

# GIS STUDY ON THE GREEN SPACES OF THE CITY OF BRAȘOV, ROMANIA

Commission III, WG III/7

Teodora Balint\*

ESRI Romania

**KEY WORDS:** Remote sensing, GIS, Green spaces, Land cover, Urban development

## ABSTRACT:

Urban sprawl is often the result of the transformation of the vegetation – covered land into build-up land. This expansion is caused by economic development, population growth and changing in living standards. For the progress of a city, a vision is needed in what will be achieved and methods by which this will be made possible. Due to the development of the city, the increase of the population number and other external factors, a study was needed to determine the area of the existing green spaces in the city of Brașov, Romania, in relation with the population number. Brașov is the most representative city, located in the Center of Romania, for economic and structure change. To analyze the green areas, we used remote sensing data from 2017 and 2021. Sentinel-2A images provided the support to analyze the land cover and the changes. The images were classified using ArcGIS Pro. This process gave a better understanding of the changes that took place in Brașov. The results indicated that the green areas almost doubled from 2017 to 2021. As a result of this growth, the citizens benefit due to the spaces created for recreation and outdoor activities.

## 1. INTRODUCTION

Satellite image classification is a very good method for determining land cover. With the rapid development of Earth Observation technologies, more and more high-resolution satellite images are being used. These types of images can detect urban objects in more detail, allowing for urban monitoring, urban planning and development, and rapid responses to emergencies.

Currently, the most widely used methods of image classification is supervised classification, which is based on prepared training samples and grouping pixels into classes. Lately, statistical methods, traditional machine-learning methods and deep learning methods have become the focus of the current trend.

In the last decade, due to population growth and migration in addition to the need for housing, the need for the green area increased. This aspect directly affects the inhabitants, giving them pace for outdoor activities and green spaces are covered and supported by European directives.

In Romania, this are included in the ecological network of Natura 2000 (European Commission, 2020) protected areas.

### 1.1 Related work

Studies at European and global level have shown that green areas are very important and contribute to the environmental quality and citizens well-being. For citizens, the green areas help with physical and psychological health and reduce stress and the appearance of diseases. Similar studies were made at European level, to compare the built-up areas with the number of green areas across the European cities (Wicht, Kuffer, 2019). In this research the authors used the night light images of the International Spaces Station to delimit the built-up area of selected European cities and to calculate the urban green area shape. The results showed that the green areas are rarely in the proximity to the living areas. Another way to see the land cover changes is by using multi-temporal remote sensed imagery (Fichera C. R, Modica G., Pollino M, 2017). By integrating Remote Sensing and GIS techniques, it becomes possible to analyse and classify the patterns of changes in land cover over a

long period of time, thus leading to a better understanding of the changes in the area of interest. With the help of GIS techniques, effects can be analysed such as: population density, land slope, land use in the area, etc.

In the study “Land Cover classification and change-detection analysis using multi-temporal remote sensed imagery and landscape metrics” (Fichera C. R, Modica G., Pollino M, 2017), the authors used supervised classification and post-classification comparison methods to extract land cover information in Province of Avellino, Campania region (Italy). This region was severely hit by the Iripinia earthquake in 1980. Following the earthquake, urban development plans were made. Four-time intervals were used to determine the changes that took place in the region.

Using Remote sensing image and GIS techniques, this paper follows the evolution in the period 2017-2021 of green areas of Brașov. Due to the accentuated development of the city of Brașov, such study is necessary to establish the green spaces because these have an impact on the population (Figure 1).



Figure 1. Location of Brașov

\*tbalint@esri.ro

## 1.2 Studied area

Braşov was and still is an industrial and cultural centre that favours tourism. Due to the industry that Braşov had, people were brought over time to carry out their activities here. Over time, more and more people left rural areas and migrated to urban areas, so Braşov in 2011 had a population of 253200 inhabitants.

Braşov is the only city in the world that includes in its administrative territory a natural reserve, Mount Tâmpa, and a mountain peak, Postăvaru peak. Braşov is in the Bârsa Country Depression, with arable land in the North, and wild mountainous regions in East, South, and West. As species of animals that live here, we find brown bear, Carpathian deer, wolf, boar, weasel, lynx, and others.

For this study, satellite images were downloaded for free from Copernicus Open Access Hub, in the Braşov area. The acquisition dates for the images were 11.11.2021 and 29.05.2017. These images were taken by Sentinel-2A satellite (ESA, 2021), both images have a spatial resolution of 10x10 m. The study area has 775.62 ha (Figure 2).



