

SPATIAL AND TEMPORAL DYNAMICS OF URBAN SPRAWL IN THE ROMANIAN PLAIN OVER THE LAST CENTURY

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Key-words: urban sprawl, built-up areas expansion, spatial analysis, Romanian Plain.

Abstract. The current study is a spatial and temporal assessment of urban sprawl dynamics, considered as a key parameter for quantifying urban sprawl. The assessment was carried out in a large geographical unit, i.e. Romanian Plain, located in the southern and south-eastern part of Romania and characterised by favourable natural and socio-economic conditions for urban growth and sprawl over time. The authors carried out an historical evolution of the built-up areas in order to explain urban growth over the past century using different cartographic materials (Austrian maps, 1912 and topographical maps, 1970) and Landsat satellite images (1990, 2002 and 2016). In order to identify and understand the spatial differentiations, the spatial and temporal statistical analysis was performed for four time frames: 1912–1970, 1970–1990, 1990–2002 and 2002–2016. The results were quantified using two indicators able express the magnitude of the built-up areas expansion at each LAU2 level: the Built-up Areas Expansion and the Annual Expansion Rate. Furthermore, in order to detect the geographical expansion trend of the built-up areas, the data on the annual expansion rate were interpolated using the global polynomial function. The spatial analyses revealed significant spatial differences in the urban sprawl process during the analysed intervals in relation to the main triggering factors.

1. INTRODUCTION

Urban sprawl is a global phenomenon regularly driven by population growth, increase of economy and infrastructure initiatives and large scale migration (Sudhira *et al.*, 2004). Urban sprawl is currently one of the most important land use/cover changes which is affecting Europe with impacts on the environmental (e.g. surface sealing, transport emissions, ecosystem fragmentation), social (e.g. segregation, lifestyle changes), and economic (e.g. distributed production, land prices) functions (EEA, 2006; Patacchini and Zenou, 2009). In Europe, in particular, urban sprawl has developed over the past decades, notably contributing to how cities have expanded, thus leading to an increase in the housing, transport and infrastructure demand (EEA, 2006). In 2014, almost three quarters (72.5 %) of European Union (EU) 28 inhabitants lived in cities, towns and suburbs, however with significant differences in terms of size and spatial distribution of urban development. Population projections indicate that this pattern is expected to continue during the next 35 years (Eurostat, 2016).

The traditional urban development model of van den Berg *et al.* (1982) distinguishes four main stages: urbanization, suburbanization, desurbanization, and reurbanization, the first two generally characterising the urbanisation processes which took place in Europe during the last century. The urbanisation refers to different processes of change in the rural countryside induced by the urban centres, with different spatial patterns and forming different spheres of influence around the main cities (Antrop, 2000). The 20th century has been generally characterised by record population and economic growth, urban development increasing gradually through the concentration of population inside towns and cities mainly under urban-industrial growth. To the end of the 20th century, urban growth has pushed cities further and further out (Glaeser and Kahn, 2004). Thus, the compact urban areas which have characterised the largest part of the 20th century have increasingly been replaced by diffusive, leapfrogged, linear or clustered growth (Allen and Lu, 2003; Cheng and Masser, 2003;

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Wilson *et al.*, 2003; Berling-Woff and Wu, 2004) with new functions (e.g. commercial, housing, logistic) outside the city outskirts. New suburbs and metropolitan areas emerged characterized by decentralized homes and jobs (Glaeser and Kahn, 2004). In many cities, people have tended to move out of the inner cities to suburban and peri-urban areas (hybrid areas of fragmented urban and rural characteristics) on the outskirts of existing metropolitan areas (Eurostat, 2016). It normally takes place in radial direction around the city centre or in linear direction along the highways. Usually sprawl takes place on the urban fringe, at the edge of an urban area or along the highways (Sudhira *et al.*, 2004).

In Central and South-East European countries, urban growth, under the form of suburbanisation, has become the foremost urban development process bringing in population deconcentration and major spatial transformations related to land use/land cover patterns (Bičík and Jeleček, 2009). Suburbanisation has been described as a general model of development by linear tendencies along the main transportation axes, as well as low-density residential areas in the outskirts of towns in several post-communist metropolitan areas e.g. Budapest (Kok, Kovacs, 1999; Soós and Ignits, 2003), Prague (Sýkora, 2006; Ourednicek, 2007; Sýkora and Ourednicek, 2007; Bičík and Jeleček, 2009; Špačková and Ouředníček, 2012), Warsaw (Degórska, 2004; Lisowski, 2004; Degórska, 2012) or Sofia (Hirt, 2007; Hirt and Stanilov, 2007; Stanilov and Hirt, 2014).

