ca/publications/forets/connaissances/Analyse_retombees_LiDAR-Finale.pdf)

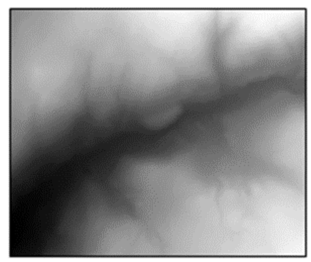
1. Derivative Products

The four basic products derived from LiDAR data are 1) Digital Terrain Models, 2) Shaded Relief, 3) Canopy Height Models and 4) Slope Analysis. These products are in raster format and can easily be viewed in most GIS software packages, including ArcGIS.

The following is a list of technical characteristics common to the four products presented in this document:

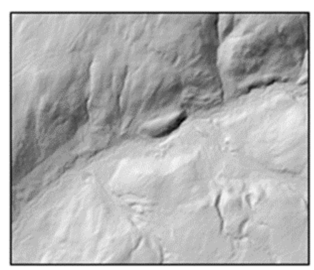
Geodetic reference datum	GRS 80 Ellipsoid
Geodetic reference system	NAD 83 SCRS
Projection	Transverse Mercator
Production method	Processed using Lastools, R, Gdal and ArcGis
Data-viewing software	ArcGis, QGis, MapInfo, etc.

1.1. Digital Terrain Model (DTM)



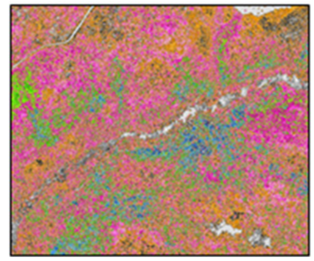
This raster file provides real numerical values representing altitudes in metres relative to the mean sea level. The raster file's pixel elevation values correspond to the linear interpolation of the network of irregular triangles created from the ground points. The raster's spatial resolution is 1 metre.
A DTM is a basic product derived from LiDAR. It serves primarily to create Shaded Relief and Slope Analysis. It is also used for hydrological models, road construction, flood risk management, visual landscape analyses, and so on.

1.2. Shaded Relief (Hillshaded Digital Terrain Model)



This raster file simulates the three-dimensional appearance of a relief map. It therefore does not contain altitude values. Shadow and light are shades of gray associated with integers from 0 to 255 (from black to white). The spatial resolution of this raster is 2 metres.
A Shaded Relief presents a very detailed image of the terrain and can be used for interpretation of surface deposits, drainage, wetlands, etc.

1.3. Canopy Height Model (CHM)



This raster file provides numerical values representing forest canopy heights or the heights of other raised elements (e.g. buildings). It corresponds to the difference between the digital surface model and the digital terrain model. The MHC_nofeuillet.lyr file represents a symbology (range of colours) for height in metres. The spatial resolution of this raster is 1 metre.

The CHM can be used to measure height, density and stand structure, and to construct statistical relationships in order to map volumes, land surfaces, etc.

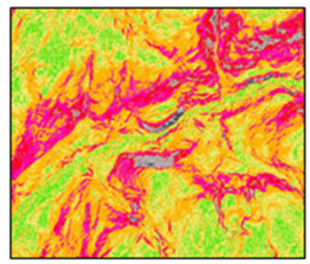
It should be noted that different elements must be taken into account before using the CHM to evaluate the height of trees or vegetation:

1. Tree heights are generally underestimated by LiDAR. The disparity is greater in coniferous forests than in deciduous forests. It is also greater when the point density is lower. For example, a study done in the Parc des Laurentides showed an underestimation of -0.98 meters based on 431 tree measurements and a LiDAR datum with a density of 7.1 points/m^2 (Sadeghi et al., 2016). On the other hand, given that several factors have to be taken into account (forest type, point density, forest cover, etc.), **it is strongly suggested that users carry out their own field measurement campaigns** to determine the adjustment associated with the data set.

2. The CHM can accurately determine the height of trees and vegetation. Based on the tops of fir and spruce trees, the CHM may initially make it appear that the crowns are much lower than they actually are, because sometimes only one pixel, located on the highest point of the tree (e.g. 20 m), shows the actual height of the tree. The other surrounding pixels indicate lower values for the crowns (e.g. 15 m).

3. Finally, it should be noted that expertise is required to integrate tree heights into the polygons derived from a CHM. It is necessary to take the local maxima (maximum height of each crown) from the CHM and choose from a multitude of calculation methods to integrate the various heights (example: 95 th percentile, modal height, etc.).

1.4. Slope Map (Slopes)



This raster file provides real numeric values representing slopes. The product is generated from the digital terrain model. The file Pentes_nofeuillet.lyr represents a symbology (range of colours) for slope classes: A (0 to 3%), B (3 to 8%), C (8 to 15%), D (15 to 30%), E (30-40%), F (40-50%), X1 (50-70%), X2 (70% and +). The spatial resolution of this raster is 2 metres.
The slope map can be used as a support tool for forest operations or the construction of roads and trails.

2. Availability of LiDAR Derivatives Products

The first areas benefiting from these products in 2016 are the Saguenay-Lac-Saint-Jean region (UA 024-51), the Mauricie region (UA 041-51) and the entire Outaouais region. For information on the areas for which products will be released in the future, please see the LiDAR planning map derivatives availability calendar, at:

ftp://ftp.mrn.gouv.qc.ca/Public/DIF/Diffusion/LiDAR/Disponibilite_produits_derives_LIDAR.pdf

Figure 1. Planned availability of LiDAR derivatives products

3. Access to LiDAR Derivatives Products

These products are available, free of charge, via the interactive map showing ecoforestry data for Quebec, supported by the open geographic infrastructure, known by its French name *Infrastructure Géomatique Ouverte* (IGO).

Through the map, users can **view the shaded relief model** and **download, free of charge, the basic derivative products**, as listed above. To do this:

1. Access the interactive map: http://geoegl.msp.gouv.qc.ca/igo/mffpecofor/.
2. Double-click on the option "Produits dérivés de base du LiDAR".
3. Check the box to the left of "Téléchargement des produits dérivés de base" in the menu.
4. Query the layer, using the upper menu button "Information et téléchargement" to access the free download links.

It is also possible to download these products directly from the Données Québec website (the Québec Government's collaborative, open data Internet portal). To do this:

1. Consult the Données Québec fact sheet of basic LiDAR derivatives: https://www.donneesquebec.ca/recherche/fr/dataset/produits-derives-de-base-du-lidar;

Option 1

1a. Download the file "URL par feuillet" in csv format.

1b. Open the file using a program similar to Microsoft Excel, in order to access the free-download links.

Option 2

2a. Download the file "URL par feuillet" in shapefile format.

2b. Open the file using a GIS (e.g. QGIS), in order to access the free-download links.

The document also contains other useful information pertaining to the use of these products, such as metadata (year of acquisition, point density and presence of leaves).

