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MULTIVARIATE VERSUS TRADITIONAL METHODOLOGY FOR THE IDENTIFICATION AND CLASSIFICATION OF LANDSCAPES

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1. INTRODUCTION

On October 20, 2000, the Council of Europe opened to the signature of its Member States the European Landscape Convention. In it Article 6 establishes the "specific measures" to be developed, for the "Identification and Evaluation" of landscapes. Only from a detailed and systematic knowledge of the types of existing landscapes and their distribution will their evaluation be possible (COOPER *et al.*, 1992).

There are several methods of classification of the landscape. These vary between subjective evaluations made by experts, in line with traditional cartography, to methods based on semiquantitative assessments, in which a first analysis of the variables involved is performed through GIS techniques, to later establish the types according to criteria predetermined by experts (ENGLISH NATURE, 1993). In addition, there are more empirical and objective studies, using both GIS techniques and multivariate analysis (BUNCE *et al.*, 1981). There are a limited number of variables that the human mind can simultaneously process and, in parallel, a large number of possible parameters to consider when analyzing a landscape. Multivariate classifications can make this information more accessible to allow its management to facilitate the identification of subtle spatial patterns (CHERRILL, 1994).

The classifications of the landscapes developed at the different national levels have been made by methods based on multivariate statistics as well as others, based on an update of traditional cartography. Among the latter are the Map of Natural Areas (ENGLISH NATURE, 1993) for the English territory, the Differentiation of Landscapes of Germany (GHARADJEDAGHI *et al.*, 2004) and, in Spain, the Atlas of Landscapes of Spain (SANZ HERRÁIZ *et al.*, 2003). Whereas for landscape classifications based on multivariate methods, we can cite the typological classification of the landscapes of the Czech Republic by CHUMAN *et al.*, (2010). Due to the proliferation of landscape classification studies, according to one or another methodology, the need arises for comparative studies of landscape classifications, such as those developed by HAINES-YOUNG (1992).

The main objective of the present study was to analyze the degree of similarity in the classification of the landscapes in the province of Huelva made using GIS and multivariate methods (ALCÁNTARA *et al.*, 2015) with the classification of the landscapes of the same province presented in The Atlas of Landscapes of Spain.

2. MATERIALS AND METHODS

2.1. AREA OF STUDY

The province of Huelva has an area of 10,128 km^2 and it is located in Andalusia, Spain. It has a climate that can be characterized as oceanic Mediterranean. There are two great geostructural units represented in Huelva: to the North, the Southern Hesperian Massif (Sierra Morena) and to the South, the Guadalquivir Depression. Sierra Morena is composed mostly of hard materials such as slates, vulcano-sedimentary rocks, etc. It is also abounding in intrusions of plutonic materials. On the other hand, the Depression of the Guadalquivir, constitutes an alluvial plain that receives sediments (MOREIRA, 2003).

