Exercise: The Optical Telegraph

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This exercise is designed as an introduction to Geographic Information Systems and, in a more general perspective, in how geospatial computational technologies can be applied to the research about Cultural Heritage.

Through this exercise, we will use different types of geospatial digital data to represent and analyse an early Nineteenth Century communication network based in the intervisibility between different towers, known as the optical telegraph. For more information on the system, its history, and the specific materials of this tutorial, the following lectures are recommended:

Dilhac, J. M. (2001). The telegraph of claude chappe-an optical telecommunication network for the xviiith century. Institut National des Sciences Appliquées de Toulouse. https://ethw.org/w/images/1/17/Dilhac.pdf

Aguilar Pérez, Antonio and Gaspar Martínez Lorente. "La telegrafía óptica en Cataluña. Estado de la cuestión." Scripta Nova. Revista electrónica de geografía y ciencias sociales 7.133-156 (2003). http://www.ub.edu/geocrit/sn/sn-137.htm


One of the towers of the Optical telegraph and the code designed by its creator, Claude Chappe

The exercise has been created in a way that can be completed without any previous knowledge of GIS. We will be using QGIS (the present document has been elaborated using the 3.12 version, note that some inconsistencies might arise due further updates. Contact your instructor if you encounter any problem).

For this exercise we will use several files. Those need to be download and saved in your computer. Working with GIS is recommended to store all the files for each exercise in a specific folder, which can be a sub-folder. For example: My Documents (or any other location in your PC) *-> GIS_exercises -> Exercise 1*).

Complementary materials:

The files used in this exercise can be download from a GitHub repository:

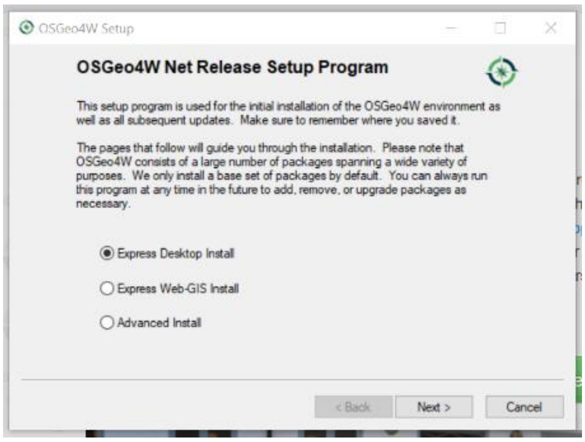
https://github.com/ArnauArqueo/training_giap/tree/main/e1_optical_telegraph

The files included are:

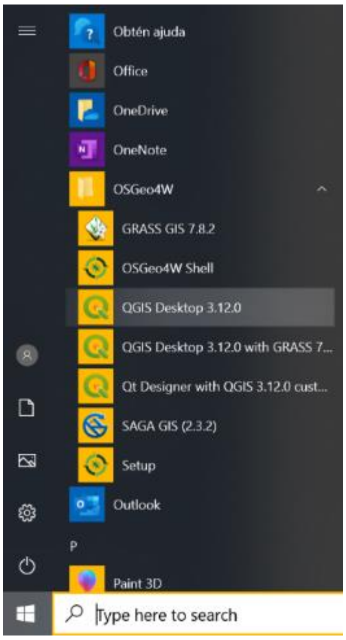
1. *telegraf_optic_cat_militar.shp* (shapefile, includes five files with the extensions .cpg, .dbf, .prj, .shp, .shx)
2. *mapa_comarcal_catalunya.shp* (shapefile, includes five files with the extensions .cpg, .dbf, .prj, .shp, .shx)
3. *telegraf_optic_cat_militar.kml*
4. *telegraf_civil_MAD_laJonquera.kml*

A file containing a DEM called *elevacions_cat.tif* will be provided by the course instructor.

1. We will start by downloading and installing QGIS (if you already have the program in your computer, you can start in point 6).
2. Go to QGIS webpage (https://qgis.org/en/site/index.html) and go to "Download now". Here we will follow the process in Windows 10. There are versions for Linux and OS as well, in that case you can find the specific instructions for your system in QGIS webpage.
3. Select the OSGeo4W Network installer (64 bits, unless you are using a 32 bits system) https://download.osgeo.org/osgeo4w/osgeo4w-setup-x86_64.exe.
4. When the installer is downloaded open the .exe file and select the Express Desktop install. Keep default options and click next until you complete the installation.

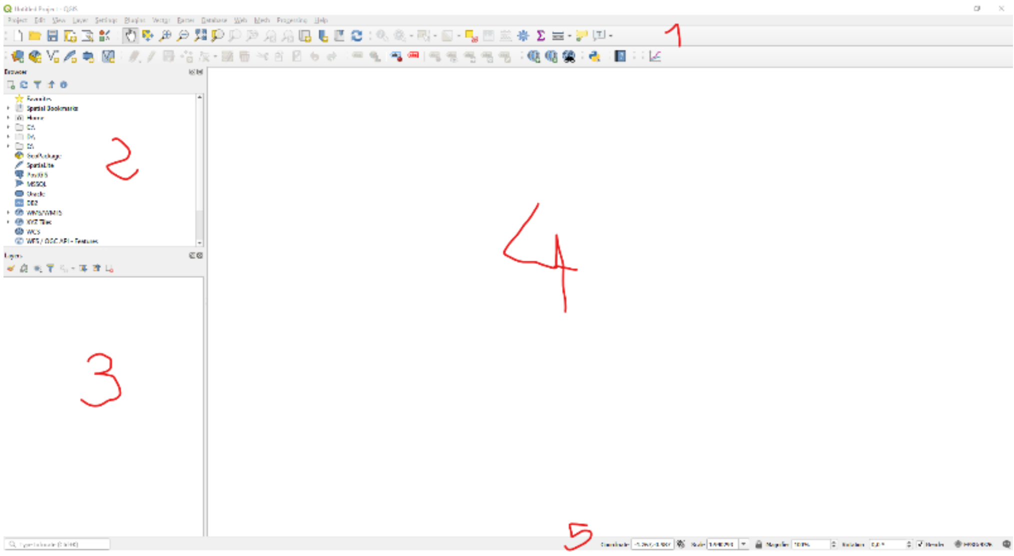


5. When the installation is finished, you'll find the different programs in the windows menu. For this first exercise you can use both QGIS desktop and QGIS desktop with GRASS versions.



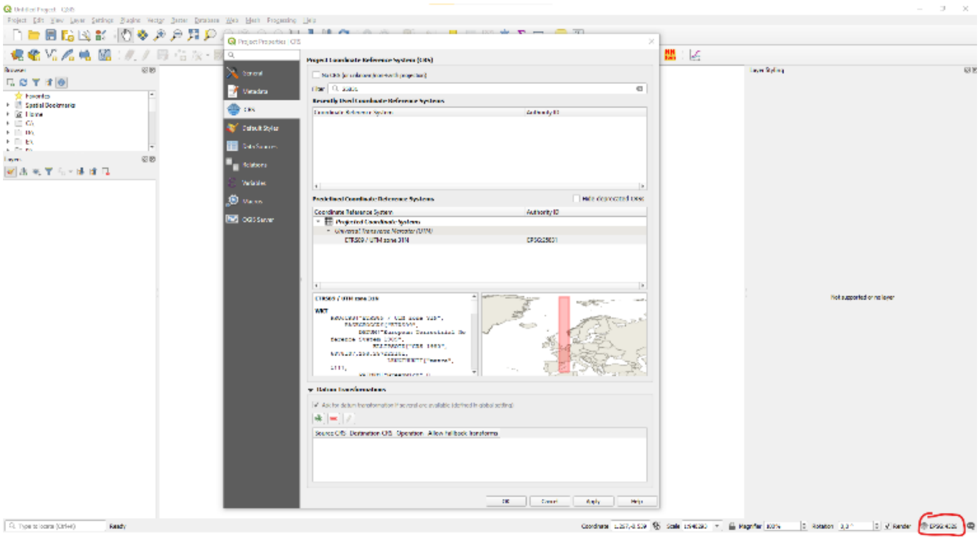
6. We will open the program and create a new project:

Project -> New project or Ctrl+N or Icon 



Now we can take a look at the different parts of the screen. On **1)** there is a bar which contains the **menu** and icons that give you direct access to the most commonly used tools. **2)** is the **browser panel**, which gives you access to computer folders where the data is stored. The panel below, **3)** is the **layers panel** and will show the datasets used on the project and that will be displayed in **4)** a **canvas** where the data will be visualised based on its spatial information. In **5)** there is the lower bar, with the information about the **coordinate system** and **scale**.

7. Before importing the data, we will make a first stop in the coordinate system (CRS, which stands for Coordinate Reference System) and specify which one we are going to use. Described in a very simple way, a CRS are different mathematical systems to translate the irregular shape of the Earth into a sphere (Geographic coordinates, expressed usually in Grade-minutes-seconds) or a two-dimension cartesian plan (Projected Coordinates, expressed in X-Y). Geomatic is the scientific discipline that focus on the measuring and representation of the Earth.
   We can see that by default the CRS defined is WGS84 (EPSG 4326). A geographic system commonly used in the present. For that exercise we are going to use the projected system ETRS89/UTM zone 31N (EPSG:25831). A projected system based on the UTM (Universal Transverse Mercator) zones. Click on the EPSG (red circle) or go to *Project -> Properties* and select CRS)

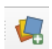


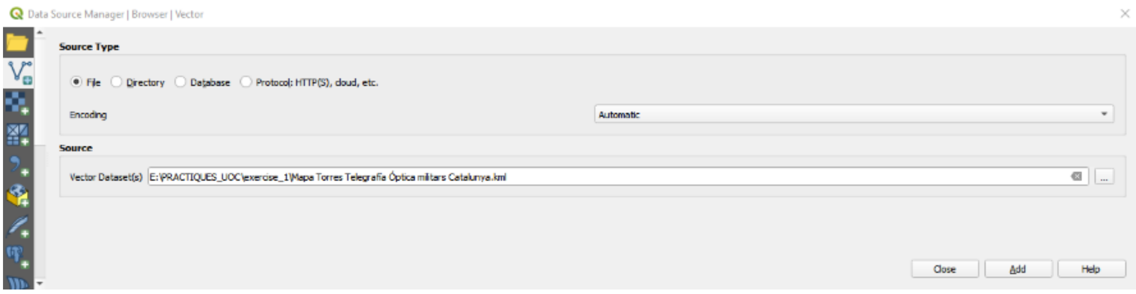
To select the desired CRS, first type the number *25831* in the filter box and select ETRS89/UTM zone 31N.

In the map you will see which area covers each specific CRS. Since we are using a UTM based system, instead of covering the whole world or a specific country, the region is based on a central meridian. For example, regarding the Iberian Peninsula we would use 31N zone if we are working in Catalonia and the Balearic Islands, our case. 30N is the UTM zone for central regions and 29N for Portugal and Galicia.