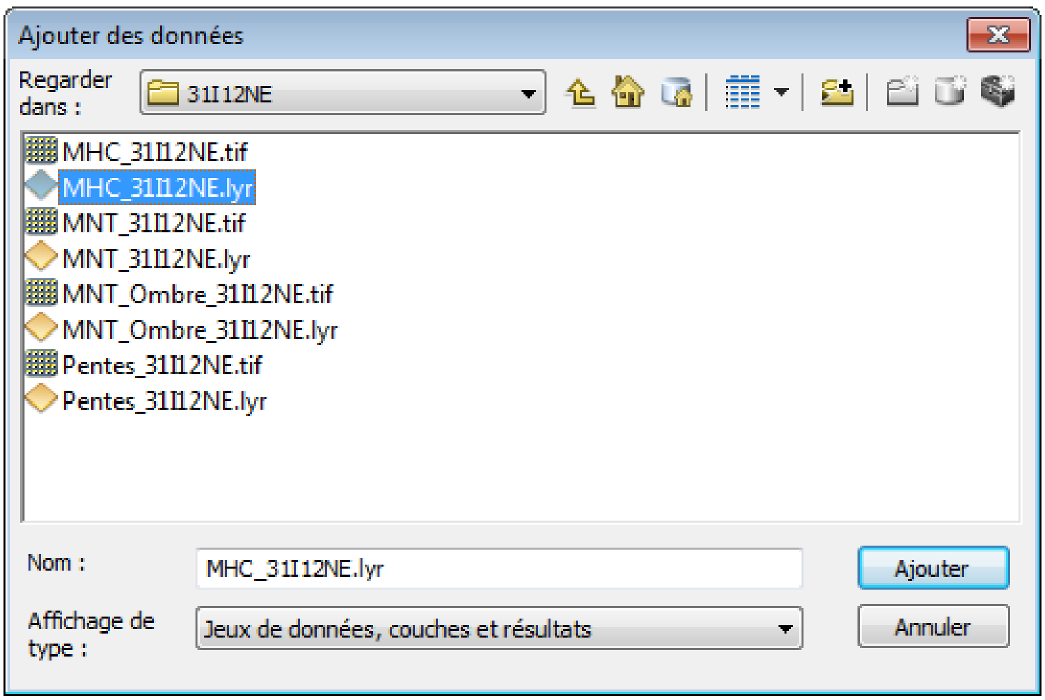
4. Basics of Using Raster Data

This section presents several basic manipulations to facilitate the use of LiDAR data. These manipulations are based on the commercial software, ArcGIS. While the techniques can all be applied with other software, including QGIS, the proposed symbology will not work with these other programs.

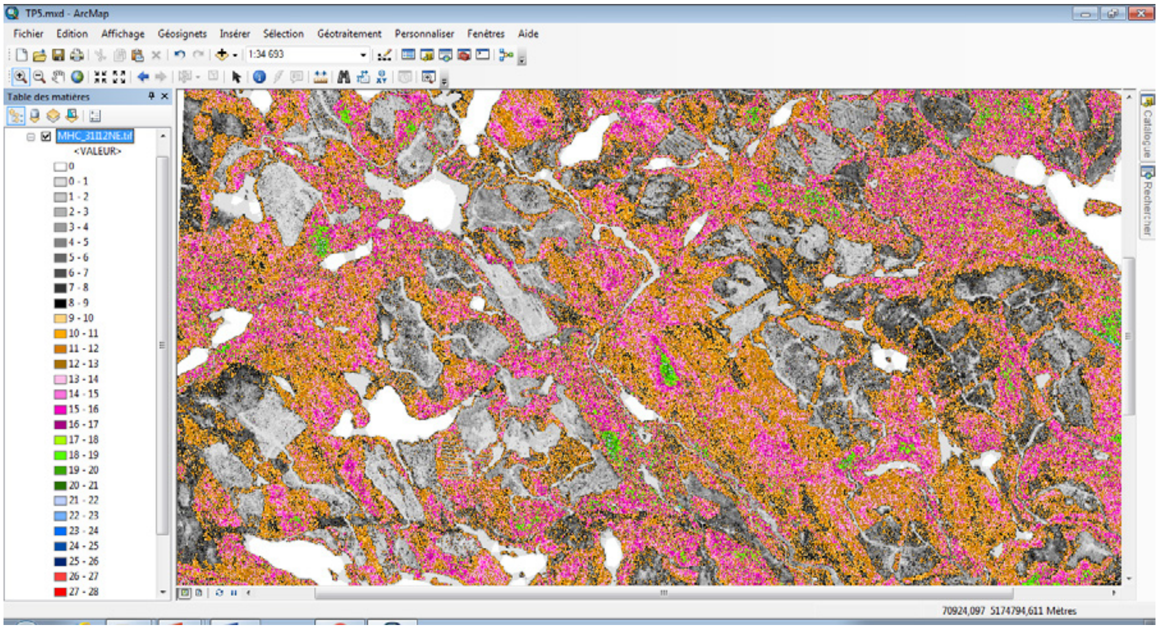
4.1. Visualizing Raster Data

When the products are downloaded, you can open the files in GIS software, such as ArcGIS, by pressing the "add data" button. 

Once the "Add Data" dialog box appears, select the ".lyr" file.

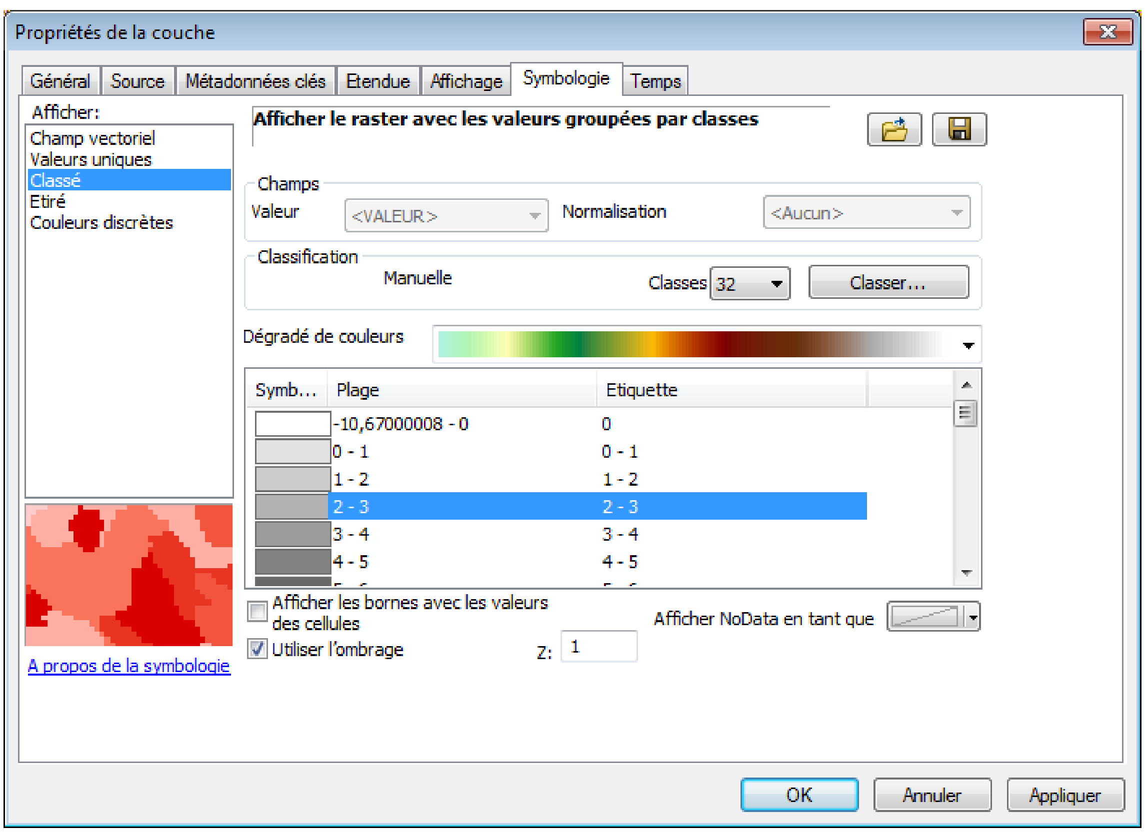


You can then start work. The symbology we have proposed will appear.

