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SPATIAL PROFILE OF THE EVOLUTION OF URBAN SPRAWL PRESSURE ON THE SURROUNDINGS OF ROMANIAN CITIES (2000-2013)

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Abstract: The pressure exerted by towns and cities upon surrounding natural and agricultural environments is an acute problem facing present-day societies due to the serious effects that phenomena such as urban sprawl can have on the ecological balance of the area concerned. One of the ways in which this pressure manifests itself is when part of the urban population settles in areas close to towns, leading to the reduction, fragmentation and destruction of natural ecosystems and agricultural landscapes. The present study pinpoints the existence of certain spatial limits within which changes in land use are caused by the phenomenon of urban sprawl. In addition, the spatial profile of residential pressure for the period 2000-2013 is modelled, as is the spatial profile of the appearance of new artificial surfaces in relation to their distance from the centres of the cities concerned (for the period 2000-2006, using Corine Land Cover data). Finally, results are presented as concerning the absolute and relative losses suffered by areas of agricultural land and natural and semi-natural areas in the proximity of cities of over 200,000 inhabitants.

Key words: Corine land-cover, CLC, land-use change, landscape metrics, urban growth, urban sprawl, peri-urban, post-socialist cities, urban-rural fringe, Romania.

1. INTRODUCTION

The loss of space caused by the expansion of cities is a contemporary problem associated with, inter alia, the reduction of natural habitats (Hepcan et al., 2013), the diminution of biodiversity (Lin & Fuller, 2013; Meffert & Dziock, 2013; Capotorti et al., 2013), the fragmentation of natural landscapes (Park et al., 2014), the increase in the number of kilometres travelled each year by the resident population (Bento et al., 2005), air pollution (Glaeser & Kahn, 2010; Wang et al., 2014) and the destruction of natural resources (Haase & Nuissl, 2007; Haase, 2009). In a word, urban growth can have the effect of undermining the quality and functionality of natural ecosystems (for a summary presentation see Chen et al., 2013; Alberti, 2005). In fact, the 500 most cited studies of the phenomenon of urban sprawl published in the period from 1991 to 2011 demonstrate that urban growth is associated not only with "urban form and development" but especially with issues connected with "Land use/land development" and "environment/ecology/biology" (Zeng et al., 2014). Furthermore, approximately 40% of all studies devoted to urban sprawl originate in the area of "Environmental Sciences and Ecology" (Zeng et al., 2014).

The problem of the spatial extension of cities and the using-up of agricultural land and natural areas has also occupied a central place in European Union policy-making during the past decade, as reflected in the activities of European Environment Agency (EEA). These are justified concerns, since, by contrast with what can be seen in other regions of the world such as the United States, the phenomenon of periurbanisation as experienced in Europe is far more diverse, as it depends to a greater degree on political factors and on the socio-economic history of each country (Zeng et al., 2014).

While recent study trends assign great importance to approaches based on the use of "remote sensing" (Poelmans & Van Rompaey, 2009;

Fichera et al., 2012; Herold et al., 2002; Ward et al., 2000), the present work will confine itself to GIS analysis of Corine Land Cover data, since this has yet to be exploited to its full potential for the study of the phenomenon of urban expansion in Romania.

In this context, our study will present an analysis of the development of the built environment and of demographic pressure in the proximity of cities in Romania, with a view to determining a spatial profile of the pressure cities exert upon their environment. The study of the intensity of the phenomenon of urban sprawl in relation to distance from the city centre, distance from the city limits and distance from major transport arteries is not a new subject; previous approaches of this kind that could be cited include analyses of the spatial evolution of Warsaw (Solon, 2009) and of the metropolitan area to the south of Madrid (Díaz-Palacios-Sisternes et al., 2014).

Throughout this work the term "urban sprawl" will be employed in a broad sense that corresponds to that of the expressions "étalement urbain" in the relevant literature in French and to "dispersión urbana" in Spanish. Another point to be noted is that the phenomenon of periurbanisation will be understood in its role of a distinct step in the evolution of urban systems, occurring after that of sub-urbanisation, from which it differs in being far more diffuse in nature, conducive to urban decentralisation, and capable of contributing to the formation of new satellite towns.

2. STUDY AREA: GEOGRAPHICAL SITUATION, SPECIAL FEATURES, PREVIOUS APPROACHES

Periurbanisation is of the nature of an "innovation" and for this reason conforms to the laws governing the spatial diffusion of new phenomena. It begins at different times and displays different levels of intensity depending on the relative size of the city, its position within the urban system and its degree of demographic and economic development. Since it is a process specific to post-Fordism, periurbanisation appeared once the Romanian economic system took on features resembling those characteristic of this stage in capitalist economies. However, the geographical base upon which it superimposed itself and the economic context in which it manifested itself were and are (1) very unlike the western model and (2) different from one country to another even within the category of ex-communist countries.

