Centre for Research and Technology Hellas
Information Technologies Institute

Workshop on Changes in Wetland and Floating Vegetation Cover followed by training event on space image processing

Tutorial on 'Hydroperiod estimation for wetland areas using spaceborne time series imageries'

Date: 16-06-2022

Lecturer: Dr. Ioannis Manakos, Researcher Grade B' / Topic: Remote Sensing
Tutorial Material prepared in cooperation with MSc Katsikis Eleftherios and MSc Michail Sismanis

References: This training material was generated according to the training material that was initially produced for the needs of the training of Protected Area Management personnel by Dr. Ioannis Manakos and Dr. Georgios Kordelas for the needs of ECOPOTENTIAL project and used in the training that took place in Pisa in 20-02-2018.

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1. **Title**: Hydroperiod estimation for wetland areas using spaceborne time series imageries
2. **Aim:** This course aims to show the process followed to generate hydroperiod maps, which count the days a pixel is covered by water within a defined period for Ukraine (Odessa area) utilizing Sentinel-2 data. The hydroperiod maps may be showcased.
3. **Prerequisites:** None
4. **Learning Outcomes:**
   • Enhance understanding in Remote Sensing and develop capacity for critical thinking and utilizing its tools;
   • Ability to theoretically tackle with and plan Remote Sensing application for inland water delineation;

- Communicate knowledge and experiences to specialists within a research working group to confront with an issue that requires an integrated approach;
- Be able to improve knowledge and capacity in a self-directed or autonomous manner.

5. **Syllabus:** This tutorial examines electromagnetic radiation and its interaction with the Earth's surface and the performance of passive (i.e. Sentinel-2 spaceborne data) imaging systems. It focuses on digital image processing. Emphasis is placed on the extraction of the hydroperiod of a Protected Area (PA) by interpolating series of water masks, which are generated using Sentinel-2 (S2) data acquired on dates falling in the time period between the set starting and the ending date of hydroperiod. The water masks are produced by automatically detecting and applying thresholds on the SWIR band, and on the NDVI index, derived by radiometrically corrected S2 data.

6. **Component Delivery:** The tutorial shall be delivered through oral lecture supported by practical on screen implementation.

7. Timetable:
   - ~10' preprocessing: Image download, Crop & merge, Bands & Proxies, Histogram Thresholding
   - ~20' water mask generation: Multicriteria analysis, Ukraine case, Your case ?
   - ~10' hydroperiod map generation: Data take frequency, Resolution expectations, Interpolation in time, Ukraine case, Your case ?

8. Recommended reading:
   - G. Kordelas, I. Manakos, G. Lefebvre, B. Poulin, Automatic Inundation Mapping Using Sentinel-2 Data Applicable to Both Camargue and Doñana Biosphere Reserves, 2019, Remote Sensing Journal, 11(19), 2251, DOI: https://doi.org/10.3390/rs11192251
   - I. Manakos, G. Kordelas, K. Marini, Fusion of Sentinel-1 data with Sentinel-2 products to overcome non-favourable atmospheric conditions for the delineation of inundation maps", 2019, European Journal of Remote Sensing, DOI: 10.1080/22797254.2019.1596757
   - G. Kordelas, I. Manakos, D. Aragones, R. Diaz-Delgado, J. Bustamante, Fast and automatic data-driven thresholding for inundation mapping with Sentinel-2 data , 2018, Remote Sensing, 10, 910, DOI: 10.3390/rs10060910

9. Equipment & Software:
   - Laptop with Windows operating system
   - QGIS free and open-source cross-platform desktop GIS

General background for RS applications in inland water delineation in many languages: http://lms.seos-project.eu/learning_modules/resources/resources-c00-p02.html | http://lms.seos-project.eu/learning_modules/remotesensing/remotesensing-c00-p01.html |

http://lms.seos-project.eu/learning_modules/earthspectra/earthspectra-c00-p01.html

