THE SOIL BIODIVERSITY AS A SUPPORT TO ENVIRONMENTAL SUSTAINABILITY IN VINEYARD.

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Abstract
The environmental biodiversity is important to guarantee essential services to the living communities, its richness is a symptom of a minor disturbance and improves he environment biological quality. The edaphic communities, in particular, ensure plant development in natural habitats and cultivated land although the human intervention may disturbs their stability and equilibrium. The assessment of soil biodiversity, quite complex for the huge number of edaphic species and the limited availability of simple and inexpensive methods, is useful for estimating soil biological quality and the impact of the human activity. The QBS-ar method assess biodiversity and biological quality of the soil evaluating the microarthropods' level of adaptation to the soil life. By applying this method, a study was carried out to assess soil biodiversity in vineyards, observe the variability between plots and estimate the influence of soil physical and chemical characteristics on edaphic community.
The study started in 2015 in the Barolo winegrowing area (north-west Italy). The area is characterized by soil homogeneity but wide geospatial heterogeneity, which is why the commercial vineyards under observation were also characterized by this point of view. For each vineyard pedological survey were executed analysing the soil profile, the chemical and physical composition, the soil hydrological constants and the microarthopods community.
In Barolo area, the abundance of individuals and the QBS-ar index showed diversity among the vineyards but were not affected by the weather variability or geospatial variability. It emerged a possible correlation with the physical characteristics of the soil, such as density and porosity; these properties are dependent on the soil texture but they also vary depending on the management practices. The index reveals a good potential for rapid assessment of elements linked to environmental quality although many aspects still remain to be defined including, for example, the relationships with crop management.

Keywords: soil quality, soil hydrology, micro-arthropods, QBS-ar, Barolo.

1 INTRODUCTION
The biodiversity of an environment, namely the presence of organisms taxonomically different and able to perform several tasks and functions, is important to guarantee essential services to the survival of the living communities, its richness is a symptom of a minor contamination of the environment and improves its biological quality (Delgado-Baquerizo *et al.*, 2016). The edaphic communities, in particular, ensure plant development in natural habitats and cultivated land although the human intervention may disturbs their stability and equilibrium. In fact, they are sensitive to environment peculiarities (Parisi et al. 2005, Marinari and Vittori Antisari 2010, Lagomarsino et al. 2012) but also to soil management techniques (Marinari et al. 2000; Gardi et al. 2002; Tabaglio et al. 2009). The assessment of soil biodiversity, despite quite complex for the huge number of edaphic species and the limited availability of simple and inexpensive methods, is useful for estimating the soil biological quality, and could be of interest for land plot discrimination and for evaluating the impact of the human actions. A way to study soil biodiversity and quality is to consider edaphic microfauna. Among proposed methods, that developed from Parisi (2001), the QBS-ar method, is based on a general evaluation of microarthropods. To avoid the difficulties of the microarthropods classification at the species level, this method is based on a simplified eco-morphological index and is on the concept that individuals strongly adapted to soil life (e.g. loss of pigmentation and visual apparatus, reduction of appendices) may be more numerous in soils of good quality and less disturbed, and are the first to disappear in the presence of poor soils. Thus, being an expression of the functioning of the soil, the presence of microarthropods may be used as a bioindicator able to identify the environmental stress and changing. The purpose of the method is to identify *taxa* according to the biological form approach (morpho-type), it means to recognize the different adaptation levels to soil environment for every systematic group(eg Collembola, Protura, Symphyla) and, to each *taxon*, an eco-morphological score (EMI) is assigned. The groups with the highest quality (EMI20) are credited with 20 points(eu-edaphic form, i.e. deep soil-living) whereas 1, 5 or 10 point are assigned to the other *taxa*, depending on their degree of adaptation to soil life (hemi-edaphic forms, i.e. intermediate soil living; epi-edaphic forms. i.e. surface-living).The QBS-ar index is calculated by adding up the values assigned to all systematic units captured.

