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CORINE LAND COVER CHANGE DETECTION IN SERBIA AND BOSNIA AND HERZEGOVINA

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ABSTRACT

The structure of land cover in Bosnia and Herzegovina (BiH) and the Republic of Serbia has been constantly changing due to a number of different factors. The war profoundly influenced life, particularly the socio-economic structure, which furthermore has a meaningful impact on current land cover. In this research CORINE land cover (CLC) databases are used (from 2000 to 2018) for analysis and comparison of land cover in the aforementioned countries. The analysis is conducted by ArcGIS Pro 2.9.0 software to interpret changes in land cover over the period 2000-2018. The result showed that in the period from 2000 to 2018 agricultural land has a trend of a significant decrease in both countries. In addition, artificial surfaces enlarged their surface, especially to the detriment of all agricultural categories which is directly linked with the process of the post-war reconstruction of the countries. In this paper, land cover changes in Serbia and BiH that occurred during the period 2000-2018 are analyzed and presented in graphical forms. The results show that the period 2000-2006 has undergone the most intense changes. A total of 1,223.14 km² of agricultural land was transferred to other types of land cover in Serbia in the period 2000-2006 while in BiH it amounted to 1,045.76 km². Most of these changes can be attributed to the past war and its implications, but also to the challenges of the current economic situation. The CLC database established in this way serves as a necessary framework for providing information on vulnerable ecosystems and habitats, as well as a basis for regional spatial planning, natural resource inventory and environmental monitoring.

Keywords: *Corine Land Cover, mapping, GIS, land use, Serbia, Bosnia and Herzegovina*

INTRODUCTION

The key prerequisite for making decisions focused at sustainable management of the environment and natural resources is knowing accurate and quality information about the existing biosphere and the changes that are happening in it. Consequently, The European Community accepted and developed a program for coordinating information on the environment and natural resources called CORINE (COoRdination of INformation on the Environment). The purpose of the program is the identification and meaningful categorization of land cover (LC) and land use (LU) data, which includes a defined nomenclature coding and creating a quality database, necessary for monitoring, organizing and managing natural resources on the regional and national level. The CORINE Land Cover (CLC) program is the most thorough and consistent cartographic

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source about changes in the European landscape during the period 1985–2018 (Feranec et al., 2016). Uniform legend and method of identification of 44 LC classes enable the research of landscape changes at the European level as well as at the regional and national level (Soukup et al., 2016).

Complete overviews of the use of CLC for assessment of changes in land-use and land-cover pattern can be found in Popovici et al. (2013), Feranec et al. (2007), Büttner (2014) and Martínez-Fernández et al. (2019). Fal'tan et al. (2020) compared official CLC data and national statistics (NS) of LU in Slovakia during the period 2000 - 2018 at national, county, and local levels. Dinç et al. (2021) applied linear and polynomial regression functions to the CLC data in order to quantitatively estimate the future changes in land use for Istanbul, Izmir and Ankara. To better understand urbanization and to implement proper protection of natural resources, it is crucial to observe and monitor the land cover changes. Up to date, there were seldom studies on CLC database utilization to determine CLC changes in different parts of the Republic of Serbia (e.g., Ostojić et al. (2019), Stojković (2017), Stankov et al., (2016) and Nestorov et al. (2007)). In BiH, Taletović et al., (2010), Vojniković et al., (2013) and Drašković et al., (2020) conducted research on land changes in this country, but none of the aforementioned studies compared changes in land cover, both in BiH and in Serbia in the period 2000-2018. Considering the fact that these two counties were in this period in the process of post-war reconstruction, as well as social and economic changes, studies have been prepared for the area of the Republic of Serbia and BiH. Hence, the aim of the study is to compare and analyze the changes that occurred on the territory of two countries that were in the post-war reconstruction at the beginning of the investigated period, to explain the causes of the changes and their impact on the environment.

STUDY AREA

The study area includes two countries in the Western Balkans - the Republic of Serbia and BiH (Figure 1). The Republic of Serbia (Serbia) is located between 41° 53N' and 46° 11'N and 18° 49'E and 23° 00'E. With an area of 88,361 km² and 7.2 million habitants (Population Census 2011, without data for AP Kosovo and Metohija), Serbia is the biggest and most populated country of the Western Balkans. It is divided into three units by administrative boundaries: Autonomous Province of Vojvodina (21,614 km²), Central Serbia (55,968 km²) and Autonomous Province of Kosovo and Metohija (10.887 km²). Belgrade is the capital of Serbia, with about 1,732,000 inhabitants (according to the 2011 census). Located at the confluence of the Sava and the Danube, Belgrade is one of the oldest cities in Europe and, next to Athens, the largest urban area in the Balkans.

The northern part of the Republic of Serbia is occupied by plains and in the southern regions there are hills and mountains. There are over 30 mountain peaks 2,000 m.a.s.l., and the highest peak is Velika Rudoka (The Šar Mountains) with a height of 2,660 m.a.s.l. With an average height of 545 m, it is considered a relatively hypsometrically high country, compared to the rest of European countries.

Serbia's climate is diverse. It is defined by the extensive Pannonian Plain in the north and the mountainous valley relief in the south. The climate of the Pannonian Plain is steppe- continental, and in mountainous and low eastern Serbia it is typically continental. In the wide and low valleys, the climate is 'parish' (variety between temperate continental and mountain climate), and in the high mountains it is mountainous, which changes to a typical alpine climate on the highest mountain peaks.

BiH covers an area of 51,129 km² and has 3.5 million habitants (Population Census 2013). It is located between 42° 33' 00" and 44° 16' 30"N and 15° 44' 00" and 19° 37' 41"E. The capital is Sarajevo, which is also the largest city in BiH, with a total of 275,524 inhabitants. It is administratively divided into the Federation of Bosnia and Herzegovina, Republika Srpska and the Brčko District of Bosnia and Herzegovina. The Federation of Bosnia and Herzegovina has an area of 26.110 km² and it is divided into 10 cantons and the cantons into municipalities. The Republic of Srpska (RS) covers an area of 24,666 km² or about 48.5% of Bosnia and Herzegovina's territory. Brčko District of BiH is a unique administrative unit of local self-government that is under the sovereignty of BiH. It was officially established on March 8, 2000. The Brčko District of Bosnia and Herzego-

vina is located in the north of BiH, on the right bank of the Sava River on an area of 493 km², which is about 1% of the area of BiH.

