The role of the environmental factor as a component of the terroir in Spain (A.O. Cigales, NW Spain)

L'effet des facteurs environnementaux comme composant du terroir en Espagne (AO Cigales)

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Abstract

The components and the methodology for characterization of the terroir in Spain have been described by Gómez-Miguel et *al*. (2003) and Sotés et *al*. (2003), taking into account the full range of environmental factors (i.e: climate, vegetation, topography, soils, altitude, etc.), landscape variables (derived from photo-interpretation and a digital elevation model) and specific variables of the country's viticulture (i.e: size and distribution of vineyards, varieties, phenology, productivity, quality, designation regulations, etc.). This paper describes: the integration of the resulting database in a Geographic Information System (GIS) that allows the spatial and statistical analysis of all variables; the parametric system of variable quantification; the selection of main endogenous and exogenous variables for *terroir* characterization; and the role of the variables that describe the landscape in the final results. The analysis has been carried out over 2.4 million ha. This paper presents the results of a case studied in the Cigales region (A.O. Cigales) that expands on 62,210.5 ha and includes 2,351.5 ha of vineyards. The observed distribution of vineyards in this region is ¿well? correlated to the integrated landscape-terrain classification and productivity but does not depend on the total available area for cultivation. It is significant that a subset of geological formations that accounts for 59 percent of the total area sustains over 95 percent of the vineyards.

The results of the study have general implications for landscape-terrain classification in Spain and define a set of methodological guidelines: a) definition of the set of variables that define the landscape (characterization of the lithological and morphological components; homogenization of lithological units; cartography of the geological formations; integration of a digital elevation model to derive altitude, orientation, exposure and slope. The spatial scale should be at least 1:25,000); b) definition of the Homogeneous Land Units (UHM) (The parameter characterization was carried out from the units which were previously defined from the data of the environmental analysis); c) experimental design (Selection of Homogeneous Land Units and characterization within the units); d) final zoning: integration of the Homogeneous Land Unit with the plant (variety and rootstock) and the product (must and wine).

Key words: terroir, zoning, landscape, climate, soil, GIS

Introduction

Gómez-Miguel *et al.* (2003-2007) and Sotes *et al.* (1992-2004) described the general methodology for *terroir* zoning and characterization that takes into account the specific conditions in Spain, such as land use, vineyard size and distribution, and occupation index of the designation regulations. The methodology is based on the integrated spatial analysis of environmental variables (i.e.: climate, vegetation, topography, soils, altitude, etc.), landscape variables (derived from photo-interpretation and a digital elevation model) and variables specific of the country's viticulture (i.e.: size and distribution of vineyards, varieties, phenology, productivity, quality, designation regulations, etc.). The resulting database is integrated in a Geographic Information System (GIS) that allows the spatial and statistical analysis of all variables and the results are presented in maps. The parametric system of variable quantification and the selection of main endogenous and exogenous variables for *terroir* characterization is based on methodologies described previously (Budan and Popa, 1978; Astruc *et al.*, 1980; Merieux *et al.*, 1981; Morlat *et al.*, 1984, Morlat and Salette, 1997). Finally, the main influential variables are selected, quantified and integrated, providing the basis for *terroir* characterization (zoning).

This paper describes the role of the environment defined by the effects of climate (figure 2), lithology (lithologic groups, figure 3), geomorphology and landscape (geoforms, altitude, figure 4) and soils (soil map units) (figure 4) on the *terroir* (zoning areas, figure 5) in the Cigales region (*Denominación de Origen Cigales* -(AO Cigales-, NW Spain, figure 1).

