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Evaluating the land use patterns of medium-sized Hellenic cities

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Land use morphology has profound effects both on city functions and peri-urban areas. They can either lead to conflicts with negative side effects or generate positive synergies. This study focuses on land use spatial configurations and interprets the interactions among them. In order to evaluate spatial planning policies, the measurement of urban land use patterns is considered to play an important role in the urban development process and deserves further attention. A comparative analysis of the land use patterns of the medium-sized Hellenic cities is attempted, there are also used using pre-existing metrics, some new data from the European Environment Agency Urban Atlas 2006 geodataset and population and construction census data concerning the last decade from the national Hellenic Statistical Authority data set. The Larger Urban Zones of the medium-sized Hellenic cities are chosen as a suitable study level based both on population size and socio-spatial procedures. The results provide interesting information about the diversification among medium-sized cities, while some particularities concerning urban procedures appear to emerge for some of them. Many discussion points arise from this study concerning the data availability, the method, the functional city area delineation and the Larger Urban Zones definition.

Keywords: land use; spatial metrics; European Urban Atlas; Large Urban Zones; Hellenic cities

1. Introduction

Land use mix is a critical issue of the city function as a whole. Two opposite cases are theoretically possible. On the one hand, cities with functional specialization stand, often as a result of zoning. On the other hand, cities that have emerged from spontaneous procedures, driven principally by *self-promoted strategies*. The Hellenic cities development mode is a typical example of the second case, in contrast with the common post-war western European cities. The loose spatial planning framework in Greece, combined with the predominant self-promoted housing development, has established an ad hoc urban expansion mode. In other words, cities have been developed without – or with partial respect to – the spatial planning framework. The way city growth took place amplifies the urban sprawl in an excessive way (Chorianopoulos et al. 2014, 2010; Leontidou et al. 2007; Economou 2004).

Historical, political and economical reasons interpret the Hellenic particularity according to the cities' development mode. The urban areas expansion, already by the beginning of the twentieth century, differs substantially from the typical European city (Karidis 2006; Giannakourou 2005a, 2005b; Economou 2004). The urbanization process has not

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been the result of the industrialization, and the Hellenic cities never confronted the important problems caused by industrial hyper-concentration and functional hyper-specialization as has been the case for many European cities (Karidis 2006).

In this context, the need for planning does not appear with the imperative way that happened in other European cities. The limited planning framework, which was gradually established with a significant lag, led so that common practices were not adopted. More specifically, (a) Large-scale urban regeneration projects never took place, although that was a usual practice for many European cities already from the middle of the nineteenth century. On the one hand, the regeneration projects of the period focus on solutions to the urban lack of transport infrastructure, the sanitation problems and the lack of public spaces caused by the intensive urbanization and, on the other hand, the projects focus on ensuring a better position for the city within the context of the international cities competition.

(b) Large-scale public housing projects (social housing) appropriate to provide low-cost public housing were never integrated (or they took place in an extremely limited way) in the Hellenic spatial planning policy. In central and north European countries, low-cost public housing projects were incorporated as a principal dimension in cities development. The council housing in UK, suburbs with 'habitation à loyer modéré' in France, extensive municipal public housing projects in German cities, etc. are typical examples.

(c) The increase in housing demand and the urban expansion during the 1970s did not drive to new cities development projects, on the contrary, the residential demand was covered by uncontrolled expansion in peri-urban areas and mostly located: (1) in littoral and forest areas; (2) in peri-urban agricultural zones, including grazing lands and (3) along roads. Urban sprawl had been strengthened as an effect of the residential area production process in the 1990s culminating in the Olympic games period (2004). Although urban sprawl is not exclusively a Greek practice, it took excessive character (Salvati, Sateriano, and Bajocco 2013). It had negative effects not only due to its volume but mostly due to the receptor areas character (Sayas 2006). In European countries, during the same period, a completely different approach was adopted. Many new city development projects took place. Cergy-Pontoise, Marne la Vallée, Melun-Sénart, Évry, St. Quentin en Yvelines in proximity with Paris are characteristic examples for the new cities development projects of the period.

In Greece, the dominant mode of residential areas construction was realized with two principal mechanisms that developed a particular and complementary relationship (Karidis 2006). The first mechanism concerns the housing construction out of the 'urban plan zone', in rural areas. This housing mode is very often followed by partially or completely non-legal practices (despite the loose institutional framework for building in such areas). In these activities, the state for political reasons (clientelism linked to the residential areas development) reacted with great tolerance, complicity in cases. These 'hybrid' areas (rural areas with intensive urban functions) were 'nominated' urban areas by the ex post application of the Urban Plan. The second mechanism concerns the building construction within the 'urban plan zone'; in this case, a peculiar practice called '*antiparochi*' (very limited practice in European cities) is the dominant mode.

The '*antiparochi'* is an economical contract between a proprietor of a land plot and a construction enterprise. The proprietor acquires a number of apartments (percentage of the total constructed apartments) by transferring its property to the enterprise for building a block of flats. The rest of the apartments are sold by the construction enterprise so as to provide the construction capital and the enterprise profit. This practice is considered the principal mode of housing construction as it was proved very successful in Greece because of two particularities. First, the small-size properties characterized of important ownership fragmentation and second, the political choice of the state to amplify this kind of housing construction by adopting favourable legislative end economical regulations.

Many are the side effects of adopting this peculiar residential areas development mode. (1) The mainstream practices in housing construction established the building autonomy towards the urban tissue development. The housing areas developed by ad hoc procedures are the triumph of the spatial 'individualization' over any collective property. Within this context, land use conflicts and land speculation phenomena are frequent. (2) Commonly residential zones are very poor in social and technical infrastructures as well as in public open and green spaces. (3) Political clientelism is maintained and reinforced, mostly at local level, and land plots speculation practices are flourishing. It is important to notice here, that apart from significant handicaps, describing the residential area development mode, in cases positive issues appear. The loose land use planning system has allowed activities (retail, café, restoration, small companies, etc) to locate themselves almost spontaneously. In this way, functional enrichment is established and lively neighbourhoods are shaped instead of monotonous areas, which are usually an outcome of functional hyper-specialization and over-segregation (Karidis 1996).

The principal objective of the study is to quantify principal characteristics of the land use patterns. They are considered as the 'foot print' of the peculiar and probably unique transitory that the Hellenic cities development mode follows. The ability to quantify land use patterns composition and spatial configuration in order to evaluate urban and regional planning policies is indisputably considered as an important purpose. For Hellenic cities, there are no studies that interpret this issue by adopting similar methodology. Besides, EU has also acknowledged the negative impacts of sprawl on the European territory (EEA 2006). Towards this direction, many frameworks were established concerning the measurement of urban compactness (Burton 2000, 2002; Stathakis and Tsilimigkas 2015) and urban sprawl (Kasanko et al. 2006) in European cities, as well as the application of spatial metrics for the identification of urban patterns in general (Herold, Couclelis, and Clarke 2005).

However, this has been a difficult task until recently due to the lack of data regarding land use. Even when the data were available, the methodologies of their production varied significantly thus obstructing any effort to make comparisons among cities (Kasanko et al. 2006, Prastacos, Chrysoulakis, and Kochilakis 2012). This situation was significantly reversed in 2009 when the European Environmental Agency (EEA) through the Global Monitoring for Environment and Security (GMES) program released the Urban Atlas the first European data set concerning land uses. The Urban Atlas was introduced to provide comparative spatial data to support the decision-making processes affecting urban planning (EEA 2013; EC 2011).

