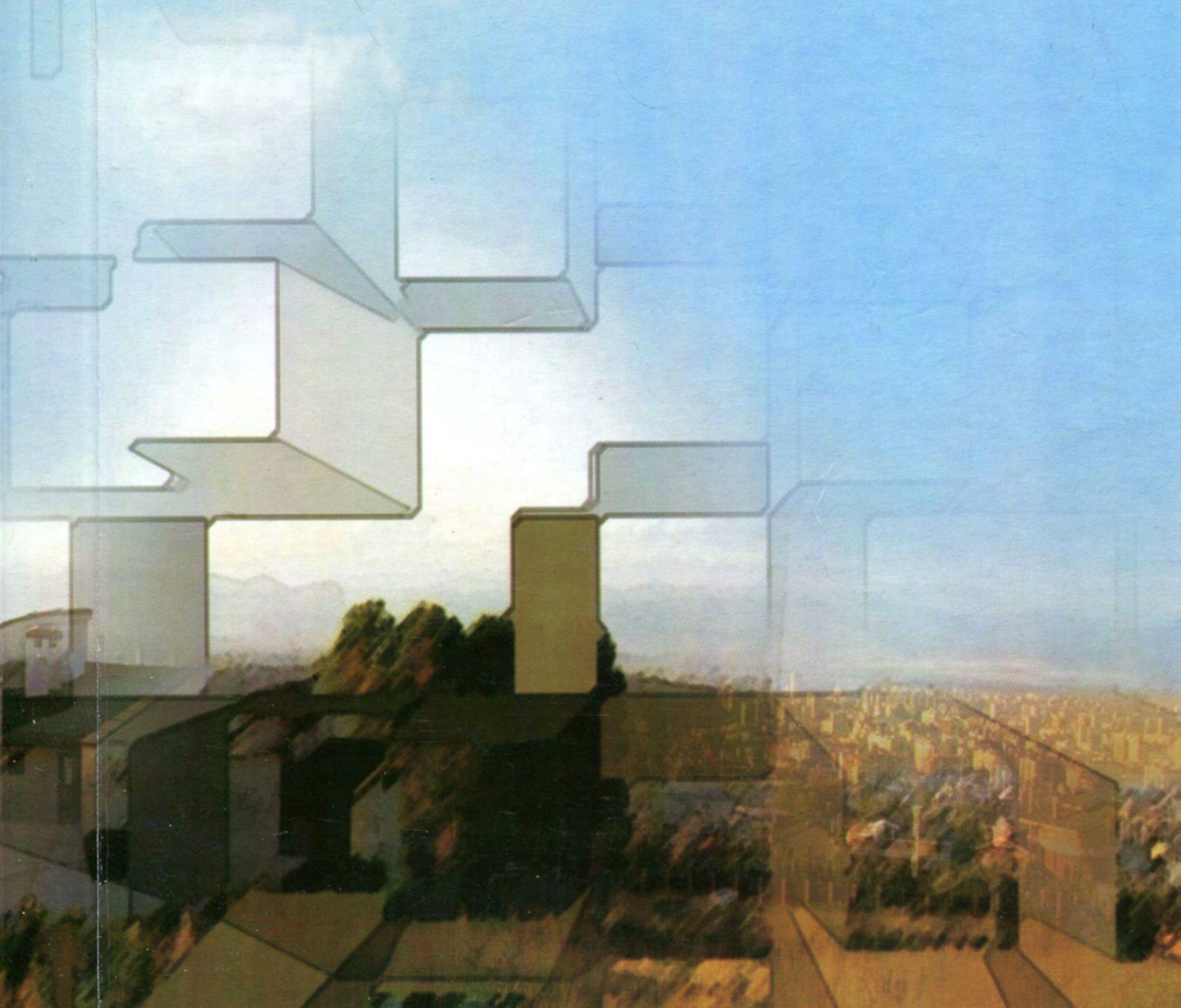
FORMS OF URBAN GROWTH IN SOUTHEAST EUROPE:

TRANSITIONING TOWARDS URBAN RESILIENCE AND SUSTAINABILITY

2

Editors: **Miodrag Vujošević and Slavka Zeković**



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VOLUME 2

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THE ROLE OF MARKET AND STRATEGIC PLANNING AND GOVERNANCE IN URBAN GROWTH AND DEVELOPMENT: THE CASE OF THE METROPOLITAN AREA OF BELGRADE (SERBIA)

Compendium of contributions of the IAUS team to the Project TURaS

Content

Further extension of urban zones and "filling" within the existing urban block have been observed since 2006 in all the three cities. Detected trends in land cover changes and population dynamics should be taken into account when planning and developing both central and peri-urban city areas. Apart from further research of causalities in land cover changes, successful management of cities necessitates understanding of the citizens' preferences concerning the surroundings they live in on the one hand, and interests of investors, local authorities and other subjects of overall urban development on the other hand.

3.2. Recent trends in population dynamics and land cover changes in metropolitan areas

Nikola Krunić and Aleksandra Gajić

3.2.1. Introduction

This paper presents re-analysed, updated and revisited findings of previous internal reports for the TURaS Project (published internally on the project website: Krunić, 2013; Krunić et al., 2014a) and published papers (Krunić et al., 2014b). In this contribution additional research has been undertaken for the year 2012, with a view to analyse the relationship between the dynamics of the total population change, on the one hand, and the correspondence of the land cover change, on the other. The analyses were performed at the level of administrative units at local level ("municipalities") within the metropolitan areas, i.e. cities of Belgrade, Sofia and Rome. The following indicators have been utilized to this end, viz.: absolute (total) population; population size dynamics; population density (measured via the number of inhabitants per unit of artificial land area, that is, "land surface"); the structure of land cover by category (Corine Land Cover); changes within the abovementioned land cover categories, respectively; and the ratio between total and artificial surface of the administrative units. Also, changes within the structure of migrants and commuters have also been analysed, but only for the City of Belgrade.

This survey covers the municipalities (administrative units) of three cities, viz.: Belgrade, Rome and Sofia. To note, there is a significant difference regarding the administrative division in two cities, that is, Belgrade and Rome. The previous administrative division of the City of Belgrade comprised 16 municipalities, but currently comprises 17 municipalities. Compared to that, considerable changes have taken place in the case of the City of Rome, now comprising 15 administrative units, as compared to its previous size of 19 administrative units. According to the available information, no change of the kind has taken place with regard to the administrative division of the City of Sofia.

Due to the inconsistency of data, the findings of this analysis should be interpreted as conditional. Relevant data sets for population dynamics often do not match data sets on land cover changes for the same time period. Nevertheless, the obtained results are fairly reliable, and represent a solid base for future research, either in terms of looking for specific insights, or for the purpose of more general analyses.

3.2.2. Case study - Metropolitan areas of Belgrade, Sofia and Rome

The selected case study cities of Belgrade, Rome and Sofia differ considerably in terms of their geographical position and surroundings, historical and social conditions, and established political systems. Beside the observed land cover changes which were intensified in the mid-20th century, the important common feature of the three cities is the fact that they have been developing in the conditions of formally organised legal, spatial and urban planning systems, though with very different experiences regarding the implementation of planned urban development at the local administrative level. This problem is especially noticeable in the analysed period (Maksin-Mićić and Perišić, 2005; Montanari and Staniscia, 2012; RIMED Report 13, 2005; Krunić et al., 2014b).

3.2.2.1. The City of Belgrade

Similarly to other post-socialist cities, the development of the City of Belgrade commenced with the process of suburbanization, which was initiated at the end of the 1960s and intensified during the 1970s and 1980s when the construction of new settlements was planned. In parallel with this process commenced the process of deurbanization, followed by population decrease in the city centre, and increasing demographic development along with illegal/unplanned construction with low density in the peri-urban zone around the whole city (Grčić, 1993; Živanović Miljković, 2008; Spalević, 2010; Petrić and Krunić, 2013, Krunić et al., 2014b). As a result, Belgrade did not manage to maintain its compactness – from the year 2000 onwards, the dominating process had the characteristics of urban sprawl.

3.2.2.2. The City of Sofia

The main changes in the development of the City of Sofia were initiated in the 1960s with the construction of residential areas around the urban core. By 1990, the city grew up managing to keep clear and compact urban form. After the 1990s, the urban development was characterized by growth inside and outside the city boundaries (Hirt and Kovachev, 2006). The process of urban sprawl occurred spontaneously along the roads axis and periphery of the City (RIMED Report 13, 2005). The largest population increase was registered in low density suburban areas. Slaev (2012) notes that the reason for these process lies in the expansion of the housing market in the first decade of the 21st century.

3.2.2.3. The City of Rome

In the City of Rome, the first changes occurred during the intensive population growth in the period of the 1960s and 1970s, when originally compact city started to gain a more dispersed urban form. In the period of stable population growth, after the 1980s, socio-economic changes lead to urban growth which was followed with rapid sprawl and land use changes in suburban areas. Montanari and Staniscia (2012) observe that the movement of economic activities from cores towards suburbs in metropolitan areas in Rome, which took place in the 1991–2001 period, was of small scale and scattered, due to job growth and the continuing attractiveness of the city centre for many tertiary sector businesses.

