A COMPARATIVE ANALYSIS OF THE PATTERNS OF LAND USE IN THE EUROPEAN CITIES

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Abstract: There is a growing interest in what concerns the land uses changes, particularly in the urban areas because nowadays the city is the "engine" of our development, being the defining element of the human civilization. In other words, the city is not a fixed entity, stable in time and space, but a centrifugal or centripetal flow node which facilitates and maximizes economic, social, political and cultural interactions. Therefore, it is an open system which constantly changes as it is submitted to different pressures either from the inside or from the outside. The present work intends to find a defining model for the urban areas in the European Union. For the present study 295 cities were selected and analysed in order to identify similar patterns of land use. The comparative analysis was based on 2 main variables: the Moran's I coefficient of autocorrelation and the G Index. Finally, a proposal was made to define the urban land use pattern for the EU cities.

Keywords: *land-use patterns, Moran's I, geographical linkage coefficient, spatial autocorrelation, cluster analysis*

1. Introduction

The beginning of the twenty-first century represents an unprecedented expansion of the urban areas at the expenses of the rural ones. The city, a well-defined and organized area with a relatively slow growth, started to develop and to integrate new meanings, becoming synonymous with the urban agglomeration, metropolis, megalopolis or conurbation, concepts which are the opposites of its primary meaning. Today the city is not a mononuclear settlement with a slow growth but, on the contrary, a dynamic pole in a continuous expansion, whose limits are becoming more and more difficult to be determined within the territory. In less than half a century, the city grew from a small, closed perimeter into a complex organism that is both a unique and national phenomenon, a universal and international manifestation (since the year 1980) (Laborde, 2005)

Therefore, the diversity of meanings the city acquires in literature is not surprising. Thus, Remy Allain considered that a correct and complete analysis of a city could only be done by studying its landscape, an essential part of its structure that also allows us to eliminate a superficial analysis of the urban space (Allain, 2004). However, at the same time, there is a risk of making a description from the point of view of a behavioural geography, the environment being more important than social interactions. Giacomo Corna Pellegrini defines cities as projections on a restraint territory of the natural conditions, historical heritage, economic forces, technological progress, administrative constraints and daily habits, as well as of conscious or unconscious aspirations of people (Pelegrini, 1973). This view is closer to that of the Marxists, which define the city as a result of social, legal, political and ideological interactions. On the other hand, the sociologist RE Park, founder of the Chicago School,

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regards the city more as a state of mind, as a set of customs and traditions or even as a set of attitudes and feelings. A vision that puts social actors in the spotlight is also promoted by Paul Claval, who considers the city as an organization designed to maximize the social interactions between the citizens. (Claval, 1981).

The main hypothesis of this study is the fact that there is a spatial model of a European city, a general pattern which can be found with smaller or larger adjustments throughout the whole European continent, mainly due to the common history in terms of the urbanization of the territory. However, it is difficult to capture the "essence" of it. A city itself bears the imprint of its geographical location and also of its functional specificity. “The "European City" stands out primarily through individualized realities dictated by the geographical and social diversity, which confers individual features compared to other continents, doubled by the size of its geodemographical and functional characteristics.” (Boyer, 2003)

Therefore, this paper has an approach that is based on the study of the present research literature in this domain and also on various statistical data, aggregated using interdisciplinary methods, from geographical to statistical and even mathematical ones, in order to respond to the complex nature of modelling the land use for the EU cities.

2. The study area

The perimeter of the study is the area of the European Union, more precisely the 27 states for which the European Environment Agency provides data on land use for 295 cities (see Fig. 1) with more than 100 000 inhabitants.