After the fall of the communist regime, Romania's urban areas passed through a process of radical transformation at both a structural and a functional level (Banica & Piciorus, 2012). The effects of these transformations showed themselves on the one hand in the spatial behaviour of the population and their manner of inhabiting space and on the other in the territorial dynamics of cities.

The return to private ownership of property and to the market economy, in combination with the absence of strict regulations governing the extension of the built environment, led to a situation of uncontrolled urban sprawl. This spatial extension of cities was characterised by an excessive consumption of agricultural and undeveloped land and a negative impact on the natural environment.

In Romania, the phenomenon of the extension of the built environment is particularly characteristic of large and medium-sized cities and less so of small ones. For this reason we selected for the present study only municipalities that had a population of over 50,000 in the year 2000 – that is, before the explosion of the phenomenon of periurbanisation (Fig. 1).

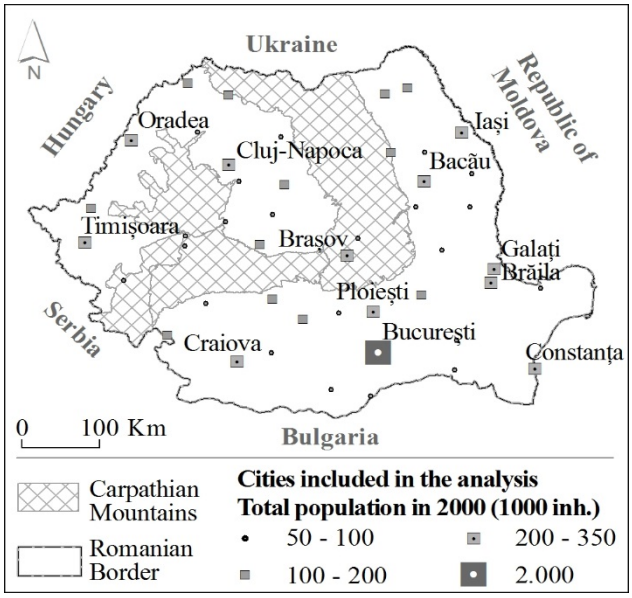

Figure 1. Study area (source: the authors)

Previous discussions of periurban land use in Romania have principally concentrated on grasping the dynamics of the Bucharest metropolitan area: Ioja et al., (2014) on the identification of areas of conflict in land use; Cirnu (2014) on the fractal dimension of the phenomenon of urban sprawl; Cirnu (2013) on residential areas; Zoran et al., (2013) on changes experienced by vegetation. Studies of other cities in Romania have focused on changes to the landscape in the periurban areas of Bacau (Banica & Piciorus, 2012), Iasi (Iatu et al., 2011; Cimpianu & Corodescu, 2013), Cluj-Napoca (Corpade et al., 2014) and Sinaia (Huzui et al., 2012).

There have also been discussions of the process of urban sprawl at a whole-country level, oriented either towards discussing the legal context and what is actually happening at ground level (Suditu, 2012) or towards the sociological or environmental implications of the phenomenon.

Given this context, our study sets out to fill a gap in the specialist literature by determining a spatial model for the evolution of the built environment and of demographic pressure exerted by proximity to urban centres. The research achieved this by analysing two distinct territorial aspects: modifications in land use, and the dynamics of the population as a whole.

3. DATA AND METHODOLOGY

The methodological approach involves the following stages:

3.1 Determining the radius of periurban residential development for different categories of cities

3.1.1 Categories of towns and cities forming part of the study

The first phase of the research was deliberately limited to municipalities with a population of 50,000 or more in the year 2000, since these were the places most apt to be affected by the process of urban sprawl. This figure of 50,000 inhabitants coincides with the new criteria for identifying those "urban centres" in the OECD and the European Union that are most likely to give rise to commuting behaviour. As for the choice of date, this may be explained by the need to take into account the demographic potential of cities at a point at which they had not yet entered the expansive phase of the process of periurbanisation. Cities were divided into four categories depending on their population in 2000: 50,000-100,000 inhabitants, 100,000-200,000 inhabitants, 200,000-350,000 inhabitants, and the special case of the Municipality of Bucharest (Table 1).

