Soil typologies in the wine-growing areas of Mallorca, with special emphasis on available water content.

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ABSTRACT Under the conditions of the semi-arid Mediterranean climate, soil depth and water retention capacity are the most important characteristics of the soil related to the quality of the wines. The availability of water will mark the development of the vines and the development and maturity of the grape. The characterization and agronomic evaluation of the soil has been carried out from the excavation of 38 soil pits in the main wine growing areas of Mallorca. Cambisols are the most predominant soil typology followed by Cambisols, Regosols and Luvisols. The water classification of the soils has been made according to the maximum water availability (useful water) in 2 m of soil (mm water / 2 m soil). The proposed levels are: very low (<120 mm), low (120-180 mm), Medium (180-240 mm), High (240-300 mm) and Very high> 300 (mm). The most abundant soil type we find that 47% have high soil water availability, 27% very high, 14% normal and 14% low. Establishing an area based on available water content is a tool that allows us to adjust the selection of the most suitable grape varieties in each soil, thus taking advantage more efficiently of the potential of each type of grape.

1 INTRODUCTION

Grapevines are well adapted to semi-arid climate such as the Mediterranean, due to the large and deep root system and physiological drought avoidance mechanisms, such as an efficient stomatal control of transpiration and of xylem embolism, and/or the ability to adjust osmotically. However, the combined effect of drought, high air temperature and high evaporative demand during summer in these areas are known to limit grapevine yield, berry, and wine quality. The use of irrigation in these environments arises as a solution to prevent excessive canopy temperature, maintain quality in wine production and, in more extreme cases, guarantee plant survival. Nevertheless, irrigation is subject of social debate because the scarcity of water resources [1]. On the other hand in deep, rich soils, vines are vigorous and highly productive, but better wines are generally produced when the vines are cultivated on poor soils [2] . Growing certain grape varieties on un-irrigated fertile soils, promoting cultural practices that favor high yield, have been the cause of the poor quality of wines [3].

Traditionally, to overcome the limitations of poor soils, Mallorcan farmers developed different agronomic works carried out for the conservation of groundwater. Prior to planting, deep work is done to gain groundbreaking volume from the roots and facilitate penetration. With the crop already planted, surface tillage is done to eliminate competition with the weeds and maintain soil moisture [4].

Thus, when the availability of water in the soil is limited, if irrigation is not available, it is a matter of fine-tuning the water conservation tasks. On the other hand, when the objective is to limit the vigor, tillage can be reduced, favoring competition for water from spontaneous vegetation and direct evaporation from the soil [5].

Each viticultural variety has particular requirements, which makes it more suitable for specific conditions. Taking as reference two varieties of Mallorca: Prensal Blanc (white variety) and Callet (red variety), the first reaches its enological and productive potential on land with good water availability. On the other hand, in lands where water is a limiting factor, its production is reduced and quality is not improved significantly. Callet has very different behavior pattern; also, on land with good water availability is where it obtains the highest productions but it is well recognized that, in these conditions, the oenological quality is low. In thinner soils it reaches a reduced vigor, with more limited productions and a better oenological quality[4].

The soil acts on the functioning of the vine essentially through water supply and the nitrogen nutrition [6]. These effects are often in relation to the soil depth: in a deep soil, water and nitrogen supply are most of the time not limiting or not very limiting [7]. In order to gain a more synthetic approach than pedology, while continuing to use the concept of pedogenesis, Bodin and Morlat [8] put forward a terrain model based on the depth of soil and the degree of profile evolution [9].

2 MATERIALS AND METHODS

The characterization and agronomic evaluation of the soil has been carried out from the excavation of 38 soil pits in vineyard growing areas of Mallorca. Once made the opening of the soil pit, the description of the profile and the collection of soil samples from each area were taken.

The measurement of the water retained at 33 kPa was determined on soil samples, minimally altered, maintining the original structure of the soil and the coarse elements. The remaining determinations were made on air-dried soil and sieved at 2 mm. The determination of the water retained at 1.5 MPa (permanent wilting point) has been made on fine earth. The water retained by the coarse elements (gravel and stones) at 1.5 MPa was determined independently, correcting the results according to the proportion of fine earth and coarse elements. The plant available water capacity of the soil was calculated for each layer from the difference between the water retained at field capacity and the permanent wilting point. The maximum available water of each of the soils was calculated from the maximum reserve of useful water of the upper layers that constitute the solum plus an estimate of the water available in the parent rock or original material up to a depth of 2 m. This depth give us a realistic idea of the reserves that the soil has, taken into account the depth of the roots as well as the rise by capillary action of the water. The Soil classification proposed according to its maximum useful water reserve agrees with the appreciations of the vine-growers in the area [3]. (Table 1).

Soil classification has been carried out according to the criteria of the World Reference Base of Soil Resources [10].

