THE "RESOURCES PROFILE®": A RELEVANT DECISION AND SUPPORT SYSTEM FOR ADAPTING VITICULTURAL PRACTICES TO SOILS AGRONOMIC PROPERTIES AND LIMITING THEIR ENVIRONMENTAL IMPACTS.

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Abstract

Soil is a three-dimensional complex system, which constitutes a major component of Terroir. Soil characteristics strongly influence vine development, grape oenological potentialities and thus wine quality and style.

Soil profile description by means of pits is essential for a relevant characterization of the soil. However, the interpretation of results is very difficult for non-specialists, as for most of advisors or winegrowers, due to the multitude of parameters and their variability within the soil profile.

We propose here a novel method to represent soil parameters variability, integrating thickness and depth of the different horizons, providing an operational Decision and Support System (DSS) for winegrowers and advisors.

For each parameter, soil profile is represented by a vertical block divided in 10 centimeters layers, in order to highlight the thickness of the different horizons. According to the parameter value, a specific color code, based on analytical references, is applied for each horizon. This method has been applied on different soil parameters : coarse fragments content, clay content, slaking and compaction index, carbonate content, pH, organic content and stock, carbon/nitrogen ratio, cation exchange capacity, exchangeable cations contents, base saturation percentage.

This method, called « Resources Profile® », has been tested on a large number of soil types, representative of soils variability in Bordeaux wine production area (France). It allows to easily visualize soil parameters variability within soil profile and to evaluate agronomic properties, such as hydrological soil properties, organic and calcic status, mineral resources or degradation sensitivities.

We believe that the « Resources Profile® » is a relevant DSS for adapting viticultural practices to soils characteristics and for limiting their environmental impacts. This DSS is likely to facilitate the spread of soil science knowledge to the vinegrowing industry.

Keywords: winegrowing soils, soil profiles, soil horizons, soil analysis, agronomic properties, viticultural practices, Decision and Support System.

1 INTRODUCTION

Soil is a three-dimensional complex system, which constitutes a major component of Terroir. Soil characteristics strongly influence vine development, grape oenological potentialities and thus wine quality and style.

Soil profiles and horizons. Soil formation results from the alteration of a geological parent material under the influence of climate (rain and temperature), relief, biological activity (fauna and flora) and human activities (agricultural practices, urbanization…). Consequently different homogeneous layers can be distinguished, according to their colors, components, structure, physical properties as well as chemical environment. Soil horizons constitute the key elements to enable the description, the sampling, the analysis, the understanding and the classification of soils. They are identified and categorized very precisely by pedologists, according different criteria and reference sources (Baize et al., 1995).

Analytical approach vs systemic approach. The usual analysis carried out in laboratories permit to determine the major components contents of a soil sample, such as granulometric fractions, carbonates, organic matter, mineral elements... The development of these analysis has led to great progress in soil agronomic characterization and therefore in the assessment of the hydric and mineral resources availability for cultures.

When dealing with vinegrowing, most of the time, these analysis are only used to characterize soil superficial horizons (0-30 cm), thanks to samples collected with hand auger, mainly in order to manage fertilizers inputs. In the case of a plantation, an additional sample is usually analyzed to characterize the subsoil (30-60 cm), in particular to evaluate chlorosis risks (carbonated soils) and therefore decide about the appropriate rootstock. Such a use of analysis is not enough to get a global view of soil functioning, because the characteristics of intermediary as well as deep horizons are not taken into account.

The digging of pits reveals the thickness and the profile of soils. Each identified horizon can be described according to several parameters: coarse fragments content, texture, structure, physical properties (compactness, porosity…), moisture, colors, hydromorphy signs, root development… (Baize et al., 1995). Additionally, one sample for each horizon is collected to carry out analysis in laboratory. This method allows to thoroughly characterize the different horizons of the profile and to understand their vertical organization and interactions. Nowadays, this systemic approach appears essential to get a global view of soil functioning and assess its agronomical properties in a relevant way. It should be the first step for reasoning agricultural practices related to plantation (plots demarcation, drainage system, soils preparation, plant material choice) as well as weed and fertility management in producing plots (Roger-Estrade *et al.*, 2004 ; Peigné *et al.*, 2013).

