# THE CHALLENGE OF ASSESSING THE SPATIAL TRANSFORMATION CAUSED BY MINING IN B&H – GIS AS A SOLUTION?

**DOI: https://doi.org/10.18509/GBP23071s**
**UDC: 314.114:622.2]:[528.8:004.6(497.6)**

**Luka Sabljić**
**Dragica Delić**
Faculty of Natural Sciences and Mathematics, University of Banja Luka, Republic of Srpska, **Bosnia and Herzegovina**

## ABSTRACT

Bosnia and Herzegovina (B&H) has a long tradition of mining. Until modern times, mining became the backbone of the overall economy of the entire society. However, the spatiality of mining and the effects of the processes that accompany it are not known to the general public. The paper deals with the identification of spatial-temporal changes caused by mining on the example of a surface coal mine in the northeast of B&H. The process of ore exploitation in the first place requires space and usurps land, which represents the economic basis for the inhabitants of rural areas. Therefore, the authors focused on monitoring changes in land cover. The methodology of monitoring land cover changes is based on the use and processing of Corine Land Cover data using QGIS software. The change in the demographic size of settlements affected by mining activities was analyzed using official demographic statistics. The results of the study reveal the dynamics of mining activity, the spatial scale of exploitation over time, and changes in land use in the area of the case study. The research is useful for spatial planning after the exploitation of the ore, but also for the creation of various development policies for the population. This type of study opens up space for monitoring other changes that occurred during exploitation, both in the area of this and other surface mines.

**Keywords:** mining, spatial-temporal transformation, GIS assessment, Bosnia and Herzegovina

## INTRODUCTION

The beginning of the extraction of ore and mineral resources is linked to the distant past. From the first excavations until today, the process of mining exploitation has been modernized and is gaining in scope and intensity. In many countries, the extraction of ores and minerals, along with other activities of the secondary sector, represent the main support for the development of the economy. However, the development of digital tools for monitoring spatial-temporal processes happened later. Considering the complexity and multidimensional character, extraction processes are difficult to monitor and analyze temporally and spatially, and to determine their spatial effects, as well as the direction and extent of the spatial transformations they cause. With the development of digital tracking tools, that process is somewhat easier. As expected, countries with advanced technology were the first to create and implement digital tools and platforms for monitoring transformations in Geospace. In particular, the use of Geographic Information Systems (GIS) in combination with different spatial data is represented for the purpose of monitoring the range of disturbance of the vegetation cover due to mining [1], [2], [3], [4], [5], [6], [7], [8], [9], [10], as well as in the management of land cover after the closure

of the mine [11], [12], [13]. The use of GIS for the analysis of mining activities has been present for more than a decade in B&H and in the region [14], [15], [16], [17], [18], [19]. The methodology applied in this paper also appears in earlier studies dealing with mining worldwide [20], [21]. We emphasize that the use of such methodologies for the purpose of monitoring spatial-temporal transformations in mining regions has not been applied to examples from B&H, although there are papers with a similar methodology for the purposes of analyzing other spatial resources [22], [23], [24]. An example of a coal basin in B&H, which will be the subject of this paper, is the area of the municipality of Ugljevik, which belongs to the coal-bearing basin of northeastern Majevica. Coal mining in the area of this case study has a long tradition and has been going on since 1899. The mining tradition, and the production of electricity based on it, represents the economic basis of the population of this municipality, but also of the B&H. The positive effects of this activity are reflected in the multiplication of jobs and income, also putting this municipality in the group of economically developed ones. However, mining activity is accompanied by negative effects on the land cover. Therefore, the subject of the paper represents the identification of changes in land cover due to mining activity and its effect on settlement system in municipality.

## METHODS AND DATA

The input data for the research area are vector data about the border of the municipality of Ugljevik, and the borders of settlements in the study area. For the comparative analysis of changes in the structure of study area land, data from Corine Land Cover – CLC (https://land.copernicus.eu/pan-european/corine-land-cover) 2000 and 2018 were used. Using QGIS software (https://qgis.org/), data on land use structure was extracted to the level of the study area. Categorization of land within the paper was carried out by the method of joining land classes from the official CLC nomenclature, to land categories that appear in the cadastral structure of land use (Tab. 1).

