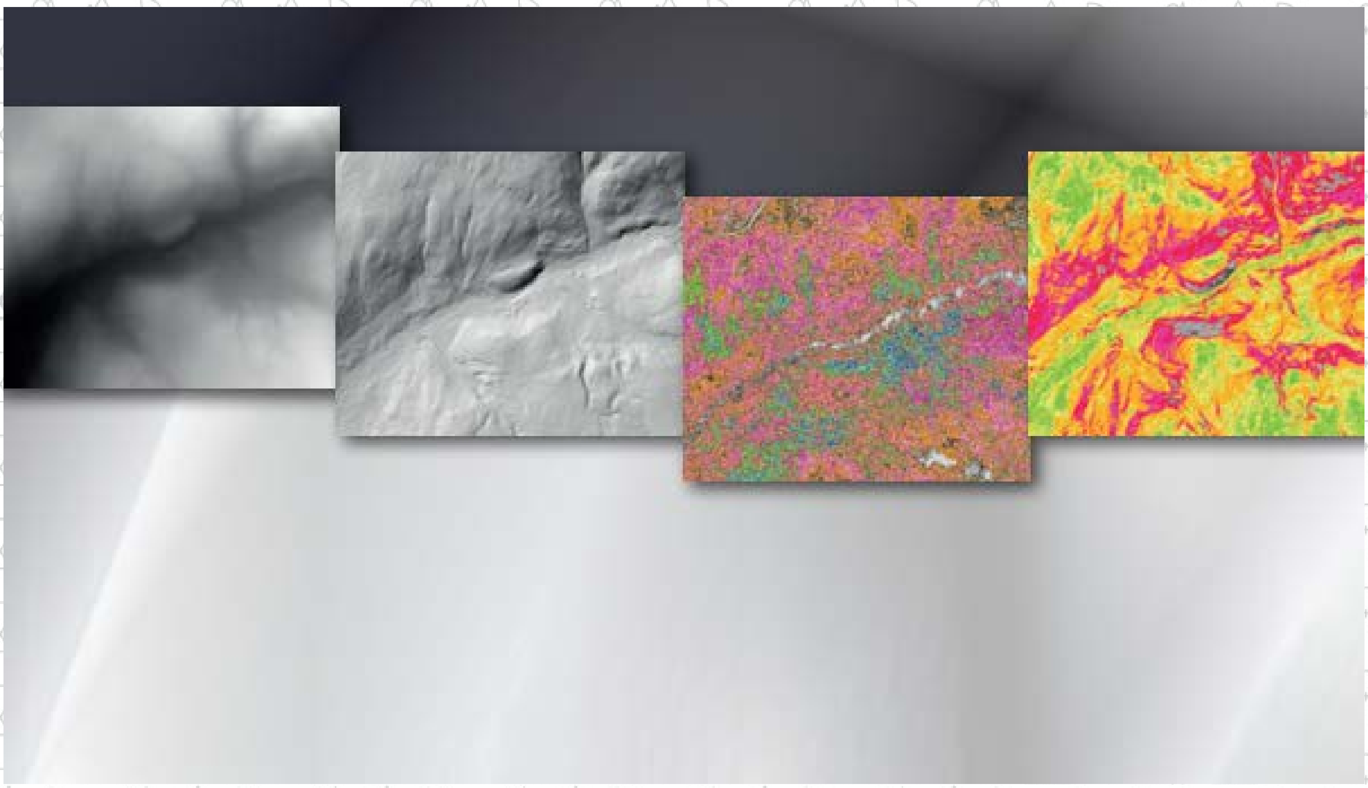
User’s Guide: Products Derived from LiDAR Data - 2nd edition

March 2021

MINISTÈRE DES FORÊTS, DE LA FAUNE ET DES PARCS



Votre gouvernement

Québec

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Legal Deposit – Bibliothèque et archives nationales du Québec, 2021
ISBN 978-2-550-88939-7 (2nd edition, 2021)
ISBN 978-2-550-77405-1 (1st edition, 2016)

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Table of Contents

INTRODUCTION

It has often been shown that the information obtained from aerial LiDAR[6] surveys generates significant economic benefits for the forest industry and for several other Québec government activity sectors (Lebœuf et al., 2015[7]). 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 therefore to:

i) present the basic products derived from LiDAR data that are available as open source data;
ii) explain the basic tools that facilitate their use in **ArcGIS**;
iii) explain the basic tools that facilitate their use in **QGIS;**
iv) present the tools that can be used to develop new derived products (e.g. generate contour lines, convert rasters to polygons, fill lakes, delimit drainage basins (watersheds), reclassify rasters, generate a focal CHM, generate a topographic wetness index, etc.).

[6] LiDAR: *Light Detection and Ranging*.
[7] Available online: https://mffp.gouv.qc.ca/documents/forets/inventaire/Analyse_retombees_LiDAR-Finale.pdf

1 LiDAR DERIVED PRODUCTS

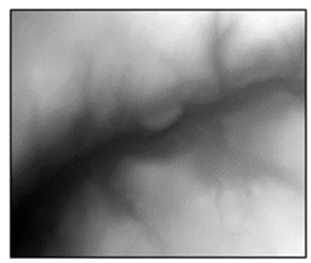
The four basic products derived from LiDAR data are the: 1) Digital Terrain Model (DTM), 2) Hillshade (Shaded Relief), 3) Canopy Height Model and 4) Slope Model. These products are in raster format and can easily be viewed in most basic GIS software packages, including ArcGIS and QGIS.

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	Modified Transverse Mercator (MTM)
Production method	Processed using Lastools, R, Gdal and ArcGIS
Data-viewing software	ArcGIS, QGIS, MapInfo, etc.

1.1 DIGITAL TERRAIN MODEL (DTM)

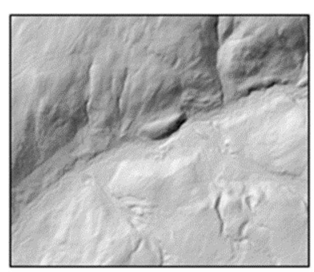
This raster file provides real numerical values representing altitudes in metres relative to the mean sea level. The raster file's pixel elevation values correspond to the linear interpolation of the network of irregular triangles created from the ground points. The spatial resolution of this raster is 1 metre.



The DTM is a basic product derived from LiDAR. It serves primarily to create the Hillshade and Slopes. It is also used for hydrological models, road construction, flood risk management, visual landscape analyses, and so on.

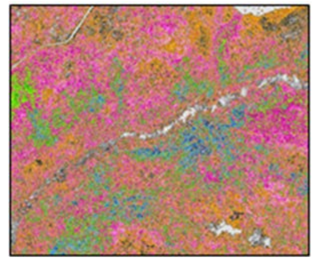
1.2 HILLSHADE (SHADED RELIEF)

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 grey associated with integers from 0 to 255 (from black to white). The spatial resolution of this raster is 2 metres.



A hillshade presents a very detailed image of the terrain and can be used for the identification and interpretation of surficial 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, basal areas, etc.

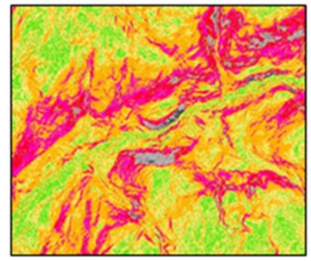
It should be noted that different elements must be taken into account before using the CHM to evaluate the height of trees or vegetation:

1. Tree heights are generally slightly 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 “reserve faunique des Laurentides” showed an underestimation of -0.98 metres 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 if any adjustments to the data set are necessary.

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 smaller in width 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 a certain expertise is required to integrate tree heights derived from a CHM to forest stand polygons. 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 Model (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][8]3 to 8 %], C]8 to 15 %], D]15 to 30 %], E]30 to 40 %], F]40 to 50 %], X1]50 to 70 %], X2]70 % and +].

The slopes map can be used as a support tool for forest operations or roads construction.

[8] The open bracket shows that the value is excluded from the class.

2 Availability of LiDAR Derived Products

The first areas benefiting from LiDAR derived products in 2016 were the Saguenay – Lac-Saint-Jean region (UA 024-51), Mauricie region (UA 041-51) and the entire Outaouais region. In the following years, several other regions of Québec were also able to benefit from these products. LiDAR products are expected to be available for all of southern Québec by the end of 2022. For information on the areas for which products will be released in the future, please refer to the LiDAR product availability schedule at:

https://mffp.gouv.qc.ca/wp-content/uploads/Disponibilite_produits_derives_LiDAR.pdf

3 ACCESS TO LIDAR DERIVED PRODUCTS

LiDAR derived products are available free of charge and can be viewed or downloaded through three different ways.

A) Through the *Forêt ouverte* interactive map, users can **view** different basic LiDAR products and **download them free of charge**. To do this:

1. Access the interactive map: https://www.foretouverte.gouv.qc.ca;
2. In the menu, click on the "Cartes prédéfinies (Map themes)" tab.
3. Choose the "LiDAR" theme.
4. View the layers of your choice by clicking on the eye (it must be green).
5. If the eye next to a layer is grey, zoom in.
6. To download LiDAR derived products, display the layer "LiDAR — Téléchargement (pleine qualité)" and click on the map sheet you wish to download.
7. If layers are superimposed, select the "LiDAR — Téléchargement (pleine qualité)" layer in the new window that opens at the bottom of the screen.
8. Select a product by clicking on the "Accéder" button.

B) You can also view and download the data in a GIS (geographic information system) from the following Web map service (WMS):

https://geoegl.msp.gouv.qc.ca/ws/mffpecofor.fcgi?

C) It is also possible to download these products directly from the Données Québec website (the gouvernement du Québec collaborative, open data internet portal). To do this:

1. Refer to the "Données Québec" LiDAR fact sheet. This fact sheet also contains other information pertaining to the use of these products, including metadata (year of acquisition, point density and presence of leaves).

2. Directly access the data directory, where data is categorized by map sheet: https://diffusion.mffp.gouv.qc.ca/public/Diffusion/DonneeGratuite/Foret/IMAGERIE/Produits_derives_LiDAR/.

4 Raster Data in ArcGIS

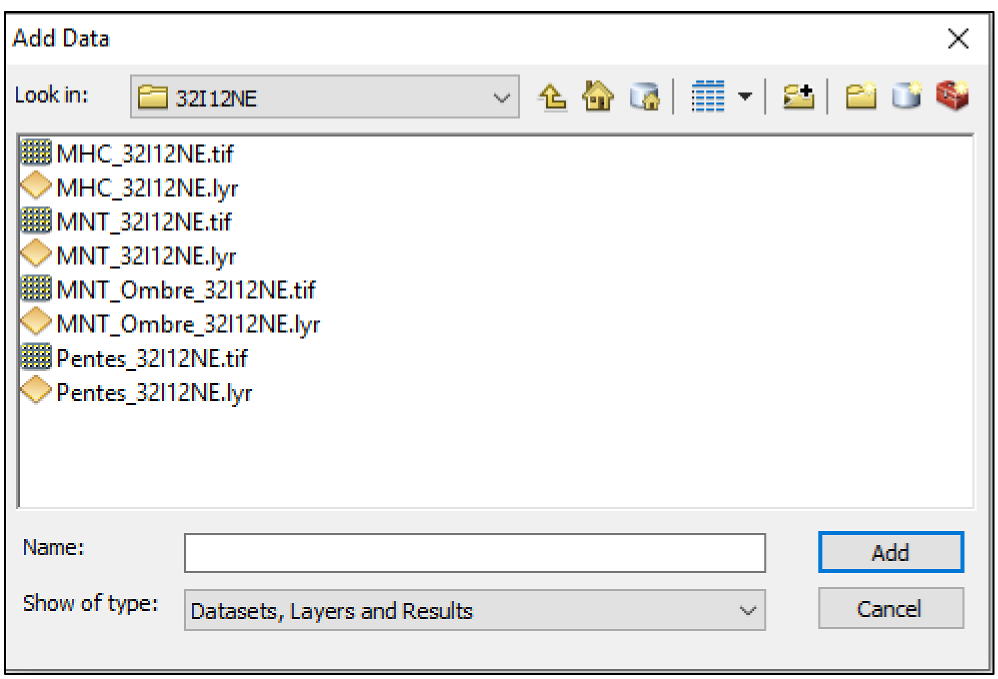
This section covers basic operations used to facilitate the use of LiDAR derived products with the commercial software package ArcGIS. While these techniques can all be used with other GIS software, the procedures will differ from one to another (operations for QGIS are described in Chapter 5). Also, take note that the proposed ".lyr" symbology will not work with other GIS applications.

4.1 Basic Features

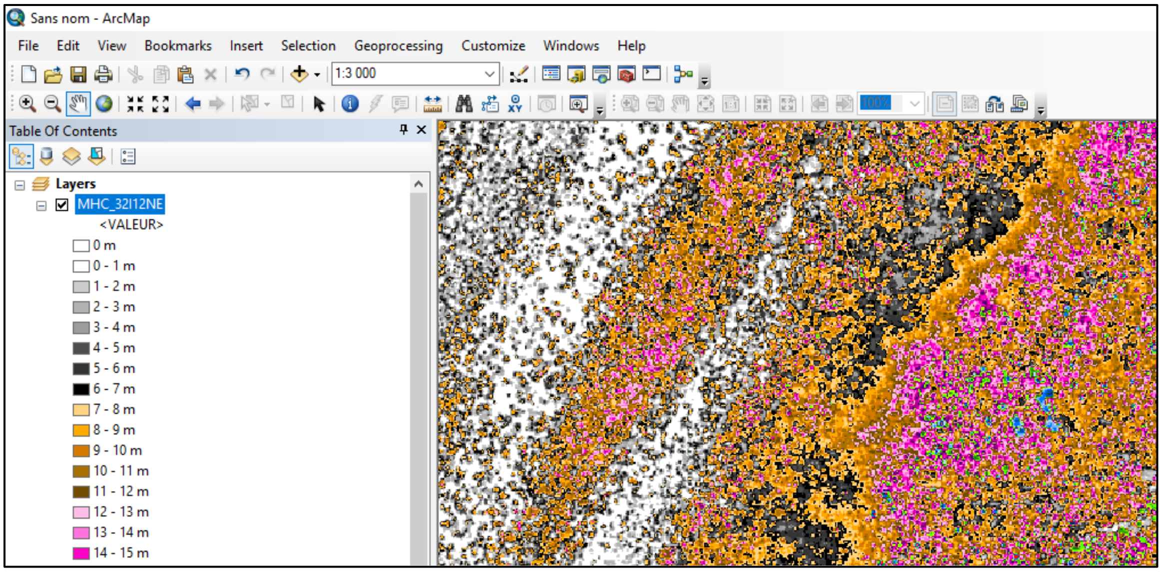
4.1.1 View Raster Data

Once you have downloaded the LiDAR derived products (see chapter 3), you can open the files in ArcGIS by clicking on the "Add Data" button.

In the following window, select the ".tif" file of the map sheet you wish to view, or select the ".lyr" file to view the symbology proposed with the data (Note: MHC = CHM, MNT = DTM, MNT_Ombre = Hillshade and Pentes = Slopes).

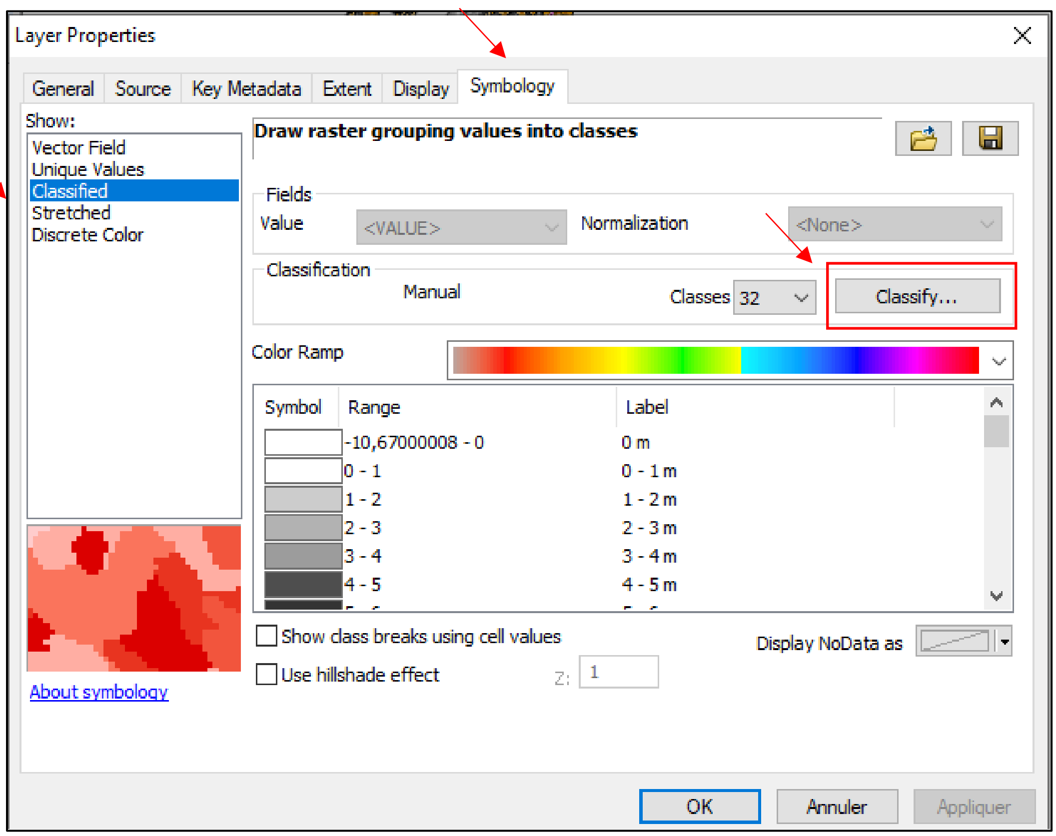


The proposed symbology will appear if you selected a ".lyr" file.

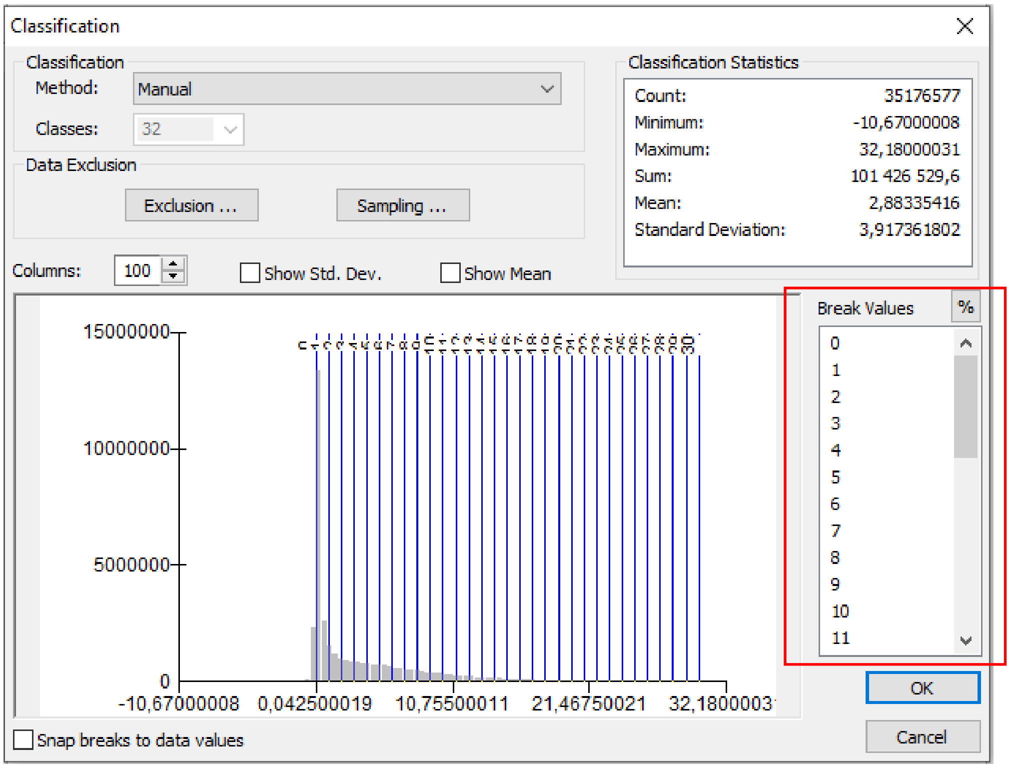


4.1.2 Change the Symbology and Select Classes

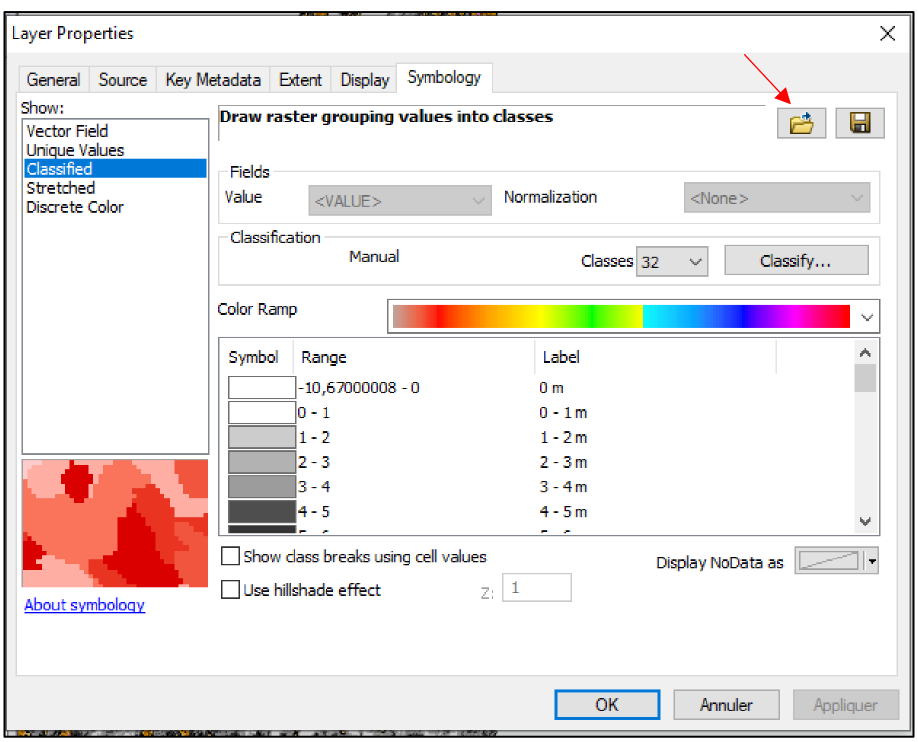
To modify the proposed symbology, place the cursor over the layer name, right-click and select the layer's properties. The following window will appear. In the "Symbology" tab, click on "Classified" to change the number of classes. Then click on "Classify ..." to change the class break values.



The following window will open where you can change the class break values.



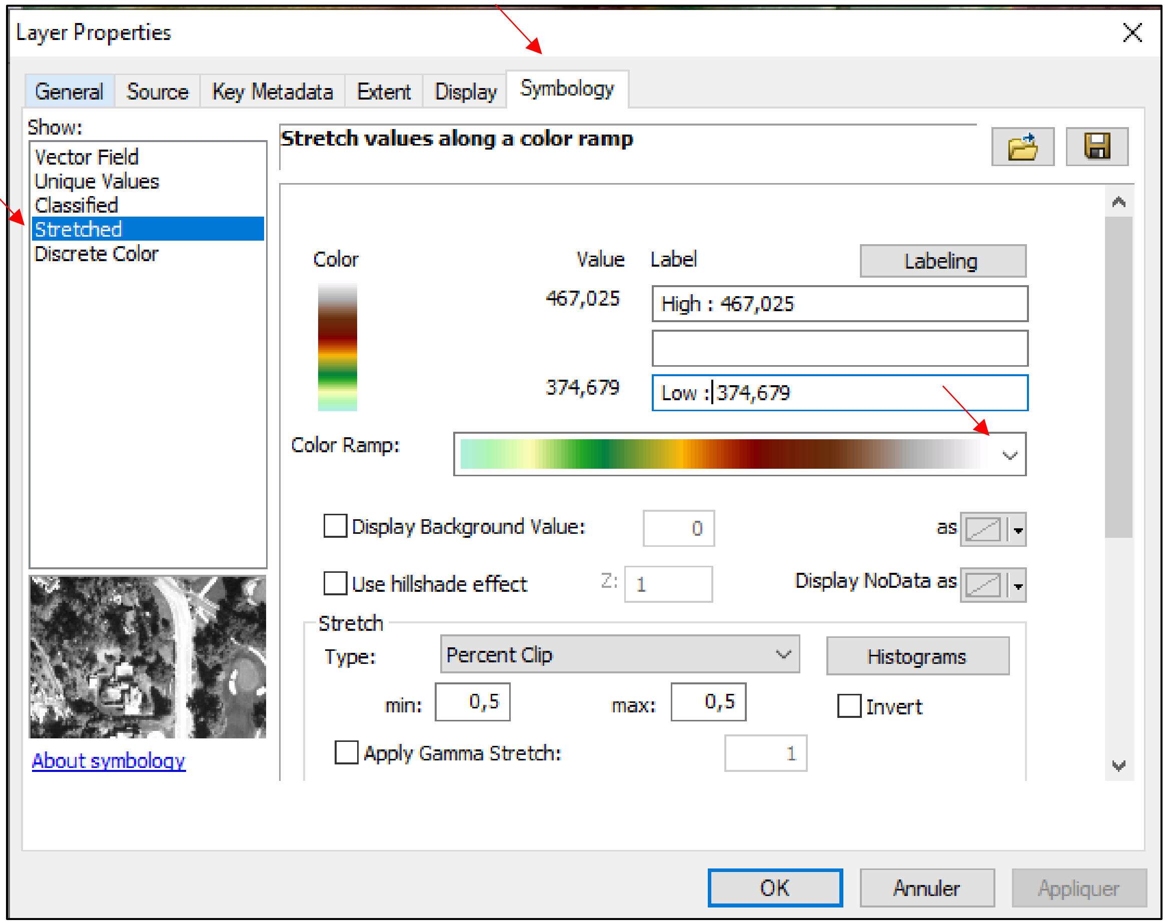
To save the new symbology, place the cursor on the layer name, right-click and select "Save as layer file". You can then import this new ".lyr" symbology using the "Import" icon, as shown on the following image.



