



GEOMEDIA FOR EDUCATION IN SUSTAINABLE DEVELOPMENT IN SPAIN. AN EXPERIENCE IN THE FRAMEWORK OF THE AIMS OF DIGITAL-EARTH.EU

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Abstract

The use of geographic media in schools and teacher education is increasingly more important due to the growing number of geo-visualization tools. The present paper selects several maps obtained from the digital viewer SIU and from the data provided by the European project Corine Land Cover. Both express the cartography of the evolution in the occupation of land uses during the years 1987-2006 in the main metropolitan and urban Spanish areas, and therefore the growth of urban sprawl. However, this work does not only deal with the analysis and conclusion of urbanization processes, but also analyzes the benefits of using geographic media in geographic education, both to acquire competences for spatial thinking and educate on sustainable development.

Keywords: Geo-media, land use, urbanization, Spain, metropolitan areas, education, sustainable development.

1. INTRODUCTION

Among the geographic phenomena that are having the highest influence nowadays on spatial changes is that of urban sprawl as an expression of a new period of growth in urbanization processes. The progressive destruction of agricultural and forest soils due to the building of new urban areas is occurring, contradictorily, in a moment in which, the approaches on sustainable development, which advocate an adequate and rational use of energetic and natural resources including the soil, are becoming generalized. Several studies, carried out some years ago, on the processes of suburbanization in the main European countries, especially in the Mediterranean Basin (Indovina, 1990) (Steinberg, 1991) (De Miguel, 2001) (Font, 2004) or the United States (Fulton, 2001), analyzed the causes of the phenomena of low-density expansion of large urban areas and explained the consequences of urban sprawl, and its impact in the economic, social and environmental future of European cities and regions.

The European project Corine Land Cover has published in 2010 the Raster data on land cover for the CLC2006 inventory. The total amount of these data for Spain can be obtained by geo-media SIU (System of Urban Information, *Sistema de Información Urbana*, in Spanish) from the Housing Department of Spanish Government. This map viewer offers the updated data, an interface of visualization with Google Earth which facilitates the

cartographic elaboration and comprehension, and at the same time allows to add the data at regional, metropolitan and local level. As a SIG tool, SIU makes maps on urban planning, developing areas and land use from Corine Land Cover data.

The dynamic visualization of the processes of urbanization over three moments (1987, 2000, 2006) becomes an excellent teaching resource to understand one of the phenomena which has most influenced in the recent spatial changes in Spain: Suburbanization process and urban sprawl and growth of areas on the fringes of major cities. The variation in the categories of land uses result in the fact that the total of artificial surfaces has grown 52% over the last two decades, with the resultant disappearance of agricultural and forest soil and the loss of biodiversity. The major urban changes are happening in the main Spanish metropolitan regions of Madrid and Barcelona and in the Mediterranean coast, with exceptions such as Menorca or Bilbao.

In any case, the increase of artificial surfaces in Spain has intensified in the first decade of the twenty-first century until the arrival of economic crisis and the bursting of the real state bubble in 2008, in a way that processes so rapidly changing find in cartographical models such as SIU an excellent vehicle of cartographic representation of the contemporary geographic dynamics. And of course as tools for the performance of teaching materials in the learning of urban Geography and education in sustainable development at schools.

2. STUDY OBJECTIVES AND METHODOLOGY

The main objective of this paper is to quantify and map, with the latest data available, the changes produced in land use in Spain. From this general idea, a complementary objective is paying special attention to the processes of transformation of natural soil in artificial soil and to the growth of the category of CLC discontinuous urban fabric, as an element to verify the hypothesis put forward in the continuation and growth of urban sprawl. The empirical work is developed by comparing such changes in the use of the soil in the eight main urban and metropolitan areas in Spain. The ultimate goal is the performance of a dynamic cartography of the eight urban areas as a teaching resource from which a statement on how students of secondary education can learn basic notions of the curriculum of Geography, such as territorial sustainability.

The main data which have served this study are those corresponding to the European Project Corine Land Cover in the editions of 1990 (although the data in Spain are referred to images from 1987), 2000 y 2006, broken down at level 3, which are contained in the System of Urban Information and which come from images of the Landsat (CLC1990 & CLC2000) and SPOT (CLC2006) satellites. Data tables come from another source, that of the Statistical Atlas of Urban Areas. The working method followed in the analysis of the uses of the soil has consisted of three variables: distribution of the surfaces of the different types of uses of the soil, changes in land cover between 1987 and 2006 and conversion of land uses.

The analysis of cases has been completed with a series of socioeconomic data, mainly demographic and urban, which explain that in just eight areas the 22% of the new artificial soils of the country has concentrated. Finally, the collection and systematization of data leads to a series of generalizations and conclusions which imply Geography, urban and regional planning, but especially to sustainable development, hence its interest as a learning content in the teaching of a discipline increasingly related to the principles of sustainability.

