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GOOGLE EARTH ENGINE IN WATER RESOURCES MANAGEMENT

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ABSTRACT: *The article proposes the use of facilities offered by the Google Earth Engine platform for the study and analysis of problems and documentation of decisions in the field of water resources management. The features of the Google Earth Engine (GEE) platform are presented, including the input of data sources, and their use is exemplified by implementing automated procedures using the JavaScript language. Available geospatial data are processed for the purpose of identifying and monitoring water bodies using the Automated Water Extraction Index (AWEI).*
Keywords: *Google Earth Engine (GEE); remote sensing; AWEI (Automated Water Extraction Index); drought monitoring*;

1. Introduction

Google Earth Engine is a web-based Cloud Computing platform created by Google for large-scale geospatial data processing and analysis. It allows users to apply image processing and geospatial analysis algorithms using Python and JavaScript to large geospatial datasets stored in the cloud. Access is free for research, education and non-profit organizations. Commercial versions are available for companies. The web interface allows users to view and explore data, create and run scripts for processing, and export results.

Choosing the right level of processing depends on the availability of data, the type of analysis and the available image corrections. The geospatial data available within the GEE platform is remote sensing data collected by satellite sensor systems. The data are organized in collections (catalogues), for different geographical areas, time periods, types of sensors or bands of the electromagnetic spectrum used. For example, the data characterizing the atmosphere or the land surface are organized separately, as a standalone collection. Thus, the users can find easier the information they need for various applications. Grouping by multiple criteria facilitates the quick retrieval of data specific to a certain issue or area of interest.

Remote sensing includes methods of acquiring, measuring, recording and viewing images resulting from electromagnetic radiation emitted, reflected or transmitted by objects and phenomena on Earth. The information obtained through remote sensing can be used in various fields, such as agriculture, environment and conservation, geology, topography, meteorology, urban planning and spatial planning, management of natural resources of water, soil and forests, transportation and infrastructure, security and defense. The Sentinel-2 satellite remote sensing program provides high-resolution, wide-coverage imagery at a global refresh frequency of 5 days. Sentinel-2 provides free high-quality data with multiple levels of spatial resolution. The data is processed in different levels, each level providing different information about the image data. Atmospheric correction of Sentinel-2 imagery includes correction for the dispersion of air molecules (Rayleigh dispersion), absorption and scattering effects of atmospheric gases, especially ozone, oxygen and water vapors, and correction for absorption and scattering due to aerosol particles. The two main levels are Level-1C and Level-2A.

Level-1C: This processing level provides orthorectified top-of-atmosphere (TOA) reflectance data with sub-pixel multispectral recording. The cloud mask and the dry/water mask are included in the product. Level-1C data are radiometrically corrected to ensure consistency and calibration.

Level-2A: This level of processing provides radiometrically and atmospherically corrected Earth surface reflectance images. Each Level-2A product is composed of 110x110 km² tiles. Level-2A data are suitable for analyzes that require atmospheric correction, such as vegetation analysis or terrain classification.

2. Material and Method

The Google Earth Engine catalog provides a wide range of data, including satellite imagery, meteorological data, geographic data, and modeling data. The catalog can also be used to document data availability and find information about terms of use. The main features of this data are spatial resolution, temporal repeatability, free access and global availability. Once the data of interest has been identified, users can retrieve it into the platform for analysis and processing. Google Earth Engine provides a variety of tools and features to help users carry out these activities (Fig. 1).

following bands:
- BLUE (B2);
- GREEN (B3);
- NIR (B8);
- SWIR1 (B11);
- SWIR2 (B12).

The blue band is sensitive to blue light, which is reflected by water at a higher intensity than by other materials. The green band is sensitive to green light, which is reflected by water at a lower intensity than by other materials. The difference between reflectance in the blue band and reflectance in the green band is used to identify water bodies. Water has a higher reflectance in the blue band than in the green band. Therefore, AWEI values greater than 0, indicate the presence of water.

