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BASICS OF GIS FOR IMPROVING SPATIAL PLANNING IN FORCIBLY DISPLACED SETTINGS

PART 1

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1. INTRODUCTION

Planning settlement infrastructures require a good understanding of the terrain on which they will be built. Geographical Information System (GIS)[1] and Computer Aided Design (CAD)[2] coupled with Remote Sensed (RS)[3] data allow the planner to design solutions adapted to the specific realities of the terrain. This saves time and money and make possible to plan more efficient solutions, as well as to monitor their implementation. In addition, risk management and other non-classical engineering thematic, may be included the design process, thus improving the resilience of the planned infrastructure.

The goal of this document is to introduce GIS for engineers beginning with such software. It is a big asset for planners to improve their working knowledge of GIS, since this is the "Swiss knife" for preparing robust data that will be then imported into CAD for the detailed design of infrastructure. The basic GIS procedures are here presented, as well as how to synchronize GIS data and CAD.

This tutorial uses use the flood phenomenon as an example, as it is one of the main external elements constraining the settlement design, but GIS can be used for many other settlement planning, monitoring and management tasks. This document presents how to measure specific characteristics, such as the area (of a plot, block, etc) in order to compute hydrologic parameters important for flood protection. However, it doesn't replace more in depth GIS trainings[4] available elsewhere and it relies on the "Basic notions of GIS for settlement mapping, part 1".

There is a strong link between GIS and CAD and both are useful tools for the planner to map and design settlements. Most often, GIS software are used to represent the reality of a terrain (existing or as a possible scenario), while CAD software are used to design new features. The two worlds come with their strengths and weaknesses and the bridge between them, while important, can sometimes be tricky. For the topic covered in this document, GIS is used chronologically before CAD, in the step of data preparation, and therefore this document focusses on GIS only, but some hints will be given regarding CAD.

This document is composed of two sections. In the first part, some theoretical elements necessary for understanding the GIS world are presented. The second part provides a practical guidance enabling photointerpretation and simple image analysis.

2. THEORETICAL ELEMENTS

2.1. General information

GIS is a database with spatial references. It allows the retrieval of data from a spatial database (potentially with links between different datasets) and displays the combination of all these data at the correct place (even if the sources are not with the same projection). This enables superposing data and analysing the results.

Indeed, GIS by displaying data in correct places allows to create yet non-existing data on a given location, especially in the form of maps (i.e. thematic map).

In settlement planning activities, GIS is the tool for:

- Acquiring/checking spatial data
- Producing thematic maps and identifying hot spots
- Preparing data to export towards CAD for design of infrastructures.

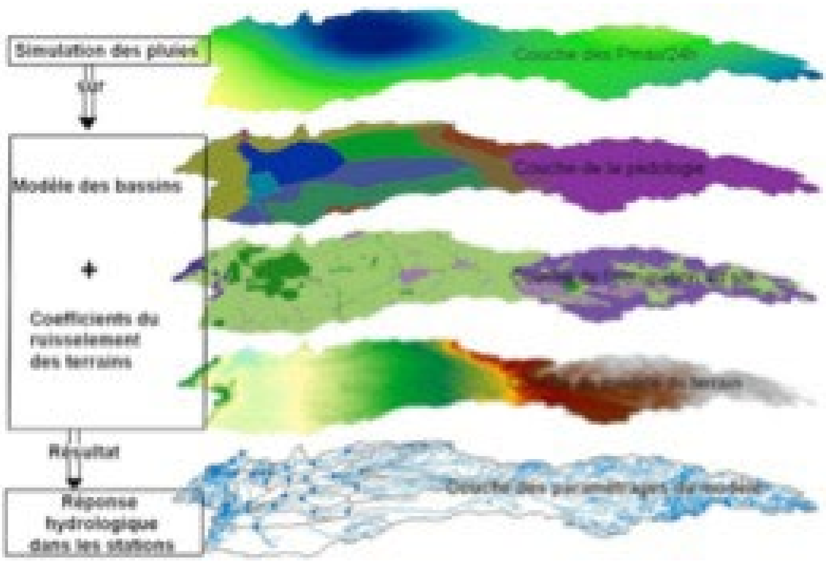

Figure 1. Example of layer assemblage for flood analysis (source: Reynard et al. 2012).

1 Well-known GIS software are Arcmap (proprietary) and QGIS (open source)
2 Well-known CAD software used for mapping are AutoCAD (proprietary) and QCAD (open source)
3 Often used acquisition sources are satellite, drones, airplanes, etc.
4 https://docs.qgis.org/3.22/en/docs/gentle_gis_introduction/
https://gistbok.ucgis.org/bok-basic-page/welcome-gist-body-knowledge
https://volaya.github.io/gis-book/en/Cartography.html
https://www.esri.com/training/mooc/

2.2. Vector data

Vector data is represented with different geometries, divided into 3 types of primitive elements, namely

- Point
- Line 
- Polygon 

In GIS, each file contains only one geometry[5] . The main reason for this is that each geometric element comes with a table of attributes since GIS creates spatially referenced databases. For example, linear elements will not be depicted with an attribute related to “areal characteristics”.

The standard data format for saving vector information is named shapefile.

- For being functional it requires a minimum of 3 files with the same name and the following extensions .shp, .dbf, .shx.

Be aware that for exchanging data with your colleagues, you need to share at least these 3 files.

- The spatial index of the shape .sbn or .sbx, and a file defining the projection system .proj are often added (see § 2.4).
- In the table (stored in the XX.dbf file), the name of the attributes (fields, columns), associated to an element, is limited to 10 characters.
- Avoid naming the shapefile with characters other than english one (i.e., no accent) and spaces.

2.3. RASTER data

Raster data cover the whole extent of a grid. Each element of the grid (pixel) represents a value. The size of a pixel is equivalent to the resolution of the RASTER and is regular on the whole grid system. 

By applying calculus to the grid (to each pixel) it is possible to produce new information. It is also possible to use spatial mathematics for computing the statistic of the grid values on a given vector polygon.

Typically, a RASTER is a digital picture, with on a rectangle (the grid system) each pixel giving an information about the colour. This is the background satellite/airborne imagery that you will use to visualize a settlement and design features.

For application to settlement planning,a widely use RASTER is the Digital Elevation Model (DEM), which contains the altitude of each pixel on the area under study. DEM can be generated with information collected with drones (stereo-imaging), satellite or other methods. Most often the first result you will get is a Digital Surface Model (DSM), which includes in the model the canopy of tree and the roofs of the tents/shelters. Although it is very useful, it cannot be used for analysis of slopes including hydrological computations. For that you need a Digital Terrain Model (DTM) or a DEM.

2.4. Projections

The earth is a 3D spherical[6] object and a map is a 2D sheet of paper (or computer screen). Therefore, one should transform the position of the element to be coherent (see Figure 2). This transformation is what we call a projection.

