A METHODOLOGICAL PROPOSAL FOR THE ANALYSIS OF SUSTAINABILITY IN THE PROVINCE OF CUENCA [1]

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The aim of this study is to define a synthetic —or global— index for sustainability, on a municipal level, which is capable of integrating its three main dimensions: economic, social and environmental. This index is expected to provide an approximate measure of sustainability on a harmonised scale whereby land managers, authorities and local communities can assess the gap between each municipality and its optimum global sustainability. In addition, the index will help establish comparisons among municipalities to aid decision making in terms of regional and/or sector planning.

A second aim is to propose an operational methodology for estimating the integrated index of sustainability on the most elementary analysis level from an administrative-regional point of view: the municipal level.

Finally, the situation of each municipality is represented in a three-axis diagram corresponding to the values of the three indices that show the three dimensions of sustainability, which are then integrated into one final synthetic index. Thus, it is possible to classify municipalities according to their characteristics and, above all, their sustainability. This enables regional and county planning to be designed in accordance with each typology.

I. STUDY AREA

The county selected for this study was the Sierra Media Conquense for being representative of medium-height mountain areas which are abundant in the peninsular inland. This

1 The original study is part of the Research Agreement titled «Agenda 21 de la Sierra Media Conquense (2005X144)», directed by Javier Martínez Vega and financed by Asociación SEDECUCE.

natural county has an area of 1,797 km², which contains 28 municipalities. It is located on the centre of the province of Cuenca, in the Autonomous Region of Castilla-La Mancha. This geographical space is shaped by its mountain ranges or *sierras*, which are in the central part of the province. The study area has 12,201 inhabitants and a low population density (7.15 inhab/km²) which shows its degree of underpopulation. The county has a worrying demographic ageing index (36.52%) and a negative population growth rate, which reached -2.22‰ between 1991 and 2001.

Some of the features of this county, which are a risk for its sustainability, are as follows: demographic ageing together with a negative population growth, a concerning illiteracy rate, major groups in danger of social exclusion, soil loss due to erosion, a loss or degradation of woodland as a result of forest fires, a decrease in surface water quality caused by direct spills from the sewage and the presence of illegal rubbish dumps.

II. MATERIAL AND METHODS

This study is based on calculating 28 composite indicators of sustainability, measured on a municipal level. These indicators were selected by a group of experts for being the most significant and relevant. The indicators synthesize 137 variables from several sources of information. Most of the indicators selected are statistical and the data was provided by various censuses (Population and Housing Census, Municipal Census of 2007, Agrarian Census of 1999 and the Cattle Census of Castilla-La Mancha). Other sources were provided by the town councils, the Consortium of Waste Products of the Provincial Council of Cuenca, the Chamber of Commerce of Cuenca, the Cadastre or by public transportation companies. Among the surveys, it is worth highlighting the Survey of Local Infrastructures and Services and the survey carried out by the research team of the authors. The rest of the indicators selected are cartographic and were calculated using spatial analysis. Several thematic maps were also used, some of which form part of national series but others were produced by this research team.

The land use map, one of the intermediate products, was produced by means of visual analysis and by digitising over a Landsat (ETM) orthoimage. The survey on the degree of satisfaction of the population with respect to local community management was the means of mining for reliable information regarding one of the common European compulsory indicators. This was a direct survey on a representative sample of resident population over 20 years old, keeping a balanced distribution in terms of gender and age groups, with a confidence level of 95.5% and a margin of error of +/- 6% which equals to 272 interviews.

The workflow is structured into seven phases. The first phase consisted in classifying the 28 indicators selected into one of the three sustainability dimensions, according their degree of affinity with each of the three. The second phase was one of the most difficult: finding thresholds of sustainability for each of the indicators, which were then normalised in the third phase. In the fourth phase, the three sector indicators of sustainability were integrated, by means of a weighted sum, from the simple and composite indicators of each of the sustainability dimensions. A series of equations for each of the sector indices were defined: the social sustainability index (ISS), the economic sustainability index (ISE) and the environmental sustainability index (ISA). In order to reduce the bias, the weights of each indicator were assigned taking into account three criteria. The first was the opinion of the experts from the research team and the experts from the local administrations that were consulted. The second criterion was to assign more weight to some compulsory European indicators. Finally, the third criterion was to take into account the priorities and concerns of the local population which were recorded in the surveys that were carried out under the Local Agenda 21 framework.