**Table 1**. Categorization of land use structure

| | | | |
|---|---|---|---|
| Productive | Agricultural | Cultivable | 2.1.1 Non-irrigated arable land; 2.4.2 Complex cultivation patterns; 2.4.3 Land principally occupied by agriculture, with significant areas of natural vegetation; 2.2.2 Fruit trees and berry plantations |
| | | Uncultivable | 2.3.1 Pastures |
| | Non-agricultural | | 3.1.1 Broad-leaved forest |
| Unproductive | | Thermal power plant | 1.2.1 Industrial or commercial units |
| | | Mining area | 1.3.1 Mineral extraction sites; 1.3.2 Dump sites |
| | | Built-up areas | 1.1.2 Discontinuous urban fabric |

The basic division within the categorization is based on productive and unproductive land. Productive land includes agricultural and non-agricultural lands (CLC: 3.1.1). Agricultural land is divided into cultivable land (CLC: 2.1.1; 2.4.2; 2.4.3; 2.2.2) and uncultivable land (CLC: 2.3.1). Unproductive lands include the following categories: built-up areas (CLC: 1.1.2), and lands with dominant mining activity (CLC: 1.2.1; 1.3.1; 1.3.2).

The impact of mining activities on the demographic characteristics of the area was analyzed based on the available data in the 1991 and 2013 censuses. The estimate of the number of inhabitants at the settlement level is not available for the post-census period,

and for this reason, the reference periods of the analysis of changes in land use structures and changes in demographic characteristics do not coincide.

## RESULTS AND DISCUSSION

In the analyzed period, changes were observed in the structure of land use at the municipal level. As expected, given the existence of mining activities for the surface exploitation of coal and thermal power plants for burning coal, increased areas of those land categories are visible (Fig. 1, Tab. 2).

**Table 2**. Changes in the structure of land use at the level of the municipality of Ugljevik in the period 2008-2018

| | Productive | | | Unproductive | | |
|---|---|---|---|---|---|---|
| | Agricultural | | | | | |
| | Cultivable | Uncultivable | Non-agricultural | Thermal power plant | Mining area | Built-up areas |
| Area (ha) 2000 | 10396.53 | 115.09 | 5568.32 | 59.47 | 581.84 | 321.38 |
| Area (ha) 2018 | 9774.48 | 114.24 | 6004.12 | 78.28 | 813.93 | 257.59 |
| Absolute change 2018/2000 | -622.05 | -0.85 | 435.80 | 18.80 | 232.09 | -63.79 |
| Index of change 2018/2000 | 94.02 | 99.26 | 107.83 | 131.62 | 139.89 | 80.15 |
| Share in the total land area in 2000 | 61.00% | 0.68% | 32.67% | 0.35% | 3.41% | 1.89% |
| Share in the total land area in 2018 | 57.35% | 0.67% | 35.23% | 0.46% | 4.78% | 1.51% |

The increase of surface area in favor of land under mining activities caused changes in other land use categories. The results of the analysis indicate changes in the area of productive land through the reduction of the area of agricultural land in both subcategories: the area of cultivable land decreased by -622.05 ha, and the area of uncultivable land by -0.85 ha. The increase in the area of non-agricultural land (forest) by 435.80 ha can be interpreted as an increase in recultivated areas that were used for mining in the past. The area of unproductive land in the observed period increased in the categories of land used for mining activities. The space for the thermal power plant infrastructure expanded by 18.80 ha, while the mining area expanded by 232.09 ha. The data indicate a decrease in the area under the built-up areas category, but subsequent validation of the data established that there was no change in that category of land use. Those surfaces are not located near the area of mining activities, and are not the subject of a detailed analysis. The change in the share of mining land in the total is positive, but at the municipal level, that share is still small (about 5 %).

