Monitoring for IWRM

Manual for 3rd training course – Oct 2025

Monitoring for IWRM

Manual

Executive summary

This document contains instructions and tips on how to use public data for monitoring related to IWRM. Data are obtained from various sources, including Google Earth Engine.

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Client

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List of abbreviations

3R	Recharge, Retention and Reuse
GEE	Google Earth Engine
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index
MNDWI	Modified Normalized Difference Water Index

1 Introduction

This manual is part of the third training course organized by INWRDAM, IHE and Acacia Water in Oct 2025. The training builds upon the first training held in Amman in September 2023, the online Quantum GIS training offered by IHE in April – May 2024, and the second face-to-face training course in Amman in May 2024.

This guide shows how to use Google Earth and Google Earth Engine to obtain and use public data to monitor the environment and water resources for IWRM.

2 Basic Remote Sensing applications for monitoring in IWRM

2.1 Monitoring of open water bodies

In this assignment we are going to use different methods to monitor open water bodies over time. These methods build upon the approaches introduced during the Remote Sensing introductory session.

2.1.1 Changes in reservoir size: manual inspection using Google Earth

- If you do not have Google Earth installed on your laptop, download and install Google Earth through the following link:
  Earth Versions – Google Earth
- After installation, open Google Earth and go to Kufranjah Dam, either by zooming or using the search bar
- In the toolbar shown at the top of the map, click on 'Show historical imagery' and use the time slider to select a clear image in the period 2019 - 2021.
- To inspect the total surface area of the reservoir, click on the ruler icon 'Show Ruler' in the toolbar and click on 'Polygon'
- Now start drawing the polygon around the reservoir by clicking (Figure 1). When finished, you can inspect the total surface area. Save the polygon and give it an appropriate name (including the date).

As you might have noticed, this method is rather time-consuming, especially when analyzing many points in time. In addition, Google Earth provides imagery only for limited dates. While it is excellent for quick visual inspections, it is less suitable for monitoring changes over longer periods or at specific intervals. For such analyses, multispectral remote sensing data is often the better choice, as it offers consistent and regularly collected observations.

