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East Sarajevo (Bosnia and Herzegovina) twenty years later –changes in land use

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Abstract

The city of East Sarajevo is a newborn city, formed twenty years ago, after the war in Bosnia and Herzegovina, in the area of the former southern and eastern Sarajevo municipalities. Changes that occurred in this area were not only administrative-political.Thepopulation moved from one area to another place, and changed in number and structure, which has resulted in significant changes in land use and land cover types. The aim of the paper is to analyze the types of land cover in the area of East Sarajevo using methods based on remote sensing, in order to find out the degree of these spatial changes in the period from 2000-2012, and also to define spatial development trends.

Within the European project of remote research of land cover types and forms of land use, namedCORINE Land Cover (CLC),spacious facilities were identified from middle and large scale spatial resolution, with 5 first-level classes, 15 subclasses, and 44 subclasses of the third level of cover. Analyzing the area of East Sarajevo there are identified 3 of the first-class level, 10 second-class, and 16 third-class level types. Geodataare related to three observation periods: 2000, 2006, and 2012, comparing the situation at the beginning of the period with the situation after 12 years.

Keywords: East Sarajevo, remote sensing, land cover, spatial trends

Introduction

In November 1995, the Dayton Peace Agreement established two basic political entities in Bosnia and Herzegovina: the Federation of Bosnia and Herzegovina and the Republic of Srpska and verified the boundaries between them. The former border between municipalities and cities had been changed. One of the cities with significantly changed borders was East Sarajevo. The territory that belongs to the city of East Sarajevo is mainly a rural area with few urban zones and poor industry, but since it was at that time the capital of the Republic of Srpska[1]with the most important institutions, expectationsabout rapid economic development were very high. The plans for the city were optimistic and enthusiasm was at a high level. Today, twenty years later, some questions are: what has been done, could it be better, and what we can expect in the future regarding spatial development of the city of East Sarajevo?In order to obtain objective responses we need specific data related to changes in land use in the city area in the previous period, which can be collected by using remote sensing and geographic information systems.

[1] Even today, East Sarajevo is formally the capital of Republic of Srpska because, in the Constitution, it was not changed despite the fact that the government and all of the most important institutions are located in city of Banja Luka.

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The city of East Sarajevo covers 1,447.58 square kilometers and according to its area it is the largest city in the Republic of Srpska. The original name, Serb Sarajevo,was amended in 2003 to East Sarajevo. The city consists of two parts: the larger northern part (1,403.67 square kilometers) and the smaller southern part (43.91 square kilometers). According to the 2013 census (Source: Agency for statistic of Bosnia and Herzegovina, 2013),there are 64,969 residents. Today, it is the cultural, economic, and university center of the eastern part of the Republic of Srpska. The city consistsof 6 municipalities: IstočnaIlidža, Istočno Novo Sarajevo, Pale, Sokolac, Trnovo, and IstočniStari Grad. The city is very heterogeneous, with two territorially disconnected parts, without an integrated urban zone, and with three important centers. The first urban center is the area next to the border with Sarajevo, which belongs to the municipalities of IstočnaIlidža and Istočno Novo Sarajevo.The second is Pale, and then Sokolac (Figure 1). Most of the territory belongs to the rural area with less population density, including the mountains of Jahorina, Romanija, Treskavica, and Trebević. According topopulation parameters, the municipality of Pale is the largest, with 22,282 inhabitants, followed by IstočnaIlidža with 15,333, Sokolacwith 12,607, and Istočno Novo Sarajevo with 11,477. However, IstočnaIlidža and Istočno Novo Sarajevo are the only municipalities within the city, which, according to the European nomenclature of statistical territorial units, belong to LAU[2] level 1, a functional urban area with a population density respectively of 524 and 303 inhabitants per square kilometer. Other municipalities, either becauseof their large territoriesor missing populations, have a population density less than 50 per square kilometer, and under this criterion they belong tothe rural areas level of classification. By the same criterion (a minimum of 50 inhabitants per square kilometer), the city of East Sarajevo would not have the status of urban area, as population density in its territory is only 44.88 inhabitants per square kilometer. Just to illustrate, even 81.75% of the territory of the municipality Trnovo covers deciduous, coniferous, and mixed forests.

According to the Spatial Plan of East Sarajevo of 2015, 43.44% of the total area of the city falls in the high-altitude zone of 800-1000m. Nearly two-thirds of the territory has a surface area of between 800-1200meters, and 3.41% of territory is above the height of 1400 meters, while the share of the terrain with altitudes below 500 meters is only 0.87% (Institute for Urban Planning of Republic of Srpska, 2008). Larger settlements are mostly situated in the valleys: Sarajevo, Pale, Trnovo, Mokro, and others.

