VITICULTURAL ZONING APPLICATIONS AT THE DETAILED SCALE OF A COOPERATIVE WINERY: *TERROIRS* IN ST-HILAIRE-D'OZILHAN (AOC CÔTES-DU-RHÔNE)

APPLICATIONS DE ZONAGE VITICOLE AU NIVEAU COMMUNAL D'UNE CAVE COOPERATIVE : LES TERROIRS DE ST-HILAIRE-D'OZILHAN (AOC COTES-DU-RHONE)

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Mots-clés : zonage, terroir, niveau communal, cave coopérative, réserve utile

ABSTRACT

Wine quality needs to be monitored at the detailed local scale of the winery or viticultural farm territory. The territory covered by the cooperative winery of Saint-Hilaire-d'Ozilhan (AOC Côtes-du-Rhône), is a 1 670 hectares-commune area, nearly 310 hectares of which are grown into vine. This winery has been working for nearly a decade on geographical and enological management. Wine-making processes are based on 9 'terroir' land divisions, defined with the substrata indicated in soil map units. Distinct selections of the same unit can lead to different wines, thus indicating the spatial heterogeneity of some of the units defined. A zoning obtained from soil and landform spatial analysis, is available for this winery from another source, with a detailed soil landscape map. The comparison of the varied documents available may apply to different harvest selections. Moreover, the use of pedotransfer functions enabled to estimate the soil available capacity.

RESUME

La maîtrise de la typicité du vin s'élabore au niveau local ou communal d'une exploitation viticole et/ou d'une cave, unité de vinification. La cave coopérative de Saint-Hilaire-d'Ozilhan (AOC Côtes-du-Rhône), dont le territoire communal s'étend sur une superficie de 1 670 ha, couvre près de 310 ha cultivés en vigne. Elle réalise des vinifications « au terroir », en utilisant des regroupements d'unités de sol en 9 unités de terroir potentiellement viticoles, définies en s'appuyant sur la parenté des substrats. Diverses sélections d'une même unité peuvent aboutir aussi à des vins différents, ce qui suggère une hétérogénéité spatiale de certaines unités définies. Une carte des terroirs issue d'une approche par l'analyse spatiale géomorpho-pédologique est par ailleurs disponible pour la cave coopérative, munie de son niveau plus détaillé, la carte des unités de pédopaysage. La comparaison des différentes cartes disponibles suggère diverses options applicables aux sélections de vendange. Par ailleurs, l'utilisation de fonctions de pédotransfert a permis d'estimer la réserve utile.

INTRODUCTION

Wine quality is monitored at the detailed local scale of the territory under control of a winery or a viticultural farm: along with viticulture production, management and market related data, it needs to geographically manage viticultural land divisions. This is aimed at by viticultural zoning, which leads to the delineation of 'terroir' units. Improvement or acquisition of technical and human skills in digital database and geographical information systems in wineries should facilitate the monitoring of grape harvest, from the plot to the cellar (SMITH and WIGHAM, 1999; VAUDOUR, 2002). The aim is actually to monitor viticultural lands extending over areas of several hundreds to several thousands hectares.

The communal territory of Saint-Hilaire-d'Ozilhan extends over 1 670 ha, nearly 310 of which are grown into vine and administrated by the cooperative winery (AOC Côtes-du-Rhône) (figure 1). This paper deals with ongoing and forthcoming viticultural zoning applications at this winery, which has been working for nearly a decade on geographical and enological management.

DESCRIPTION OF THE STUDY AREA

The study basin is a Neogene and Pleistocene piedmont embankment situated at the outlet of canyons and karstic valleys (VAUDOUR, 2001). It develops laterally from medium and higher fluviatile terraces of the Gardon river. The deep substratum is made of thick layers of hard reef limestones dating from the Early Cretaceous (Urgonian), which outcrop over the NE karstic plateau of Uzès-Remoulins. Elevation ranges from some ten meters in the S-SW floodplain of the Gardon river near Remoulins, to not more than 300 meters over the NE karstic plateau. Slopes and landform are gentle and the mean slope between the floodplain and the plateau do not exceed 2 %. The study basin is filled with clastic wedge, which express late Pleistocene periglacial conditions: frost debris are sometimes embedded in an eolian matrix. At the periphery of the Urgonian limestones, the clastic wedge of fan slopes or alluvial fans spreads on Miocene carbonate sandstone or calcarenite ("molasse"); towards the center of the area, it relies on pliocene bluish clayey marls (figure 2).