3.1.2 Calculating the distance in kilometres between local administrative units and the municipalities they belong to

The first step of this stage involved calculating the road distance in kilometres between each of Romania's 13,618 localities (villages and small towns) and the nearest town/city with a population of over 50,000. As each local administrative unit comprises one or more localities, the second step consisted in extracting a single value for each of the 2,951 local administrative units that existed in 1999 (the LAU2s). This was achieved by using the minimum value as a starting-point: the distance given between each LAU2 and the nearest city represents in fact the distance that separates the nearest-to-the-city locality in that LAU2 from the city concerned (this compromise was unavoidable because of the unavailability of locality-by-locality data – figure 2).

The statistical data employed (total population per local administrative area, total number of dwellings, and number of dwellings completed per year for the years 1990-2013) come from the National Institute of Statistics, while the spatial data (local administrative divisions, network of localities) are as supplied by the National Land and Buildings Information Registry (ANCPI, 2012).

Tabel 1: The 43 urban centres covered by the study

Population category	No of cities	Names of cities
50.000 – 100.000 inh.	20	Alba Iulia, Alexandria, Barlad, Bistrita, Calarasi, Deva, Focsani, Giurgiu, Hunedoara, Medias, Onesti, Resita, Roman, Slatina, Slobozia, Targoviste, Targu Jiu, Tulcea, Vaslui, Zalau.
100.000 – 200.000 inh.	11	Baia Mare, Botosani, Buzau, Drobeta-Turnu Severin, Piatra-Neamt, Pitesti, Ramnicu Valcea, Satu Mare, Sibiu, Suceava, Targu Mures.
200.000 – 350.000 inh.	11	Bacau, Brasov, Braila, Cluj-Napoca, Constanta, Craiova, Galati, Iasi, Oradea, Ploiesti, Timisoara.
> 350.000	1	Bucarest

Once achieved, this process was repeated for each of the four categories of cities. When cities belonging to different categories were lying less than 40 km apart, the smaller city was excluded from the study in order to avoid having to take account of the influence of the higher-population-category city on periurban rural administrative areas belonging to the lower-population-category city.

3.1.3. Obtaining developmental indicators characteristic of each periurban fringe

Once the distance between each rural administrative area and the city generating periurbanisation was known, the next step was to collate the data for sets of rural administrative areas defined in terms of their distance from the city centre. Periurban fringes were defined in 2 km rings for cities with fewer than 350,000 inhabitants (6-8, 8-10, …, 28-30) and in 3 km rings for rural administrative areas around Bucharest (6-9, 9-12, …, 48-51).

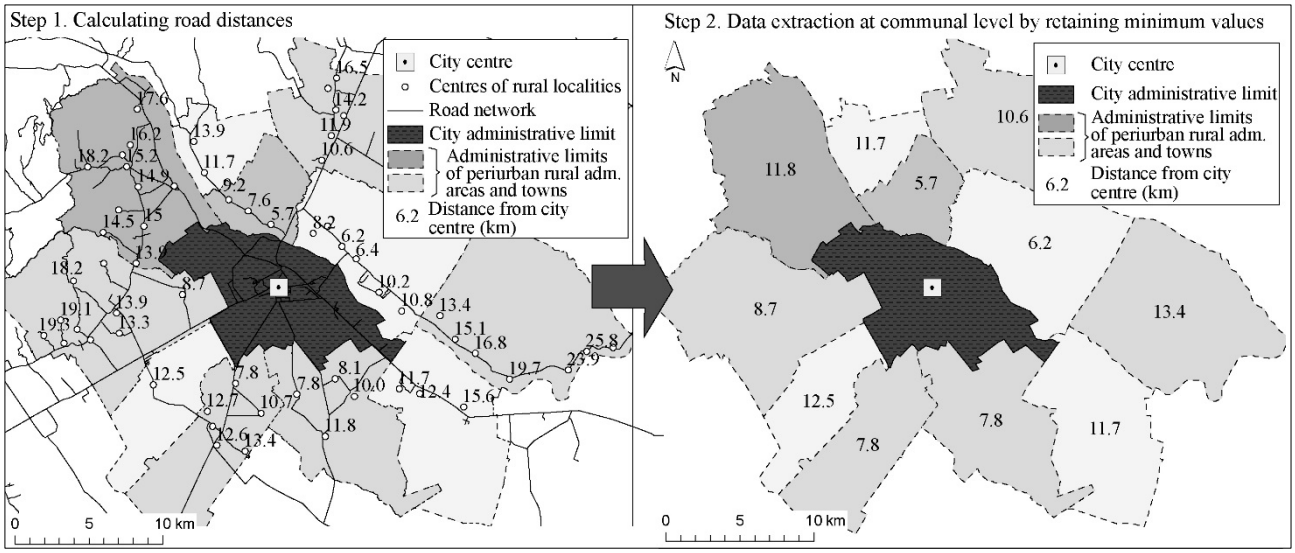

Figure 2. Calculating distances between rural administrative areas and cities

For each of these rings, changes in population numbers and in the number of dwellings completed were calculated for the periods 2000-2008 and 2008-2013. The process was repeated for each category of cities (see results in Table 2).

