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Urban Growth and Long-Term Transformations in Spanish Cities Since the Mid-Nineteenth Century: A Methodology to Determine Changes in Urban Density

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Abstract: The current work models urban growth in the continuous built-up areas of 47 Spanish cities from the mid-nineteenth century through to the present day. We did this by compiling a comprehensive Geographic Information System (GIS) dataset, based on a series of historic maps and aerial images, and then used this to study urban growth and to make spatial comparisons. Our chosen indicator of expansion: population density, was calculated by dividing the total population of each city (based on its municipal area) by its built-up area during each period. Our results revealed four different stages of growth, each of which was characterised by a certain political and economic reality. They showed the clogging up of the walled city, the shaping of the urban *ensanches*, the maturity of the compact city and the process of metropolisation.

Keywords: urbanisation; population density; built-up area; GIS; Spain

1. Introduction

The way in which modern cities have evolved has generated an intense debate within the academic community between the models of compact cities and dispersed cities. In Europe, Mediterranean countries have a tradition based on urban compactness, but recent trends show different patterns, leading to the consumption of more space [1–4]. The main characteristic of the compact city is its high level of population density. This depends on its population and the size of its built-up area, which tend to be in a state of constant evolution. As a result, the means used to measure population density may differ greatly, depending on each particular situation. A city may contain neighbourhoods in which high-density blocks of housing can be found alongside others mainly composed of detached housing, yet everything is computed in an aggregated way. Calculations of urban density therefore include important differences from area to area which should be considered when measuring the occupied built-up surface. In our opinion, the limits of the urban fabric should be clearly identified in order to provide the best possible measurements of density, instead of using the whole surface of the municipality, as has previously been common practice. Although this is a complex and time-consuming process, particularly for long-term analyses, in this article, we highlight its interest and show how it can be made feasible.

Recent patterns of territorial expansion in Spanish cities have been accompanied by a major reduction in their population density, which has resulted in serious social and environmental problems. New urban developments have emerged on the urban fringes of the most dynamic cities, contributing to the creation of larger agglomerations [5–8]. New urban sectors tend to be more specialised, either in

socioeconomic status or in terms of land use [9]. Commuting journeys for work and education are now longer. People are more dependent on private cars, which in turn has led to higher rates of spatial and social exclusion [10]. The supply of public utilities and public transport is more expensive. Further, and more importantly, huge amounts of peri-urban lands are being urbanised in a non-return process, although very profitable for some economic agents [11,12]. Many of these cities have evolved from an initial stage of urban compactness due to the existence of consolidated historical centres [13]. This is important because most previous studies only started paying attention to this phenomenon in the 1990s. As a result, until now, important periods of the morphological evolution of these cities have been ignored. Moudon claimed that "the study of urban form can only be understood historically because the elements that define it are subject to continuous transformations and modifications" [14]. With this in mind, we proposed extending the time scale of this type of analysis back in time.

Outside the Spanish context, and at other scales, researchers have based their analysis on variations in urban population [15,16]. The wide time scale adopted for these studies have made it possible to observe cycles of population concentration and dispersion in urban areas and the consequent modification of their land uses and urban landscapes. This overview of the recent bibliography also shows a set of works that we have used as references for our research. It seems clear that there is great interest in related issues such as the impact of urban expansion on the corresponding rural environment. Good examples are provided by works dedicated to Athens, Toulouse, Rome and Spain [17–20]. In more general terms, researchers have also paid attention to the correlation between the rural environment and the distribution of population [21]. Other studies, more based on demographic data, have analysed interdependence and the formation of metropolitan subcentres [22,23]. All of these studies have mainly focused on the period after 1960. There are few cases in which the research conducted has included statistics dating back to the 19th century, such as a demographic study of Italy; and a geographical study of Great Britain, Belgium and the Netherlands [24,25]. On the other hand, most of these authors have analysed data at the municipal level, without using historic cartography to interpret spatial changes in urban morphology. Our methodology can thus shed new light on this subject.

Returning to the Spanish case, this process of urban expansion has been particularly intense due to historical circumstances. The decision taken in 1959 to drastically liberalise its economic policy was a watershed in the history of modern-day Spain. The country's economic potential had been repressed during the Civil War (1936–1939) and the subsequent years of political autarky. The liberalising policies of 1959 produced an explosion of the latent energy that had hitherto been lain dormant. As a result, the period 1960–1973 marked the beginning of a process of rapid transformation in terms of domestic migrations and was associated with intense urban growth. From an urban planning perspective, ensuring the understanding of the urban growth phenomenon and helping to define appropriate policies to implement are key considerations. Housing supply and housing demand should be balanced between and aligned with the location of economic activities and land uses. An unbalanced evolution of such variables can lead to uncertain scenarios, in which geographical specialisation undermines the proper functioning of cities and their surrounding areas. All in all, our research would seem particularly appropriate at this moment in time.

We have therefore focused on the evolution of the 47 provincial capitals in Spain's continental territory. Many of these have expanded from initially being compact urban units based on, and around, consolidated historical centres, but the current urban landscape is far more heterogeneous. The initial research question aimed to show whether these cities maintained a level of demographic stability in terms of their population densities, or if—on the contrary—they exhibited significant changes over time. The sample of cities chosen also allowed us to make a geographic reading of the results obtained and to identify different patterns in different regions. We therefore began by defining an indicator of population density. This was calculated by dividing the total urban population by the continuous built-up area of each city in each period. The objective was to interpret the process of urban transformation which converted the small cities of the nineteenth century—many of which had

been walled enclosures—into modern-day urban metropolis [26,27]. We quantified the phenomenon using GIS (Geographic Information System), estimating the extension of the urban fabric to determine changes in the continuous built-up area. We also proposed extending the scale of our analysis back in time for a century and a half using historic cartography. The wider time scale helped us to observe cycles of concentration and dispersion of population in specific urban areas, and particularly to identify which cities developed the most. Our innovation in relation to previous studies is that we propose combining large series of population data with a new variable of built-up areas to estimate the fluctuation of population density within a context of constant urban growth [28,29].

The article is divided into five sections. After this introduction, we explain the information compiled to create our dataset. We then describe the methodology employed to generate indicators of the built-up area and the density of urban population. The fourth section presents the results obtained and the fifth includes a discussion and historical contextualisation.

2. Materials and Methods

2.1. Sources of Data for the Reconstruction of the Built-Up Area

As mentioned, the objective of the current work was to measure urban growth and to determine the population density of Spain's provincial capitals since the middle of the nineteenth century. Our selection of provincial capitals provided us with a wide range of reliable historic cartography from 1850 onwards [30]. Their various sizes and geographical distribution throughout the country also ensured a coherent sample (Figure 1).