Vineyards and orchards easily ripen under the Mediterranean warm temperate climate. They are surrounded by garrigue vegetation on the NE karstic formations. The predominant plant varieties are Grenache noir and Shiraz, which respectively cover about 50 and 25 % of the wine-growing area.

AVAILABLE APPROACHES ON VITICULTURAL ZONING

Three approaches on viticultural zoning have been successively performed on the territory of Saint-Hilaire-d'Ozilhan since the 1990's, in partnership with the union of grapegrowers of the Southern Côtes-du-Rhône Appellation or *Syndicat général des Vignerons des Côtes-du-Rhône*. The first of them was carried out by the French National Geological Service (BRGM, *Bureau des Recherches Géologiques et Minières*, LAVILLE, 1990), the second by a private engineering firm, "Sigales" (LETESSIER, 1992). The third study was realized at the Institut National Agronomique Paris-Grignon (VAUDOUR, 2001).

The BRGM approach models so-called "landscape units", considering an area of 8800 hectares which comprises the 3 communes of Saint-Hilaire-d'Ozilhan, Castillon-du-Gard and Valliguières. This area corresponds to the global inter-communal area managed by the cooperative winery, although this paper deals with the communal territory of Saint-Hilaire d'Ozilhan only. This is one of the earliest approaches on viticultural zoning using Geographic Information System (GIS). First, a principal component analysis (PCA) is performed on quantitative data derived from a 60 × 90 m grid -digital elevation model (DEM), taking the 6 following variables into account : elevation (m), slope (%), mean southward aspect (0-180°), mean westward aspect (90-270°), theoretical sun exposures at summer solstice and autumn equinox. Cells showing most frequent and significant correlations to principal components factors are isolated and used as training areas in a maximum likelihood classification, the result of which is interpolated to a 30 × 30 m grid (using inverse distance weighted interpolator) and finally combined to a rasterized lithology map with 10 classes. From the 104 output map units, 47 are retained after elimination of those extending over less than 1 ha. Map output is made at the medium 1/50 000 scale. Applications of this approach by wine professionals appeared to be somewhat tricky. As a matter of fact, a GIS map output at a larger map scale was needed and made the users uneasy with the grid format because of the lack of boundaries and the difficulty to find obvious visual references of known sites. Such problem was due to a coarse resolution, as well as the reduced number of input data, which were themselves correlated and couldn't substitute for soil data.

The conventional soil survey carried out by the "Sigales" firm was therefore intended to overcome such problems, considering the same 8 800 ha-area as the above-mentioned approach. It was based on about 50 soil profiles, 25 of which were situated in the communal territory of Saint-Hilaire d'Ozilhan and related to 104 horizons: 37 map units, 17 of which are described by one map polygon area only, are described in this territory. The area covered by each map unit varies from 0,6 ha to 374 ha (mean : 27,7 ha; median: 7,7 ha). As the wine makers needed broader map units in order to better manage the harvest, the technical advisers of the Wine Cooperative Institute (ICV, Institut Coopératif du Vin, BARCELO *et al.*, 1997) grouped 19 vine-growing soil map units into some ten units, 9 of which have been put into application. Each of these potential *terroir*-units was defined on the basis of similar parent material, and named after this material, such as, "sandy screes with some concretions" (unit "01", not in Saint-Hilaire-d'Ozilhan), "loess and reworked loess" (unit "02"), "screes over rocky layer of marly limestone" (unit "03"), "thick screes" (unit "04"), "screes over marls" (unit "05"), "stony loamy sands and stony reworked sands" (unit "06"), "marls and reworked stony marls" (unit "07"), "fine colluvium" (unit "08"), "sandy soils fom sandstones" (unit "09"). Units extension varies from 12 to 171 ha (mean: 70 ha ; median: 33 ha) (figure 3). A set of 5 viticultural plots was sampled for each ICV *terroir*-unit and for both the Grenache and Shiraz varieties, notably on the basis of age and vegetational health. Successive phenological and harvest observations have been recorded since 1991. The variables measured or estimated at harvest are the following : sugar content (*SC*, expressed in potential alcohol percent); titratable acidity (*TA*, in g H_2SO_4/l); anthocyanin content (*AC*, estimated by DO520); total phenolics content (*TPC*, estimates by DO280), pH (*pH*); mean berry weight (*MBW*, in g, from 200 berries).