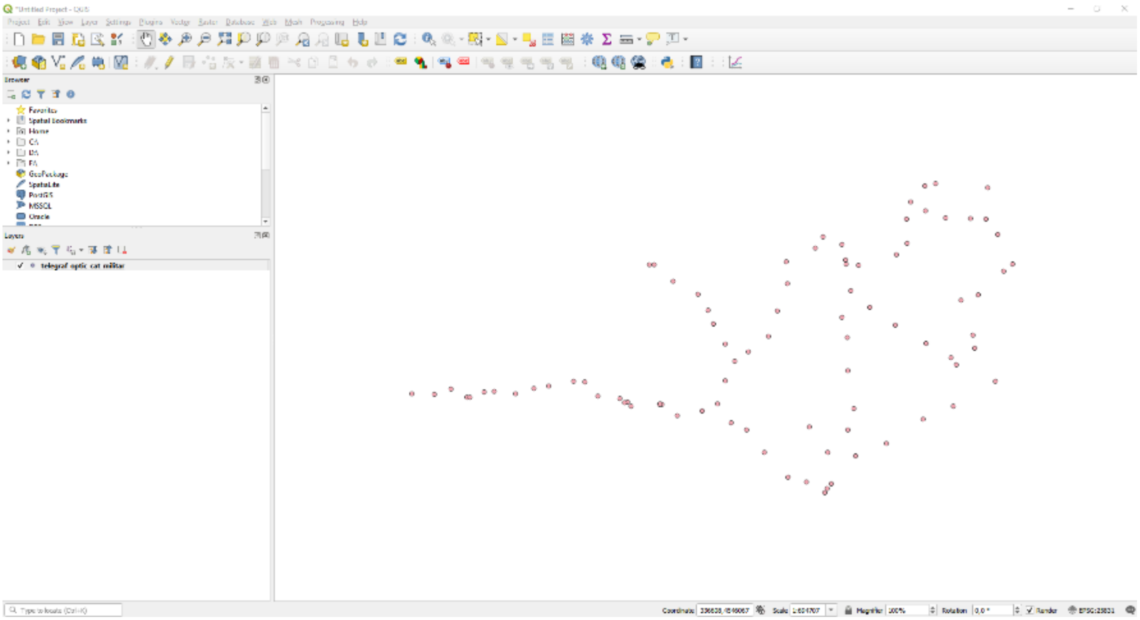
8. Now you can save the project in the exercise folder.
9. In the next step we will visualise **vector data**: that will include observations points (towers), represented as points and the administrative division of modern Catalonia, represented as polygons. Most GIS handle two kinds of data: **vector** and **raster**. The former is used to represent various kinds of singularised features (site, a river, a road or a region) as shapes such as **points**, **lines**, and **polygons**. **Raster** are instead grids which are used to represent things that are continuous values over space, such as elevation or temperature; but also aerial images or scanned maps are raster files, as images are a grid of coloured pixels.
10. We will start by displaying the known towers (Data elaborated from: https://www.coettc.info/telegrafia-optica-coettc-2/). We will use the file *telegraf_optic_cat_militar.shp*. For adding the dataset:

Layer -> Add Layer -> Add vector layer

Alternatively, we can use the browser panel or the icon 

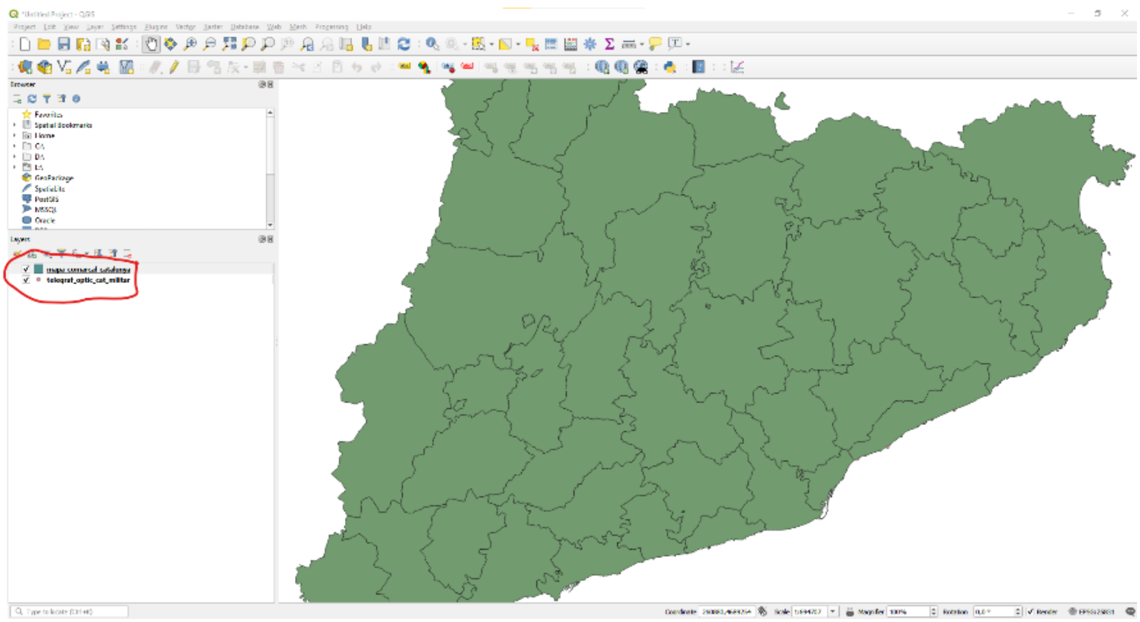


It will appear a window where we can select the type of data we want to import. In that case is a vector layer. Search for the *telegraf_optic_cat_militar.shp*, specifically the file with the .shp extension.



At this point, we can see the points in an empty space. We can check the coordinates in the lower bar, which indicate we are somewhere, but we don't have any other context.

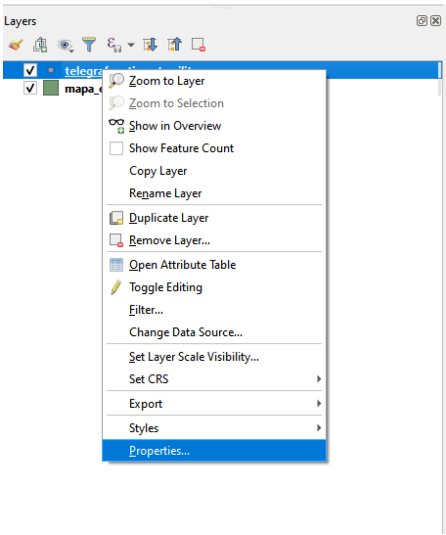
11. To visualize in which area we are, we will add another vector layer which will contain the limits of Catalonia with each administrative division in "comarques". We will repeat the same process but with the *mapa_comarcal_catalunya.shp*, again remember to select the .shp file.



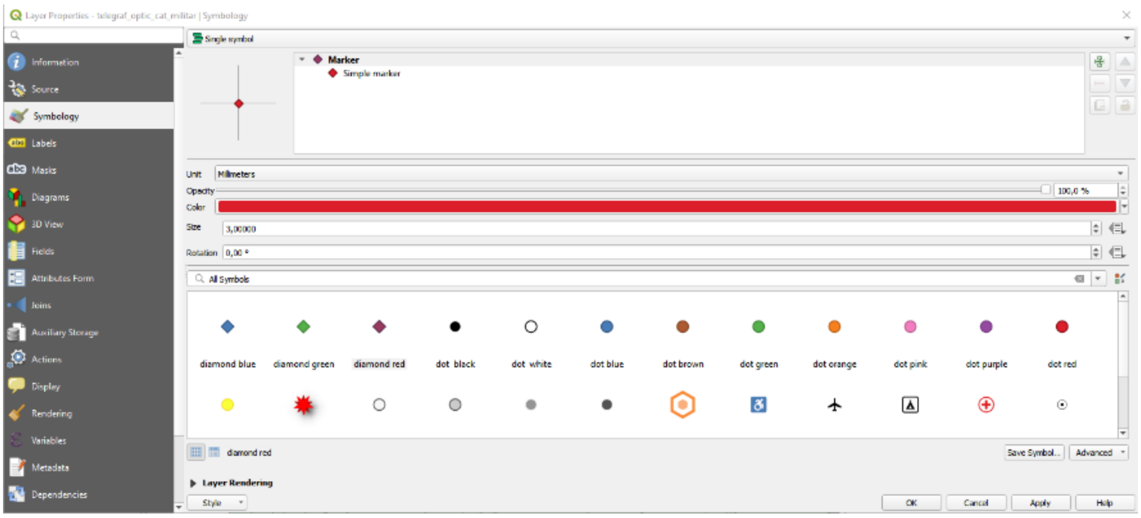
Now we can see the map, but we have "lost" the points. Check the layer panel and change order of display. Now the points are on top. You can also display or not the dataset but check/ uncheck the tick box on the left.

12. Now we will take a moment to check the properties of each layer. For that right-click the layer and select "properties". You can also access the windows using the menu:

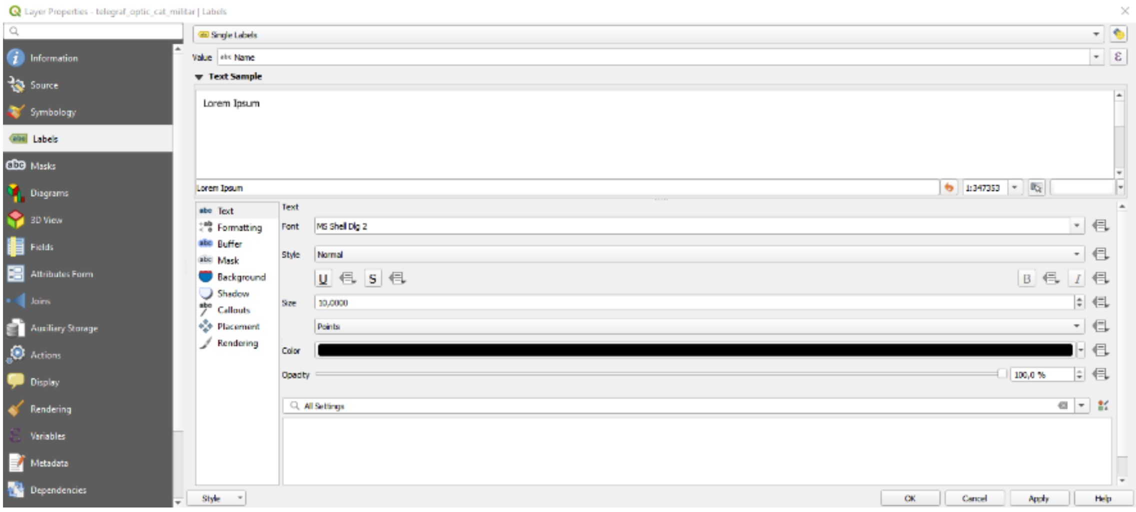
Layer -> Layer properties…



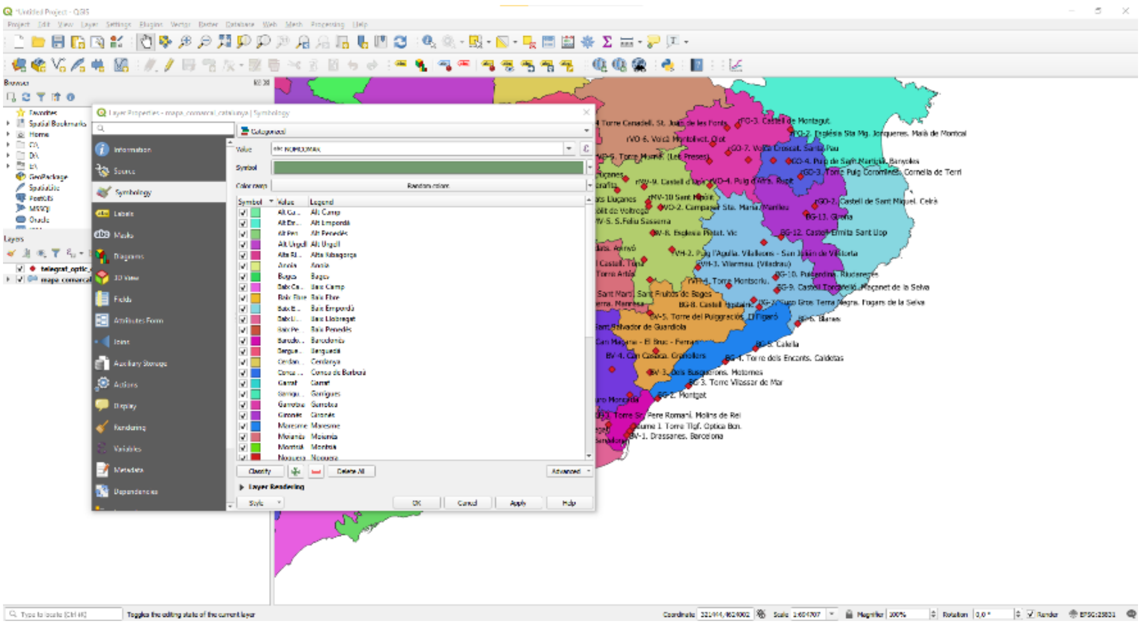
13. On the properties window, select **symbology** to change the colour and size of the icon.