3. LAND USES IN SPAIN BETWEEN 1990 AND 2006. THE EUROPEAN CONTEXT

The average growth of artificial soil in Europe between 1990 and 2006 has been 8.93% against the 51.87% in Spain. In instalments, between 1990 and 2000 was 5.4% in Europe and

29.5% in Spain and between 2000 and 2006, 3.35% and 13.56%, respectively (Fig. 1). Despite the recent growth of urban land uses has been nearly six times bigger in Spain than in Europe, the map continues reflecting the density of urban networks in the central countries which make up the European megalopolis, European backbone or Blue Banana (Brunet, 1989). In other words, the historical European urban growth linked to the processes of industrialization from the mid-nineteenth century has created an urban space much more widespread. Thus, the average of artificial surfaces in Europe is around 5% of the total surface, while other countries such as Germany are at 10% and others such as United Kingdom, Belgium and Holland exceed it.

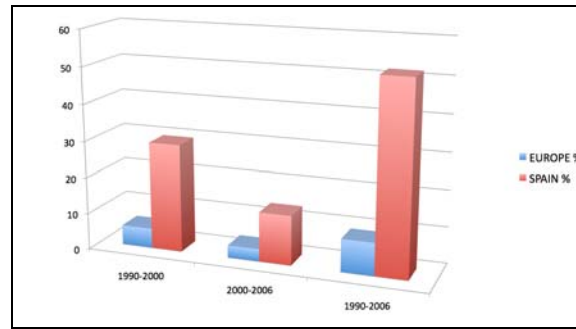


Figure 1. CLC Land Use. Growth artificial surfaces (1990-2000-2006)

Spain has gone from 1.31% in 1987 to 1.76% in 2000 and to 2% in 2006 of artificial surfaces respect to the total of the national surface. That is, urban density in Spain is still lower than the average European density, although the growth has been very high, with the consequent implications for sustainability. For instance, the set of new artificial surfaces amounts to 346,566 new hectares (Tab. 1), which means that in twenty years almost half of the artificial urban space, made in twenty centuries, has been transformed.

Table 1. Total artificial surfaces in Spain according to CLC

	Hectares
1987	668,130.47
2000	893,435.84
2006	1,014,696.96

As said before, the data between 2000 and 2006 provide that, while the European average of growth of artificial surfaces is around 3.35%, in Spain it rises to 13.56%. Nevertheless, in this period there are countries whose percentage grows more, such as Iceland, Ireland or Cyprus. (Fig. 2), but they are smaller countries than Spain and had an initial artificial surface still much smaller (in 2000). However, the absolute growth shows that Spain has been the country where there has been a bigger number of new artificial surfaces in this period: 121,261 hectares, a fifth of Europe's total, widely overtaking the second country (France, 82,291 ha.) and doubling other big European countries such as Germany or Italy. (Fig. 3). In any case, it is clear that the biggest countries of the Mediterranean represent around 40% of the recent artificial growth, verifying some territorial processes already targeted in the report on urban sprawl in Europe.

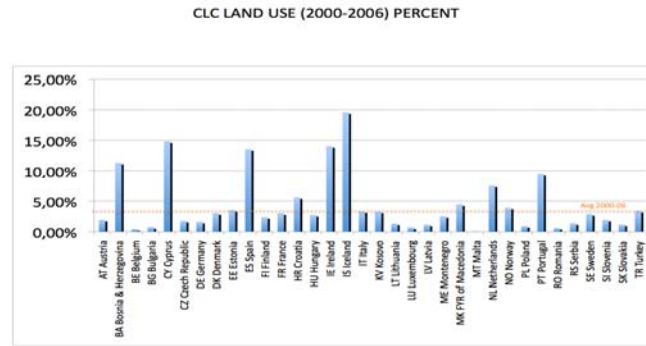


Figure 2. CLC Land Use. Growth artificial surfaces in Europe by country 2000-2006 (%)

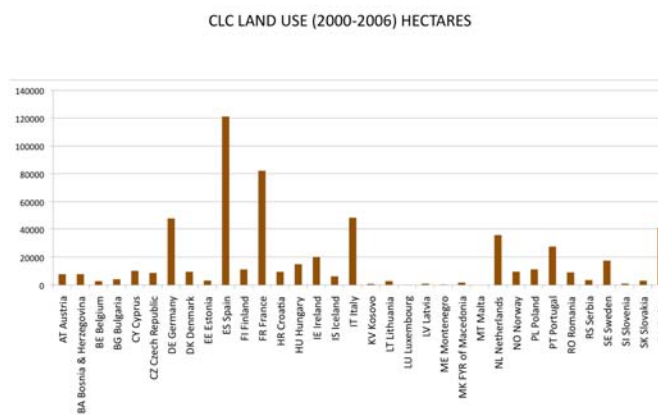


Figure 3. CLC Land Use. Growth artificial surfaces in Europe by country 2000-2006 (Hectares)

The breakdown of the figures of land use to level 3 of CLC, within the category of artificial surfaces confirms that, Spain besides knowing an important absolute and relative growth, this has occurred mainly by means of discontinuous urban fabric (discontinuous built-up areas with multi-flat houses, with family houses, or with greenery). The urban morphology characteristic of Southern European countries resulted in a predominance of the continuous urban form: old town, grid extension (*Ensanche*), blocks, apartment towers, etc. In the CLC-1990 Spain still had a bigger surface of continuous urban fabric than discontinuous. In the CLC-2000 the urban areas had a similar quantity of each of the two subcategories.