AWEI - automatic water extraction index in binary mode calculates value 0 or 1 depending on the areas where water is found. In general, the blue and green bands are used to identify water bodies in satellite images because they are sensitive to blue and green light, which are reflected by water in a characteristic way. These

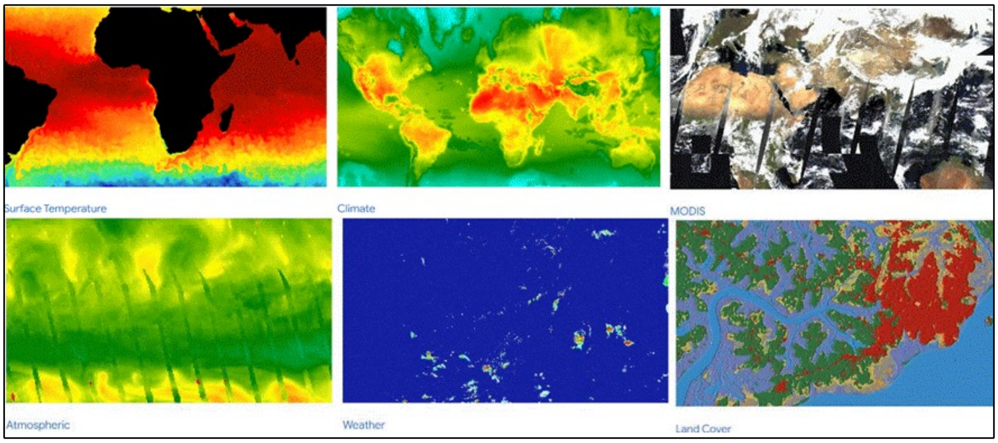


Fig. 1. Earth Engine Data Catalog

In this article, for the analysis of remote sensing information that can be used in water resources management, we have used the Automated Water Extraction Index (AWEI). AWEI is a valuable tool for identifying water bodies in satellite imagery and can be used for a variety of applications such as:
- Mapping and monitoring of water resources;
- Detecting changes in the extent and volume of water;
- Flood risk assessment;
- Sustainable management of water resources.

The AWEI value is calculated using the

bands are also relatively robust to noise and artifacts in satellite imagery and are available on most satellite sensor systems.

NIR stands for near-infrared. It is a region of the electromagnetic spectrum that lies between the visible spectrum and the infrared spectrum. NIR has a wavelength between 700 and 1,000 nanometers. In satellite imagery, NIR is used to identify a variety of features, including vegetation, soil, snow, and water.

Vegetation strongly reflects NIR light, meaning it has a higher reflectance in this band than in other spectral bands. NIR is used to create vegetation indices such as NDVI and EVI. These indices are used to measure vegetation health and productivity.

Soil has lower NIR reflectance than vegetation. This is because soil absorbs more NIR light than vegetation. NIR can be used to identify soil types and measure soil moisture.

Snow has a very high reflectance in the NIR. This is because snow effectively reflects NIR light. NIR can be used to identify snow and measure snow thickness.

Water has lower reflectance in the NIR than vegetation, soil and snow. This is because water absorbs more NIR light than these materials. NIR can be used to identify water bodies.

SWIR1 and SWIR2 are shortwave infrared (SWIR) bands that are used in satellite imagery to identify a variety of features, including water bodies, vegetation, soil, and snow. SWIR1 has a wavelength of 1,610-1,680 nanometers, while SWIR2 has a wavelength of 2,100-2,200 nanometers. Both bands are sensitive to light in the infrared spectrum that is absorbed by water molecules.

Water bodies strongly absorb light in the infrared spectrum, meaning they have low reflectance in these bands. Vegetation, on the other hand, effectively reflects light in this wavelength range, meaning it has higher reflectance in these bands. Soil and snow have intermediate reflectance in the SWIR bands. SWIR1 and SWIR2 are commonly used to generate vegetation indices such as NDVI and EVI. These indices are used to measure vegetation health and productivity. SWIR1 and SWIR2 are also used to identify bodies of water. Thus, the Automatic Water Extraction Index (AWEI) uses the difference between reflectance in the SWIR1 band and reflectance in the SWIR2 band to identify water bodies.

