TUTORIALS TO SUPPORT PRACTICAL CLASSES – WORK GROUP PROJECT PLANNING

TUTORIAL 2. QUANTIFICATION OF THE WETNESS INDEX FOR PILOT AREA COMPANHIA DAS LEZÍRIAS

VANDA ACÁCIO, PATRICIA MARÍA RODRÍGUEZ-GONZÁLEZ

FRAME AND OBJECTIVE

The objective of this tutorial is to learn how to use an index to quantify soil moisture and water accumulation in the landscape and discuss the results applied to the case study Companhia das Lezírias.

After applying the method, the students are expected to discuss and reflect on the implications for decision making in the context of their Work Group.

BACKGROUND

Soil moisture is one of the most important environmental factors that determines vegetation composition, structure and functioning of terrestrial ecosystems. The spatial distribution of soil moisture can be indirectly calculated with the Topographic Wetness Index (TWI), which is a widespread index in hydrological analysis to describe the tendency of an area to accumulate water (Mattivi *et al*. 2019). This index has shown good results to indirectly estimate soil moisture when compared to other proxies commonly used (Raduła *et al*. 2018).

The TWI is defined as:
$TWI = \ln (SCA / \tan\varphi)$, where, SCA is the Specific Catchment Area (or basin area) and ϕ is the slope angle.

The index assumes uniform soil properties and spatially invariant conditions for infiltration and transmissivity. Areas prone to water accumulation (large contributing drainage areas) and characterized by low slope angle will be linked to high TWI values. On the other hand, well-drained dry areas (steep slopes) are associated to low TWI values. However, the range of TWI values that correspond to wet soils will vary with landscape, climate and scale (Ågren *et al*. 2014). The index has shown good correlations with the real distribution of soil moisture in many small catchments. However, the TWI does not perform well in flat landscapes, where the distribution of soil moisture is mainly driven by variables such as soil properties, land-use and vegetation.

In QGIS, there are several tools that can be used to calculate the TWI, usually involving several geoprocessing steps (Mattivi et al. 2019). One exception is the "SAGA Wetness Index", which can be quantified in a single step using the digital elevation model as input data. The 'SAGA Wetness Index' is similar to the 'Topographic Wetness Index' (TWI), but it is based on a modified catchment area calculation, which does not think of the flow as a very thin film. As a result, it predicts a more realistic, higher potential soil moisture for cells situated in valley floors, compared to the standard TWI calculation.

INPUT DATA

- DEM – Digital Elevation Model for Portugal (https://gis.ciimar.up.pt/)
- Limit of the study area Companhia das Lezírias ("Charneca_do_Infantado_limites")

STEPS TO CALCULATE THE WETNESS INDEX WITH QGIS

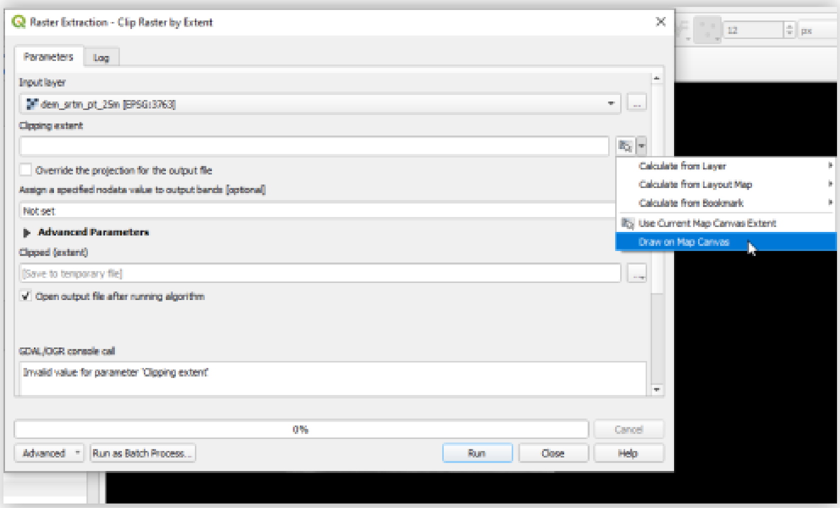
Step 1. Download the Digital Elevation Model (DEM) and clip it for the study area

1.1. Georeferenced elevation data for mainland Portugal can be downloaded from the site https://gis.ciimar.up.pt/ (SRTM, ASTER, ALOS, TerraSAR in raster format with 25m resolution and CRS epsg:3763).

