SOIL SURVEY AND CHEMICAL PARAMETERS EVALUATION IN VITICULTURAL ZONING

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Abstract

The most recent methodological developments in soil survey and land evaluation, that can be taken as reference in the viticultural field, go over usage of the GIS and database. These informatic tools, which begin to be widely utilised, consent to realise evaluations at different geographic scale and with different data quality and quantity in entrance.

Realising a territorial study with zoning purposes however, it is always necessary to respect the coherence between aims of work, scale of considered processes, intensity of survey and evaluation model utilised. Thus, the less detailed the scale of investigation, the lower the degree of purity and confidence of geographical information, and the more generic the evaluations.

On the other hand, the way of dealing with the typological information should be different. If the soil survey model individualises soil typologies corresponding to soil series, it is possible to find the soil characters that can be functional for viticultural and oenological results, and the geographic levels at which they can be pointed out.

In the present work, an example is brought of the possible treatment of information at different geographic generalisation levels, utilising data of some chemical analysis and a soil survey realised in Trentino (northern Italy).

Key words*: soil survey, data interpretation, viticultural zoning, Trentino, Italy.*

Riassunto

Caratterizzazione pedologica e interpretazione di dati chimici nella zonazione vitivinicola.

I più recenti sviluppi metodologici della cartografia pedologica e della valutazione del territorio che possono essere presi come riferimento in campo vitivinicolo riguardano l'uso dei GIS e database. Questi strumenti informatici, che cominciano a essere utilizzati diffusamente, consentono di realizzare valutazioni a differente scala geografica e con diversa qualità e quantità di dati in ingresso. Realizzando uno studio territoriale con finalità di zonazione però, è necessario tenere presente la necessità di rispettare la coerenza tra finalità del lavoro,

scala dei processi considerati, intensità dei rilievi e modelli di valutazione utilizzati. Così, a scale di indagine meno dettagliate corrisponderanno valutazioni più generiche, diminuendo il grado di purezza e di confidenza dell'informazione cartografica. Diverso è il caso che riguarda l'informazione tipologica. Se si utilizza il modello di rilevamento dei suoli per tipologie pedologiche corrispondenti alle serie, è possibile individuare i diversi caratteri pedologici che possono essere funzionali al risultato viticolo ed enologico e i livelli geografici a cui si evidenziano. Nel lavoro viene riportato un esempio di come è possibile trattare le informazioni a diversi livelli di generalizzazione geografica, utilizzando i dati relativi ad alcune analisi chimiche routinarie e di microelementi, per il giudizio sulla fertilità chimica dei suoli nella zonazione viticola della Val d'Adige e Val di Cembra.

***Parole chiave**: rilevamento pedologico, interpretazione dei dati, zonazione viticola, Trentino.*

1. Soil survey and viticultural zoning

The term "viticultural zoning" has been utilised to indicate the subdivision of a territory into areas with different quanti-qualitative yield suitability, on the basis of one or more natural and anthropic factors. Viticultural zoning can be carried out at different scales and encompass geographical areas whose dimensions can vary ranging from a Region to a single vineyard. Considering the practical applications, the most effective experiences are the interdisciplinary ones, with multiannual plot trials covering territories of some thousand hectares and map scales ranging from 1:5.000 to 1:50.000, generally from 1:10.000 to 1:25.000 (Costantini and Pinzauti, 1992; Falcetti et al., 1997). When a specific experiment scheme cannot be realised, then suggestions for the viticulture of a territory can be given on the basis of knowledge regarding crop requirements that was the object of more indepth studies carried out in similar environments (Falcetti and Campostrini, 1996). In all viticultural zoning, in any case, a specific influence of soils on vine cultivars is sought as well as contemplating a soil survey and mapping (Parodi, 1997), but what is the most suitable methodology to survey soil and evaluate data in a viticultural zoning?

In pedology many different investigation methodologies and survey intensity levels can be adopted. In particular, even when considering only the deterministic approaches, the so-called "detailed" and "reconnaissance" surveys present some important conceptual and operative differences. At the detailed level, limits between delineations should follow the real boundaries between natural soil bodies so that they are put in the field or, when a characteristic pattern can be recognised, in photointerpretation. Soil units generally correspond to phases of "soil series" (Soil Survey Staff, 1975). On the other hand, at the reconnaissance level, map delineations frequently do not refer to soil limits, but rather to soil models (soil toposequences) that have been recognised in characteristic pedolandscapes or "windows"; limits follow lithological and physiographical criteria or, in some cases, vegetation, land use, drainage etc. Traditionally, soil units belong to categories higher than series.