In Romania, urban development, manifested through urbanisation and suburbanisation processes, has significantly affected the landscape over the last almost one hundred years. The scientific investigations on the urban development phenomenon throughout the last century underlined a strong relationships between the spatial dynamics and patterns of the built-up areas and the foremost explanatory driving factors (e.g. political, economic, demographic, natural) (Popovici *et al.*, 2013; Grigorescu *et al.*, 2015; Kucsicsa and Grigorescu, 2018). The scientific literature on urbanisation processes mostly explained the role of industry in the territorial planning and urban development (Şandru *et al.*, 1984; Popescu, 1994; Ianoş, 2001; Săgeată and Dumitrescu, 2004) but also, reversibly, the role of deindustrialization and urban shrinkage after the fall of communism (Popescu, 2014). However, many studies have focused on the characteristics and typologies of suburbanisation and urban sprawl at national scale (Nicolae, 2002; Suditu *et al.*, 2010; Suditu, 2012; Ioja *et al.*, 2011; Ianoş *et al.*, 2012; Petrişor, 2012; Grădinariu *et al.*, 2015; Dumitrache *et al.*, 2016; Iaţu and Eva, 2016), but also at the level of different metropolitan areas (e.g. Bucharest, Constanţa, Iaşi, Suceava, Braşov, Cluj-Napoca) or other urban areas (Sinaia). The largely addressed issues include: residential development and real-estate market (Conway *et al.*, 1995; Niculiţă *et al.*, 2011; Zilişteanu, 2011; Grigorescu *et al.*, 2012a; Pocol and Jitea, 2013), spatial transformations and conflicts triggered by land cover/land use changes (Bălteanu and Grigorescu, 2006; Simion, 2010; Pătroescu *et al.*, 2011; Ioja *et al.*, 2011; Ioja *et al.*, 2014; Grigorescu *et al.*, 2012b, 2015), counter-urbanisation process and rural-urban fringe patterns (Ianoş *et al.*, 2010; Gură-Nica and Sofer, 2011; Gură-Nica and Sofer 2012), suburbanization and metropolization processes (Erdeli and Simion, 2006; Dumitrache *et al.*, 2016; Gură-Nica *et al.*, 2016); the relationships between urban sprawl and transportation (Iaţu *et al.*, 2011), environmental issues (Cocheci, 2014) or different socio-demographic processes (Sârbu, 2012; Istrate, 2015; Coche ci and Mitrea, 2016).

In spatial analyses, urban growth is regularly quantified by considering the impervious or the built-up as the key parameter of assessing urban sprawl (Sudhira *et al.*, 2004; Rahman *et al.*, 2011; Shahraki *et al.*, 2011). Urban sprawl can be assessed using different methodologies and tools, such as: logistic regression models (Cheng and Masser 2003; Allen and Lu 2003; Abebe 2013; Duwal 2013; Corodescu and Cîmpianu 2014; Shu *et al.* 2014; Kucsicsa and Grigorescu, 2017), remote sensing (Sudhira *et al.*, 2004; Şandric *et al.* 2007; Feng, 2009; Bhatta, 2010; Rahman *et al.*, 2011; Huzui *et al.* 2013; Tayyebi *et al.*, 2013; Mihai *et al.* 2015); a combination of methods (Torrens, 2006, 2008) urban sprawl indices (Oueslati *et al.*, 2015), bibliometric analysis (Chen *et al.*, 2014) etc.

The population in the Romanian Plain is in continuous dynamics especially in the urban and suburban areas. This general trend which stimulates the urban sprawl process is putting significant pressures on land resources at the expense of agricultural or abandoned land use categories through

built-up areas dynamics. As a result, the current study is aimed at assessing the spatial distribution of built-up areas expansion over a large period of time in order to identify and understand the spatial disparities of urban sprawl in relation to the social, economic and political features of the selected intervals.

2. STUDY-AREA

The Romanian Plain, together with the Danube Floodplain, also known as the Lower Danube Plain, is the largest plain area in Romania located in the southern and south-eastern part of the country. It stretches west to east over 500 km along the Danube River (which delimits it to the south, east and west on a distance of 840 km) and the Getic Piedmont, the Curvature Subcarpathians and the Moldavian Plateau in the north. The total area of this vast plain is of 52,600 km², which is 21% of the territory of Romania, the second largest relief unit after the Carpathians (28%) (Posea and Iordan, 2005; Bălteanu, 2016).

This relief unit stands out as country's main agricultural region mainly due to its specific natural conditions. E.g. the relatively low altitudes of 10–200 m (locally 300 m), low declivity, the existence of large areas covered with high fertility soils (e.g. chernisols, brown and reddish-brown argilluvic), relative homogeneity of morpho-hydrographic and climate features, high percentage of arable land (80–90% of total agricultural surface) (Posea and Iordan, 2005). To these, the political and socio-economic factors the area had faced over time, had led to significant spatial transformations which have significantly changed the landscape aspect and pattern.

The Romanian Plain (including the Danube Floodplain) comprises about 650 localities which are totally overlapping its territory and more than 100 LAU 2 which are located at the border with the neighbouring relief units (Getic Piedmont, Curvature Getic, Moldavian and Dobrogea Plateau). In order to analyse urban sprawl dynamics, out of the border localities, the authors took into the consideration only the LAU 2 with more than 50% built-up area included within the Romanian plain limits. Thus, for the current study, 762 LAU2 (67 cities and nearly 695 communes) were analysed (Fig. 1).

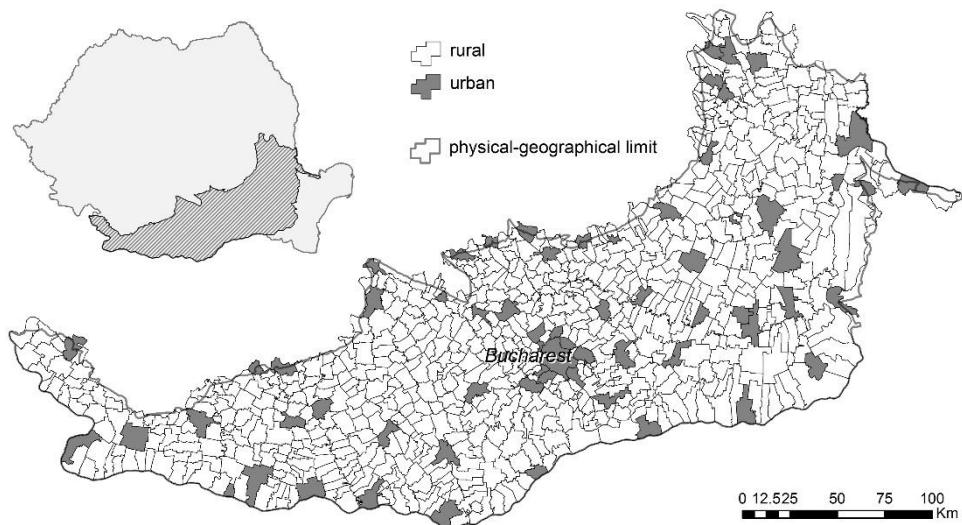


Fig. 1 – The local administrative units (LAU2 level) included in the Romanian Plain.