The formula for calculating the AWEI is as follows:

$$AWEI = 4\cdot(GREEN - SWIR2) - (0.25\cdot NIR + 2.75\cdot SWIR1) \quad (1)$$

For the calculating of the AWEI, pixel values must be converted to reflectance. Multiplying the pixel values by the scale factor gives us the reflectance value. The scale factor value is 0.0001 for Sentinel-2 data. Once the reflectance have been calculated, the AWEI can be calculated using the above formula.

3. Case studies

3.1. Case study 1: Generating the AWEI script and testing it on a watershed

In the first phase, an asset was created in the code editor in GEE. In GEE, an "asset" is a geospatial data resource or data set that can be uploaded, stored, managed and used in GEE for geospatial analysis and processing. Assets can include satellite imagery, vector data, shapefiles, terrain data, and more (Fig. 2).

For this case study, a vector map (shape file type - Fig. 3) representing the Bahlui catchment was uploaded, in order to customize the script strictly on a well-defined area (Fig. 4).

The steps to implement the AWEI script are:

1. A vector data set containing the geometry and names of the hydrographic basins is loaded. This is stored in the variable "bh".

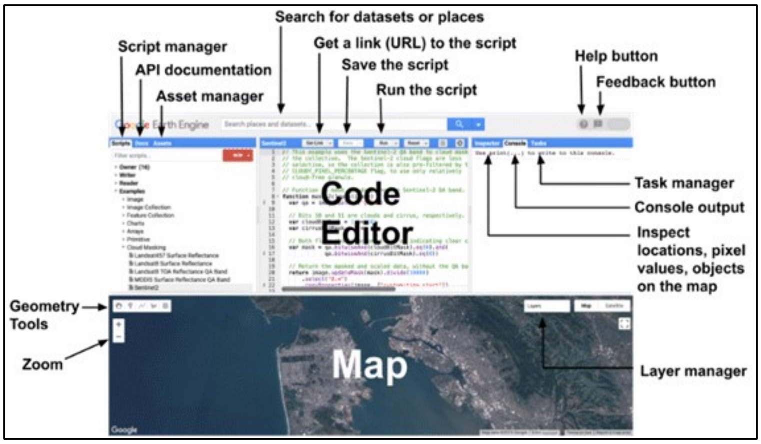


Fig.2. Code Editor in Google Earth Engine

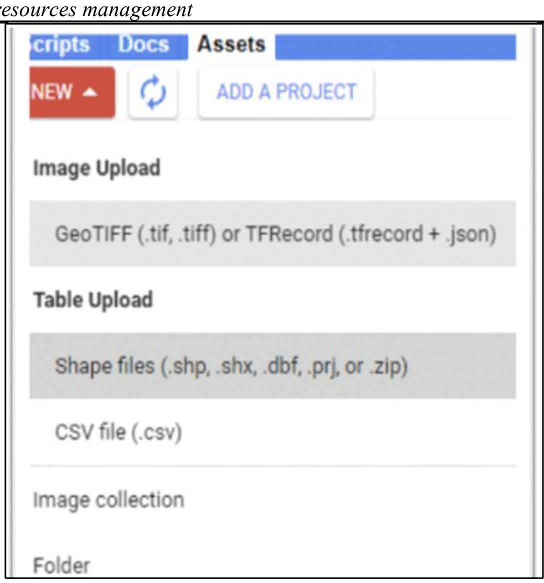
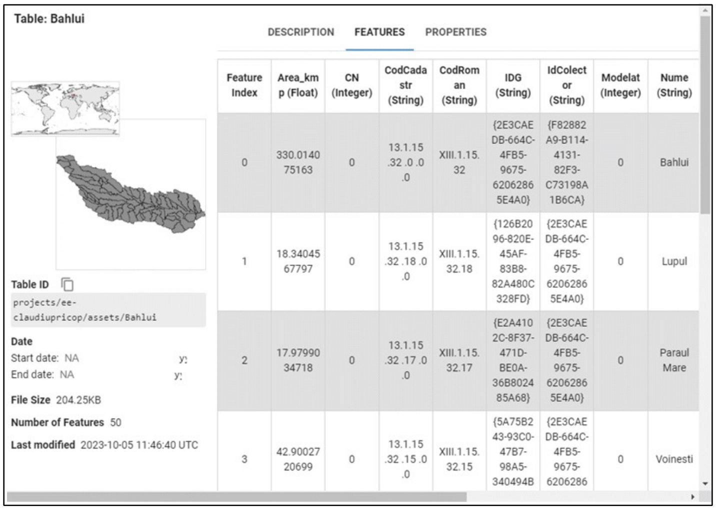


