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# Understanding the Quality of Local Vineyard Soils in Distinct Viticultural Areas: A Case Study in Alcubillas (La Mancha, Central Spain)

Raimundo Jiménez-Ballesta <sup>1,\*</sup> , Sandra Bravo <sup>2</sup> , José Angel Amorós <sup>2</sup> ,  
Caridad Pérez-de los Reyes <sup>2</sup>, Jesús García-Pradas <sup>2</sup> and Francisco J. García-Navarro <sup>2</sup> 

<sup>1</sup> Department of Geology & Geochemistry, Autónoma University of Madrid, 28049 Madrid, Spain

<sup>2</sup> Higher Technical School Agricultural Engineers of Ciudad Real, University of Castilla La Mancha, 13003 Ciudad Real, Spain; sandra.bravo@uclm.es (S.B.); joseangel.amoros@uclm.es (J.A.A.); caridad.perez@uclm.es (C.P.-d.l.R.); jesus.garciapradas@uclm.es (J.G.-P.); fcojesus.garcia@uclm.es (F.J.G.-N.)

\* Correspondence: raimundo.jimenez@uam.es; Tel.: +34-914-974-810

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**Abstract:** The essential features of the soils of a pilot zone in La Mancha (Central Spain), namely the Alcubillas municipality, have been characterized. The soil properties that may contribute to a better understanding of the impact of soil on grape production have also, been evaluated. For this, several soil profiles have been described and analyzed and the profiles have been mapped. The soils are mainly Entisols, Inceptisols and Alfisols, with their evolution controlled by the action of a xerophytic Mediterranean climate. Most of these soils have a loamy clay texture, with medium clay contents and sufficient nutrient contents (despite the low content in organic matter 1.39% and 1.04%, and the high concentrations of calcium carbonate 23.7% and 26.9% in the surface and subsurface horizons, respectively). Drainage problems were not observed and it can therefore be stated that the Alcubillas vineyards are based on a ‘terroir’ term for the production of high quality grapes. In general, the soils are not subjected to treatments to control possible diseases or pests and we have therefore postulated that the soils represent the ideal scenario to establish a distinctive zone and for the increasingly valued ecological and natural viticulture.

**Keywords:** viticulture; ecological systems; terroir; red soils; petrocalcic horizons; soil mapping; Alcubillas (La Mancha)

## 1. Introduction

The cultivation of vine in La Mancha is widespread (473,811 hectares) [1]. However, it is only in recent decades that some measures to differentiate levels of quality have been proposed to define the characteristics of the wines produced (nine Denominations of Origin, one Protected Geographical Indication and 10 “Pago”, another type of Denomination of Origin). This situation differentiates La Mancha from other regions such as Andalusia (southern Spain), where there are more than 20 longstanding wine-producing sub-regions, with each sub-region producing representative wines due to their local soil characteristics [2]. The terroir (a complex French term) is regarded as an interactive ecosystem that is related to a specific location [3,4] and one question that arises is: Could there be more quality terroirs in La Mancha than there are currently?

Soil is one of the most important factors in viticulture because its composition and water retention capacity-amongst other factors-provide anchorage and water to the vine while providing nutritional elements for the growth of the vine. Thus, soil characteristics such as depth, permeability, structure, fertility, acidity, and texture affect vine root growth and nutrient absorption [5–8]. Renouf et al. [9]

showed that soil type has an influence on wine quality. In fact, different soil types led to significant differences in the total sugar and total acid contents and also had an effect on the phenolic, anthocyanin and tannin contents [10–12].

Under the denomination of viticultural soils there is a wide range of soils throughout the world dedicated to the cultivation of the vine. For example, the soils in the Champagne region of France are classified as Mollisols and were developed on Mesozoic chalk [13], while in la Rioja (Spain) the vineyard soils developed on a wide range of soils: Mollisols, Inceptisol, Alfisols and exceptionally Aridisols [14]. In Australia, many vineyards grow on limestone (as happen in Coonawarra's), usually associated with red soils (Terra Rossa), that is, Alfisols according to Soil Taxonomy or Luvisols in the FAO-ISSS-ISRIC system.