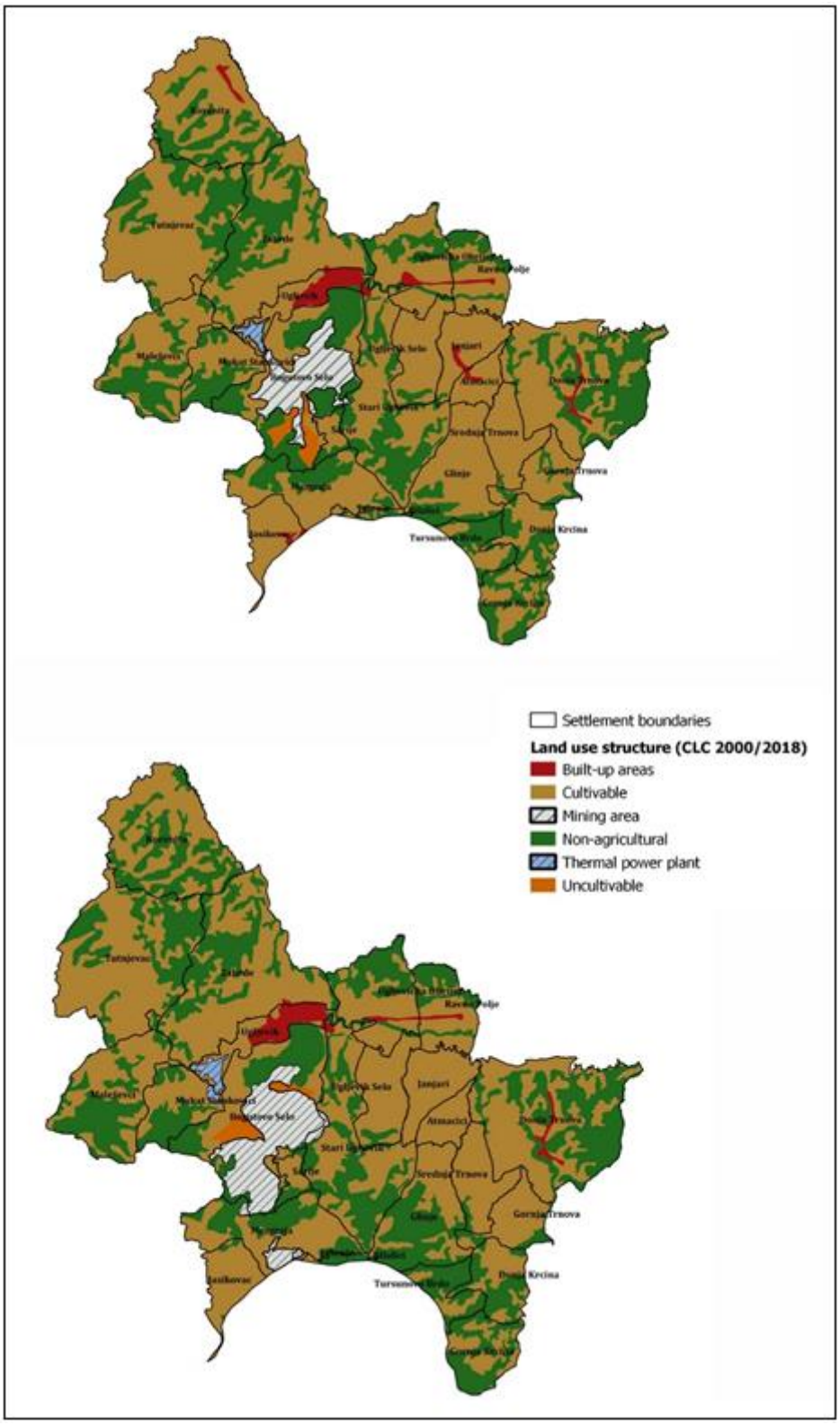


**Figure 1**. Change in land use structure at the level of the municipality of Ugljevik (CLC 2000 –up; CLC 2018 –down)

Changes in the structure of land use were also analyzed at the level of the settlement system, in order to identify settlements whose land has been usurped by mining activities, as well as the intensity of these changes. The settlements where the land is used for mining

activities has been identified: Stari Ugljevik, Ugljevik, Bogutovo Selo, Jasikovac, Mezgraja, Mukat Stankovići (Fig. 1) and they make up 24 % of the settlements in the total settlements network, and occupy 28.22 % of the total territory of the municipality. For a simpler presentation, the results of the analysis are given in summary for all 6 settlements (Tab. 3).

