

QGIS

Graphical Model Designer

Workshop



Course goals

By the end of this workshop, you will be able to use the QGIS Graphical Model Designer to turn geodata processing workflows into reusable and adaptable models. You will learn how to create, run, and use your own models as processing tools.

Maya Mielena

Welcome to this QGIS Graphic Modeler course. To show you some cool workflows, we'll tell you a story. The story of Maya and her bees. The characters and events are fictitious. To make the story more interesting, we may have gotten a little carried away here and there. We hope you'll forgive us for any inaccuracies and liberties taken, especially if there are beekeepers among the participants.



This is Maya Mielina.

Maya worked as a GIS specialist in Zurich during her professional career. Now she's retired and moved back to her home village of Lavertezzo. As a child, she had helped her grandmother with beekeeping, and now she's starting to make her long-held dream come true as a hobby beekeeper. For quite some time now she has used QGIS for planning and documenting her beekeeping. With the impact of climate change she has experienced a change in her bee population and most recent flooding events have led to some lost hives. This is why Maya has partnered with ETH Zurich to develop a methodology for identifying the most suitable locations for bees, both now and in the long term, taking into account potential changes in environmental conditions.

Criteria for suitable bee locations

Bees are quite resilient creatures. However, certain criteria need to be met in order for a bee to collect a suitable amount of pollen and nectar for the hive. Here is a list of criteria that need to be met:

1. **Distance to water:** A bee should not fly more than 1 km to retrieve water (they can fly longer distances but this will lead to longstanding damage). But to account for the potential **threat of flooding** it should be further away than 100 m.
2. **Natural areas:** Bees require natural areas. Also the area needs to be sufficiently large to accommodate a whole beehive, at least 500 m².
3. **Accessibility / transport:** Bees do not like to be moved, and we want the hives being easily accessible by car. Distance to roads should not exceed 150 meters.
4. **Topography:** We do not want to place hives in very steep areas, so the slope should be maximum 25 degrees.
5. **Bees require sun:** Hence the hives should be located in South-East to South-West-exposed areas.
6. Optional: The **vegetation** needs to be **healthy** for them to actually retrieve sufficient pollen for their beehives.

From workflow to model – a reusable and adaptable approach

To make the methodology **applicable to different locations** and allow the analysis to be quickly repeated with **adjusted parameters**, Maya has converted the workflow into a **model** using the Model Designer in QGIS.

Note: The screenshots of the intermediate results in this script refer to a different area (Mostar, Bosnia and Herzegovina), which should not confuse you 😊.



The model designer

The model designer can be accessed through the toolbox of QGIS. With an easy interface you can create simple and complex models to optimize your workflows and make them more efficient. The modeler interface looks like in the image below.

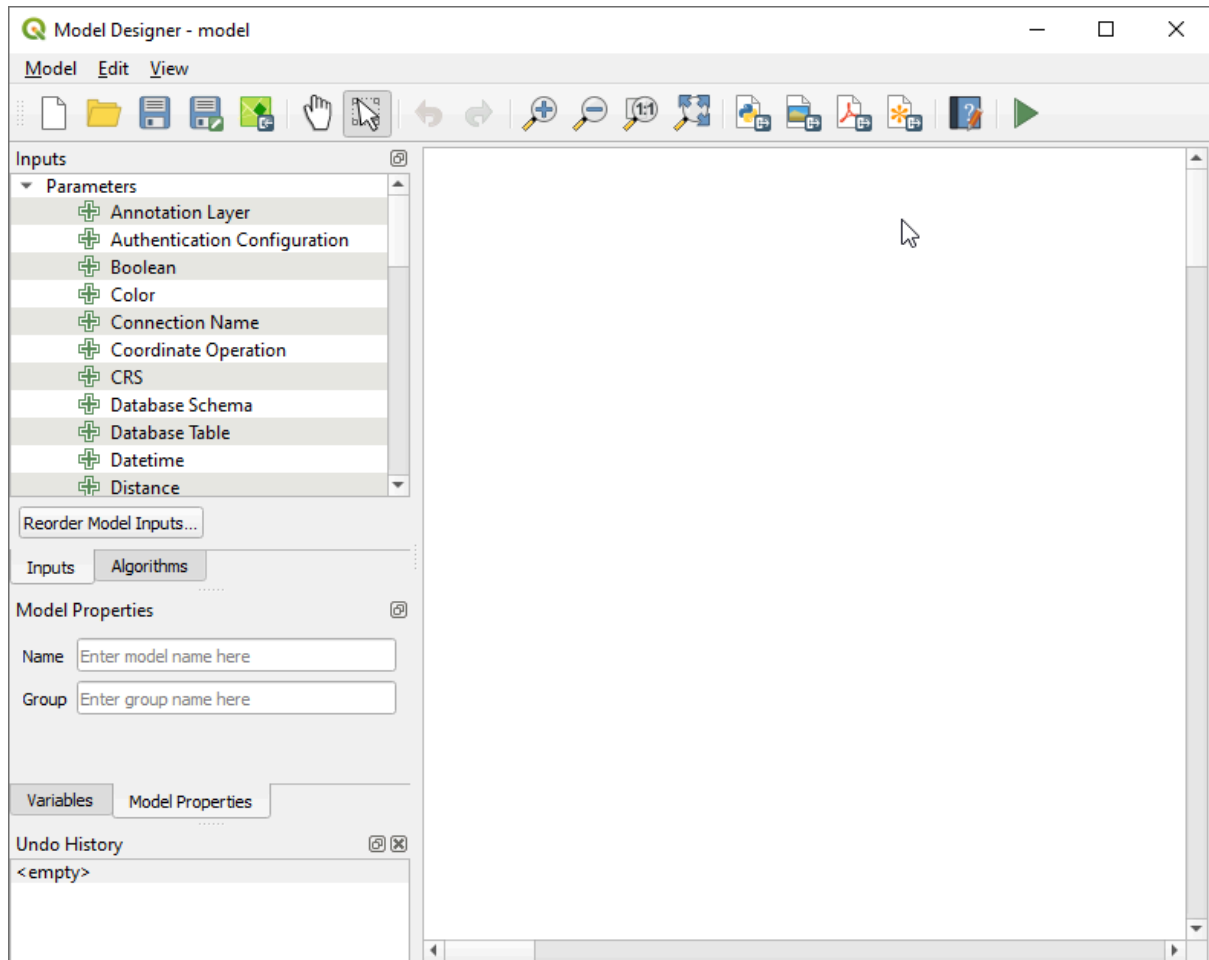


Image: The Graphical Modeler Interface in QGIS

First, you need to give your model a name. If later on you would like to create multiple models for different projects, you can also organize them into groups. When you access and run your models from the Processing Toolbox, they will be grouped accordingly, making it easier to find and manage them.

At the top of the image you find the navigation toolbar, which allows you to save your model and to navigate on it. There are multiple options to export your model. If you are more familiar with python you can also export it as python code and customise it to your needs.

To create a model two things are required:

- **Input variables:** These will be added through the input parameter window.
- **Processing algorithms:** These will be added through the algorithms window. Almost all processing algorithms can be executed inside the models, with a few exemptions.

To read more about the model designer, access the [QGIS Documentation](#).

Input parameter

The image below shows an example of an algorithm window: As input layer you can specify what parameter to use:

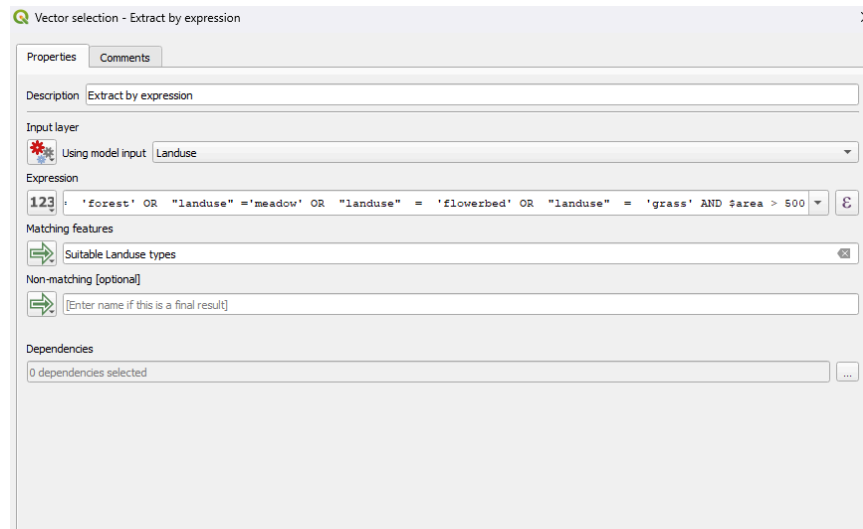


Image: Example of a QGIS Processing algorithm dialog inside the model designer

123 Value: This option allows you to enter different static values as input. Depending on the parameter, there are several options available. It can be a number, a string, a 'select layer' or a pick item from a list

-  Pre-calculated Value: You can open the expression builder and add an expression. The expression is calculated before the main process is executed.
-  Model Input: The model Input is one of the possible input parameters added to the model.
-  Algorithm Output: Can assign the output of another algorithm as an input.

Output parameter

A model output parameter can have the same options as the input.

Dependencies

To specify the order of the model to be executed, it is possible to add a parent to any algorithm.

QGIS Project

Data

For this course you will need a few datasets, which you have been given at the beginning of the workshop:

- osm_data.gpkg
- DEM_90m_cropped.tif
- 2 Sentinel-2 satellite image tiles (T32TNS_20260912T102019_B04_10m.jp2, T32TNS_20260912T102019_B08_10m.jp2)

Models

- OSM_importer.model3
- waterways.model3
- DEM.model3
- NDVI.model3
- ndvi_reclassification.model3

Maya is used to the open-source GIS software QGIS.

→ Open a new QGIS Project. We will start with adding a basemap layer to QGIS. In your browser panel you can now direct to the *Project Home* and locate all the datasets.

→ Let's save the project and also add the datasets and the model to the same folder.

Plugin Extension (OSM Place Search)

To easily identify her area of interest, Maya uses the plugin extension OSM Place Search.

→ Direct to **Plugins > Manage and Install Plugins...** > and look for "OSM Place Search". Then you can type your area of interest, and also add it as a (temporary) layer to your project.

OSM Model

Maya was lucky to receive an already prepared model that converts OSM data in their raw format to some general feature layers that she has included in her methodology. Maya is a great supporter of open data. The raw OSM data could also be retrieved through the QGIS plugin Quick OSM.

