UNIVERSITÀ DEGLI STUDI DI PADOVA

Multi Criteria Analysis (MCA) with GIS

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Find the best land for growing Mangoes in Madagascar using MCA!

Objective: use provided raster layers on precipitation and height above sea level (DEM) and new derived raster layers (distance from rivers, distance from farms, interpolated average yearly temperature) to create a final "suitability map" for Mango cultivation.

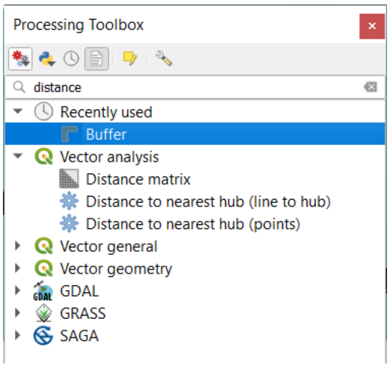
Literature references:

- Ecological requirements of Mango - https://www.nda.agric.za/docs/Infopaks/mango.htm
- Story about MC Analysis - https://storymaps.arcgis.com/stories/b60b7399f6944bca86d1be6616c178cf

Materials: data from Madagascar Dataset in Moodle Course Page

- Country borders: UNEP WFS service - http://preview.grid.unep.ch:8080/geoserver/wfs
- Rainfall data (mean annual precipitation and number of rainy days): http://geoportal.org >> UNEP download service http://geodata.grid.unep.ch/
- GLOBCOVER (land use – land cover - LULC): http://due.esrin.esa.int/page_globcover.php
- Country borders and provinces: https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/countries
- Rivers and farms: vectors from Open Streetmap
- Mean annual temperatures from WorldClim database rasters (see http://www.worldclim.org/): raster was randomly sampled at point positions and temperatures converted to °Celsius
- DEM from EarthExplorer web portal (see PDF on how to download Geodata) - dataset description at link

Glossary: in text **PT** = Processing Toolbox in QGIS
MCA = Multi Criteria Analysis



Idea for lab-project: use information from https://www.nda.agric.za/docs/Infopaks/mango.htm or other sources of information about requirements of any other crop, and data from WorldClim - http://worldclim.org/version2 - to provide a more detailed multicriteria analysis over an area and a crop of your choice.

Method: for reaching the objective we will simulate that Mango has the following characteristics in Madagascar:

- Does not grow above 1000 m a.s.l.
- Is sensible to salinity, so cannot be closer than 1 km to the coastline
- Be closer than 50 km from existing rivers and farms
- Ideal mean annual temperature at 26 °
- Ideal number of rainy days, 50

We will classify the following rasters in **4 classes from 0 to 3. Zero means that mango cannot absolutely grow in that area/cell/pixel (e.g. inside a river bed, in slopes greater than 60° or above 1000 m a.s.l.), 3 is highly suitable (ideal) area/cell/pixel region for mango**.

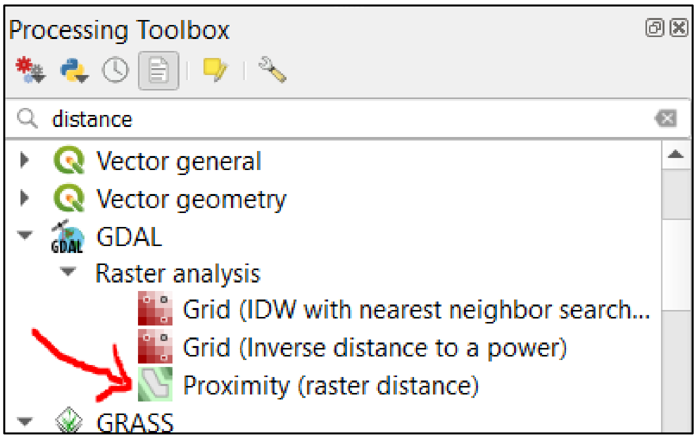
- Distance from rivers
- Distance from farms
- Average yearly temperature
- Slope
- Average yearly rain
- Number of days with rain

So each raster will be reclassified to values of 0, 1, 2 or 3. Very simply we will create the final suitability class by calculating the average (sum of raster layers divide by 6). An added

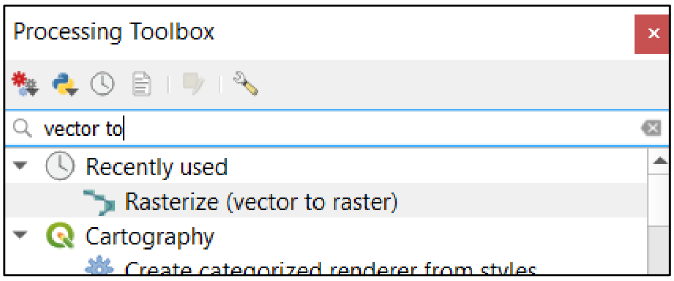
Step 1. Calculate a map of distance/proximity from rivers and from farms.

Why? Because we want to consider an advantage to have your Mango farm close to a river, for irrigation, and close to other farms to create a cooperation strategy with fellow neighbouring farmers growing other crops.

How? Search for “distance” in the PT: we will use “Proximity” tool from the GDAL set. BUT if you open the tool, you will see that it requires a raster as input: but our rivers and farms are vectors! …we have to make an extra step: convert a vector to a raster.



