URBAN SPRAWL IN THE MEDITERRANEAN: EVIDENCE FROM COASTAL MEDIUM-SIZED CITIES

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Abstract

Urban sprawl processes taking place in European cities constitute an important problem opposing sustainable growth and environmental protection. This is particularly evident in the Mediterranean, where intense tourism development and coastalization continuously impose urban land pressures on agricultural areas and natural land. In the present study a set of 14 coastal medium-sized cities of Spain, Italy, Greece, Mediterranean France and Malta is used to explore recent urban sprawl trends and to analyze different typologies of urban form and structure. Based on recent data from European databases (Urban Atlas, Corine Land Cover and the Imperviousness-Soil Sealing Degree dataset), soil sealing degree profiles are estimated and the distribution of different urban land uses is analyzed for year 2006 using a set of spatial metrics. Urban growth between 1990 and 2014 is estimated based on data from the Global Human Settlement Layer (GHSL). Results reveal important differences between the cities in terms of urban form and structure. Geomorphology, different levels of population growth and tourism development, differences in the historical and socioeconomic context constitute among others, the reasons for this differentiation.

Keywords: Urban sprawl, Urban form, Coastalization, Medium-sized cities, Soil sealing, Land use

JEL classification: R110, R140

1. Introduction

Recent urbanization taking place along the coastal areas of the Mediterranean usually in the form of low dense urban expansion and sprawl, constitute an important issue changing radically the traditional compact structure of Mediterranean cities. It is certain that the distinct political, social and cultural history of Mediterranean cities plays an important role in the way urban growth has taken place. The Mediterranean has been an area of intense urbanization since the antiquity, but it is only recently that such extensive urban land pressures and sprawl are observed (Catalan et al. 2008).

Coastalization, periurbanization and mass tourism development are three important processes reshaping the form of Mediterranean cities. Coastalization is a term referring to the concentration of population and economic activities in the coastal areas, leading to a densification of urban development along the coast but also extending many kilometers to the inland. As Membrado (2015) point outs by examining a 10-km-deep coastal strip, the Mediterranean coast of Spain is mainly occupied by urban sprawl. Coastalization is also related to mass tourism development in the Mediterranean, which accounted for 58 million arrivals in 1970, growing to 314 million arrivals in 2014 and according to Plan Bleu projections show that this trend is expected to grow up to even 500 million in 2030 (Fosse & Le Tellier, 2017).

In the same time urban population continues to grow. In 1960 the urban population represented 57% of the whole EU-Mediterranean population, whereas in 2010 around 76% (Horizon 2020 Mediterranean report). What is more important is that the way population is distributed around the cities is changing and important periurbanization trends are observed. Urban areas spread along agricultural and natural land, increasing human pressure on the natural environment, creating more need for infrastructure. The traditional compact structure of cities is gradually changing with central areas presenting population loses and people moving to suburban areas with urban land expanding in agricultural and natural areas, posing important pressures on the vulnerable ecosystem of the Mediterranean as a whole. If we also take into account issues like water pollution, forest fires, earthquakes, floods, environmental degradation and climate change, all of which are directly related to urban development, we clearly understand the importance of the issue.

Although a lot of work is already published on these issues (Munoz, 2003; Sayas, 2006; Catalán et al., 2008; Garcia-Palomares, 2010; Chorianopoulos et al., 2010; Salvati et al., 2013; Salvati & Morelli, 2014, Salvati & De Rosa, 2014; Vaz and Nijkamp, 2014, Tombolini et al. 2015 etc.) the need for a more thorough analysis of urban sprawl in the Mediterranean is urgent. The recent economic crisis has importantly affected all Southern European countries since 2008 and the previous growth-wave seems to slow down. However, the need to evaluate recent changes and to target policies aiming to control this sprawling process remains important. During the past three decades the problem of sprawl has become evident in the case of Mediterranean cities, and along with coastalization, tourism development and new infrastructure taking place in periurban areas, poses a threat to the Mediterranean ecosystem, consuming important land resources and causing environmental degradation. Planning policy facilitated this dynamic, as regional administrations did not implement regional land planning instruments leading to urban expansion without coordinated planning (Valdunciel, 2014). Recently, the policy implications and strategies put in effect in Mediterranean cities (Paul & Tonts, 2005; Archibugi, 2006; Salvati, 2013) promote polycentric structure and sprawl containment; however, it is debatable whether this target has been reached.

Recent databases monitoring urban land changes and providing high resolution data on urban form and structure, make possible the calculation of metrics and indices evaluating urban land pressures and sprawl in a better way. In the context of this paper we focus on a set of 14 medium-sized cities located along the coast of Mediterranean, in Greece, Italy, Malta, Spain and Mediterranean France (Côte d'Azur area). The choice of using cities located only on the EU part of the Northern Mediterranean Coast (and not in Turkey, South Mediterranean countries etc.) was based on the fact that these cities share a more or less common model of urban development in spatial and socioeconomic terms. Moreover, recent comparable data on land use distribution are available for these cities as they are included in the European database of Urban Atlas. Medium-sized cities constitute an important part of the European urban system as a whole and given some conditions could present certain potential in terms of their efficiency, growth, productivity and could adapt successful urban development strategies more easily than large urban agglomerations. On the other hand medium-sized cities could be more vulnerable in terms of economic competition resource management and efficient response to rapid changes.

The need to quantify and evaluate changes in urban patterns is urgent in order to establish a more sustainable way of urban growth. Using a set of methods and based on recent data from European databases (Urban Atlas, Corine Land Cover and the high resolution Imperviousness-Soil Sealing Degree Raster dataset) we aim to explore recent urban sprawl trends and to analyze different typologies of urban form and structure. Soil sealing degree profiles are analyzed in order to identify low density development and to compare its share against denser, compactly developed areas. The distribution of different urban land use categories in each city is also discussed, and a set of spatial metrics is used to analyze their geometrical and distributional characteristics. Spatial metrics have been used extensively to describe the aggregation, dispersion and proximity patterns of the different land uses in an urban area. Estimations are based on discrete areas characterized by a specific land use (patches). Applications on the use of metrics for urban analysis include Herold et al. (2002), Weng (2007), Ramachandra et al. (2012), Schwarz (2010), Aguilera et al, 2009, Prastacos et al. (2017) among others. Finally, based on recently released the Global Human Settlement Layer (GHSL, Paresi et al., 2015) and specifically the GHSL built-up grid, urban growth trends are estimated for the period 1975-2014 and are compared with population growth.

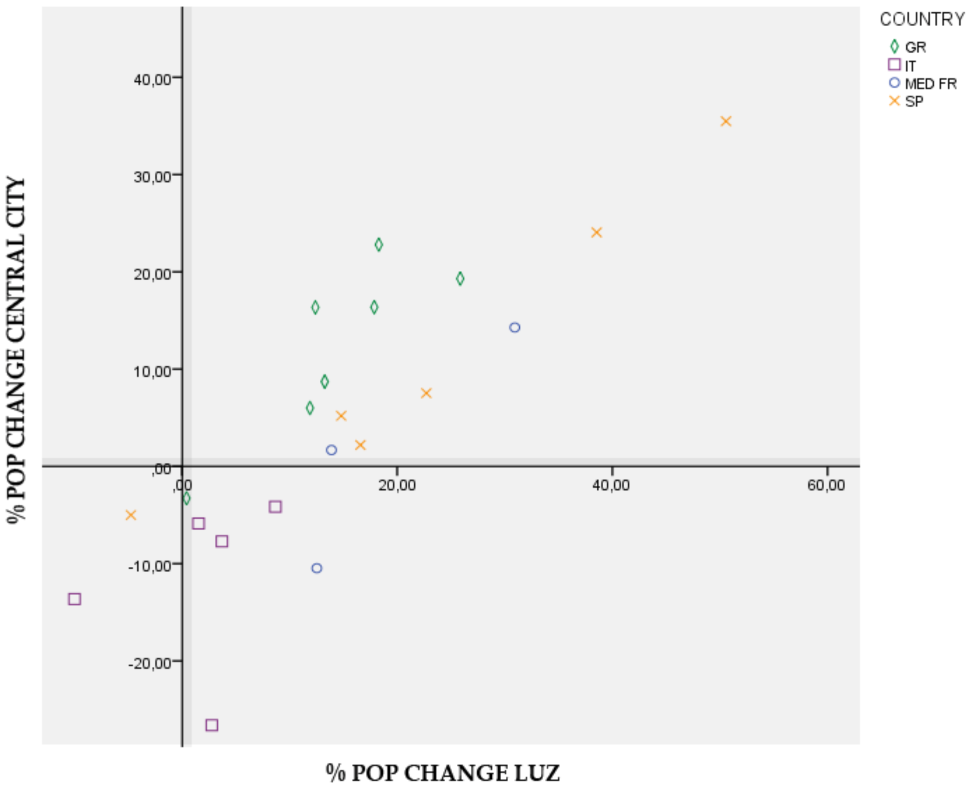
The paper is organized into five sections. First the general context of urban sprawl in the Mediterranean is presented and the basic processes driving urban changes are outlined (section 2). In a next section (section 3) the data and methods used are presented, while in section 4, the case study areas and the results are presented. In a fifth section, results are discussed, the differences between the cities are identified and explained, and a summary of the conclusions is presented.

