

TOT Training Part 1

Topic 15:

## Change Detection (Part 1)

Practical Exercise



IDEAMAP  
SUDAN

## General Information

---

### Goal:

- Apply an algebraic change detection method between two Sentinel images of a part of Khartoum.

### Content:

- Calculate the Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) of Sentinel-2 images of 2017 and 2020
- Perform an algebraic change detection method
- Perform an expert rule-based classification of both images, then identify the change matrix.

### Software Requirements:

- QGIS
- The data for this practical which can be downloaded from Canvas.

### Data to be used:

- **S2\_2017\_20m\_B2348.tif** – Sentinel-2 image from 2017
- **S2\_2020\_20m\_B2348.tif** – Sentinel-2 image from 2020

## Background

---

We will be using spectral indices in this practical. Review the information about spectral indices in the lecture slides of **Topic 11: Access to EO data and spectral indices (25 - May)** (starting on slide 28).

Look at Figure 1 showing spectral indices and the formulae for NDVI and NDWI below. What values do you expect for the three different classes in Figure 1?

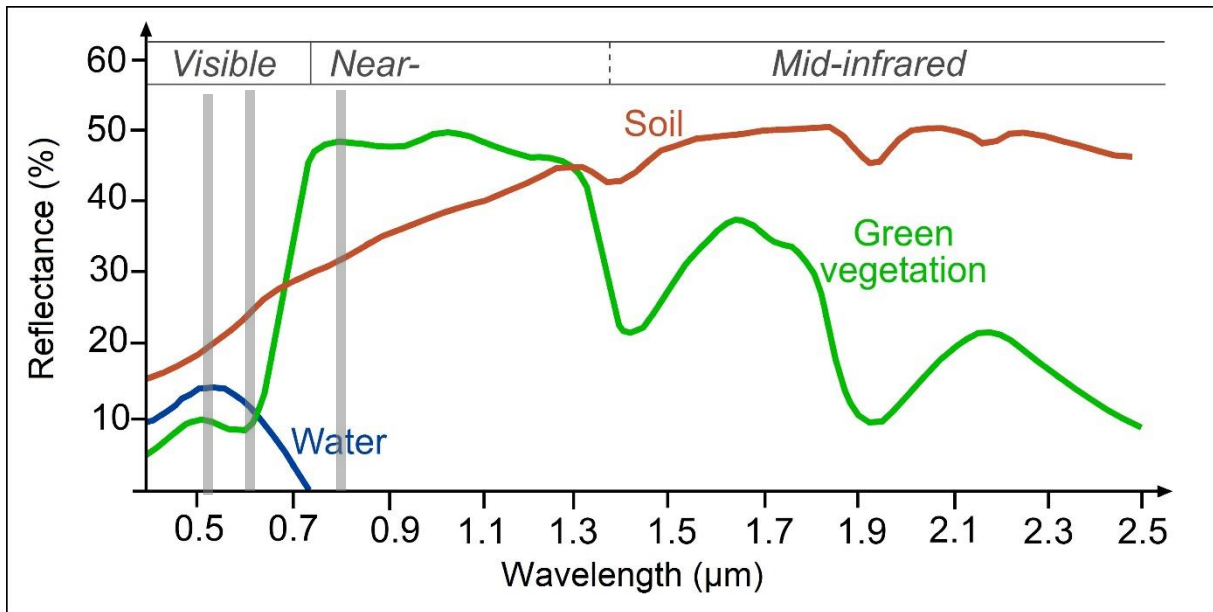


Figure 1 – Typical spectral signatures of water, soil, and green vegetation. The grey bands approximate the locations of (from left to right) the Green, Red, and NIR spectral bands of Sentinel-2. (Source: <http://www.eumetrain.org/data/4/461/navmenu.php?tab=5&page=2.0.0>)

$$NDVI = \frac{NIR - red}{NIR + red}$$

$$NDWI = \frac{green - NIR}{green + NIR}$$

In literature, we can find that common values for NDVI and NDWI are as follows:

Class	NDVI	NDWI
Bare terrain / built-up areas	-0.1 to 0.1	-0.4 to 0.2
Vegetation	0.2 to 1	-1 to -0.4
Water	-1 to -0.1	0.2 to 1