→ Let us start with adding the model into our project environment.

Direct to the Processing Toolbox. The small  corresponds to the icon for the model. Open an existing model, direct to the directory and add the .model3 file to the project.

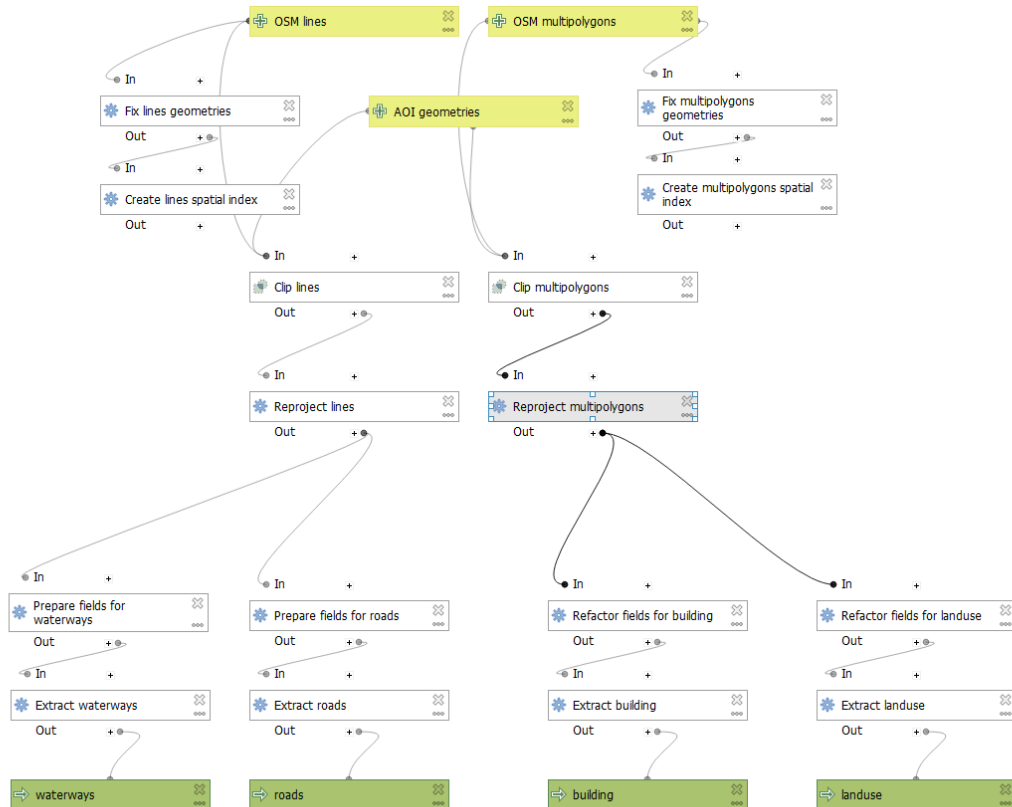


Image: Prepared OSM Model

The model appearing contains three input variables and four output layers as well as 16 processing steps. First we fix the geometries of the downloaded raw osm data and create a spatial index to optimize the performance when working with the output datasets. Following, the data are clipped to an AOI and reprojected into a desired projection system. As a final step the required feature types and their corresponding fields for further analysis are extracted.

→ Let's run it by hitting the  icon. It will ask you for the three input layers, which we will select from the osm.gpkg dataset provided.

Success! Now Maya has all the essential background layers that she requires to apply the methodology.

Model Suitable Locations

Waterways

Let's have a look at the criteria again. Bees require access to water. Maya will start with creating a buffer around the existing waterways to make sure the locations are not too far away from the next water source.

→ Open a new model and give it a name.

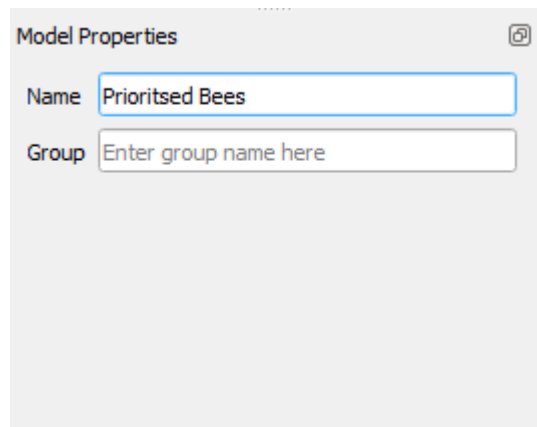


Image: Model parameters

→ Add one Input Variable called “waterways” and specify the geometry type. Once you hit OK it will appear in the designer user interface.

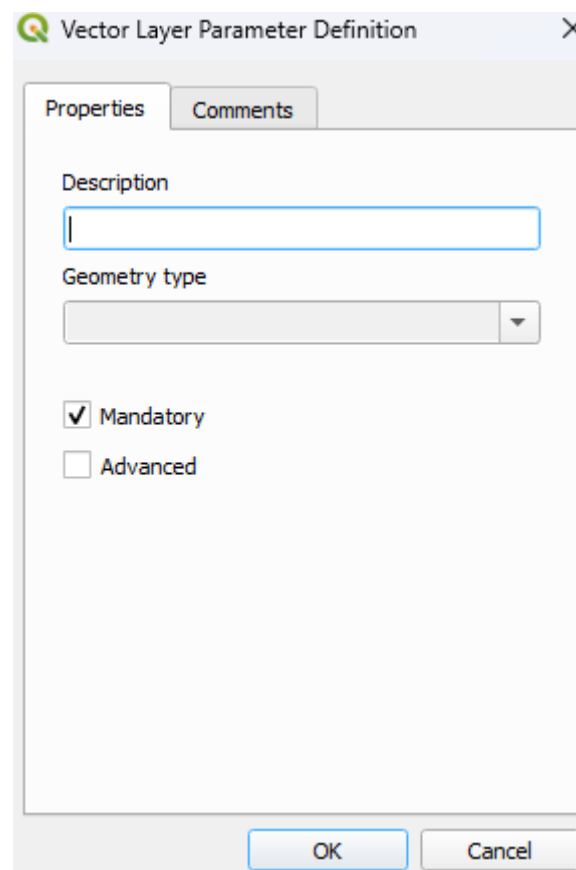


Image: Input Variable parameters

Now we need to add the buffer tool into the model.

→ From the toolbox panel look for the buffer tool and double click. The window below will appear. We will customise it to our needs.



Image: Algorithm dialog of the buffer algorithm

→ Set the input layer as *Model Input* and select the *waterways*.
 → In this case we can set a predefined value for the distance already. Set the value to 1000. We want to dissolve the output to later only have to deal with one feature. As the output type we can enter a name. For example: *waterways_buffer_1km*. Hit ok.

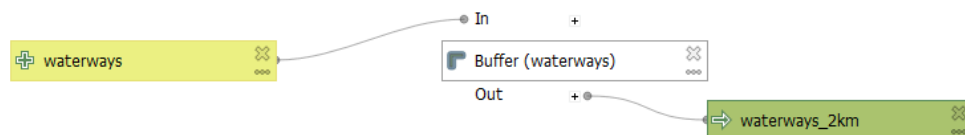


Image: User Interface for a simple first model with one input, one processing step and one output

Immediately the output layer will be added to the UI. If you run the model now, it will be equivalent to the buffer processing tool that you already know. But wait: The suitable areas for water also have to be at least 100 meters away from the riverbed.

→ Let us just copy the buffer process right below the created step but set the buffer distance to 100 m instead.

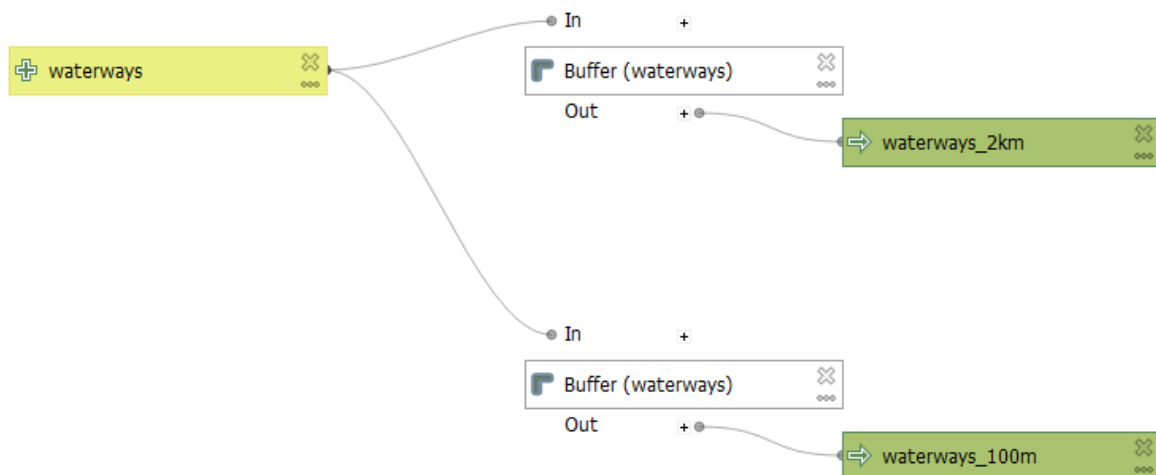


Image: User interface with the two buffer operations.

To exclude the 100 m buffer zone for the suitable locations, we will add another step to our model: the *Difference algorithm*. This time, we can use the model outputs of the buffer operations directly. If you want, you can also set dependencies for this operation.