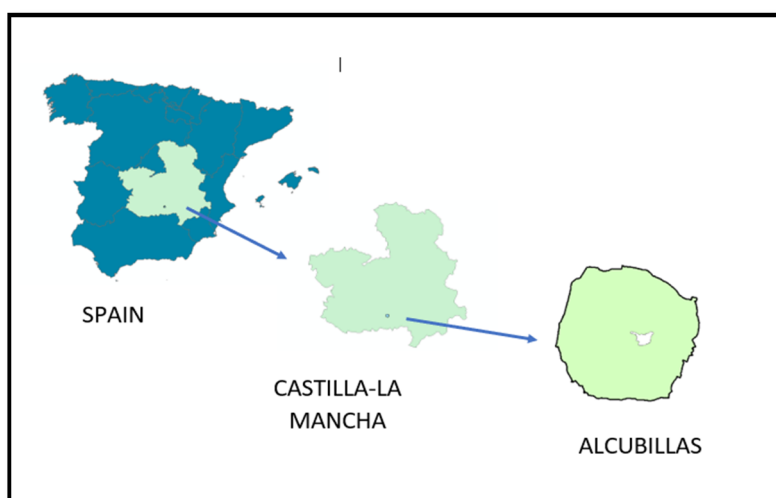
La Mancha (Central Spain) is one of the largest areas in the world for the cultivation of vine and a distinctive feature of this region is the remarkable pedodiversity [15,16]. Within La Mancha there are numerous small towns that traditionally devote a significant part of their territory to vineyards. However, these locations are often not known since the wine produced is largely sold in bulk and only a small proportion is bottled wine. This is the case with Alcobillas (La Mancha), a small town in which the land is traditionally used for agricultural purposes with a total of 4879 hectares [17,18]. The cultivation of wine grapes in Alcobillas has been carried out for centuries and, as in other areas of Castilla La Mancha, the local cooperative plays a major role in the wine sector. It is interesting to consider whether there a specific terroir in Alcobillas that would make it different from the surrounding vineyards. Furthermore, one must ask whether Alcobillas is a distinct viticultural area. In this sense, modernly the practice of ecological viticulture has spread in the last years; this practice (without herbicides, insecticides etc.) includes a series of ecological and integrated techniques as mechanical control of diseases, for sustainable biodiversity and environment.

In the work reported here we provide an overview of the existing soil types and their properties in an effort to ascertain whether their soils and associated characteristics are unique to the small town of Alcobillas, an area traditionally dedicated primarily to viticulture.

## 2. Materials and Methods

### 2.1. Study Area

The municipality of Alcobillas is located in the Mancha region (Central Spain) at the western end of the so-called Campo de Montiel and it occupies an area of 4647 hectares [17,18]. The geographical coordinates are: Latitude: 38.7579077 and Longitude:  $-3.1412646$  ( $38^{\circ}45'7''$  N and  $3^{\circ}8'5''$  W (Figure 1).



**Figure 1.** Geographical location of the study area.

The soils of Alcubillas have traditionally been used for the cultivation of the vine, cereal and olive groves, as well as small areas for vegetables (Consejería of Agriculture, Water and Rural Development, <https://www.castillalamancha.es/gobierno/agriaguaydesrur/actuaciones/cifras-sobre-cultivos>). Vineyards currently occupy 1592 hectares [17] with a wine intensity of 32% (one of the highest in the region). White grapes are cultivated on 940 hectares and red grapes on 652 hectares. In recent years there has been intensive restructuring of the vineyards (with European Community aid) and this has affected approximately half of the total vineyard, with changes in variety driving the adoption of the trellis system and drip irrigation. Around 90% of the vineyards are directly owned by the winegrowers. The most widely cultivated varieties are by far the native ones Airén (932 hectares) and Tempranillo-Cencibel (641 hectares), although in recent year plantations of other varieties have become established. The most commonly used rootstocks are 110 Richter (869 hectares) and 41-B Millardet (407 hectares), with some other free-standing plantations [17].