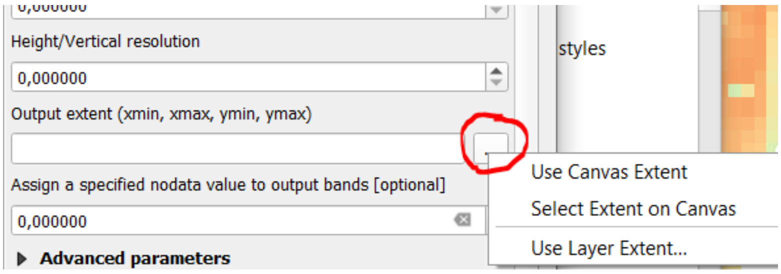
Search a vector to raster tool in the PT .



Basically vector to raster will create a raster with all cells with value=0/nodata except where vectors overlap the cells, that will have a value that the user defines in parameter 1 (a fixed value to burn).

Another important set of parameters which are not immediate to understand is “Output raster size units”, “Width/Horizontal resolution”, “Height/Vertical resolution” and “Output extent”. These are related and define the number of cells/pixels of your raster:

- “Output extent” is simply the borders of your raster (see Figure 1 to the right) – you can set these by using the current view (canvas) in QGIS, or draw your rectangle by hand (Select Extent on Canvas), or use any existing layer (Use Layer Extent).



- “Output raster size units” can be:
  - **Pixels** – if this is selected, parameters “Width/Horizontal resolution” and “Height/Vertical resolution” will refer to width and height (number of columns and rows if you imagine your raster as a matrix) of the raster determined by the number of pixels – in image below it would mean setting Width=8 and Height=8 to the left-most image, and Width=4 and Height=4 in the middle image. When you set this, the spatial resolution of the raster is consequential.

- ○ **Georeferenced Units** – if this is selected, “Width/Horizontal resolution” and “Height/Vertical resolution” will set the <u>spatial resolution</u> of the cell, i.e. size of the single cell. <u>The Width and Height is consequential</u>.