## Datasets

---

### Input images

We will use two **Sentinel 2a images** with a spatial resolution of 20m for the change detection exercise. One is from 2017 and the other is from 2020. The input bands 2 – 4 and 8 are available:

Sentinel-2 Band	Central Wavelength ( $\mu\text{m}$ )	Band number in image
Band 2 – Blue	0.490	1
Band 3 – Green	0.560	2
Band 4 – Red	0.665	3
Band 8 – NIR	0.842	4

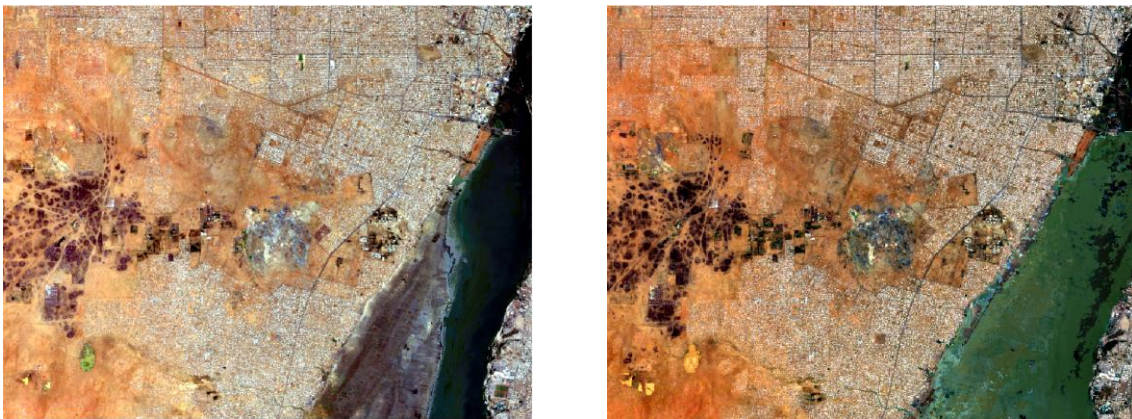
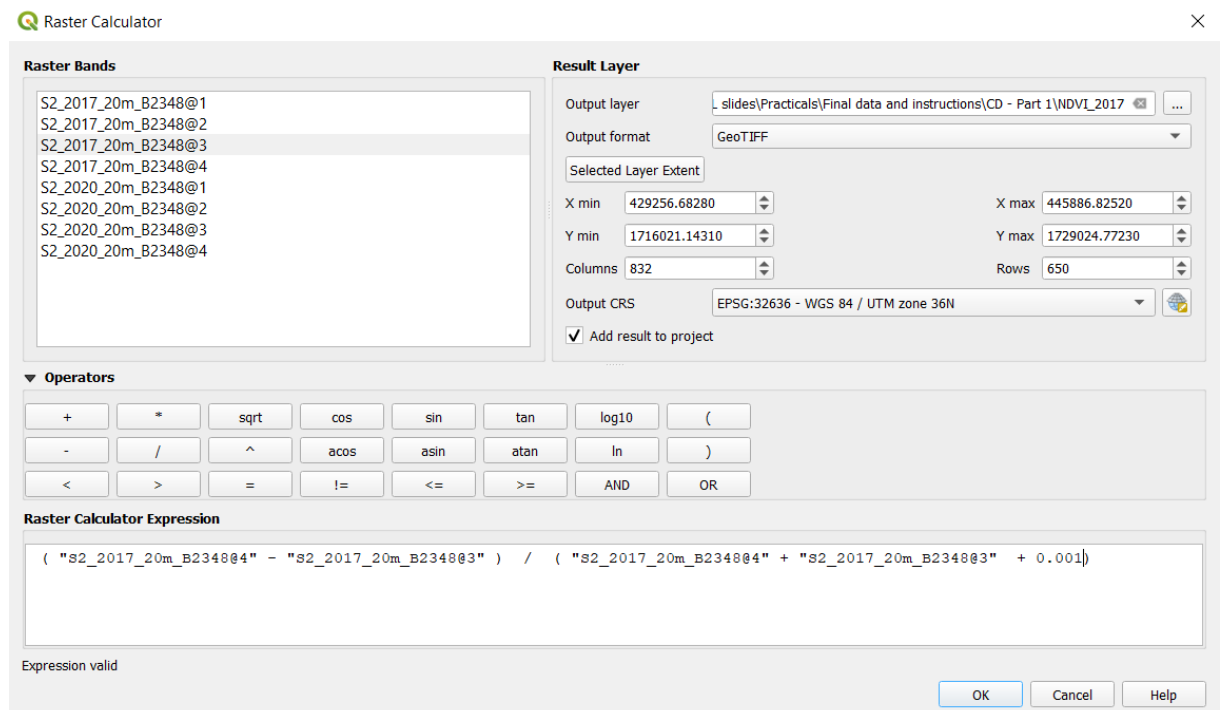