Methods and data

Remote sensing is the process of acquisition of information about an object or phenomenon without making physical contact with the object and is, thus, in contrast to on-site observation. In geospatial research, it mainly refers to data collection via airplane or satellite. One of the main ways of remote sensing is analysis of land cover and land use types, from the global to the local level. This method of analysis is particularly gaining in importance with the development of satellite imagery and geographic information systems, as well as increasing anthropogenic pressure on natural resources. Over the last few decades, numerous teams of scientists have been working on projects to determine types of land cover and land use changes in different parts of the world.

With the aim of establishing a common typology, a group of scientists from the US Department of Agriculture (Anderson et al, 1976), in cooperation with the US Geological Survey, have developed a three level classification system of land cover types and forms of land use. The first level refers to the five main categories of land cover: artificial surfaces, agricultural areas, forest and semi-natural areas, wetlands, and water. The second level (15 classes) covers physical and physiognomic entities at a higher level of detail (urban zones, forests, lakes, etc.). The third level is the most detailed and divided into 44 classes with the aim to define the differences within urban areas, agricultural land, or types of forest vegetation. The differences within subclasses are defined by spatial interpolation based on which defined the trends of the future spatial development.

CORINE Land Cover[3] (CLC) is a European program initiated in 1985, coordinated by the European Environment Agency (EEA), in order to collect land cover types data and their changes. It is based on photo-interpretation of satellite images (SPOT, Landsat TM, and MSS), high resolution images of the national teams' participating countries. Ancillary data (aerial photographs, topographic or vegetation maps, statistics, and local knowledge) were used to refine their interpretation and the assignment of the territory into the categories of the CORINE Land Cover nomenclature (European Environment Agency, 2007.).Visual interpretation is a method of recognizing, identifying and assessing of objects recorded in aerial or satellite images. This method was applied creating the CLC database. It is based on analysis of interpretation ele-

[2] Local Administrative Units. For example, in Serbia, the neighbouring country,the LAU 1 level is the level of municipalities and the LAU 2 level is the smaller local community.

[3] CORINE - COoRdination of INformation on the Environment.

ments, of the recorded landscape objects (Kostra, Arnold, 2014.).

The first CLC geodatabase data refers to 1990, when it covered 29 European countries (Bosnia and Herzegovina was not included). Later data were amended in 2000, 2006, and 2012, and the number of states participating in the project has risen to 39.

One of the major tasks undertaken in the framework of the CORINE programme has been the establishment of a computerised inventory of land cover. Data on land cover is necessary for environmental policy, as well as for other policies such as regional development and agriculture. At the same time, it provides one of the basic inputs for the production of more complex information on other themes (soil erosion, pollutant emission into the air by vegetation, etc.). The objectives of the land cover project are to provide those responsible for and interested in the European policy on the environment with quantitative data on land cover, consistent and comparable across Europe.The Eionet network National Reference Centres Land Cover (NRC/LC) is producing the national CLC databases, which are coordinated and integrated by EEA (Corine Land Cover, 1994).

The first CORINE Land Cover project in Bosnia and Herzegovina started in 1998 and successfully completed in 2000 (Đug, et al., 2015). The result of this project was the creation of the CORINE Land Cover 2000 (CLC 2000) geodatabase of land cover in Bosnia and Herzegovina. The CLC geodatabase included the identification of types of land cover at the level of the major classes and subclasses of the third level, with a detailed description of the structural characteristics. The next levels of database are CLC 2006 and CLC 2012, which are the starting points for monitoring of changes in land cover surface.

Spatial detail survey depends on the size of the area to be surveyed, so it is common for the continental or

Table 1. Evolution of CORINE Land Cover

	CLC1990	CLC2000	CLC2006	CLC2012
Satellite data	Landsat-5 MSS/TM single date	Landsat-7 ETM single date	SPOT-4/5 and IRS P6 LISS III dual date	IRS P6 LISS III and RapidEye dual date
Time consistency	1986-1998	2000 +/- 1 year	2006+/- 1 year	2011-2012
Geometric accuracy	≤ 50 m	≤ 25 m	≤ 25 m	≤ 25 m
Min. mapping unit/ width	25 ha/ 100m	25 ha/ 100m	25 ha/ 100m	25 ha/ 100m
Geometric accuracy, CLC	100 m	better than 100 m	better than 100 m	better than 100 m
Thematic accuracy, CLC	≥ 85% (probably not achieved)	≥ 85% (achieved)	≥ 85% (not checked)	≥ 85%
Number of countries involved	26 (27 with late implementation)	30 (35 with late implementation)	38	39

Source: Copernicus Land Monitoring Services, 2016.