Why controlling the projection is important? Different applications need distinct projection systems. Not paying attention to it will cause the data to be impossible to superpose coherently and accurately (on the position X, Y Z of any point)

Note also that data providers (like UNOSAT/UNITAR, FAO, etc.) will probably use different projections than the one that you will use for planning.

In the context of settlement planning, the importance of projection can be summarized as follows:

- The most common projection issued for satellite data is a non-projected system in Latitude and Longitude (expressed in degrees). The name of this projection is WGS84.
- WGS84 is the one used by GPS, as it is valid all over the globe (WGS84 refers to a geoïde defined in 1984 and it is used in several forms)
- The European Petroleum Survey Group (EPSG) gives a code to all projections and this WGS84 projection is given the EPSG code: 4326 (https://epsg.io/4326). The EPSG code is convenient for searching the right projection in the GIS module dedicated to it. It is another name for the Coordinate Reference System (CRS).

5 *Which is not the case in CAD where one file may contain different geometries.*
6 *To be correct the exact shape, the spheroid, is more similar to a “potato” called the geoïde !*

The problem is that this projection (WGS 84) prevents to make any calculus linked to the slope, which is necessary for many analyses, for example flood risk. This is due to the fact that the algorithm that computes slope from the altitude digital model (the DEM) could be applied only on a RASTER grid with perfect squares. WGS84 grid, as linked to the geoïde, presents a grid with rectangles (changing from place to place). It follows that for settlement planning activities:

You need to use a projected-type of projection such as the Universal Transverse Mercator, UTM, which is also available for the whole globe, when you are working for design purposes.

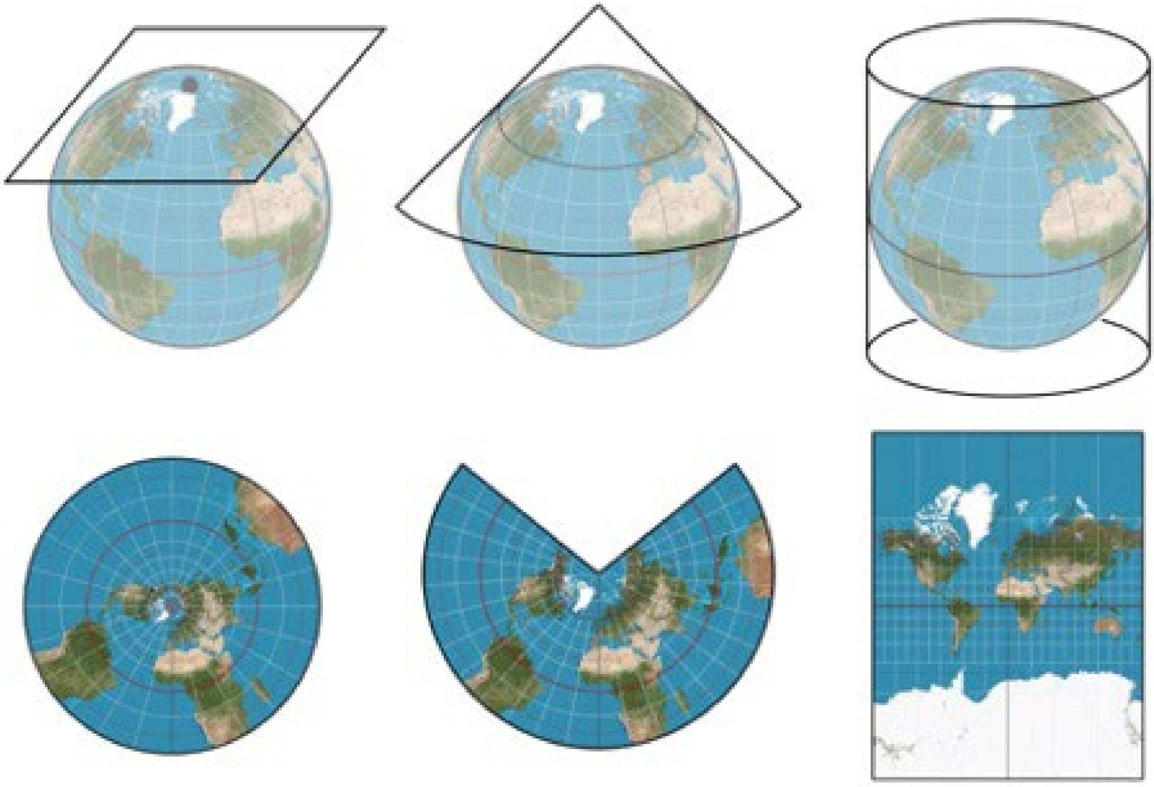

Figure 2. Example of different projection and their results (source UCGIS).

2.5. Use of DEM

In the context of settlement planning, the main use of the digital elevation model is to analyse the topography of the terrain to see if some hazards may threaten the site, such as floods or landslides. For those applications you need to compute the slope (gradient) of the terrain (therefore the need of having these data in projected format).

Here is a brief example of how RASTER data may be processed by GIS for enabling new information emerge from a single source. The example in Figure 3 illustrates how to obtain the slope, but it may be used for other applications.

Slope / gradient =

$$\arctan\left(\sqrt{\left(\frac{z_2-z_8}{2\cdot R}\right)^2+\left(\frac{z_6-z_4}{2\cdot R}\right)^2}\right)$$

Azimut / direction =

$$\arctan\left(\frac{z_2-z_8}{z_6-z_4}\right)$$

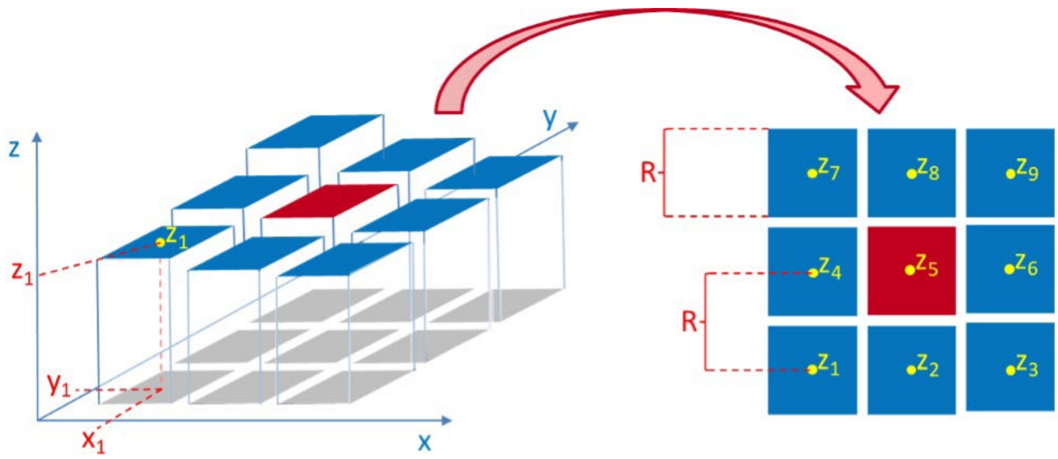

Figure 3. Slope is computed from the square pixels of a regular grid, by looking to the adjacent cells/pixels. See algorithm on the left side

3. GIS PROCEDURES

The procedures below are prepared with the version 3.22.4 of the long term release (ltr) of QGIS downloadable at : https://qgis.org/en/site/forusers/download.html#

On the images below :

a red box means mouse click, and a green box a right-click, while the field where you need to type in a command are highlighted with a yellow box .

