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Urban growth (1956-2012) and soil sealing in the metropolitan area of Valencia (Eastern Spain)

Crecimiento urbano (1956-2012) y sellado del suelo en el área metropolitana de Valencia (E España)
Crescimento urbano (1956-2012) e selagem do solo na Área Metropolitana de Valência (Espanha Oriental)

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ABSTRACT

The aim of this study is to understand the urban growth dynamics from the mid-1950s to 2012 in the Metropolitan Area of Valencia, eastern Spain, and its impact on soils. The study area is a very interesting example of the many changes in land use and land cover in the landscape of Mediterranean alluvial plains. The analysis of urban growth was based on photo interpretation of aerial photographs and GIS based methodology. At a detailed scale (1:10,000), results show that there has been a highly dynamic process produced by the extent of land developed as urban area. In 1956 only 3,441 hectares (9.3% of the overall study area) were occupied by urban use. In 2012 the total sealed surface was 10,523 hectares, around 30% of the studied area. The increase in built-up areas for the whole period was 206%, representing an average annual rate of 126 ha/yr. In the Metropolitan Area of Valencia much of the land converted to urban use was once highly productive agricultural soils. Around 5,763 ha of soil types with very high and high land capability, mainly Calcaric Fluvisols, were sealed throughout the study period.

RESUMEN

El objetivo de este trabajo es entender las dinámicas de crecimiento urbano desde mediados de los 50 hasta 2012 en el Área Metropolitana de Valencia (E España) y su impacto en los suelos. El área de estudio es un ejemplo muy interesante de muchos de los cambios de ocupación del suelo en los llanos aluviales mediterráneos. El análisis del crecimiento urbano se basó en la fotointerpretación de fotos aéreas y en metodologías SIG. Los resultados muestran, a escala muy detallada (1:10.000), un proceso muy dinámico producido por la expansión de la superficie urbanizada. En 1956 solo 3.441 hectáreas (9,3% del total del área de estudio) estaban ocupadas por usos urbanos. En 2012 la superficie total sellada era de 10.523 hectáreas, aproximadamente el 30% del área analizada. El incremento de las áreas construidas durante todo el periodo fue del 206%, a un ritmo medio anual de 126 ha/año. En el Área Metropolitana de Valencia 5.763 ha de suelos con elevada y muy elevada capacidad de uso, principalmente Fluvisoles Calcáricos, fueron sellados durante el periodo analizado.

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RESUMO

O objetivo deste estudo é o de perceber as dinâmicas de crescimento urbano desde meados dos anos 50 até 2012 na Área Metropolitana de Valência (Espanha oriental) e o seu impacto nos solos. A área de estudo constitui um exemplo muito interessante de muitas das alterações no uso e ocupação do solo inserido na paisagem das planícies aluvionares mediterrâneas. A análise de crescimento urbano baseou-se na fotointerpretação de fotografias aéreas e em metodologias GIS. Os resultados mostram, a uma escala detalhada (1:10.000), um processo muito dinâmico devido à expansão da superfície urbanizada. Em 1956 apenas 3441 hectares (9,3% da área total de estudo) estavam ocupadas por usos urbanos. Em 2012 o total de área selada era de 10523 ha, aproximadamente 30% da área analisada. O aumento das áreas construídas durante todo o período foi de 206%, a um ritmo médio anual de 126 ha/ano. Na Área Metropolitana de Valência, grande parte da terra convertida para uso urbano correspondia a solos agrícolas altamente produtivos. Cerca de 5763 ha de solos com elevada a muito elevada capacidade de uso, principalmente Fluvissolos Calcários, foram selados durante o período analisado.

KEY WORDS
High quality agricultural soils, land capability, urbanization, soil degradation, Mediterranean cities.

PALABRAS CLAVE
Suelos agrícolas de alta calidad, capacidad de uso, urbanización, degradación de suelos, ciudades mediterráneas.

PALAVRAS-CHAVE
Solos agrícolas de elevada qualidade, capacidade de uso, urbanização, degradação do solo, cidades mediterrâneas.

1. Introduction

Land use and land cover (LULC) changes, generally considered a local environmental issue, have transformed large landscapes across the world and are becoming practices of global importance (Foley et al. 2005). One of the main driving forces of LULC changes is urbanization, which modifies and creates new structure and organization of natural landscape attributes (Alphan 2003; Alberti 2010). Numerous studies have shown that urban growth has profound impact on the natural environment. Harmful ecological effects of urbanization and their associated transportation infrastructure are, for example, impacts on hydrological processes (Jacobson 2011); air, soil and water pollution (Rodríguez Martín et al. 2015); creation of urban heat islands (Morabito et al. 2016); impacts on carbon balance (Zhang et al. 2012); reduction and fragmentation of natural habitats (Alberti 2005); disappearance of agricultural, forested and natural land (Ceccarelli et al. 2014); and impacts on food security (Gardi et al. 2015).

Soil sealing induced by urban growth has become an important environmental issue in European countries due to changes in the LULC pattern since the mid-1950s. This process is one of the major threats identified within the Thematic Strategy for Soil Protection launched by the European Commission (CEC 2006). Soil sealing, understood as the permanent covering of soil with impervious materials (e.g. asphalt and concrete), creates pressure on soil and may impair its ability to deliver a wide range of ecosystem services for human well-being and soil functions, such us, for example, food and other biomass production, filtering and purification of water, buffering contaminants, nutrient cycling, storing carbon, biological habitat and contributing significantly to Earth's gene pool (Scalenghe and Ajmone-Marsan 2009; Kibblewhite et al. 2012). A sealed soil is not able to fulfil these functions (**Figure 1**). As a consequence, the soil, an essential and largely non-renewable natural resource in a human time perspective, loses its multifunctional role (Blum 2014; García Rodríguez and Álvarez García 2017). The process of urbanization and the consequent soil sealing is reversible only at very high cost, although recent studies suggest that soil sealing is an irreversible process (Prokop et al. 2011; Constantini and Lorenzetti 2013).

