

## MAPS AND SATELLITE IMAGES –TOOLS FOR AN EFFECTIVE MANAGEMENT OF THE HISTORIC CENTER OF SIGHISOARA, AN UNESCO WORLD HERITAGE SITE

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### **Abstract**

*Mapping has had an essential role in history, by capturing and transmitting models and visions of nature and social relationships. The emergence of the first maps was related to the need for orientation of the first humans and the need to delimit hunting and cultivated areas. The first aerial photograph acquired from a balloon above Paris, brought a great evolution of the knowledge of the territory. We now have various images captured by a multitude of satellites, providing valuable Earth observation information.*

*This study focuses on the Sighisoara area in order to create a geodatabase, containing maps and pictures from 1918 to the present. We used Sentinel 1, Sentinel 2 images from Copernicus Open Access Hub platform, and Landsat 8 images from Earth Explorer platform, free of charge. Image processing is made with SNAP (Sentinel Application Platform) software available for free; for Sentinel 1 images we applied a noise reduction filter, a geometric correction (geocoding based on a digital elevation model) and then cropping of the image. The Sentinel 2 and Landsat 8 optical images were used to create natural color image red-green-blue combinations of spectral bands, which were initially resampled and cropped. All the products obtained have been integrated into a geodatabase using the QGIS program, also available for free, all data being kept for future use.*

**Key words:** cultural heritage, Earth observation, maps, photography images, satellite.

### **INTRODUCTION**

The Historic Centre of Sighisoara was included on the World Heritage List (WHL) in 1999 at the 23rd Session of the World Heritage Committee. Sighisoara (Figure 1) is a remarkable example of a small fortified city in a border area between the Latin culture of Central Europe and the Byzantine, Orthodox culture of Southeastern Europe.



Figure 1. The Sighisoara Citadel

The Historic Centre of Sighisoara is defined as the most representative medieval city in Transylvania as it has preserved unchanged the organization of urban space.

The monitoring of the cultural heritage brings fresh information about areas of interest and it enables comparisons of the current and past stages.

One of the monitoring methods was the map, a horizontal plane representation of the surface, generalized and shrunk according to a certain scale, and based on a cartographic projection.

We now have a wider range of information from satellite sensors, advanced processing programs, and everything in a very short time.

This study was carried out to create a geodatabase, containing maps and pictures from 1918 to the present. We used Sentinel 1, Sentinel 2 images from Copernicus Open Access Hub platform (<https://scihub.copernicus.eu/dhus/#/home>), and Landsat 8 images from Earth Explorer

platform (<https://earthexplorer.usgs.gov/>), free of charge.

## **MATERIALS AND METHODS**

Sentinel-1 is the first of the Copernicus Program satellite constellation conducted by the European Space Agency (ESA) (<https://www.esa.int/ESA>).

This space mission is composed of two satellites, Sentinel 1A and Sentinel 1B, that carry a C-band Synthetic Aperture Radar (SAR) instrument which provides a collection of data in all-weather, day or night.

Currently, both Sentinel 1-A and 1-B have been launched. The first satellite, Sentinel 1A was launched on 3 April 2014, while Sentinel 1B was launched on 25 April 2016. Both satellites lifted off from the same location in Kourou, French Guiana, and each on a Soyuz Rocket.

There are a wide range of applications for the data collected via the Sentinel-1 mission. A part of these uses include marine and land monitoring, emergency response due to environmental disasters, and economic applications.

Sentinel-1 mission includes C-band imaging operating in four exclusive imaging modes with different resolution (down to 5 m) and coverage (up to 400 km). It provides dual polarisation capability, very short revisit times and rapid product delivery. For each observation, precise measurements of spacecraft position and attitude are available. Sentinel-2 is an Earth observation mission developed by ESA as part of the Copernicus Programme.

It consists of two identical satellites built by Airbus DS, Sentinel-2A and Sentinel-2B, with two additional satellites being constructed by Thales Alenia Space.

Sentinel-2 carries an optical instrument payload that samples 13 spectral bands: four bands at 10 m, six bands at 20 m and three bands at 60 m spatial resolution. The orbital swath width is 290 km.

The twin satellites of Sentinel-2 provide continuity of SPOT and Landsat -type image data, contribute to ongoing multispectral observations and benefit Copernicus services and applications such as land management,

agriculture and forestry, disaster control, humanitarian relief operations, risk mapping and security.