Figure 2. Study zone

## 2. METHODOLOGY

Sentinel-2 provides data feeding services for applications in the Copernicus priority areas of land monitoring, emergency management and security. The Copernicus land monitoring services provides geographical information on land cover and on variables related on topic as vegetation state and water cycle. It also supports applications as: spatial planning, forest management, water management, agriculture, and food security. ArcGIS Pro is a desktop GIS application that allows the users to view data and perform advanced analysis.

### 2.1 Image processing

Sentinel-2 bands were the satellite images used for this study. The bands were clipped to remain only the study area. Then using a RGB (Red, Green, Blue) band combination was created the natural colour images (ESRI, 2021) using the bands 4, 3, and 2 for both images (Figure 3).



Figure 3. Natural colour image for year 2021

After creating RGB image for each year, was created a supervised classification. This classification is a procedure for the quantitative analysis of data from remote sensing. This procedure requires field test samples to be considered representative of each unit that will be classified. The classification based on the Maximum Likelihood Classification algorithm (ESRI, 2021) and (Simiyu W, 2021) is the most used and based on it, can be determined probability functions, average values, variance-covariance matrix, etc.

The Maximum Likelihood Classification is an algorithm that considers both the means and covariances of the class signatures when the pixels are assigned in the classes. Assuming that the distribution of the class sample is normal, each class is characterized by the mean vector and the covariance matrix.

The samples for the Maximum Likelihood algorithm can be obtained in two ways: by collecting data from the field with specialized equipment or by vectorizing.

The first method has a better accuracy, but the weak points are: long time for data collection and the equipment that has high costs. Trained personnel are also needed for field work. The second method is faster but requires more attention for good results. The costs are low, but the operator must know the study area very well to obtain accurate results when vectoring.

The samples were chosen by vectorizing the representative areas. The accuracy of this method is lower because the samples are not always pure and depend very much on the accuracy of the operator.

After the classification, points were placed on the natural colour images which represented the control points. These have been transformed into pixels and combined with classified images. Using statistical tools, the error matrices for each year were extracted and accuracy assessments were performed.

### 2.2 Normalized Difference Vegetation Index

Normalized Difference Vegetation Index (NDVI) is a standard index that allows the arrangement of green vegetation in an image (relative biomass) (Vorovencii I., 2005). The index is based on the contrast of two spectral bands in the dataset: the absorption of chlorophyll pigments in the red band (RED) and the high reflectivity of plant matter in the near infrared band (NIR). NDVI is used worldwide for monitoring droughts, monitoring, and estimating agricultural production, specifying areas prone to vegetation fires, etc. The vegetation index is preferred for monitoring vegetation worldwide because it helps compare changes in lighting such as aspect, terrain slope and other external factors.

The differentiated reflexion between red band and near infrared band allows the monitoring of the density and intensity of the green vegetation using the spectral reflectivity of the solar radiation.

The green leaves show a better reflexion in the near infrared wavelength than in the visible spectrum. Leaves that are water deficient or sick or dying become yellower and their reflectivity decreases greatly for the infrared wavelength. The values of resulting pixels are in the range [-1, 1], where the negative values represent surfaces under water or covered in snow, around 0 the land is devoid of vegetation, and the high values of index represent dense and healthy vegetation. NDVI is calculated as the difference between the near infrared band and red band, divided by the sum of the same bands. The green colour represents the areas without vegetation and the orange (red) colour represent the areas with dense vegetation.

### 3. EXPERIMENT

A project and a geodatabase have been created in ArcGIS Pro, and the satellite images were imported. Using the geoprocessing tools, the images were cropped so that only the area of interest remained. For Sentinel 2A images the band combination for creating a natural colour image is 4,3,2. Using the natural colour image for both years, training samples were created for the Maximum Likelihood supervised classification: buildings, streets, and green areas. These samples were used for spectral signature creation. Each class had 30 elements for making the spectral signatures. Based on the spectral signatures the pixels were divided into classes using the Maximum Likelihood algorithm (L3Harris, 2021). The red colour represents areas with buildings, the grey colour represents areas with streets and green represents area with vegetation (Figure 4, Figure 5).