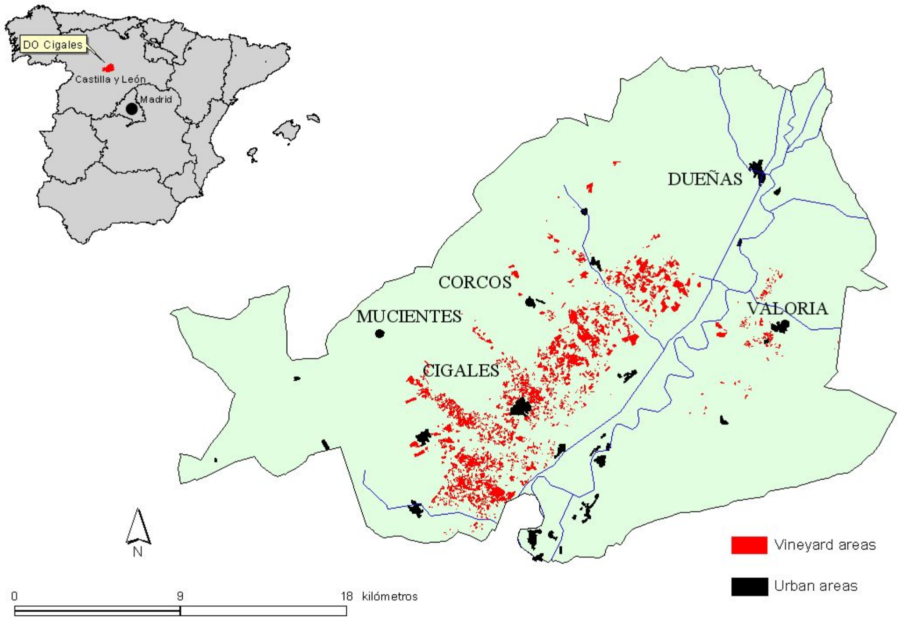

Figure 1 Location and vineyard distribution of the AO Cigales (Spain)

Methods

There has been a debate among the studies that try to correlate geology and wine quality. Branas (1974) and Fregoni (1980) relate these two factors, but Duteau (1981) considers that the mother rock does not have an influential role on wine quality. Seguin (1983) relates wine quality and type (red, dry white and sweet) to the soil stratigraphic column, and describes the influence of soil mother rock on wine properties, such as aromatic and tasting characteristics, or color. Our experience in analyzing over 2.5 million hectares, is that environment (climate, lithology, geomorphology, landscape and soils) is an important factor for wine quality.

The influence of topography has been evaluated by growing the plants in pots of uniform soil composition to eliminate the effects of different soils (N.J. Becker cited by Coombe, 1987). In the valley, with high day temperatures and low night temperatures, plants are too susceptible to frost, but the fruit composition is quite acceptable. In the plateau, plants are exposed to low day temperatures and therefore have ripening problems. In the slopes, the phenology and maturation are advanced and there is a higher content of sugar in berries. Calame *et al*. (1977) in Valais (Switzerland) obtained similar results in their study comparing location in valleys and river plains, and showed that plants located in the lower part of the slopes are exposed to a lower frost risk, mature earlier and produce a better must quality. Therefore, slopes seem to be the preferable topographic factor in areas where varieties are susceptible to low temperatures. As a conclusion, the slope relates directly to frost risk, and radiation and temperature determine thermal regime, affecting phenology, maturation, fruit composition, and overall quality (Veres, 1973). Becker (1984) attempted to establish uniform criteria for topographic evaluation.

In general, the altitude affects maturity and wine quality since it affects temperature regimes. Falcetti *et al.* (1990) and Scienza and Falcetti (1991) correlated the highest altitudes with quality elements and the lowest altitudes with complexity reduction and persistence in the Trentino region. Furthermore, wines produced from plots in the northern slopes are more complex, except in years unusually cold and humid. Fregoni (1973) measured in Etna a decrease in average temperature of 1 degree C per 170 m, a decrease in sugar content of 0.5 to 1 degree per 200 m, and an increase in acidity of 0.1 percent per 100 m.

Falcetti *et al.* (1992) showed the interactions between slope and altitude. Fregoni *et al*. (1992, 1998) support previous results and correlate the main grapevine bio-climatic indices, in particular Winkler index, highly correlated with wine quality, with four orographic factors (altitude, relative slope position, exposure and valley size) and propose a statistical linear regression model that includes these factors.