The field names you need to click on are highlighted in ***blue bold italic***.

3.1. Prepare your GIS for analysis

The first step for any analysis, is to get a «background» image. Here is the way to display these images, from several sources.

In the browser, right-click on ***XYZ tiles*** (green box on Figure 4), and then click on ***New Connection...*** (red box in Figure 4).

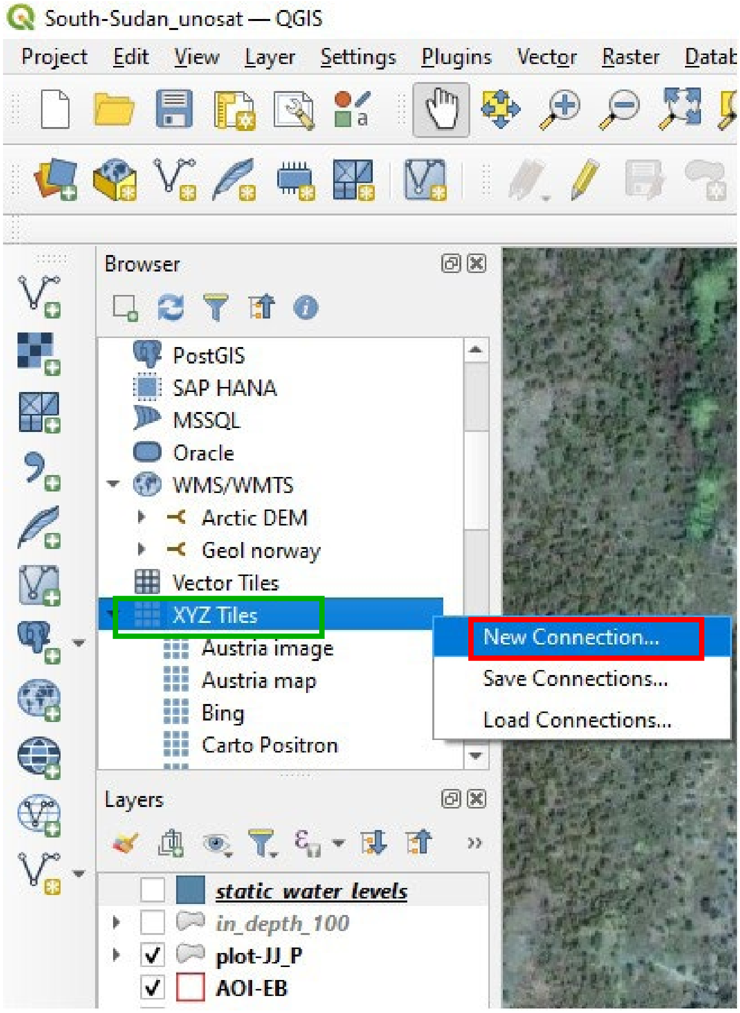

Figure 4. Adding a new XYZ tiles connexion (background images)

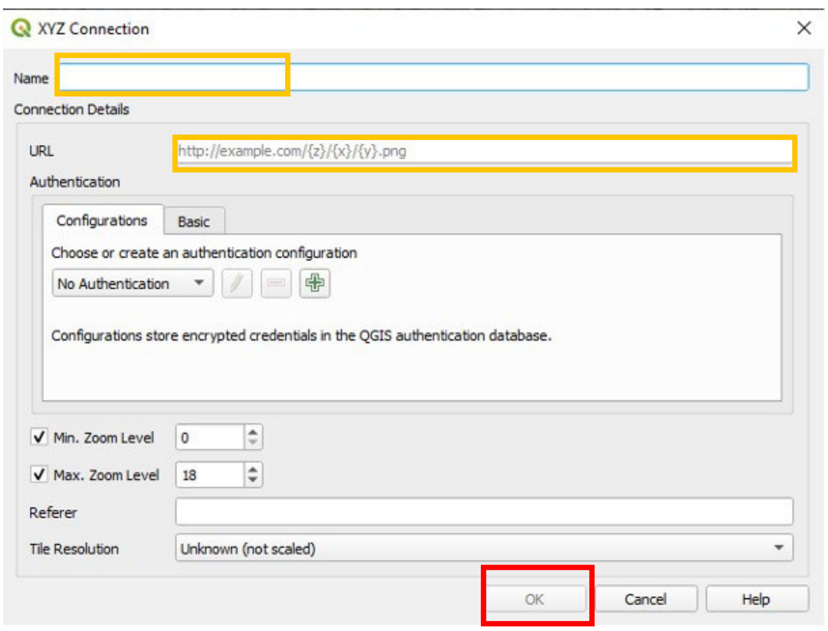

Figure 5. Window for adding new YXZ tiles connexions.

In the window appearing (Figure 5), provide a name and paste the URL of the wanted XYZ tiles (yellow boxes), then click ***OK*** (red box).

Below are useful sources for settlement planning tasks (copy & paste the link into the URL)

- Bing (satellite) http://ecn.t3.tiles.virtualearth.net/tiles/a{q}.jpeg?g=1
- Google earth (satellite) http://www.google.cn/maps/vt?lyrs=s@189&gl=cn&x={x}&y={y}&z={z}
- Esri (satellite) https://server.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer/tile/{z}/{y}/{x}
- OSM humanitarian http://a.tile.openstreetmap.fr/hot/{z}/{x}/{y}.png
- Open street map (OSM) https://tile.openstreetmap.org/{z}/{x}/{y}.png
- ESRI topo https://server.arcgisonline.com/ArcGIS/rest/services/World_Terrain_Base/MapServer/tile/{z}/{y}/{x}

Be aware that these images are provided by third parties, and they may not be up-to-date in the area under analysis. Comparing different sources will help get a better idea of the area.

Adding proprietary/dedicated airborne images is also possible by importing a RASTER file under. geotiff format. This will be explained in § 3.5.

Displaying the background images on your project map is done by :

Right-click on the source you choose (here ***Bing***, green box in Figure 6), then click on ***Add Layer to project*** (red box on Figure 6). Alternatively, just double-click on the source.

The background map should now be visible on your screen, as in Figure 7.