With its 13 spectral bands, 290 km swath width and high revisit frequency, Sentinel-2's MultiSpectral Instrument (MSI) supports a wide range of land studies and programmes, and reduces the time required to build a European cloud-free image archive. The spectral bands of Sentinel-2 provide data for land cover/change classification, atmospheric correction and cloud/snow separation.

Landsat represents the world's longest continuously acquired collection of space-based moderate-resolution land remote sensing data. Four decades of imagery provides a unique resource for those who work in agriculture, geology, forestry, regional planning, education, mapping, and global change research. Landsat images are also invaluable for emergency response and disaster relief.

As a joint initiative between the United States Geological Survey (USGS) and the National Aeronautics and Space Administration (NASA), the Landsat Project and the data it collects support government, commercial, industrial, civilian, military, and educational communities throughout the United States and worldwide.

The Landsat project is an integral part of the Remote Sensing Missions component of the USGS Land Remote Sensing (LRS).

On July 23, 1972, launch of the Earth Resources Technology Satellite (ERTS-1), which was later renamed Landsat 1. The launches of Landsat 2, Landsat 3, and Landsat 4 followed in 1975, 1978, and 1982, respectively.

When Landsat 5 launched in 1984, no one could have predicted that the satellite would continue to deliver high quality, global data of Earth's land surfaces for 28 years and 10 months, officially setting a new Guinness World Record for "longest-operating Earth observation satellite." Landsat 6 failed to achieve orbit in 1993.

Landsat 7 successfully launched in 1999 and, along with Landsat 8, which launched in 2013, continues to provide daily global data. Landsat 9 is planned to launch in late 2020.



Figure 2. Landsat missions

The Sentinel 1 and Sentinel 2 images were downloaded from the Copernicus Open Access Hub platform (<https://scihub.copernicus.eu/dhus/#/home>). The Sentinel 1 image was downloaded as a Ground Range Detected (GRD) Level-1 product that represents a detected, multi-looked image projected to ground range using an Earth ellipsoid model. For data identification and download, the area of interest was delineated (Figure 3) and then different search criteria such as the season of acquisition (Figure 4), in our case summer of 2017.



Figure 3. Extent of the area of interest

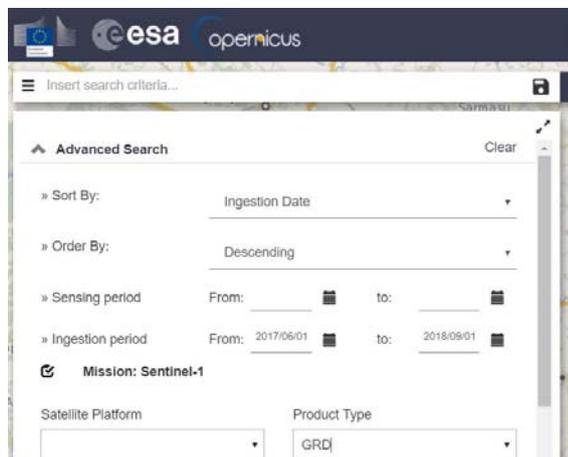


Figure 4. Advanced search criteria for Sentinel-1 images within the Copernicus Open Access Hub

Sentinel 2 image has a search criteria depending on the clouds coverage of the image, in our case a coverage of maximum 10% was imposed (Figure 5).

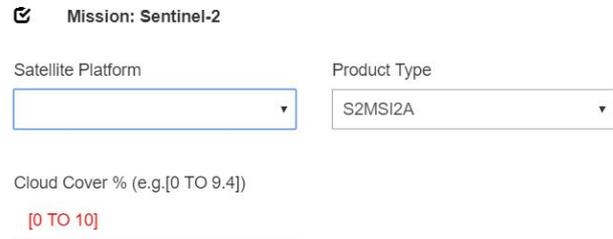


Figure 5. Search criteria for Sentinel-2

The Landsat 8 image was downloaded from the Earth Explorer platform (<https://earthexplorer.usgs.gov/>). The first image search criterion was the area of interest and then the acquisition time (Figure 6).