Table 1. Soil classification proposed according to its maximum useful water reserve

	Maximum useful water reserve (mm water in 2m depth)
Very low	< 120
Low	120-180
Medium	180-240
High	240-300
Very high	>300

3 RESULTS AND DISCUSSION

The most relevant differences between the soil types are found in the contents of total carbonates and active limestone with minimum values in the Luvisols and maximums in Regosols and Calcisols. The presence of carbonates affects the pH of the soil, being basic in all cases (values between 8.2 and 8.4). The soils texture oscillates between loam and clay soil with high clay values varying between 36% and 54%. Organic matter presents moderate values and similar levels in all soils (organic carbon contents between 1.1% and 1.4%). Parallel occurs with the contents of total nitrogen, reaching a balanced C/N ratio with values between 8.1 and 9.6. The coarse elements constitute a widespread component in the studied soils, affecting the volume of soil available for the roots. Regarding the capacity of water retention the values of field capacity are high; similarly the permanent wilting point is reflecting the high content of the fraction of clays (Table 2).

Most of the studied soils are Calcisol Haplic Calcisol (Aric, Clayic) (58%) followed by Calcisol Skeletic Calcisol (Aric, Clayic) 13% and Cambisol Calcaric Cambisol (Aric, Clayic) 8% (Table 3).

According to soil water availability 47% have high soil water availability, 27% very high, 14% normal and 14% low only 3% have very low. The Calcisols have variable water retention capacity, it depends on the thickness. In these soils, when the calcium carbonate is cemented and hard (petrocalcic horizon) it is an insurmountable barrier for roots limiting plant development. On the other hand, when the accumulation of carbonates has a soft consistency, the water reserve on this level may be important, greatly increasing the water reserve.

The water retention capacity of the soil is mainly due to the depth of the soils, the texture, the presence of coarse elements and degree of weathering of the parent rock. The parameters described above can give us an idea of the water content, but in order to have a realistic idea, a specific analysis must be made for this purpose. In certain cases, lands with high clay content are associated with high rock content and have limited depth which makes the availability of water moderate, while soils with the highest water retention capacity had a moderate content of clay but they are deep soils with few coarse elements.

These results agree with Van Leeuwen 2010 where he states that despite the closeness of pedology to agronomy, it is not possible however to transform a soil map into a map of potential wine quality. Sometimes, small differences between two soil profiles (differences in the amount of organic matter or in soil depth, for example) can modify the quality potential for wine production, without modifying the soil type in the pedological classification [8].

Table 2: Physical and chemical data of the arable layer of the representative soils from the Mallorca.

	Calcisols	Cambisol	Regosol	Luvisol
Coarse fragments (g/kg)	414	308	77.4	64
Sand (g/kg)	274	289	183.4	56
Silt (g/kg)	364	307	357.4	404
Clay (g/kg)	362	403	459.2	540
$CaCO_3$ (g/kg)	321	99.6	206.1	38
Fine $CaCO_3$ (g/kg)	57	14.5	76.5	8
Organic carbon (g/kg)	13.5	13.4	10.8	11.9
N (g/kg)	1.4	1.39	1.34	1.4
C/N	9.6	9.6	8.1	8.3
pH (H_2O; 1:2.5)	8.2	8.4	8.4	8.3
Bulk density (t/m^3)	1.62	1.62	1.07	1.31
FC (-33 kPa; mm/m))	224	256.7	287.9	352
WP (-1,5 MPa; mm/m)	128	143.9	162.5	207

FC: Field capacity; WP: Wilting Point.

Table 3: Distribution of Soil typologies in the wine-growing areas of Mallorca

		Soil water availability					
Unit	Soil types (IUSS Working Group WRB, 2014	Very low	Low	Medium	High	Very high	Total
Calcisol	Endopetric Calcisol (Aric, Chromic, Siltic)		1				1
Calcisol	Haplic Calcisol (Aric, Chromic, Siltic)			1			1
Calcisol	Haplic Calcisol (Aric, Clayic)		3	3	10	6	22
Calcisol	Skeletic Calcisol (Aric, Clayic)		5				5
Calcisol	Skeletic Calcisol (Aric, Loamic)		1				1
Luvisol	Calcic Rhodic Luvisol (Aric, Clayic)			1			1
Luvisol	Rhodic Luvisol(Aric, Clayic, Profondic)					1	1
Cambis ol	Calcaric Cambisol (Aric, Clayic)		2	1			3
Regosol	Calcaric Epileptic Regosol (Aric, Loamic)	1					1
Regosol	Calcaric Regosol (Aric, Loamic)					2	2
Total		1	12	6	10	9	38

4 CONCLUSIONS

The vineyards in Mallorca are cultivated on different types of soil. Calcisols (78%) are the most predominant ones followed by Cambisols (8%), Regosols (8%) and Luvisols (6%). According to soil water availability 47% have high soil water availability, 27% very high, 14% normal and 14% low only 3% have very low. It is not possible to establish a direct relationship between these two classifications

The soil typology provides partial information about the agronomic aptitude. For example, the Calcisol, which is the dominant typology, covers practically the entire range of water availability.

The soil depth, the volume of fine earth, the texture and the type of parent material, are key parameters in the availability of water but a specific analysis must be done to have a real value.

To obtain quality grape production it is necessary to know in addition to the chemical fertility conditions the capacity of water retention and to apply the management of suitable work and irrigation. Even sometimes for some varieties, deep soils with high water retention can be conflicting to achieve optimal grape quality.

Having a classification of the soils according to the water capacity can be a very useful resource for choosing the right varieties for each soil and establish the cultivation tasks for the conservation of water and, also, the irrigation needs.

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