3.2.3. Methodological Framework

Initially, the analysis of land use changes was based on researching the possibilities for application of the MOLAND (Monitoring Land Use / Cover Dynamics) technology for detecting, understanding and predicting the land use change process for the metropolitan areas. The MOLAND was a research project carried out at the Institute for Environment and Sustainability of the European Commission’s Joint Research Centre (JRC). The aim of the MOLAND Program was to provide a spatial planning tool that can be used for assessing, monitoring and modelling the development of urban and regional environments. The most important product of this project is the developing of an urban growth model, which is used to assess the likely impact of current spatial planning and policies on future land use development. To date, this specific methodology has been applied to around forty urban areas in Europe. The MOLAND comprises three interrelated fields: 1. CHANGE (Change detection) – where land use changes are measured, and merged with socioeconomic data sets; 2. UNDERSTAND (Understanding) – where a number of environmental indicators are identified with the aim to be used for measuring the sustainability of the study area; and 3. FORECAST (Development of scenarios) – where an urban growth developing models with different scenarios are created, using dynamic models based on cellular automata concepts. This research covered the first field of MOLAD methodology – measuring land use change and population dynamics. The MOLAND develops land use classification which is based on the CORINE land cover classification (CLC), adding a forth, more detailed level for artificial and natural surfaces. Due to the lack of appropriate data sources for creating MOLAND extended land use classification, we used basic CLC data sets for this research.

3.2.4. Results

The results of the conducted analysis and respective comments about the following demographic and spatial features and processes are given: population dynamics, population density, land cover structures and land cover changes. The analysis covered the 1990–2012 period, with respective and necessary estimations according to the statistical data about population provided by the official national statistical authorities. Regarding migration and commuting, the analysis was conducted for the City of Belgrade based on the available statistical data for the 1990–2011 period, while the data for the City of Sofia and the City of Rome were not provided.

3.2.4.1. General trends in development of metropolitan areas - Urban Morphological Zone

Urban Morphological Zone (UMZ) is defined as “a set of urban areas laying less than 200m apart” (ETCTE, 2013). Those urban areas are defined from land cover classes contributing to the urban tissue and function. The Corine Land Cover classes used to build the Urban Morphological Zone data set are the following ones:

- Core Classes (111 – Continuous urban fabric, 112 – Discontinuous urban fabric, 121 – Industrial or commercial units, 141 – Green urban areas)
- Enlarged core classes: 123 (Port areas), 124 (Airports) and 142 (Sport and leisure facilities), are also considered if they are neighbours to the core classes or to one of them touching the core classes.
- 122 (Road and rail networks) and 511 (Water courses), when neighbours to the enlarged core classes, cut by 300m buffer.
- Forests and scrub (311, 312, 313, 322, 323, 324), when they are completely within the core classes.

Although the data about the UMZ for Belgrade were not officially provided, they were reconstructed using the same UMZ methodology. The UMZ of the City of Belgrade for the observed 1990–2012 period was changed and extended by the index of 146.1 overall, the UMZ of the City of Sofia was slightly extended, by the index of 105.1, and the UMZ of the City of Rome extended by the index of 109.4 (Table 1).

Table 1. Changes of the UMZ 1990-2012

City	UMZ 1990 (km^2)	UMZ 2012 (km^2)	Change Index
Belgrade	172.9	252.6	146.1
Sofia	169.8	178.5	105.1
Rome	267.0	292.0	109.4

3.2.4.2. The City of Belgrade

Municipalities with the largest share of artificial surfaces (ratio between the total area of the municipality – TA and total artificial surfaces – AS) in the City of Belgrade in 2012 were inner-city municipalities: Vračar (1.0), Savski Venac (1.00) and Stari Grad (0.82). Contrary to this, artificial surfaces in the peripheral municipalities occupied less than 10% of the total land: Sopot (0.05), Barajevo (0.07), Palilula (0.09) and Mladenovac (0.09). During the observed period, land cover of the City of Belgrade slightly changed in favour of artificial surfaces. The CLC land cover changed in the general process of transition from “natural” land cover to artificial surfaces.

In total, artificial surfaces covered about 22% more in 2012 than in 1990, at the expense of agricultural areas which decreased by 4%. In terms of the dynamics of land occupancy (“antropogenisation”)[9], considerable changes took place in general, and particularly in the following municipalities: Barajevo (250.3), Palilula (170.6), Lazarevac (149.7), Zemun (143.5), Rakovica (130.1) and Voždovac (130.0). A minor occurrence of “deantropogenisation” was detected in the municipality of Čukarica (98.1) (Table 2, Figure 1 and Figure 2).

Table 2. City of Belgrade – population development and spatial changes

	Municipality	Population Change Index 2011/1991	1990		2012*	
			Population Density (inh/ha)	Artificial/ Total Area Ratio	Populat. Density (inh/ha)	Artificial/Total Area Ratio
1	Barajevo	125.2	35	0.03	18	0.07
2	Voždovac	98.0	62	0.18	47	0.23
3	Vračar	80.8	241	1.00	195	1.00
4	Grocka	120.8	22	0.11	25	0.12
5	Zvezdara	108.1	95	0.47	92	0.53
6	Zemun	115.1	47	0.21	38	0.30
7	Lazarevac	99.6	20	0.08	13	0.12
8	Mladenovac	94.2	25	0.07	18	0.09
9	Novi Beograd	95.6	94	0.59	80	0.66
10	Obrenovac	103.3	17	0.10	18	0.10
11	Palilula	110.8	63	0.06	41	0.09
12	Rakovica	111.1	76	0.43	65	0.55
13	Savski Venac	82.0	34	1.00	28	1.00
14	Sopot	99.2	16	0.05	15	0.05
15	Stari Grad	68.4	159	0.82	109	0.82
16	Surčin	123.0	13	0.10	13	0.12
17	Čukarica	117.2	35	0.28	41	0.28
	Mean	***103.1***	***62***	***0.33***	***50***	***0.36***

**Based on demographic datasets for the year 2011.*

[9] Dynamics of land occupancy (“antropogenisation”) represent a change of artificial surfaces in the observed period.

The population of the **City of Belgrade** increased moderately in the analysed period (Table 2). The most significant rise in population size (measured by 1991–2011 change ratio) was recorded predominantly in peripheral municipalities: Barajevo (125.2), Surčin (123.0), Grocka (120.8) and Čukarica (117.2). Contrary to this demographic trend, a significant decrease ("depopulation") was recorded in three inner-city municipalities (Stari Grad – 68.4, Vračar – 80.8 and Savski Venac – 82.0), as well as in the peripheral municipality of Mladenovac (94.2).

According to the available digital data on soil imperviousness (**Soil sealing)** in 2012, around 22% of the City of Belgrade was covered with a certain degree of soil sealing (Table 3). This data represents free open access database available via Internet, which indicates the sealed surfaces due to anthropogenic impact, (Burghardt, 2006). As such, they directly reflect the percentage of built-up land given in the scale from 0 to 100 (Figure 5.). Its main use is the characterization of the human impact on the environment. The database is developed by the European Environment Agency (EEA) and is available in two spatial resolutions of 20 m and 100 m, respectively. The database with the resolution of 100 m was selected for the purpose of this research.

However, compared to the same data from 2006, an increase in the total area covered by impermeable anthropogenic materials can be noted, which is measured by the total number of pixels that have a certain value of soil sealing degree (SSD). On the other hand, an increase (21%) in soil sealing values within the existing pixels indicates the increase in built-up density. The main changes in the soil coverage with impermeable materials in the observed period were noted in municipalities Palilula, Zemun and Barajevo.

Regarding the population density of the City of Belgrade in the year 2012, here measured by the ratio between the total population and total artificial surfaces area (inhabitants/ha), the most populated were inner-city municipalities Vračar (195) and Stari Grad (109), whereas the lowest densities were observed in the peripheral municipalities: Surčin (13), Lazarevac (13), Sopot (15), Barajevo (18) Obrenovac (18) and Mladenovac (18). During the observed period and in relation to land cover changes (1990–2012), population density considerably increased in the municipalities of Čukarica (index 119.5), Grocka (114.8), Obrenovac (103.0) and Surčin (101.3). Contrary to this, a substantial drop in population density was observed in most municipalities where high "antropogenisation" was detected: Barajevo (50.0), Palilula (65.0), Lazarevac (66.5), Mladenovac (74.2) and Voždovac (75.4). It is important to note that population density also decreased in the inner-city municipalities of Stari Grad (68.6) and Vračar (80.8), without land cover change, thus indicating "depopulation". (Table 2, Figure 3).

Table 3. City of Belgrade-spatial Distribution of SSD values

	Municipality	SSD pixels ratio 2006-2012 (Change Index)	2006		2012	
			Sum SSD values	Mean SSD values	Sum SSD values	Mean SSD value
1	Barajevo	106.0	41235	11.8	51208	13.8
2	Voždovac	102.7	125130	29.2	136113	30.9
3	Vračar	100.0	24338	84.2	24724	85.6
4	Grocka	99.3	140933	20.8	136276	20.2
5	Zvezdara	99.8	83017	45.7	87316	48.2
6	Zemun	108.8	209247	43.4	320146	61.1
7	Lazarevac	84.1	334193	32.0	269998	30.8
8	Mladenovac	101.5	117729	20.5	107192	18.4
9	Novi Beograd	101.7	152114	55.9	173117	62.5
10	Obrenovac	105.5	132127	18.6	158799	21.2
11	Palilula	119.5	209717	34.8	512792	71.1
12	Rakovica	99.7	53829	35.2	56435	37.0
13	Savski Venac	99.9	70797	54.7	71398	55.2
14	Sopot	103.2	50523	12.6	51792	12.6
15	Stari Grad	100.4	36012	79.3	36664	80.4
16	Surčin	104.9	129220	31.1	143066	32.9
17	Čukarica	104.1	155094	32.3	173724	34.7
	∑/Mean	*101.8*	*2065255*	*37.8*	*2510760*	*42.15*

The share of migrants in total population slightly increased in the observed period (106.6). In 2011, the most intensive migration processes occurred in the peripheral municipalities Grocka, Barajevo, Palilula, Surčin, where more than 55% of total population was migrant population. In the structure of migrants the majority of migrants were from other regions (51%) with the biggest share in the municipalities of Rakovica (63%), Zvezdara (62%), Vračar (60%), and Stari Grad (58%). Migrants from other countries participate significantly in the total structure of migrants, with the largest share in the following municipalities: Zemun (44%), Novi Beograd (39%) and Savski Venac (34%) (Table 4).