Recently however, with the advent of GIS and databases, information about soil map units and polygons could be easily distinguished from those regarding typological units (Gardin et al., 1996). This means that it is possible to deal with typological units like soil series at both levels (Napoli et al., in press). In other words, the two approaches can differ essentially in the way they spatialise information, not necessarily in the typology of information. Moreover, with the aid of information technology, it is possible to distinguish the "geographical" intensity of pedological observations (auger holes, profiles etc.), from the "typological" intensity. In this way the survey standards should be considered both in terms of "observations by surface unit" and "observations by soil unit".

It is well known that total observation density follows a set of variables: cartographic scale, soils distribution complexity, site accessibility, remote sensing, financial budget, thematic maps and information technology available; nonetheless, the same total amount of observations can be focused either on improving typological knowledge of soils or aimed at appreciating their geographical distribution. Thus, the fewer the number of observations, the more the uncertainty about soils: in terms of the number and kinds of soils which are really present and significant for the study area, and/or the precision of soil limits, and/or the purity of soil map (inclusions inside the polygons).

Zoning with practical purposes for farms or wine territories, especially when aimed at addressing the quality of wine, deals with detailed processes, because the interaction between specific environmental factors and vine genotype is considered (Morlat, 1997). As this interaction can vary significantly even at the plot level (Champagnol, 1997), then the soil typological information has to be detailed enough to consider all the possible vine functional characters and qualities. In practice, it means that several observations by soil typology are needed, and the survey intensity should take into account not only the territory's area, but also the contemplated number of typologies present in the territory.

Tab. 1 - Pedolandscapes organisation and surface (approximate value in hectares) of the Adige and Cembra valleys viticultural territory.

Pedological province	*Pedological district*	*Series*	*Phase*
Adige valley flat and alluvial fans of its affluents (726)	Soils of the depressed areas, with high water table and prevailing silty parent materials	Fateni (250)	FA1: silt loam (183); FA2: hydromorphic (48); FA3: backswamps (9); FA4: loam (10)
	Alluvial soils with water table inside and prevailing sandy parent materials	Salorno (207)	SA1: loam (91); SA2: sandy loam (40); SA3: gravelly loam (77)
	Soils of overfloaded fans	Ischiello (38)	IS1: silt loam (38)
	Soils of Adige tributaries fans	Lavis (231)	LA1: loam (115); LA2: gravelly (30); LA3: sandy loam (64); LA4: rendollic (22)
Hilly and mountainous relieves (1274)	Soils of debris or little alluvial fans with prevailing dolomitic parent materials	Zambana (24)	ZA1: flaggy (18); ZA2: coarse loamy (6)
	Soils of benches or linear slopes with prevailing dolomitic parent materials	S.Valentino (136)	SV1: flaggy (40); SV2: coarse loamy (15); SV3: fine loamy (51); SV4: lithic (29)
	Soils on gypsipherous parent materials.	Sorni (18)	SO1: of slopes (12) SO2: of colluvia (6)
	Soils on prevailing red silts parent materials.	Pressano (397)	PR1: fine silty (50); PR2: coarse silty (95); PR3: coarse loamy (163); PR4: fine loamy (6); PR5: loam (23); PR6: hydromorphic (11); PR7: of colluvia (38); PR8: cobbly (11)
	Soils on prevailing porphyry debris and rocks	Faver (83)	FV1: loamy skeletal (23); FV2: coarse loamy (6); FV3: loam (46); FV4: loam and coarse loamy (8)
	Soils of terraces, slopes and paleo-landslides with fluvi-glacial parent materials (617).	Cembra (497)	CE1: sandy loam (207); CE2: loam (55); CE3: loamy sand (93); CE4: mollic (71); CE5: gravelly alluvial (6); CE6: loam alluvial (209); CE7: gravelly loam (15); CE8: gravelly sandy loam (30)
		Meano (120)	ME1: gravelly coarse sandy loam (25); ME2: leached (81); ME3: at high elevation (14)

Once the soil units are assessed and the soil map is charted, it is possible to interpret the viticultural and oenological results in relation to either the soil units as a whole (Lulli et al., 1989), or the characteristics that can be assumed as functional for the varieties considered (Costantini and Lizio-Bruno, 1997, Costantini et al., 1996).