With an average altitude of 625 m and a maximum elevation of 2,386 m.a.s.l (the peak Maglić), BiH is one of the hypsometrically higher countries in Europe. Its relief is mainly hilly and mountainous, but at the same time it is also very divided by valleys. In the sector of the Neum Bay, it opens onto the Adriatic Sea, with a 24-kilometer coastal facade. Due to the influence of geographical and climatological factors, the climate of BiH is very complex and is conditioned by its geographical location. The continental climate occurs in the north, the mediterranean climate in the south, and the line that separates these two regions is the area of high mountains, plateaus and gorges, in which, depending on the altitude, the mountain climate dominates.

The above-mentioned countries were most affected by the events during the Yugoslav war and were consequently chosen as the research area.

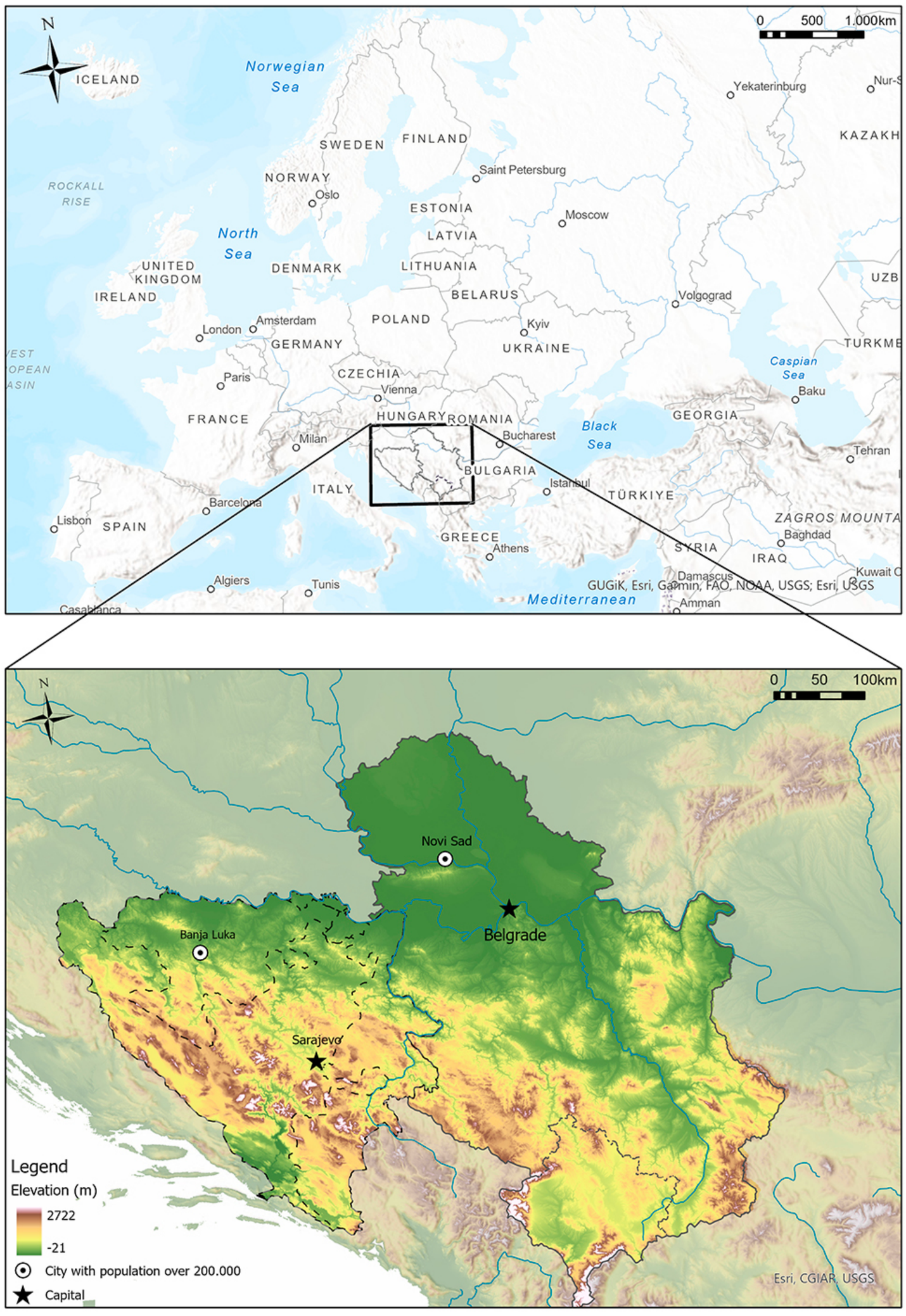

Figure 1. Location of the study area

Source: Author

MATERIALS AND METHODS

The standard approach to creating a CLC database is based on the visual interpretation of high-resolution satellite images according to the accepted standard CLC methodology, providing vector data on the land cover at a scale of 1:100,000, a minimum polygon width of 100 m and a minimum mapping area of 25 ha, i.e. 5 ha for the database land cover change. The standard CLC nomenclature includes 44 classes, arranged in 3 levels, each of which describes a different land cover. The five main categories are: artificial surfaces, agricultural surfaces, forest vegetation and other natural surfaces, wetlands and water surfaces. In addition to the main level of nomenclature (level 1), there are two more standard levels of nomenclature. The advantage of using CLC is unified hierarchical legend which allows data comparability (Falťan et al., 2020). The limiting factor for the usability of the data at the local level is the minimum size of the mapped area, which is 25 ha, and the minimum width of line elements, which is 100 m, but this database is optimal for research at the country level. All CLC data layers are available online and downloaded from the EEA website: https://land.copernicus.eu/pan-european/corine-land-cover/view for the years 2000, 2006, 2012 and 2018.