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I. Preprocessing

Image download

Sentinel-2 images can be downloaded from the following link:
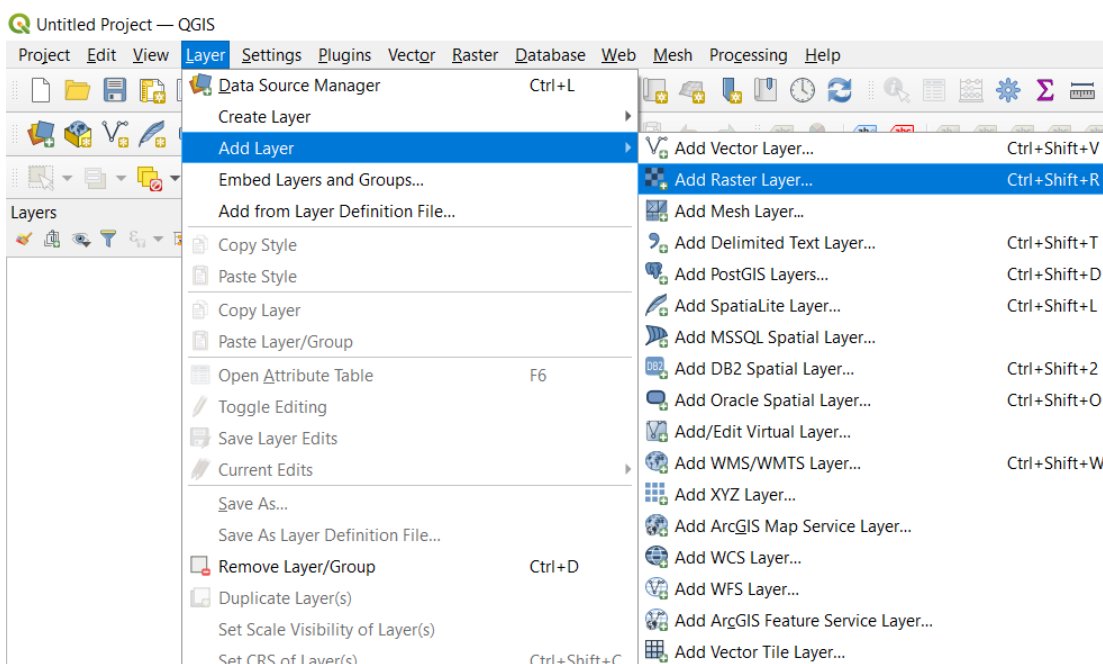
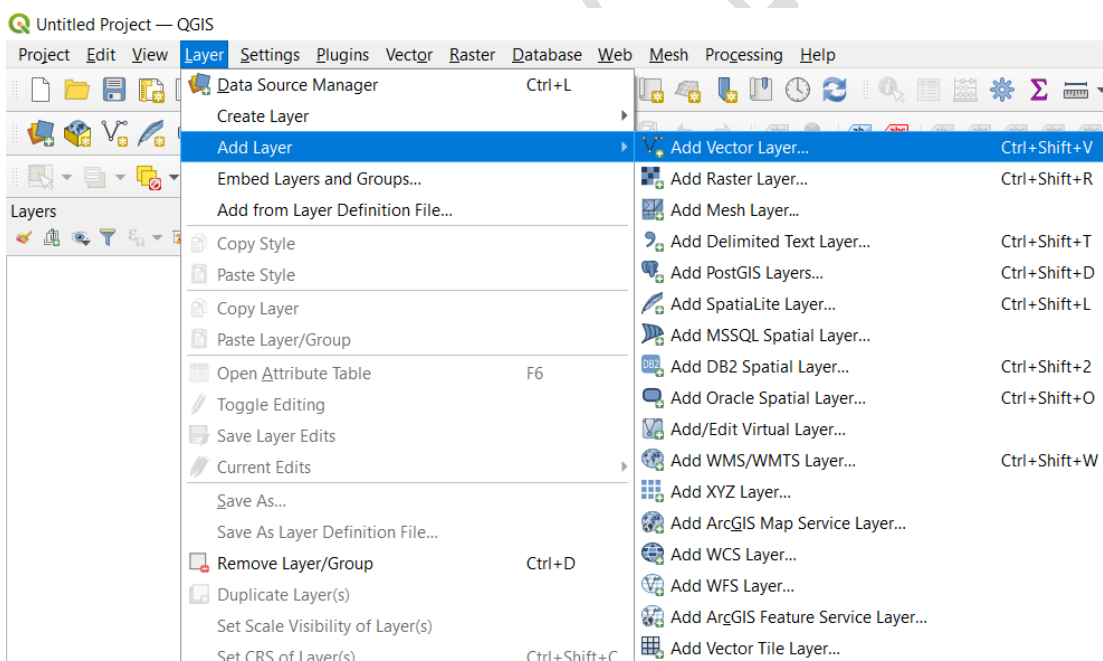https://scihub.copernicus.eu/dhus/#/home
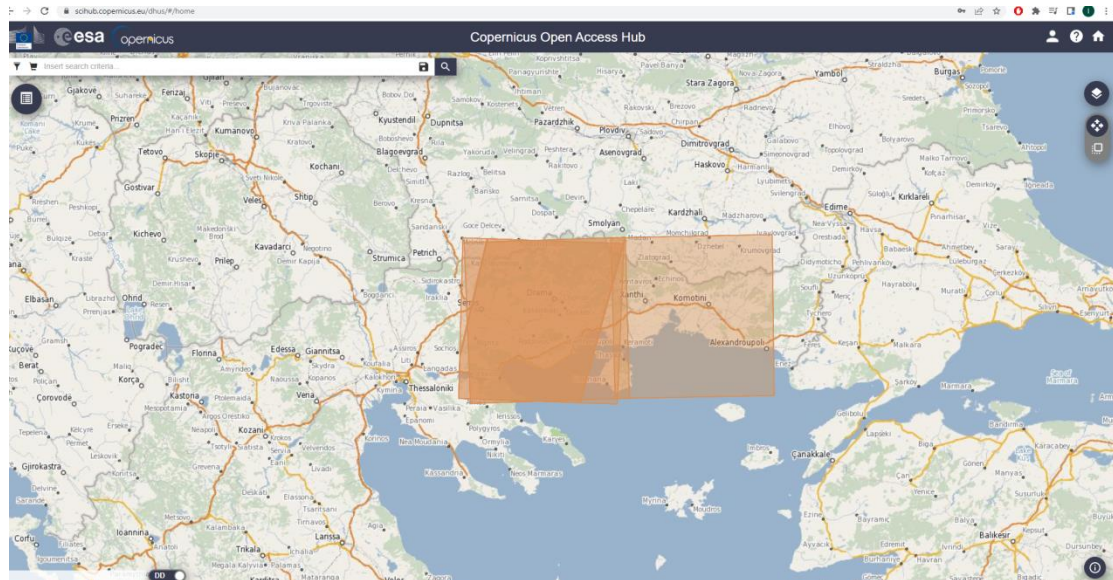
Steps:

1. Denoting the area of interest

2. Define the criteria for downloading data (Sensing Period, Cloud Coverage, etc.)

Add layers

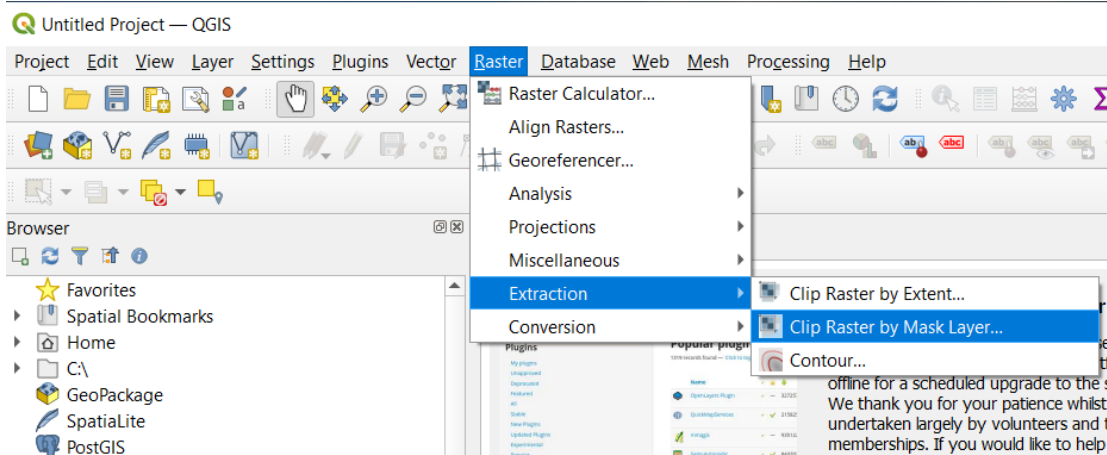1. Add raster layer as shown below:

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2. Add the shape file as shown below:

Crop to the boundaries of the shapefile

1. Clipper is initially selected as shown below:

2. Inputs/Outputs:

(a) Insert path to input layer (pick one of the ".jp2"),

(b) Insert path of the mask layer (select the .shp file),

(c) check box "No data value" and set value to -1

(d) check "Match the extent of the clipped raster to the extent of the mask layer" and "keep resolution of input layer"

(e) Insert path to Clipped (mask) to save the output

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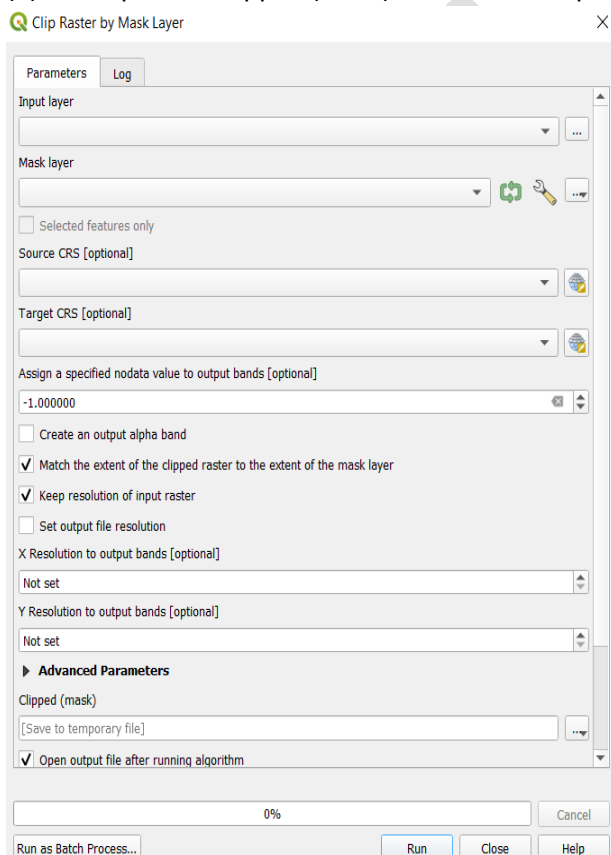
Bands and Proxies estimation

Sentinel-2 Bands	Central Wavelength (µm)	Resolution (m)	Bandwidth (nm)
Band 1 – Coastal aerosol	0.443	60	20
Band 2 – Blue	0.490	10	65
Band 3 – Green	0.560	10	35
Band 4 – Red	0.665	10	30
Band 5 – Vegetation Red Edge	0.705	20	15
Band 6 – Vegetation Red Edge	0.740	20	15
Band 7 – Vegetation Red Edge	0.783	20	20
Band 8 – NIR	0.842	10	115
Band 8A – Narrow NIR	0.865	20	20
Band 9 – Water vapour	0.945	60	20
Band 10 – SWIR – Cirrus	1.375	60	20
Band 11 – SWIR	1.610	20	90
Band 12 – SWIR	2.190	20	180

1. Raster Calculator is initially selected as shown below:
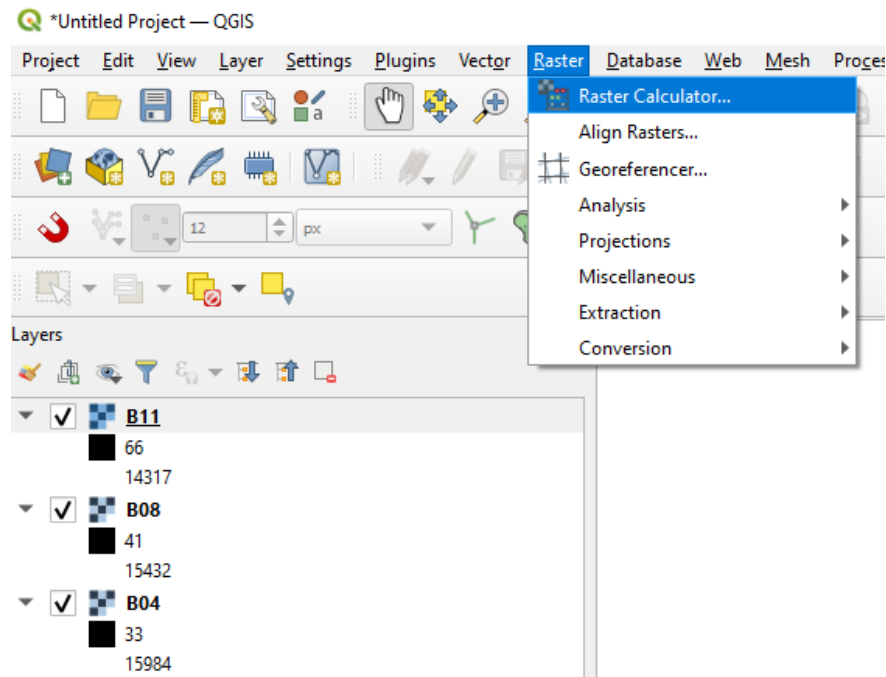
2. Via raster calculator different proxies may be estimated and different thresholding may be applied.