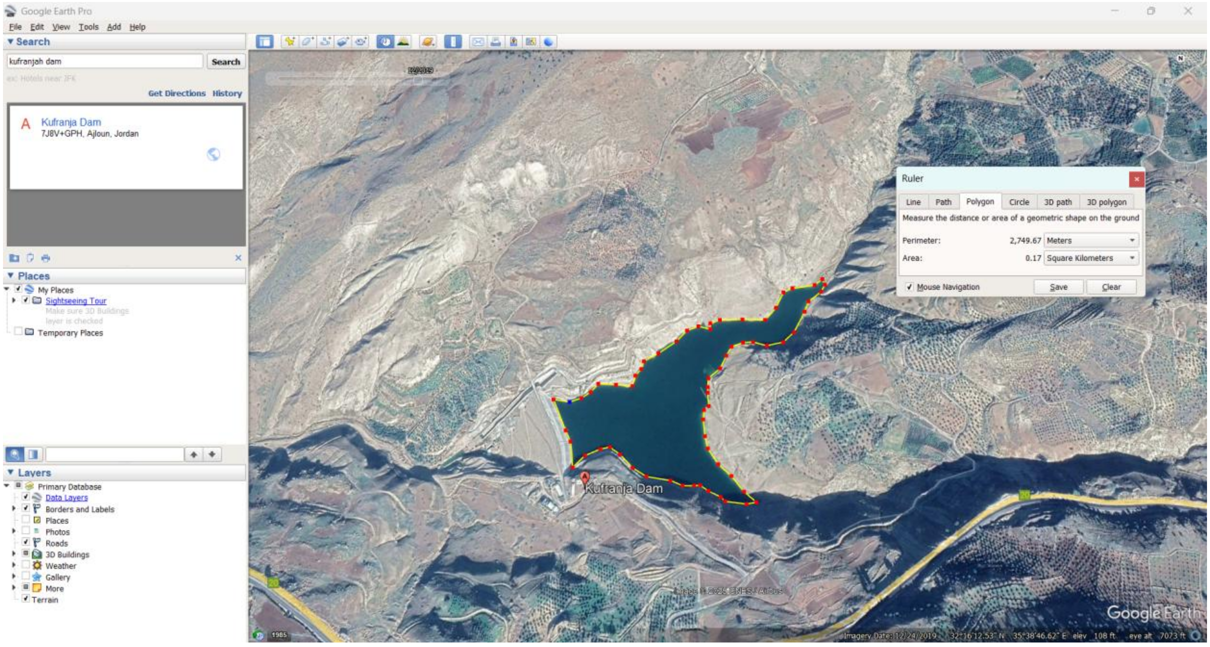


Figure 1. Manual determination of reservoir size in Google Earth.

2.1.2 Changes in reservoir size: automated determination using Google Earth Engine

Several approaches have been developed to extract water bodies from multispectral images. One of them is by calculating the NDWI. As water bodies strongly absorb light in the visible to infrared electromagnetic spectrum, NDWI uses green and near infrared bands to detect water bodies (McFeeters, 1996).

NDWI = **(Green - NIR) / (Green + NIR)**

When using Sentinel-2 data the NDWI is calculated as follows:

NDWI = **(B03 - B08) / (B03 + B08)**

Index values greater than 0 usually correspond to water. However, this threshold may vary depending on local conditions. For example, shadows can introduce noise, meaning the threshold value is not fixed but dynamic.

Temporal variation in reservoir size

We will inspect the changes in reservoir size over 2019 and 2020 for Kufranjah dam. To process time-dependent data from, for example, Sentinel-2 or Landsat satellite missions, we employ cloud computing and Google Earth Engine. These technologies enable the creation of on-the-fly time series and cloud-free mosaics of multispectral data.

Now open https://code.earthengine.google.com/ and log in to your Google account. This will open a tab showing the GEE interface (Figure 2).