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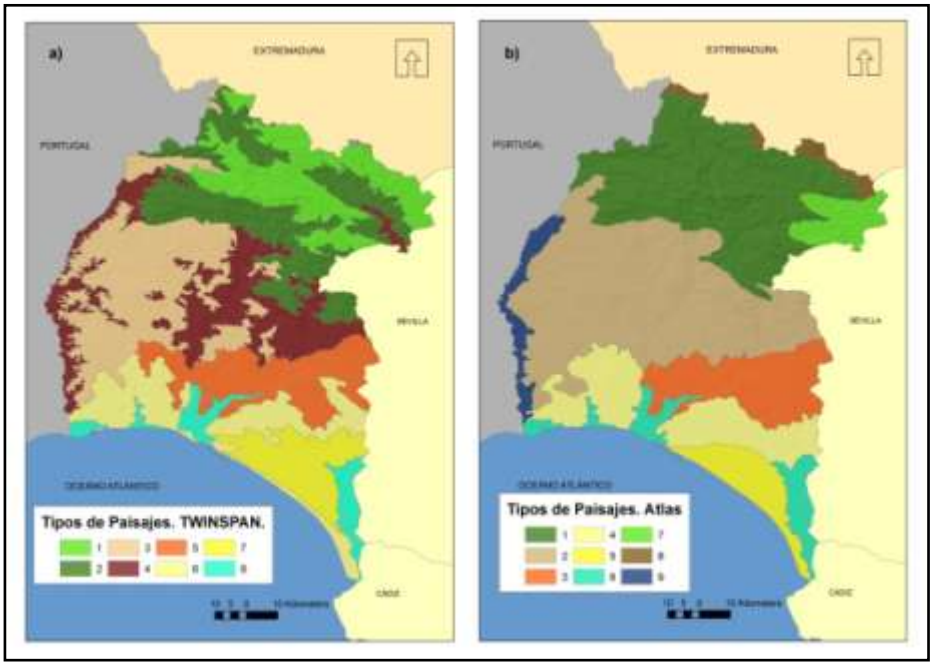
2.2. THE MULTIVARIATE CLASIFFICATION OF THE LANDSCAPE IN THE PROVINCE OF HUELVA. REFINEMENT PROCESS.

ALCÁNTARA *et al.*, (2015) shows the process of obtaining the classification of landscape types of the province of Huelva (Spain). The province was divided into georeferenced grids of 1 km x 1 km, obtaining 10,464 grids. These were then associated with information on land uses and vegetation cover, lithology and relief. The multivariate classification method, TWINSPAN, was used to arrange the grids. Figure 1a) shows the classification of landscape types of the province of Huelva (Spain) as obtained and once refined, (ALCÁNTARA *et al.*, 2015).

FIGURE 1

a) Types of Landscapes in Huelva according to the Multivariate Classification. b) Types of Landscapes of the Huelva Province according to the Atlas of Landscapes of Spain



Source: a) Our results. 1, High Sierras; 2, Low Sierras; 3, Peneplains and Foothills; 4, Slopes, Hills and Knolls; 5, Countryside; 6, Coastal and pre-litoral dunes; 7, Sand strips; 8, Marshes. b) Source: SANZ HERRÁIZ *et al.* (2003). 1, Sierras and Valleys of the Sierra Morena; 2, Slopes, Hills and Knolls of Andévalo; 3, Andalusian Countryside; 4, Coastal and pre-litoral Plains and Glacis; 5, Doñana Coastal Dunes; 6, Andalusian Marshes; 7, Mountain Slopes and the Valleys of Sierra Morena to the Guadalquivir; 8, Southwestern Peneplains; 9, Gorges and Valleys on the Portuguese Border.

2.3. THE CLASSIFICATION FROM THE ATLAS OF THE LANDSCAPES OF SPAIN

SANZ HERRÁIZ *et al.*, (2003) generated a hierarchical taxonomy composed of three levels: A basic level characterized by what have been called *landscape units or landscapes*. The second level that is composed of the *Types of landscape*: "each type results from the grouping of units whose structures are repeated in the territory." At the highest level of taxonomy they have defined the *type Associations*: "groupings that integrate nearby types". Figure 1 b) shows the Atlas of the Landscape Types in the province of Huelva.

2.4. COMPARISON OF THE CLASSIFICATION BY MULTIVAREATE METHODS (CMM) AND THE ATLAS OF THE LANDSCAPES OF SPAIN (CAPE)

The level of comparison has been established between the Landscape Types of the Atlas of the Landscapes of Spain and the Types of Landscapes of the Multivariate Classification of the Landscapes of Huelva. Automatic comparison methods are usually based on contingency tables (LEGENDRE *et al.*, 1998). A two-way contingency table analysis was use for this comparison. To carry out this analysis, a regular mesh of 10,412 points (minimum distance between points, 1 km) distributed throughout the territory of Huelva has been generated. Information was associated with each point depending on the type of landscape unit in which it is located and depending on the classification in question, and these elements have been analyzed. In the contingency table analysis the null hypothesis was the independence between descriptors. The statistical method used was the Pearson's Chi square, with a significance level of $\alpha < 0.05$ for the rejection of the null hypothesis. To recognize which cells in the contingency table contributed to the relationship between the descriptors, the value of the adjusted residue was used.