14. Use **labels** to display certain information, for example, the names of the tower.



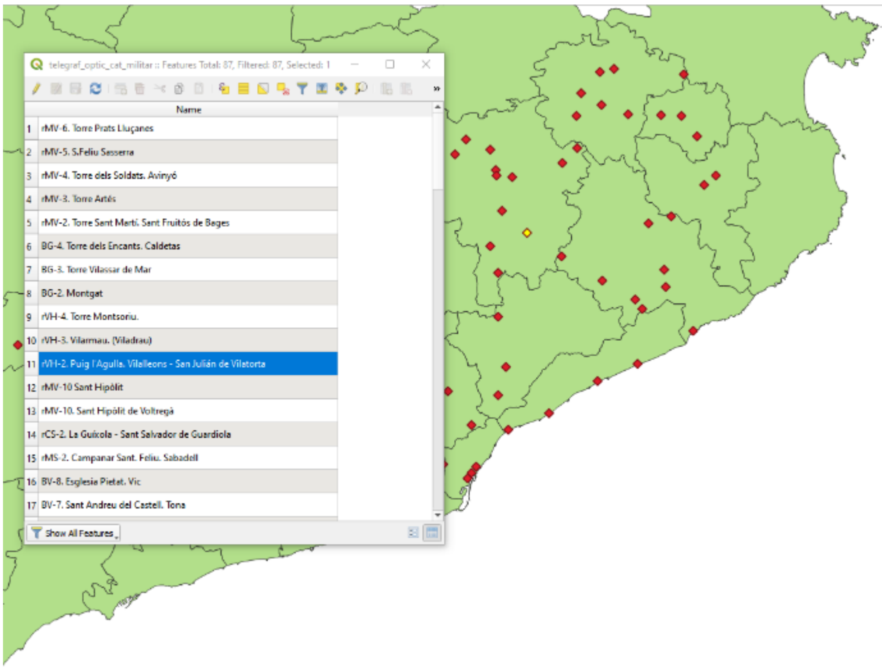
15. We can also display the features symbols according to different characteristics, for example, we can display each *comarca* with a different colour.



You can try different options until you are happy with the results.

16. All the information we have used to visualise the different characteristics of each features is contained in an associated table. To access the table, Right-click and select open attribute table or:

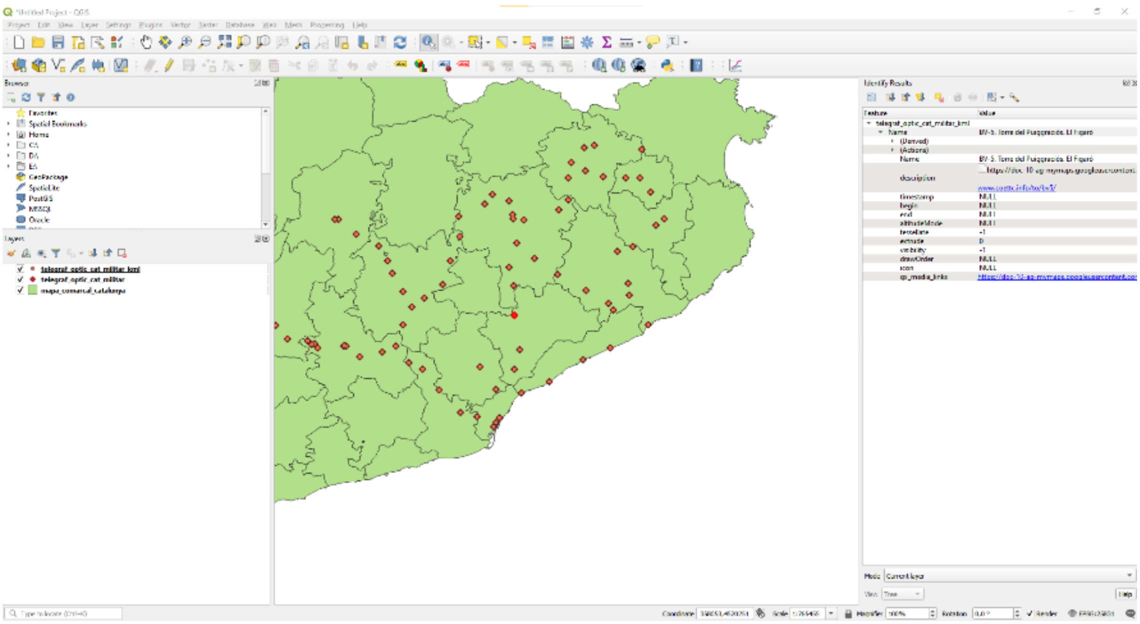
Layer -> Open Attribute Table



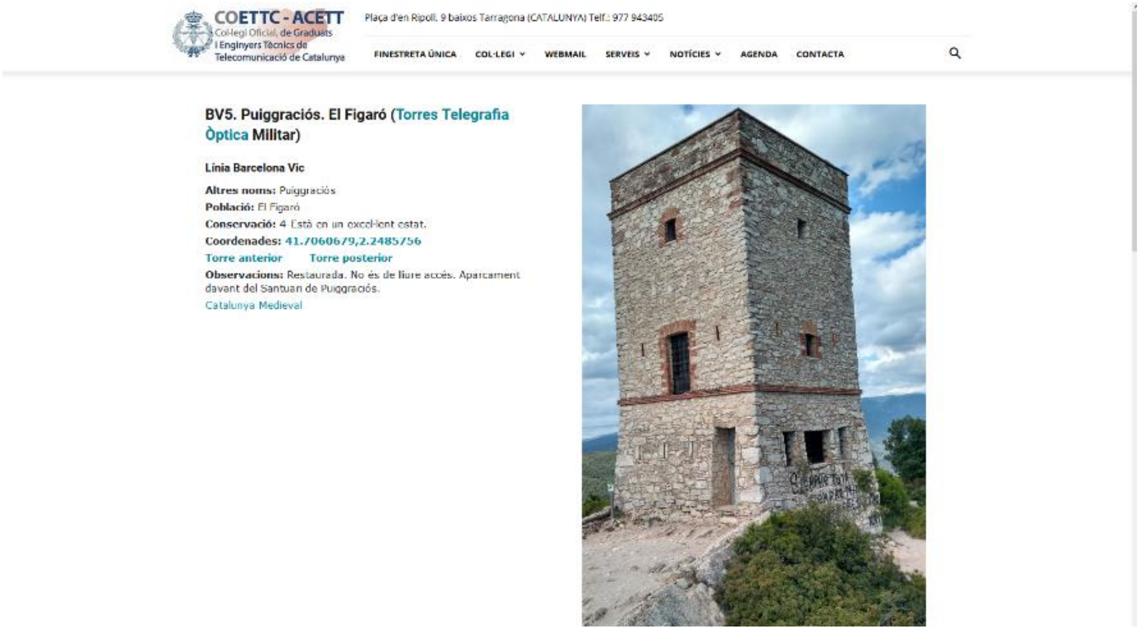
In the example, the tower layer has only one column which contains the name. Note that selecting a row will automatically display the point selected (yellow) on the maps.

Inversely, selecting the point in the map (icon ) selects the row in the attribute table.

5. For the next step, we will import vector data with another format. We will import the tower points but in .kml format. This is the format for *Google Earth* and sometimes is useful to share data with people not working in GIS formats (.shp, .GeoJSON, etc…) Repeat the process but select the *telegraf_optic_cat_militar.kml* with the .kml extension.
   We will include this layer to visualize information for the towers. Use the information icon () in one of the points. A panel will pop out in the right side of the canvas. Remember to check and select in the Layer panel the dataset you want to obtain information off. Note as well, that the selected point is highlighted in red in the canvas.



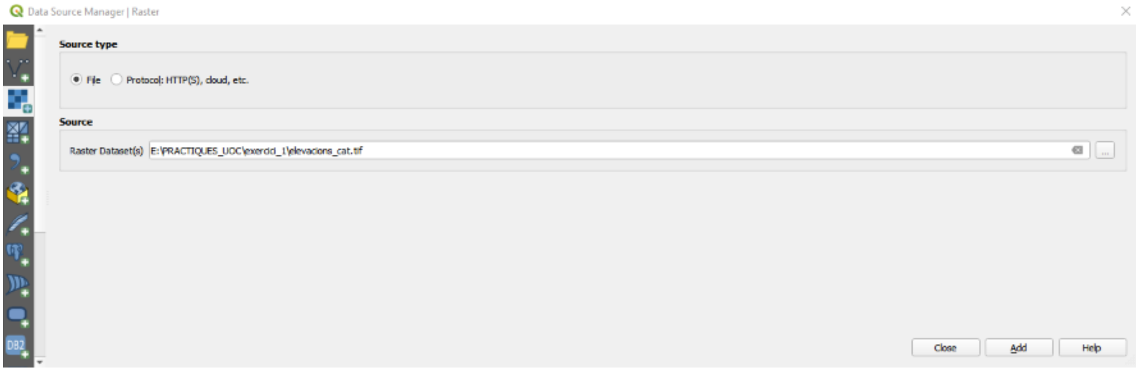
17. Click at the description link and you will access the COETTC webpage which contain extra information and images of the tower. That layer is included with this sole purpose. For the analysis we will use the .shp file.



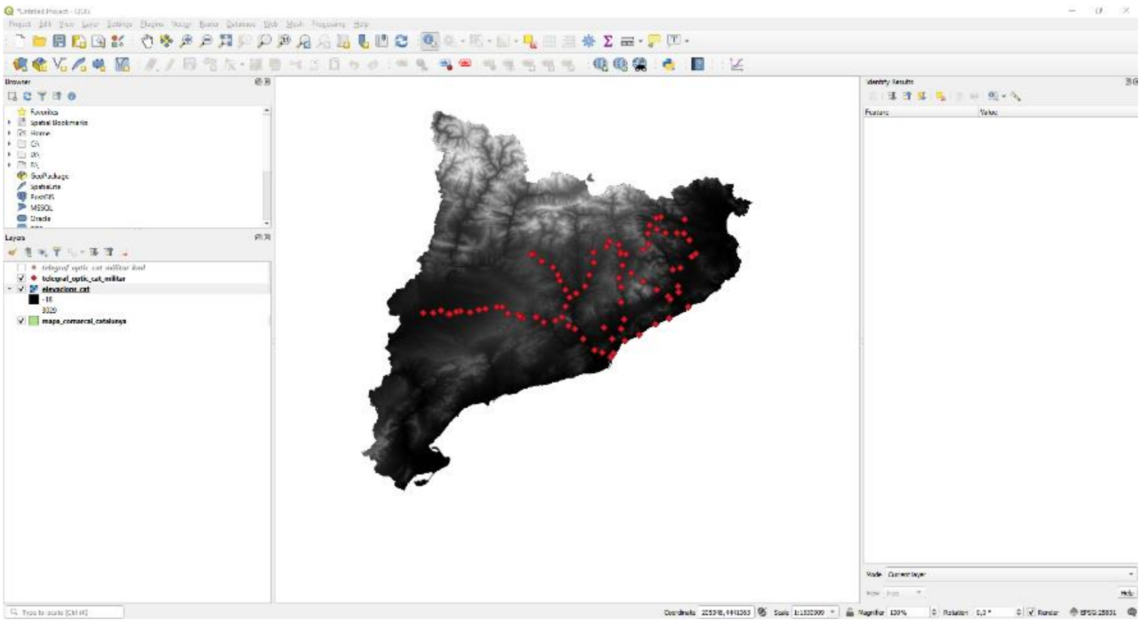
Example of one of the towers in the webpage.