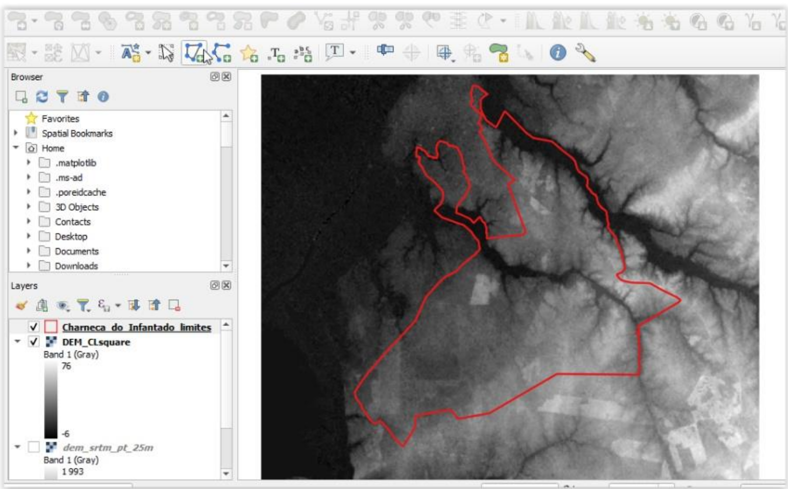
Go to the site and download the Digital Elevation Model (https://www.fc.up.pt/pessoas/jagoncal/dems/; chose SRTM-DEM EPSG:3763, GSD=25m)
Note: if your browser does not allow the download for security reasons, right-click and chose "Save link as " ("Guardar link como").

1.2. In QGIS, add the dem_srtm_pt_25m as a raster layer 

1.3. Go to the *Raster Menu > Extraction> Clip Raster by Extent* and choose "*Draw on Map Canvas*", to clip the DEM into a larger square area around the study area (Companhia das Lezírias). This larger area aims to include the drainage basins around the study area to allow a better calculation of the TWI. Save the output raster file as "DEM_CLsquare".



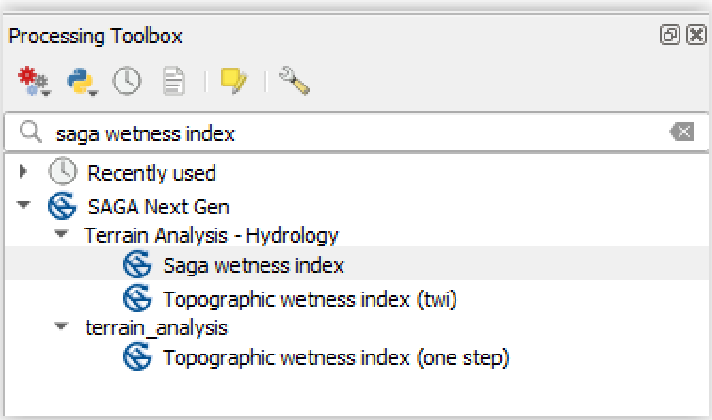
The output raster file (DEM_CLsquare) should look like the image below



Step 2. Calculate the Saga Wetness Index using DEM_CLsquare as input data

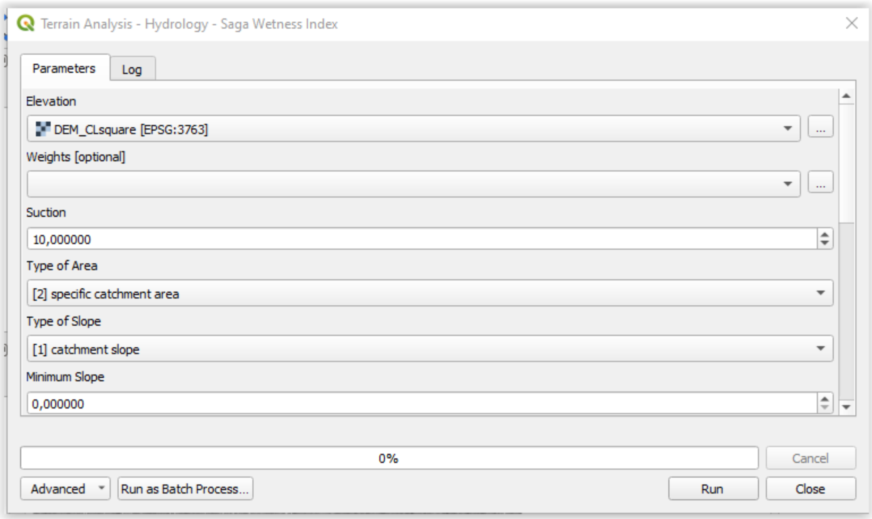
2.1. In QGIS go to the Menu *Processing* > *Toolbox*, to open the Processing Toolbox and write "Saga wetness index"