Table 4. Structure of migrants 1990 and 2011 (%)

	Municipality	Migration change index 1991-2011	1991			2011			
			Same muni-cipality	Other muni-cipality	Other country	Same muni-cipality	Other muni-cipality	Other region	Other country
1	Barajevo	138.0	17.0	66.1	17.0	7.8	48.4	24.3	17.2
2	Voždovac	104.3	1.3	53.3	45.4	1.7	9.1	57.5	28.6
3	Vračar	94.3	0.0	49.1	50.9	0.0	4.6	60.2	29.7
4	Grocka	120.2	11.1	66.7	22.2	7.8	35.2	38.9	16.1
5	Zvezdara	104.9	0.0	54.7	45.3	0.0	6.5	62.3	28.2
6	Zemun	105.8	2.0	35.3	62.6	0.8	4.8	48.2	43.5
7	Lazarevac	94.2	43.5	37.9	18.6	24.0	11.8	47.4	14.6
8	Mladenovac	94.1	34.0	47.1	18.9	13.3	17.0	51.4	15.0
9	Novi Beograd	97.8	0.0	41.7	58.3	0.0	4.0	53.6	38.8
10	Obrenovac	111.0	28.3	50.6	21.0	22.3	22.1	36.7	16.7
11	Palilula	110.1	4.5	51.0	44.5	8.6	14.5	49.6	25.0
12	Rakovica	98.2	0.0	54.5	45.5	0.0	6.7	62.6	28.3
13	Savski Venac	98.3	0.0	45.2	54.8	0.0	4.3	55.3	33.7
14	Sopot	124.9	34.0	52.4	13.6	19.8	39.2	24.6	14.3
15	Stari Grad	96.5	0.0	46.3	53.7	0.0	4.4	58.4	31.5
16	Surčin	114.3	21.6	40.4	38.0	6.5	28.9	33.1	28.9
17	Čukarica	104.5	5.9	54.3	39.8	3.8	12.9	52.1	28.3

Daily urban systems have an important role in determining size and influence of the urban centre on surrounding areas. Daily urban systems consist of the city and its surroundings between which exists an interaction manifested in labour migration and residents who commute to satisfy their need for social, economic and cultural character (Tošić et al., 2009). In the development of daily urban systems labour mobility represent an important indicator of spatial and functional dependencies of the centre and the periphery.

Daily urban systems are specific, dynamic, diversified and unique forms of connections and relationships between urban settlements and regional or local environment, arising from the specific geographic, demographic, social and economic conditions (Krunić, 2012). Their development is correlated with the increased mobility of the population and the orientation of labour to live outside the urban core (Van der Laan, et al; 1998).

Regarding daily migration, in the observed period commuting increased in almost all municipalities, with the total increase index of 117.8. The highest increase of commuters was in the following municipalities: Zvezdara (210.1-Index), Novi Beograd (169.5) and Palilula (130.3), while in the municipalities of Zemun (44) and Lazarevac (98.4) there was a decrease in commuting. In 2011, the majority of commuters were employed in other municipalities, which is not very noticeable in the peripheral municipalities of Surčin (79%), Barajevo (77%), Grocka (74%), and Čukarica (72%) (Table 5, Figure 4).

Table 5. Commuters 1991-2011 (%)

	Municipality	Commuting 1991-2011 (Change Index)	1991			2011		
			Same muni-cipality	Other muni-cipality	Other region	Same muni-cipality	Other muni-cipality	Other region
1	Barajevo	114.9	17.8	81.6	0.4	21.6	77.4	1.0
2	Voždovac	115.4	14.2	77.5	7.4	18.9	67.3	13.3
3	Vračar	116.1	0.9	57.4	37.6	0.0	47.5	48.9
4	Grocka	114.7	9.7	88.7	0.6	24.0	74.4	1.6
5	Zvezdara	210.7	3.0	57.6	32.2	0.0	55.5	42.6
6	Zemun	44.4	33.9	60.2	4.5	20.5	52.4	26.4
7	Lazarevac	98.4	91.3	7.9	0.1	87.4	8.2	4.4
8	Mladenovac	112.6	66.8	32.3	0.4	50.3	46.1	3.5
9	Novi Beograd	169.6	1.5	50.4	37.5	0.0	59.2	39.0
10	Obrenovac	111.1	49.7	49.3	0.5	50.7	47.1	2.1
11	Palilula	130.4	39.8	54.4	4.2	30.2	62.7	6.8
12	Rakovica	106.9	4.2	75.6	17.1	0.0	60.5	37.4
13	Savski Venac	115.4	1.2	58.0	37.1	0.0	44.6	52.1
14	Sopot	112.4	19.9	79.2	0.4	31.0	68.1	0.9
15	Stari Grad	101.4	3.6	53.2	39.2	0.0	46.2	51.4
16	Surčin*		0.0	0.0	0.0	18.7	79.3	2.0
17	Čukarica	110.3	21.7	73.7	3.6	19.2	72.5	7.9

* The municipality of Surčin was formed in 2004, while it previously administratively belonged to the municipality of Zemun. Statistical data on commuting were not available for 1991.

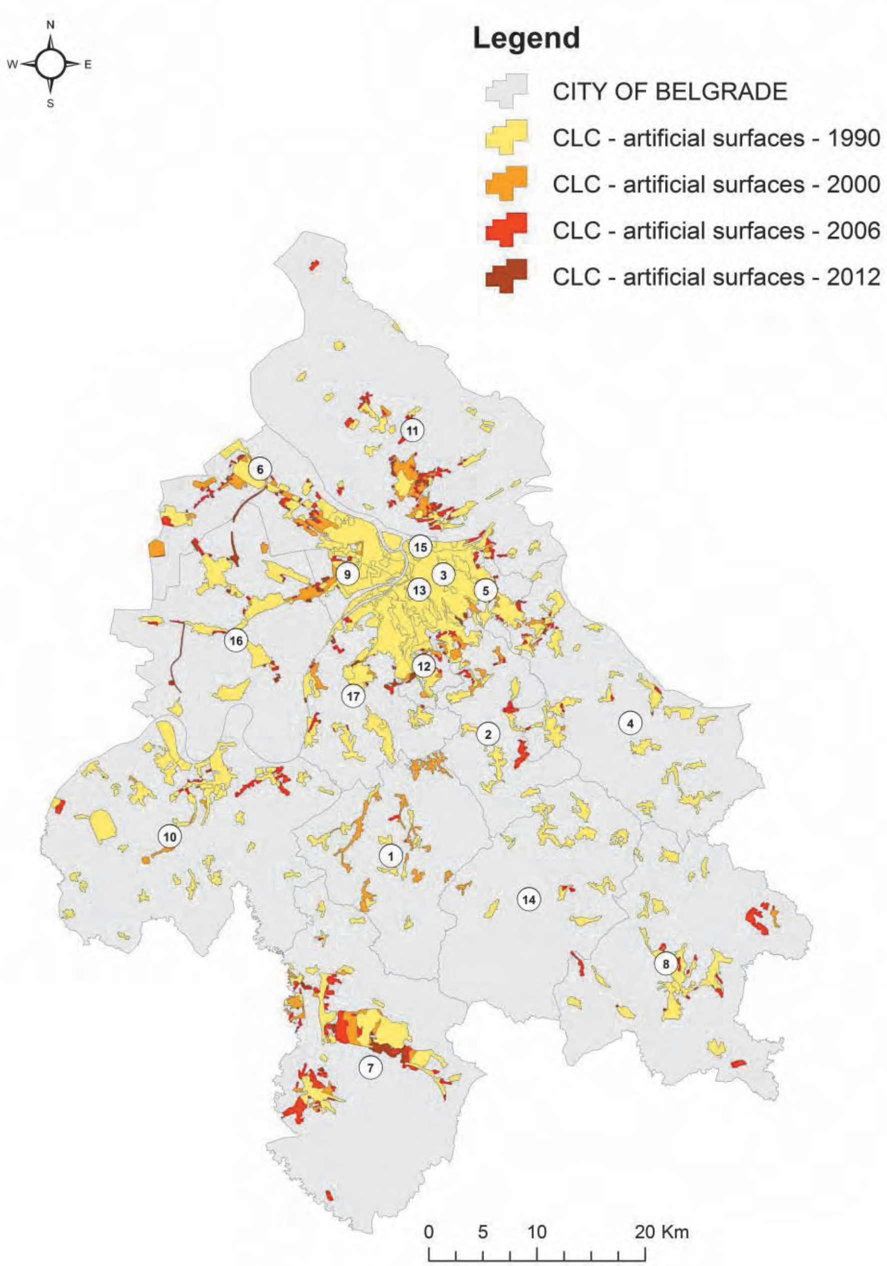

Figure 1. City of Belgrade – Artificial surfaces and land cover change (1990–2012)