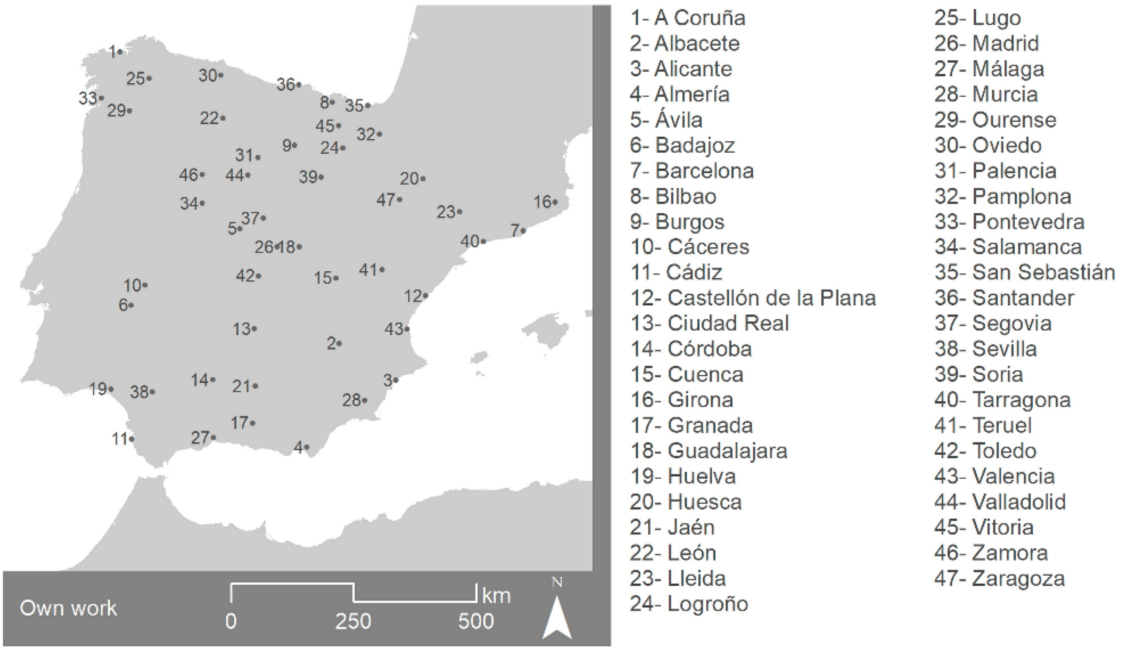

Figure 1. Spatial location of our sample of cities.

Given the evolution of cartographic techniques throughout the period under study, we had to consult and combine different kinds of sources to cover comparable periods at 25-year intervals. For the initial periods, we mainly used historical maps and city plans. Later, we relied on aerial orthophotography obtained from different sources. Finally, for the most recent periods, we used the Corine Land Cover (CLC) database created by the European Environment Agency (EEA).

We selected our source documents bearing in mind three basic characteristics: firstly, the fact that each urban block had to be visually identifiable; secondly, the preferred system for representation was the orthogonal projection; and, thirdly, the minimum scale had to be 1:50,000 to ensure enough

precision. This allowed the use of the first series of the National Topographic Map (1875–1968) for those cities where more detailed data sources were not available.

Collecting the historic maps and plans proved the most laborious part of the research. The Atlas of Spain and its Overseas Possessions, by Francisco Coello, which is associated with the "Geographical Dictionary of Spain", was our initial source. Although this atlas is incomplete, its map series covers 223 cities between 1847 and 1870 [31]. Another relevant collection was the work entitled "Regional Spain", which contains urban plans of the main provincial capitals at the beginning of the twentieth century [32]. The 25-year periods that these major collections left uncovered were filled using maps and plans obtained from surveys by public authorities. When this material was not available, we used secondary source materials included in travel guides and other publications used by commercial associations to promote their businesses [33]. Although not all of the sources were official cartographic surveys, they provided revisions and upgrades with a sufficient degree of accuracy to meet our needs.

In the case of aerial photography, we mainly worked with two photogrammetric flight series. The first, referred to as Series A, corresponded to flights carried out by the US military between 1945 and 1946; this was the first aerial photography project to cover the whole of mainland Spain [34]. The second, called Series B, was also produced by the US military and dated from 1956 and 1957. Both flight series responded to the geostrategic need to control the territory during the Cold War period. On the Spanish side, the main motivation for the authorities was to access graphic material of great value without any economic cost to the taxpayer.

For the most recent periods, we obtained information about the space occupied by cities from the Urban Morphological Zones (UMZ) database of the EEA. These are based on polygons, generated using data from the CLC, which delimit the space occupied by urban areas as a type of land use. They were available for the years 1990, 2000 and 2006. As we shall see in the next section, the way they were represented also served as a point of reference for homogenising the rest of our data.

As a result of this data compilation, we obtained over 400 examples of cartographic evidence relating to the urban growth of Spain's 47 mainland provincial capitals [35]. The exhaustive procedure applied involved recompiling all the information available and leaving only a limited number of gaps for specific cities and periods (Table A1 in the Appendix A).

As regards demographic data, the information used was obtained from Spanish population censuses. We selected the census years that were closest to most of the cartographic sources. As a result, we used the population censuses for the years 1860, 1887, 1920, 1940, 1960, 1991 and 2001. In this regard, Spain experienced several changes in its municipal boundaries during the period under study, especially in rural areas suffering depopulation and in the surroundings of the largest cities. To facilitate historical comparisons, we used a dataset in which total population at the municipal level was homogenised for the 2011 municipal boundaries. The data and methodology used for this purpose were explained in previous papers [36,37]. The sources mentioned in this section were combined as described below.

2.2. Methodology for Defining H-UMZ and Estimating Urban Density

Compiling cartographic information from a diverse variety of sources requires specific work to process the information and make it comparable. Differences in scale, orientation or projection made it difficult to read and analyse the material depicted on the maps [38]. We had to devise a specific methodology for the construction of a homogeneous GIS showing the evolution of Spanish cities. We therefore opted for the creation of Historical Urban Morphological Zones (H-UMZ). Although there had been a precedent for UMZ in Spain, based on the Land Use Information System (whose Spanish acronym is SIOSE), we preferred to define a new methodology that could be readily assimilable with the EEA's UMZ (Figure 2) [39,40]. This enabled us to start from an existing database and to create a retrospective view by projecting backwards until the mid-nineteenth century.

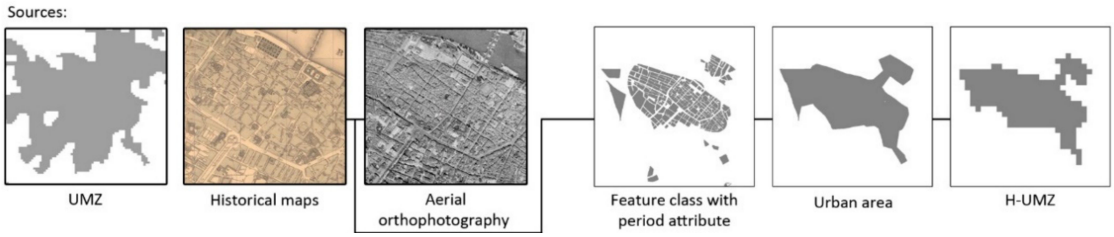

Figure 2. Process of adapting the historical sources to the Urban Morphological Zones (UMZ).

The process of transcribing the cartographic sources was carried out manually and involved identifying the urban fabric constructed in each period and city with respect to the cartography. We established the year in which each plot, or urban block, was developed by using GIS [41–44]. We did so by assigning a binary variable: value of 1 to urban blocks already built and value of 0 to the rest. This part of our work required various iterations until we were able to ensure that the resulting GIS map matched our old urban maps. We acknowledge that finding spatial relationships between recent and historical sources can be confusing and tends to be rather subjective. It can result in geometric distortions, distort our understanding of urban change or even cause a lack of correspondence between the present and historic urban fabric of the city [45]. The quality of the sources has a direct influence on the reliability of the results, especially for the initial periods when it is easier to misread the original data.

A representation of the city at the plot level was therefore first transformed into one of urban areas for each period and then into H-UMZ. The objective behind defining the urban areas was to group together all the blocks that formed part of the urban fabric to create a single polygon. The parameters used for the grouping of these elements also made it possible to include the river courses and channels of communication belonging to the urban space. The EEA's UMZ finally grouped together residential, commercial, industrial and gardened zones, as well as the river courses and communication channels which separated neighbouring plots within the built-up area.

The result was a polygon of continuous urban areas that did not distinguish between different land uses. The next task was to aggregate the H-UMZ. By definition, these zones had to be "a set of urban areas lying less than 200 m apart" [46]. We began by using previously generated urban areas, which we spatially aggregated with other neighbouring areas lying less than 200 m from them. Finally, we converted the resulting polygons into a 100 × 100 m vectoral grid in order to morphologically harmonise across cities and periods. In this process, we also eliminated any elements that were smaller than 25 ha in area: the minimum cell size for the CLC.