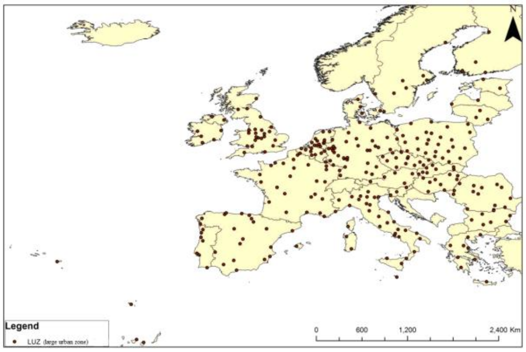

Figure 1 – Spatial distribution of analysed cities

This area was chosen for the study primarily because of the constraints related to the availability and relevance of the necessary data needed in order to establish a pattern for the development of the cities and to capture the phenomenon of urban sprawl and also because in the current social, economic and political trend the European Union is one of the key poles in what concerns the innovation and modernization across the Globe. Nor must we forget that Europe was the place of emergence of the phenomenon of "urban boom”, encouraged by the industrial revolution of the 18th century, a phenomenon that, during the following centuries, had a different intensity depending on the cultural and political context of the period of time. Consequently, the study area includes cities with a diversified past, both from the point of view of history and of the type and way of implementing urban expansion policies.

The Two World Wars, the economic crisis lasting from 1929 to 1932, the Cold War and the establishment of communism in the Central and Eastern part of Europe brought major changes to the expansion plans of urban areas, which were not always focused on the protection and preservation of the environment and implicitly not in favour of the population, the central element which both the positive and the negative effects of these changes reflected upon.

Nowadays, after more than 20 years from the fall of communism and the liberalization of the social , economic and political life, the urban areas present different expansion plans , bearing the imprint of the integration or, on the contrary, the neglection of the principle of spatial equity . Each city has different challenges which need to be faced in terms of infrastructure and territorial planning, starting from the spatial context, pace of the urban sprawl and its level of development and also from the country it belongs to. Thus, urban areas are "regenerating" in different ways and at a different intensity depending on the opportunities and obstacles that need to be managed. Cities with a developed economy and a high standard of living generally have more funds that can be invested in territorial re-planning, which can thus be organised for a long period of time through constant investments. In the meantime, developing cities have to face a bigger number of problems, territorial re-planning of the already built spaces being not a priority, under the circumstances of a preference for investing in designing new spaces in accordance with the expansion principles promoted nowadays, since they generally prove to be less expensive in both financial and temporal terms.

3. Database and the methodology

3.1 Database

The database of this study is represented by the maps developed by the European Environmental Agency (EEA) as part of the local component of the GMES land monitoring services The GMES Urban Atlas provides inter-comparable and high-resolution land use maps for Large Urban Zones and their surroundings, with more than 100.000 inhabitants as defined by the Urban Audit for the reference year 2006, at a scale of 1: 10,000. The GMES Urban Atlas is a joint initiative of the European Commission, the European Space Agency and the European Environment Agency. The Urban Atlas was created by the French company Systèmes d' Information à Référence Spatiale (SIRS).

The maps were made using satellite images which have a 2.5 m multispectral resolution. The types of images used were SPOT 5, ALOS, and RAPID EYE QUICK BIRD. 2 TB of satellite images were processed, which indicates a careful and detailed approach, both temporally and spatially, which could only materialize in a vectorial set of data with a high degree of accuracy, both in the classification by classes (minimum 80%) and also in what concern the spatial position (+ / - 5 m).

The final sets of maps use a classification of 20 classes depending on the type of land use (residential, industrial, green urban areas etc.).The data and the satellite images were processed by specialists in accordance with the cartographic guide GSE, spatial adjustments being made where necessary, just like the automatic labelling of polygons. Also, topographic maps at different scales of analysis were used in order to increase the accuracy degree of the final maps, while for the transport infrastructure the COTS navigation data was the main support.

This study worked with the following four categories (see fig. 2):

a) Continuous Urban Fabric (CUF) - built-up areas with an average degree of soil sealing greater than 80%; predominant residential use, independent of their housing scheme (Single-family houses family houses or high rise dwellings, city centre or suburb).

b) Forest (natural and plantation) – land with ground coverage of tree canopy > 30%, and the tree height > 5 m, including bushes and shrubs.

c) Green Urban Areas (GUA) - public green areas with a predominant recreational use (e.g. gardens, zoos, parks).

d) Industrial, commercial, public, military and private units (IND) – the most of the surface is covered by artificial structures (e.g. buildings) or artificial surfaces (e.g. concrete, asphalt or otherwise stabilized surface, e.g. compacted soil, devoid of vegetation), the land being used for industrial, commercial, public, military or private activities.