Chose and click on: *SAGA Next Gen > Terrain Analysis > Hidrology > Saga Wetness Index*



Note: In case you don't have SAGA installed, follow the instructions to install it in the link https://www.youtube.com/watch?v=ceBOzPtQvms

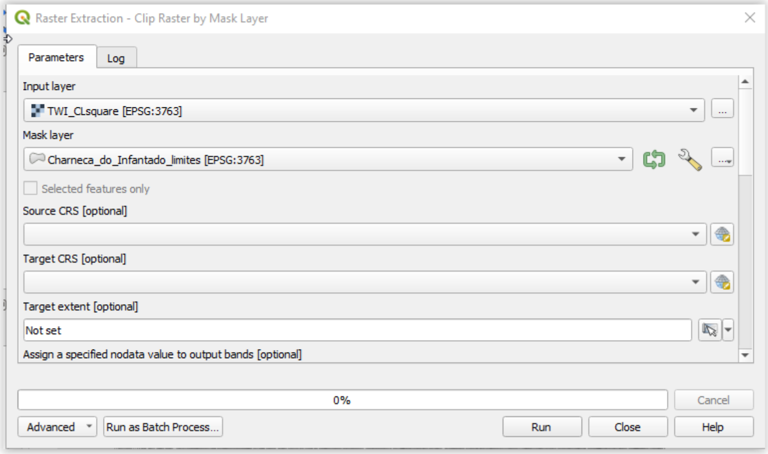
2.2. Calculate the Topographic Wetness Index using DEM_CLsquare as input data; save the output raster as "TWI_CLsquare".



Note that the output raster from the Saga toll used will be a sdat file (instead of a GeoTIff file). You can export it as a GeoTIFF file (by right-clicking the output layer). You can also choose the temporary file option as output and then save it as GeoTIFF.

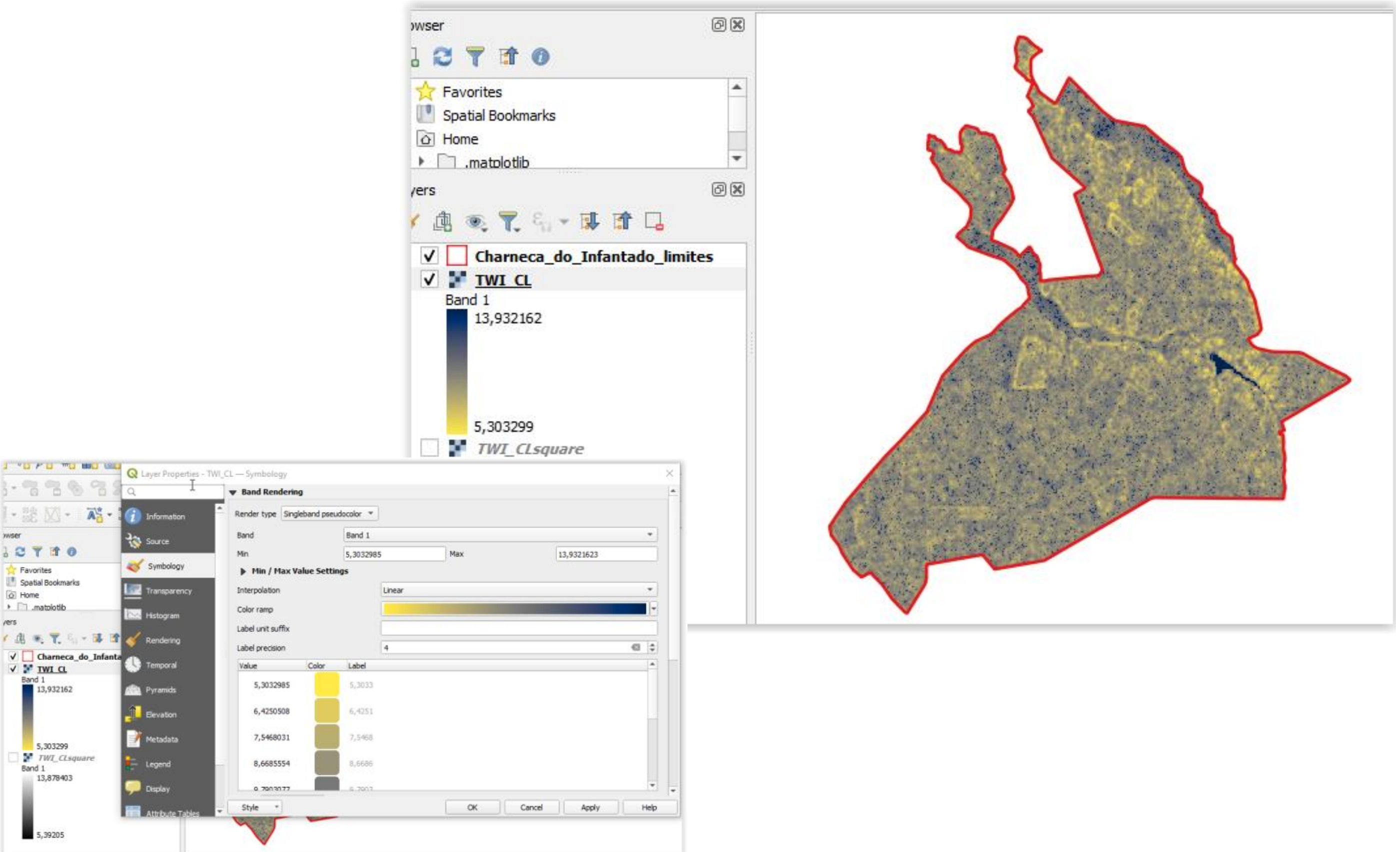
Step 3. Clip the TWI for the study area (CL)

