Mapping terroirs at the reconnaissance level, by matching soil, geology, morphology, land cover and climate databases with viticultural and oenological results from experimental vineyards

Cartographie des terroirs au niveau de la reconnaissance par l'adéquation des bases de données sur le sol, la géologie, la morphologie, l'occupation des sols et le climat avec les données expérimentales des vignobles de référence

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Abstract: This work was aimed at setting up a methodology to define and map the «Unités Terroir de Reconnaissance» (UTR), combining environmental information stored in a Soil Information System with experimental data coming from benchmark vineyards of Sangiovese vine.
A Soil Information System stored geography (reference scale 1:100,000) and attributes of i) land cover, ii) lithology, iii) morphology, iv) soil typologies, v) soil properties, vi) soil geography, vii) long term average Winkler bioclimatic index and average rainfall, and viii) appellation of origin area, of the whole Province of Siena. Soil functional properties were selected and classified after a statistical analysis of the relationships with the viticultural and oenological results obtained in 69 vineyards over a time span of 2-5 years.
All the vineyards of the province were grouped in terms of lithology, morphology, and soil functional properties, so as to create homogeneous UTR. The result was that the whole province was characterized by 363 UTR, which covered a total of 16,650 ha, each UTR having a size ranging from 2 to 474 ha. The GIS map highlighted and explained the environmental diversity of viticultural areas of the province, providing information about peculiarities, constraints and potentialities of each UTR.

Key words: terroir**,** reconnaissance**,** Sangiovese, database, Siena

Introduction

A terroir is constituted by the set of factors which interact and determine the different typologies of a high quality product, in the ambit of an appellation of origin production area. A « terroir » has a wide array of components. For a viticultural territory, the singling out of the terroirs should take into account climate, soils, geology and geomorphology, landscape, variety, viticultural husbandry, oenology, tradition, and possibly others (Vaudour, 2003).
The large number and complexity of the factors makes the terroirs difficult and time consuming to map. It is possible, however, to split the process up into steps, where the first step is singling out landscape units, with a specific degree of generalization of land attributes, in function of the topographic scale and detail of characterization. The French authors, when they are working at the detail level, call these landscape units «Unités Terroir de Base» (UTB) (Morlat, 2001); we have called them «Unités Terroir de Reconnaissance» (UTR), as we were operating at the reconnaissance level.
This work was aimed at setting up a methodology to define and map UTR, combining environmental information stored in a Soil Information System with experimental data coming from benchmark vineyards.
The research project was financed by the administration of the Province of Siena (central Italy), which had requested a suitability map of its territory of competence, to be used for the planning of agricultural policy.

The reference vine variety was Sangiovese, which is used in the production of the famous « Chianti », « Brunello di Montalcino » and « Nobile di Montepulciano » wines.

Material and methods

Yield components and vine phenological phases of Sangiovese were monitored in 69 experimental vineyards over 2 to 5 years, between 1989 and 2003. During the years 2002 and 2003, in 10 out of the 69 experimental vineyards, 50- to 80-kg samples of grapes were processed using the standard technique for small-lot wine making. Wines were analyzed with particular attention to color intensity and total polyphenols (Di Stefano *et al*., 1997) and submitted to an organoleptic analysis involving a panel of 14 people.
Relationships between soil and viticultural and oenological parameters emerged from the Principal Component Analysis (PCA) (Costantini *et al*., 2006). The long term year rainfall and the index of Winkler (1974) were used to characterize the influence of climate on vine. Climatic and bioclimatic values were elaborated using the data of 109 meteorological stations and were spatialized through ordinary kriging (rainfall) or a relationship with the DEM (20 m).
A Soil Information System was created, which stored geographic (GIS) and semantic (DB) data (fig. 1). The soil information was 1,642 observations (697 analyzed profiles, 176 of which in vineyard) grouped in 128 functional typologies. The scale of the reference polygon layer, i.e. the map of land units, was 1:100,000. Land units had attributes of lithology, morphology and land cover, the legends of which were appropriately generalized for the reference scale. Within a land unit, each specific combination of lithology, morphology and land cover formed a land element, which could have one or more soil typology.

