GOSTEAM Hands-on Activity Template *(Classroom-Formal)*

## Title:

Monitoring drying inland water body using satellite remote sensing: a case study of Lake Mead (U.S.A) using Landsat satellite imagery data

## Short Description (Max 500 words):

a) Practical exercise where students will process multi-spectral satellite imagery data from Landsat missions to understand environmental changes over times (2000-2021)
b) Learn to how to process raster and vector data, and spatial analysis using QGIS
c) Calculation of water surface areas in 2000 and 2021
d) Discussion on reasons why water surface areas are declining (climate changes? Or human activities?)

## Keywords (Up to 5):

Lake, satellite remote sensing, changes, water body, monitoring

## Information about the Implementation

Age and language of the students: 9-12 12-15 15-18 18+

Language: English Age: ☐ 9-12 ☐ 12-15 ☒ 15-18 ☐ 18+

Number of Lessons – Duration (per lesson):

Number of Lessons: 3 Duration per Lesson: 45

Subjects

For which subject(s) the activity is usable, is it an interdisciplinary activity?

Science ☐

Physics ☐ Chemistry ☐ Biology ☐ Geosciences ☒ Environmental ☒ Other ☐

Technology ☐

Engineering ☐

Arts ☐

Mathematics ☐

# Information about the Scenario

## Curriculum and country:

Link of the current activity to the curriculum:

Country: Sweden

Class: geography

Grade: 10-12

Topic: Cartography

## Objectives (Max 100 words):

Description of the learning objectives

- knowledge on multispectral Landsat satellite images.
- knowledge on how to classify water surfaces from Landsat images.
- knowledge on spatial analysis using QGIS.

## Materials (Max 100 words):

Which resources and materials (software, hardware) are needed?

- Computer with internet connection
- Software: QGIS

## Spatial concepts, skills and abilities:

Which spatial concepts and skills are covered by the activity?

### Spatial concepts:

**Primitives:** Identity/Name ☐ Location ☒ Space/Time ☒

**Simple:** Distance ☒ Direction ☐ Connectivity ☐ Movement ☐

| | | | | |
|---|---|---|---|---|
| | Boundary ☒ | Shape/Area ☒ | Adjacency ☐ | |
| **Difficult:** | Overlay ☒ | Buffer ☐ | Topology ☐ | Coordinate ☐ |
| | Map ☒ | Scale ☐ | Shortest Path ☐ | Navigation ☐ |
| | Surface ☐ | Slope/Gradient ☐ | Aspect ☐ | Contour ☐ |
| **Complex:** | Interpolation ☐ | Map Projection ☐ | Spatial Dependency ☐ | |
| **Other:** | | | | |

**Spatial skills:**

- ☒ Map literacy
- ☐ Navigation/orientation
- ☐ Estimating distances and directions
- ☐ Recognizing and understanding patterns/Understand and identify models of spatial organization
- ☐ Select an ideal location based on the given spatial features
- ☒ Visualization
- ☐ Understand and identify spatial correlations/ dependencies
- ☐ Categorize spatial entities/ geographic features and identify hierarchies
- ☐ Compare spatial entities and draw analogies among them
- ☐ Identify/determine connections/relations
- ☐ Understanding scale in space and time
- ☒ Delineation of spatial regions/ zones based on given features/ properties

## Short Description

Navigation/orientation: Finding one's way in unfamiliar environments, interpreting and giving walking and driving directions.
Estimating distances and directions: Measure paths, weighted distances, angles.
Map literacy: Using, interpreting/understanding, learning from, and communicating acquired spatial knowledge from maps, comprehension of geographic features represented as points, lines, or polygons.
Recognizing and understanding patterns/Understand and identify models of spatial organization. Delineation of spatial regions/zones based on given features/properties: Regionalization processes, pattern recognition and clustering identification in the 2d and/or the 3d world.
Select an ideal location based on the given spatial features: Single or multi-criteria siting and optimal areas identification.
Visualization: Visualizing spatial entities from written/oral verbal descriptions, from their 2d or graphical representations or through mental transformations; such as axis rotation or perspective taking.
Understand and identify spatial correlations/ dependencies: The ability to realize, identify and explain patterns, clusters and relevant spatial dependencies.
Categorize spatial entities/geographic features and identify hierarchies: Identify the hierarchical form of data and gradients between spatial entities.

Compare spatial entities and draw analogies among them: Calculate and compare different geometric objects' shapes, area and, boundaries.
Identify/determine connections/relations: The ability to identify links and common characteristics among spatial entities and between humans and spatial entities.
Understanding scale in space and time: The understanding of changes/transitions through space and time for different spatio-temporal scales.

**Geospatial concepts and spatial abilities documentation (see Section 3.2):**
**http://www.gosteam.eu/wp-content/uploads/2021/05/GOSTEAM_IO1_A1_final.pdf**

# Description of the activity in detail

## Classroom activities

Lesson 1 (45 minutes):

- The first lesson is more focused on theoretical backgrounds, also get students involved in trying and discussion.
- Short introduction on environmental changes, and ask students how could we monitor such changes for discussion?
- Introduction to the importance of satellite remote sensing for monitoring environmental changes, by showing impressive satellite images https://earthengine.google.com/timelapse/ and get sense of changes in large lakes, e.g. Lake Mead in USA, Lake Urmia in Iran, Aral Sea between Kazakhstan and Uzbekistan. Let students try different areas of interest and discuss what they find and think about the changes.
- The teacher presents the basics of satellite remote sensing (definition, how it works, spatial and temporal resolutions etc.)
- Introduction to satellite missions Landsat and show students on how to download the Landsat data, and considering what aspects for data choice (e.g. cloud cover, and time)
- Present how to classify water body from other areas (explain why water surface appears dark in satellite images)

Lesson 2 (45 min)

- The second lesson is more focused on the whole data processing
- Divide students into groups, so they could help each other during hands-on exercises.
- The lecturer will demonstrate each data processing steps for students by taking example for satellite image in the year 2000. Explain the functions and purpose of QGIS processing. Students can directly ask questions during the processing.
- QGIS processing includes mainly: open and display multiple bands satellite imagery data, making composite data (2 or 3 bands); perform raster calculation to extract water surface area; different ways to calculate the surface area (based on raster data grid cells VS, converting raster data to shapefile)
- Let the students compare and discuss the differences between surface area calculations from the two different ways. (Raster vs. Vector). Also discussion some problems on extracted water surface areas.