2. Urban sprawl in the Mediterranean: the general context

The term 'urban sprawl' refers to a form of low density and usually discontinuous and uncoordinated development expanding at agricultural areas at a rate that by far outreaches population growth. During the past decades, urban sprawl in the Mediterranean changes the traditional compact character of cities, with new structures scattered in periurban areas in the form of low density development, usually expanding in an uncoordinated way. High losses of agricultural land, suburbanization, massive new transport infrastructure (Catalán et al, 2008) as well as relocation of commercial and industrial facilities in periurban areas, are some of processes taking place.

Although Mediterranean cities continue to attract more people, central city areas in many cases present a decrease in population as people move from the congested centers towards the periphery of the city in newly developed housing. In Madrid and Barcelona, population located in the central areas decreases during the period 1981-2001 and then a re-urbanization process is observed, while in the meantime the total population of the larger urban zone (LUZ) as a whole grows by 37% and 19.5% respectively (in the case of Madrid this corresponds to over 1.7 million people). Population in the central municipality of Athens decreased by 14% between 1991 and 2011, while total population of LUZ area increased by 8.7%. In almost all major Italian cities, central population decreases gradually since the '80s (in Milan, Naples and Turin the decrease rate is over 20%). These data clearly show the ongoing suburbanization process.

Figure 1: Population changes in cites of Greece and Italy and Spain (past 2 decades)

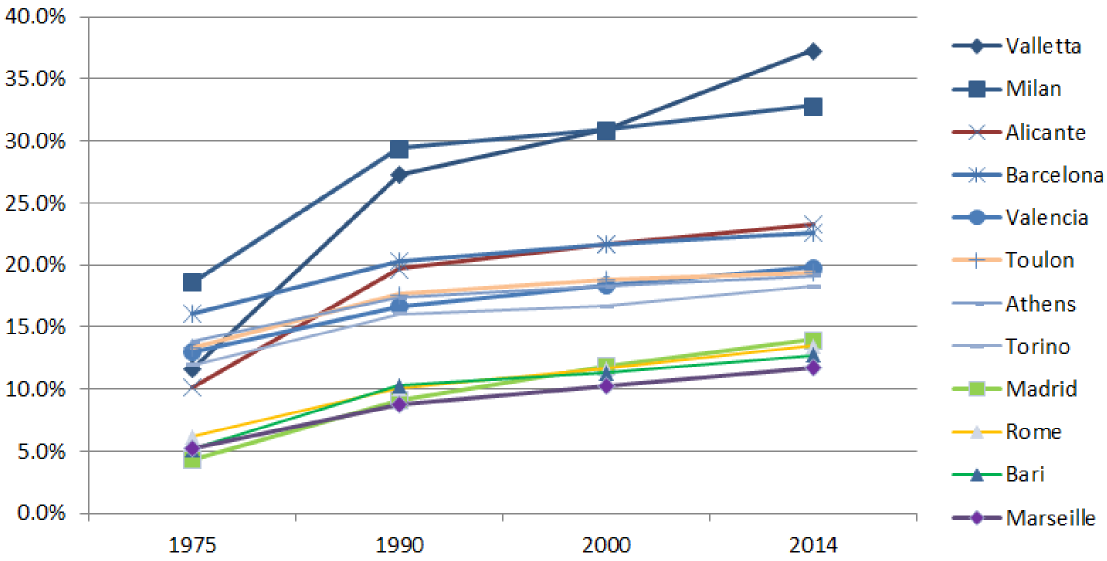


Source: Elaboration on data from www.citypopulation.de (census data)

However, the case of medium-sized cities is different, as central city areas (especially in Greece and Spain) retain or even increase their population. Figure 2 presents rates of population change compared between the central city areas and the LUZ areas (1991-2001 period for Spain, Italy and Greece, 1982-1999 period for France) for a selection of medium to large cities (Cities over 1 million are excluded). The Italian cities form a distinct group as they present population decrease in the central city area accompanied by a stability or slight increase of population in the LUZ area. Most of the Greek and Spanish cities on the other hand (except for Kavala and Bilbao) present considerable increase of population both in the center and the LUZ area. In the case of Greek cities population growth in the central area is generally more important than in the LUZ area, while in the case of Spanish cities the growth rates are almost equally balanced. In the case of the Mediterranean French cities, only Montpellier presents considerable increase in the central city area, while LUZ population grows by at least 10% in all cities.

The suburbanization process has been accompanied by a spectacular expansion of urban land. This can be shown by figure 2, where urban growth data for a sample of cities are estimated from the Global Human Settlement Layer (GHSL, period 1975-2014). The most important growth rate is observed in Valletta where the percentage of urban land increases from 11.6% of the total LUZ area in 1975 to 37.3% in 2014. On the overall, data show that most urban areas in Spain, Italy, Malta and Southern France double their size in a period of 30 years. The only exception appears to be the case of Greece, where urban land growth appears to be more modest. It becomes clear that as this expansion takes in most cases the form of low density periurban development, the urban land pressures imposed on the agricultural land and the natural areas are very important.

Figure 2: Urban land expansion in selected Mediterranean cities between 1975-2014, % of built-up land inside the LUZ area



Source: Elaboration on data from GHSL built-up grid

Numerous studies have been trying to analyze recent urban changes in the Mediterranean in a quantitative way, while the hypothesis of a 'hybrid' type of process leading to a transition from compact to more dispersed growth and a sharp divide between the compact central areas and the sprawling hinterland has been stated (Díaz-Pacheco, 2014). Studying a set of 15 European cities, Kasanko et al. (2006) find out that cities of South Europe form a distinguishable group, with research findings confirming that Southern European cities have started to experience rapid urban expansion but that they remain very compact in comparison to other European cities. Tomobolini et al. (2015) comparing three major Mediterranean cities (Athens, Rome and Barcelona) identify different patterns of urban expansion, as Athens appears to be more compact and Rome more dispersed, with Barcelona being an intermediate situation with a polynucleated structure. Vaz and Nijkamp (2014) examining the regional dynamics in the region of Venice in Italy, and connecting them to recent land use changes, find out that inter-regional pulls work as urban sprawl attractor.

According to Membrado (2015) recent economic growth in Spain was mainly based on the construction sector, leading to the Spanish housing bubble 1997-2007 with local developers constructing thousands of single-family homes. A similar case is identified in Greece, where lack of planning regulations protecting periurban land promoted a low dense uncoordinated form of development. The general model of periurban growth in Greece is characterized as unplanned and in certain cases illegal expansion in areas outside of the city plan, based on self-financed housing, with limited public expenditure for urban infrastructure (Kourliouros, 1997). This process led to a rapid increase of housing prices, which collapsed gradually since 2006 and mainly after 2008 as a result of the global financial crisis. House prices in Greece decreased heavily during the past 10 years and construction activity practically collapsed (decreasing from almost 26 million sqm. of constructed space in 2005 to 1,3 million in 2015).

In general, the Mediterranean case of sprawl is characterized by important particularities and is recognized to be considerably different from the US model or Northern-European type of sprawl (Leontidou, 1990). Tombolini et al. (2015) mention that inner districts in Mediterranean cities have retained high population density and in most cases there is a marked urban-rural divide. Dura-Guimera (2003) identifies certain particularities of the Mediterranean cities such as the fact that recent sprawl took place in the context of the postindustrial and globalization era, the role of migration from the Third World countries and the presence of tourism as a major factor of urban and suburban growth. Immigrants usually occupy central locations in the city as natives move out towards the suburbs and this procedure has an important effect in housing prices, also leading to an important re-distribution of social classes across space (Arapoglou & Sayas, 2009). Catalan et al. (2008) point out the role of medium-sized cities located close to large urban centers and the way they can absorb the negative effects of dispersion and lead to polycentric structure. This can mostly be seen Spain and Italy, but in Greece a network of former agricultural settlement also exists and usually acts as a nucleus of new development.