In BiH, the CORINE program started in 1998, after war events. Consequently, BiH is not covered by the CLC 1990 database. CORINE Land Cover 2000 (CLC2000) program was implemented in Serbia in 2005. The main goal was to coordinate the activities of Serbia with the activities of other European countries when it comes to monitoring the condition and changes in land cover resources. For the analysis we used data from standard level 2 CORINE nomenclature for the years 2000, 2006, 2012 and 2018.

The analysis has been facilitated by the ArcGIS Pro 2.9.0 software to interpret land cover changes that happened in the period 2000 – 2018 in BiH and Serbia. In this case, the ArcGIS Pro Clip tool is used to extract the territory of the aforementioned countries and to analyze CLC data together with land cover change. The data were then exported to Excel and summarized using the SUBTOTAL tool by land cover types and changes for all three CLC levels and all four periods in both countries (Figure 2).

When there are different time periods of data collection, it is possible to monitor and visualize the changes occurring in the space. By overlapping data layers from several time periods, we can calculate the spatial coverage of changes and obtain information about which areas have undergone the most significant changes. The obtained information allows us to evaluate the loss and gain within each land-use class, identify the forms of change, and analyze changes in space and time (Popovici et al., 2013).

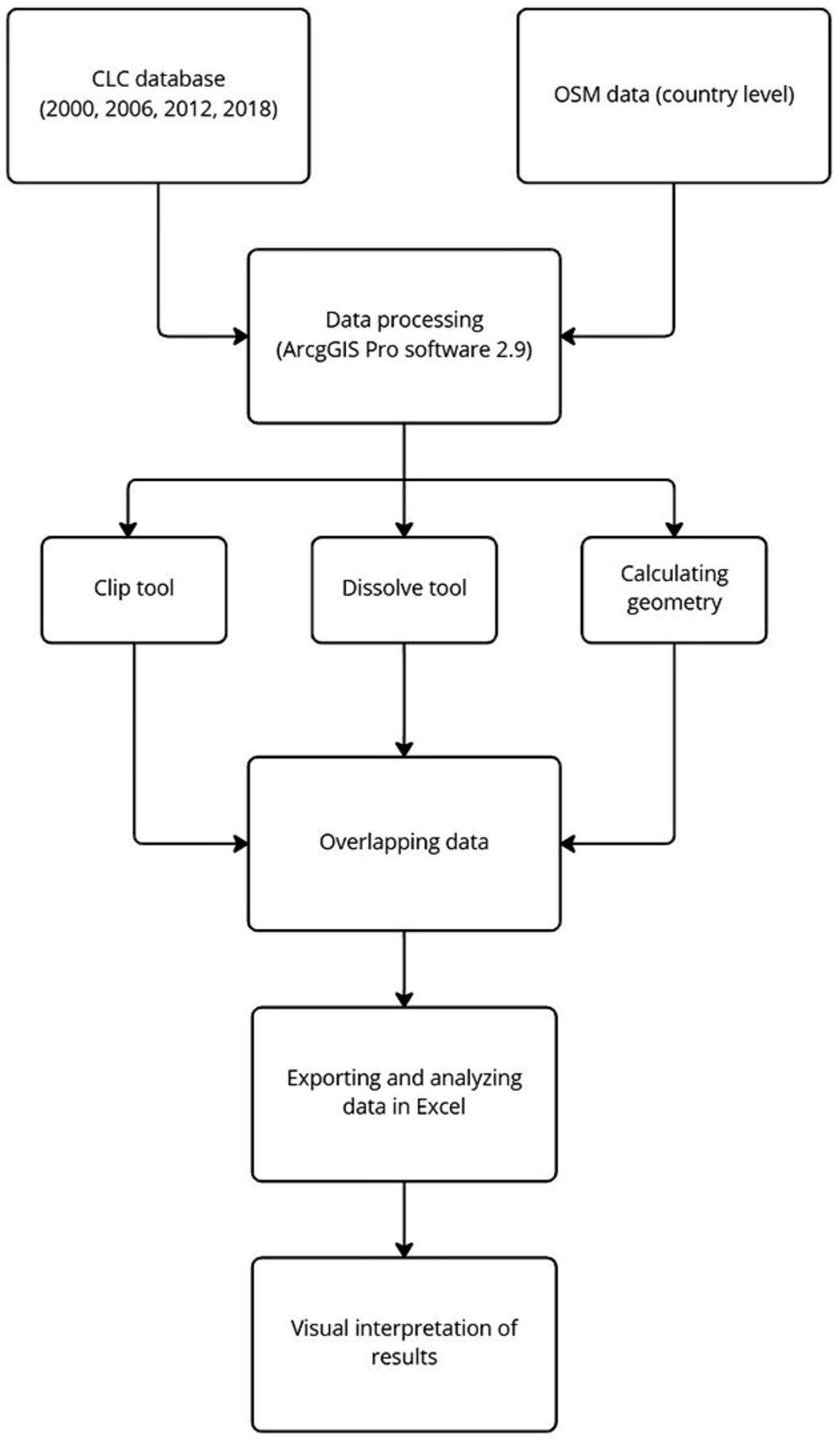

Figure 2. Methodology flowchart

RESULTS

After analyzing the types of land cover, according to the CLC nomenclature, the following information was obtained: in 2018, in Serbia, there were 5 first-class levels (out of 5), 13 second-class (out of 15) and 31 (out of 44) third-class levels, with the following definitions (Table 1).