However, this systemic approach is not widespread used, because it require specific skills for the description of profiles in the field and for the interpretation of soil analysis results. For each soil horizon, the interpretation of analysis results remains complex for non-specialists, because of numerous interactions between different parameters (APCA, 2011). Furthermore, vertical relations with over and underlying horizons need to be considered for each soil horizon. In these conditions, it is difficult to characterize soils agronomic properties and to assess hydric and mineral resources availability for vines.

Decision Support System (DSS) for sustainable soil management. Since 2012, the Gironde Chamber of Agriculture conducted an experimental program on weed and soil fertility integrated management. One of this program objectives is to elaborate Decision Support Systems (DSS), in order to promote sustainable vinegrowing soils management. From this perspective, practices and technical processes should be better adapted to soil agronomic properties, to limit their environmental impacts. For this purpose, the digging of pits to characterize soils should become an essential step of agronomic diagnosis.

In order to make this approach more accessible to vinegrowing actors (scientists, advisors, winegrowers and students), first step was to elaborate a guide and a notation form for soil profiles description in the field. Second step was to develop a method to facilitate the interpretation of soil analysis results, obtained from samples collected on different soil profile horizons (Cazenave, 2013). This method has been called « Resources Profile® ».

2 MATERIALS AND METHODS

Methodological framework and indicators. The « Resources Profile® » method offers a formalized framework to structure the interpretation of soil analysis results, in order to facilitate the assessment of soil agronomic properties. It proposes to characterize the soil according four profiles : textural, calcic, organic and mineral. For each profile, different indicators have been selected.

Textural profile is defined by three main indicators : coarse fragments content (EG), clay content (A) and texture (TEXT). Coarse fragments content is evaluated in the field, during the profile description (Baize et al., 1995). Clay content is measured in laboratory, with a granulometric analysis (5 fractions). Texture is defined with the granulometric analysis results, using a simplified soil texture triangle, elaborated by the Gironde Chamber of Agriculture (Cazenave, 2013). Additionally, two others indicators are also calculated to evaluate soil resistance to degradation : slaking index (IB) (Baize, 2000) and compaction index (IT) (Rémy *et al.*, 1972).

Calcic profile is defined by five indicators : total carbonates content ($CaCO_3$ total), active carbonates content ($CaCO_3$ active), water pH, KCl pH and amount of calcium according to cation exchange capacity (Ca/CEC).

Organic profile is assessed according 3 indicators : organic matter content (MO), carbon to nitrogen ratio (C/N) calculated for superficial horizons and organic matter stock calculated for the first 30 centimeters (STOCK 0-30) (Arrouays, 2001).

Mineral profile is defined by five indicators : cation exchange capacity (CEC), saturation rate (S/T), phosphorus (P), potassium (K) and magnesium (Mg) contents.

Repositories and interpretation thresholds. For each indicator, threshold levels for interpretation have been determined according to local, regional or national repositories (Table 1).

Results representation : the « Profile Block ». In order to get a global view of soil functioning, vertical relations with over and underlying horizons need to be considered for each soil horizon. For this purpose, it is recommended to present analysis results in the form of "elements profiles" according to the depth (Baize, 2000).

With this in mind, soil profile has been symbolized by a vertical bloc, called the "Profile Block" (PB), divided in fifteen ten centimeters layers, representing a total thickness of 1,50 meters. Thus, each soil horizon can be represented according to its thickness. For each indicator, the PB is associated with a specific color code, defined to facilitate the interpretation of the results and their variability within the soil profile.

Application. This method has been applied to characterize the soils agronomic properties of a 25 plots network, dedicated to an experimental program on weed and soil fertility integrated management. These plots, mainly situated in Gironde (France), offer a good representation of soils variability in the Bordeaux vinegrowing area.

3 RESULTS AND DISCUSSION

Figures 1 to 4 illustrate results obtained with 2 very different soils : a carbonated clayey soil (a) and an acid gravelly sandy soil (b).

Textural profile. For the Texture PB, low in clay horizons appear in yellow whereas rich ones in brown, dark brown or black. Coupled with the EG PB, this graphical representation allows to assess soils permeability profiles. Considering field observations (topographic setting, physical properties and hydromorphy features), it permits to understand soils hydric functioning : slow drainage for very clayey soils (a), much filter for gravelly sandy soils (b) or perched water tables for soils with impermeable clayey profound horizons (textural discontinuity). This assessment of soils hydric functioning can be useful for choosing the most adapted varieties and rootstocks at the time of plantings.
Additionally, slaking index (IT) and compaction index (IB) alert users on structural breakdown risks, with a color code from green (no risk) to red (significant risk).