Despite the 'idiosyncratic' character of Mediterranean sprawl (Sayas, 2006), it has been recognized as an important problem and certain planning policies have been introduced in all countries and also on the European level. Paul & Tonts (2005) analyzing policies applied in Barcelona to contain sprawl, mention that while numerous territorial strategies and plans have attempted to guide development in the rural-urban fringe of Barcelona, their success has generally been limited. In Spain the so-called 'tsunami' of urbanization (Díaz-Pacheco, 2014) has taken in most cases the form of large scale development in a more organized and planned manner, with new suburban areas designed in the form small towns located in the periphery of large cities, along with clearly defined industrial and commercial zones. Díaz-Pacheco (2014) mentions that this process was related to a legislative framework which facilitated the entry of vast quantities of land onto the market and permitting municipal administrations to find a method of financing and economic reactivation that made possible the sale of great quantities of land.

In Greece, the lack of a regulatory framework controlling urban land expansion in the periurban areas, has led to a totally different form of growth based on unplanned, discontinuous and usually illegally built housing in areas outside the city plan. In the meantime commercial uses started relocating from central cities towards the periphery usually in the form of malls, radically changing the periurban landscape. This process was accompanied by new transport infrastructure, which in the case of Athens was further reinforced by the organization of the Olympic games in 2004. It was not until very recently that urban planning in peripheral communities of Greek cities has been at stake, defining zones for the expansion of existing periurban settlements and regulating land uses in order to protect vulnerable ecosystems and natural areas, as well as to protect highly productive agricultural land.

3. Data and Methodology

3.1. Data

Land use data for this study come from Corine Land Cover (CLC) and Urban Atlas (UA). Corine Land Cover provides land use data for a wide temporal range starting from 1990, and included 44 land use categories organized in 5 broader categories of Artificial surfaces, Agricultural areas, Forest and semi-natural areas, Wetlands and Water bodies. A spatial resolution of 100x100m is used for urban areas and 250 x 250m for agricultural areas, while the minimum mapping unit is 25ha for areal phenomena and 100m for linear features. The low spatial resolution in relation to the fact that urban fabric areas are divided into only 2 categories depicting continuous built-up areas and discontinuous built-up areas, makes the use of CLC data problematic in the analysis of urban sprawl.

UA was created by the Environmental European Agency (EEA) starting from 2006 (temporal reference 2005-2007) and recently updated for 2012. Minimum mapping unit is 0,25ha for artificial areas and 1ha for non-artificial areas. UA 2006 covers all cities with a population over 100,000 (305 cities) in 27 European countries, while the list has been extended for 2012 (temporal reference 2011-2013), covering all cities with a population over 50,000. Twenty different land use types are distinguished and urban fabric areas are classified into five categories based on land cover density as expressed by the soil sealing degree.

The Imperviousness-Soil Sealing Degree dataset is also used in this study (EEA, 2011). This is a raster dataset produced in the frame of GMES precursor activities and Geoland2, and are distributed by EEA in the framework of the Copernicus land monitoring service, covering both urban and agricultural areas in 39 countries. The data are updated every three years and already available for 2006, 2009 and 2012 at a resolution of 20m or 100m. Soil sealing degree ranges from 0-100, 0 representing a cell that is completely unsealed, and 100 representing a cell fully built-up or covered with artificial structures.

Table 1. Spatial datasets used in the study

Database	Data source	Data type / projection	Spatial resolution	Coverage	Dates available	Information
Corine Land Cover (CLC)	EEA	Raster, Shape file (ETRS89, LAEA)	100m, MMU= 25 ha	all Europe & Turkey	1990, 2000, 2006, 2012	44 land use categories
Urban Atlas (UA)	EEA	Shape file (ETRS89, LAEA)	MMU= 0.25 ha (artificial structures)	27 EU countries / cities over 100,000 (2006) and 50,000 (2012)	2006, 2012	20 land use categories (26 for 2012)
Imperviousness-Soil Sealing Degree (ISSD)	EEA	Raster (ETRS89, LAEA)	20m /100m	39 countries (28 EU plus11 more)	2006, 2009, 2012	Imperviousness degree (0-100)
Global Human Settlement Layer (GHSL)	Joint Research Centre (JRC)	Raster (Spherical Mercator, EPSG:3857)	20m (approximately)	all earth	1975, 1990, 2000, 2014	Built-up areas (0 = no built-up 1 = built-up)

To examine changes in built-up areas, the Global Human Settlement Layer (GHSL) as provided by the Joint Research Centre (JRC) is used. This is a raster dataset projected in Spherical Mercator (EPSG:3857) approximately at a resolution of 20m, covering the whole world. Data are reproduced for years 1975, 1990, 2000, 2014 depicting built-up areas. Information about all the land use/land cover datasets used in the study is presented in Table 1. Population data came from the City Population database (https://www.citypopulation.de/) where temporal data are available and data are collected come from national census data. Two levels are distinguished: City population (usually referring to the central municipality), and a larger zone corresponding to urban agglomeration/province or LUZ area, depending on data availability. For the Greek cities, population data come from the National Statistical Service.

3.2. Methods

Several methods are used to analyze different typologies of urban form and structure in the case study cities. Using the UA data, the distribution of different urban land use categories are estimated for 2006, and spatial metrics are used to quantify their geometrical/distributional characteristics and their mixture. Using the ISSD data, soil sealing degree profiles are estimated for year 2006. Urban growth is estimated based on data from the Global Human Settlement Layer (GHSL) in the period 1975-2014.

Soil sealing describes the covering of soil through urban development. The soil sealing (imperviousness) profiles for each area are estimated for year 2006. The original soil sealing raster of 20m resolution was resampled at 60m (mean value of the 3x3 original cells). In this way, the map represents better the scale of the urban block rather than the scale of individual buildings/structures. Areas with zero soil sealing are excluded and the soil sealing degree (S.D.) is categorized to 10 categories (S.D. 1-10, S.D. 11-20 etc). The sprawling type of development could best be identified by using a threshold of 30% regarding the sealing degree.

Using the Urban Atlas data we estimate the distribution of different land uses and also a set of spatial metrics describing their distributional and geometrical characteristics. From the original 20 classes of the UA dataset only the urban fabric classes were used, plus the industrial/commercial/public buildings class and the urban areas/sports and leisure facilities (Table 2). All other land use classes were treated as background so as not to distort the results. Using a specific methodology, individual patches of each land use type were identified by reclassifying the local road network the dominant neighboring land use (Prastacos et al., 2017; Lagarias & Sayas, 2017). According to this rule, roads with a width larger 20m still separate neighboring land uses, while in all other cases the division of nearby blocks of the same land use imposed by the local road network is eliminated. The FRAGSTATS software was used McGarigal et al., (2012) for the estimation of the following spatial metrics:

- Patch Density (PD): the number of patches divided by the total area.
- Mean Patch Size (MPS): the mean size (area) of the patches.
- Euclidean Nearest-Neighbor Distance (ENN): the mean distance to the nearest neighboring patch of the same class, calculated as the shortest edge-to-edge distance.
- Interspersion and Juxtaposition Index (LJI): A measure of the distribution of adjacencies among unique patch types. The range is 0-100, approaching 100 when all patch types are equally adjacent to all other patch types.

