FIRST CONTRIBUTIONS TO THE DEFINITION OF THE "CINQUE TERRE" DOC WINES TERROIR (NW-ITALY)

IVANO RELLINI[1*], CLAUDIA SCOPESI[1], PAOLA PIAZZA[1], SILVIA OLIVARI[3], MATTEO PERRONE[2], MARCO FIRPO[1]

[1]Dipartimento di Scienze della Terra, Ambiente e Vita (DISTAV), Università di Genova, C.so Europa 26, 16132 Genova, Italy; [2]Parco Nazionale delle Cinque Terre, Via A. Discovolo snc, c\o Stazione Manarola, Riomaggiore, 19017 Spezia, Italy; [3]Reparto Carabinieri Parco Nazionale "Cinque Terre", Via Fegina 34 bis, 19016 Monterosso al Mare, Spezia, Italy.

[*]Correspondence: rellini.ivano@dipteris.unige.it

ABSTRACT

Terroir is the greatest determining factor of all great wines. The acknowledgement of the territory vocation is founded on the research of its peculiarities that determine the uniqueness of that production area. In this paper, results concerning the first contributions to characterize *terroir* environment components and wines in Cinque Terre National Park are presented and discussed. GIS was used to improve the process of landscape characterization. Several profiles from four distinct production vineyards were selected for full pedological description and analysis. Moreover, a solar-powered field station connected to multiple sensors was installed to monitor the soil moisture content and temperature. Finally, the wines (Cinque Terre DOC) from 2014 vintage of the four distinct production vineyards, in which the soil characterization was performed, were analyzed. Biochemical characteristics and total content of phenols were determined. The analyses conducted highlight a number of distinctive features of soils and wines from Cinque Terre vineyards and the usefulness of an accurate description of soils and wines proprieties in the perspective of the implementation of the official DOC Cinque Terre wines production protocols.

KEY WORDS: Territory vocation, Wine quality, DOC Wines, Terraced soils, Polyphenols, Soil monitoring, Soil moisture, Vineyards, GIS.

INTRODUCTION

The valorization of *terroir* is mostly considered one of the most promising prospects of development for national agriculture within global market thanks to the increasing attention for the quality of cultivations, which become also a landmark driving the reputation and image of a territory. *Terroir* is the greatest determining factor of all great wines. The "*terroir* concept" is a complex approach to vine growing and wine making including environmental factors as well as socioeconomic and historical aspects of a given area (Deloire et al., 2008; Van Leeuwen & Seguin, 2006). The acknowledgement of the territory vocation is founded on the research of its peculiarities that determine the uniqueness of that production area. In particular, the application of this concept involves a scientific approach of the ''*terroir* environment components'' in order to achieve a rigorous zoning of vineyards. Several studies have shown that physical and climatic factors explain most of the *terroir*. The effect of climate in viticulture is not able and climatic conditions of the vintage greatly impact the grape composition (Pereira et al., 2006). Numerous studies have been carried out on the effect of soil type and water supply on vine functioning and grape quality (Likaret al., 2015; Costantini & Bucelli, 2014; Morlat & Bodin, 2006).

In this paper, results concerning the first contributions to characterize *terroir* environment components and wines in Cinque Terre National Park are presented and discussed. Here, an ambitious project is being carried on with the challenging goal of benefit local wine producers by creating firms that, while being value-added and having pricing power, are able to move from local products and services to regionally- or globally-branded products.

STUDY AREA

With only 2500 ha of vineyards Liguria is one of the smallest wine producing regions of Italy, not only for its dimensions, but also for its distinctive geographical and geological features (Brandolini et al., 2013). The whole Liguria, both on the coastlines and in the inner valleys, has been subjected to intense agricultural exploitation leading to the construction of hundreds of kilometers of the peculiar "*muretti a secco*" (dry stone walls) (Terranova, 1984). Terraces provide a stable topographic base for crops, and favour soil moisture conservation in the crop root zone, which is particularly important in the Mediterranean regions.

Figure 1. The terraced landscape of Cinque Terre in the XX Century (Riomaggiore) and at present time (Manarola). A large extension of well-maintained vineyards is visible on very steep slopes where mechanization is quite impossible.

In particular, the Cinque Terre area represents one of the most impressive example of coastal stepped landscape in the Mediterranean (Terranova et al., 2006). Since about 1100 A.D., cultivation of grapes was developed upon these man-made terraces (Fig. 1); most of the historical terraces are of bench type with dry stone walls (few are grassed wall-bench terracing) that run for a total linear distance of nearly 6000 km calculated on an area of ca. 2000 ha (Terranova, 1984). In the Cinque Terre, the progressive decrease of the rural activities (especially vineyards) induced the abandonment of the stepped slopes. It implied significant environmental problems in terms of soil erosion and control of the meteoric waters. The National Park of the Cinque Terre extends for 3.860 ha (Fig. 2) and it was established in 1997 by a decree of the Ministry of Environment with the aim to preserve a terraced areas developed since medieval times on steep mountains slopes (up to 100%) to cultivate vines. In 1997 UNESCO included the Cinque Terre in the World Heritage List as a "cultural landscape". Due to the extraordinary value of this territory, it can be considered as a symbol of the harmonious interaction between man and nature and a guarantee of outstanding quality for its products. This area preserves a traditional millenary lifestyle, which goes on playing a leading socioeconomic role in the social life. Since the Cinque Terre's landscape belongs to the World Heritage, it meets the criteria of integrity and authenticity belonging to its uniqueness aspects and to the typical shapes of the agricultural landscape, characterized by the rural settlement and by the terraces supported by "dry-stone walls".

The vineyards are evenly distributed along all Cinque Terre area, but the major viticultural area is located in the valley behind Corniglia and Manarola (Fig.1). In the majority of the cases, the vines are trellised at not more than 5 feet from the ground, with the traditional "pergola" system, so that all the works have to be done by hand and almost every time lying down on the ground. In the last years the "pergola" has been partially abandoned and substituted with the more rational "Guyot" system (this system trains one or two fruiting arms along a main wire) or the "Bush" system (the vines were arranged according to a regular geometric design in the form of a rhomboid, quincunx). These latter systems are optimal to protect from continuous winds and to shadow the grapes cluster from excessive temperatures, which could prevent the synthesis of the aromas (Terranova et al., 2006). The highest areas were (and still are) covered with woods that supplied the villages with wood and leaves that were used to fertilize the soil cultivated with vineyards.