Calcic profile. The CaCO3 PB (total and active) reflect the carbonated (a) or non-carbonated (b) nature of soils, with colors from yellow to red, according to carbonate contents. This representation allows to alert on chlorosis risks and to choose rootstock according carbonate content and depth of carbonated horizons.
For the pH PB (water and KCl), acid horizons appear in red, orange or yellow, neutral ones in green and basic ones in blue. Additionally, the CA/CEC PB alert on decalcification and leaching risks. This representation highlights soils affected by acidification, which necessitate regular basic amendments to maintain their fertility.

Organic profile. For the MO PB, poor horizons in organic matter appear in yellow and richer ones in brown, dark brown or black. The same color code is used for C/N indicator, calculated for superficial horizon. Low values associated with quick mineralization appear in yellow, whereas high values related to mineralization problems linked to acidity and/or hydromorphy appear in dark brown or black.
With no local repository to interpret the Stock 0-30 indicator, no color code has been defined. Values are presented for information. It permits to acquire references, for given textural and calcic profiles.

Mineral profile. For the CEC PB, horizons presenting low values appear in yellow, whereas ones with higher values in brown, dark brown or black. The S/T PB alert users on base cations leaching risks with a red color. This representation allows to assess soils mineral resources levels, rather important (a) or low (b).
For the P, K and Mg PB, each cation is associated with a color : yellow for phosphorus, purple for potassium and grey for magnesium. These colors vary from light for low contents to dark for high contents.
This representation allows to highlight, for example, links between high phosphorus contents and high organic matter contents (b). For potassium, different repartition within the profile can be distinguished : superficial accumulation (a) or subsoil richness (b).

4 CONCLUSION

Formalized framework. The « Resources Profile® » method proposes a formalized framework to describe soil composition and the vertical variability of its components in a structured and objective manner. It allows a better valorization of classical soil analysis, routinely accessible in most laboratories. This method could be applied in every vinegrowing area in the world, with adaptation of interpretation thresholds to local repositories. Complementary indicators could be also added to respond to specific issues, such as sodium for example in areas concerned with salinization.
Within research and development programs based on plots networks, this method could be used to elaborate objectively soils typologies on a given territory. It could be applied to assess soils profiles influence on plots sensibility to climatic effect, in terms of vegetative development, pest vulnerability, yield building, or oenological potentialities. In this regard, the main objective of work conducted in Gironde is to elaborate a typology of vinegrowing soils hydric functioning, according to their textural profiles (Guinoiseau, 2012). In 2015-2016, more than one hundred of plots have been characterized with this method. Next step consists in improving this textural classification, by incorporating topographical indicators, calculated with a digital terrain model.

This DSS could also permit to take account of soils agronomic properties more systematically, in particular at the time of plantings as well as weed and fertility management in producing plots. In this perspective, this method has been used to establish agronomic diagnostic on a 25 plots network, to determine technical agricultural processes the more adapted for reducing herbicides and fertilizers inputs.

Soil science dissemination tool. We believe « Resources Profile® » is a relevant Decision and Support System to raise vinegrowing industry awareness of issues related to sustainable soil management and to facilitate the spread of soil science knowledge to a greater public.
The way soil analysis results are presented (profiles blocks and color codes) facilitates the understanding of soil functioning in a global view and the assessment of his main agronomic properties. It allows to approach complex concepts such as oenological potentialities, agricultural constraints or fertility degradation, in a more concrete manner.
In order to test its accessibility, this method has been presented to the Gironde Chamber of Agriculture advisors and dozens of winegrowers, within the context of professional training about sustainable soil management. The teachers of Gironde agricultural schools have also been initiated to this method, which could be used as an efficient pedagogical support to raise student's awareness about soil sciences.
In 2014, an automated prototype has been developed on the website of Vinopôle Bordeaux-Aquitaine. It has been made progressively available to scientific partners, teaching teams and advisors. Following this test phase, a second version will be developed in 2016, with the aim of automating results recording and formalizing the different DSS outputs. The access of « Resources Profile® » DSS should be open to a larger public in 2017.