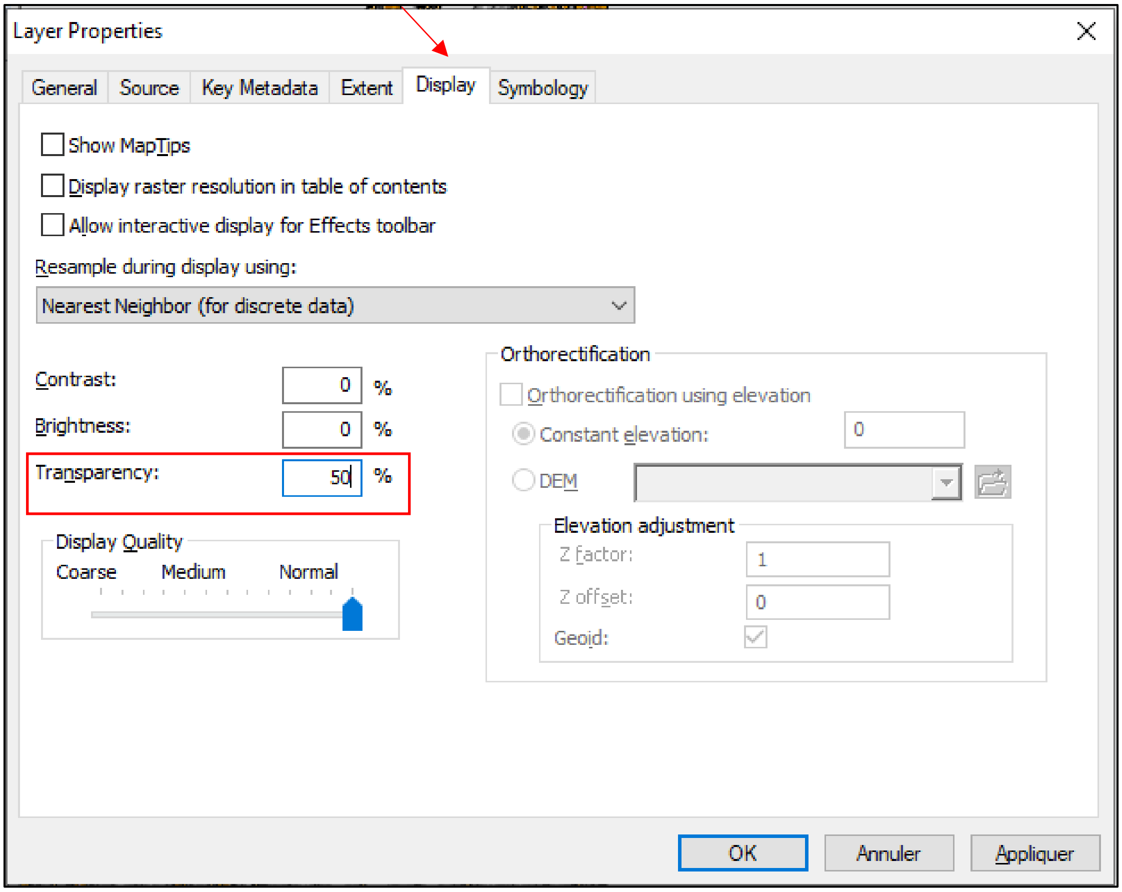
4.1.3 Create a Transparent Layer of a DTM Combined With a Hillshade

Combining a DTM and a Hillshade can be used to interpret certain terrain features. First, you must modify the DTM's symbology. To do so, position the cursor on the layer name and right-click to select the layer's properties.

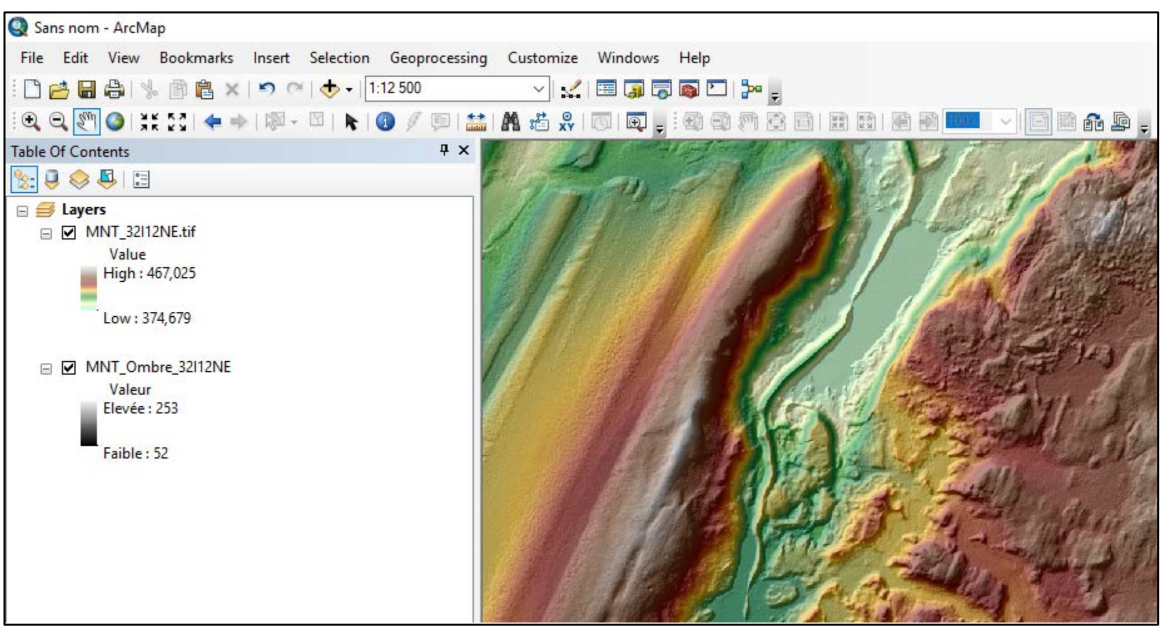
Next, in the "Symbology" tab, select the "Stretched" category and choose a color ramp. You can also import the DTM's ".lyr" to apply the predefined symbology (see section 4.1.1).



Next, go to the "Display" tab of the layer's properties window and apply a 50 % transparency.



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

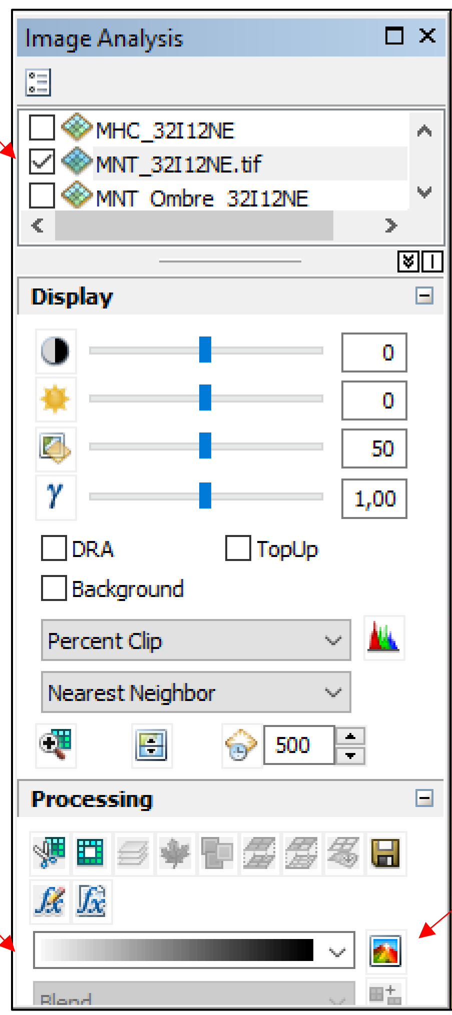


4.1.4 Create a Hillshade from a DTM

The proposed Hillshade was designed with ArcGIS's default azimuth value of 315°. In some cases, depending on the direction of the glaciers, it may be appropriate to generate a hillshade at another azimuth for the relief of certain terrain structures to stand out, such as eskers.

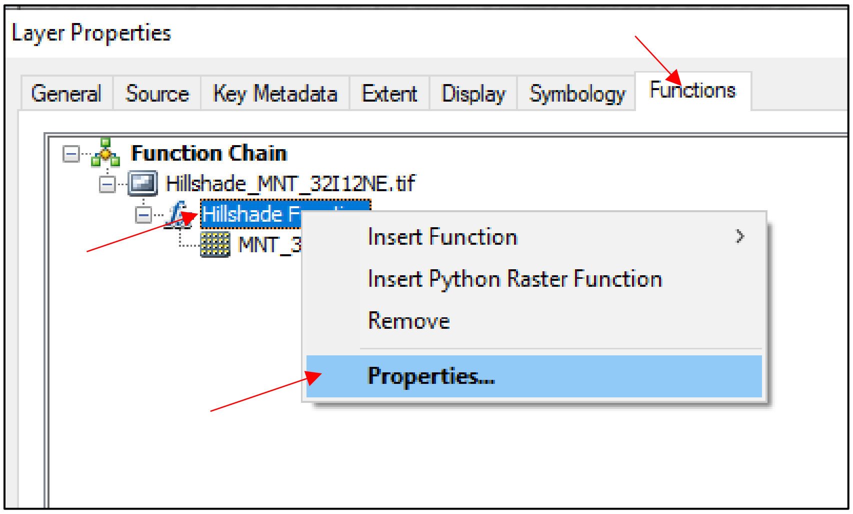
To generate a new hillshade, you must add the DTM to ArcGIS. Next, open the image analysis window by clicking on "Windows" and then "Image analysis".

When the window appears, check the DTM to be edited. In the "Processing" section, select the desired colour gradient (black and white in the following example) and click on the "Hillshade" icon: 

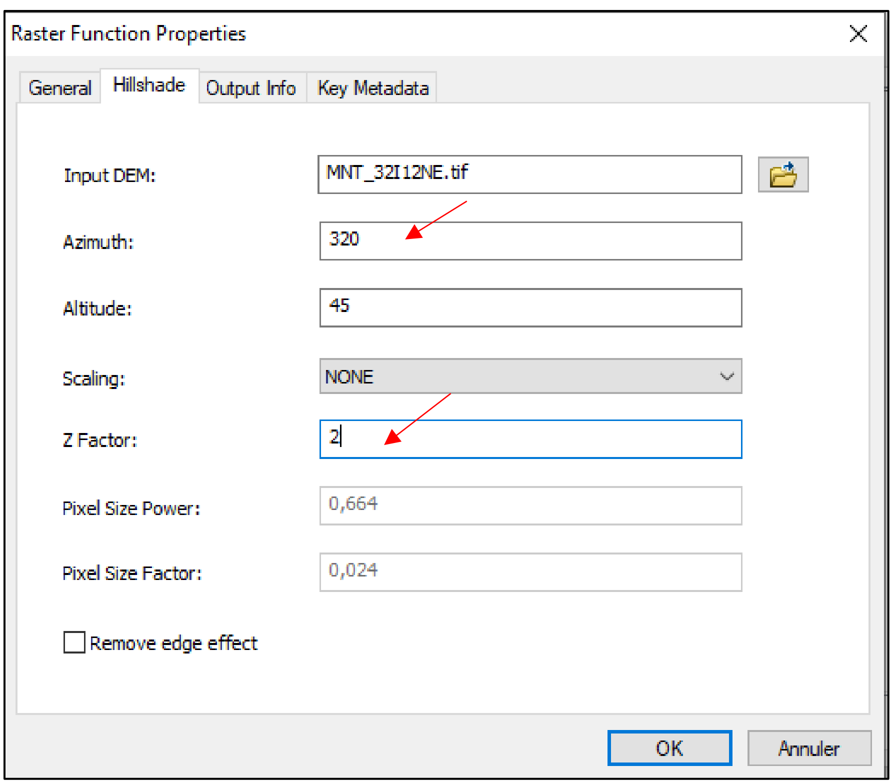


The hillshade will appear in ArcGIS.

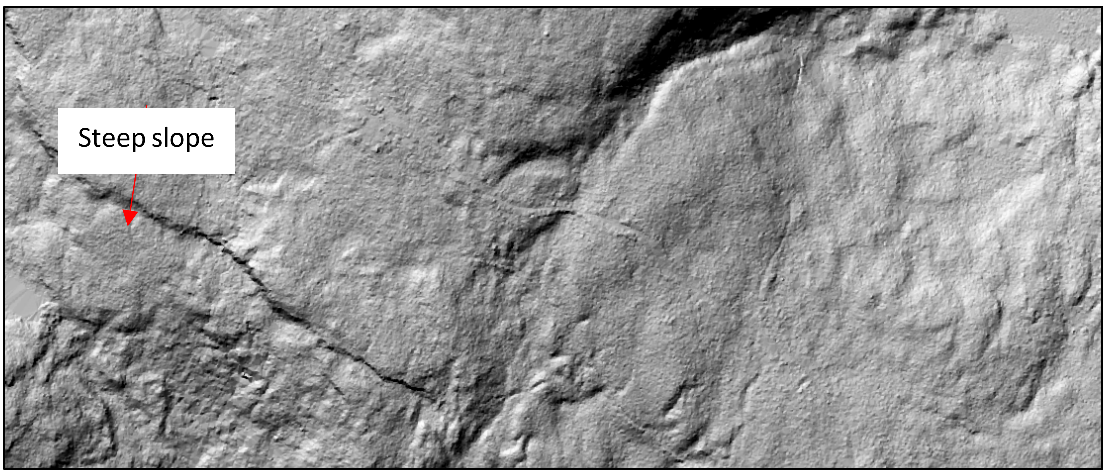
To change the azimuth of the hillshade, place the cursor on the name of the newly generated layer and right-click to select the layer's properties. Select the "Functions" tab, place the cursor on the hillshade function, right-click and then click on "Properties".



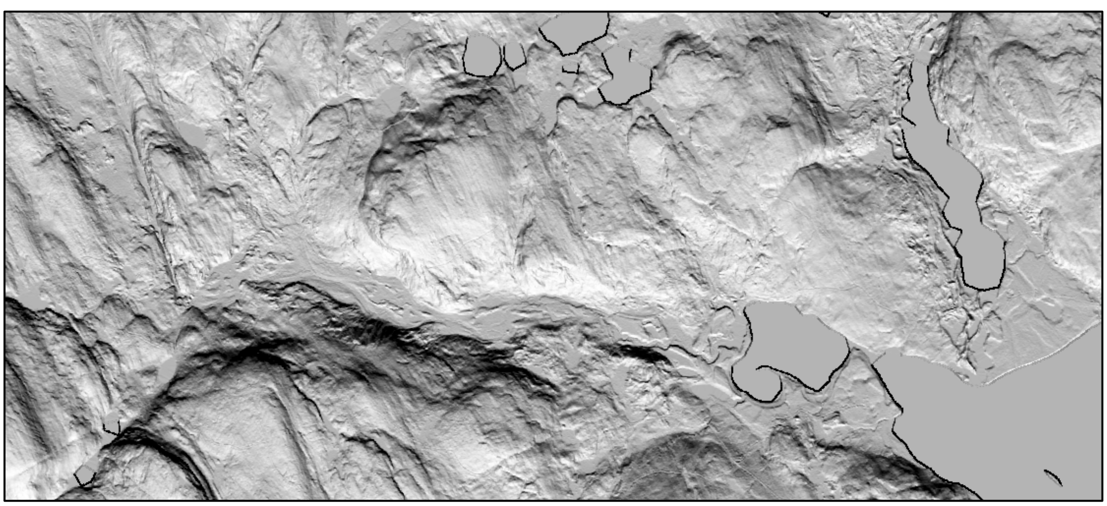
The following window, in which you can change the azimuth and Z factor in the "Hillshade" tab, will appear. We recommend that the Z factor be set to 2. It is preferable to set the azimuth to a value perpendicular to the land structures to be detected, as shown in the two examples below, where the angle of 320° makes it possible to identify a steep slope, something that cannot be done using an angle of 270°. A southern azimuth angle (e.g. 180°) should not be used because the topography will be reversed, as in the third example below.



Example 1: Hillshade with a 270° azimuth and a Z factor of 2.



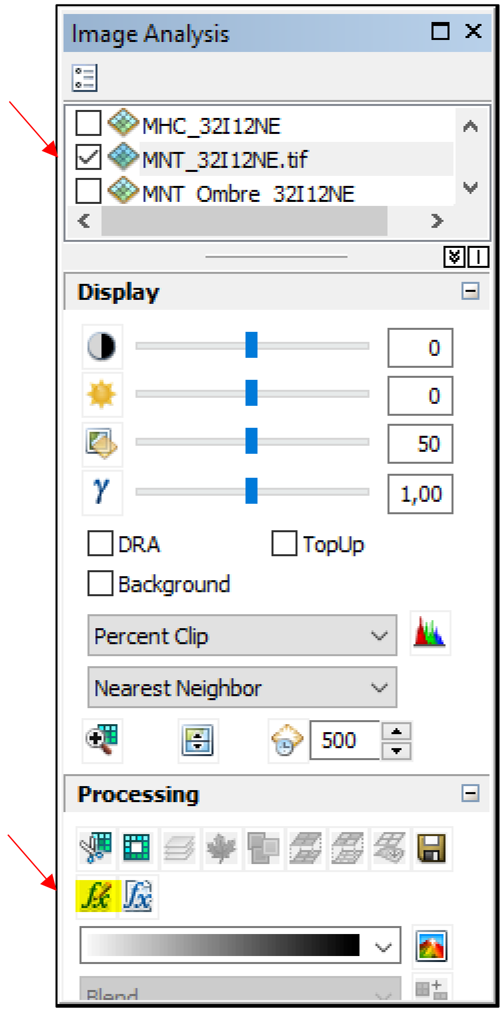
Example 2: Hillshade with a 320° azimuth and a Z factor of 2.



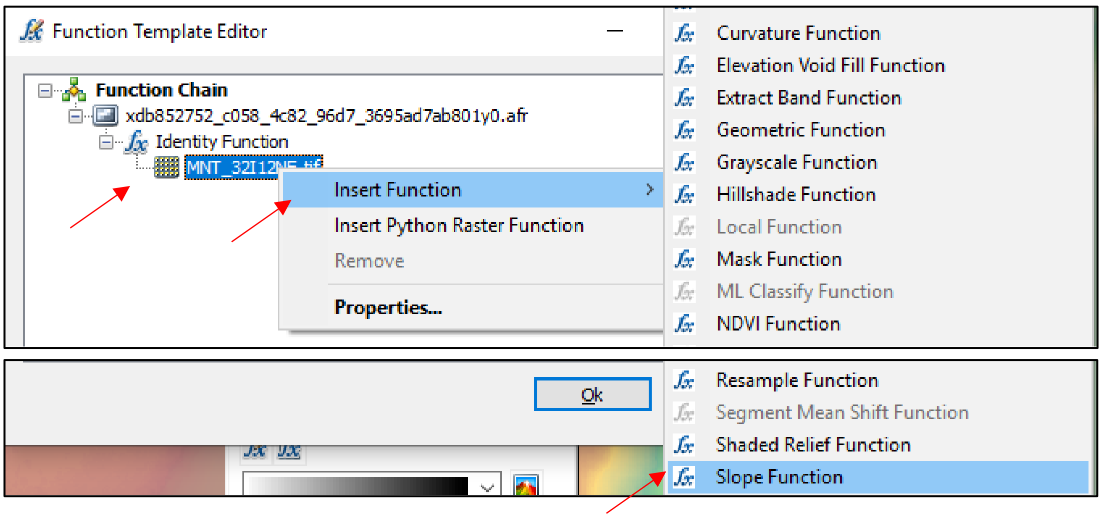
Example 3: Hillshade wtih a 180° azimuth (south) showing reversed topography.

4.1.5 Create a Slope Model

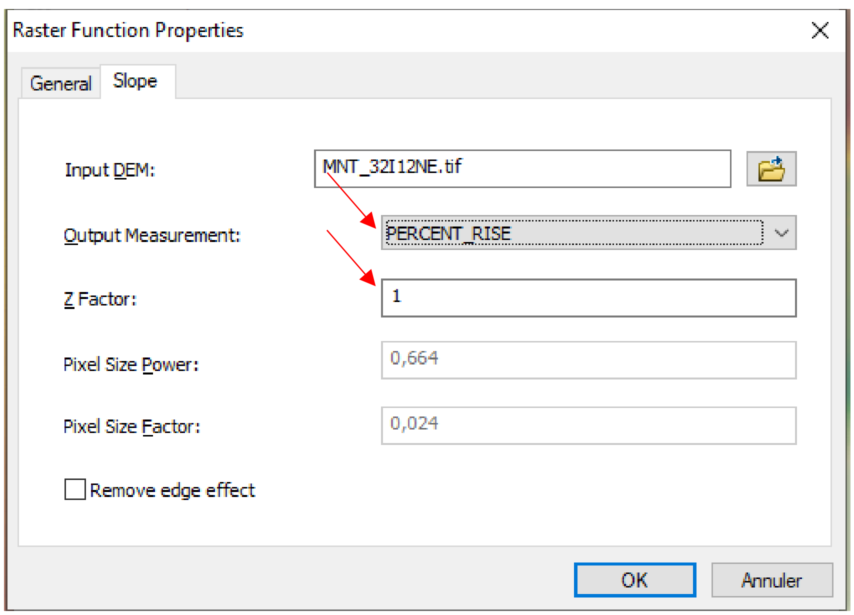
To create a slope model, a DTM must be added to the map's table of contents. Next, click on "Windows" in the toolbar and select "Image Analysis". When the window opens, select the DTM on which you wish to work and then click the "Add a function" button (in yellow in the image below) in the "Processing" section.



A new window will open. Place the cursor on the DTM, then right-click and select "Insert Function". Select "Slope Function" from the list of functions.



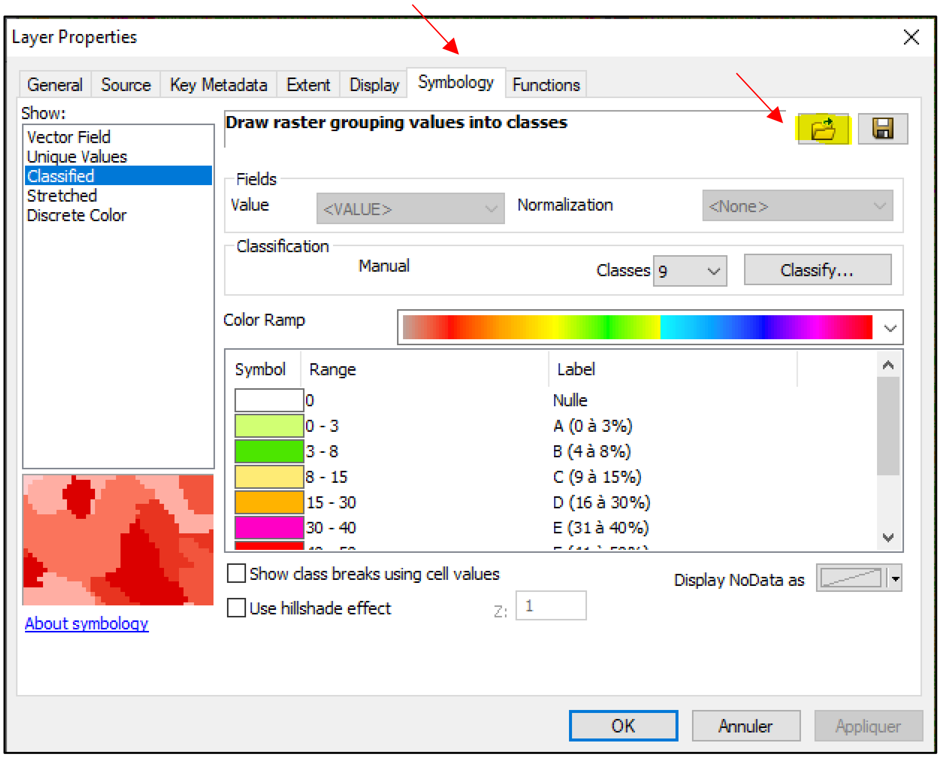
A new window will open where you should select PERCENT_RISE as the output measure. Leave the Z factor at 1 and click on OK.



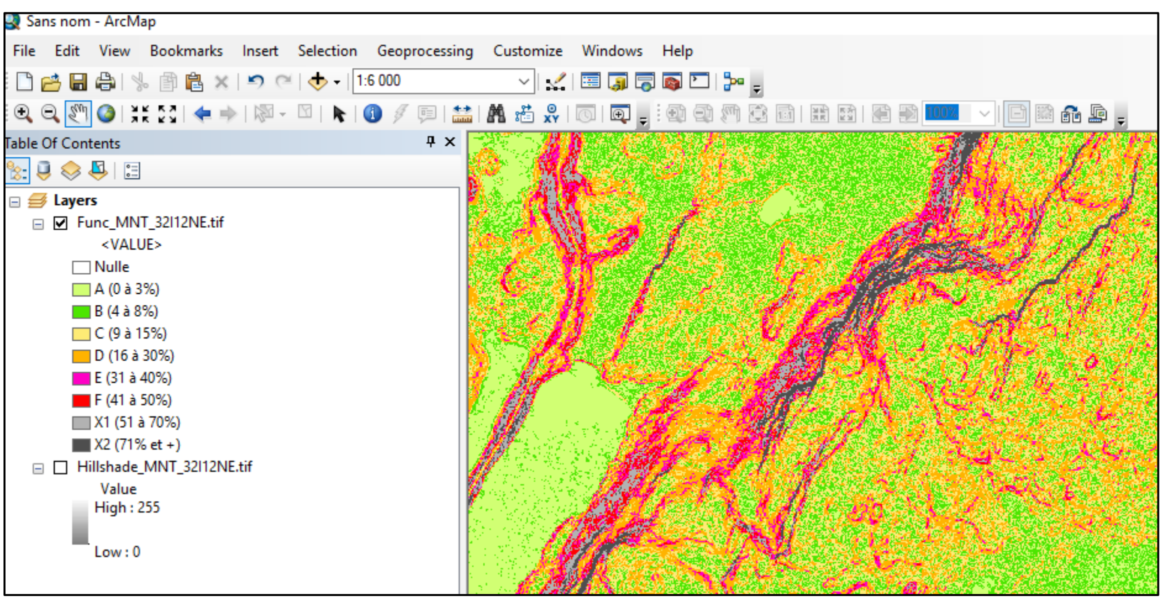
Then click on OK in the "Function Template Editor" window, and you will obtain a black-and-white slope model. You can change the symbology (see section 4.1.2) or apply a ".lyr" file containing the desired symbology (see section 4.1.1 or next page). You can downlowd the proposed ".lyr" for slopes from the "Symbologie.zip" file at:

https://diffusion.mffp.gouv.qc.ca/public/Diffusion/DonneeGratuite/Foret/IMAGERIE/Produits_derives_LiDAR/

To change the symbology, right-click on the layer you have created and select "Properties" to open its properties. In the "Symbology" tab, click on the "Import" button (in yellow in the image below), then select the ".lyr" file containing the symbology (e.g. "Pentes_32I12NE.lyr") and click on OK.