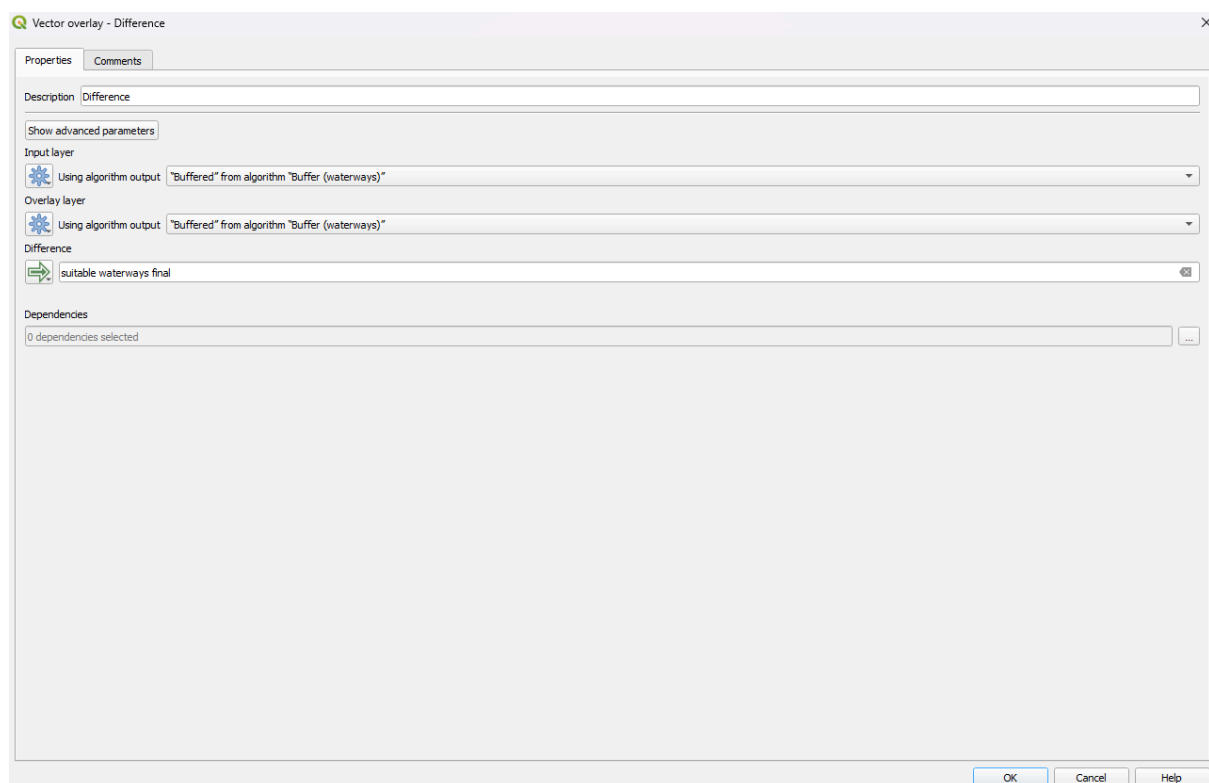


Image: Difference processing tool

Lets try and run the model. Wow! This looks good. We have successfully created our first model.

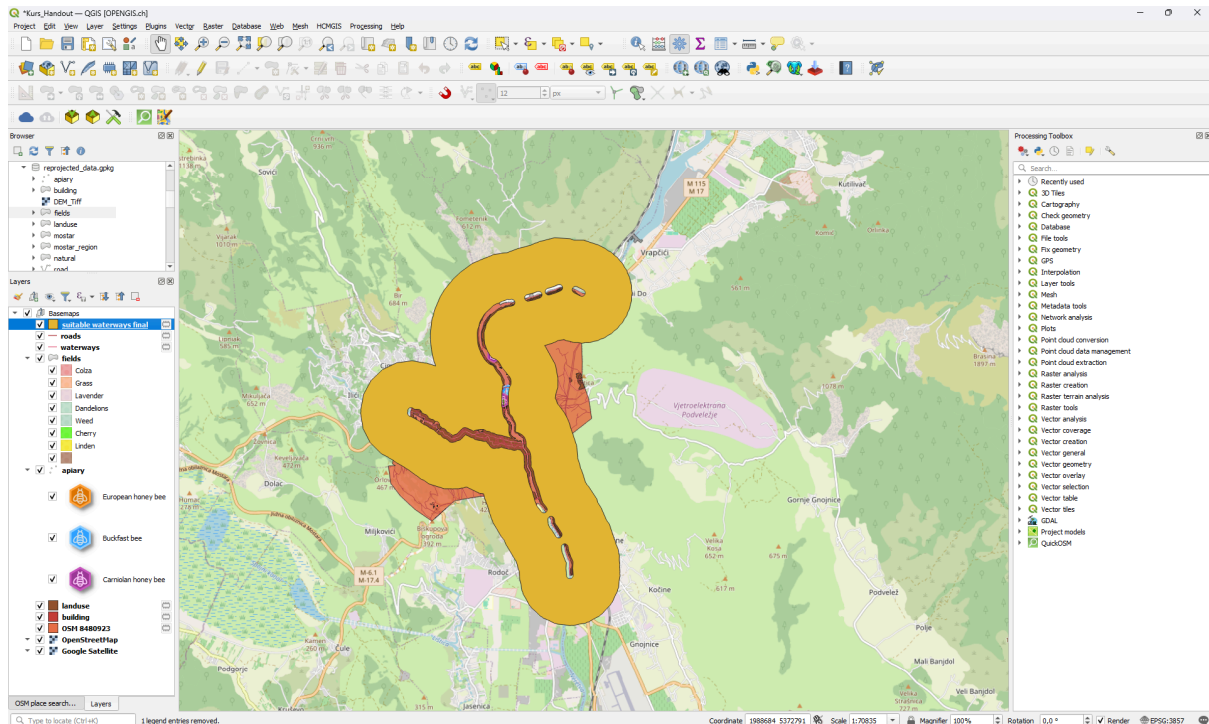


Image: Output of locations with suitable distances to the waterways

Natural Areas

Maya knows that bees require natural areas. In general they will prefer flowerbeds over grassland but also chestnuts and cherries over dandelions. Also, the area needs to be sufficiently large to accommodate a whole beehive. In the layer **landuse** there is some valuable information regarding this.

In the feature layer **landuse** there are more than 10 categories but bees only can benefit from some of them. We will create a model that selects the right land use types.

→ Add the land use as a new input variable. We will extract the suitable land use types using the *Extract by expression* algorithm. Use the expression provided below.

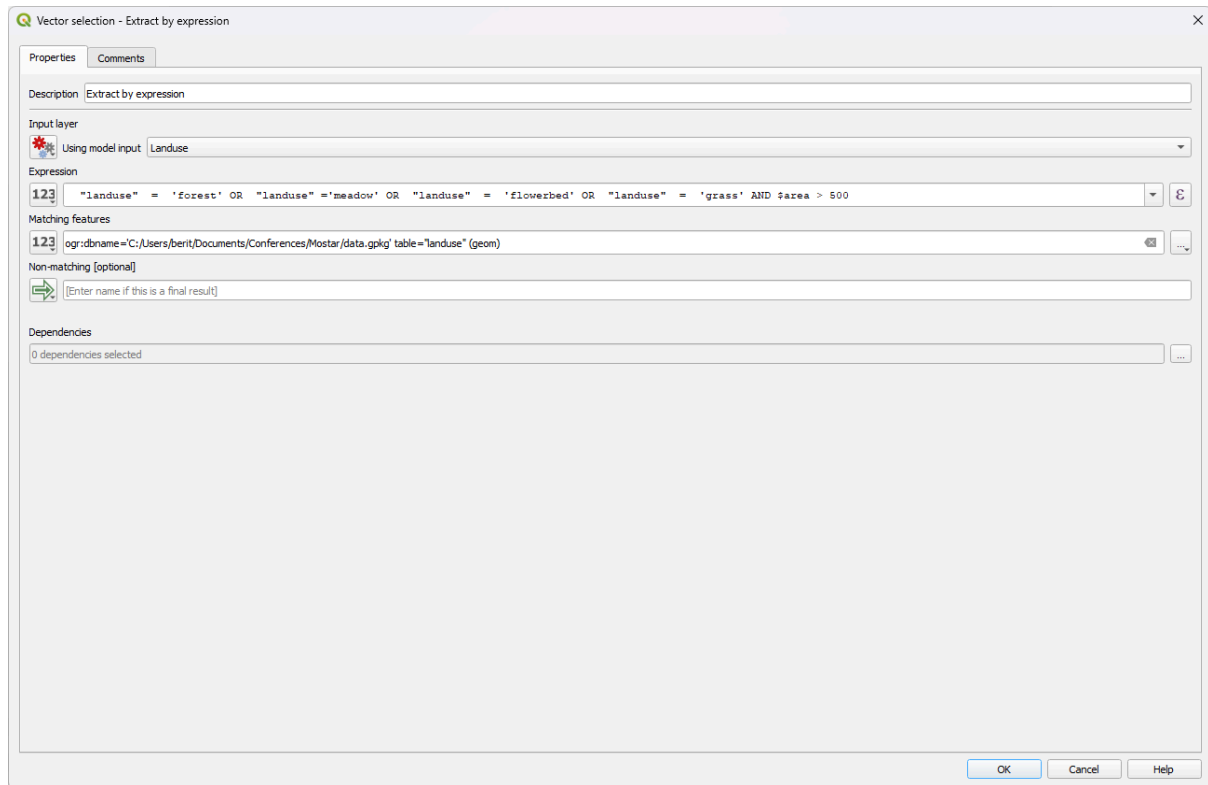


Image: Extract by Expression algorithm window

```
("landuse" = 'forest' OR
"landuse" = 'meadow' OR
"landuse" = 'orchard' OR
"landuse" = 'farmland' OR
"landuse" = 'flowerbed' OR
"landuse" = 'grass' )
AND $area > 500
```

As output type you could simply just add a temporary layer as before but in the option below we have set a predefined value. Using this option you can create a new gpkg to which the algorithm output will directly be saved. This is not required but can be useful in some cases.

Road accessibility

Maya knows that bees do not like being relocated and are vulnerable to excessive movement. Furthermore, she wants the hives to be easily accessible and to avoid carrying heavy materials over long distances. Therefore, she suggests that the beehives should not be located more than 150 m from roads.

We will create another buffer around the roads to make sure that the beehives are easily accessible.

- Add a new input variable for the roads.
- Add another buffer algorithm to the model and select 150 m as your distance.

Adding models together

Now we have three separate parts that we want to put together. Let's first order the model nicely by adding group boxes to the different parts of the model (waterways, landuse, roads).

→ In the navigation toolbar **Edit > Add Group Box**. Give the group boxes suitable names and place them around the respective steps for the algorithm.

Which tool is now missing to combine the three results? (→ The *Intersection Tool (multiple)*).

The *Input layers* will, of course, be the outputs we created in the previous steps. Since we want to overlay more than two layers, we need to provide the additional input layers as a pre-created value. One layer we can select as a new input layer, but then we still need to add the other two output layers as overlay layers.

→ Open the Expression Builder.

As you can see, there are more variables available than usual. These correspond to the variables that have been created within the model. We need to select the variables corresponding to the two suitable output layers and combine them into an array.