Table 1. CORINE Land Cover nomenclature (identified in Serbia in 2018)

LEVEL 1	LEVEL 2	LEVEL 3
Artificial surfaces	11 Urban Fabric	111 Continuous urban fabric 112 Discontinuous urban fabric
	12 Industrial, commercial and transport units	121 Industrial or commercial units 122 Road and rail networks and associated land 123 Port areas 124 Airports
	13 Mine, dump and construction sites	131 Mineral extraction sites 132 Dump sites 133 Construction sites
	14 Artificial, non-agricultural vegetated areas	141 Green urban areas 142 Sport and leisure facilities
Agricultural areas	21 Arable land	211 Non-irrigated arable land
	22 Permanent crops	221 Vineyards 222 Fruit trees and berry plantations
	23 Pastures	231 Pastures
	24 Heterogeneous agricultural areas	242 Complex cultivation patterns 243 Land principally occupied by agriculture, with significant areas of natural vegetation
Forest and semi natural areas	31 Forests	311 Broad-leaved forests 312 Coniferous forests 313 Mixed forests
	32 Scrub and/or herbaceous vegetation associations	321 Natural grasslands 322 Moors and heathland 323 Sclerophyllous vegetation 324 Transitional woodland-scrub
	33 Open spaces with little or novegetation	331 Beaches, dunes, sands 332 Bare rocks 333 Sparsely vegetated areas 334 Burnt areas
Wetlands	41 Inland wetlands	411 Inland marshes
Water bodies	51 Inland waters	511 Water courses 512 Water bodies

CORINE 2018 in BiH is characterized by 32 out of 44 CORINE nomenclature classes at level 3, 14 out of 15 second-class levels and 5 out of 5 first-class levels (Table 2).

Table 2. CLC nomenclature (identified in BiH in 2018)

LEVEL 1	LEVEL 2	LEVEL 3
Artificial surfaces	11 Urban Fabric	111 Continuous urban fabric 112 Discontinuous urban fabric
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Water bodies	51 Inland waters	511 Water courses 512 Water bodies
	52 Marine waters	523 Sea and ocean

Concerning differences in both countries, BiH has one class more than Serbia on the second level CLC nomenclature - marine waters (code 52). As previously mentioned, BiH has narrow access to the sea with a length of 24 km. As regards the third level of classification, Serbia has a category port areas (code 132) with an area of 2 km² while BiH does not have the specified class. This information does not signify that there is no port on the territory of BiH, but that no port in this country has an area larger than the area required for CLC mapping (25 ha). The largest ports in BiH are located in Brčko and Bosanski Šamac. Belgrade, Pančevo and Novi Sad are the largest ports in Serbia.

As regards the territory of BiH, on the third level classification, it has 2 more classes than Serbia; permanently irrigated land (code 212) with an area of 22 km² and sea and ocean (code 523) with an area of 0.02 km², according to the CLC 2018 database.

As for the first level of classification in the reference period, neither in Serbia nor in BiH were there any large deviations in the percentage share of classes during the period (Figure 3). However, when compared in km², many changes can be observed and analyzed.