Table 2. Radius of occurrence of the phenomenon of urban sprawl in the period 2000-2013 (source: the authors)

Category of city (inhabitants)	Radius of occurrence (km as measured from the city centre)	
	2000-2008	2009-2013
50.000 – 100.000	10	6
100.000 – 200.000	16	15
200.000 – 350.000	20	18
Bucuresti	27	30

3.1.4. Graphical representation and modelling of results

This stage involved the graphical representation in diagram form of the spatial profile of periurban areas, based on the values characteristic of each periurban fringe. When presenting a spatial model of the Bucharest periurban area (Fig. 4), the method employed was to construct a classic diagram using population growth figures for each successive 3km periurban fringe ring (this was modelled by using three polynomial functions, the aim being to complete).

Alongside its advantages (it takes account of which local administrative area newly constructed dwellings come under; it makes it possible to build up a model of the spatial profile of urban growth), this methodology does also present a number of risks. The non-availability of geo-localised databases covering newly constructed dwellings and even of centralised data for each locality made it necessary for research to be limited to local administrative unit (LAU2) level, which involved compromises (i.e. generalisations, as described in steps 3.1.2. and 3.1.3. above) when correlating demographic and housing stock change with distance from city centres. The study did not take account of periurbanisation that has taken place outside the morphological limits of each city but still within its administrative limits – a widespread occurrence. However, from this point of view, the deficiency will be made good via analysis of the development of artificial surfaces in relation to distance from the city centre, irrespective of the administrative area to which the newly-formed plots of land belong.

3.2. Determining changes in land use

In this step the previously-determined limits within which the process of residential periurbanisation takes place will be used as spatial limits when defining which areas should be selected for a study of developments in land use. These developments will be determined by looking at changes that occurred in the period 2000-2006.

The model followed here is that proposed by Díaz-Palacios-Sisternes et al., (2014), who studied changes in periurban land use to the south of Madrid and distinguished between three types of processes: urbanisation (when natural or agricultural land becomes part of the built environment/built-on surfaces), renaturalisation (when built-on or agricultural land reverts to a wild/natural state) and agrarianisation (when new areas are exploited for agricultural purposes). The authors split the zone of occurrence of these three processes into nine concentric 10 km wide buffers by using the criterion

of distance from the outer limits of the city.

In our case it is only the first of these three phenomena that was looked at, our goal being to determine a spatial profile of the development of built-on land, in concentric 1 km wide buffers around each city that had a population of over 200,000 in 2000. The data used are represented by Corine Land Cover sets belonging to the years 2000 and 2006, with a resolution of 100m.

Distances from each plot of land to the city centre were calculated in kilometres along routes forming part of the major communication networks – rural administrative area, county, national and European roads (this was done by making use of the Network Analyst extension of ArcGIS 10.2.2). In the case of plots not lying directly on a road belonging to one of the above-mentioned categories, the distance from the closest point on the network to the plot concerned was calculated. To the figure thus obtained was added the straight-line distance between the plot and the nearest road in the network.

4. RESULTS AND DISCUSSIONS

4.1. Spatial limits of residential pressure

Among the factors that have driven cities to spill over into neighbouring natural and agricultural environments, that of residential needs holds prime place. Demographic pressure has expressed itself in differentiated ways in relation to spatial profile. Without entering into an analysis of the complex causes underlying these processes, the present study has cast light upon the morphological features of this expression, more precisely the spatial limits of its expression.

In the case of municipalities with a population of over 200,000, urban sprawl displays different degrees of intensity as a function of distance from the city, with three distinct zones being distinguishable (Fig. 3): (1) a zone of relatively intense periurbanisation within the 8 km isoaccessibility perimeter of the city centre, (2) a zone of diffuse periurbanisation within the 14 km isoaccessibility perimeter, generally seen along the major communication arteries and (3) a zone of sporadic periurbanisation lying outside this limit, also to be found along the main roads but only in certain special cases (extremely busy communication arteries, beauty spots).