→ Select the variables corresponding to the two suitable output layers and add them to an array:

```
array(variable 1; variable 2)
```

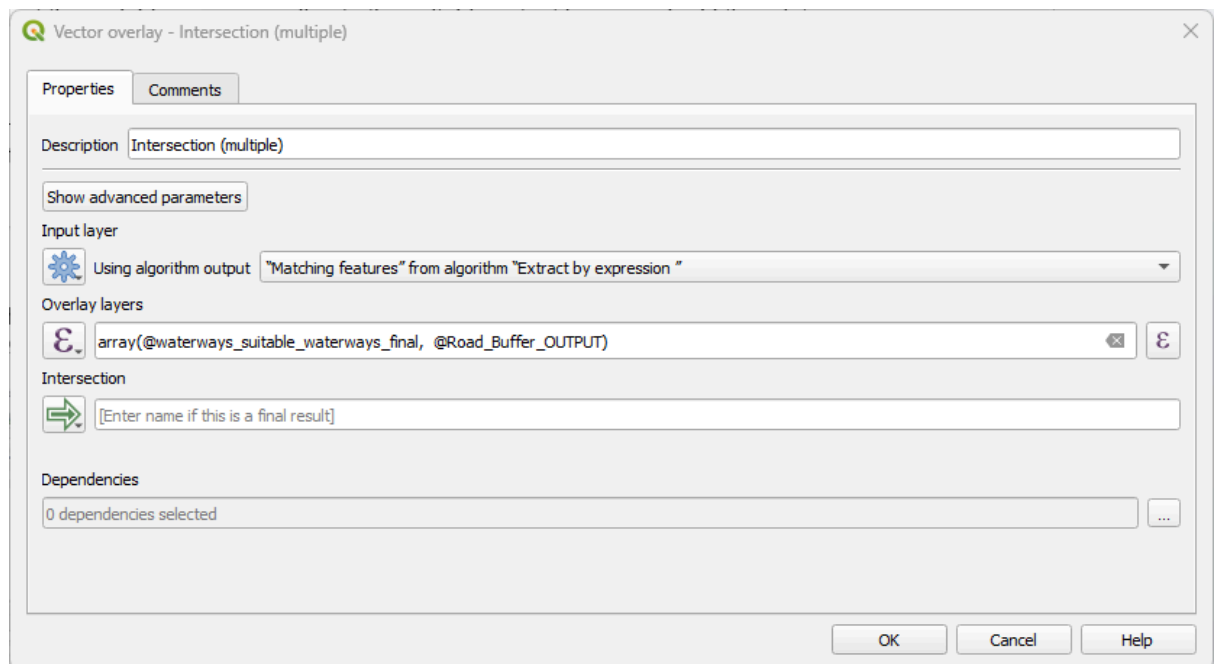


Image: The intersection tool (multiple)

Possibly, you would want to dissolve the result (*Dissolve Tool*) as a very last step.

→ If we want, we can now adjust the order in which input variables and output variables are stored **Model > Change Input Order / Output Order**.

→ You could also have saved the different parts of the workflow as separate models. By navigating to *Models* through the *Algorithms / Toolbox Panel*, you can then import these models into the Model Designer. In the screenshot below, the waterways workflow was saved as a separate model and subsequently reimported. When doing so, you may need to define the input parameter(s) again.

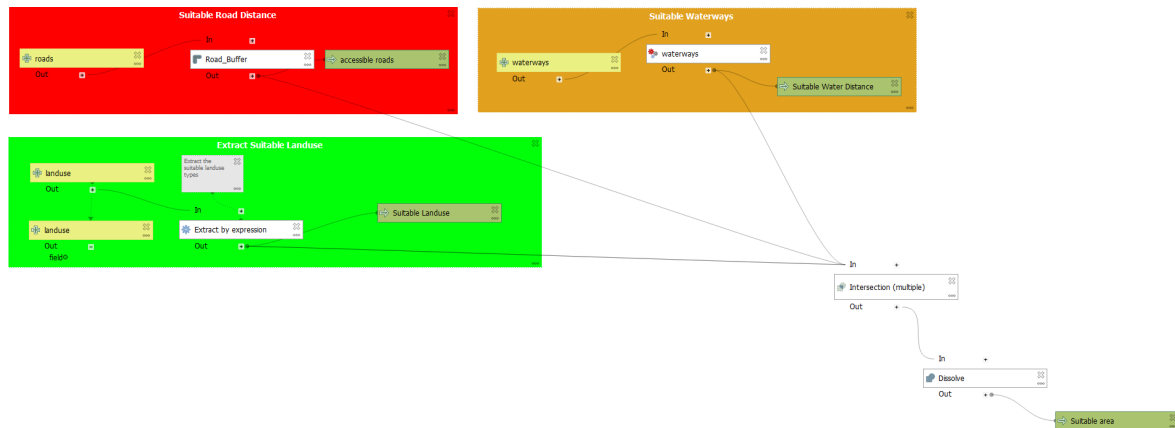


Image: Our model, containing three separate processes, with the waterways workflow saved as a separate model and subsequently reimported.

Raster analysis (DEM)

Maya remembers that she should also take topography and sun exposure into account when identifying suitable locations. For this purpose she needs a digital elevation model (DEM). After asking around, her friend Linda is telling her about a global DEM that is available with a 90 m resolution that she can use, regardless of where she is:

Global DEM

We will create another model that we can integrate with the existing one later. In the workshop data, a cropped version of the DEM has been included.

→ Add it to the project.

If you do not already have a cropped DEM available, it makes a lot of sense to first crop (and possibly reproject, if necessary) your DEM, either manually or within the model. Using a small DEM allows the model to run much faster.

Slope

To have good access to the beehives, the slope should not be too high (≤ 25 degrees)

→ Add a new *input parameter* to the model. This time it needs to be a *Raster Layer* and give it a name.

→ Under process algorithms search for *Slope* and add it to the model. As an input parameter we add the DEM. Click OK and run the model.

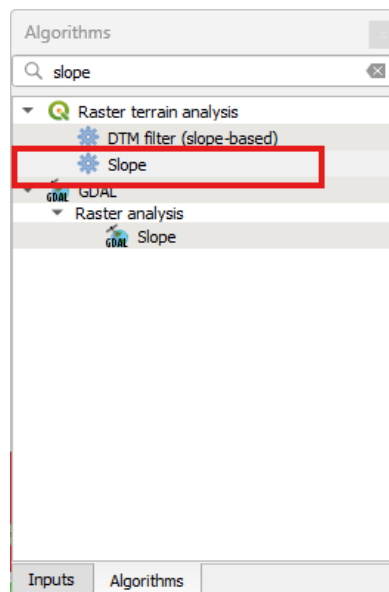
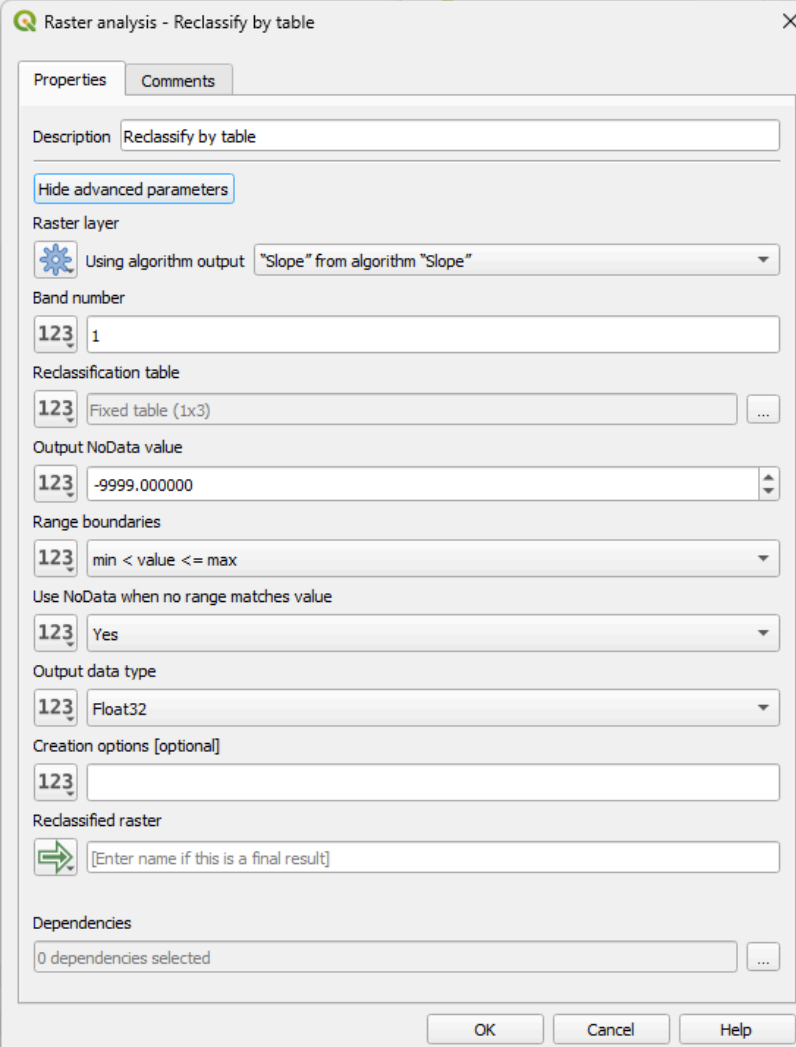


Image: Slope Algorithm

In the next step we will use the *Reclassify by table* tool to reclassify the pixel values to 1 and NoData.

For doing so, we can click on *Show Advanced Parameters* in the algorithm dialog and then set the option *Use NoData when no range matches* value to *Yes*.



Raster analysis - Reclassify by table

Properties | Comments

Description: Reclassify by table

Hide advanced parameters

Raster layer: Using algorithm output: "Slope" from algorithm "Slope"

Band number: 123 | 1

Reclassification table: 123 | Fixed table (1x3) | ...