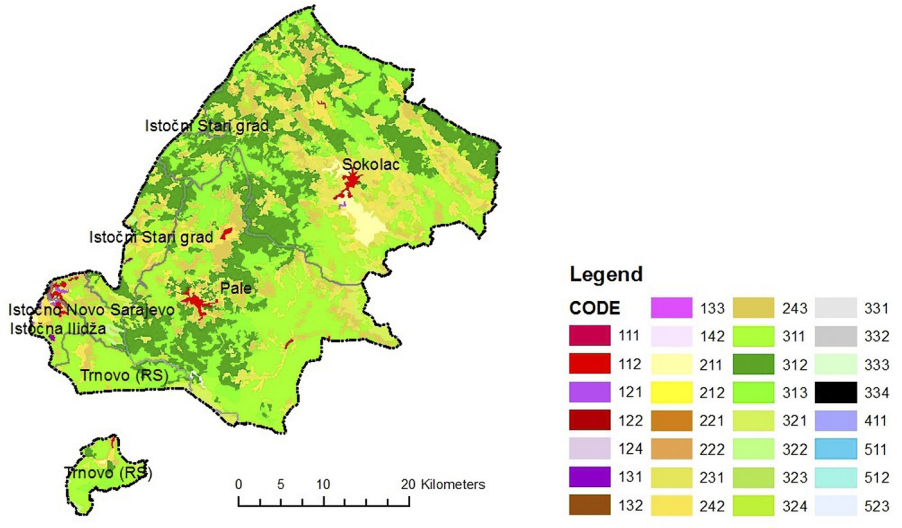

Figure 1. Map of land cover types in the area of East Sarajevo (according to the CLC 2012 geodatabase)

regional level to use land cover data at a small scale, with a spatial resolution of satellite images of 0.5 kilometers or less. Research types of land cover and land use at the national or at the lower administrative level of the organization commonly use satellite imagery with spatial resolution of 0.25 to 0.10 kilometers or higher. The smallest surfaces mapped (minimum mapping units) correspond to 25 hectares (Table 1). Linear features less than 100 meters in width are not considered. The scale of the output product was fixed at 1:100,000. Thus, the location precision of the CLC database is up to 100 meters.

Based on the CLC2000, CLC2006, and CLC2012 data, there are layers of land cover in the area of the city of East Sarajevo (Figure 1). Due to the different time periods of data acquisition, it is possible to monitor and visualize dynamic changes in the area.

Analysis of the types of land cover, according to CLC nomenclature, has found that in East Sarajevo, there are 3 first-class levels, 10 classes, and 16 (out of 44) second class levels of third-level cover, with the following designations and definitions (Corine Land Cover, Methodology and Nomenclature, 1994):

1. Artificial surfaces

1.1.2. Discontinuous urban fabric- Most of the land is covered by structures. Buildings, roads and artificially surfaced areas are associated with vegetated areas and bare soils, which occupy discontinuous but significant surfaces;

1.2.1. Industrial or commercial units - Artificially surfaced areas (cement, asphalt, tarmacadam or stabilized e.g. beaten earth) without vegetation occupy most of the area, which also contains building and/or vegetation;

1.3.1. Mineral extraction sites - Areas with open-pit-extraction of construction material (sand pit, quarries) or other mineral (open-cast mines). Includes flooded gravel pits, except for river-bed extraction;

1.4.2. Sport and leisure facilities- Camping ground, sport ground, leasure parks, golf courses, race courses, etc. Includes formal parks not surrounded by urban areas.