Taking into consideration methodologies presented in respective literature along with the particularities that characterize medium-sized Hellenic cities development mode, this paper focuses on quantifying land use pattern composition and spatial configuration of the Larger Urban Zones (LUZ). The main hypothesis adopted is that land use pattern spatial configuration has a significant impact both on cities and on their functional peri-urban areas. It can lead through synergies to a higher complexity level of socio-spatial structure or through conflicts to disturbances of the total functional integrity. In the selection of the sample, special attention is paid to the homogeneity of the socio-spatial profile of the cities for reasons of comparability and meaningful interpretation. This homogeneity is adequately depicted on a number of plain variables (population size, population density, construction processes, urban expansion mode, etc.).

Quantification of land use pattern morphology and spatial configuration can provide information on critical issues in understanding LUZ functions. The study of spatial heterogeneity shaped on the land use structure geometry facilitates a meaningful interpretation of socio-spatial systems. It is considered that in this way it contributes to predicting issues that have to do with the city development as well as the prevention of dangers and threats. To illustrate the argument, the peri-urban wild fires are a good example. They are a common threat in the Mediterranean space and, more particularly, in Greece. The importance of the phenomenon and its frequency is closely correlated to the land use typologies and its spatial distribution (Tsilimigkas and Gourgiotis 2013). The study of the land use pattern morphology and spatial configuration can provide zones with higher potentiality for wildfire events manifestation.

The paper is organized in three parts. The first one delineates materials and methods. More specifically, it includes the required clarification concerning the geospatial data sets used, the analysis methods chosen and the case study area definition. The second part presents the results; that is, general and specific observations concerning the LUZs quantitative outcomes of the land use patterns spatial configuration. In the third part, discussion points out the cities and their functional area delimitation and the LUZ characteristics that emerge. Finally, the conclusions underline the importance of land use quantitative measurement on city and on peri-urban areas interpretation.

2. Materials and methods

2.1 Data and major land use categories definition

Two data sets are used in this study. The geospatial data set is provided by the European Environment Agency from the Urban Atlas project for the period 2005–2007, while the statistical data is obtained from the Hellenic Statistical Authority for the period 2001–2011. The European Urban Atlas is part of the local component of the GMES/Copernicus land monitoring services. The data are suitable for 1/10.000 scale, with a minimum mapping unit of 0.25 ha (EEA 2011). The land use data are produced by high-resolution satellite images in combination with locally available topographic and land use maps (EEA 2013; EC 2011). Urban Atlas is chosen because it provides suitable information on the research question and because more efficient data sets at national level do not exist.

Since Urban Audit II, urban entities that have been defined as ‘cities’ may correspond to three available representations: (1) the Core Cities generally fit with the eponymous central at LAU2 level, (2) the sub-city that consists in a subdivision of the city according to population criteria and (3) LUZs (ESPON 2013). As a suitable spatial representation according to the study question, LUZ is chosen. It is representing the city and its surroundings. LUZ delineation follows the administrative boundaries that approximate the functional urban area, means the area around the core of the city, actually defined by the percentage of everyday commuters and differs from country to country (European Urban Audit 2012, EC 2011). In other words, LUZ is the city and the *functional urban region* means an area defined by a ‘…significant share of the resident commute into the city…. To ensure a good data availability, the Urban Audit works with administrative boundaries that approximate the functional urban region’ (ESPON 2013) .

The corresponding statistical European data set would be the Urban Audit. The Urban Audit was launched by Eurostat in 2004 in order to provide comparable city statistics. More than 300 variables of demographic, economic and social aspects are collected by member states every 3 years. Even though population data derived by the Urban Audit project have advantages for compatibility reasons (same reference zone, common methodological approach at European level means pan-European comparative analysis is permitted), we chose the population data of the Hellenic Statistical Authority census of the last decade (2001–2011). Unfortunately, the Urban Audit contains significant inaccuracies as far as population data are concerned. Therefore, national data have to be used to eliminate the statistical error. Census data have to be processed to correspond to the spatial units the Urban Atlas.

The second chapter issue concern major land use categories definition. The 20 land use classes of the Urban Atlas 2006 are far too detailed for the scope of this paper. Thus, grouping in five major categories is suitable for the proposed analysis (Table 1). These groups are: (1) High Density Urban Fabric composed of *Continuous Urban Fabric* (11,100; S.L. > 80%), *Discontinuous Dense Urban Fabric* (11210; S.L.: 50–80%) and *Discontinuous Medium Density Urban Fabric* (11220; S.L.: 30–50%). The average degree of Soil Sealing (S.L.) is the principal criterion to define classes. Empirically, it is considered that areas with S.L. up to 30% are principally described by their dense urban

Table 1. Urban Atlas land uses classes grouped in major categories.

Classes	Land use	Land use %	Major categories
11,100	Continuous Urban Fabric (S.L. > 80%)	0.69%	High Density Urban Fabric
11210	Discontinuous Dense Urban Fabric (S.L. 50%–80%)	1.20%	High Density Urban Fabric
11220	Discontinuous Medium Density Urban Fabric (S.L. 30%–50%)	0.82%	High Density Urban Fabric
11230	Discontinuous Low Density Urban Fabric (S.L. 10%–30%)	0.46%	Low Density Urban Fabric
11240	Discontinuous Very Low Density Urban Fabric (S.L. < 10%)	0.08%	Low Density Urban Fabric
11300	Isolated structures	0.31%	Low Density Urban Fabric
12100	Industrial, commercial, public, military and private units	1.66%	Low Density Urban Fabric
12210	Fast transit roads and associated land	0.12%	Infrastructures
12220	Other roads and associated land	1.79%	Infrastructures
12230	Railways and associated land	0.06%	Infrastructures
12300	Port areas	0.02%	Infrastructures
12400	Airports	0.22%	Infrastructures
13100	Mineral extraction and dump sites	0.40%	Work site
13300	Construction sites	0.12%	Work site
13400	Land without current use	0.09%	Work site
14100	Green urban areas	0.12%	Non-urban and open space
14200	Sports and leisure facilities	0.12%	Non-urban and open space
20000	Agricultural areas, semi-natural areas and wetlands	77.74%	Non-urban and open space
30000	Forests	13.21%	Non-urban and open space
50000	Water	0.77%	Non-urban and open space

Source: European Environment Agency 2011; GMES Urban Atlas 2006.

character. This category refers to 138.26 km^2 (2.71%) of the total studied LUZs. (2) Low Density Urban Fabric is composed of *Discontinuous Low Density Urban Fabric* (11230; S.L.: 10–30%), *Discontinuous Very Low Density Urban Fabric* (11240; S.L. < 10%), *Isolated Structures* (11300) and *Industrial, commercial, public, military and private units* (12100). These areas are dominated by their 'hybrid character' combining patchworks of residential and/or industrial clusters in rural areas. This class covers 127.75 km^2 (2.51%) of the total studied LUZs. (3) Infrastructures are composed of *Fast transit roads and associated land* (12210), *Other roads and associated land* (12220), *Railways and associated land* (12230), *Port areas* (12300) and *Airports* (12400). It covers 112.67 km^2 (2.21%) of the total studied LUZs. (4) Work site is composed of *Mineral extraction and dump sites* (13100), *Construction sites* (13300) and *Land without current use* (13400). It concerns 30.97 km^2 (0.61%) of the total studied LUZs. (5) Non-urban and open space is composed of *Green urban areas* (14,100), *Sports and leisure facilities* (14,200), *Agricultural & Semi-natural areas & Wetlands* (20000), *Forests* (30000), *Wetlands* (40000) and *Water bodies* (50000). In fact, this is the predominant category covering 4,687.55 km^2 (91.96%) of the total studied LUZs.