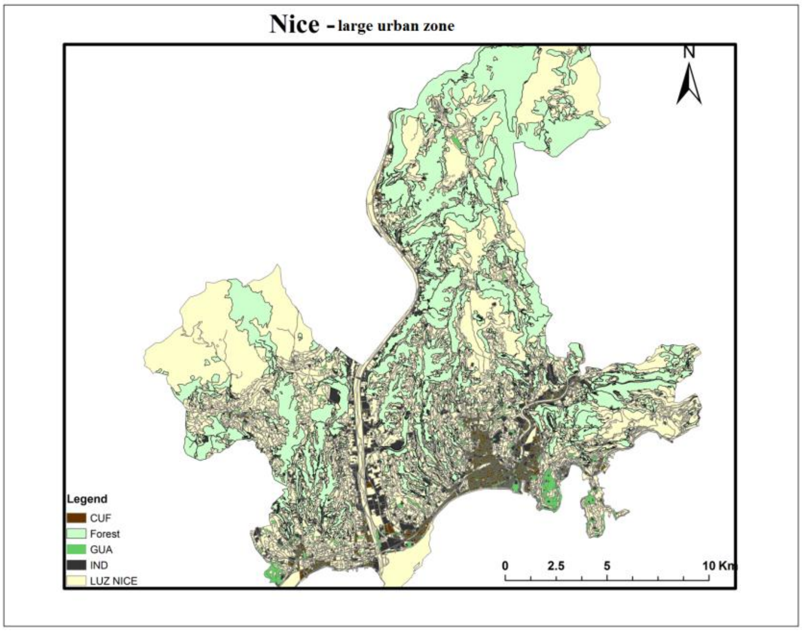

Figure 2 – Types of analysed categories - Nice (France) (Source: GAMES Urban Atlas)

These four categories were chosen as they are defining for the current changes in the land use patterns of urban areas, as it follows: the CUF were chosen because the main element which triggers a change is the social factor – population. A greater surface covered by residential buildings means a greater susceptibility to changes in the close future because of the dynamics induced by the population which needs space for some new facilities which would ensure their well-being. GUA were selected because sustainable development is a necessary tool nowadays in an environment which is becoming more and more artificilised. Finally, the IND were chosen because, without industry and commerce, there would be no concentration of population and therefore no urban areas. The decrease or increase in terms of the surface of this category is a good indicator for the attractiveness of a city and for its future evolution.

Therefore, a city is generally organized around a dense node of population and characterized by a specific urban landscape, which is defined by a characteristic pattern and has its own structure which includes the biological component, the physical environment and the anthropogenic elements (Tudor, 2009), all of them being clustered around a core defined and preserved during a long period time when the major political projects that succeeded one another allowed its persistence during the years to come.

3.2 *Methodology*

Urban areas cause the fastest transformation of the way the land is used, because they are in a continuous expansion, mainly due to the growth of the inhabitants, a fact which triggers the need imagine new residential, commercial and recreational spaces. Therefore, the methodology of this study takes into account the complex nature of the urban areas in terms of their morphological evolution, which requires diversified analysis methods that could capture both positive and negative aspects of the artificialisation of the natural areas .The geospatial and statistical methods used for the analysis and modelling of the urban areas in the European Union include the spatial autocorrelation coefficient - Moran 's I and the coefficient of geographical linkage, resulting in a final set of 5 indicators, which were then used in order to draw up four hierarchical ascendant classifications grouping the 295 cities according to the similarities in what concerns the policies of land use and their management.

3.2.1 The spatial autocorrelation coefficient - Moran's I

The spatial autocorrelation is a key concept in geography because it allows the quantification of the presence or absence of a geographical structure of a phenomenon in space. In general, there is a dependant relationship between spatial units (for example, a city within a region cannot evolve independently and different from other cities in the region because, in order to develop, it establishes a relationship of interdependence). This relationship will ensure continuous flow caused by the population movement or the exchange of goods and services, made, of course, in both directions, but with different intensities depending on the importance and level of development of the city, as well as the local and regional influence of each urban area.

Thus, the spatial autocorrelation measures the extent to which the presence of a certain phenomenon in space constrains or, on the contrary, favours the emergence and development of another phenomenon in the neighbouring regions. Therefore, if there is a pattern in the spatial distribution of a pair of variables, then we can say that they are spatially autocorrelated. In the cases in which the neighbouring regions have similar characteristics, we can speak of a positive spatial autocorrelation. If the neighbouring regions show differences, then we have a negative spatial autocorrelation, while the random characteristics of neighbouring areas indicate a lack of spatial autocorrelation.