Lesson 3. (45 min)

- Lesson 2 demonstrates all steps-by-steps processing for satellite image in 2000. In Lesson 3, students need to apply what they have learned in Lesson 2 to process a new satellite image in 2021.
- Students also need to make a map showing the boundary of water surface area in 2000 and 2021, and compare and discuss the changes. Expected results is shown as below.
- Finish the lesson and the topic by discussing advantages and disadvantages of using optical satellite imagery data (Landsat data used in this exercise, suffering from cloud cover) and then briefly mention the microwave satellite remote sensing by showing Sentinel-1 satellite image for flood mapping without influence on cloud cover.
- Also ask students about what they think about this topic and exercise, and any other questions to discuss. Description of activities for face-to-face teaching in the classroom

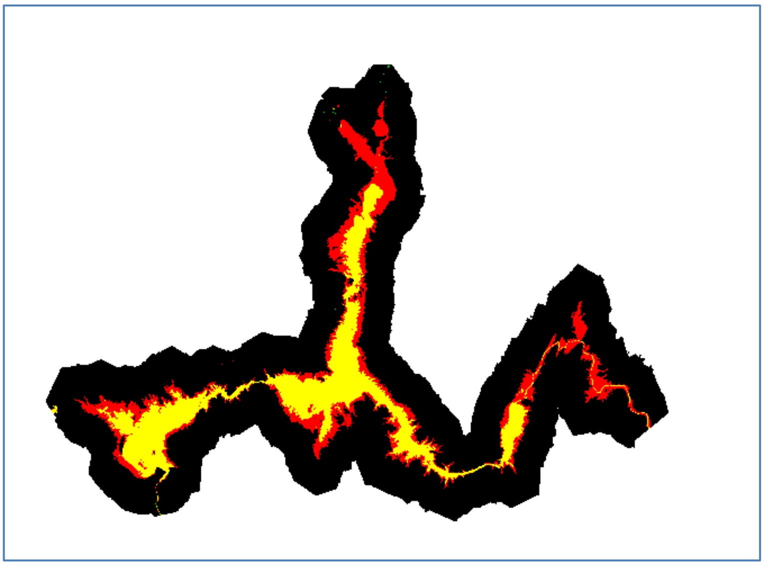


*Figure 1: Lake surface area of Lake Mead, USA in 2000 (red) and 2021 (yellow)*

## Processing steps

1. **Downloading Landsat satellite images from USGS EarthExplorer** (registration is needed, the data has been downloaded and will be provided to students)

Visit the https://earthexplorer.usgs.gov/ and zoom in the study area (Lake Mead), as shown in **Figure 2.**

**Search Criteria:** Select the Date range from 2000 to 2021.

**Data Sets:** Select Landsat Collection 2 Level-2, check Landsat 8 and Landsat 4-5.

Then click Search and check the Tab **Results (Figure 3)**. On the left panel, the searched results are listed, and for each image, we can check Footprint and show the Metadata and Browse. Here it is important to select the images with low ratio of cloud coverage and the images can fully cover the study area.  For this exericse, we will use the two satellite images.