The result was the H-UMZ database for Spain, which made it possible to identify the space occupied by urban zones in the main Spanish cities during each period. Figure 3 shows the practical application of this method for San Sebastián, with seven time-slices between the years 1867 and 2006. This harmonised process allowed us not just to quantify the physical extension of each city, but also to cross this information with other types of data such as population censuses.

Finally, we calculated the population density based on the relationship between the population and the built-up area corresponding to each period and city. Population density is often measured by dividing the population of a given administrative area by its total surface area. Our method relied on the division only by the actual built-up area, estimating the real density of the city and excluding any bare land (Equation (1)). This measure gave us a comparable indicator with which to assess changes in urban density, both in qualitative and quantitative terms.

$$\text{'Net' Population Density} = \frac{\text{Population (inhab.)}}{\text{Built} - \text{up Area (Ha)}} \quad (1)$$

Two main criticisms can be levelled against this approach. First, it is important to note that some small rural nuclei were included within the municipal areas. Although these lacked sufficiently

large size and were omitted by the H-UMZ estimation, we included their populations, assuming the deviation that this implied was fairly small. In any case, this omission underestimated the growth in the built-up areas, limiting the decrease in our calculations regarding population density. Second, it is worth noting that urban areas in large cities tended to overspill their municipal boundaries, which means that the actual built-up area considered in our study was limited by the administrative boundaries. However, this effect was only significant for interpreting the last two periods and for certain specific cities, most notably Barcelona and Bilbao.

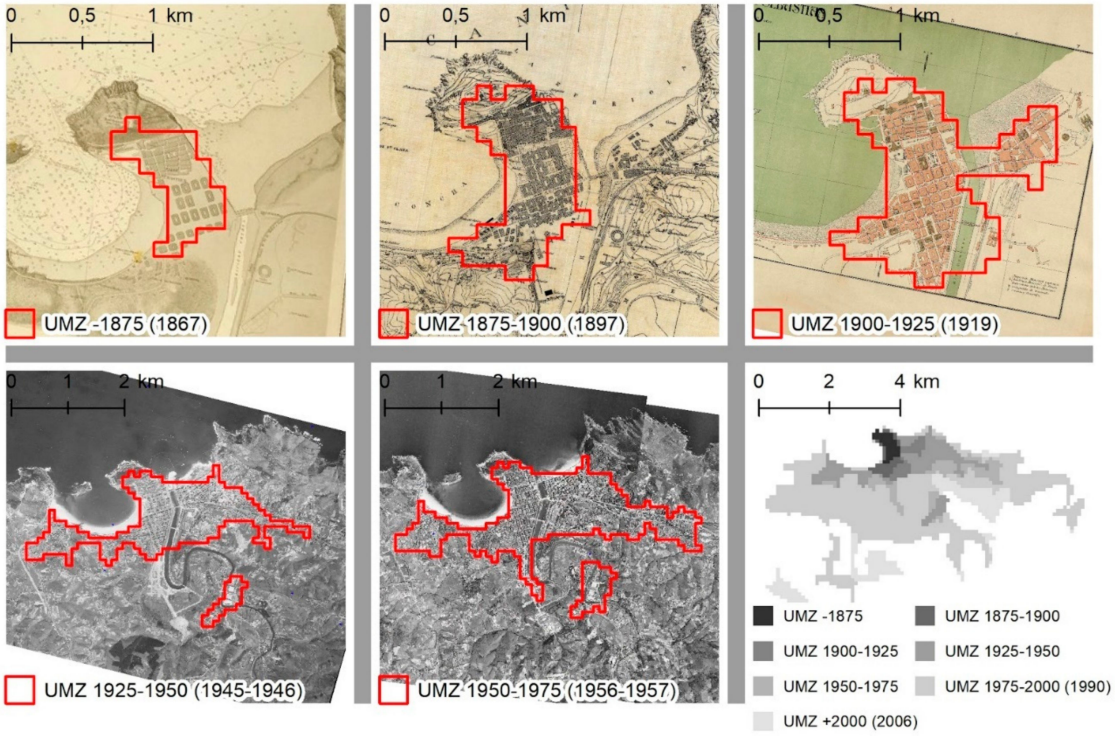

Figure 3. Evolution of the H-UMZ for San Sebastián based on cartography and historical reference photograms.

3. Results

The total built-up area of the municipalities analysed grew continuously from the beginning of the period studied. Its total size expanded from 63 km^2 to over 1400 km^2 in 2006. This means that its siza multiplied by a factor of 22 in a century and a half, implying an average annual growth rate of about five per cent.

Table A2 (in the Appendix A) shows the results considering the increases in the size of the built-up area for all of the periods and cities studied. As expected, Madrid was the largest city in all of the periods analysed, having started at 966 ha. It was followed by Sevilla and Barcelona, both with initial areas slightly over 400 ha. At the other extreme were cities such as Logroño, Ourense and Pontevedra, with initial built-up areas of less than 30 ha. Whereas in the last period, the smallest cities were Soria, Cuenca and Huesca, whose areas ranged in size from 529 to 640 ha. The largest cities in the latest period were Madrid (27,858 ha), Zaragoza (8667 ha) and Barcelona (8464 ha).

The average size of the cities studied was 133 ha in the initial period, while by the final period it had grown to over 3000 ha. This evolution shows the tremendous growth experienced by all of the cities. In absolute terms, it has been the initial largest cities that have grown the most. For example, the initial surface areas have multiplied by factors of 28, 43 and 20 in Madrid, Zaragoza and Barcelona respectively. However, in relative terms Alicante, Santander, Burgos and Ourense are the cities that have experienced the greatest urban growth, multiplying their initial surface areas by factors of more than 60. In contrast, the municipalities that have grown least have been Soria, Cuenca, Cádiz and

Huesca, whose total growth in urban area ranged from 488 ha in the case of Soria, to 596 ha in that of Huesca. In relative terms, the cities that have grown least have been Cádiz, Granada, Jaen and Segovia. In the case of Cádiz, the total built-up area has multiplied by a factor of five, while it has multiplied by almost eight in the other cities [47].

Figure 4 shows the percentage of municipal area occupied by the urban fabric by periods. We can observe that the greatest growth in the total built-up area has taken place during the last two periods. In 1975–2000, the total growth for the whole sample was 78,001 ha, while it was 35,057 ha in the very last one. The factors that most determined these results will be explained in the discussion section.