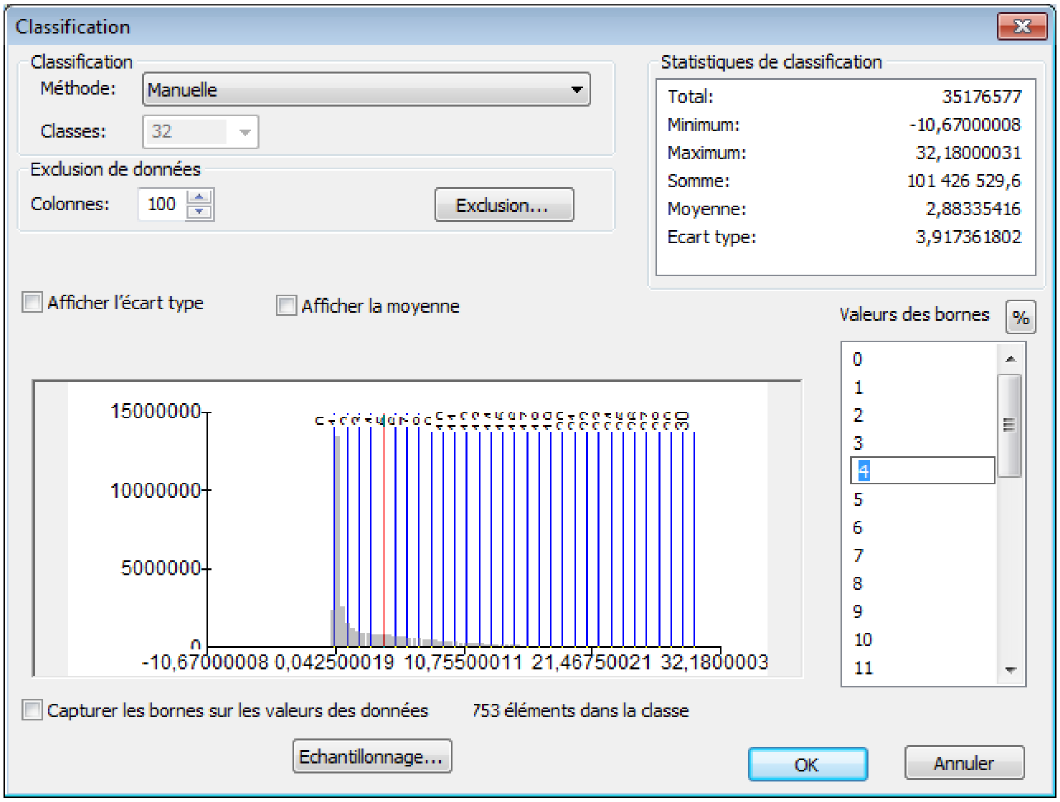


4.2. Adjusting Symbology and Choosing Classes

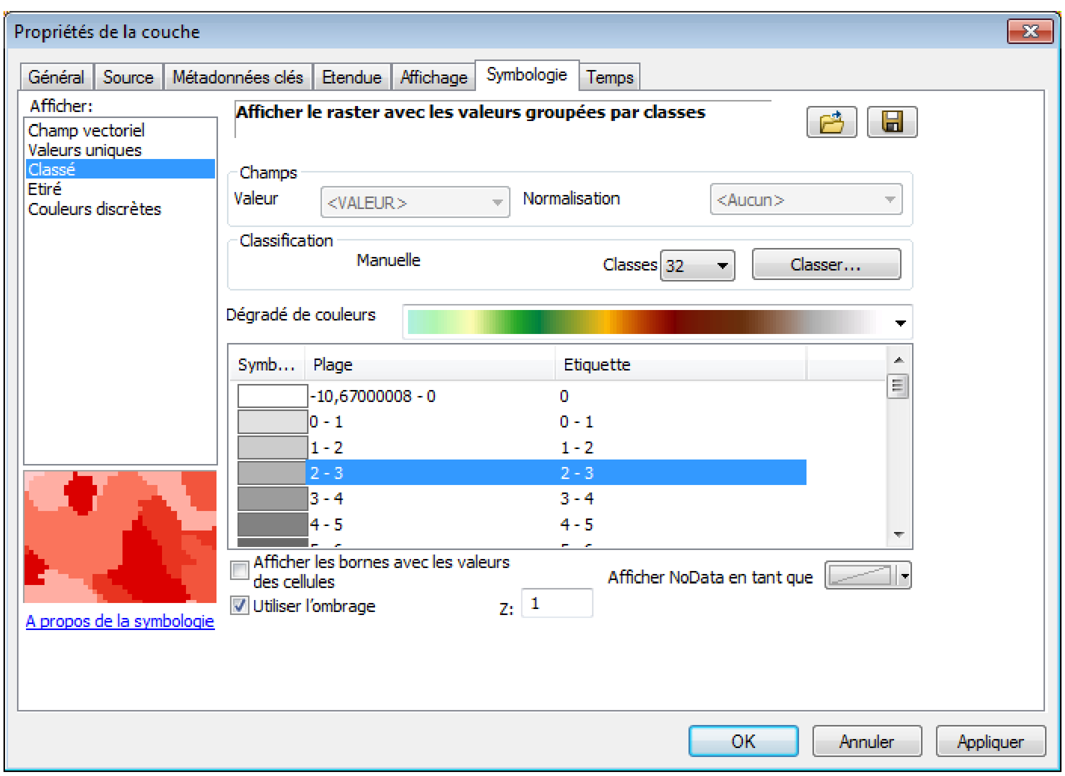
If you want to modify the proposed symbology, right-click on the layer to select its properties. The following dialog box will appear.



Click "Classify ..." in order to change the value of the class breaks.



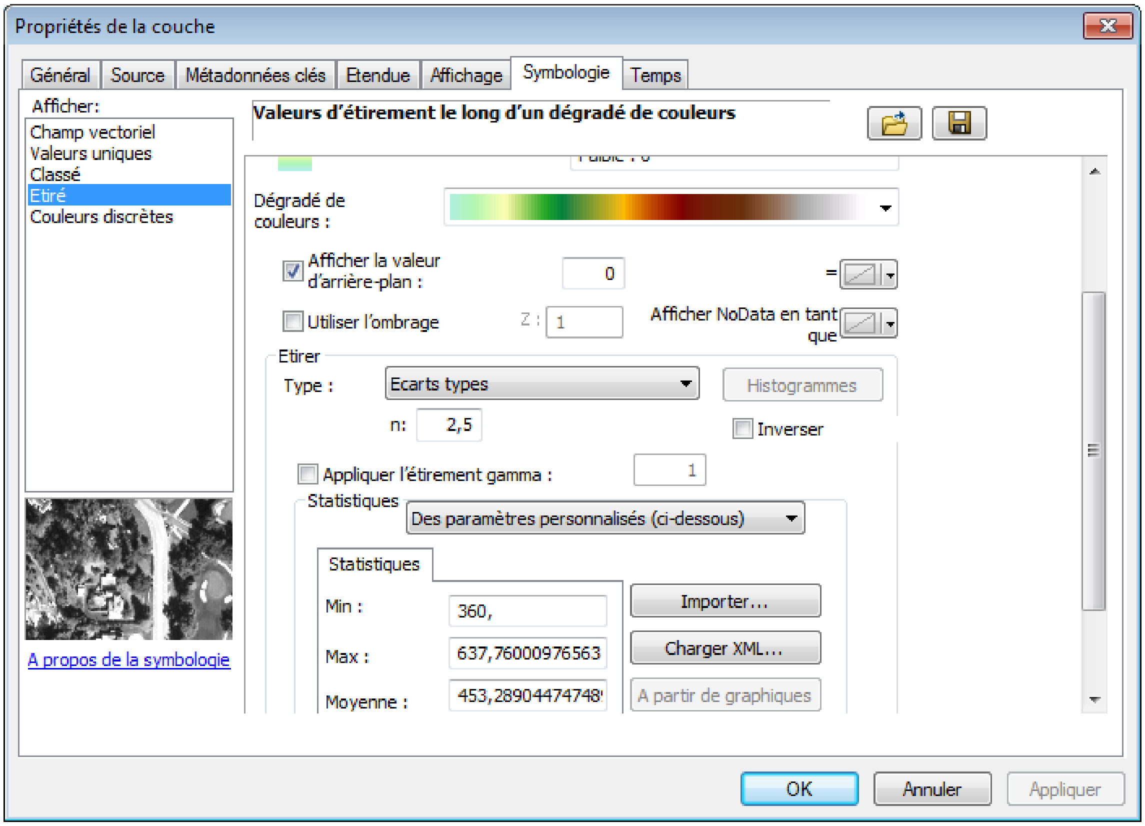
You can save the new symbology by right-clicking on the image and choosing the option "Save as layer file". You can then import this new symbology using the "import" icon.