Fig. 3. Asset - Shape file



Feature Index	Area_kmp (Float)	CN (Integer)	CodCadastr (String)	CodRoman (String)	IDG (String)	IdColector (String)	Modelat (Integer)	Nume (String)
0	330.014075163	0	13.1.15.32.0.0.0	XIII.1.15.32	{2E3CAEDB-664C-4FB5-9675-62062865E4A0}	{F82882A9-B114-4131-82F3-C73198A1B6CA}	0	Bahlui
1	18.3404567797	0	13.1.15.32.18.0.0	XIII.1.15.32.18	{126B2096-820E-45AF-83B8-82A480C328FD}	{2E3CAEDB-664C-4FB5-9675-62062865E4A0}	0	Lupul
2	17.9799034718	0	13.1.15.32.17.0.0	XIII.1.15.32.17	{E2A4102C-8F37-471D-BE0A-36B802485A68}	{2E3CAEDB-664C-4FB5-9675-62062865E4A0}	0	Paraul Mare
3	42.9002720699	0	13.1.15.32.15.0.0	XIII.1.15.32.15	{5A75B243-93C0-47B7-98A5-340494B	{2E3CAEDB-664C-4FB5-9675-6206286	0	Voinesti

Fig.4 Asset - Vector map for Bahlui catchment

2. Filter the table by the pool name "Bahlui" using .filter() and store the result in "selected".
3. Extract the geometry of the Bahlui basin from the "selected" object using .geometry() and store it in the "geometry" variable.
4. A collection of Sentinel 2 images, stored in "sentinel", is loaded.
5. Filter the image collection by the Bahlui Basin using .filter() with geometry boundaries. It is also filtered by clouds and date. The result is in "filtered".
6. Create a median image from the filtered collection using .median() and clip it to the geometry with .clip(). The result is in "image".
7. Calculate the AWEI value on the filtered image, using the formulas given in the comments. The result of the AWEI value is stored in "awei".
8. 3 color palettes are defined for visualization: rgbVis, ndviVis, ndwiVis.
9. Center the map on the basin geometry with Map.centerObject().
10. Add the AWEI visual layer to the map with Map.addLayer(), using the ndwiVis palette.