Municipalities with a population of between 100,000 and 200,000 also display three steps of periurbanisation, but with much lower levels of intensity and with more restricted spatial extension. Thus, the rural administrative areas closest to the city (less than 8 km from the centre) experience a 20% increase in population, an intensity that matches that of the second zone of periurbanisation around cities that function as hubs for their regions (Fig. 3).

Beyond this distance, the phenomenon of periurbanisation occurs in a sporadic way, somewhat more densely in the first 12 km (with an average population increase of 10%) and more as an exception for rural administrative areas located further away. However, in relative terms, this second category of urban centres may be regarded as that most powerfully affected by periurbanisation, since the loss of urban population has not been fully compensated for by inward migration, as has happened in the case of a number of the cities belonging to the first category (for example, Cluj-Napoca). Thus, on average, cities in this category lose a fifth of their population (caused both by periurbanisation and by emigration), while the population of municipalities with over 200,000 inhabitants declines by "only" 10%.

For municipalities with populations of below 100,000, periurbanisation is a patchy phenomenon that normally only affects some of the rural administrative areas located in the immediate vicinity of the city (Fig. 3). Nevertheless, this category of cities was the one most affected by the 2008 financial crisis, with the dynamic of periurbanisation shrinking (on average) from a radius of 10 km from the city centre in 2000-2008 to only 6 km in the period following the crisis.

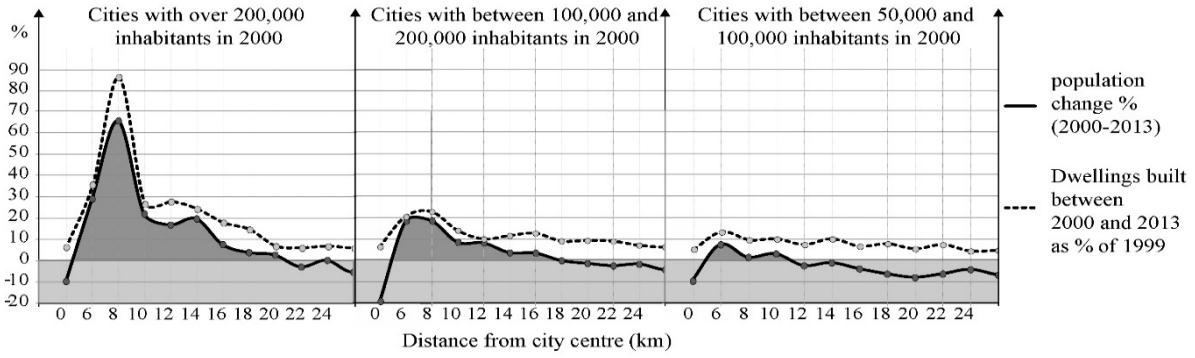

Figure 3. Spatial profile of residential periurban area by category of city (source: the authors)

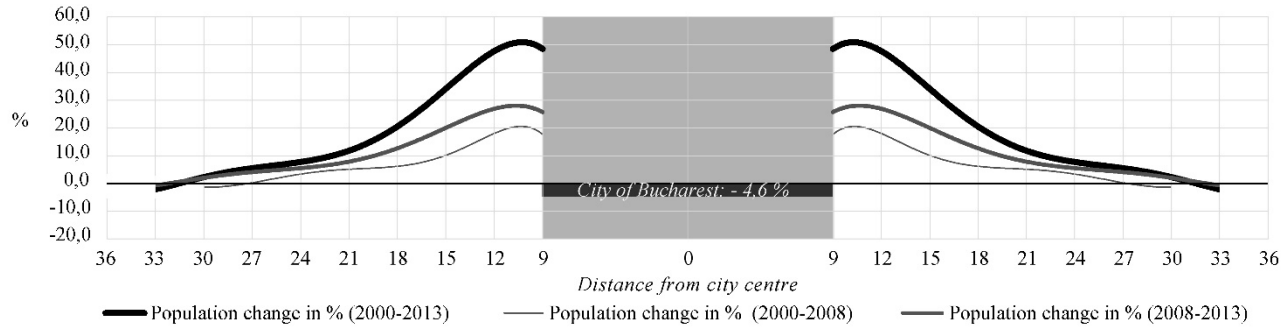

Figure 4. Spatial profile of the Bucharest periurban residential area (source: the authors)

By contrast with the other categories of cities, whose periurban area displays positive demographic dynamics over a range that has been declining since 2008, the Municipality of Bucharest has been experiencing a spatial extension of this zone, which appears to be reaching (for the first time) a further limit of 30 km (Fig. 4).