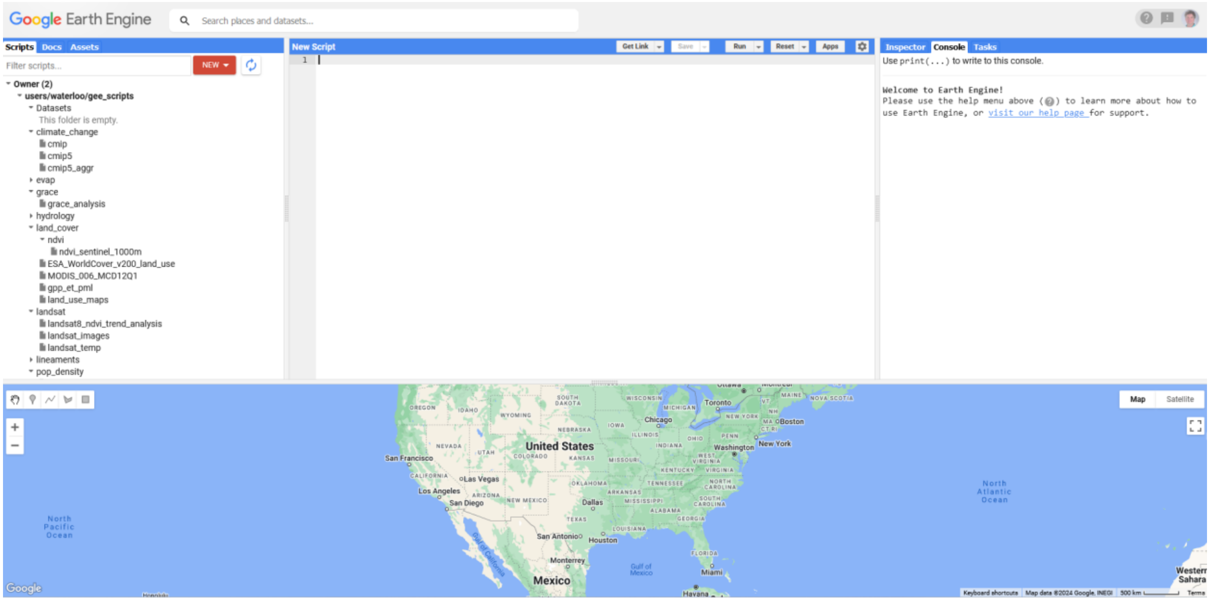


Figure 2. GEE interface window in your browser.

The script that we will use for this exercise can be found on the OCW platform under 'Day 2 presentations and material'.

1) Download the script (*ndwi_calculation_sentinel2.txt)* from the OCW platform. Copy and paste the code to create a new script in GEE.
2) Now, zoom to Kufranjah and draw a rectangle around the dam reservoir (Figure 3). This will be the area covered in the analysis.
3) Change the name of the area of interest (*aoi_name*) and set the start and end dates so that the analysis will cover the years 2019 and 2020.

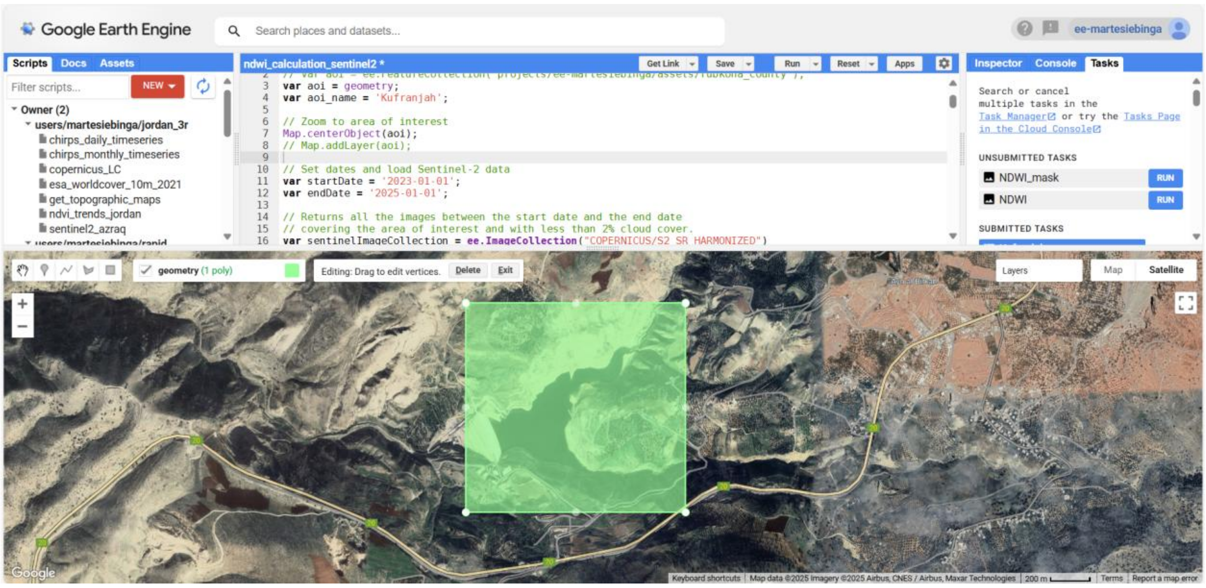


Figure 3. Polygon around Kufranjah dam.

4) Run the script and inspect the results
5) If the mapped surface water area does not align well with the True Color image (RGB). Try to adjust the NDWI threshold in line 68 of the script.

6) Now, validate your results with the results from the manual inspection in Google Earth (2.1.1). Do they differ?

We will also inspect a different dam reservoir.