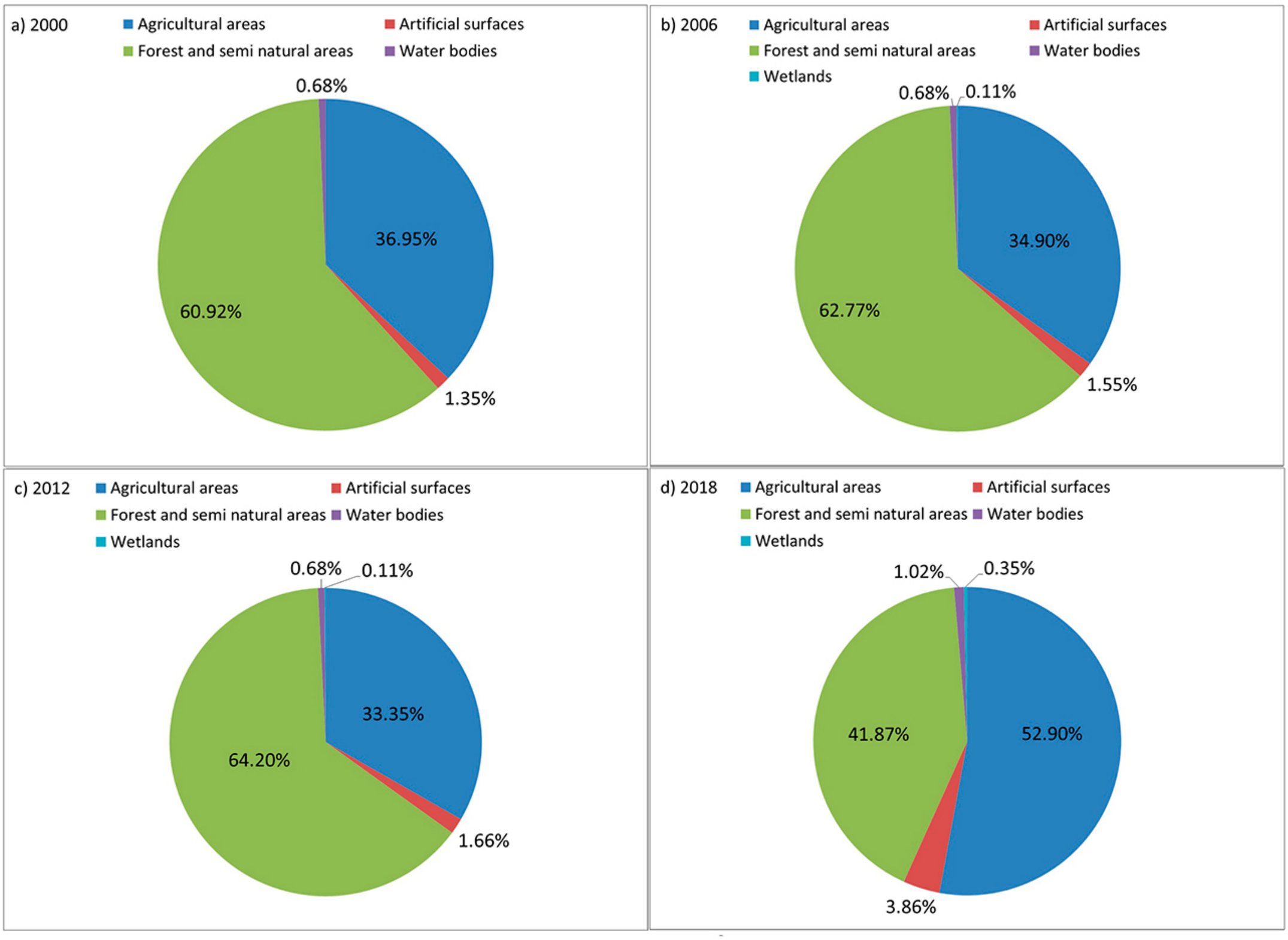

Figure 3. Coverage of CLC level 1 classes in Serbia in 2000-2018

When comparing changes in the land cover area in the presented periods, it can be observed that the period 2000-2006 has undergone the most intense changes. A total of 1,223.14 km² of agricultural land has changed to other types of land cover in the period 2000-2006. Total of 1,875.5 km² for the observed period, in percentage; from 55% to 52.9% of the territory of Serbia. Forest and semi-natural areas had increased their surface by 1,165.2 km². For comparison, the global area under forests increased by 4% in the period from 2000 to 2018, while in Serbia the percentage is negligible – 1.31%. In BiH, the coverage and changes in the first level classification are distinctive (Figure 4).

According to the CLC database, in 2000, forest and semi-natural areas represent the biggest land coverage at 60.92% (code 3), followed by agricultural areas at 36.95% (code 2), while artificial surfaces cover 1.3% (code 1) and the class water bodies covers 0.68% of the country. At the end of the reference period, forest and semi-natural areas cover 64.2% of the area, agricultural areas 33.3%, artificial areas increased their percentage to 1.71%, and water bodies and wetlands covered 0.68 and 0.11, respectively. Due to the fact that the first level of CLC classification is simplified, the usage of the second level is of great importance for the more thorough analysis of land use changes (Table 3).

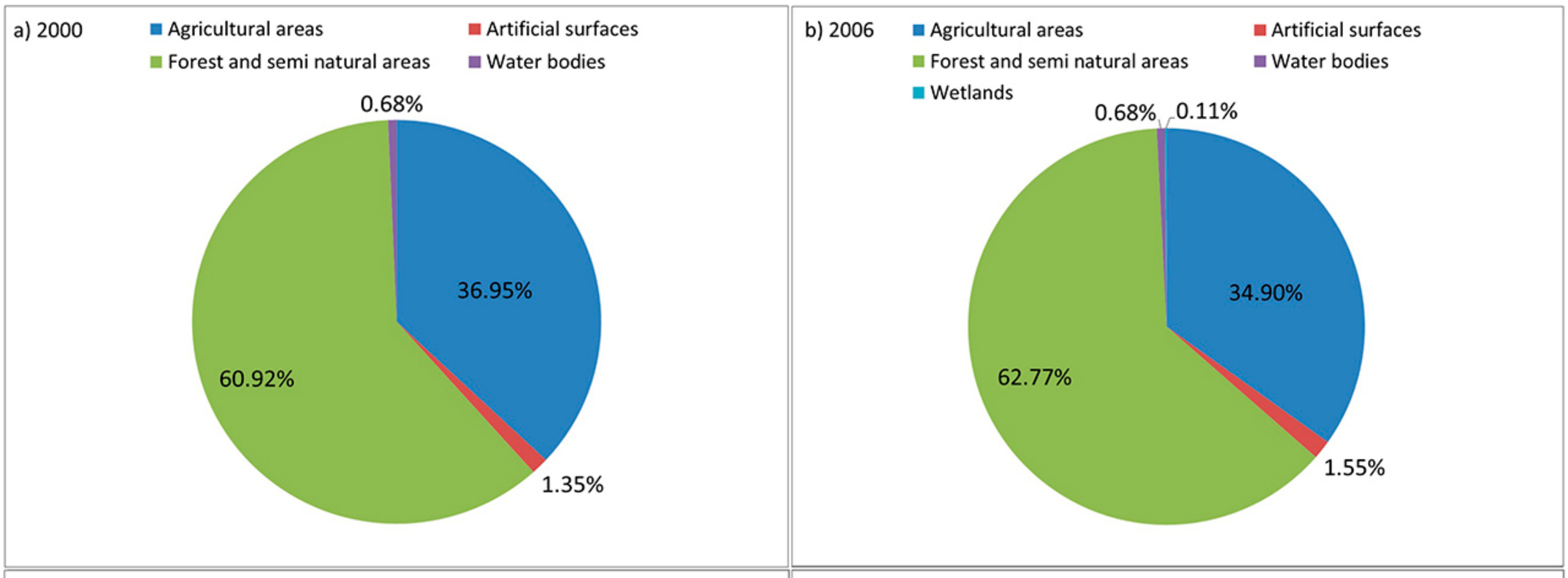

Figure 4. Coverage of CLC level 1 classes in BiH in 2000-2018

Table 3. CORINE Level 2 changes 2000 – 2018 in Serbia (in km²)

CORINE class level 2 - Serbia	CLC 2000	CLC 2006	CLC 2012	CLC2018
Arable land	21,270.72	22,894.48	23,005.42	23,022.87
Artificial, non-agricultural vegetated areas	60.12	79.33	79.96	80.3
Forests	27,269.21	27,537.81	27,642.55	27,603.49
Heterogeneous agricultural areas	25,663.07	22,644.43	21,966.91	21,952.23
Industrial, commercial and transport units	236.18	298.28	331.74	348.43
Inland waters	879.31	912.14	910.21	912.69
Inland wetlands	250.59	279.92	315.34	313.8
Mine, dump and construction sites	123.29	144.6	172.34	170.4
Open spaces with little or no vegetation	394.54	389.07	431.38	421.89
Pastures	1,821.09	1,848.06	1,749.25	1,708.64
Permanent crops	281.31	426.08	488.36	476.95
Scrub and/or herbaceous vegetation associations	8,496.62	9,064.71	9,224.89	9,300.19
Urban fabric	2,405.39	2,632.53	2,833.07	2,839.56