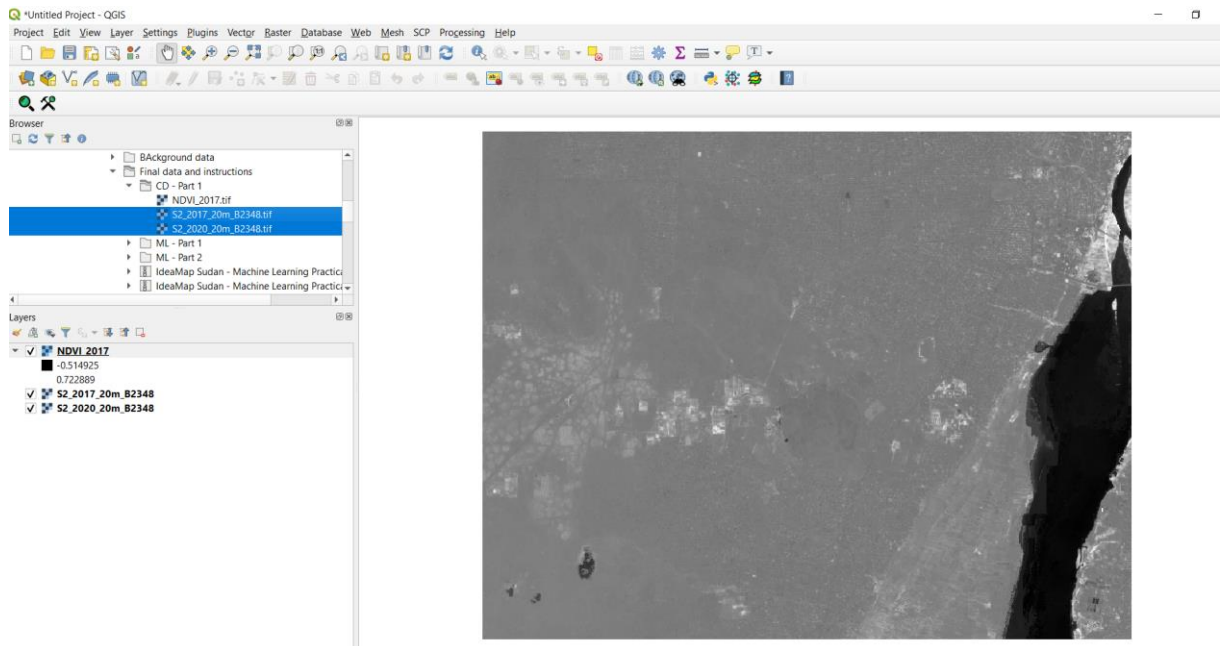
Figure 2 - The Sentinel images from 2017 (left) and 2020 (right). Remember you can visualize the true-color image by using the band combination 3-2-1 in QGIS.