(1) Image on 20210606 from Landsat-8:  LC08_L2SP_039035_20210606_20210615_02_T1

(2) Image on 20000612 from Landsat-5:  LT05_L2SP_039035_20000612_20200906_02_T1

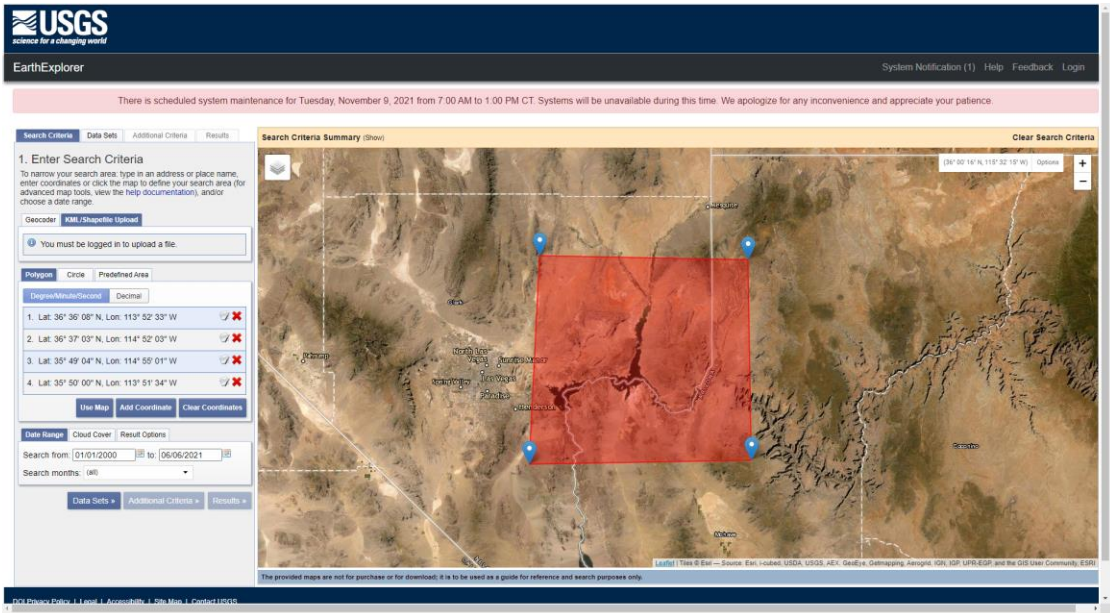



Figure 2. USGS EarthExplorer search criteria

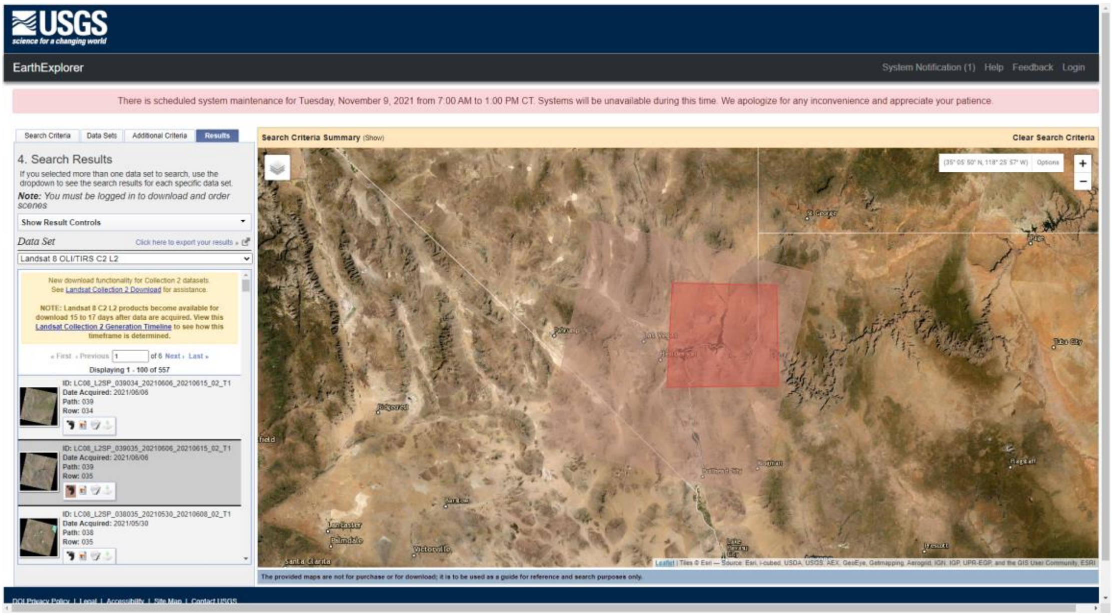



Figure 3. USGS EarthExplorer searched results of Landsat images

Download the selected images, and the most important files are GeoTIFF from different bands. Figure 4 shows the GeoTIFF files of different bands from Landsat-8 image, note SR_B1 means the surface reflectance of band 1 B1. An overview of all bands for Landsat satellite imagers can be found at https://www.usgs.gov/faqs/what-are-band-designations-landsat-satellites?qt-news_science_products=0#qt-news_science_products. **Figure 5 and 6** are copied from that link to provide the band information for Landsat-8 and Landsat-5 missions. Then open QGIS and load the GeoTIFF file to have a look at different bands images.

LC08_L2SP_039035_20210606_20210615_02_T1_SR_B7.TIF
LC08_L2SP_039035_20210606_20210615_02_T1_SR_B6.TIF
LC08_L2SP_039035_20210606_20210615_02_T1_SR_B5.TIF
LC08_L2SP_039035_20210606_20210615_02_T1_SR_B4.TIF
LC08_L2SP_039035_20210606_20210615_02_T1_SR_B3.TIF
LC08_L2SP_039035_20210606_20210615_02_T1_SR_B2.TIF
LC08_L2SP_039035_20210606_20210615_02_T1_SR_B1.TIF
LC08_L2SP_039035_20210606_20210615_02_T1_QA_RADSAT.TIF
LC08_L2SP_039035_20210606_20210615_02_T1_QA_PIXEL.TIF

Figure 4. Example list of some bands GeoTIFF files from the selected Landsat-8 image covering Lake Mead.

**Landsat 8-9 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)**

| Bands | Wavelength (micrometers) | Resolution (meters) |
|---|---|---|
| Band 1 - Coastal aerosol | 0.43-0.45 | 30 |
| Band 2 - Blue | 0.45-0.51 | 30 |
| Band 3 - Green | 0.53-0.59 | 30 |
| Band 4 - Red | 0.64-0.67 | 30 |
| Band 5 - Near Infrared (NIR) | 0.85-0.88 | 30 |
| Band 6 - SWIR 1 | 1.57-1.65 | 30 |
| Band 7 - SWIR 2 | 2.11-2.29 | 30 |
| Band 8 - Panchromatic | 0.50-0.68 | 15 |
| Band 9 - Cirrus | 1.36-1.38 | 30 |
| Band 10 - Thermal Infrared (TIRS) 1 | 10.6-11.19 | 100 |
| Band 11 - Thermal Infrared (TIRS) 2 | 11.50-12.51 | 100 |

Figure 5. List of spectral bands of Landsat-8 mission

**Landsat 4-5 Thematic Mapper (TM)**

| Landsat 4-5 | Wavelenth (micrometers) | Resolution (meters) |
|---|---|---|
| Band 1 | 0.45-0.52 | 30 |
| Band 2 | 0.52-0.60 | 30 |
| Band 3 | 0.63-0.69 | 30 |
| Band 4 | 0.76-0.90 | 30 |
| Band 5 | 1.55-1.75 | 30 |
| Band 6 | 10.40-12.50 | 120 (30) |
| Band 7 | 2.08-2.35 | 30 |

Figure 6. List of spectral bands of Landsat-5 mission

## 2. Selection of right bands for further processing

The surface reflectance for different land cover types vary from bands to bands, as shown in **Figure** 7. In order to distinguish Water and non-water types, MNDWI has been proposed. MNDWI makes use of the contrasting difference in the surface reflectance in different bands (Green Band and Middle Infrared Band-MIR) for water and non-water. As shown in Figure 7 and MNDWI equation, **the calculated MNDWI will be > 0 for water while < 0 for non-water.**

- For Landsat-5, Green Band is Band2, MIR Band is B5
- For Landsat-8, Green Band is Band 3, MIR Band is Band6 (B6)