2. Agricultural areas

2.1.1. Non-irrigated arable land- Cereals, legumes, fodder crops, root crops and fallow land. Includes flowers and tree (nurseries cultivation) and vegetables, whether open field or under plastic or glass (includes market gardening). Includes aromatic, medicinal and culinary plants. Does not include permanent pasture;

2.3.1. Pastures - Dense grass cover, of floral composition, dominated by graminaceae, not under a rotation system. Mainly for grazing, but the folder may be harvested mechanically. Includes areas with hedges (bocage);

2.4.2. Complex cultivation patterns- Juxtaposition of small parcels of diverse annual crops, pasture and/or permanent crops. This includes:mixed parcels of permanent crops (fruit trees, berry plantations, vineyards and olive groves), interstices of non-mineralized free spaces in discontinuous urban fabric > 25 ha, complex cultivation patterns areas with scattered house inserted within a patchwork structure when built-up parcels cover less than 30 % of the patchwork area, hobby/city gardens;

2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation- Areas principally occupied by agriculture, interspersed with significant natural areas. Land occupied by agriculture with areas of natural or semi-natural areas (including wetlands and water bodies, outcrops);

3. Forests and semi-natural areas

3.1.1. Broad-leaved forest- Vegetation formation composed principally of trees, including shrub and bush under storeys, where broad-leaved species predominate. Broad-leaved trees represent more than 75 % of the planting formation;

3.1.2. Coniferous forest- Vegetation formation composed principally of trees, including shrub and bush under storey, where coniferous species predominate. Coniferous trees represent more than 75 % of the formation;

3.1.3. Mixed forest - Vegetation formation composed principally of trees, including shrub and bush under storeys, where neither broad-leaved nor coniferous species predominate. With a crown cover of more than 30 % or a 500 subjects/ha density for plantation structure. The share of coniferous or broad-leaved species does not exceed 25 % in the canopy closure. Three heights under normal climatic conditions are higher than 5 m;

3.2.1. Natural grasslands - Low productivity grassland. Often situated in areas of rough, uneven ground. Frequently includes rocky areas, briars and heatland. Natural grasslands are areas, where herbaceous vegetation (maximum height is 150 cm and gramineous species are prevailing) which cover at least 75 % of the surface covered by vegetation;

3.2.2. Moors and heathland - Vegetation with low and closed cover, dominated by bushes, shrub and herbaceous plants (heather, briars, broom, gorse, laburnum). Temperate shrubby area veg-

etation: includes dwarf forest trees with a 3 m maximum height in climax stage. lt is possible to distinguish subalpine moors, formation based on rhododendrons, bilberries and calluna, generally succeeding subalpine forest and grazing land;

3.2.4. Transitional woodland-shrub - Bushy or herbaceous vegetation with scattered trees. Can represent either woodland degradation or forest regeneration / recolonization;

3.3.2. Bare rocks - Scree, cliffs, rock outcrops, including active erosion, rocks and reef flats situated above the high-water mark;

3.3.3. Sparsely vegetated areas - Includes steppes, tundra and bad lands. Scattered high-altitude vegetation. Sparsely vegetated and instable areas of stones, boulders, or rubble on steep slopes where vegetated layer covers between 15 % and 50 % of the surface. Karstic areas of gramineous, ligneous and semi-ligneous vegetation;

Results and discussion

According to the CLC 2012 data, in the area of the city of East Sarajevo,in the first level of classification, forests and semi-natural areas represent the biggest land coverage, at 70.59% (code 3), followed by agricultural areasat 28.33% (code 2), while the category of artificial surfaces (code 1)covers 1.08%. At the second level, the most common categories are: forest vegetation (code 310) covering 62.05% of the land, arable land (240) covering 15.62% of the land, and other types of surface cover.

The most common individual classes on the third level of classification are the broad-leaved forest vegetation (code 3.1.1.) covering 25.22% of the land, coniferous forest vegetation (3.1.2.) covering 22.72%, and mixed forest (3.1.3.) at 14.12%. After thatare pastures (2.3.1.) with 11.43% and agricultural areas with significant natural vegetation (2.4.3.), which covers 10.46%. The less represented were transitional woodland-shrub (3.2.4.) with 5.77%, complex culture (2.4.2.) with 5.16%, natural grassland (3.2.1.) at 2.43%, and irrigated arable land (2.1.1.) at 1.28%. Among other types of surface cover having representation below 1% was discontinuous urban area (1.1.2.), covering 0.87%.

Speaking of the trends of spatial development, notable is the significant growth of urban areas in the amount of 29.17%. Analyzing two periods, there was recorded almost a double intensity of urbanization during the period from 2000 to 2006 (20.14%), compared to the period from 2006 to 2012 (11.31%). In addition to the global trend of urbanization, two factors that are mostly affecting the trends in the second period are a reduction in the intensity of out-migration of the population[4] and the economic crisis in Bosnia and Herzegovina, which significantly slowed down economic development.