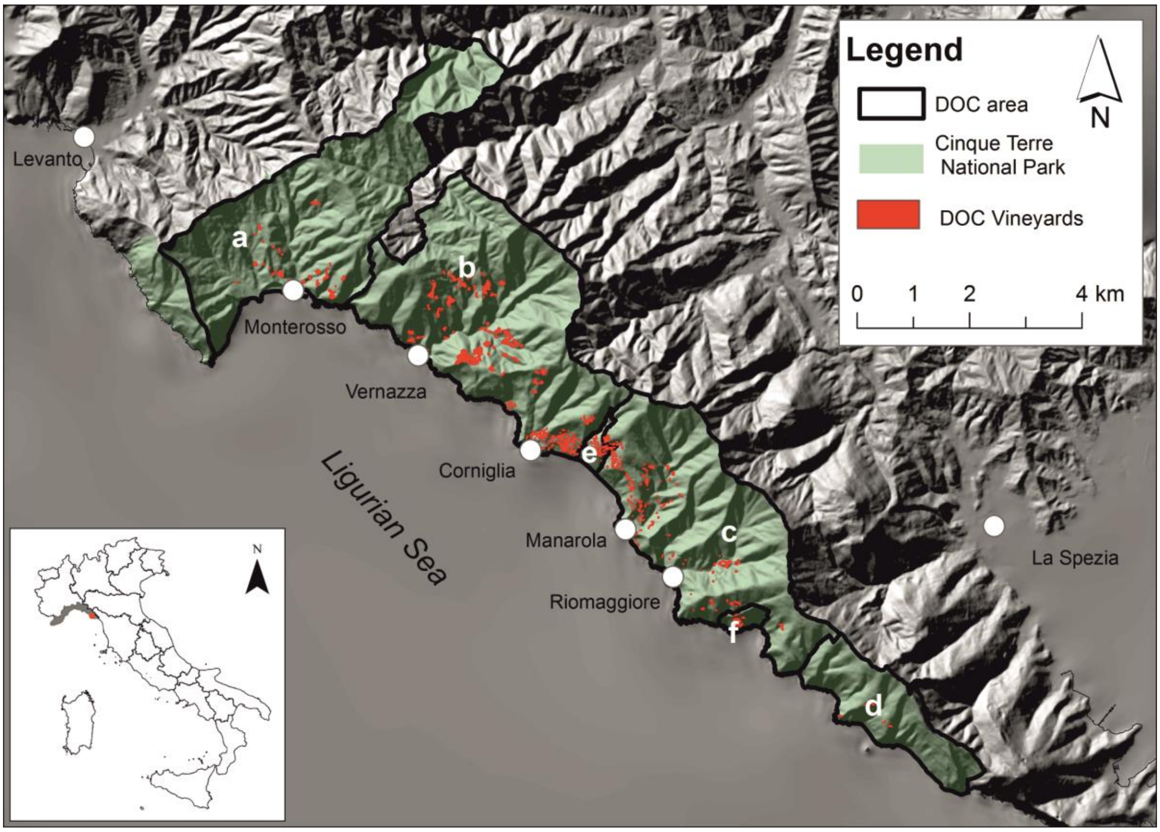

Figure 2. Location of the Cinque Terre National Park and DOC areas with DOC vineyards distribution spread over the municipalities of Monterosso al Mare (a), Vernazza (b), Riomaggiore (c) and partly La Spezia (d, "Tramonti") with sub-zones of "Costa de Posa" (e) and "Costa de Sera" (f). Hillshade map.

The eastern coast of Liguria has a subarid climate (Csa-type, *sensu* Köppen 1936), with hot, dry summers and cool, wet winters. According to the data of the national weather service (i.e. the weather station of the *Servizio Idrografico Italiano*, sited in Levanto, 65 m above sea level), the mean monthly temperatures vary from a minimum of 9 °C (in January and February) to a maximum of 22 °C (recorded in August and July), and the mean monthly rainfall ranges from 30 mm (July) to 150 mm (October).

Wines

In the past, agriculture was the main activity in this area and it was especially dedicated to the grapevine cultivation. The study area is covered almost completely by vineyards of the famous denomination DOC (Controlled Designation of Origin) Cinque Terre and Sciacchetrà. DOC is a quality assurance label for Italian wine. After the 1992 enforcement of the European labels PDO, PGI, and TSG, this quality certification system has been exclusively used to distinguish quality wines. The DOC label is granted to wines produced in usually small or medium-size holdings and bearing their geographical name. DOC wines are commercialized only after undergoing thorough chemical and sensorial analyses. DOC Cinque Terre was established in 1973; since then productive hectares decreased from 150 to the current 88 ha. The DOC area in Cinque Terre corresponds to the boundaries of municipalities (Fig. 2) and there are no systematic works correlating the soil and climatic factors and the quality of the wines. This is a very interesting task for our project concerning the understanding of the subtle liaison between wine and *terroir*.

The “Cinque Terre” DOC is a dry white usually released 6 months after harvest. It is a yellow wine displaying dry herbs and grass hints, nutty and mineral, fresh, savory and sometime briny. The “Cinque Terre Sciacchetrà” DOC is a sweet wine obtained by grapes of the autochthonous vine variety “Bosco”, “Albarola” and “Vermentino”, dried on cane hurdles. It displays hints of honey, dried apricot, raisin, dry date, tobacco leaves, nut and almond. If the origins of this name seems to be shrouded in mystery, someone thinks it comes from the Semitic word “*shekar*” with which, 3000 years ago in Palestine, the fermented drinks were called; others think that it comes from the dialect “*sciacàa*”, meaning the Italian “*schiacciare*” (to crush), used to mean the pressing of grapes, it is certain that this fine wine has become the symbol par excellence of the Cinque Terre. The wine “Cinque Terre Sciacchetrà” DOC must be obtained from partial withering of the grapes after the collection, in suitable, ventilated places, until catching up a tenor of sweetness corresponding to at least 17° of alcohol.

Materials and Methods

Geographical information systems (GIS)

GIS provide a powerful tool for the integration of large and complex environmental databases and models and are proposed to improve the process of landscape characterization. ArcGIS 9.2 Desktop version (ESRI, Redmond, USA) was used to process the digital elevation model (DEM) data with 5 m resolution. This DEM was based on the interpolation of contour lines of a 1:5000 topographic map (Carta Tecnica Regionale Ligure, 2007 available at https://geoportal.regione.liguria.it) using a thin plate spline algorithm proposed by Hutchinson

(1996). We performed a detailed Terrain Analysis on the DEM using GIS tools and we extracted some topographic characteristics as slope, aspect, altitude. These are successively overlaid with the map of the area registered in the vineyard of the DOC, mapped by Global Positioning System (Carabinieri Forestali) to analyze the relationship between DOC vineyards and topographic or geological characteristics.