In Serbia, according to the CLC 2018 database, on the second level, the categories that cover most of the area are: forests (code 31) at 31.19%, arable land (code 21) at 26.01% and heterogeneous agricultural areas (code 24) covering 24.81%. Regarding changes, in the period 2000-2006 the largest number of changes in land use was recorded, counting 6,046.25 km². While the smallest number of changes was recorded in the period 2012-2018, it amounted to 237.53 km². Namely, the category arable land in the period 2000-2018 increased the total area by 1,752.15 km². The increase of the category industrial, commercial and transport units, from 236.18 km² to 348.43 km² is very important for understanding the process of urbanization in the reference period. Also, another change related to urbanization occurred, the total area of urban fabric class, from 2,405.39 km² to 2,839.56 km². In BiH, the total area of changes is smaller in the reference period, but not negligible (Table 4).

Table 4. CORINE Level 2 changes 2000 – 2018 in BiH (in km²)

CORINE class level 2 - BiH	CLC 2000	CLC 2006	CLC 2012	CLC2018
Arable land	1,150.55	1,861.99	1,824.81	1,825.42
Artificial, non-agricultural vegetated areas	5.19	7.81	14.15	14.15
Forests	22,644.74	23,212.37	23,751.07	23,714.19
Heterogeneous agricultural areas	13,567.25	12,476.65	11,829.14	11,821.2
Industrial, commercial and transport units	68.66	79.75	89.07	97.78
Inland waters	343.51	347.49	347.99	349.14
Inland wetlands	53.62	53.7	57.96	58.19
Marine waters	1.63	1.27	0.02	0.02
Mine, dump and construction sites	105.16	85.93	95.28	107.81
Open spaces with little or no vegetation	640.07	739.68	1,092.87	1,058.28
Pastures	4,089.42	3,418.12	3,269.46	3,249.31
Permanent crops	60.9	65.48	105.59	109.25
Scrub and/or herbaceous vegetation associations	7,825.66	8,103.04	7,940.97	8,012.35
Urban fabric	512.5	615.56	650.46	651.75

In BiH, the biggest losses within the CLC classes in the reference period occurred in the class heterogeneous agricultural areas, with a total area of 1,746.05 km². In addition, there is an evident trend of the progressive development of forest vegetation, which moves from lower forms of vegetation to higher ones (forest succession), over a total area of 1,069.45 km². This also indicates a pattern of abandonment of agricultural land and gradual conversion to forest vegetation, most likely as a result of wartime events. It can be assumed that these changes are the result of past population migrations, as well as war events. The total area of land cover changes in industrial, commercial and transport units category, as well as in urban fabrics, amounted to 29.12 km² and 139.25 km², respectively. Furthermore, in addition to heterogeneous agricultural areas, which had the biggest losses in the reference period, the pasture category also had losses in the total area of 840.11 km². In Figure 5 are represented CLC changes in the third-class nomenclature for the reference period in Serbia.

Concerning the third level of classification, the largest changes are related to the complex cultivation patterns (code 242). The total area of the class decreased 3,043.83 km² in the observed period. Additionally, land principally occupied by agriculture with significant areas of natural vegetation (code 243) also suffered area reduction, from 11,457.98 km² to 10,790.97 km². Moreover, there are notable changes associated with the reduction of the area of pastures (code 231) and natural grasslands (code 321). These two classes reduced by 112.45 km² and 110.32 km², respectively. On the other hand, the total areas of industrial or commercial units (code 121), discontinuous urban fabric (code 112) and transitional woodland-shrub (code 324) have increased by 99.45 km², 433.95 km², 884.42 km², respectively. Other individual changes of area are considerably smaller. Figure 6 shows changes in land cover in BiH for the reference period.