# Instructions

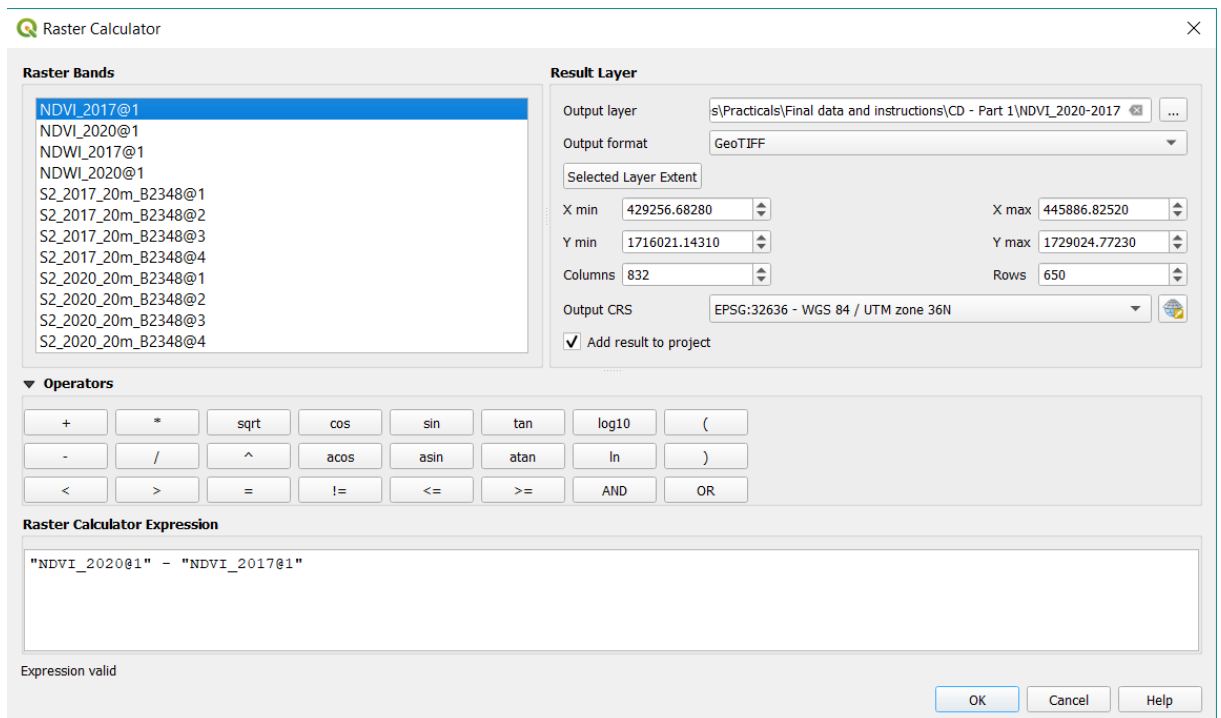
1. Open a new QGIS project and load the two images: **S2\_2017\_20m\_B2348.tif** and **S2\_2020\_20m\_B2348.tif**. Do a visual analysis of the images. What kind of changes do you see?
2. We will perform an algebraic change detection method with two spectral indices: the NDVI (which targets vegetation) and the NDWI (which targets water). The formulas for these indices are provided in the Background section above. In the Sentinel images, the red band is Band 4 (= the third band in the image), NIR is Band 8 (= the fourth in the image), and green is Band 3 (= the second in the image).

We start with the NDVI for the 2017 image. In QGIS, go to “Raster → Raster Calculator”. Enter the formula for NDVI by selecting the bands in the *Raster Bands* section and using the buttons for the mathematical operations. Save the output as **NDVI\_2017.tif** in your output directory under *Result layer*. The output will look as follows:

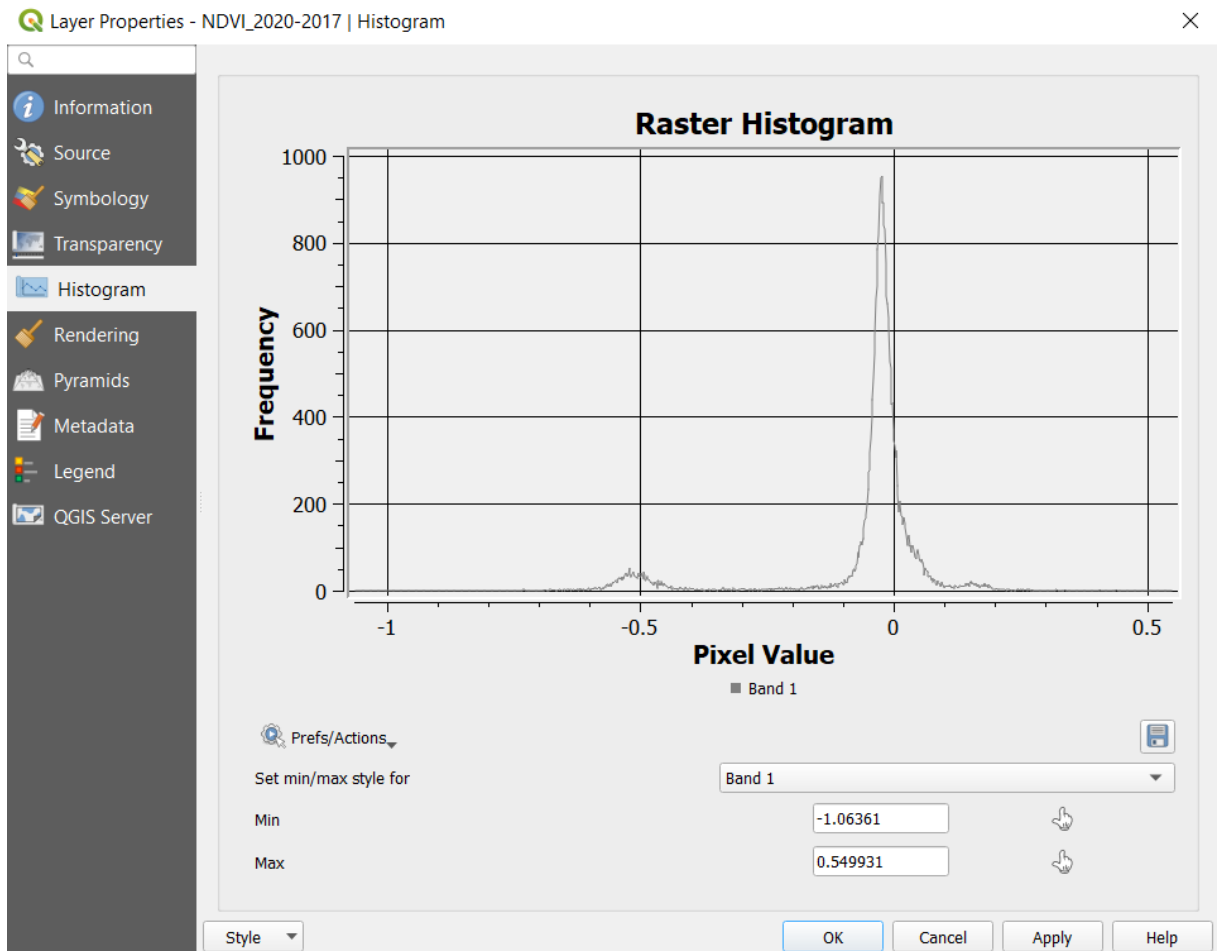




3. Apply the same steps as above to calculate the NDVI for 2020, and the NDWI for 2017 and 2020. Use the NDWI formula presented above. Save the output layers as **NDVI\_2020.tif**, **NDWI\_2017.tif**, and **NDWI\_2020.tif**.
  
4. Look at the image, what values do you see for the NDVI and NDWI for:  
vegetation, water, bare land, and built-up areas? Use the  icon to inspect the values of each raster in different places.
  
5. Calculate the NDVI difference image. Open the Raster calculator again, then calculate  $NDVI_{2020} - NDVI_{2017}$  and save the output as **NDVI\_2020-2017**.



6. Do the same with the NDWI. With the Raster Calculator, calculate NDWI\_2020-NDWI\_2021 and save the output as **NDWI\_2020-2017**.
  
7. These two rasters show how the NDVI and NDWI have changed from 2017 to 2020. What do high values mean in the resulting layers? What about very low values? Look at the image and try to understand what you see.
  
8. The second step of the algabreic method is to determine the threshold above which we consider that a change has occurred. We can use the histogram to help show us which value to select. Right-click on **NDVI\_2020-2017.tif** and go to "Layer Properties → Histogram". Select "Compute Histogram".