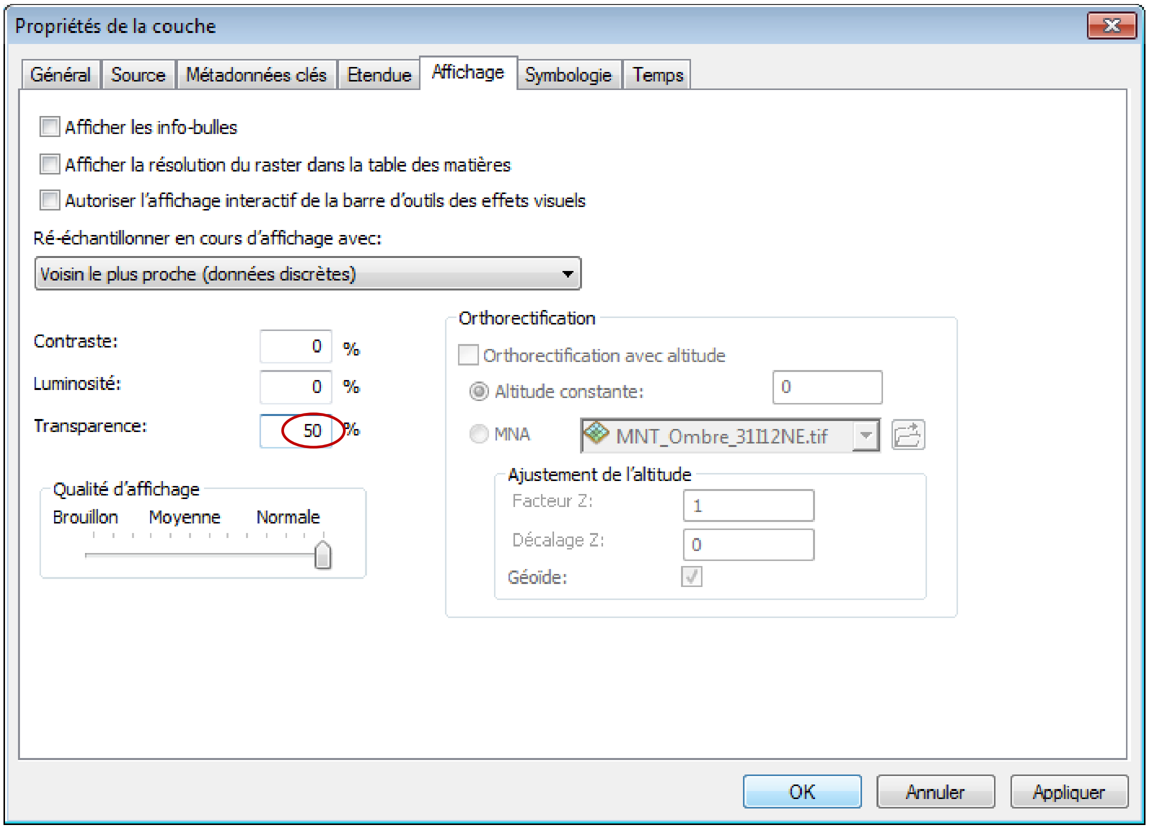
4.3. Creating a Transparent Layer of a DTM and a Hillshade

A combination of DTM and Hillshade can be used to interpret certain terrain features. To create this product, you must first modify the DTM's symbology. To do so, right-click on the layer to select its properties.

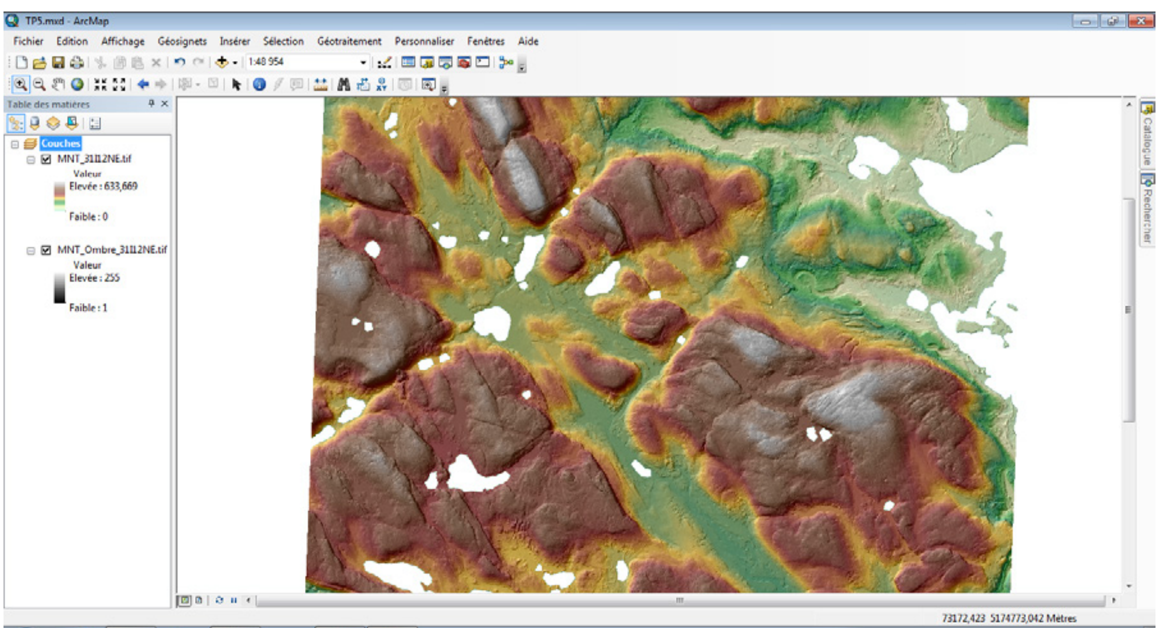
Next, select a colour ramp and set the custom settings in accordance with the raster's minimum altitudes, other than 0 (which is usually no data).



Next, go to the "Display" tab and apply a 50% transparency.



When you then overlap the DTM with the Hillshade, interpretation of the two combined layers provides information about both altitude and terrain.