By applying this method, a study was carried out to assess aspects of soil biodiversity in vineyards, observe the variability between plots and estimate the influence of soil physico-chemical characteristics on microarthropods community. The work was carried out in Barolo winegrowing area (north-west Italy). This area is a part of a complex system of hills (named "Langhe") and it is characterized by a quite homogeneity of the soils but wide geospatial and vineyard microclimatic heterogeneity mainly due to characteristics such as altitude, slope, exposure and the distance from valley floor. Despite the richness in different environments, the most important wine produced in this area is Barolo, which is an aging wine produced just from Nebbiolo grape variety. Thus, this variety is cultivated in very different environment, giving rise to a wide variability in term of grape and wine quality. This situation makes the Langhe hills an ideal zone for studying *terroir* properties (Van Leeuwen et al.2004, Van Leeuwen and Seguin 2006). Soil biodiversity is one of the aspects that may help to improve the quality of these studies. The activities of the first year aimed to conduct observations concerning soil characteristics from a physical and chemical point of view, assess aspects of soil biodiversity by means of the QBS-ar index. The study falls within the scope of the studies concerning *terroir* and would like to contribute to the identification of the environmental reasons that may explain differences among grapes and wines.

2 MATERIALS AND METHODS

The study started in 2015 identifying 9 vineyards in the Barolo winegrowing area (north-west Italy), historically and traditionally subdivide in numerous *cru*. For each vineyard, the geographic characteristics, such as location, altitude and exposure, were recorded. A soil profile useful to the soil horizon description was executed (Soil survey division staff, 1993); a soil sample was taken from each horizon to perform physical and chemical analysis of some of them. Soil texture, pH, total and active limestone content, percentage of organic carbon, nitrogen content, C/N ratio, cation exchange capacity were assessed following the official method (DM 1/08/1997). In middle spring, three replicates of the top soil (10 cm) were sampled within each vineyard for the analysis of soil biodiversity according to the QBS-ar method (Parisi 2001, Parisi et al. 2005). Richness and abundance of the edaphic microarthropods and the QBS maximum were evaluated by counting the total number of individual and *taxa* and the total number of individual and *taxa* belonging to groups of EMI20, the more adapted to edaphic conditions. QBS maximum (QBSmax) for each vineyard was calculated as the sum of the maximum value assigned to each *taxa* observed in the vineyard, regardless the replicate or the total number of individuals. In order to acquire more information regarding the influence of soil parameters on its biological properties, a Principal Component Analysis (PCA) was performed using SAS 9.4 for Windows (SAS Institute, Cary, USA).

3 RESULTS AND DISCUSSION

The study took in consideration some of the most reputed cru of the Barolo production area (Figure 1), zone extended in a 1997 hectare surface. Two main exposition of the slopes predominated among the considered vineyards: south-est (vineyards in Guarene, La Morra, and Barolo), and south-west (vineyards in Serralunga and Castiglione Falletto). The vineyard altitude ranged from 258 m above see level of the Gustava to 378 m above see level of Bricco Voghera; the elevation is independent on the exposure of the slope (Table 1).

The analysis results showed an homogeneous distribution of the main parameters usually used for describing the relationship between soil, vineyards and sites: soils were quite homogeneous in term of texture, pH, limestone, silt content, only with few exceptions; the sand content was, instead, quite variable (Table 2).

From the point of view of the taxonomy, all soils are affected by a great anthropogenic activity occurring during vineyard establishments with soil horizon mixing and low attention to strategies for soil conservation in the past. In the first year of activity, an attempt to individuate soil parameters best describing vineyards and having closer relationships with the management practices, has been done.

In the area 20 *taxa* of microarthropods were identified, 15 of which present in the 50% of the samples; 14 taxa, on average, were identified in each vineyard, 5.5 of which classified such as eu-edaphic forms (EMI20). The average number of individuals for each vineyard was equal to 922, variable from 385 to 1485; the individuals EMI20 ranged from 11 to 135 (Table 3). Pseudoscorpions, Diplopoda, Pauropodi, Symphylans, Chilopoda, Protura, Diplura, were the EMI20 taxa; with the only exception of Diplopoda and Diplura, they were present in more than 50% of the samples analyzed. Referring to bibliographic data it is possible judging favorably the situation emerged from these vineyards particularly when compared with other agricultural environments (Menta et al., 2008). Nevertheless, a wide diversity among vineyards has been evidenced even if the results were not affected by the geographic variability (altitude and aspect). It was highlighted, however, a greater correlation with the physical characteristics of the soil, which may depend on the soil texture and on the management practices. Among vineyards, in fact, a certain variability emerged in terms of physical parameters such as bulk density, total porosity, air capacity and available water capacity (AWC) (Table 4).