Output NoData value: 123 | -9999.000000

Range boundaries: 123 | min < value <= max

Use NoData when no range matches value: 123 | Yes

Output data type: 123 | Float32

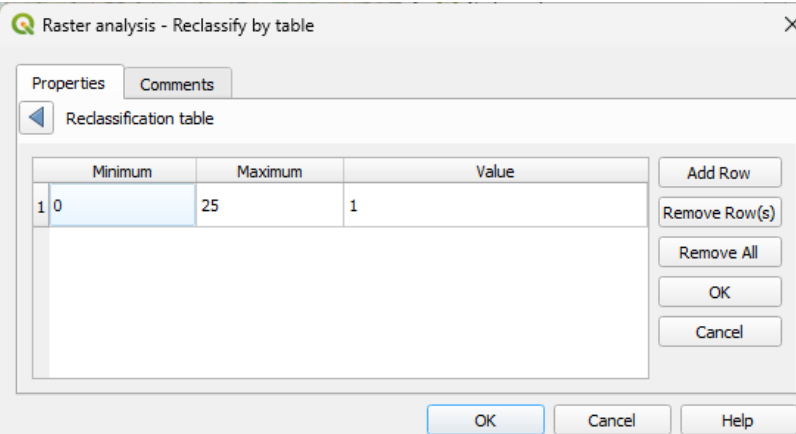
Creation options [optional]: 123 |

Reclassified raster: [Enter name if this is a final result]

Dependencies: 0 dependencies selected | ...

OK Cancel Help

Image: Reclassify by Table Algorithm



Raster analysis - Reclassify by table

Properties | Comments

Reclassification table

	Minimum	Maximum	Value
1	0	25	1

Add Row
Remove Row(s)
Remove All
OK
Cancel

OK Cancel Help

Image: Classification table of Reclassify by Table Tool

Sunny areas

The direction of the sun is another important factor and with it the amount of shading that bees have access to. To account for this, we will determine the aspect of the DEM and identify the areas that are directed **south-east** to **south-west**.

→ Add the tool *Aspect* to the model. Your DEM will once again be the *Input parameter*.

Now that we have the aspect, we can determine the sunny areas. We want to only consider south-east to south-west exposed locations, thus the aspect should range between 112.5° and 247.5°.

All areas that do not lie within this range need to be excluded from the suitable areas. For this, we will once more reclassify our raster, this time using the *Raster Calculator*, which results in suitable and non-suitable areas with the values 1 and 0, respectively.

→ Add the *Raster Calculator* algorithm and choose the Output of the Aspect tool as an *Input*. Set the expression to `"A@1" >= 112.5 AND "A@1" <= 247.5`

The two output rasters now represent suitable areas using the required values. The slope raster contains a value of 1 for suitable areas and NoData for unsuitable areas, while the aspect raster contains values of 1 and 0 for suitable and unsuitable areas, respectively.

The goal is to eliminate the unsuitable areas from the analysis. To achieve this, the slope raster can be divided by the aspect raster. Since division by zero is not possible, cells with a value of 0 in the aspect raster will be excluded from the result. The remaining suitable cells retain a value of 1, resulting in a raster that represents areas suitable according to both criteria.

→ Add another *Raster Calculator* algorithm. This time the input parameter will correspond to the two outputs of the previous processes (slope and aspect).

For this, we need an array of inputs. Change the *input parameter* to  and type the expression: `array(variable 1; variable 2)`

For the expression add `"A@1" / "B@1"`.

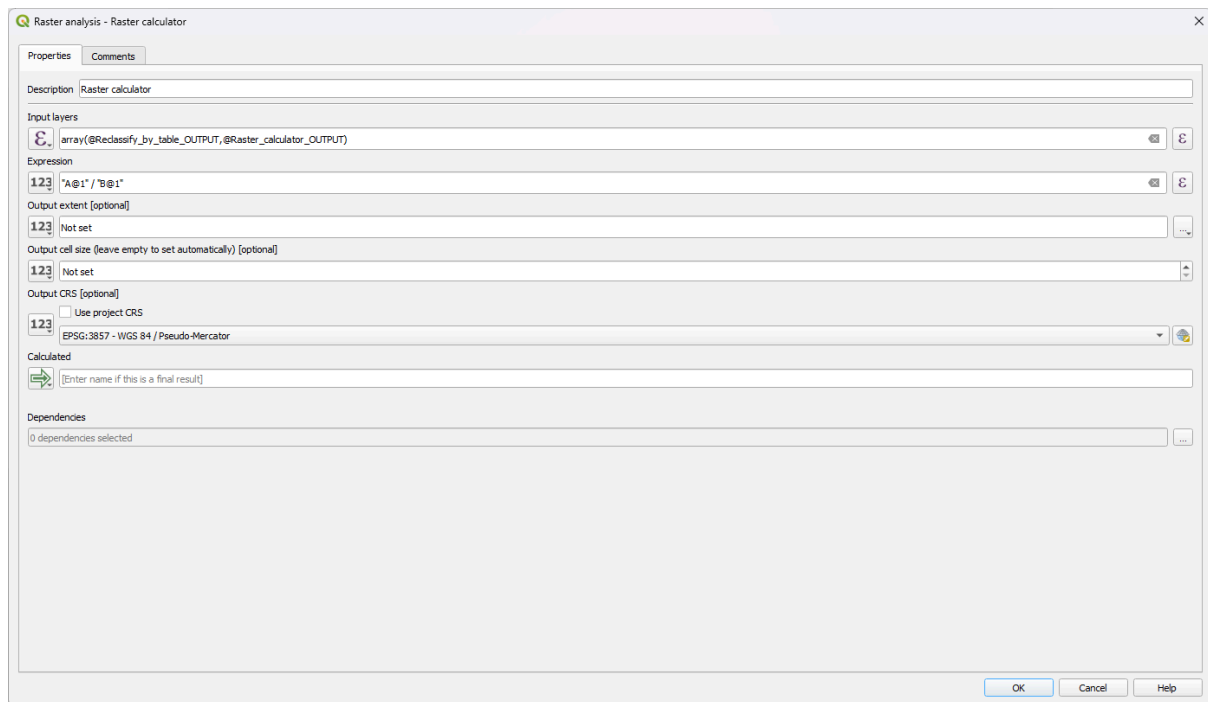


Image: Raster Calculator

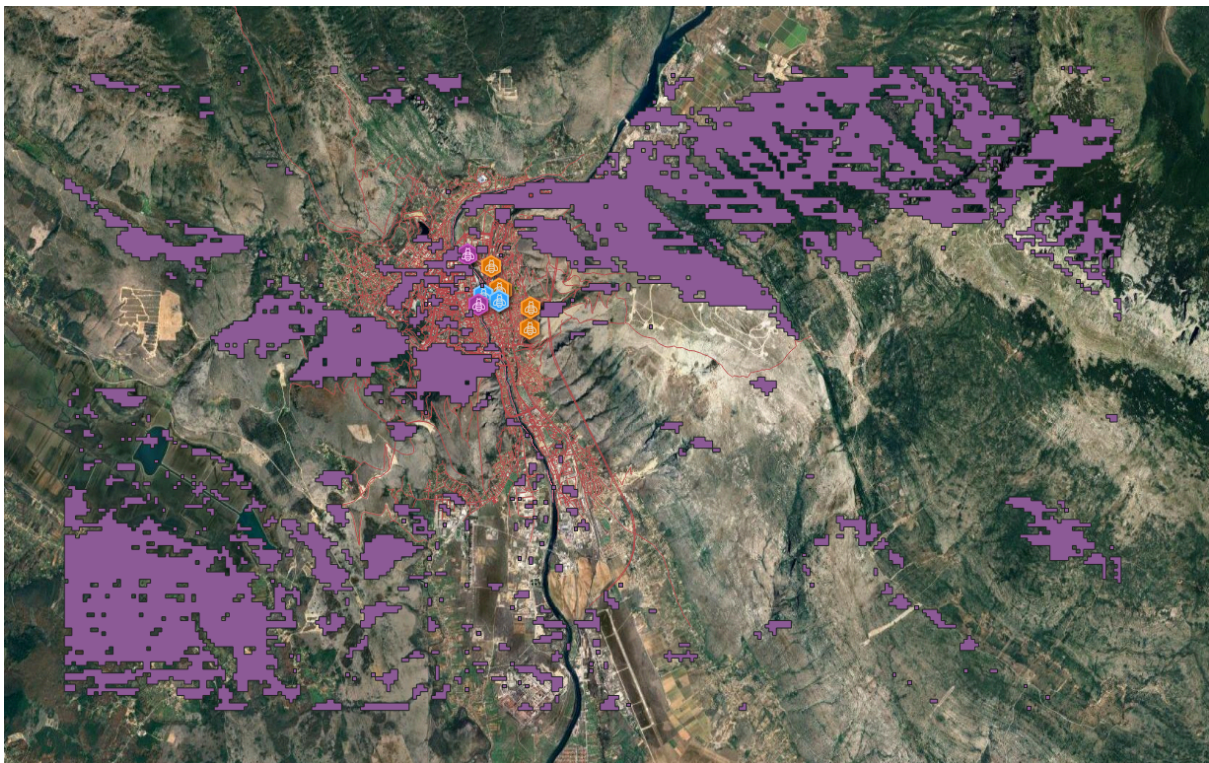


Image: Sunny areas with moderate slope

Now that we have the suitable area - sunny and not too steep -, we have to polygonize the result in order to combine it with our remaining suitable locations.

→ Direct to the *Polygonize (raster to vector)* tool and add it to the model. The *input parameter* is the latest output of the *Raster Calculator*.

Once done and added to the project, you can change the symbology to have a look at what the data looks like.

Finally, save the model. As you already know, fill in the name of the model and, optionally, the group in which you would like to group it. Next save the model using Menu -> *Model* -> *Save model as*. To avoid confusion or accidentally overwriting files, it is recommended to use the same name for the model and the corresponding .model3 file.

Optional part 1: NDVI Calculation

Maya knows that it is important to use up-to-date datasets that reflect current conditions. She therefore obtains recent Sentinel-2 satellite imagery to calculate the Normalized Difference Vegetation Index (NDVI) for the area of interest.