Spatially, Frecătei, Borcea, Măraşu, Stăncuţa, Făcăeni, Borduşani and the towns of Galaţi and Bucharest are the largest LAU 2 (>20,000 ha), while Copăceni, Dobroeşti, Bărbuleşti, Cosoba, Goleşti and Chitila are the smallest (<1,500 ha).

According to the most recent classification of the urbanization process in Europe (carried out at LAU 2 level), the classification of the urbanisation level includes three major categories: densely-populated areas; intermediate areas (moderately populated areas) and thinly-populated areas. This classification was defined using a criterion of geographical contiguity in combination with a minimum share of population based on grid square cells of 1 km^2 living in different types of clusters defined by the according to their size and density (DEGURBA, 2011).

In the Romanian Plain the largest part of the densely-populated and intermediate areas overlap the main towns (including growth and development poles) and their suburban areas, while the thinly-populated areas are covering the urban void between the urbanised/suburbanised areas, as well as the peripheral areas, thus pointing to a visible spatial dispersion of urban growth phenomena from a demographic point of view (Fig. 2, Tab. 1).

Table 1
The characteristics of the urbanization level

Urbanisation degree	Urban/rural structures	Characteristics	
Densely-populated areas	Cities/large urban areas	At least 50% lives in high-density clusters	high-density clusters = contiguous grid cells of 1 km^2 with a density of at least 1,500 inh./ km^2 and a minimum population of 50,000 inh. (alternative names: urban centre or city centre)
	Towns and suburbs/small urban areas	Less than 50% of the population lives in rural grid cells and Less than 50% lives in high-density clusters	
Thinly-populated area	Rural areas	More than 50% of the population lives in rural grid cells	rural grid cells = 1km^2 grid cells outside urban clusters; urban clusters = clusters of contiguous grid cells of 1 km^2 with a density of at least 300 inh./ km^2 and a minimum population of 5,000 inh.

Source: DEGURBA, 2011

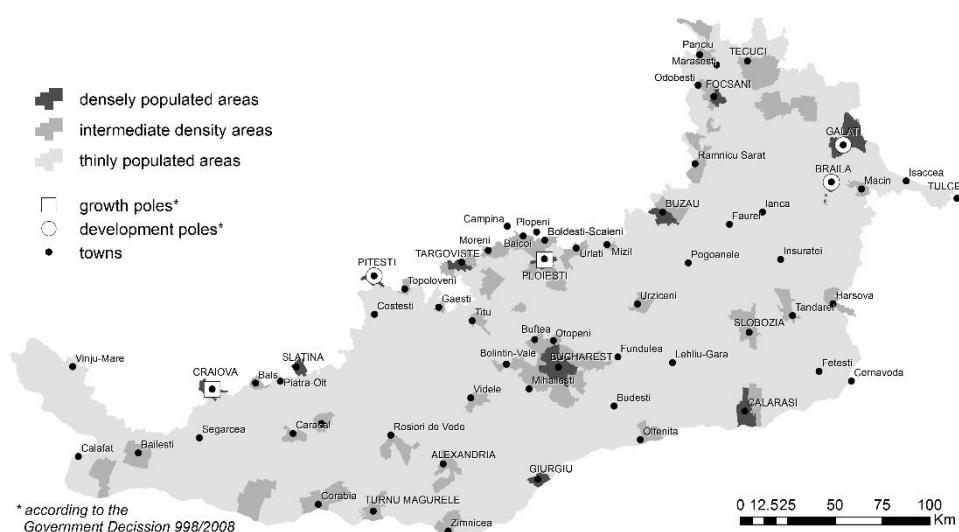


Fig. 2 – The urbanization degree in the Romanian Plain (processed after DEGURBA, 2011).

Rural-urban relations in the Romanian Plain have changed significantly in the last century in favour of the urban structures (Urucu and Bordânc, 2005b), in terms of demographic size (cities concentrate over 50% of population) and by the increasingly high and complex pressure exerted on the agricultural rural space which represents the largest land use category of this relief unit (over 80%). Regularly, the large cities developed as growing poles, generating emergent peri-urban and metropolitan areas (e.g. Bucharest, Galati, Craiova), while the small and medium-sized towns have a reduced influence on the surrounding rural areas.

3. METHODS AND DATA

The current assessment provides an historical overview on the built-up areas dynamics in the Romanian Plain, one of the areas largely affected by major spatial transformations over the last almost one hundred years (1912–2016) in relation to the socio-economic and political context.

The historical assessment of the territorial analysis was carried out using multi-temporal geospatial such as: cartographic materials from 1912 (Austrian maps scale 1: 100 000) and 1970 (topographical maps scale 1: 100 000) and Landsat satellite images (Table 2). In order to highlight the local differences, the authors used the boundaries from LAU2 database (2013). For further spatial differentiations, the spatial and temporal statistical analysis was performed for four time frames: 1912–1970, 1970–1990, 1990–2002 and 2002–2016. The first two intervals (1912–1970 and 1970–1990) overlap the largest part of the 20th century which involved significant political and socio-economic changes principally related to the main land reforms (1921, 1945) and the consequences of the communist policies on agriculture, town planning and industry. The last two analysed intervals (1990–2002 and 2002–2016) refer to the post-communist period characterised by the transition to the market economy followed by pre- and post-accession to the European Union. The resulted spatial transformations included major land use/cover changes related to the intensification (the intense use of land through investments in production means and labour force) and extensification (the conversion of additional land for the cultivation of commodities) of agriculture, deforestation and urban growth (mainly suburbanization) (Popovici *et al.*, 2013; Grigorescu *et al.*, 2015).