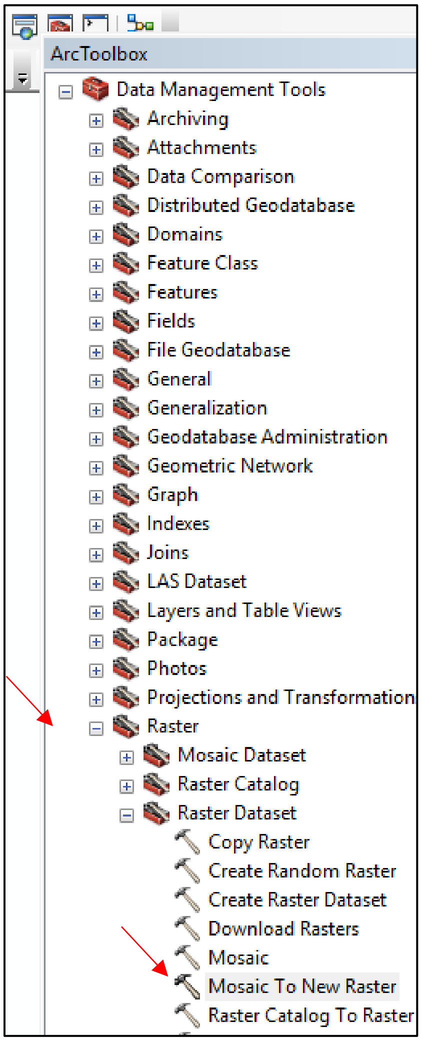


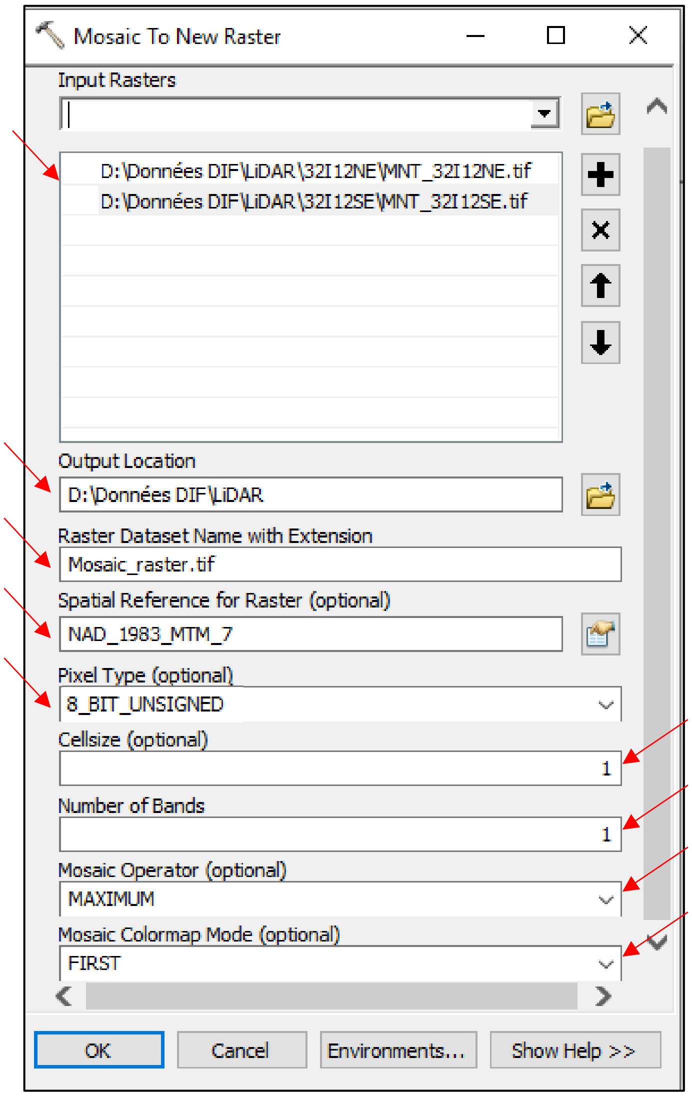
This will give a slope layer with the desired symbology, similar to the image below. In the proposed symbology for slopes, the upper value of each class is included, e.g. the 0 to 3 % includes the value 3.000000 %, and the 3 to 8 % class starts at 3.000001 % and includes the value 8.000000 %.



4.1.6 Assemble Several Rasters

To assemble multiple raster images together, you can use the "Mosaic to New Raster" tool by clicking on "Data Management Tools > Raster > Raster Dataset > Mosaic To New Raster" in ArcToolbox. Assembly is best done using a limited number of map sheets. With more than 10 map sheets, the generated raster will probably be too large to use.



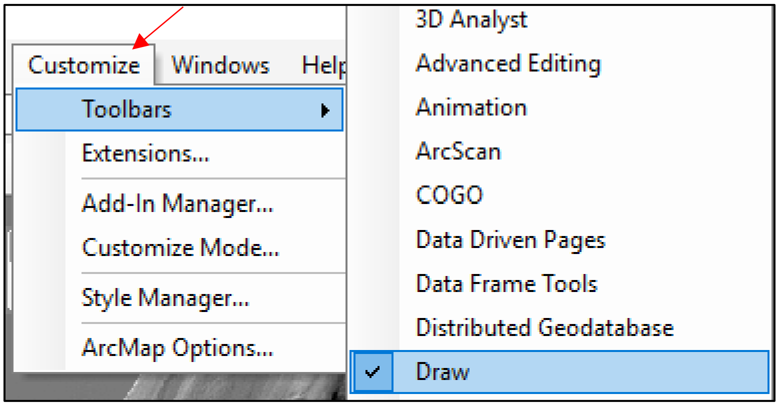


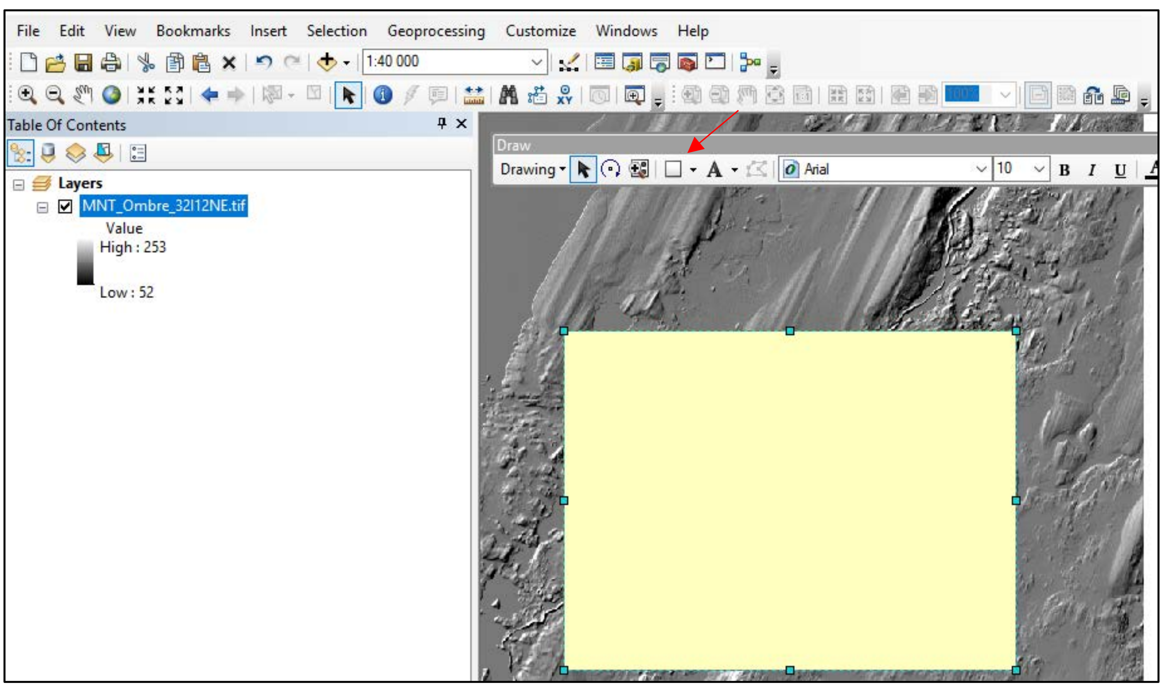
1. ***Input Rasters:*** Select the .tif images, not the .lyr files.
2. ***Output Location***: Select the file in which the new raster will be saved.
3. ***Raster Dataset Name with Extension***: Assign the name of the output raster with the .tif extension.
4. ***Spatial Reference for Raster (optional)***: Select the reference for one of the data layers.
5. ***Pixel Type (optional)***: Select 8_BIT_UNSIGNED for a hillshade and 32_BIT_FLOAT for other products.
6. ***Cell size***: Select the desired resolution (1 m is used in this example).
7. ***Number of Bands***: Select 1.

8. ***Mosaic Operator (optional)***: Select "Maximum", because the overlapping pixels are generally similar. However, other types of operators would have little impact on the result.
9. ***Mosaic Colormap Mode (optional)***: Select "First".

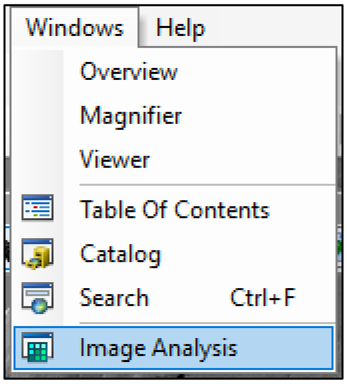
4.1.7 Clip Raster Data in a Given Area

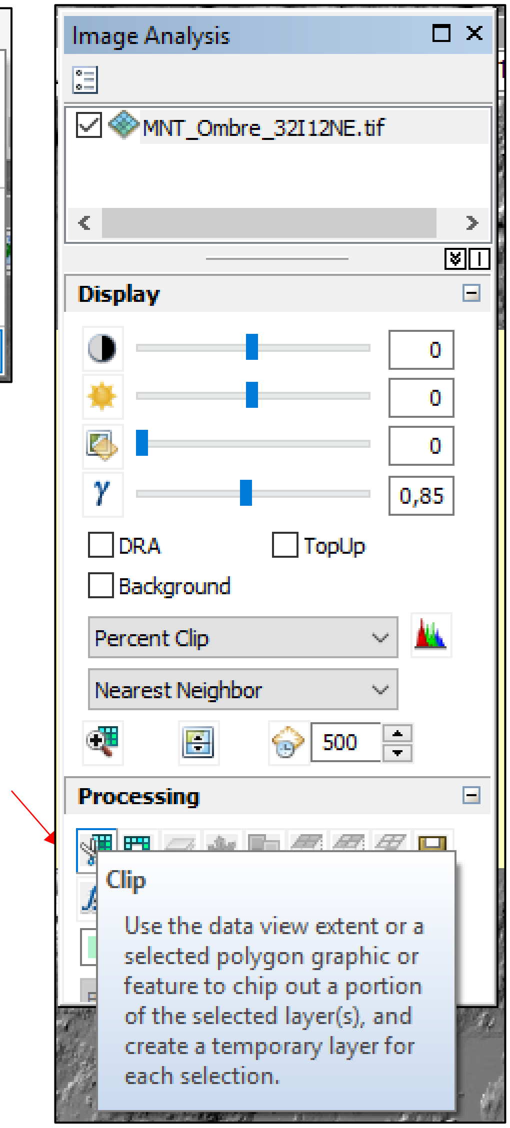
To clip a raster, first select the raster to be clipped. Then select "Customize" > "Toolbars" and "Draw". Use the rectangle tool to create a rectangle for clipping.



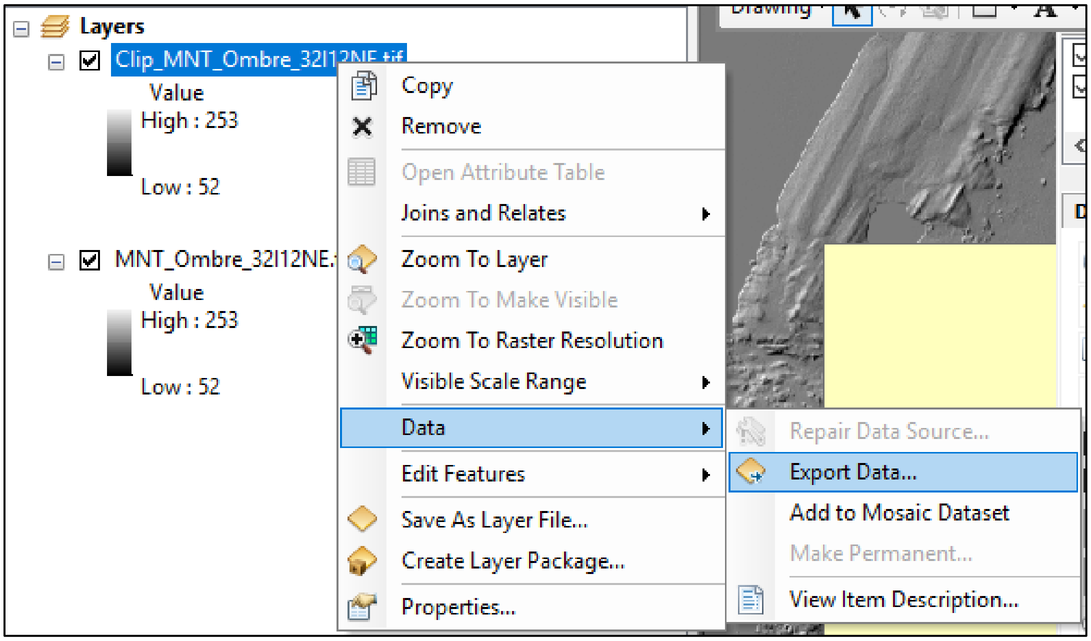


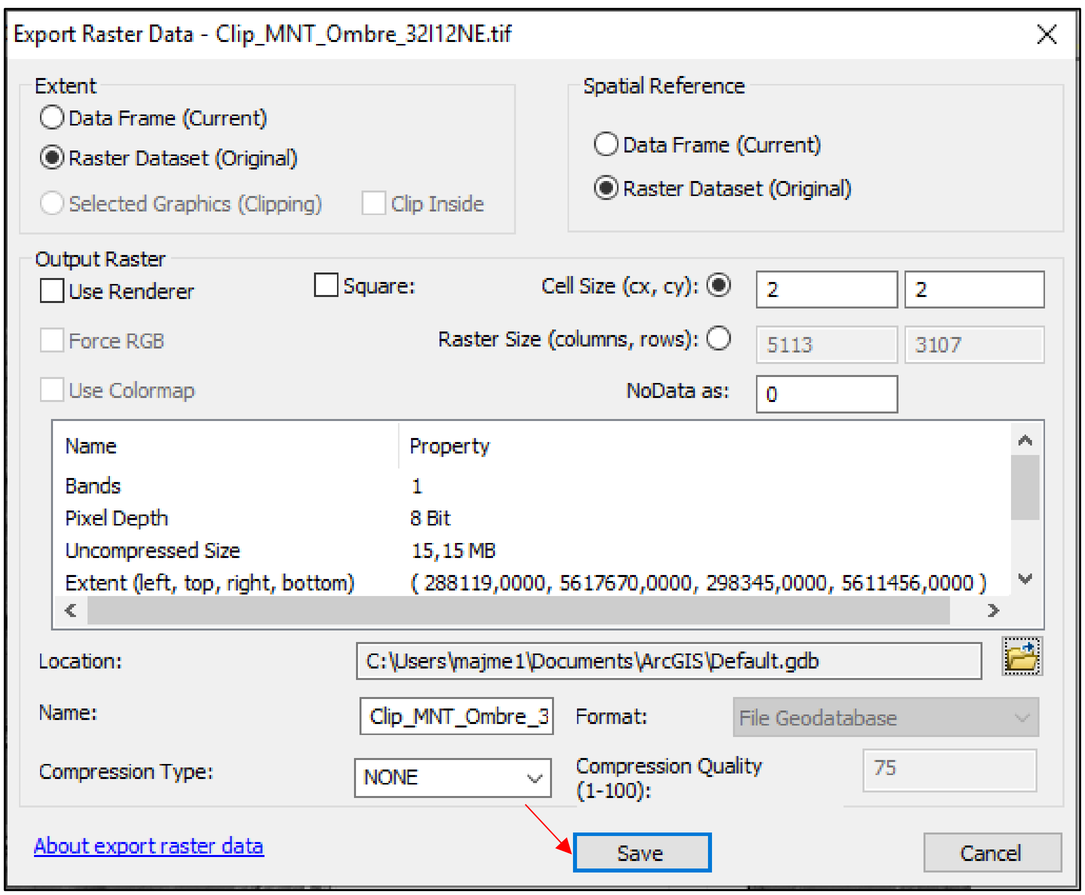
Open the image analysis window by clicking on "Windows" > "Image Analysis". In the image analysis window, click on the "Clip" tool.





Lastly, right-click on the name of the clipped image and then on "Data > Export Data". This will enable you to save the new clipped raster.





4.2 Advanced Features

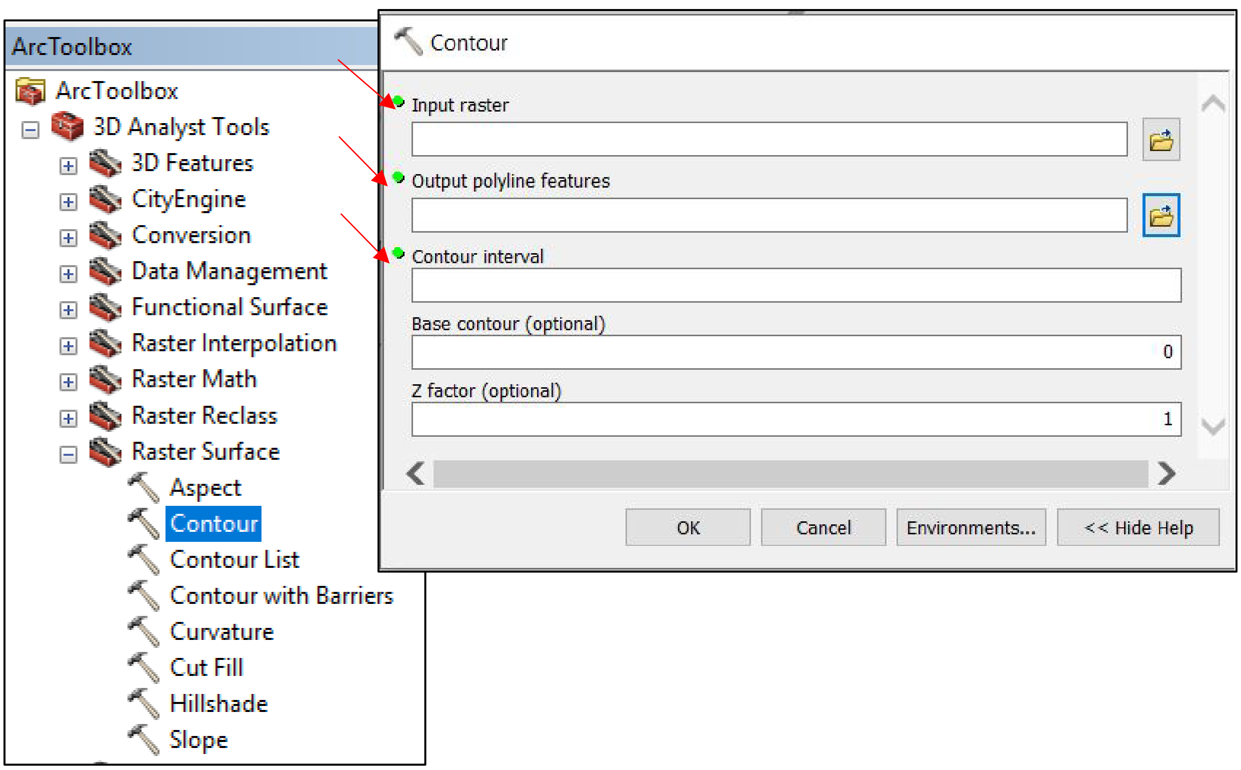
Other products can be created from basic LiDAR derived products using territorial analysis. Both applications previously mentioned (ArcGIS and QGIS) offer tools that can be used to obtain contour lines, convert rasters to polygons, fill lakes, delimit drainage basins (watersheds), reclassify rasters, generate a focal CHM, generate a topographic wetness index, etc.

4.2.1 Create Contour Lines

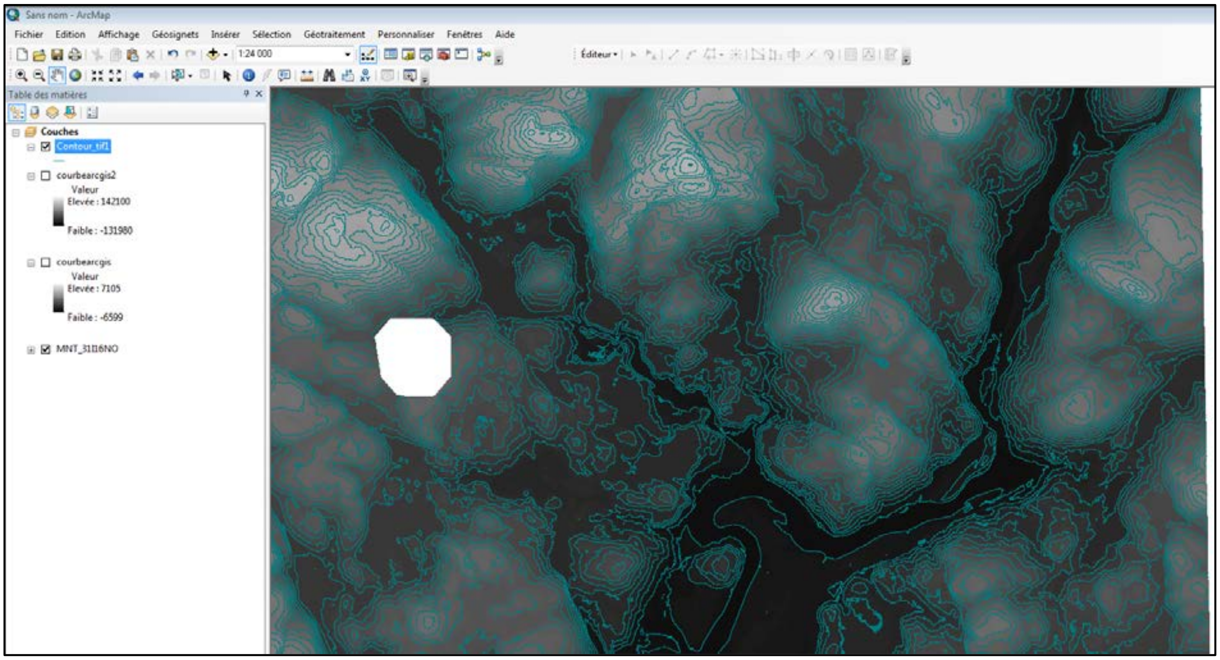
Requires the 3D Analyst licence (see the licence-free process with QGIS in section 5.3.1).

To create contour lines, you will need one or more DTMs for the region for which you want the contour lines. The DTMs should ideally be clipped (see section 4.1.7) or combined to obtain the desired area only, since this will increase processing speed. Once the area is ready, open ArcToolbox and select "3D Analyst Tools" > Raster-surface > Contour". The following window will open.

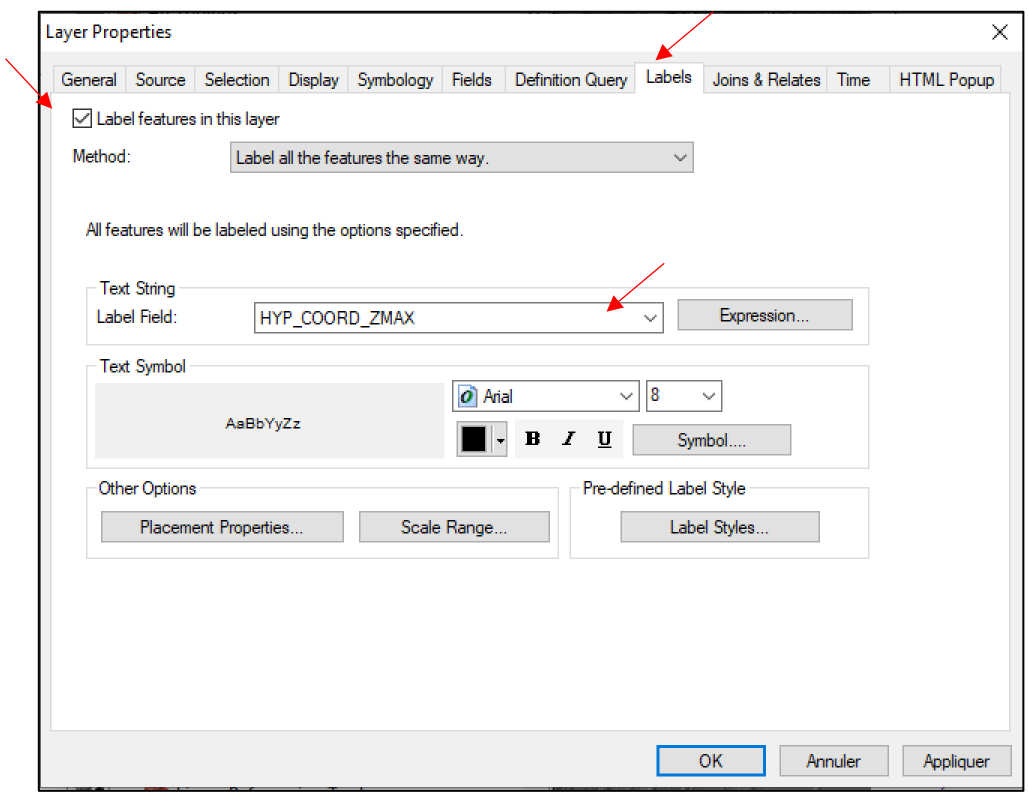
In the new window, select your "Input raster", select the output location ("Output polyline features" field) and enter the required distance between each line in the "Contour interval" field.