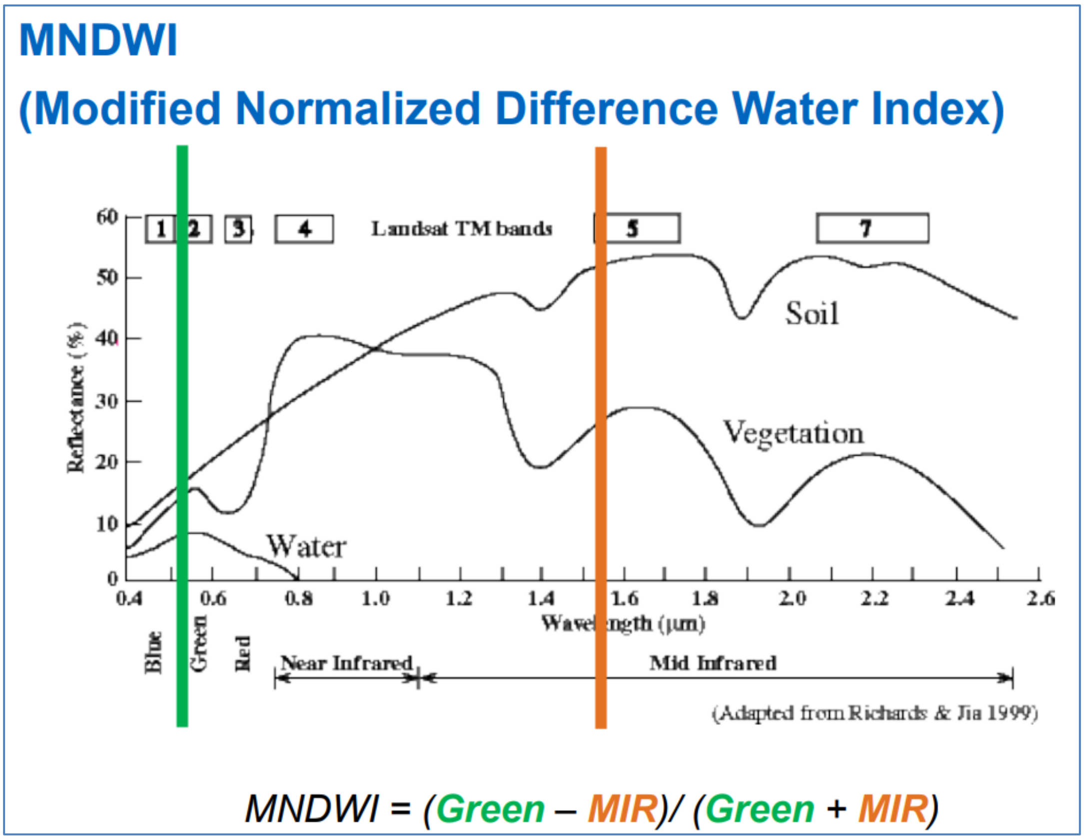



Figure 7. The relevant bands for MNDWI that can be used for separating water from non-water

3. Subset

Now we focus on extracting the Landsat-5 image acquired on 2000-06-12.

Load relevant bands (B2 and B5) and the LakeMead_Buffer shapefile to QGIS (shown as **Figure 8**). The whole scene satellite image is too large for us, as we only focus on Lake Mead, thus it is better to perform Subset to extract data in a smaller scope.

On the Main menu of QGIS, click **Raster → Extraction → Clip Raster by Mask Layer**, then a new menu pops up (**Figure 9**). Select the right band to Input Layer, and Mask Layer (the buffer area of Lake Mead shapefile), scroll down and save the clipped file in your local drive using a output name that you like, for example "L5_20000612_B2_Subset". Then click Run to perform the subset.

Repeat above processing to all other bands (in this case B5) using the same Mask file.

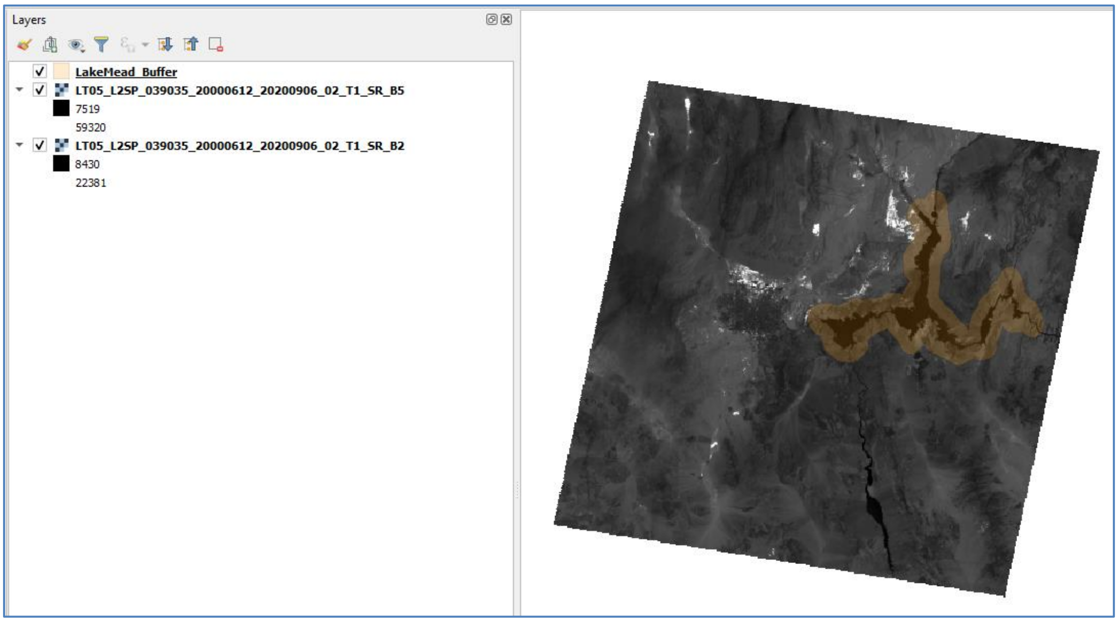



Figure 8. Load selected bands B2 and B5 and the buffer area of Lake Mead shapefile in QGIS