Table 2

Cartographic sources and satellite images used. Built-up area resulted after vectorisation

Maps					
Source		Year		Scale	Area (ha)
Austro-Hungarian map		1912		1:100 000	190,547
Topographic map		1970		1:100 000	304,171
Satellite images					
source	year	data	Path/row	resolution	Area (ha)
LANDSAT 4-5 TM	1990	July 07 August 21	182/029 183/029	30 m	357,943
LANDSAT 7 ETM	2002	August 23 September 15	182/029 183/029	30 m	373,448
LANDSAT 8 OLI_TIRS	2016	July 07 April 09	182/029 183/029	30 m	400,237

The statistical analysis of the spatial and temporal dynamics of urban sprawl in the Romanian Plain was carried out based on the processing, integration and querying of the geospatial data using the Geographical Information Systems (GIS) – ArcMap software 10.4. The initial geospatial data resulted from the extraction of built-up areas from the maps/satellite images in the selected years: 1912, 1970, 1990, 2002 and 2016 resulted from the raster data vectorisation. The delineation of built-up areas also included areas with farms, parks/green spaces inside towns, spaces under construction etc. As a result,

the authors computed two spatial indicators at LAU2 level: *Built-up Areas Expansion*, *Annual Expansion Rate*. The first indicator (*Built-up Areas Expansion*, ha) measures the difference between the built-up area computed for the last (Y) and first year (X) for the period under review, at LAU2 level: $E = (Y-X)$, while the second indicator (*Annual Expansion Rate*, ha) was calculated based on the ratio between the built-up area expansion (E) over a certain analysed period and the number of years (ny) of each period under review: $R = E/ny$ (Grigorescu *et al.*, 2015). Both indicators were computed for each LAU2, as well as for the entire Romanian Plain in order to spot the areas subject to historical built-up areas dynamics under urbanization/suburbanization processes over the analysed period. Furthermore, in order to detect the geographical expansion trend of the built-up areas, the data on the annual expansion rate were interpolated using the global polynomial function.

4. RESULTS AND DISCUSSIONS

Over the last century, Romania experienced significant structural and functional transformations which have triggered land use/cover changes, thus imprinting specific territorial development at different spatial scales. Generally, the twentieth-century is characterized by widespread and diversified environmental changes mainly triggered by a continuous population growth which required the expansion of agricultural areas for extensive and intensive farming, followed by the intensification of the urbanization and forced industrialization processes. Together with the demographic growth and the upsurge of the urbanization process, the modernization and diversification of the communication means also occurred, the main roadways starting to spread by modernising some of the old routes or by opening new ones.

Until 1990, both the demographic increase and the landscape transformations were strongly influenced by the consequences of the two World Wars and the two agrarian reforms of 1921 and 1945. The first agrarian reform was endorsed after the Greater Union of Romania (1918), leading to the expropriation of large surfaces of state property which were fragmented and distributed to peasants. The second land reform, enacted after World War II, had in view the abolition of the great landowners property, preparing the transition to the socialist regime characterised by the centralised ownership, collectivisation and state farms (Bălteanu *et al.*, 2006; Popovici *et al.*, 2013). In the context of agricultural land expansion, after 1963 land betterment works continue to expand and intensify through the construction of dams and drainage systems in wetland areas (e.g. Danube Floodplain) and large irrigation systems in drought-prone areas (e.g. Oltenia Plain, Mostiștea Plain). Apart from the transformations which took place in agriculture, the second half of the 20th century was also characterised by rapid urbanization and forced industrialization which played a decisive role in the country's urban development, the industrial town becoming the representative urban settlement type (Dumitrescu, 2008; Grigorescu *et al.*, 2015). Consequently, the post-war industrialisation and urbanisation policies were followed by the gradual transition from the traditional rural-agrarian society to the urban-industrial society of the 1990s (Mitrică, 2014). After 1945, the regional polarization, aimed at diminishing regional imbalances, was carried out mainly through the establishment of new industrial plants in the new county seats or small and medium-size towns, including the towns located along the Danube Floodplain e.g. the metallurgical sector (e.g. Galați, Buzău, Zimnicea, Călărași), the chemical sector (e.g. Turnu Măgurele), machine building (Alexandria), textiles and food industry (e.g. Focșani, Tecuci), machine tool industries (e.g. Târgoviște). As a result, the economy of some towns boomed and their population tripled or quadrupled between 1966 and 1990 (Popescu, 2014). The development of the industrial platforms had contributed to the spatial transformations through industrial diffusion, i.e. the extension of the old industrial nuclei or the establishment of new industrial units in the rural areas located on the outskirts of towns (Popescu, 1994), thus acting as means of spatial expansion and as centres of towns' planning and development (Urucu and Bordânc, 2005b). As a result, the urbanization process has developed rapidly, over 10 new cities being built in the vicinity of the existing industrial centres or on bare land following the implantation of the

new industrial sites. However, in most cases, the new industrial sites were located in small towns with agricultural or commercial functions (fairs) or even in rural settlements, leading to an explosive growth as a result of migratory flows (Săgeată and Dumitrescu, 2004). In line with that, the continuous increase in the number of inhabitants, especially after 1966, favoured largely by some facilities for commuting in industry and other non-agricultural activities in the surrounding of the main towns (e.g. Bucharest, Craiova, Slatina, Galați, Oltenița, Călărași) (Urucu and Bordânc, 2005b), triggered significant spatial transformations, mainly related to built-up areas expansion. From the second half of the 20th century, especially after 1960–1965, the Romanian Plain could be also defined as a space (or production) supplier for other activities than housing and agriculture, i.e. industry, construction (build-up), transport, storage (warehouses), recreational areas, tourism, experimental fields for cultural and research institutions, etc. (Urucu and Bordânc, 2005a). The magnitude of these changes has increased significantly within the last decades, especially after 1990, with notable spatial and functional differentiations.