The spatial autocorrelation coefficient was calculated using the coefficient “Local Moran's I" , which is based on the Pearson correlation coefficient between a variable and its spatial lag. It should be noted that the Pearson correlation coefficient interpretation must be made with reluctance because it does not give information on the degree of significance of the relationship, which is dependent on the number of observations.

The Moran's I coefficient allows the testing of a set of continuous data in order to determine whether they present or not spatial autocorrelation. It is based on the product of the deviations from the mean for a number “n” of observations for a variable x in different locations i, j.

The Moran's I can take values ranging from -1 to +1, the value 0 indicating no spatial autocorrelation. This index is calculated according to the following formula:

$$I = \frac{n}{S_0} \frac{\sum_i \sum_j w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_i (x_i - \bar{x})^2}$$

where $\bar{x}$ is the average of the variable X, w_{ij} represents the elements of the correlation matrix and S_0 is the sum of the elements contained in the correlation matrix: $S_0 = \sum_i \sum_j w_{ij}$.

The advantage of using the spatial autocorrelation coefficient Moran's I is the fact that it is a descriptive method that allows us to take into account the spatial location of an area and its attributes, as well as the distance. However, it should be considered that distance can be both a physical value and a social or cultural one. Therefore, we can interpret or identify characteristics of spatial variations of a phenomenon based on location, which is not possible when using conventional statistical elements, such as the average, as they do not provide any indication of the spatial distribution.

It should be noted that ArcGIS v9.3 was used, but not the tool called Spatial Autocorrelation (Moran’s I), since it does not allow the recording of the results of data processing for each city in a dbf file (database file), but it provides a visual result that can be recorded only manually by the user for each category analysed, which is time-consuming and not viable for a large database. An alternative was chosen, building a Model Builder, based on the formula for the index of Moran's I described earlier, which allows us to record automatically the autocorrelation coefficient for each category considered for this study. (see Fig 3).

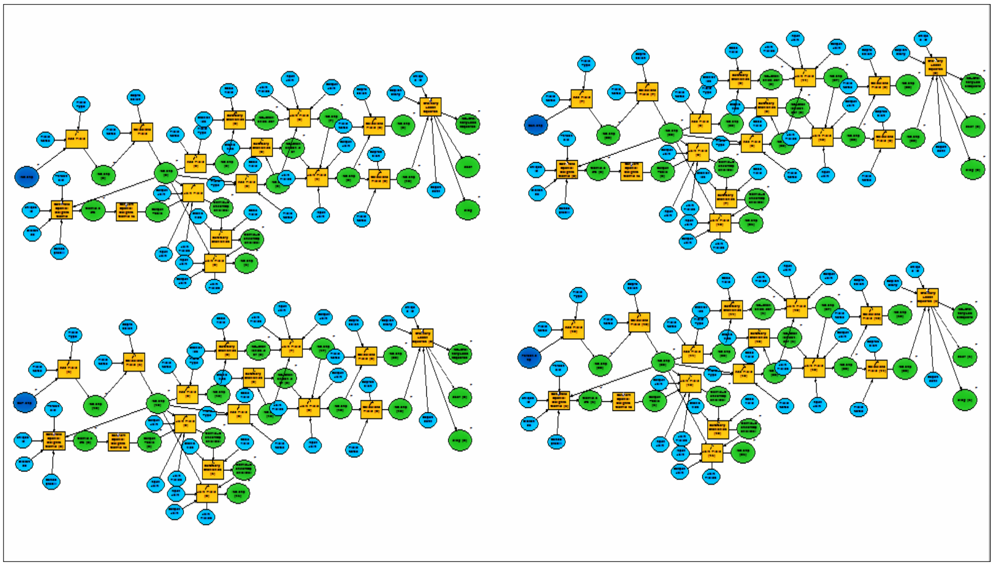

Figure 3 - Model Builder – the spatial autocorrelation coefficient - Moran's I for all four categories analyzed (Nice - France) (Source: GMES Urban Atlas)

The robustness of the model was verified by applying both the Instrument Spatial Autocorrelation (Moran’s I) developed by ESRI and our own model in order to analyse a sample of cities, confirming the fact that our algorithm is correct.