The latest zoning approach considers the whole Appellation area and relies on soil and landform spatial analysis, using remotely sensed imagery from satellites as a major synthesis tool (VAUDOUR, 2001, 2003; VAUDOUR *et al.*, 2002). First, a soil conceptual model is built, using field knowledge, satellite image processing, examination of stereoscopic photographs, together with multiple topographical, geological and pedological maps. Second, soil landscape units are aggregated into broader-scale potential terroir-units using cluster analysis. Third, potential *terroir*-units are validated into terroir-units across successive harvests of grapes in quality clusters over a long series of 17 vintages. The output documents comprise both a map of global *terroir*-units, defined on the whole Appellation area, and the detailed version of it: a soil landscape map, the delineation of which was carried out over 36 000 ha. The potentially wine-growing study area of Saint-Hilaire-d'Ozilhan is characterized by 13 of these global *terroir*-units and 17 detailed soil-landscape units, which extend over nearly 630 ha (figure 3). Table 1 reports these 13 *terroir*-units, the area of which varies from 0,7 to 218,3 ha (mean: 52,1 ha; median: 46,5 ha), including 4 units of negligible extent (less than 3 ha: P_2C, $WDPH_2$, WH, G_3CSYP), 2 dominantly forested units (P_2 and K_2), and 7 other units extending over 12 to 218 ha (mean : 88 ha ; median: 63 ha) : those are, by increasing extent, the TYG, G_2, Y_3K, G_2Y, DY, Y_2, D_3 units. No application of such recent zoning has been performed yet at the cooperative winery.

DATA HARVEST AND WINERY RESULTS

In Saint-Hilaire-d'Ozilhan, harvest selections based on ICV *terroir*-units finally came to focus on 4 of these units (GOUEZ and BARCELO, 1997) : unit "02" (about 22 ha) produces rather small berries with low *SC* and the highest *TA*, the estimated *AC* of which is moderate and generally accompanied by low *TPC*, as well as steady blackcurrant and raspberry flavours ; unit "04" (117 ha) produces rather bulky berries with low *TA*, elevated *pH*, low to moderate *AC*, moderate *TPC* and the lowest *SC* ; unit "06" (37 ha) produces rather bulky berries with moderate to high *SC* ; unit "07" (155 ha) produces medium-sized berries with moderate to low *SC*, moderate *TA*, *pH*, *AC* and *TPC*. According to Mr. SAUVAGNAC, the winery director, the wines elaborated with the harvest collected from those 4 units prove to show distinct sensory characteristics which make them valuable for vintage selection at the production level of the cooperative winery. However, distinct selections of the same units sometimes lead to different wines.

Five global *terroir*-units defined by the latest zoning approach were validated by frequential analysis of Grenache data harvest across the 1982-1998 vintages with 67 plots disseminated over 36 000 ha (VAUDOUR, 2001): both unit D3 (218 ha) and unit WDPH2 (3 ha) produce bulky late-ripening berries with high *TA*, low *SC*, *pH*, *SC/TA* rate; unit Y3K (52,9 ha) produces medium-sized to rather bulky berries with low *TA*, high *SC*, *SC/TA* rate, *pH*; unit G3CSYP (0,7 ha) produces either the same berries as unit Y3K, or earlier-ripening, bulkier berries than observed in this unit, with medium *SC*, high *pH*, low *AT*, high *SC/TA* rate.

DISCUSSION

Geographical management of grape harvest

The boundaries of both the *terroir*-map obtained from the Sigales's soil map and the *terroir*-map obtained from soil and landform spatial analysis are very similar, but semantically divergent (figure 3, table 2): this latter is likely to lead to spatially distinct harvest selections. In particular, D3 mainly corresponds to unit "08" ; G3CSYP is entirely included within unit "09"; WH is entirely included within unit "08". Y2 mainly corresponds to unit "04", but comprises near 57 % of the unit "02" area, which roughly corresponds to the soil landscape unit called Y14lcf (periglacial fan slopes with loess and frost debris over deep Miocene molassic sandstones, at the periphery of the Urgonian limestone plateaus) and near 54% of unit "03". WDPH2 is mainly included within unit "07", like G2Y, G2, DY, P2C: as unit "07" is spatially composed of several distinct other units, this may explain why wine response may appear sometimes different. More, for several human reasons, the selected plots for harvest may change at the winery, and therefore the wine response is not strictly identical and comparable for a given ICV unit from one vintage to the other.