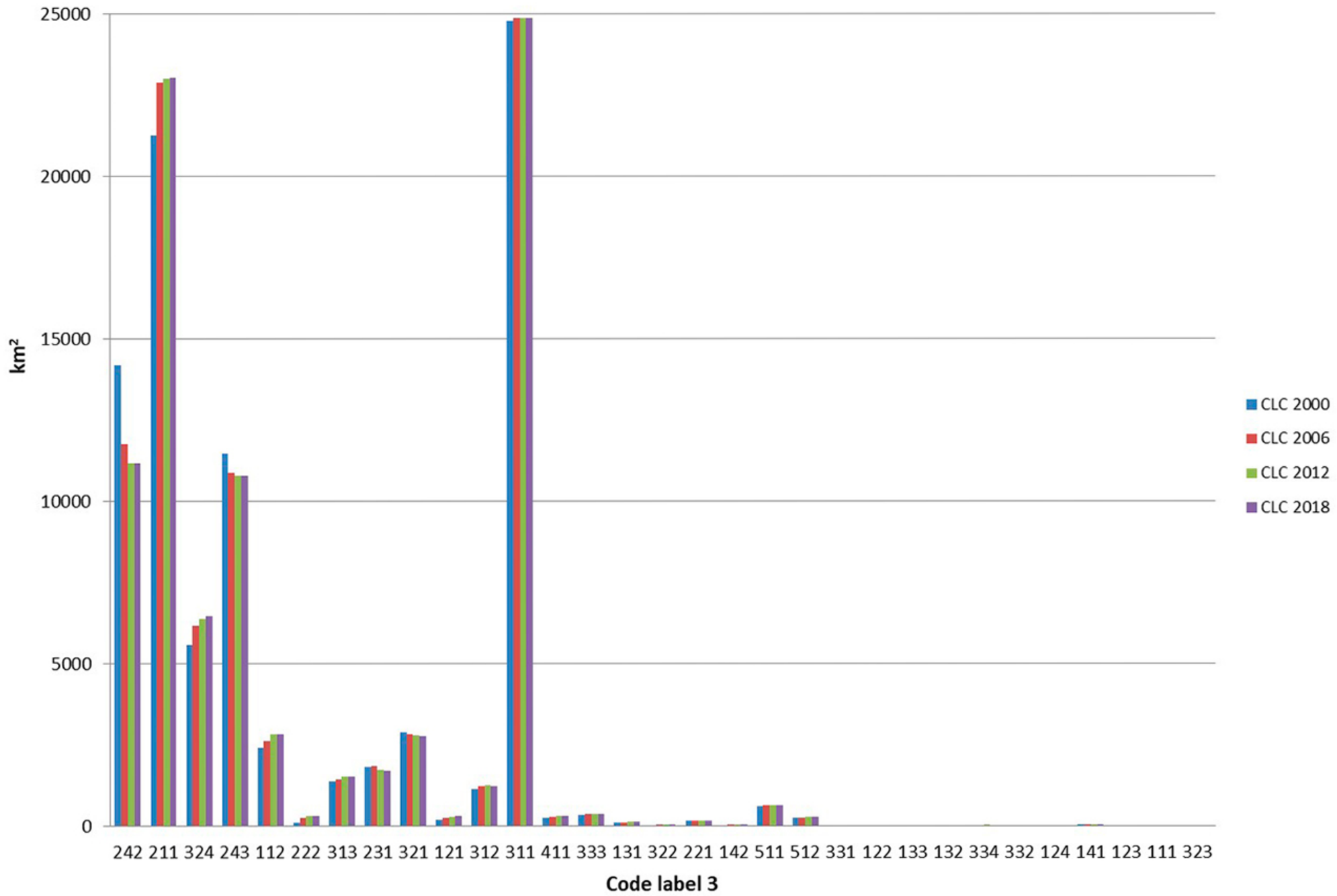

Figure 5. Land cover changes on CLC level 3 in Serbia in the period 2000–2018

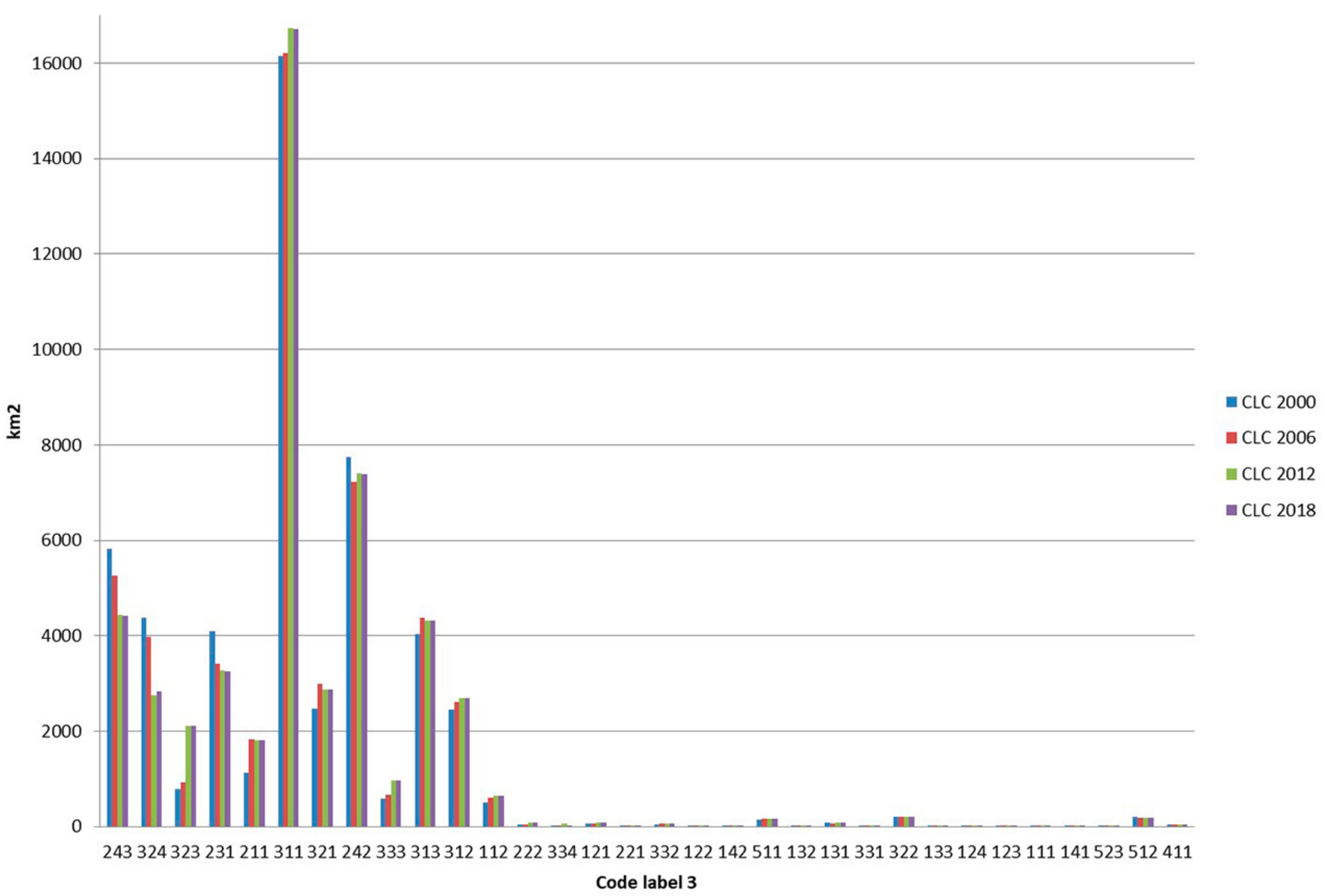

Figure 6. Land cover changes on CLC level 3 in BiH in the period 2000–2018

Regarding spatial changes in third-level classification in the period 2000–2018 in BiH, the extension of broad-leaved forest (code 311) is evident (from 16,156.03 km² to 16,713.71 km²). At the same time class transitional woodland-shrub (code 324) decreased by 1,540.38 km² (from 4,373.3 km² to 2,832.92 km²). The information indicates an increase of forests from succession vegetation. Furthermore, sclerophyllous vegetation (code 323) increased by 1,328.71 km² (from 778.67 km² to 2107.38 km²), as well as natural grasslands (code 321) and non-irrigated arable land (code 211) with 395.53 km² and 674.56 km², respectively. Among the land-use categories with a negative record in the study period were: land principally occupied by agriculture, with significant areas of natural vegetation (code 243) which decreased by 1,389.29 km² (from 5,815.49 km² to 4,426.2 km²), pastures (code 231), which area shrank by over 840 km² and complex cultivation patterns (code 242) which area decreased from 7,751.76 km² to 7,394.48 km².

DISCUSSION

Existing sources of land cover data for BiH and Serbia are outdated, inconsistent and mostly irrelevant. There are no official data on permanent land loss, and it is clear that the data from the previous century are still used in research and literature. This raises two very serious questions. First, which sources should be considered more reliable, and second, how much confidence can be placed in the consistency of the obtained data. The CLC database identifies both, land cover use and land cover change over time. Storing this database in a GIS system enables manipulation and analysis of the data required for sustainable spatial development and planning. This database provides accurate and comparable data at the same resolution and quality over time. Given the minimal mapping area (25 ha), the precision provided by CORINE land cover for identifying specific types of transformation is limited and is not sufficient for local analyses. Therefore, the need for a more detailed land cover dataset is noticed. However, the CLC database at a scale 1:100,000 is suitable for the analysis at the country level.

In this paper, changes in the land use pattern were detected for Serbia and BiH for the period 2000-2018. The first interval (2000-2006) represents the period of post-war reconstruction for both countries. During the aforementioned period, the biggest changes occurred. This was mainly related to the civil war in the former Yugoslavia, which led to the large-scale emigration of the Serbian population from the republics of Croatia and BiH (Ostojić et al., 2019). In this period, artificial surfaces in Serbia enlarged by 329.76 km², especially to the detriment of all agricultural categories. In addition, most of the changes took place within forests and semi-natural areas that have a growing trend, as well as artificial areas, while the area under agricultural land is decreasing. In most regions where forests were renewed, there was a combined impact: forest protection and a reduction in the number of male workers, as well as the withdrawal of livestock from forest complexes closer to settlements. In some areas, such as national parks, areas of exceptional characteristics and reserves, forest restoration was faster and more successful than in other, less protected areas. The second interval (2006-2012) largely overlaps with processes of urbanization in Southeastern Europe. Vast agricultural areas were transformed into urban areas during this period. With new residential complexes, industrial and commercial units (logistics parks, supermarkets, etc.), sports and leisure facilities, etc., their spatial function changed significantly. In this period, the area of artificial surfaces