7) Delete the old geometry and zoom to King Talal Dam. Change the name of the area of interest and draw a polygon around the dam reservoir. Now rerun the script. What do you notice?

To find out what the differences are between Kufranjah Dam and the King Talal Dam we will inspect their spectral signatures. The spectral signatures show the reflectance or emittance of a surface (or a pixel) across multiple wavelengths of the electromagnetic spectrum - so in this case, across all different sentinel-2 bands.

1) Go to https://browser.dataspace.copernicus.eu. Select a date within your timeseries (e.g. May 2020), set the max. cloud cover, and zoom to the Kufranjah dam
2) Now in the right toolbar, click on "Mark point of interest", place the point of interest in the reservoir and open the "Spectral explorer" (Figure 4). Screenshot and save the image.
3) Do the same for the King Talal Dam. What difference do you observe? What could have caused this difference? The graph below might help (Figure 5).

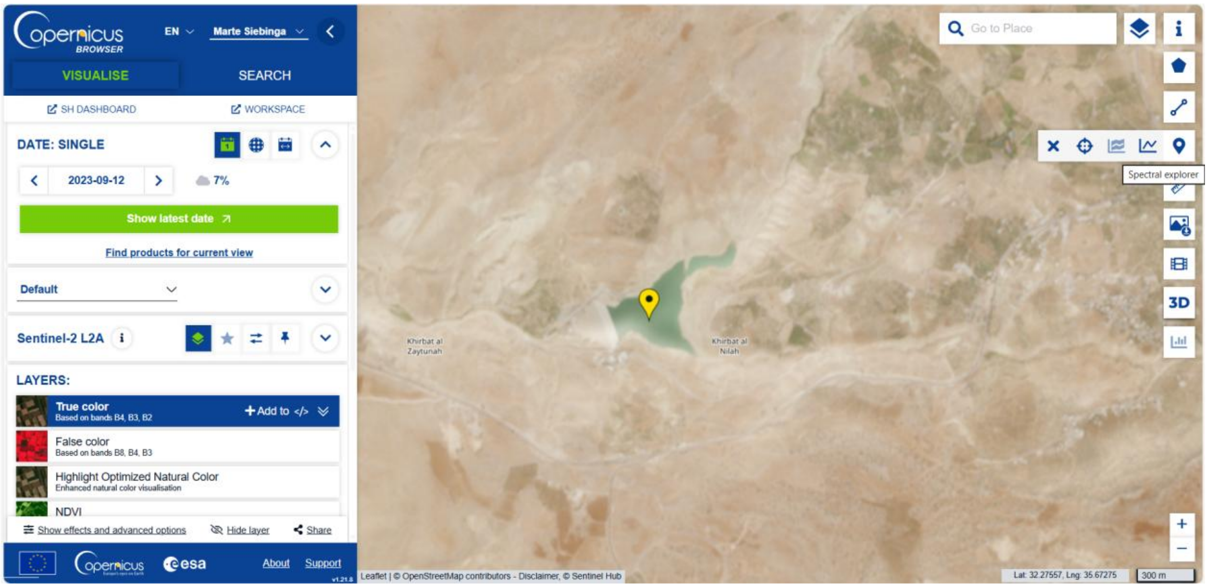


Figure 4. Spectral explorer in Copernicus Browser.

