Image Classification Methods to Detect the Growth of Industrial Areas

Tamas Jancso
Alba Regia Technical Faculty
Óbuda University
Szekesfehervar, Hungary
jancso.tamas@amk.uni-obuda.hu

Andrea Podor
Alba Regia Technical Faculty
Óbuda University
Szekesfehervar, Hungary
podor.andrea@amk.uni-obuda.hu

Éva Hajnal
Alba Regia Technical Faculty
Óbuda University
Szekesfehervar, Hungary
hajnal.eva@amk.uni-obuda.hu

Rezso Nagy
Eötvös Loránd University
Faculty of Science
Budapest, Hungary
nagy.rezso17@gmail.com

***Abstract*—The incorporation of agricultural areas is an increasing problem. During the construction, we can typically observe the expansion of industrial parks, logistics centers or the construction of leisure centers, sports facilities or buildings and halls for other purposes realized as part of state investments. In the article, we try to show the changes in the agricultural area using several image classification methods. The purpose of the presented three types of classification is to compare the values of the calculated areas and to present the possibilities of the applied software.**

***Keywords*— remote sensing, image classification, environmental analysis, GIS**

I. Introduction

The size of industrial areas within a city can be increased if the industrial area is located on the outskirts of the city. In such cases, industrial areas grow mostly at the expense of agricultural areas. In addition, municipal or state investments can also reduce the size of areas suitable for cultivation.

The sample area on the outskirts of Székesfehérvár refers to such a case, where a sporting complex is being built and the expansion of the aluminum processing plant is observed at the same time. The decrease in agricultural land is clearly visible if we compare the space images taken in 2011 and 2022 (See Fig. 1 and 2.

Fig. 1. WorldView-2 RGB composite image (2011)

Fig. 2. Sentinel2 RGB composite image (2022)

If we want to find out how much the size of the industrial area has been increased at the expense of agricultural areas, we have to face several challenges [4], [5]. TheWorldView-2 image has a resolution of 2 m, while the Sentinel 2 image has a resolution of 10 m. If we want to compare the two images, we have to reduce the resolution of the higher resolution WorldView-2 image to resolution of 10 m.

Another problem is that buildings in industrial areas have very diverse spectral properties, so for image classification based on training areas, samples would have to be taken in many places. Therefore, it is more appropriate to choose another solution for the separation of thematic classes.

In this article, we try to determine the increase in the size of the industrial area in three ways for three types of software. The obtained results are discussed in the conclusion chapter.

II. Image Classification

A. Image classicifation in Idrisi by NDVI

The normalized difference vegetation index (NDVI) index is suitable for distinguishing the vegetation within an area.

The NDVI is calculated by the formula (1) [1].

$$NDVI = \frac{NIR-R}{NIR+R} \quad (1)$$

Since the WorldView-2 and Sentinel 2 images have red (R) and near infrared (NIR) channels, we can obtain the NDVI index image for both years. Fig. 3 and 4 show the NDVI maps.

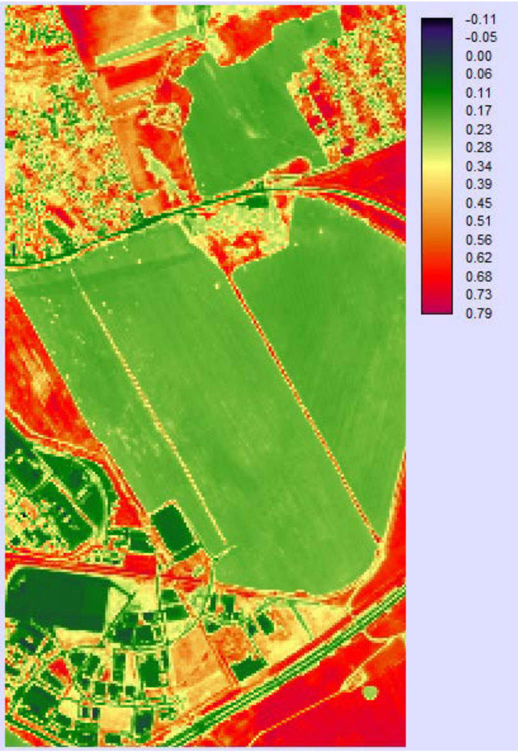

Fig. 3. WorldView-2 NDVI map (2011)