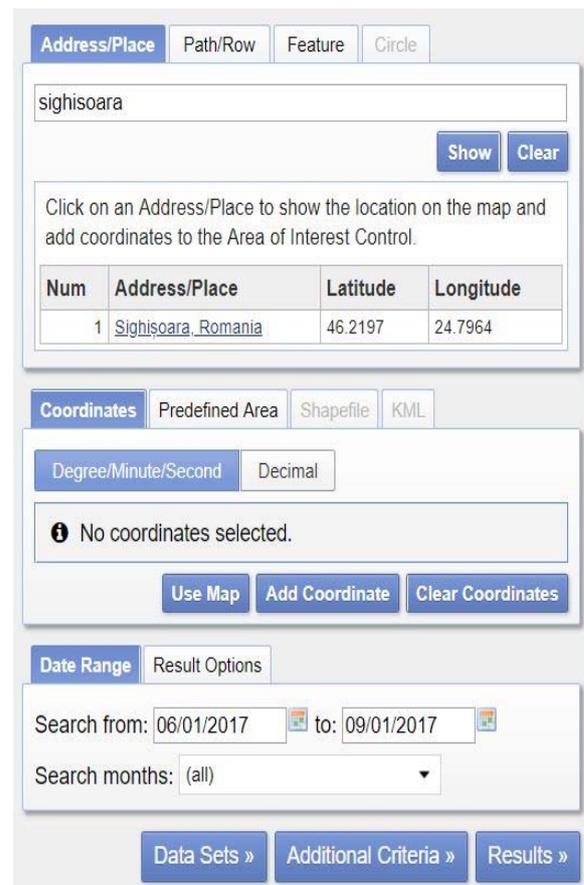


Figure 6. First selection criteria for Landsat images within the Earth Explorer platform

From the Data Sets section we can choose the satellite mission that acquired the image (Figure 7).

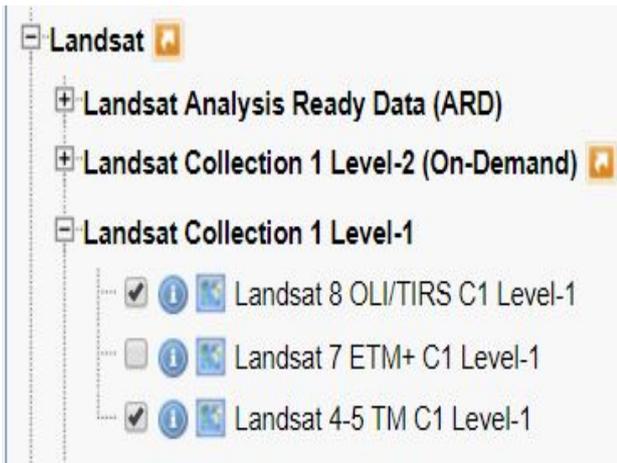


Figure 7. Part of Landsat collections available in Earth Explorer, as search criteria

A final criterion is cloud cover, in our case a maximum of 10%. (Figure 8).

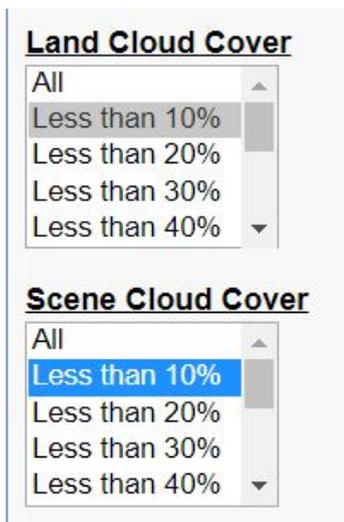


Figure 8. Land and scene cloud cover as search criteria for Landsat images in Earth Explorer

The Sentinel-1 images were filtered to reduce the speckle noise (Figure 9).

A Refined Lee filter was applied with an edge threshold of 5000. Next, the Sentinel-1 image was geocoded (Figure 10) using the Range Doppler orthorectification method that enables the correction of the topographic distortions in SAR imagery based on a Digital Elevation Model (DEM). The Shuttle Radar Topographic Mission (SRTM) DEM with the spatial resolution of 3 arc seconds is automatically downloaded by SNAP for the area of interest. Finally, the image were cropped in order to cover only Sighisoara and its close surroundings (Figure 11).