In Spain, expansion of urban areas and related infrastructure is occurring in and around the major cities and, above all, on the coast (Serra et al. 2014). Moreover, in the Spanish

Figure 1. Example of soil sealing in Torrent, Valencia. Source: Valera (2011).

coastal areas several researchers show that most of the urbanization and land consumption is taking place on fertile soils, thereby causing a loss of prime agricultural land (Añó et al. 2005; Valera 2011; Navarro et al. 2012). Therefore, evaluation of soil sealing by urban growth is a key element to understanding soil degradation and the disappearance of good-quality soil. From this perspective, the loss of highly productive agricultural soils due to conversion to artificial surfaces constitutes an indicator to assess land degradation in Spain (Barbero-Sierra et al. 2013).

In the Valencian Community, eastern Spain, LULC changes caused by urban growth have affected especially the metropolitan cities of the coastal plains. The socio-economic transformations that have occurred over the last 60 years have exerted great pressure on the land as a consequence of growing metropolitan areas, and these changes have modified the traditional natural landscape. Most of the population and economic activities of the region are concentrated in these urban zones and, for historical reasons, urban agglomerations are often located in areas with high-quality agricultural land. In the Valencian Community most of the soils well suited for intensive agriculture are located in the plains of these metropolitan areas. The main objective of the present study is to assess the impact of urban growth on soils in the Metropolitan Area of Valencia from the mid-1950s to 2012 at a detailed scale (1:10,000).

2. Materials and Methods

2.1. Study area

The Metropolitan Area of Valencia is the economic and administrative center of the Valencian Community, and it is the third largest metropolitan area in Spain. With a population of around 1.3 million people the study area comprises 37 municipalities covering nearly 37,000 hectares (**Figure 2**).

In this urban agglomeration the Huerta of Valencia area, the traditional agricultural landscape, has been gradually replaced by urban uses. The Huerta of Valencia is a complex agricultural system with an intricate network of irrigation canals of Muslim origin. According to the European Environment Agency's Dobris Assessment, the Huerta of Valencia is a restricted-range landscape present in only five other places in Europe. In this irrigated plain, soils are highly productive and can support an intensive and profitable agricultural system. The main crops are horticultural produce and citrus fruits (oranges). Thus, the anthropogenic sealing of these soils has very important environmental implications (**Figure 3**).

2.2. Methods

In this study, the analysis of urban growth dynamics was based on aerial photo interpretation, GIS analysis techniques and change detection by post-classification. Two sets of panchromatic aerial photographs at 1:30,000 scale (1956 and 1984) and three digital orthophotos with a spatial resolution of 1 meter (1998), 0.5 meter (2006) and 0.25 meter (2012) were the input data from which urban changes were established. The reasons for using visual interpretation of aerial

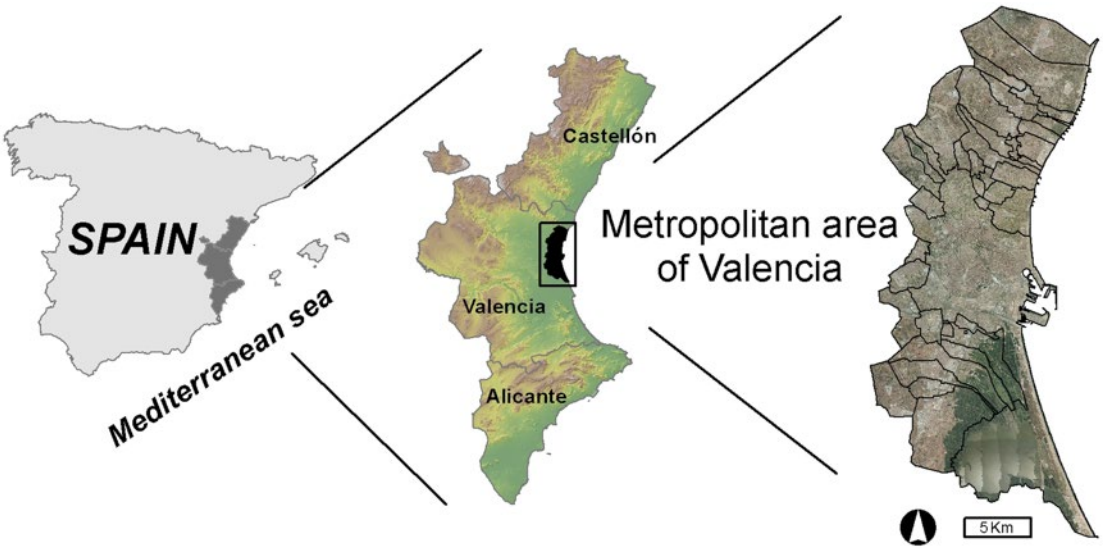

Figure 2. Location of the study area.

photographs were, first, the reliable results of these techniques in the main projects of LULC mapping in Spain (CORINE Land Cover and Spanish Land Cover/Use Information System), and second, the need for a reference date in the 1950s and the application of the same procedure for different time points. Satellite images with proper spatial and radiometric resolution are not available for the entire period. In order to minimize the problems associated with the use of multitemporal source data, a preliminary pre-processing for the aerial photographs was required. Analogue aerial photographs were scanned at high resolution to provide digitized images. These images for 1956 and 1984 were georegistered to the 2012 orthophoto and a digital terrain model, obtaining two orthophotos with a spatial resolution of 2 meters.

Figure 3. Examples of urban growth and soil sealing on Calcaric Fluvisols. Huerta of Valencia. Soil sealing modified hydrological processes, reduced the production of food, limited carbon storage and increased habitat fragmentation.