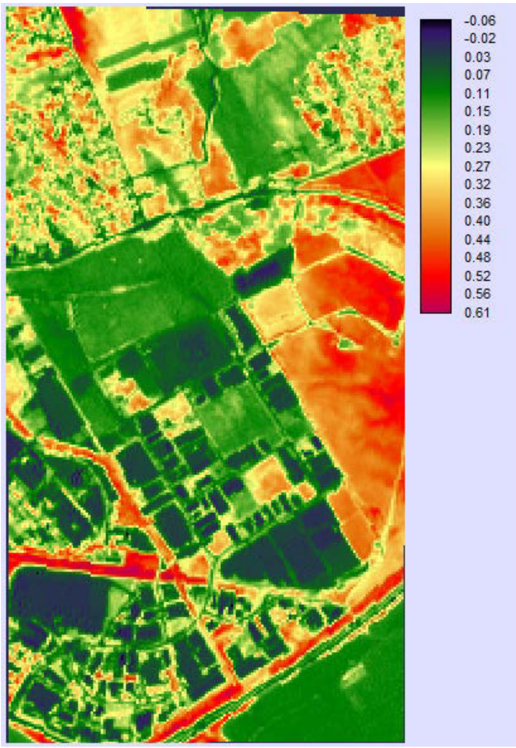

Fig. 4. Sentinel2 NDVI map (2022)

After the visual interpretation, the NDVI map can be divided into three categories. Table I shows the NDVI value limits of each category, where Min is greater than or equal to, and Max means values less than the given value.

TABLE I. NDVI LIMITS

	WorldView-2		**Sentinel 2**	
Categories	**Min**	**Max**	**Min**	**Max**
Built-in area	-0.11	0.14	-0.06	0.08
Soil and bare land	0.14	0.39	0.08	0.29
Vegetation	0.39	0.8	0.29	0.62

Applying the RECLASS function by Table I, we can produce thematic maps with three categories in Idirisi. Fig. 5 and 6 show the resulting maps.

Fig. 5. WorldView-2 thematic map (2011)

In Fig. 6, we can notice that red stripes have appeared at the edges of the image. The reason of this that empty areas appeared at the edges of the Sentinel 2 image field during the image transformation to the Hungarian HD72 projection. We can cut off these empty areas later.

Fig. 6. Sentinel 2 thematic map (2022)

In Fig. 5 and 6, we can see that the vegetation and soil categories show large differences. The reason for this is that the recordings were taken at the beginning and at the end of summer during different vegetation periods. If these two categories are combined, the built-up area becomes clearly visible. The result of this can be seen in Fig. 7 and 8.

Fig. 7. WorlView-2 classified image with 2 categoris (2011)

Fig. 8. Sentinel 2 classified image with 2 categories (2022)

Using the AREA function, we can calculate the size of built-up areas in hectares. By subtracting the two areas, we get that the size of the built-up area increased by 39.71 hectares in 10 years.

The Idrisi software provides the possibility to fit the individual processing steps into a model. this model is shown in figure 9.

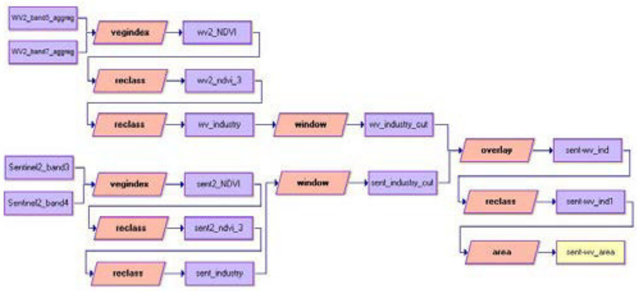

Fig. 9. Classification process built in the Idrisi macromodeler

B. Image classification in ArcGIS Pro

In ArcGIS Pro the first step of the image classification is the preparation of segmentation. Image segmentation in ArcGIS Pro is using the Mean Shift method (Comanicu- Meer, 2002). The characteristics of the image segments is based on spectral detail, spatial detail, and minimum segment size. The approach is applying the moving window technique, which calculates an average pixel value within the window, and as the window is moving it recalculates the value to make sure that all segments are correct. The outcome is a gathering of pixels in the picture into a segment of average color.