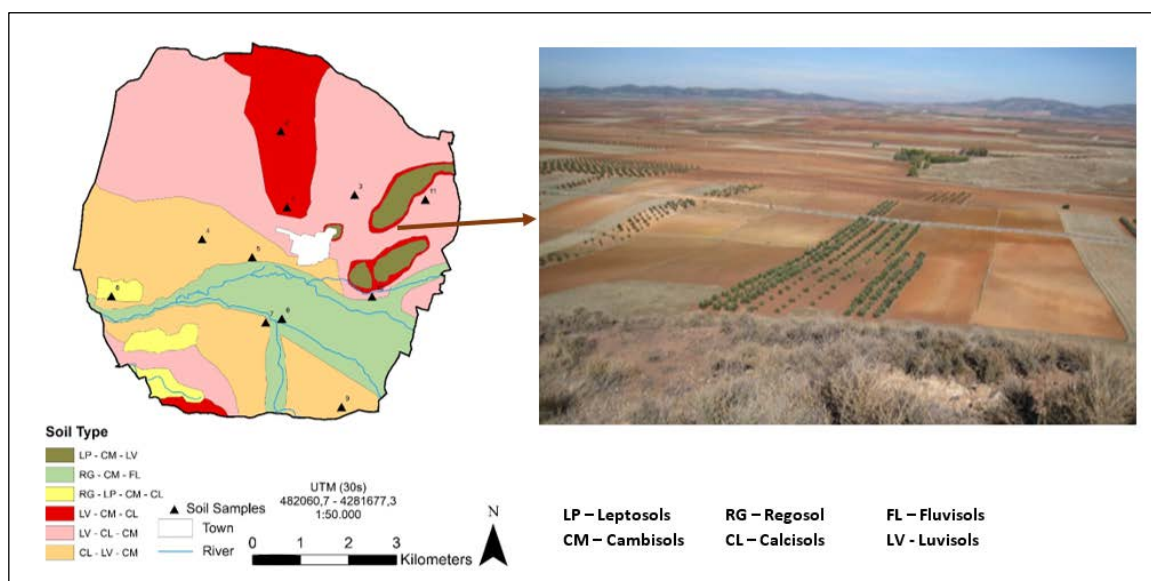
The traditional cultivation of the vine zone (Alcubillas) has been in dry land, with conduction systems in “gobelet” [17]. The favourable climate in summer (low rainfall and very low relative humidity) provides almost organic farming conditions with very few pests and diseases (very little use of pesticides). Traditional fertilization has been based on manure from nearby livestock areas. In the last 20 years, sponsored by the European Union vineyard restructuring policies (R.C.E.E. 1227/2000 and successive), the conduction system has changed (the trellises reach 30% of the surface), irrigation has increased (almost 50% of the surface has irrigation, almost always drip- system) and new varieties have been introduced (Chardonnay, Sauvignon Blanc and Verdejo for white wines and Syrah, Cabernet Sauvignon for red wines).

The viticultural lands are in a practically flat or curve backed physiographical configuration and this is interrupted by residual reliefs in the form of island mountains (inselberg) as well as an alluvial plain. There are clear signs of karstification with the appearance of numerous sinkhole. The average altitude is approximately 804 m a.s.l. The most abundant geological materials are limestones interspersed with marl and tertiary sediments, to which some hills of quartzite (sometimes sandstone) and paleozoic slate are added. Finally, there are also quaternary alluvial deposits of calcareous clay-sand mixture.

From a climatic point of view, the mean annual temperature is 13.5 °C and the annual rainfall is 480 mm. (data obtained from Spanish Meteorological Institute). The average number of hours of sun per year is estimated to be between 2600 and 2800 h. This area is, depending on the conditions in a given year, a type III or IV area [19], which allows the cultivation of white and red varieties of medium or late maturation that can give wines with high contents of alcohol and coloring matter [20].