However, in the CLC-2006 it appears that discontinuous urban fabric has surpassed the traditional urban form (Tab. 2), with this category being the one which has grown more in absolute terms and the one with the biggest superficial extension within the types of artificial land uses in Spain, setting a new suburban landscape characteristic for the proliferation of detached and semi-detached houses, especially in the urban fringes of mayor metropolitan areas such as the one analyzed later, or, in the tourist zones (Balearic and Canary islands, Mediterranean coast and mountain areas). In turn, to the 337995 hectares of discontinuous urban fabric should be added a big part of construction sites, of suburban shopping centres and green urban areas that accompany the processes of residential sprawl.

Table 2. Total artificial surfaces in Spain according to level 3 of CLC

	1987	2006	Growth (Ha.)	Growth %
Continuous urban fabric	252,753	292,435	39,682	15.70
Discontinuous urban fabric	230,104	337,995	107,891	46.89
Industrial or commercial units	76,500	146,319	69,819	91.27
Construction sites	16,569	71,028	54,459	328.68
Road and rail networks & port areas & airports	26,324	50,532	24,208	91.96
Mineral extraction sites & Dump sites	52,047	81,277	29,230	56.16
Green urban areas & Sport and leisure facilities	13,429	34,601	21,172	157.66
TOTAL	668,130	1,014,696	346,566	(AVERAGE) 51.87

The average data of growth of 51.87 reflects the variety situations: from the biggest relative growth in construction sites (328%, which is explained by the housing bubble) to the development of activity zones or leisure facilities. The growth of 47% in discontinuous urban fabric is smaller than the average of the growth in artificial surfaces, but still is spectacular: more than 100,000 new hectares between 1987 and 2006, equivalent to the total growth of artificial surfaces in Italy and Germany together (in the period 2000-2006) o 28000 new hectares (for the same period 2000-2006) involving all the growth of artificial surfaces in Portugal or a little less than the one in Netherlands. Thus, recent data show that the surface of suburban areas is the biggest within the whole of artificial surfaces in Spain, extending in a third of these (Fig.4).

The cited study on changes of land use in Spain (OSE, 2006) quantified the flows between some types and others of land use. Between 1987 and 2000, nearly half of the new artificial surfaces came from the conversion of arable land and permanent crops (46%), a fourth (24%) from pastures and heterogeneous agricultural areas, and almost the other remaining fourth (27%) from forest and semi natural areas.

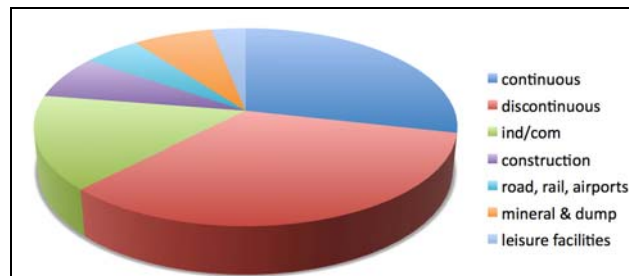


Figure 4. Artificial surfaces distribution in Spain, 2006

The conclusion of these figures is that, while artificial surfaces are increased, the processes of urbanization and urban sprawl are accelerated, agricultural and forest areas of high environmental value are lost, both in urban fringes and in other areas where the landscape is very valuable, such as mountain and coastal areas. And similarly becomes bigger

the ecological footprint which measures the impact on the geographical space, the use of natural resources and the level of sustainability of urban and metropolitan areas.

4. ANALYSIS OF LAND USES IN THE MAIN FOR URBAN AREAS.

The 85 large Spanish urban areas are well defined by the Atlas of urban areas of the Housing Department. 747 municipalities are included (9.2% of all the municipalities in Spain in 9.6% of the whole national surface), but account for the 68% of the total Spanish population. In turn, the eight main urban and metropolitan areas in Spain are composed of 362 municipalities (4.3 % of the total of municipalities in 2.6% of the total national surface) and account for 36% of the population. As far as the growth of the soil, the 85 big urban areas have involved half (51%) of the total of new artificial surfaces between 1987 and 2006, divided between 23 % of the 8 main urban areas and 28% the remaining 77 big urban areas. The other half corresponds to small urban areas (between 5,000 and 50,000 inhabitants) and non-urban municipalities (less than 5,000 inhabitants), with a 13 and 36 %, respectively (Fig. 5).