The most significant increase in the surface covers types is in the natural low-productive grassland (code 3.2.1.) and mixed forest vegetation (3.1.3.), while moderate growth was recorded in the transitional woodland-shrub (3.2.4.), non-irrigated arable land (2.1.1.), land principally occupied by agriculture with significant areas of natural vegetation (2.4.3.), and areas with complex cultivation (2.4.2.).

The most significant decrease happened in the grassland areas (2.3.1.), showing a reduction of 23.22% (especially during the 2006-2012 period), followed by moors and heathland (3.2.2.) and coniferous forest (3.1.2.). The process of reducing the area under forest vegetation, among other causes, is related to the developed wood industry in the municipalities of Pale, Sokolac, Istočni Stari Grad, and Trnovo.

By municipalities, the highest level of urbanization are within the municipalities of Istočna Ilidža and Istočno Novo Sarajevo, increasing in discontinuous urban areas (1.1.2.) as much as 72.33% and 67.63%. In particular, the high level of urbanization was recorded in the area that geographically borders the urban zones of the city of Sarajevo (Federation of Bosnia and Herzegovina).[5]These municipalities are followed by the municipality of Sokolac, with an increas in urban zones of 17.98%, and Pale, with an increase of 11.82%. Pale municipality recorded a decrease in coniferous forest vegetation (3.1.2.) of 8.56% and moors and heathland (3.2.2.), and an increase in the surface area of mixed woods (3.1.3.). Also reduced was the area of pastures, as well as an increase in the surface area of low productive grassland. Within the municipality of Sokolac, grassland areas (2.3.1.) have been reduced by 23.3%, while there was an increase in the area of low productivity grassland. The relatively small area of non-irrigated arable land (2.1.1.) in the period from 2000 to 2012 increased by 29.29%, indicating a tendency toward agricultural development. The municipalities of Istočni Stari Grad and Trnovo had no significant changes in land cover, since

[4] According to AnnexVIIof the DaytonPeace Agreementin Bosnia and Herzegovina,all refugees anddisplaced personshad the right toreturn to their homes, and this process wasintensefrom2000 to 2006,more so than from2006 to 2012.Also, many decidedto stay livingin anew place, so after a temporaryreturn andsale of theirestates theybuilt a newhome inplaces theychose. Inthe process ofethnic homogenization,a significant numberof former residentsof Sarajevo moved toEastSarajevoand this isoneof the reasons forthe high rate ofurbanization.

[5] Spatial/urban developmentshould be expectedin municipalitieswhose urban zonesborder the city ofSarajevo, which have the opportunity to developthanks tothe process of decentralizationof the state institutionsand the factthat a significantnumber ofthe population livesin these municipalitiesandwork ingovernment and otherinstitutions and companiesin Sarajevo.

Table 2. CLC subcategories cover the area of the city of East Sarajevo in 2000, 2006, and 2012, as well as inter-period relative spatial changes(RP) in land cover distribution.

CODE	CLC 2000		CLC 2006		CLC 2012		RP (%)	RP (%)	RP (%)
	P (km²)	(%)	P (km²)	(%)	P (km²)	(%)	2000-2006	2006-2012	2000-2012
1.1.2.	8,91	0,62	11,16	0,77	12,58	0,87	20,14	11,31	29,17
1.2.1.	1,27	0,09	1,62	0,11	1,6	0,11	21,61	-1,26	20,63
1.3.1.	0,57	0,04	0,37	0,03	0,59	0,04	-52,08	36,47	3,39
1.4.2.	0,67	0,05	0,86	0,06	0,86	0,06	21,77	0,42	22,09
2.1.1.	13,99	0,97	13,15	0,91	18,6	1,28	-6,35	29,28	24,78
2.3.1.	203,89	14,08	198,31	13,69	165,47	11,43	-2,81	-19,85	-23,22
2.4.2.	72,71	5,02	72,69	5,02	74,63	5,16	-0,02	2,59	2,57
2.4.3.	149,21	10,31	148,31	10,24	151,44	10,46	-0,61	2,07	1,47
3.1.1.	366,52	25,32	365,26	25,22	365,01	25,22	-0,35	-0,07	-0,41
3.1.2.	337,25	23,30	337,39	23,30	328,85	22,72	0,04	-2,60	-2,55
3.1.3.	188,85	13,05	190,60	13,16	204,36	14,12	0,92	6,73	7,59
3.2.1.	6,33	0,44	24,27	1,68	35,13	2,43	73,91	30,92	81,98
3.2.2.	19,18	1,32	4,93	0,34	4,51	0,31	-289,17	-9,28	-325,28
3.2.4.	77,82	5,38	78,78	5,44	83,53	5,77	1,21	5,69	6,84
3.3.2.	0,33	0,02	0,31	0,02	0,33	0,02	-6,90	6,45	0,00
3.3.3.	0,08	0,01	0,09	0,01	0,09	0,01	14,16	-3,56	11,11