3.2.2 The coefficient of geographical linkage

The coefficient of geographical linkage highlights the degree of association of two sets of different or similar variables through systematic evaluation of the similarities and dissimilarities in their distribution.

This coefficient was applied for modelling the spatial distribution of the industry in Shanghai, China in the article “Interpreting Location Quotient. Local Moran’s I and Geographic Linkage for Spatial patterning of Industries in Shanghai, China" by Jing Feng and Ji Minh, using the following formula:

$$G = 100 - \frac{1}{2}\sum_{i=1}^{n}|S_i - P_i|$$

, where “n” is the number of observations, S_i is the percentage of one of the observations in the area i, and Pi is the percentage of the second observation in the area i;

A high value of this coefficient (G > 80) indicates a congruence in the distribution of the pairs of observations and, implicitly, a high spatial association. On the contrary, a low value of the coefficient (G < 60) reveals the existence of some dissimilarities in the distribution of any pair of observations. In fact, this index is an expression of a proximity coefficient expressing the interdependence between two variables, as a direct consequence of the geographical distance.

In this paper, the index was adapted to analyse the spatial proximity of two of the four areas analysed: the urban green areas and the industrial and commercial ones. In other words , we intended to identify the extent to which green areas are found or not within economic areas, whereas the spatial proximity of green spaces to the urban areas, responsible for the degradation of the environment, indicates an urban planning in accordance with the principles of sustainable development.

In order to facilitate the calculation of the G index, a Model Builder was once again designed, which fastens the analysis of the 295 cities in this study. (See Fig .4)

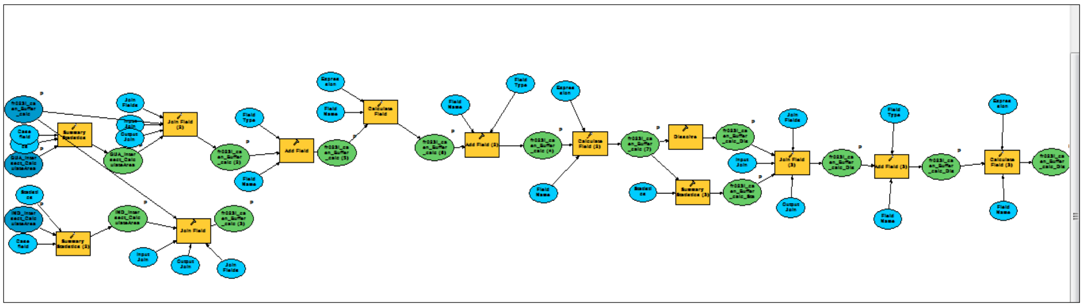

Figure 4 – Model Builder – The coefficient of geographical linkage

4. Results and discussions

As Jacqueline Beaujeu - Garnier states, "the urban phenomenon is undoubtedly one of the most characteristic traits of the contemporary civilization."(Garnier, Chabot, 1971). Therefore, studying and understanding the urban development is a challenge which requires the application of some interdisciplinary methods that could capture the multiple dimensions of this phenomenon, which becomes more and more demanding as the society progresses. However, as even Charles Abrams mentions, the major problems of any city are the available space for urban expansion and the way in which the entire process of urbanization is managed in order to get optimized. - "In cities all over the world land is used for specialized purposes such as housing and industry. One of the main problems of any city is how to control these uses to enable the city to function and evolve."(Kingsley, 1973)

The type of land use in urban areas has become a major issue in society since the intensification of the socio-economic processes, because the population is in a continuous growth and the city, as an entity itself, must be capable of providing optimal development conditions in order to meet the needs of each person. It should also be noted the fact that in the context of promoting a sustainable development, the land use policies must not only take into account not only the ability of providing the required space for the residential, industrial, commercial and recreational areas, but they should also ensure the existence of an equilibrium between them. But, it’s much easier to only say it than put it into practice, because bringing order in a chaos determined by a previous faulty territorial planning represents a problem for which an acceptable solution is yet to be found by the government and land-use planners.