During the fifth phase, the sector indices were integrated into one super-index, named the Global Sustainability Index (IGS), which was obtained from a simple, un-weighted average. In order to study the relationships between each of the four sustainability indices proposed and their respective building indicators, a series of backward linear regression were performed, where the sustainability indices were considered as the dependent variables and the indicators were considered as the independent variables. The internal cohesion of the indicators was analysed using the Cronbach Alpha coefficient. A correlation matrix was calculated to carry out an analysis of the relationships among the indicators of which each index is composed of, and also among the three sector indices that form the IGS. Alternatively, a factor analysis extracted the principal components of each of the sector indices using a rotation method known as the Kaiser and Varimax Normalisation. In the sixth phase, a cluster analysis classified the municipalities into homogeneous groups according to their social, economic and environmental features. Finally, in the seventh phase, the location of the study cases were plotted in order to compare its position in relation to both the sector and global sustainabilities. A cube was chosen as an alternative method of representing the global sustainability in the municipalities under study. The values of the indices ISA, ISE and ISS are represented in the x, y, z axis of the cube respectively, and are scaled from 0 to 100.

The IGS was plotted on a map and each centroid of each municipality was assigned the IGS value of that municipality. A spatial interpolation was then applied on the point cloud to obtain a raster model with a 20m grid spacing. Several direct and analytical methods were tested. One of these was an interpolation method which was direct, linear, un-biased, exact and local, based on a nearest neighbour system with an inverse distance weighting. Other methods that were tested were geostatisical methods of a topo-probabilistic nature, which were designed to analyse regionalised variables that have a spatial distribution and, therefore, a correlation or a spatial variability. These analytic methods, which are exact and local, are based on simple and ordinary *kriging* as well as *co-krigining*. The geostatistical layer, which was produced to store IGS values, was then used to extract the most significant isolines having the same global sustainability. Isolines were represented using a shading effect, and the gaps between isolines were mapped using a scale of greys. In order to obtain an assessment of the error in the interpolated model of global sustainability, a model was produced using a simple kriging based on 80% of the observations, leaving the remaining 20% of the cases to validate the model. Observed *versus* estimated values in those six points or municipalities (i.e. 20% of all the cases) were then compared.

III. RESULTS

The regression model between the ISA index and the construction indicators excluded factors air and noise since they do not register a variation in the variables. The non-standardised coefficients reveal that the weight of each of the predictor variables is the same. The Principal Component Analysis reduces the four indicators to just two components: the first is related to factors water and soil and the second is related to energy and waste.

Despite these statistical analyses, their results were not taken into consideration because, in the case of the ISA, only four factors out of the six indicators were selected, namely soil, water, energy and waste, meaning that the factors related to air and noise were ignored. It is true that these two last components did not register a variation in the variable in the study area. However, we believe that they are significant because all municipalities reached the maximum value (100%) since air quality is excellent, due to the absence of industry, large cities or other sources of atmospheric pollution, and there are no substantial sources of noise. Consequently, by using the weighted sum method, these two factors increase the environmental sustainability as a whole. In contrast, the results are lower when they were obtained using principal components, which does not take into account these two factors. In addition, since this is a methodological proposal that can be applied to other geographical environments, it is preferable to maintain components air and noise because they could vary significantly in other zones, especially in the urban-rural interface. To a certain extent, it is fair to say that the ISA index, taking into account the principal components extracted, underestimates reality.

Each index of sector sustainability is linked to an iconographic matrix that shows the municipalities in rows, and in columns are the results of the simple or composite indicators, which built the index. The cells of the matrix contain the absolute or relative values of each indicator per municipality. A level of grey is assigned to each cell according to the distance of the value of the indicator, which is measured as the standard deviation to a given threshold of sustainability. The mayors and managers of each municipality can read the table horizontally and can thus identify quickly and visually the strengths and weaknesses of their territory in environmental, economic and social terms.

Regarding the survey on the degree of satisfaction of the population with the local community in terms of the quality of the services received, it can be said that, on the whole, the citizens are reasonable satisfied. The cleaning of the streets, inter-urban transportation as well as health and education services are the aspects that the citizens in these municipalities judged most negatively. Consequently, the managers must put a considerable effort to improve these services and to thus increase the social sustainability. At county level, the services which were most favourably valued were the electric and water supply as well as the sewage system, all of which received an average mark above eight, in a one to ten scale (ten being the highest satisfaction).

As a result of the hierarchical cluster of the three standardised sector indices, five groups of municipalities were obtained.