Table 2. Basic land use classes in UA and as used in the current analysis

UA Class	Land Use Class (spatial metrics)
11100 Continuous Urban Fabric (S.D. > 80%)	Class 1: Dense Urban Fabric
11210 Discontinuous Dense Urban Fabric (50% < S.D. < 80%)	Class 2: Medium Dense Urban Fabric
11220 Discontinuous Medium Density Urban Fabric (30% < S.D. < 50%)	Class 3. Low to Medium Dense Urban Fabric
11230 Discontinuous Low Density Urban Fabric (10% < S.D. < 30%) 11240 Discontinuous Very Low Density Urban Fabric (S.D. < 10%) 11300 Isolated structures	Class 4: Low Dense Urban Fabric
12100 Industrial, commercial, public military, private and transport units	Class 5: Industrial, Commercial & Public
14100 Green urban areas 14200 Sports and leisure facilities	Class 6: Green/Sport Areas

4. <u>Case study and results</u>

4.1. Case study areas

14 cities are compared in this study, located in coastal areas of Greece, Italy, Spain and Mediterranean France (figure 3). Medium-size cities were selected with population ranging from a minimum of 70,000 to a maximum of 850,000 people (population size referring to the LUZ area). Some basic information about the cities are presented in Table 2, and the land use

maps based on UA 2006 data are presented in Figure 4. Data show that selected cities present important rates of growth in terms of population and urban land. According to data from the GHSL database, urban land increased by 36.6% in Valletta in a period of just 25 years, while in all cities, growth rates are over 9%. In the same period, population growth is important and especially in the case of Spanish cities it exceeds 20%. Population growth is modest (less than 10%) only in the Italian cities and in Kavala in Greece. Population density is high in most cases but shows important variation. Greek cities present similar densities ranging from 58-84 people/ha, while in the case of Malaga, Toulon and Bari, densities exceed 100 people/ha and the insular communities of Cagliari and Palma di Mallorca present the lowest densities (< 50 people/ha). This difference observed in densities could be a result of the way LUZ areas are defined. In Table 1 we used the LUZ areas as defined initially in Urban Audit, so that the population and land use data correspond exactly to the same spatial reference. However, in the land use analysis that follows in the next section (as well as in the maps of figure 3) we preferred to use the LUZ areas as revised with the release of UA 2012 (http://land.copernicus.eu/local/urban-atlas/urban-atlas-2012).

Figure 3: Map of Mediterranean basin, indicating the location of the 14 cities of the case study

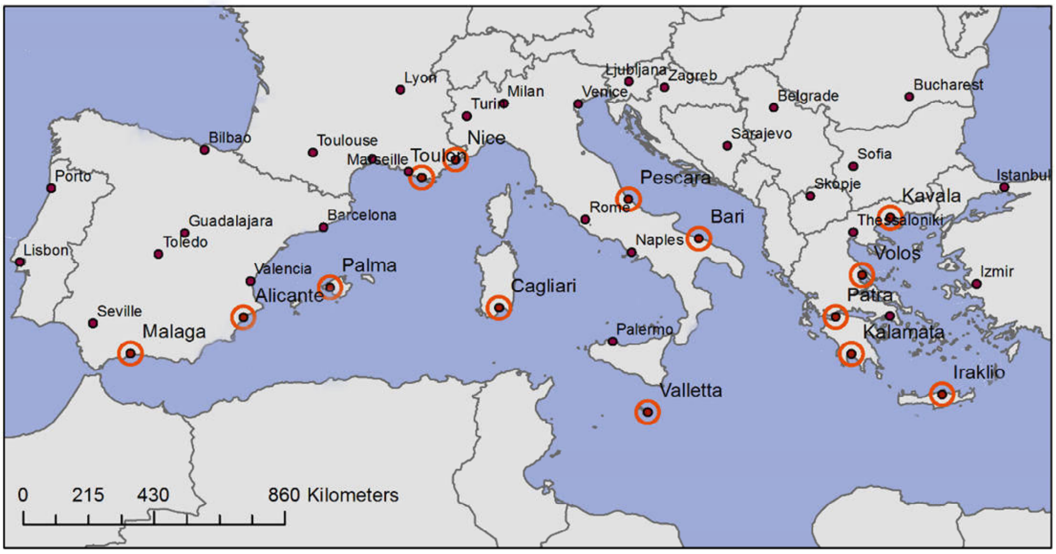


Table 2. Basic data about the 14 cities

CITIES	Population[1]	Population Density[2]	Total area (LUZ)	% Artificial area	% Urban growth 1990-2014[3]	% Population Growth[4]
Patra (Gr)	233,909	84.0	50,750	10.7	14.0	11.9
Heraklion (Gr)	206,909	60.8	60,440	10.2	11.6	25.9
Volos (Gr)	139,051	68.6	30,460	13.9	9.2	13.3
Kavala (Gr)	75,073	68.1	44,189	7.1	24.6	0.4
Kalamata (Gr)	72,258	58.2	35,158	6.2	23.9	12.4
Malaga (Sp)	850,556	125.9	152,185	16.7	22.8	22.7
Palma de Mallorca (Sp)	680,516	48.2	201,843	12.1	19.2	50.6
Alicante (Sp)	464,061	87.1	35,581	21.9	18.3	38.5
Nice (Fr)	847,750	65.9	104,973	44.2	9.9	13.9
Toulon (Fr)	547,844	107.5	309,704	37.9	12.4	12.5
Bari (It)	577,283	204.3	75,526	5.9	24.1	3.7
Cagliari (It)	467,788	36.1	16,054	9.0	19.5	2.8
Pescara I)	231,545	62.4	167,028	11.2	12.1	8.7
Valletta (Mt)	381,675	98.0	24,677	35.7	36.6	10.6

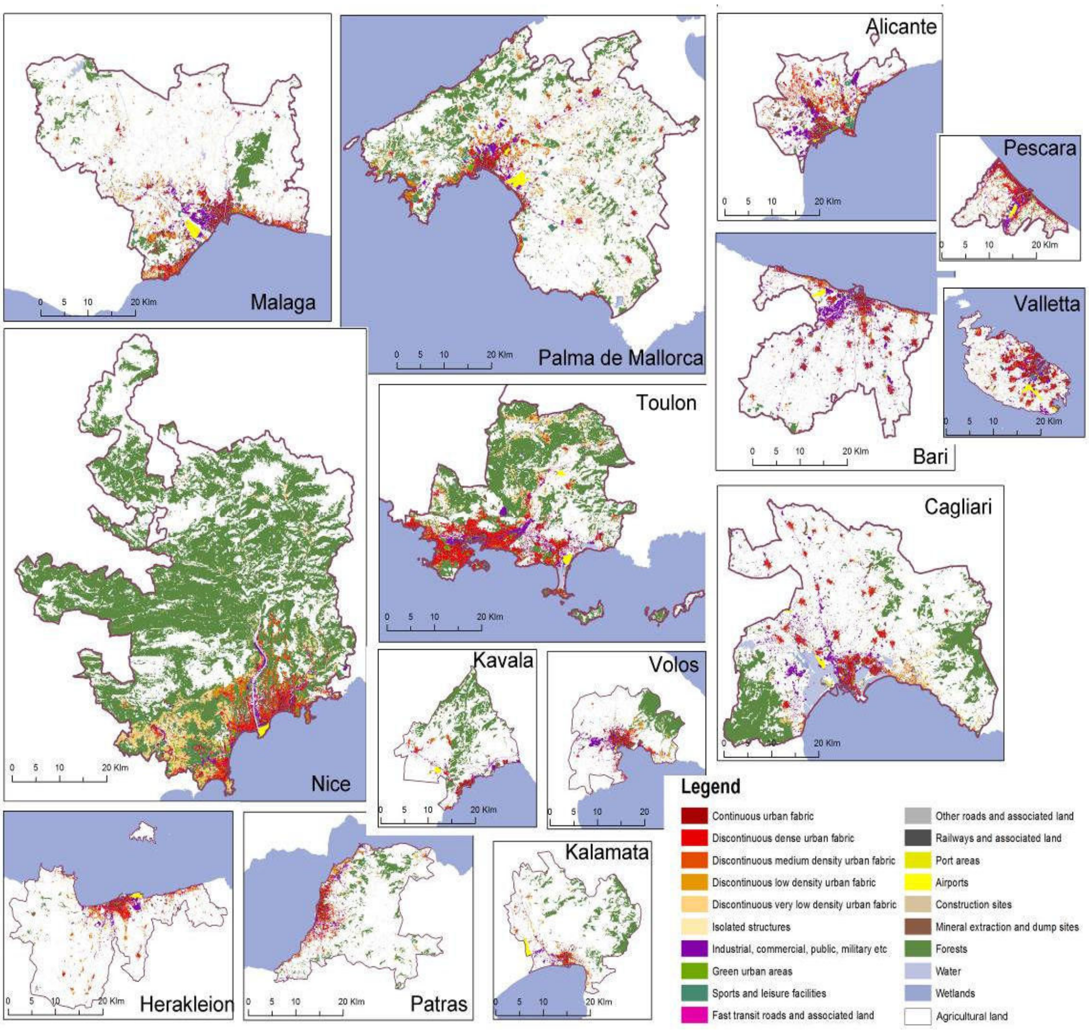
1. Most recent data from Eurostat, on the LUZ level as defined in Urban Audit.