By handling spatial viticultural database, the winery can monitor the quality of harvest at the plot scale, and control several hundreds of plots spread over several thousands hectares. Most vine-growing plots extend over 0,3 ha in the study region. The average total area of communal territories within the southern part of the Côtes-du-Rhône Appellation is about

2 000 ha. The geographical management of harvest requires to plan both distances from plots to winery and distances between plots with the same variety. If wine volumes are about 600 hl, with an average estimated yield of about 50 hl/ha, the minimum harvest area is 12 ha and about 30 plots have to be managed. The soil landscape map is likely to lead to more detailed selections, which benefit the winery provided they are carried out over areas of more than 12 hectares: this is the case of 11 soil landscape units (mean area: 55 ha; median : 47 ha).

Explanation of *terroir* functioning

More, varied thematic mappings have been carried out with the available soil data. The applying of pedotransfer functions (PTF) developed by B.J. COSBY *et al.* (1984) on conventional soil analyses data enabled to estimate the soil available water capacity (PERNES, 2001) with the soil map extracted from the soil landscape map. Such an estimation, which must be validated and could be improved by some variables such as bulk density, offers a preliminary approach to the water balance functioning of the viticultural soils of Saint-Hilaire-d'Ozilhan (figure 4). The predicted soil available water capacity of the cultivated part of the communal territory is "low" (105-125 mm) or "very low" (85-105 mm) at the periphery of Urgonian limestones on miocene material and pleistocene fan slopes debris, whereas it is "high" (145-165 mm) or "very high" (165-185 mm) towards the pliocene clayey marls and holocene silty clay deposits, and "medium" (125-145 mm) anywhere else. For instance, the "Y11lc" soil landscape unit which belongs to *terroir*-unit Y3K, show a rather shallow vine root profile, whereas the "Y14sa" soil landscape unit which is situated within *terroir*-unit DY, has deeper root profile and its water regime depends on deep almost permanent waterlogging which may provide roots with water and explain the lower *SC* observed, probably due to higher vigour.

CONCLUSION

Viticultural zoning is worth being applied at the communal scale of Saint-Hilaire-d'Ozilhan, with several maps at its disposal, which have a spatial resolution compatible with wine-makers needs. The soil landscape map could renew the winery strategies for harvest selection, together with the map of predicted soil available water capacity. Soil and root profiles suggest distinct water balance functionings, the study of which has to be carried on.

BIBLIOGRAPHY

AFES, 1998. *A sound reference base for soils. The « Référentiel pédologique »*. INRA, Paris, 322 p.

BARCELO J.M., BREMOND L.M., FABRE F., GOUEZ B. (1997). Un exemple de valorisation d'une étude de terroir au sein d'une unité coopérative de production à Saint Hilaire d'Ozilhan (Gard), dans les Côtes-du-Rhône. In : *1er Coll. Int. "Les Terroirs Viticoles", 17-18 juillet 1996, Angers (France). INRA Angers-Montpellier.*

COSBY B. J., HORNBERGER G. M., CLAPP R.B., GINN T.R. (1984). A statistical exploration of the relationships of soil moisture characteristics to the physical properties of soils. *Water Resour. Res., 20(6), 682-690.*

GOUEZ B., BARCELO J.M. (1997). Les relations entre les terroirs, les raisins et les vins. Une étude ICV sur 6 millésimes à Saint-Hilaire-d'Ozilhan. *In : 2èmes Rencontres rhodaniennes. Institut Rhodanien, 31-34.*

GIRARD M.C., GIRARD C. (1999). *Traitement des données de télédétection*. Dunod, Paris.

LAVILLE P. (1990). Etude du terroir de 3 communes gardoises : appui à la gestion des vignobles de Castillon-du-Gard, Saint-Hilaire-d'Ozilhan et Valliguières. *BRGM, private research report. SGVRCDR, Avignon, 11 p + appendices + maps.*

LETESSIER I. (1992). Zonage des potentialités viticoles (communes de Castillon du Gard, Saint-Hilaire-d'Ozilhan et Valliguières), étude du milieu naturel : sol-topographie, rapport de synthèse. *SIGALES, ONIVINS, Syndicat Général des Vignerons des Côtes-du-Rhône.*

PERNES P. (2001). *Variabilité spatiale des horizons au sein d'unités de sol. Application à la modélisation cartographique de la réserve utile à l'aide de fonctions de pédotransfert*. DEA National de Science du Sol, Université de Nancy I, INA-Paris Grignon, ENSA-Montpellier, ENSA-Rennes, 21 pages + annexes.