**Table 3**. Changes in the structure of land use in settlements where mining activities take place

| | Productive | | | Unproductive | | |
|---|---|---|---|---|---|---|
| | Agricultural | | | | | |
| | Cultivable | Uncultivable | Non-agricultural | Thermal power plant | Mining area | Built-up areas |
| Area (ha) 2000 | 2268.48 | 114.88 | 1610.02 | 59.13 | 581.79 | 175.71 |
| Area (ha) 2018 | 2151.92 | 114.24 | 1476.24 | 77.93 | 813.72 | 175.95 |
| Absolute change 2018/2000 | -116.55 | -0.64 | -133.78 | 18.80 | 231.93 | 0.25 |
| Index of change 2018/2000 | 94.86 | 99.44 | 91.69 | 131.80 | 139.86 | 100.14 |
| Share in the total land area in 2000 | 47.16% | 2.39% | 33.47% | 1.23% | 12.10% | 3.65% |
| Share in the total land area in 2018 | 44.74% | 2.38% | 30.69% | 1.62% | 16.92% | 3.66% |

As expected, the areas of mining categories of land increased in the period under review (by 250.73 ha in total), while the areas of other categories decreased. The area of productive land was reduced by a total of -250.98 ha, and this difference represents the conversion of land for mining activities needs. The share of productive land in the total area of settlements covered by mining activities decreased in the observed period by -5.22 % (from 83.02 % to 77.80 %), while the share of mining land increased by 5.21 % and makes 18.54 % of the area of the observed settlements. A detailed analysis at the level of each settlement, separately, indicates the direction of mining activities. The largest increase in mining areas is noticeable in the settlement of Bogutovo Selo, where this category of land increased by 142.96 ha. Smaller increases occurred in the settlements of Mezgraja (by 64.00 ha), Stari Ugljevik (by 18.14 ha) and Jasikovac (by 6.80 ha). In the settlements of Mezgraja and Jasikovac, coal exploitation begins in the observed period, which was not visible at the beginning of the period. The increase in the area under the thermal power plant infrastructure occurred in the settlements: Mukat Stankovići (by 14.98 ha), Ugljevik (by 3.82 ha) and Bogutovo Selo (by 0.001 ha), and this category of land was present even before the observed period in the mentioned settlements. Looking integrally at the land categories used for mining activities (mining area and thermal power plant), they occupy the most space in the settlement of Bogutovo Selo (45.43 %) and the settlement of Ugljevik, where the thermal power plant is located (15.61 %), while in other settlements occupy less than 10 % of the area.

The conversion of land for mining activities had different effects on the structure of land use in certain settlements. In the settlement of Bogutovo Selo, the area of non-agricultural land (forest) was reduced, while in other settlements, agricultural (cultivable) land was reduced to varying degrees. Mining activities, although small in area, due to their nature have effects on a wider area: changes in the morphophysiology of the relief, changes in infrastructure, changes in microlime and environmental pollution. The local population, which is the driver of economic development, is directly exposed to the above-mentioned effects. Therefore, it is important to assess the demographic characteristics of the area

usurped by mining activities. Changes in the demographic size of identified settlements where mining activities take place are shown in Table 4.

**Table 4**. Changes in the demographic size of settlements where mining activities take place

| | Settlement | Total population 1991 | Total population 2013 | Absolute change 2013/1991 | Index of change 2013/1991 | Share in the total population in 1991 | Share in the total population in 2013 |
|---|---|---|---|---|---|---|---|
| Area of mining activities until 2018 | Bogutovo Selo | 499 | 294 | -205 | 58.92 | 1.95% | 1.94% |
| | Jasikovac | 1118 | 96 | -1022 | 8.59 | 4.37% | 0.64% |
| | Mezgraja | 714 | 459 | -255 | 64.29 | 2.79% | 3.04% |
| | Ugljevik | 2981 | 3922 | 941 | 131.57 | 11.65% | 25.94% |
| | Mukat Stankovići | 458 | 330 | -128 | 72.05 | 1.79% | 2.18% |
| | Stari Ugljevik | 1126 | 707 | -419 | 62.79 | 4.40% | 4.68% |
| | **Total** | 6896 | 5808 | -1088 | 84.22 | 26.95% | 38.42% |

The demographic size of settlements where mining activities take place decreased in the intercensal period (1991–2013). The settlement of Ugljevik increased its demographic size because it is the only urban settlement in the municipality. In the settlements of Bogutovo Selo and Stari Ugljevik, mining activities were present even before the observed period, while in the other settlements they started after 2000. Therefore, in those settlements, the number of inhabitants can be expected to decline in the process of the expansion of mining and the emigration of the local population. In 1991, the population of settlements where mining activity is currently taking place was 26.95 % of the then population. Today, although they are demographically reduced, these settlements comprise 38.42 % of the municipality's population, which indicates the number of the population that faces the effects of mining activities.