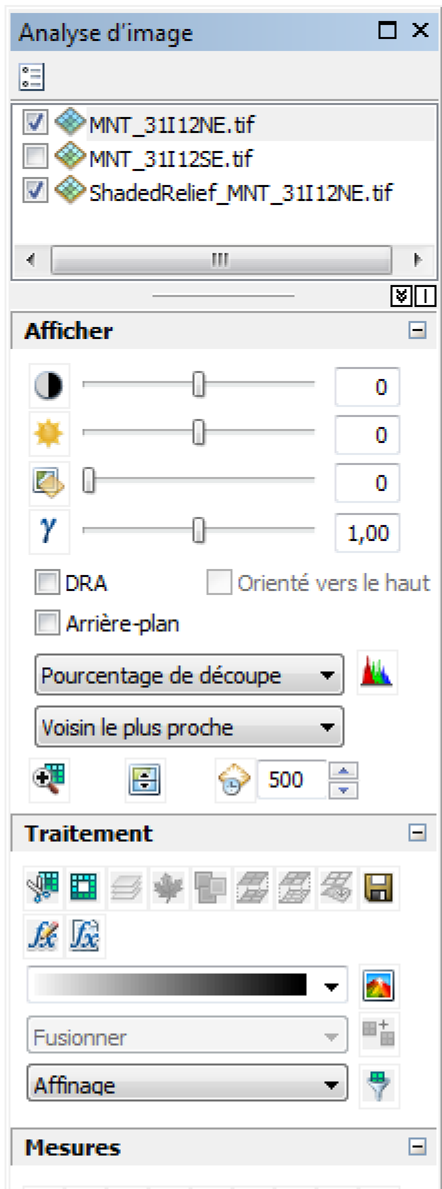


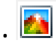
4.4. Regenerating Shaded Reliefs

The proposed shaded relief was conceived with ArcGis's default azimuth value of 315 degrees. In some cases, depending on the direction of the glaciers, it may be pertinent to generate a shaded relief at another azimuth to bring out the relief of certain structures, such as eskers.

To generate another shaded relief, you must add the DTM to ArcGIS.

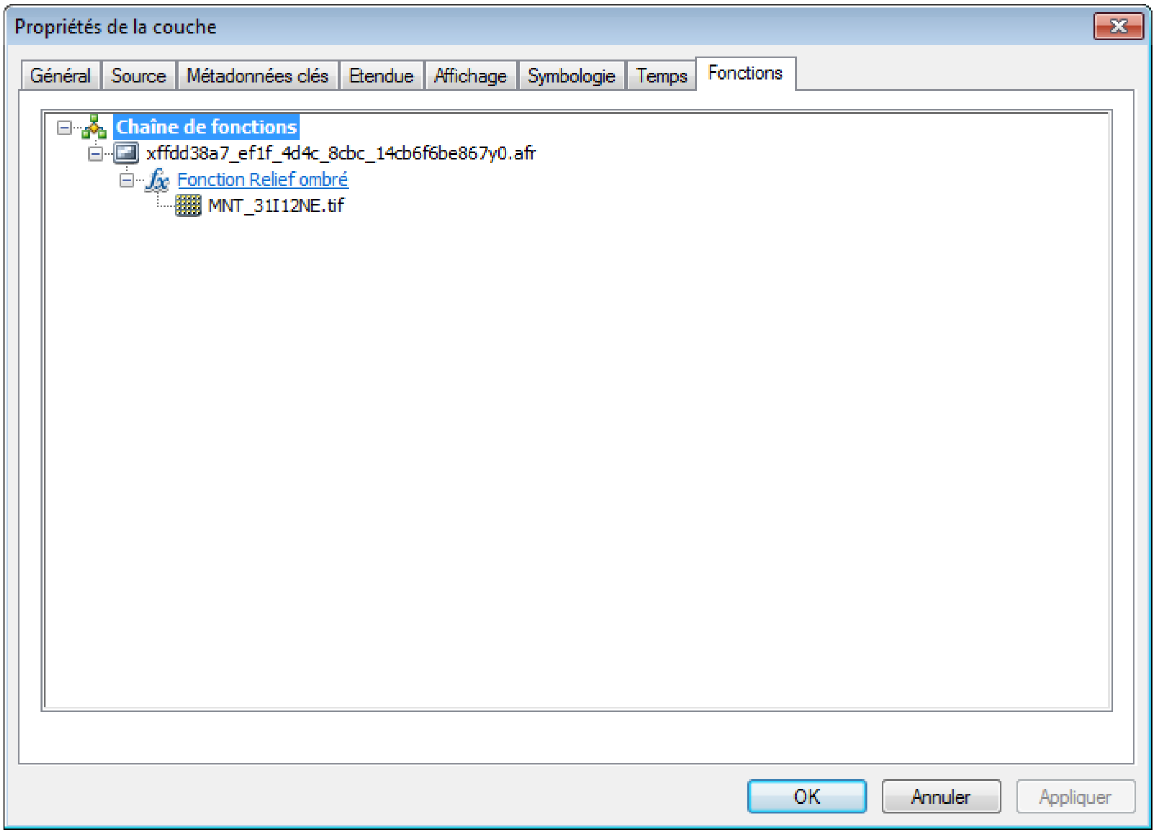
Open the image analysis window by clicking on Window/Image Analysis.



When the window appears, check the DTM to be edited, select the desired colour gradient (black and white in the example) and press the "Shaded relief:" icon. 