This will give a result similar to the following image.



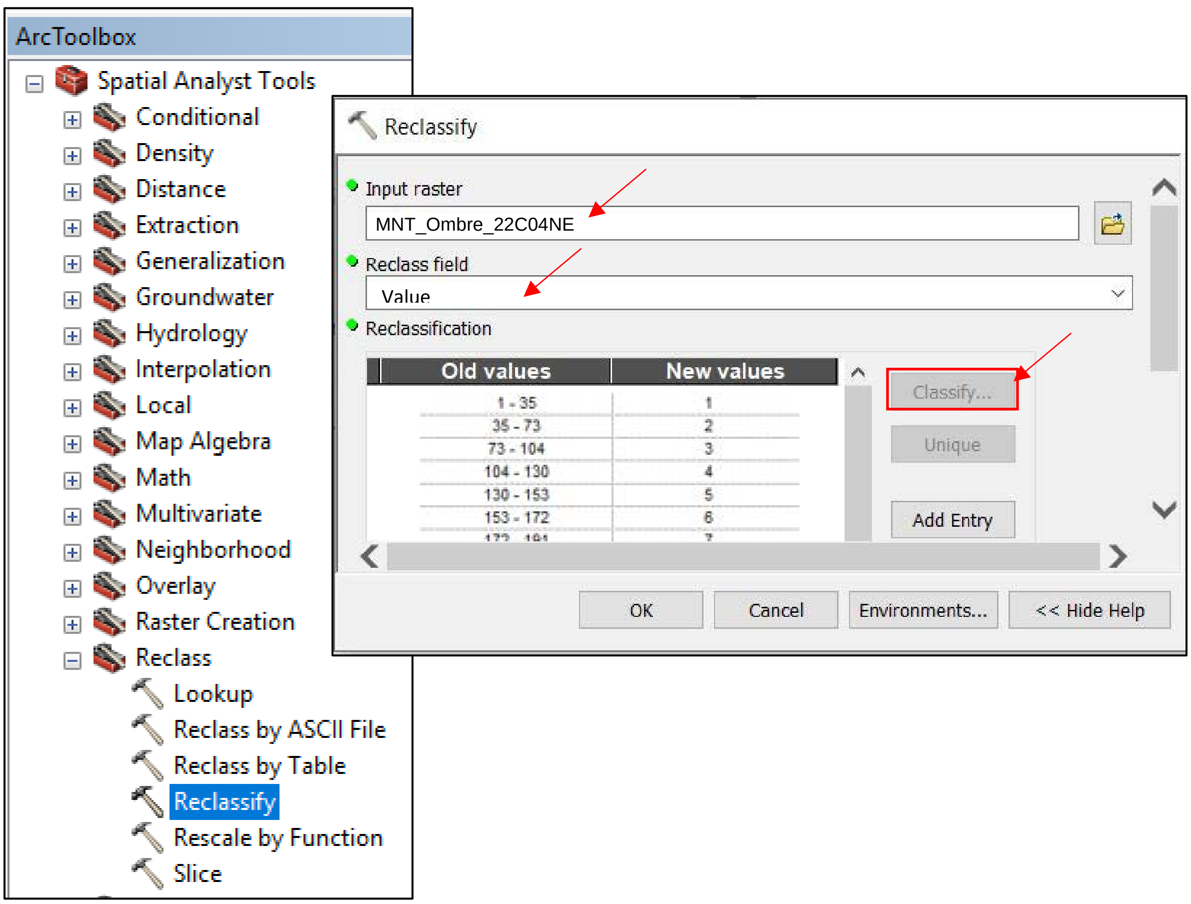
The colour of the lines can be changed by right-clicking on the layer and selecting the "Symbology" tab of the "Layer Properties" window. Labels can also be displayed using the "Labels" tab in the "Layer Properties" window. Check "Label features in this layer" and select the "Label Field" you wish to display.



4.2.2 Reclassify Rasters

It can be useful to reclassify rasters, among other things to convert a raster file into a vector layer. This operation requires the "Spatial Analyst" extension and is carried out using the Hillshade layer. First, the desired Hillshade must be added to the project's table of contents. Next, open ArcToolbox and select "Spatial Analyst Tools > Reclass > Reclassify". The following window will open.

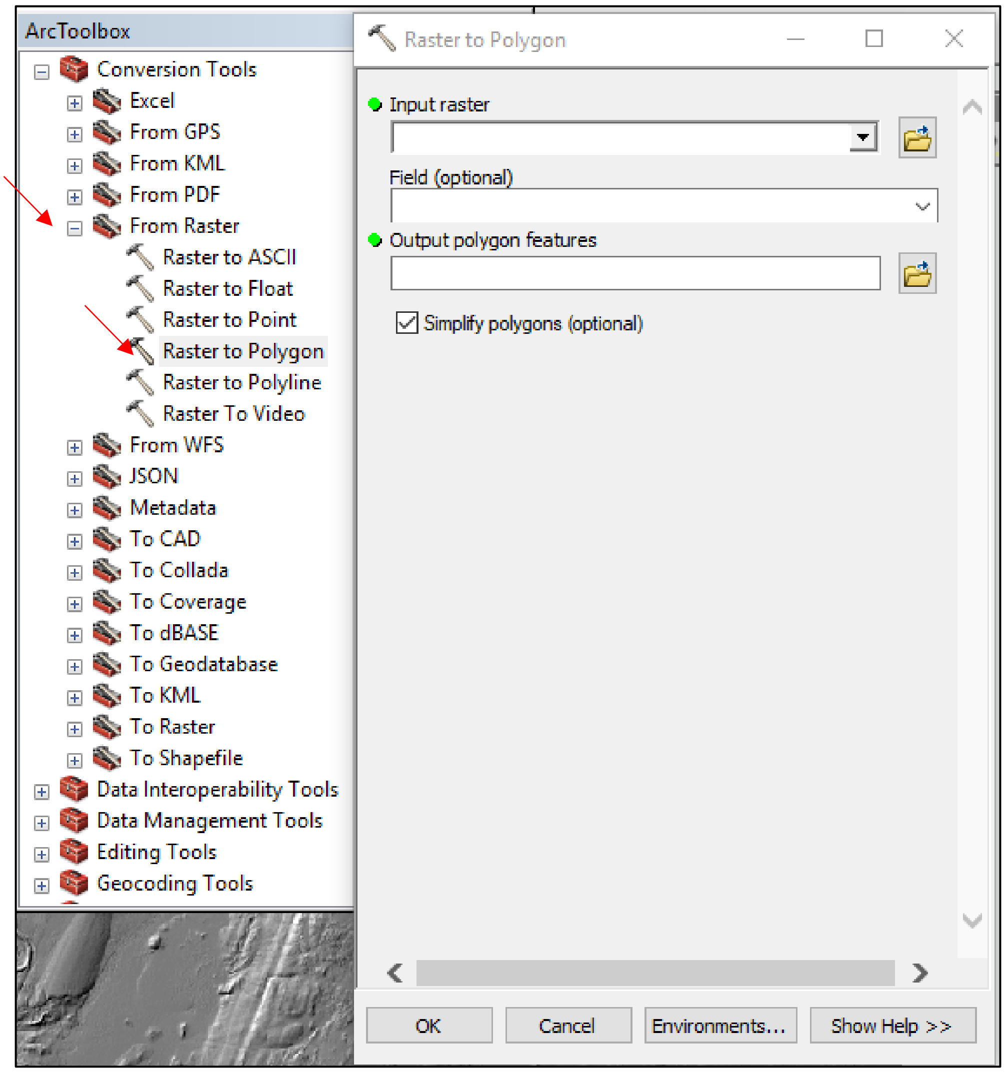
Next, select the raster on which you wish to work and select "Value" in the "Reclass field". To reclassify the values, click on the "Classify" button in the reclassification section. The list of values will then appear in the field on the left-hand side, and a predefined classification will be offered. You can change it as you wish. Once the classification values have been chosen, select a location for your output raster and click on OK. Your new raster will be added to your map's table of contents.



4.2.3 Convert a Raster Image to Vector Format (Polygons)

Converting a raster image to vector format allows LiDAR data to be used on certain types of GPS devices that are unable to read raster files. Please note that the process is very time-consuming, so make sure you have clipped the area you want (see la section 4.1.7) before starting the process. In addition, we recommend reclassifying the raster (see section 4.2.2) to avoid producing a polygon for each pixel, which would make the layer too big to use.

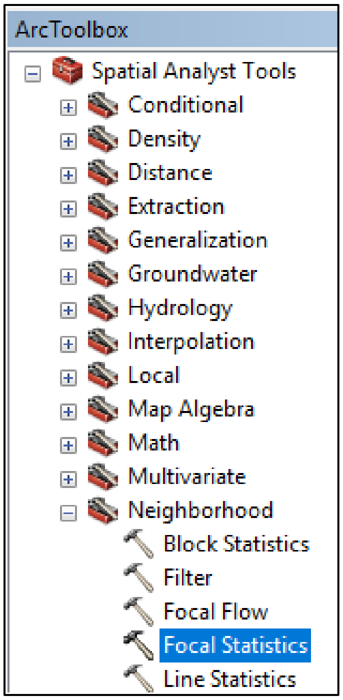
To convert a raster, start by adding the raster you wish to convert to the project table of contents. Then, from Arc Toolbox, select "Conversion Tools > From Raster > Raster to Polygon". Next, select the desired input raster, select a location for the output polygon file, and click on OK.

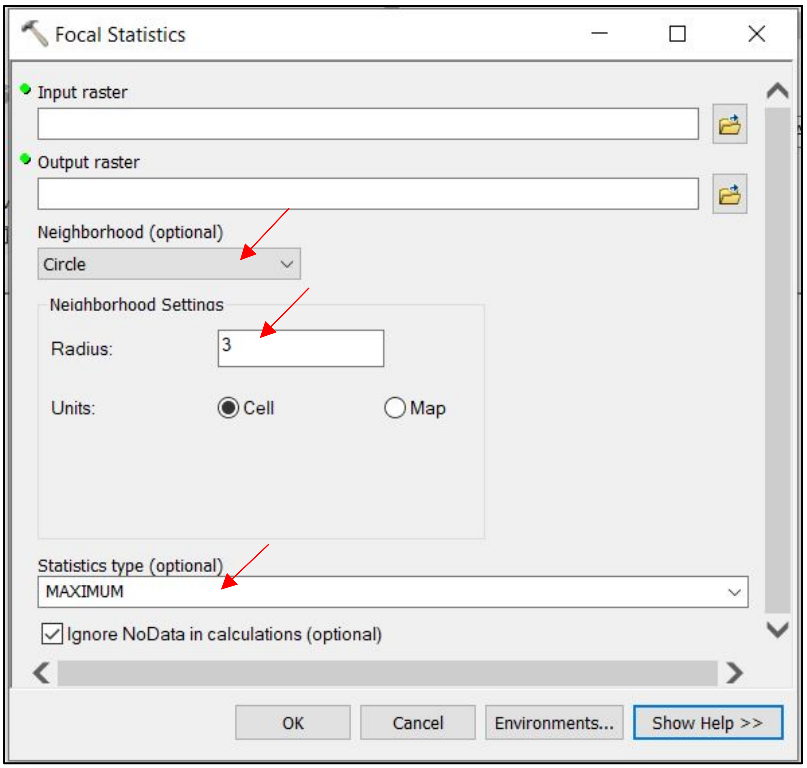


4.2.4 Create a Focal CHM

A focal CHM can be created from a CHM. The focal CHM better indicates the maximum canopy height value for coniferous trees, making it easier to interpret stand height. However, the focal CHM artificially expands canopy diameter and thereby significantly overestimates cover density.

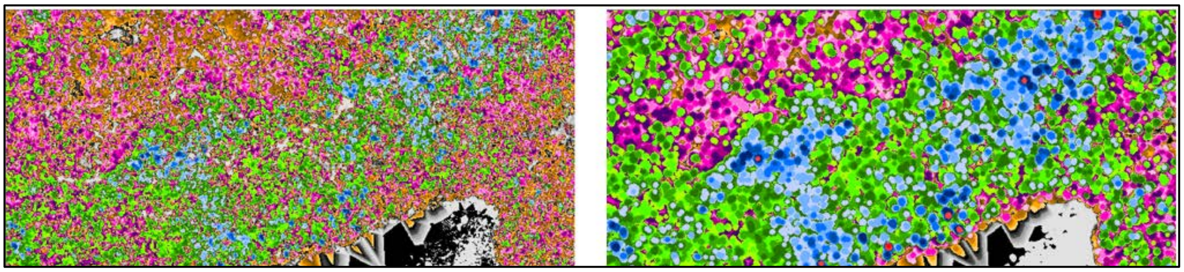
To create a focal CHM, start by adding the desired CHM to the project table of contents. Next, in Arc Toolbox, select "Spatial Analyst Tools > Neighborhood > Focal Statistics". The following window will open. In this new window, select the CHM you want as the input raster and select a location for your output raster. Next, select "Circle" in the "Neigborhood" drop-down menu and "MAXIMUM" in the "Statistics type (optional)" drop-down menu. For a CHM of a coniferous or mixed forest, you should test several radius values, but the value 3 generally gives good results and provides a better view of the maximum coniferous stem value.





After processing, you will obtain a raster similar to the following image.

Standard CHM *Focal CHM*

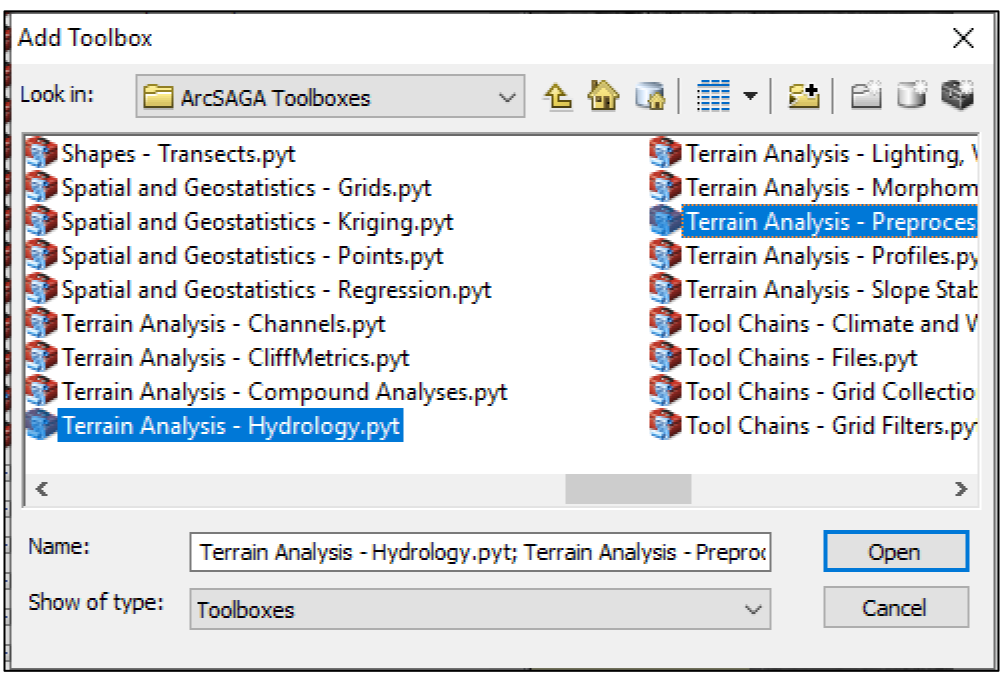


4.2.5 Topographic Wetness Index

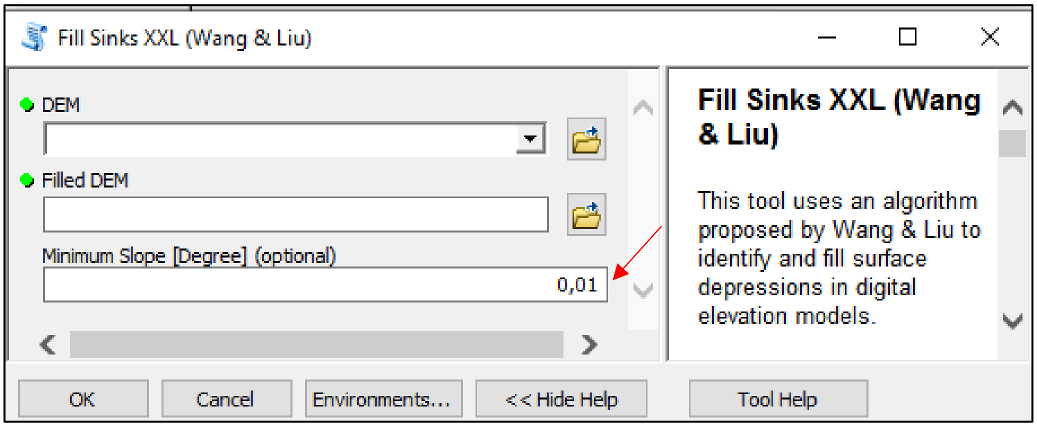
The topographic wetness index (TWI) is used to assess the ground's capacity to retain moisture. It takes into account water accumulation and slopes at a specific location.

You must first download the SAGA file from: https://sourceforge.net/projects/saga-gis/.

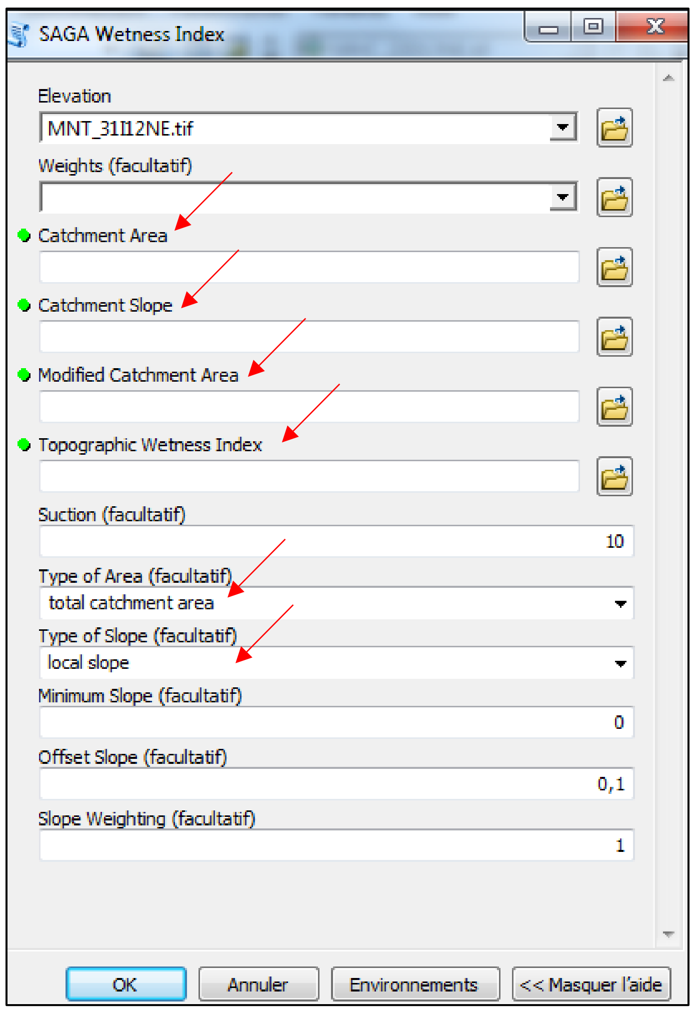
Next, install the necessary SAGA toolboxes. To do this, right-click on "Arc Toolbox" and select "Add a toolbox". Then select the folder in which you saved your SAGA file (it must be unzipped first). In the SAGA file, select "ArcSAGA Toolboxes" and install the "Terrain Analysis - Preprocessing" and "Terrain Analysis - Hydrology" toolboxes.



Once the toolboxes have been installed, the first process is to fill surface depressions. To do this, select "Preprocessing > Fill sink XXL". In the new window, select the DTM you want in the "DEM" field, then select the location of the output file ("Filled DEM" field) and enter 0.01 as the "Minimum Slope [Degree] (optional)".



Next, open "Hydrology > SAGA Wetness Index". The window on the right will be displayed. Select the DTM resulting from the first process (Filled DEM) in the "Elevation" field. Next, select a location for the output files, namely "Catchment Area", "Catchment Slope", "Modified Catchment Area" and "Topographic Wetness Index". Lastly, select "total catchment area" for "Type of Area" and "local slope" for "Type of Slope". The other settings should be default values.



This will give you the TWI in raster format. You can then change the symbology if you want (see section 4.1.2).

For more information about this method, see the following video on YouTube, produced by Sylvain Jutras and his team from Université Laval:

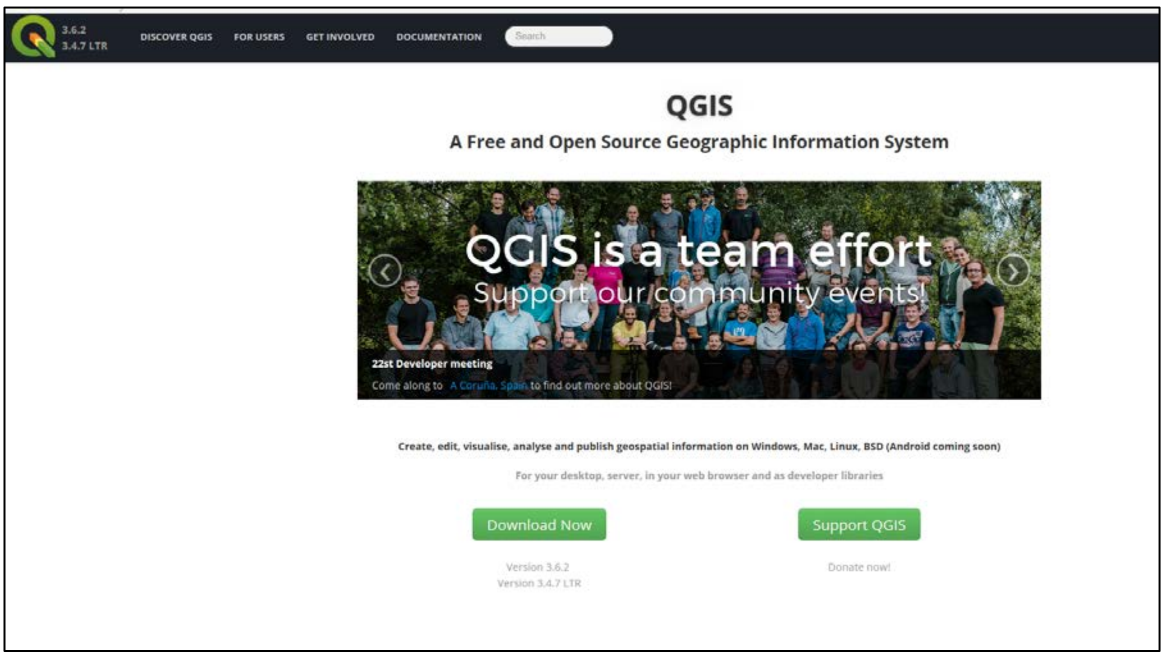
https://www.youtube.com/watch?v=V2hTDlhwo7s.

5 Raster Data in QGIS

This section covers basic operations for an easy use of LiDAR derived products in the open source software QGIS. These techniques work in other GIS applications, however the methods used differ from one to another. Also, take note that the suggested ".qml" symbologies will not work with other GIS applications.

5.1 Download and Install the Application

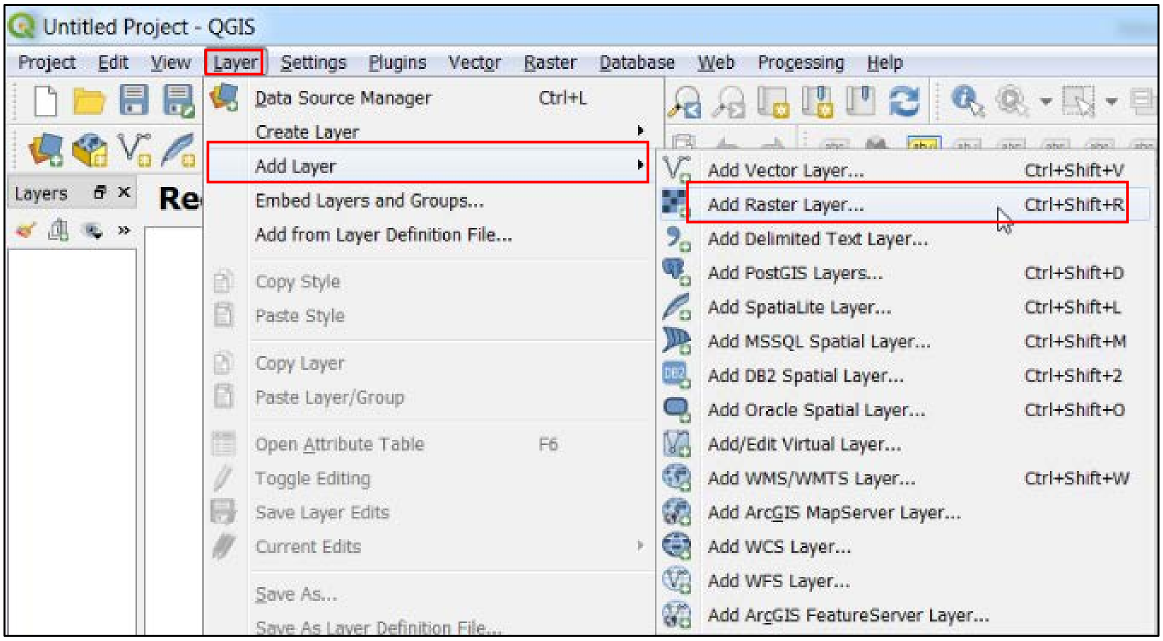
QGIS is a free and open source geographic information system. It is user-friendly and designed for the general public. It can be downloaded from the QGIS website (https://qgis.org/en/site/index.html) and installed on multiple workstations free of charge. The application is created and constantly upgraded thanks to an extensive network of volunteers and user donations.