Soil

The knowledge of soil is limited in Cinque Terre National Park and the only few soil data available are stored in old paper and not always freely accessible (Fregoni, 1977). Several profiles from 4 distinct production vineyards (i.e. corresponding to the Cinque Terre DOC dry wine “Litan”, “Burasca”, “Begasti” and “CheO” and pertaining to four different agricultural holdings), on sandstone-claystone bedrock, were selected for full pedological description and sampling (Fig. 3b). Complete soil analyses were carried out for each horizon in the pits. The set of analyses was carried out by the Regional Soil Analysis Laboratory in Sarzana (Spezia, Liguria) (ISO 9001 certified). For each horizon laboratory routine analyses were performed in compliance with the proposed official Italian methods (MiPAF, 1999). Moreover direct survey of soil hydraulic conductivity (Ksat) was carried out using a Compact Costant Head Permeameter (Amoozemeter), for the whole study vineyards. Finally, we installed a solar-powered field station connected to multiple sensors to monitor the soil moisture content and temperature at four different depth (S1= 30 cm; S2= 60 cm; S3= 80 cm; S4= 120 cm) in the “Cheo” agricultural holding (Fig. 3).

Wines

The sampling set consisted of 4 wines (Cinque Terre DOC) from 2014 vintage of the 4 distinct production vineyards, in which the soil characterization was performed. Biochemical characteristics commonly used to assess wine quality were also determined: glucose and fructose, acidity (total and volatile), alcoholic strength by volume, metals (Fe, Cu, Zn), total sulfur dioxide, alcohol level and total dry matter. All methods were carried out according to OIV (*Organisation Internationale de la Vigne et du Vin*) standards by the Regional Soil Analysis Laboratory in Sarzana (Spezia, Liguria). Moreover, total content of phenols is measured using spectrophotometric methods (Folin-Ciocalteau protocol) by DICCA Laboratory (University of Genoa).

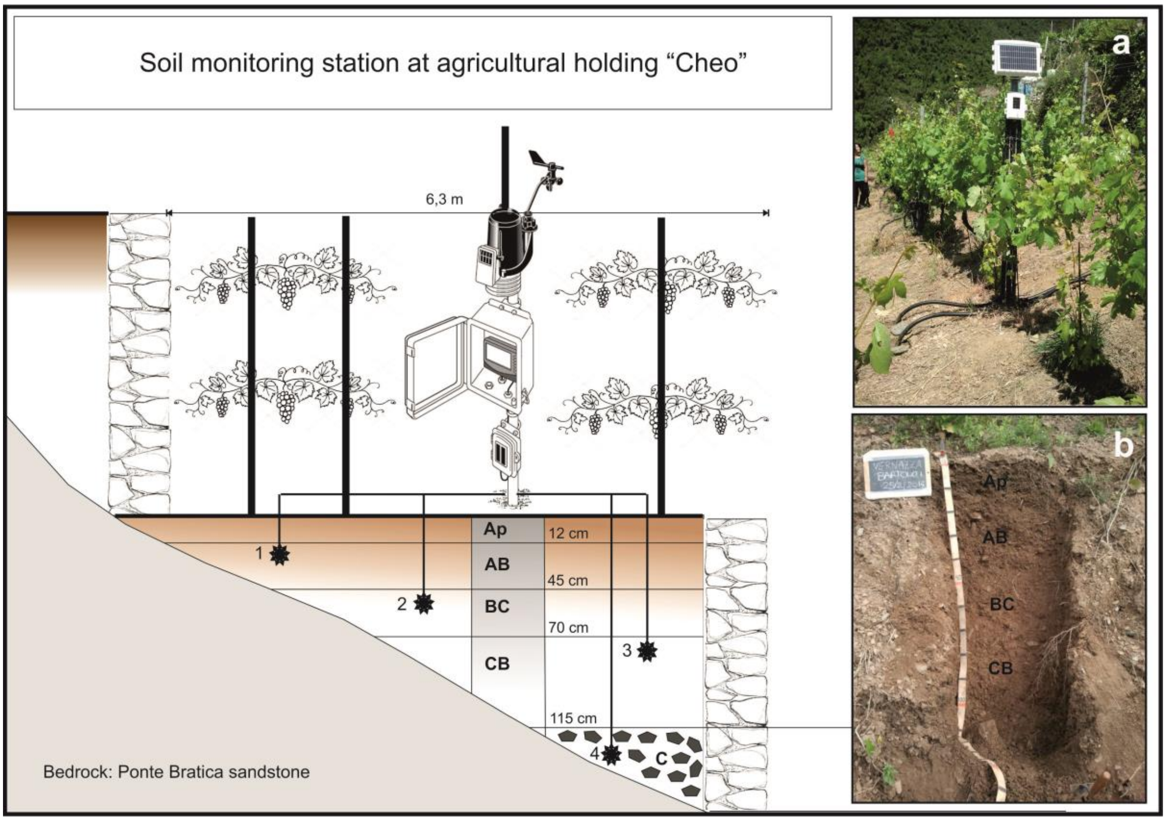

Figure 3. Monitored terrace section showing the position of multiple sensors at four different depth. Note the terrace structure characterized by dry stone wall at external edge and a drainage layer consisting of very coarse material at the base, overlain by filling materials (the true soil). Usually terrace walls are commonly filled with earthy material collected in nearby areas and often mixed with manure. a) view of solar-powered field station connected to multiple soil moisture/temperature sensors; b) soil profile selected for full pedological description and sampling.

RESULTS

GIS analyses

We have analyzed the relationships between DOC vineyards distribution and altitude, aspect, slope and geology. The results of the analysis (Fig. 4) show that maximum frequencies correspond to the elevation class from 100 m to 300 m. The frequency tends to decrease from 400 m to 700 m and we don't have actually used vineyard over 700 m. All DOC vineyards are set on sedimentary rocks: in particular the maximum frequency corresponds to turbiditic sandstone-claystone (Macigno, Ponte Bratica, Canetolo) while the minimum frequency of vineyards were found on debris and carbonates (Pignone, Groppo del Vescovo). The relationship between DOC vineyards and slope shows that the maximum frequencies of vineyards correspond to the slope between 16° and 34°. Furthermore, the maximum density of vineyards was observed on south facing and west facing scope.