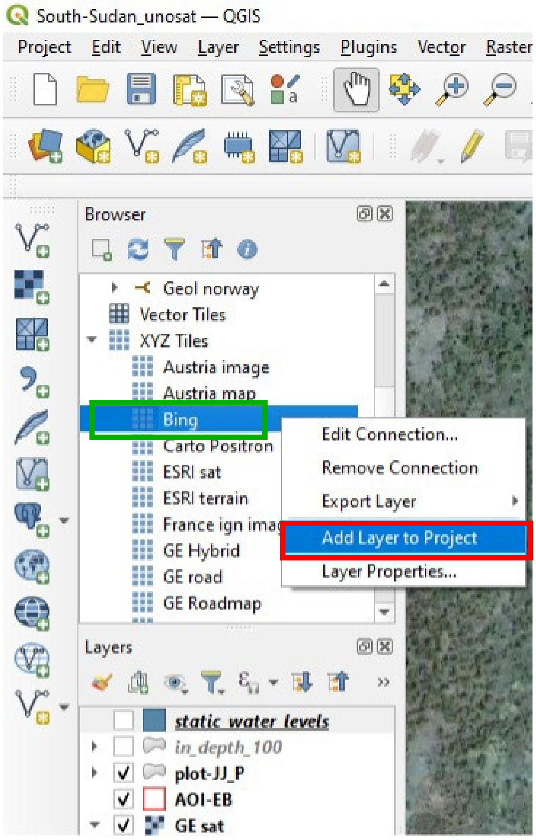

Figure 6. Importing XYZ tiles (here with a Bing image) in a blank project.

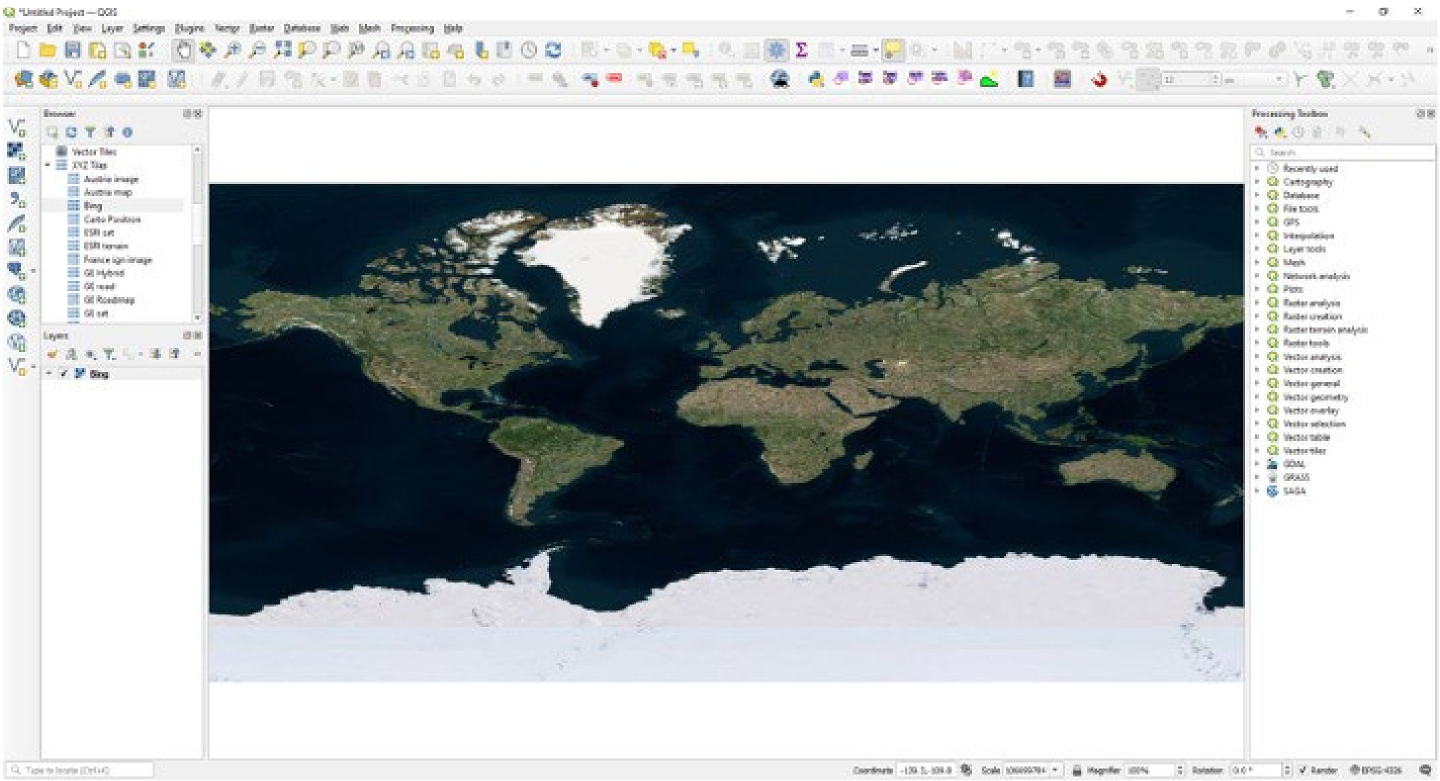

Figure 7. Bing image imported in the GIS project.

3.2. From the world to your working location

Go on the lower right of the QGIS window and enter the coordinates and scale corresponding to your working location, as in the yellow box in Figure 8.

You should obtain the map as in Figure 9. Another possibility for zooming directly to the work location is to add a shapefile of the location, right-clicking on it and selecting ***Zoom to layer*** from the drop-down list.

Looking more closely to the image, it seems that the Bing images on the example of Jamjang camp in South Sudan aren't recent. If the river is well marked, shelters are missing. In this particular case, Google Earth images are more accurate.Once this is done and once your layer is in edition mode (see § 3.4) the drop-down list appears when you are entering info on the given column.

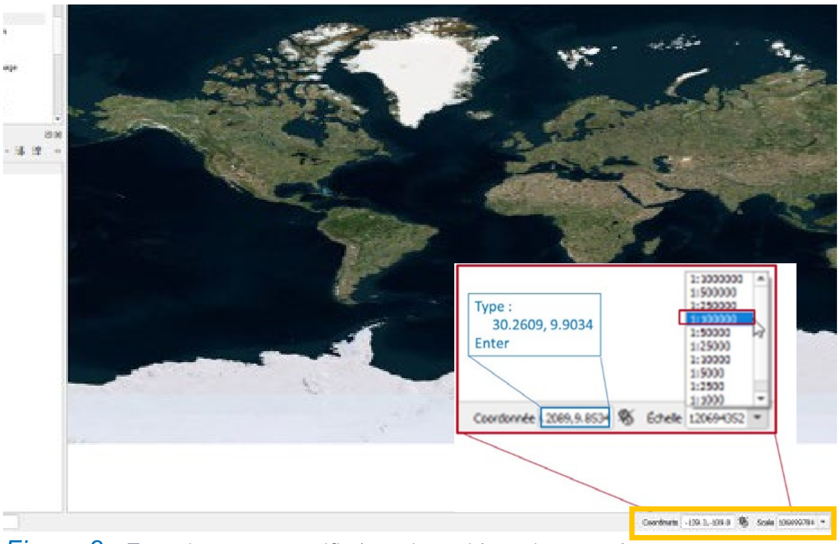

Figure 8. Zooming to a specific location with a given scale.