Principal Component Analysis were applied to all the analysed parameters; the major discriminate power was find in a model including the following: QBSmax, total number of individual and of *taxa*, soil bulk density, soil porosity, air capacity and AWC. The first two principal component (Prin1 and Prin2) provided a good summary

of the data accounting for 51% and 30% of the total variance, respectively; with Prin3 the variance explained increased to 92%. Following the eigenvalues, Prin1 was represented as a linear combination of the variables bulk density (that showed a negative loading on this component), air capacity and porosity; Prin2 was represented as a combination of the number of total *taxa* and QBSmax. AWC represented Prin3 with a negative loading on the component. It emerged a positive correlation between the number of individual and bulk density (R^2=60), but also between QBSmax and soil porosity (R^2=55); a negative correlation emerged between the number of individual and porosity (R^2=-47). These preliminary results evidenced that the edaphic microarthropods seem to find good conditions for living even when soil density exceeds 1.4 kg dm^{-3} and porosity and air capacity decrease; nevertheless a higher soil porosity seems to improve the presence of *taxa* of greater ecological value
The vineyards located in the second quadrant of the Cartesian plane identified by Prin1 and Prin2 (Figure 2), were characterized by higher soil bulk density, while those in the first and in fourth showed lower values. The vineyards located in the upper part of the plane were characterized by a high value of QBS index and by a greater number of taxa compared to those of the III and IV quadrants. However, in vineyards with similar porosity QBS index showed differences likely due to some other factors not yet identified or assessed. Since soil physical characteristics may vary greatly depending on the human activity, it is possible that soil management techniques can, both in short and long term, modify soil physical properties and, therefore, the equilibrium of edaphic community.

4 CONCLUSION

This work revealed some common features to the whole area. In particular, the vineyards under observation showed similarities for soil chemical and physical parameters usually considered in *terroir* studies, such as pH and texture. Therefore, evidence of major differences emerged with regard to aspects so far little considered in this kind of studies, such as soil porosity and density and biodiversity indices. From this latter point of view, it also emerged that the soil biological quality of the considered vineyards was quite high, especially when compared to that of other agricultural environments. Showing possible relationships with the human impact, the QBS-ar index may be useful to study the anthropic aspect of the *terroir* variability and to contribute to the identification of the environmental properties able to explain differences among grapes or wines. It revealed a good potential for rapid assessment of elements of environmental quality although many aspects still remain to be defined including the detail of the relationships with crop management.

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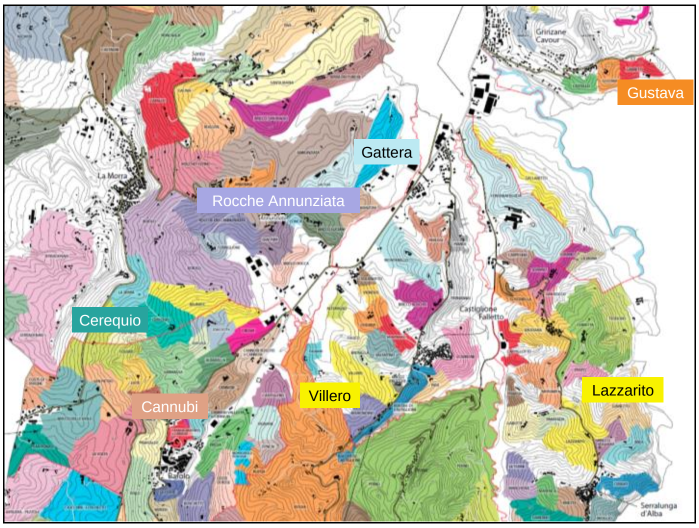

Figure 1: Map of the Barolo area highlighting the vineyard cru where the study was carried out. Different colors represent different geographical designations of origin for Barolo wines *(from "Consorzio di tutela Barolo Barbaresco Alba Langhe e Roero")*.

Table 1: Name and location of the cru and owner. Coordinates, aspect and elevation of the vineyards.