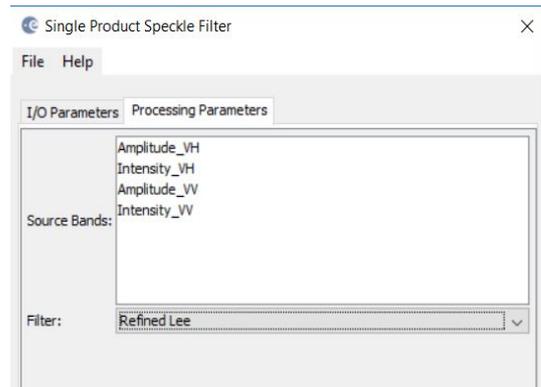


Figure 9. Speckle filtering of the Sentinel-1 image using the Single Product Speckle Filter in SNAP

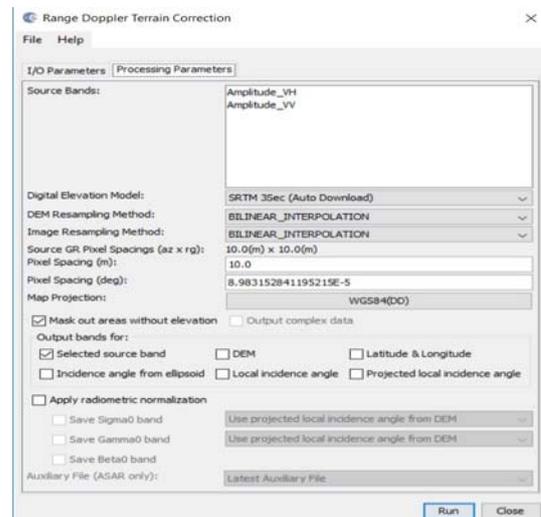


Figure 10. Terrain correction using the Range Doppler method implemented in SNAP

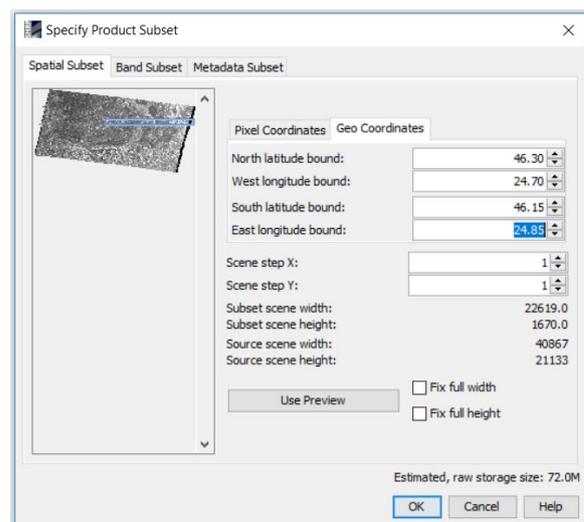


Figure 11. Subset of the Sentinel-1 image using geographic coordinates

The image was exported to the GeoTiff format for use in QGIS – a free and open source software (Figure 12).

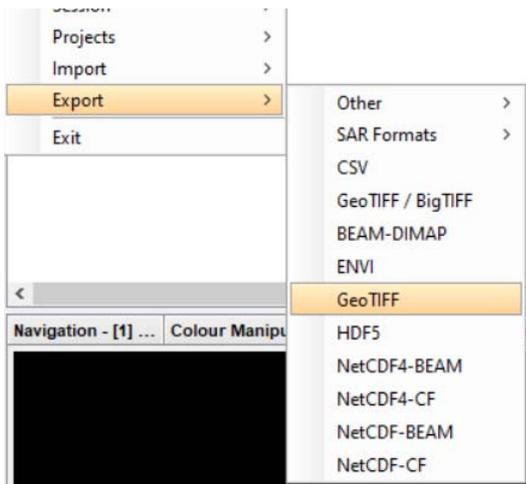


Figure 12. Export of the geocoded Sentinel-1 image from the DIMAP format to GeoTiff

For the Sentinel-2 and Landsat images, the same processing steps have been applied; the images were opened in the SNAP program and then resampled (Figure 13), so all the bands have the same spatial resolution.

They were cropped and exported in GeoTiff format using the same approach like in the case of Sentinel-1 images.