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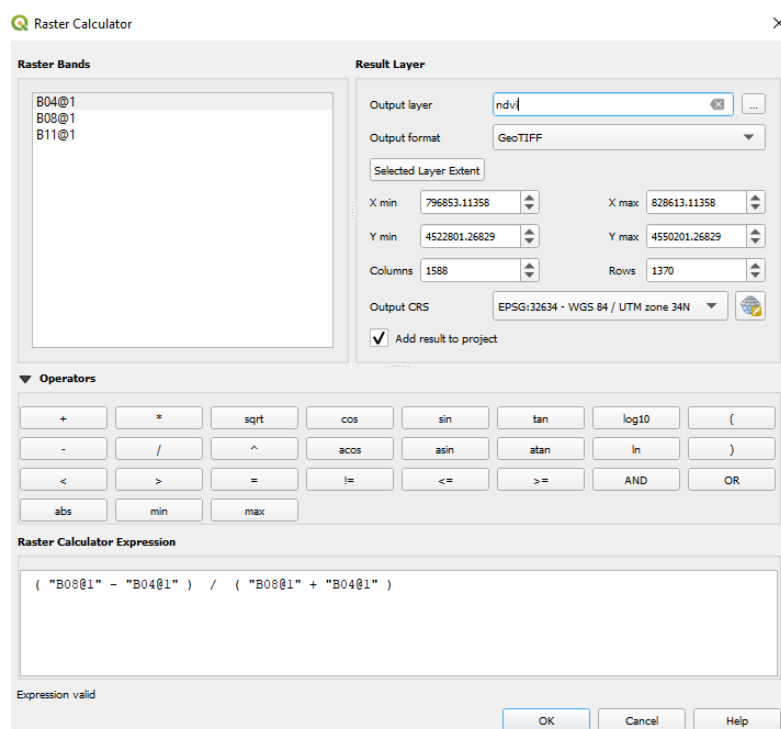
E.g.: ("B08@1" - " B04@1") / (" B08@1" + " B04@1")

As output layer give the name NDVI and select the path to be saved.

II. Water mask generation

Multicriteria Analysis

Multicriteria analysis aims to identify pixels of water (open water or water with sparse vegetation) and water-vegetation (water with emergent dense vegetation) categories

Water Detection

In SWIR band lower values corresponding to water covered areas can be separated from other areas by applying thresholds on SWIR histogram. SWIR is better for delineating water in wetlands, since it less sensitive to sediment-filled waters and therefore more suitable for delineating the boundaries between water and dry ground in shallow wetland areas (*Díaz-Delgado, R., Aragonés, D., Afán, I., Bustamante, J. (2016). Long-term monitoring of the flooding regime and hydroperiod of Doñana marshes with Landsat time series (1974–2014). Remote Sensing, 8(9), 775.*). CERTH has verified this claim by comparing masks generated relying on S2 data.
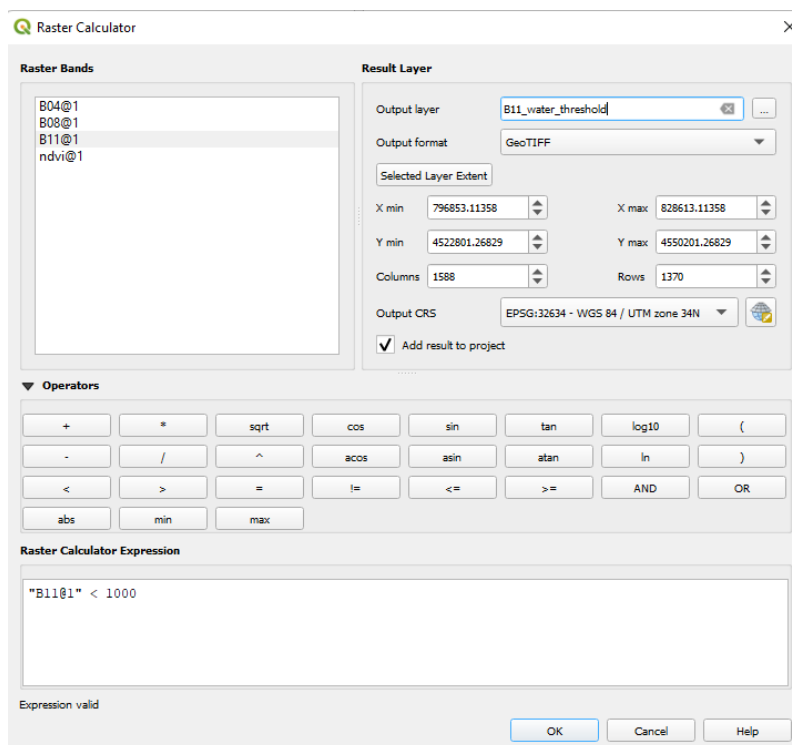
SWIR histogram visualization:

On a layer on the Layers Panel->Right Click->Properties->Histogram. For Band 11 is estimated histogram:
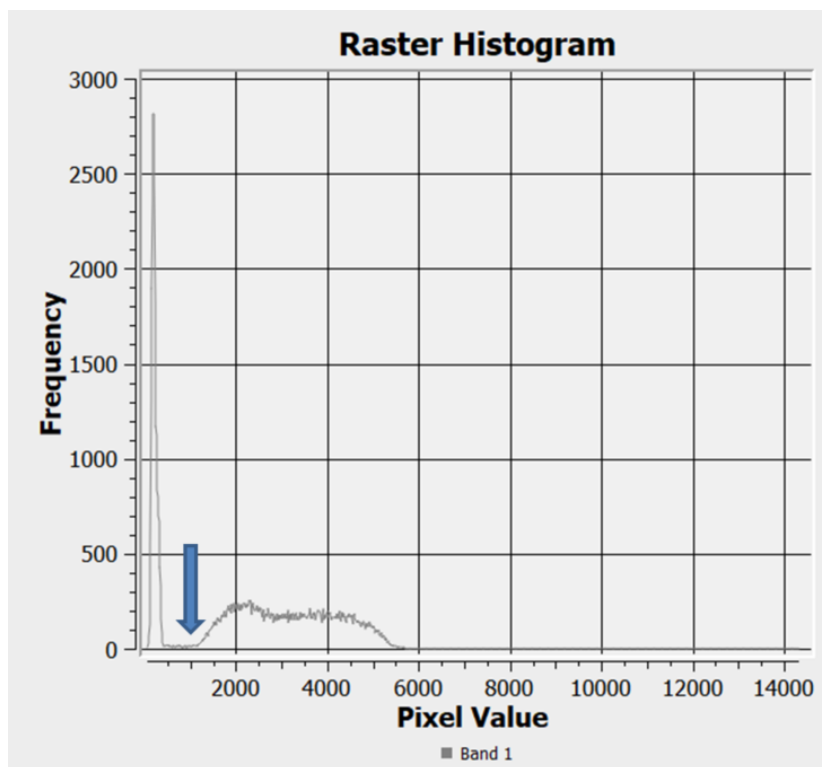
From the histogram it is shown that there is a deep valley around intensity 1000, which is useful for separating water from non-water covered areas.