The NDVI is a commonly used indicator of vegetation condition. It provides information on the presence, density, and vitality of green vegetation and can also be used to detect changes in vegetation health. For Sentinel-2 imagery, the NDVI is calculated using the red (Band 4) and near-infrared (Band 8) reflectance values according to the following equation:

$$NDVI = (NIR - R) / (NIR + R)$$

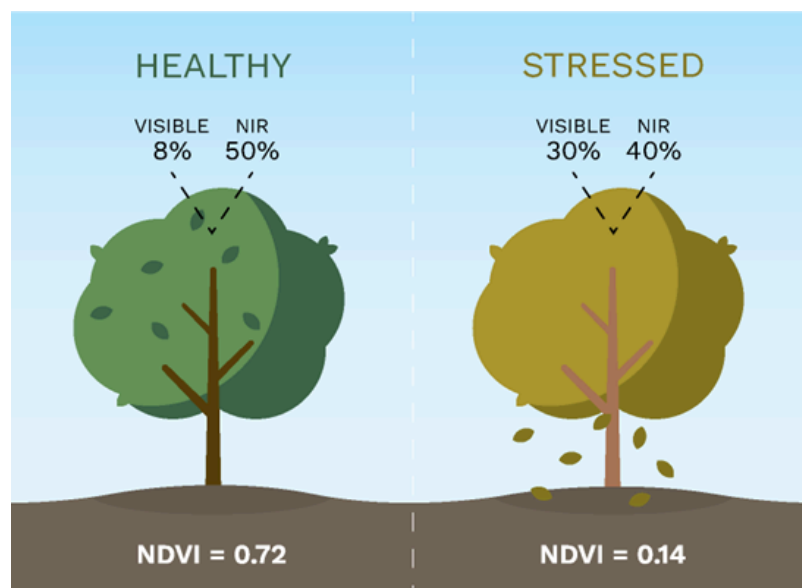


Image: Differences in spectral reflectance between healthy and stressed vegetation in the visible/ red and near-infrared (NIR) bands, resulting in different NDVI values. (Source: <https://geoimage.com.au/blog/what-ndvi-and-its-fundamental-advantages>)

For this, the necessary Sentinel-2 image bands have been downloaded for the exercise already. You will find them in the workshop materials.

→ Open a new QGIS Model and find the *Raster Layer* in the list of inputs.

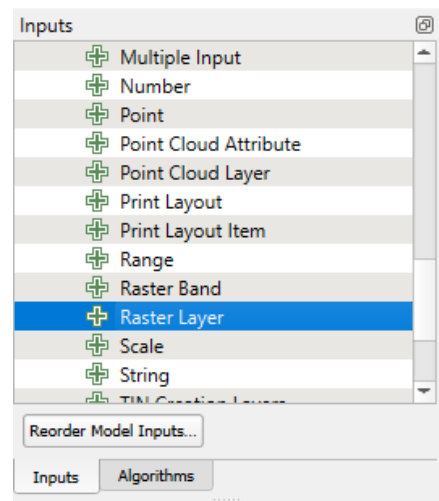


Image: Input parameter raster

→ Double-click to open the dialog box and name this object *B04* (Band 4). Leave the other parameters at their default values.

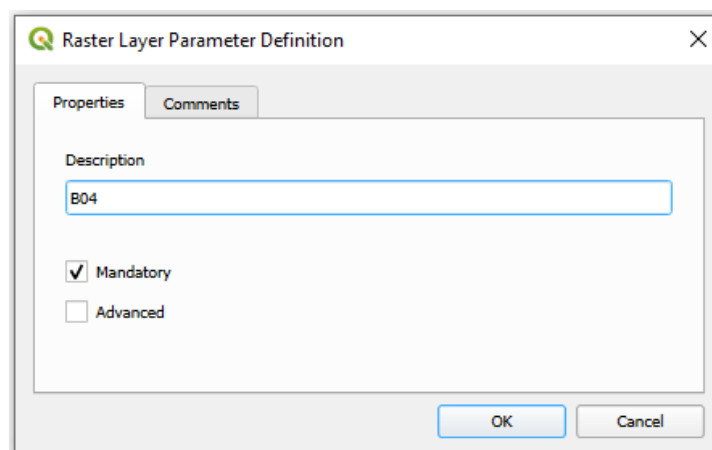


Image: Description of the parameter

→ We have to do the same steps for *B08* (Band 8). The created object should look like this:



Looking at the default coordinate system of the two satellite images, we realise that they are different from the rest of our data. Hence, we will have to change this.

→ In the list of available inputs, find *CRS* (Coordinate Reference System).

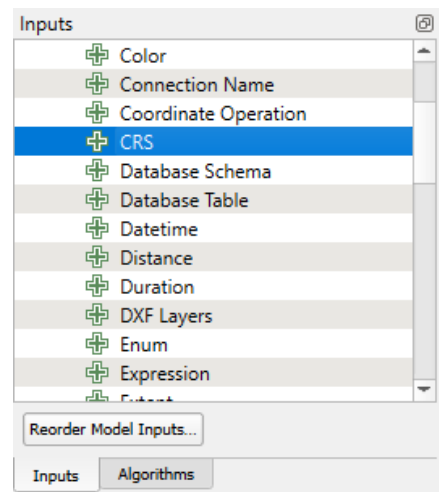


Image: CRS Input parameter

→ Name it *Output CRS* and select EPSG:3857 as the default coordinate system. You can define it according to your needs.

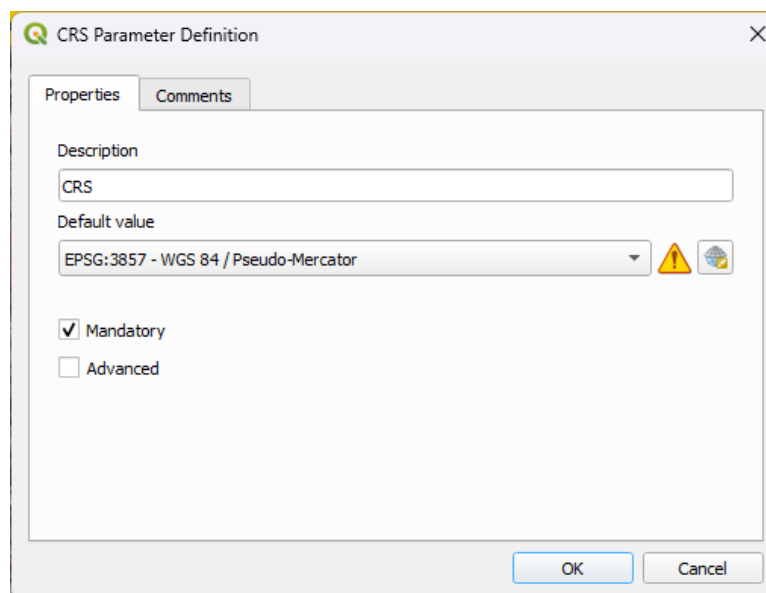


Image: Assign CRS

The last necessary element to add will be the *Area of Interest* as the images are not yet cropped and they are quite big. This will speed up other operations in the future (similar as for the DEM).

→ Select *Vector Layer* from the list of input parameters.

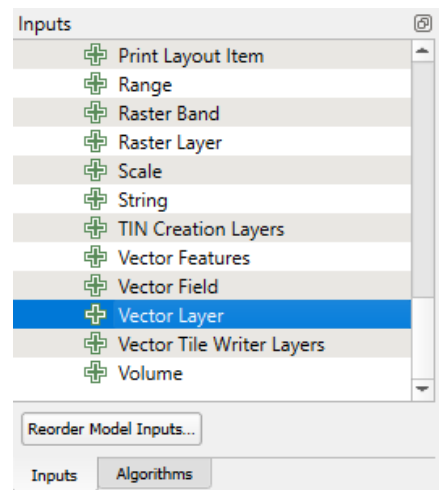


Image: Add vector layer as input parameter

We now have all the inputs, so we can start cropping the rasters (satellite image bands) to the area of interest.

→ From the list of algorithms, select *Clip raster by mask layer*.

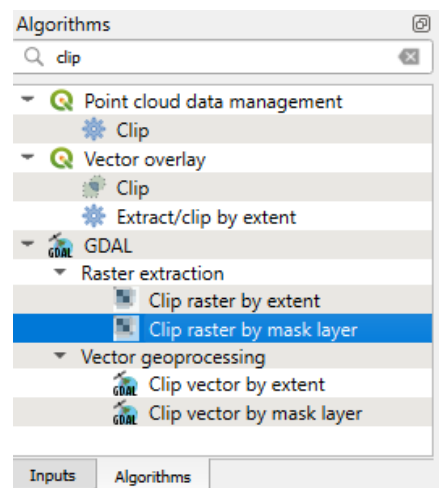


Image: Input Parameter Clip raster by mask layer

→ Next set the parameters:

1. Using Model input: *B04*
2. Mask Layer: *Area of Interest*
3. Target CRS -> Using model input: *Output CRS*

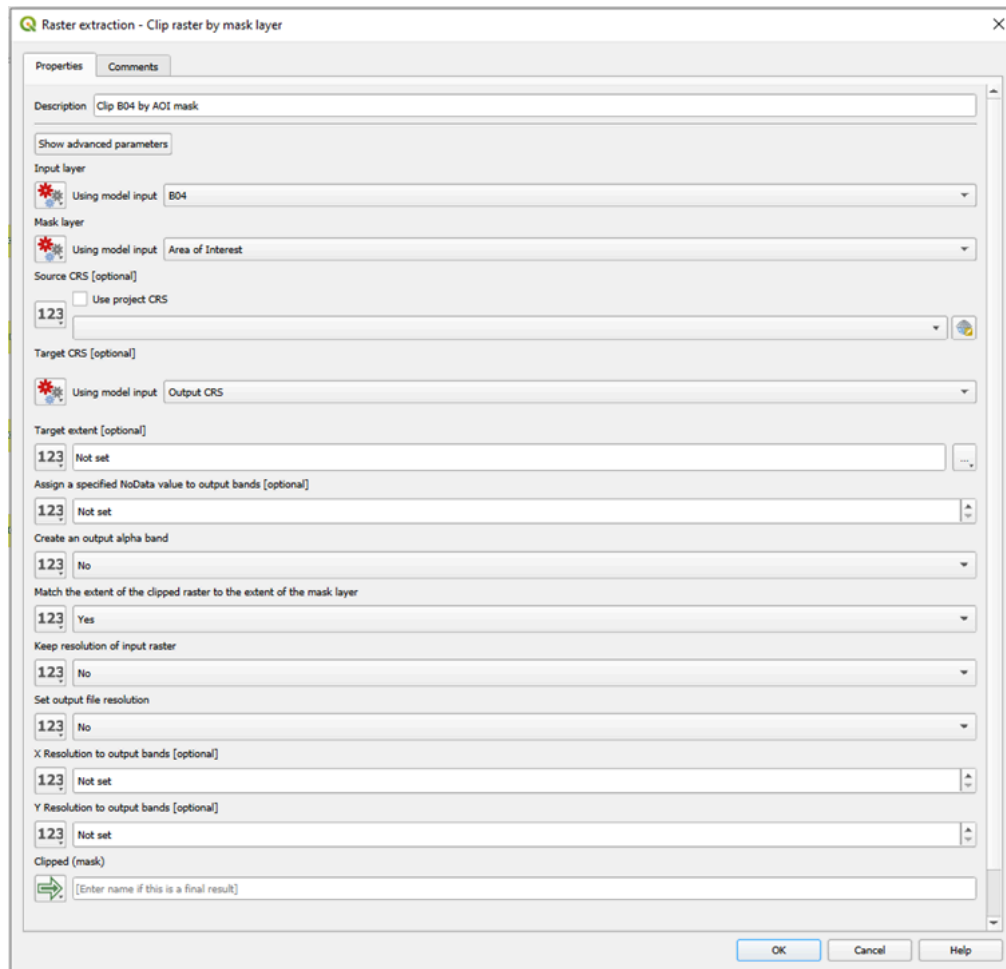


Image: Clip raster by mask layer

Set the B08 raster clip in the same way:

1. Using Model input: *B08*
2. Mask Layer: *Area of Interest*
3. Target CRS → Using model input: *Output CRS*

Great! Now, we have the rasters clipped to our desired area. It is now time to use the raster calculator to calculate the NDVI.