## 2.2. Soil Mapping and Sampling

The soil samples were taken from ten geo-referenced profiles opened by a machine. The selection criteria of the sampling profiles is based on geomorphological criteria of the terrain and morphology of the soils; to this is added our experience gained in the Soil Atlas of Castilla La Mancha [15]. The profiles were excavated to a depth of approximately 1.5 m to obtain a full description according to FAO Guidelines [21]. The dominant soil type was identified in the map (Figure 2). Given the experience gained in the Soil Atlas of Castilla La Mancha [15], the map was prepared according to the following criteria: photointerpretation, control of it in the field, and description and sampling of profiles, with a final check after analyzing the samples in the laboratory. The soil parameters were determined by taking soil samples from horizon to horizon (of the profiles) separately from the parent material, including C horizon (32 samples). The main parent materials of the area are metasedimentary Hercynian rocks, (quartzose sandstones or quarcites interbedded with shales, tertiary calcareous rocks composed of limestones (with karstification) and marls, colluvial quaternary slope deposits and alluvial deposits. Selected areas were sampled superficially in order to contrast the mapping units and to confirm the spatial variability (75 samples).



**Figure 2.** Schematic soil map of the Alcubillas municipality. Detail of spatial variability at metric or decametric scale.

The morphological features of soil profiles generally showed a sequence of Ap-Bt-Ckm type horizons, but in some case the sequence was Ap-Bw-Ck. It is clear that the argilic (Bt) horizon, as a characteristic diagnostic feature of Red soil, contains a higher clay content (near 40%), which is leached from the upper layer (argiluviation). In some cases, the occurrence of horizons with more pebbles than the ploughed layer may indicate lithological discontinuity caused by the covering up of fossil soil or by anthropogenic activity.

### 2.3. Laboratory Methods

Soil samples were collected from eleven profiles and some surficial horizons selected from different geomorphological and vineyard types (Figure 1). After field sampling, all of the soil samples were dried at room temperature to constant weight and carefully sieved through a 2-mm mesh. The coarser material was discarded and the remaining fine-earth fraction was homogenized prior to chemical analysis. Selected soil properties were determined using the prepared samples and the data are presented in Table 1.

**Table 1.** Procedures for physiochemical characterization of soil samples from the study area.

| Soil Property     | Basic Procedures   | References |
|-------------------|--|------------|
| pH                | Potentiometrically measured in 1:2.5 soil/water suspension, pH meter | [22]       |
| EC                | Salinity measured in 1:5 soil/water suspension, EC meter             | [23]       |
| Texture           | Hygrometer method  | [24]       |
| Bulk density      | Determined by the cylinder method                                    | [25]       |
| CaCO <sub>3</sub> | Determination by the Bernard method, calcimeter                      |            |
| Active Limestone  | Determination by ammonium oxalate                                    | [26]       |
| OM                | Determination by dichromate digestion (Walkley and Black method)     | [27]       |

Table 1. Cont.

| Soil Property            | Basic Procedures   | References |
|--------------------------|--|------------|
| CEC                      | Percolation of a 1.0 mol/L ammonium acetate solution, pH = 7 | [28]       |
| P                        | Determination by the Olsen method                            | [29]       |
| N                        | Determination by the Kjeldahl method                         | [30]       |
| Major and trace elements | Determination by FRX   |            |

EC: Electric conductivity; OM: Organic matter; CEC: Cation exchange capacity; P: Available phosphorus; N: Nitrogen (total).

#### 2.4. Statistical Analysis

Summary statistics of the data set were calculated first with SPSS 24.0 by IBM (Inc., Chicago, IL, USA.). The maps of soils were calculated by Inverse Distance Weighting (IDW) was applied to interpolate the sampled points to map the spatial variation of the studied elements (used to estimate the values for points in an area not actually sampled). The data were processed in ArcGIS 10.1 using a topographic map (1:25,000) of the study area as the base map.

### 3. Results

#### 3.1. Soil Surface Characteristics and Soil Mapping

The most widely developed soils were Alfisols, Inceptisols and Entisols according to Soil Taxonomy [31]; which correspond to Luvisols, Cambisols, Regosols and Leptsols according to FAO-UNESCO-ISSS [32]. Red soils (Luvisols) dominated with calcium or petrocalcic horizons (Figure 2). Many of these horizons have been broken by “intensive tillage practices due to a long history of cultivation enhance soil aggregates breakdown.