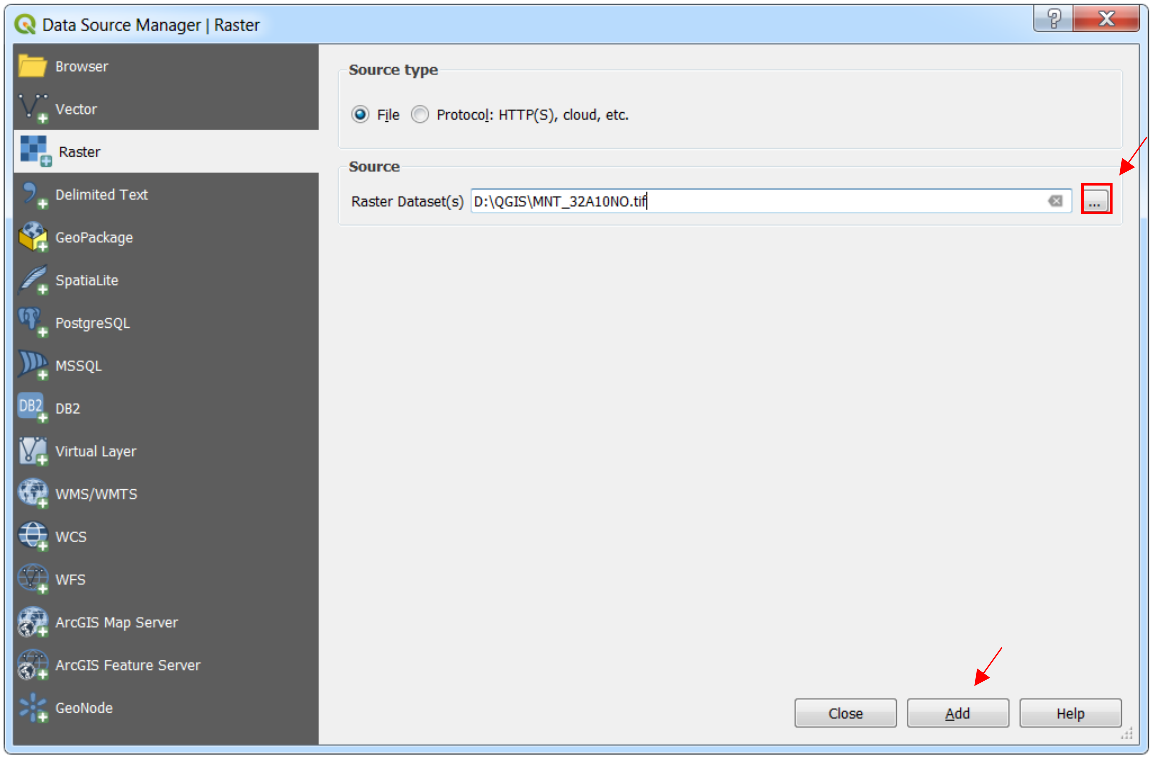
5.2 Basic Features

5.2.1 View Raster Data and Download Predefined Symbologies

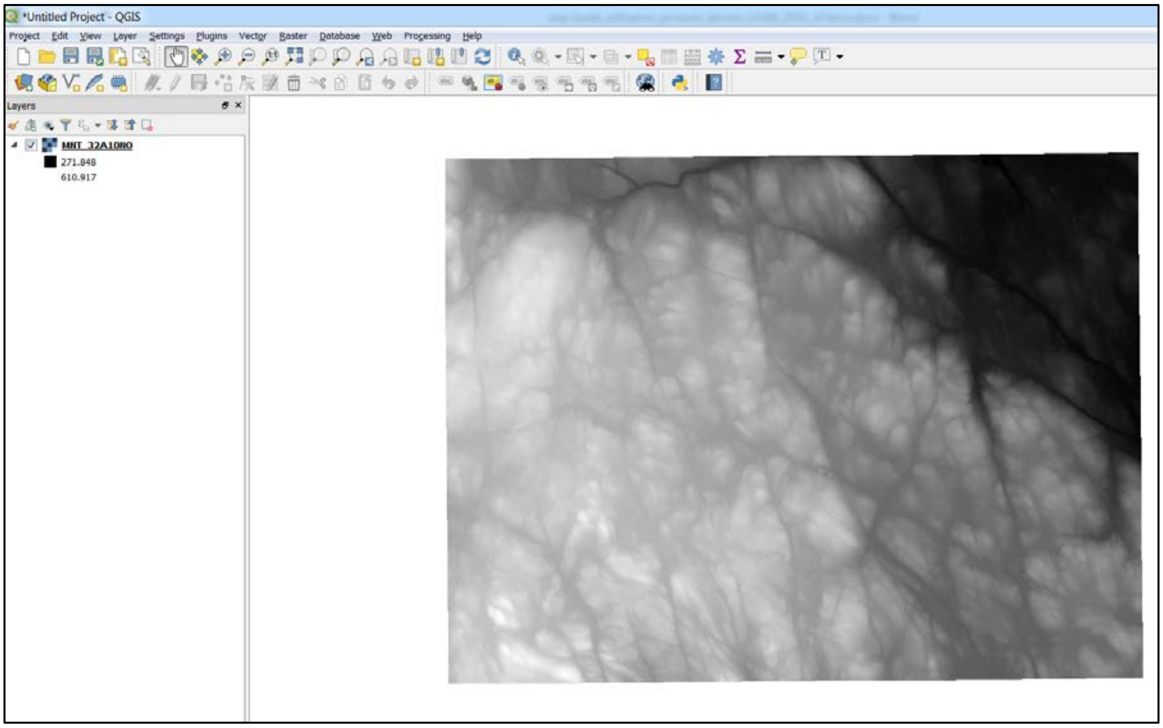
Once you have installed QGIS and downloaded the LiDAR derived products (see chapter 3), you can open the files by clicking on the "Layer" tab, then "Add Layer" and "Add Raster Layer…".



Once the following window opens, click on the "…" to select the ".tif" file of the map sheet you wish to view, and click on "Add" (Note: MHC = CHM, MNT = DTM, MNT_Ombre = Hillshade and Pentes = Slopes).

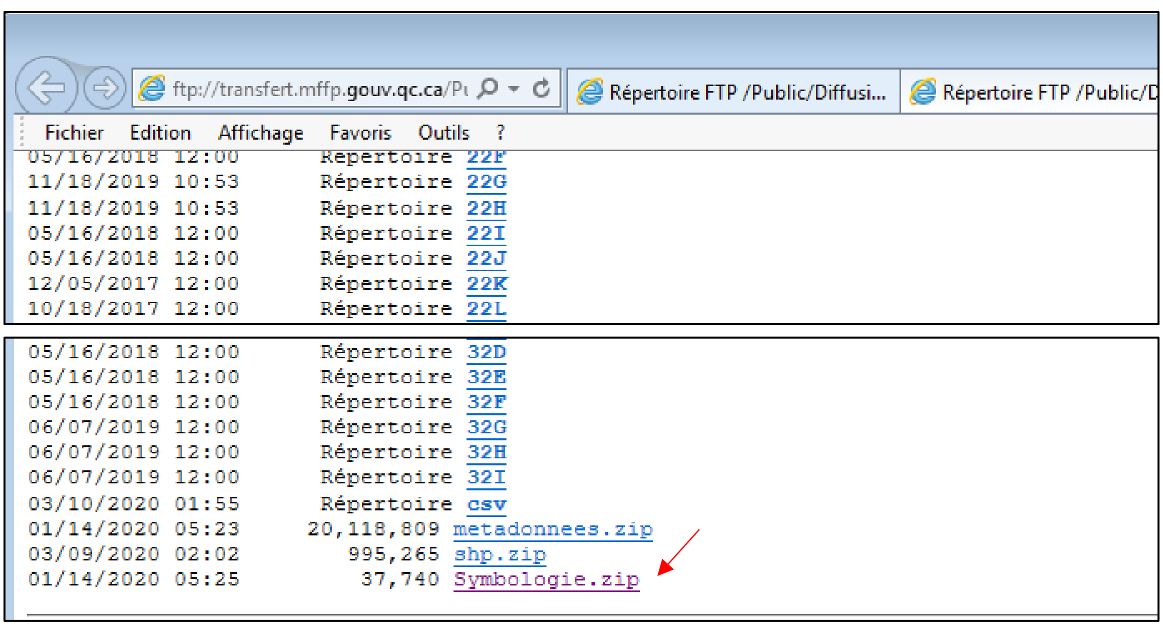


Once the file opens, a black-and-white layer will appear on the screen.



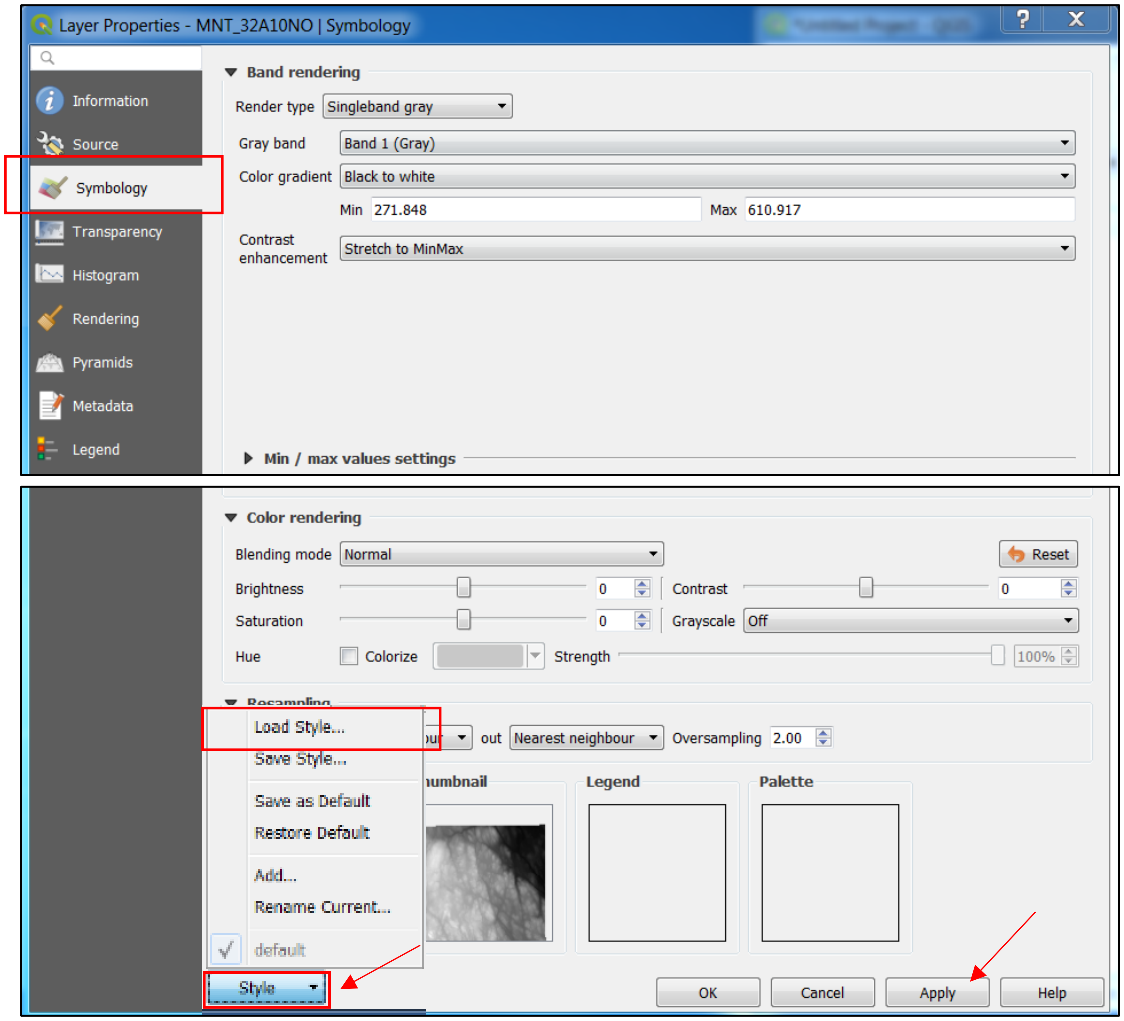
The predefined symbologies are not included in the ".tif" file. Separate ".qml" files must be downloaded (the ".lyr" format does not work in QGIS). These symbologies are in the Symbologie.zip file at:

https://diffusion.mffp.gouv.qc.ca/public/Diffusion/DonneeGratuite/Foret/IMAGERIE/Produits_derives_LiDAR/.

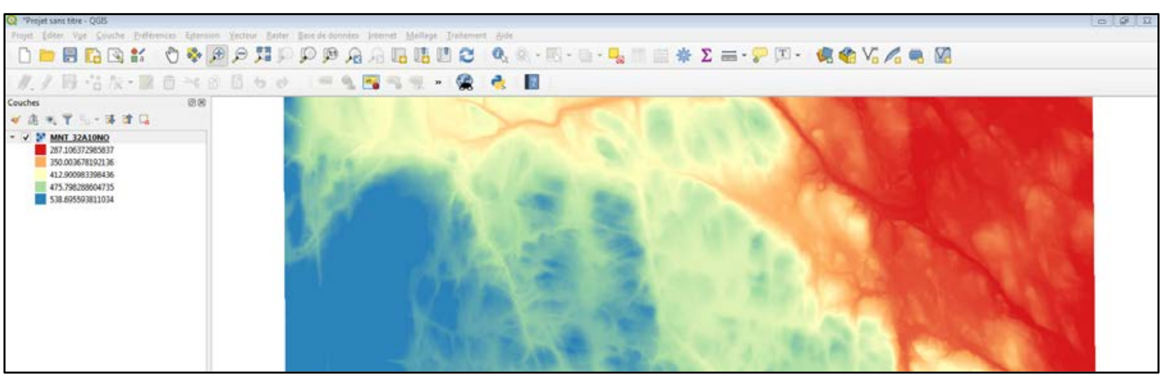


To display the downloaded symbologies in QGIS, place the cursor over the layer name, right-click and select "Properties" to display the layer properties. The following window will appear.

To upload the desired ".qml" file, select the "Symbology" tab and then "Load Style" from the "Style" drop-down menu.



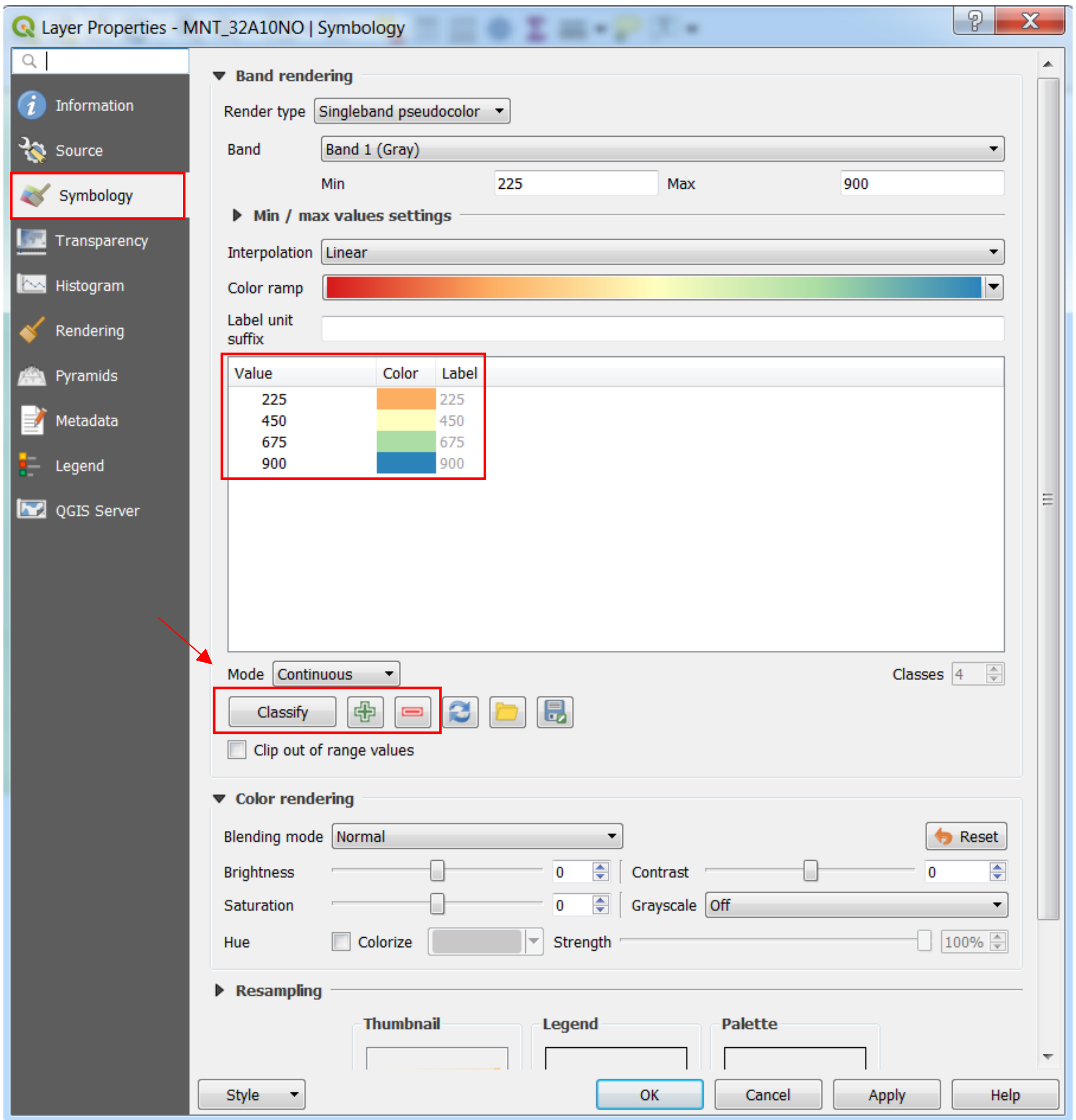
The proposed symbology will be applied to the chosen layer.



5.2.2 Change the Symbology and Select Classes

The proposed symbology can be changed to suit your needs. To do this, select the layer's properties (right-click on the layer name and select "Properties").

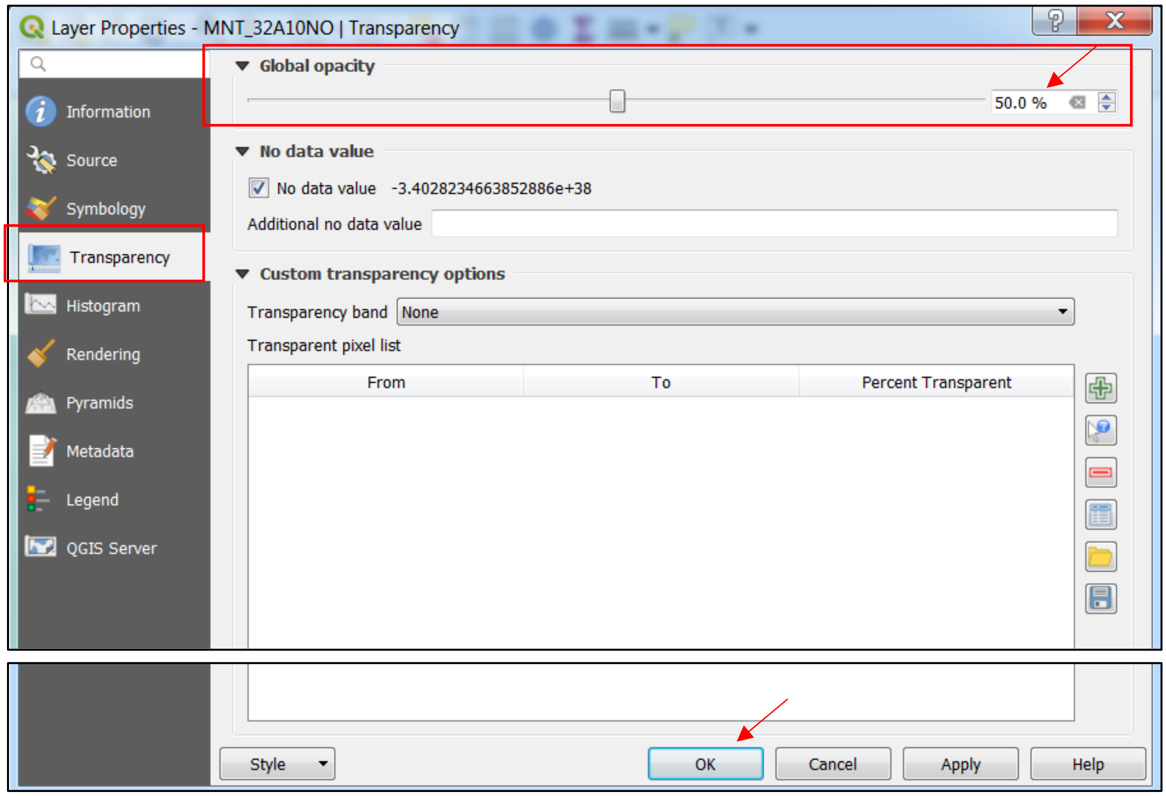
Using the "Symbology" tab in this window, you can change the limit values and colours associated to each class interval by double-clicking on the colour box. You can also use the "Mode" drop-down menu to select different types of class intervals ("Continuous", "Equal Interval", and "Quantile"). Finally, you can change the number of classes by selecting the "+" and "-" buttons next to "Classify".



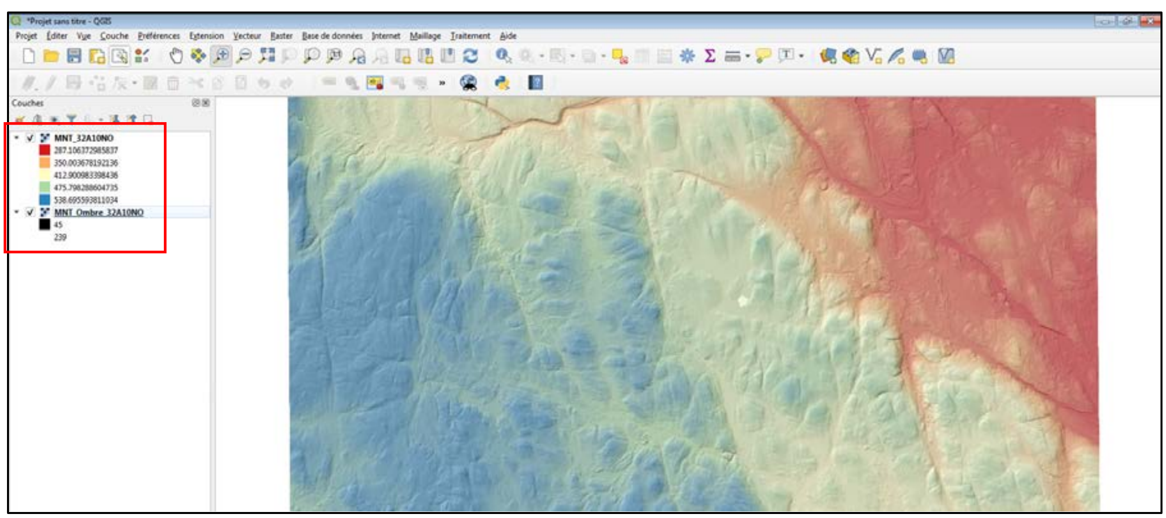
5.2.3 Create a Transparent Layer of a DTM combined with a Hillshade

As mentioned in section 4.1.3, a combination of a DTM and a Hillshade can be used to interpret certain terrain features. First, start by adding the DTM and Hillshade to QGIS and then load the ".qml" symbology for the DTM, as described in section 5.2.2.

Next, in the DTM's "Layer Properties" window (right-click on the layer name, select "Properties"), select the "Transparency" tab and reduce "Global opacity" to 50 %.



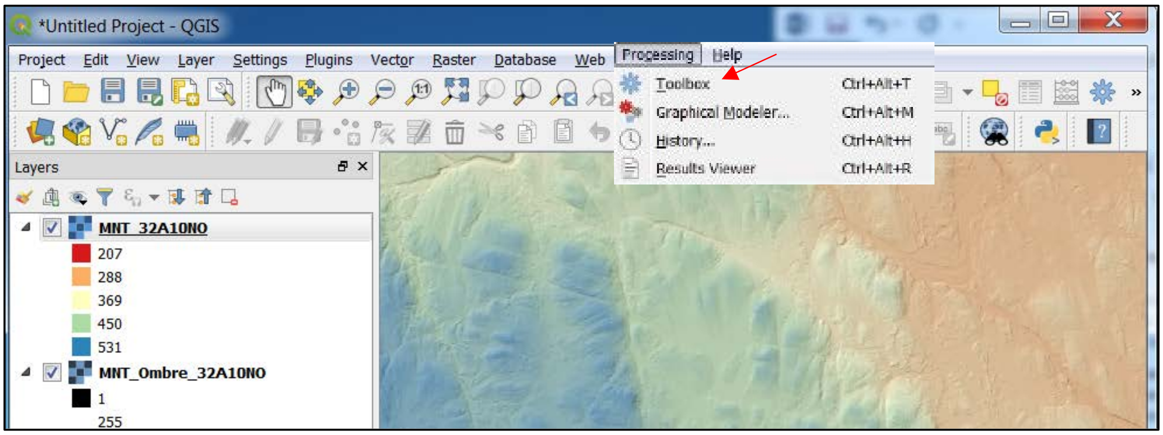
Finally, overlap the DTM with the Hillshade. The combination of these two layers provides information on both altitude and terrain.