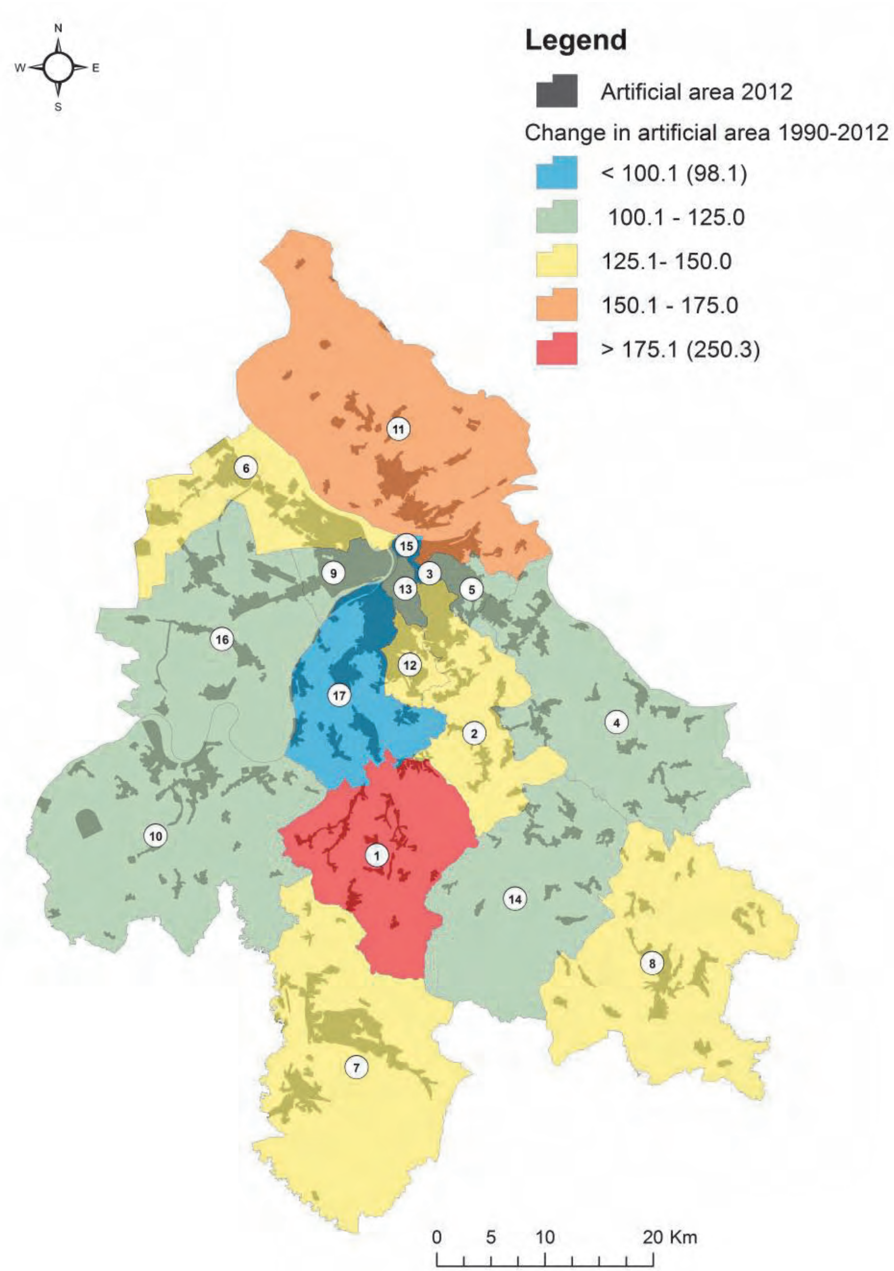

Figure 2. City of Belgrade – Dynamics of land occupancy ("antropogenization") 1990-2012

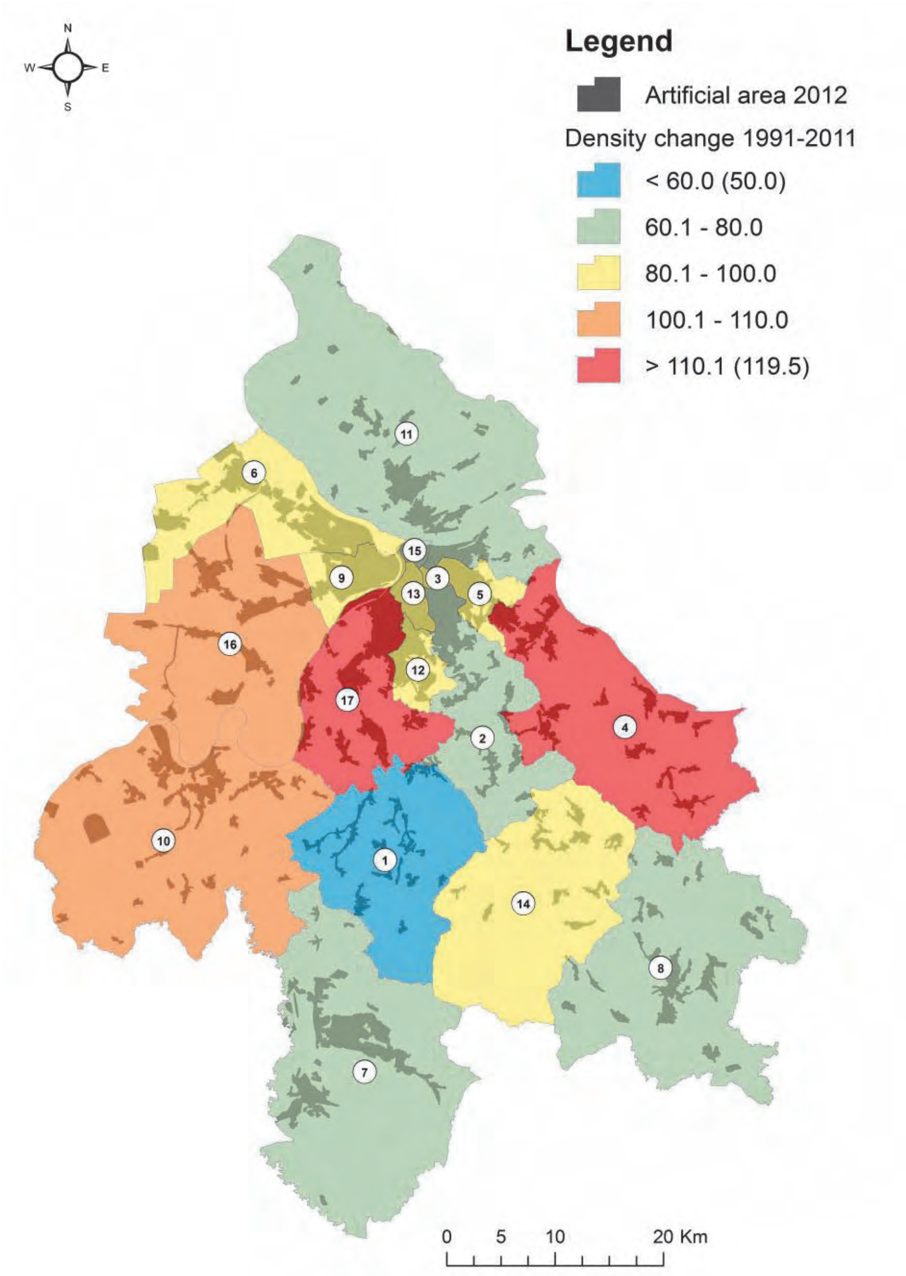

Figure 3. City of Belgrade – Population density changes within administrative units (1990–2012)