## CONCLUSION

In the paper, the CLC digital database of spatial data was used for the analysis of changes in land use. The CLC is an important digital database for monitoring changes in land use because it provides a standardized and consistent classification of land types over 20 years.

The research identified the spatio-temporal dimension of mining activities in the selected research area. Areas under mining activities had a different effect on the reduction of other categories of land use in certain settlements. A regularity was observed: reduced agricultural (cultivable) land in all settlements, with the exception of the settlement Bogutovo Selo, where was a decrease in non-agricultural land (forest). The results indicate the intensity of mining activities, which is the highest in Bogutovo Selo, where was a mine even before the observed period. The expansion of mining activities in the new settlements, Jasikovac and Mezgraja, has been observed. The population living in settlements where mining activity takes place makes up more than a third of the total population of the municipality. The identified population is directly faced with changes in the land use (and therefore sources of income) and potential emigration due to land expropriation.

Namely, mining activities represent activities that take place rapidly in space with dynamic intensity and changing direction of movement. But new CLC data is available

every 6 years, and this is precisely one of the shortcomings of the CLC database in terms of researching mining activities in space. If the analyst wants to track the causes and consequences of mining activities in space for a period of time that is shorter than 5 years, it will not be possible with the CLC database. An alternative solution is the use of satellite images and their classification for the defined time period. The authors of the paper believe that the results of the analysis could be of higher quality and more credible if changes in space (with an emphasis on mining activities) were followed by comparative use of the CLC database and user-classified satellite images.

Certainly, this type of research has a contribution in identifying the spatiality of mining activities in the network of settlements and determining the future effects of mining on the land fund in the network of settlements. The results obtained from this kind of research provide the basis for the creation of government policies regarding the strategic management of human capital and the land fund in the identified settlements.

## REFERENCES

[1] Liu, Y., Zhou, W., Yan, K., Guan, Y., & Wang, J. (2022). Identification of the disturbed range of coal mining activities: A new land surface phenology perspective. Ecological Indicators, 143, 109375.

[2] Shang, H., Zhan, H. Z., Ni, W. K., Liu, Y., Gan, Z. H., & Liu, S. H. (2022). Surface Environmental Evolution Monitoring in Coal Mining Subsidence Area Based on Multi-Source Remote Sensing Data. Frontiers in Earth Science, 10, 790737.

[3] Song, W., Song, W., Gu, H., & Li, F. (2020). Progress in the remote sensing monitoring of the ecological environment in mining areas. International journal of environmental research and public health, 17(6), 1846.

[4] Iwatsuki, Y., Nakajima, K., Yamano, H., Otsuki, A., & Murakami, S. (2018). Variation and changes in land-use intensities behind nickel mining: Coupling operational and satellite data. Resources, Conservation and Recycling, 134, 361–366.

[5] Rudke, A. P., de Souza, V. A. S., Dos Santos, A. M., Xavier, A. C. F., Rotunno Filho, O. C., & Martins, J. A. (2020). Impact of mining activities on areas of environmental protection in the southwest of the Amazon: A GIS-and remote sensing-based assessment. Journal of environmental management, 263, 110392.

[6] Madasa, A., Orimoloye, I. R., & Ololade, O. O. (2021). Application of geospatial indices for mapping land cover/use change detection in a mining area. Journal of African Earth Sciences, 175, 104108.

[7] Nascimento, F. S., Gastauer, M., Souza-Filho, P. W. M., Nascimento Jr, W. R., Santos, D. C., & Costa, M. F. (2020). Land cover changes in open-cast mining complexes based on high-resolution remote sensing data. Remote Sensing, 12(4), 611.