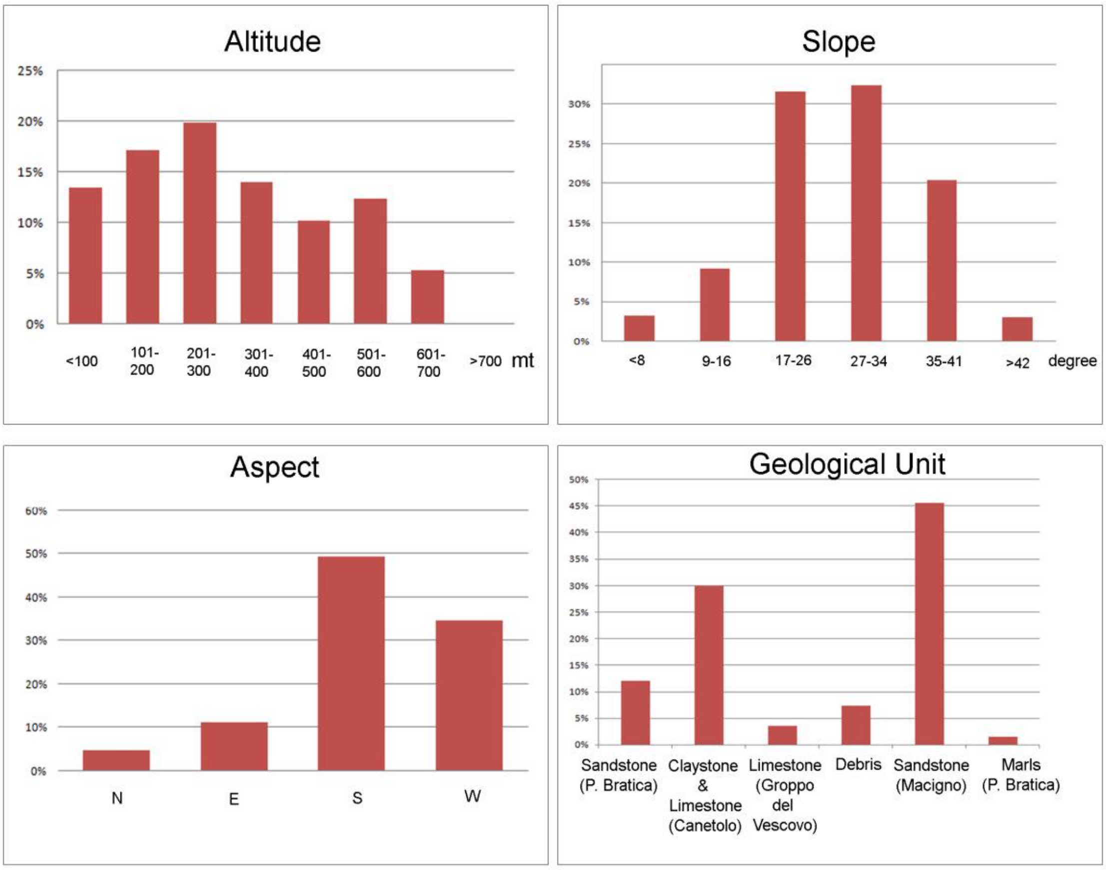

Figure 4. Graphs showing relationships between DOC vineyards and altitude, slope, aspect, geology in Cinque Terre National Park.

Soil

The described soils showed no significant profile development or early stages of horizon differentiation and weakly weathering of the parent material (Regosol or Cambisol, IUSS, 2015). The pedogenesis occurs under a strong human influence (human reworked substrate and addition of organic residues - fertilizers). The main morphological, physical and chemical data are reported in Table 1.

Particle size analysis showed that soils were rich in sand, often exceeding 50%. At the same time, some profiles were characterized by an increasing clay content with depth probably due to a weak accumulation of illuvial clay. Organic matter is concentrate mainly in surface horizon with a significant accumulation even in depth. Generally, their C/N ratios are near 10, indicating a Mull humus form, characterized by well-humified organic matter rich in stable mineral-organic complexes. The CEC values are medium and correlate to the amount of organic matter content in the horizons. However, the N is high, whereas the available P can show considerable differences related to different addition of organic residues or fertilizers. The horizons display a complete leaching of carbonate, and were predominantly acid and strongly desaturated. The microelement concentrations were medium to high. Fe content varies, for instance, from 10.6 to 92 mg/Kg while Mn from 3.7 to 27.6 mg/Kg. The electrical conductivity often increases in surface horizons, indicating the presence of a certain quantity of dissolved salt due to a natural processes of sea-salt aerosols deriving from the evaporation of sea-spray droplets produced by wind and waves in coastal zones.

Table 1. The main chemical and physical features of the benchmark profiles of the 4 studied production vineyards.[d] O.M.: organic matter; [e] Cond.: electrical conductivity; [f] C.E.C.: cation exchange capacity; [g] B.S.: base saturation.

Horiz.	**Depth** (cm)	**Grain size**			**pH**	**$CaCO_3$** (%)	**O.M.**[d] (%)	**N** (g/kg)	**C/N**	**Cond.**[e] (dS/m)	**C.E.C.**[f] (meq/100 g)	**Exchangeable bases** (meq/100 g)				**B.S.**[g] %
		sand	**silt**	**clay**	**H_2O**							**Ca**	**Mg**	**K**	**Na**	
CHEO soil profile																
Ap	0-12	43,2	45,1	11,7	5,6	0	4,8	3,2	8,8	0,4	23	7,7	4,0	0,6	0,2	54,3
AB	12-45	48,5	42,8	8,7	5,2	0	2,1	1,6	7,5	0,4	19,8	4,3	2,6	0,4	0,1	37,4
BC	45-70	47,3	41,8	10,9	5,4	0	1,9	1,4	7,9	0,3	20,4	4,7	3,7	0,2	0,2	43,1
LITAN soil profile																
Ap	0-10	60,4	33,6	6,1	4,9	0	6,4	3,3	11,4	0,5	18,4	4,5	1,2	0,6	0,2	35,3
A	10-20	70,7	26,2	3,1	5,1	0	6,9	3,1	12,8	0,4	20,5	4,2	1,2	0,3	0,2	28,8
CB1	20-40	55,6	37,6	6,8	4,6	0	3,4	1,9	10,6	0,4	16,2	1,0	0,4	0,2	0,1	10,5
CB2	40-80	44,3	37,4	18,3	4,7	0	1,9	0,7	14,6	0,4	15,2	0,7	0,2	0,2	0,1	7,9
BURASCA soil profile																
A1	0-2	58	31,6	10,4	6,1	0	10,8	5,7	11	0,5	22,3	10,4	2,6	1	0,2	63,7
A2	2-15	59,3	32,8	7,8	5,5	0	9,6	4	13,9	0,4	22,9	7,7	1,6	0,4	0,1	42,8
CB1	15-30	56,4	36,2	7,4	5,8	0	3,9	2,2	10,3	0,3	18,7	6,4	1,5	0,2	0,2	44,4
CB2	30-70	52,6	35,1	12,2	5,7	0	3	1,5	11,4	0,3	16,4	5,9	1,5	0,1	0,2	46,9
BEGASTI soil profile																
Ap	0-5	52,5	42,4	5,1	5,4	0	3,3	1,8	10,6	0,4	16,9	5,3	2	0,4	0,1	46,2
AB	5-20	49,4	44	6,6	5,2	0	3,8	2,1	10,5	0,3	17,6	5,1	1,9	0,2	0,1	41,2
BC1	20-70	59,2	35,5	5,4	6,5	0	0,2	0,7	11,3	0,3	15,2	6,8	3	0,2	0,1	66,4
BC2	70-90	49,2	38	12,8	6	0	0,6	0,3	11,3	0,3	13,1	4,0	2,2	0,1	0,2	49,6