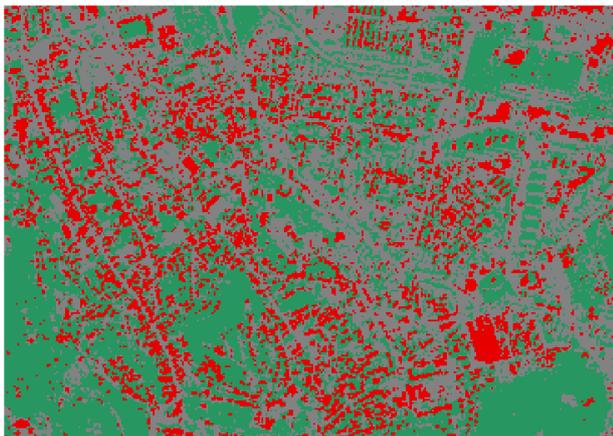


Figure 4. Classified image for year 2021

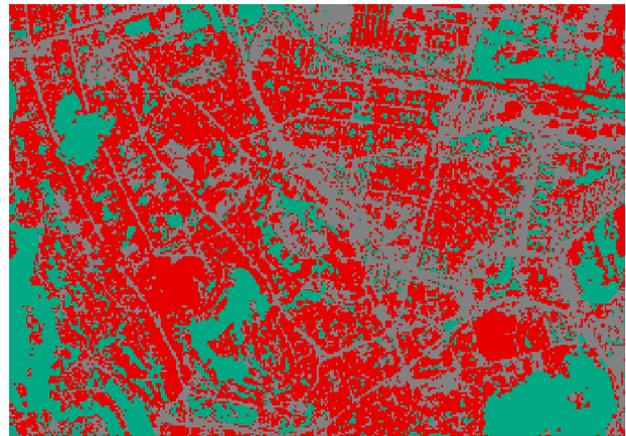


Figure 5. Classified image for year 2017

The method used in this study to determine the changes occurred was the post-classification comparison. Each image obtained from the classification was processed with transformation tools so that each pixel of the raster was transformed into a polygon. Based on the obtained polygons, the surfaces were summed and the final values of the surfaces of the three classes were obtained. Based on the surface obtained for green spaces, a graph was made to compare the evolution of green spaces (Figure 8).

Another method of analysing green spaces is to use NDVI. With the help of the red and infrared bands, the maps for differentiating the vegetation were created for the two years. The colour palette was chosen so that the green colour represents the areas covered with vegetation, where the temperatures are lower and the red colour (orange) represents the areas with buildings (or with precarious vegetation), where the temperatures are higher (Figure 6, Figure 7).

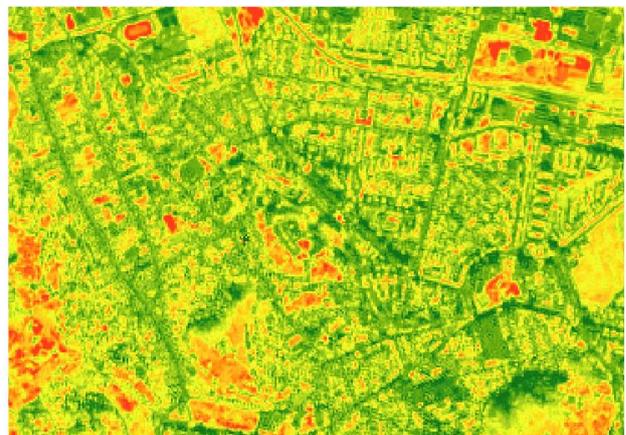


Figure 6. NDVI for year 2021

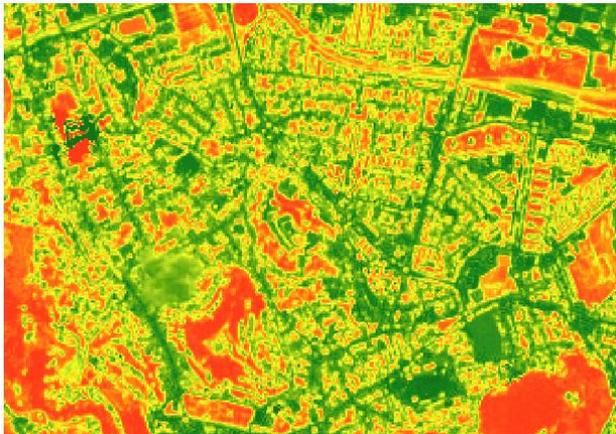


Figure 7. NDVI for year 2017

#### 4. RESULTS

For each image were placed sets of points corresponding to the three classes. These have been converted into pixels and combined with the classified images. The resulting tables were exported as pivot tables, obtaining two matrixes, one for each year (Table 1, Table 2).