There are very few vineyards in paleozoic geological formations (inselberg), since they contain lithic soils (Leptosols) with a shallow depth. However, these geological materials, which consist of slate and sandstone quartzites, have generated by prolonged weathering the red soils commonly used for vineyards. These processes has been observed in the field, on the slopes of the hills, as well as occasionally the presence of ferricretes [33,34].

In locations close to the Jabalón river and its tributaries, quaternary sediments accumulate and these are often from old red soils, hence they are red-colored. However, despite their topographic position they are rarely affected by hydromorphic processes.

Around the inselberg the edaphic development generates shallow soils, (rarely under vineyards), on which a layer of stones (gravel) was observed, which makes them more prone to heat retention and can lead to earlier ripening of the berries. Another equally important aspect is the reflective and re-radiative effect of the soil, which is related to the aforementioned layers of stones.

As a consequence, of the practically flat topography of the municipality of Alcubillas, erosive effects of the hillside are barely detected. However, there are slight slopes around the inselberg and erosion here is a key factor in soil depth. Indeed, the soils are shallow in the upper part of the hillside but become somewhat deeper downhill and are stony colluvial soils near the base of these hills. In fact, the erosion and deposition processes are mainly restricted to the alluvial channels of rivers and streams (Jabalón river).

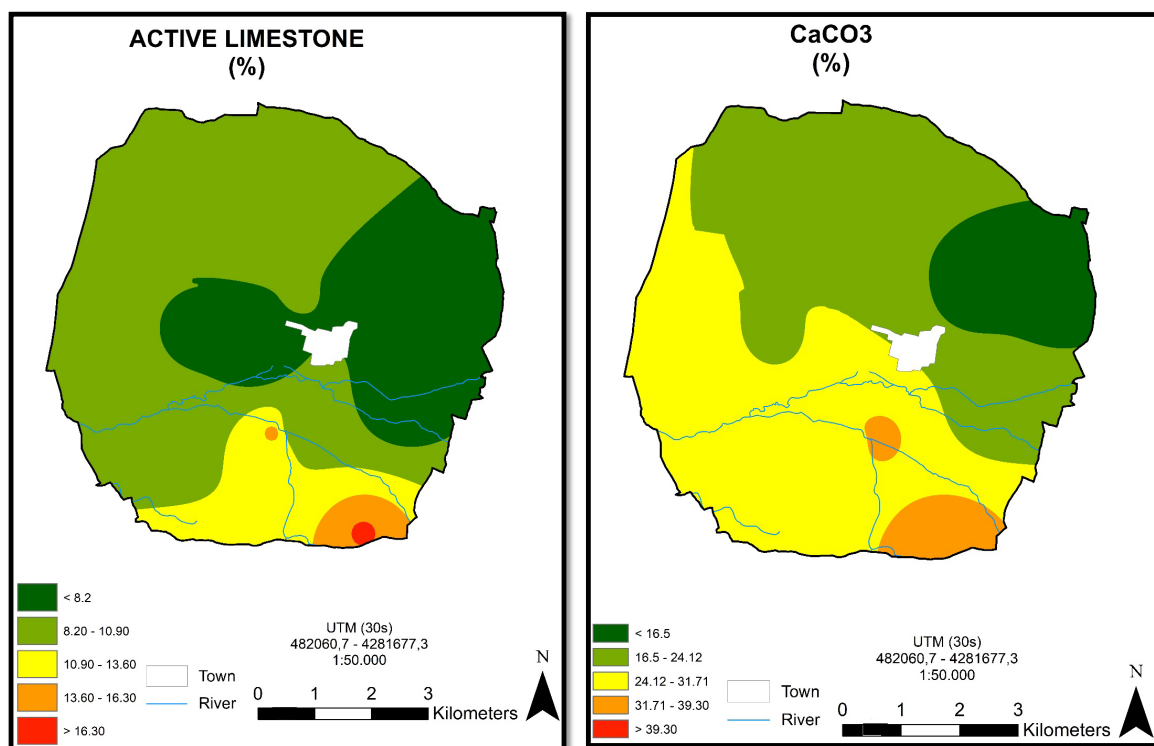
#### 3.2. Soil Texture and Bulk Density

Alcubillas soils are normally loamy textured (Table 2). The most common texture class is clay loam (and other types of textures) and this changes with depth. The clay contents have a marked influence on the water and nutrient holding capacity of soils [35]. Bulk density (BD) governs the water retention/transmission and root proliferation characteristics of soils. The moderate bulk density