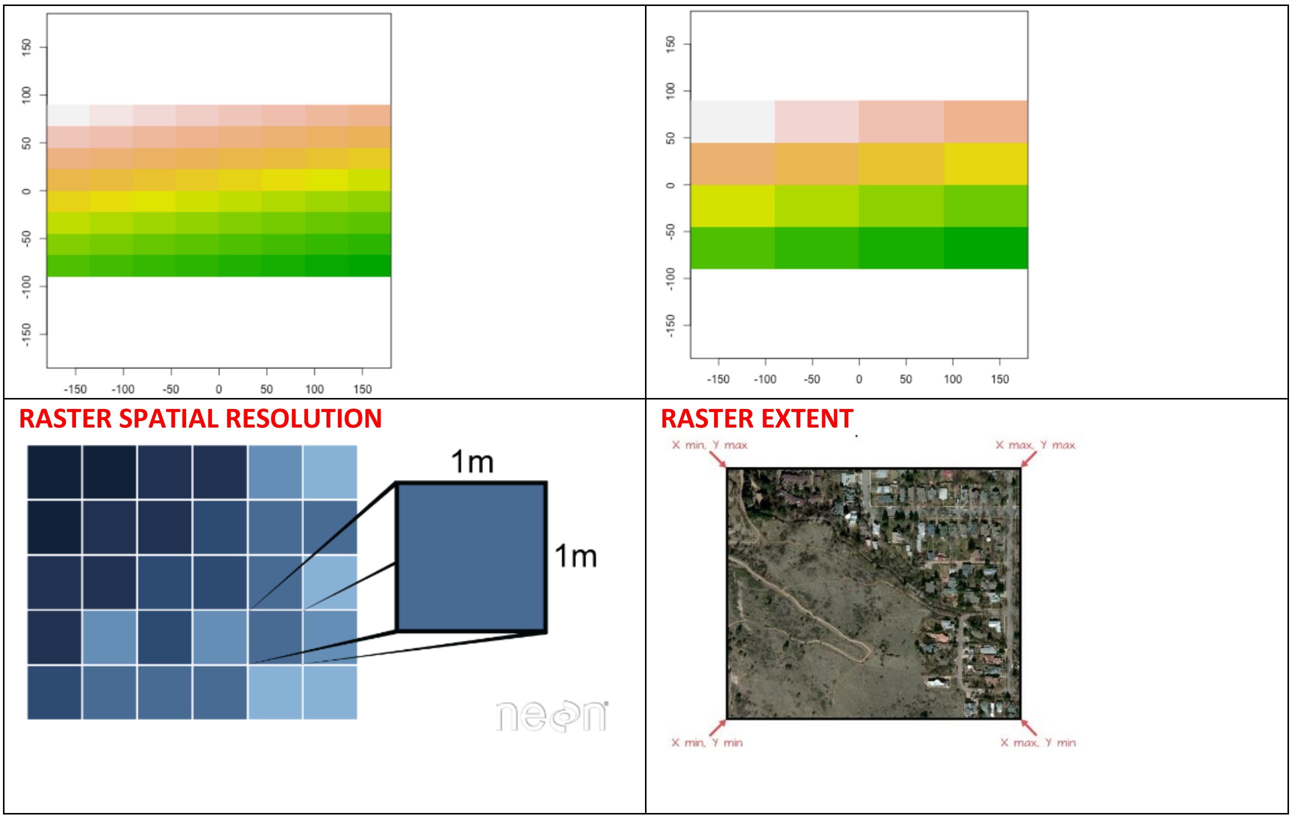
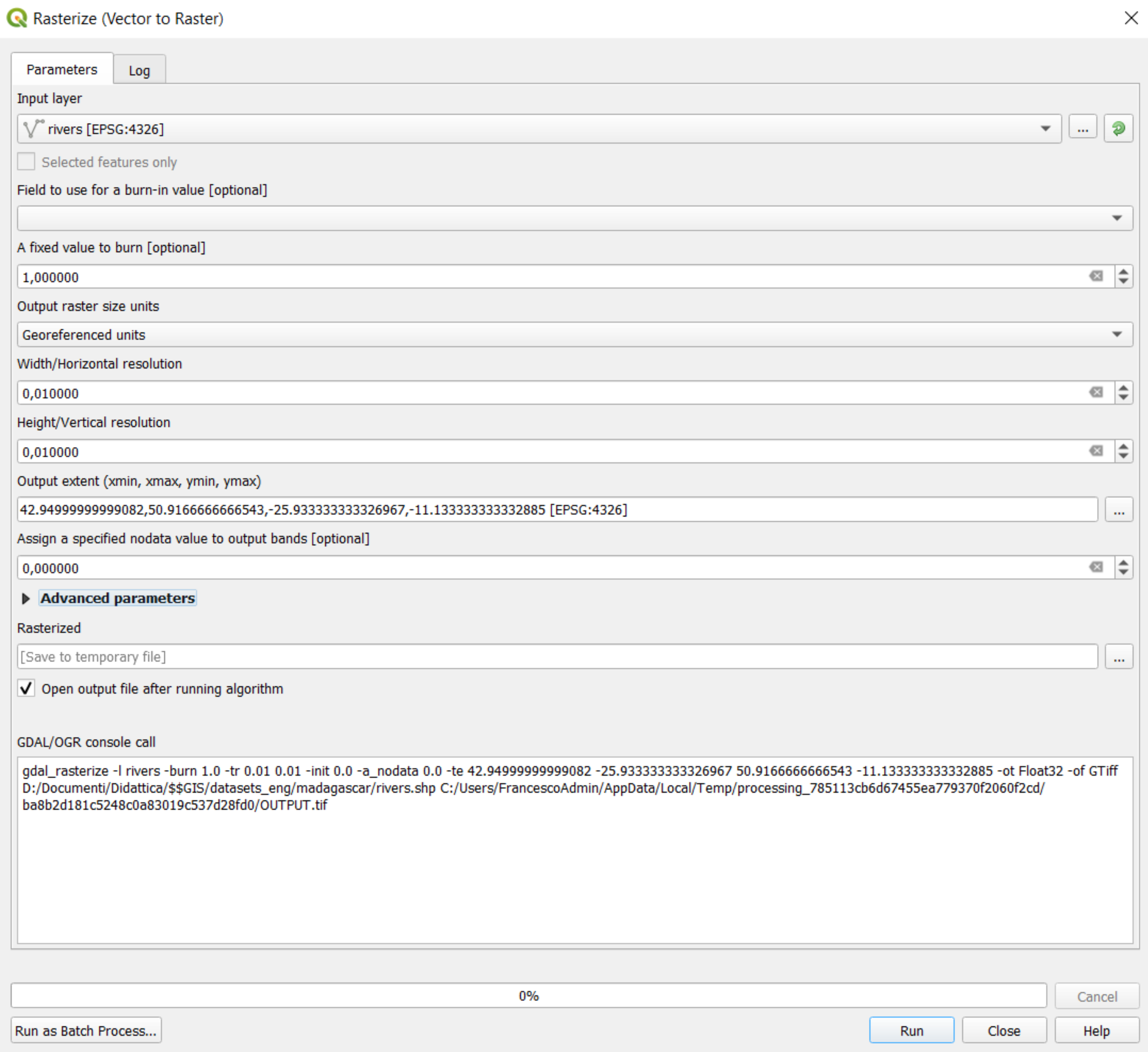


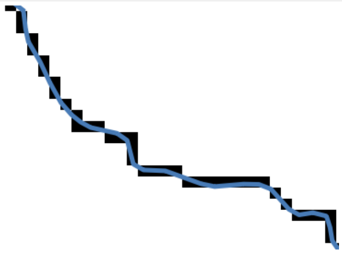
Figure 1 left and middle different spatial resolution of raster Courtesy of https://www.neonscience.org

Se we will set parameters the following way:

- Values to Burn = 1: why? Because we want our pixels to have value 1 where rivers or farms overlap.
- “Output raster size units” = Georeference Units: why? Because we want to set raster spatial resolution
- “Width/Horizontal resolution” and “Height/Vertical resolution” = 0.01: Why? Because our data is in latitude and longitude and we want a cell size similar to the resolution of the DEM as we choose to work in that resolution – if look at properties➔Information of the “Madagascar_dem” layer, you will see that it has a resolution 0.008333 – 0.01 is ok.
- Output extent = “Madagascar_dem” layer extent