3. RESULTS

The results of the contingency table (Table 1) show how the classifications follow a Chi-square distribution, rejecting the null hypothesis of independence between the two. The highest absolute values of adjusted residue appear in cells with significant positive association (Table 2). Two positive associations unique among types of landscapes are shown: Type 5, Countryside (CMM) - Type 3, Andalusian Countryside (CAPE) (79.8); Type 8, Marshes (CMM) - Type 6, Andalusian Marshes (CAPE) (86.3). The remaining positive associations between types of landscape are various.

TABLE 1

Contingency table comparing the CAPE and CMM classification of landscape types. The names of the Landscape types are in Fig. 1. Pearson's Chi square statistic: $x^2 = 31\,849.659$ ($\nu = 56$, $p<0.05$)

Multivariate Classification of Huelva	Classification of the Atlas of the Landscapes of Spain									
	1	2	3	4	5	6	7	8	9	Total
1	1043 *(361.8)*	0 *(466.0)*	0 *(135.5)*	0 *(160.2)*	0 *(69.0)*	0 *(67.0)*	158 *(52.6)*	181 *(27.3)*	0 *(42.5)*	1382
2	1381 *(470.7)*	227 *(606.3)*	0 *(176.3)*	0 *(208.4)*	0 *(89.8)*	0 *(87.2)*	178 *(68.4)*	12 *(35.6)*	0 *(55.3)*	1798
3	191 *(567.1)*	1858 *(730.4)*	0 *(212.4)*	16 *(251.1)*	0 *(108.2)*	0 *(105.1)*	2 *(82.4)*	12 *(42.9)*	87 *(66.6)*	2166
4	111 *(431.7)*	1261 *(556.1)*	3 *(161.7)*	0 *(191.2)*	0 *(82.4)*	0 *(80.0)*	58 *(62.7)*	0 *(32.6)*	216 *(50.7)*	1649
5	0 *(291.4)*	107 *(375.3)*	857 *(109.1)*	143 *(129.0)*	0 *(55.6)*	6 *(54.0)*	0 *(42.3)*	0 *(22.0)*	0 *(34.2)*	1113
6	0 *(305.8)*	58 *(393.9)*	139 *(114.5)*	752 *(135.4)*	151 *(58.3)*	51 *(56.7)*	0 *(44.4)*	1 *(23.1)*	16 *(35.9)*	1168
7	0 *(180.4)*	0 *(232.3)*	1 *(67.6)*	280 *(79.9)*	365 *(34.4)*	43 *(33.4)*	0 *(26.2)*	0 *(13.6)*	0 *(21.2)*	689
8	0 (117.0)	0 (150.7)	21 (43.8)	16 (51.8)	4 (22.3)	405 (21.7)	0 (17.0)	0 (8.8)	1 (13.7)	447
T	2726	3511	1021	1207	520	505	396	206	320	10412

TABLE 1
Adjusted residue to check the significance of individual cells in the Contingency Table. Values> 3 (in bold) identify cells with positive association in which the number of observations differs significantly (p <0.05) from the expected frequencies.