2.2 Case study

Any comparison among cities with great differences in size can make the results difficult to interpret. For this reason, only medium-sized cities are chosen for the analysis (Figure 1). In specific, cities suitable for comparison are considered to be those having a LUZ with population between 80,000 and 220,000. However, population size is not the only parameter considered for the selection of the sample. In fact, the primary criterion is the homogeneity of the temporal socio-spatial patterns of the cities. Within this context, the LUZs of Athens (3,855,211 inhabitants) and Thessaloniki (953,814 inhabitants) are excluded from the analysis since they constitute metropolitan conurbations with international significance, combining administrative services and important infrastructures with completely different characters from the other cities. Because of their role and size, they represent a separate distinct class. On the other hand, the cities of Patra (214,456 inhabitants), Heraklion (192,370 inhabitants), Larissa (181,061 inhabitants), Volos (136,046 inhabitants) and Ioannina (124,646 inhabitants) are listed as primary national poles that demonstrate a dynamic profile.

Patras and Hraklio have a distinct position in the analysis as the most important medium-sized cites in Greece. Their development was based principally on ad hoc procedures and self-promoted strategies for housing areas development, and only partially urban plans and important urban projects took place. Important ports are also settled in these cities and their development is strongly connected with that. In these cases, due to port infrastructure localization, character and function mode, land use conflicts and important pressures in urban tissue carrying capacity are occurred, and there are negative effects on the overall city function (land use conflicts, traffic jam, pollution, etc.).

As far as Kavala (74,186 inhabitants) and Kalamata (70,006 inhabitants) are concerned, they are both characterized as secondary national poles (OGG 2008). Neither of them qualifies for population standard. However, Kavala was included in the case study because of its similarity to the urban processes which took place in the most medium-sized Hellenic cities as well as because of its administrative services, productive infrastructures and its urban amenities that are developed in Kavala. Regarding Kalamata it was exclude from the analysis. The city suffered important disasters from earthquakes in 1986; despite the significant (for the Greek practice) urban plans and projects which

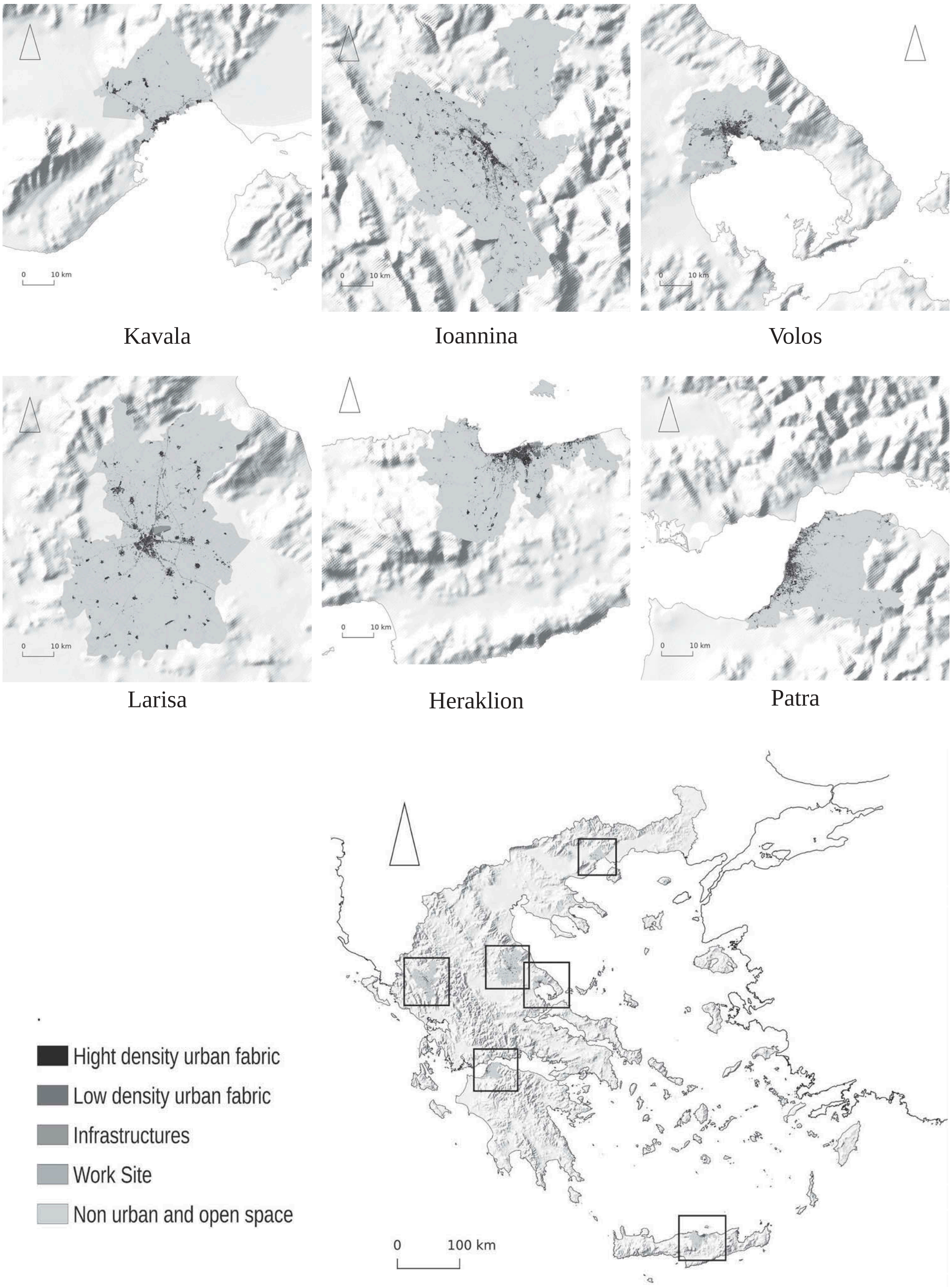

Figure 1. Case Study area; LUZ of medium-sized Hellenic cities. Source: European Environment Agency 2011; GMES Urban Atlas 2006.

followed up the important disasters and an attractive and less dense urban tissue that has been developed, with green areas and open spaces we consider that the city could not play an important development role.

Patras, Volos, Heraklion and Kavala present a common typology, since they are all coastal cities delimited by natural borders. Patras and Volos are surrounded by mountains Panachaikon and Pelion, respectively, while Kavala is limited by forest areas. All of them were transformed through time into powerful industrial centres with industries and manufacturing located near their historical centres. However, the urban expansion of residential areas in combination with traffic problems, and the general decline in the industrial sector drove these land uses out of city centres. The abandoned industrial buildings dispersed located within central areas created functional problems and discontinuities to the urban tissue. At the same time, these traditional port cities lost part of their glory due to the competitive overland transportation systems that had left extended areas of the ports degraded for a long time (Loukakis 2004). In an effort to reverse this surge, the focus turned on other growth sectors. This procedure coincides with the cities' tertiarization. Their strategic location, a range of inherent natural and cultural resources and the government's policy to locate higher education facilities in peripheral areas in the context of regional development, allowed these cities to act as poles of tourism and research and technology centres (OGG 2008, Loukakis 2004). Subsequently, they all began to receive intensive urban functions related to tourism, second housing and recreation (Loukakis 2004).

More specifically, Patras is considered a national pole of growth. Located in the western part of the country, Patras plays the role of a portal to Europe through the Adriatic. It is also the intersection of the traditional Eastern development axis, shaped by the highway of "PATHE" (it connects the major national poles of Patras, Athens, Thessaloniki, with the principal country's gate to the Balkans, Evzonous) and the recent but not yet completed Western axis of Ionian highway (it starts at the Ioannina city, interchange of the Egnatia Odos and it follows the western coastline of mainland Greece down to the Gulf of Corinth). In addition, the port and the Rio–Antirrio Bridge have significantly contributed to Patras' emergence as a transportation node (the bridge approximately 3 km long, multi-span cable-stayed bridge, that crosses the Gulf of Corinth near Patras, to link by road the town of Rio on the Peloponnese peninsula to Antirrio on mainland Greece). The accompanying development of transit trade and the operation of the university offered the chance for the development of research, innovation and technology (OGG 2003c).