values, i.e., between 0.9 and 1.7 ( $\text{g}/\text{cm}^3$ ), do not restrict root growth and do not reduce water storage in the soil profile. The presence of Ckm horizons were common in the area, and they suppose a root-limiting layers, until rarely at a depth greater than 80–90 centimeters. In some case the bulk density is high as a consequence of compaction, sometimes with mechanical crust formation. If such ‘scabs’ appear, the farmers carry out operations aimed at reducing the compaction of soils since they may adversely affect the hydrological functioning of vineyards by influencing soil infiltrability and soil erosional processes.

### 3.3. Other Soil Properties

The pH values of the soils were generally basic or moderately basic (pH between 8.2 and 8.4 in surface horizons, and 8.2 and 8.7 in depth horizons), so the soil nutrients are more easily absorbed. Therefore, vegetative vine growth and fruit quality probably will improve [36]. The electrical conductivity of the soils was low (maximum 0.35 and minimum 0.09  $\text{dS}/\text{m}$ ). On the other hand, high carbonate contents were detected (between 38.4% and 8.9% in the Ap horizons, while in the deep horizons the values varied between 48.7% and 16.5%). In addition, the active limestone was proportionally high (between 5.5% and 16.7%) and very widespread. Figure 3 showed the spatial variability in Ap horizons of calcium carbonate and active limestone respectively) Petrocalcic horizons were common, as indicated in previous studies [37,38], and this horizon was at a shallow level, which means that the root system is in a relatively shallow space and is nourished in the first few centimeters (<80 cm).



**Figure 3.** Spatial variability of active limestone (a) and calcium carbonate contents (b).

**Table 2.** Descriptive statistics of selected physico-chemical and chemical parameters of soil samples.

| Soil Hor. | Statistics | pH<br>(1:2.5) | EC<br>(dS/m) | CaCO <sub>3</sub> | Active<br>CaCO <sub>3</sub> | OM   | Sand  | Silt  | Clay  | Bulk<br>Density<br>(g/cc) | N<br>(%) | P<br>(mg/kg) | CEC  | Ca    | Mg   | Na   | K   | V% (%) |
|-----------|------------|---------------|--------------|-------------------|-----------------------------|------|-------|-------|-------|---------------------------|----------|--------------|------|-------|------|------|-----|--------|
|           |            |               |              |                   |                             |      |       |       |       |                           |          |              |      |       |      |      |     |        |
| Ap        | Mean       | 8.4           | 0.20         | 23.7              | 9.13                        | 1.39 | 47.1  | 36.2  | 16.6  | 1.23                      | 0.06     | 11.2         | 17.6 | 16.84 | 0.45 | 0.09 | 0.2 | 100    |
|           | Max        | 8.7           | 0.35         | 38.4              | 16.6                        | 2.2  | 59.7  | 50.3  | 25.9  | 1.78                      | 0.08     | 14.2         | 23.5 | 22.3  | 0.9  | 0.1  | 0.3 | 100    |
|           | Min        | 8.2           | 0.09         | 8.9               | 5.5                         | 0.7  | 35.1  | 24.7  | 7.6   | 0.9                       | 0.03     | 9.2          | 13.9 | 13.4  | 0.2  | 0    | 0.1 | 100    |
|           | SD         | 0.14          | 0.08         | 8.5               | 3.31                        | 0.46 | 8.13  | 6.10  | 5.39  | 0.24                      | 0.02     | 1.5          | 2.96 | 2.78  | 0.17 | 0.03 | 0.1 | 0      |
| Bt or Bw  | Mean       | 8.5           | 0.14         | 26.9              | 10.26                       | 1.04 | 38.86 | 33.29 | 27.88 | 1.49                      | 0.04     | 10.1         | 19.9 | 19.13 | 0.64 | 0.09 | 0.2 | 100    |
|           | Max        | 8.7           | 0.19         | 48.7              | 16.7                        | 1.6  | 61.6  | 44.7  | 36.6  | 1.88                      | 0.06     | 13.3         | 29.1 | 27.6  | 1.2  | 0.1  | 0.4 | 100    |
|           | Min        | 8.2           | 0.10         | 16.5              | 5.5                         | 0.5  | 19.3  | 21.2  | 17.2  | 1.26                      | 0.03     | 7.8          | 12.5 | 11.8  | 0.3  | 0    | 0.1 | 100    |
|           | SD         | 0.14          | 0.02         | 10.7              | 3.61                        | 0.38 | 11.87 | 8.05  | 7.44  | 0.23                      | 0.01     | 1.4          | 4.67 | 4.42  | 0.25 | 0.03 | 0.1 | 0      |