Results and Discussion

Through a first PCA, we found the relationship existing between viticultural parameters and oenological results, i.e. scores obtained at the organoleptic evaluation of a panel test, color intensity, total polyphenols (fig. 2). These statistics highlighted viticultural variables « yield per plant », « number of clusters », « cluster weight », « titratable acidity of the must », « berry weight », « sugar content » (BRIX) and « sugar accumulation rate » (BRIX_DAY).
Then, a further PCA helped us to individualize the relationship between the viticultural parameters which were significantly correlated with wine and soil parameters (fig. 3). The soil parameters statistically correlated to the viticultural variables were those determining water availability, namely clay and sand content, internal drainage, available water capacity (AWC), rooting depth, coarse fragments and stoniness. These seven parameters were therefore called « soil functional properties ».
The Unités Terroir de Reconnaissance (UTR) were the land units with vineyard land cover that were homogeneous for lithology, morphology, and soil functional properties. They were also described for long term average Winkler bioclimatic index and rainfall, hectares and appellation of origin area. The process of conveying information from the GIS layers and database to the UTR is sketched in figure 1. Figure 4 shows an example of the UTR information coming from the selection of a polygon. The legends of lithology and morphology were those used for the land units, whereas soil functional parameters were classified according to a standard soil survey manual (Gardin *et al*., 2002), except for rooting depth, clay and sand content, which were classified in such a way that the oenological and viticultural results corresponded to the differences in soil properties.
The whole province was characterized by 363 UTR, which covered a total of 16,650 ha, each UTR having a size ranging from 2 to 474 ha. The GIS map highlighted and explained the environmental diversity of viticultural areas of the province, providing information about peculiarities of each UTR (fig. 5).

Conclusion

The methodology used to create the UTR of Siena is simple and straightforward enough to be easily applied by other administrations having a similar Soil Information System. The reliability of the result, in terms of effective correspondence with the land suitability for Sangiovese vine, should be rather high for other territories too, because of the extensive set of environments, experimental vineyards and year replications used to assess the soil functional parameters, as well as the array of viticultural parameters and oenological analyses performed.
UTR were mostly small (46 hectares on average) and composed of few polygons, as every change in lithology, morphology or soil functional property caused a differentiation. However, this methodology

stressed the peculiarities of each environment and depicted well the variability of terroirs which form the vineyard of Siena.

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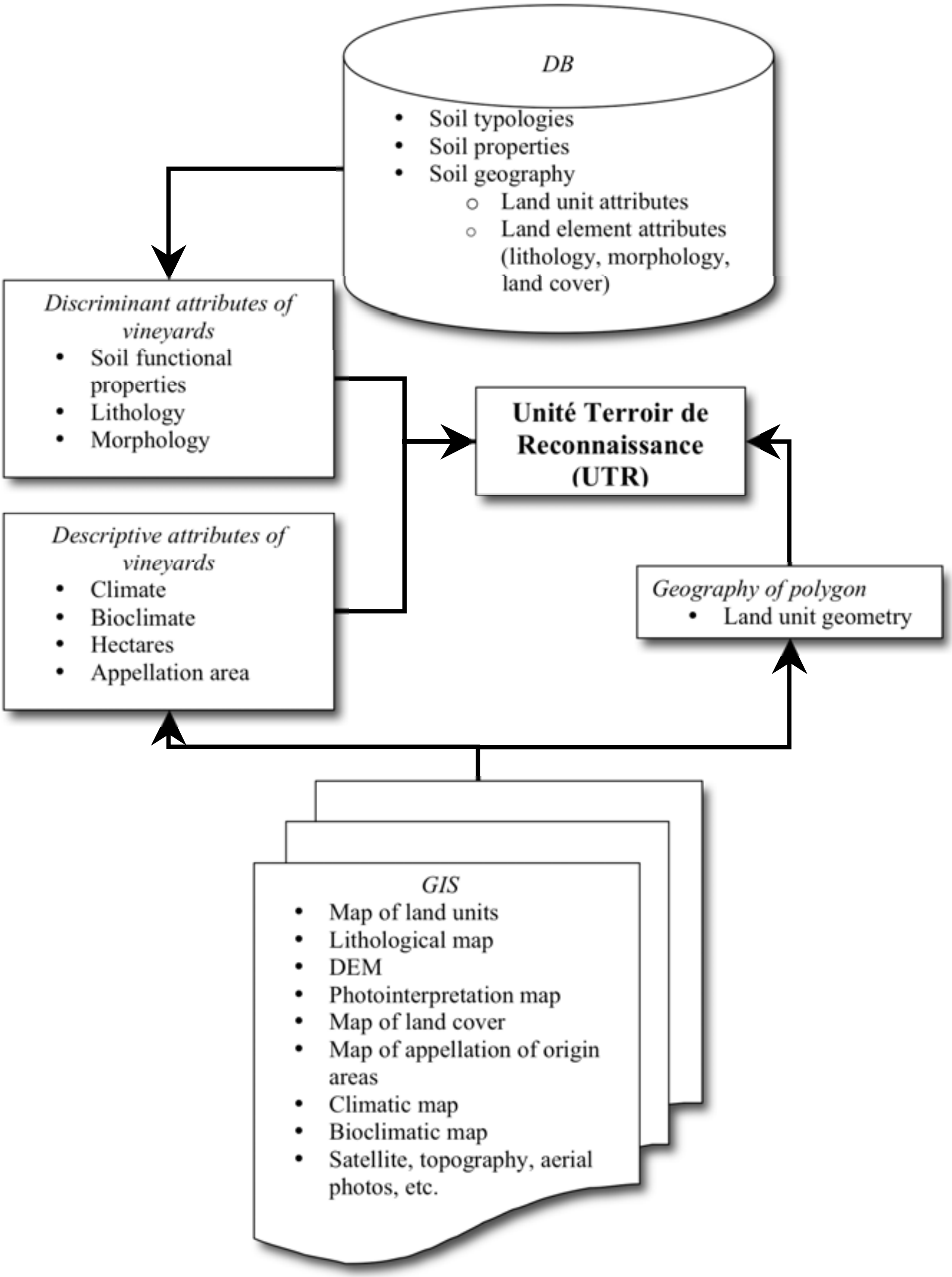