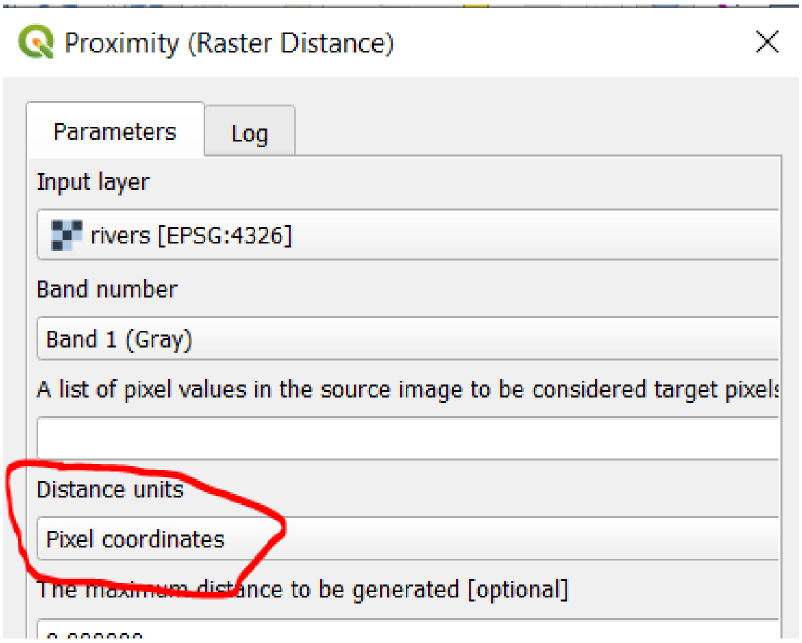
Click RUN and you will see, zooming in your rivers, black cells where rivers are like in the image on the right.



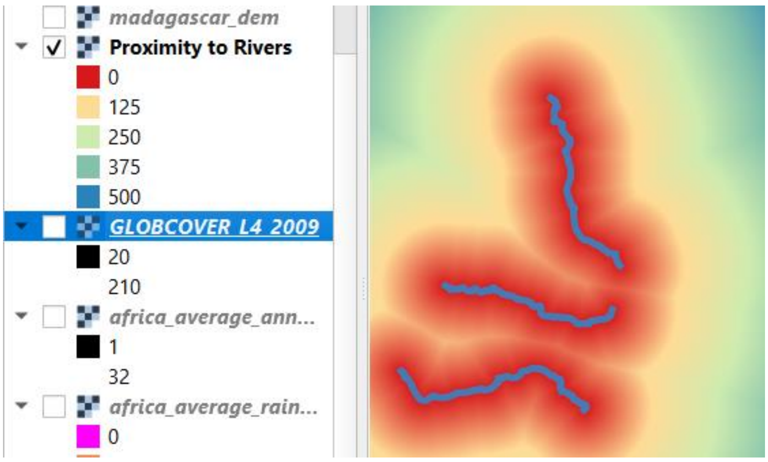
Use the two new raster, rasterized rivers and rasterize farms, as “input layer” for the tool Proximity. For this tool the only parameter to set is the “Distance Units”:

- Pixel coordinates will return a raster with cell values representing how many pixels each cell is from the river/farm
- Georeference coordinates will return a raster with cell values representing how many units, in the current CRS (coordinate reference system) , is each cell from the river/farm – in our case we are in CRS 4326 Longitude and Latitude, therefore the units are degrees! In other CRS (projected) the units would be meters.

We choose pixel coordinates. Why? Because we know our pixel size is approximately 1 km, so it is easy to convert pixel distance to metric distance.



Now we have two raster layers, respectively for distance (proximity) from farms and from rivers… use styling to create a color scale to get a better visual!



Step 2. **Calculate temperature map interpolating points** with temperature information.

We use the vector layer "temperature_points" to interpolate a raster. What is interpolation? Interpolation is estimating a value from near-by measured values. In our case nearby measures are the points and we want to estimate the values of all cells in our raster. There are very many methods for interpolation: we will use TIN – triangular irregular network, but QGIS provides many more – IDW, Kriging, Splines etc… TIN is Delauney triangulation of points (uses the minimum-circumcircle criterium) – it then intersects cell centers at each triangle to find a linear weighted average of the value of the point from.