18. We have now the position of the observation points and targets, but to develop visibility analysis we need to incorporate the third dimension. Since the terrain is not completely flat, we will need information about the elevation; of the observations points, the targets and of potential obstacles. For that object, here we will use a model of the topography known as DEM (Digital Elevation Model). In this kind of raster, each pixel has information on the altitude of its coordinate in the real world.
19. To upload the DEM we will open the data source manager and select raster.

Or *Layer -> Add layer -> Add raster layer*



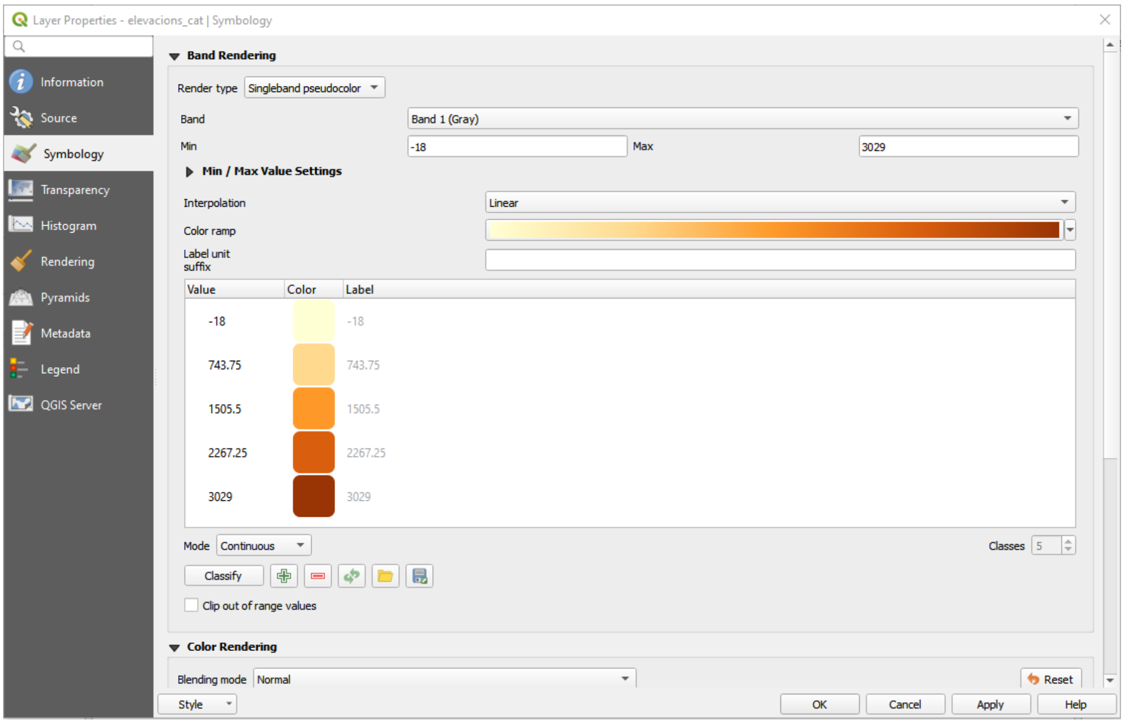
Browse your computer to find the file provided by your instructor (*elevacions_cat.tif*). In your canvas should appear an image similar to that:



In this black and white image, white represent the higher elevation (see e.g. the Pyrenees mountains in the north) and lowlands appear as black (see the coast in the East).

20. Next step will be to give some colour to the image to help its visualization. For that, like in vector data, we can right click on the layer to access the symbology window. Or select the layer in the layers browser and use the menu:

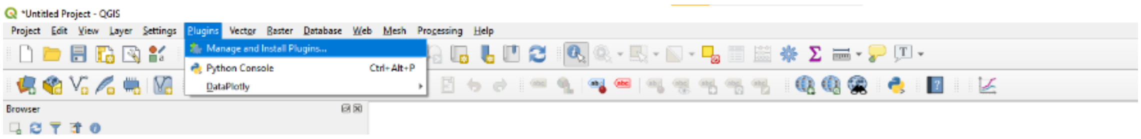
Layer -> Layer properties



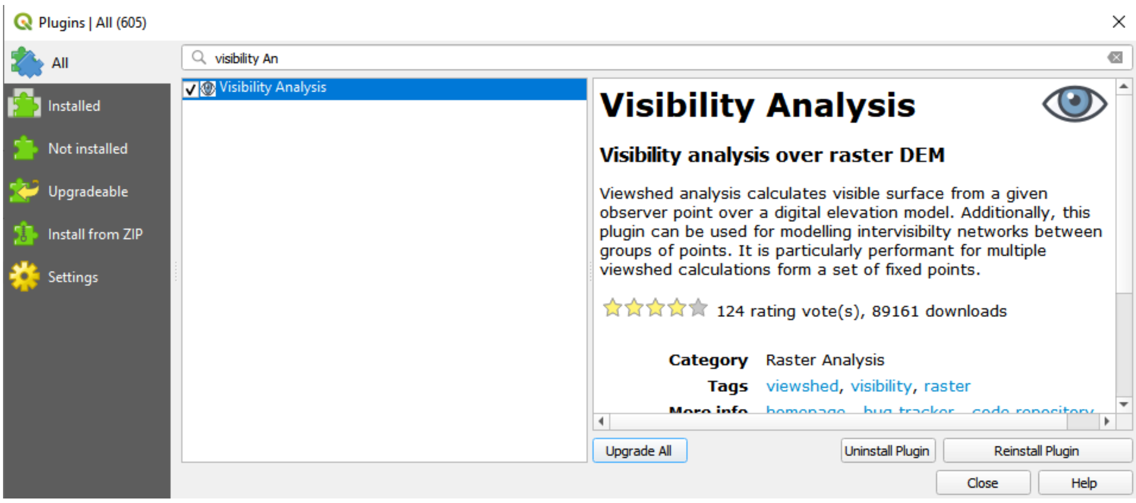
The symbology window has some differences respect what we have seen working with vector layers. For now, we are going to use a pseudocolour single band, changing the black and white to other colour combination. You can do different probes until you are OK with the result.

21. At this point we have all the data we need to perform the analysis, but we are not ready, yet. GIS incorporate extensive *toolboxes* of specialised programs or *plugins*. The most commonly uses are already installed and accessible through the menu, but for specific tasks we will need to install them. In that case we need to install the *Visibility Analysis* plugin.

Plugins -> Manage and install Plugins



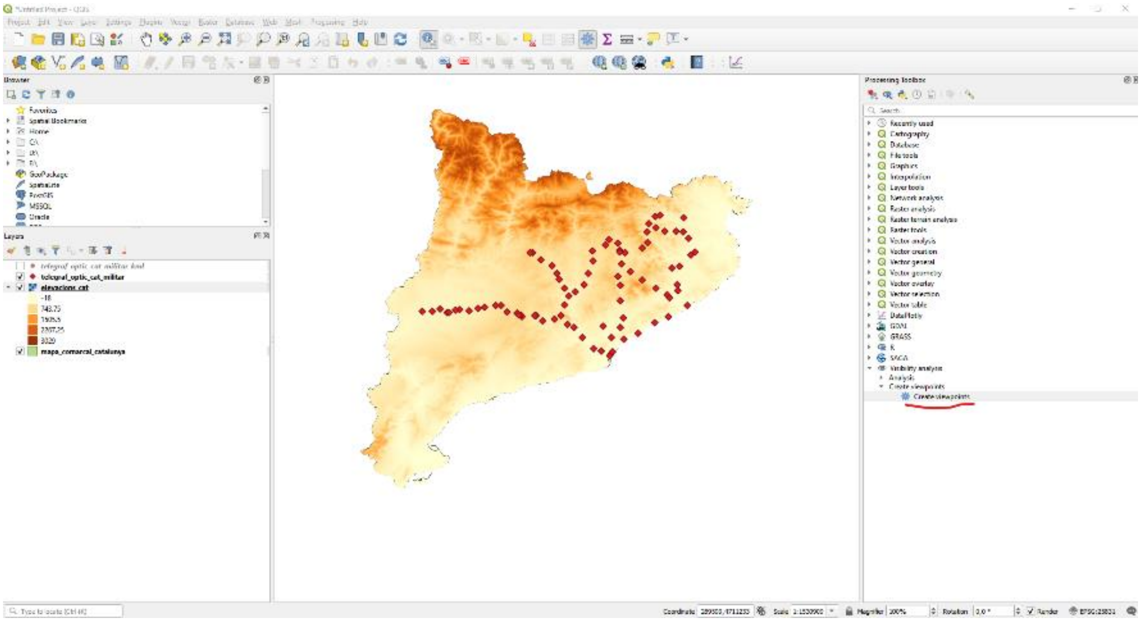
22. That will open the Plugins window. Search for the "visibility Analysis" install it and check it.



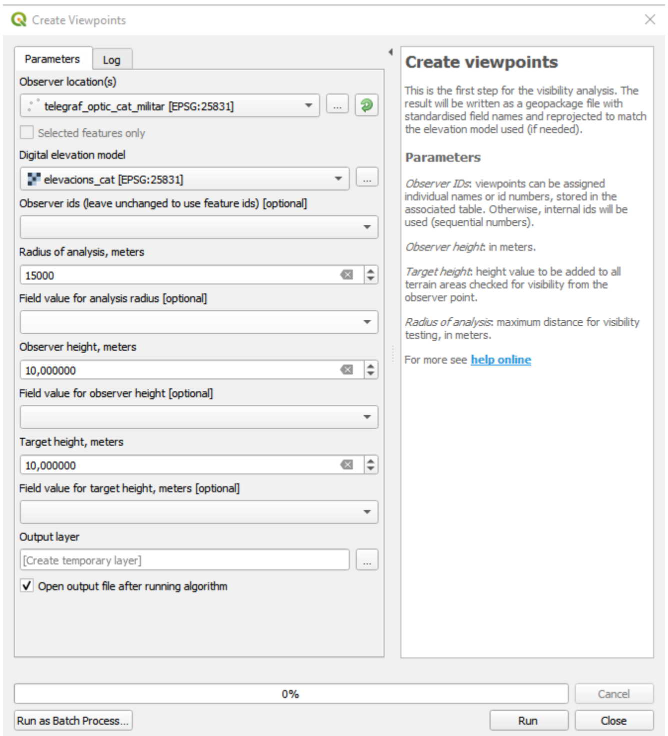
23. And finally we have all the sources and instruments we need to perform a visibility analysis: the position of the observers/ targets, a model of the elevations and the instruments to compute.
24. We will start the analysis by accessing the **processing toolbox panel**.