The reference land use database (2012) was photo-interpreted according to the previously defined legend. A minimum mapping unit (MMU) of 0.25 ha was selected for land use classes. The map legend contained three land use classes: non-urban, low-density urban and high-density urban. The areas strongly affected by human activities related to housing, industry, and commerce were considered urban. The difference between urban classes may vary depending on the percentage of vegetation cover or bare soil in the built-up matrix. When a built-up area was higher than 80% of the digitized unit it was considered a high-density urban area. The units between 60% and 80% were classified as low-density urban areas. The density of houses and infrastructures was the main criteria to attribute a polygon to a land cover class. The threshold of 80%, which divides the continuous and discontinuous classes, was derived from the CORINE land use classification and is commonly used in European countries (Kasanko et al. 2006). A high threshold to separate urban and non-urban areas was selected because of the low size of the MMU. Non-urban areas only included buildings smaller than 0.25 hectares and this underestimation of soil sealing was expected to be compensated by the overestimation on non-impermeable surfaces (smaller than 0.25 ha) into the urban classes. In addition, most of the areas included in urban classes that were not buildings or infrastructures, were small brownfields or urban parks where soil has been partially or fully removed or landfilled.

The geometric elements of a digital topographic map from the Instituto Cartográfico Valenciano were used as ancillary data in the interpretation and delineation of polygons in GIS software at the approximate spatial scale of 1:10,000. Vertices of the polygons and lines of the digital topographic map were the spatial reference points for the accurate delineation of land use units. Numerical identifiers corresponding with the map legend were assigned to each polygon to complete the GIS database. In order to avoid mismatch errors related to the differences of georegistered aerial photos and orthophotos, the last date (2012) was delineated first over high resolution orthophotos (0.25 x 0.25) and then backdated (Thomson et al. 2007). Once the urban land use map for 2012 was completed and revised, the maps for 1956, 1984, 1998 and 2006 were obtained by adding or removing parts of the delineated units or by changing the attribute classes in the database. The maps obtained were revised, validated and corrected by fieldwork. Transect routes across the study area were established and the information of the polygon units of the first version of the map was gradually updated according to the defined legend classes.

Existing soil association and land use capability maps were used to obtain the potential for agricultural use of sealed soils. Soil maps were produced in the late 1980's at a scale of 1:100,000 (LUCDEME - Combating Desertification in the Mediterranean Area – project; Rubio et al. 1996a; Rubio et al. 1996b; CSIC-Universitat de València nd). The soil association map was adapted to WRB (IUSS Working Group WRB 2015) by the authors. Digital land capability maps were produced in the early nineties at a 1:50,000 scale within the framework of two projects financed by COPUT (Generalitat Valenciana). Soil and land capability spatial datasets were intersected in GIS. The smallest discordant areas were reassigned by nearest neighbor algorithms. Cartographic analysis based on GIS and cross-comparison matrices were applied to obtain LULC changes and to overlap urban growth with soil and land capability maps. Spatial and temporal dynamics were analyzed based on this information. According to Lathrop et al. (2007), simple metrics for analyzing, monitoring, and communicating information about environmental change are often referred to as environmental indicators.

This paper provides the results of thirteen indicators applied in the Metropolitan Area of Valencia and mainly focused on soil sealing (Valera 2011). This aspect of urban growth is especially significant because of its impact on critical land resources (Hasse and Lathrop 2003). These indicators were based on five indicator sets used in the analysis of urban land use dynamics and population evolution in 15 European cities from the mid-1950s to the late 1990s within the framework of the MOLAND project (Kasanko et al. 2006). The nomenclature, source and calculation process of the indicators are described in **Table 1**.

3. Results

3.1. Urban growth (1956-2012)

The dynamics of urban growth in the Metropolitan Area of Valencia are synthesized in **Figure 4**. The built-up area covered 3,441 ha (9.3% of the total study area) in 1956 and 10,523 ha (28%) in 2012. The increase in built-up areas for the whole period was 206%, representing an average annual rate of 126 ha/yr. The highest average annual urban growth rate was between 1998 and 2006 (184 ha/yr). Nevertheless, the rate was of 63 ha/yr between 2006 and 2012 (**Table 2**). These changes are linked to regional economic and demographic dynamics, particularly the concentration of population and economic activities in coastal areas. During the past fifty years the increase in population was approximately 90%. In 1956, the population density was 1,794 inhabitants per km^2. Due to earlier industrialization, mainly in the city of Valencia, this value was higher than in other Spanish urban areas. In 2012, the population density was 3,406 inhabitants per km^2. Comparing urban and population growth, some differences can be noted. Between 1956 and 2012 the growth of urban areas was higher than the population growth. As a consequence, the available built-up area increased from 52 to 83 m^2 per person. The sealed surface per capita