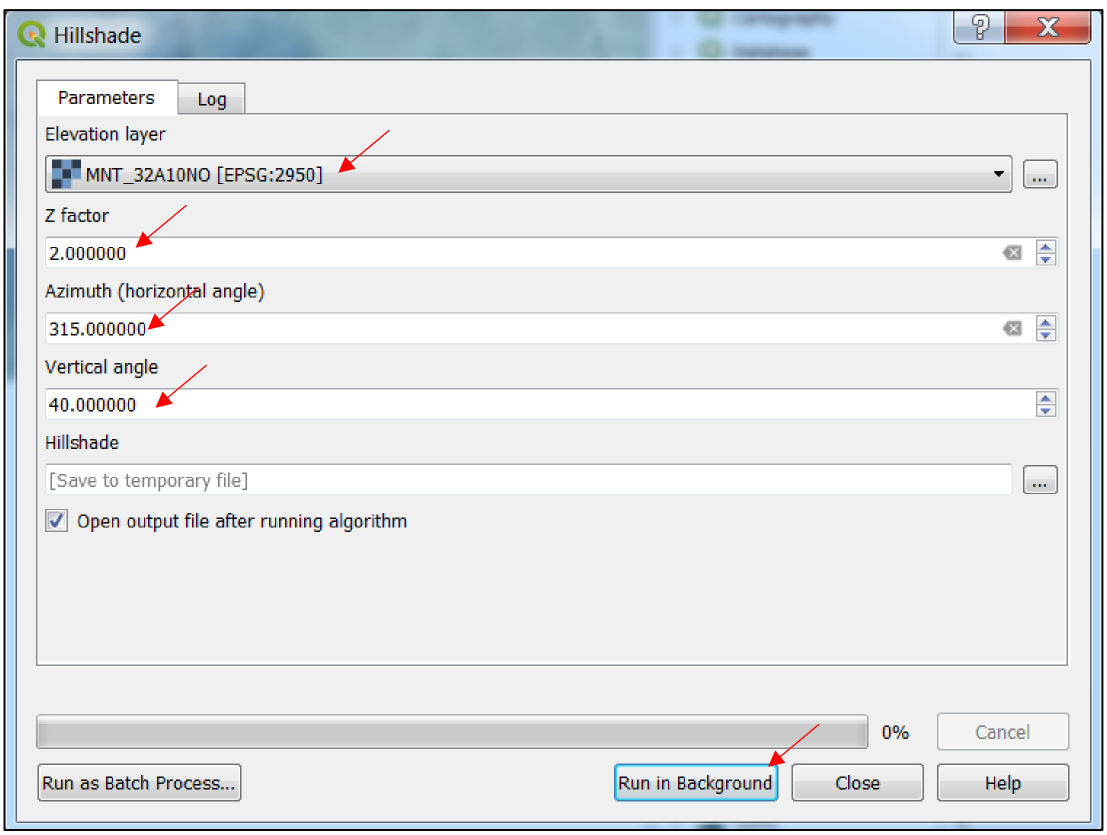
5.2.4 Create a Hillshade from a DTM

The proposed Hillshade was designed using ArcGIS’s default azimuth of 315°. In some cases, depending on the direction of the glaciers, it may be appropriate to generate a hillshade at another azimuth for the relief of certain terrain structures to stand out, such as eskers.

To generate a hillshade in QGIS, you must add the DTM to your project. Next, click on “Processing” in the main toolbar and on “Toolbox”.



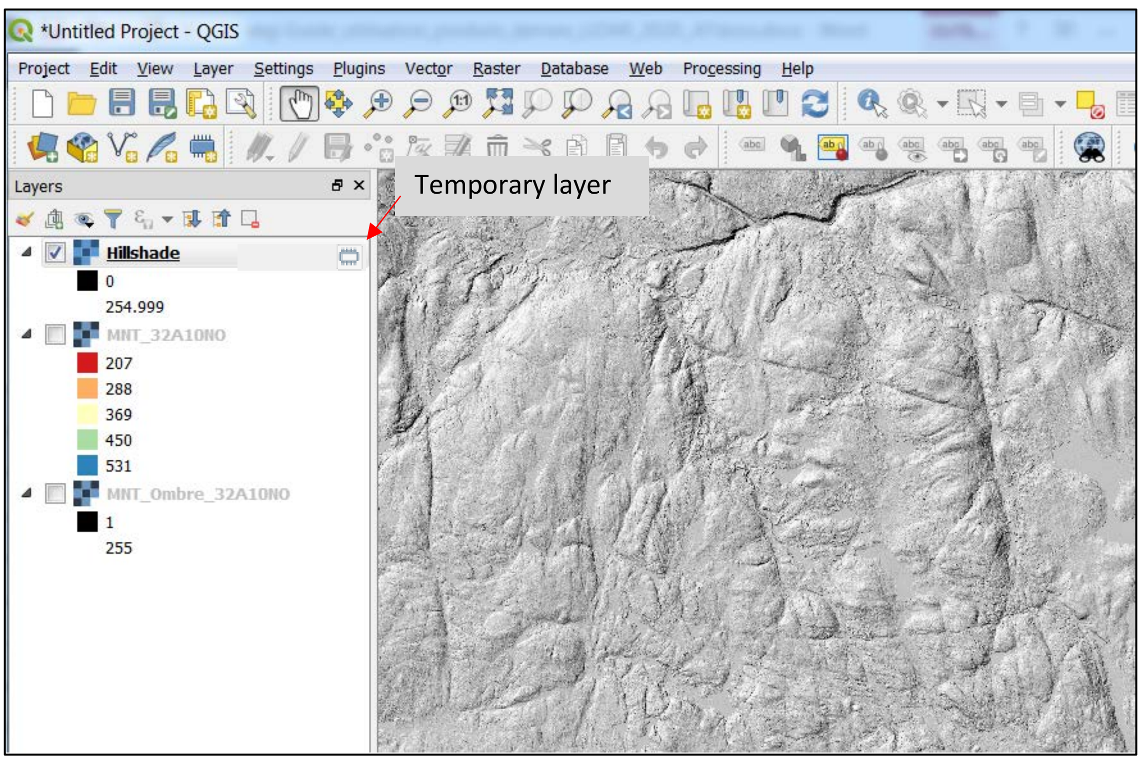
The “Processing Toolbox” will then appear. Click on “Raster terrain analysis” and then on “Hillshade”.



In the above "Hillshade" window, select your DTM as "Elevation layer" and identify the "Z factor" and desired "Azimuth" for the hillshade you want to create. The standard azimuth (horizontal angle) is 315° and the recommended Z factor is 2. We also recommend a vertical angle of 40°. Lastly, if you wish to save the final layer, select a file location and name in the "Hillshade" field. Otherwise, the layer created will be lost once you close the project. Click on "Run in Background".

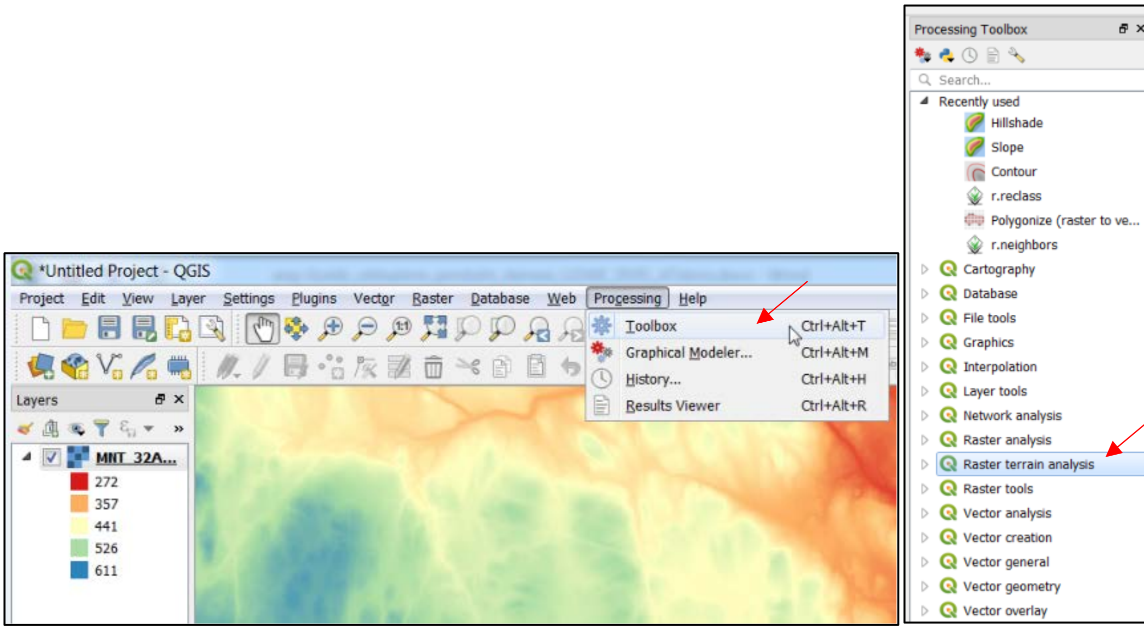
As mentioned in section 4.1.4, it is preferable to set the azimuth at a value perpendicular to the land structures to be detected, and to avoid using a southern azimuth angle (e.g. 180°) which will reverse the topography.

This tool will produce a result similar to the following image. The small sign next to the layer name indicates that this is a temporary layer because no output location was given. To save the file permanently, right-click on the layer name, then on "Export" and "Save as". In the new window, click on "Scroll" to the right of the "File name" field and select a location and layer name. Before closing a project, it is a good idea to check if any layers you wish to save for further use have this symbol.

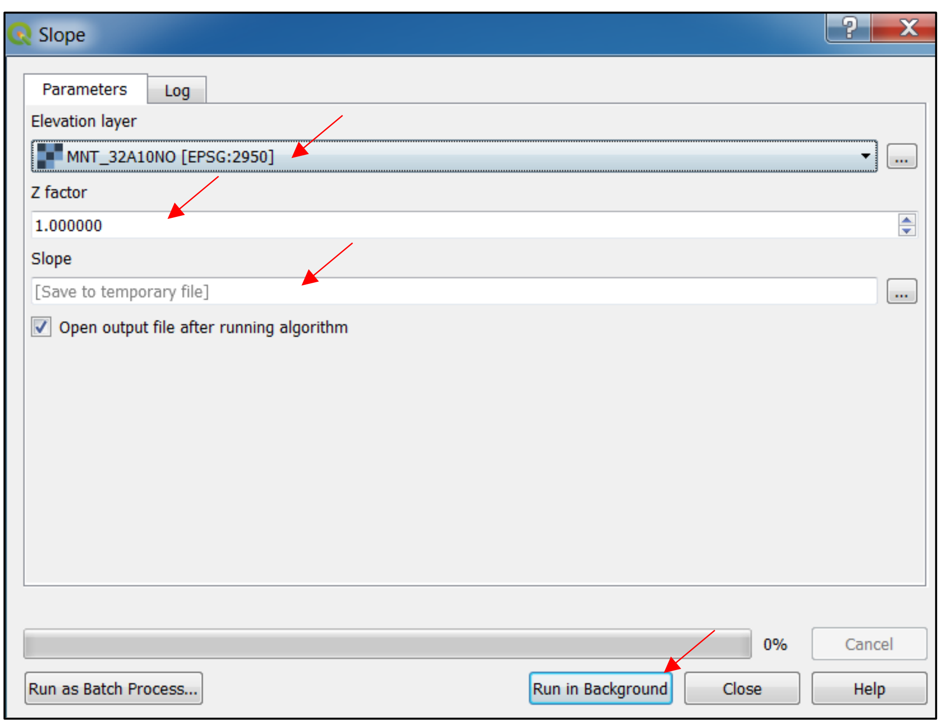


5.2.5 Create a Slope Model

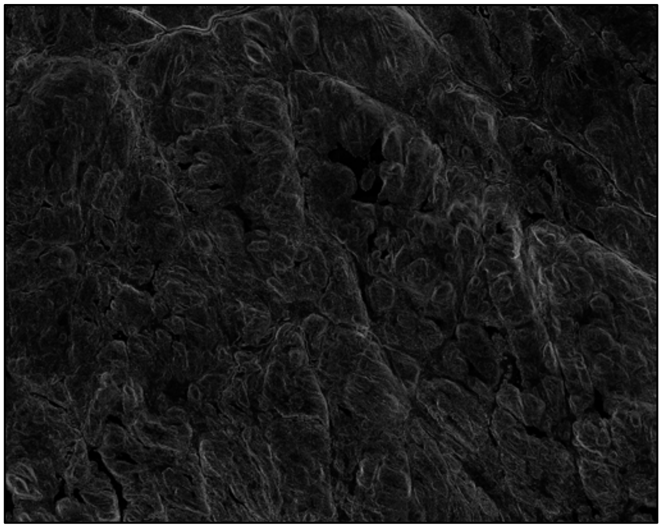
To create a slope model using QGIS, you must start by adding a DTM to your project. Next, in "Processing Toolbox" ("Main toolbar" > "Processing" > "Toolbox"), click on "Raster terrain analysis" and then on "Slope".



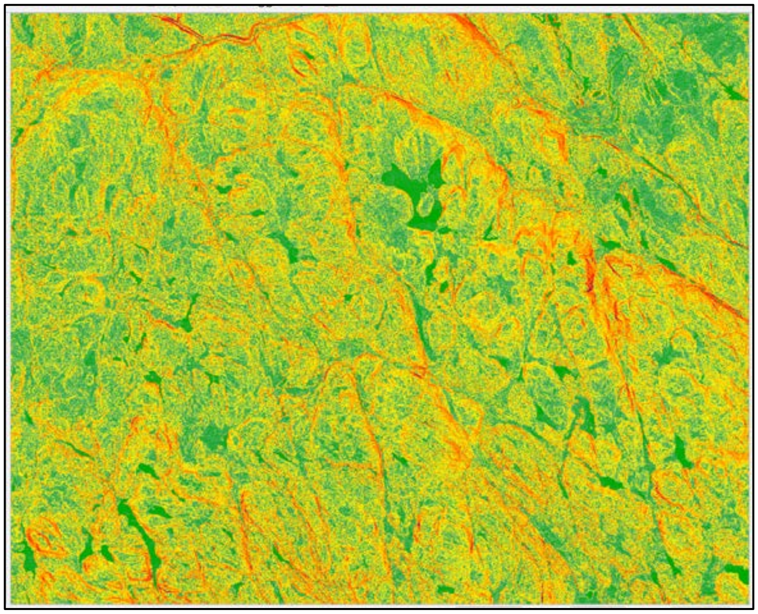
The following window will be displayed. In this window, select your DTM as your elevation layer, leave the Z factor at 1 and select, if desired, an output location in the "Slope" field. If not, the created layer will be temporary, and will disappear once the project is closed. Lastly, click on "Run in Background".



The new raster file will be in black-and-white.

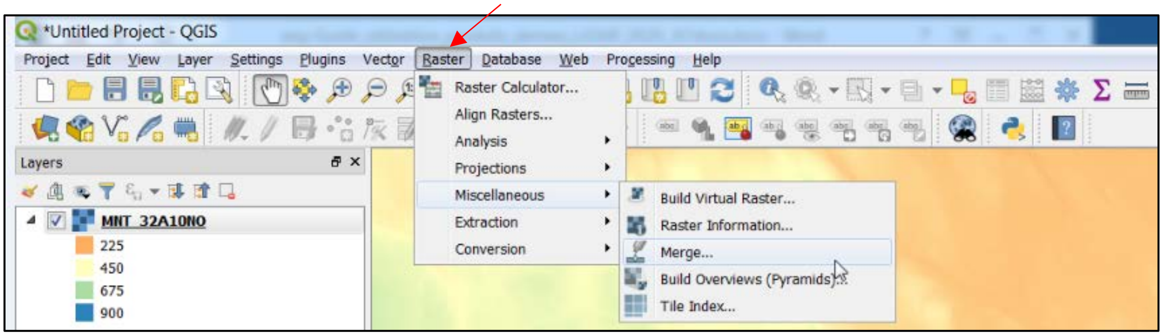


To obtain the predefined symbology, you will need to load it by following the steps described in section 5.2.2. Select the "Pente.qml" file. This will result in an image similar to the one below.



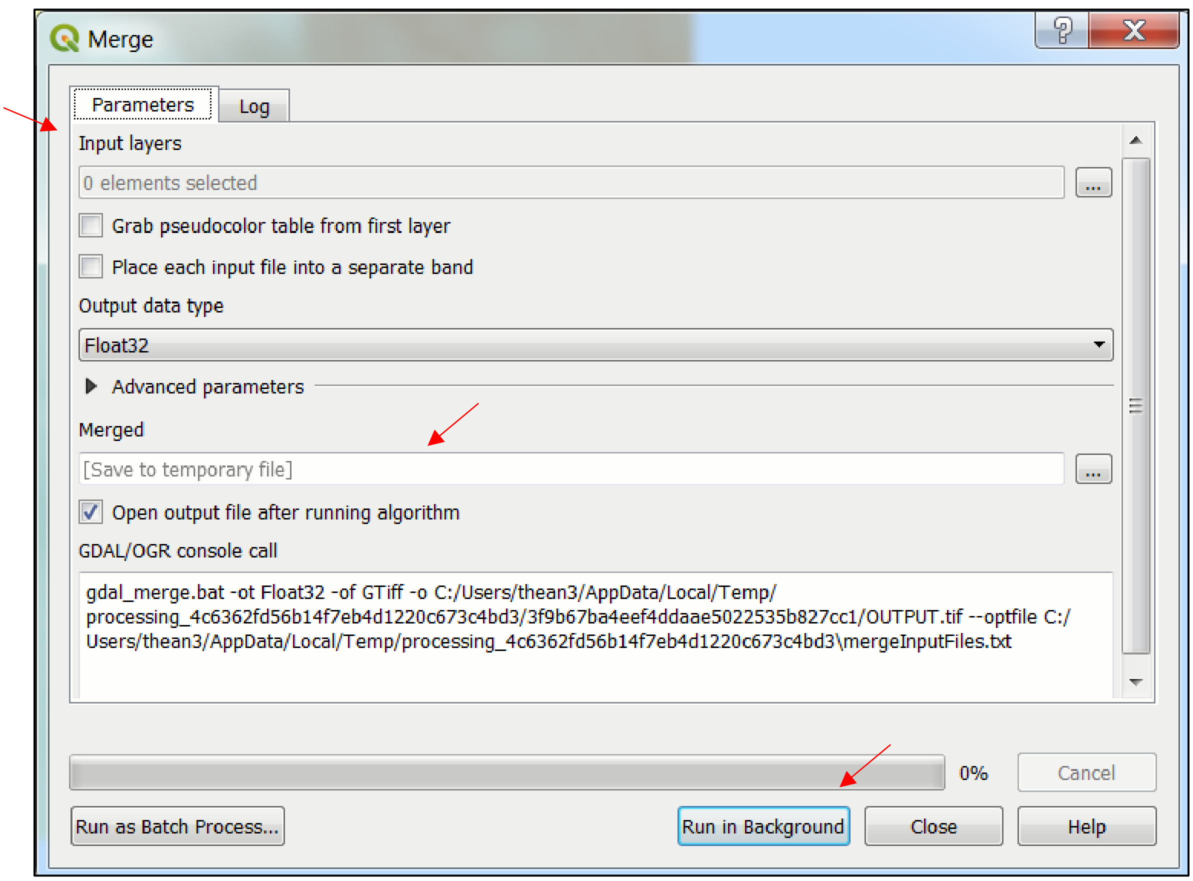
5.2.6 Assemble Several Rasters

To assemble multiple raster images together, click on "Raster" in the main toolbar and then "Miscellaneous" and select "Merge".



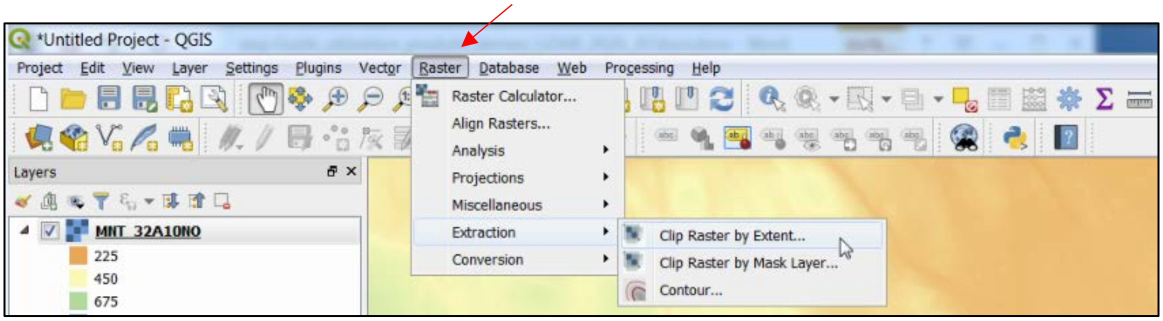
The following window will open. Assembly is best done using a limited number of sheets. Above 10 sheets, the generated raster will probably be too large to use.

In this window, select the rasters to be assembled as input layers and select the output location in the "Merged" field. Otherwise, the layer you create will be temporary, and will disappear once the project is closed. Next click on "Run in Background".

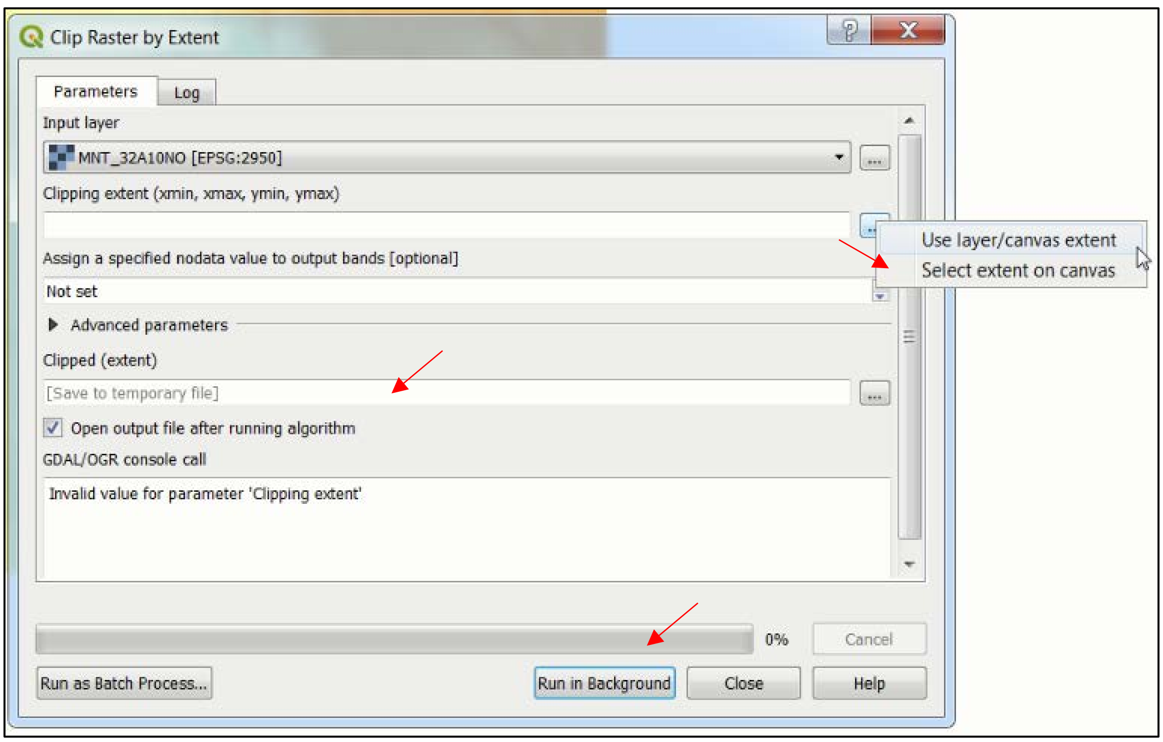


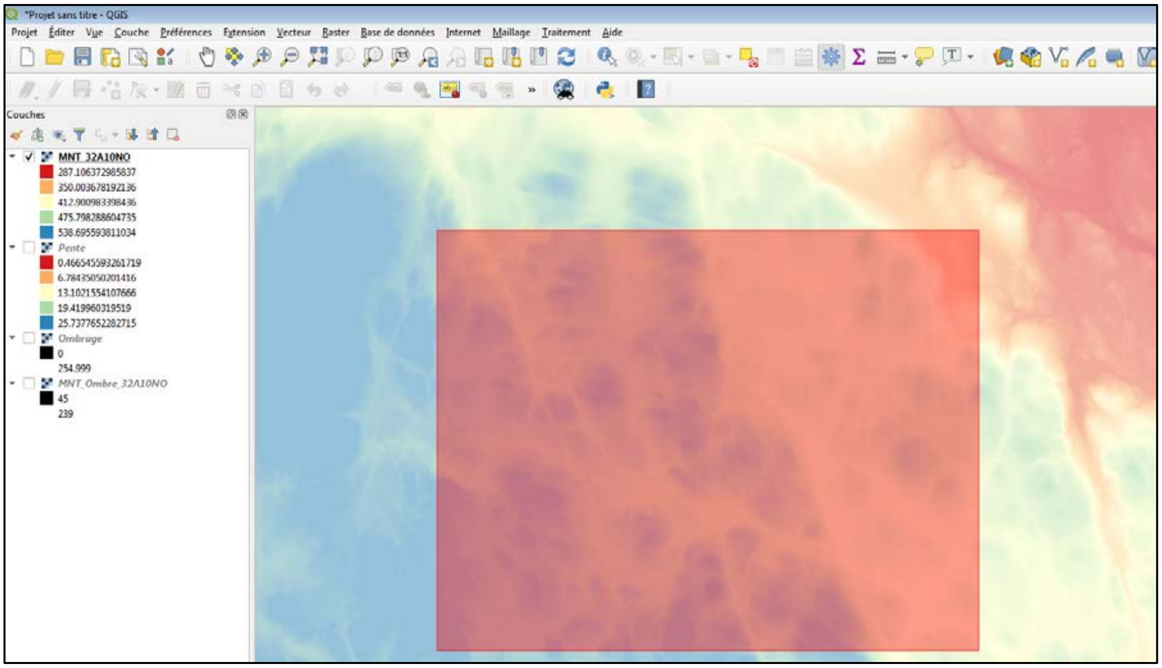
5.2.7 Clip Raster Data in a Given Sector

To clip a raster, first display the raster to be clipped. Then click on "Raster" in the main toolbar and select "Extraction" then "Clip Raster by Extent".