    Processing -> Toolbox

    You can now see at the end of the list the different analyses offered by the *Visibility Analysis* plugin.
25. The first step of the analysis is to create viewpoints that we will use as observer and target points.



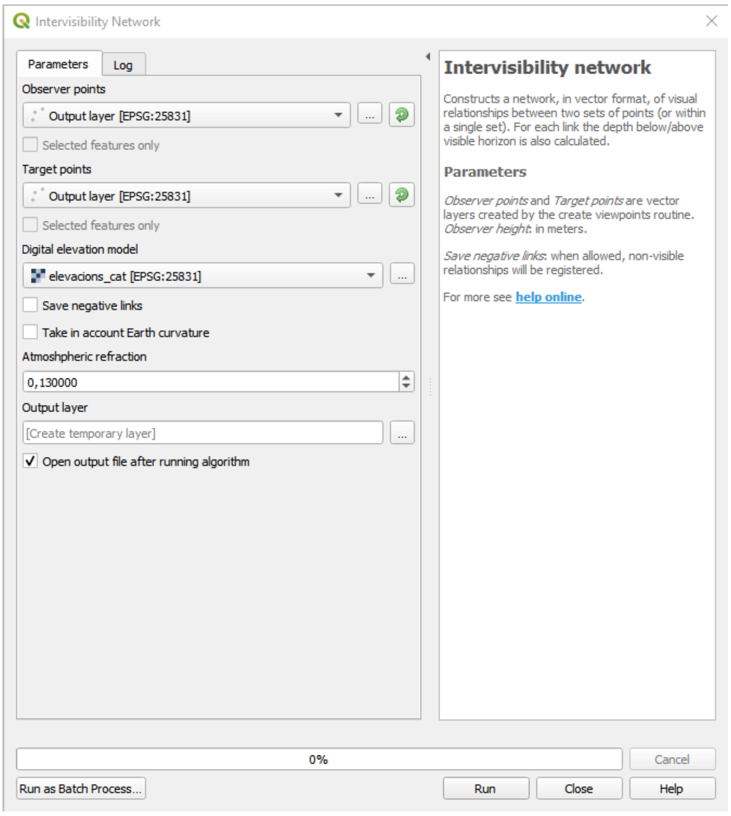
26. Double click and open the panel.



The window allows us to introduce the parameters regarding the position and altitude of the observed and target points. For this exercise we will select:

a. Observer location: select the tower points *telegraf_optic_cat_militar.shp*
b. Digital Elevation Model: select *elevacions_cat.tif*. Pay attention to the CRS, it has to be the same.
c. Radius: select 15kms. It is approximation the distance stablished in the instructions given to the engineers in charge of their construction ("entre 2 y 3 leguas"). In fact, known towers tend to be no more than 12 kms of each other.
d. Observer height: here we will introduce a generalization. Not all towers had the same altitude, but in the ones built on purpose for the line, and that are well preserved, the observation instruments were placed at 10 m altitude from the ground.
e. Target height: use the same value; as the towers were acting as both transmitters and receivers.

27. Click on run and, after the calculations, the plugin would create a layer called *output layer*. It is a temporary layer, we can save it (*Layer->Sav As*) or keep it like it is. We can also rename it (Right click, note that this action only changes the name displayed on the layer panel and has no effect on the file).
28. Back to the Processing toolbox panel, we can expand "Analysis" and then double-click on "Intervisibility network".

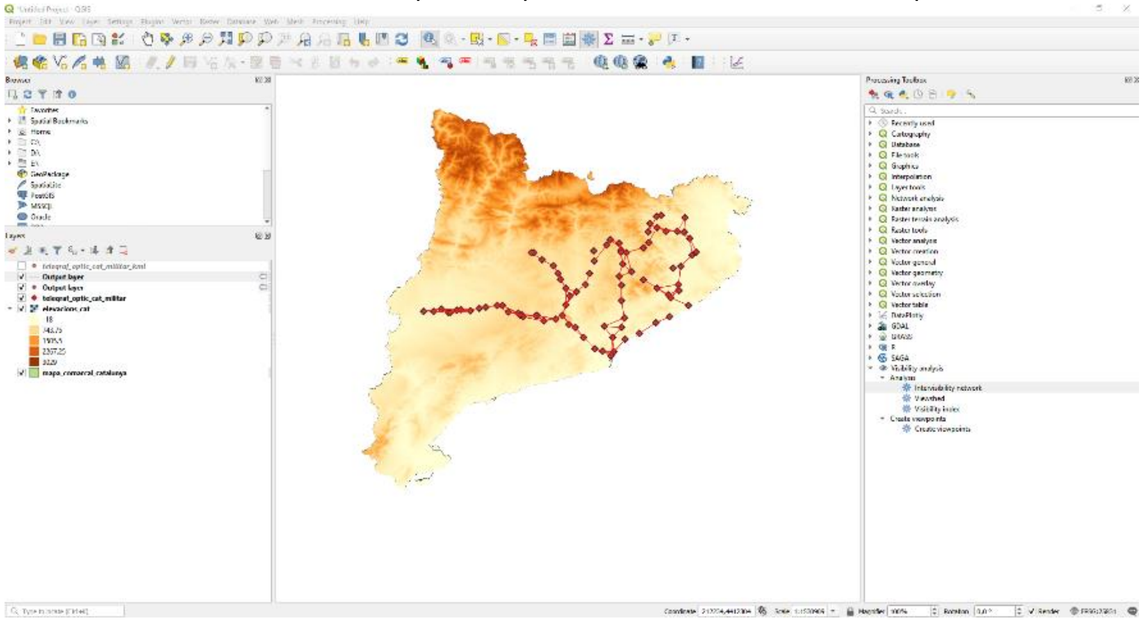


It will open a new window, where we can introduce the parameters that will be used on the computation. In this exercise we will use:

a. Observer points: select the recently created layer.
b. Target points: this time we are using the same layer here.
c. Elevation Model: select *elevacions_cat.tif*

Apart of those, keep all default values.

29. Click run and when the calculation is finished it will appear a new *ouput layer*. In that case a line will represent positive relation between the points.

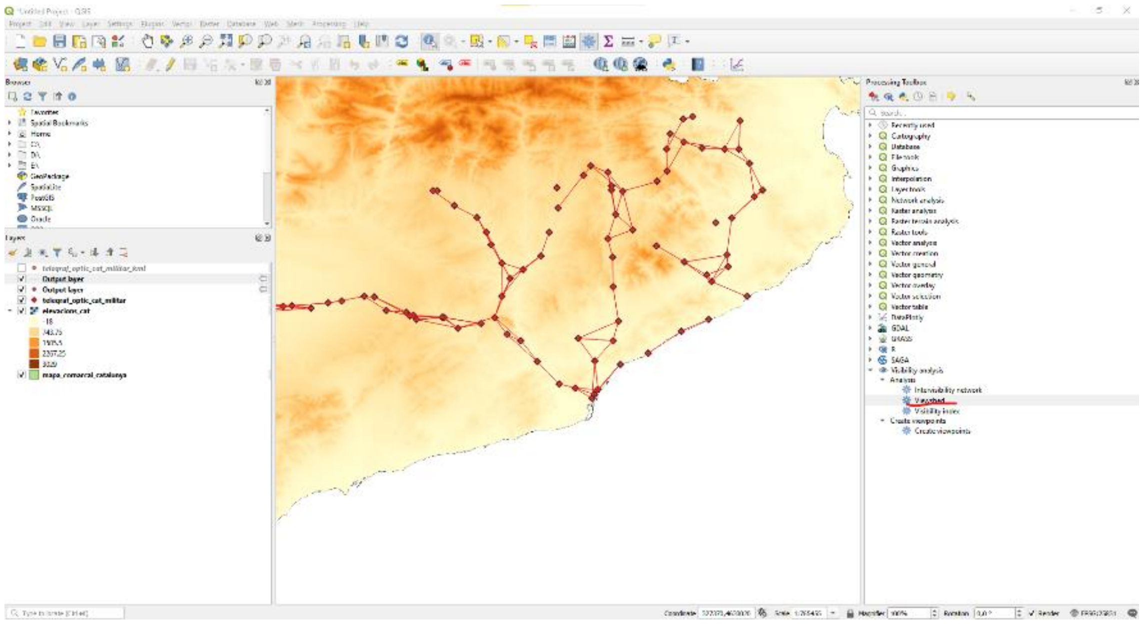


Check the resulting map. Are any gaps between some of the points? What could be the reason? We can see that indeed there are few gaps. We can formulate few hypotheses:

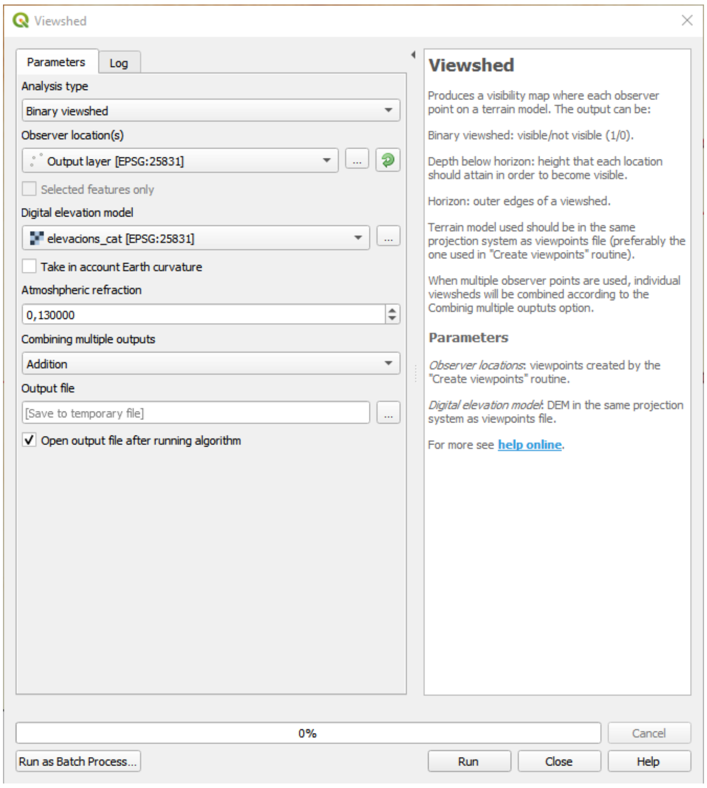
   a. Height: would change using 15 m instead of 10? – We should measure exactly all the points.
   b. A more precise DEM? 15m/ 2m.
   c. Missing point. The line was not completed or there is a tower we haven't found.

We will assume we have done 1 and 2 and it is still not connecting some points. Now we will use another tool called "viewshed" to formulate hypothesis based on the areas visible from the different towers. So the question won't be if we can create a visual link between to points but to explore which areas are visible from one or more points.