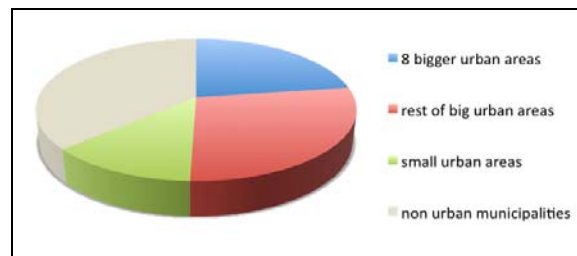


Figure 5. New artificial surfaces by urban areas 1987-2006.

It is evident that the eight main Spanish urban areas become a quarter of the total national of new artificial surfaces, and in absolute terms, almost the same growth as in seventy-seven areas, thus demonstrating the urban dynamism of the cities which are at the head of the urban hierarchy.

Madrid. With an absolute growth of 81% and relative of nearly 40,000 hectares, Madrid is probable the major European urban region of greatest urban growth in the last two decades. The increase in discontinuous urban fabric (CLC1987-2000, 45%; CLC2000-2006, 14%) has resulted in the transformation of thousands of hectares of agricultural and forest surfaces in scattered fragments of town. The extension of residential urban sprawl at the end of the period amounts to 37,204 hectares, to which most of the 9,000 hectares, which are construction sites, should be added, which would result in at least 42,000 hectares. In other words, the extension of suburban areas in 2006 almost reaches the level of the total of artificial surfaces of 1987. The intensity of the processes of urban transformation and residential land changes (Lopez, 2003) has been accompanied by a massive urbanization for other artificial uses. The growth of industrial and commercial units (CLC1987-2000, 107%; CLC2000-2006, 10%) is reflected in the construction of more than 140 shopping and leisure centres, of new centres of tertiary activity, etc, until a total of 13,900 hectares in this category, an amount equivalent to all the increase of artificial surfaces in Barcelona in the same period. Having reached 1,000 kilometres of fast roads, the introduction of the high-speed train and the extension of the airport of Madrid Barajas has made the total of artificial surfaces for infrastructures to be 10% of the total of artificial surfaces (CLC1987-2000, 2.9%; 2000-2006, 44%). To all this must be added the equally significant number of construction sites which amounted in 2006 an extension similar to the total of infrastructures.

Barcelona. Despite having a lower relative growth (20%), the extent and magnitude of the metropolitan area of Barcelona has meant that, in absolute terms, it is the second urban

growing area, with a transformation of a compact city into a metropolitan territory where low density stands out (discontinuous urban fabric growth CLC1987-2000, 8%; CLC2000-2006, 2%) (Font, 2005) with a total extension of 30,288 hectares, not much smaller than Madrid's. As far as industrial and commercial units are concerned, the same phenomenon happens: Barcelona started from an initial situation of bigger extension than Madrid and during the observed period it grew less (CLC 1987-2000, 42%, CLC2000-2006, 9'62%) than this area, but at the end of the period the surface ends up being nearly identical, only 100 hectares less. As regards the surface for infrastructures it is clearly seen the impact of the construction of new ring roads (especially for the Olympic Games of 1992), the expansion of port and airport (CLC1987-2000, 672%; CLC 2000-2006, 123%).

Valencia. Its growth approaches the national average, with growing values of discontinuous urban fabric (CLC1987-2000, 14%; CLC2000-2006, 8%) and industrial and commercial (CLC1987-2000, 48%; CLC2000-2006, 15%). The growth in surfaces for infrastructures is more remarkable, which nearly doubles, due to the construction of the bypass and the transformation of the port. The growth in construction sites stands out (CLC1987-2000, 535%; CLC-2000-2006, 46) which implies the processes of urban sprawl, the port, cultural facilities, etc.

Sevilla. It has growth rates in artificial surfaces similar to Valencia, but also in the categories of discontinuous urban fabric, industrial and commercial units and infrastructures. In Seville the growth of construction sites stands out, above all in the first period which is partly explained by the works for the Universal Exhibition of 1992 (construction sites: CLC1987-2000, 266%; CLC2000-2006, 8%).

Málaga. The growth in artificial surfaces has been more moderate than in the previous cities, although it has been remarkable in the categories of infrastructures (CLC1987-2000, 375%; CLC2000-2006, 21%) and in sport and leisure facilities (more than 200% in the in the overall period) due to the extension of the port and the airport, but also to the proximity to the Costa del Sol and the construction of new leisure centres such as golf courses.