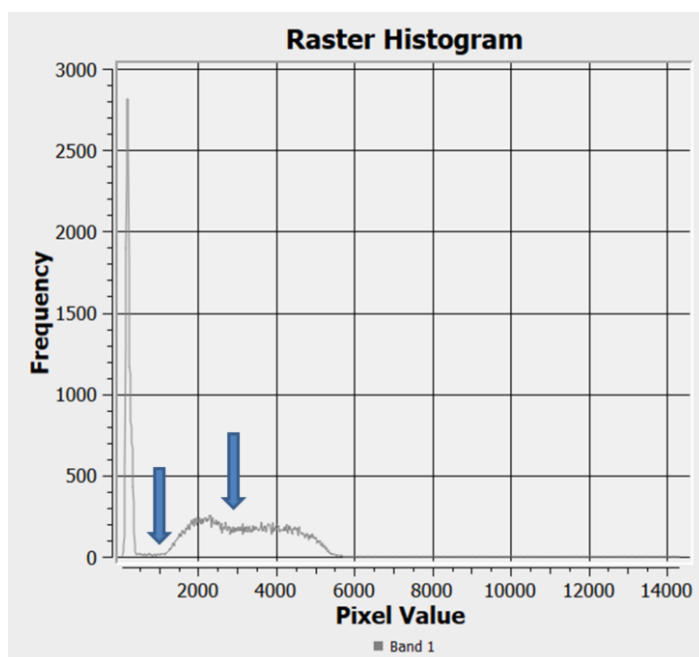To raster calculator run the command: ("B11@1"<1000)

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From the resulting mask it is obvious that the water has been successfully recovered. This mask is given in: "B11_water_threshold/B11_water_threshold_2020_08_06.tif"

Water-Vegetation Detection

SWIR values indicating the possible presence of water and vegetation

There are areas where water is covered by emergent dense vegetation. The SWIR value of the pixels in these areas is higher compared to the SWIR values of the pixels having water or water with sparse vegetation. An upper threshold, which is the SWIR value for which the valley right after the first valley is detected in the SWIR histogram, is assumed to be the upper threshold for pixels comprising areas of water covered by dense vegetation. This threshold is evident in the histogram:

The mask with the pixels with SWIR values between these thresholds of this is found by executing in the Raster Calculator:
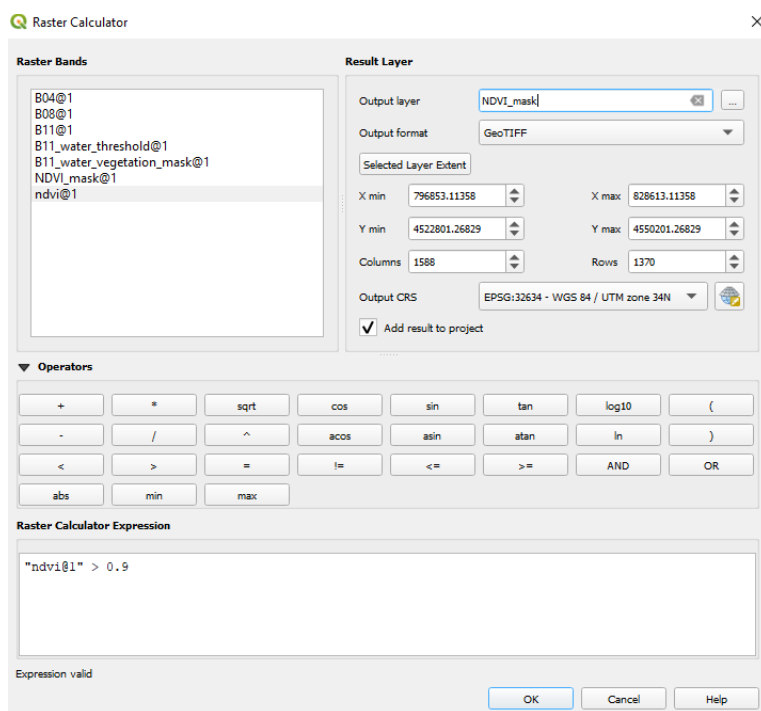
("B11@1">1000 AND "B11@1"<=3000)
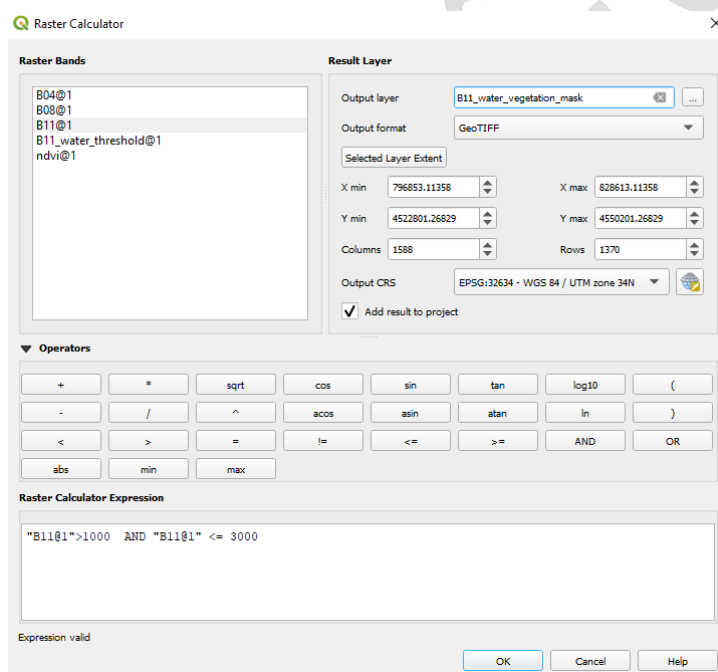
NDVI values indicating dense vegetation