Similarly, Heraklion, located on the island of Crete, also plays a national role as a centre of commercial activity and diffusion of advanced research and technology due to the University of Crete and the Institute of Technological Research. Furthermore, it is a city that has kept a dynamic population profile despite the general decline in population observed in the majority of the Hellenic cities during the last decade. The significant growth mainly caused by a natural growth in population size rather than migration indicates young human power and high potentiality for future development (OGG 2003a).

As far as Volos is concerned, it has developed as a traditional industrial port city in the inner side of the gulf of Pagasitikos – Eastern Greece, following the declining path of industry. Only few of the efforts to reuse the abandoned buildings as recreation and cultural places in order to revive the urban tissue yielded the desirable result. However, a number of technical infrastructures, such as the railway network, the port and the University of Thessaly campus along with the natural beauty of the surrounding area, gave Volos a distinct role among the Hellenic cities (OGG 2003b). The case of Kavala, a small port in North Greece, resembles the above as it also constitutes an industrial port. The predominant economic growth was based on marble mining, export trade of silk and tobacco as well as oil extraction in the marine area of the prefecture. In this differential economic basis lies the fact that, despite Kavala is not the capital of the periphery nor acts as a pole of national significance, it still holds a key role in the geopolitical landscape (OGG 2003e).

A similar typology is also apparent for Larissa and Ioannina since they are both inland medium-sized urban centres having in common the lack of natural borders and the fact that they never underwent industrialization processes. Their development was based on the powerful presence of both the agricultural sector and commerce. On the one hand, located in the biggest plain of central Greece, Larissa has long played the role of a dynamic capital for the surrounding rural areas. The strategic central location on the highway of 'PATHE' in the middle of the distance between the two biggest cities (Athens and Thessaloniki) has definitely contributed to its classification as a primary national pole (OGG 2003b). On the other hand, settled in the most mountainous periphery of Greece, Ioannina has lately been traversed by the Egnatia highway.

For many years, Ioannina has also acted as the capital for a large mountainous area with high dependencies developed among the residential network due to the lack of significant urban centres to act as competitive poles. Furthermore, the geopolitical significance of the potential hydrocarbons extraction along with the reduction of isolation of the past finally repositioned Ioannina on the map. Both Larissa and Ioannina currently act as nodes of transportation and trade, while Ioannina is being noticed because of the University of Ioannina and the surrounding natural environment offering opportunities for alternative tourism (OGG 2003d).

An identifying approach to the socio-spatial attributes of the case study cities is attempted with the calculation of some plain indices (Table 2). Density definitely constitutes one of the most common indicators used to identify urban forms. Since it is hard to devise an optimal density value, it makes sense to examine the density combined with other variables somehow reflecting the quality of the urban fabric. Such an indicator is the ratio between the area covered by urban green spaces and the total urban area (openspaces indicator) (Stathakis and Tsilimigkas 2015). More specifically, the indicator named *Density* is calculated by dividing the population (census data from the Hellenic Statistical Authority) with the surface covered by urban built-up areas (Urban Atlas land use classes 11100–12400), while the *Openspaces* indicator was calculated as the surface covered by *Green urban areas* and *Sports and leisure facilities* (Urban Atlas land use classes 14100 and 14200 respectively) divided by the urban built-up areas as described previously.

Table 2. Population and area index values for Hellenic LUZs.

LUZ	Urban green (ha)	Urban areas (ha)	Population 2011	Open spaces	Density (per/ha)	Population change 2001–2011 (%)	Urban expansion
	1	2	3	5 = 1/2	6 = 3/2	7	8
Kavala	89	2,503	70,501	0.036	28	−5.0	0.032
Ioannina	236	9,376	132,979	0.025	14	6.7	0.035
Volos	119	4,214	137,630	0.028	33	1.2	0.059
Larissa	229	11,646	195,120	0.020	17	7.8	0.034
Heraklion	153	6,176	211,370	0.025	34	9.9	0.067
Patras	326	5,512	217,555	0.059	39	1.5	0.077

Source: European Environment Agency 2011; GMES Urban Atlas 2006; Hellenic Statistical Authority for the last decade (2001–2011).

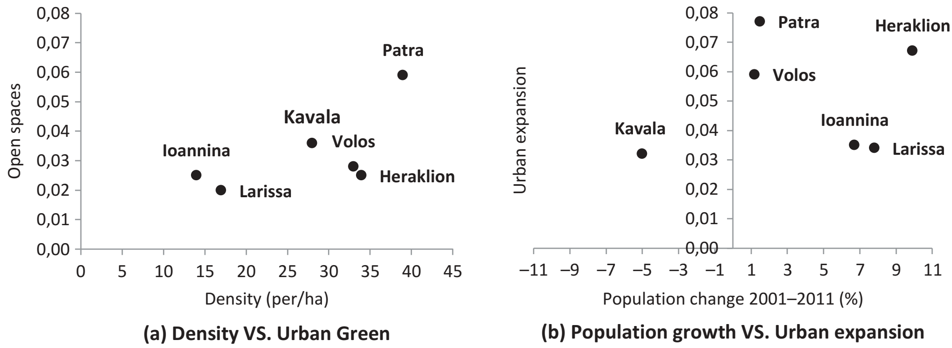

Figure 2. (a) Density vs. Urban green, (b) Population growth vs. Urban expansion.

This way reveals an interesting pattern (Figure 2(a)). It seems that cities that tend to have higher densities also have higher ratio of open green spaces than those with the lowest densities. In fact, this trend can be better documented while the edges (Patras and Ioannina–Larissa) are compared, indicating that density might not be responsible for the deterioration of the urban tissue as it is does not take place at the expense of open public spaces or at least this seems to be the case for the Hellenic cities studied.

Monitoring of the population growth along with the growth of the city can also depict socio-spatial patterns. Consequently, the percentage change of the population during the last decade (population change 2001–2011) is worth being examined along with the intensity of the urban expansion. This trend can be captured as a ratio between the newly built-up surfaces during the period 2001–2011 and the total built-up urban area. The newly built-up surfaces are calculated as the total surfaces declared in construction permits provided by the Hellenic Statistical Authority for the period 2001–2011, and then they are divided by the total built up areas (Urban Atlas land use classes 11100–12400). (Figure 2(b)).

When the trends emerged in Figure 2(b), analysed four cases appear to exist. The first one is composed of cities that maintained low population growth within the decade, but the urban expansion demonstrated a high value, such as Patras and Volos. The second case consists of cities with both a substantial population growth and a corresponding growth in construction processes (Heraklion). The third case is about cities with growing population that maintained their low rates of expansion (Larisa and Ioannina) and the last case is cities with both a decrease in population and in urban expansion intensity such Kavala. Among these cases, what constitutes an unusual phenomenon is the first one, as it fails to explain how a stagnant population sustains increasing construction rates; this means that the expansion is probably incited by either market inactivity or, even worse, an incorrect policy which promotes urban expansion without the saturation of the old urban fabric first

Conclusively, the socio-spatial patterns of the cities selected as the case study appear to be quite homogenous. In this way, the results can be interpreted in a meaningful manner. As a matter of fact, two different typologies of cities can be distinguished within the sample. The first typology includes the industrial coastal cities of Patras, Heraklion, Volos and Kavala, while the second one includes the two inland cities of Larissa and Ioannina. A first clustering appears to emerge.