Fig. 10. The results of the segmentation process

Based on the segmented image we can implement the supervised image classification. During the classification we used the support vector machine method. In this case we also acquired 3 types of class, bare land, built-up area and vegetation.

Fig. 11. The results of classification process in ArcGIS Pro (grey-built-up area, green-vegetation, orange-bare land)

Following the classification, the images were transformed into HD72 projection, and after vectorization the areas of the different classes were calculated.

TABLE II. THE AREAL DIFFERENCES BETWEERE THE TWO IMAGES

Image	Bare land (ha)	Built-up area (ha)	Vegetation (ha)
WV 2	221,702	99,279	149,906
Sentinel 2	155,9186	116,8466	200,836
Difference	-65,7836	17,5676	50,9296

The comparison of the result shows that the built-up area increased during the given period. The difference in the vegetation shows that the two images were taken at different vegetation period.

C. *Image classification in QGIS*

Image classification was made with SCP Python plugin [2] of QGIS software. For the sake of comparability, the resolution of the WorldView image was reduced to the resolution of the Sentinel recording using the QGIS raster calculator. During the rescaling, the resolution had to be reduced for each band, and then the recording had to be stacked again. The Worldview recording was originally recorded on 8 bands, but only the red, green, blue and near-infrared bands were used. At the end of the operation, we received a version of the original image with the same resolution as the Sentinel-2 recording. In the false color method, in the last phase of preparing the images, the order of allocation of the bands was determined in such a way that the categories targeted by the study could be better distinguished: Industry and inhabited area, Vegetation and Soil and bareland. In the case of the new band allocation, we tried to make the two images as uniform as possible, i.e., the near-infrared band was placed first, the green band was placed second, and the red band was placed third. This is how we achieved that the vegetation became a bright red color, the buildings and roads were white or blue, while the soil became gray, brown or pink (Fig 12).

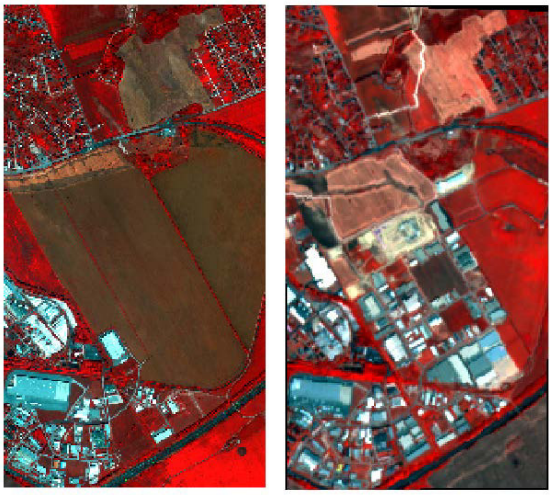

Fig. 12. QGIS false color image (left WorlView 2 image 2011, right Sentinel 2 image 2022)

The first task was the classification of each area into the three categories mentioned above. For both images, sample areas for all three categories were specified, based on which the artificial intelligence algorithm classified the pixels into one of the classes. When trying the algorithms of the SCP plugin for the classification, the use of the minimum distance algorithm gave the most accurate result. Increasing the number of sample areas per category could also increase the accuracy, but above four or five sample areas, the accuracy no longer increased. Classification errors can be checked visually (Fig 13), and their value can be inferred from the standard deviation obtained by different methods. After the classifications, the two classified images were compered in the SCP Land cover change function. The result was that the built-up area increased by 40.23 hectares.

The second method used was classification based on the normalized vegetation index (NDVI). Using the formula (1) presented in the previous chapter, the NVDI maps were created, and then classified pixels based on the classification table. The limit values in Table III were used for the classification, so that the lower values were greater than or equal to, while the upper values worked with a smaller condition. Value limits were determined based on the histogram of the individual rasters.