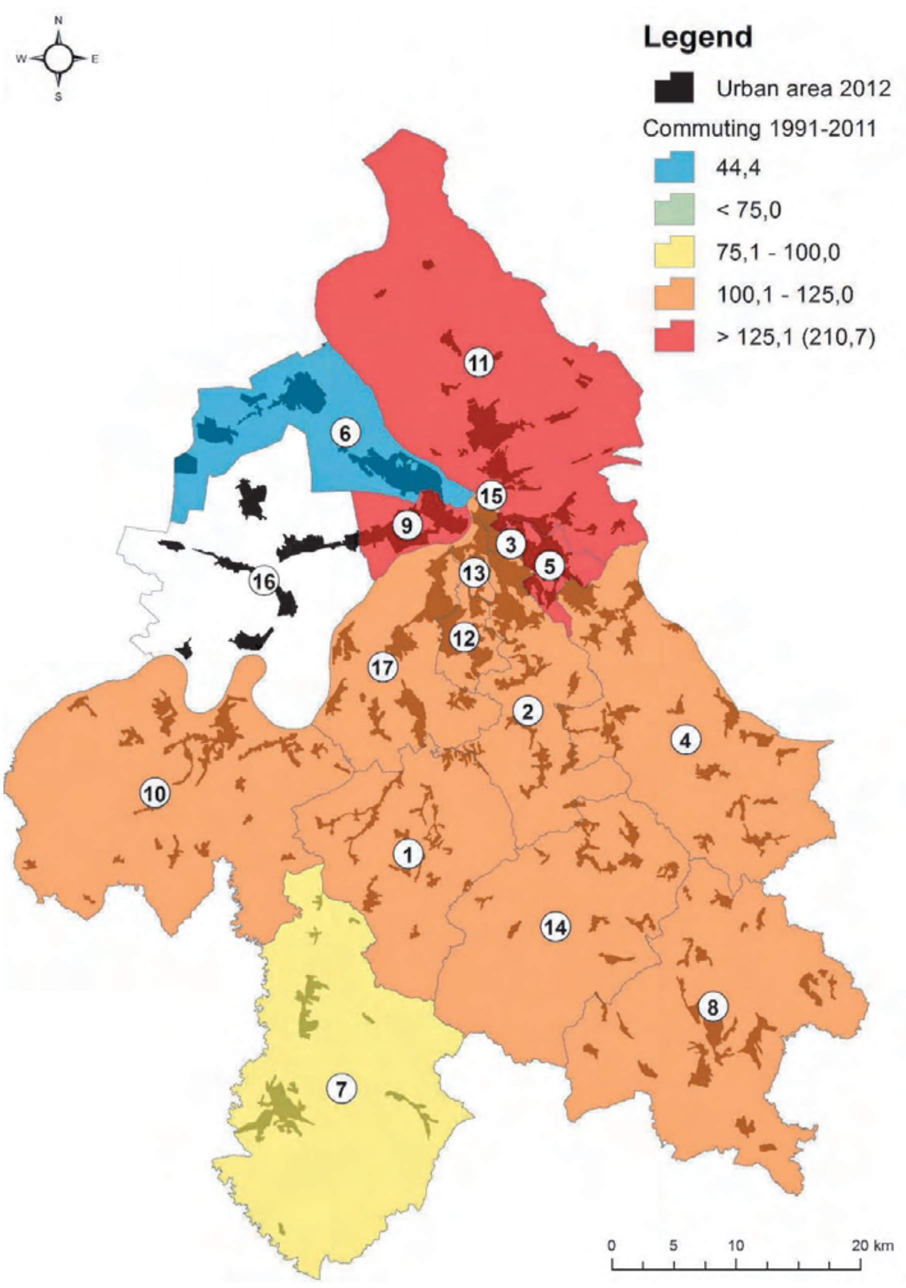

Figure 4. City of Belgrade – Commuting 1991 - 2011

3.2.4.3. The City of Sofia

Municipalities with the largest share of artificial surfaces in the **City of Sofia** in 2012 were inner-city municipalities of Oborishte, Krasno selo, Sredets, Vazrazhdane, Izgrev, Ilinden, Poduyane, and Slatina with artificial surfaces coverage up to 92–100%. Contrary to this, artificial surfaces in peripheral municipalities occupied less than 20% of the total land: Pancharevo, Novi Iskar, Kremikovtsi and Bankya. Regarding the land cover of the City of Sofia, there was a minor change in favour of artificial surfaces. Artificial surfaces accounted for about 1/5 of the total area in 2012.

Table 6. City of Sofia – population development and spatial changes

	Municipality	Population Change Index 1992/2011	1990		2012	
			Population Density (inh/ha)	Artificial/Total Area Ratio	Population Density (inh/ha)	Artificial/Total Area Ratio
1	**Sredets**	78.9	136	1.00	107	1.00
2	**Vazrazhdane**	92.4	138	1.00	128	1.00
3	**Oborishte**	88.6	132	1.00	117	1.00
4	**Ilinden**	94.7	104	1.00	99	1.00
5	**Serdika**	103.7	33	0.73	35	0.71
6	**Poduyane**	145.2	53	0.94	76	0.94
7	**Slatina**	117.9	45	0.91	51	0.93
8	**Izgrev**	101.2	73	1.00	73	1.00
9	**Lozenets**	138.5	54	0.77	64	0.90
10	**Triaditsa**	104.8	80	0.82	78	0.88
11	**Krasno selo**	108.3	128	1.00	138	1.00
12	**Krasna Polyana**	100.2	87	0.68	85	0.70
13	**Nadezda**	95.9	73	0.46	69	0.47
14	**Iskar**	97.8	45	0.56	44	0.57
15	**Mladost**	100.8	80	0.75	80	0.76
16	**Studentski**	150.4	80	0.65	113	0.69
17	**Lyulin**	100.5	126	0.43	117	0.47
18	**Vitosha**	159.7	18	0.18	24	0.21
19	**Ovcha Kupel**	147.0	38	0.24	44	0.29
20	**Bankya**	147.5	9	0.17	11	0.19
21	**Pancharevo**	124.0	12	0.05	14	0.05
22	**Vrabnitsa**	120.6	36	0.25	39	0.28
23	**Novi Iskar**	99.1	12	0.11	12	0.11
24	**Kremikovtsi**	54.1	10	0.16	6	0.14
	Mean	***111.3***	***67***	***0.62***	***68***	***0.63***

The CLC land cover changed in the general process of transition from “natural” land cover to artificial surfaces. In total, artificial surfaces coverage in 2012 was only about 0.1% higher than in 1990, at the expense of agricultural areas which, in total, decreased by 1%. With respect to the dynamics of “antropogenisation”, considerable changes occurred in general, but principally in the municipalities of the outer-city and periphery: Ovcha Kupel (by the 125.1 index), Vitosha (118.4) Lozenets (116.2), Bankya (115.7), and Vrabnitsa (110.9). A relatively modest rate of “deantropogenisation” was noticed in the municipality of Kremikovtsi (87.4), Novi Iskar (97.9) and Serdika (98.0) due to land recultivation, where previously exploited mine areas were reduced in favour of agricultural, forest and semi-natural areas (Table 6, Figure 5 and Figure 6).

Similarly to the City of Belgrade, a moderate rise in the population of the **City of Sofia** was noted. The population size most significantly rose in some central municipalities (e.g. Poduyane – 145.2), but mostly in southern peripheral municipalities: Vitosha (159.7), Studentski (150.4), Bankya (147.5) and Ovcha Kupel (147.0) As opposed to this trend, some inner-city municipalities (e.g. Sredets – 78.9, Oborishte – 88.6 and Vazrazhdane – 92.4) went through a substantial “depopulation”, as well as north-eastern peripheral municipality of Kremikovtsi (54.1) (Table 6).

According to the data from 2012, only about 25% of the City of Sofia suffered a certain degree of sealing by anthropogenic impervious materials (Table 7). Compared to 2006 an increase of 26% in the total sum of SSD values can be noted. The increased number of pixels with the SSD values indicates the expansion of surfaces covered by anthropogenic materials with the highest index of change in municipalities Vitosha and Pancharevo.

The highest density in the **City of Sofia** in 2012 was present in some inner-city and outer-city municipalities (Krasno selo – 138, Vazrazhdane – 128 and Oborishte – 117). Extremely low densities were observed in the peripheral municipalities: Kremikovtsi (6), Bankya (11), Novi Iskar (12) and Pancharevo (14). Consequently, during the observed period and related to land cover changes, the population density noticeably increased in the municipalities of the outer-city and periphery: Poduyane (144.2), Studentski (141.2), Vitosha (134.9), Bankya (127.5), Lozenets (119.3), Ovcha Kupel (117.5). Quite the opposite trend, i.e. a significant decline in population density, was present in the majority of municipalities, particularly in Kremikovtsi (61.9) and Vazrazhdane (94), and also in the inner-city municipalities of Sredets (72) and Oborishte (86), without land cover change, thus indicating “depopulation”. (Table 6, Figure 7).

Table 7. City of Sofia-spatial Distribution of SSD values

	Municipality	SSD pixels ratio 2006-2012 (Change Index)	2006		2012	
			Sum SSD values	Mean SSD values	Sum SSD values	Mean SSD value
1	Sredets	100.4	19986	73.5	19827	72.6
2	Vazrazhdane	100.0	25219	87.6	25094	87.1
3	Oborishte	100.8	22474	85.1	21667	81.5
4	Ilinden	100.3	21632	70.7	21250	69.2
5	Serdika	101.4	90997	68.2	94348	69.7
6	Poduyane	100.6	68625	67.8	76162	74.8
7	Slatina	95.8	75230	63.4	78889	69.4
8	Izgrev	100.0	20856	64.4	20714	63.9
9	Lozenets	102.5	47009	65.1	47974	64.8
10	Triaditsa	102.2	44895	60.3	48350	63.5
11	Krasno selo	100.0	46724	77.2	47102	77.9
12	Krasna Polyana	102.2	35841	59.6	38477	62.7
13	Nadezda	100.5	67044	62.2	72097	66.6
14	Iskar	96.2	79320	57.4	86932	65.5
15	Mladost	98.7	87683	62.2	94752	68.2
16	Studentski	102.2	36911	57.0	40819	61.7
17	Lyulin	103.9	64478	53.8	79133	63.6
18	Vitosha	142.8	129135	44.8	422444	102.7
19	Ovcha Kupel	107.6	63369	45.8	75379	50.7
20	Bankya	104.0	37704	33.7	40110	34.5
21	Pancharevo	109.4	121164	36.3	186895	51.2
22	Vrabnitsa	103.7	69268	43.9	83848	51.3
23	Novi Iskar	100.2	112917	34.9	116504	35.9
24	Kremikovtsi	92.0	213180	48.0	189188	46.4
	∑/Mean	*104.5*	*1601661*	*59.3*	*2027955*	*64.8*