The soil organic matter contents were low (the highest value was 2.2%). Organic matter content is one of the important soil attributes for evaluating soil quality and farmers supplement this by adding organic-rich waste. In any case, although these low contents cause some limitation on soil productivity, the situation is that the plant will tend to show limited vigor and fruits of very good quality will be produced [39].

Essential macronutrients include nitrogen, phosphorus, potassium, calcium, magnesium and sulfur, while micronutrients include iron, zinc, manganese, copper, boron, molybdenum and chlorine. Of these, N, P, K, Ca, Mg, Fe, Zn and B are most frequently involved in nutrient imbalance situations. The values obtained from the analyses performed show that the contents of plant-available nutrients are moderate (Table 2). For this reason, the farmers add fertilizers during irrigation in moderate quantities because, given the abundance of calcium, the formation of aromatics and anthocyanins in grapes is ensured.

The abundance of calcium (between 412.7 and 81.9 g/kg) improves the soil structure [40], which in turn improves root penetration, accelerates soil heating in the spring and improves internal drainage. Meanwhile, potassium (in average proportions, i.e., between 196 and 11.2 g/kg) tends to regulate the opening and closing of stomata, thus providing vigor and yield while facilitating the accumulation of sugars in grapes [39]. The available potassium (which varies between 0.1 and 0.3 cmol/kg) is governed more by the inorganic soil fraction (mineralogical composition) rather than by the organic fraction, as noted by Gebreyaw [41].

The problem of iron warrants a special comment as blockage of this element occurs in these soils due to the generally high pHs and this influences the cultivation of the vine through the careful choice of carrier [8]. The information provided above leads the wine growers to opt mostly for 110 Richter and 41-B Millardet rootstocks, as indicated in the section on site description.

#### 4. Discussion

The fact that the type of soil influences the quality of the wine has been addressed by Renouf et al. [9], who mapped the soils of seven of the most prestigious farms in the Bordeaux area in high resolution (between 1/1000 and 1/5000), covering 400 hectares of vineyards [4,42,43].

The bedrocks from the soils of Alcubillas are characterized by being relatively rich in carbonates, like many other famous viticultural environments (Champagne, Burgundy, Saint-Emilion, Loire Valley in France; Tuscany in Italy; La Rioja in Spain and Coonawarra in Australia) [36,44,45]. In addition to this common denominator (high availability of lime) of the soils of Alcubillas, it is necessary to highlight the good drainage (with suitable aeration), which contributes to and appropriate development of the root. However, although calcium helps to nourish the plant's root system and promotes sap growth, while also contributing to the generation of sweeter grapes, its abundance can cause iron deficiency in grapes. Perhaps this is one of the main problems associated with some soils of Alcubillas: high concentrations of lime, which can lead to certain extreme imbalances with other trace elements such as molybdenum, copper and manganese. However, these imbalances can be resolved by the use of appropriate rootstocks [8] and by fertilization-fertigation correction with appropriate micronutrients.

The different types of soils, the distribution of which is shown on the map (Figure 2), determine different physical structures and mineral nutrient contents. Table 3 shows the map legend including the FAO and Soil Taxonomy systems [31,32].

Most of these soils have a loamy textured, medium clay contents, are permeable to rainfall in the area and have a favorable nutrient content (despite the low content in organic matter and high concentrations of Ca). The higher clay content in the lower horizon depth might be due to the deposition of clay (illuviation process) that had migrated from the upper layer (eluviation process); but eluvial horizons (e.g., E type) were not found in any sample. The stability of the topographic surfaces must have contributed to this situation.