2. Estimated by dividing total LUZ population to urban fabric land as presented in UA 2006

3. Estimated through the GHSL database

4. Population changes estimated between the last censuses for each Country (1991-2011 for Greece, Italy and Spain, 1982-1999 for France, 1995-2011 for Malta) through www.citypopulation.de (on the level of urban agglomeration, province or LUZ area).

Figure 4: Land use maps of the cities in the case study



Source: UA, 2006 (revised version)

Geomorphology plays an important role in shaping urban form. In the Mediterranean rugged topography and sloping landscapes reduce the availability of buildable land, promoting urban growth mainly along the sea coasts or in the main lowland (Tombolini et al., 2015). In Nice, the LUZ area covers a vast mountainous hinterland mainly covered up by forests, a fact that constrains urban growth mainly along the coast and the Valley of Paillon River; while a similar case is observed in Toulon. In Malaga a large plain opens up towards the west and this is reflected in the form of the city which expands mainly towards this direction. A similar asymmetrical development is observed in Palma de Mallorca towards the east, while in Alicante (located in the touristic area of Costa Blanca) urban growth towards the hinterland is not bounded by any physical barrier. In Greece, LUZ areas are considerably smaller and in the case of Volos, Patras and Kavala, development is bounded between the sea and the mountains, resulting to more compact structure. In Heraklion and Kalamata urban land expands more freely towards the hinterland. Finally, in Valletta the whole island is covered by the LUZ area, and the urban areas occupy almost all the northern coast and expand towards the central part of the island, leaving only the southern coast undeveloped.

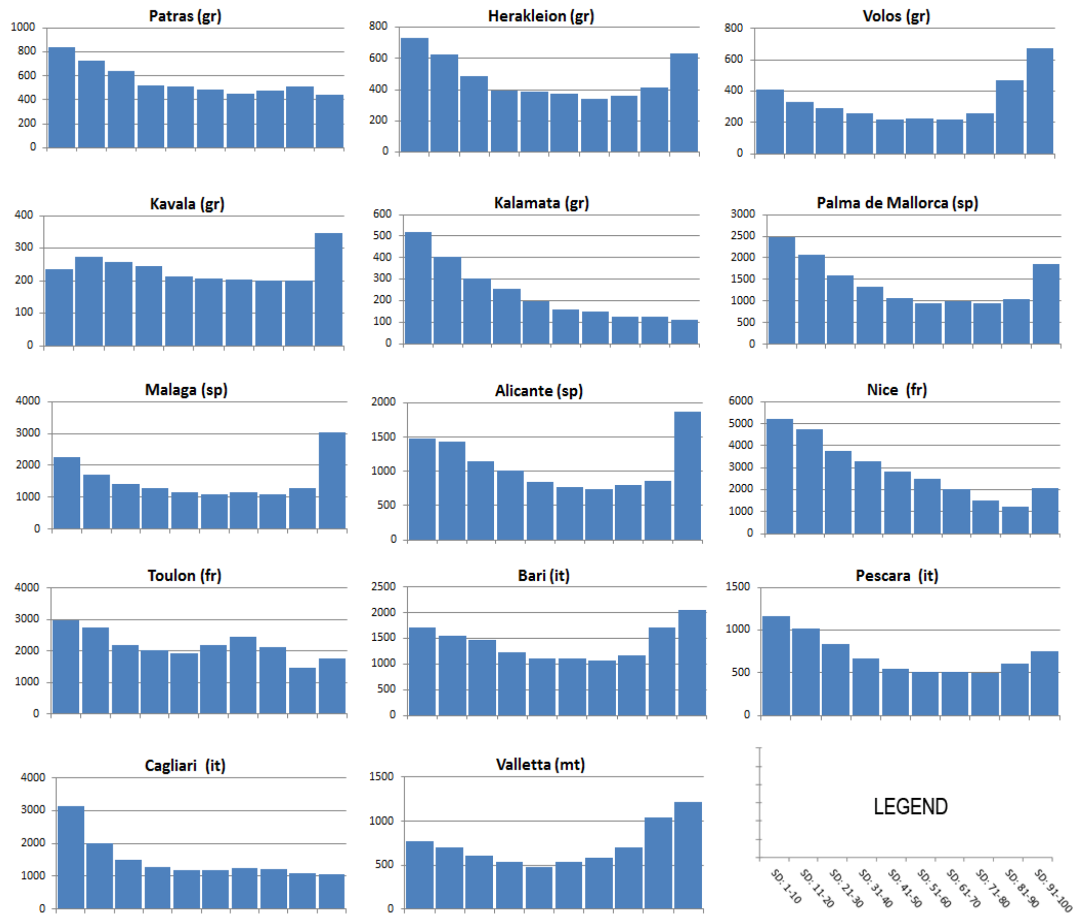
4.2. Results

4.2.1. Soil sealing degree profiles – Urban fabric densities

Based on the ISSD dataset for 2006, the soil sealing degree profiles were estimated. Figure 5 presents the graphs for the 14 cities. Data show that Nice, Cagliari, Palma de Mallorca and

Kalamata are the most sprawling cities, with soil sealing degree profiles asymmetrical to the left. Low density development (as identified by S.D. < 30) is over 52% in Kalamata, 47% in Nice, 45% in Cagliari 43% in Palma de Mallorca. On the other side lie Volos and Valletta which appear to be the most compact cities as their profiles are asymmetrical to the right. High density development (S.D. > 70) is maximized for Volos (42)% and Valletta (41%), followed by Malaga (35%), Bari (34%), Alicante (32%) and Kavala (31%). Cities like Heraklion and Bari form a more symmetrical, U-shaped curve presenting a balance between high and low density development, while in Toulon the distribution is more equal between the different sealing degree categories with medium density covering an important part of the city, and the curve forming a local peak at the range S.D. 50-80.

Figure 5: Soil sealing degree profiles for the 14 cities (2006, ISSD dataset)

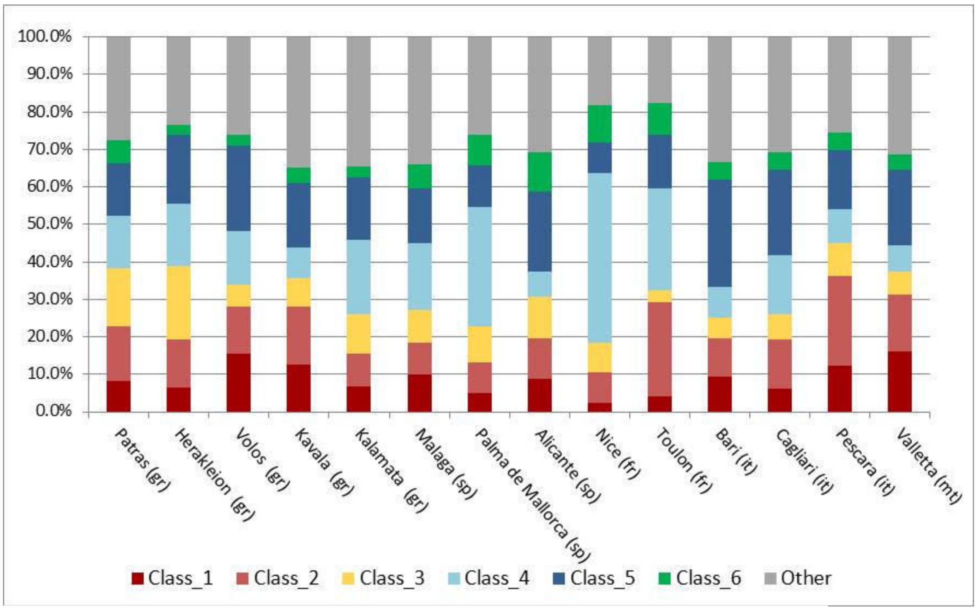


4.2.2. Land use patterns

The distribution of different land use categories shows that UF ranges from 40% to 65% for all cites except for Alicante and Bari where it falls beneath 40% (Figure 6). In Bari this is mainly due to high concentration of industrial/commercial land uses which cover almost all the southwestern part of the city, while in Alicante there are important areas covered by green/sport areas (and also touristic/leisure facilities) on the western sector. In Toulon, Nice, Palma de Mallorca, the urban land is mainly residential (urban fabric land), and percentages of industrial/commercial are relatively low while in cities like Volos, Bari, Cagliari and Alicante the percentage of industrial/commercial uses exceeds 20%. Volos, Kavala, Valletta an Pescara appear to be the more compact cities as class 1 (high density urban fabric) accounts for 12-16% of total artificial land.