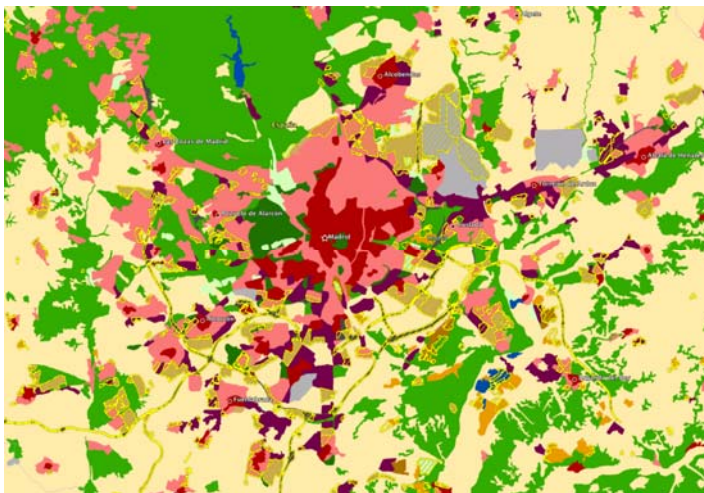
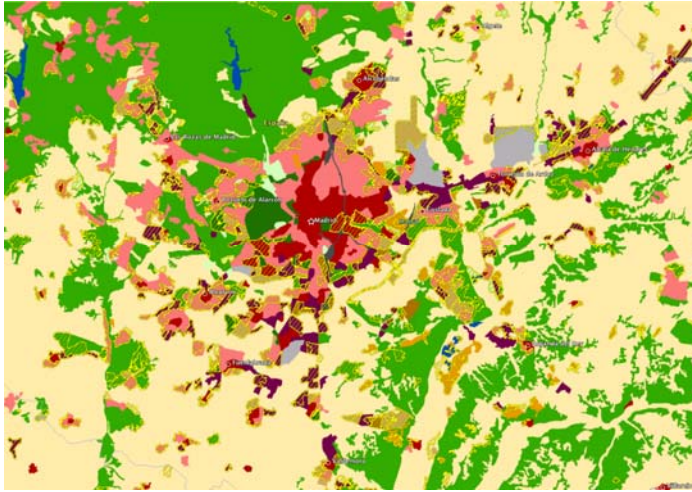
Bilbao. It is the big city which grows less, only 16%, a quantity equivalent to the double of Europe for the overall period. And even in the 2000-2006 stretch it grows at a rate similar to the European average (4.25%), due to relief conditions and also to the urban and territorial regulation, but also to the fact that a significant amount of its growth happened before the studies of the CORINE project. These reasons explain that the ending of the construction sites amounts to a total extension in 2006 of less than 100 hectares and to a relative decrease (CLC1987-2000, -19%%; CLC2000-2006, -67%). However the transformation of the port and the performances throughout the whole of the Nervion estuary have involved a growth of 150% in soil for infrastructures.

Asturias. The most polycentric urban structure of the big urban areas (Oviedo, Gijon, Aviles, Siero, Mieres, Langreo) has also known a limited growth, even becoming the only among the 85 urban areas which loses artificial surfaces between 2000 and 2006 (-0.71%), which is not so much an actual loss as the balance of the corrections made to CLC2006. Thus, the growth is mainly concentrated in the first period (1987-2000), when there have been increases of discontinuous urban fabric of 18% or surfaces for infrastructures of 100%.

Zaragoza. It is the eighth in population rank among the largest urban areas, and however the third in absolute terms, doubling the number of new artificial surfaces between 2000 and 2006 with respect to cities of similar or bigger size. The growth is due to implementation of ring roads, of high speed train and strategic projects of logistics and residential projects (De Miguel, 2010), especially in this sexennium and until the International Exhibition of 2008. Hence the highest increases are in infrastructures (CLC2000-2006, 172%) and construction sites (CLC2000-2006, 268%).

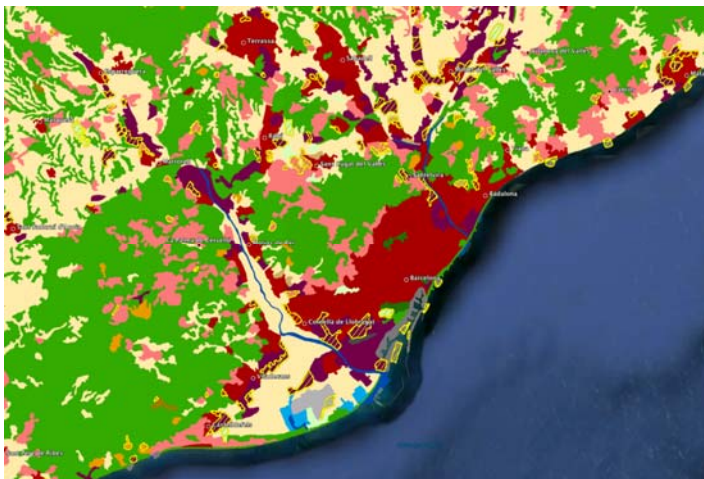
The maps below (Fig. 6a & 6b, 7a & 7b, 8a & 8b) are the expression of Geomedia