Go to Algorithms → Raster Calculator

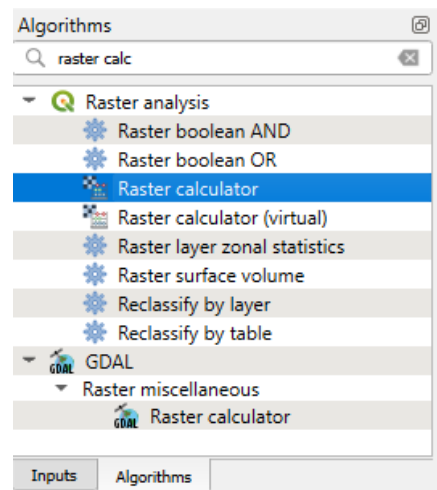


Image: Algorithm Raster Calculator

→ Assign the following parameters:

1. Description: *Raster calculator*
2. Input Layers → Click 3 dots on the right and choose:

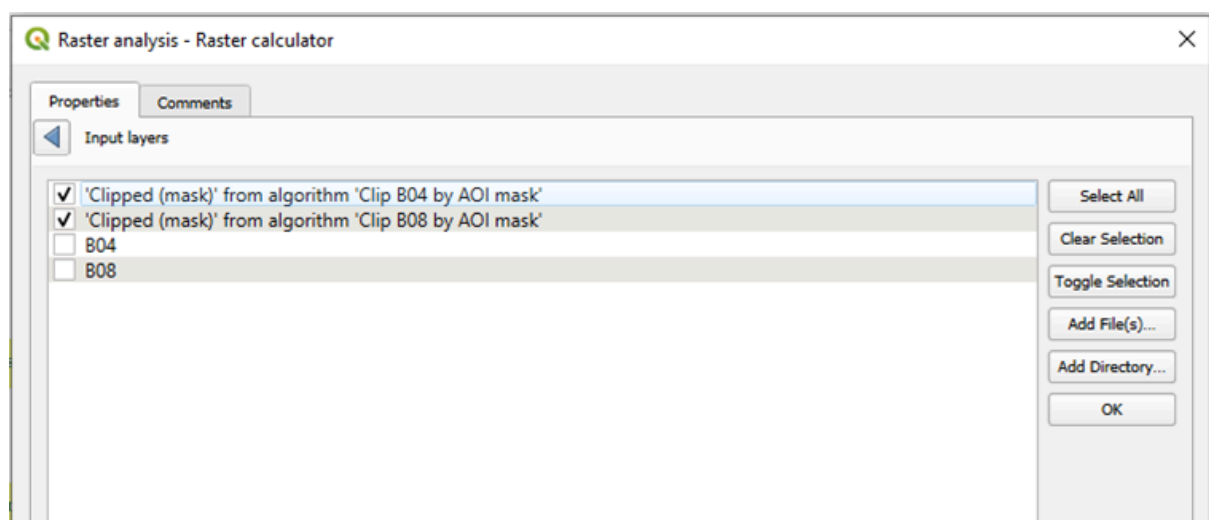


Image: Choice of input layers in the Raster Calculator

3. Expression: $(\text{"B@1"} - \text{"A@1"}) / (\text{"B@1"} + \text{"A@1"})$
4. Calculated: *NDVI*

Image: Filled raster calculator parameters

The final model should have the following form:

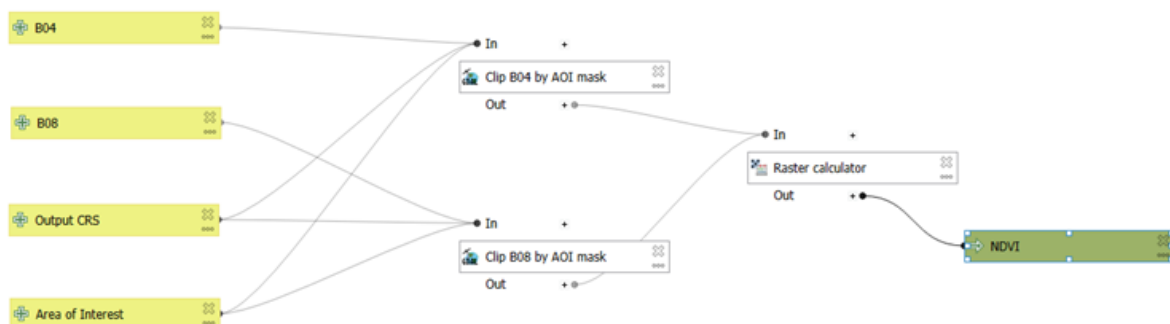


Image: Completed NDVI Model

Finally, save your model as described earlier.

Optional part 2: NDVI reclassification

Maya knows that the vegetation needs to be healthy. The calculated NDVI gives her an indication of where the vegetation is healthy enough for beehives to be located. Grouping the NDVI into classes will be a good way to identify the suitable locations.

We will create an algorithm that reclassifies the NDVI raster layer into 4 classes and converts them into vectors. This will allow us to perform easier analyses in the following steps.

→ Open a new model and find the *Raster Layer* in the list of input parameters.

→ Double-click to open the dialog box. Name this object *NDVI to reclassify*. Leave the other parameters at their default values.

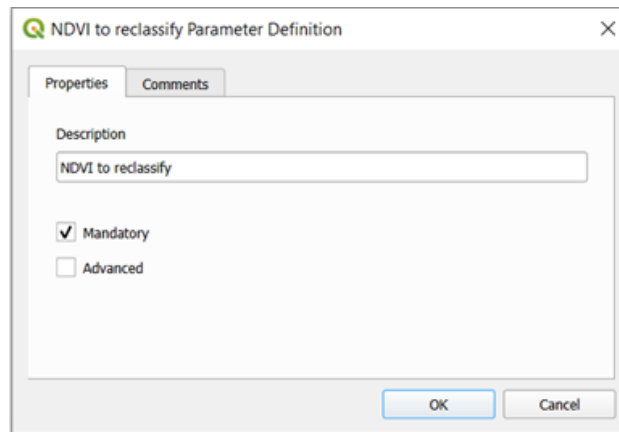


Image: Input parameter of NDVI Classification

→ Next, from the algorithms choose once more *Reclassify by table* and set the parameters as follows:

Description: *Reclassify using table*

Raster layer: *Using model input: NDVI to reclassify*

Band number: *1*

Reclassify table: Click the 3 dots on the right side and set the values as you see on the screenshot of the classification table.

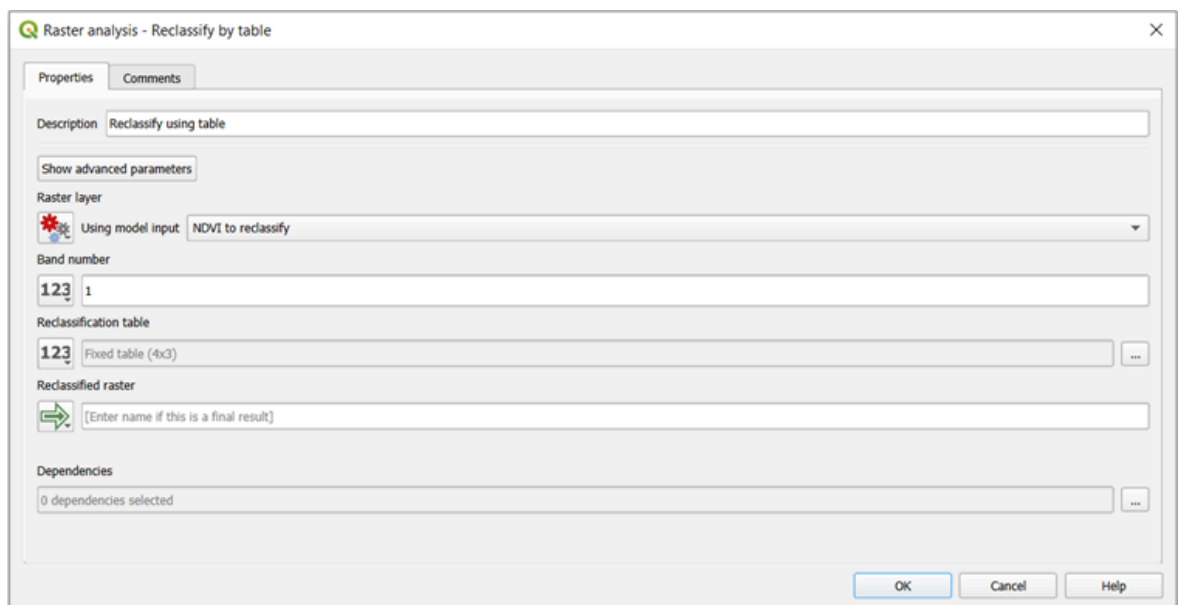


Image: Process dialog of Reclassify by table

The value range of the NDVI is -1 to 1. Negative values of NDVI (values approaching -1) correspond to water. Values close to zero (-0.1 to 0.1) generally correspond to barren areas of rock, sand, or snow. Low, positive values represent shrub and grassland (approximately 0.2 to 0.4), while high values indicate temperate and tropical rainforests (values approaching 1).