**Table 3.** Soil map units and equivalence between FAO and Soil Taxonomy.

| Soil Map Unit | FAO         | Soil Taxonomy              |
|---------------|-------------|----------------------------|
| 1             | LP CM LV    | Entisol Inceptisol Alfisol |
| 2             | CM RG FL    | Inceptisol Entisol         |
| 3             | RG CM LP CL | Entisol Inceptisol         |
| 4             | LV CM CL    | Alfisol Inceptisol         |
| 5             | LV CL CM    | Alfisol Inceptisol         |
| 6             | CL LV CM    | Inceptisol Alfisol         |

LP: Leptosol, CM: Cambisol, LV: Luvisol, RG: Regosol, FL: Fluvisol.

Drainage problems were not observed and, since there are marked diurnal temperature differences, it is expected that high levels of photosynthesis are promoted and this is accompanied by high concentrations of sugar [37]. Given the contents of calcium carbonate and active limestone respectively is required greater care with lime-sensitive rootstocks, especially in the southern half of the area, probably due to the proximity of the riverbed of the Jabalón River and the presence of certain tertiary materials, as marls.

On the basis of the above information, one can ask the question: Are the soils of Alcubillas ideal for the vineyard? The best way to answer this question is to plant vines and make wine. The cultivation of vines has been carried out in this area since two last centuries. Wine has also been produced in this region for a very long time but certainly the main objective is to produce larger quantities. Consequently, it can be affirmed that the Alcubillas vineyards are based on an allied edaphic terroir for the production of high quality grapes and above all high productivity. Furthermore, the grapes are not subjected to treatments to eradicate possible diseases and plagues, and it is therefore possible to affirm that this is an ideal scenario for the authentic, ecological and organic viticulture, all of which are appreciated in certain foreign markets.

It is understood that the best wine grapes are produced when the vine experiences periods of water stress, which leads to the appearance of tannins in the skin of the grapes while imparting astringency to wines made with those grapes. It seems that wines are also produced that show exceptional flavors. However, stress on wine vines should not be confused with the deprivation of water or essential nutrients. However, these are precisely the conditions that the farmer has promoted in recent times: i.e., an increase in extra water contributions in order to increase the yield per hectare.

On the understanding that the depth of the soil, in terms of viticulture, refers fundamentally to the depth of rooting, we can point out that a considerable proportion of Alcubillas soils have an expressive but shallow rooting, thus providing water at a slower rate. This increases the vigor and yield of the vine, while tending to decrease the quality of the grapes. Morlat and Bodin [46] and Bodin and Morlat [47] investigated the effect of soil depth on grape quality in the Loire Valley (France) and they concluded that the greatest potential for grape quality was obtained on soils with limited depth and availability of water in the soil. Similar results were obtained by Coipel et al. [48] in the Rhone Valley, where the highest quality potential for garnacha was obtained in shallow soils where nitrogen and water were more limited. It is not unusual, therefore, that this is why wine growers are now looking for moderately fertile soils that do not promote too vigorous a vine [37,40]. However, despite the quality of the soils in Alcubillas it is clear that better marketing of the product is required.

## 5. Conclusions

An understanding of the soil status is essential for the selection of growing practices and to improve the quality of grapes. In this respect, a spatial information system is of great importance. In this pilot screening survey, we researched the soil properties and variability to provide a model of soils in Alcubillas (La Mancha) and other regions. The different types of soils have a balanced texture, with medium clay contents, and they have a permeable nature with respect to the rainfall in the area. In addition, the soils have a favorable nutrient content after fertilization, despite the low organic matter content (there are high concentrations of Ca). As a consequence, the Alcubillas vineyards are based on

a soil ally for the production of grapes of high quality and high productivity. Since the soils are not normally subjected to treatments to suppress possible diseases and pests, we deduce that this is an ideal scenario for authentic, ecological and organic viticulture, which is highly appreciated in certain foreign markets. However, these investigations should be continued by including plant material testing and grape and must analyses, which would contribute to the characterization of wines produced in this area.

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