The estimation of a set of spatial metrics (PD, MPS, ENN, LJI) for the different land use categories (class level) as well as the landscape as a whole (mean value for all classes), helps us quantify the geometrical/distributional characteristics of land use patches as well as their mixture. In Valletta, Pescara, Palma de Mallorca, Bari, Alicante and Toulon, the overall density of urban patches (PD) is higher (Figure 7), and this is an index of more intense development within the LUZ area. We observe that PD4 is the highest in most cases, showing that patches of class 4 (low density development) are more numerous. On the other hand, the abundance of patches of class 1 and 2 (medium/high density urban fabric) is lower. This is a result of the fact that built-up areas of class 1 and 2 are usually more clustered together forming larger patches.

Figure 6: Land Use distribution (% of total artificial land)



Source: Elaboration on data from UA database, 2006 (classes defined as in Table 2)

This can be seen from the Mean Patch Size graph (Figure 8), where the MPS1 is in most cities the highest. An exception is observed in the case of Toulon and Nice, where MPS is maximized for class 2, a fact that shows that areas of medium density form larger patches. For classes 3 and 4 representing low dense development and sprawl, the MPS are relatively high in Nice, Heraklion, Alicante, Kavala and Toulon. This shows that low density areas are more clustered together at least on the local level. Industrial/commercial areas appear to form larger spatial entities in the case of Alicante and all French and Italian cities, along with Valletta. Large scale tourism development is also considered in class 6 and this probably justifies the high values for MPS6 in Alicante, Malaga and Palma de Mallorca, where tourism development along with parks and sport facilities forms continuous zones along the coast.

Figure 7: Patch density

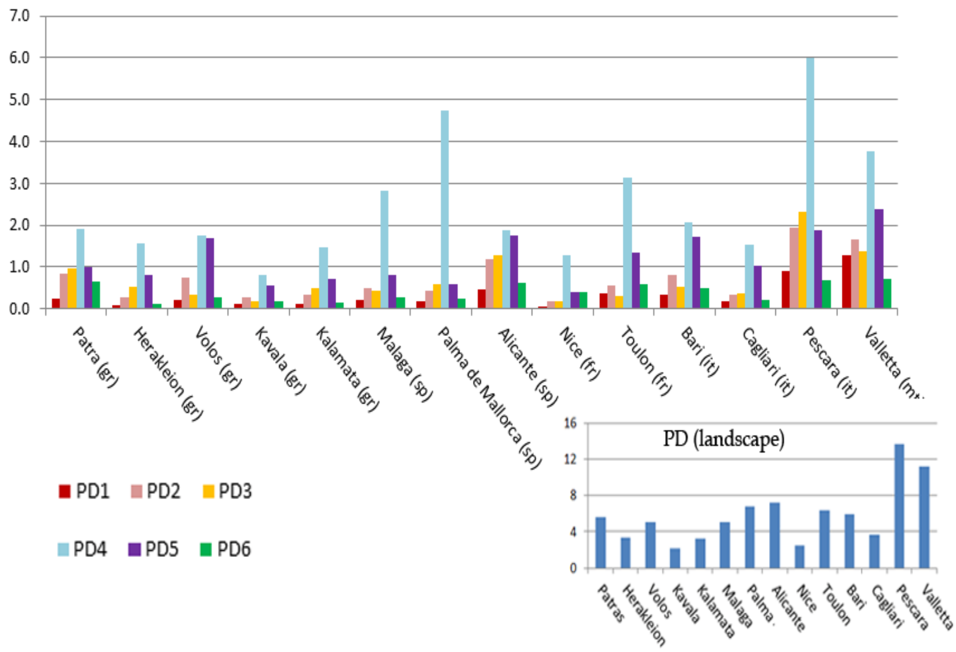
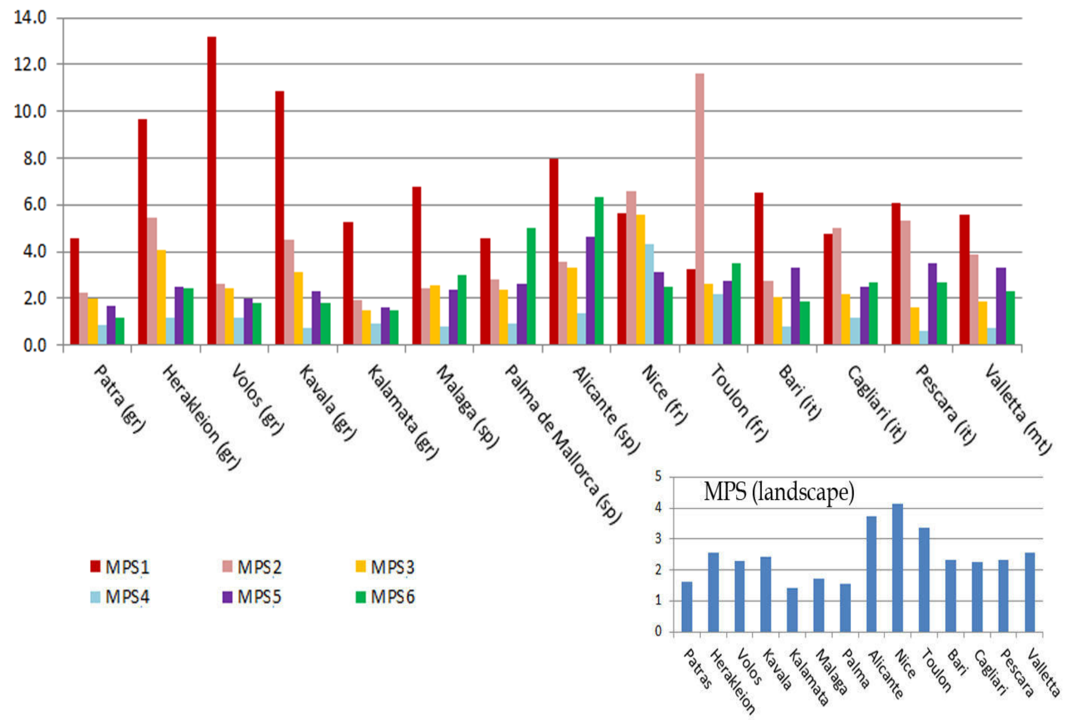
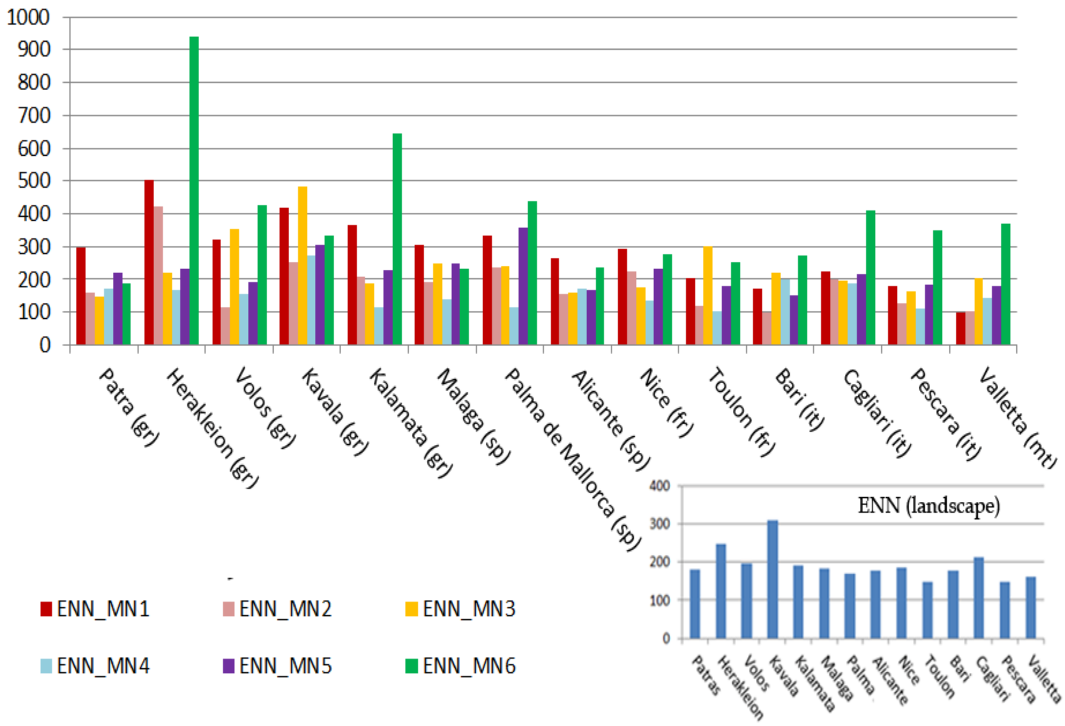