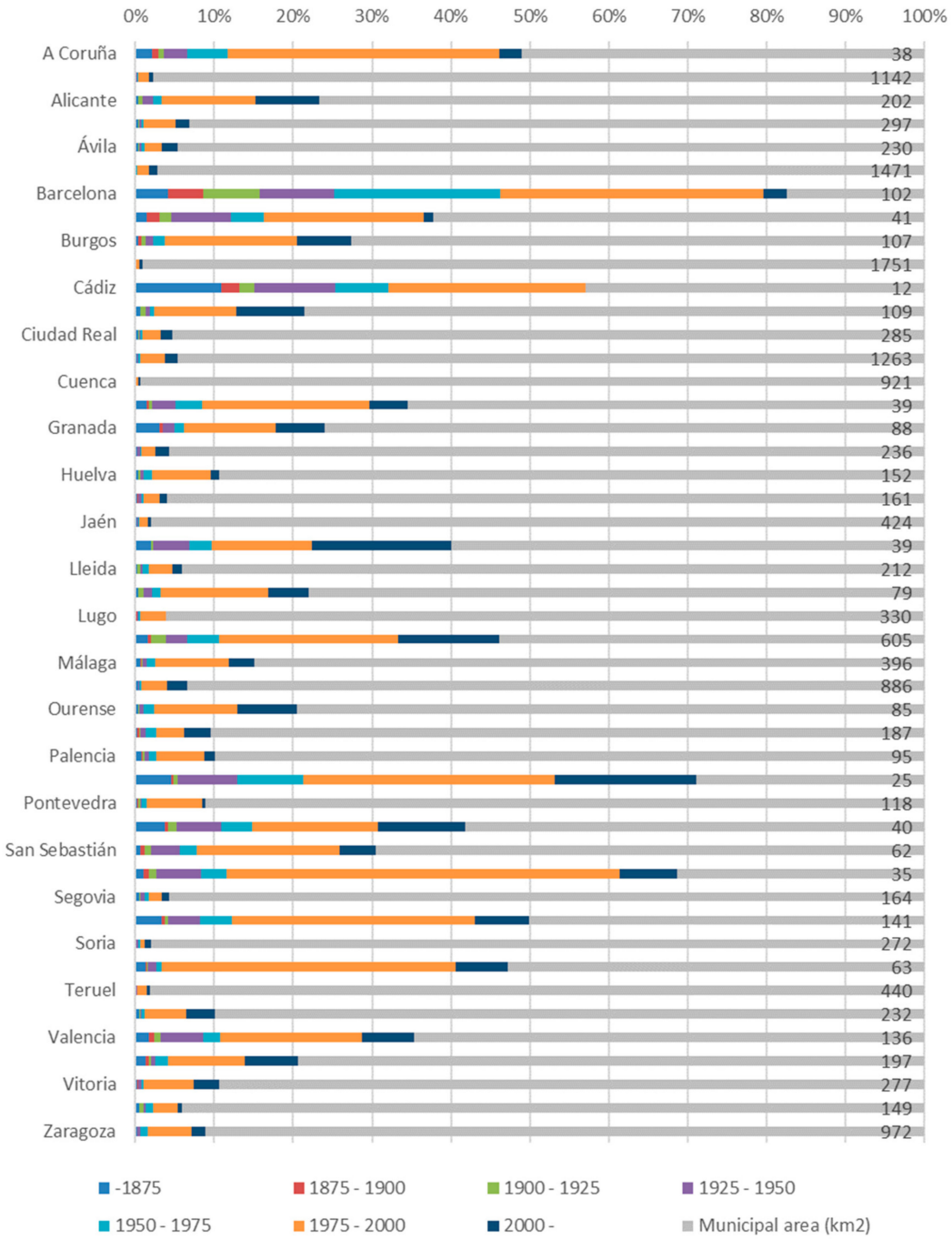

Figure 4. Percentage of municipal area occupied by urban fabric. In the right margin, the total surface area of the municipality is given in ha.

Some results should, quite logically, be treated with a certain degree of caution. Cases such as Barcelona and Cádiz present a high percentage of surface occupation of flat terrain. Meanwhile other areas of their municipalities correspond to zones in which the characteristics of the terrain have made construction either difficult or almost impossible. As a result, their expansion has spilled over into neighbouring municipalities. Pamplona and Santander also presented a high percentage of occupation because their municipal areas are relatively small. In contrast, those of Caceres and Cuenca are very large and predominantly rural in character. Taking this into account, we compared this information with the total population figures for these cities.

This growth in the built-up area has been accompanied by an increase in population from 2 to 13 million, considering all 47 cities. Although this increase has been considerable, it has been much smaller than that in the total built-up area. The difference between the rhythm of growth of the urban area and that of population has resulted in variations in the population density of each municipality which, in turn, serves as an indicator for analysing the compactness of these cities. The reduction from 323 inhabitants per ha (the average population density in the first period) to 84 in the last one can be explained by the transition from the compact city to a new model more characterised by urban sprawl. Even so, these changes have not been homogeneously spread over space and time.

Table A3 (in the Appendix A) shows data for the population density of the built-up areas organised by periods. The shaded squares in the table show periods of higher population growth related to the expansion of the surface areas. Bilbao, for example, went from having a population density of 516 per ha in the initial period to one of 719 per ha in that of 1900–1925. During the latter periods, there has been a general fall in population density, with all of the cities studied losing compactness. The largest decreases in population density were recorded in the period 1975–2000 and are attributable to rapid expansion and urban sprawl. In this period, all of the cities experienced declines in their population density. Good examples of this tendency are provided by Murcia, whose population density fell from 379 to 93 inhabitants per ha, and A Coruña, where it fell from 395 to 142 per ha.

Analysing these variables by region, or autonomous communities, allows us to confirm the general patterns, but also to identify some singularities. Figure 5 plots the evolution of the two disaggregated variables: population growth and growth of the built-up area of those cities under study.

In terms of population growth, the figure shows a gradual tendency for growth in average terms, but the different regions perform differently. The cities in the northern regions, País Vasco, Asturias, Cantabria and La Rioja, showed high rates of population growth in the first two periods, as did the capital, Madrid. In the final period, cities in Navarra led the growth followed by those in La Rioja, País Vasco, Valencia and Cataluña. Murcia and Aragón, on the other hand, were the regions whose cities had the lowest levels of average population growth throughout the study period. These results are in line with those of previous related studies [13].

In terms of the built-up area, the growth trend has been exponential, with virtually zero growth in the first periods and a pronounced final rise. The regions with cities showing the highest growth coincide with those with the highest population growth: Cantabria, La Rioja and País Vasco. On the other hand, in Murcia, Castilla y León, Andalucía, Navarra and Castilla La Mancha, the average growth values of cities lag far behind those in the leading regions.

Whatever the case, the disaggregated data obtained by region was not considered significant enough to perform more detailed analyses. We therefore opted to interpretat the aggregate results, including all the cities analysed.

Figure 5. Disaggregated growth in population (**left**) and built-up area (**right**) by region.

4. Discussion

Variations in the rhythm of growth of the built-up areas and the total population of the municipalities allowed us to distinguish four different stages of development in terms of urban compactness (Figure 6). Stage A (1875–1925) was characterised by a slight increase in population densities in the cities. In Stage B (1925–1975), densities began to decline at a moderate rate. Stage C (1975–2000) showed the most pronounced extension of the built-up area. Finally, in Stage D (from 2000 onwards), the main characteristic has been stagnation in terms of total population numbers. In this section, we examine these four stages and contextualise their evolution with respect to the historical, political and economic reality of Spain.

4.1. Stage A—The Clogging Up of the Walled City

Although we did not have any previous data, we believe that this stage probably represented the historical tendency and lasted until around the first third of the twentieth century. This stage was not characterised by any significant urban development, but it provided the base for subsequent urban growth leading to population extending beyond the limits of the old walled Spanish city.

During this period, the first stages of industrialisation produced a multitude of changes at every level, which included a new spatial distribution of population [48]. The progressive mechanisation of agriculture and the creation of new places of work in cities gave rise to a rural exodus. Migratory movements towards cities became continuous from around 1860 onwards and then suddenly accelerated with the spread of railways and the arrival of imported cereals [49–51]. In addition, the liberal revolution of 1833 and a new territorial division initiated a centralising process at the national level that benefited the state capital. The accumulation of infrastructure and services was such that Madrid became the

centre of the country in every respect. This same process was repeated at a lower scale when an intermediate level of administration was created between that of the state and the municipalities: the province. The capital of each province concentrated new activities in the tertiary sector, such as administrative and social services, which attracted population from its sphere of influence [52]. In fact, the populations of all the cities studied doubled during this period. In this respect, it is particularly relevant to highlight the cases of Bilbao, San Sebastián and Huelva, whose urban populations increased significantly (by 327, 297 and 274 per cent, respectively). Only the populations of Cádiz, Teruel and Burgos grew at rates of less than 20 per cent during this stage (Figure 7).