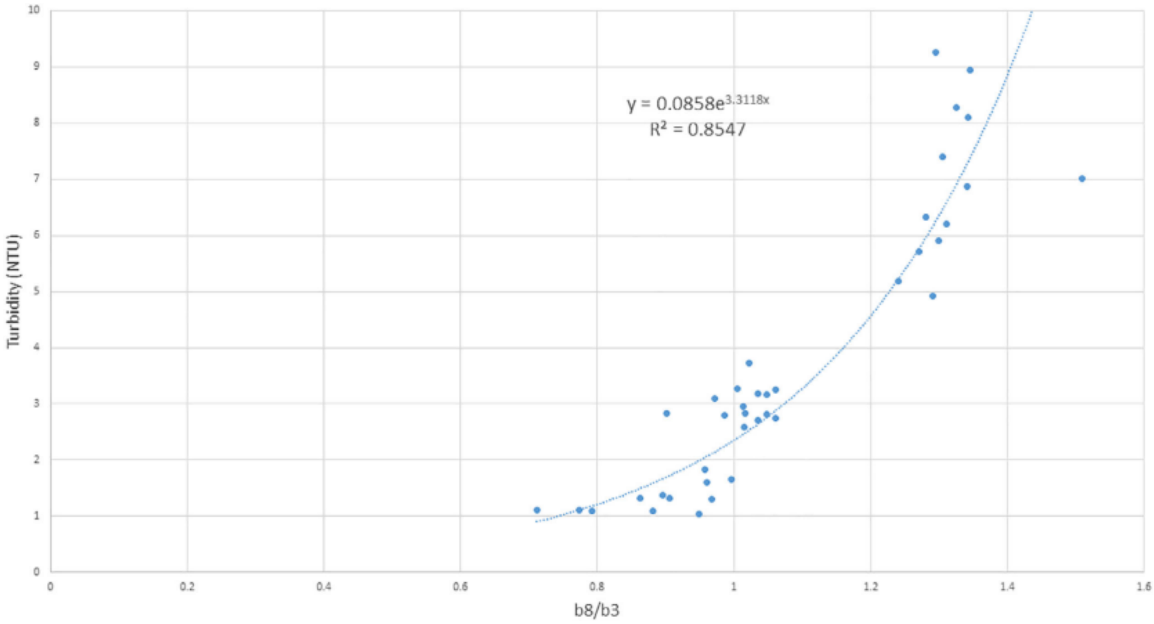


Figure 5. Regression between Sentinel-2 NIR/Green (B8/B3) band ratio and measured turbidity at King Talal Dam (Hussein, Assaf, & Abohussein, 2023).

2.1.3 Creating reservoir level – volume relations

In the previous assignment, we inspected temporal variations in reservoir surface area. The next step is to combine surface area data with water level measurements to estimate the storage of a reservoir or hafir. In this assignment, we will use the same script as in the previous assignment together with water level measurements to establish a stage height – reservoir volume relation. We'll do this for one of the storage ponds in Muwaqqar.

As experienced, using the NDWI in turbid waters generally provides poor results. Also, in urban areas NDWI can produce positive values for built-up areas. To reduce such errors, Xu (2006) developed the modified NDWI that replaces NIR with SWIR. As water absorbs strongly in SWIR, even when its turbid, using the mNDWI is preferred when mapping turbid waterbodies. Since erosion is a common issue in the Muwaqqar catchment (remember the field excursion in May 2024), we'll adjust the script to use the mNDWI.

The downside of using this index is that the Sentinel-2 SWIR band holds a coarser resolution of 20 m, while the Green and NIR both have a resolution of 10m.

MNDWI = **(Green - SWIR) / (Green + SWIR)**

For Sentinel-2, this translates into the following:

MNDWI = **(B03 – B012) / (B03 + B012)**

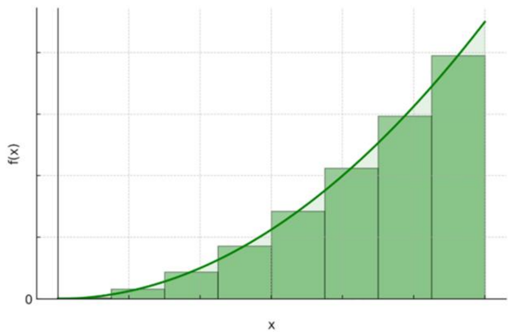
1) Go back to your Google Earth Engine script
2) In the left panel open the 'Assets'
3) On the OCW platform you'll find a shapefile covering the extent of the storage pond in Muwaqqar (*muwaqqar_pond_shape.zip*). Download this folder, extract the data and add the shapefile to your 'Assets' in Google Earth Engine through the