Thus, finding an optimal model for the urban areas of a society that is in a constant process of development and, at the same time, wishing for a sustainable development, by reducing the human pressure on the environment, is a challenge to which those responsible for urban land-use planning need to find an answer.

The urban patterns highlighted from now on are based on the variables obtained by processing the database GMES Urban Atlas, which were aggregated with the aid of the Hierarchical Ascendant Classification.

The Hierarchical Ascendant Classification known also as the cluster analysis, identifies a set of homogeneous clusters by grouping the variables in order to minimize the variation in the class and maximize the variance between classes. (Babuc, 2003)

Having the five variables mentioned earlier (the spatial autocorrelation coefficient Moran's I for all the four categories and the values of the geographical linkage index), two Hierarchical Ascendant Classifications were derived, the aid of Microsoft Excel, more specifically the add-in XLSTAT.

The first ascending Hierarchical Ascendant Classification uses as an aggregation method the Ward's linkage, which is based on the increase of the "sum of the squares of the errors" after their merging into one group. The Ward's method selects the clusters that minimize the increase of the square sum of the errors. It should also be noted that the values of the coefficients were centred and then reduced. In what concerns the metric used, it is the Euclidean one, which represents the distance between two points given in the Cartesian coordinates by the Pythagorean formula. The cities were classified into seven classes based on the similarities found between them. (See Figure 5)

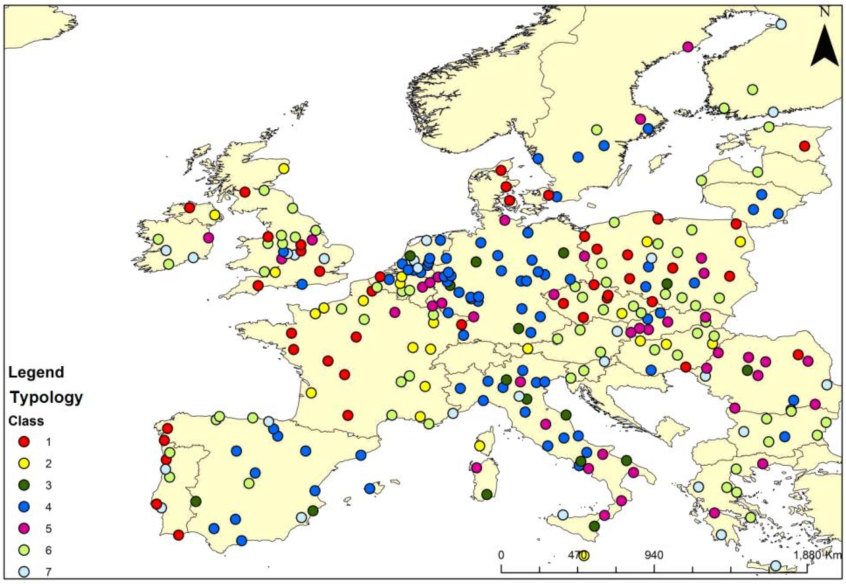

Figure 5 – The typology of EU cities - Hierarchical Ascendant Classification (XLSTAT - Ward method)

This typology reveals a few regional patterms, such as the tendency of the most cities in Germany, Italy, the Benelux to group in the same class (3), which also comprises cities from Spain and Sweden, which does not allow us to speak of the delimitation of a central-western european pattern of land-use. Some similarities can also be noticed in the central-south-eastern part of the European Union: most of the cities in Poland, Romania, Bulgaria and Greece fall within classes 5, 6 and 7. However, again, these types of classes are also found in the western part of the European Union, which indicates that urban planning policies were not directly determined by the historical and socio-economic realities of these countries.

The profiles of the classes (see Fig. 6) show a lack of spatial autocorrelation for the industrial areas, in what concerns Class 5, which reveals their random distribution, probably because they are inserted within or lying in the proximity of the residential or green urban areas. Class 3 indicates the fact that the organization pattern of the urban areas in the European Union does not have a compact distribution, grouped by categories, but it is in fact tesselated. Class 1, which indicates the existence of a positive autocorrelation and a strong geographical linakge, can be identified only for a few number of cities, especially those in Denmark, which indicates the existence of some coherent urban planning policies at national level.