30. To open the viewshed window, go back to the processing tools panel and select viewshed.



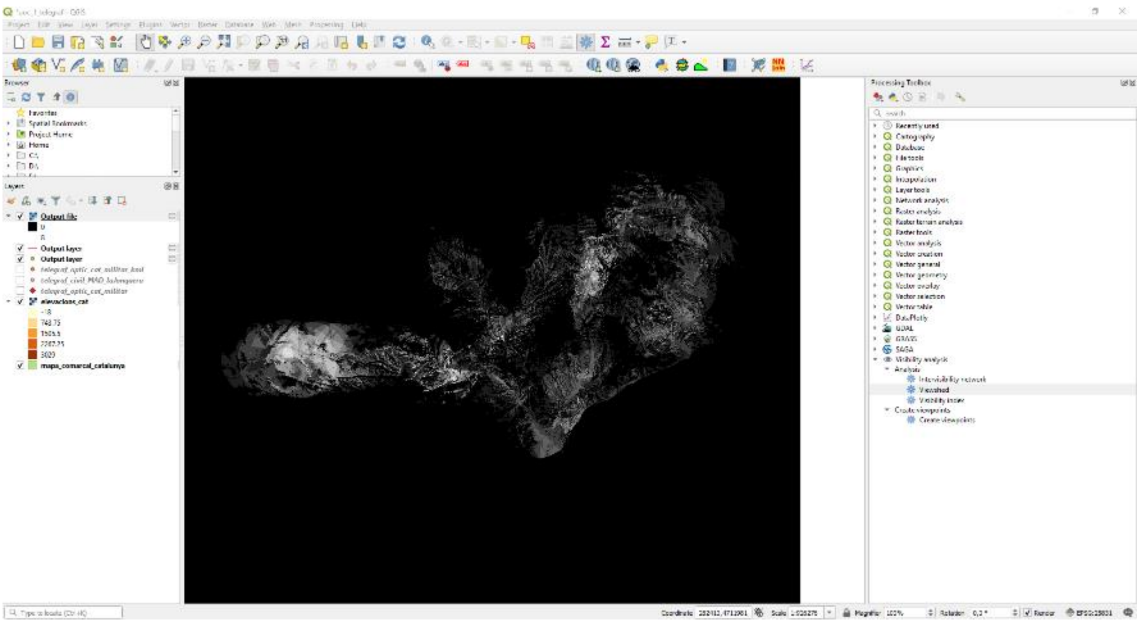
31. We will have another window where we can introduce the viewshed parameters.



a. Analysis type: keep binary viewshed as option.
b. Observer location: Use the viewpoints field (*utput layer*) you created in point 26.
c. Digital Elevation Model: select *elevacions_cat.tif*.
d. Combining multiple outputs: keep the option addition.

Keep the default values for the rest of the parameters.

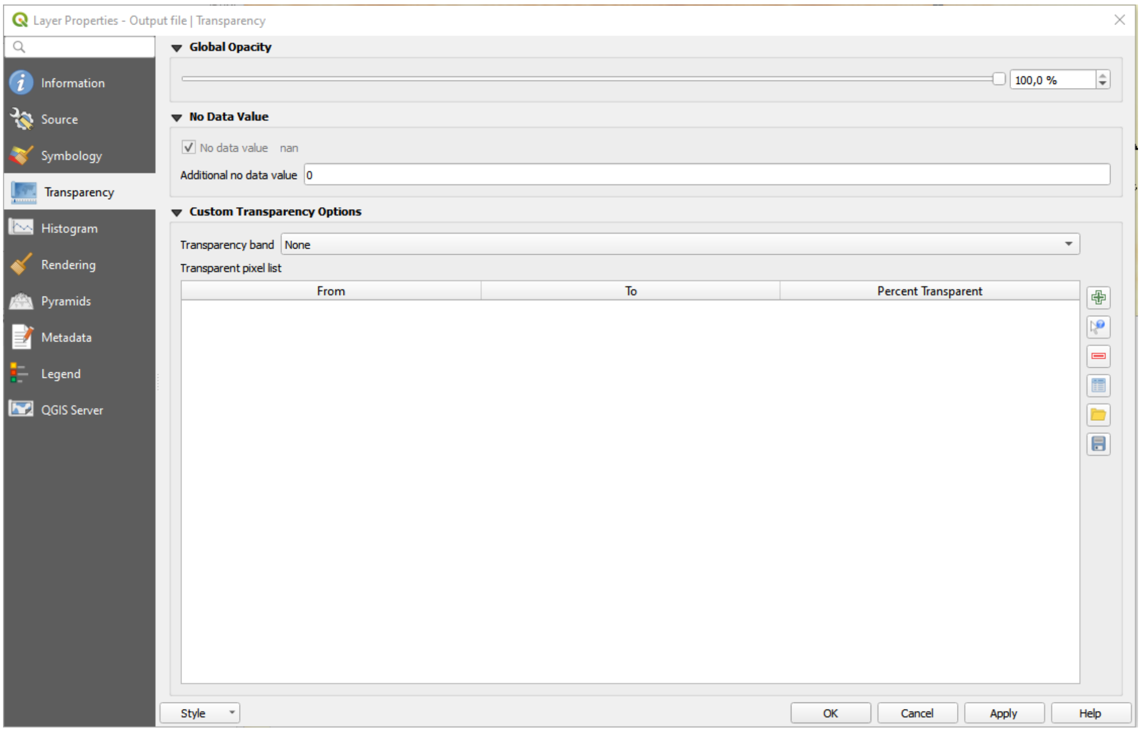
32. Click run. This time the *output layer* will be a raster file. Each square will have a number from 0 to 8 depending on the number of points from which is visible.



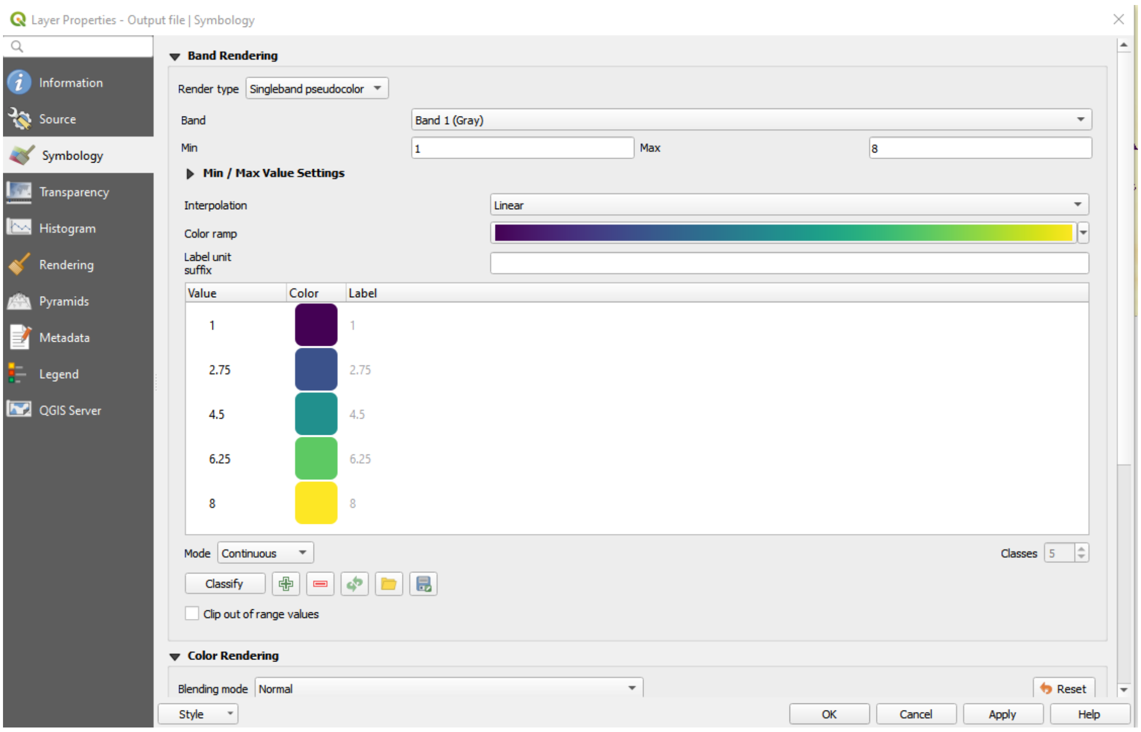
33. We can access the layer properties to change the visualization. Remember to right click the layer or use the menu:

Layer -> Layer properties...

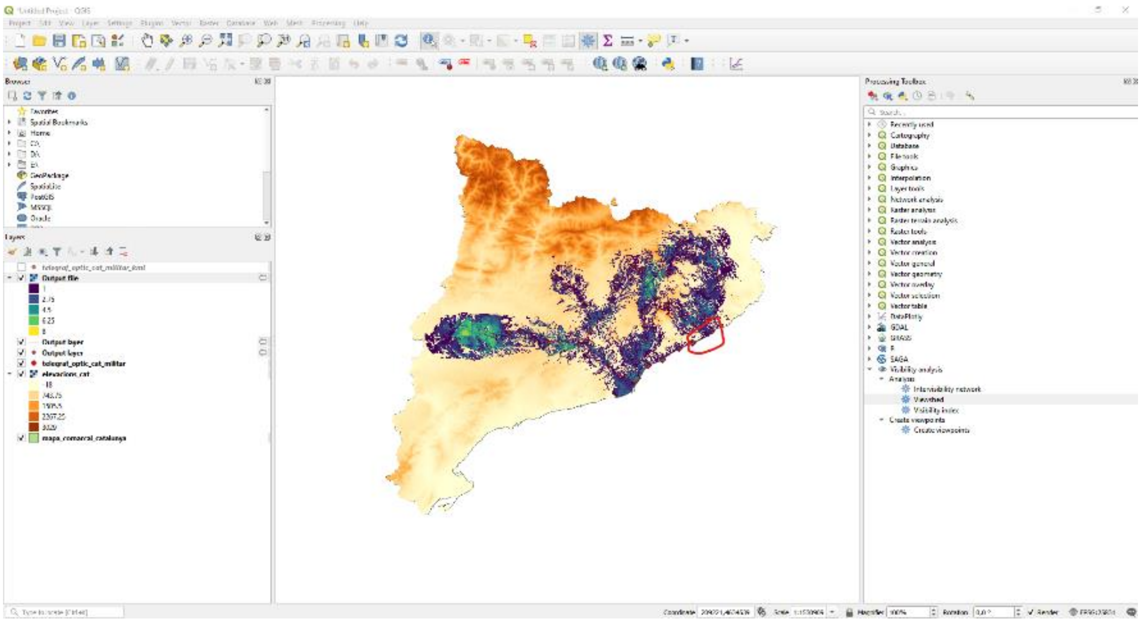
34. If we want to make invisible the areas not visible from any point, we can go to the transparency panel and add 0 as additional no data value.



35. Like we have done with the DEM, we can also change the colour scale, going to symbology and using a singleband pseudocolor.



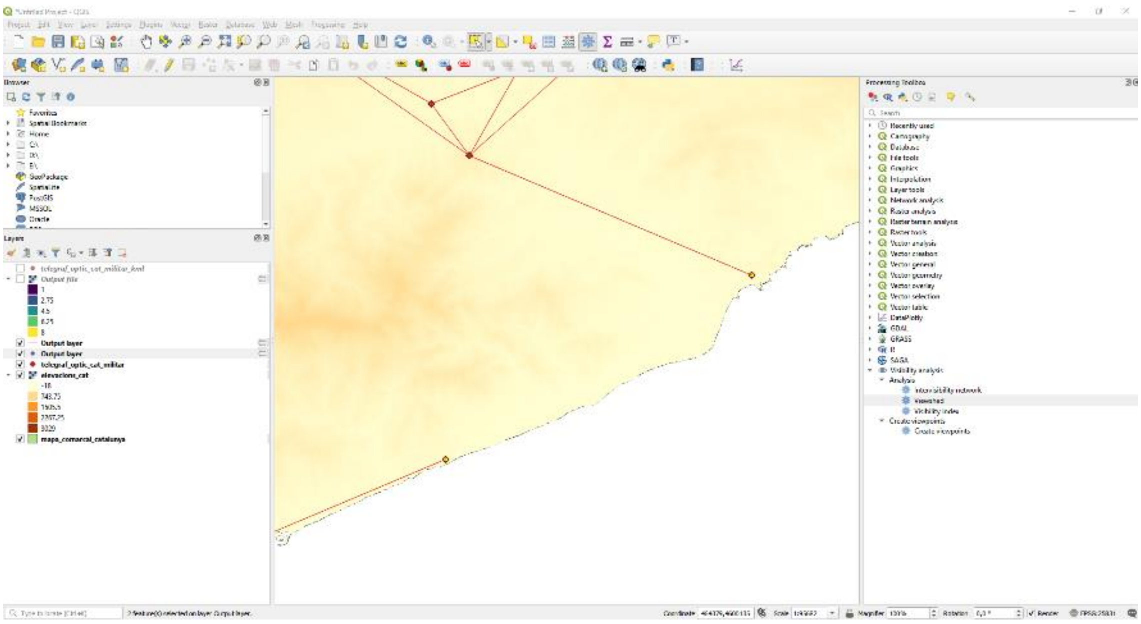
36. Finally, the result in your canvas will look something similar to that.