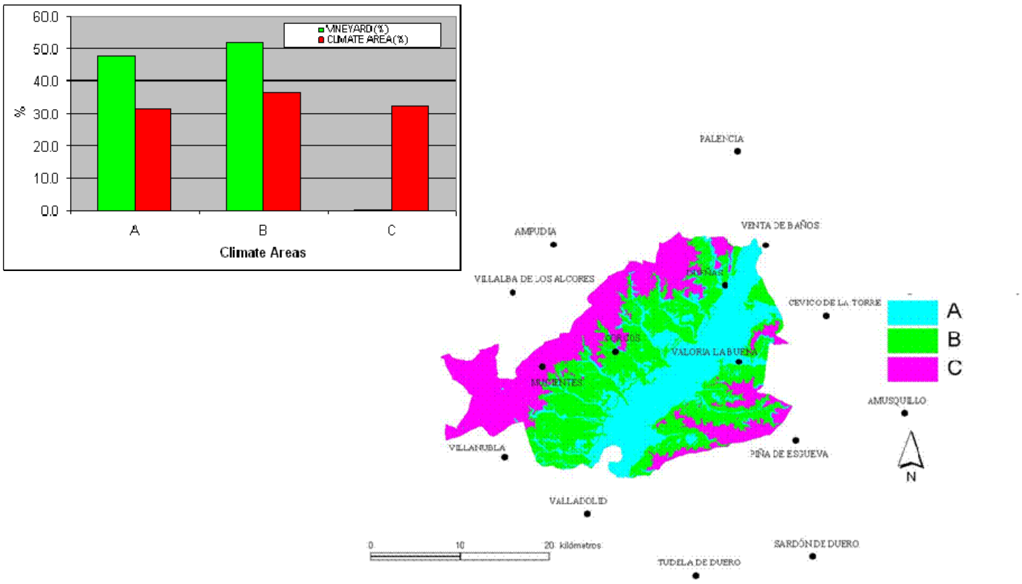

Figure 2 Climate zones and Meteorological sites

Results

The spatial scale of the analysis is 1:20,000, allowing adequate segregation of both geoforms and lithology analysis. Results will be published at 1:50,000. Environmental factors are derived from aerial photo interpretation, field analysis of lithology and geoforms, and a digital elevation model. Several of these factors are also included in the concept of soil series, but their segregation allows definition, quantification and direct evaluation. The digital elevation model allows the consideration of variables that are not included in traditional cartography but are important in viticulture, such as altitude, orientation, exposure and length and inclination of the slope.

The climate zones are included in figure 2. Two zones (67.9 % of the region area) account for 99.8 % of the vineyard. The influence of geology (lithology and stratigraphy) in the relationship soil/grapevine is evaluated by the nature of the rock and the presence of rock in the surface. Figure 3 shows the lithological groups and their distribution in the AO Cigales. Only four zones (Upper and Middle Miocene, middle terraces and old glacis) are of special relevance with 95.6 % of the vineyard (58.7 % of the region area).

Figure 4a shows the geographic distribution of the units of the AO Cigales, derived from aerial photo interpretation, API (total area 62.210,5 ha; vineyard area 2,351.5 ha). The legend consists of six digits (only four in the figure) that include lithology, geoforms, slope, erosion and others. The importance of such cartography is due to the fact that each unit includes all attributes. For instance, the Cigales vineyards remain under 900 m (Figure 4b): in the 700-800 interval 96.9 % (50.6% of the region area).