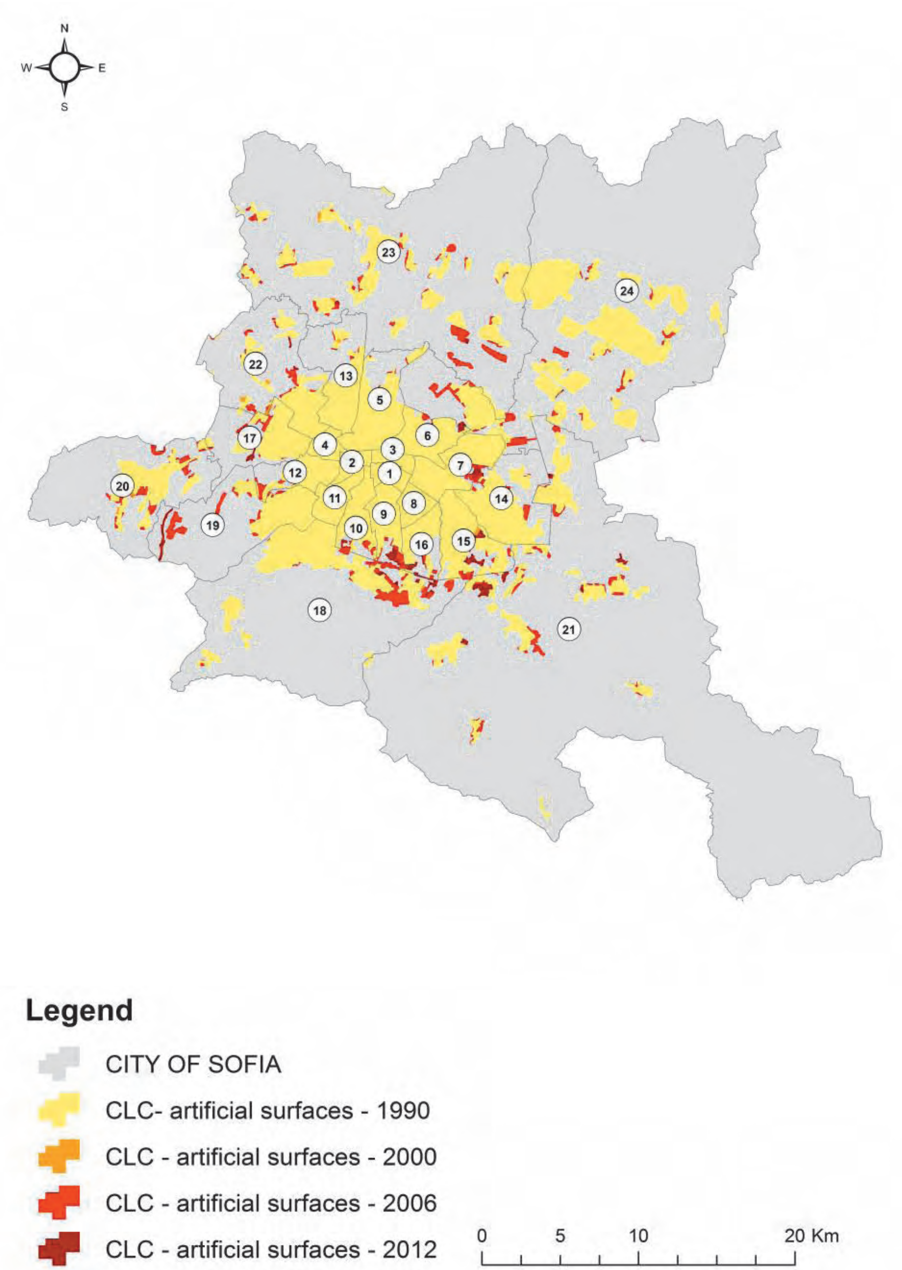

Figure 5. City of Sofia – Artificial surfaces and land cover change (1990–2012)

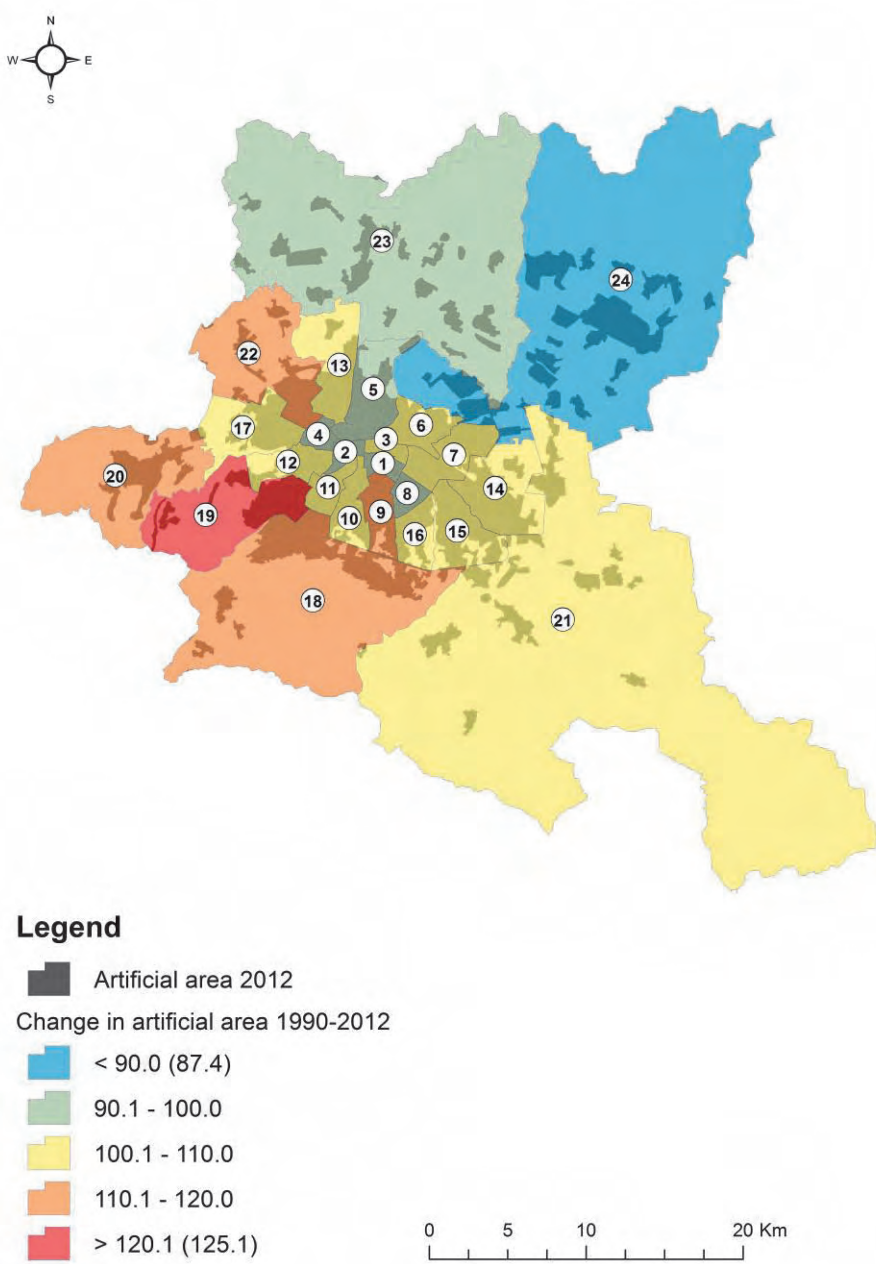

Figure 6. City of Sofia – Dynamics of land occupancy ("antropogenization") 1990-2012

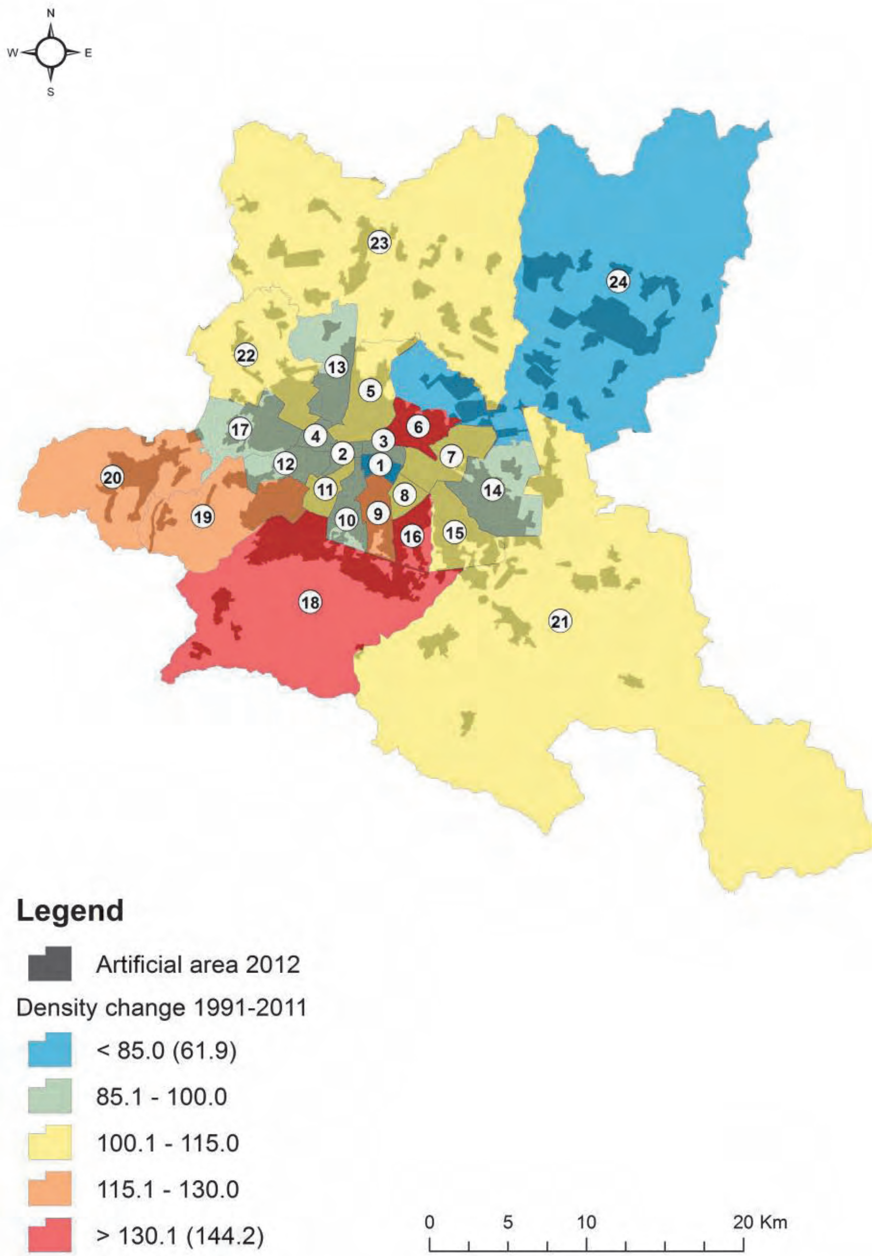

Figure 7. City of Sofia – Population density changes within administrative units (1990–2012)

3.2.4.4. The City of Rome

The data about land cover in 2012 for the **City of Rome** show that the inner-city municipalities I (0.98), II (0.98), V (0.72) and VII (0.69) had the greatest share of artificial surfaces. In contrast, less than 30% of the total land in peripheral municipalities was occupied by artificial surfaces: XIV (0.16), XV (0.21), IX (0.24), III (0.26), XIII (0.27) and X (0.29). Land cover of the City of Rome slightly changed in favour of artificial surfaces. In 2012 artificial surfaces covered around 1/3 of the total area. Similarly to Belgrade, the CLC land cover changed in the general process of transition from "natural" land cover to artificial surfaces. In total, artificial surfaces covered about 10% more in 2012 than in 1990, while agricultural areas decreased around 4%. In terms of the "antropogenisation", there were substantial changes in almost all municipalities, particularly in municipalities VI (by the index 134.6), IV (118.9), IX (117.7) and XIII (115.6). A certain "deantropogenisation" was noticed in the municipality VIII (97.3) (Table 8, Figure 8 and Figure 9).