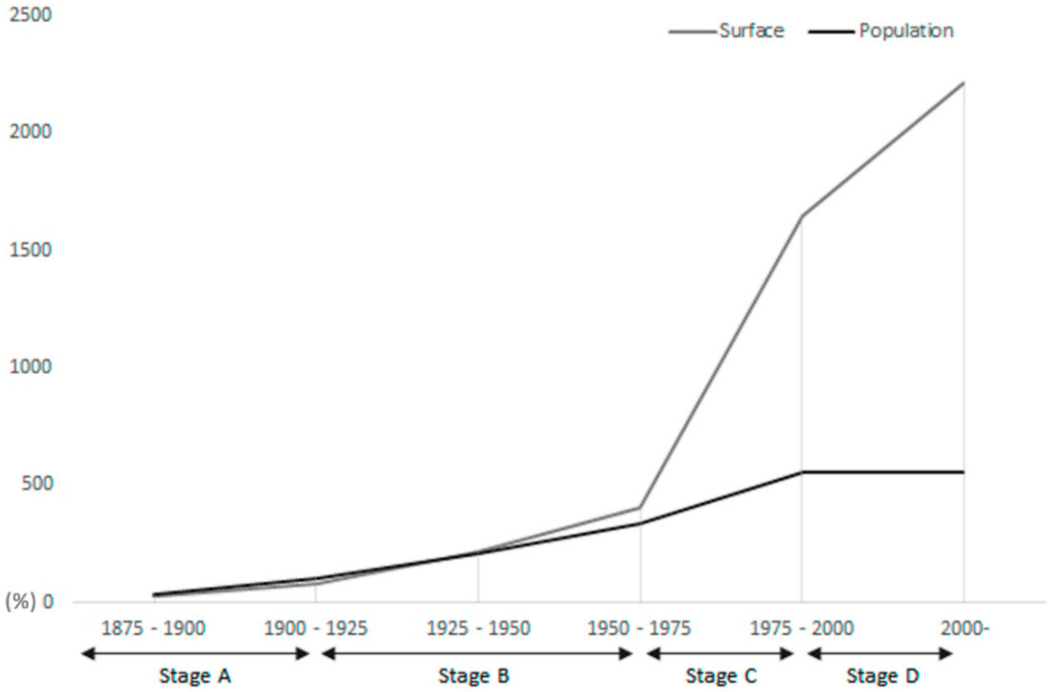

Figure 6. Aggregated growth in built-up area and total population for all of the cities analysed (per cent).

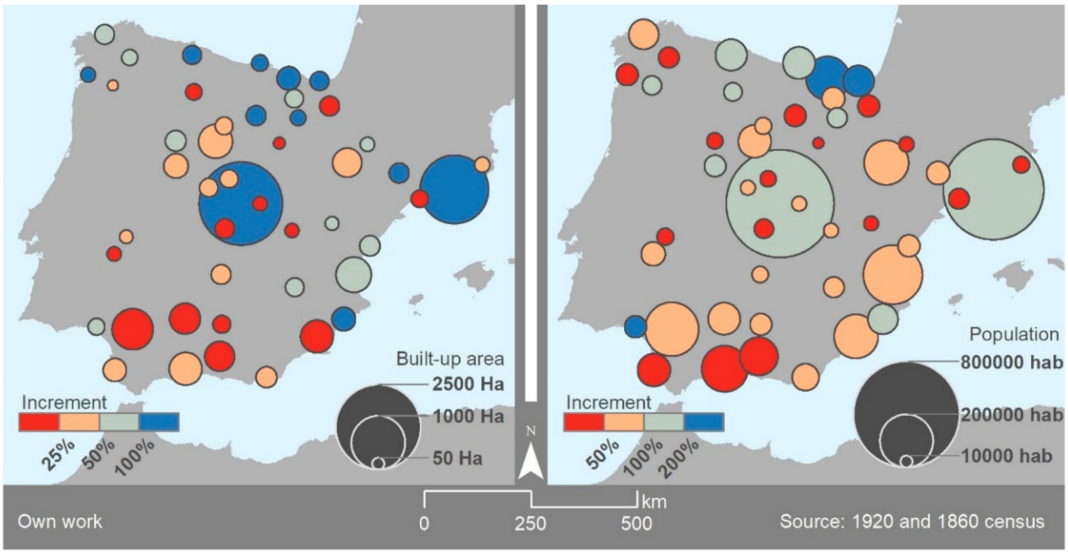

Figure 7. Total built-up area (**left**) and population (**right**) of the provincial capitals for the period 1850–1925. Size indicates magnitude of the variable (at the end of the period) and colour expresses change.

The initial reaction to population growth in the cities was internal reform. More specifically, construction pattern changes and this led to an increase in the height of buildings. There were also some significant changes in land use and ownership, such as those that took place following the disentailment of ecclesiastical properties which heralded the founding of a new liberal state in the 19th century [53,54]. These new policies permitted the creation of new urban spaces in order to meet the growing demand for housing within the walled city.

The defensive wall remained present in most cities and was still considered a key piece of infrastructure, even though it obviously limited the growth of the built-up area. Even in the 1840s, 145 population nuclei were still considered *Plaza Fuerte* (fortified squares), with contemporary legislation impeding construction in their immediate surroundings due to military constrains [55].

Despite this reticence to eliminate the old city walls, population growth within cities increased, so maintaining them was no longer a viable option because of this demographic pressure. Moreover, the densification within the city walls brought with it health problems given the deficient hygienic conditions. This led to the creation of the first extramural neighbourhoods (*arrabales*). These took the form of continuous built-up areas outside the city walls. It also led to the creation of suburbs that infringed contemporary regulations; and these became the first set of informal settlements. This phenomenon developed even further with the spread of railways and the location of new stations outside the old city walls [56,57].

In an attempt to deal with all these situations, plus the growing interest of the upper-middle class in having their own urban space, public authorities promoted the development of the first *ensanches*. Those areas of planned urban expansion were based on the growth of the urban fabric by the continuous extension of its infrastructure and the real estate business created around it [11]. Cerda's project for Barcelona, approved in 1859, was the first example. It defined an orthogonal grid of streets and urban blocks and sought to organise growth and interconnect the old settlements on the plain next to the city. From this moment onwards, the occupation of urbanised land progressively responded to new needs. These were driven by the increase in population and demands for a better quality of life from the upper classes and the emergent middle classes [58–62].

Whatever the case, while the resulting increase in population was higher than 100 per cent on average, the expansion of the built-up areas did not reach 80 per cent. The process of urban densification within the city walls was therefore even more important in aggregate terms than the construction of the newly planned areas outside them; this was a situation that persisted until the second third of the twentieth century (Table A3 in The Appendix A).

A detailed analysis of this phenomenon also reveals regional differences. The growth was consistent in both the built-up area and population, particularly in the northern half of the peninsula (Figure 7). Bilbao is a relevant case to highlight, having been clearly affected by its relatively early industrial development.

4.2. Stage B—The Shaping of the Urban Ensanches

This development stage was characterised by a marked economic growth concentrated from the first to the third quarter of the twentieth century. One of the consequences of this was a rural exodus and rapid urban growth in some regions of the country. In urban terms, two phenomena occurred simultaneously. The urban bourgeoisie took advantage of the new transport modes to locate their houses in the new planned neighbourhoods, in a similar way to what happened in the Anglo-Saxon context with the garden cities [63]. Workers and immigrants predominantly remained in the old city, although in some cases the demographic pressure was sufficiently high that areas of informal housing were created on the peripheries of Spain's largest cities.

This urban growth and the associated economic development were then abruptly interrupted by the Spanish Civil War (1936–1939). As a result of the subsequent destruction, the first years after the conflict were dedicated to urban reconstruction and the rebuilding of basic infrastructure. After the civil war came the toughest period of the dictatorship: that of autarky (1939–1959). During this period,

Spain was subjected to an international commercial embargo, which clearly limited the economic performance and expansion of its cities. Later, from the 1950s onwards, the Spanish economy was gradually reopened, and the country underwent a period of industrial development that favoured urban growth in all senses. Credit facilities from foreign countries and tourism subsequently started to yield important benefits. Both the public and private sectors played a key role in the development of new urban areas for working and upper-middle class people, respectively. In this regard, *ensanches* played a key role in structuring the shape and defining the location of housing, industry and other land uses [64,65].