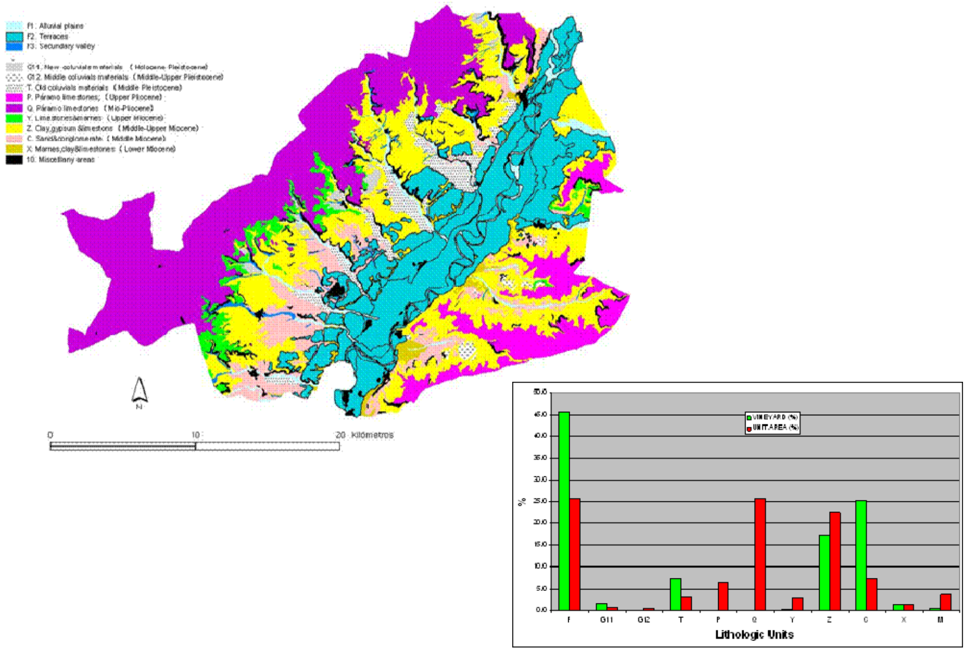

Figure 3 Geological zones (lithology andstratigraphy groups)

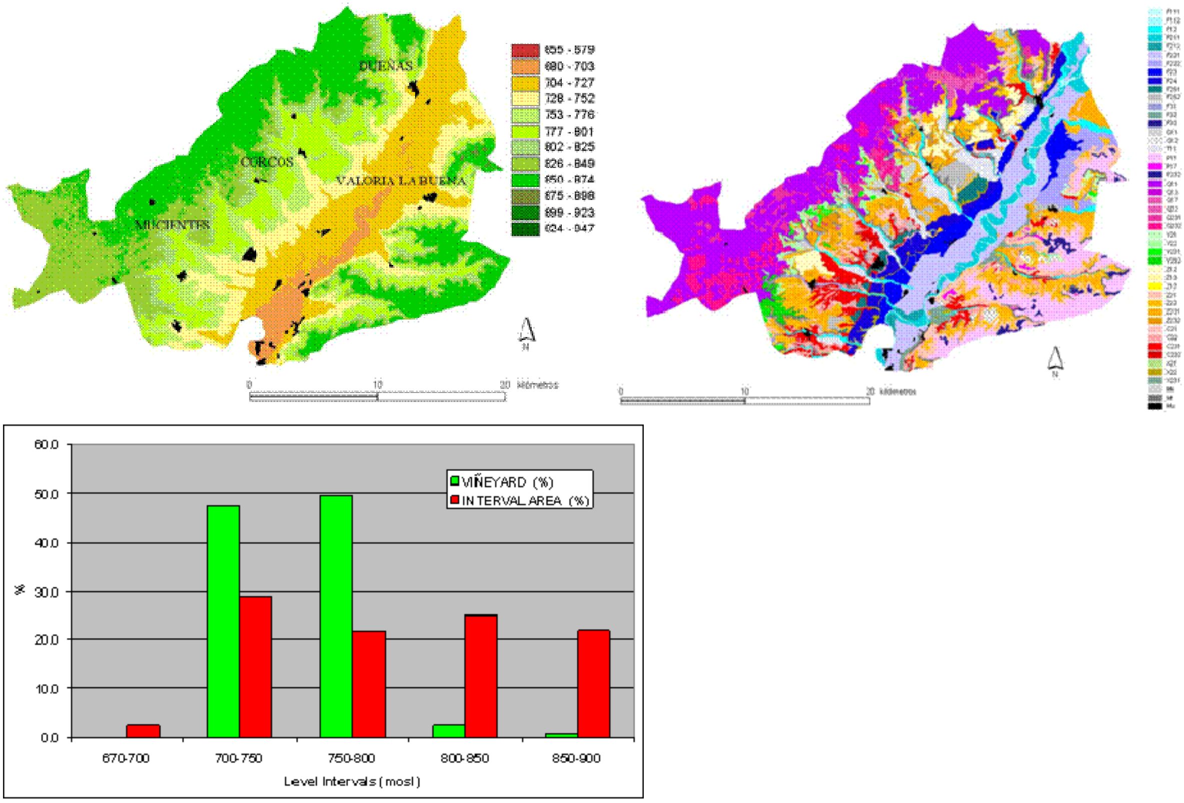

Figure 4 (a) Altitude areas and (b) API units (Geoforms)