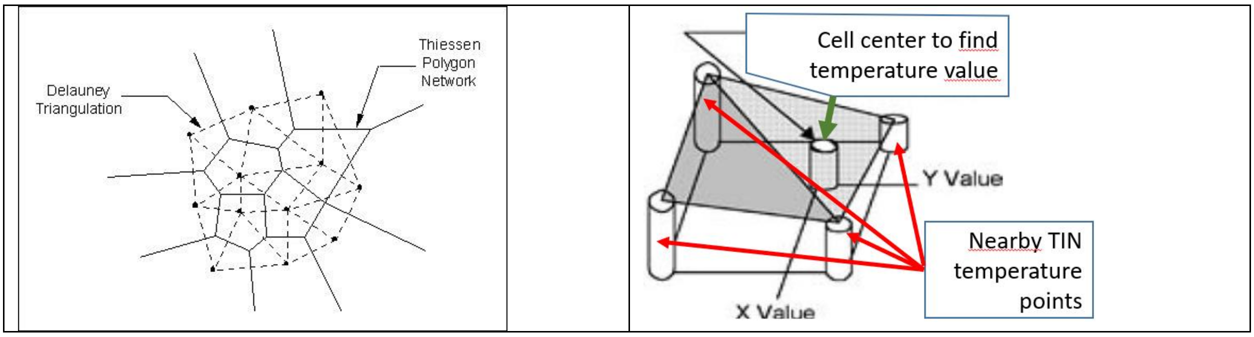
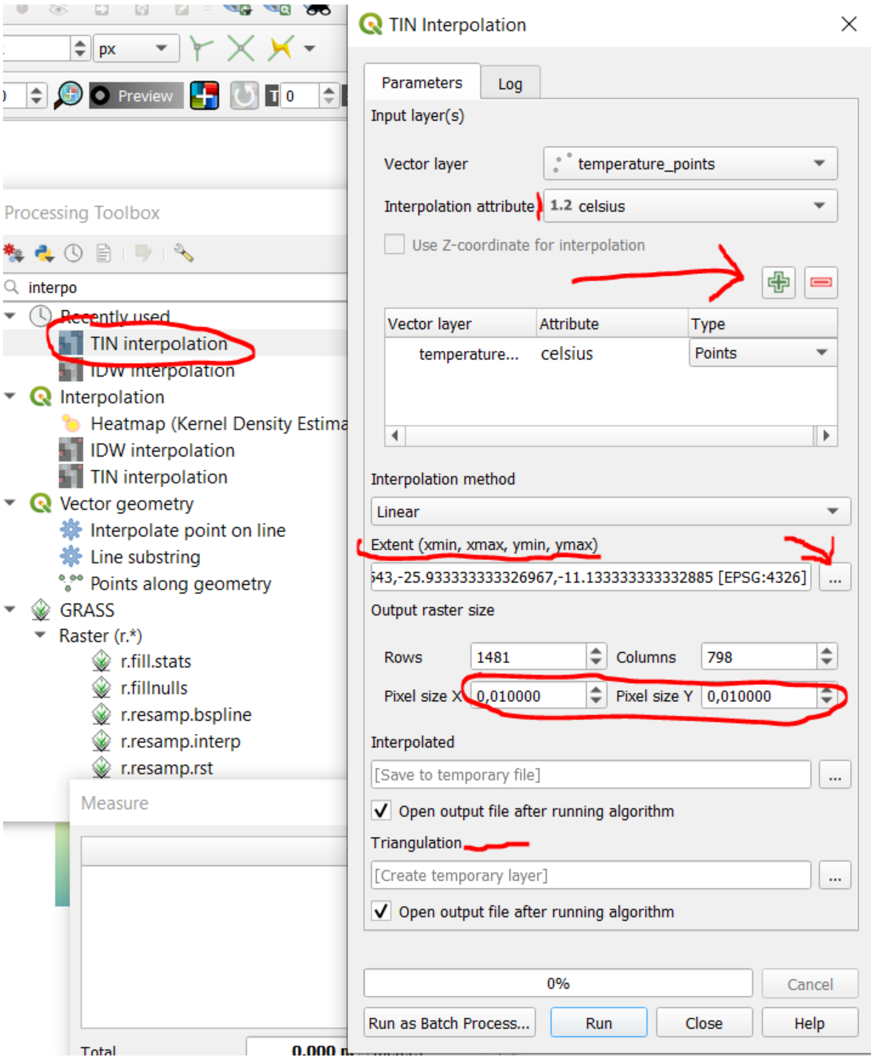


Figure 2 – left: from https://www.xmswiki.com/wiki/SMS:Natural_Neighbor_Interpolation – right: adapted from [Michael D. Proctor](#)

We find the tool in the PT and open the panel. From the TIN interpolation panel. (i) select the column with attributes that you want to interpolate, and push the green plus button to add them[1]; (ii) choose the extent using the layer "Madagascar_dem" as we did before; (iii) choose the resolution of our raster cells/pixels, the usual 0.01 degrees.

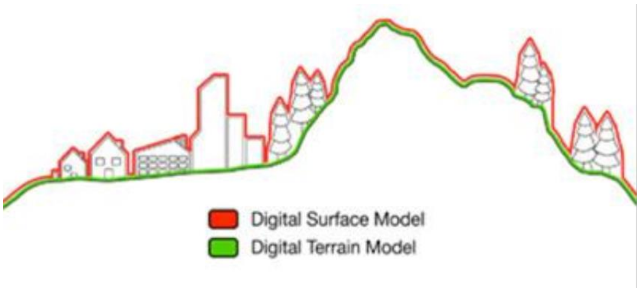
An extra layer that you can create is the actual Delaunay triangulation, to do this select Create Temporary Layer and Open Output for the Triangulation section at the bottom. But this layer is not required for the next steps.

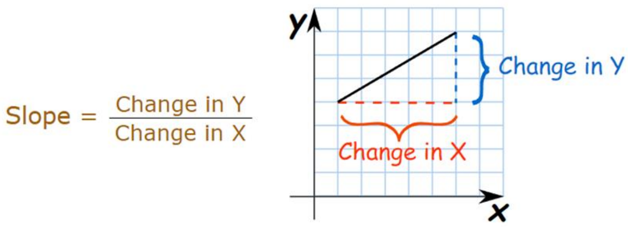


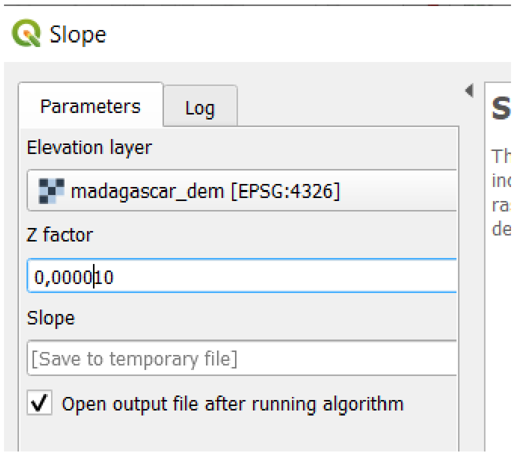
Step 3. **Calculate slope from DEM**. Slope is more correctly calculated from DTM (digital terrain models) whereas we have a DEM (digital elevation model) which is a generic term indicating actually a DSM (digital surface model). The DSM provides the height above sea level of terrain and above-terrain elements. We will use the DEM for slope anyway, as a 1 km resolution DEM will not be very different from a DTM. In the slope tool we set a Z factor of 0.00001. Why? Because it is the conversion factor of one degree to one meter, and the height values in the DEM are in meters, therefore we must provide a conversion factor because slope. In the bottom figure, "change in X" in our raster is in degrees, and "change in Y" is in meters