No.	Classes	Buildings	Streets	Green areas	Total
1.	Buildings	19	1	1	21
2.	Streets	2	23	0	25
3.	Green areas	4	0	13	17
4.	Total	25	24	14	63

Table 1. Matrix for the image from 2021

No.	Classes	Buildings	Streets	Green areas	Total
1.	Buildings	25	1	0	26
2.	Streets	1	26	0	27
3.	Green areas	2	0	26	28
4.	Total	28	27	26	81

Table 2. Matrix for the image from 2017

For both classified images were made accuracy assessments. The following elements were calculated: total accuracy, kappa coefficient, ground truth, commission, omission, user's accuracy, producer's accuracy, based on matrixes.

- Total accuracy is calculated as the number of correctly classified pixels divided by the total number of pixels.  
For year 2021 overall accuracy is 0.873, and for year 2017 overall accuracy is 0.950.
- Kappa coefficient reflects the difference between actual agreement and agreement expected by chance.  
For year 2021 kappa coefficient is 0.806, and for year 2017 kappa coefficient is 0.925. This means that the agreement between the classified data and the reference data is strong.
- Ground truth is calculated based on data measured on the field (Table 3, Table 4).

No.	Classes	Buildings	Streets	Green areas
1.	Buildings	76	4.16	7.14
2.	Streets	8	95.83	0
3.	Green areas	16	0	92.85

Table 3. Ground truth for the image from 2021

No.	Classes	Buildings	Streets	Green areas
1.	Buildings	89.28	3.70	0
2.	Streets	3.57	96.29	0
3.	Green areas	7.14	0	100

Table 4. Ground truth for the image from 2017

- Commission errors are calculated by reviewing the classified sites for incorrect classifications. This is done by going across the rows for each class and adding together the incorrect classification and divided them by the total number of classified sites for each class (Table 5, Table 6).

No.	Classes	Classified pixels	Total number of pixels	Commission error
1.	Buildings	2	21	9.52
2.	Streets	2	25	8
3.	Green areas	4	17	23.52

Table 5. Commission error for the image from 2021

No.	Classes	Classified pixels	Total number of pixels	Commission error
1.	Buildings	1	26	3.84
2.	Streets	1	27	3.70
3.	Green areas	2	28	7.14

Table 6. Commission error for the image from 2017

- Omission errors are calculated by reviewing the reference sites for incorrect classifications. This is done by going down the columns for each class and adding together the incorrect classifications and dividing them by the total number of reference sites for each class (Table 7, Table 8).

No.	Classes	Buildings	Streets	Green areas
1.	Buildings	76	4.16	7.14
2.	Streets	8	95.83	0
3.	Green areas	16	0	92.85

**Table 7.** Omission error for the image from 2021

No.	Classes	Buildings	Streets	Green areas
1.	Buildings	89.28	3.70	0
2.	Streets	3.57	96.29	0
3.	Green areas	7.14	0	100

**Table 8.** Omission error for the image from 2017

- User's accuracy is calculated by reviewing the sites for correct classifications and dividing them by the total number of classified sites for each class (Table 9, Table 10).

No.	Classes	Classified pixels	Total number of pixels	User's accuracy
1.	Buildings	19	21	90.47
2.	Streets	23	25	92
3.	Green areas	13	17	76.47

**Table 9.** User's accuracy for the image from 2021

No.	Classes	Classified pixels	Total number of pixels	User's accuracy
1.	Buildings	25	26	96.15
2.	Streets	26	27	96.29
3.	Green areas	26	28	92.85

**Table 10.** User's accuracy for the image from 2017

- Producer's accuracy is calculating by reviewing the sites for correct classifications and dividing them by the total number of reference sites for each class (Table 11, Table 12).

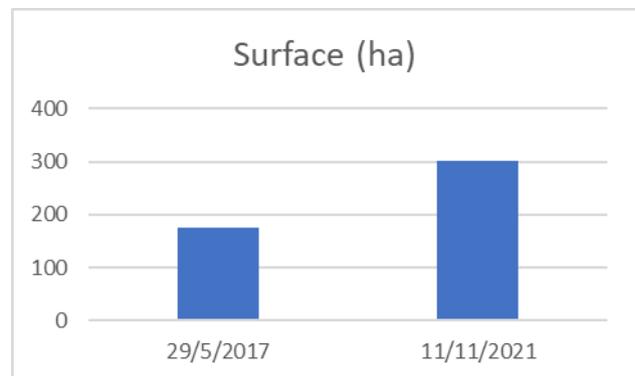
No.	Classes	Classified pixels	Total number of pixels	Producer's accuracy
1.	Buildings	19	25	76
2.	Streets	23	24	95.83
3.	Green areas	13	14	92.85

**Table 11.** Producer's accuracy for the image from 2021

No.	Classes	Classified pixels	Total number of pixels	Producer's accuracy
1.	Buildings	25	28	89.28
2.	Streets	26	27	96.29
3.	Green areas	26	26	100

**Table 12.** Producer's accuracy for the image from 2017

To determine the surfaces, the Raster to Polygon tool was used. This function transformed the pixels into polygons and then the surfaces of these polygons were summed using Summary Statistics function. After the analysis for the city of Braşov, using the supervised classification, it was shown a significant increase of green areas, from 174.24 ha in 2017 to 301.64 ha in 2021 (Figure 8).