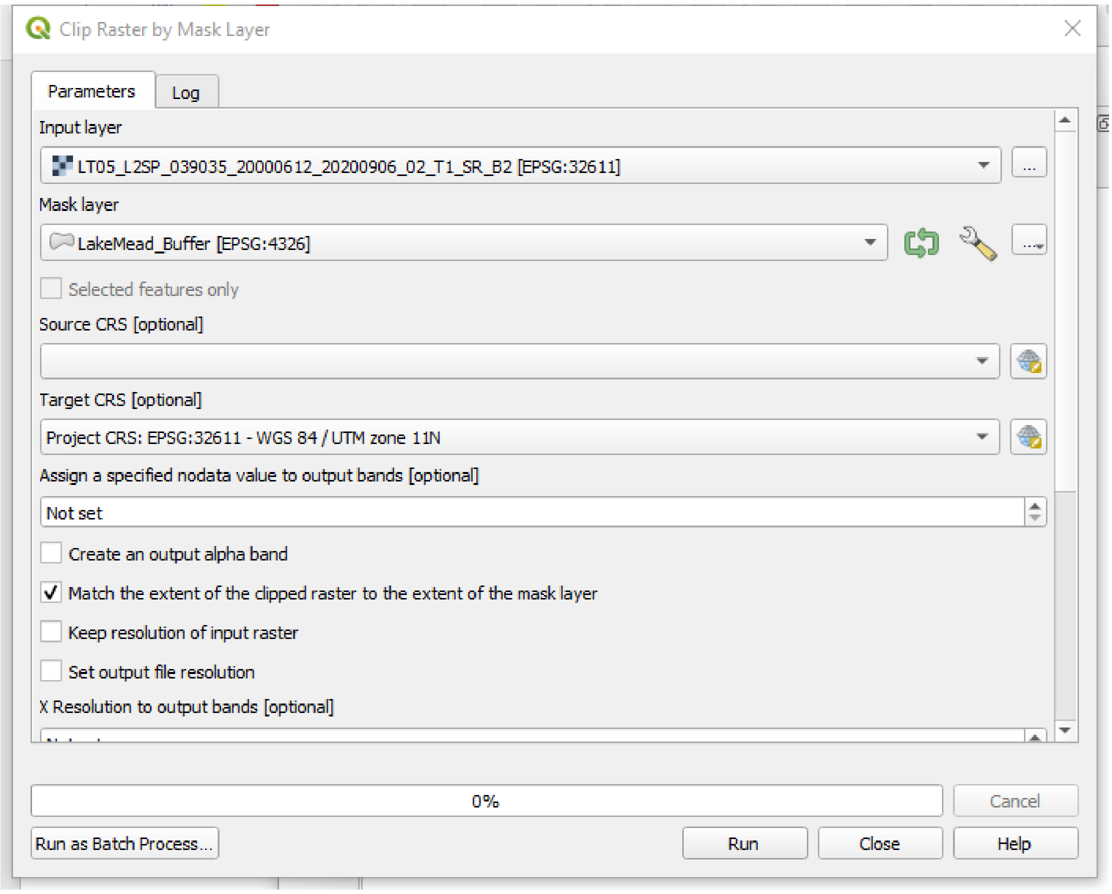



Figure 9. Subset in QGIS

## 4. Calculation of MNDWI and extraction of water

Now we have two new subset images B2_Subset and B5_Subset in QGIS. We can calculate the MNDWI by using **Raster Calculator**.

On main menu of QGIS, **Raster → Raster Calculator,** select the bands to calculate MNDWI, then save the output as "L5_20000612_Subset_MNDWI" (see **Figure 10**). Then Click OK to perform this calculation. The new file will be added automatically on QGIS. Now you can have a look at some pixels within the lake and outside the lake, you will see the pixel values are > 0 for water.

Then we can extract water by using conditional statement in **Raster Calculator** by writing

"L5_20000612_Subset_MNDWI > 0" (see Figure 11). Save the output as "L5_20000612_Subset_Water". This conditional statement will yield a new image file with raster values (0 and 1), the raster value 1 means MNDWI > 0 and thus from water.