[1] With this module you can add multiple sources for your interpolation, for example if you have isotherms or other points with temperature information from other layers.

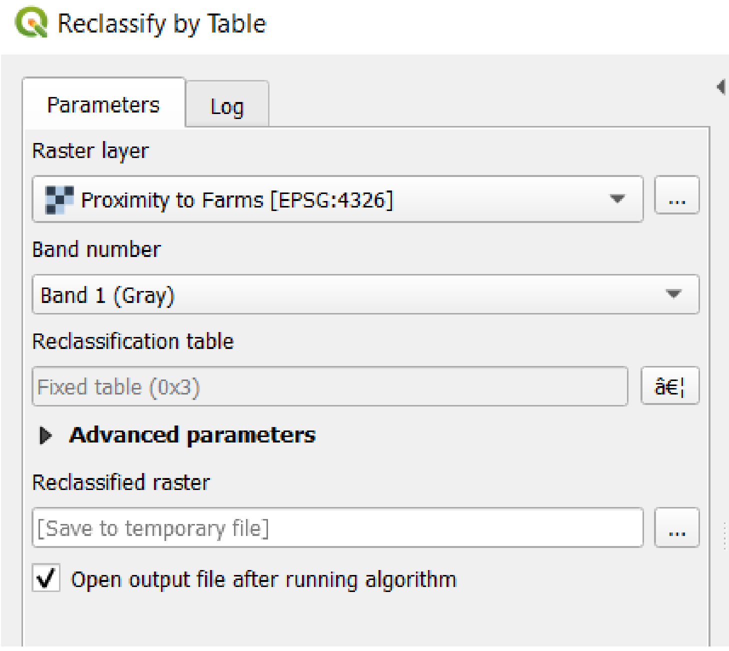
– therefore we must provide a conversion factor the convert “change in X” to meters – if we divide one degree by 0.00001 we get 100’000 – that is how many meters are in one degree at the latitude of Madagascar (approximately).
If you don’t believe it? Check https://en.wikipedia.org/wiki/Decimal_degrees .







Step 4. We now have 6 rasters with information related to factors that influence our choice. One approach is to divide each raster in N suitability classes; in this example we will divide into **4 classes from 0 to 3. Zero means that mango cannot absolutely grow in that area/cell/pixel (e.g. inside a river bed, in slopes greater than 60° or above 1000 m a.s.l.), 3 is highly suitable (ideal) area/cell/pixel region for mango**. To do this we use the “Reclassify by Table” tool, which allows us to provide values for each range that we decide belongs to each class. To do this we select the raster then open the “Reclassification Table” which allows to define ranges and new values. In the next images the table for each of the six layers is shown. New rasters are saved, for example, in the case of raster of “proximity to Farms” naming is “proximity to Farms CLASSES”.



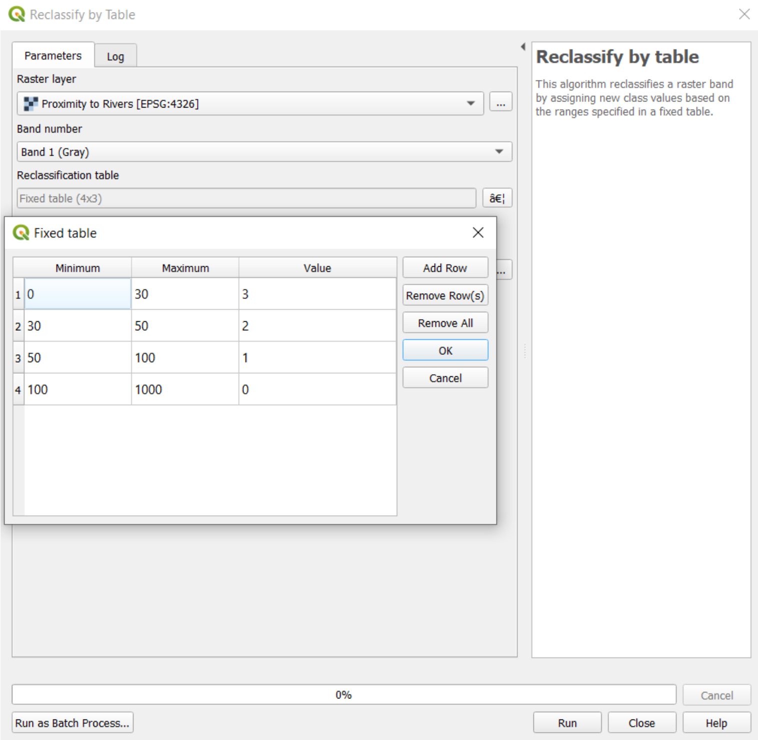


Figure 3 – PROXIMITY TO RIVERS CLASSES (SAME CLASSES TO "PROXIMITY TO FARMS")- best class is closet han 30 pixels – one pixel is about 1 km so in our simulation the best class is when a cell is closer than 30 km to a river or to a farm.