Municipalities were plotted in a cube, whereby the two municipalities of group 5 are the most sustainable as a whole and have IGS values near 70. Although these are not the municipalities in the county with the highest environmental sustainability, their environment has good attributes and a high value. In addition, they have the highest average of both ISE and ISS. Although these municipalities are close to the provincial capital (Cuenca) and therefore they benefit from their localisation, they have also preserved their environment. As expected, this group of villages is located in at the back of the upper right of the cube.

On the opposite side is group 2, which has only one municipality. It is the less sustainable village in the county and registers IGS value below 56. Within the cube, it is located at the front of the lower left-of-centre. Despite its acceptable sustainability value, which is similar or even higher than other groups, its economic sustainability is lower than most other groups and its social sustainability is the lowest in the whole county (ISS = 37).

Group 3 is made of seven municipalities which are located in the upper left-of-centre of the cube. These municipalities are close to the A3 motorway (Madrid-Valencia) and the A40 motorway (Tarancón-Cuenca). This group has average values of global sustainability as well as social and economic sustainability. It is worth noting that their average environmental sustainability is the lowest in the county. These zones have mostly cultivated land and therefore woodlands are scarce.

Group 4 is also made of seven municipalities which are located at the front of the cube, in the lower right-of-centre. They have medium values for environmental sustainability, but the most notable feature is their low economic sustainability, compared to other values in throughout the county.

Finally, the largest of all is group 1, which is made of eleven municipalities, almost 40% of the county. Within the cube, it is located at the front right-of-centre since it has a medium-low social sustainability and a medium economic sustainability. In contrast, this group has the highest environmental sustainability values in the county, with a 73 ISA average. With some exceptions, these municipalities have large woodlands.

Out of all the interpolation methods used, those which are inexact or do not show the autocorrelation of the data were rejected. Among the exact methods, which maintain the original values of the sampling data, the two methods selected produce the best results, according to the literature. The first is the method that weights the data by applying a weight which is the inverse of the distance. The second method selected was kriging, in this case the simple version.

The prediction of global sustainability in the county of the study area was mapped having calculated the simple kriging. The most sustainable zones are in the eastern part of the county, along the axis that goes from Chillarón de Cuenca, in the NE, to Piqueras del Castillo, in the SE. There also two belts located in the SW and NW, which have high global sustainability values. In contrast, the central zone has the lowest values.

IV. DISCUSSION AND CONCLUSIONS

The analysis capacity in sustainability indicators usually only reaching down to a municipal scale, since the basic territorial units are municipalities. This level of analysis may suffice to analyse large areas in a national or regional scale, but we believe that this level is insufficient in order to study counties on a local level. In this level, it is possible to use a basic information unit which is smaller than the municipality, such as a district, neighbourhood or a 1 km^2 grid.

Another important difficulty is to establish sustainability thresholds per indicator that all social groups can accept. All systems specify the sources and the methods of calculating indicators but they usually do not mention which thresholds mark the limit between what is sustainable and what is un-sustainable.

Form a statistical point of view, it is necessary to increase the number of cases in order to be able to carry out more robust statistical analyses. Future research will extend this methodology to the rest of the province of Cuenca, which has 238 municipalities.

Regarding spatial interpolation methods, there is a certain amount of discussion in the specialised literature concerning the effectiveness of direct *versus* analytic methods. The results in this study show that interpolation, using an inverse distance weighting, and kriging differ slightly. In short, it is necessary to carry out further research on the usefulness of each method, testing with a larger number of cases and validating the results more consistently.

The results show that the municipalities in the study area have a medium-high sustainability which entails, in most cases, strengths in the environmental dimension and weaknesses in the economic dimension and even more so in the social dimension.

Geographical Information Systems have proved once more their usefulness when it comes to processing a large volume of information in order to generate new geographical information, to convert it into indicators and to georeference parameters susceptible of being spatialised, among which is sustainability.

In addition, surveys on the local population provide very relevant information, especially concerning their opinion on the services received from the local administration and their quality. This is a relevant sustainability indicator which can only be accessed by means of surveys.

The synthetic sustainability index proposed in this study integrates a large volume of information into just one value that both local population and authorities can find easy to understand.

Cluster analysis was capable of grouping municipalities according to their sustainability features and was also capable of processing social, economic and environmental problems in a different manner.

Finally, the method of plotting and mapping sustainability is very illustrative since it shows the relative position of each municipality with respect to the total municipalities and it shows territorial gradients of sustainability.