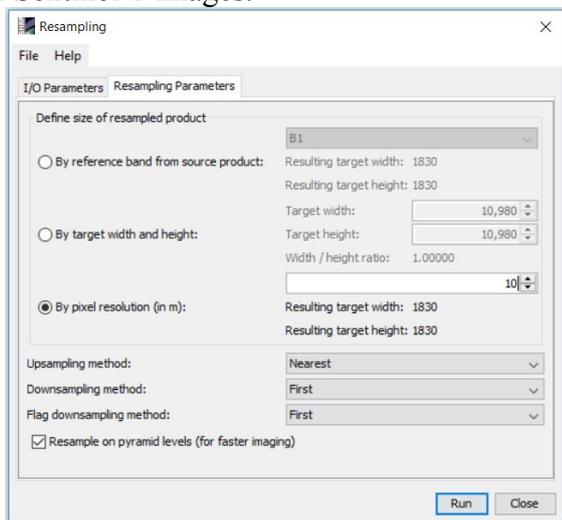


Figure 13. Resampling of the Sentinel-2 spectral bands

In the case of optical images, we want to get a combination in natural colors, using the red-green-blue (RGB) spectral bands. For the optical images of this study (both Sentinel-2 and Landsat-8) the combinations consist of the following: red-band 4, green-band 3 and blue-band 2 (Figure 14).

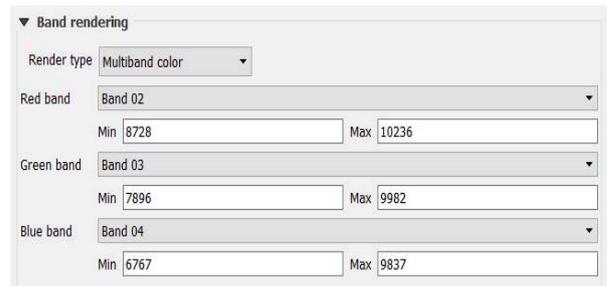


Figure 14. RGB composition for natural colors

We used the SNAP (<http://step.esa.int/main/download/>) and QGIS (<https://qgis.org/en/site/forusers/download.html>) programs for image processing, available for free. SNAP is a program for satellite imagery acquisition with various satellites, in our case Sentinel-1, Sentinel-2 and Landsat 8. The QGIS program was used to create products of combined raster and vector layers, namely the processed SNAP images with the location vectors of localities, national and communal roads, railways, administrative boundaries and water bodies.

## RESULTS AND DISCUSSIONS

The Sentinel-1 image was acquired using the Interferometric wide-swath (IW) mode with a spatial resolution of  $5 \times 20$  meters.

The Sentinel-2 image was resampled to have a 10-meter spatial resolution for all the spectral bands. It has the following spectral bands: band1 costal aerosol, band 2 blue, band 3 green, band 4 red, band 5 vegetation red edge, band 6 vegetation red edge, band 7 vegetation red edge, band 9 water vapor, band 10 SWIR-Cirrus, band 11 SWIR, band 12 SWIR (SWIR - Short Wavelength Infrared).

The Landsat 8 image was also resampled for a 30-meter resolution, with the following spectral bands: band1 costal aerosol, band 2 blue, band 3 green, band 4 red, band 5 near infrared, band 6 SWIR, band 7 SWIR, band 8 panchromatic, band 9 cirrus, band 10 Thermal Infrared, band 11 Thermal Infrared.

In order to have a better view of the evolution of technology we have added the oldest map we have been able to find (Figure 15).



Figure 15. The historic map of Sighisoara(1918)  
 (© <http://www.geo-spatial.org/>)

The available vector layers were overlaid on the Sentinel-1 image that enables a detailed view of the morphological features in the area of interest (Figures 16, 17 and 18). The image acquired by the Sentinel-1 satellite on 04.06.2017 along with position vectors allocated to national and communal roads are represented in Figure 16.

allocated to railways are represented in Figure 17.

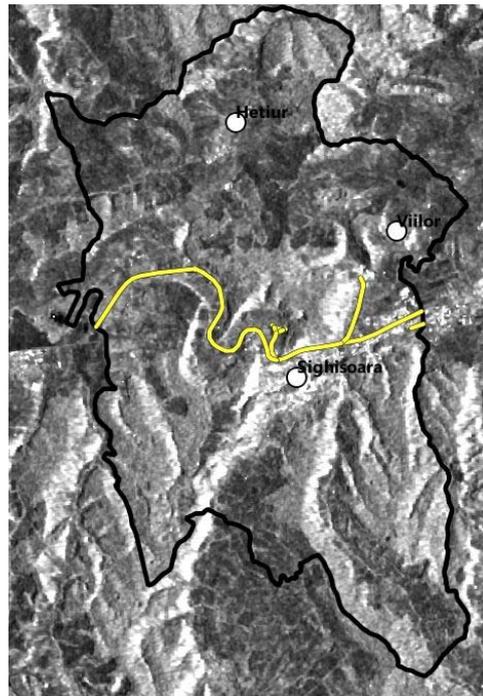


Figure 17. Railway vector lines (in yellow) and administrative boundary (in black). Background: Sentinel-1 image (© ESA 2017).