The period that followed the year 1990 brought in major spatial and structural changes triggered by the fundamental political and socio-economic transformations which took place after the fall of the communist regime (1989). The resulted spatial changes embodied different forms in relation to the particularities of the two periods wherein of the post-communist periods: transition (1990–2003) and post-transition (2003-to date). The first period marked a major changeover in the economy in terms of replacing the old centralised system with the free market system, decollectivisation and privatisation of agriculture. The immediate consequences of these changes included the excessive land fragmentation, the conversion of big farms into small, peasant-type family farms, the degradation of the productive quality of agricultural terrains (Popovici *et al.*, 2013), and land abandoned (mainly arable lands and permanent crops land use categories) which, in turn, led to the conversion to other urban sprawl-related categories (e.g. residential, commercial, warehouses) (Grigorescu *et al.*, 2015). During the post-transition period, the main spatial transformations were related to Romania's pre- and post-accession to the European Union and the implementation of the Common Agricultural Policy (CAP) when the most important land-use changes were related to the conversion of agricultural, forest or pastures to residential, commercial and industrial/logistic under suburbanisation processes (Kucsicsa and Grigorescu, 2018). Thus, the major land transformations involved built-up areas dynamics which emerged mainly along the main transport axes (e.g. along the main motorways: Bucharest – Ploiești, Bucharest - Giurgiu, Bucharest – Urziceni, or along the highways: Bucharest-Pitești, Bucharest – Constanța) and, generally at city outskirts, taking the form of a leapfrog suburban sprawl (Sýkora, 2007) and linear built-up area expansion or “ribbon sprawl” which generally triggered new functional areas such as commercial, logistic or residential (Torrens, 2008; Kucsicsa and Grigorescu, 2018). Moreover, the conversion of non-urban areas within the remaining open spaces within the already existing built-up areas occurs under the form of “infill” development describing an outward direction of the urban development in the nearby urban fringe, sometimes called urban fringe development (Camagni *et al.* 2002; Abebe 2013; Duwal 2013).

Built-up areas dynamics. After 1900, in the Romanian Plain a continuous expansion of the built-up areas has been registered, a process related to the demographic evolution (e.g. positive birth rate, the transformation of rural settlements in towns and the migratory movements mainly after the Second World War or related to rural-urban migration) (Deică *et al.*, 1983), with significant differences both spatially and temporally (Fig. 3). Thus, the resulted spatial data revealed that in 1912 the built-up area covered over 190,000 ha (3.8% of the entire study area) with larger surfaces registered mainly in Bucharest (~6,000 ha), and in some emerging industrial towns: Ploiești (~1,300 ha), Giurgiu (~1,200 ha), Galați (~1,100 ha) and rural settlements with predominantly agricultural functions: Costești (~1,000 ha), Suseni (~1,200 ha), Tătărăștii de Jos (~1,000 ha), Nicorești (~800 ha), Poiana Mare (~700 ha) etc. Compared to 1912, in 1970 the built-up area grew by almost 60% (+ 113,600 ha) in most of localities, with an average annual growth rate of 3.8 ha, predominantly in Bucharest (+7,500 ha), Brăila (+1,160 ha), Ploiești (+1,150 ha), (Galați (+940 ha), but also in Corabia, Fetești,

Băileşti, Dăbuleni, as well as in Dor Mărunt, Bârla, Brazi, Radomireşti, Dragalina, Snagov etc. An important fact shown by the spatial analysis is that during this period new villages emerged, especially in the western half of the Romanian Plain, e.g. Nicolae Bălcescu (in Vânu Mare Town), Bistreşti (in Devesel Commune), Cozia (in Prislop Commune), Gemeni (in Dărvari Commune), Pisculeşti (in Piscu Vechi Commune), Vârtopu and Tudor Vladimirescu (in Corabia Town) or the nuclei of new settlements such as: Ştefan cel Mare, Urzica, Bucinişu, Traian (Olt County) or Gruia (Mehedinţi County). These new localities developed through the strengthening of their agro-industrial function or compensating the local polarisation role of the urban settlements which were insufficiently covering the area. At the end of this period (1968), a large number of rural localities were declared towns in the Romanian Plain, most of them having an important role as local centres in agricultural areas (e.g. Segarcea, Topoloveni, Vânu Mare), in the food industry (e.g. Tăndărei) or as railway centres (Făurei) (Deică *et al.*, 1983).