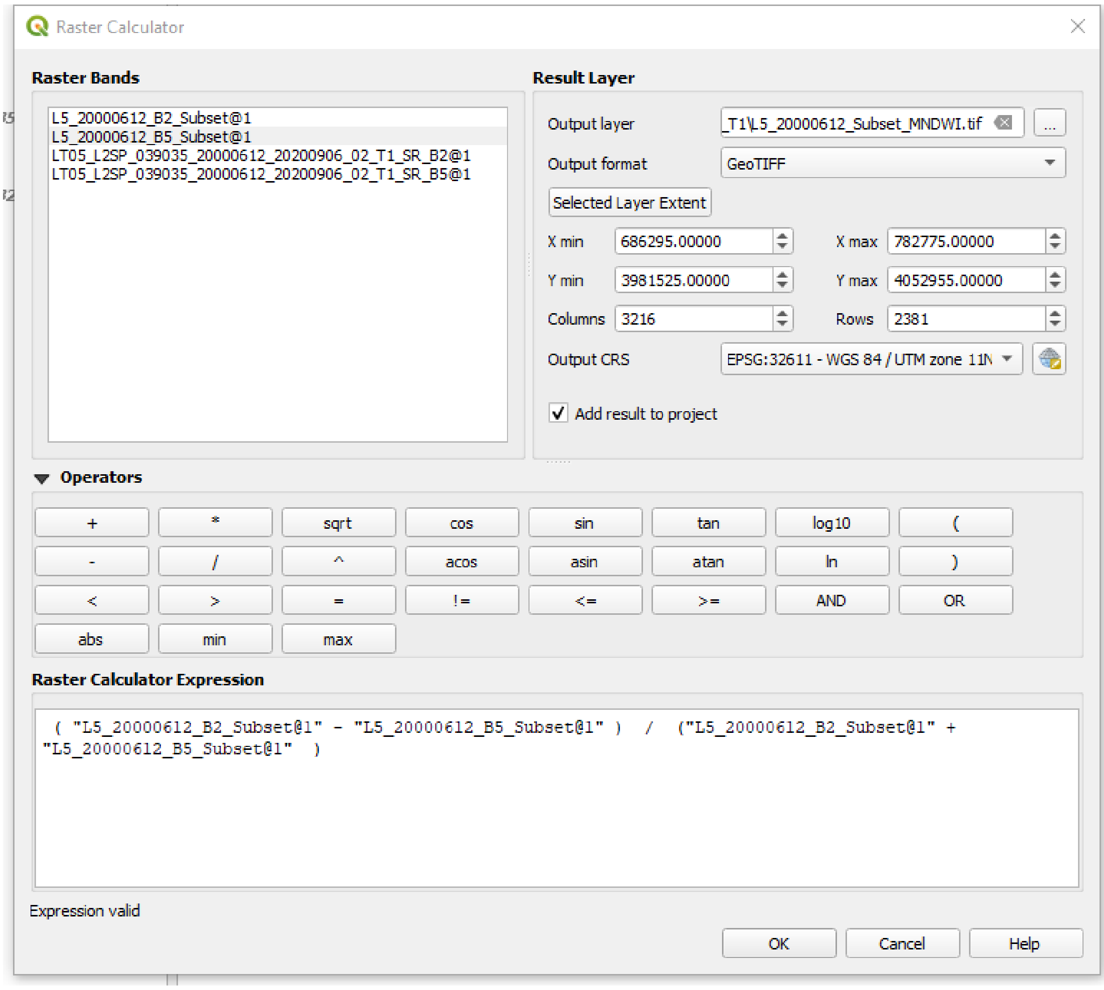



Figure 10. Raster calculator in QGIS for performing MNDWI

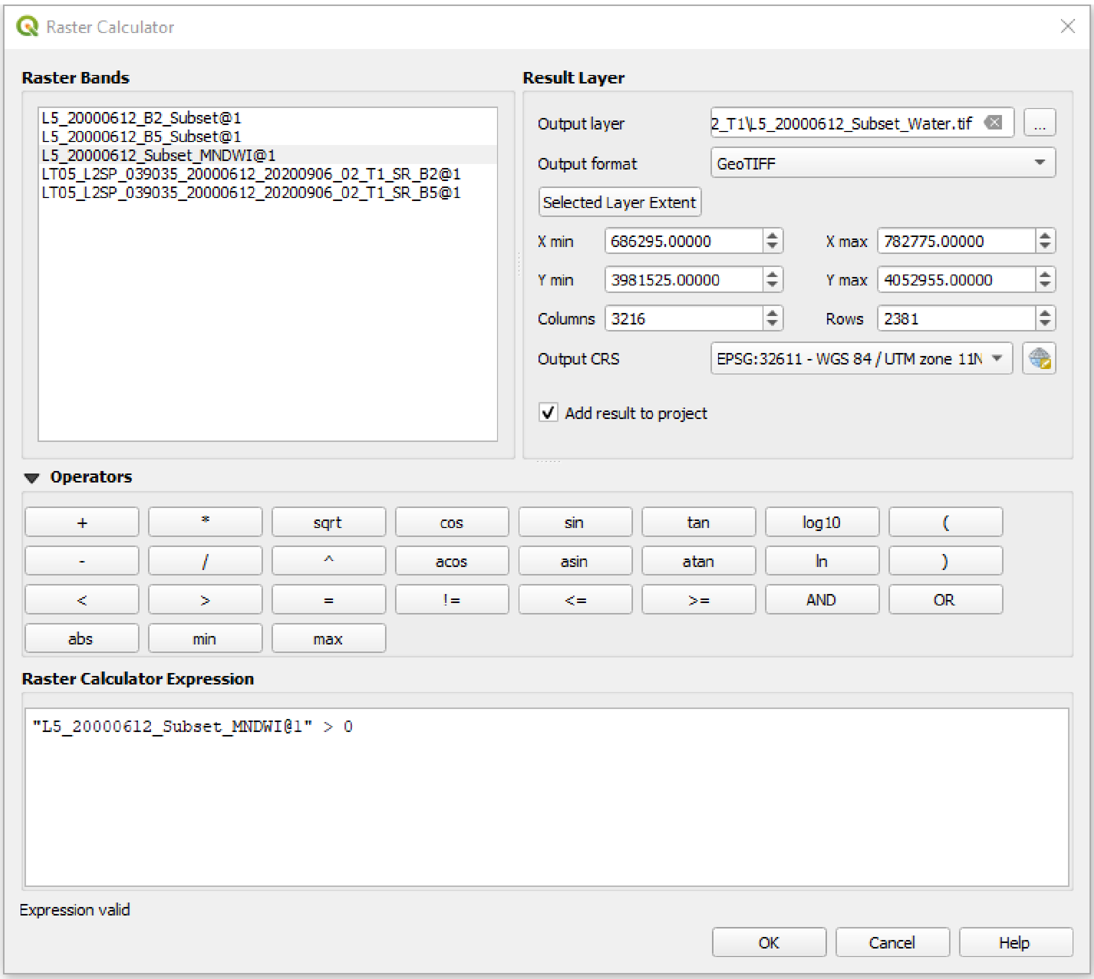
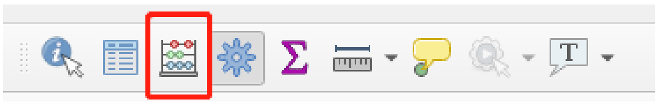



Figure 11. Raster calculator in QGIS for performing conditional statement

## 5. Converting lake outline and calculation of surface area

Usually it is nice to see the lake outline as shapefile. We can do it by covering the Raster to Vector. On QGIS main menu, **Raster → Conversion → Polygonize (Raster to Vector)**. Select the Water file from last step as Input layer, and here you do not need to save the file to your folder. Then click **Run.** A new file named as "Vectorized" will be added automatically and now we need to extract only lake outline and save it to the local folder.