Go to the *Raster Menu > Raster Extraction > Clip Raster by Mask Layer*, using the TWI_CLsquare as Input layer and the study area limit as Mask Layer, in order to clip the calculated TWI for the study area.



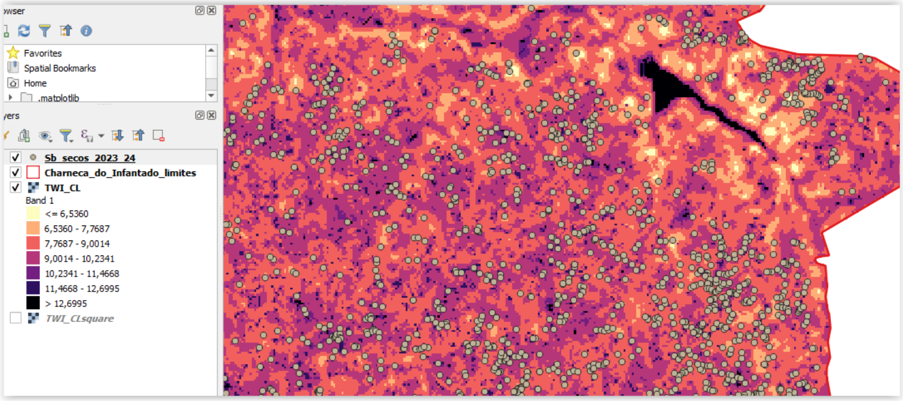
Step 4. Visualize the spatial distribution of TWI within the study area using a color ramp

The TWI for Companhia das Lezírias varies between 5,3 and 14. Apply different color ramps to visualize the range of TWI values across the study area (*Layer Properties, Symbology tab*)



Step 5. Compare TWI values with cork oak mortality

Add the vector layer with locations of dead cork oaks and compare it visually with the values of TWI. By visually inspecting the map, it seems that there is an association between mortality in 2023-2024 and higher TWI values (areas with higher water accumulation). Nevertheless, statistical analyses are needed to confirm this hypothesis. In addition, as already explained, other variables may be important to determine water accumulation in the study area (with a gentle/flat slope).



References

Ågren A.M., Lidberg W., Strömgren M., Ogilvie J., Arp P.A. (2014) Evaluating digital terrain indices for soil wetness mapping–a Swedish case study. Hydrology and Earth System Sciences 18(9):3623–34. https://doi.org/10.5194/hess-18-3623-2014

Boehner J., Selige T. (2006) Spatial prediction of soil attributes using terrain analysis and climate regionalisation. In: Boehner, J., McCloy, K.R., Strobl, J. [Ed.]: SAGA - Analysis and Modelling Applications, Goettinger Geographische Abhandlungen, Goettingen: 13-28.

Mattivi P., Franci F., Lambertini A., Bitelli G. (2019) TWI computation: a comparison of different open source GISs. Open Geospatial Data, Software and Standards 4:6. https://doi.org/10.1186/s40965-019-0066-y

Raduła M.W., Szymura T.H., Szymura M. (2018) Topographic wetness index explains soil moisture better than bioindication with Ellenberg's indicator values. Ecological Indicators 85: 172-179. https://doi.org/10.1016/j.ecolind.2017.10.011