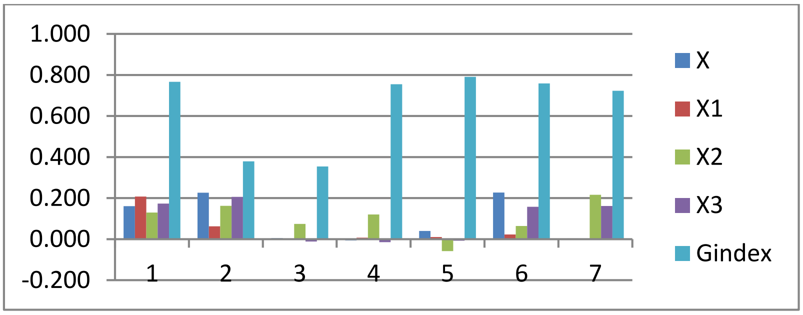

Figure 6 – The classes profile - Ward's method (XLSTAT)

The second Cluster Analysis was again made with the XLSTAT, keeping the same variables and changing only the proximity matrix in order to achieve the grouping of the cities according to their spatial proximity and their national affiliation. We chose a value of 500 km, this being the average diameter of an average size country. The Hierarchical Ascendant Classification divised urban areas into seven classes (see Fig. 7) based on the variation of the variables.

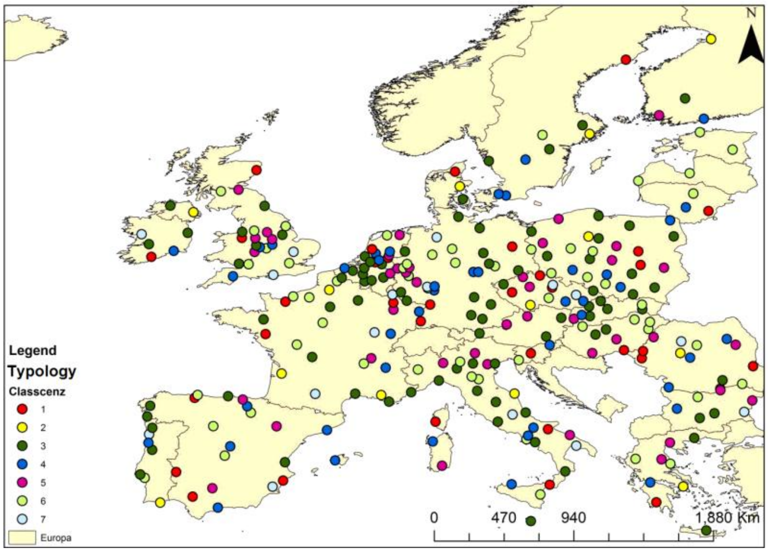

Figure 7 – The typology of EU cities - Hierarchical Ascendant Classification (XLSTAT – 500 km – proximity matrix)

The analysis of the results indicates a high heterogeneity of urban land-use patterns within countries , despite the fact that a constraint of distance was introduced. However, the method is a promising one, because it emphasizes three regional concentrations: Benelux, Eastern Germany and Slovakia - South Poland - northern Hungary, an increase of the distance (to 700 m) being maybe necessary. Nevertheless, strong internal dissimilarity can be spotted within developed countries (such as Spain, France, Germany , the United Kingdom of Great Britain and Northern Ireland, Italy), as well as in the countries with an average living standard (such as Poland, Romania, Bulgaria, Greece etc) (see Fig . 7).

Thereby, we can summarize that by means of the two Hierarchical Ascendant Classifications we can define three patterns of land use in the EU urban areas. The first one, which is characterized by a positive spatial autocorrelation of all the four areas analyzed , points out the fact that their concentration is brought about by their internal characteristics, grouping the cathegories with a negative impact on the environment with the ones with a positive effect, meant to counterbalance the former ones. We are therefore dealing with a homogeneous urban landscape, which presents a concentrated distribution of residential areas, green urban spaces and areas for economic activities .

A second model, which shows negative coefficients for all indicators or at least for the most part of them , describes a heterogeneous urban landscape . It is obvious that this model reveals a chaotic distribution without a territorial logic behind the decisions which were made during the past time . A third model can be identified in the case of the presence of only 2 - 3 positive coefficients while, the rest are negative, which shows an agglutination of the urban area in question and which results in a combination of the two categories described above.