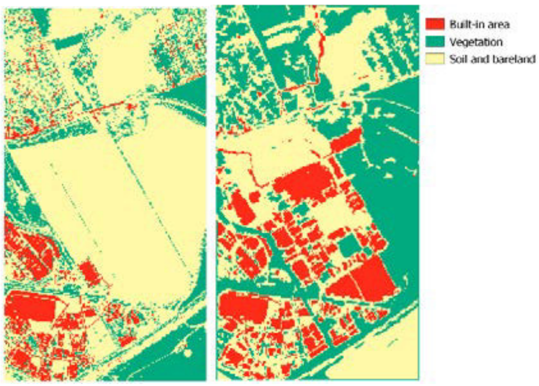

Fig. 13. Images after classification

After the classification was completed, the raster "surface area" function were ran on both classified images (Fig 14). Based on the calculations, the size of the built-up area increased by 38.06 hectares.

TABLE III. NDVI LIMITS IN QGIS SOFTWARE

	WorldView-2		Sentinel 2	
Categories	**Min**	**Max**	**Min**	**Max**
Built-in area	-0.63	0.03	-0.1	0.22
Soil and bareland	0.03	0.18	0.22	0.38
Vegetation	0.18	0.8	0.38	0.8

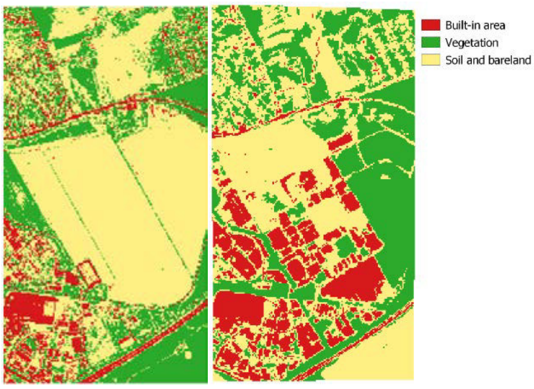

Fig. 14. Classification by NDVI. Left WorldView-2 image(2011) Right Sentinel-2 (2022).

III. CONCLUSION

The change in the size of the built-up area was determined in a given area is located on the outskirts of the Székesfehérvár city between 2011 and 2022. The task was complicated by the fact that the resolutions of the available satellite images were different. Another difficulty was that the recordings were made in different vegetation periods. On one, the agricultural area is completely bare, on the other, the same area is covered with green vegetation. In the course of the solution, several methods and software (Idrisi, ArcGIS, QGIS) were used, the results obtained are more or less consistent with one exception. Taking into account all the results obtained, the change in the built-in area was 33.9±10.9ha. If the outlier was skipped, the increase of the built-in area 39.3±1.1ha. The most accurate results were provided by NDVI-based methods. However, an interesting question is why the NDVI index limits, which can be determined based on the histogram of values, differed in the case of Idrisi and QGIS software.

ACKNOWLEDGMENT

The paper was supported by the Bilateral Chinese-Hungarian Project No. 2019-2.1.11-TÉT-2020-00171 with the project title of "Investigation of the characteristics of surface shapes in rural environment based on point clouds and remote sensing data".

REFERENCES

[1] pJ. R. Jensen, "Introductory Digital Image Processing: A Remote Sensing Perspective", Pearson, 4th Edition, pp. 656, 2015

[2] Congedo, L., "Semi-Automatic Classification Plugin: A Python tool for the download and processing of remote sensing images in QGIS", Journal of Open Source Software, 6(64), 3172, 2021

[3] Comanicu D., Meer P., "Mean shift: A robust approach toward feature space analysis", IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 24, no. 5, May 2002.

[4] Verőné Wojtaszek M., Balázsik V., Jancsó T., Horoszné Gulyás M., Meng Q., "Comparison of Three Image Classification Methods in Urban Environment", Journal od Geoscience and Environment Protection, 2015 : 3 pp. 54-59. , 6 p., 2015

[5] Zhou X. , Verőné Wojtaszek M., Chen Ch., Jancsó T., "Urban Land Cover Mapping Based on Object Oriented Classification Using WorldView 2 Satellite Remote Sensing Images", In: Neményi M ; Heil B (ed.), The Impact of Urbanization, Industrial and Agricultural Technologies on the Natural Environment : International Scientific Conference on Sustainable Development and Ecological Footprint, Sopron, Hungary, 2012.03.26. - 2012.03.27., Sopron: Nyugat-magyarországi Egyetem Kiadó, Paper ZVWChJ. 7 p., 2012