Find the "Select Feature" icon on QGIS and then click the lake area in the vectorized shapefile. The selected feature (lake outline) will be highlighted in yellow color (**Figure 13**). Now right click the vectorized shapefile and select "Save selected feature as", then save it to your local folder as the output name like "L5_20000612_Subset_Water_outline".

Then we can calculate the surface area of Lake Mead on the date 2000-06-12 using **Field Calculator**  on QGIS toolbars. Click the Field Calculator, then a new menu pops up as shown in Figure 15. On this menu, you need to fill in Output field name "area", select the Output field type as "Decimal number (real)". Then click the $area function under the Geometry. Then click OK. Now right click the shapefile "L5_20000612_Subset_Water_outline" and select Open Attribute Table, we will see a new field area is added, and the corresponding value is 577706019.316 $m^2$ = 577.7 $km^2$.

Above is all processing for one image in 2000, and now students need to process the second image taken in 2021 to obtain the outline of Lake Mead and corresponding area. Then students can open both outlines to see the changes in area of Lake Mead. By processing more satellite images on a more regular basis (e.g. every month), then we can detect the monthly changes in lake surface area over long term. Such information can help us to understand the lake dynamics (available water resources) and impacts of climate change or human activities (e.g. over-use of water from lakes leading to shrinkage of lakes) on the important water resources.