SMITH L., WHIGHAM, P. (1999). Spatial aspects of vineyard management and wine grape production. In: *Proceedings 11th Coll. Spatial Information Research Centre, University of Otago, Dunedin, New Zealand, december 13-15th 1999.*

VAUDOUR E. (2001). *Les terroirs viticoles. Analyse spatiale et relation avec la qualité du raisin. Application au vignoble AOC des Côtes-du-Rhône méridionales.* Thèse de Doctorat *INA PG*, 343 p.

VAUDOUR E. (2002). The quality of grapes and wine in relation to geography : notions of *terroir* at various scales. *Journal of Wine Research, under publication.*

VAUDOUR E. (2003). *Les terroirs viticoles*. Dunod, Paris, under publication.

VAUDOUR E, GIRARD M.C. FABRE F. (2002). Le zonage viticole par l'analyse spatiale : application aux terroirs méridionaux d'AOC Côtes-du-Rhône. In : *4e Coll. Int. "Zonage viti-vinicole", 17-20 juin 2002, Avignon (France). Syndicat des Vignerons des Côtes-du-Rhône, InterRhône.*

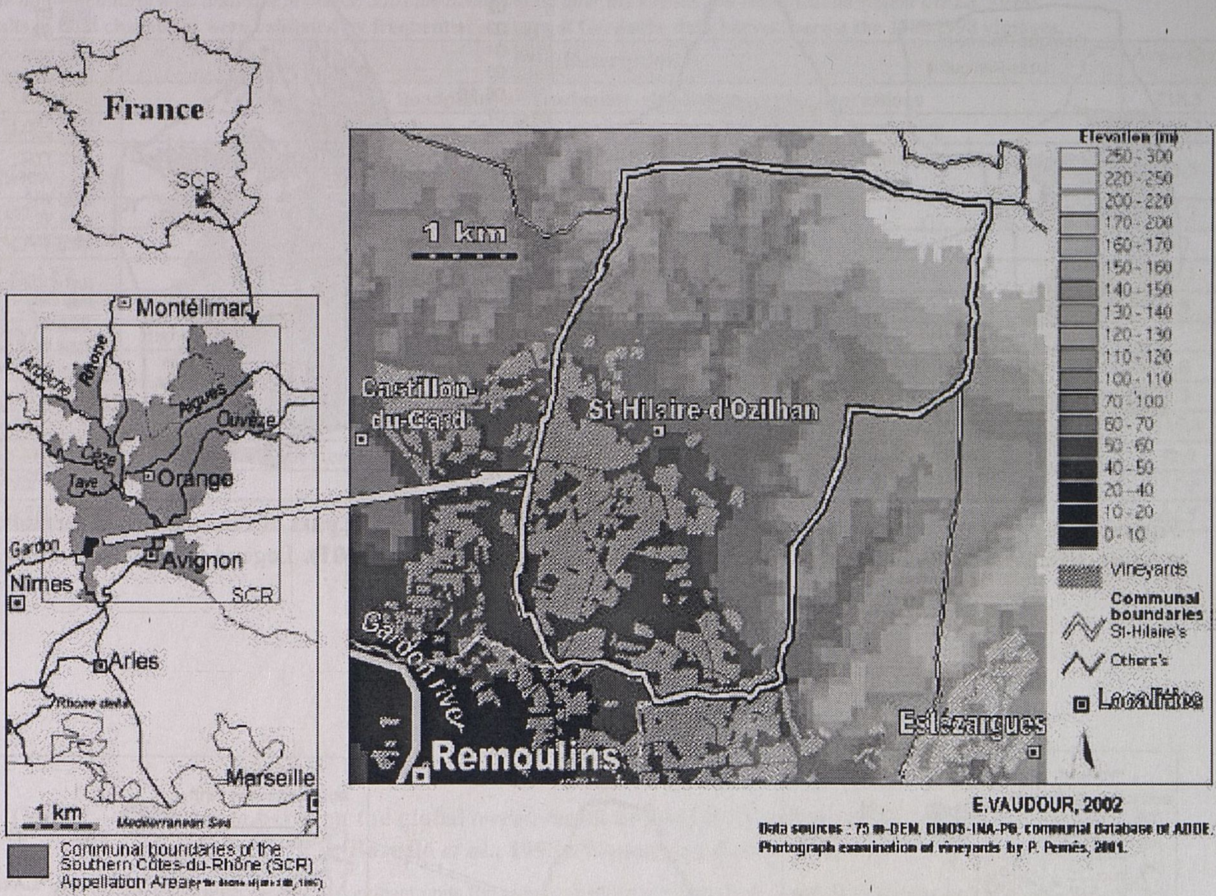
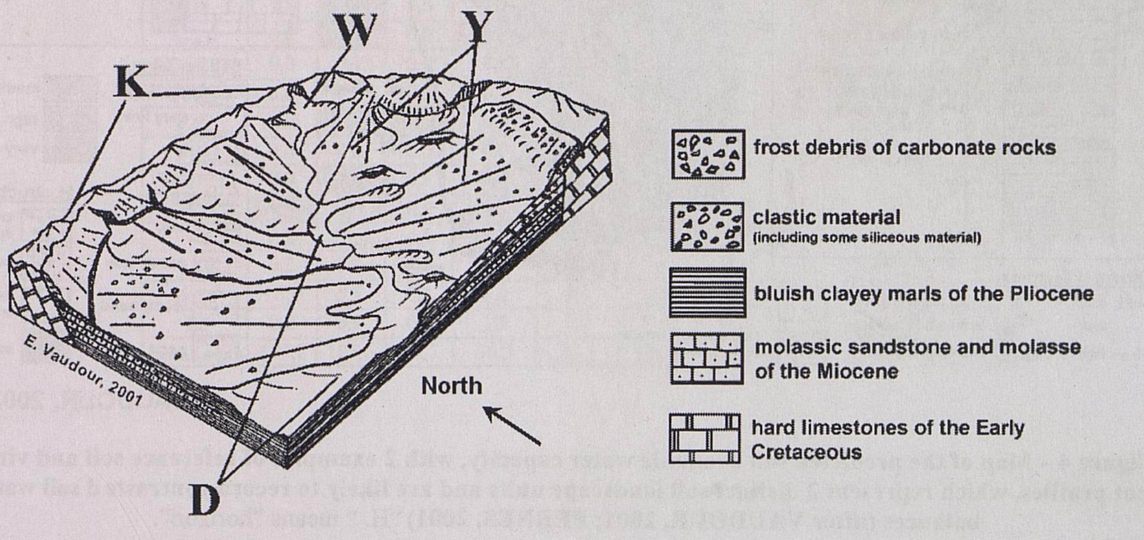