Table 1. Indicators: nomenclature, source and calculation process

Indicator	Calculation
URBAN GROWTH	
Built-up area (BU)	Overall built-up area (low and high density urban), including residential, industrial or commercial areas and transport infrastructure. Source: (a).
Ratio of built-up area (PBU)	*PBU = (BU / TS) x 100*
	Where *BU* is the sum of the built-up area and *TS* is the surface of the study area. Source: (a).
Construction sites (CS)	Overall area under construction development for which earthworks and urban non-constructed lots are typical. Source: (a).
Growth of built-up area (GBU)	$GBU= ((BU_1-BU_0) / BU_0)) \times 100$
	Where BU_1 is the sum of the built-up area at the end of the study period and BU_0 the built-up area at the beginning. Source: (a).
Annual growth of built-up area (ABU)	$ABU = (BU_1-BU_0) / t$
	Where BU_1 is the sum of the built-up area at the end of the study period, BU_0 the built-up area at the beginning, and t are the number of years in the period. Source: (a).
URBAN DENSITY	
Ratio of high density urban areas (PHD)	PHD = (HDU / BU) x 100
	Where HDU is the sum of high-density urban areas and *BU* is the sum of the built-up area. Source: (a).
Available built-up area/person (BUP)	*BUP= BU / P*
	Where *BU* is the sum of built-up area (in m^2) on the specified date and *P* the number of inhabitants. Source: (a) and (b).
URBAN GROWTH IN ENVIRONMENTALLY SENSITIVE AREAS	
Ratio of built-up area within the first kilometer from the sea (PBK)	PBK = (BUK / K) x 100
	Where BUK is the sum of built-up area within the first Km from the sea, and K the total area of the coastal fringe. Source: (a)
Ratio of built-up area within protected areas (PBP)	PBP = (BUP / PA) x 100
	Where BUP is the sum of built-up area within protected areas, and PA the sum of protected areas. Source: (a) and (c)
POPULATION	
Population growth (PG)	$PG= ((P_1-P_0) / P_0)) \times 100$
	Where P_1 is the sum of inhabitants at the end of the study period and P_0 the inhabitants at the beginning. Source: (b).
Population density (DD)	*DD = P / TS*
	Where P is the sum of inhabitants in the study area, and TS the total area in Km^2. Source: (b)
SOIL SEALING	
Soil sealing (SS)	Overall soil sealing. Source (a), (d) and (e).
Loss of high quality agricultural land (SL)	Overall sealing of highly productive soils (classes A and B). Source: (a) and (d).

Sources: a) Land use/cover maps elaborated by the authors.
b) Instituto Nacional de Estadística (INE). Instituto Valenciano de Estadística (IVE).
c) Conselleria de Medi Ambient, Territori i Habitatge. Fungobe 2011. www.redeuroparc-es.org.
d) Land capability maps. COPUT project.
e) Soil Maps. LUCDEME project.

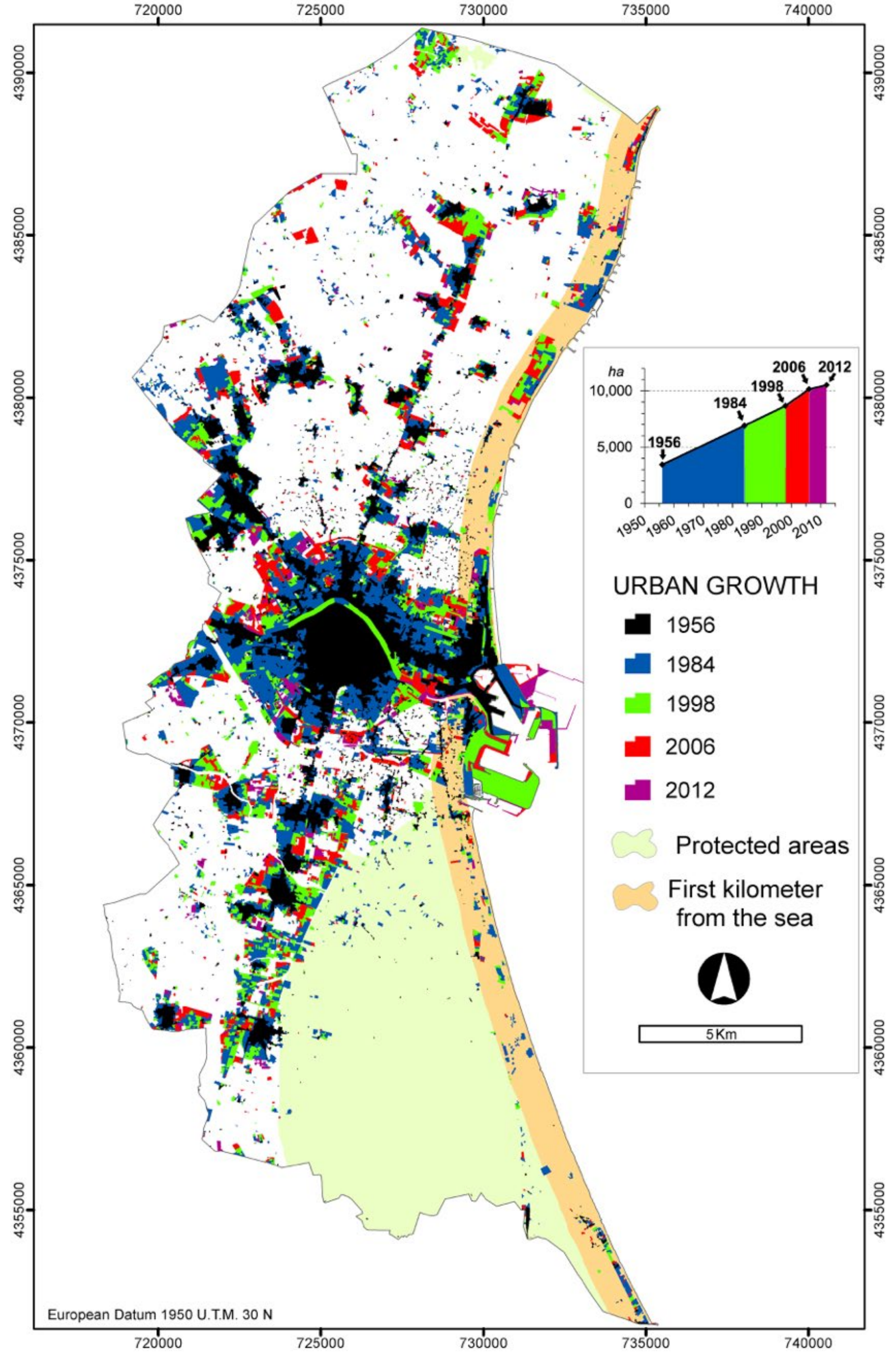

Figure 4. Urban growth (1956-2012) in the Metropolitan Area of Valencia.