At the same time is has to be ensured that vegetation is present. To identify the vegetated areas, it is estimated an NDVI threshold that should be over 0.3. The histogram of the NDVI is the following and the threshold is about 0.9:
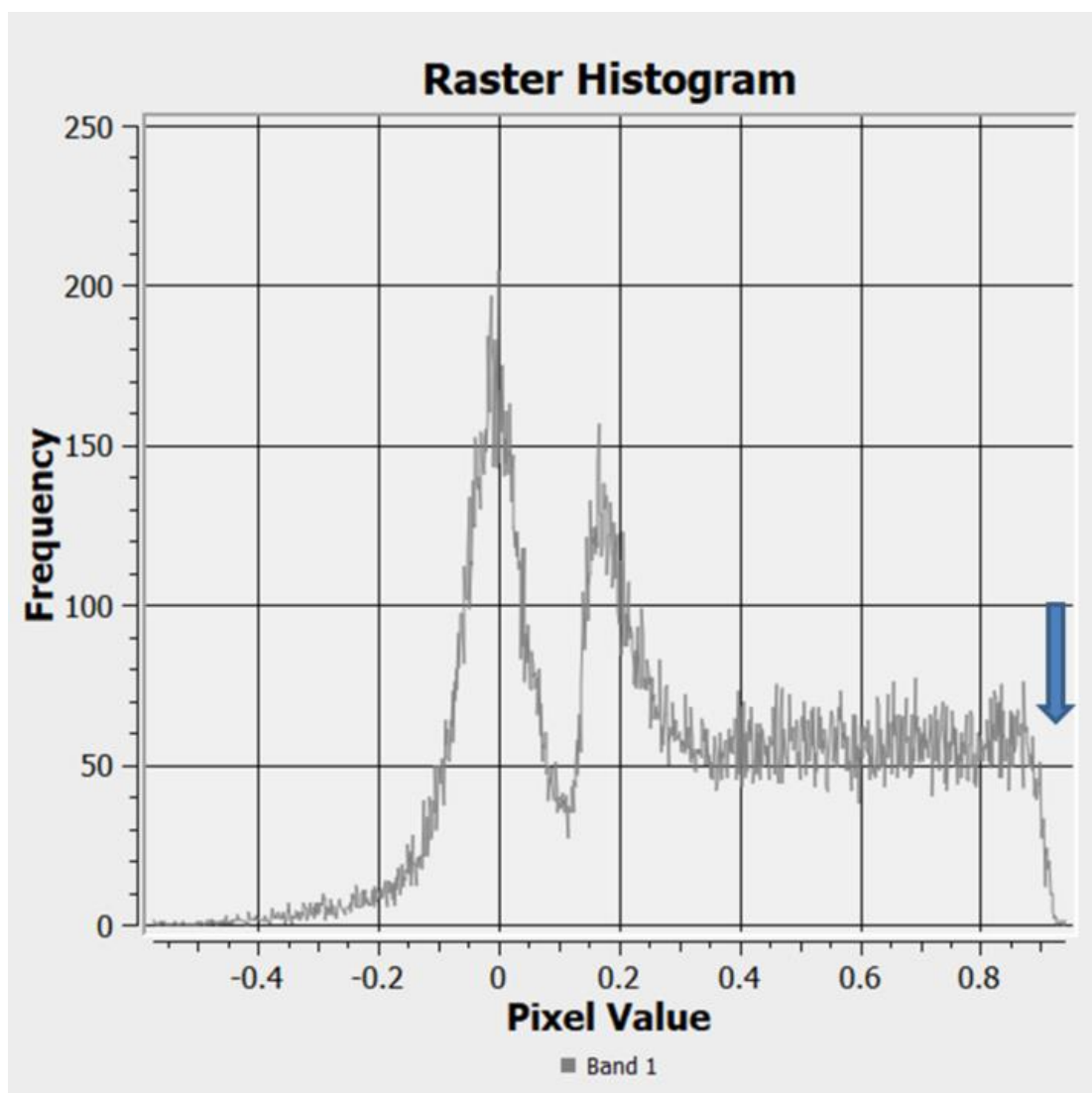
The mask with these pixels of this is found by executing in the Raster Calculator:
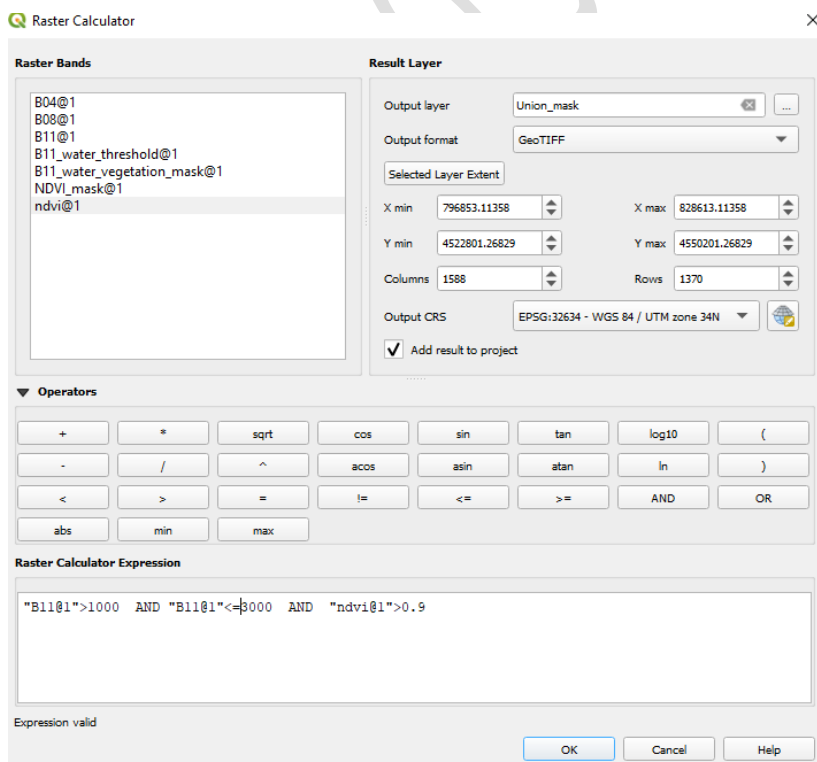
("NDVI@1">0.9)