The following window will open. The input layer is the raster you wish to clip. For the size of the clip, click on the "…" next to the "Clipping extent" field. Next, select "Select extent on canvas" and use the cursor to select the area to be clipped on your raster. Lastly, select the location for the output file in the "Clipped (extent)" field. Otherwise, the created layer will be temporary and will be lost when the project is closed. Lastly, click on "Run in Background".



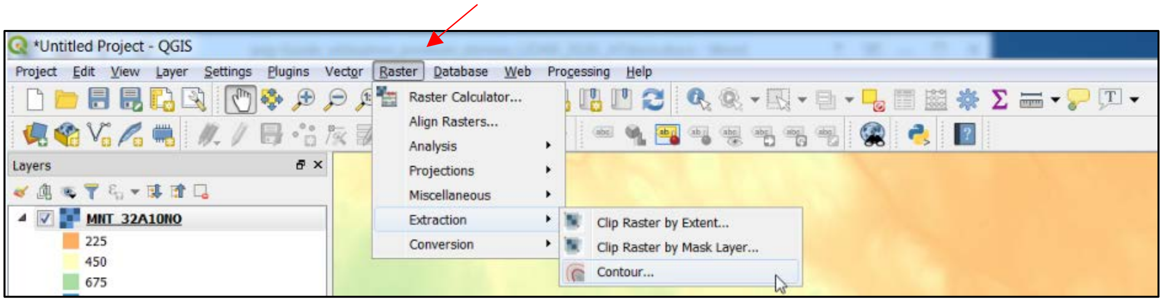

*Projet sans titre - QGIS
Projet
Éditer
Vue
Couche
Préférences
Extension
Vecteur
Raster
Base de données
Internet
Maillage
Traitement
Aide
Couches
MNT_32A10NO
287.106372985837
350.003678192136
412.900983398436
475.798288604735
538.695593811034
Pente
0.466545593261719
6.78435050201416
13.1021554107666
19.419960319519
25.7377652282715
Ombrage
0
254.999
MNT_Ombre_32A10NO
45
239

5.3 Advanced Features

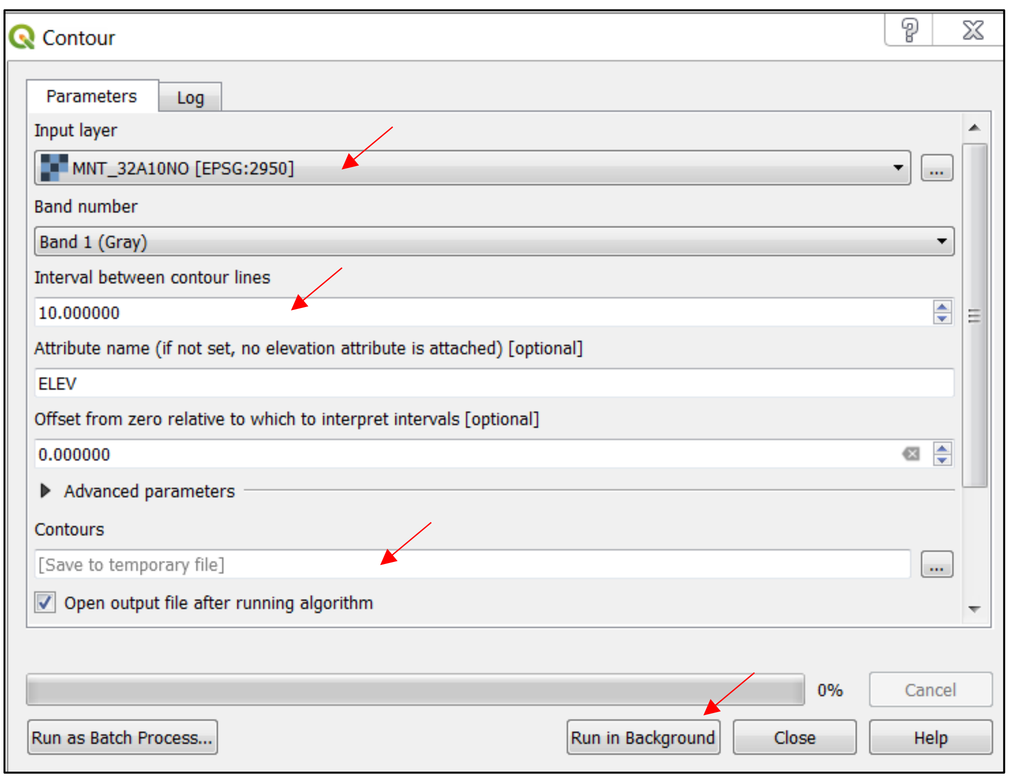
Other products can be created from basic LiDAR derived products using territorial analysis. Both applications previously mentioned (ArcGIS and QGIS) offer tools that can be used to generate contour lines, convert rasters to polygons, fill lakes, delimit drainage basins (watersheds), reclassify rasters, generate a focal CHM, generate a topographic wetness index, etc.

5.3.1 Create Contour Lines

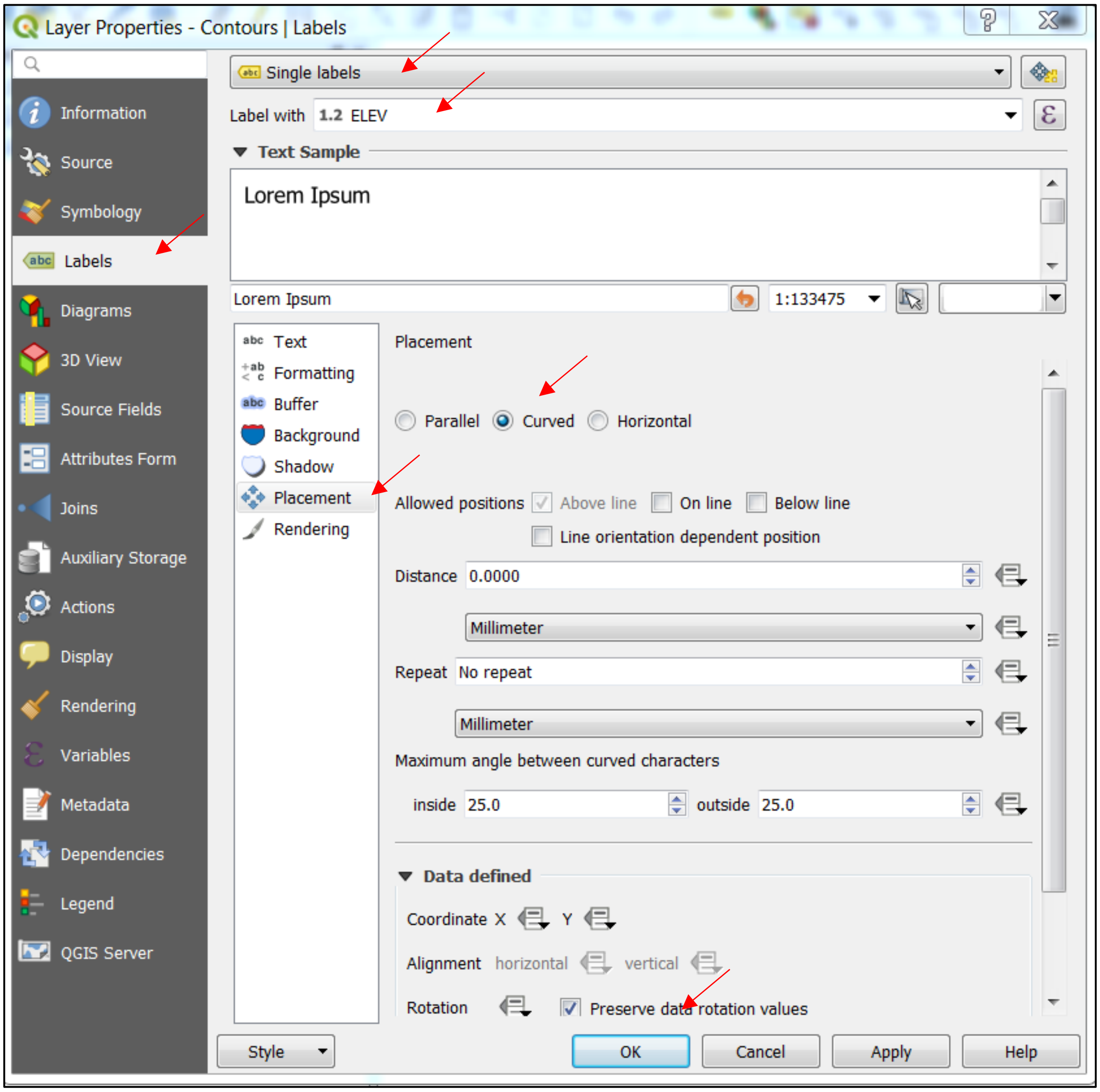
To create contour lines, you will need one or more DTMs of the region for which you want the contour lines. The DTMs should ideally be clipped or combined to obtain the desired area only, since this will increase processing speed. Once the area is ready, click on "Raster" in the main toolbar and select "Contour" in the "Extraction" tab.

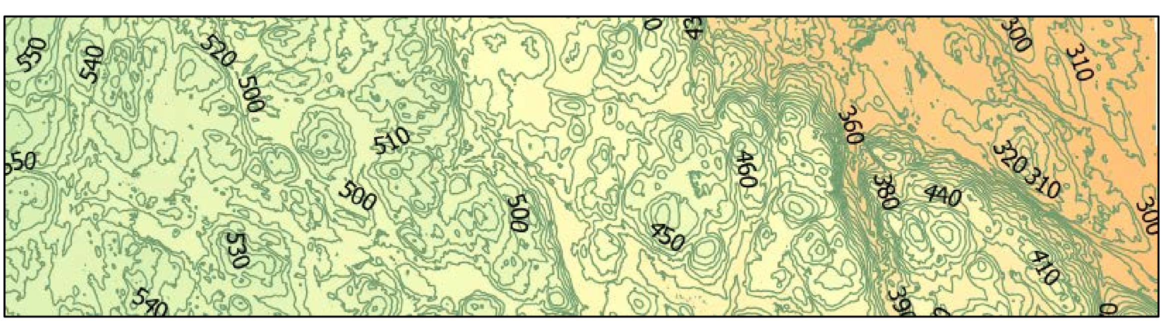


The following window will open. In this window, select the raster of your choice as the input layer and select a location for your output file (the "Contours" field). Use the "Interval between contour lines" field to choose the desired interval between the contour lines, then click on "Run in Background". A file containing the contour lines will be added to your table of contents.



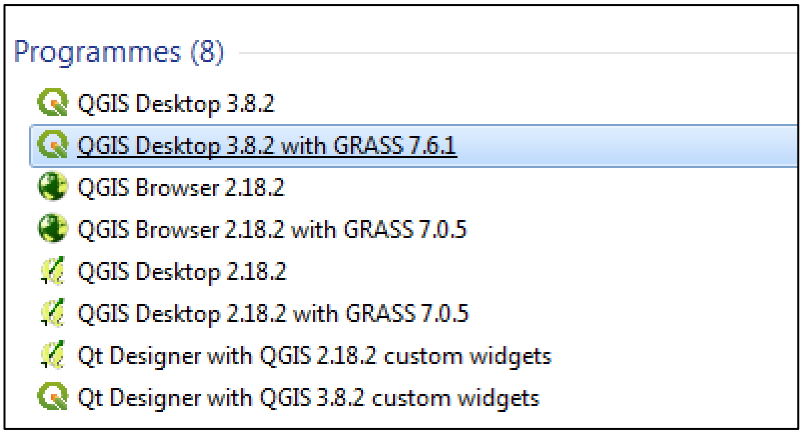
Thereafter, in the "Layer Properties" window (right-click on the layer title > "Properties"), you can change the colour of the contour lines ("Symbology" tab in the side menu) and the altitude can be shown by displaying the labels. To do so, click on "Labels" in the side menu, then choose "Single labels", followed by "ELEV" in the drop-down menu "Label with". Next, click on "Placement" and select "Curved" to make the labels follow the lines.





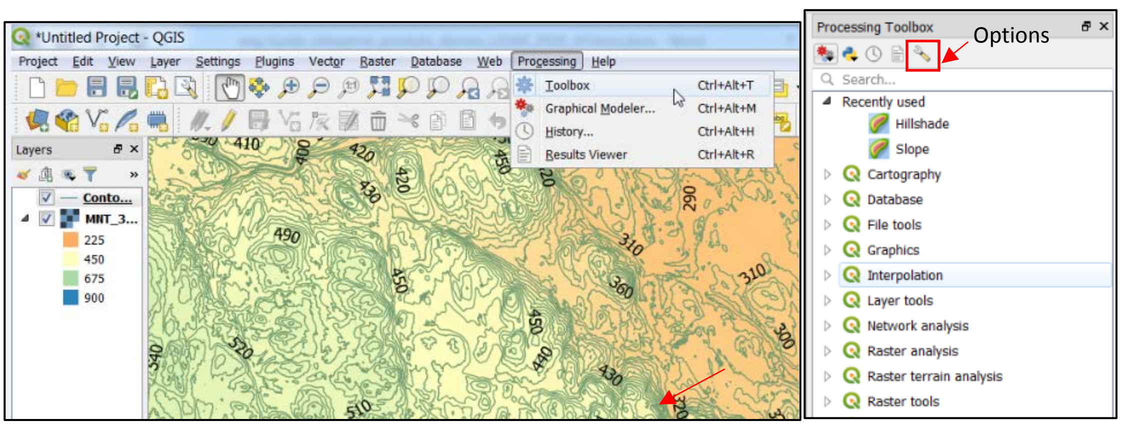
5.3.2 Reclassify Rasters

To reclassify rasters in QGIS, you will need to use the GRASS GIS extension that is usually downloaded at the same time as the QGIS application. It is important to open the version of the application that includes this extension.

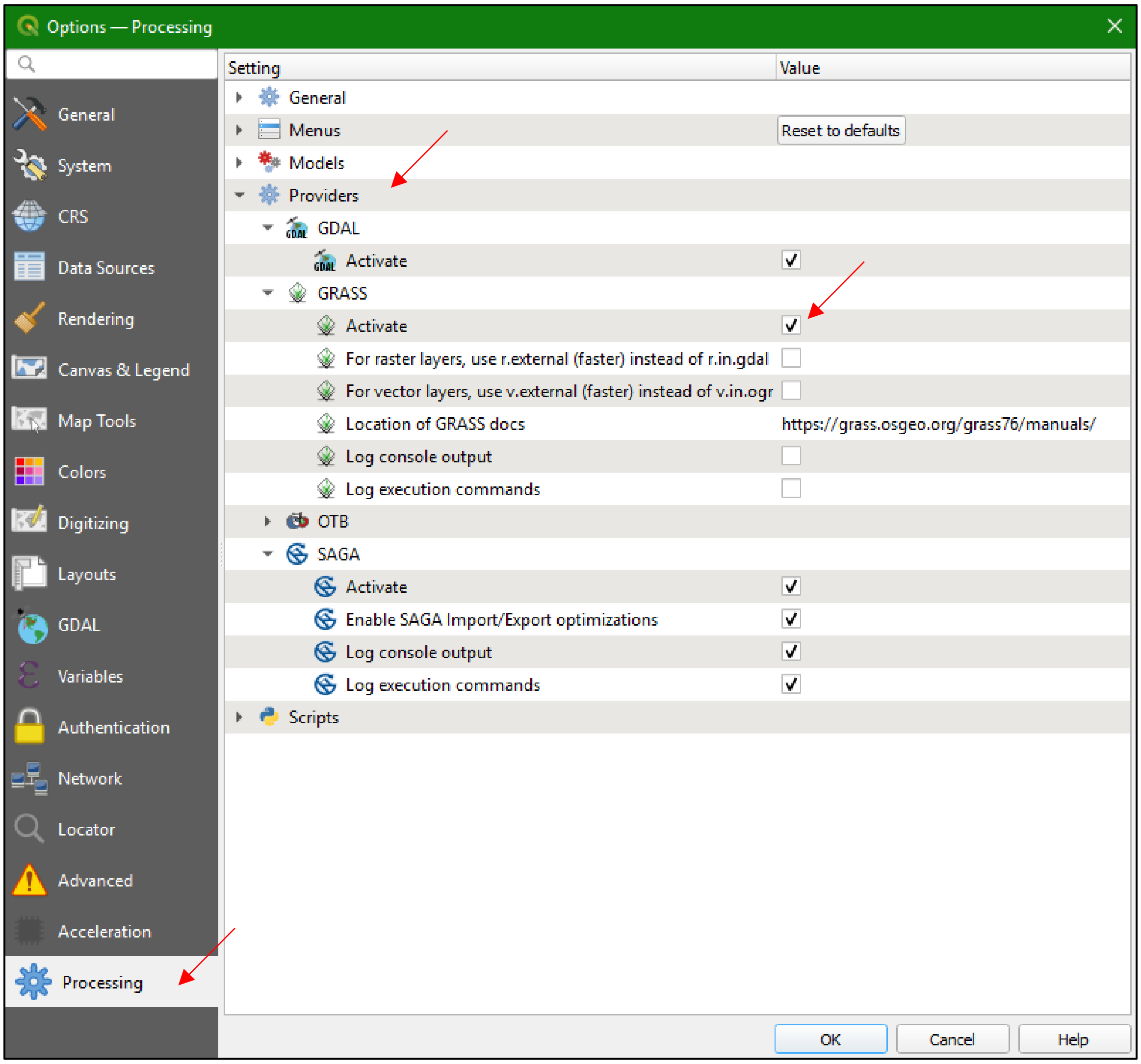


If you do not have the extension, you can download it here: https://grass.osgeo.org/download/.

Once the application has been downloaded and the correct QGIS version is open, you can access the GRASS toolbox in "Processing Toolbox" (main toolbar >"Processing" > "Toolbox"). Otherwise, click on "Options" in the "Processing Toolbox" taskbar.

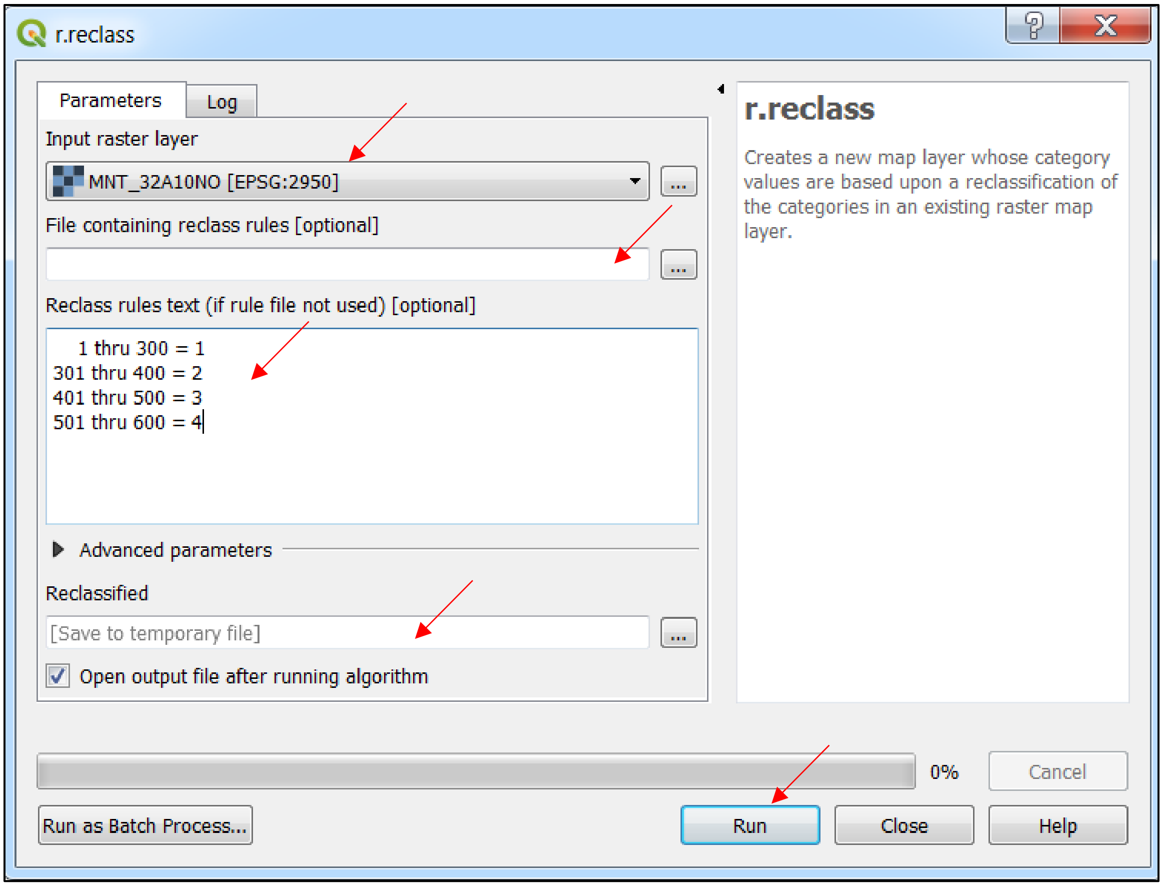


In the new window, select the "Processing" tab, followed by "Providers" and "GRASS". Make sure the "Activate" field is checked.

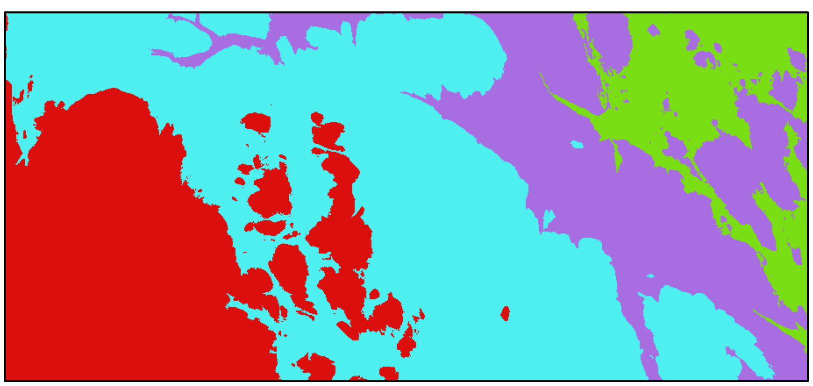


In the GRASS toolbox, click on Raster (r.*) and then on "r.reclass". The following window will open.

In this window, select the input raster in the "Input raster layer" field. You must also indicate the reclassification rules, which can be applied either by importing a document containing the reclassification rules in the field "File containing reclass rules" or by entering them manually in the "Reclass rules text" section. Lastly, in the "Reclassified" field, select the location for your output file, so that it is saved and click on "Run".



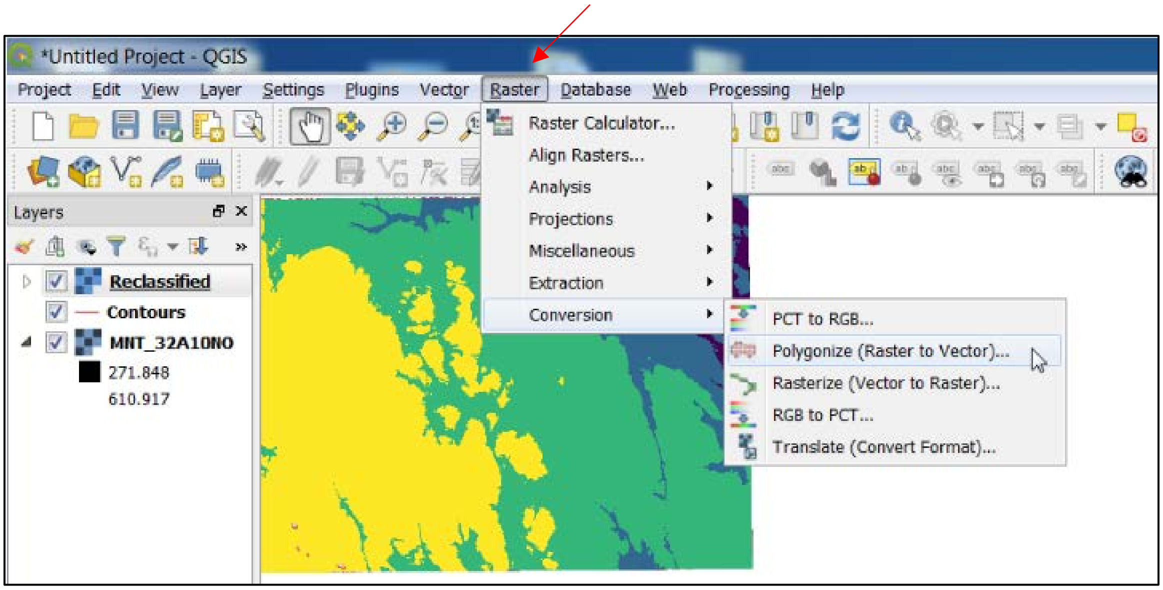
Your raster, with the new classification criteria, will be displayed on the screen. In the above example, the DTM values will be reclassified into four categories, based on altitude.