New>table upload menu. Upload the .shp, .shx, .dbf and .prj files and wait until these are imported

4) Change the dates of the script so we'll cover the period February, March, April 2025. Also change the name of the area of interest (*aoi_name*)
5) Now adjust the script to calculate the MNDWI instead of the NDWI (B8 to B12)
6) If necessary, adjust the threshold to 0, and run the script
7) Inspect and validate the results for a specific date (*exportDate* line 15), adjust the threshold if the results do not correspond to the RGB image
8) When satisfied, use 'Tasks' to download the .csv file. The file will be saved in your Google Drive, which is part of your Google account services. Exporting the file may take a while and you have to wait until the fields in the 'Tasks' window turn blue
9) Download the file from your Google Drive (https://www.google.com/drive/) and save it

The next step is to establish the stage height – volume relation. To do this, we'll use water level measurements from last year.

10) From the OCW platform download the Excel *waterlevel_volume.xlsx*. In the first tab, you'll find the same steps as listed here for your reference.
11) The second sheet contains the raw data, including the water level measurements (*Depth m* column). From this data, create a pivot table showing daily average water levels
12) In the waterlevel-volume sheet copy your results from the csv file exported by the GEE script in the first two columns (*date* and *area*). Now in the water level column, paste the right water level measurements by looking them up and copying them from the pivot table that you just created
13) The next step is to create a scatter plot showing the water level data on the x-axis against the water area on the y-axis
14) From this point we can move on to calculate the volume at a certain water level. How would we do this? The illustration below might help to get the answer.



15) For all measurements, calculate the change in volume between two consecutive water levels
16) After calculating the change in volume between consecutive water levels, calculate the total volume at each water level (this is the cumulative of the volume increments, so the total area under the curve)
17) What could be another way to estimate the volume at a certain water level?

2.2 Monitoring of vegetation

The Normalized Difference Vegetation Index (NDVI) is a well-known and widely used indicator that measures vegetation health and coverage. It compares the strong reflectance of green leaves in the near-infrared spectrum with the absorption of light by chlorophyll in the red spectrum:

NDVI = **(NIR - Red) / (NIR + Red)**

When using Sentinel-2 data the index looks like this:

NDVI = **(B8 – B4) / (B8 + B4)**

The values range from -1 to 1:

- Negative values usually indicate water.
- Values near zero typically correspond to barren areas such as rock, sand, or snow.
- Low positive values (approximately 0.2 to 0.4) are characteristic of shrublands and grasslands.
- High positive values (approaching 1) indicate dense vegetation, such as temperate and tropical forests.

2.2.1 NDVI change detection

To detect changes in NDVI over time, we perform a pixel-wise trend analysis across a defined time period. For each pixel, a NDVI time series is constructed, and linear regression is applied to estimate the slope of NDVI change. The slope indicates the direction and rate of change.

To evaluate whether the observed trend is statistically significant, we use the p-value. A low p-value indicates that if there were actually no real trend, the probability of observing data this extreme (or more extreme) would be very small. By masking out non-significant results (p-value > 0.05), only trends that are significant at the 95% confidence level are retained.

This approach allows us to map areas with a positive NDVI trend (regreening) or a negative NDVI trend (vegetation decline). The figure below illustrates a statistically significant NDVI trend over the past decade around Azraq.