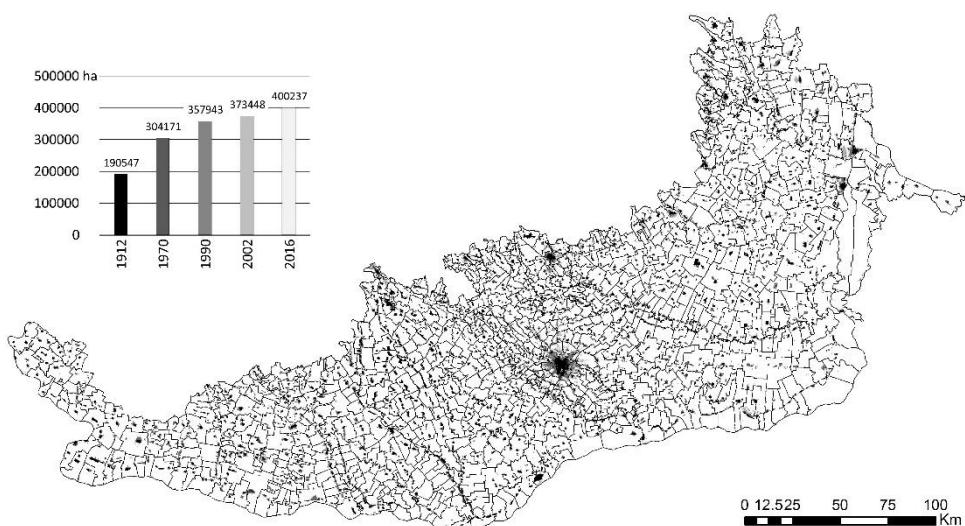


Fig. 3 – The spatio-temporal dynamics of built-up areas in the Romanian Plain (1912–2016).

Between 1970 and 1990, the annual expansion rate is reduced to 3.0 ha, due to the general slowdown of urbanisation in the 1980's (Benedek, 2006). However, significant increases were registered in the cities of Bucharest (+3,850 ha), Galați (+1,900 ha), Buzău (+8,020 ha), Ploiești (+650 ha) and Brăila (+550 ha). At the same time, the built-up areas records significant increase in some new industrial towns along the Danube Floodplain (e.g. Turnu Măgurele, Zimnicea, Giurgiu, Oltenița, Călărași) or in some localities near Bucharest (e.g. Popești-Leordeni, Otopeni, Pantelimon). The increase of the urban density after 1968, contributed to more complex relations between cities and the surrounding rural areas. As a result, urbanization has been accompanied by an intensification of the city's influence on the suburban areas, incorporating new suburban localities into their administrative territory (Deică *et al.*, 1983; Șandru *et al.*, 1983). The main scope of this process was to improve urbanisation indicators and provide a faster territorial diffusion of urbanisation (Benedek, 2006).

Within the 1990–2002 interval, the built-up areas expansion is further reduced to an annual expansion rate of 1.5 ha. However, following the post-communist period, the urban sprawl-related processes, i.e. suburbanization, in the environs of the main cities has been characterised by the spreading of population in the urban-rural interface, triggering built-up areas expansion, mainly at the expense of agricultural and forested lands (Grigorescu *et al.*, 2015). Thus, significant increases were registered in Bucharest (+630 ha) and in some localities in its metropolitan area: Voluntari (+530 ha),

Pantelimon (+220 ha), Otopeni (+180 ha), Snagov (+160 ha), Chiajna (+140 ha), Bragadiru and Popeşti-Leordeni (+130 ha each). Also, significant increases have been recorded in the cities of Galaţi (+190 ha), Ploieşti and Piteşti (+150 ha each), Giurgiu, Buzău and Amara (+130 ha each), Olteniţa (+120 ha) etc.

After 2002, large cities with developing services (e.g. Bucharest), as well as towns with high value-added manufacturing industries (e.g. Piteşti) continued to grow (Benedek, 2006), so as the small towns and rural settlements located under the influence area of large cities or the medium-sized towns with mixed functions. Thus, during the 2002–2016 period, the built-up areas dynamics grown to an annual expansion rate of 1.8 ha, with significant increases registered in Bucharest (+1,310 ha) and its neighbouring localities (e.g. Bragadiru, Pantelimon, Chiajna, Corbeanca, Popeşti-Leordeni, Domneşti, Otopeni, Măgurele, Voluntari with 300–600 ha each), followed by Galaţi (+ 170 ha) and Vâňători (+ 200 ha) in its metropolitan area, Focşani (+ 150 ha), Piteşti (+ 110 ha), Buzău and Slobozia (+ 90 ha each) etc.

Overall, after 1912, the most significant increase of the built-up areas were recorded in Bucharest (+13,310 ha), Galaţi (+3,210 ha), Ploieşti (+1,950 ha), Brăila (+1,800 ha), Voluntari (+ 1,640 ha), Buzău (+1,530 ha), Călăraşti (+1,360 ha) and Piteşti (+1,310 ha). At the opposite side, the lowest increases were registered in the localities Păuneşti (+20 ha), Râca (+23 ha), Malu (+40 ha), Robeasca (+42 ha), Colelia (+44 ha), Gălbinaşti (+62 ha), Bueşti (+ 64 ha), Drăgăneşti de Vede (+65 ha) and in some localities situated at contact of the plain with the hilly or the plateau relief units (Fig. 4).

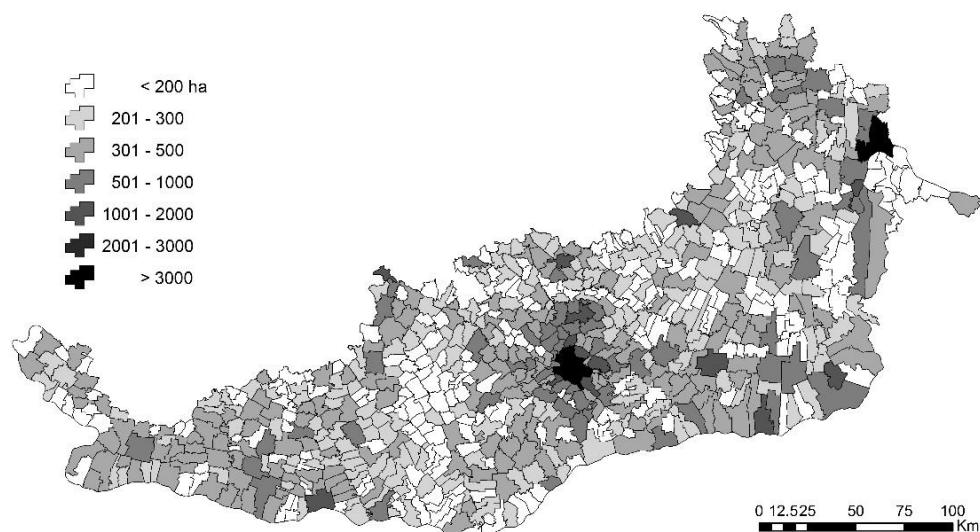


Fig. 4 – Built-up areas expansion in the Romanian Plain after 1912 (LAU2 level).