increased by 262.38 km² in Serbia and 59.92 km² in BiH and the loss of the agricultural surfaces was 603.1 km² in Serbia and 729.81 km² in BiH. The third interval (2012-2018) represents a period with a lower intensity of changes in each class in both countries. The trend of increasing areas under forest vegetation is less pronounced and negligible, as in other classes. The reason for the low changes is that both countries have encountered a population crisis in recent years. Hence, the intensity of changes has decreased and there is a probability that it will decrease even more in the coming years.

CONCLUSION

Given the fact that land is an essential factor for life, as well as the need to preserve this resource, there is a need for a functional system that will have quality and organized databases with the ability to perform spatial analyzes and monitor the situation on the ground. It is crucial to have reliable data on areas and the state of land resources in order to submit proposals for financing from agricultural funds, to plan support schemes for agriculture, support in negotiating for different funds, preparation of an efficient agricultural policy, etc. Although there are certain limitations of the CLC database (minimum mapping area of 25 ha, the possible interpretation errors of satellite images), it can be deduced that the CLC database is a reliable source for monitoring and quantifying spatial and temporal land use and land cover changes at the national and regional levels.

In BiH and Serbia, the application of GIS technology is still in the initial phase, where a certain amount of time is needed before it begins to be more significantly applied in state institutions, as well as in decision-making. However, bearing in mind the numerous changes in land cover that are primarily a consequence of the war in the above-mentioned countries, as well as the post-war reconstruction that took place as a result of increased and mostly unplanned urbanization, it was necessary to do a more detailed analysis and identify these changes. Until the completion of the CLC database, there was no consistent and complete land cover dataset covering all of Serbia and BiH. A GIS-based assessment of land use change in the period 2000–2018, according to the CLC database, highlighted a wide range of land use changes in both countries. The results obtained indicate that three types of change characterize the investigated area: urbanization and industrialization, loss of agricultural land and afforestation. Agricultural land suffered the greatest surface losses in both countries, especially complex cultivation patterns and land principally occupied by agriculture with significant areas of natural vegetation, while in BiH the extension of the broad-leaved forest is noticed. In today's situation where countries in the Western Balkans face many challenges such as political and economic changes, global climate change, energy production issues and sustainable development issues, there is a growing awareness of the need for land cover information. The CORINE methodology (data design, nomenclature and unified hierarchical legend) ensures useful land cover data. Statistical information on the proportion of each land cover class in the country's total area, especially detailed information on land cover dynamics through the years, is a valuable and meaningful indicator of the state of land cover resources. It is therefore reliable information for authorities and the general public. Combining land cover status data with other thematic data provides new insights into the status and change of natural resources in a variety of areas, including agriculture and forestry, regional spatial planning, natural resource inventories, and environmental monitoring. This study can serve as an initiative with a proposal to make more efforts to investigate and compare the land use changes in other European countries.

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