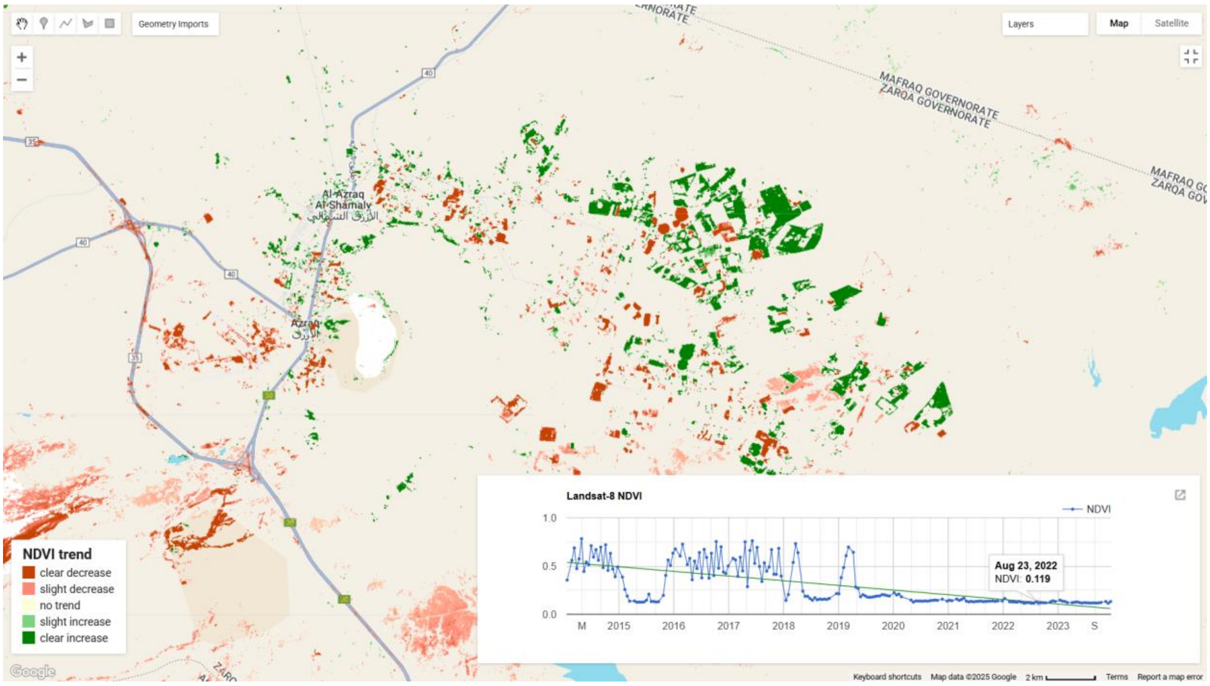


Figure 6. Statistically significant NDVI-trends around Azraq for the period 2014 - 2024.

For this assignment you can select your own ‘area of interest’ (AOI) and time period for which you want to study the NDVI trends. Note that the script uses Landsat-8 imagery, which is available from 2013 – present. The script that we’ll use can be found on the OCW platform under ‘Day 3 presentations and material’.

1) Download the script from OCW (*ndvi_trends_jordan.txt*). Copy and paste the code to create a new script in GEE.
2) In QGIS create a shapefile covering your AOI and upload it to your ‘Assets’ **or** draw a polygon around you AOI in GEE immediately.
3) Adjust the time period, run the script and inspect the results. Are there any interesting observations? Which areas have experienced significant changes? By clicking on the map, you get a graph showing the NDVI trend over the selected period. Can you find any explanations for the significant trends? (by making use of other RS imagery, for example through https://browser.dataspace.copernicus.eu)
4) Create a slide of the results

3 References

Hussein, N. M., Assaf, M. N., & Abohussein, S. S. (2023). Sentinel 2 analysis of turbidity retrieval models in inland water bodies: The case study of Jordanian dams. . *The Canadian Journal of Chemical Engineering 101(3)*, 1171-1184.

McFeeters, S. K. (1996). The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features. . *International journal of remote sensing, 17(7)*, 1425-1432.

Xu, H. (2006). Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery. *International journal of remote sensing, 27(14)*, 3025-3033.

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