Although the distances involved are becoming greater and greater, most of the people migrating out of the city are not moving beyond an annulus bounded by the 10 km isoaccessibility line as measured from the city limits (18-20 km from the city centre) – a practice that has been shown to be the case for some other Eastern European capital cities as well (see e.g. Kährik & Tammaru, 2008, for Tallinn). In addition, Tallinn's process of periurbanisation occurred exponentially over a period of time, with the majority of the buildings started in 1996-2005 being completed in 2004-2005 (Kährik & Tammaru, 2008), exactly as happened in the case of the Municipality of Bucharest.

As the results obtained for the whole period under study show, periurbanisation is characterised by a sharper rise in the number of homes in periurban rural administrative areas when compared with the rise in population there (Fig. 3). What is somewhat surprising is the fact that this phenomenon is particularly typical of the post-crisis period (2008-2013).

Although affected by the 2008 financial crisis, periurbanisation is still an ongoing phenomenon, which means that it is imperative that land improvement planning should take account of it – and not only when large cities are concerned but also when dealing with those of medium size. It raises multiple issues that are specific both to the phenomenon in itself and to the territorial, socio-economic and environmental context in which it occurs.

For the particular situation of cities in Romania, researchers have highlighted the way their locally administered facilities and services and infrastructure quality have lagged behind the spread of new residential neighbourhoods, the problems involved in adapting public transport systems to the new directions in which the city is growing (Iatu et al., 2011, for the Municipality of Iasi), the challenges posed by changes in land use, the way the population may become segregated according to socio-economic criteria, and so on.

Periurbanisation presupposes a transfer of population from urban centres to the adjacent rural environment, the process being accompanied by a transformation in domestic living conditions and facilities in the host areas. Although in statistical terms this process has contributed to an improvement in the human capital of the Romanian rural environment, the situation on the ground is that periurbanisation has taken the form of the creation of residential enclaves, with people becoming isolated both from the village as a naturally welcoming environment and from the city from which they had moved out and become estranged (Badescu, 2011).

In Romania viewed as a whole, the process of periurbanisation has entered a phase of (temporary?) stagnation in the lengthening of its radius of expression – with a number of exceptions, Bucharest among them – but has not diminished in intensity; in terms of new building, cities are continuing to expand more rapidly in their periurban areas than within their own administrative limits (Fig. 5).

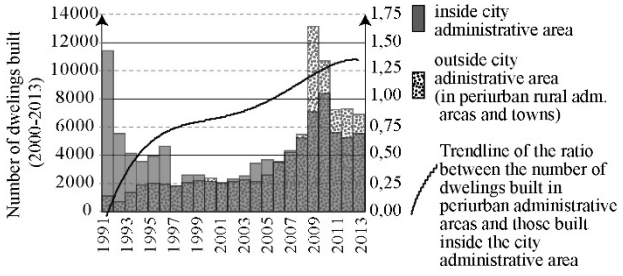

Figure 5. Changes in the relationship between the number of homes completed in urban centres and those in periurban rural administrative areas, for cities with between 200,000 and 350,000 inh. (source: the authors)

Furthermore, certain Romanian cities (the capital, and a number of the more dynamic regional centres) are showing the first signs of a shift to urban explosion. This involves a move from periurban areas that are relatively poorly supplied with infrastructure and have secondary or tertiary economic activities to far more complex areas, given shape by major communication arteries, along which appear settlements that resemble new towns in which a residential function is found in combination with economic activities that spring from the internal dynamics of the urban centre. One example of such a settlement (in formation) would be the rural administration area of Floresti near Cluj, whose population grew from 7,000 in 2003 to 22,000 in 2013 and whose local economic turnover raised from 97 million RON to over 700 million RON between 2003 and 2011, in parallel with a growth in the number of CAEN categories in which this population was involved from 3 to 16.

The dynamics of cities in Romania are showing signs of a move in the direction of the Western model of periurbanisation. The fall in city populations and the corresponding demographic growth taking place in neighbouring rural administrative areas may be regarded as symptoms of the beginning of a shift "from urban centres to urban craters" (Borsdorf, 2012) that cities in the West have already experienced.

4.2. Spatial limits of the growth of paved areas/artificial surfaces in the proximity of cities

By contrast with demographic indices, those relating to land use have the advantage of giving a more detailed picture of "what is actually happening on the ground", since changes to the landscape may be the result of processes that are far more diverse than the simple migration of citydwellers to periurban areas (the appearance of new shopping centres, industrial sites, recreational facilities, transport infrastructure systems etc.).