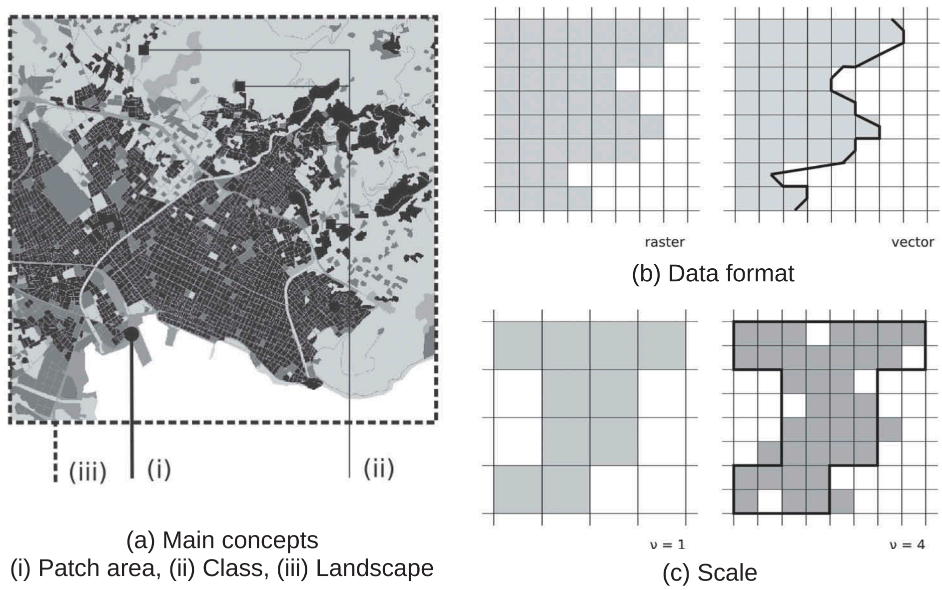

Figure 3. (a) Main concepts, (b) data format and (c) scale effect.

2.3 Indicators and methodological choices

To capture spatial heterogeneity, landscape metrics provide numerous methods. The main concepts used here are *patch area, classes*, and *landscape* (Figure 3(a)). *Patch area* is defined as the 'surface area that differs from its surroundings in nature or appearance' (McGarigal, Cushman, and Ene 2012). Patches are considered to be homogeneous areas concerning a specific factor of interest which differentiates them from their surroundings. This factor can be each time defined according to the hypothesis adopted for the study. All patches belonging to the same category constitute a class. The principal concept adopted in this study is the landscape. Many different interpretations for the definition of the 'landscape' are proposed. Ultimately, the definition of landscape depends on the phenomenon under consideration. In general, an area that is heterogeneous in at least one factor of interest stands as a landscape (McGarigal, Cushman, and Ene 2012; Turner, Gardner, and O'Neill 2001). For the purposes of this paper, landscape is considered to be an area of land containing a mosaic of five major categories of land use patches.

Apart from the spatial extent, the overall study area, which here matches the LUZs delineation data format and the working scale, have profound influence on the chosen landscape metrics. These factors are widely discussed in the literature. A reference to these restrictions is also attempted here. However, detailed analysis of these issues is beyond the scope of this study.

The first question concerns the data format (raster or vector) (Figure 3(b)). 'Edge lengths will be biased upward in a raster because of the stair-step outline and the magnitude of this bias will vary in relation to the image resolution' (McGarigal 2002). Because of this, the metrics involving edge or perimeter will be affected. Even though the initial data set is provided in a vector format, in this study, the conversion to a raster format was preferred for one main reason. The process of raster data is more efficient for the metrics chosen. Besides, any distortion due to the conversion is similar to all LUZs, that is, the stair-step outline effect is finally minimized. The second factor influencing landscape metrics is the scale effect (Figure 3(c)). The values of applied metrics are affected by the size of the pixel. The research question determined our working scale in 1/10.000 which is considered as the most suitable scale to capture the spatial heterogeneity of the land use patterns. It is also a common scale for physical planning officially adopted for many studies. The Urban Atlas 2006 data set happens to fit well in this scale, so the data raster conversion is performed in resolution 10 × 10 m (Tobler 1988).

To study land use patches composition and spatial configuration, a number of basic landscape metrics is chosen. The *Greatest patch area* (GrPA), the *Number of patches per class* (NumP), the *Patch density* (PD) and the *Edge density* (ED) are the metrics approved in order to study the spatial character of the patches themselves. Another interesting aspect when analysing land use structures is the city shape. Being able to quantify in a meaningful manner how cities differ from those having a compact and geometric shape to those with linear growth and many vacant spaces within the urban fabric has been a challenge recently. In the meantime, the quantification of urban sprawl is both a field of discussion among the scientific community and a significant parameter in landscape analysis. These two aspects seem to be captured by two metrics, that is, coreness (Stathakis and Tsilimigkas 2015) and spawl.

3 Results

3.1 Spatial configuration of land use patterns

3.1.1 Number of patches per class

NumP is a patch-based metric that provides a simple measurement of the fragmentation of each land use class into patches. High values indicate more fragmented land use classes and subsequently substantial spatial distribution. The class ‘Infrastructures’ receives the highest value in all cases that can be explained by the land use character itself. In fact, this land use class provides ‘connectivity’ which explains the inflated spatial dispersion. In technical terms, this means many patches and high dispersion in patterns (Prastacos, Chrysoulakis, and Kochilakis 2012). Concerning the urban fabric, the results are also reasonable. The *High density urban fabric* class receives significant lower values than the *Low density urban fabric* class in all cities; that is, the high density of urban fabric represents more compact areas.

3.1.2 Greatest patch area

GrPA is also a patch-based metric that provides a simple measurement of patch size per land use class. High values, under conditions, show higher homogeneity and lower dispersion. The *Non-urban and open space* category obtains by far the highest values representing the most homogeneous category of all. This is reasonable because of the land use character that creates areas with low spatial dispersion. It is clear that here this metric has limited interpretive value due to the fact that this category represents on average almost the 90% of the studied LUZ areas.

3.1.3 Patch density

PD is defined as the ratio between the number of patches of each land use class and the total area (Figure 4(a)). It is an index of the spatial distribution of a certain land use class patch (Prastacos, Chrysoulakis, and Kochilakis 2012). Like NumP, PD often has limited

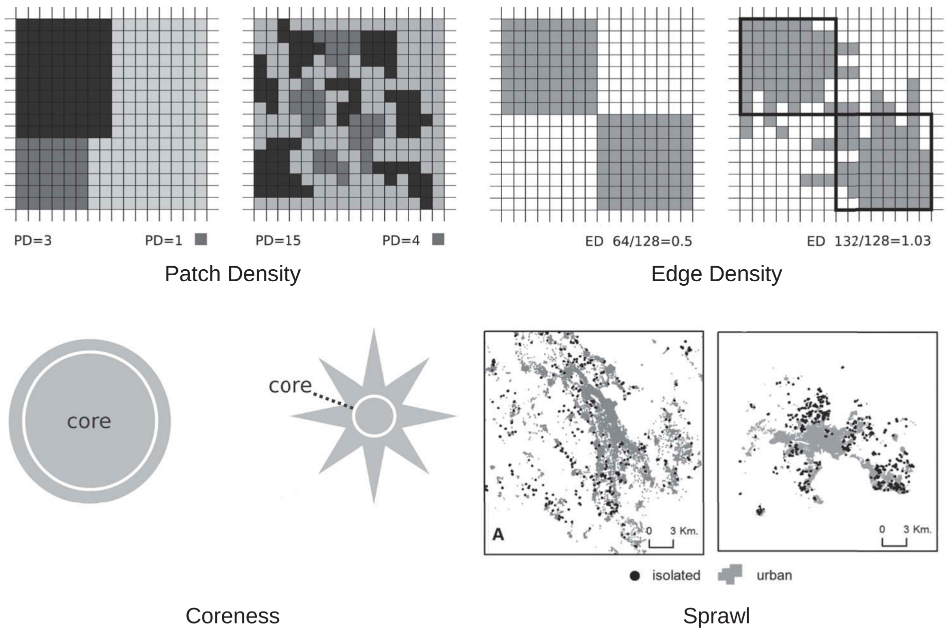

Figure 4. (a) Patch density, (b) edge density, (c) coreness and (d) sprawl.