Table 2. Indicators result (1956-2012)

Indicator	1956	1984	1998	2006	2012	
Built-up area (BU)	3,441	6,907	8,669	10,144	10,523	ha
Ratio of built-up area (PBU)	9.29	18.66	23.41	27.40	28.42	%
Ratio of built-up area within the first kilometer from the sea (PBK)	10.59	19.38	24.47	26.70	27.84	%
Ratio of built-up area within protected areas[1] (PBP)	0.70	2.62	3.15	3.40	3.46	%
Ratio of high density urban areas (PHD)	81.76	81.84	80.06	79.35	78.38	%
Available built-up area/person (BUP)	51.79	64.06	77.92	81.98	83.45	m^2/inhab
Population density (PD)	1,794	2,912	3,005	3,342	3,406	inhab/km^2
	1956-2012	**1956-1984**	**1984-1998**	**1998-2006**	**2006-2012**	
Growth of built-up area (GBU)	205.85	100.76	25.50	17.02	3.74	%
Annual growth of built-up area (ABU)	126.47	123.81	125.83	184.38	63.18	ha/year
Population growth (PG)	89.80	62.30	3.18	11.22	1.91	%
Soil sealing (SS)	7,135	3,543	1,748	1,473	371	ha
Loss of high quality agricultural land (SL)	5,763	2,818	1,396	1,215	334	ha

[1]From official protected areas in 2011.

in the Metropolitan Area of Valencia was lower than the mean value in the European Union with 200 m^2/person in 2006 (Prokop et al. 2011), likewise in the USA with 274 m^2/person in 2005 (Nowak and Greenfield 2012). High-density urban areas maintained their predominance compared to low-density areas throughout the study period (**Table 2**). This datum is lower than in regions where the phenomenon of second residence or tourism have higher incidence (Parcerisas et al. 2012; Pons and Rullán 2014).

Valencia is the municipality most affected by urban growth. Urban use increased from 2,013 ha in 1956 to 4,591 ha in 2012. It should be emphasized that of the total area (13,444 ha) included in the municipality, 5,685 hectares are protected from urbanization. The remaining municipalities showed similar behavior, with coalescence and compaction of previous urban sites. Some small towns built-up more than 80% of their surface. In other larger municipalities, the constructed area currently exceeded 60%.

The available data have allowed the analyzation of urban growth in two environmentally sensitive areas: the first kilometre from the sea and the protected areas. In the coastal fringe, urban sprawl was partially limited by the presence of extensive wetlands currently protected as well as the high land price in peri-urban agricultural areas. The low incidence of tourism in the metropolitan area also restricted the urban growth in the coastal fringe. However, artificial surfaces within the first kilometer from the sea increased from 10.6% in 1956 to 27.8% in 2012. These values were very similar in the entire study area (**Table 2**). It is important to highlight that 19% of the Metropolitan Area of Valencia is protected land, and is located mainly on the southern coastal fringe. The Albufera of Valencia was declared Natural Park in 1986 and was included as a wetland of international interest in the Ramsar Convention. Urban growth in these areas was very low compared to the entire metropolitan region. Thus, the percentage of built-up area within protected areas only increased from 0.7% in 1956, to 3.5% in 2012.

3.2. Sealing of high productive soils

In the Metropolitan Area of Valencia much of the land converted to urban use between 1956 and 2012 was highly productive agricultural land. In the non-protected area, soils are mainly Calcaric Fluvisols (**Figure 5**). These are young soils developed on flat surfaces, with limited