Despite the low resolution of the Corine Land Cover data, a study of the differences observable between 2000 and 2006, correlated with distances from the benchmark cities, gives a first impression of the magnitude and spatial profile of the pressure that the urban exerts upon natural and agricultural environments.

The results obtained for the spatial profile of the growth of the built environment around cities (Figures 6, 7 and 8) supplement the results of previous research studies which, employing the same sets of Corine Land Cover data, had demonstrated that the transformation of land into artificial areas as a consequence of urbanisation is second only to deforestation in its importance as a category of change taking place in Romania (Popovici et al., 2013).

The results of the present study show that changes in land use, in the sense of its shifting to the category of "artificial areas", were observable for all cities with populations above 200,000. However, the intensity and magnitude of the growth of the phenomenon in terms of spatial profile displays significant variations from one city to another, even in the case of urban centres of identical size and with a similar range of functions (Fig. 7).

Thus cities such as Cluj-Napoca and Constanta generated a more compact growth of artificial surfaces, which cluster within the 8 or 10 km nearest to the city centre.

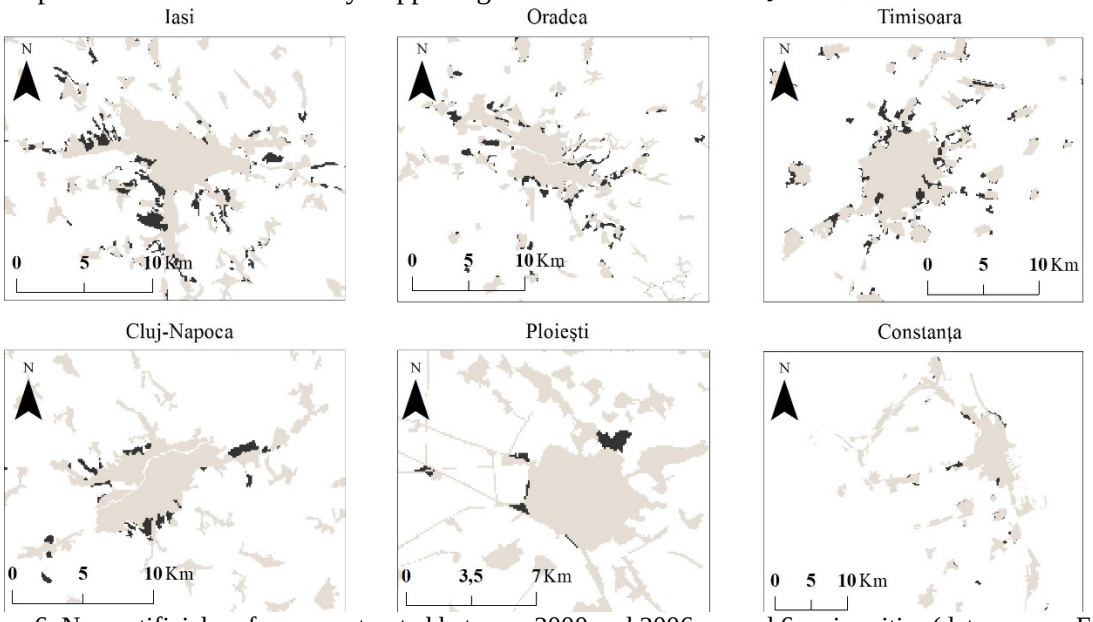

Figure 6. New artificial surfaces constructed between 2000 and 2006 around 6 major cities (data source: EEA)