Within the relief sub-units of the Romanian Plain, the largest built-up areas growth took place in the localities of the Vlăsia Plain (e.g. Bucharest, Voluntari, Otopeni, Pantelimon, Corbeanca, Buftea, Baloteşti), the Prahova Piedmontan Plain (e.g. Ploieşti, Târgovişte, Brazi) and in the Danube Floodplain (especially Galaţi, Brăila, Feteşti, Călăraşti, Turnu Măgurele and Corabia). Significant increases have also been recorded in the localities of Mostiştia Plain (e.g. Dor Mărunt, Dragalina, Perişoru), Romanătă Plain (e.g. Dăbuleni, Amărăştii de Jos, Caracal, Celaru, Daneti), Galaţi Plain (e.g. Matca, Cudalbi, Pechea, Vâňători), and along the Olt (e.g. Rusăneşti, Izbiceni, Tia Mare, Băbiciu), Argeş (e.g. Piteşti, Ştefăneşti, Găeşti, Bradu, Bolintin Vale, Cornetu, 1 Decembrie, Colibaşii), Ialomiţa (e.g. Tăndărei, Slobozia, Urziceni), Bârlad (e.g. Tecuci, Drăgăneşti, Barcea, Umbrăreşti) and Buzău (Buzău) rivers.

The spatial trend of the built-up areas expansion. In order to detect the expansion trend of the built-up areas, the data on the annual expansion rate were interpolated using the global polynomial

function. Thus, according to the data on the annual expansion rate during the entire analyzed period (1912–2016), there is a more evident expansion trend in the Municipality of Bucharest and the neighbouring localities with average values of 4–10 ha/year. A significant trend is also noted close to the municipalities of Galați, Călărași, Oltenița, Tecuci, Pitești, Târgoviște, Calafat and Fetești (Fig. 4).

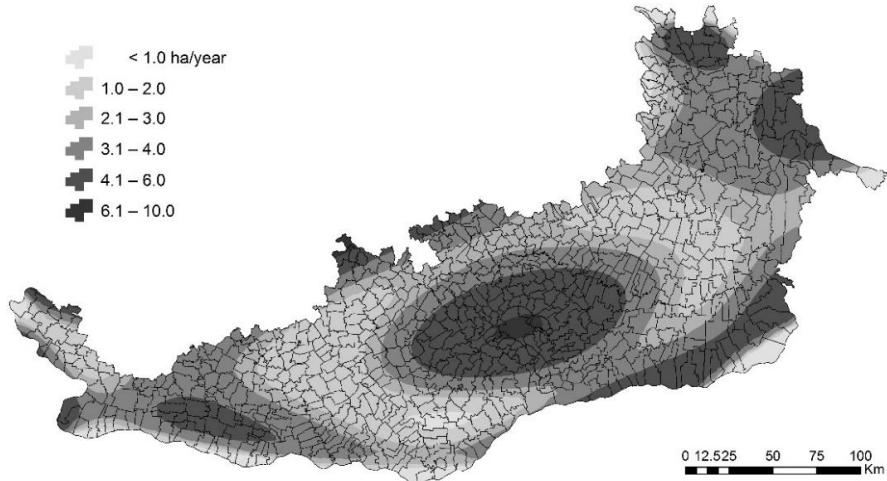


Fig. 5 – The built-up areas expansion trend (1912–2016).

The temporal analysis of the data reveals significant spatial differences in the built-up areas expansion trend between 1912 and 2016 (Fig. 6).