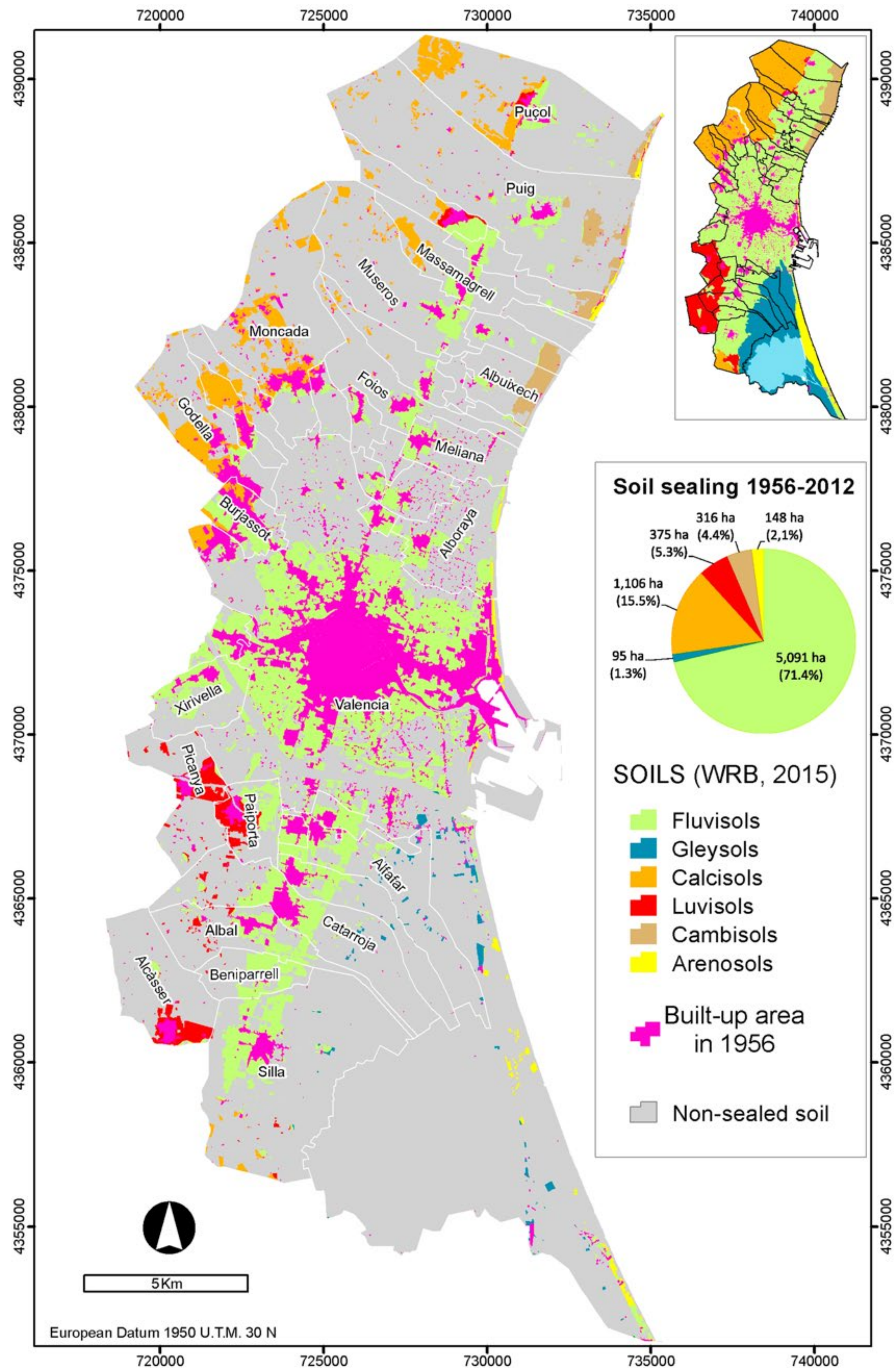

Figure 5. Sealed soils within the study area. Based on LUCDEME Project.

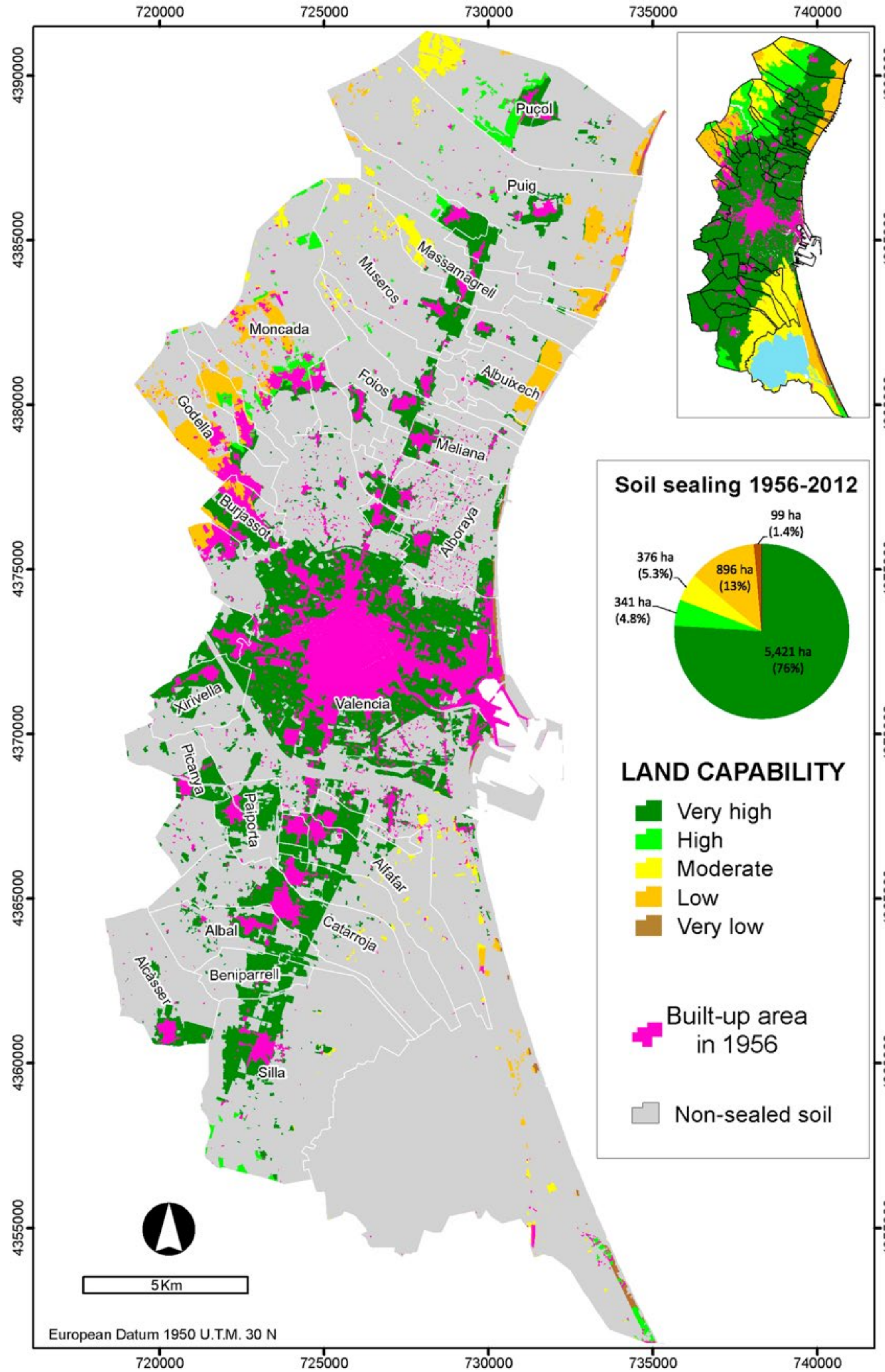

Figure 6. Land Capability of sealed areas within the study area. Based on COPUT Project.

profile development. Their morphology is characterized by lithological discontinuities, with stratified gravel layers that reflect the successive fluvial depositional events. They are deep soils, not stony, with a balanced texture, calcareous with high permeability. According to Zdruli et al. (2011) these soils are highly productive under irrigation and extensive fertilization and are allocated mainly to cash crop production. In the study area built-up areas were mainly enlarged at the expense of the Huerta of Valencia: the traditional agricultural landscape characterized by irrigation through traditional management of water resources.