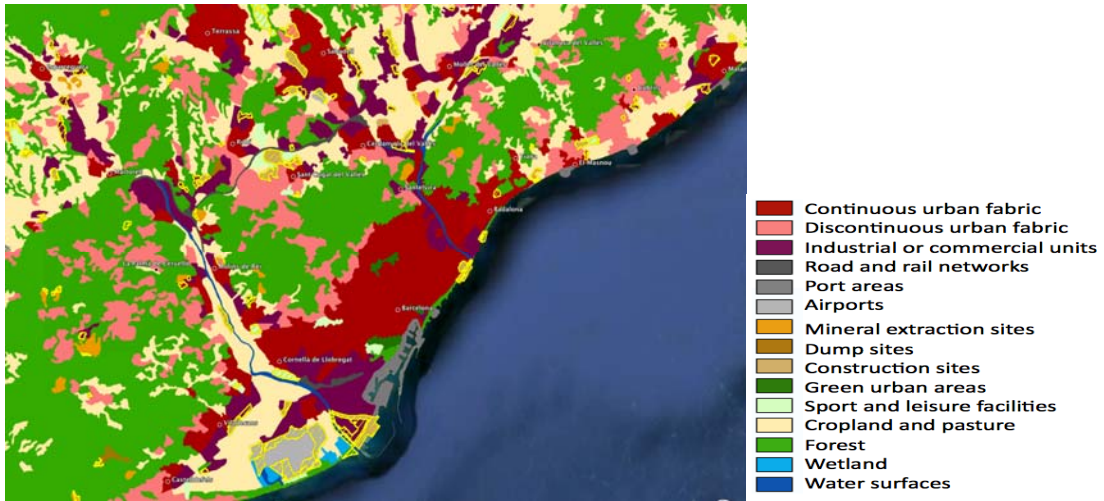
products which can be obtained with the tool SIU. They refer to CLC1987-2000 and to CLC2000-2006 and expresses the growth in artificial surfaces in three of the biggest Spanish urban areas: the first in absolute and relative terms (Madrid), the second in absolute terms (Barcelona) and the second in relative terms (Zaragoza).



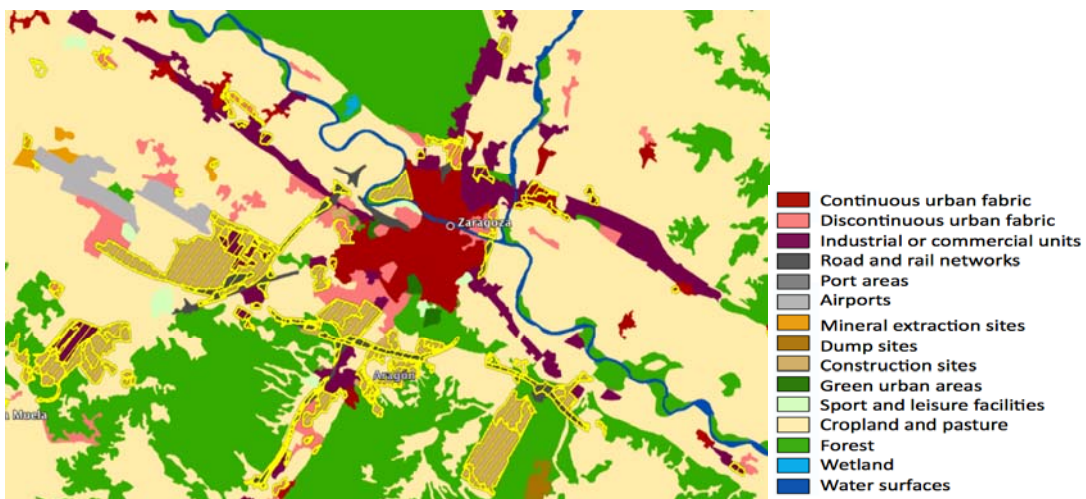
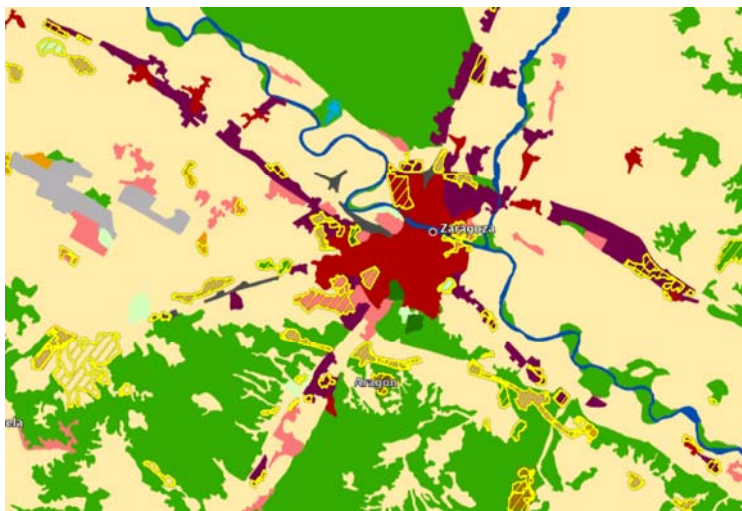
- Continuous urban fabric
- Discontinuous urban fabric
- Industrial or commercial units
- Road and rail networks
- Port areas
- Airports
- Mineral extraction sites
- Dump sites
- Construction sites
- Green urban areas
- Sport and leisure facilities
- Cropland and pasture
- Forest
- Wetland
- Water surfaces