Figure 1 – Flow diagram of the UTR creation process

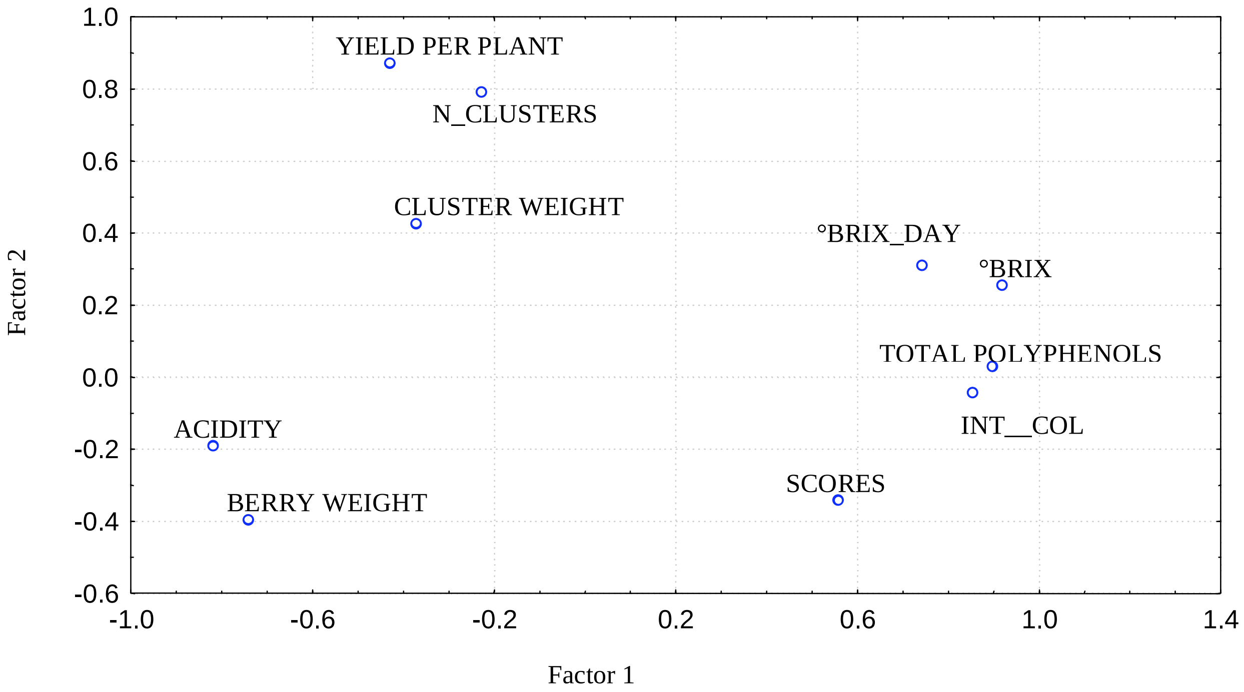

Figure 2 – PCA showing the relationships between oenological and viticultural results of Sangiovese in 10 experimental vineyards for 2 years in the province of Siena.