Table 8. City of Rome – population development and spatial changes

	Municipality	Population Change Index 2011/1991	1990		2012	
			Population Density(inh/ha)	Artificial/Total Area Ratio	Population Density (inh/ha)	Artificial/Total Area Ratio
1	I (Historical Center-Prati)	93.0	109	0.98	101	0.98
2	II(Parioli/Nomentano-San Lorenzo)	89.6	102	0.98	91	0.98
3	III (Monte Sacro)	95.0	96	0.23	80	0.26
4	IV (Tiburtina)	97.2	81	0.46	67	0.54
5	V (Prenestino/ Centocelle)	88.7	153	0.67	127	0.72
6	VI (Delle Torri)	132.3	65	0.25	64	0.34
7	VII (San Giovanni/ Cinecittà)	93.6	118	0.62	99	0.69
8	VIII (Appia Antica)	93.1	85	0.36	81	0.35
9	IX (Eur)	124.4	37	0.21	40	0.24
10	X (Ostia)	127.8	45	0.26	52	0.29
11	XI (Arvalia Portuense)	94.3	71	0.32	61	0.35
12	XII (Monte Verde)	90.4	71	0.31	62	0.31
13	XIII (Aurelia)	101.2	86	0.23	75	0.27
14	XIV (Monte Mario)	103.2	97	0.14	89	0.16
15	XV (Cassia Flaminia)	112.3	40	0.19	40	0.21
	Mean	***101.7***	***84***	***0.41***	***75***	***0.45***

The population of the **City of Rome** suffered a mild decline in the observed period. The most significant growth in population size was recorded primarily in some peripheral municipalities[10]: VI (132.3), X (127.8) and IX (124.4). The opposite demographic trend, i.e. considerable "depopulation", was recorded in all inner-city municipalities, especially in municipalities V (88.7), II (89.6), XII (90.4) and municipality I (93.0) (Table 8).

In 2012 about 43% of the City of Rome was to a certain extent sealed by anthropogenic impervious materials (Table 9). Compared to 2006, there is an increase in the total number of pixels in each municipality, followed by slight enhancement of the SSD values, which indicates the spread of artificial surfaces. The major change in the number of pixels and SSD values in the observed period was present in municipalities VII, V and XV.

Table 9. City of Rome-spatial Distribution of SSD values

	Municipality	SSD pixels ratio 2006-2012 (Change Index)	2006		2012	
			Sum SSD values	Mean SSD values	Sum SSD values	Mean SSD value
1	I (Historical Center-Prati)	103.0	117690	64.5	132578	70.3
2	II(Parioli/Nomentano-San Lorenzo)	104.2	105298	63.9	112993	65.9
3	III (Monte Sacro)	101.2	152191	41.5	157740	42.5
4	IV (Tiburtina)	103.0	173753	52.6	185064	54.4
5	V(Prenestino/Centocelle)	106.1	145834	67.5	160578	70.1
6	VI (Delle Torri)	102.3	288178	50.0	307424	52.2
7	VII (San Giovanni/ Cinecittà)	106.3	201865	58.8	226070	61.9
8	VIII (Appia Antica)	103.7	93672	44.4	100500	45.9
9	IX (Eur)	101.7	261183	38.2	273914	39.3
10	X (Ostia)	103.5	240853	45.2	255947	46.4
11	XI (Arvalia Portuense)	100.7	161639	46.8	167939	48.2
12	XII (Monte Verde)	104.2	113558	46.3	122307	47.8
13	XIII (Aurelia)	103.3	112315	43.4	118501	44.3
14	XIV (Monte Mario)	103.5	142161	38.4	152021	39.7
15	XV (Cassia Flaminia)	104.0	174684	31.3	185746	32.0
	∑/Mean	*103.1*	*2484874*	*48.8*	*2659322*	*50.7*

[10] The new administrative division of the City of Rome, which was adopted in 2013, was used in this research. In accordance with this division, the number of municipalities which belong to the administrative area of the City of Rome has been reduced from the previous 19 to the present 15 municipalities.

In 2012 the highest population density in the **City of Rome** was registered in the inner-city municipalities V (127), I (101) and VII (99), while the least populated were peripheral municipalities IX (40), XV (40) and X (52). Related to land cover changes, population density increased in the following municipalities: X (by the 116.0 index), IX (105.6), XV (100.1).

On the other hand, most municipalities with high "antropogenisation" experienced a considerable fall in population density: IV (81.7), V (82.6), III (83.6), VIII (84.0) and XI (85.9). In addition, population density also decreased in the inner-city municipalities I and II, without land cover change, which indicates "depopulation" (Table 8, Figure 10).

3.2.5. Brief discussion and concluding remarks

As already elaborated (Krunić et al. 2014b), it is hard to detect relationship between the expansion of soil sealing in periphery of the metropolitan areas and differences with regard to the natural surroundings, historical, social and economic development of the cities. Simply, different factors caused similar trends in land cover structure and population dynamics in the case study cities.

Occupation and sealing of productive soil in peri-urban zones was not proportional to the population dynamics of the cities. Population of the **City of Belgrade** increased moderately, in total, by the index of 105.3. The most significant increase in population size was recorded predominantly in peripheral municipalities, while a significant decrease was observed in inner-city municipalities. The population of the **City of Rome** slightly increased in total, by the index of 101.1. Again, the most significant increase in population size was noted primarily in some peripheral municipalities. In contrast to this demographic trend, all inner-city municipalities suffered a significant "depopulation". The population of the **City of Sofia** also increased moderately in total, by the index of 108.5. The population size most notably rose in some central municipalities, whereas some inner-city municipalities, as well as the north-eastern peripheral municipality, experienced "depopulation" to a considerable extent.

There were also differences in the dynamics of spatial changes. Namely, while the UMZ of Belgrade extended for about 70km^2, the UMZ of Rome and Sofia extended for about 25km^2 and 9km^2 respectively. It is interesting to note that spatial dynamics of the UMZ or respective artificial surfaces have accelerated after the year 2000 in the cases of all three cities. The development of the UMZ of all three cities was a dynamical process which differed throughout the observed period. There was an obvious correlation between the sealing degree and the intensity of human activity.

Land cover pattern also changed, concurrently with the UMZ development and dynamics. Artificial surfaces development corresponded with the UMZ changes and dynamics. In all three cases, artificial surfaces were mainly developed at the expense of agricultural areas. By using the CLC land cover classification it was not possible to track changes inside artificial surfaces, i.e. in the cities' urban tissues.