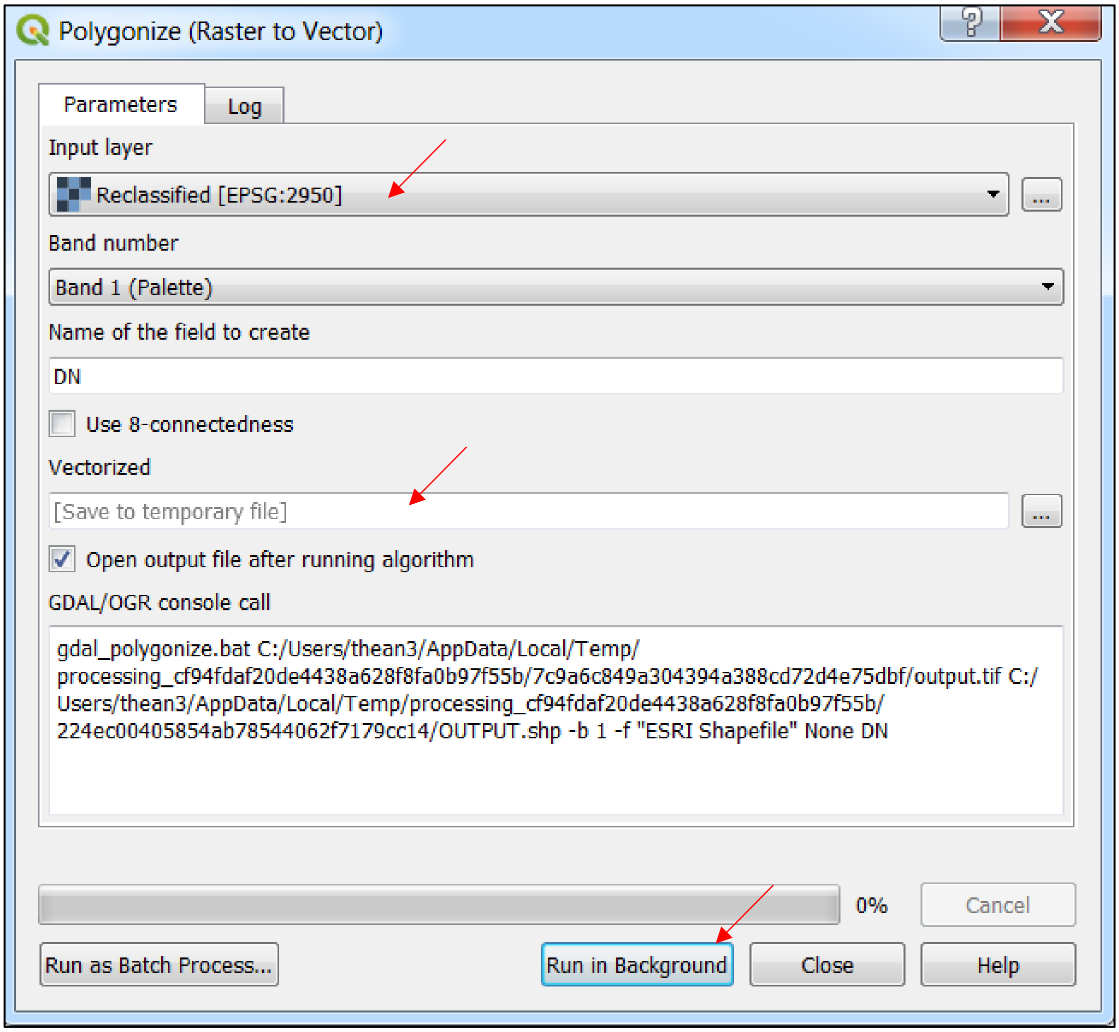
5.3.3 Convert a Raster Image to Vector Format (Polygons)

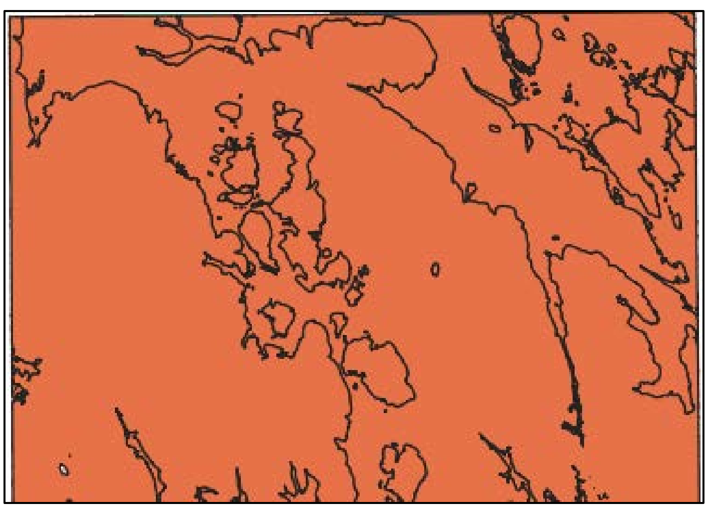
Converting a raster image to vector format allows LiDAR data to be used with certain types of GPS devices that are unable to read raster files. Firstly, make sure that the area of interest has been clipped as this is a very time-consuming procedure (see section 5.2.7). In addition, we recommend reclassifying the raster (see section 5.3.2) so as to avoid producing a polygon for each pixel, which would make the layer too big to use.

To convert a raster to polygons in QGIS, click on "Raster" in the main toolbar, then select "Conversion" and click on "Polygonize (Raster to Vector)".

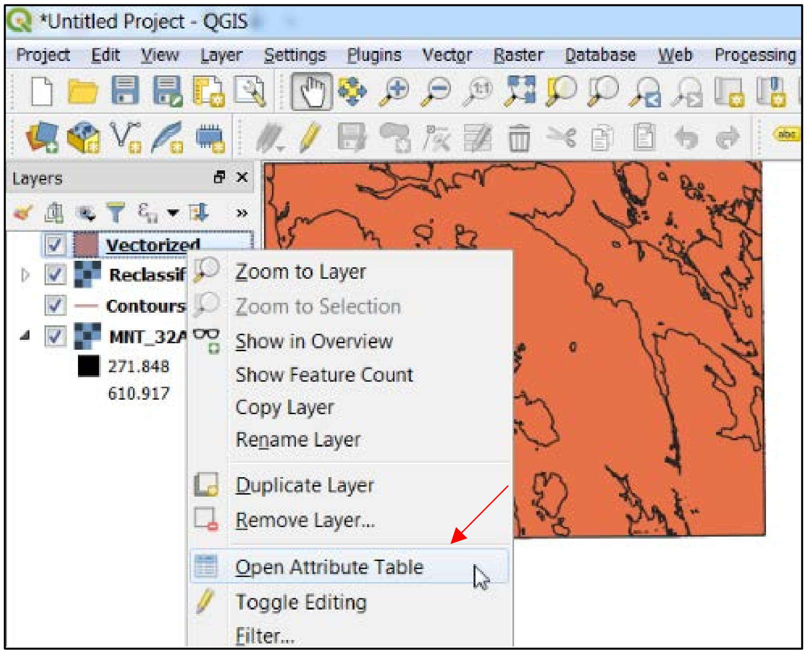


The following window will open. The “Input layer” is the raster to be converted to polygons. In the “Vectorized” field, select a location to save the layer permanently. Click on “Run in Background”. You will obtain a file similar to the image shown below.

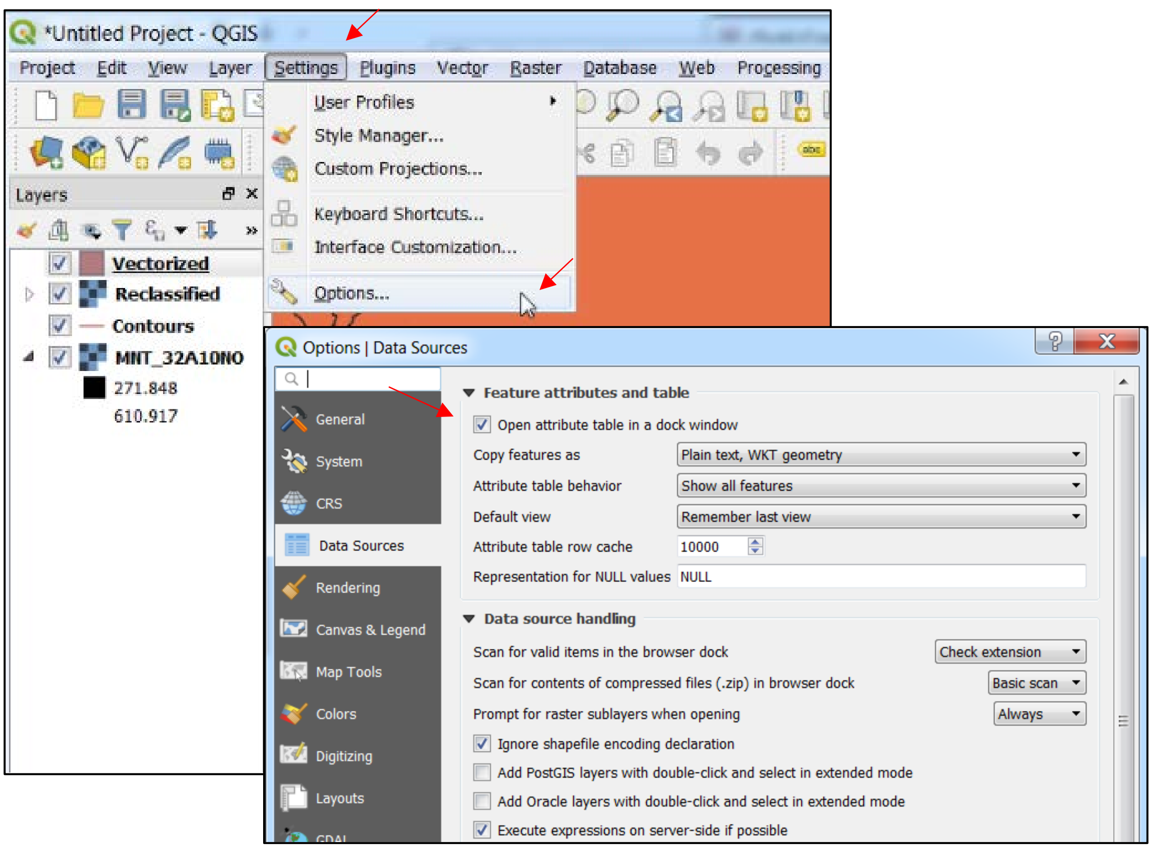




To open the new layer's attribute table, right-click on the layer title and on "Open Attribute Table".



If you want the table to be included in your project window, click on "Settings" in the main toolbar, and then on "Options". In the new window, select "Data Sources" and check "Open attribute table in a dock window".

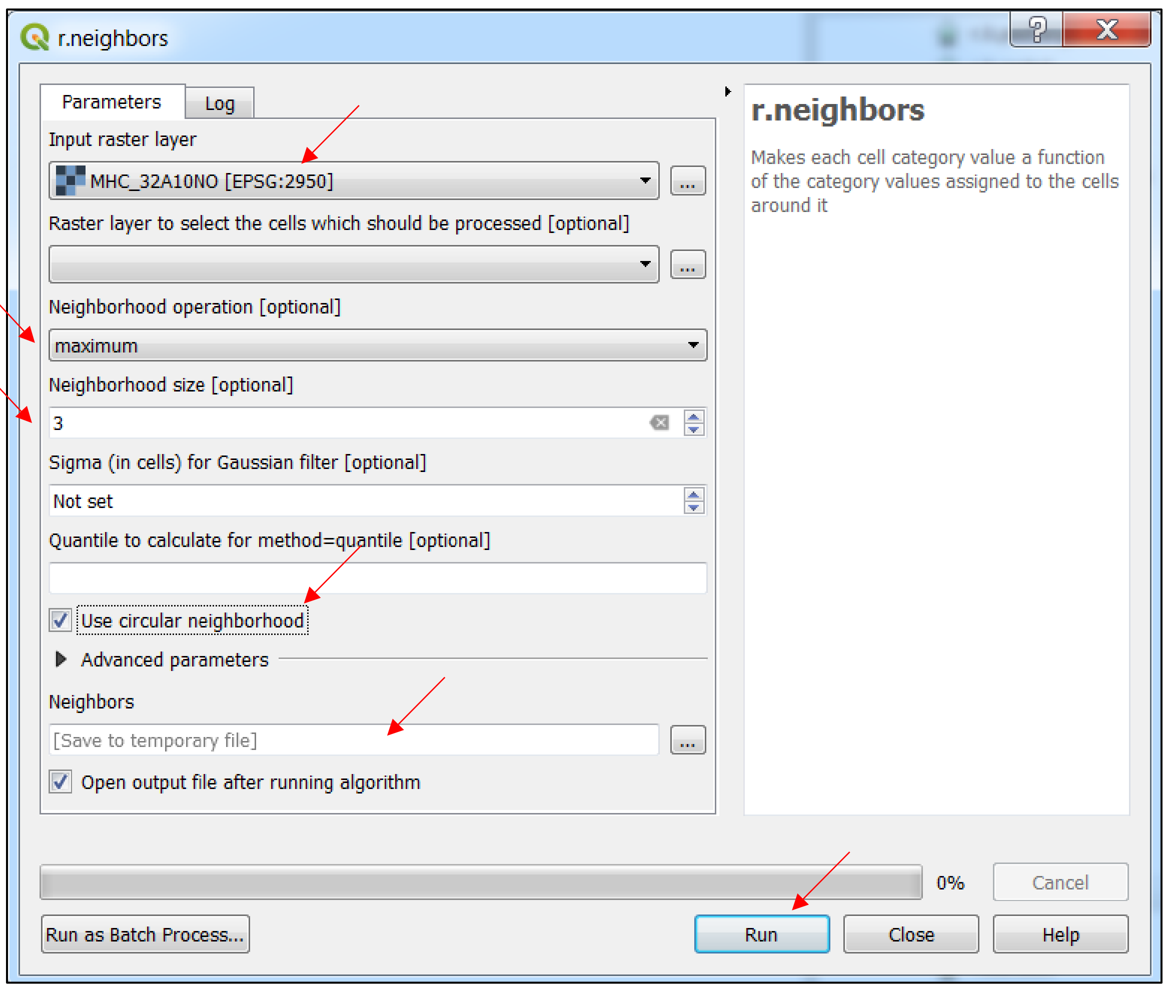


5.3.4 Create a Focal CHM

A focal CHM can be created from a CHM. The focal CHM better indicates the maximum canopy height value for coniferous trees, making it easier to interpret stand height. However, the focal CHM artificially expands canopy diameter and thereby significantly overestimates cover density.

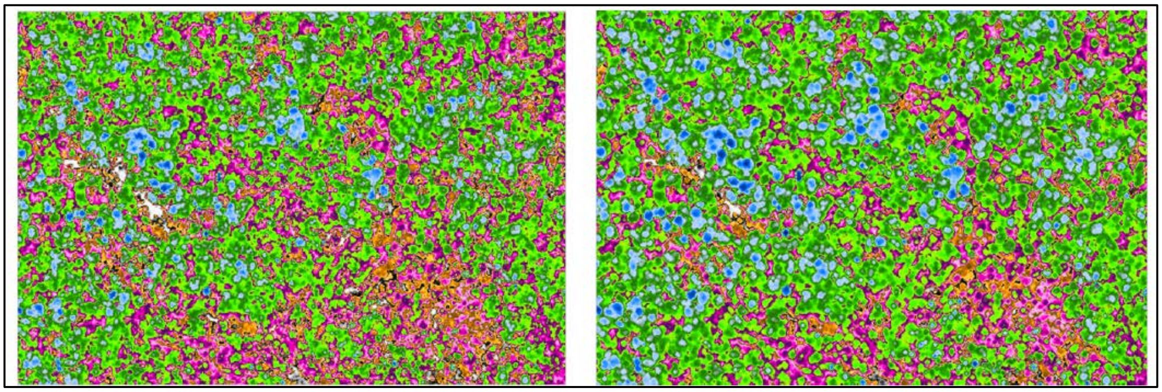
To create a focal CHM, start by adding the desired CHM to the project's table of contents. Next, in "Processing Toolbox" (main toolbar > "Processing" > "Toolbox"), select the GRASS box (see section 5.3.2 to install the GRASS extension if necessary), then click on "Raster (r.*)" and on "r.neighbors".

The following window will appear. First, select the CHM you want to use as the input raster ("Input raster layer"). Next, select "maximum" in the "Neighborhood operation" field, enter "3" in "Neighborhood size" and check "Use circular neighborhood". Lastly, select a file location to save your output focal CHM (the "Neighbors" field) and click on "Run". The circular option may not be available in some versions of QGIS, meaning that you will obtain a focal CHM with square canopies.



After processing, you will obtain a raster similar to the following image.

Standard CHM *Focal CHM*



5.3.5 Topographic Wetness Index

Another tool that can be created using LiDAR products and QGIS is the topographic wetness index (TWI), which is used to view areas having a potential for high moisture retention capacity. To do so, you must first have installed the "SAGA" extension.

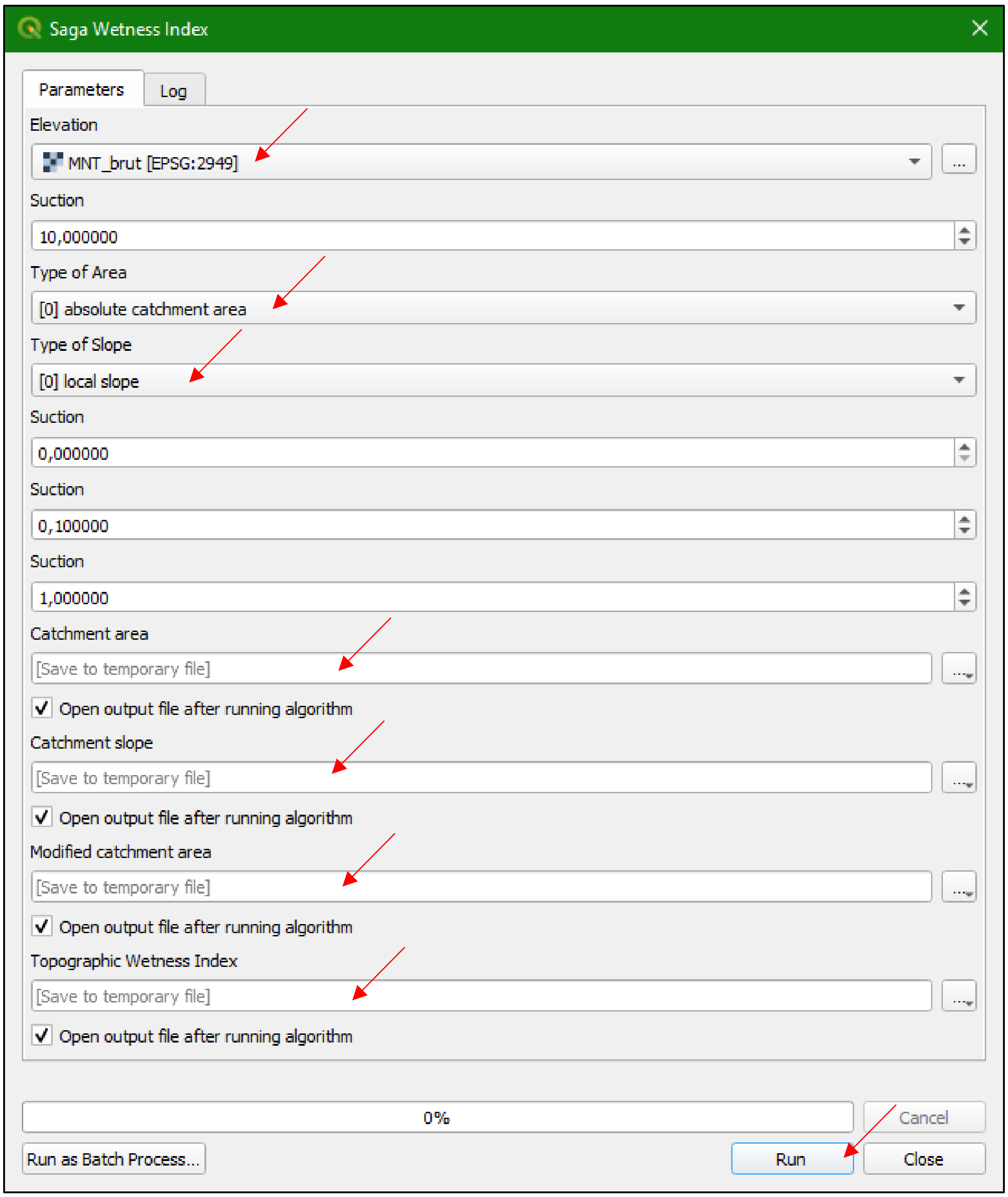
The SAGA file can be downloaded here: [https://sourceforge.net/projects/saga-gis/.](https://sourceforge.net/projects/saga-gis/)

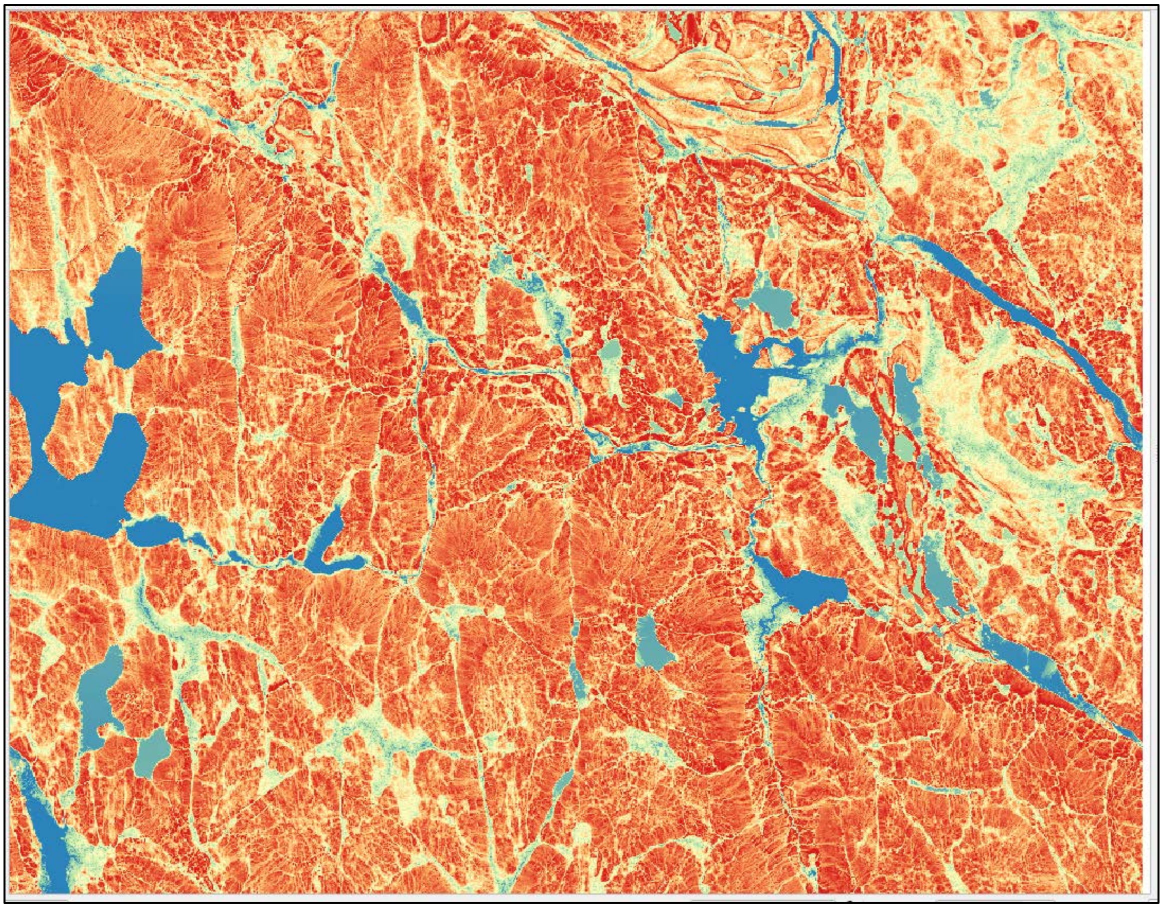
The SAGA toolbox can be found in "Processing Toolbox" (main toolbar > "Processing" > "Toolbox"). If not, click on "Options" in the "Processing Toolbox" taskbar.

The first step in creating a TWI is to fill depressions in the digital terrain model. To do this, select "Preprocessing > Fill sink XXL" (see section 4.2.5).

Next, in the "Processing Toolbox" taskbar (main toolbar > "Processing" > "Toolbox"), select "SAGA", then "Terrain Analysis-hydrology" and finally, "SAGA Wetness Index".

The following window will open. In this window, you must use the filled DTM raster completed in the previous step in the "Elevation" field. Next, select "absolute catchment area" in the "Type of area" field, and "local slope" in the "Type of slope" field. Lastly, you must select locations to save the four output files ("Catchment Area", "Catchment Slope", "Modified Catchment Area", and "Topographic Wetness Index"). This will generate a TWI similar to the following image, once the colours have been changed. Please note that this process is very long and modelling should be limited to the area of interest.





6 CONCLUSION

This document is intended to help with the use of products derived from LiDAR data. For comments or to suggest improvements, please contact the Direction des inventaires forestiers:

inventaires.forestiers@mffp.gouv.qc.ca

7 REFERENCES

LACROIX, S. and F. CHARRETTE (2013). *Une meilleure planification grâce à l'inventaire forestier amélioré par LiDAR*, Rapport Avantage, vol. 14(1), 8 p.

LEBŒUF, A., S. LACROIX and S. VÉZEAU (2015). *Projet d'acquisition de données par le capteur LiDAR à l'échelle provinciale. Analyse des retombées et recommandations*, 18 p. [https://mffp.gouv.qc.ca/documents/forets/inventaire/Analyse_retombees_LiDAR-Finale.pdf].

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, vol. 9(1): 381-397.

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