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Table 1: Ranges and threshold levels for "Resources Profile®" indicators

Parameters	Units	Ranges / Threshold levels	References
Textural profile			
EG	%	< 5 ; 5-15 ; 15-30 ; 30-50 ; > 50	Baize and Jabiol, 1995 AUREA regional repositories
A	%	< 10 ; 10-20 ; 20-30 ; 30-40 ; > 40	Simplified soil texture triangle (Gironde Chamber of Agriculture)
TEXT	-	LL ; LLS ; SL ; S ; LM ; LMS ; SA ; LA ; LAS ; AS ; AL ; A ; ALO	
IB	-	< 6 ; 6-7 ; 7-8 ; 8-9 ; > 9	Baize, 2000 AUREA regional repositories
IT	-	Variable according to granulometric composition	Rémy and Mathieu, 1972, in Baize, 2000
Calcic profile			
CaCO3 total	%	< 5 ; 5-10 ; 10-25 ; 25-50 ; > 50	Spring *et al.*, 2003 AUREA regional repositories
CaCO3 actif	%	< 1 ; 1-5 ; 5-10 ; 10-20 ; > 20	
pH_{eau} / pH_{KCL}	-	< 5,0 ; 5,0-6,0 ; 6,0-6,5 ; 6,5-7,5 ; 7,5-8,0 ; > 8,0	AUREA regional repositories
Ca/CEC	%	< 50 ; 50-75 ; 75-85 ; 85-100 ; > 100	Baize, 2000 AUREA regional repositories
Organic profile			
MO	%	Variable according to A% levels : - *A% < 10 :* < 0,8 ; 0,8-1,1 ; 1,2-1,5 ; 1,6-2,0 ; > 2,0 - *10 < A% < 30* : < 1,2 ; 1,2-1,7 ; 1,8-2,3 ; 2,4-3,0 ; > 3,0 - *A% > 30 :* < 2,0 ; 2,0-2,4 ; 2,5-3,0 ; 3,1-3,5 ; > 3,5	Spring *et al.*, 2003
C/N	-	< 6 ; 6-8 ; 8-12 ; 12-16 ; > 16	Baize, 2000 AUREA regional repositories
Stock 0-30	T/ha	No interpretation	Arrouays *et al.*, 2001
Mineral profile			
CEC	$cmol^+/kg$	< 5 ; 5-10 ; 10-15 ; 15-20 ; > 20	AUREA regional repositories
S/T	%	< 20 ; 20-50 ; 50-80 ; 80-95 ; > 95	Spring *et al.*, 2003
P / K / Mg	$cmol^+/kg$	Variable according to CEC levels	AUREA regional repositories

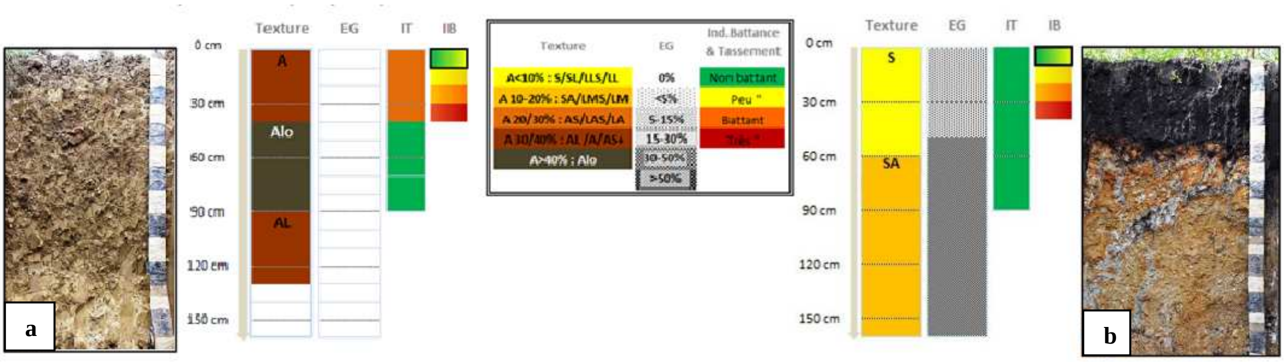

Figure 1: Textural profiles of a carbonated clayey soil (a) and an acid gravelly sandy soil (b).