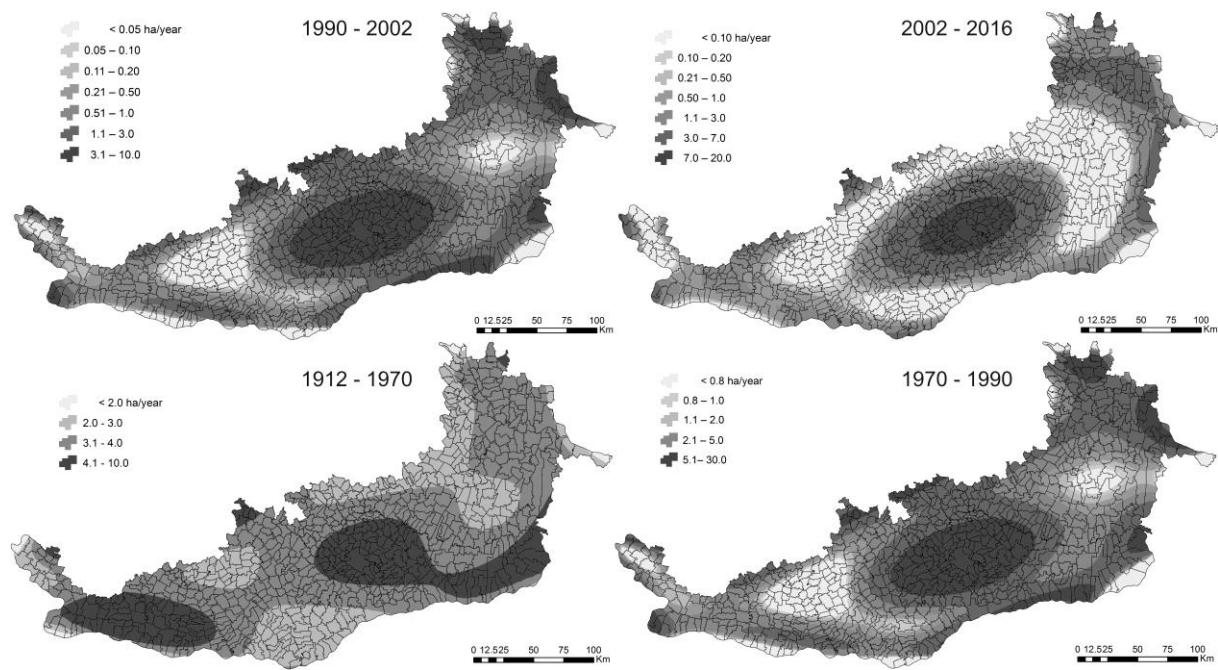


Fig. 6 – The built-up areas expansion trend during the four analysed periods

Thus, between 1912 and 1970, several regions with developing urban growth are starting to emerge in the central, south-eastern and western parts of the Romanian Plain. This trend predicts significant spreading in the settlements located in the Vlăsia Plain, in the south-eastern part of Bărăgan

Plain and Oltenia Plain. Between 1970 and 1990, the trend of growth emerged in the central part of the Romanian Plain, especially in the southern half of the Vlăsia Plain, but also in the Mostiștea, Burnas and Prahova Piedmontan Plains. At the same time, another important nucleus is formed in the north-eastern part of the Romanian Plain, around the towns of Galați and Tecuci.

After 1990 the built-up areas expansion becomes more evident especially in Bucharest and its surrounding localities, with a significant increase after 2002 when the annual expansion rate reaches maximum values. During this period, the nuclei around the cities of Galați and Tecuci become better outlined.

Within the last almost thirty years, the continuous built-up areas expansion trend was mainly triggered by the shifting of most of agricultural related functions to residential, commercial or logistics in some of the settlements located in the urban-rural interface (Grigorescu *et al.*, 2015). Overall, the built-up areas dynamics analysis over the last century in the Romanian Plain highlighted significant spatial and temporal differences in the urban sprawl phenomenon (urbanization and suburbanization) as a result of urban and rural development, but also in relation to the changing the urban-rural relations through time.

5. CONCLUSIONS

The current study is an analysis of the urban sprawl phenomenon in the Romanian Plain over the last one hundred years using an analytical method for cross-examining, comparing and evaluating built-up areas dynamics, the main parameter used for the spatial quantification of urban processes. The main scope was to identify urban transformations and their spatial differences and understand them in relation to the key socio-economic and political changes of the analysed period.

Since the beginning of the 20th century the Romanian Plain was subject to a continuous expansion of the built-up areas, with significant differences both spatially and temporally. In order to pinpoint the spatial differences, a detailed analysis for four time frames (1912–1970, 1970–1990, 1990–2002 and 2002–2016) was performed. Thus, between 1912 and 1970, the total built-up area grew with almost 60%, from over 190,000 ha in 1912 to more than 300,000 ha in 1970 with an average annual expansion rate of 3.8 ha/LAU2. During this interval, extensive urban growth was registered in Bucharest followed by some emerging towns (e.g. Ploiești, Giurgiu, Galați, Brăila) and rural settlements with predominantly agricultural functions (e.g. Suseni, Tătărăști de Jos, Nicorești, Poiana Mare).

Between 1970 and 1990, a slight decrease of the built-up area of nearly 54,000 ha was registered, thus triggering a relatively shrinkage of the average annual expansion rate (3.0 ha/LAU2). This could be largely explained by the spatial transformations caused by the land management works which were carried out especially in the Danube Floodplain, sometimes at the expense of different built-up areas categories. Moreover, this built-up areas drawback was also explained by the restrictive regulations of the communist period regarding urban development. Nevertheless, individually, notable increases were registered in Bucharest, Galați, Buzău, Ploiești, Brăila or in other new industrial towns along the Danube River (e.g. Turnu Măgurele, Zimnicea, Giurgiu, Oltenița, Călărași) or small settlements near Bucharest (e.g. Popești-Leordeni, Otopeni, Pantelimon).

After the fall of communism, the unleashing urban polices explained the increase in the built-up during the 1990–2002 interval (15,500 ha). However, the reduced average annual expansion rate (1.5 ha/LAU2) justifies a higher growth in the localities where urbanization and suburbanization processes were more dynamic. During the last interval (2002–2016), under an overall increase of 26,800 ha and an average annual expansion rate of 1.8 ha, the built-up areas growth was largely registered in Bucharest and some localities from its metropolitan area (e.g. Bragadiru, Pantelimon, Chiajna, Corbeanca, Popești-Leordeni, Domnești, Otopeni, Măgurele, Voluntari), mainly triggered by suburbanisation.

The spatial trend of built-up areas dynamics highlights the general evolution of the urban sprawl phenomenon from the first delineation of areas with urban growth occurrence until 1970, to the more compact growth nuclei which emerged and developed between 1970 and 1990. After 1990 the built-up

areas expansion becomes more obvious in some towns (e.g. Bucharest, Galați, Brăila, Pitești) and the surrounding localities, with a significant increase after 2002 when the annual expansion rate reaches the maximum values.

The results of such study provide detailed spatial information on the urban sprawl phenomenon that might become useful for future planning interventions, as well as identifying planning strategies and projects that will enable urban and regional adaptive development. On the other hand, the already built database on the spatio-temporal build-up areas expansion represents essential information for predicting future urban spatial growth in relation to its explanatory driving factors.

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Image courtesy for the LANDSAT satellite images of U.S. Geological Survey available at: www.usgs.gov.

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