Figures 6a&6b. Madrid. CLC changes. 1987-2000 & 2000-2006.





Figures 7a & 7b. Barcelona. CLC changes. 1987-2000 & 2000-2006.



Figures 8a & 8b. Zaragoza. CLC changes. 1987-2000 & 2000-2006.

5. URBAN GROWTH VERSUS POPULATION GROWTH

Bearing in mind the implications of all this urban growth for sustainability, the question to answer is if this urban growth is justified by a demographic or economic growth of similar dimensions. In Europe, new artificial surfaces have had a harmonious development of the population, 9% and 8%, respectively, in the two decades analyzed. On the contrary, in Spain the repeated data of 52% of new urban surfaces is difficult to sustain with a demographic growth of 17% (Fig. 9). That is to say, population and land uses grow in Europe at the same rate and in Spain artificial surfaces grow three times more than the population, although it can be noted that in the period 2000-2006 this gap has been cut (Fig. 10).

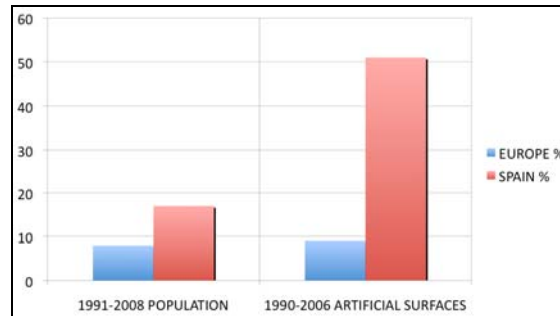


Figure 9. Population and artificial surfaces growth in Europe and Spain.

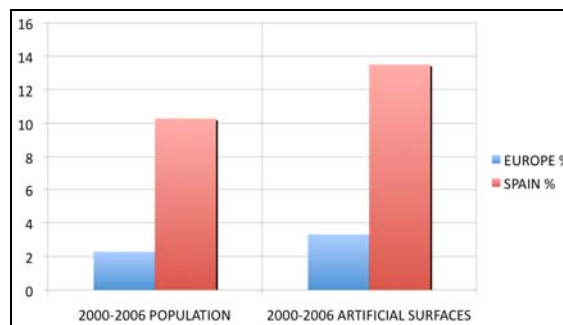


Figure 10. Population and artificial surfaces growth in Europe and Spain (2000-2006).

These same differences are transferred to the field of urban areas. Those with biggest growth in uses of urban surfaces (over 100% and sometimes 200%) have an average growth of the population of 43%. So the five areas of biggest relative urban growth have had increases of population of 66%, 72%, 48%, 27% y 7%, respectively. On the contrary, the fact that population growth has been bigger than urban growth has happened: the five urban areas with the biggest population growth (between 85 and 250%) have had an average growth of artificial surfaces of 57%, slightly superior to the national average.

This same comparison, carried out with the eight biggest urban areas in Spain results in the fact that the city with the biggest difference in growth rates is Asturias, eight times bigger the urban uses than the population, which is explained by the near stagnation in terms of population growth. It is followed by Zaragoza, being the artificial surfaces growth six times bigger than the population. In fact, being the third of biggest absolute growth of artificial surfaces, it is situated in the fifteenth position in absolute population growth. Madrid's urban surfaces grows four times more than the population, whereas in Valencia and Seville the proportion is 3 to 1, in Barcelona 1.4 to 1 and in Malaga 1.2 to 1. A separate issue is Bilbao, which with a decrease in population, has new needs of urban surfaces (Fig. 11).

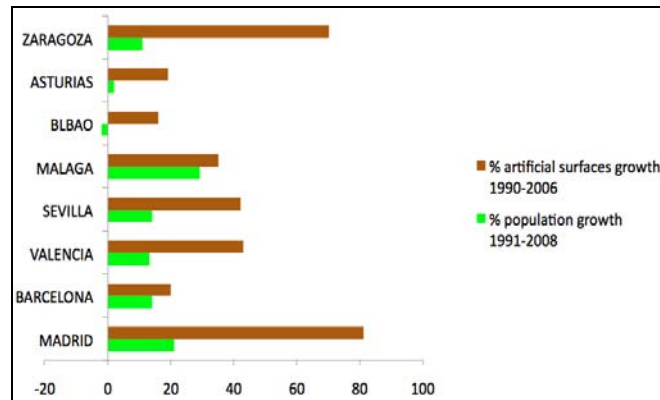


Figure 11. Population and artificial surfaces growth in biggest Spanish urban areas.