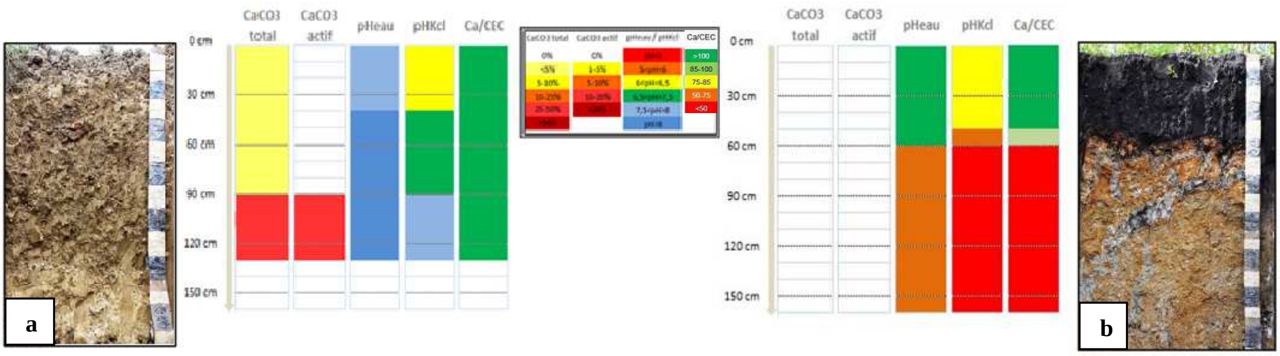

Figure 2: Calcic profiles of a carbonated clayey soil (a) and an acid gravelly sandy soil (b).

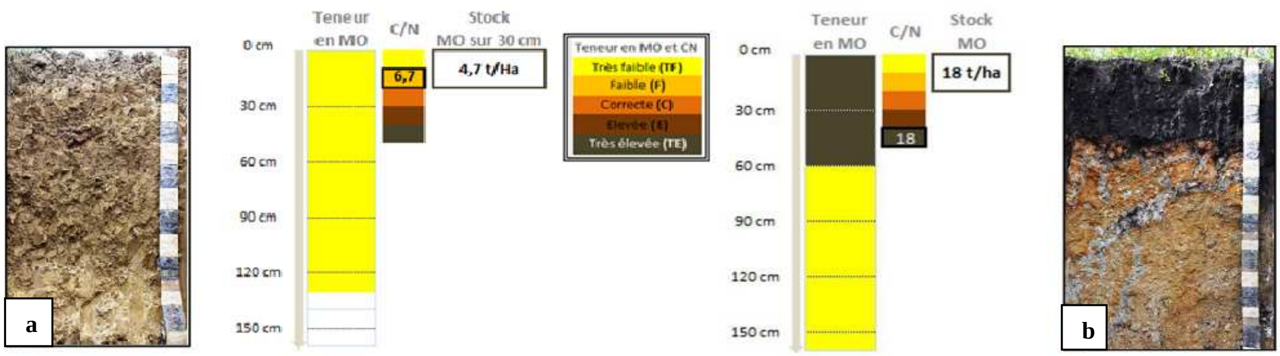

Figure 3: Organic profiles of a carbonated clayey soil (a) and an acid gravelly sandy soil (b).

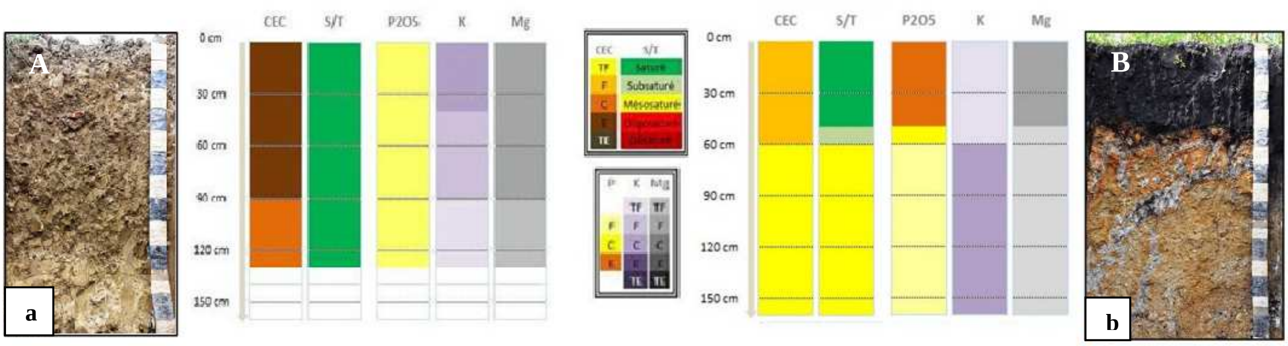

Figure 4: Mineral profiles of a carbonated clayey soil (a) and an acid gravelly sandy soil (b).