In Figure 8, it is possible to see how the growth in the built-up urban area was relevant in all of the cities studied. In fact, only five of the cities analysed: Castellón de la Plana, Ciudad Real, Murcia, Granada and Teruel, failed to see their built-up areas doubled in size. It is relevant to highlight the cases of Zaragoza and Ourense whose urban areas grew by more than 400 per cent with respect to Stage A. In general, the greatest dynamism continued to be found in the north of mainland Spain, as this was the most industrialised and expanding part of the country, albeit to a lesser extent than during the previous stage.

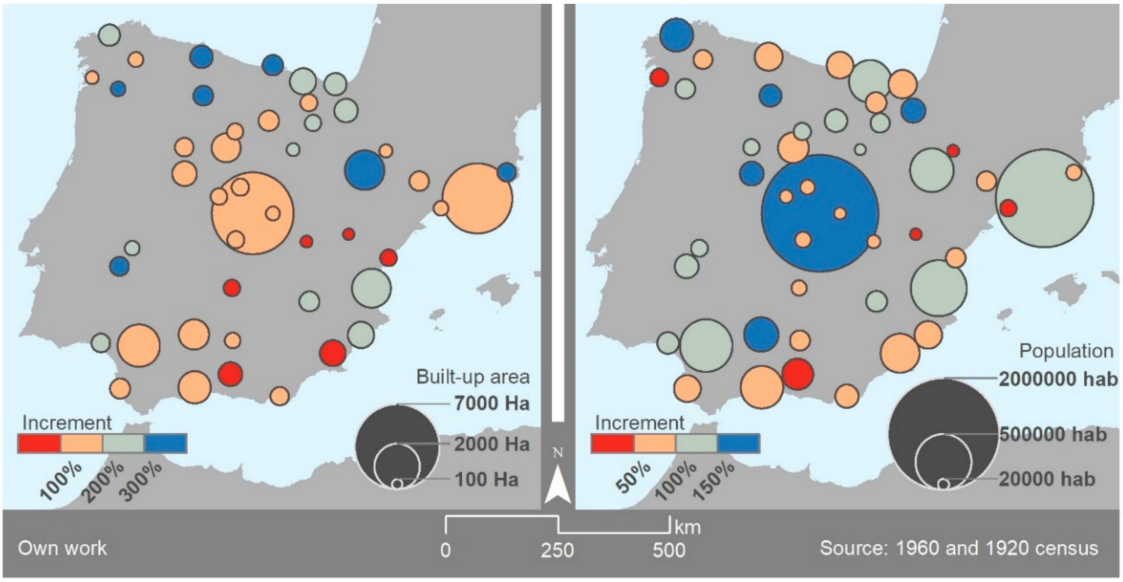

Figure 8. Built-up area (**left**) and population (**right**) of the municipalities for the period 1925–1975. Size indicates magnitude of the variable (at the end of the period) and colour expresses change.

Demographic growth was also positive but limited in relative terms. This resulted in widespread falls in population density (Table A3 in the Appendix A). In fact, only Palencia and Zamora saw their population densities increase during this period: from 184 inhabitants per ha to 187 and from 124 ha to 126, respectively. Such small variations were attributable to the fact that in these cities, as in Madrid and Ciudad Real, the growth in the built-up area took place at almost the same pace as the growth in population; as a result, the population density remained stable.

4.3. Stage C—The Maturity of the Compact City

This stage corresponded to the period between the end of the dictatorship (1975) and the turn of the twenty-first century. Although the data for this period have been presented in line with the main milestones in Spanish history, it would perhaps be more logical to establish the beginning of this stage in the 1960s. The reason for this was that the Stabilisation Plan of 1959 heralded an important change in every aspect of life in Spain. It marked the end of the period of autarky and set the country on the road to industrial modernisation, with a consequent increase in productivity [66]. This activated a large-scale rural exodus towards the largest cities on an unprecedented scale [67]. The Economic

Development Plans of the 1960s led to rapid industrialisation in some regions and played a vital role in this new strategy. A new period of growth started in 1986 when Spain joined the European Economic Community (EEC). This catalysed the country's economic growth and transformed its society and its urban dimension, under the recently installed democratic system [68].

The popularisation of the transport modes also played a decisive role in the acceleration of urban expansion. In fact, the industrial growth that occurred near cities could not be explained without considering the fact that workers began to have their own vehicles at popular prices. As a result, working-class people no longer needed to live near their places of work. The freedom provided by the motor car, combined with a lack of regulatory instruments, led to the explosion of the cities [69,70]. People created new housing necessities, including that of having parking spaces where they lived, as well as more modern utilities and lower density areas with parks and green spots. Cities grew not only in a continuous way, within their respective built-up areas, but also by spread out across the urban fringe.

Another important factor was the development experienced by the tourism sector from the 1960s onwards. This required a large-scale consumption of land near the coast for the construction of resorts and tourist-oriented neighbourhoods. This was particularly evident in the Mediterranean area, where second housing fiercely competed for land with hotels and other tourism-related uses [71]. From 1950 to 2001, the percentage of second homes climbed from less than 3% to 16%, reaching 3.3 million dwellings in total [72]. According to data gathered from the 1991 census, the likelihood of owning a second house in Spain was almost 12% on average (16% using current data), with an important concentration in absolute numbers in Madrid (15,4%) and Barcelona (14,2%). In terms of socioeconomic status, belonging to the upper class raised the probability of owning a second house more than 3 times in relation to working classes [73]. This phenomenon was surpassed though by the large number of foreign residents owning houses in specific regions. In Alicante, for instance, some municipalities show percentages of foreigners over 70% of the total ongoing population censuses [74].

The municipality of Tarragona provides a clear example of the development of the built-up area during this period: its urban area increased by 1108 per cent with respect to the previous stage. In Tarragona, this was associated with the combination of the large-scale development of the petrochemical industry, which occupied a large area of land around the city's port, and its consolidation as a tourist destination.

During this period, the size of Spain's built-up area grew at a much faster rate than that of the population in all of the cities studied (Figure 9), which caused a generalised fall in population density (Table A3 in the Appendix A). During this stage, the population densities of cities such as Murcia, A Coruña, Pontevedra, Badajoz, Ourense and Lugo fell by over 200 inhabitants per ha.

4.4. Stage D—The Metropolisation of the City

The main characteristic of this stage was stagnation in terms of population growth in most of the municipalities studied. The reason was that Spanish population decreased, and the country's total population only remained at the same level because of immigration. Furthermore, the main cities did not attract new residential population, which tended to drift towards smaller municipalities lying within their areas of influence. By 1997, the seven largest cities (with the exception of Zaragoza) were already clearly supramunicipal in character, which meant that their urban built-up areas spread across several municipalities [75]. This phenomenon has been masked by the fact that we only studied provincial capitals, but contemporary literature clearly highlights this trend as well [76].

In contrast, in terms of urban development, this has been a dynamic period. The property business enjoyed its heyday between the late-1990s and the mid-2000s, until the bursting of the construction bubble in 2008. Before 2008, a significant increase in the number of low-density housing estates was heavily linked with the increase in rates of car ownership. As with population, the municipalities that have most attracted this type of investment have been those nearest the major cities. A clear example of this is the metropolitan area of Barcelona, outside the city itself. This increased daily commuting

journeys and led to a fall in housing-related costs at a time when the price of a square metre of urban land in the city centre rocketed. The rise in peripheral municipalities consolidated, thus, the process of metropolisation [77,78].