interpretive value due to the fact that it conveys no information about sizes and the spatial distribution of patches (McGarigal 2002). Notwithstanding the weaknesses of the metric, it seems to work well in capturing the degree of aggregation (or else *clumping*) of different patch types. Thus, it is conspicuous that high values represent more fragmented land use classes. On the one hand, the class *Infrastructures* by far obtains the highest values. This was expected considering the land use character as already mentioned. On the other hand, the *Non-urban and open space* class yields the lowest values. This was similarly expected because of the land use character as already mentioned. Regarding the urban fabric, high-density zones receive lower values than the low-density urban fabric categories in all cases. It stands as a reasonable result explained mainly by the land use character. More specifically, high density areas create more compact and homogeneous urban tissues, while the results are also coherent with the above analysis of the NumP per class index and the GrPA per class index.

To conduct a comparative analysis among the medium-sized cities, some of the above metrics were discarded due to their inability to yield a meaningful geographical interpretation. Subsequently, the values of *ED, PD, Coreness* and *Sprawl* were standardized to provide comparable and more 'comprehensible' results. The standardization was performed according to the following formula :

$$\text{Standardized value} = \frac{\text{Value} - \text{mean}}{\text{Standard deviation}} \tag{1}$$

3.1.4 Edge density

ED is defined as the division of the total patch perimeter by the total patch area (Figure 4 (b)). It is an indicator of the complexity of the patch morphology of the land uses. It is characteristic that the ED does not indicate any significant variation among the urban fabric of the cities (both high- and low-density urban fabric categories). We consider this to be due to the similar mode of the settlement development and the urban sprawl phenomenon, which takes place in all the studied LUZs.

On the one hand, Volos and Patras obtained the LUZ population density highest values: 452.30 per/km^2 and 424.10 per/km^2, respectively (Table 3). The cities tend to have significant spatial fragmentation concerning both 'High density urban fabric' and 'Low density urban fabric' categories (high PD values). It is important to highlight also (Figure 5) that the two categories in these cities tend to create patches with important complexity (Figure 5) concerning their patterns morphology (high ED values). Apart from common to all studied cities, interpretative factors such as the mode of the settlement development, the loose spatial planning framework, the tolerance in urban sprawl (Chorianopoulos et al. 2014, 2010; Karidis 2006), physico-geographical and development factors, such as the cites sea proximity and the important port infrastructures, are emerged as significant interpretative factors for both cities. On the other hand, Ioannina and Larisa obtained the LUZ density lowest values 100.26 per/km^2 and 125.42 per/km^2, respectively, both because of exaggeration in LUZ delineation. The cities as it is shown in (Figure 4) create comparatively significant spatial homogeneous areas (low PD values) concerning 'High density urban fabric' and 'Low density urban fabric' categories. It is also mentioned that they do not tent to create patches with important complexity concerning their patterns morphology (low ED values).

3.1.5 Coreness

City core is obviously related to the city shape. Cities with a big core tend to have more compact and geometric shapes. On the contrary, cities with smaller urban cores indicate that the edges abstain more and are less affected by the core. Such kinds of cities usually present extensive urban sprawl. Here, core area is defined as the part inside the edge of the city based on a buffer distance. Consequently, the core is less close to the city limit, and its characteristics less affected by it. Within this context, coreness is defined as the ratio of core built-up area by the total built-up area (Figure 4(c)). To find the core built-up areas, an internal buffer distance of 20 meters has been used being considered as pertinent according to the working scale. The exact distance is not so important since the point here is to make comparisons amongst cities using the same value (Stathakis and Tsilimigkas 2015).

3.1.6 Sprawl

Sprawl seems to depict a big part dispersed off-plan construction of a city. More specifically, the Urban Atlas land use of isolated structures (code 11300) offered an idea for this new metric (Figure 4(d)). By measuring the average distance of every isolated structure to the nearest polygon of continuous built-up area, an indicator of the city dispersion arises. High values indicate extended sprawl, as the more an isolated structure abstains from the city, the more the city edges expand.

Examining the relationship between the shape of the city (coreness) and urban dispersion (sprawl), an interesting result has come to confirm the theoretical contrast between these two urban patterns. It is conspicuous that a negative relationship does exist between these two metrics (Figure 6). In other words, Hellenic cities which tend to be more compact as far as their shape is concerned also tend to be less

Table 3. Spatial metrics of medium-sized Hellenic cities.

	Coreness	Sprawl	NumP	GrPA	PD	Normalized PD	ED	Normalized ED
Kavala	0.40	0.01						
High density urban fabric			82	3.29	0.000000233	−1.20	0.0014	−0.49
Low density urban fabric			473	0.64	0.000001346	−1.13	0.0008	−1.09
Infrastructures			5772	1.41	0.000016424	-	0.0032	-
Work Site			55	0.81	0.000000156	-	0.0002	-
Non-urban and open space			36	326.62	0.000000102	-	0.0032	-
Ioannina	−1.38	1.41						
High density urban fabric			900	3.72	0.000000679	0.12	0.0012	−0.74
Low density urban fabric			3285	0.89	0.000002477	0.46	0.0013	−0.16
Infrastructures			24996	3.06	0.000018846	-	0.0041	-
Work Site			323	1.78	0.000000244	-	0.0003	-
Non-urban and open space			139	878.70	0.000000105	-	0.0048	-
Volos	0.43	−1.17						
High density urban fabric			244	3.10	0.000000802	0.49	0.0031	1.63
Low density urban fabric			1036	2.73	0.000003405	1.77	0.0023	1.82
Infrastructures			11051	1.86	0.000036318	-	0.0064	-
Work Site			125	0.82	0.000000411	-	0.0003	-
Non-urban and open space			101	187.23	0.000000332	-	0.0057	-
Larisa	−1.34	0.95						
High density urban fabric			462	2.18	0.000000297	−1.01	0.0012	−0.69
Low density urban fabric			2060	1.21	0.000001324	−1.16	0.0008	−1.14
Infrastructures			39100	11.18	0.000025138	-	0.0064	-
Work Site			269	0.56	0.000000173	-	0.0001	-
Non-urban and open space			199	550.11	0.000000128	-	0.0062	-
Heraklion	0.40	0.77						
High density urban fabric			345	3.30	0.000000571	−0.20	0.0019	0.10
Low density urban fabric			1259	1.66	0.000002084	−0.09	0.0015	0.31
Infrastructures			14297	4.38	0.000023662	-	0.0042	-
Work Site			132	0.53	0.000000218	-	0.0002	-
Non-urban and open space			88	434.97	0.000000146	-	0.0044	-

(*Continued*)

Table 3. (Continued)

	Coreness	Sprawl	NumP	GrPA	PD	Normalized PD	ED	Normalized ED
Patra	0.05	0.59						
High density urban fabric			639	3.33	0.000001246	1.80	0.0027	1.11
Low density urban fabric			1166	0.41	0.000002273	0.18	0.0015	0.30
Infrastructures			16656	5.40	0.000032469	-	0.0054	-
Work Site			188	0.44	0.000000366	-	0.0002	-
Non-urban and open space			320	436.21	0.000000624	-	0.0051	-

Source: European Environment Agency 2011; GMES Urban Atlas 2006; (a) Coreness; (b) Sprawl; (c) Number of patches per class (NumP); (d) Greatest patch area (GrPA); (e) Patch density (PD); (f) Normalized patch density; (g) Edge density (ED); (h) Normalized edge density.