[8] LaJeunesse Connette, K. J., Connette, G., Bernd, A., Phyo, P., Aung, K. H., Tun, Y. L., ... & Songer, M. (2016). Assessment of mining extent and expansion in Myanmar based on freely-available satellite imagery. Remote Sensing, 8(11), 912.

[9] Mi, J., Yang, Y., Zhang, S., An, S., Hou, H., Hua, Y., & Chen, F. (2019). Tracking the land use/land cover change in an area with underground mining and reforestation via continuous Landsat classification. Remote Sensing, 11(14), 1719.

[10] Kuzevic, S., Bobikova, D., & Kuzevicova, Z. (2022). Land Cover and Vegetation Coverage Changes in the Mining Area – A Case Study from Slovakia. Sustainability, 14(3), 1180.

[11] Vasileiou, E., Stathopoulos, N., Stefouli, M., Charou, E., & Perrakis, A. (2012). Evaluating the Environmental Impacts after the Closure of Mining Activities Using Remote Sensing Methods – the Case Study of Aliveri Mine Area. In Annual Conference (pp. 755–763).

[12] Karan, S. K., Samadder, S. R., & Maiti, S. K. (2016). Assessment of the capability of remote sensing and GIS techniques for monitoring reclamation success in coal mine degraded lands. Journal of environmental management, 182, 272–283.

[13] Antwi, E. K., Krawczynski, R., & Wiegleb, G. (2008). Detecting the effect of disturbance on habitat diversity and land cover change in a post-mining area using GIS. Landscape and Urban Planning, 87(1), 22–32.

[14] Amović, M. Z., Vasiljević, S. S., Višnjić, R. I., Regodić, M. D., & Sekulović, D. J. (2015). Podaci GIS u rudarskim istraživanjima. Proceedings of SYM-OP-IS 2015. 115.

[15] Tomašević, A., Kolonja, Lj., Obradović, I., Stanković, R., & Kitanović, O. (2012). Razvoj ArcGIS geobaze površinskog kopa korišćenjem UML CASE alata. Podzemni radovi, 20, 29–38.

[16] Станчић, Н., & Ковачевић, Ј. (2018). ГИС технологије у праћењу промена на површинским коповима Рудника бакра бор. ГИС Журнал 2018. 24–29.

[17] Smajić, S., Kovačević, M., & Pavić, D. (2021). Identification and geovisualization of landscape transformation of surface mine areas in the Đurđevik coal basin (Bosnia and Herzegovina). Geographica Pannonica, 25(1).

[18] Smajić, S., Kadušić, A., Omerović, A., & Kovačević, M. (2020). GIS analysis of landscape topography transformation of the open pit "Grivice" (Bosnia and Herzegovina). Revija za geografijo-Journal for Geography, 15(2), 33–50.

[19] Mancini, F., Stecchi, F., & Gabbianelli, G. (2009). GIS-based assessment of risk due to salt mining activities at Tuzla (Bosnia and Herzegovina). Engineering Geology, 109(3-4), 170–182.

[20] Sari, H., & Ozsahin, E. (2016). Spatiotemporal change in the LULC (Landuse/Landcover) characteristics of Tekirdag Province based on the CORINE (Thrace, Turkey). Fresenius Environmental Bulletin, 25(11), 4694–4707.

[21] İlgi, A. T. A. Y. (2021). Detecting the Proximities of Mines to Settlements in Turkey through the CORINE Database. Mehmet Akif Ersoy Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 12(1), 136–149.

[22] Taletovic, J., Đuzo, F., Vojnikovic, S., Ljuša, M., & Čustovic, H. (2012). Osnovni principi, metodološki pristup Corine Land Cover u BiH i analiza rezultata CLC2000 i CLC2006. Geodetski glasnik, 46(42), 20–32.

[23] Drašković, B., Ponosov, A., Zhernakova, N., Gutalj, M., & Miletić, B. (2020). Land cover types and changes in land use in Republic of Srpska (Bosnia and Herzegovina) over the period 2000-2018. Journal of the Geographical Institute" Jovan Cvijic", SASA, 70(1), 81–88.

[24] Drašković, B., Gutalj, M., Stjepanović, S., & Miletić, B. (2021). Estimating recent forest losses in Bosnia and Herzegovina by using the Copernicus and Corine land cover databases. Šumarski list, 145(11-12), 581–589.