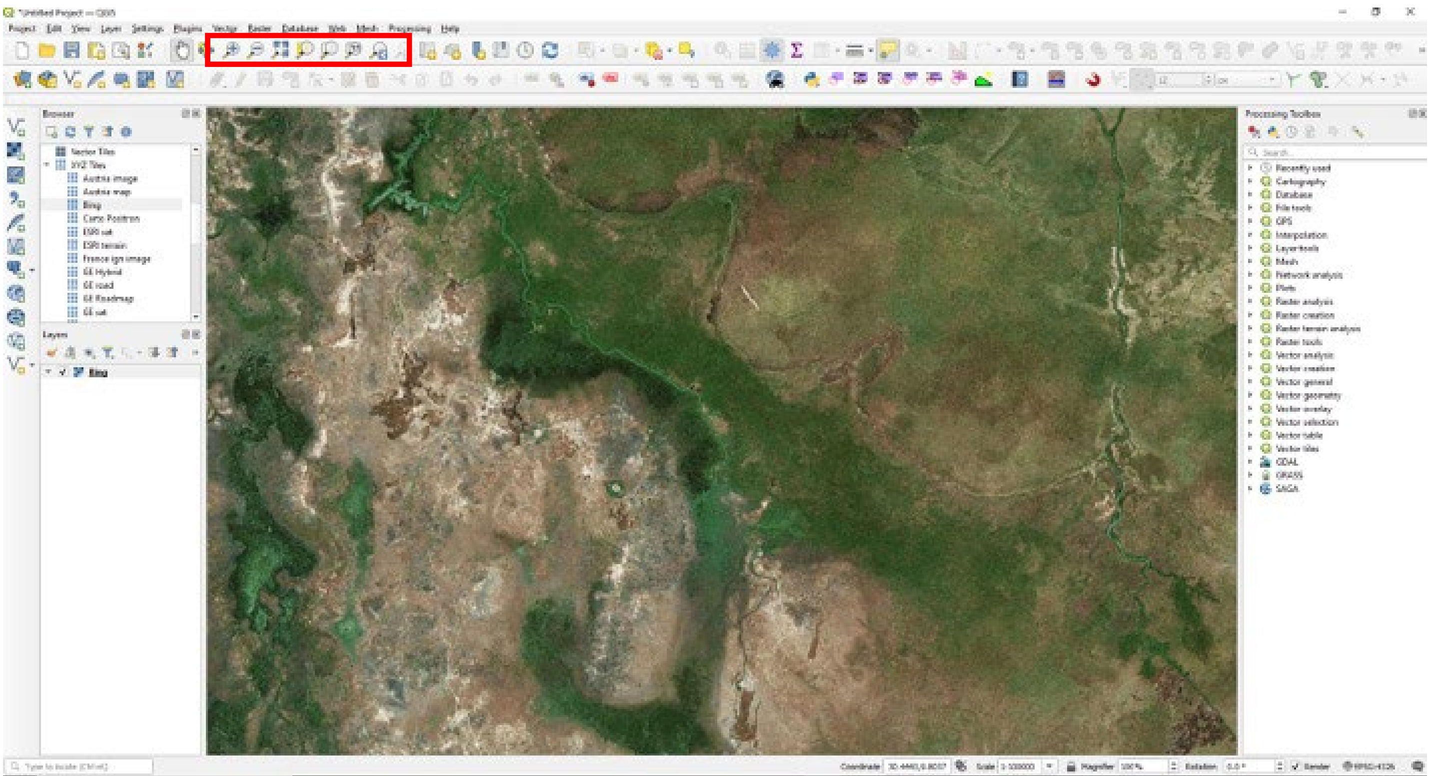

Figure 9. Visual inspection of images on the working location (here Jamjang settlement, South Sudan). Other zoom options are in the red box and the scroll wheel of your mouse may also be used.

3.3. Adding existing vector data

For adding existing vector data, go to:

Layer --> Add Layer --> Add vector layer

as in Figure 10.

Alternatively, click on the left red box on Figure 11.

Then navigate to the file you want to import (middle red box in Figure 11), and finally click on ***Add*** (bottom red box on Figure 11).

Most often vector data are shapefiles, with a .shp file extension (but look also to § 2.5), but you can also import other file formats such as .kml.

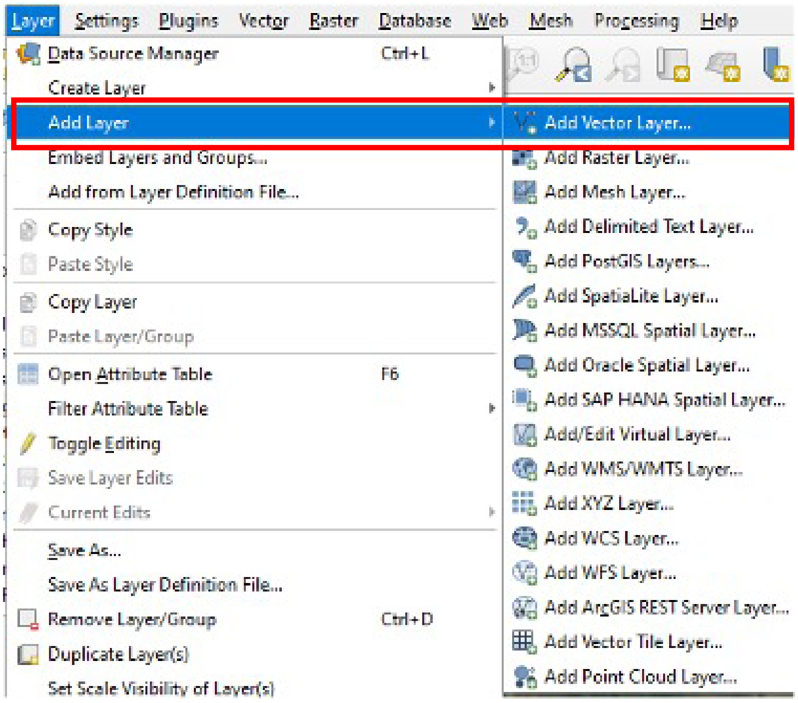

Figure 10. Adding layer by the drop-down menu.