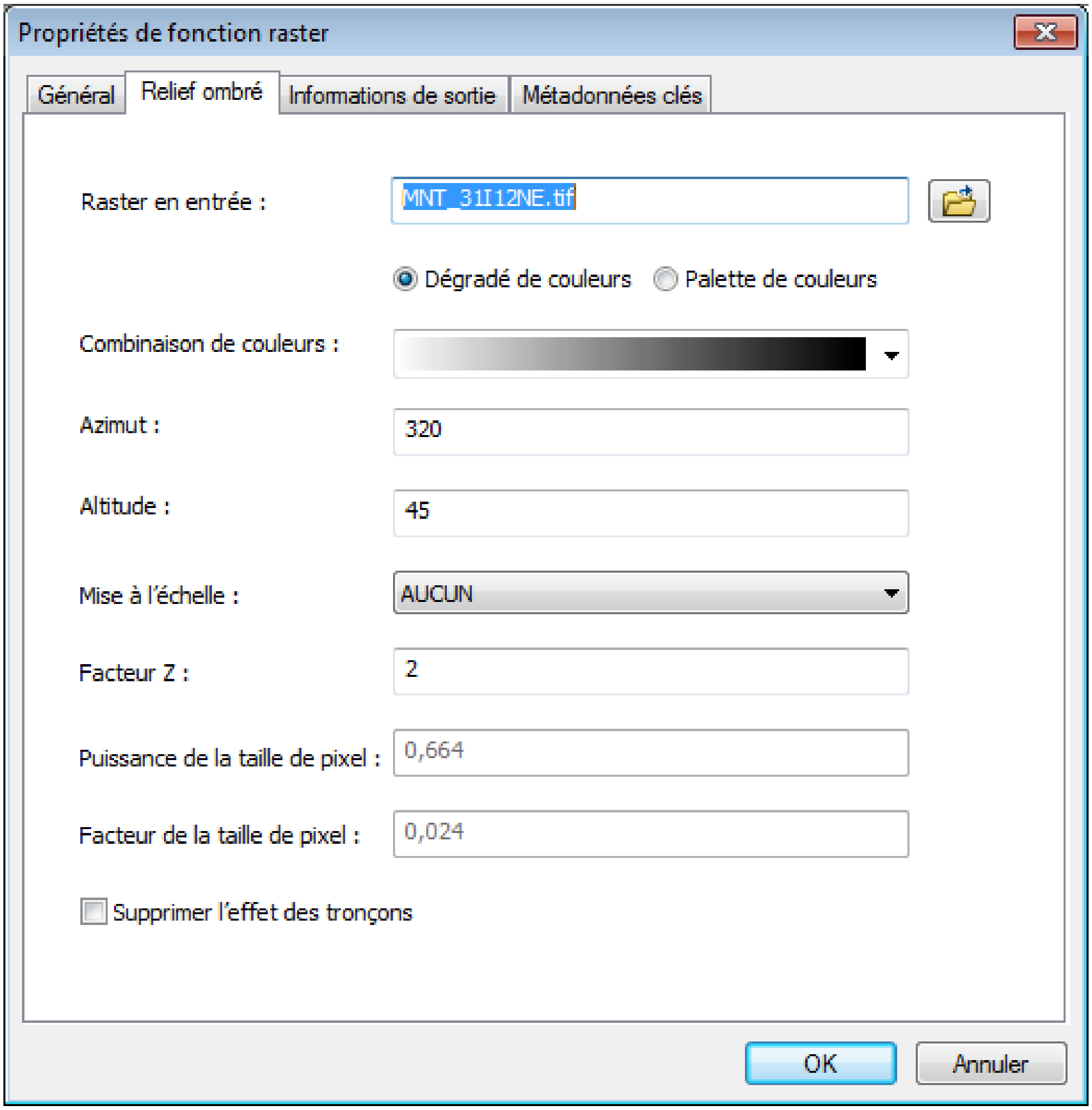
The shaded relief will appear in ArcGIS

To change the azimuth of the shaded relief, right-click on the newly-generated layer. Then click on the layer properties and select the "function" tab.



Then, right-click on the shaded relief function and click on Properties.

The following window will appear.



You can therefore change the azimuth and the Z factor. It is recommended to set the Z factor to 2.

It is preferable to set the azimuth to a value perpendicular to the land structures to be detected, as shown in the two examples below, where the angle of 320° makes it possible to identify a steep slope, something that cannot be done using an angle of 270°.

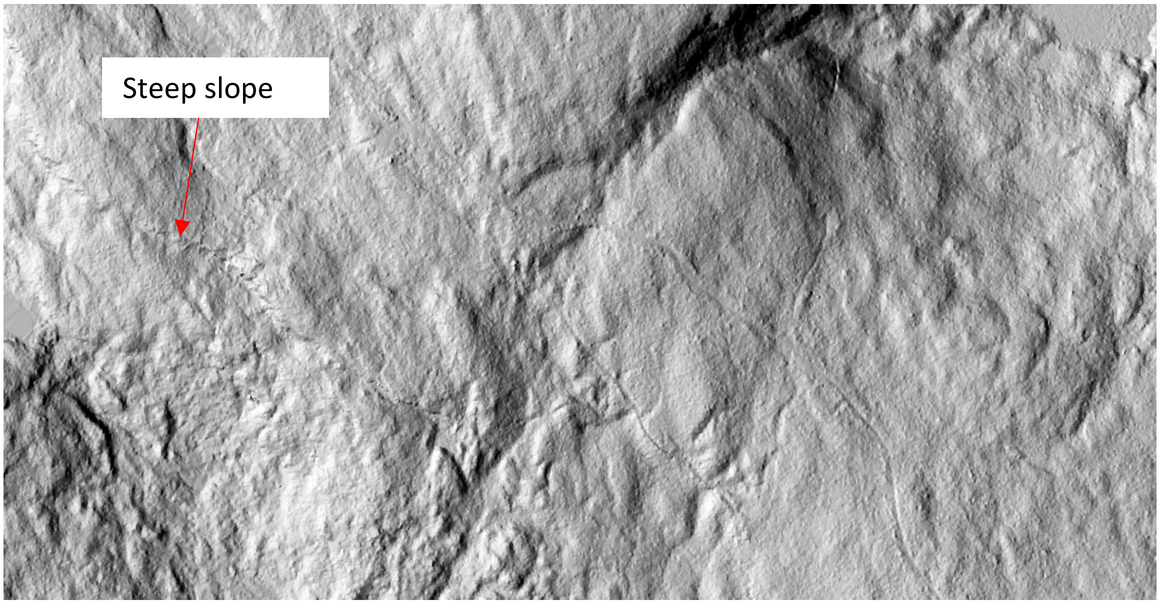


FIGURE 2. Shaded relief at 270° of azimuth and a Z factor of 2

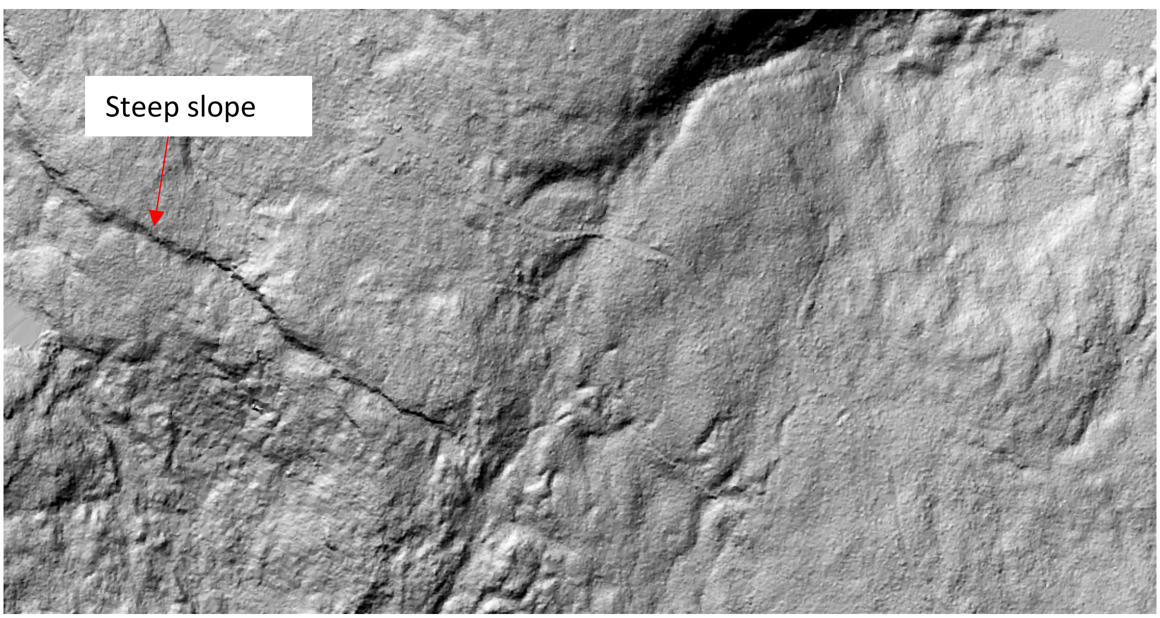


FIGURE 3. Shaded relief at 320° of azimuth and a Z factor of 2

A southern azimuth angle (e.g. 180°) should not be used, because the topography will be reversed, as in the following example.