Multivariate Classification Huelva	Classification of the Atlas of the Landscapes of Spain								
	1	2	3	4	5	6	7	8	9
1	**44.8**	-28.5	-13.2	-14.5	-9.2	-9.0	**15.9**	**31.9**	-7.1
2	**53.7**	-20.8	-15.4	-16.9	-10.7	-10.5	**14.9**	-4.4	-8.3
3	-20.7	**57.6**	-17.2	-17.7	-12.0	-11.8	-10.1	-5.3	2.9
4	-19.6	**40.0**	-14.3	-16.0	-10.1	-10.0	-0.7	-6.3	**25.7**
5	-21.0	-18.0	**79.8**	1.4	-8.1	-7.1	-7.0	-5.0	-6.3
6	-21.6	-22.1	2.6	**59.8**	**13.2**	-0.8	-7.2	-4.9	-3.6
7	-16.2	-19.4	-8.8	**24.6**	**59.8**	1.8	-5.4	-3.9	-4.8
8	-12.9	-15.4	-3.7	-5.4	-4.1	**86.3**	-4.3	-3.1	-3.6

4. DISCUSSION

The study of the degree of similarity between the CMM and the CAPE by means of a contingency table allows a more objective analysis than the visual one, which in turn, can be considered more versatile than the automatic methods. However, the advantage of the automatic methods is that they are explicitly defined, consistent and repeatable.

From the analysis of the simmilarities and the differences between the two classifications is derived:

A high degree of simmilarity for the Southern half of the province.

- They present the same number of lanscape units: 4.

- There is a clear positive association (with maximum adjusted residuals, Table 2) between two of these four units: Countryside (CMM) and Andalusian Countryside (CAPE) and Marshes (CMM) and Andalusian Marshes (CAPE). Which shows a remarkable correlation between their limits in both classifications.

- If the singular character of the positive association is lost for the other two units is due to the difference in the layout of the boundaries (especially in the eastern part) depending on whether the classification is one or the other. For this reason, although the Coastal and Pre-litoral Dunes (CMM) essentially coincide with the Coastal and Pre-litoral plains and Glacis (CAPE) (adjusted residual value 59.8), the contingency table shows that there is also a positive association with the Coastal Sandunes of Doñana (CAPE), although with an appreciably lower residue value (13.2, Table 2). A similar situation occurs with the association between the Sand strips (CMM) and the Coastal Sandunes of Doñana and the Coastal and Pre-litoral plains and Glacis (CAPE).

For the Northern half it should be highlighted:

- That the east-west boundary that divides the Sierra Morena into two halves presents a similar layout in the two classifications. Although it should be noted that these two landscape units are considered as Landscape Types in themselves in the CAPE, whereas in the CMM they are subdivided into two Landscape Types (Figure 1).

- A second difference of importance is the one that results from the presence of two landscape units in the CAPE (Mountain Slopes and Valleys of Sierra Morena to the Guadalquivir and Southwestern Peneplains), of reduced superficial extension in Huelva, and whose delimitation is considered justified by the broader scope of this classification.

From the methodological standpoint, the differences between these two classification systems can be summarized in three points. First, the differences related to the degree of automation, which in the

development of the CMM has resulted in the appearance of islets belonging to a landscape type within areas of another. Second, the use of cultural variables, which in the case of the CMM was reduced to land uses, while in the CAPE topography and historical-cultural criteria have been used in the differentiation of the landscape type "Gorges and Valleys in the Portuguese border". Finally, the work scale, which has determined the differentiation in the CMM of four types of landscapes, compared to the two types of the CAPE (Figure 1). These differences in relief for these types of landscapes are addressed in the Atlas, where lower-level landscape units are established as landscapes.

In general, taking into account the different frames of reference (national and provincial) and the methodological differences, the degree of similarity between the two classifications can be considered optimal. This implies a validation of both classifications for the territory of study.

5. CONCLUSIONS

1) TWINSPAN has been confirmed as valid of a method for the classification of the landscape of the territory of Huelva as it is the mapping based on traditional methods.

2) The multivariate method has a number of advantages: a higher degree of objectivity and reliability of the results, greater operability and accessibility to data, reproducibility, and greater efficiency.

3) However, since the process of refinement requires the expert criterion and the traditional mapping methods, it is possible to consider that the optimal and complete result in the identification and characterization of landscapes, is that which derives from their combined use. That is, the multivariate techniques, for the objective classification and identification of diagnostic characters of the landscapes, and the traditional ones for the cartographic delimitation and identification of entities.

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