Figure 1 – Study area location



D - hydro-eolian depressions and lower alluvial plains
K - erosional plateaus in cretaceous karstic terrains and their associated cryoclastic steep sides

W - floodplains, thalwegs and watercourses
Y - fan slopes with cryoclastic material and alluvial fans at the outlet of canyons and karstic arroyos

Figure 2 – Piedmont screes of the garrigue plateau of Uzès-Remoulins, downstream the Gardon river (westward, not represented on the diagram) (VAUDOUR, 2001b, 2003)

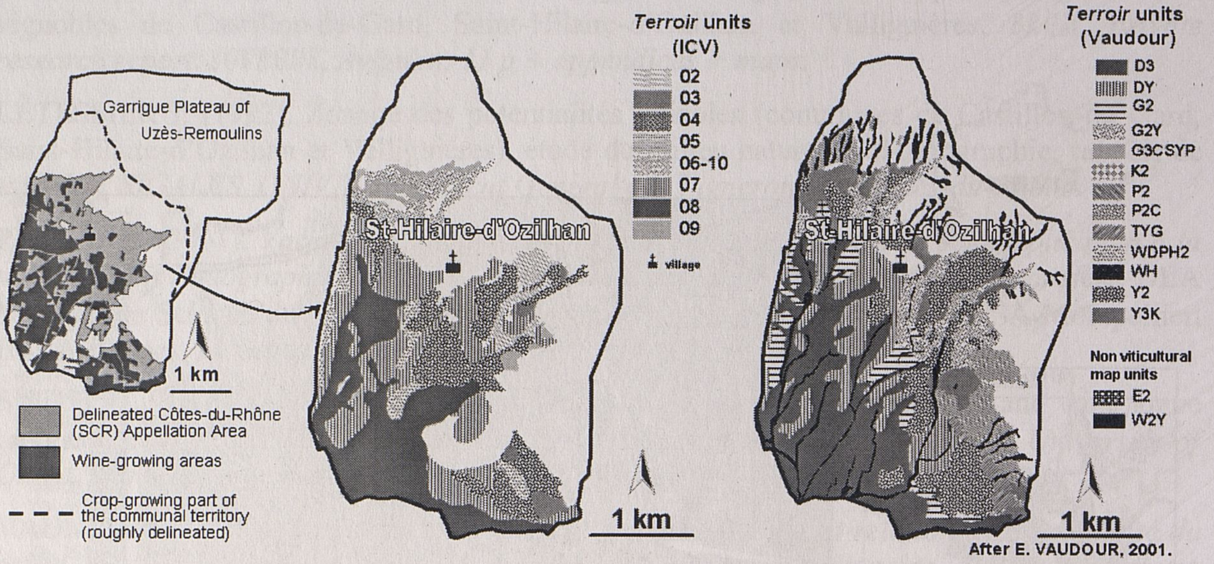


Figure 3 – Comparison between *terroir*-maps describing the crop-growing part of the communal territory of Saint-Hilaire-d'Ozilhan : left, map by ICV ; right, map by Vaudour (2001). Legend of the *terroir*-units is indicated in table 1.

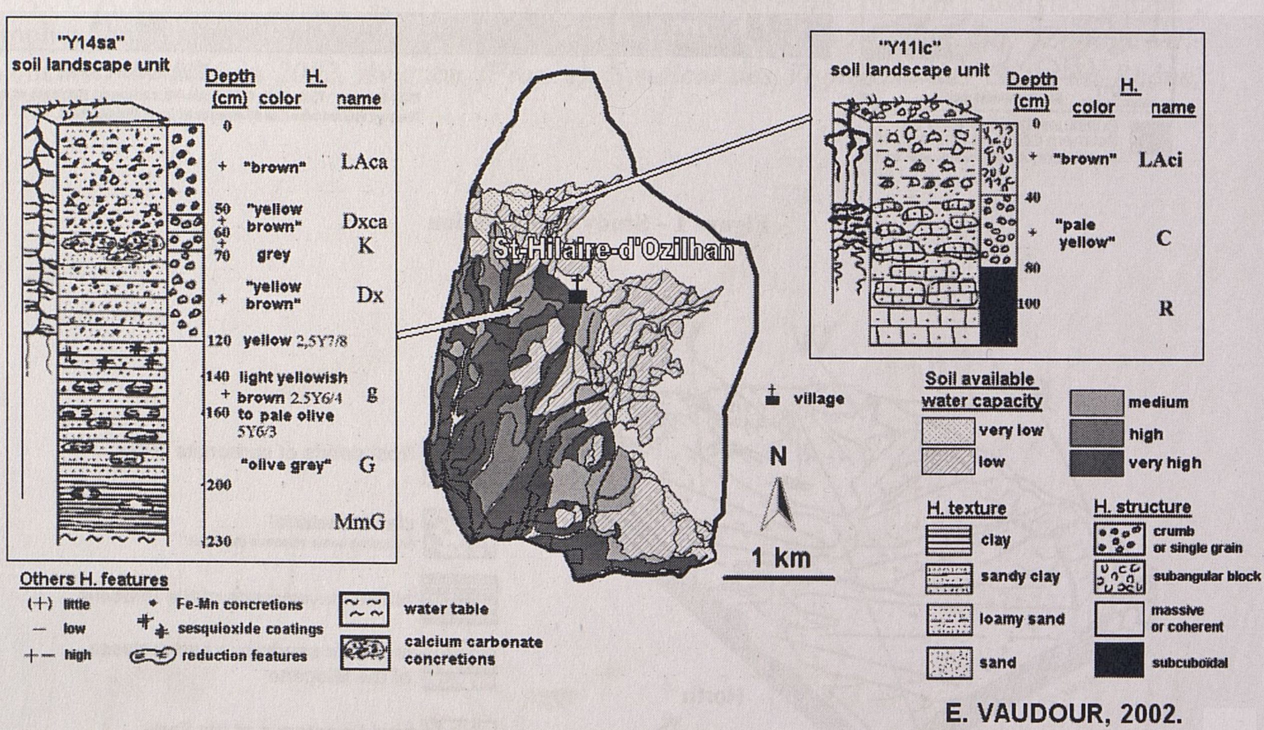


Figure 4 – Map of the predicted soil available water capacity, with 2 examples of reference soil and vine root profiles, which represent 2 distinct soil landscape units and are likely to record contraste d soil water balances (after VAUDOUR, 2001; PERNES, 2001) "H. " means "horizon".