Soil hydrology and temperature

The soils are well-drained. The measured values of permeability are high (from 3.5 μm/s to 20 μm/s) because of the sandy texture and skeleton abundance that may greatly modify the permeability rates. Unfortunately, we observed the soil often displaying a very compact surface horizon with massive structure. The compaction by compression is due to continuous heavy foot or trampling of the man working between the vine rows creating impermeable layers that reduce water infiltration. This process can cause effects such as increased surface water run-off, soil erosion or reduced groundwater recharge.

The repeated-measures analysis of daily soil moisture followed the expected Mediterranean cycle. During the summer, the daily soil moisture decreased at the four depths studied. In autumn and winter the soil-water storage is quickly refilled, with immediate increases in soil-water content for all depths except in the subsoil at 120 cm depth (sensor S4). During the spring daily soil moisture showed fluctuations for all depths (Fig. 3), but in particular for top-soil (sensors S1 and S2). Daily moisture contents of the sub-soils were similar at the 60 cm and 80 cm.

Soil temperatures did not change significantly with the soil depth in the soil. After March, daily soil temperatures significantly increased at all the soil depth as weather warmed. The greatest temperature changes occurred in the top-soil (sensors S1 and S2). The topsoil had significantly higher daily temperatures than sub-soils (sensors S3 and S4) from March to August, but they significantly decrease after September compared to subsoils.

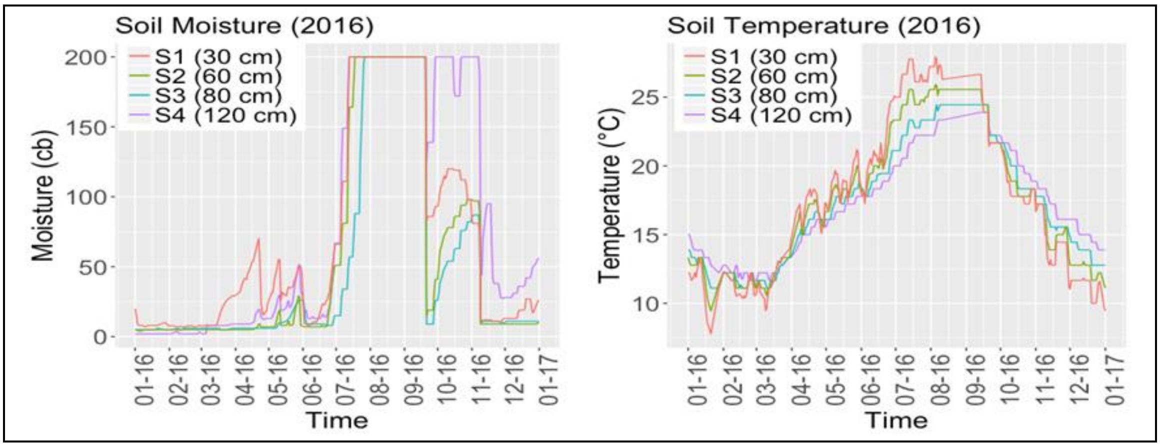

Figure 5. Daily soil moisture content (centibars) and temperature (°C) throughout the study period (January 2016 to January 2017).

Wines

Biochemical characteristics commonly used to assess wine quality showed significant differences (Table 2). The values corresponding to the quality parameters included in the disciplinary protocols for the production of Cinque Terre DOC dry wine (i.e., acidity total, total dry matter and minimum alcoholic strength) are all comprised in the threshold established by this procedural guidelines. Some major differences are instead noticeable in terms of sulfur dioxide (mg/l) varying between 56 and 102, the content in glucose-fructose ranging from 0.28 g/l to 0.62 g/l and Cu content, that is absent in one wine (Cheo dry white DOC) and varies up to 0.16 mg/l in the others.

Finally, analyses of the total content of phenols highlighted a remarkable feature: samples showed high total polyphenols content, measured by Folin-Ciocalteu method (IFC between 10.4 and 18.5, corresponding to 0.31 to 0.54 mgGAE/mL).

Table 2: The main biochemical characteristics of the sampled white wines.

Wine	**sulfur dioxide** mg/l	**total dry matter** g/l	**glucose - fructose** g/l	**alcoholic strength** % vol	**acidity total** g/l	**acidity volatile** g/l	**Fe** mg/l	**Cu** mg/l	**Zn** mg/l	**Total polyphenols** mgGAE/mL
Begasti	98	22	0.34	12.7	5.73	0.16	0.5	0.16	0.21	0.54
CheO	56	21.1	0.28	12.7	6.34	0.16	0.6	0	0.41	0.50
Litan	102	21.7	0.62	12.29	6.75	0.21	0.8	0.06	0.47	0.44
Scorza	83	19.7	0.29	12.75	5.96	0.17	0.2	0.01	0.4	0.31

DISCUSSION

The geomorphological analyses documented an overall similar environment of the soils examined, belonging to terraced vineyards with low-medium altitude, south-facing and steep slopes (strongly dissected topography), influenced by a semiarid climate on parent rock poor in carbonates and rich in sand, often modified profoundly through human activities. In fact, terraced soils are artificially constructed by humans and are often manually filled with soil collected from the surrounding area but also using transported material to improve soil properties or nutrient status. For all these reasons, terrace soils are now considered constructed pedoenvironments with typifying characteristics (Stanchi et al., 2012) and the linkage between bedrock and the overlying soil is in many cases weak. Many of the soil properties analyzed during this study were rather homogeneous, e.g. rapid drainage, due to the sandy texture of the filling material and abundance of skeleton that increased with increasing soil depth, acid reaction, good organic carbon content and total nitrogen contents in the A horizons and in the depth. These data demonstrated the strong human influence and soil uniformity of the vineyards within the study area. As a whole, nitrogen nutrition and water supply during certain phases of the vegetative cycle of the vine are considered essential factors for wine grape quality. The rapid drainage, due to the texture, may produce water deficit on grapevine, in Mediterranean or Sub-Mediterranean climates, with decreased berry size and number (Zsófi et al., 2011).