Figure 8: Mean Patch Size



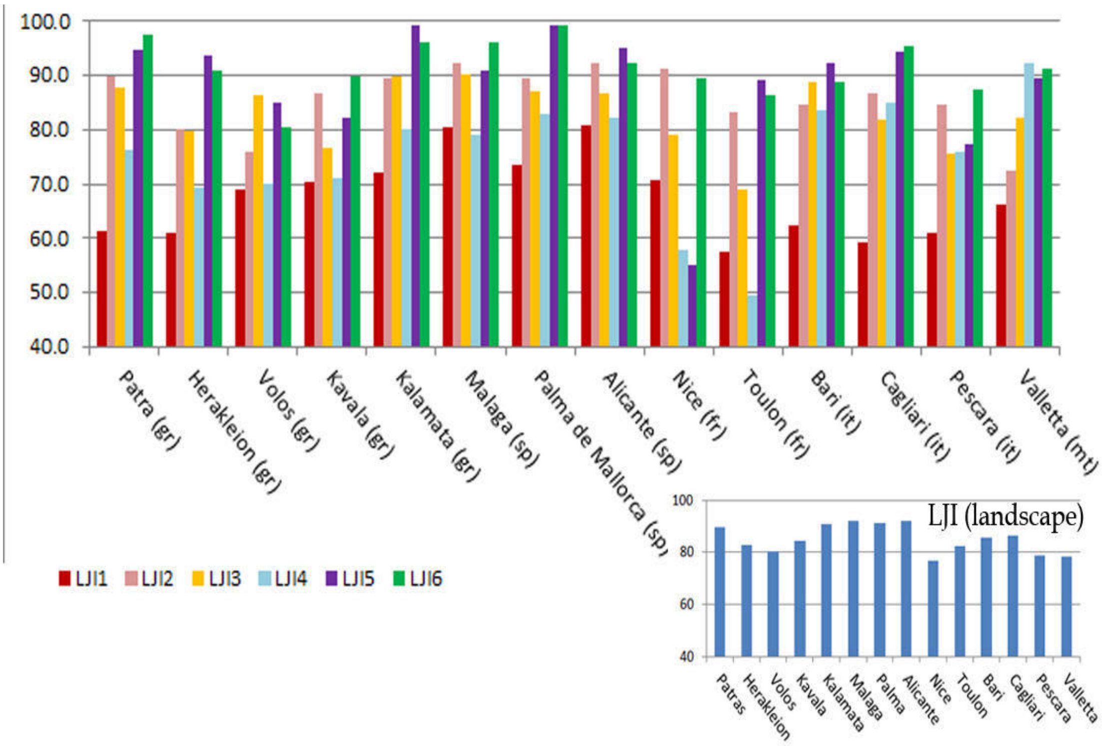
Considering the ENN metrics (Figure 9), important information is obtained regarding the distribution of urban patches across space. ENN values as a mean are higher in the case of Greek cities, (especially Heraklion and Kavala) and also in Cagliari. In most cities the patches of the same type are more closely located to each other belong to classes 3 and 4. This is a result to a homogeneous dispersion of low densities areas across space, leading to smaller nearest-neighbor distances. Medium and high density areas are usually located in central areas of the city and in the core areas of periurban settlements. Industrial/commercial facilities are more dispersed in the case of Palma de Mallorca, Valletta, Cagliari and almost all Greek cities, and this shows that organized zones for such uses have not been planned effectively.

Figure 9: Patch distances



Regarding patch mixture, LJI landscape values show that on the overall the Spanish cities along with Patras and Kalamata are characterized by the highest land use mixture (Figure 10). Different land uses are more separated in Nice, Volos, Heraklion, Valletta and Pescara. Patches of classes 5 and 6 are more clustered together presenting low mixture with the other land use classes. This is particularly evident in Palma de Mallorca, Alicante, Patra, Kalamata, Cagliari and Valletta. Urban fabric classes are more intermixed, with classes 2 and 3 presenting the lowest mixture with other land use classes, and class 1 the highest.

Figure 10: Patch adjacencies/mixture



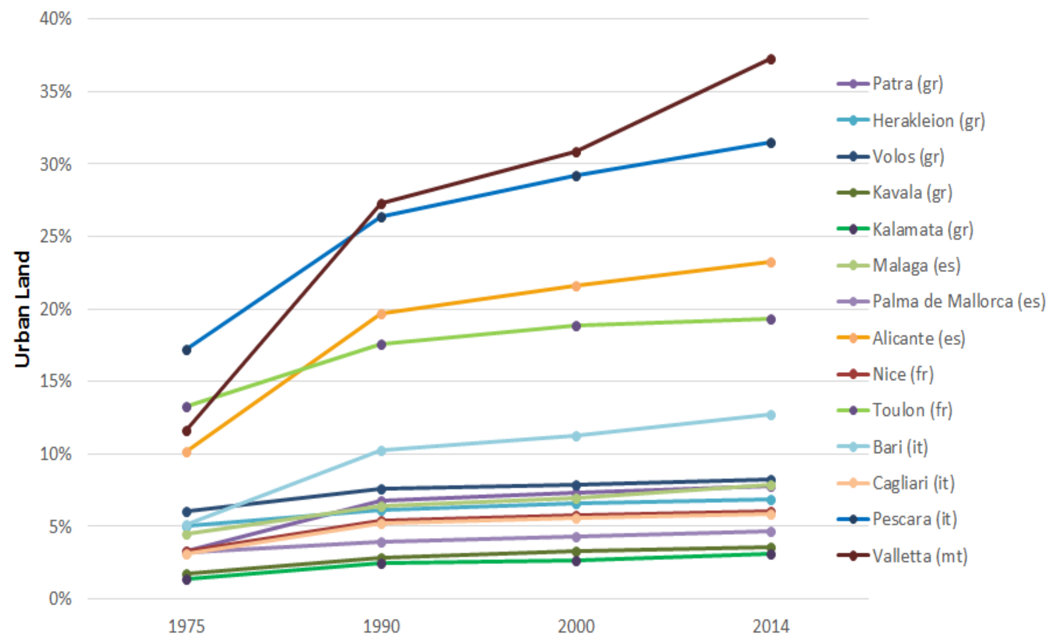
4.2.3. Urban growth trends

According to CLC data, the rate of urban land growth in the period 1990-2012 (considering only urban fabric and industrial/commercial areas) is the highest in the case of Alicante (95%), Palma and Malaga (49%) while for the Greek and Italian cities the rates range from 8-30%. However, as CLC does not depict in detail low density areas with scattered development, and also usually ignores infill in already developed areas, these data are not considered very accountable. Therefore, urban growth trends were evaluated in two different ways: a) by considering the GHSL data for a period covering the past three decades (1975-2004) and showing the long-term trends of urban expansion in the case study areas b) by considering the more recent changes in the period 2006-2012 based on UA data, referring to differing land use categories and distinguishing between high density, medium density and low density areas.

GHSL data are presented in Figure 11. Valletta presents the most impressive growth in terms of urban land growing from 11.6% to 37.3%. This means that more than one third of the total island area is covered by artificial structures). Pescara also presents rapid urbanization trends with urban land expanding at a rate of 53% in the period 1975-1990 and then dropping to the level of 10% and 8%. Generally for most cities the growth-wave seems to gradually slow down, after the first period, however in certain cases (Kalamata, Bari, Alicante, Palma de Mallorca, Valletta) the rates of growth continue to be important (over 12% in the period 2000-2014). Patras and Kalamata appear to be the cities with the most rapid urban expansion in Greece, while in Spain the same holds for Alicante and in Italy for Bari. Heraklion, Volos and Toulon are the three cities with the lowest rates of growth, less than 45% in the period 1975-2014.

Recent changes in period 2006-2012 can be examined by taking into account the UA data (Table 4). The increase of artificial area in the period 2006-2012 ranges from 0.6% in Alicante to 12% in Kavala (in the case of Kavala, this corresponds to only 137 ha of new urban land, mainly attributed to industrial/commercial areas and construction sites). Urban fabric grows by less than 10% in all cities except for Patras, Malaga and Pescara.