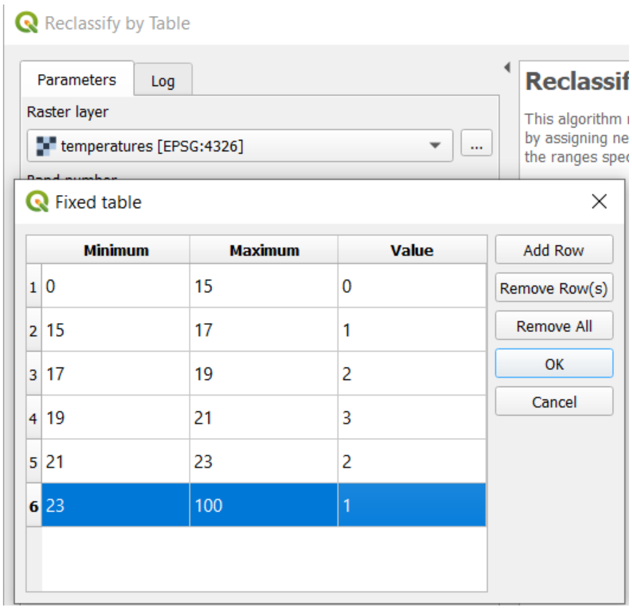


Figure 4 – TERMPERATURE CLASSES – best mean temperature is between 19 and 21.

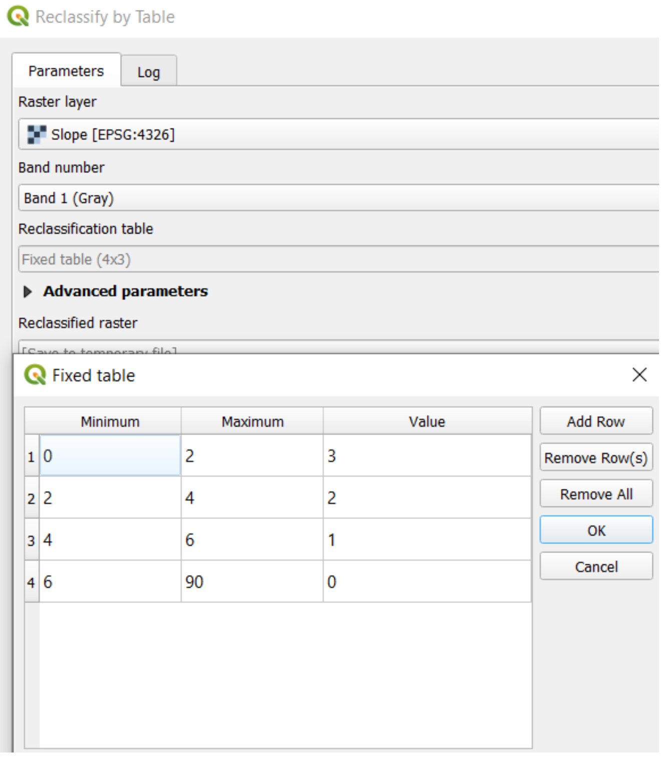


Figure 5 – SLOPE CLASSES – best class is when terrain is flat or maximum 2 degrees.

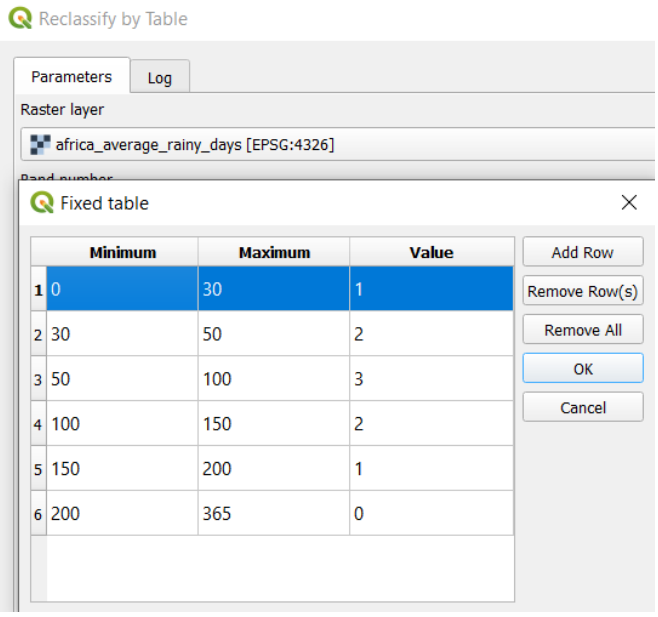


Figure 6 – AVERAGE RAINY DAYS CLASSES – best class is from 50 to 100 days of rain.