Our measurement of actual soil water content shows a moderate water deficit. Using the available textural and organic matter data the wilting point was then calculated for the monitored soil (Saxton and Rawls, 2006). At near 70-75 cb, sandy loam soils will be nearly 100 depleted of available soil. The repeated-measures analysis of daily soil moisture compared with the climatic data obtained by automatic weather station (Fig. 6) showed that during Winter water content values in the soil are always above the saturation point, due to the constant rains. At the beginning of Spring (April), instead, some variations are visible with decreasing saturation values especially in the top soils, due both to the increasing atmospheric temperatures (and thus of evaporation phenomena) and to the effect of the uptake of the vine roots during vegetative phase of the plants. In this period, vines are not influenced by water stress and they start their florescence with all the soil water available until July, being the water contents under the estimated wilting point. Water content starts to reduce in the first half of summer, during the grapes maturation period, and only from the end of July to September there is the true water stress period in the soils. This condition of moderate water deficit may have a beneficial effect on berry size and sugar concentration (Van Leeuwen & Seguin, 1994), in fact larger berries have lower sugar concentrations than the smaller ones due to the dilutions of sugars. After September rains start to recharge the soil with a more evident effect in the superior layers, while the deeper ones, corresponding to the drainage artificial layer, called “vespaio”, need a longer period of water recharge. At these depths water availability increases above the wilting point only at the beginning of winter, due to rains and infiltration component but also to hypogeous water supply.

The differences in the main biochemical characteristics of the sampled white wines can be considered as due to different procedures during winemaking or to the influence of oenological technologies (Fig. 7). Except the values included in the compulsory formal protocol for DOC product quality certification (Art. 6), other features are not regulated, and, thus, they can belong to a number of different wine makers practice.

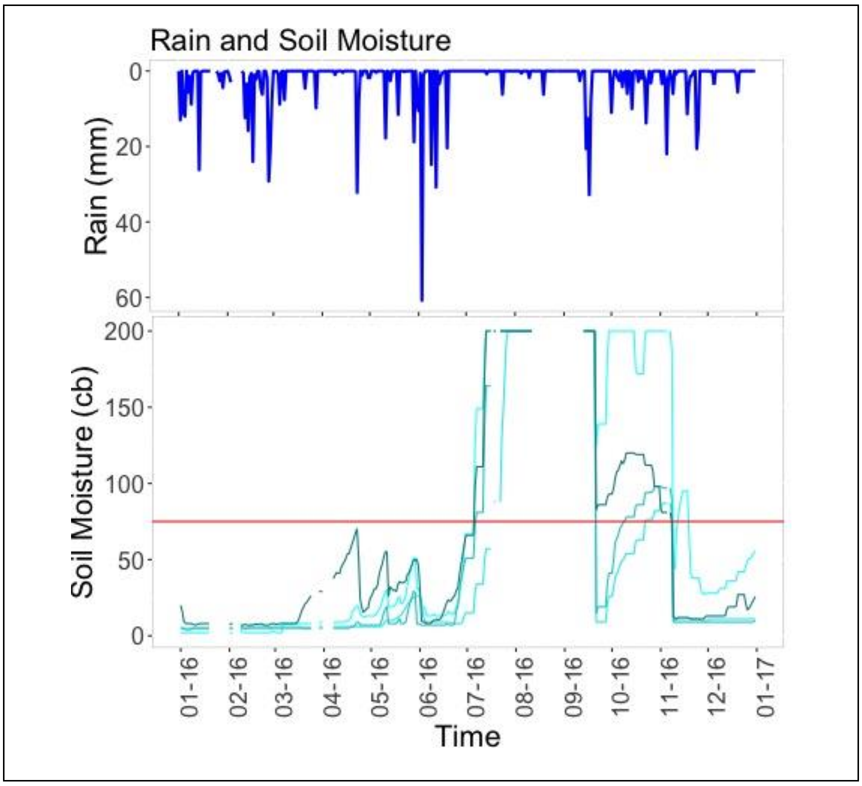

Figure 6. Soil moisture content (centibars) and rain data throughout the study period. A lower (near 0 cb) reading indicates saturated soil conditions. Readings near 6-10 cb indicate the soil is near field capacity. At near 75 cb (horizontal red line), the soil will be nearly 100% depleted of available water (wilting point).

The values of total polyphenols content are considerably higher than traditionally cited German and Italian white wines (0.1-0.3 mgGAE/mL and IFC between 4 e 12), as showed in the Fig. 8.Our result on total polyphenols content of Cinque Terre white wines could be considered remarkable, even if not yet supported by newest analytical procedures, due to the uniqueness of the data and distinctive of one aspect of the local *terroir*, being connect to pedo-climatic condition of the area. Indeed, several author have noted that the concentration of berry skin phenolic compounds (anthocyanins and tannins) is higher if vines are exposed to moderate water deficit (Roby et al., 2005; Castellarin et al., 2007), according to our measurements.