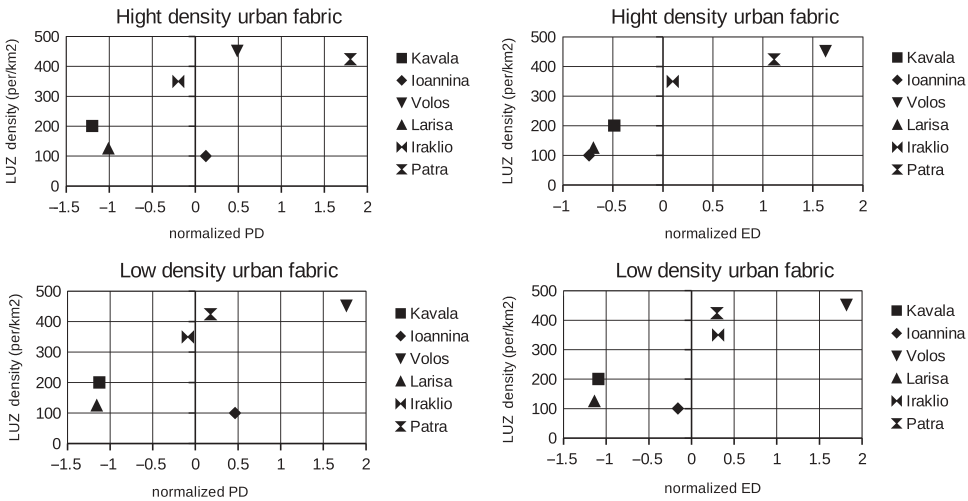

Figure 5. (a) Edge density (standardized values) and (b) Patch density (standardized values).

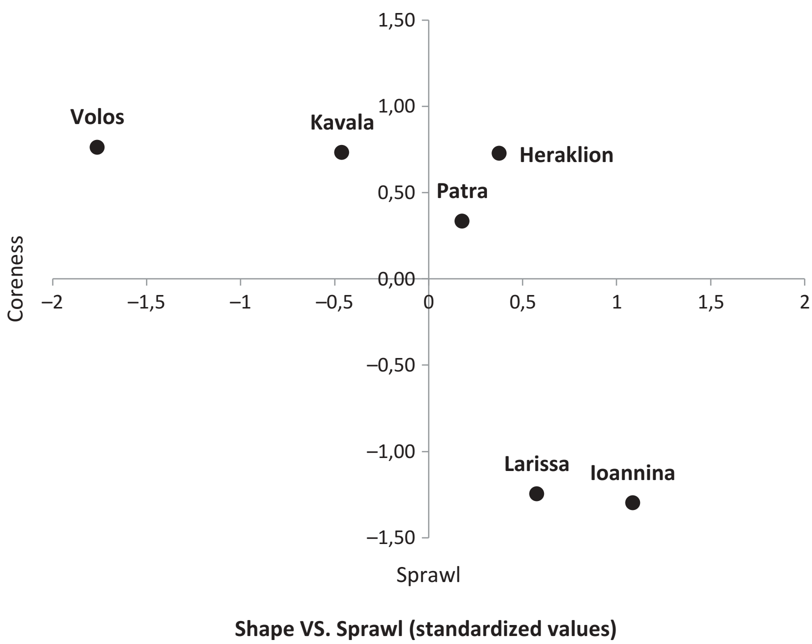

Figure 6. Shape vs. Sprawl (standardized values).

dispersed. What is more, some kind of clustering becomes obvious among the cities (coastal vs. inland). This pattern comes to verify the concept adopted in the case study selection.

In an effort to fuse all the above-mentioned metrics to create some kind of geographical city profile, Figure 7 was constructed. In detail, every peak of the polygon stands

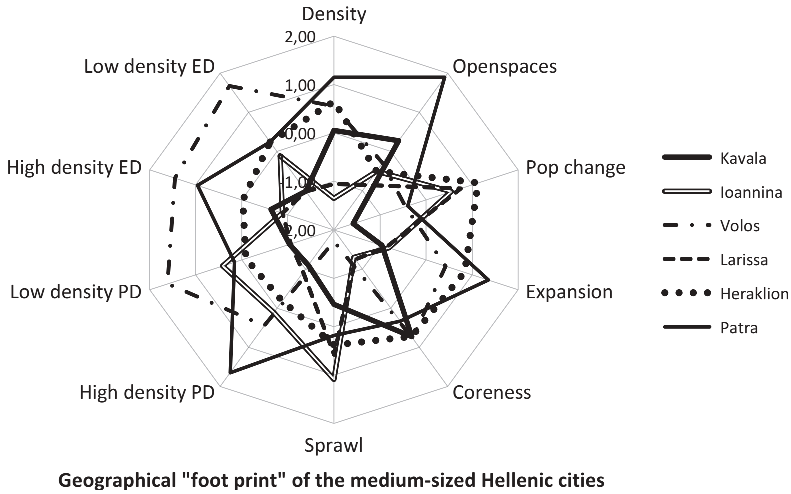

Figure 7. Geographical ‘foot print’ of the medium-sized Hellenic cities.

for each of the 10 metrics presented above. It is obvious that any effort to strictly cluster the cities under the light of all of these parameters is difficult. However, interesting patterns reveal a complex and rather particularities of Hellenic urban reality.

4. Discussion

The first discussion point is about boundaries delineation and the different cities typologies that LUZs represent. Two main arguments emerge; the first is enhanced with the important difference in population between the Hellenic LUZ (Table 2). On the one hand, Kalamata (69,849 km^2) that is described as secondary national poles, and on the other hand, the metropolitan areas of Thessaloniki (951,408 km^2) and Athens (3,791,874 km^2) that represent completely different socio-spatial systems. Therefore, they are excluded from the study that focused only in medium-sized cities. The second argument emerged from the restriction of the LUZ delimitation to follow the national administrative boundaries that approximately represent the functional urban region in order to ensure a good data availability (European Urban Audit 2012, ESPON 2013). It is important to highlight here that very often administrative boundaries do not follow geographical (but political) criteria. For that reason, this obligation results in very different geographical realities which are illustrated, among others, and in the LUZ population density (Table 2). On the one hand, there are Ioannina (100.26 per/km^2) and Larisa (125.42 per/km^2), and on the other hand, there are Patras (424.10 per/km^2) and Heraklion (349.68 per/km^2). The main argument concerning the need to create data sets, which can be updated easily, and are compatible at European scale, therefore the restriction to follow national administrative boundaries (in Local Administrative Unit, LAU 1 level) in Greece’s case falls into the void. The ratification of the ‘Administrative Reformation project of Kallikratis’ (OGG 2010) introduces a new delineation that drive in different administrative boundaries concerning the local government boundaries. Not for all the LUZs but for the majority of them the boundaries between the LUZ and the local government are not the same (except for Kalamata).

The second discussion point is about LUZ geography. It is emphasized above, in the first discussion point, the important difference that characterizes the LUZ density is caused principally by difficulties in LUZ delineation because of administrative restrictions. A second argument about the topic is based on the different physico-geographical characteristics and different human geography factors of LUZ. The minimum density shown in Ioannina (100.26 per/km^2) means a wide functional area compared to the population. This could be the result of the excessive physico-geographical fragmentation and the peripheral city position in correlation with the principal development centres and national axis. These factors create functional dependencies from Ioannina for a wide mountainous area. On the other hand, the different geography of the level area in Larisa characteristic which encourages the functional dispersion by the diffusion of housing and productive activities and the infrastructures spread in a wide area (1,674.74 Pop/km^2).