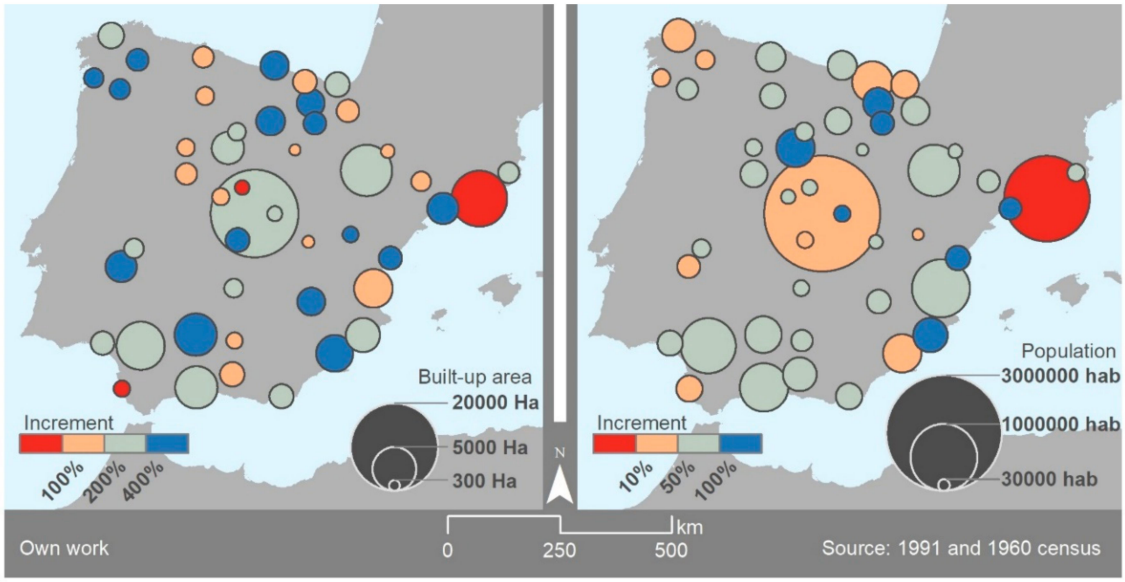

Figure 9. Built-up area (**left**) and population (**right**) of the municipalities for the period 1975–2000. Size indicates magnitude of the variable (at the end of the period) and colour expresses change.

In this stage, the provincial capitals near Madrid have experienced high rates of growth in their built-up areas. This can be explained by the fact that they belong to the great area of influence of the capital, which often extends beyond the border of its own autonomous community. It has also been possible to appreciate high levels of growth in the built-up areas of some coastal municipalities, including Castellón de la Plana, Alicante and Murcia, all located on the Mediterranean coast. These were the most dynamic areas for new urban development promotions prior to the bursting of the property bubble. By contrast, 13 capitals have lost population, with the most outstanding of these being the major cities: Madrid, Barcelona, Bilbao and Valencia. These losses have, however, been compensated by the growth of the municipalities within their areas of influence. The capitals that have grown in population have done so at much lower rhythms than in earlier periods. This difference between the rhythms of growth of population and in the built-up areas has meant that all of the municipalities studied, with the exception of Lugo, have experienced further falls in their urban population densities (Table A3 in the Appendix A).

5. Conclusions

This article proposes a new methodology to quantify the growth of built-up areas over time in order to better understand the evolution of population density in compact cities. To do this, we combined old cartography with aerial photography and the EEA's UMZ database. With this input, we created a database which included the size of built-up areas from the middle of the nineteenth century through to the present day. The data showed how the size of the total built-up area multiplied by a factor of 22 over the study period (from 133 ha in our first period to more than 3000 ha). Population growth was also high, with the total population of these cities having increased from just under 2 million to almost 13 million. These data were useful for the calculation of population density. The average population density for all of the cities initially analysed rose from 323 inhabitants per ha, in the first period, to 337, between 1900 and 1925, before subsequently falling to 84 in the final period.

These path variations made it possible to identify four stages of development in the cities analysed. The first stage, the clogging up of the walled city, shows how population growth was greater than

the increase in surface area. It implied a densification of the old city contained within its walls. Construction patterns then changed, as did land uses and the ownership structure. This allowed an increase in the height of new buildings, combined with specific interventions to ensure minimum levels of public health. The second stage, the shaping of the urban *ensanches*, includes the period between growth beyond the walls and the consolidation of the first planned urban developments. New urban sectors were built by extending the historic centres, but also by growth further away and supported by new modes of transport. In this period, population growth was lower than that of built-up area, which constituted a turning point in terms of population density. The third stage, the maturity of the compact city, corresponds to a period of strong socioeconomic and territorial development. New urban sectors were driven by public and private agents, causing unprecedented urban growth. Population growth was high, but nothing compared to the growth of the build-up area. As a result, population density plummeted. The last stage, the metropolitanisation of the city, is characterised by the overspill out beyond the administrative boundaries of the old cities. Although the urban fabric continued to grow, the municipal scale was exceeded, and metropolitan areas began to emerge. Numerous population groups decided to leave the central city and settle on the periphery. This was accompanied by population stagnation at the municipal level, which further reduced population densities.

The results of the comparison between the evolution of the built-up areas with population figures demonstrate the importance of finding new instruments to quantify population density over time. In a context of increasing urbanisation and urban expansion, our indicators allowed us to find specific patterns which could not have been identified from a simple analysis of population data. The results responded to our initial hypothesis, showing a huge divergence between variables from 1950 onwards and resulting in an important decrease in population density in the continuous urban fabric of Spain's main cities.

Our model of historical urban growth opens the way for new lines of research, some of which are already underway. These include quantitative analysis to establish the determinants of urban growth, based on such factors as physical geography and different infrastructural networks. Increasing the size of the sample analysed and seeing how cities interact with different factors would also help to improve our understanding of metropolitan areas and to find more efficient solutions to current challenges. It could also lead to investigating how public policies have contributed to urban change. The first Land Law in Spain was passed in 1956, but it was only after subsequent reforms that growth patterns clearly began to change. It could be interesting to analyse whether the current legal framework has introduced new mechanisms capable of altering these tendencies towards excessive growth.

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Appendix A

Table A1. Year and type of source for each period and city.

Municipality	–1875	1875–1900	1900–1925	1925–1950	1950–1975	1975–2000	2000–
A Coruña	1865	1884	1919	1945–1946	1956–1957	1990	2006
Albacete	1861	1876	1919	1945–1946	1956–1957	1990	2006
Alicante	1859	1878	1919	1945–1946	1956–1957	1990	2006