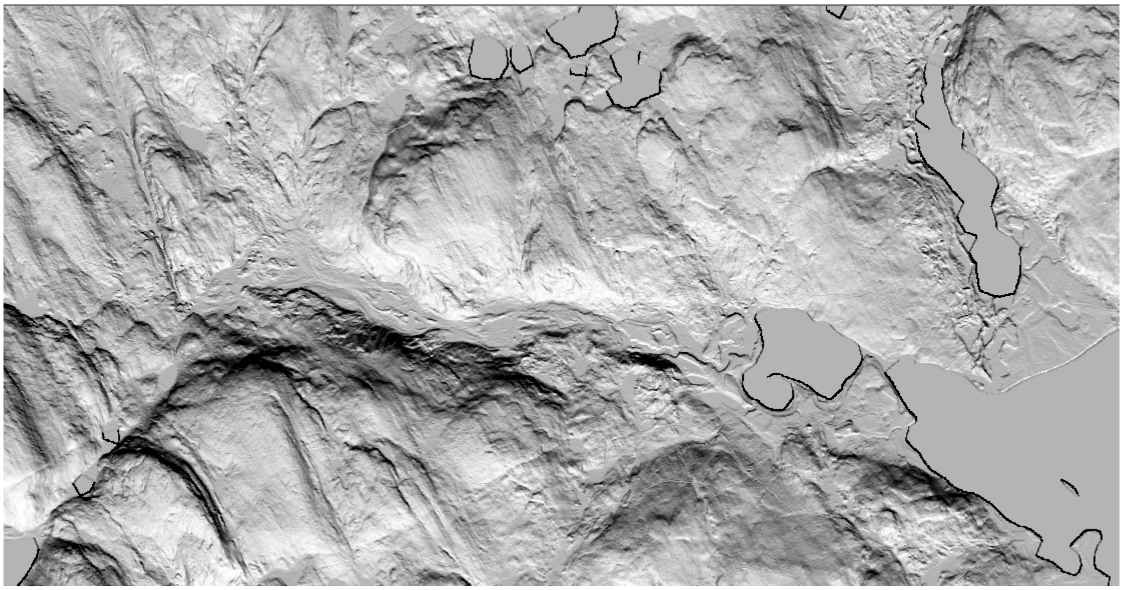
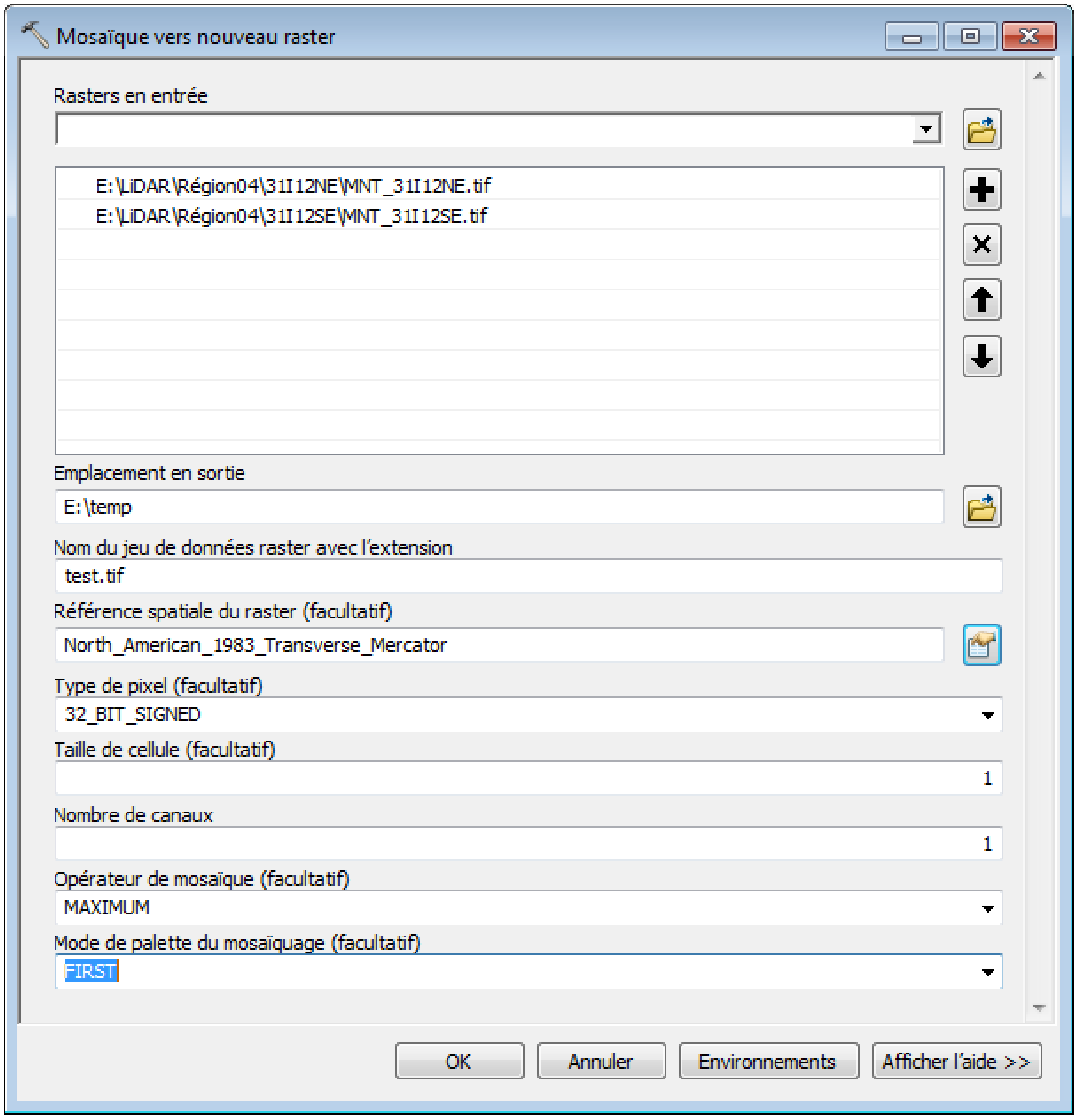


FIGURE 4. Shaded relief at 180° of azimuth (south)

4.5. Assembling Several Rasters

To assemble multiple raster images together, you can use the "Mosaic to New Raster" tool. Assembly is best done using a limited number of sheets. Over and above 10 sheets, the generated raster will probably be too large to use.



1. **Name of the raster dataset with the extension**: select the .tif images and not the .lyrs.

2. **Raster spatial reference (optional)**: the reference for one of the data layers can be selected.

3. **Pixel type (optional)**: Select 8_BIT_UNSIGNED for Shaded Relief and 32_BIT_FLOAT for the rest.

4. **Cell size**: Select the desired resolution (1 m used in this example).

5. **Number of channels**: Select 1;

6. **Mosaic operator (optional)**: Select "maximum" since the overlapping pixels are generally similar. However, other types of operators would have little impact.

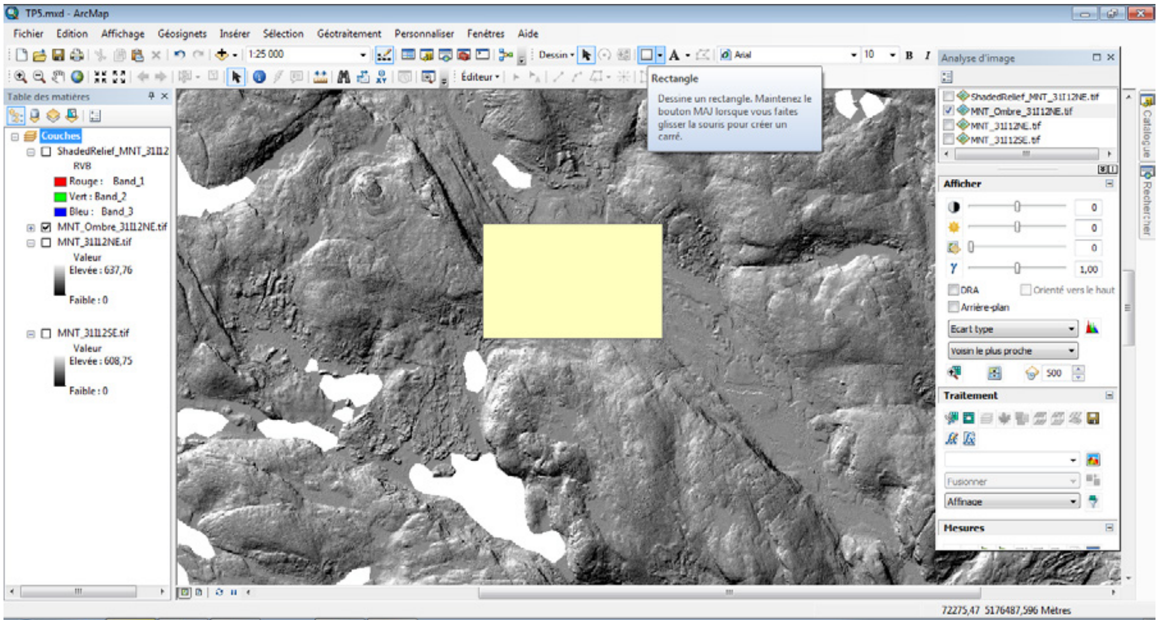
7. **Mosaic palette mode (optional)**: Select "first".