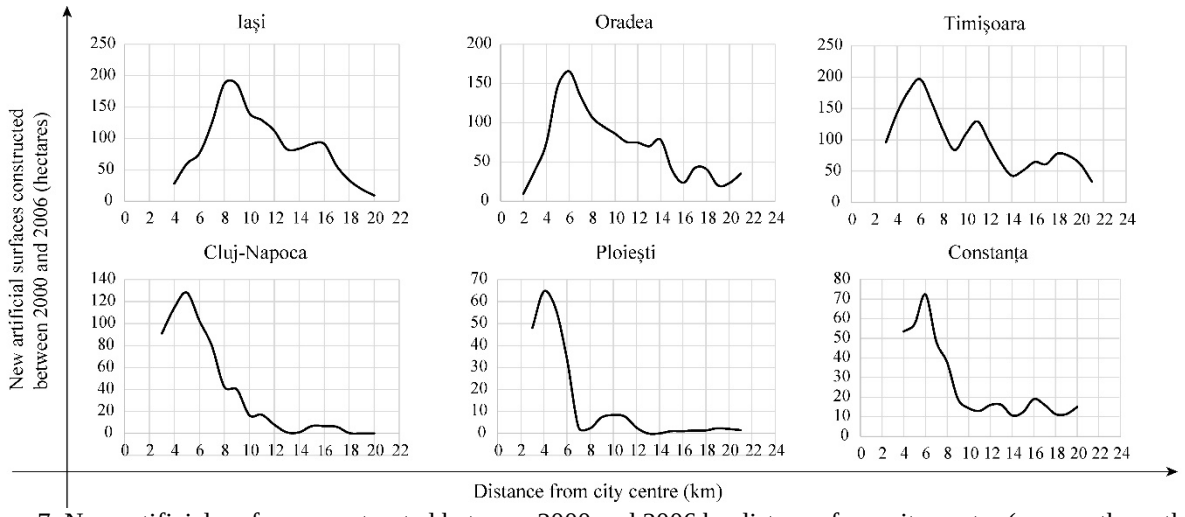

Figure 7. New artificial surfaces constructed between 2000 and 2006 by distance from city centre (source: the authors)

At the opposite end of the scale are municipalities that display a higher degree of urban diffusion, where extensions of the city include between them huge areas of agricultural land and land covered with natural vegetation. This is the case for cities such as Iasi and Oradea, where the radius of extension of new areas is much longer – up to 16 km.

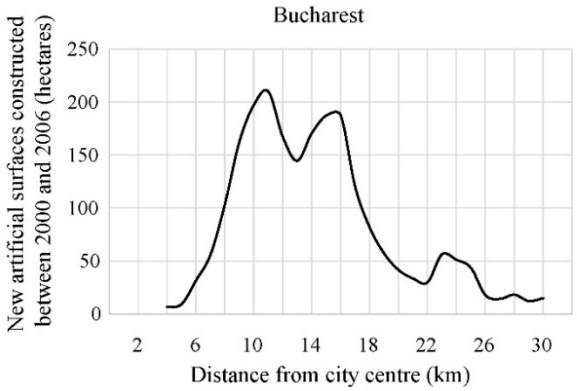

Figure 8. Spatial profile of urban pressure around Bucharest

In the case of Bucharest, the greatest intensity of appearance of new paved areas is to be seen in zones situated between 8 km and 18 km from the city centre (Fig. 8). Beyond this line, there are a lower number of new artificial areas up to a limit of 26 km from the centre, point beyond which one may state that the phenomenon disappears.

If we now bring together the changes observed in land use during the 2000-2006 time window (Table 3), we find that the areas most affected by urbanisation were natural and partially natural ecosystems (excluding forests). In the neighbourhood of cities with populations of over 200,000, the area of such land use fell by over 3,600 hectares from this cause alone. Agricultural land was likewise very much affected, with a drop in surface area of almost 2,800 hectares. These results are in line with the trend identified in previous case studies and with studies carried out on the metropolitan zones of Iasi, Constanta and Oradea (Grigorescu et al., 2013).

Tabel 3. Changes in land use within a 30 km radius around Bucharest and a 20 km radius around other cities with over 200,000 inhabitants (source: the authors)

land use category	**change 2000-2006**	
	ha	***%***
artificial areas	+ 4.578	+ 2,70
agricultural land	- 2.788	- 0,28
natural vegetation - woodland	+ 1.563	+ 0,65
other areas of natural or partially natural vegetation	- 3.622	- 17,66
rivers, lakes and wetlands	+ 276	+ 0,64

5. CONCLUSIONS

The present work has identified the spatial limits within which four categories of cities in Romania exert an increased degree of pressure on the environment via processes of urban sprawl. On the basis of statistical data regarding population change in periurban rural administrative areas the conclusion has been reached that the radius within which this pressure is felt is as much as 30 km in the case of Bucharest but does not exceed 20 km for cities with 200,000 inhabitants, 16 km for those with a population of between 100,000 and 200,000 and 10 km for the 50,000 to 100,000 inhabitants category (distances being calculated from the centre of urban areas).

Changes observed in the extent of artificial areas in the proximity of cities confirms the fact that

urban sprawl is confined within these limits, but with major differences between one city and another. In addition, again by analysing the Corine Land Cover data for 2000 and 2006, it has become clear that in areas close to cities, the changes seen in land use have principally affected natural/partially natural zones and agricultural land, which together have lost approximately 6,400 hectares to new built-up areas alone, while forested areas have grown by approximately 1,500 hectares.

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