Combination of SWIR and NDVI thresholds for identifying water-vegetation pixels

The pixels that belong to the water-vegetation category can be found by applying the above thresholds at the same time:

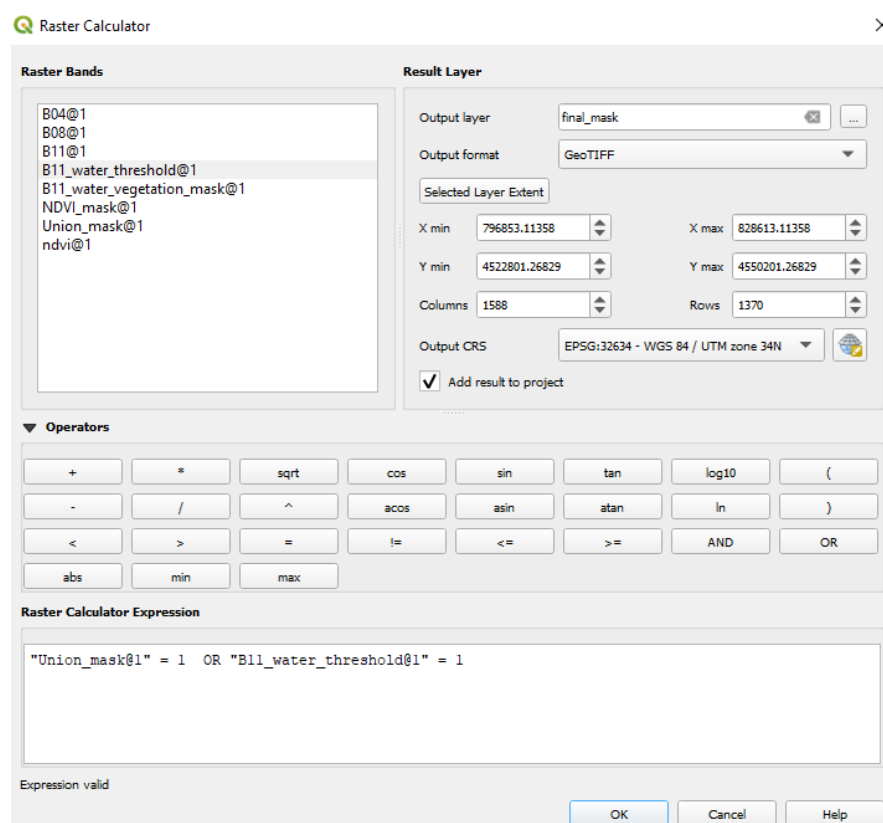("B11@1">1000 AND "B11@1"<=3000 AND "NDVI@1">0.9)

The final mask comprising pixels of both categories may be found by:

("Union_mask@1"=1 OR "B11_water_threshold@1"=1)

III. Hydroperiod map generation

Data Take Frequency

Sentinel-2 constellation revisits an area every 5 days (depending the location on the Earth this may vary). Sentinel-2A was launched on 23 June 2015, while Sentinel-2B was launched on 7 March 2017. However, the exploitation of acquired S-2 is hindered by the presence of clouds, reducing the frequency of usable data takes. Thus, the frequency can be increased by estimating water masks relying on Sentinel-2 data. The difficulties of using SAR data is that the backscatter signal is low for specific regions (i.e. sand dunes, bare ground) and these regions may be misidentified as inundated. CERTH's next training course may be to demonstrate work on the fusion of S1 and S2 data for improving the accuracy of water detection based on S1 data.

Resolution Expectation

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The resolution of the generated S2 masks can reach up to 10m, which is improved in comparison with the respective Landsat masks, that are 30m.

Interpolation in time

The hydroperiod is generated from series of water masks, which are estimated for dates falling in the time period between the starting and the ending date of hydroperiod, by applying the following interpolation approach. For two dates separated by n days, the occurrence of water is compared. If a pixel is inundated on both dates, then it is assumed inundated for n-days, but n/2 days otherwise. The total number of days of inundation is determined by accumulating the water masks throughout the year.

For the water masks between 01/03/2021 and 10/05/2021 the difference is 70 days. Therefore the interpolated map will be:

```
( "2021_03_01@1"=1 AND "2021_05_10@1"=1)*70 +
( "2021_03_01@1"=1 AND "2021_05_10@1"=0)*70/2 +
( "2021_03_01@1"=0 AND "2021_05_10@1"=1)*70/2
```

Q Raster Calculator   ✕

Raster Bands   **Result Layer**

```
2021_03_01@1
2021_05_10@1
2021_06_24@1
```

Output layer	hydroperiod1 ⊗ ...
Output format	GeoTIFF ▼

Selected Layer Extent

X min	796843.13169	X max	828623.13169
Y min	4522801.26829	Y max	4550201.26829
Columns	3178	Rows	2740

Output CRS   EPSG:32634 - WGS 84 / UTM zone 34N ▼ 🌐

☑ Add result to project

▼ Operators

| +	*	sqrt	cos	sin	tan	log10	(
-	/	^	acos	asin	atan	ln	)
<	>	=	!=	<=	>=	AND	OR
abs	min	max					

Raster Calculator Expression

```
( "2021_03_01@1"=1  AND "2021_05_10@1"=1)*70 +  ( "2021_03_01@1"=1  AND "2021_05_10@1" = 0)*70/2
+  ( "2021_03_01@1"=0  AND "2021_05_10@1"=1)*70/2
```