For this case, **NDVI values above 0.4** are high enough to ensure the amount of healthy vegetation is good enough.

→ Add the values into the classification table as shown below

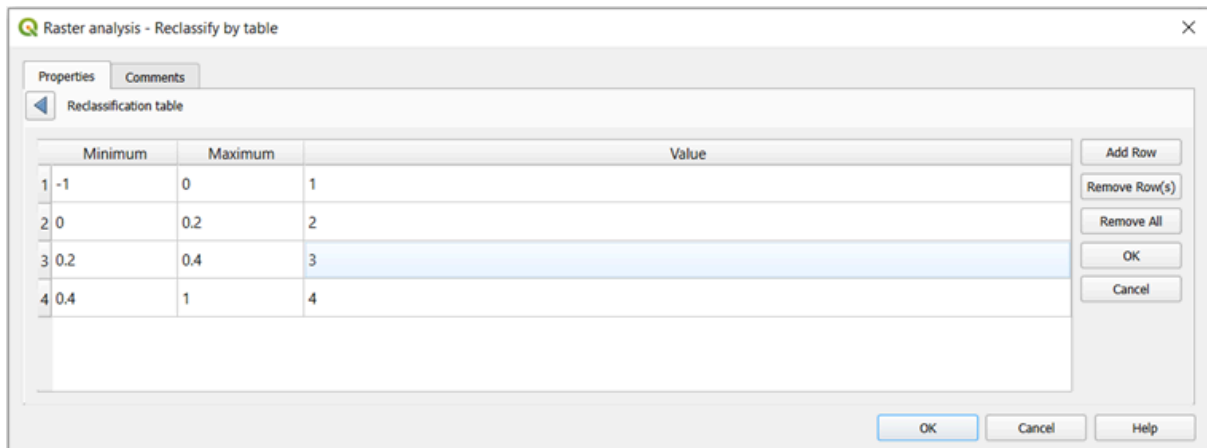


Image: Suggested classes for NDVI classification (Reclassify by table)

After running the algorithm, a raster with new values will be created, which we will vectorise in the next step.

We will once more use the *Polygonize tool (raster to vector)*.

→ In the list of process parameters find the *Polygonize tool (raster to vector)*

Description: *Raster to vector*

Input Layer: As input, we will use the algorithm output from the reclassified raster.

Band number: 1

Name of field to create: *new_ndvi_class*

Vectorized: *NDVI reclassified (vector)*

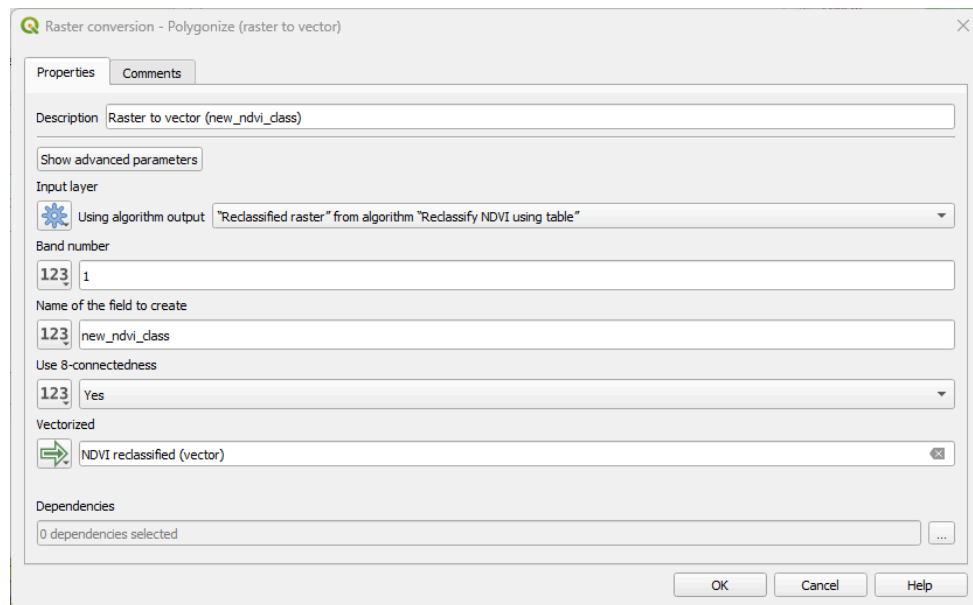


Image: Process dialog of the Polygonize Tool

The result will be vector geometry with 4 value classes.

Now how do we get only the areas with a high vegetation vitality? → *Extract by Expression* or *Extract by Attribute*

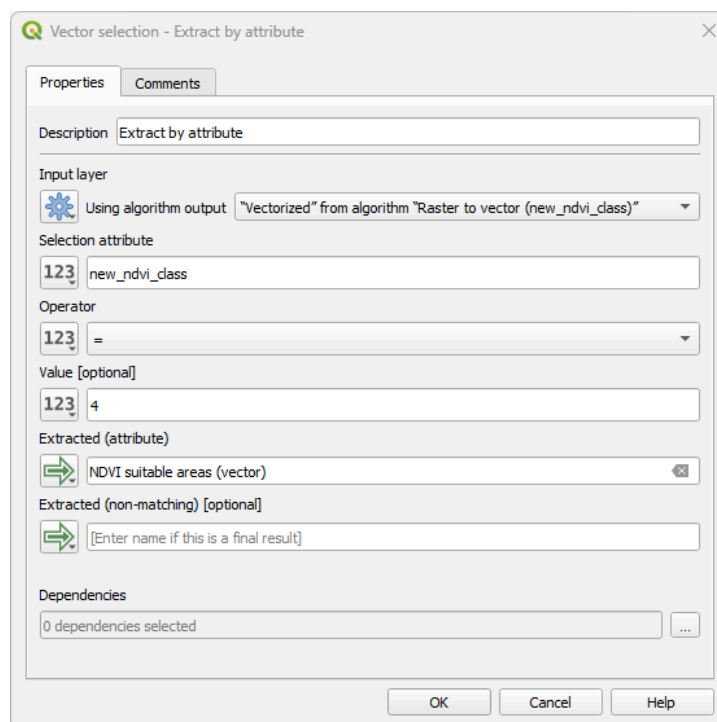


Image: Process dialog of Extract by attribute tool

In the end, the model should have the following form:

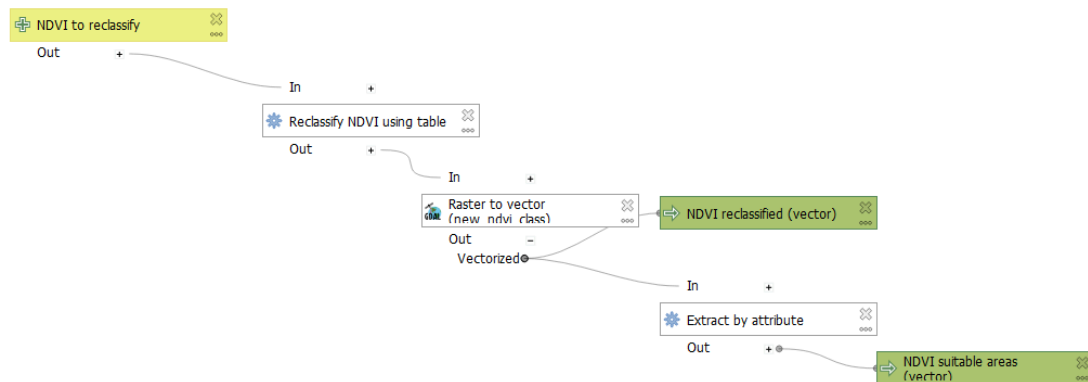


Image: Completed NDVI Reclassify Model

Once more, save your model.

Intersection of all intermediate results

The final step left is to intersect all the created output layers with each other.

Open the original model, which currently contains only the vector-based criteria. From the *Algorithms / Toolbox Panel*, import the raster models you created to the Interface. Next, create and link the necessary inputs. Finally, add the new outputs to the expression of the *Intersection (multiple)* tool to combine all the results.

Run the complete model to perform the analysis. 😊

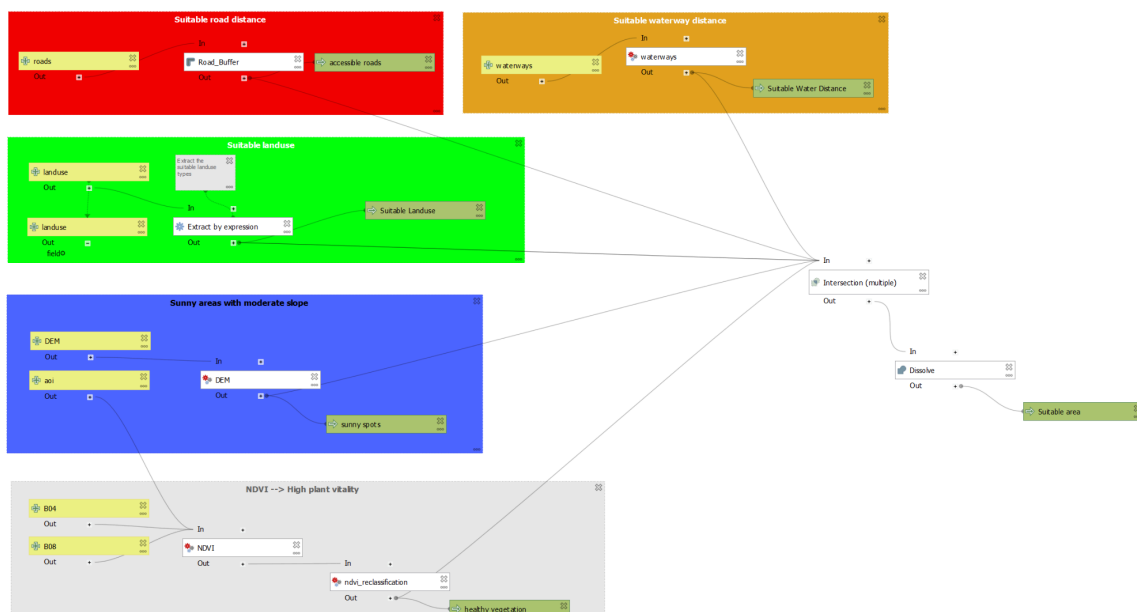


Image: Illustration of the final model

If you intend to make the model available to other users, it is furthermore recommended to provide a **clear and informative Model Help** (Menu > *Model* > *Edit Model Help*).