Cru and location	**Company**	**Geographic coordinates** (N-E)	**Aspect** (°)	**Altitude** (m above see level)
Gustava, Guarene	Pio Cesare	44°65’46.24” - 7°99’95.56”	135	258
Gattera, La Morra	Cordero di Montezemolo	44°64’04.09” - 7°95’95.13"	200	280
Rocche Annunziata, La Morra	Paolo Scavino	44°63’51.09” - 7°94’20.12”	135	338
Cerequio, La Morra	Michele Chiarlo	44°62’32.00’’ - 7°93’89.85’’	125	325
Cannubi, Barolo	Poderi Luigi Einaudi	44°61’71.45” - 7°94’92.61”	145	260
Villero, Castiglione Falletto	Cordero di Montezemolo	44°62’11.84’’ - 7°96’78.59’’	245	308
Lazzarito, Serralunga	Poderi Gianni Gagliardo	44°61’94.14’’ - 7°99’76.16’’	210	365
Bricco Voghera, Serralunga	Azelia	44°61’63.73” - 8°00’41.81”	200	378

Table 2: Chemical and physical parameter of the vineyard soils under observation.

	Average value	Minimum value	Maximum value	Standard error
Sand (%)	21.9	17.0	31.0	1.76
Silt (%)	59.0	52.8	64.1	1.39
Clay (%)	19.1	16.2	21.9	0.68
Texture (USDA)	Silty Lomy			
pH	8.0	7.9	8.1	0.03
Total limestone (%)	23.6	14.6	28.0	1.62
Organic Carbon (%)	1.47	1.02	2.0	0.11
Carbon/Nitrogen	10.7	8.8	11.9	0.365

Table 3: Biological assessments. Maximum value of QBS index, number of total individuals (abundance) and *taxa* (richness), number of EMI20 individual and *taxa* found in the samples. Average, minimum, maximum and standard errorvalues of the vineyards analyzed are reported.

	QBS max	Individuals (total number)	Taxa (total number)	Individual EMI20 (number)	*Taxa* EMI20 (number)
Average value	187	922	13.9	73.9	5.5
Minimum value	170	385	9	135	7
Maximum value	230	1485	16	11	3
Standard error	9.26	103	0.15	14.0	0.40

Table 4: Physical assessments. Bulk density (kg dm^{-3}), total porosity, air capacity and available water capacity (AWC) of the soil analyzed are reported.

	Bulk density kg dm^{-3}	Total porosity %	Air capacity %	AWC
Average values	1.41	52.0	12.8	20.4
Minimum value	1.16	46.7	6.8	17.6
Maximum value	1.54	58.1	19.5	24.1
Standard error	0.05	1.47	1.64	0.81

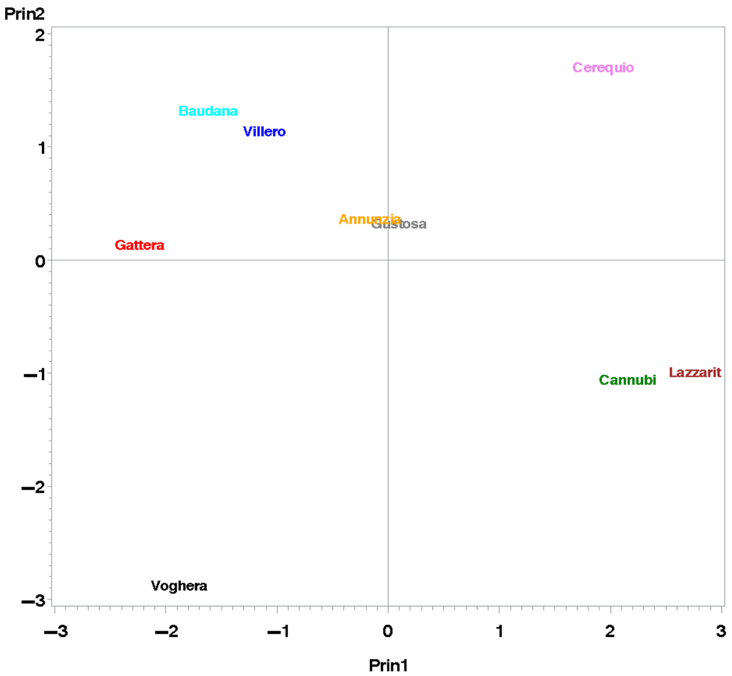

Figure 2: Principal Component Analysis: distribution of the observations in the Cartesian coordinate system identified by the first two principal components (Prin 1 and Prin 2).