6. EDUCATION IN SUSTAINABLE DEVELOPMENT

The expressed urban growth can be explained in the Spanish economic development which coincides in time with the period of analysis of the Corine Land Cover project. With an average annual growth of the Spanish GDP of 3%, since the late eighties until 2006, it turns a productive growth similar to the figure of 52% in land uses. That is why, in the acceleration of urban sprawl and the transformation of artificial surfaces so disproportionate, there has been a combination of factors: residential demands, population growth, creation of new households, tourist houses, the effect of the housing bubble, taxes and investments, etc. In the previous section the unsustainability of certain Spanish urban growth is measured, equally reflected in the annual reports of the Observatory of Sustainability in Spain. The last one (2011) considered strategic for sustainability assessment variable changes in land use.

The results obtained in the present analysis have an additional purpose: to generate geoinformation which explains the processes described with an educational purpose, as the phenomenon of extension of the cities and its implications on urban sustainability, becomes a central element which characterizes contemporary societies, and, consequently, is a nuclear content of school Geography. Environmental education has become one of the main topics in the Geography curriculum, especially in Secondary education, since it has been considered by UNESCO an essential educative principle in boosting the United Nations Decade for education in sustainable development (2005-2014).

It is in this context where the teaching of Social Sciences, and particularly Geography, are fundamental for environmental education and education for sustainability, since this discipline deals with the interpretation of the interactions between the human being and the physical support where it sits (Marrón, 2007). In other words, "Geography has a theoretical conceptual framework and a methodological competence which enables it to address the environmental issues in the classroom." (Souto, 2000), where teachers prefer to work with didactic resources complementary to textbooks (Alberto, 2002), and increasingly with geoinformation, map viewers, map resources produced with GIS, etc. (De Miguel, 2010) (Lázaro & González, 2007).

Thus, with digital maps generated with SIU to view the evolution of the processes of transformation of agricultural and forest soil into artificial surfaces in Spain, you obtain an accurate map representation and valuable didactic resources for the teaching of Geography at schools: the fact of drawing several maps with a diachronic sequence, using the simple distribution of colours identified with land uses, allows to teach Geography in a more attractive and dynamic way and enable students to read the geographic space they study in a better way. Besides, the use of these geomeia helps to fulfil the targets set in the two

International Declarations on Geographical Education of the Commission for Geographical Education of the International Geographical Union (1992 and 2000), reviewed for the Lucerne Declaration on Geographical Education for Sustainable Development of 2007, which details the criteria for the development of the Geographical curricula in the education for sustainable development.

In Spain, territorial sustainability and environmental education are collected in several sections of the curriculum of Secondary education, both in the contribution of the subject to the acquisition of basic skills (spatial thinking and spatial citizenship), and in the objectives, contents (for example, nature and environment; urbanization, sustainability and regional planning; etc.) and even in the assessment criteria. And this has allowed us to use these geomedial products both with Geography students in secondary schools and in the programmes of Geography teacher training at university, with a very satisfactory result of acceptance both of the resources of comprehension of the geographical phenomena in particular and the challenges of sustainability in general.

7. CONCLUSION

The first major conclusion of the present study is that the growth of the artificial surfaces in Spain is the biggest in Europe, with rates which do not justify within the parameters of sustainable development, and less with the population growth. This urban explosion produced recently in Spain is also unequal, concentrating mainly on the more dynamic urban areas, increasing, thus, the spatial imbalances on small towns and part of the rural territory.

The increase of artificial surfaces has also contributed to modify the metropolitan structure in big Spanish cities, extending the phenomena of urban sprawl, but also modifying the patterns of mobility and location of activities, as well as the traditional patterns of centre-periphery for the benefit of spatial models of polycentric structures, dispersed and on the net. In short, post-metropolitan structures, with consequent effects for sustainability in terms of land and energy consumption. Besides the 71,000 hectares mapped as construction sites in 2006 have suffered, for the most part, the effects of the burst of the housing bubble of the following years which have caused a financial unsustainability together with environmental unsustainability.

All this test on urban sustainability has been possible thanks to an instrument of geovisualization and quantification of spatial phenomena, the Corine Land Cover project, which also counts with a standard methodology for the whole of the European countries. This means ensuring the reliability of the data and establishing true comparative analysis which show different patterns of urban growth, ones more sustainable than others.

Finally, the very tool (SIU in Spain) that generates spatial information is able to produce digital resources for the teaching of Geography - in the framework of the aims of digital-earth.eu network-, and transferring them to the classroom so that secondary school students and Geography teachers better understand, from an environmental and territorial perspective which are the challenges of sustainability.

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