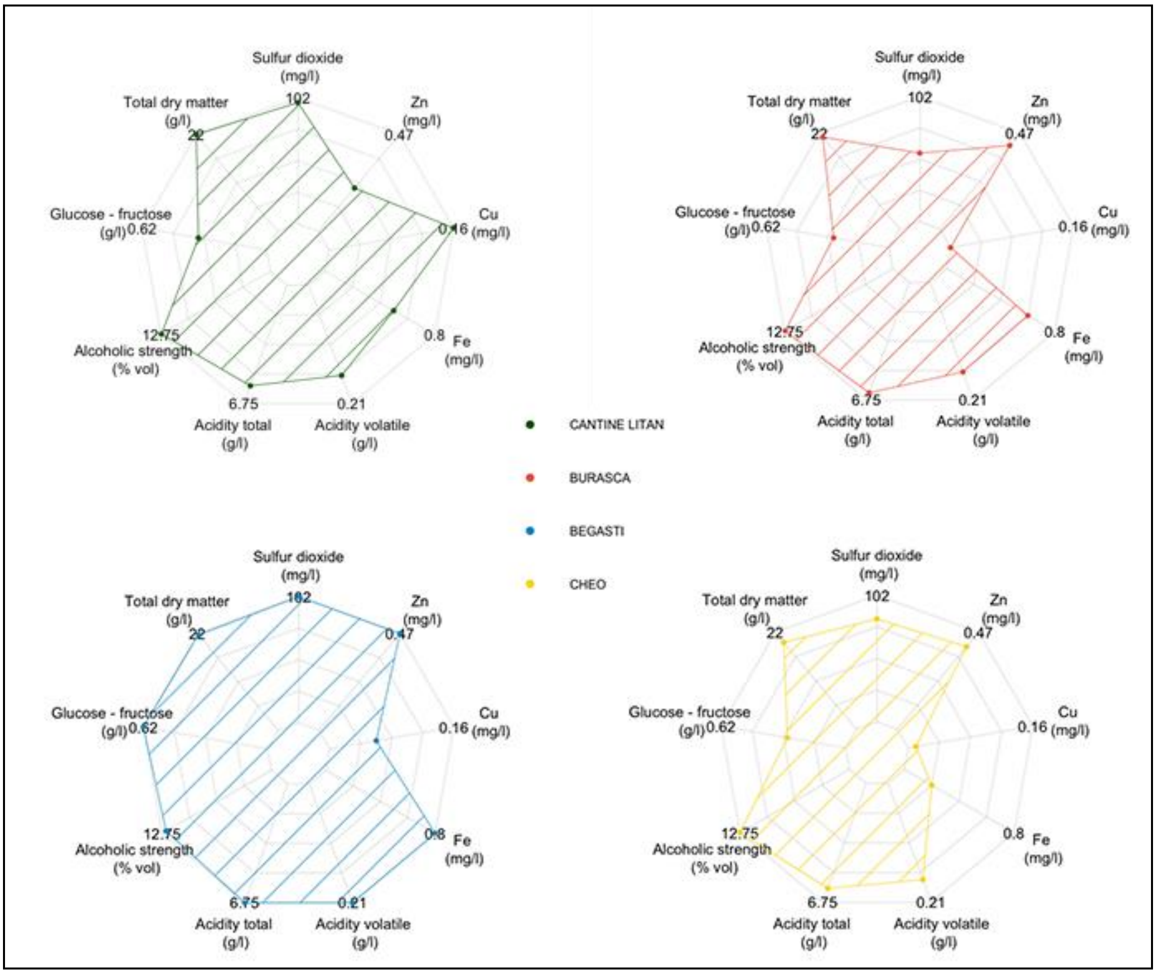

Figure 7: Radar charts of the, biochemical characteristics commonly used to assess wine quality measured by the OIV standards at the Regional Soil Analysis Laboratory in Sarzana (Spezia, Liguria). Each chart is related to the results of the 4 DOC dry wines analyzed.

CONCLUSION

The analyses conducted highlight a number of distinctive features of soils and wines from Cinque Terre vineyards and the usefulness of an accurate description of soils and wines proprieties in the perspective of the implementation of the official DOC Cinque Terre wines production protocols. At the present, in fact, production areas are defined by using municipalities boundaries (Art.3), nevertheless a more efficient cartography of soil zonation could improve the determination of the relationship existing between quality of the products and environmental features and thus the identification of *DOC* areas (Vaudour et al., 2015). Further analyses are necessary to obtain more accurate information about *terroir* definition and wine description, basing on similar protocols of analysis as the one proposed in the present study on experimental vineyards, selected in the Cinque Terre production area and showing features representative of the territory (e.g. terraces and exposition/altitude).

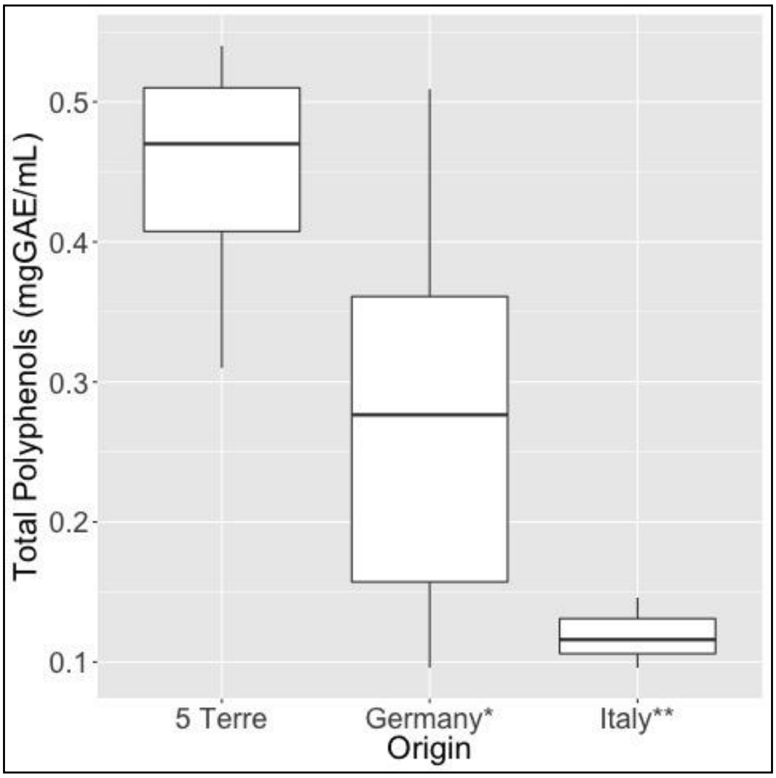

Figure 8. Boxplot of the total contents of Polyphenols, measured by Folin-Ciocalteu essay, in 3 sets of white wines with different origins. * from Nikfardjam et al. (2007); ** from Simonetti et al. (1997).

In order to identify the different contribution of single components of polyphenolic compounds class to the total content, is desirable to conduct more accurate and sophisticate essay (Morlat and Bodin, 2016) as thin layer chromatography (TLC), high-performance liquid chromatography (HPLC), gas chromatography (GC) also associated with mass spectrometry (GC/MS). The use of more advanced analytical protocols could lead to a better description of wines and their features connected to Cinque Terre *terroir* and give us a major understanding of the effects of different agronomical vineyard managements and wine-making techniques, applied by different producers.

A number of different analytical techniques have been evaluated for the purpose of wine authentication such as major and trace elements. Strontium isotopes reflect the local geological conditions of the wine terroir and may therefore be linked to the origin of the grape used for wine production (Petriniet al., 2015; Braschiet al, 2015; Di Paola-Naranjo et al., 2011). Variations in the $^{87}Sr/^{86}Sr$ isotope ratios in wine could be used to differentiate the geographic origin of wines in wine-producing areas such as Cinque Terre. All these information could be used as explanatory parameter and markers to describe the Cinque Terre *terroir*.