Source: CLC 2012 geodatabase for Bosnia and Herzegovina, European Environment Agency, 2015

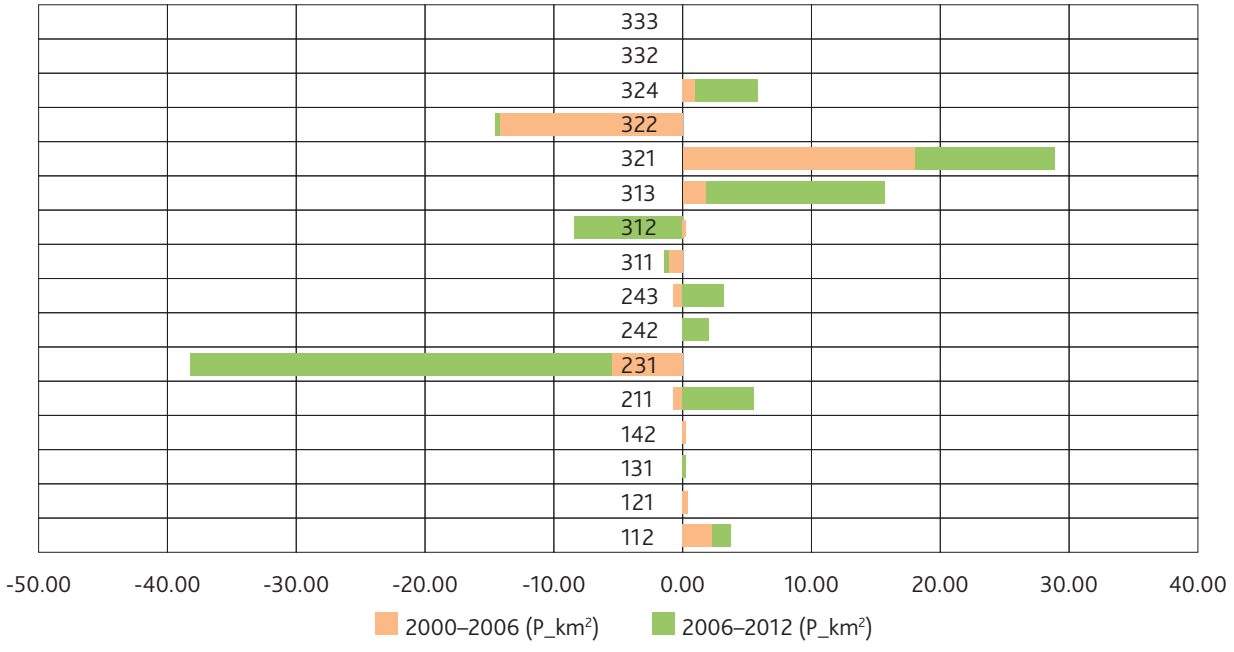

Figure 2. Inter-period relative spatial changes at the third level of sub-clasess (shown as per square kilometer) in the area of East Sarajevo (according to CLC 2000, CLC 2006,and CLC 2012 geodatabases)

they are less developed municipalities with extremely low population density (with, respectively, 13.37 and 9.16 inhabitants per square kilometer).

Conclusions

According to the CORINE Land Cover geodatabase,in the period from 2000 to 2012 in the area of East Sarajevo,there are significant changes in land use. Discontinuous urban space has increased by almost one-third as a result of population migration between municipalities and political entities, and ethnic homogenization that hit Bosnia and Herzegovina. New settlements, infrastructure facilities, and industrial and commercial areas were built, especially in IstočnaIlidža and Istočno Novo Sarajevo municipalities, which border the urban area of the city of Sarajevo. According to inter-period spatial changes, it was found that the intensity of urbanization gradually reduced and in the future can be expected to continue this downward trend because the migration population is greatly reduced in comparison to the first decade of the twenty-first century.

As for the other classes of surface cover on the first level, agricultural areas in the city are characterized by a significant reduction in grassland areas and increasing low-productive grasslands. Forest vegetation, which cover the largest percentage of the area of East Sarajevo, has also undergone significant changes: there were increases in mixed forest and transitional woodland-shrub,and decreasesin coniferous and alpine forests and heaths, which is partly due to the local economy relying on forest resources.

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