4.6. Clipping Raster Data in a Given Sector

To clip a raster, first display the raster to be clipped.

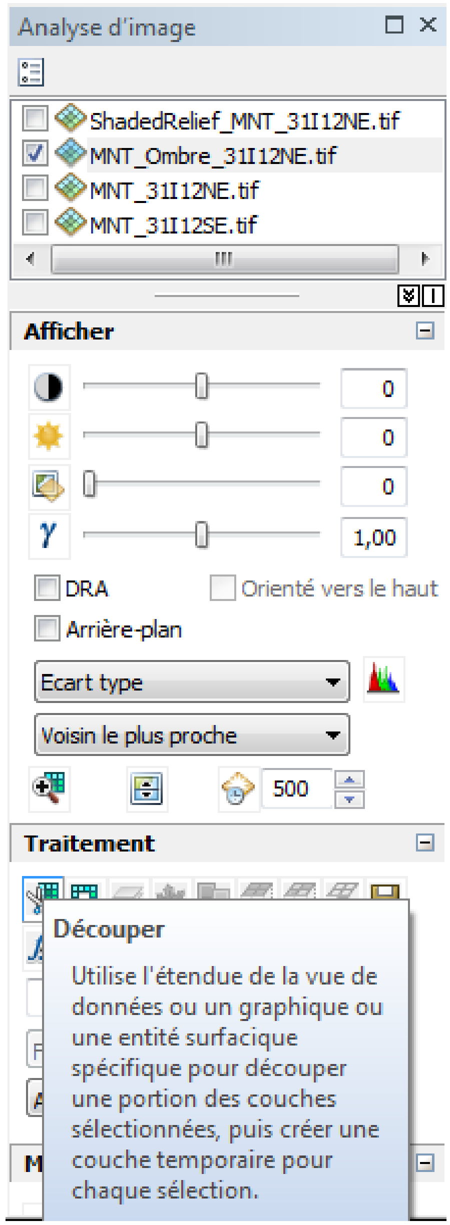
Then select Customize/Toolbars/Draw.

Use the rectangle tool to create a rectangle for clipping.

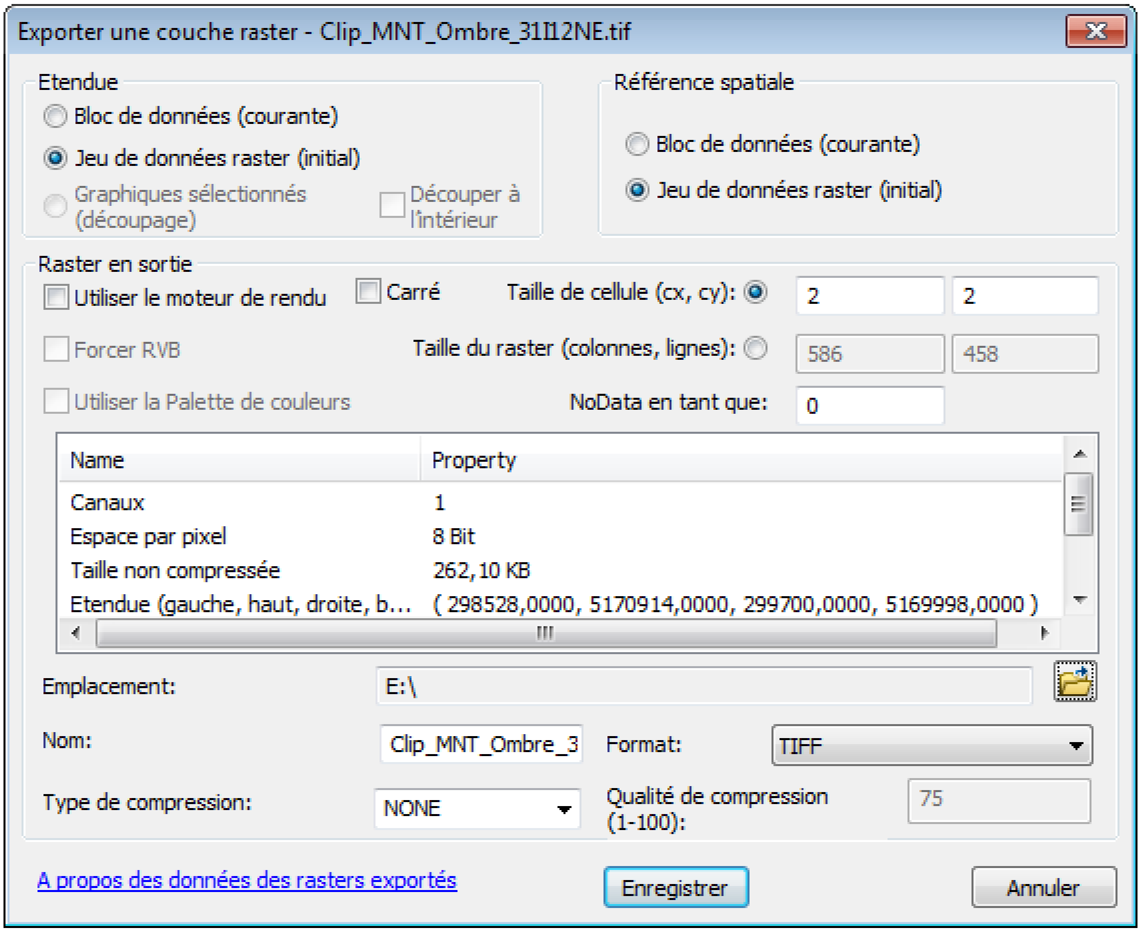


Open the image analysis window by clicking Window/Image analysis.

In the Image Analysis window, click on the Clip tool.



Lastly, right-click on the clipped image and then on Data/Export Data.



Conclusion

This document provides assistance for the use of products derived from LiDAR. However, it covers only some of the many possible manipulations. More complete versions will be published in the future. If you have comments or suggestions for improvements, please contact the Direction des inventaires forestiers.

References

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Lacroix, S. and F. Charrette. 2013. Better planning, enabled by improved forest inventory through the use LiDAR. Advantage Report. Vol. 14., No. 1, 8 p.

Sadeghi, Y., B. St-Onge, B. Leblon, and M. Simard. (2016). Canopy Height Model (CHM) Derived from a TanDEM-X InSAR DSM and an Airborne Lidar DTM in Boreal Forest. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 9(1):381-397.