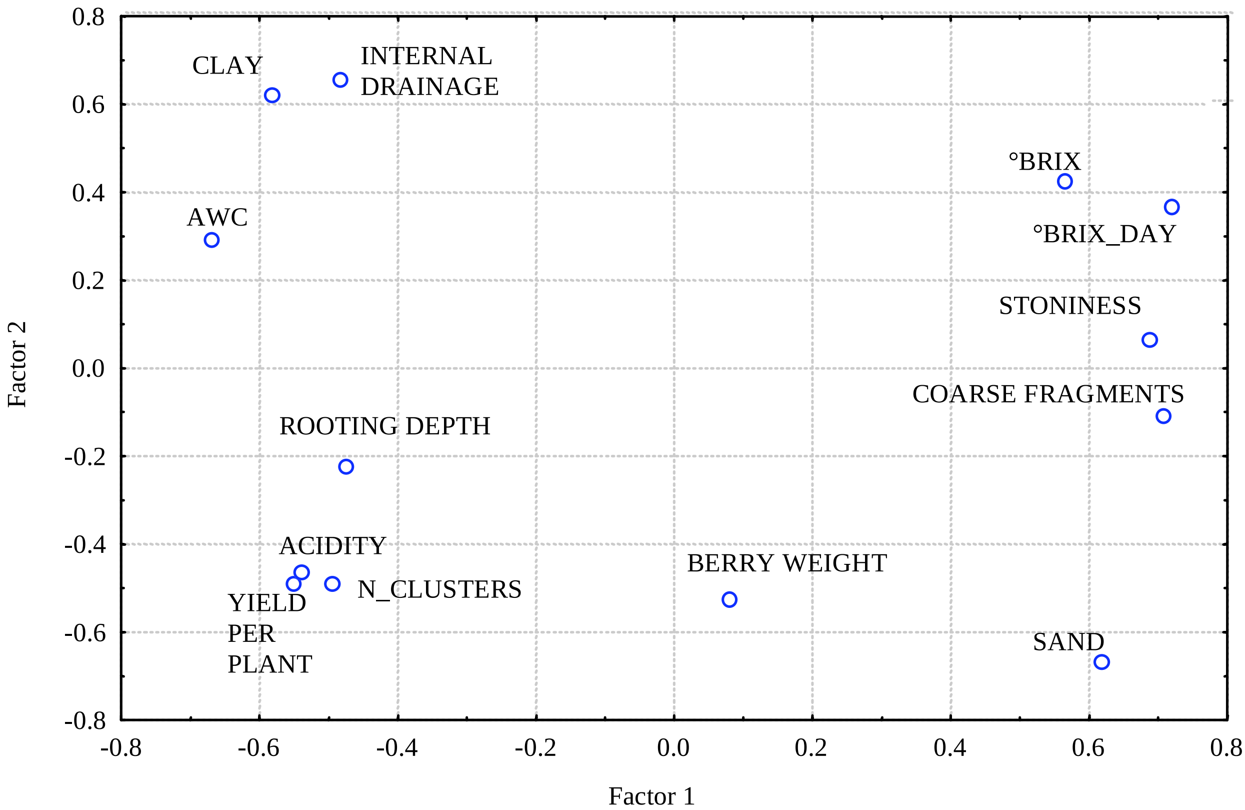

Figure 3 – PCA showing the relationships between viticultural results and soil functional parameters in 69 experimental vineyards for 2-5 years in the province of Siena.