The third discussion point is about LUZ land use structure and the excessive inequalities in land use major categories representation. The ‘non-urban and open space’ class represents in all cities the lowest spatial dispersion; it is proved by the GrPA as well as PD index (Table 3). This is explained, as it is already mentioned, because of the land use class characters of which the category is composed (Green urban areas; Sports and leisure facilities; Agricultural + Semi-natural areas + Wetlands; Forests; Wetlands; Water bodies). This class covers an important percentage of the LUZ (as an average, almost the 90%). Taking in consideration that favourable regulation is very often adopted concerning the buildings construction for LUZ, the exaggeration in their delimitation can encourage the buildings dispersion and urban sprawl in peri-urban areas. This will amplify, as it has already happened, the waste of valuable peri-urban rural land and many other negative effects correlated with unplanned city development and the urban sprawl.

In this particular vulnerable zone, the principal planning instrument applied is the Urban Development Control Zone (UDCZ) [Zoni Oikistikou Eleghou] (OGG 1983, 1997). It is a regulatory provision that concerns issues such as: the land use control, building coefficient, building construction conditions, etc. UDCZ is exclusively applied in peri-urban zones as well as in rural areas, (along coasts, lake banks, riverside, deltas and other areas of ecological value) in order to limit the urban dispersion. The efficacy of UDCZ is controversial, but clearly, the complex phenomenon of urban sprawl could not be dealt exclusively with regulations of such character. The exaggeration of the LUZ boundary delineation could have negative effects leading to the amplification of the urban sprawl phenomenon, due to the loose, inappropriate planning framework in Greece.

The fourth discussion point arises from the results of the analysis since some unexpectedly patterns emerge. In particular, Volos presents a highly fragmented urban fabric with high land use distribution as implied by ED and PD high values. This case theoretically indicates a vivid and lively urban fabric with high diversity; a parameter closely related to landscape aesthetics. This is not surprising when it is considered that industrial facilities used to be located are dispersed inside the urban tissue. Respectively, Patras also displays a mixed urban landscape which is further enhanced by the affluence in green open spaces. A decent level of land use dispersion is also the case for Heraklion. This mix of land uses is considered to be an inherent attribute of the Mediterranean cities that is also depicted on the mix of social classes. Any kind of social segregation mainly takes place vertically within the same building.

‘Vividness’ is accompanied by the notable population growth observed in Heraklion is also depicted on the construction raise (urban expansion) However, urban sprawl seems to be a problem for this island capital. The lack of natural borders south of the city combined with the loose planning system, allows this expansion to take place off-plan and at the expense of urban green spaces as implied by the corresponding indexes (sprawl and openspaces).

Similarly, both Larisa and Ioannina gain significant population, raising accompanied by high scores in *sprawl* and limited urban green. Larissa presents a radial development pattern along the traversing road network, probably because the surrounding area constitutes land of high productivity for the agricultural sector. Similarly, Ioannina demonstrates a linear development pattern expanding along the lake Pamvotis. Recently, this pattern seems to have been transformed by the construction of the Egnatia highway which attracts urban sprawl.

On the contrary, Kavala suffers from a distinctive population loss. At the same time, the relatively low values observed in all cases indicate that Kavala's inclusion in the sample might not be as effective as it was initially thought. This explains the fact that Kavala is not qualified as a primary national pole despite the similarities of socio-spatial processes.

The fifth discussion point arises from the results of the analysis since some 'paradox' patterns emerge. In a nutshell, the Hellenic particularity is condensed to the opposition between urban fabric quality and population attraction. In other words, cities which concentrate attractive conditions in terms of urban fabric quality (mix of uses, many open green spaces, low degree of sprawl, coastal front) fail to attract a respective raise in population. The quest for better urban quality and an attractive urban environment does not seem to be the case here. On the contrary, less favoured peripheral cities present a more promising future. Their differential economic basis certainly plays a role. What is more, peripheral cities traditionally used to create powerful economic dependencies with their inland being the embankment of population flee to major cities. The city of Ioannina, for example, has been the only dynamic urban centre for a whole mountainous area with no other accessibility. Similarly, Larissa's central position on the map has strengthened and enlarged the functional domain the city serves. The city of Heraklion seems to be the most privileged case of all as far as the rise in population is concerned. Its location in the biggest Hellenic island of Crete might be a fair – yet not the single – explanation. Towards this direction concludes the case of Kavala's population loss. The proximity to Thessaloniki and the easy access provided by the highway might be one of the reasons for the city's weakening.

From the aforementioned, it can be deducted that location is a key factor for a city's evolution. Not a single pattern is obvious however. Actually, it seems that the explanation lies in a combination of both centrality and isolation from the big-sized Hellenic cities which act as a magnetic pole for a large area around them. Whether we name it dynamic economy or strategic location, it is obvious that the planning system failed to ease the urban pressures these growing cities were faced with as indicated by the geographic 'foot print' developed in this paper. Extended urban sprawl and the lack of green urban spaces prove the ineffectiveness of the Hellenic spatial planning loose framework. Finally, any kind of clustering attempted above should help recognizing the prevailing patterns, but it still should not hide the fact that each city is a unique mosaic shaped by the particular conditions, advantages, constraints, opportunities and risks it was historically faced with. Within this context, the image that finally emerges based on the evaluation of the land use patterns, which was the primary objective of this paper, loses some of the deterministic attributes and becomes more composite and diverse.

5. Conclusion

This paper focuses on the recently released pan-European spatial data set of Urban Atlas, combined with nationally available statistical data in order to detect and analyse urban patterns for the medium-sized cities, Kavala, Ioannina, Volos, Larissa, Heraklion and Patras. For this purpose, indicators, both pre-existing and new, were used. The principal points that emerged from the analysis aim to quantify and to interpret the land use patterns composition and the spatial configuration in order to shed light on issues concerning the urban development mode and the urban sprawl.

The loose planning system that encouraged ad hoc procedures in city development, driven by self-promoted strategies, is very often the principal driving factor for the particularities that emerged in medium-sized Hellenic cities and are illustrated with quantitative methods in the paper. Many side effects are connected to these practices: urban sprawl, coastalization, abandonment of peri-urban agriculture, degradation of peri-urban ecosystems and valuable peri-urban landscape degradation are considered the principal among others (Chorianopoulos et al. 2014, 2010; Karidis 2006; Giannakourou 2005a, 2005b; Economou 2004). It is important to stress also that: first, the 'urban' areas created from ad hoc procedures are not located in appropriate locations concerning many parameters such as: geological suitability of the area, terrain slope appropriateness, proximity with principal infrastructures, etc. Second, the urban fabric developed in that mode does not ensure optimal solutions in parameters such as suitable residential densities, sufficient social infrastructure services, adequate urban infrastructures and open spaces.

These particularities are more or less common for all cities, but some diversities between them exist, as highlighted in the analysis results, which are interpreted by physico-geographical and human geography factors and other development choices and conjectures. The principal conclusion that emerges from this paper is that the spatial planning system as it is developed (OGG 1997, 1999) is proved, under the circumstances, inadequate to regulate the complex territorial issues raised in medium-sized cities. It is widely accepted that a broad reformation of the spatial planning system is required. It remains to be seen if the new law (OGG 2014) will contribute positively to the establishment of an integrated spatial planning framework.

Disclosure statement

No potential conflict of interest was reported by the authors.

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