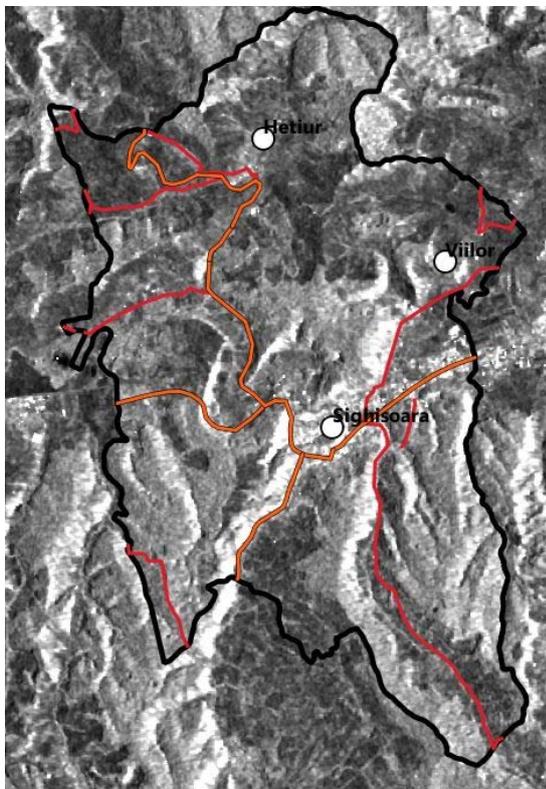


Figure 16. Road vector lines (in red) and administrative boundary (in black). Background: Sentinel-1 image (© ESA 2017).

The image acquired by the Sentinel-1 satellite on 04.06.2017 along with position vectors

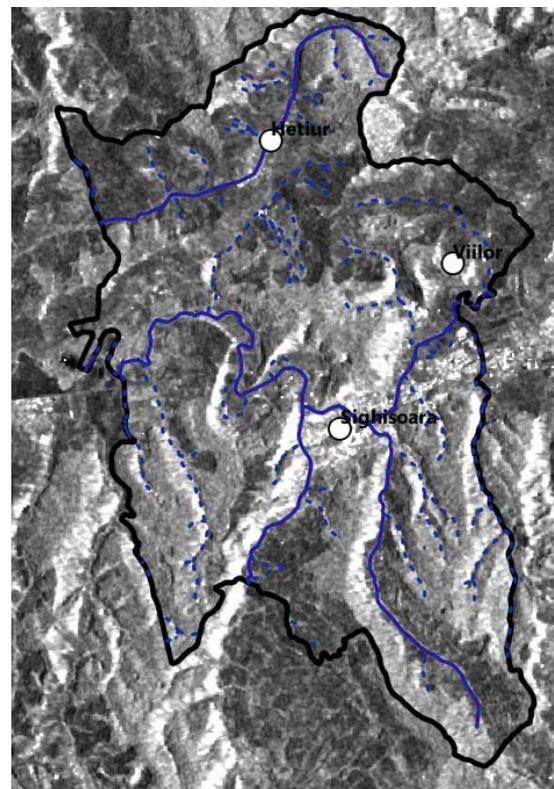


Figure 18. River vector lines (in blue) and administrative boundary (in black). Background: Sentinel-1 image (© ESA 2017).

Figures 19 and 20 illustrate the optical images that cover the area of interest, namely Landsat-

8 and Sentinel-2, the latter offering more details given the higher spatial resolution. Sentinel 1 and Sentinel 2 images were downloaded with The Copernicus Open Access Hub (<https://scihub.copernicus.eu>) and we used QGIS for representation of national and communal roads, railways and rivers.

The Copernicus Open Access Hub provides complete, free and open access to Sentinel-1, Sentinel-2 and Sentinel-3 user products, starting from the In-Orbit Commissioning Review (IOCR) phase.

Copernicus is the European Union's Earth Observation Programme, looking at our planet and its environment for the ultimate benefit of all European citizens.