**Figure 8.** Surface increase from 2017 to 2021

## 5. CONCLUSIONS AND DISCUSSIONS

The evolution of technology in recent years offers vast possibilities for Earth's surface exploitation and the impact this exploitation has on the environment.

Satellite imagery, along with dedicated GIS software, helps to obtain valuable information on land cover monitoring. The analysis of the type presented in the study have a major potential in terms of monitoring agricultural land, forest management, maritime transport, security, and many other applications.

Using GIS technology for satellite image processing it was possible to analyse the changes that took place in the city of Braşov and the need to carry out these types of studies for the planning and development of cities.

In this study was used ArcGIS Pro software to analyse the data. Although European Space Agency (ESA) provides satellite

images for free to the users, these are not widely used to study land cover and land use in Romania.

This kind of studies can influence developers' perceptions regarding to urban development and with this level of information they can increase the quality of life for the citizens. In Romania, at city level, the law imposes on the mayors a register of green spaces. Due to the advancement of technology and limited resources, town halls do not have updated data on the green spaces.

Studies like this, using satellite images and classification methods for the inventory of green spaces and land cover have not been conducted in Romania. This study is a starting point for the realisation and inventory of green spaces in other cities in Romania. This kind of studies help plan and develop residential neighbourhoods, city centres and provide recreation areas for residents. Studies can also be used for smart planning, so the cities become green cities.

Starting from this study, existing forest and the animals that live in them, endangered species, habitats in these forests and much more can be analysed. Braşov does not have many green spaces, but the fact that it is near the forest help the inhabitants carry out their recreational activities and improve their lifestyle. This fact also has repercussion on them because there is a danger of encountering wild animals. Based on this study, another study can be made that has as a perspective these areas where the animal's habitats are located so that the life of the citizens who carry out activities in the forest are not endangered.

## REFERENCES

- European Commission, 2020: Natura 2000, [https://ec.europa.eu/environment/nature/natura2000/index\\_en.htm](https://ec.europa.eu/environment/nature/natura2000/index_en.htm) (18 December 2021)
- ESA, 2021: Sentinel-2 MSI User Guide, <https://sentinels.copernicus.eu/web/sentinel/user-guides/sentinel-2-msi> (20 December 2021)
- ESRI, 2021: Accuracy Assessment. Help (ArcGIS Pro) Software, Version 2.9, <https://pro.arcgis.com/en/pro-app/latest/help/analysis/image-analyst/accuracy-assessment.htm> (5 January 2022)
- ESRI, 2021: Composite Bands. Help (ArcGIS Pro) Software, Version 2.9, <https://desktop.arcgis.com/en/arcmap/10.3/tools/data-management-toolbox/composite-bands.htm> (5 January 2022)
- ESRI, 2021: Maximum Likelihood Classification. Help (ArcMap) Software, <https://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/maximum-likelihood-classification.htm> (5 January 2022)
- Fichera C. R., Modica G., Pollino M., 2017: Land Cover Classification and change-detection analysis using multitemporal remote sensed imagery and landscape metrics. *European Journal of Remote Sensing*, 45(1), 1-18, <https://doi.org/10.5721/EuJRS20124501>
- L3Harris, 2021: Maximum Likelihood, <https://www.l3harrisgeospatial.com/docs/maximumlikelihood.html> (5 January 2022)
- Simiyu W., 2021: Image Segmentation and Classification in ArcGIS Pro, <https://www.esri.com/ethiopia-user-group/Image%20Segmentation%20and%20Classification%20in%20ArcGIS%20Pro.pdf> (10 January 2022)
- Vorovencii I., 2005: Teledetectie satelitară, Ed. Matrixrom, Bucureşti, Romania
- Wicht M., Kuffer M., 2019: The continuous built-up area extracted from ISS night-time lights to compare the amount of urban green areas across European cities. *European Journal of Remote Sensing*, 52(2), 58-73, <https://doi.org/10.1080/22797254.2019.1617642>