Table 1 – Description and spatial extent of the global terroir-units defined by Vaudour (2001), by alphabetical order

The non-viticultural map units are in italics. Soils are denominated after the French soil classification system (AFES, 1998).

Units in bold characters were validated by frequential analysis of Grenache data harvest across the 1982-1998 vintages.

Terroir-unit	Description	Area (ha)
D3	**Alluvial floodplains and carbonate-rich hydromorphic depressions**	**218.3**
DY	Bottom fan slopes, dominantly sandy, with deep hydromorphic functioning	100.2
G2	Calcosols, calcarisols from pliocene clays and marls, with surficial rhodanian pebbly colluvium, situated at the foot of the higher plio-pleistocene fluviatile terrace system of the Rhône	46.5
G2Y	Thick, carbonate-rich, redoxic, calcosols and colluviosols	63.3
G3CSYP	**Slopes and solifluction sheets in sandy unconsolidated material**	**0.7**
K2 and P2	Karstic plateaus of Urgonian limestone with calcic fersialsols and thin calcisols	21.1
P2C	**Pebbly slopes in marls and calcarenites, with steep to moderate gradient**	**1.9**
TYG	Higher fan terraces, with fersiallitic soils features, carbonate concretions and calcaric horizon over marls or clays	
WDPH2	**Lower fan slopes, valleys and hydro-eolian depressions with moderate drainage and carbonates**	**3.0**
WH	Valleys bottoms and tiny hydro-eolian silty clay depressions with poor drainage	3.3
Y2	Periglacial fan slopes with cryoclastic material and colluvial, petrocalcaric calcosols	119.4
Y3K	**Cryoclastic steep sides of the karstic limestone terrains with shallow carbonate-leached soils**	**52.9**
E2	*Urbane or forested zones*	*74.0*
W2Y	*Ravines and thalwegs*	*64.5*

Table 2 – Cross-table between the global *terroir*-units defined by Vaudour (2001) and those defined by ICV (Barcelo *et al.*, 1997 ; Gouez and Barcelo, 1997).

Figures are in hectares. Spatially dominant units found in each other unit system are in bold characters and within grey cells.

Terroir-unit	"08"	"07"	"05"	"06"	"09"	"04"	"02"	"03"	no data	total area
D3	**130,8**	**56,2**	6,2	0,4	0,3	10,1	0,0	0,5	13,6	218,1
DY	11,5	**31,3**	**11,4**	0,5	0,2	14,7	0,0	0,1	24,5	94,0
G2	2,8	**17,8**	5,5	3,0	0,0	14,6	0,0	0,0	2,8	46,6
G2Y	0,0	**18,8**	0,0	**13,0**	5,4	7,8	7,8	0,7	9,4	63,0
G3CSYP	0,0	0,1	0,0	0,0	**0,4**	0,0	0,1	0,0	0,3	0,8
P2K2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**12,4**	12,4
P2C	11,5	**31,3**	**11,4**	0,5	0,2	14,7	0,0	0,1	24,5	94,0
TYG	0,0	0,0	0,0	0,0	0,0	**5,9**	0,0	2,5	3,8	12,2
WDPH2	0,0	**2,0**	0,5	0,0	0,0	0,5	0,0	0,0	0,0	3,0
WH	**1,5**	0,0	0,0	0,0	0,3	0,4	0,0	0,1	1,0	3,3
Y2	2,2	18,4	4,5	6,4	5,0	**49,6**	**12,1**	**6,4**	14,7	119,3
Y3K	0,2	3,2	0,0	10,0	**9,0**	8,7	0,9	0,8	**19,3**	52,1
W2Y	16,6	5,5	0,3	0,2	0,4	2,8	0,1	0,0	**35,7**	61,6
E2	0,2	0,9	0,0	1,5	1,0	0,5	0,2	0,6	**61,1**	66,1
total area	177,2	185,6	39,7	35,5	22,1	130,2	21,3	11,8	223,2	846,7