Look at the values in the histogram. We see two peaks. What does the first, low peak signify? What about the second, higher peak? Write down the pixel value that you think separates change from no-change areas.

- Now we will make a change mask. In the QGIS window, select "Processing → Toolbox". You will see the toolbox open on the right side of your QGIS window. In the Processing toolbox, navigate to "Raster analysis → Reclassify by table". In the pop-up window, select the **NDVI\_2020-2017.tif** raster under "Raster layer". Next click on the "..." button under "Reclassification table". Here you will need to fill in the table as follows. In the places where you see "X" in the table below, write down the threshold value you chose in the previous step. In the "Value" column, write down 0 if you think this range represents areas that have not changed between the images, and a 1 if you think the range represents areas that have changed. Save the raster as **NDVI\_2020-2015\_reclass.tif**.

Minimum	Maximum	Value
-2	X	0 or 1
X	2	0 or 1

Fixed table ✕

	Minimum	Maximum	Value
1	-1		
2		1	

Add Row

Remove Row(s)

Remove All

OK

Cancel

Reclassify by Table ✕

Parameters Log

Raster layer  
 ⌵ ⌵

Band number  
 ⌵

Reclassification table  
 ⋮

▼ **Advanced parameters**

Output no data value  
 ⌵

Range boundaries  
 ⌵

Use no data when no range matches value

Output data type  
 ⌵

Reclassified raster  
 ⋮

Open output file after running algorithm

**Reclassify by table**

This algorithm reclassifies a raster band by assigning new class values based on the ranges specified in a fixed table.

Cancel

Run as Batch Process... Run Close Help

10. Look at the change mask you just made. Do you think it's correctly represents the changes between 2017 and 2020? Do you see any errors?