From the point of view of land capability for agriculture, **Figure 6** shows the area of high quality agricultural soils converted to urban land use. In the Valencian Community, soils with a very high and high land capability are mainly concentrated in the study area. The land capability classification (LCC) applied in the Valencian Community is based on the United States Department of Agriculture Land Capability Classification (Klingebiel and Montgomery 1961). The LCC is based on biophysical features of the Valencian Community (Antolín and Añó 1998). The LCC includes five capability classes: A (Very High), B (High), C (Moderate), D (Low) and E (Very Low). The grouping of soils in the capability classification (class, subclass and unit) is done primarily on the basis of the type and degree of limitations for agricultural purposes. The variables considered in the classification include present and potential erosion, slope, effective soil depth, surface stoniness and rock outcrops, salinity, soil hydromorphy, chemical and physical soil properties. The classification indicates the proper use of soils for general agricultural purposes; therefore land capability maps provide an effective way of presenting land resource data in forms readily understood by non-specialists.

Soils in class A have slight limitations that restrict their use; no extraordinary measures are needed to manage crops. This capability class (maximum quality) corresponds to Calcaric Fluvisols and Calcic Luvisols. Soils in class B have moderate limitations that reduce the choice of crops or require the use of some conservation practices to prevent deterioration. Class B (high quality) corresponds to soil associations dominated by Haplic Calcisols. The map showing overlapping of soil sealing by urban growth and land capability indicated that around 5,763 ha of the most productive soils were degraded or destroyed between 1956 and 2012 (**Table 3**). **Figure 7** displays the time series trends of losing soil by capability classes. These high quality agricultural soils are scarce at a regional scale. The Valencian Community with a surface area of 23,255 km^2 has only 350,000 ha of soils belonging to A (3.9% to the overall

Table 3. Soil sealing in the metropolitan area of Valencia (1956-2012)

	Land Capability Classes											
	A		B		C		D		E		TOTAL	
	ha	%	ha	%	ha	%	ha	%	ha	%	*ha*	*%*
Calcaric Fluvisols	5,043	71	48	1	0	0	0	0	0	0	*5,091*	*71*
Calcic Gleysols	0	0	0	0	83	1	11	0	0	0	*95*	*1*
Haplic Calcisols	0	0	293	4	0	0	0	0	0	0	*293*	*4*
Petric Calcisols	0	0	0	0	293	4	0	0	0	0	*293*	*4*
Petric Calcisols / Lithic Leptosols	0	0	0	0	0	0	520	7	0	0	*520*	*7*
Calcic Luvisols	378	5	0	0	0	0	0	0	0	0	*378*	*5*
Gleyic Cambisols / Calcic Solonchaks	0	0	0	0	0	0	316	4	0	0	*316*	*4*
Calcaric Arenosols / Gleyic Arenosols	0	0	0	0	0	0	49	1	99	1	*148*	*2*
TOTAL	*5,421*	*76*	*341*	*5*	*376*	*5*	*896*	*13*	*99*	*1*	*7,135*	*100*

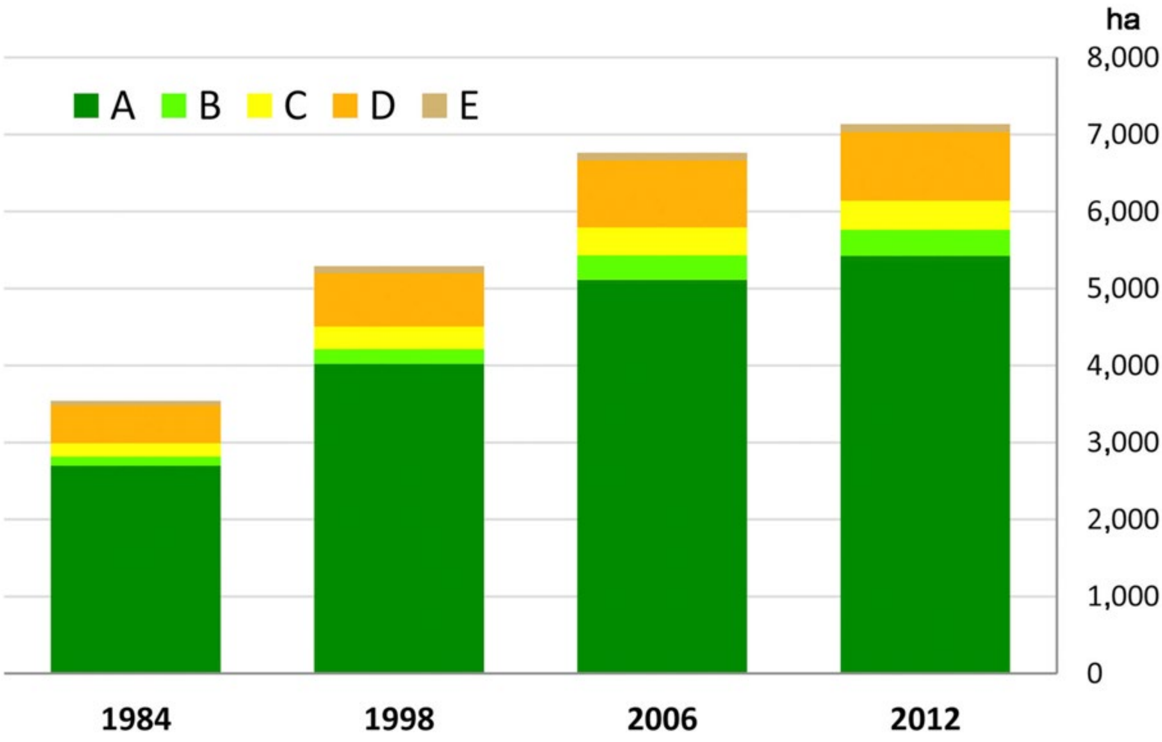

Figure 7. Sealed area by Land Capability classes.

region) and B (11.6%) capability classes (Antolín and Añó 1998).