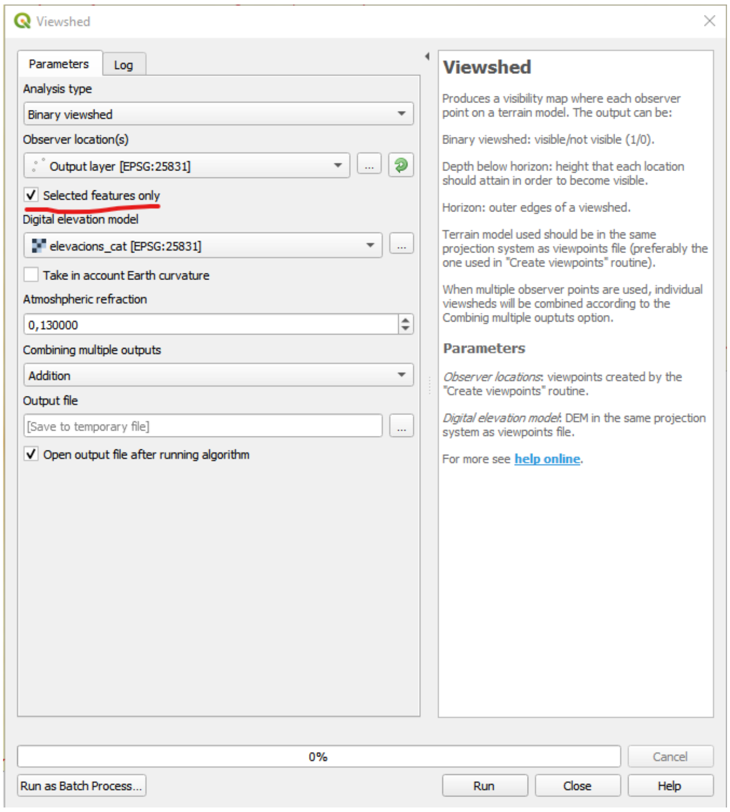
Now we can see which areas of the territory are more visible, but we don't know from which points exactly. To try to figure out possible location we will do a more detailed analysis.

37. As our study case, we are going to focus on the area between the *Comarques* of *Maresme* and *La Selva*. Start by zooming into the area marked with a red circle. Have a look at the two points where the line is broken. We will try to figure out in which points a tower connecting the two points might be placed.

38. First select the two points (use ).

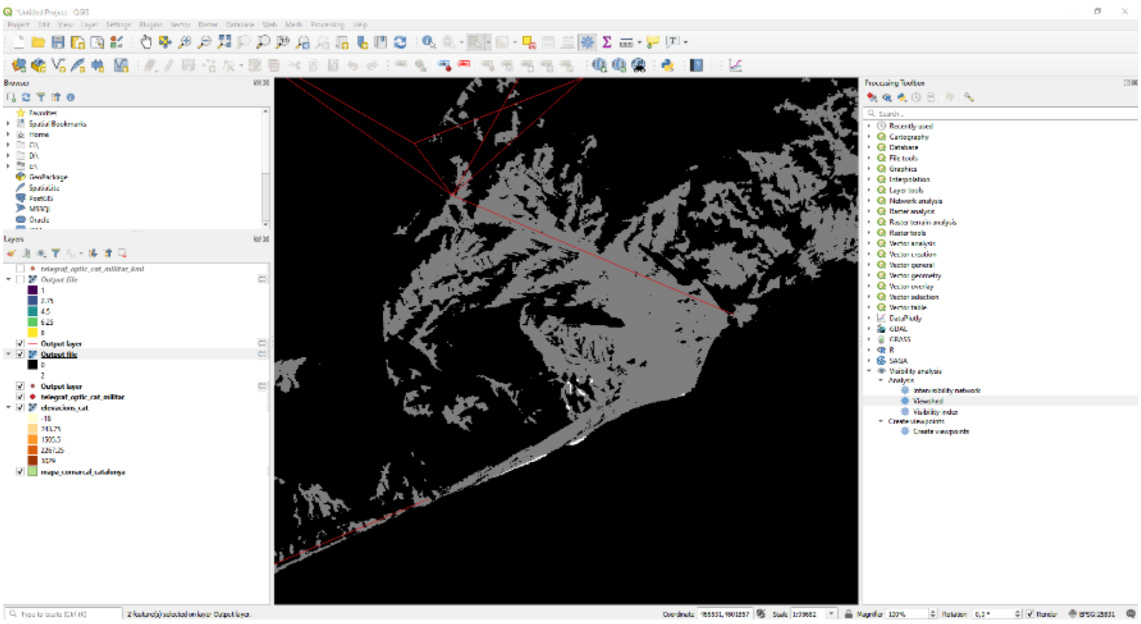


39. Now run again the viewshed analysis but using only the selected features.

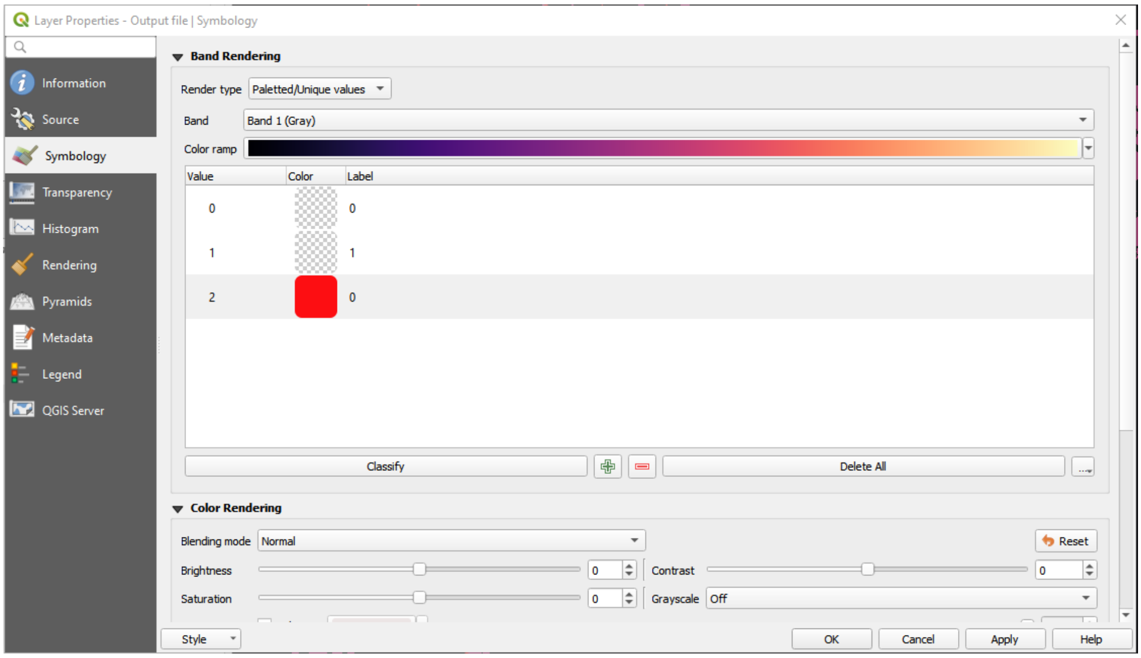


Pay attention that the box is ticked before running the analysis.

40. The result will be similar to the previous analysis but just between 0 and 2.

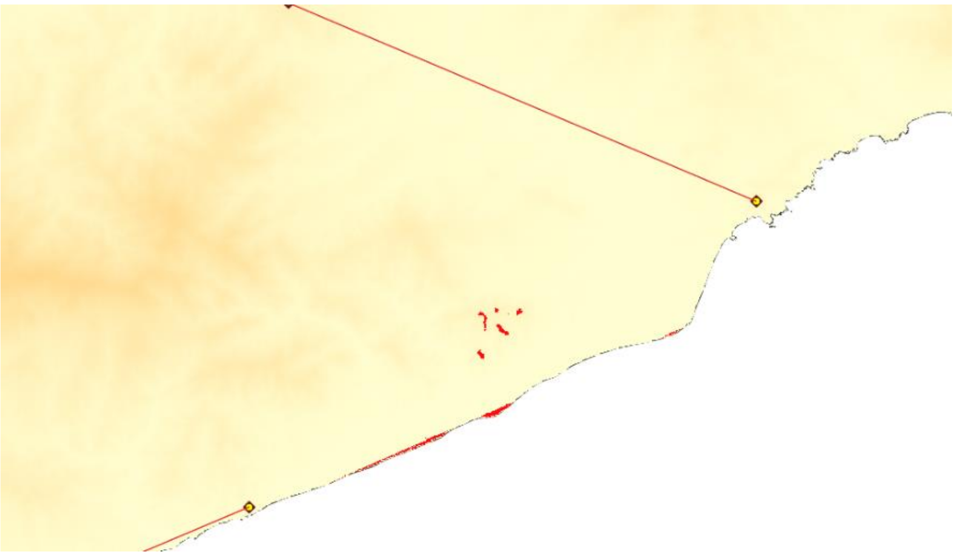


41. Go to properties to prepare the visualization.



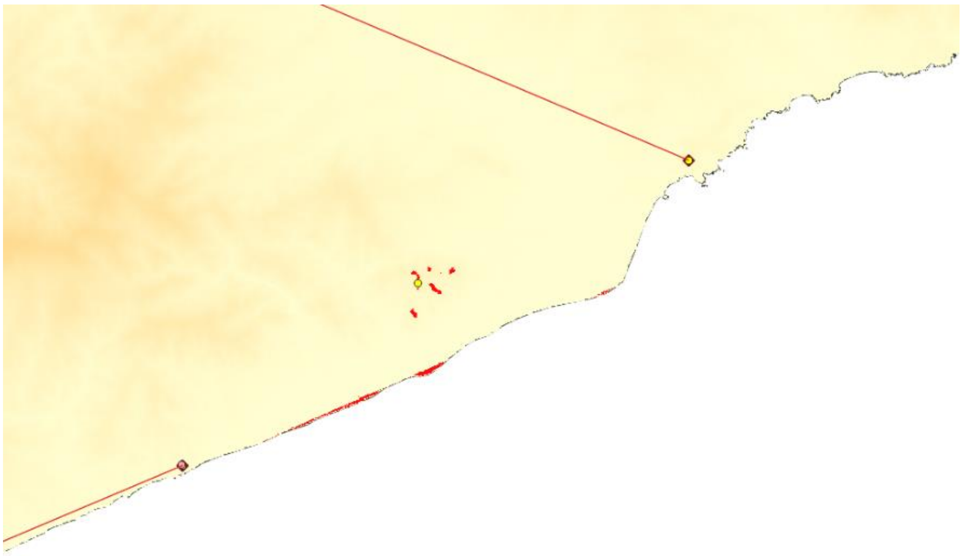
In the example above, we are using Paletted/unique value to display only the pixels with a value of two. To create this visualisation, press first classify and then change the colours.