Thus, a collection of images was filtered by a certain watershed, the AWEI value was calculated on the filtered image, and the result was displayed on the map (Fig. 5).

```
Water Extraction Index (AWEI) 4 Bahlui river basin        Get Link   Save   Run   Reset   Apps
Imports (2 entries)
  var bh: Table projects/ee-claudiupricop/assets/Bahlui_Intreg1949
  var sentinel: ImageCollection "Sentinel-2 MSI: MultiSpectral Instrument, Level-2A"
// Facem filtrare pe numele bazinului
var selected = bh.filter(ee.Filter.eq('Nume', 'Bahlui'));

// Obținem geometria bazinului
var geometry = selected.geometry();

// Filtrăm imaginea după limita bazinului
var filtered = sentinel.filter(ee.Filter.lt('CLOUDY_PIXEL_PERCENTAGE', 30))
  .filter(ee.Filter.date('2019-01-01', '2023-01-01'))
  .filter(ee.Filter.bounds(geometry));

// Decupăm imaginea mediană după geometria bazinului
var image = filtered.median().clip(geometry);

// Calculate Automated Water Extraction Index (AWEI)
// AWEI is a Multi-band Index that uses the following bands
// 'BLUE' (B2), GREEN' (B3), 'NIR' (B8), 'SWIR1' (B11) and 'SWIR2' (B12)
// Formula for AWEI is as follows
// AWEI = 4 * (GREEN - SWIR2) - (0.25 * NIR + 2.75 * SWIR1)
// Note:
// For the AWEI formula, the pixel values need to converted to reflectances
// Multiplyng the pixel values by 'scale' gives us the reflectance value
// The scale value is 0.0001 for Sentinel-2 dataset

var awei = image.expression(
    '4*(GREEN - SWIR1) - (0.25*NIR + 2.75*SWIR2)', {
      'GREEN': image.select('B3').multiply(0.0001),
      'NIR': image.select('B8').multiply(0.0001),
      'SWIR1': image.select('B11').multiply(0.0001),
      'SWIR2': image.select('B12').multiply(0.0001),

}).rename('awei');

var rgbVis = {min: 0.0, max: 3000, bands: ['B4', 'B3', 'B2']};
var ndviVis = {min:0, max:1, palette: ['white', 'green']};
var ndwiVis = {min:0, max:0.5, palette: ['white', 'blue']};

// Centrăm harta pe geometria bazinului
Map.centerObject(geometry,10);

// Adaugăm stratul vizualizat pe hartă
Map.addLayer(awei, ndwiVis, 'awei');
```

Fig. 5. AWEI (Automated Water Extraction Index) script for the Bahlui catchment

The AWEI formula is applied to the image using the "expression" function, which takes the pixel values of the green, near-infrared, short-infrared 1, and short-infrared 2 bands of the image and applies the formula to them. The resulting AWEI values are then stored in a new image band called "awei". The "rename" function is used to rename the band from the default name to "awei". Filtering the image by the basin boundary was done with:

"CLOUDY_PIXEL_PERCENTAGE DOUBLE Granule-specific cloudy pixel percentage taken from the original metadata", which refers to a metadata field in the Sentinel-2 MSI dataset: MultiSpectral Instrument, Level-1C provided by Google Earth Engine. This metadata field provides information about the percentage of cloudy pixels in a given grain, which is a single image acquired at a time. The percentage of cloudy pixels is calculated from the original grain metadata. The percentage of cloudy pixels is an important parameter for filtering images with many clouds, as it can be used to determine the quality of the image and whether it is suitable for further analysis. In general, the "CLOUDY_PIXEL_PERCENTAGE" metadata field is an important parameter for filtering images with high cloud cover and ensuring that only high-quality images are used for further analysis. The script also defines the display parameters for the image using the variables *"rgbVis", "ndviVis"* and *"ndwiVis".* These parameters are used to display the image on the map using the "Map.addLayer" function. The "rgbVis" variable is used to display the image in true color, while *"ndviVis"* and *"ndwiVis"* are used to display the *Normalized Differential Vegetation Index (NDVI) and the Normalized Differential Water Index (NDWI).*

The rgbVis, ndviVis, and ndwiVis variables are view variables used in the Google Earth Engine script to display an image on the map. These variables are defined manually and are not calculated from the image data. The rgbVis variable is defined by specifying the minimum and maximum values of the color intensity and by specifying the color bands used for the display. In this case, the minimum and maximum color intensity values are set to 0.0 and 3000, and the color bands used are B4, B3, and B2. The ndviVis variable is defined by specifying the minimum and maximum NDVI values and by specifying the color palette used for display. In this case, the minimum and maximum NDVI values are set to 0 and 1, and the color palette used is white and green. The ndwiVis variable is defined by specifying the minimum and maximum NDWI values and by specifying the color palette used for the display. In this case, the minimum and maximum NDWI values are set to 0 and 0.5, and the color palette used is white and blue. In general, the view variables are manually defined according to the user's needs and the available image data. As can be seen in the figure below, by changing the level/transparency filter, the areas where surface waters are located are identified on the map with the help of the AWEI (Fig. 6).

In the figure below, the automatic water extraction is highlighted, depending on the transparency and the time period for which the filtration is done. Areas circled in red represent filtering at a given date, over the extent of a reservoir, against the original mapping (in black) (Fig. 7).