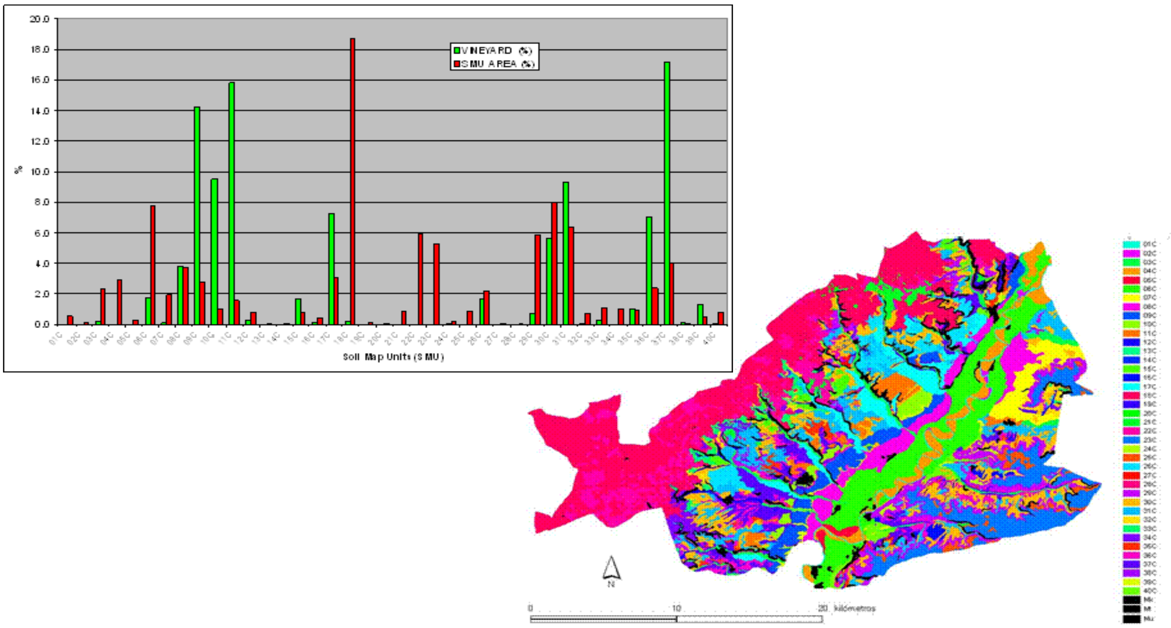

Figure 5 Homogeneous Land Units: UHM intervals (*Terroir* zoning)

Figure 5 shows the geographic distribution of the soil maps units (SMU) of the AO Cigales by accord SSS (1996, 1999). Only eight SMU (9C, 10C, 11C, 18C, 30C, 32C, 37C and 38C) are important with 86.0 % of the vineyard (29.2 % of the region area).
This geographic information is validated with the cartography generated in polygons obtained by interpolation and topographic correction at predetermined intervals, and the results define uniform areas. Vineyard surface distribution has been considered before (Dioujev, 1973) but its use as validation index is not clear. Nevertheless, its use in global terms is justified since it is assumed that viticulturists select the most adequate growing areas, especially when the available area is large (Webster and Olivier, 1990), as in the case of the AO Cigales. In this area, there are some units clearly selected for vineyard, other units with mixed selection and other units clearly disregarded for vineyards.