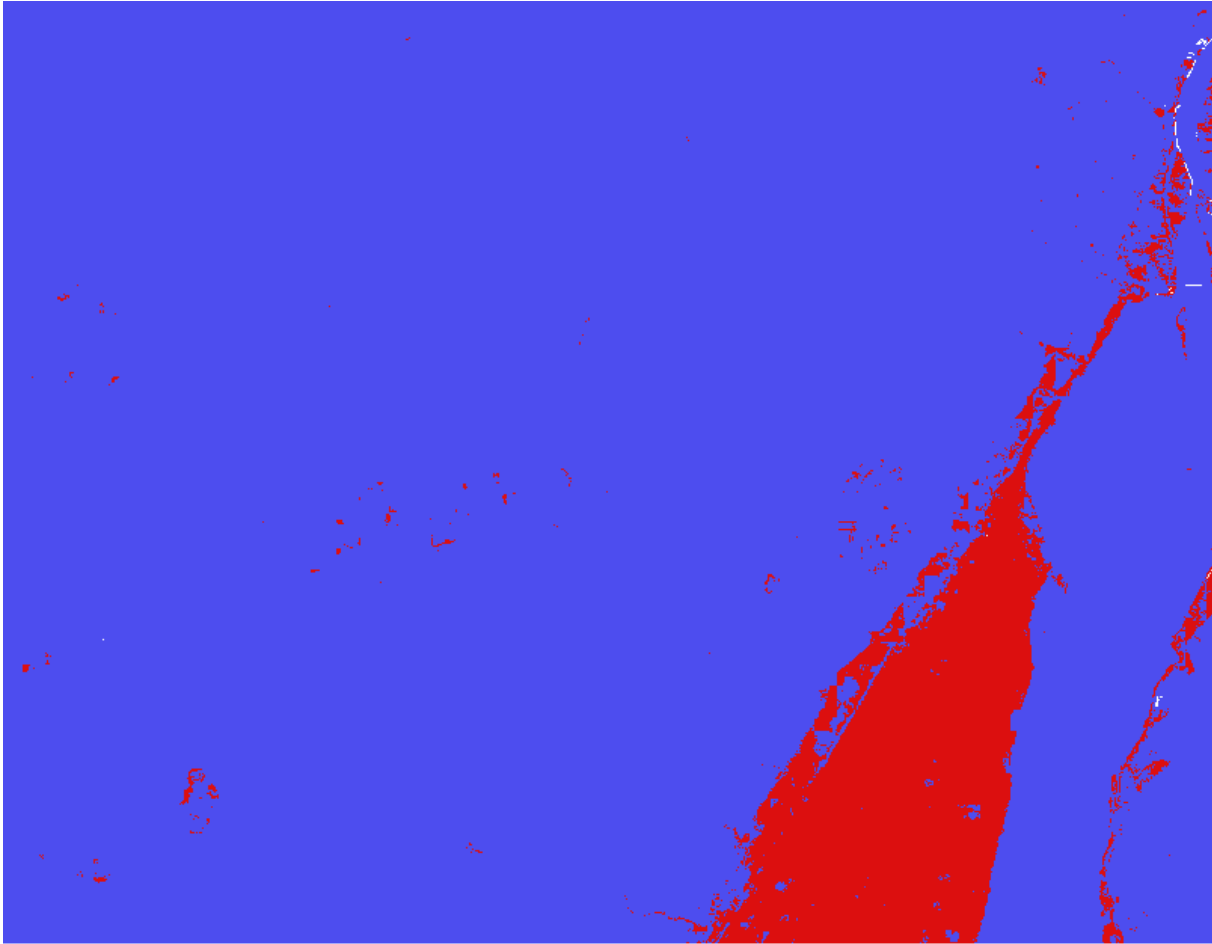


Figure 3 - The change map I got by thresholding the NDVI\_2020-2017 image. Does it match yours? Where are similarities or differences?

**ADVANCED: (1)** Look at the typical values for NDVI and NDWI. Reclass the NDVI\_2020 and NDVI\_2017 using the "Reclassify by Table" tool to make a raster of 3 land class types (water, bare soil / built-up areas, and vegetation) for 2017 and 2020. Then use "Raster calculator" with the equation below to create a new raster with two-digit numbers. The first number will represent the class in 2017 and the second number will represent the class in 2020. **(2)** Try a change detection map using the machine learning techniques you learned in the previous model.