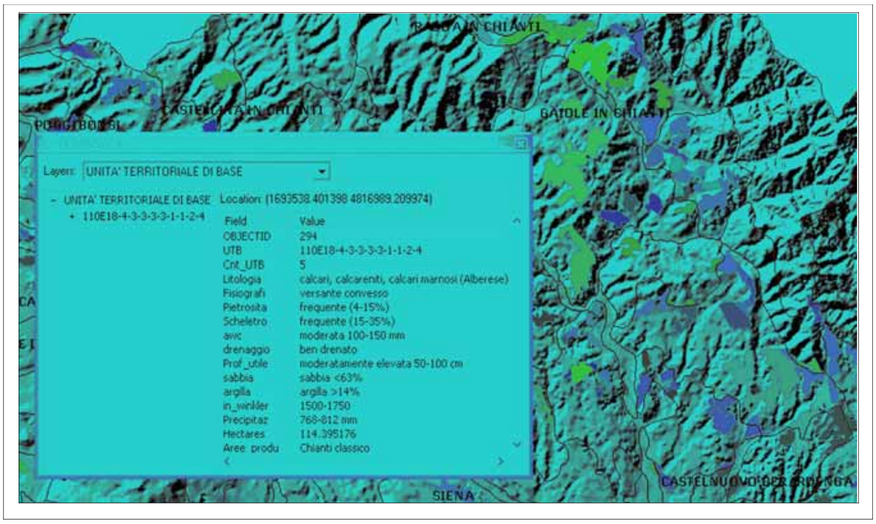

Figure 4 – In white the UTR 110E18-4-3-3-3-3-1-1-2-4; the polygon is constituted of vineyards with a specific set of lithology (code 110 of the example = limestone, sandy and marly limestone), morphology (code 110E18 = convex slope), seven soil functional parameters (codes 4-3-3-3-3-1-1 = stoniness 4-15%; coarse fragments 15-35%; AWC 100-150 mm; internal drainage: good; rooting depth 50-100 cm; sand <63%; clay > 14%;) , bioclimate and rainfall (codes 2-4 = Winkler's index 1500-1750; rainfall 768-812). The table provides also for the hectares and name of the vine cultivation area.

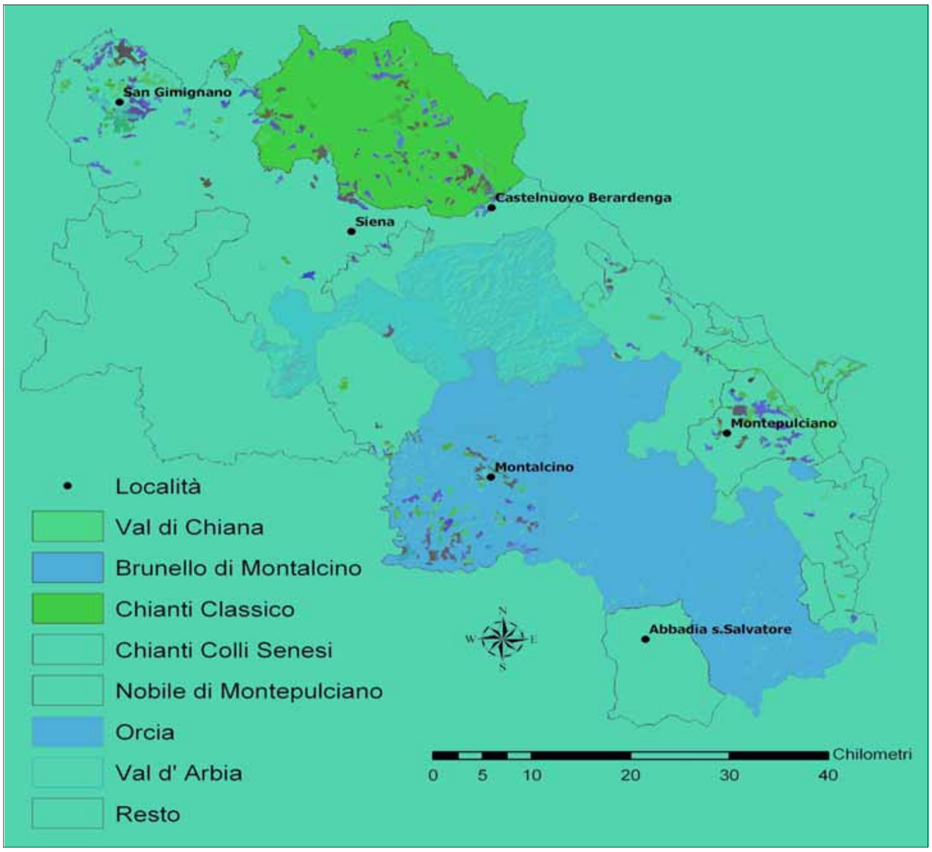

Figure 5 – The 363 "Unités Terroir de Reconnaissance" (UTR), in the vine cultivation areas of the province of Siena