3.2. Case study 2: Analysis of the impact of drought on water volumes

For this case study, we intended to make an assessment by comparison of the variation of the water surface of a reservoir, making the transition from a dry period to a normal one. The filtering necessary for the study was carried out with the help of the automatic extraction index (AWEI) (Fig. 8).

In the first image, taken on 2022-11-01, the reservoir has an area of 1,96 km². In the second image, taken on 2023-04-01, the reservoir has an area of 2,2051 km². This difference highlighted in April 2023 of 0.245 km² represents an increase of 11% of the surface of the reservoir corresponding to November 2022 (Fig. 9).

4. Results and discussion

In case study 1 the AWEI script was used to filter a collection of images by a specific

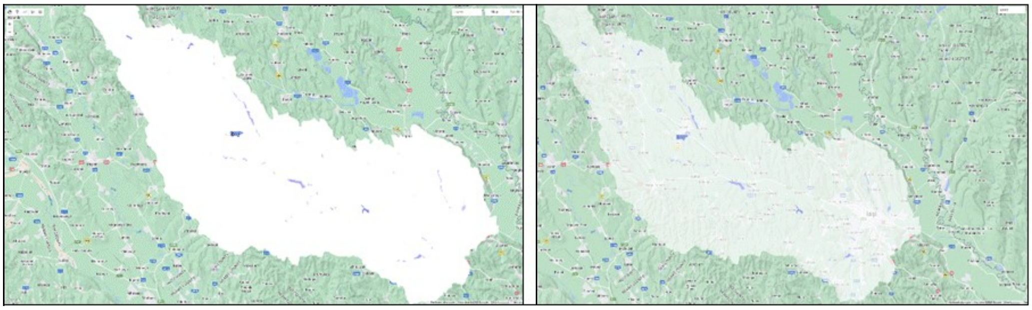


Fig. 6. Areas with the location of water bodies throughout the Bahlui catchment

Fig. 7. Automatic Water Extraction Index at a given date

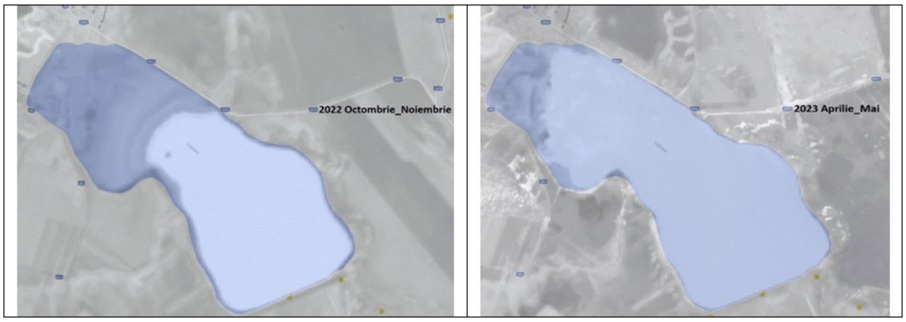


Fig. 8. Comparison of filtered images (a drought period with a normal period)