To spatialise the functional characters, i.e. to find the geographic area in which one or more functional characters are significantly different, one of the simpler and more effective methodologies that can be run utilises the hierarchical organisation of the pedolandscapes coming from the soil survey. Data undergo statistical processing, where the pedolandscape categories represent different statistical populations for each functional parameter.

2. Soil survey and data evaluation

The above described methodology is illustrated in the following example regarding the chemical analyses of vineyard soils of the Val d'Adige and Val di Cembra territory. Data derive from an interdisciplinary work carried out in collaboration with the Istituto Agrario of San Michele all'Adige, the Experimental Institute for Soil Study and Conservation of Florence, the wine cooperative of Lavis and the Earth Sciences Department of Modena University.

2.1 Material and methods.

Official analytical methods were used (MIRAAF, 1994), with the exception of assimilable K and Mg, that were extractedextractex with ammonium acetate, and of "total" Ca, Mg, K, Fe, Mn, Cu, Zn, Ni, Cr, Li, which were titled with atomic absorbent on a acid solution of "aqua regia" (Ascari, 1997). For this reason, the content of soil elements is to be considered as "highly extractable", more than "total", because it excludes those elements that are included in the crystalline lattice of the silicates.

The soil survey was detailed, aimed at producing a soil map at 1:10.000 scale. Actually, the survey intensity resulted higher than that normally indicated for this scale (Costantini et al., 1991), because of the soil distribution complexity and the disaggregated vine territory. By and large, a total amount of about 1500 auger holes and 93 profiles for about 2000 hectares were produced, i.e., an average of 136 auger holes and 8.5 profiles by soil typology and 1.3 and 21.5 hectares by auger hole and profile.

The survey methodology consisted in an "inductive" process followed by a "deductive" one. It began with the subdivision of the whole territory into few different macroscopic physiographical environments, followed by a finer distinction of the landscape into units and sub-units, since the relations between the soils and some land characteristics, like lithology of the parent materials, slope, erosion, land use, anthropic works (terraces, channels) were discovered during the field survey. The activity of singling out and delimiting soil and landscape variations was accompanied by the organisation of soil typological information into units (the soil series) and sub-units (the phases). Soil series were determined with a holistic, rather than a taxonomic criterion, i.e., they represented environmental units that were found homogeneous in terms of natural and anthropic characters and processes (Costantini and Gregori, 1996; Costantini et al., 1997). As a final result, the original rough physiographical subdivision of the area transformed into a hierarchical organisation of "pedolandscapes". Each pedolandscape became a container of information on soils and landscapes at a given level of generalisation[ISS1] and data coming from the chemical laboratories were interpreted on this basis. A brief description of the studied soils and landscapes is reported in table 1, whilst a more complete set of information can be found in Falcetti et al. (1998).

Statistics were processed with SPSS(software, submitting data to an analysis of variance with non-parametric tests because not all populations followed a normal distribution. Mean values reported in the tables are only those that were found significantly different for $P \leq 0.05$, following the Kruskal-Wallis and the Sample Median tests. As chemical parameters in the "pedological district" level substantially yielded the same results as the "series" level, it isn't reported here. Instead, the category "soil horizons" was added so as to highlight the differences in chemical contents between superficial and deep layers.

2.2 Results and discussion

Analysis of the values referring to the entire study area permit us to appreciate the great variability of almost all parameters considered (tab. 2). Overall mean values in particular highlight the mainly dolomitic nature of the substrata, as well as the quite low supply of most microelements, but copper, on the contrary, is very high, more than current legal thresholds for the spreading of compost and sludge. Of note, furthermore, is the overall high total lime and iron contents, whereas the active lime and free iron are on the average rather low.

Tab. 2 - Chemical parameters considered in viticultural zoning of the Adige and Cembra valleys. Minimum values lead us to hypothesise that some vineyards could show deficiency symptoms