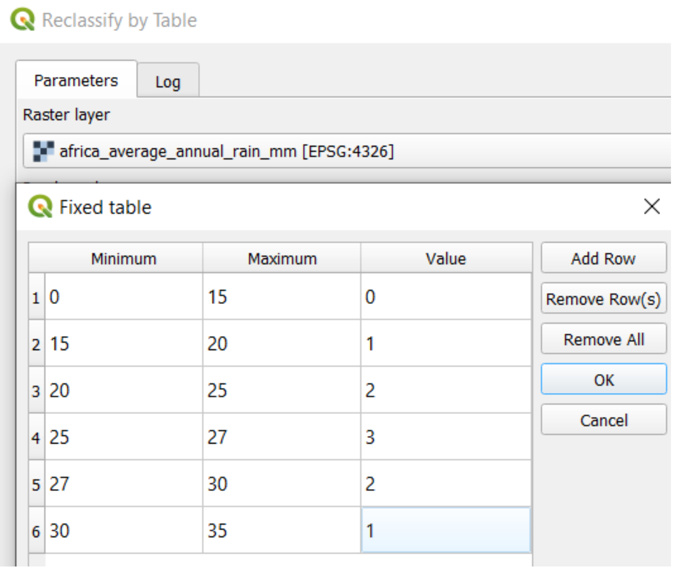


Figure 7 – AVERAGE YEARLY RAIN CLASSES – best class is when 25 – 27 mm of average rain per day

When the 6 rasters are done, you can average them with raster calculator and the following formula.

```
("temperature classes@1" + "slope classes@1" + "AVG Rainy days classes@1" + "annual rain
classes@1" + "proximity_rivers classes@1" + "proximity_farms classes@1")/6
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You will get your final raster with a suitability ranging from 0 to 3 for each pixel! See
next page for results.
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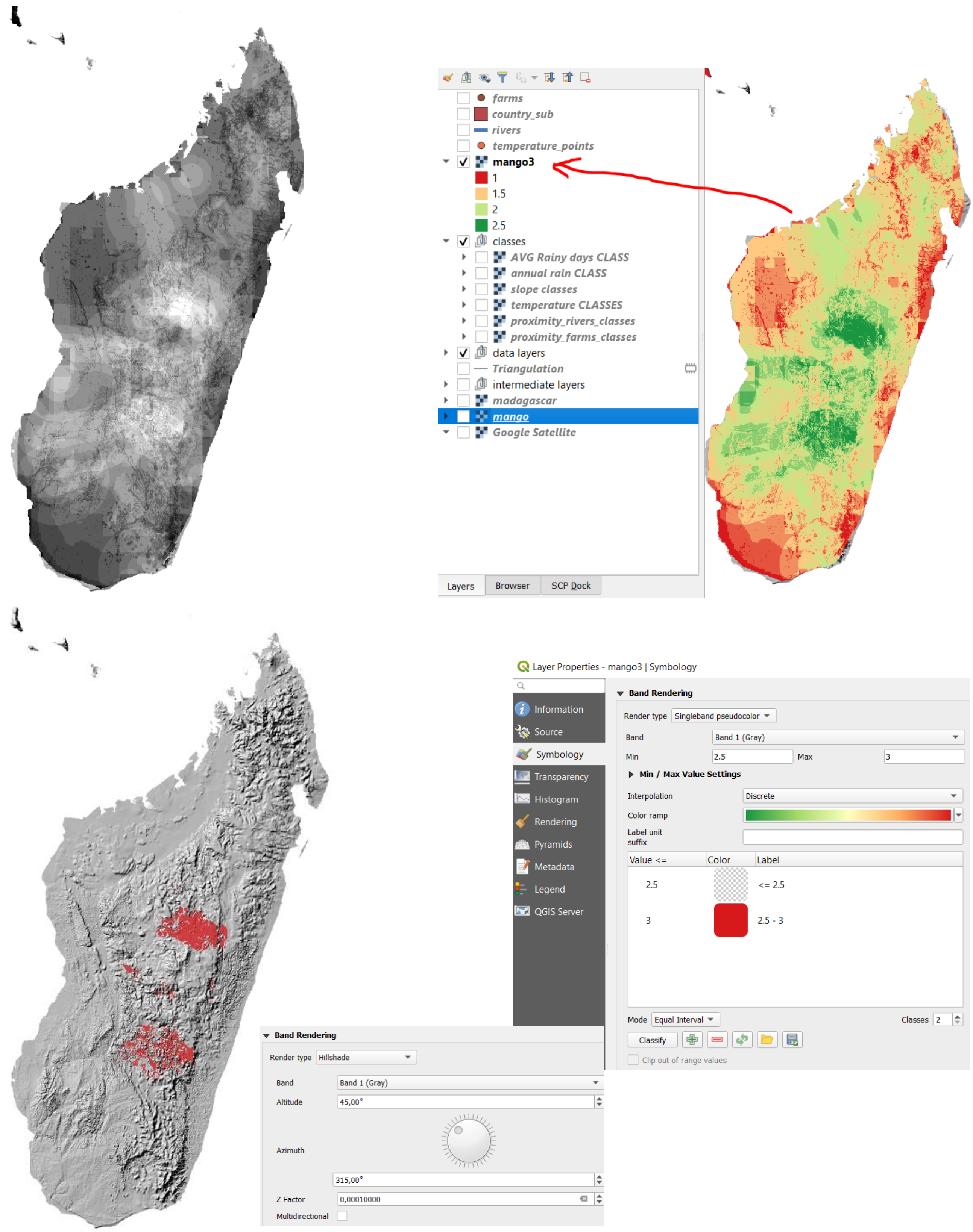

*Figure 8 - **top left** – grey-scale value of result – **top right** – color scaled value of suitability, **bottom**, result of suitability styled with red color given to very suitable areas overalapped to madagascar DEM; DEM styled with hillshade (Z-factor value is explained in "Step 3 calculate slope")*