Our results are consistent with those obtained by other authors in other conditions and countries. In central Spain, from 1989 to 2010, more than 40,000 ha of soils belong to A, B and C capability classes were sealed in the Madrid Autonomous Region (García Rodríguez et al. 2014). Also, consumption of fertile soils, particularly Calcic and Haplic Luvisols, was identified in the municipality of Madrid from 1984 to 2013 (García Rodríguez and Pérez González 2016). In the municipality of Elche, the third largest city of the Valencian Community, 2,580 ha were sealed from 1978 to 2005. Soils with high land capability were most affected by soil sealing (Navarro et al. 2012). This tendency can be seen in other Mediterranean cities. Urban areas in the Metropolitan Area of Athens increased from 53 km^2 in 1948 to 706 km^2 in 2010. Soils with high land capability and low susceptibility to soil erosion were the most vulnerable to sealing (Salvati et al. 2014). Likewise, the sealed soils in the municipality of Rome grew from 8% in 1949 to 26% in 2006 (Munafò et al. 2010). In Rome, urban growth consumed preferentially agricultural soil types classified in the first and second land capability classes (Salvati 2013).

In eastern coastal China, several studies have found that high quality agricultural soils, paddy soils located in flat plains, were most affected by accelerated urbanization (Pan and Zhao 2007; Xiao et al. 2013). For example, between 1990 and 2010 the sealing of soils increased from 4.4% to 10.6% in Zhejiang Province. Among these sealed soils, 68.6% were paddy soils (Li et al. 2015). The loss of scarce agricultural land by urban sprawl is serious in Egypt. In the northern Nile Delta during the 1984-2006 period, soil sealing took place on 247 km^2 of the most fertile soils (class I), mainly Vertic Torrifluvents (Shalaby and Moghanm 2015). Similar conclusions were reached in the study by Mohamed et al. (2015) in the middle of the Nile Delta. The impact of urban growth on agricultural soils is also a serious issue in India. For instance, during the period of 1988 to 1998 the city of Saharanpur lost 1,683 ha of soils belonging to the following land capability classes: I (527 ha), II (940 ha) and III (216 ha) (Fazal 2000). Likewise, Nowak and Greenfield (2012) estimated that 2.5% of the USA was urbanized in 2005 at a continental scale, but urban growth was taking place on prime agricultural land (Nizeyaimana et al. 2001). At a regional scale, the percentage of sealed soils was higher. For example 15% of the most highly productive soils in California were covered with impervious surfaces (Imhoff et al. 2004).

From approximately the beginning of the XXI century, the European Union has identified soil sealing as one of the most important degradation processes, especially in Mediterranean coastal areas. In 2012, the European Commission published the guidelines on best practice to limit, mitigate or compensate soil sealing (EC 2012; Artmann 2013). One of the most effective approaches to tackling soil sealing is spatial planning following an integrated approach, with full commitment of all relevant public authorities (e.g. municipalities, counties and regions). In Spain, planning legislation is the responsibility of the 17 Spanish Regional Governments called “Autonomous Communities”. The authorities responsible for land use planning in the study area are the regional government and local councils. In the Valencian Community, during the last decades, local and regional governments have become interested in attracting flows of people and capital. Thus, according to Burriel (2011), local land use planning approved exaggerated urban expansions. The development of residential areas or industrial parks in more of the metropolitan municipalities does not appear justifiable considering realistic demographic and economic forecasts. For example, more than 70,000 residences were constructed in the city of Valencia between 1990 and 2005, and this growth occurred by largely displacing traditional agrarian landscapes (Prytherch and Boira 2009). In the same period of time, population growth was less than 40,000 inhabitants. The inadequacy of effective land use planning and management at a regional scale in addition to the absence of measures to limit urban growth throughout the successive changes of the regional legislation can be considered as the main causes of this situation (Burriel 2015). Soil sealing comprises one of the main types of human-induced land degradation in the coastal areas of the Spanish Mediterranean region. Soil sealing has the greatest impacts in metropolitan areas where large extents of the land are covered with buildings and infrastructure. The rapid growth of urban areas leads to total soil loss.

4. Conclusions

The urban land transformation experienced by the municipalities of the Metropolitan Area of Valencia since the second half of the 1950s has produced an irreversible loss of the most fertile soils. At a scale of 1:10,000, results show that there was a highly dynamic process produced by the increase of built-up area between 1956 and 2012. In 1956 only 3,441 ha (9.3% to the overall study area) were occupied by urban development. In 2012, the total sealed surface was 10,523 ha, which was nearly 30% of the area studied. The built-up area increased at a higher rate than population growth. Around 5,763 ha of soils types with very high and high land capability, mainly Calcaric Fluvisols, were sealed throughout the study period.

Due to the location of prime agricultural land in the most economically and demographically dynamic area of the alluvial plains, sealed surfaces are expected to grow with time in the Metropolitan Area of Valencia. For example, more transport infrastructure will be built in order to ensure good services between peripheral sites and the centre. Since 2007, the financial and economic crisis in Spain has slowed down or stopped the process of urban growth and soil sealing. At this particular juncture, local and regional land use planning during and after the crisis could determine the degree of environmental sustainability. Nevertheless, it is necessary to regulate the trend and rate of land conversion in order to establish rational land use policy. The aim would be to prevent high quality soils suitable for agriculture from irreversible change caused by urban growth, thereby limiting the soil sealing process as far as possible. Up to now, institutional provisions for protecting soils have been inadequate. Although a specific Territorial Action Plan for the Protection of the Huerta of Valencia was designed and subjected to a public consultation process in 2010, it was abandoned by the regional government. The increased surface of high productive soils sealed in Valencia during the last decades shows the need for effective land use planning policies in these regions were soil is not only a valuable economical resource, but also an environmental and cultural heritage.

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