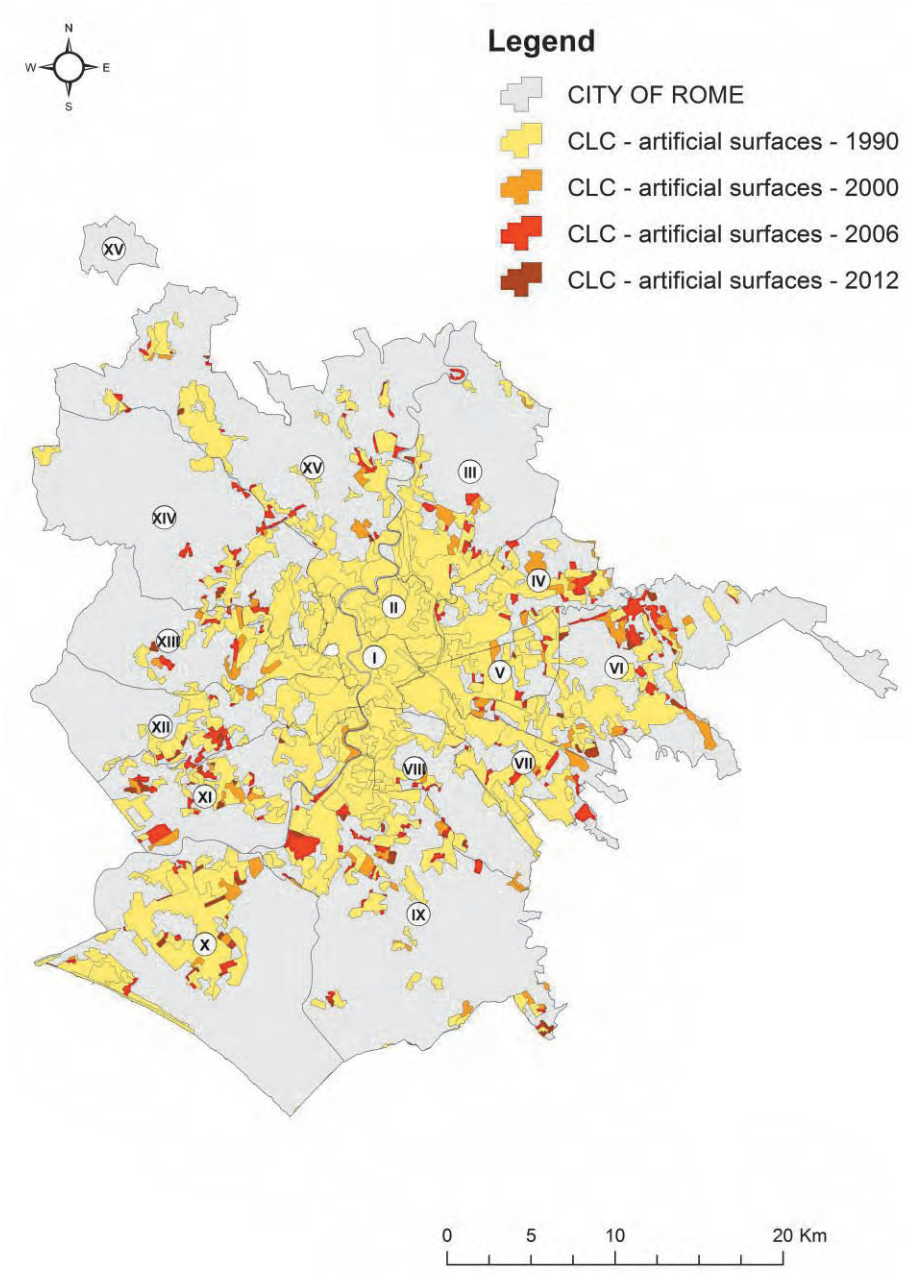

Figure 8. City of Rome – Artificial surfaces and land cover change (1990–2006)

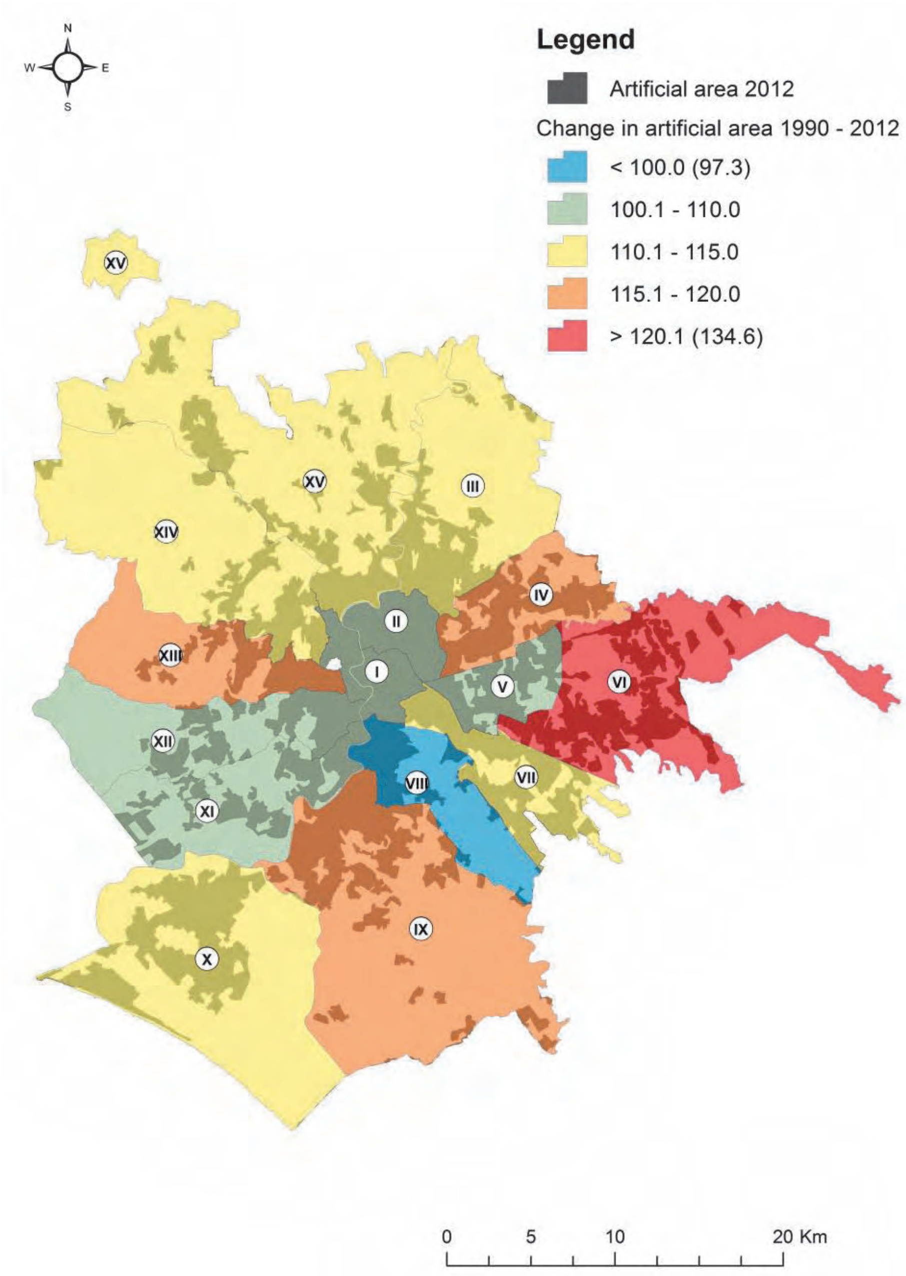

Figure 9. City of Rome – Dynamics of land occupancy ("antropogenization") 1990-2012

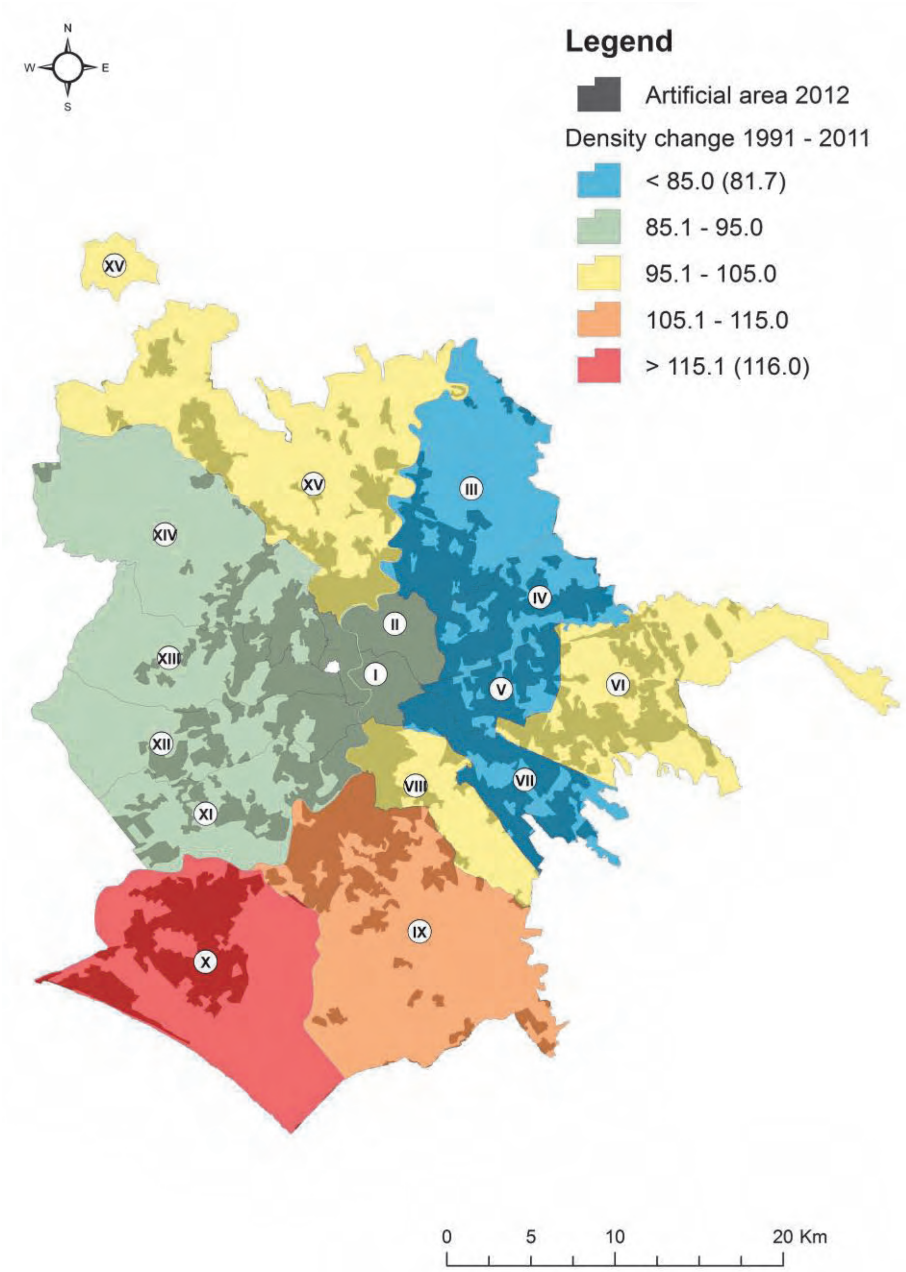

Figure 10. City of Rome – Population density changes within administrative units (1990–2012)

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