42. We are almost done! Time to check the results:



In red we have represented the areas that would be visible from the two points. The next step would be to survey those areas for remains of a tower or another structure.

Actually, if we could do that…



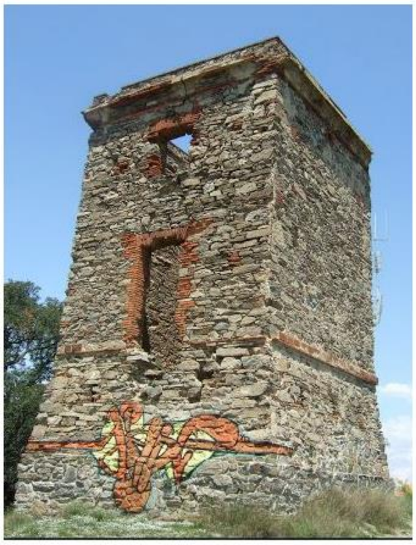
43. At the selected point we would find this:

rJB213 Torre Montagut. Malgrat Mar (Torres Telegrafia Òptica Civil)

Ramal La Jonquera Barcelona

Altres noms: Montagut
Població: Malgrat de Mar (Barcelona)
Conservació: 3– Bona conservació
Coordenades: 41.650283, 2.714763
Torre Anterior Torre posterior

Observacions: «Torre de Montagut. Abans de coneixe's el telefon i el telègraf per transmetre les noticies d'una part a l'altra amb la possible velocitat l'Estat construía en els punts més enlairats dels turons unes torres òptiques, de les quals n'era una la situada al bell cim sel turó nomenat de Montagut, del nostre terme.
Unes planxes metàl.liques de diferents colors que funcionaven en aquelles mitjançant cert mecanisme, representaven lletres, paraules, números i senyals convinguts que's passaven d'unes a altres. Ulleres de llarga vista augmentaven i facilitaven la llur visualitat.
Reportaven als serveis de terra utilitats similars a les que presten encara avui dia a les embarcacions els semàfors, els quals per medi de 18 banderes del Còdic Internacional, representant consonants combinades, es comuniquen mutuament llurs impressions.»
La Vila de Malgrat i sos contorns. Apuntaments històrics, pag. 149.
Mn. Fèlix Paradeda i Robert, Blanes,R. Roig : Impressor, 1915.



The reason that tower was not in our dataset is because it was officially part of the "civilian line" between Madrid and the French border in La Jonquera, instead of the military line we are using in the exercise. You can see this line adding the kml file *telegraf_civil_MAD_laJonquera.kml*.
In theory the two lines were independent, working in parallel and using different towers. They are some double towers, like in this example:

rJB214 Torre Calella (Torres Telegrafia Òptica Civil)

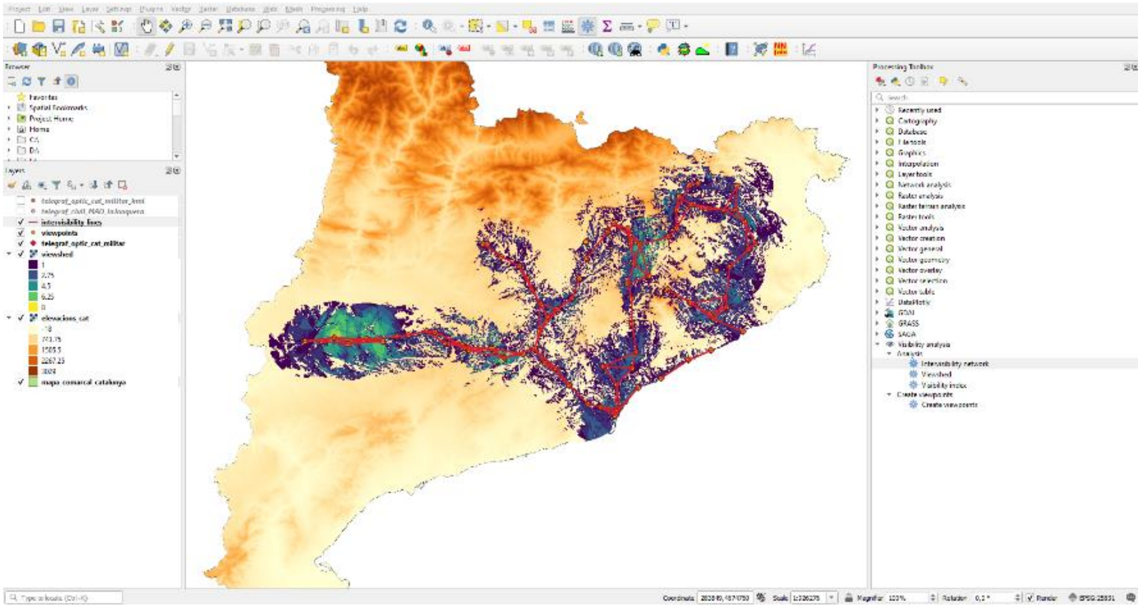
Ramal La Jonquera Barcelona

Altres noms: Les Torretes
Població: Calella (Barcelona)
Conservació: 2– Queden bastants restes
Coordenades: 41.607875, 2.641835
Torre Anterior **Torre posterior**
Observacions: Prop del Far de Calella, coincideixen les torres de les dues línies, la civil més a l'Oest i la militar, la més oriental.

Coming back to our study case, We don't know for sure what happened. Where they using the same tower? Where there two towers and only one has been found?

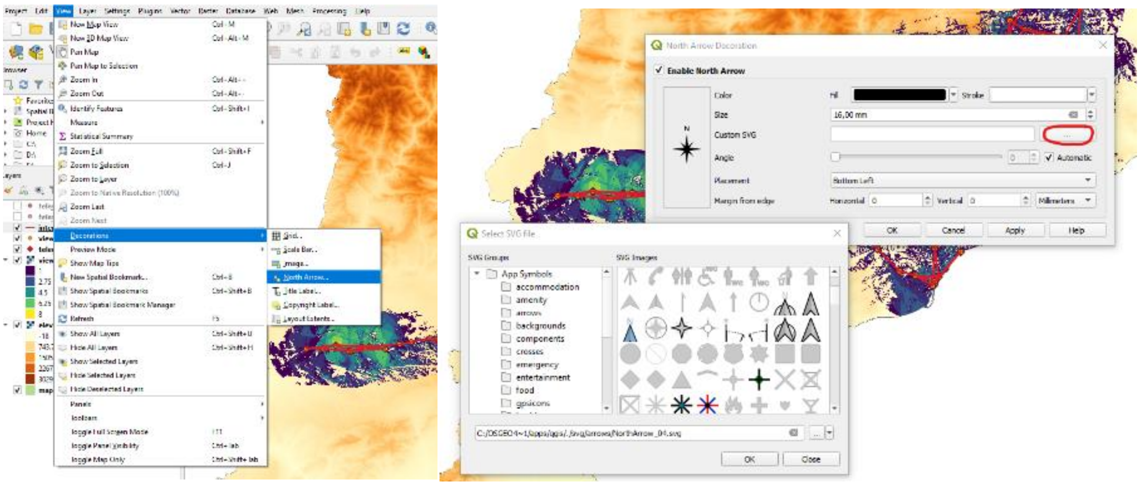
As usually, completing a research is creating new questions…

44. To finalise the exercise, we will look on a simple way to extract some images that we can include in reports or share with other colleagues.
45. Let us start by setting the canvas to display the image we want to export. For example, a general view of the exercise results.



46. Then we will add a few elements to help the reader to interpret our map. We will start by a North Arrow. In the menu select:

View -> Decoration -> North Arrow



Enable the north arrow in the new window. It is possible to browse between different designs (red circle).

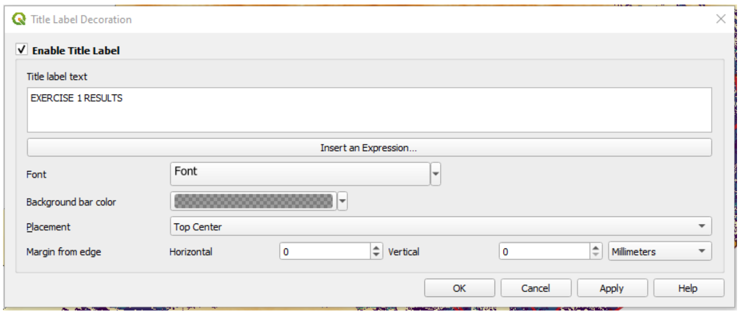
47. Repeat the process with the scale bar.

View -> Decoration -> Scale Bar

Now the canvas includes the north arrow and a scale bar.

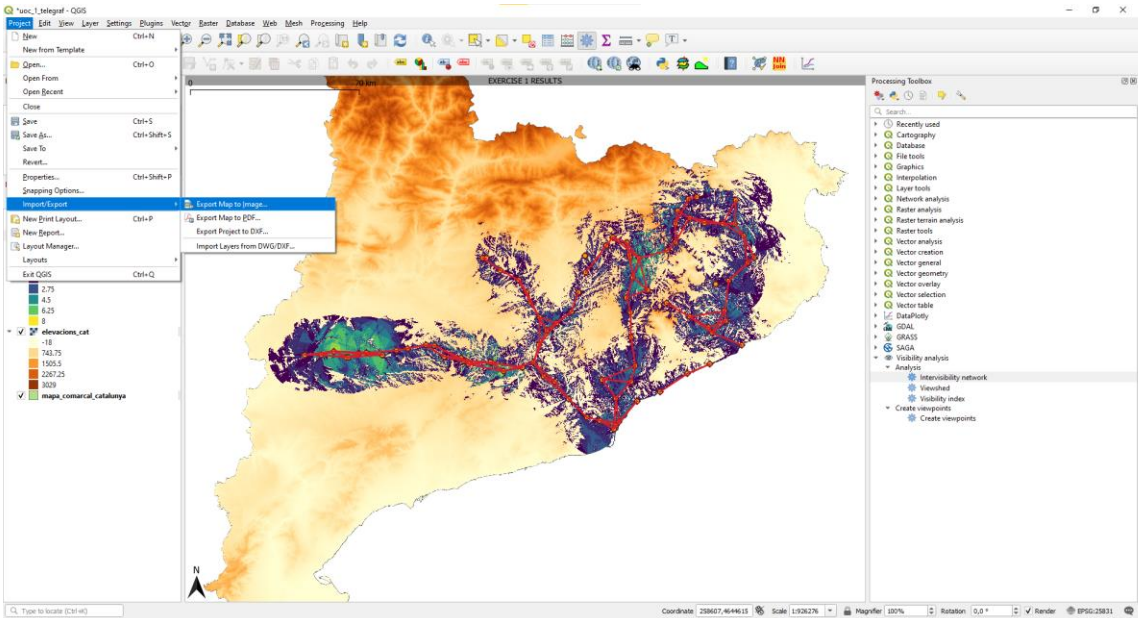
48. Finally add a title for your image (e. g. Exercise 1 results).

View -> Decoration -> Title Label



49. Now our image is ready for export. We can export to an image or a pdf from the main menu:

Project -> Import/export -> Export map to image…



50. Well done, you completed this exercise. This was designed as a first test to the use of GIS to explore cultural heritage and archaeology in particular. In other exercises we will explore other functions and consolidate the knowledge acquired here. Before closing the exercise note that the “output layers” you have created are temporal layers (see the small icon on the right, next to the layer’s name in the layers panel). If you want to keep it, remember to save it as a files (*Layer -> Save as*) before save and close the project.