AKNOWLEDGEMENTS - The authors are indebted to many people, including the director P. Scarpellini and the past president V. Alessandro of Cinque Terre National Park for their support and cooperation in the research project, and director S. Pini and the technical staff of the Regional Laboratory of Sarzana (SP) for the chemical and physical analyses. A special thank goes to Prof. Bartolo Lercari ("Cheo" agricultural holding) for valuable help during the soil monitoring. Finally, we would like to thank Prof. Michael Maerker for his critical rereading and precious suggestions on the text.

REFERENCES

Brandolini P., Faccini F., Firpo M., Rellini I. & Scopesi C., 2013. Aspetti geomorfologici e geologico-ambientali del paesaggio vitivinicolo ligure. Atti del Convegno AIGEO "Dialogo intorno al paesaggio", Culture Territori Linguaggi 4: 57-68.

Braschi E., Marchionni S., Priori S., Casalini M., Tommasini S., Natarelli L.,Buccianti A., Bucelli P., Costantini E.A.C. & Conticelli S., 2018. From vine to wine: Data on 87Sr/86Sr from rocks and soils as a geologic and pedologic characterisation of vineyards. Data in Brief 18: 731-735.

Costantini E.A.C. & Bucelli P., 2014. Soil and terroir. In: Kapur S., Erşahin S. Eds. Soil security for eco system management. Springer Briefs in Environment, Security, Development and Peace 8: 97–133,

Deloire A., Prévost P. & Kelly M., 2008. Unravelling the terroir mystique an agrosocio-economic perspective. Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources, CAB Reviews, 3, 032: 1-9.

Di Paola-Naranjo R.D., Baroni M.V., Podio N.S., Rubinstein H.R., Fabani M.P., Badini R.G., Inga M., Ostera H.A., Cagnoni M., Gallegos E., Gautier E., Peral-García P., Hoogewerff J. & Wunderlin D.A., 2011. Fingerprints for main varieties of Argentinean wines: terroir differentiation by inorganic, organic, and stable isotopic analyses coupled to chemometric. Journal of agricultural and food chemistry 59 (14): 7854-7865.

Fregoni M., Miravalle R. & Celsi S., 1977. La carta nutritiva dei vigneti delle Cinque Terre. "Provincia Notizie", La Spezia, 1/2.

Hutchinson M.F., 1996. Thin plate spline interpolation of mean rainfall: getting the temporal statistics correct, in: Goodchild M.F., Steyaert L.T., Parks B.O., Johnston C.A., Maidment D.R., Crane M.P., Glendinning S., Eds. GIS and environmental modelling: progress and research issues. Fort Collins, GIS World Inc.: 85–91.

IUUS Working Group WRB, 2015 - World Reference Base for Soil Resources 2014, update to 2015. International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports No. 106. FAO, Rome, Italy.

Likar M., Vogel-Mikuš K., Potisek M., Hančević K., Radić T., Nečemer M. & Regvar M., 2015. Importance of soil and vineyard management in the determination of grapevine mineral composition. Science of the Total Environment 505: 724-731.

Köppen W., 1936. Das geographische system der climate. In: Köppen W., Geiger R., Eds. Handbuch der Klimatologie, Vol I, Part C. Gebrüder Borntraeger, Berlin, p 44.

Ministero Delle Politiche Agricole E Forestali, MIPAF, 1999. Metodi di analisi chimica del suolo. Osservatorio nazionale pedologico e per la qualità del suolo. International Society of Soil Science, Società Italiana della Scienza del Suolo. F. Angeli (ed), Milano.

Morlat R. & Bodin F. (2016). Characterization of viticultural terroirs using a simple field model based on soil depth – II. Validation of the grape yield and berry quality in the Anjou vineyard (France). Plant and Soil 281: 55-69.

Nikfardjam M.S.P., Koler H.J., Schmitt A., Patz C.D., & Dieter C., 2007. Polyphenolic composition of German white wines and its use for the identification of cultivar. Mitteilungen Klosterneuburg 57: 146-152.

Pereira G.E., Gaudillere, J.P., van Leeuwen C., Hilbert G., Maucourt M., Deborde, C., et al., 2006. 1H NMR metabolite fingerprints of grape berry: Comparison of vintage and soil effects in Bordeaux grapevine growing areas. Analytica Chimica Acta 563(1-2): 346-352.

Petrini R., Sansone L., Slejko F.F., Buccianti A., Marcuzzo P. & Tomasi D., 2015. The 87Sr/86Sr strontium isotopic systematics applied to Glera vineyards: A tracer for the geographical origin of the Prosecco. Food Chemistry 170: 138-144.

Saxton K.E. & Rawls W.J., 2006. Soil Water Characteristic Estimates by Texture and Organic Matter for Hydrologic Solutions. Soil Science Society American Journal 70: 1569-1578.

Simonetti P., Pietta P. & Testolin G., 1997. Polyphenol Content and Total Antioxidant Potential of Selected Italian Wines. Agriculture Food Chemistry 45: 1152-1155.

Terranova, R., 1984. Aspetto geomorfologici e geologico-ambientali delle Cinque Terre: rapporti con le opere umane (Liguria Orientale). Studi e ricerche di Geografia 7: 38-90.

Terranova R., Zanzucchi G., Bernini M., Brandolini P., Campobasso S., Faccini F. & Zanzucchi, F., 2006. Geologia, geomorfologia e vini del Parco Nazionale delle Cinque Terre (Liguria, Italia). Bollettino della Società Geologica Italiana Spec 6: 115-128.

Vaudour E., Costantini E., Jones G.V. & Mocali S., 2015. An overview of the recent approaches to terroir functional modelling, footprinting and zoning. Soil 1: 287-312.

Van Leeuwen C. & Seguin G., 1994. Incidences de l'alimentation en eau de la vigne, appréciée par l'étathydrique du feuillage, sur le développement de l'appareil végétatif et la maturation du raisin (Vitis vinifera variété Cabernet franc, Saint-Emilion, 1990), Journal International des Sciences de la Vigne et du Vin 28: 81-110.

Van Leeuwen C. & Seguin G., 2006. The concept of terroir in viticulture. Journal of Wine Research 17: 1-10.

Zsófi Zs., Tóth E., Rusjan D. & Bálo B., 2011. Terroir aspects of grape quality in a cool climate wine region: Relationship between water deficit, vegetative growth and berry sugar concentration. Scientia Horticulturae 127: 494-499.

DOI: 10.15167/2612-2960/BELS2019.1.1.1070