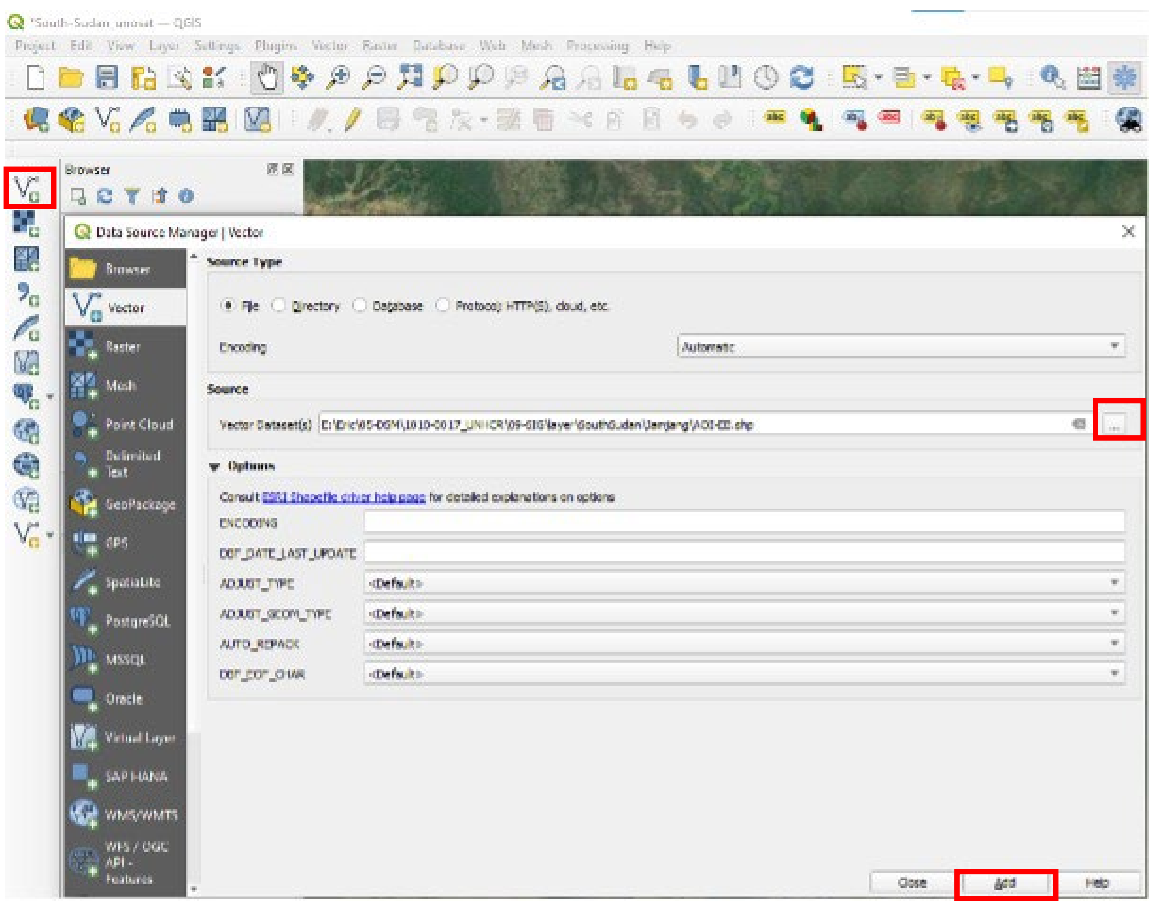

Figure 11. Adding vector data with the button found in the menu à view à panel à layers à add vector layer (Ctrl + Shift + V).

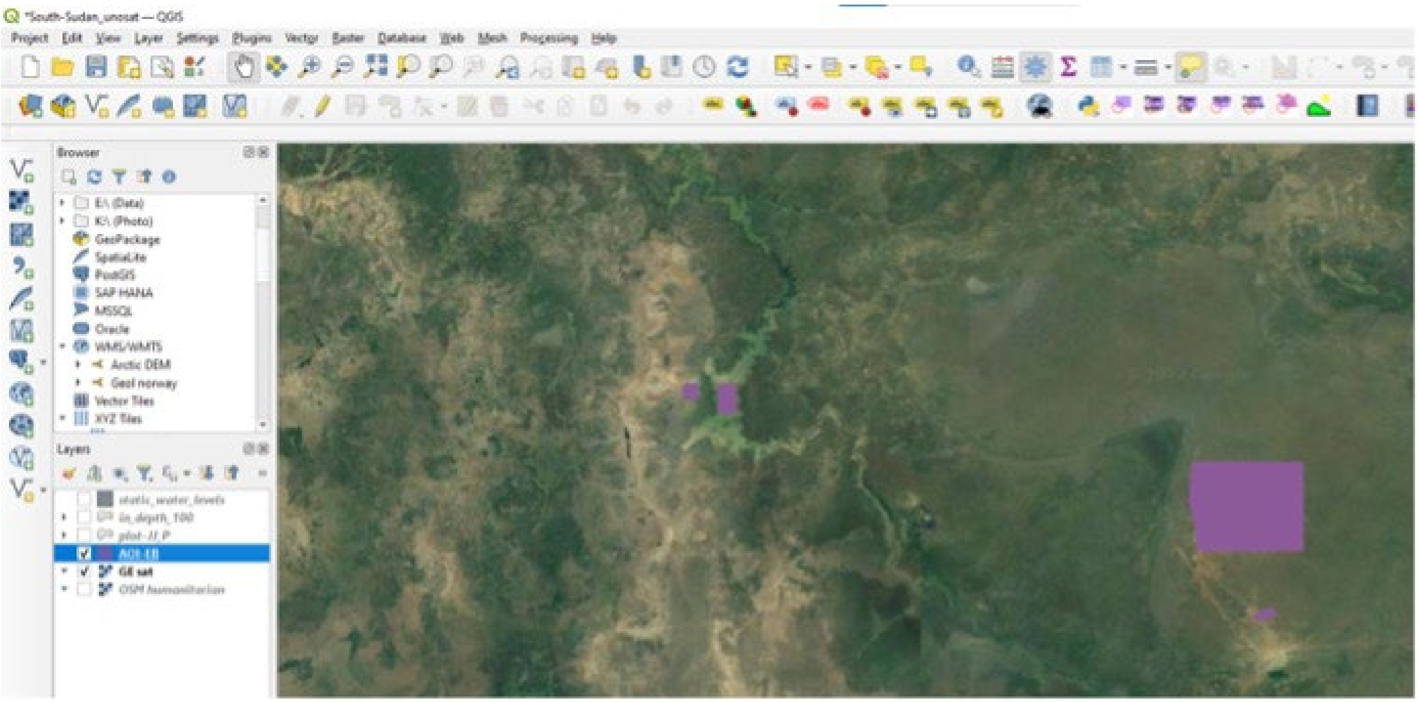

Figure 12. *The shapefile is added to the map as a new layer (if you change layer order it may become hidden beyond another one)*

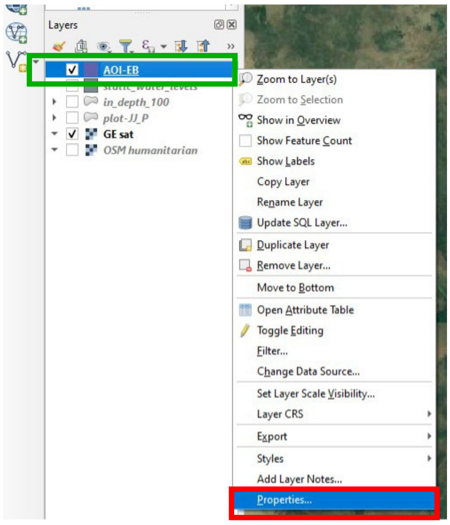

Figure 13. *. Looking to the properties of a vector layer.*

3.4. Displaying data according to your needs

Select the layer you want to edit and click. Once you get the data in the layer manager and on the map, it comes automatically with a colour (see Figure 12).