Thus, depending on the coeherence of the urban landscape, different policies should be applied. In the cases of the compact cities with a homogeneous spatial organization , the urban planning policies already implemented should be continued, aiming at preserving the positive effects and eliminating the negatives one, if possible. In the case of the urban areas exhibiting a chaotic landscape, sequentially rearrangement measures should be implemented at a local scale. It would also be indicated to apply sectorial policies for each problem area . A solution for the territorial reconfiguration of the urban areas , which will make possible the transition from an exclusive urban planning focused on the core area of the city to a spatial organisation favouring the polycentric models, would firstly be to control the suburban areas which tend to develop chaotically, generating an amorphous urban network , which generally leads to an important environmental degradation. It should also exist a focus on the revitalisation of the initial poles of economic development through measures directed against the tendencies to abandon industrial spaces, promoting a sustainaible urban regeneration.

5. Conclusions

The urban planning policies in the European Union (as revealed by the analysis made in this study) do not show a national pattern, whereas a regional pattern can’t be defined either. Thus, they vary depending on the degree of centralization of the political and administrative structure of the country and also on the national policies regarding the process of urban sprawl, policies mainly influenced by the overall shape of the urban network, the economic needs of the country; recently, they have also begun to take into account the increased sensitivity of the population when it comes to degradation (in terms of quality of the urban area and of the environment itself).

The Hierarchical Ascendant Classifications made do not reveal a general land-use pattern for the cities that lay under the influence of the communist regime until 1990, but they do show us a relatively high heterogeneity within countries. Nonetheless, there is a predominance of certain classes in the countries mentioned above, classes that are not found as often as in the case of the democratic countries. However, the presence of cities with patterns similar to those of the former socialist states in the Central - Eastern Europe indicates that the tesselated territorial organization of the urban areas is not necessarily a direct result of the communist regime . Of course, the predominance of the models lacking a coherent territorial logic for the ex-communist countries still indicates the existence of an interdependency between the ideology promoted by the regime and the spatial planning of urban areas.

Therefore, given the lack of a clearly defined zoning of the cities in the European Union, the question which appears refers to the level at which the reformulation of the urban planning policies should be made: state level or European Union level ? Is it a problem of national management, or on the contrary, an international topic? Thus, the issue of territorial planning is brought forward with its many dimensions: physical, cultural, economic and political, highlighting the fact that urban planning should take into account the numerous interdependencies existing at different scales of intervention. Unfortunately, the interests of the social component do not always come first, as the economic ones (as shown by the analysis performed in this study).

However, it is important and necessary to establish the main decision factors of the process of sustainable urban planning, as it is clear that between the State and the European Union there are differences of points of view . The state pursues its own socio-economic objectives and, taking into consideration the current context of promoting territorial cohesion within the EU member states, an overall management is required, able to adress not only the national issues but also the international ones. Obviously there will be drawbacks if the urban development policies are only made by the European Union, as the scale of analysis cannot reach a local level focused on specific issues for individual cities .

In these circumstances and considering the high diversity of the type of land-use in the urban areas of the analyzed states, the ideal solution seems to be the elaboration by the European Union of some general land use policies, adapted to each country by the national gouverment , under the careful supervision and coordination of the European Union , as it is necessary to achieve an overall territorial coherence at the macro level, enabling economic and social progress for all the states of the European Union.

All in all, the urban phenomenon itself can not be separated from the environmental dimension. In other words it is necessary to understand the mechanisms that are governing the spatial planning of the urban areas in order to be able to promote a sustanaible development which will ensure both the economic progress and the preservation of the environment, a fact that will guarantee the continuity of generations as the Brundtland report mentions: “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs”.

In conclusion ,the modelling of the land use for the cities in the European Union highlights the necessity of a preliminary study of the actual plans concerning the land use for a better implementation of the new policies, which promote the urban regeneration and sustainable development . The comprehension of the patterns of land use may prove to be a good tool both for the implementation of the expansion plans of urban areas and for the elaboration of the local, regional and national action plans for the environment, which promote a sustainable development because they offer a complex vision of urban areas. Thus, the city is one of the main elements of the macrosystem represented by the environment, as it is a node that determines both inflows and outflows, which determine the growth and the development of the urban area itself and also of the neighbouring areas.

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