	Mean value	*Minimum*	*Maximum*	*Number of data*
Main chemical parameters				
N tot. (%)	0.11	0.03	0.25	49
P_2O_5 ass. (mg/Kg)	92	2	322	40
K_2O ass. (mg/Kg)	200	27	496	56
Mg ass. (mg/Kg)	439	27	1084	27
Organic matter (%)	1.77	0	29.1	333
pH	7.93	4.85	8.87	335
CEC (cmol (+)/Kg)	11.9	2.1	73	86
$CaCO_3$ tot. (%)	24.3	0	98.2	182
$CaCO_3$ act. (%)	1.42	0	16.6	183
Electrical conductivity (µS/cm)	435	117	1827	13
Fe-DCB	0.56	0.05	1.65	115
Macroelements (mg/Kg)				
Ca	48331	700	242900	137
Mg	2600	1800	13746	136
K	1700	500	4500	136
Fe	14600	1900	43600	137
Microelements (mg/Kg)				
B	0.31	0.14	0.68	8
Mn	529	94	2947	136
Cu	129	5	769	137
Zn	76	9	266	136
Ni	25.7	4.7	90.3	135
Cr	13.6	4.5	166	137
Li	6.9	1.1	24.5	137

for some main nutrient and/or microelement, e.g. boron and iron (Fregoni, 1980). On the other hand, the maximum values of trace elements seem to indicate the possibility of excess for some metals, above all copper.

Tab. 3 - Chemical parameters significantly different at the "soil province" generalisation level (Kruskal-Wallis and Sample Median tests, P $\leq$ 0.05).

	Adige valley flat and alluvial fans of its affluents	Hilly and mountainous relieves
Main chemical parameters		
N tot. (%)	0.07	0.12
P_2O_5 ass. (mg/Kg)	40.5	95.1
CEC (cmol (+)/Kg)	14.8	11.1
$CaCO_3$ tot. (%)	13.2	27.8
$CaCO_3$ act. (%)	1.71	1.33
Electrical conductivity (μS/cm)	156	609
Macroelements (mg/Kg)		
K	2023	1664
Fe	20000	12968
Microelements (mg/Kg)		
Mn	389	572
Zn	89.7	71.3
Ni	33.5	23.4
Cr	19.4	11.8
Li	12.00	5.29

The information obtained at the "soil province" generalisation level (tab. 3), can give some indications about viticultural soil potential and constraints in the two major environments. Soils on hills resulted in a higher mean content in some of the main chemical parameters: in particular total nitrogen, assimilable P2O5, total $CaCO_3$ and electrical conductivity. The same soils showed lower mean values of CEC and active $CaCO_3$. Moreover, alluvial soils of the plain area resulted richer in K, Fe, Zn, Ni, Cr and Li, but poorer in Mn.

Some of these differences can be ascribed to different lithological nature and prevalent texture of soils in the two areas. As to the metals content in particular, it is known that schist and other metamorphic rocks are richer in metals (except for Mn) than fluvi-glacial sands as well as calcareous and porphyry rocks, i.e. the more frequent parent materials of hilly soils (Abollino et al., 1996). However, schist and metamorphites abound in the Adige basin upstream Salorno, and therefore probably affected the alluvial soils.

A major amount of information has been attained at the "series" level, for a geographical scale that can be already useful for farmers or cooperatives (tab. 4). Some of the outcomes seem to be particularly interesting for viticulture: soils belonging to the *S. Valentino* and *Zambana* series, for example, showed very large values of active and/or total $CaCO_3$, Ca and Mg, depending on the dolomitic nature of their substrata; as had *Pressano* soils, depending on the silty parent material, which moreover seems to give the soils fair quantities of secondary iron. Faver soils on porphyry were the only ones to show a significant accumulation of organic matter and a slight acidity. *Cembra* soils were, as a whole, the less fertile in terms of CEC, while alluvial soils were more provided in several elements. Among the latter, *Fateni* soils were the richest in metals and potassium.

Tab. 4 - Chemical parameters significantly different at the "series" generalisation level (Kruskal-Wallis and Sample Median tests, $P \leq 0.05$).

Main chemical parameters	*Value and series*	*Value and series*	*Value and series*	*Value and series*
Mg ass. (mg/Kg)	945 Meano	757 Lavis	564 Pressano	
Organic matter (%)	3.19 Faver			
pH			7.34 Meano	6.98 Faver
$CaCO_3$ tot. (%)	55.9 S.Valentino	50.4 Sorni	49.5 Zambana	36.0 Pressano
$CaCO_3$ act. (%)	2.11 S.Valentino			
CEC (cmol (+)/Kg)				8.22 Cembra
Fe-DCB	0.74 Pressano			
Macroelements (mg/Kg)				
Ca	124817 Zambana	100621 S.Valentino	70671 Pressano	
Mg	6067 Zambana	5721 S.Valentino	3284 Pressano	
K	2318 Fateni			
Fe	26167 Fateni			
Microelements (mg/Kg)				
Zn	106 Fateni			
Ni	47.3 Fateni	31.1 Salorno	29.8 S.Valentino	29.0 Pressano
Cr	30.5 Fateni			
Li	15.8 Fateni	11.0 Salorno	8.4 Lavis	