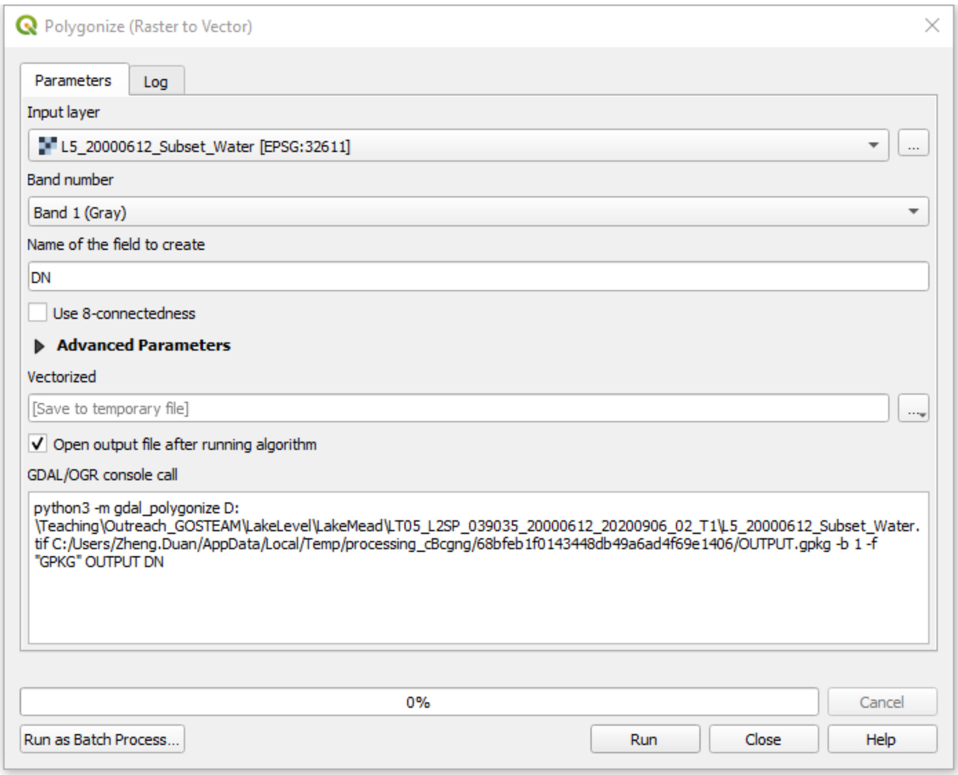



Figure 12. Covering raster to vector in QGIS

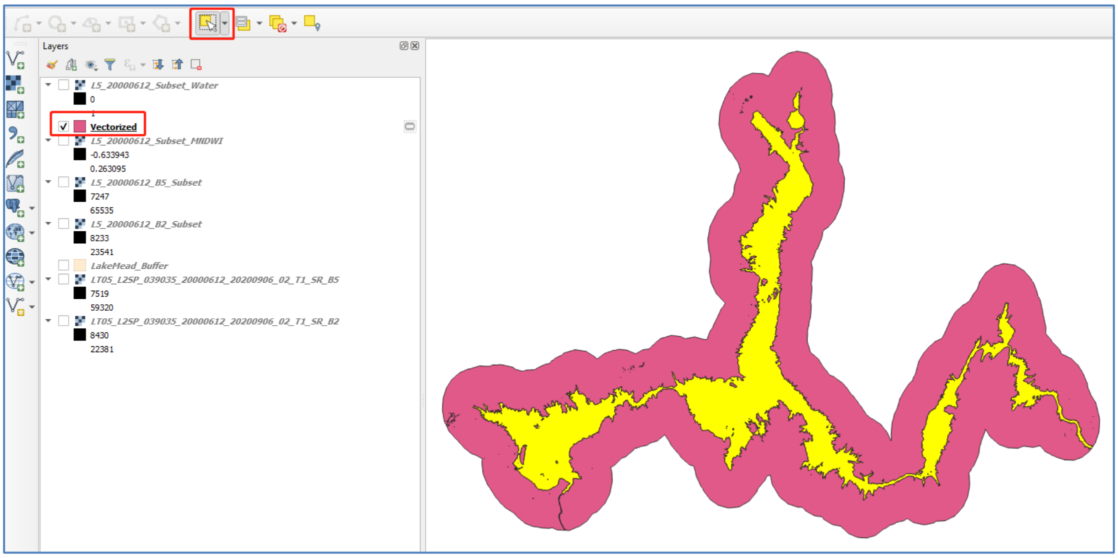



Figure 13. Extracting the lake outline in QGIS

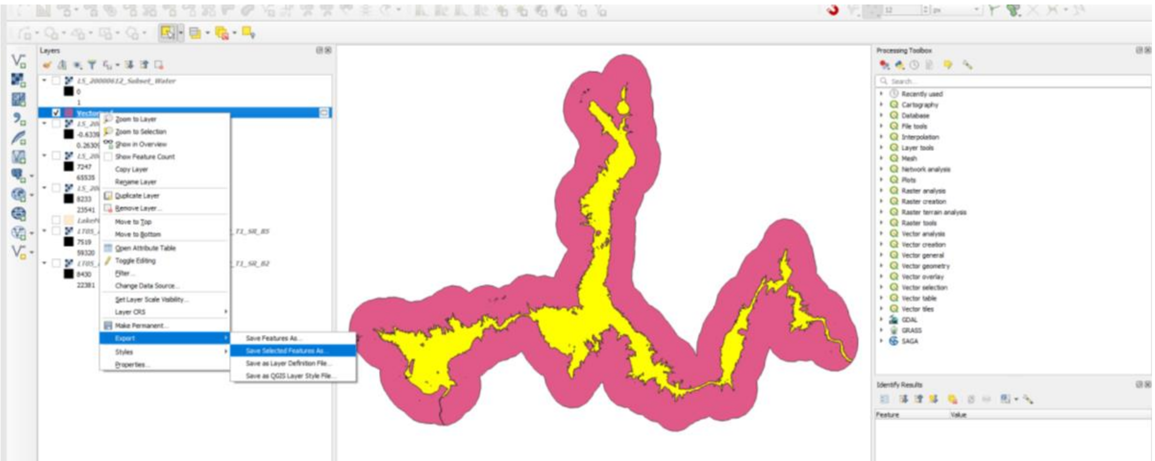


Figure 14. Saving selected feature to local folder in QGIS

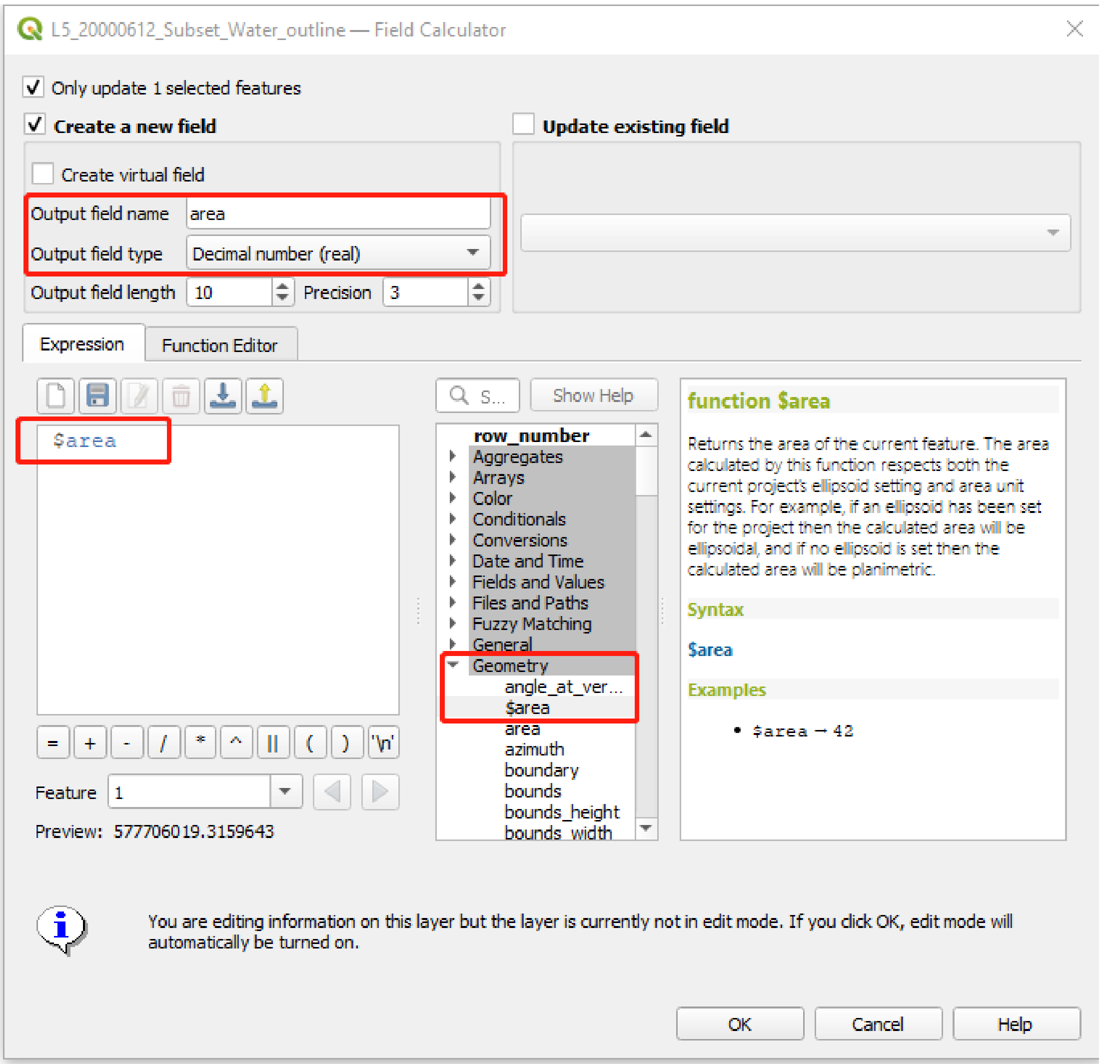



Figure 15. Calculating the surface area of lake outline in QGIS

## Online activities

## Sustainable contact:

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## References (if any):

## Assessment (if any):

Not necessary