You can edit the displaying properties to allow for easier analysis: right-click on the Layer and click on ***Properties...*** (see Figure 13).

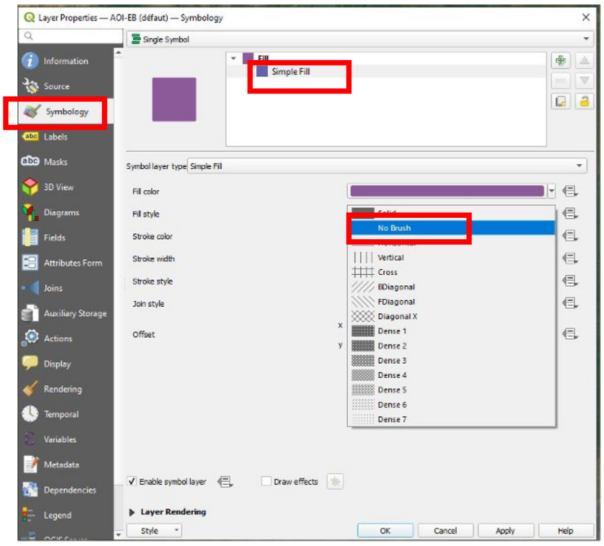

Figure 14. *How to choose an empty polygon just highlighted by its contour.*

A new window opens: click on the symbology tab (left panel, see Figure 14). In our example we want to have the contour of the file, representing the Area of Interest, with a transparent polygon to be able to analyse the camp. On the symbology click on ***Simple Fill*** and choose ***No Brush*** from the drop-down menu.

You can then change the colour, thickness and style of the stroke, as in Figure 15. Other display options are possible if you look in the menu.

Click on ***Apply***. The display is adapted as in Figure 16.

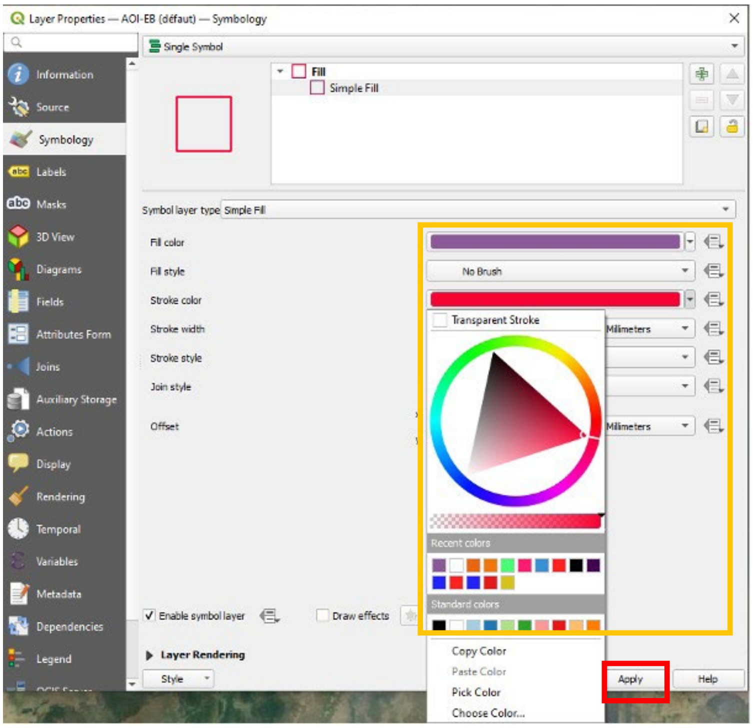

Figure 15. Choosing a colour, here for the contour but the process is the same for the main brush.