Passing to the pedo-landscape level "phases", the obtained information was even more detailed, allowing to be utilised for the single vineyard management (tab. 5). Actually, chemical parameters of the soil phases could be quite different from the mean values of series: as a rule, only few phases of a series were significantly different from the overall mean; besides, for zinc and potassium, the phases with the highest values did not belong to those series, that resulted on average the best provided. Sometimes the lithic or stony phases tended to differentiate from the rest of soils: so did *Faver skeletal* in terms of its organic matter content, or *S.Valentino lithic* and *S.Valentino flaggy* for their total $CaCO_3$, but *S.Valentino fine loamy* gave the highest content of active $CaCO_3$.

From an environmental point of view, the very high nickel supply of *Fateni hydromorphic* must be stressed, higher than current legal thresholds for compost and sludge spreading, which seems to indicate an area of [ISS2]concentration of pollutants.

Tab. 5 - Chemical parameters significantly different at the "phases" generalisation level (Kruskal-Wallis and Sample Median tests, P $\leq$ 0.05).

	Value and phase	*Value and phase*	*Value and phase*	*Value and phase*	*Value and phase*	*Value and phase*
Main chemical parameters						
Organic matter (%)	5.33 FV1					
pH		7.02 CE5	7.01 FV1	6.96 ME2	6.74 CE4	6.36 FV2
$CaCO_3$ tot. (%)	80.6 SV4	57.6 SV1	53.4 SO2	50.3 ZA1	49.2 SV2	48.5 SO1
$CaCO_3$ act. (%)	8.9 SV3					
Electrical conductivity (μS/cm)	610 SO1	608 SO2				
CEC (cmol (+)/Kg)					5.65 CE6	5.00 CE8
Fe-DCB	1.39 PR8	0.88 PR1				
Macrolements (mg/Kg)						
Ca	179250 SV4	139050 ZA2	117700 ZA1	102867 SV1	99750 PR3	
Mg	8470 SV4	7170 ZA2	5932 SV1	5800 SV2	5515 ZA1	4030 PR3
K	3020 CE2					
Fe	42150 FA2	25725 FA1				
Microlements (mg/Kg)						
Mn	1754 SV4	1583 PR8				
Zn	153 ME1					
Ni	76.1 FA2	47.5 SV3	47.1 PR8	41.9 FA4	41.5 FA1	35.6 SA1
Cr	35.6 FA1					
Li	24.2 FA2	21.6 FA4	13.3 SA1	12.2 FA1	11.5 ME2	10.6 SA2

Eventually, through the analysis of the differences between all soil horizons, the higher organic matter content and lower pH of the upper horizons was made evident (tab. 6), as well as both the superficial copper accumulation and a significantly higher content of calcium, total $CaCO_3$ and chrome in depth.

The copper accumulation, evidently linked to the viticultural treatments, is particularly impressive, because there was not any significant difference found between soils at any generalisation level.

In the cases of calcium and total $CaCO_3$, the enrichment in the C horizon seems to indicate a certain leaching process in the upper A and B horizons, whilst, in the case of chrome, a dependence of the C horizon on the alluvial sediments nature.

3. Conclusions

The soil survey and data processing methodology presented allowed the interpretation of some analytical results achieved through a research project on viticultural zoning. The information obtained can be useful in order to offer operational guidelines at varying levels and for distinct viticultural actors: farmers, cooperative, researchers, public administrators. Moreover, when integrated with the knowledge of other important vine functional land qualities, like soil available water capacity and mesoclimate, it permits the comprehension of crop yield and oenological result in the different zones of the territory, as well as singling out areas particularly suitable for the different vines cultivated and wines produced in the territory (Falcetti et al., 1998).

Tab. 6 - Chemical parameters significantly different at the "horizons" generalisation level (Kruskal-Wallis and Sample Median tests, $P \leq 0.05$).

Main chemical parameters	*Value and horizon*	*Value and horizon*
Organic matter (%)	3.17 Ap1	1.98 Ap2
pH		7.5 Ap1
$CaCO_3$ tot. (%)	34.3 C	
Macroelements (mg/Kg)		
Ca	90718 C	
Microelements (mg/Kg)		
Cu	178 Ap1	157 Ap2
Cr	25 C	

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