Table A1. *Cont.*

Municipality	–1875	1875–1900	1900–1925	1925–1950	1950–1975	1975–2000	2000–
Almería	1864	1897	1919	1945–1946	1956–1957	1990	2006
Ávila	1864	1897	1919	1945–1946	1956–1957	1990	2006
Badajoz	1873	-	1919	1945–1946	1956–1957	1990	2006
Barcelona	1857	1889	1919	1928	1956–1957	1990	2006
Bilbao	1857	1889	1919	1945–1946	1956–1957	1990	2006
Burgos	1868	1877	1919	1945–1946	1956–1957	1990	2006
Cáceres	1853	-	1919	1945–1946	1956–1957	1990	2006
Cádiz	1868	1880	1917	1945–1946	1956–1957	1990	2006
Castellón de la Plana	1852	-	1919	1945–1946	1956–1957	1990	2006
Ciudad Real	1857	1886	1919	1945–1946	1956–1957	1990	2006
Córdoba	1851	1884	1919	1945–1946	1956–1957	1990	2006
Cuenca	1854	1875	1919	1945–1946	1956–1957	1990	2006
Girona	1851	1876	1919	1945–1946	1956–1957	1990	2006
Granada	1868	1894	1919	1945–1946	1956–1957	1990	2006
Guadalajara	1854	-	1919	1945–1946	1956–1957	1990	2006
Huelva	1870	-	1919	1945–1946	1956–1957	1990	2006
Huesca	1861	1884	1919	1945–1946	1956–1957	1990	2006
Jaén	-	-	1919	1945–1946	1956–1957	1990	2006
León	1862	-	1919	1945–1946	1956–1957	1990	2006
Lleida	1851	1880	1919	1945–1946	1956–1957	1990	2006
Logrono	1851	-	1919	1945–1946	1956–1957	1990	2006
Lugo	1864	1880	1919	1945–1946	1956–1957	1990	2006
Madrid	1867	1883	1919	1945–1946	1956–1957	1990	2006
Málaga	1863	1883	1919	1945–1946	1956–1957	1990	2006
Murcia	1810	1896	1919	1945–1946	1956–1957	1990	2006
Ourense	1856	-	1919	1945–1946	1956–1957	1990	2006
Oviedo	1853	1885	1919	1945–1946	1956–1957	1990	2006
Palencia	1852	1886	1919	1945–1946	1956–1957	1990	2006
Pamplona	1861	1882	1919	1945–1946	1956–1957	1990	2006
Pontevedra	1856	1887	1919	1945–1946	1956–1957	1990	2006
Salamanca	1867	1890	1919	1945–1946	1956–1957	1990	2006
San Sebastián	1867	1897	1919	1945–1946	1956–1957	1990	2006
Santander	1865	1883	1919	1945–1946	1956–1957	1990	2006
Segovia	1849	1897	1919	1945–1946	1956–1957	1990	2006
Sevilla	1868	1884	1919	1945–1946	1956–1957	1990	2006
Soria	1860	1881	1919	1945–1946	1956–1957	1990	2006
Tarragona	1858	1880	1919	1945–1946	1956–1957	1990	2006
Teruel	1869	1881	1919	1945–1946	1956–1957	1990	2006
Toledo	1854	1879	1919	1945–1946	1956–1957	1990	2006
Valencia	1850	1882	1919	1945–1946	1956–1957	1990	2006
Valladolid	1852	1881	1919	1945–1946	1956–1957	1990	2006
Vitoria	1864	1886	1919	1945–1946	1956–1957	1990	2006
Zamora	1863	-	1919	1945–1946	1956–1957	1990	2006
Zaragoza	1853	1880	1908	1945–1946	1956–1957	1990	2006
		Historical cartography		Aerial photography		UMZ	

Table A2. Built-up area by stage, period and city (ha).

Surface (ha)		**Stage A**		**Stage B**		**Stage C**	**Stage D**
Municipality	**–1875**	**1875–1900**	**1900–1925**	**1925–1950**	**1950–1975**	**1975–2000**	**2000–**
A Coruña	83	112	134	249	440	1741	1844
Albacete	70	73	119	240	386	2028	2559
Alicante	77	83	191	454	668	3057	4698
Almería	103	124	151	235	328	1523	2016
Ávila	81	88	119	182	267	777	1234
Badajoz	70	70	70	210	341	2563	4194
Barcelona	422	886	1613	2584	4741	8159	8464
Bilbao	61	128	187	496	669	1498	1548
Burgos	46	85	136	249	405	2193	2941
Cáceres	48	48	62	134	211	1013	1545
Cádiz	133	162	185	310	392	697	697
Castellón de la Plana	72	-	143	205	269	1393	2340
Ciudad Real	91	115	133	186	264	926	1322
Córdoba	279	321	326	508	888	4676	6792
Cuenca	61	61	68	107	135	379	611
Girona	57	69	81	197	327	1153	1337
Granada	277	305	307	434	546	1565	2117
Guadalajara	69	69	74	146	188	584	1029
Huelva	57	57	96	155	333	1440	1606
Huesca	44	59	71	120	168	492	640
Jaén	108	108	108	170	234	699	829
León	78	78	91	270	378	875	1570
Lleida	49	49	136	195	369	1007	1262
Logrono	30	30	83	165	259	1339	1736
Lugo	53	81	89	137	215	1281	1231
Madrid	966	1245	2393	3974	6474	20128	27858
Málaga	268	319	369	592	1005	4697	5995
Murcia	299	360	366	401	643	3546	5875
Ourense	27	27	39	84	205	1097	1732
Oviedo	57	89	121	254	495	1165	1782
Palencia	77	90	109	160	256	836	955
Pamplona	114	120	134	325	535	1336	1786
Pontevedra	24	44	74	92	165	997	1053
Salamanca	149	163	207	431	586	1218	1655
San Sebastián	38	77	123	348	483	1611	1893
Santander	38	60	93	289	405	2134	2390
Segovia	91	92	116	185	290	555	704
Sevilla	469	530	581	1159	1734	6071	7045
Soria	41	43	47	96	163	327	529
Tarragona	86	94	104	170	212	2561	2979
Teruel	42	42	65	91	121	652	850
Toledo	124	135	136	191	281	1487	2326

Table A2. *Cont.*

Surface (ha)		Stage A		Stage B		Stage C	Stage D
Municipality	**–1875**	**1875–1900**	**1900–1925**	**1925–1950**	**1950–1975**	**1975–2000**	**2000–**
Valencia	236	323	430	1164	1463	3902	4804
Valladolid	270	347	400	498	815	2746	4067
Vitoria	63	93	117	204	281	2033	2939
Zamora	81	81	149	200	335	809	883
Zaragoza	199	227	293	673	1503	6906	8667

Table A3. Population density by stage, period and city (pop/ha.).

Pop/ha		Stage A		Stage B		Stage C	Stage D
Municipality	**–1875**	**1875–1900**	**1900–1925**	**1925–1950**	**1950–1975**	**1975–2000**	**2000–**
A Coruña	423	426	475	397	395	142	128
Albacete	238	261	253	239	180	63	58
Alicante	361	463	338	196	182	87	61
Almería	279	289	338	311	264	102	83
Ávila	107	146	129	115	105	59	40
Badajoz	309	408	579	245	266	46	32
Barcelona	595	434	444	417	322	201	178
Bilbao	516	479	719	363	434	247	226
Burgos	613	417	245	212	201	73	57
Cáceres	296	-	326	217	218	74	54
Cádiz	524	391	412	277	293	221	191
Castellón	292	-	239	212	228	96	63
Ciudad Real	117	125	141	168	140	62	48
Córdoba	157	170	223	267	214	65	45
Cuenca	161	188	223	220	208	113	76
Girona	284	258	239	137	116	60	56
Granada	253	237	337	350	284	163	114
Guadalajara	129	-	209	141	124	103	66
Huelva	160	-	356	363	225	99	89
Huesca	270	243	225	145	140	90	72
Jaén	-	-	309	302	276	148	136
León	146	-	260	169	205	165	83
Lleida	414	496	281	191	168	111	89
Logrono	389	-	340	265	229	91	77
Lugo	394	246	336	299	269	65	72
Madrid	328	398	344	333	336	150	105
Málaga	378	430	409	392	289	111	87
Murcia	293	269	375	474	379	93	63
Ourense	445	-	663	444	304	94	62
Oviedo	540	504	579	312	251	168	113
Palencia	170	170	184	203	187	93	84
Pamplona	197	258	249	163	175	135	103
Pontevedra	940	572	456	414	307	72	71
Salamanca	109	144	159	154	155	134	94
San Sebastián	446	413	547	269	267	106	94
Santander	807	704	786	330	283	90	76
Segovia	144	182	158	134	121	98	77

Table A3. *Cont.*

Pop/ha		Stage A		Stage B		Stage C	Stage D
Municipality	**–1875**	**1875–1900**	**1900–1925**	**1925–1950**	**1950–1975**	**1975–2000**	**2000–**
Sevilla	247	271	354	261	255	113	97
Soria	154	187	177	145	121	99	66
Tarragona	241	306	286	210	207	43	38
Teruel	305	299	233	181	180	44	37
Toledo	143	147	192	165	145	40	29
Valencia	597	589	575	391	343	193	154
Valladolid	164	188	191	220	185	120	78
Vitoria	374	326	320	242	249	101	74
Zamora	166	-	124	143	126	80	73
Zaragoza	360	430	480	305	202	86	71

Municipalities that experienced increases in their urban densities with respect to the previous period are shown by shaded cells.

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