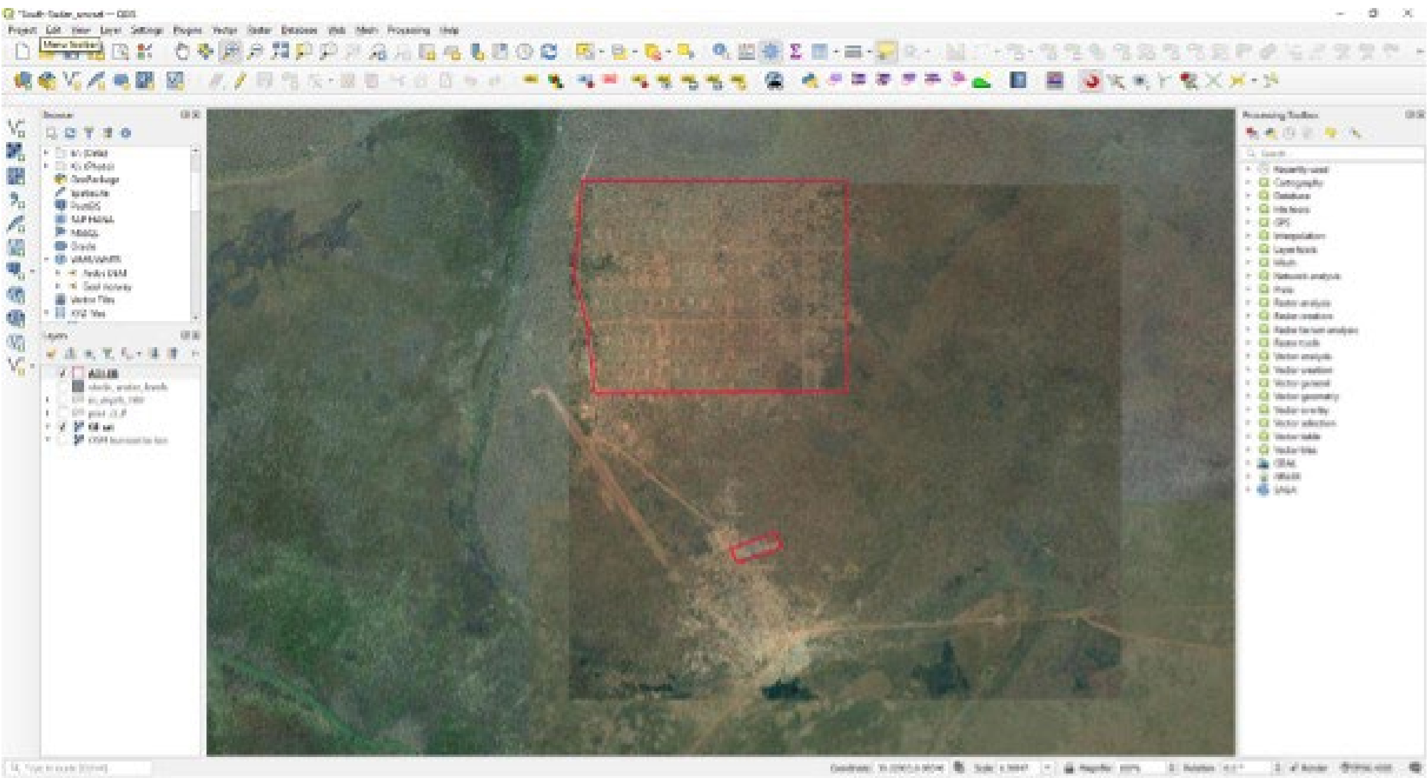

Figure 16. Resulting map with contour of polygon only.

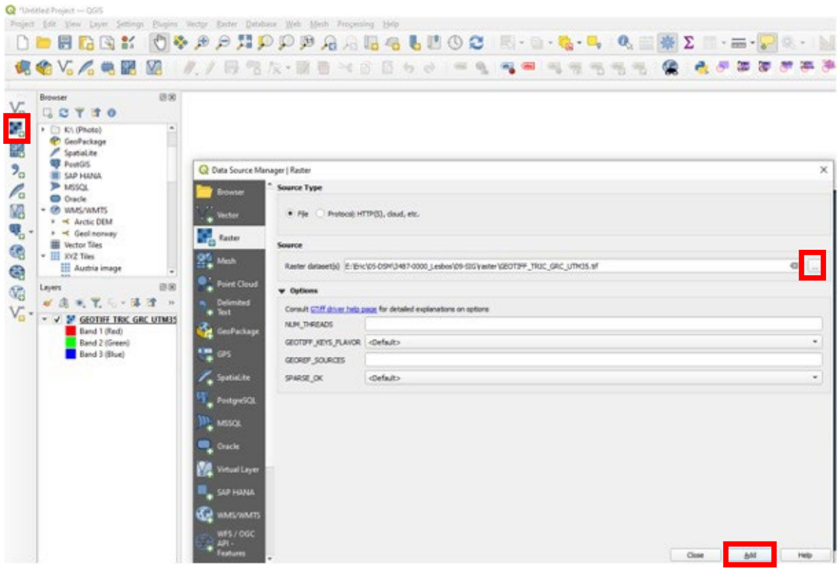

Figure 17. Adding RASTER data.

3.5. Adding existing RASTER data

For adding existing raster data, such as an aerial image, go to:

Layer --> Add Layer --> Add raster layer

Then navigate to the file you want to import and finally click on ***Add***.

Alternatively, click on the left button highlighted with the red box on Figure 17.

Georeferenced aerial images have a .geotiff file extension. It is also possible to import non-georeferenced raster data, such as scanned paper maps (site plan, hazard map, etc), but you will need to adjust manually the scale and the position of the raster map, and this goes beyond this course series.

In this example we import an airborne image in true colour (3 bands red, green, blue) for visual inspection.

By right-clicking on the layer and selecting the properties, you can access the information tab, displaying important information, such as the resolution of the grid (top orange box of Figure 18) and the Coordinate Reference System (CRS) (bottom orange box of Figure 18).

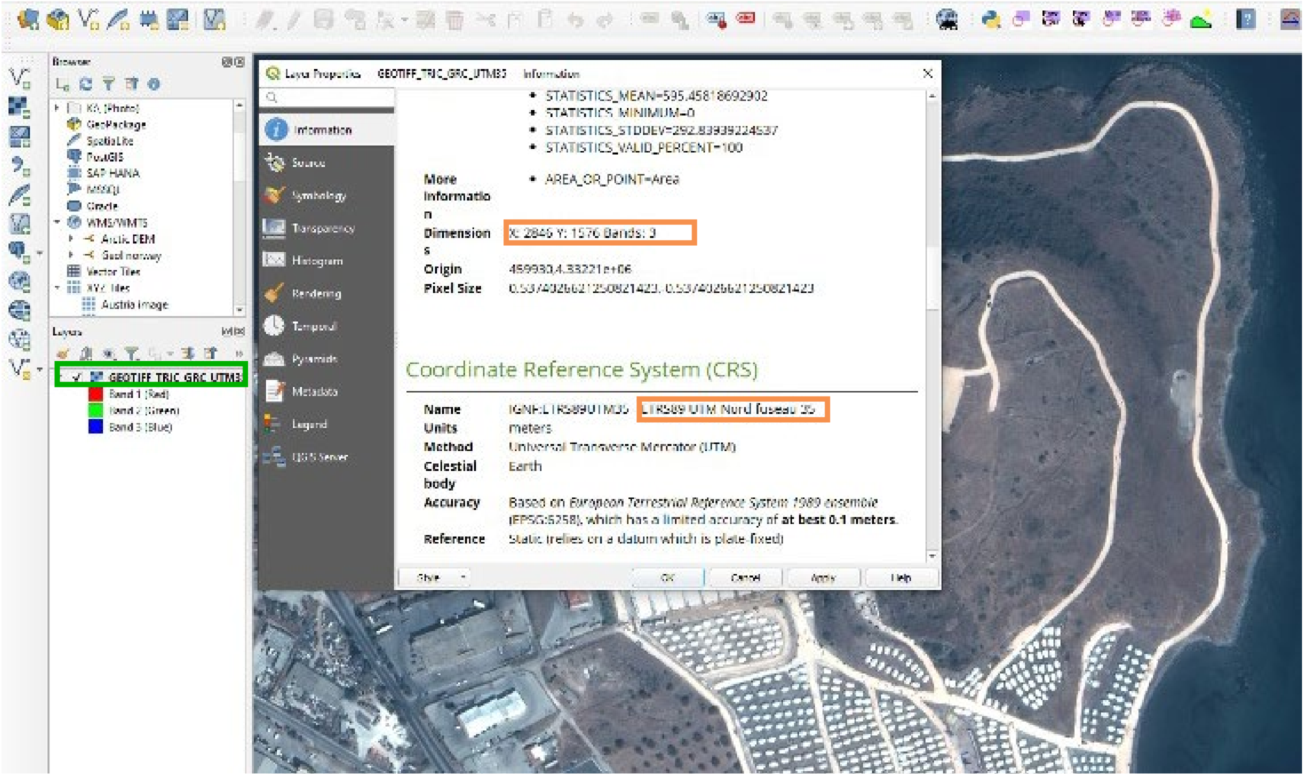

Figure 18. Looking to the information associated with the RASTER (the same is possible with vector data).