It offers information services based on satellite Earth Observation and in situ (non-space) data. The image acquired by Landsat 8 satellite on 21.07.2017 covering the Sighisoara area is illustrated in Figure 19.



Figure 19. Landsat-8 image covering Sighisoara (© USGS/NASA Landsat 2017)

7. Data collected by the instruments onboard the satellite are available to download at no charge from EarthExplorer within 24 hours of acquisition.

Landsat 8 carries two push-broom instruments: The Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS).

The spectral bands of the OLI sensor provides enhancement from prior Landsat instruments, with the addition of two additional spectral bands: a deep blue visible channel (band 1) specifically designed for water resources and coastal zone investigation, and a new shortwave infrared channel (band 9) for the detection of cirrus clouds.

The TIRS instrument collects two spectral bands for the wavelength covered by a single band on the previous TM and ETM+ sensors.

The image acquired by the Sentinel-2 satellite on 28.06.2017 covering the Sighisoara area is illustrated in Figure 20.

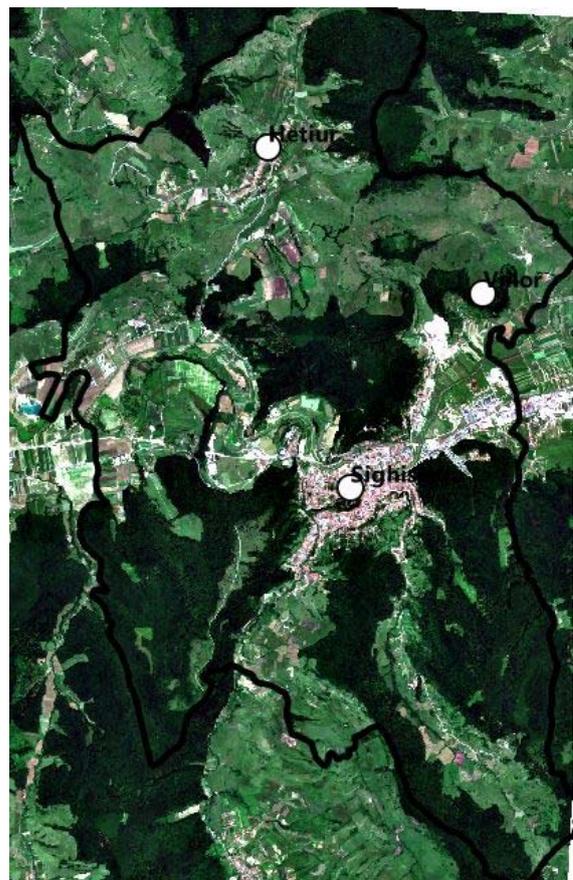


Figure 20. Sentinel-2 image covering Sighisoara (© ESA 2017)

The Landsat 8 satellite images the entire Earth every 16 days in an 8-day offset from Landsat

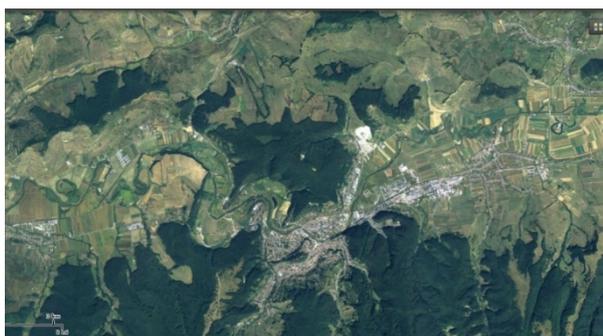


Figure 21. Aerial image (from 2010) of the Sighisoara area (©[http://geoportal.gov.ro/Geoportal\\_INIS/](http://geoportal.gov.ro/Geoportal_INIS/))

## CONCLUSIONS

The management of the cultural heritage may be supported by geospatial information derived from different sources of data (cartographic maps, aerial photographs, satellite images, etc.). The maps or other types of cartographic products have evolved, from the traditional map elaborated in 1918 that provided basic information to the satellite-derived products that offer detailed information of great diversity. During the present study, we used images acquired at different times by Sentinel-1, Sentinel-2, and Landsat 8 satellites, thus enabling a multi-sensor, multi-spectral and multi-temporal in-depth analysis of Sighisoara and its surroundings.

All the vector and raster data was projected into the same cartographic system and was used to create a complex geodatabase.

## ACKNOWLEDGEMENTS

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