In the AO Cigales, vineyard distribution is in harmony with the cartographic units derived from our analysis, with climate and soil parameters, and with the better qualified areas. The best polygons in our analysis present either a larger occupation index (IO) or more area of vineyard. In all cases, the percent area with vineyard is small since the total available surface is very large. Finally, there is a direct correlation between the best polygons and the average productivity.
The results of the distribution of vineyard by environmental factors (climate, litho-geomorphologic and soil units) allow to establish criteria related to the optimal distribution and behavior of the vineyard. Correct selection of the environmental groups allows further considerations related to soil characteristics correlations with wine production.

Figure 6 shows the final zoning of the AO Cigales, characterizing the according to the aptitude: “marginal to exclude” (5), “not suitable” (4), “not favorable” (3), “adequate” (2) and “optimal” (1). It is significant that 94.9 percent of the Cigales vineyards are located in two UHM intervals (38.44 % of the region area): zone 1 (64.8 %) and zone 2 (25.8 %).

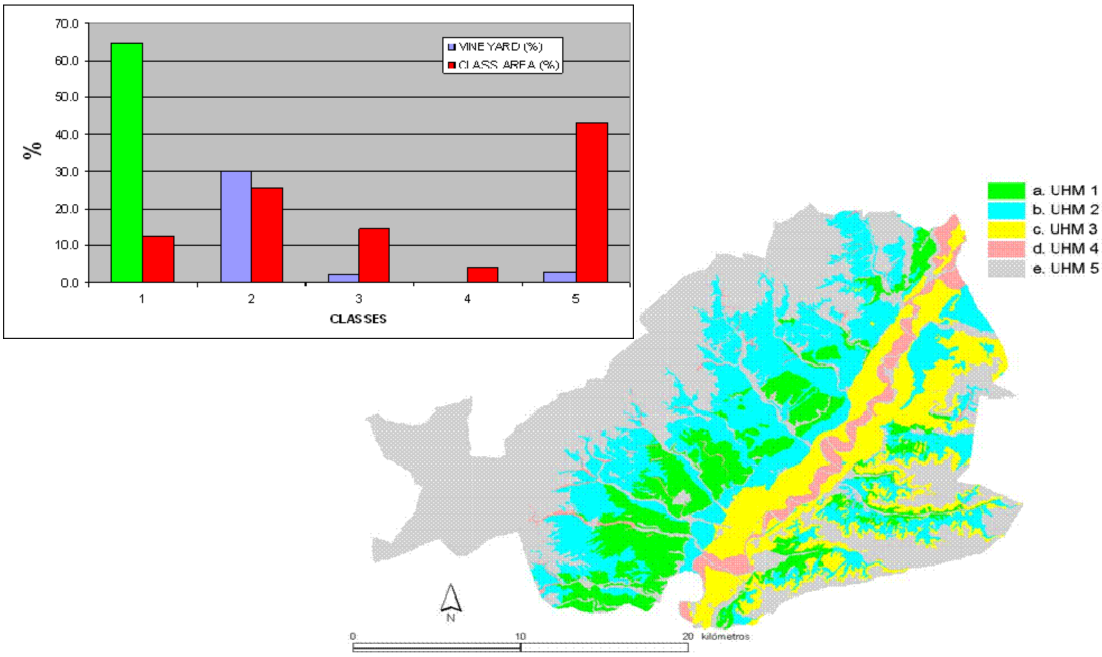

Figure 6 Map of soils (Soil Map Units, SMU)

Conclusions

The results of the study have general implications for landscape-terrain classification in Spain and define a set of methodological guidelines. The guidelines refer to:

a) Definition of the set of variables that define the landscape: characterization of the lithological and morphological components; homogenization of lithological units; cartography of the geological formations; integration of a digital elevation model to derive altitude, orientation, exposure and slope. The spatial scale should be at least 1:25,000.
a) Definition of the Homogeneous Land Units (UHM): the parameter characterization was carried out from the units which were previously defined from the data of the environmental analysis.
b) Experimental design: selection of Homogeneous Land Units and characterization within the units.
c) Final zoning: integration of the Homogeneous Land Unit with the plant (variety and rootstock) and the product (must and wine).

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