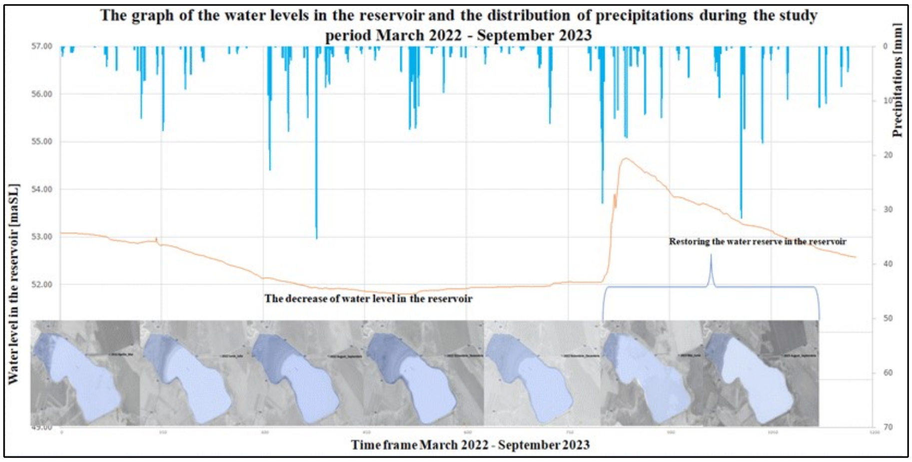


Fig. 9. Volume of water variation in the reservoir - spatial representation

watershed, calculating the AWEI index on the filtered image with geometry boundaries, clouds and date. Later, the result was displayed on the map depending on the transparency imposed by changing the filter and the time period for which the filtering was done. The images from 01.01.2019 and 01.01.2023 were chosen for comparison. The surfaces circled in red represent the filtering on 01.01.2019 on a reservoir, compared to the initial mapping highlighted in black, corresponding to the surface of the reservoir on 01.01.2023.

In case study 2 the AWEI script was used for the comparison of the water gloss surface variation of a reservoir that successively crossed a low water exploitation regime and then a medium water regime. The significant difference of the lake surface was calculated from the 2 images for which the automatic extraction index (AWEI) did the necessary filtering. Having available real measurements of the external stresses of the retention dam of the respective accumulation (precipitation produced in the area, water level in the lake), these parameters were graphically represented and were interpreted in correlation with the obtained filtered images. The surface differences between the two images are representative of the impact of the hydrological drought and can be attributed to several factors, such as:

- Precipitation. In the period between the two images, Romania territory experienced a period of abundant precipitation, which led to an increase in the water level in the reservoir.
- Evaporation. Evaporation is a natural process that can lead to a drop in the water level in the reservoir, but in this case it is likely to have been offset by heavy rainfall.
- Water intake from rivers. In the period between the two images, the flow of the rivers feeding the reservoir was probably higher.
- Climatic variations. In the period between the two images, Romania experienced a period of drought, which led to a decrease in the level and surface of the water.

5. Conclusions

The Automatic Water Extraction Index (AWEI) can help monitor and sustainable manage water resources in the context of climate change:

- AWEI enables automatic detection of water surfaces, including changes over time in the extent and volume of water resources. This information is essential for water management.
- Being calculated from satellite images, AWEI ensures real-time monitoring of water resources on a large scale, including in hard-to-reach areas.
- It can detect the effects of climate change such as drought, floods, melting glaciers, etc. on water resources.
- Information extracted through AWEI about water surfaces can be integrated into hydrological models to improve predictions and resource planning.
- Allows prioritization of management actions in areas identified as most affected by changes in water resources.
- Contributes to sustainable water use through continuous monitoring and early detection of changes, facilitating prompt response to balance water supply and demand.
- Can support efforts to conserve water resources and adapt to climate change through updated information on resource status.
- Water consumption: AWEI can be used to estimate water consumption from surface water sources. This information can be used to identify areas where water consumption is high and to take measures to reduce consumption.

The Automatic Water Extraction Index (AWEI) can help monitoring and sustainable management in the context of climate change by providing information on the amount and distribution of water in a given area. This can be useful to identify areas that are affected by drought or flooding and take water management measures accordingly. AWEI can also be used for monitoring available water resources for agriculture, potable water resource assessment, or environmental studies and natural resource conservation. In addition, AWEI can be used to identify areas with high potential for flooding or landslides and take preventive measures before they occur. Therefore, AWEI can be a valuable tool for monitoring and sustainable management of water resources in the context of climate change. Some of the advantages of using AWEI are:
It is simple and easy to calculate,

- It is effective in identifying water bodies in a wide range of environments, including urban, agricultural and natural areas,
- It is relatively robust to noise and artifacts in satellite imagery.

The extremely suggestive visualization of the change of the existing water surfaces in a reservoir at different time intervals can be a particularly valuable tool in the management of water resources and the foundation of certain decisions regarding the exploitation regime of the reservoirs.

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