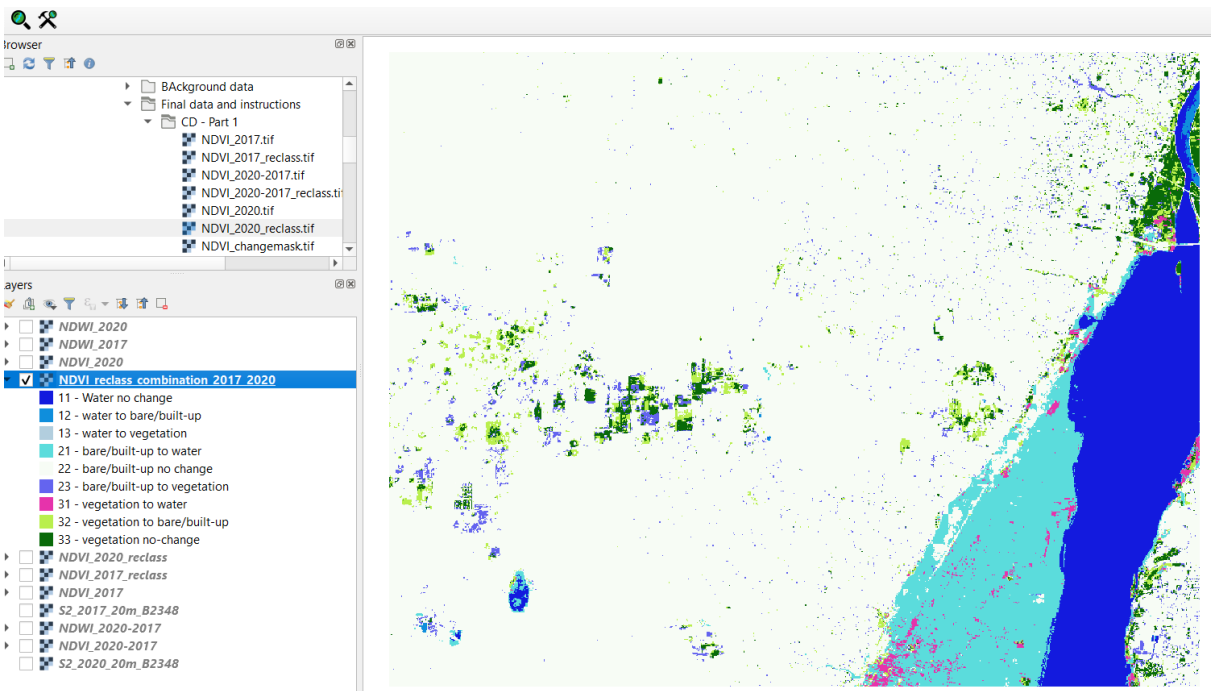
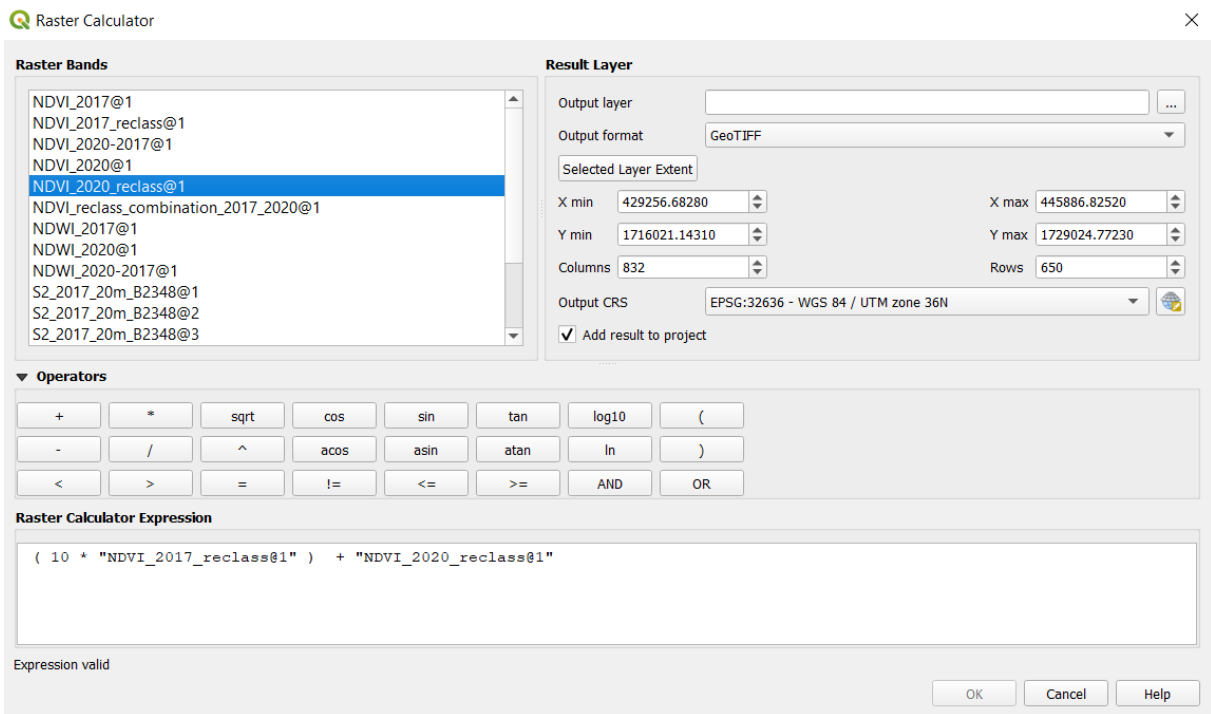


Figure 4 – My results for the Advanced exercise (1). You can see that a large part of the area changed from bare to water from 2017–2020. You can also see changes in the vegetation in the left part of the image. Some (apparently agricultural) areas were vegetated in 2017 but not in 2020.

## Analysis questions

---

- Which changes did you see with your first visual analysis and which ones became visible with the algebraic change detection method? Were there any differences?
- What do high values in the NDWI\_2020-2017 raster signify?
- Which land cover classes could you not distinguish with NDVI and NDWI? Are there any other ways you can think of to detect changes between these classes?