Expression valid

OK   Cancel   Help

For the water masks between 10/05/2021 and 24/06/2021 the difference is 44 days. Therefore the interpolated map will be:

```
("2021_05_10@1"=1 AND "2021_06_24@1"=1)*44 +

("2021_05_10@1"=1 AND "2021_06_24@1"=0)*44/2 +

("2021_05_10@1"=0 AND "2021_06_24@1"=1)*44/2
```
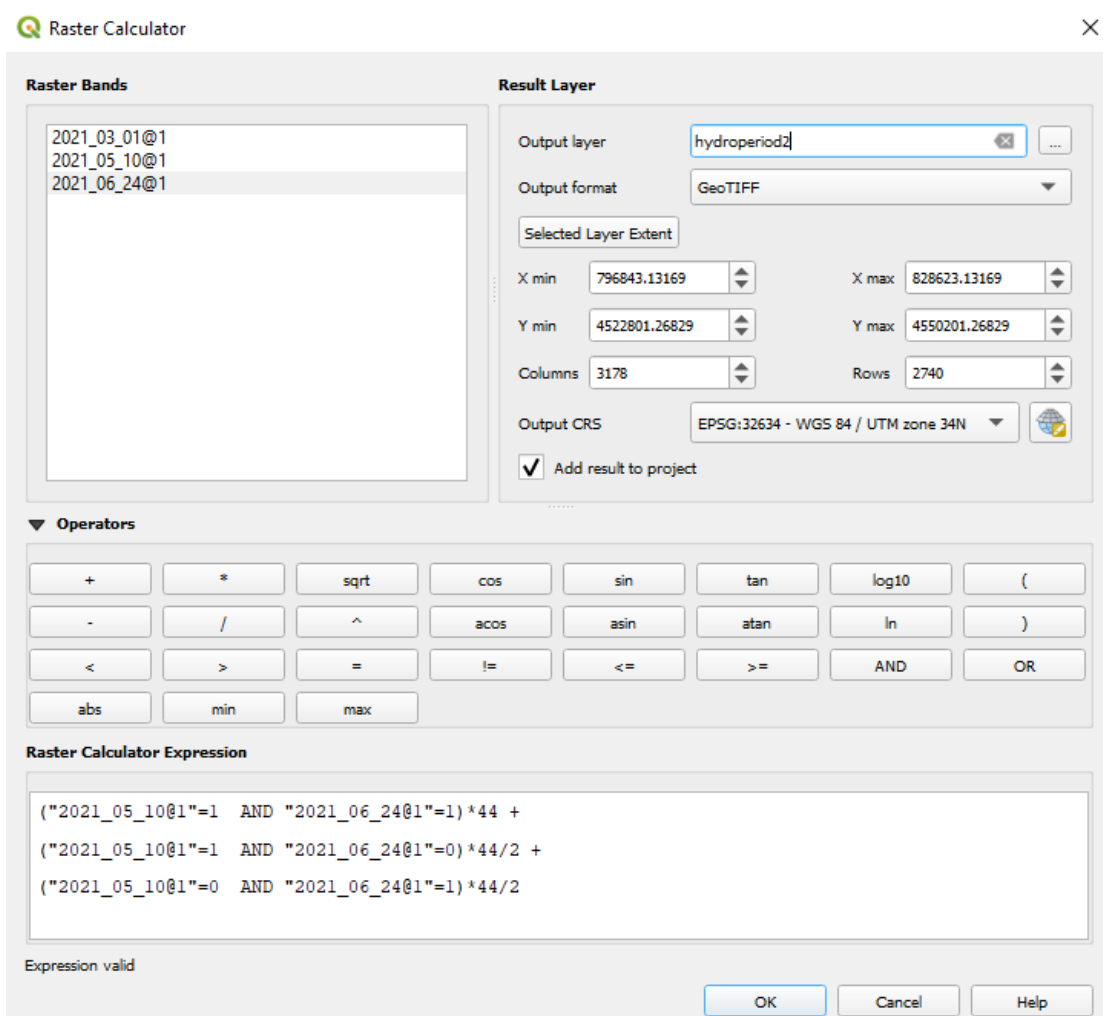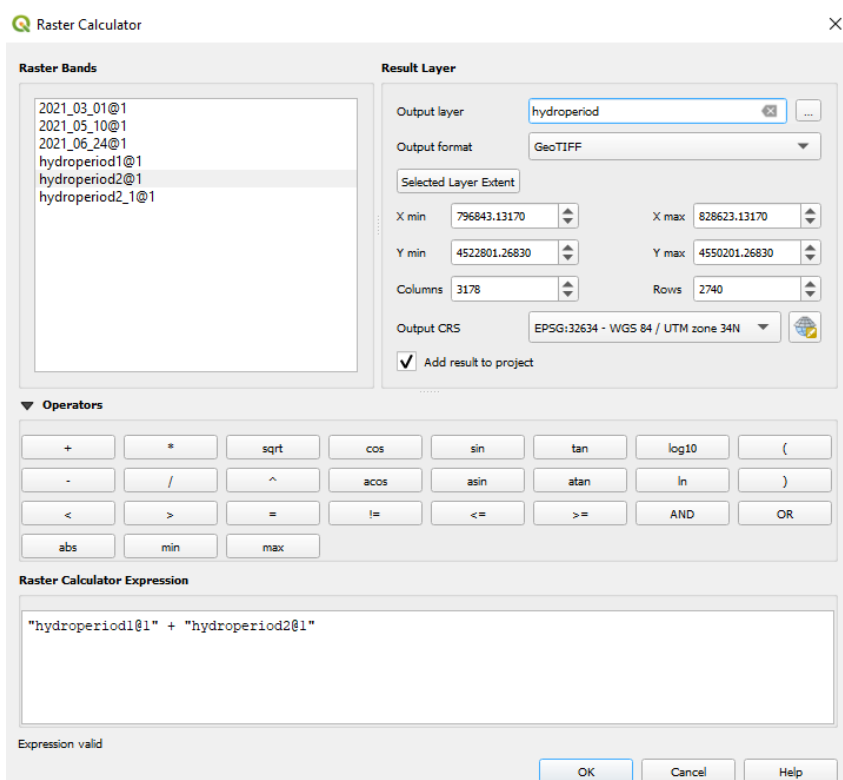
The interpolated maps for 01/03/2021 to 10/05/2021 and 10/05/2021 to 24/06/2021 are saved in Hydroperiods folder.

By adding all interpolated map within the duration of an annual period is estimated the hydroperiod map.

The interpolation map between 01/03/2021 to 24/06/2021 can be calculated by:

```
"hydroperiod1@1" + "hydroperiod2@1"
```

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Please acknowledge when referring to this material as: "Manakos I., Katsikis E., Sismanis M., 2021. Tutorial on 'Hydroperiod estimation for wetland areas using spaceborne time series imageries'. Training Webinar of ENI CBC BSB PONTOS project, funded by the European Union through the ENI CBC Black Sea Basin Programme 2014-2020."

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