Figure 11: Urban land growth in the period 1975-2014



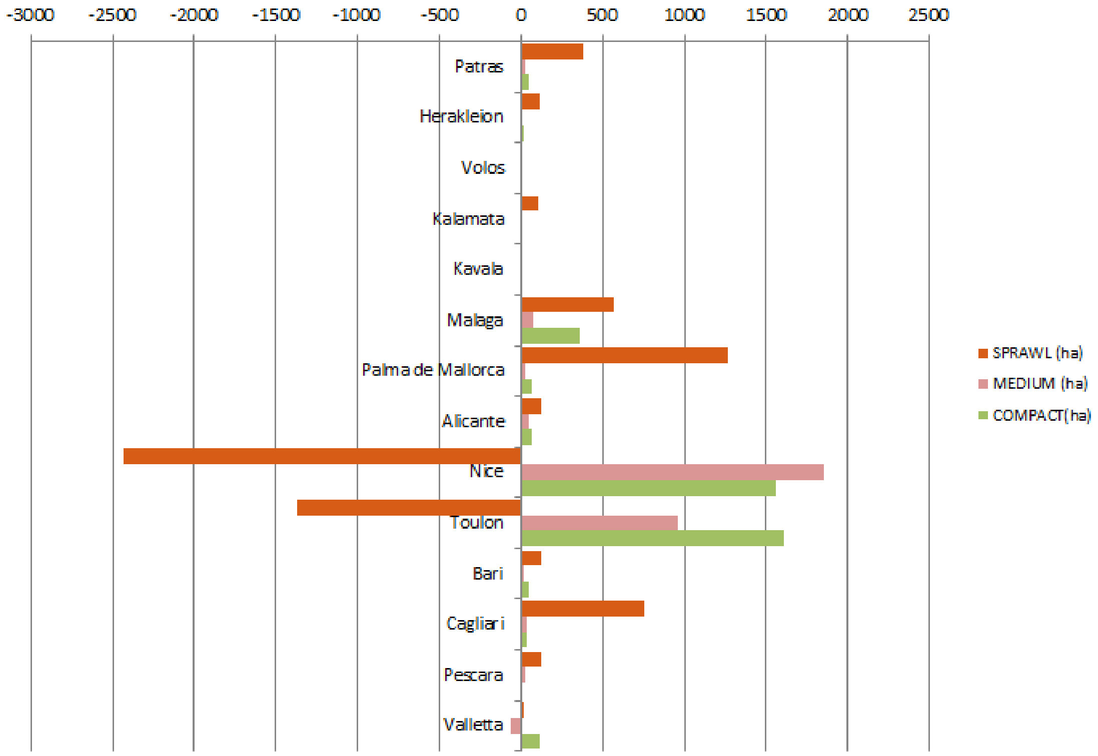
Source: Elaboration on data from GHSL database

In Volos and Valletta the rate of growth drops to less than 2% for artificial area and urban fabric land. While for Volos this could be expected due to the very compact structure of the city and the economic crisis that affected all Greek cities since 2008, for Valletta this fact shows that after decades of rapid growth, a saturation point has been reached. Industrial and commercial areas continue to grow at a rate of more than 15% in cities like Cagliari, Palma de Mallorca and Patras. This fact shows that the expansion of such facilities in the periurban areas remains an important procedure related to urban growth.

Table 4. Land use changes 2006-2012 (UA data)

CHANGES	% artificial area	% urban fabric	% high dense (class 1+2)	% medium dense	% low dense	% indust./commer.
Patra (Gr)	11.2	15.3	3.7	2.8	48.3	16.1
Heraklion (Gr)	2.1	3.7	1.1	0.4	10.5	4.4
Volos (Gr)	1.4	0.5	0.1	0.1	1.4	2.5
Kavala (Gr)	12.0	9.8	1.7	2.6	19.9	5.0
Kalamata (Gr)	5.4	1.7	0.9	2.9	3.2	11.3
Malaga (Sp)	11.4	12.4	10.8	5.0	17.5	11.0
Palma de Mallorca (Sp)	8.0	9.5	1.9	1.2	15.2	18.0
Alicante (Sp)	0.6	5.1	2.8	3.0	15.1	5.0
Nice (Fr)	5.1	8.0	21.8	121.8	-20.0	4.5
Toulon (Fr)	2.8	4.3	41.2	66.2	-15.0	5.5
Bari (It)	4.3	4.1	1.7	2.2	10.8	11.2
Cagliari (It)	4.5	4.8	0.5	4.0	22.9	17.1
Pescara (It)	10.5	11.2	0.9	3.4	27.1	13.0
Valletta (Mt)	1.8	1.5	4.0	-12.5	2.5	1.5

Figure 12. Changes in *ha* per-urban-fabric-type for the period of 2006-2012 (Data based on UA).



Source: Elaboration on data from UA database, 2006, 2012

Figure 12 shows the changes in urban fabric land distinguishing between different categories of built-up densities (Classes 1,2 were combined to account for 'Compact' areas, Class 3 accounts for Medium density areas, and Class 4 accounts for 'Sprawl'). Areas characterized by low density, sprawling development continue to grow at a high rate, while only in the French cities and partly in Malaga important newly developed compact areas appear. In most cities urban fabric expansion takes the form of low dense development which grows by 48.3% in Patra, 20% in Kavala, 17.5% in Malaga, 15% in Palma de Mallorca and Alicante, 23% in Cagliari and 27% in Pescara. The case of French cities is different since there is a densification of urban areas, with low dense areas decreasing and high and medium dense areas increasing in Nice and Toulon, as a total of 1367 ha in Toulon (20% of low density areas) and 2434 in Nice (15% of low density areas) change category from low dense development to medium or high dense development. This densification is important since it shows an intensification process, increasing compactness.

5. Discussion and Conclusions

Results reveal important similarities as well as certain differences between the case study cities. Geomorphology, different levels of population growth and tourism development, differences in the historical and socioeconomic context as well as the different urban planning policies applied, constitute among others, the reasons for this differentiation.

In the case of Spanish cities, population growth remains important since the '90s, while in Italy it is more modest. In Heraklion, Volos, Patras, Palma de Mallorca and Alicante population growth is more important than urban land growth. Therefore, the urban expansion is up to a certain degree justified by need to provide space and infrastructure for a growing population. In Palma new development had to provide space for almost 200,000 new residents, while in Alicante for about 135,000, as in both cities population was growing at a rate of at least 2% per year since the '90s. During the same period the urban land expanded only by 0.7% per year. A similar situation is presented in Heraklion, Patras and Volos, where population growth is more important than urban land expansion.

Valletta and Pescara present a relatively compact structure, with an important percentage of high density areas, but they are also expanding at a high rate. Low density development although small as a percentage, appears to be fragmented and discontinuous as identified by the relevant spatial metrics. High density development is also important in Volos, Malaga, Bari, Alicante and Kavala. On the other hand, Palma, Nice, Cagliari, and Kalamata appear to be the most sprawling cities, with high percentages of low density development. Bari appears to be the city with the highest share of industrial/commercial uses most of them located in the south-western sector of the city but also dispersed in the wider area. In Alicante, Malaga and Palma de Mallorca, tourism development along with parks and sport facilities forms continuous zones along the coast.

The two French cities present a different typology with large clusters of medium density areas and important percentages of low density development. Moreover, a process of densification and infill has been identified for the most recent period. Low levels of land use intermixture and the formation of homogeneous large urban clusters are also characteristics of Nice and Toulon. Greek cities are characterized by compact central areas and periurban development taking place discontinuously, in most cases being organized around existing periurban settlements. Urban growth rates are in most cases lower than the other cities of the case study. Kalamata is a small city affected by tourism development along the coast, and is characterized by low density development and sprawl. On the other hand is Volos, a compact city with a considerable slowdown in terms of urban expansion. In Spanish cities high population growth is related to important urban land expansion. Spatial metrics show that the Spanish cities are characterized by the highest land use mixture.

Generally, for most cities the growth-wave seems to gradually slow down, after the first period, however in certain cases (Kalamata, Bari, Alicante, Palma de Mallorca and Valletta) the rates of growth continue to be important. However, urban sprawl remains an important process reshaping the form of Mediterranean cities. During the period of 2006-2012, the largest share of urban growth takes the form of low density development which in certain cities is highly fragmented and dispersed.

To highlight our general conclusions, we could note that using high resolution land-use data, the monitoring of urban changes and the evaluation of recent urban sprawl trends is made possible. As the growth-wave seems to gradually slow down during the past years, it appears to be the right time to evaluate the new emerging form of Mediterranean cities and to target policies for the future, in order to contain sprawl and to promote a more compact and sustainable way of urban growth.

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