Abstract template

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Monitoring Soil Biological Quality in the Veneto region

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Abstract summary

Organisms living in the soil are highly sensitive to soil degradation. Intensive anthropogenic pressures have led to a global decline in biodiversity also in soils with consequences on their functionality. Following the QBS-ar methodology (Soil Biological Quality index), based on the analysis of microarthropods groups present in soil, the regional agency for environmental prevention and protection (ARPAV) carried out a soil quality monitoring plan in the Veneto region for ten years. The QBS-ar index is based on the concept that the higher the soil quality, the higher the number of microarthropod groups morphologically well adapted to the specific soil habitat. Through a network of 10 monitoring stations, more than 240 samples were collected in 18 land uses and more than 800 data were processed. QBS-ar index values above 150 occur in undisturbed environment, therefore it can be taken as quality threshold. In arable crops the index were found below 100, values below 50 indicate poor soil quality. Intermediate values, between 100 and 150, suggest medium biological soil quality.

In agriculture, QBS-ar index may be used to assess the effective impacts of agricultural practices on soil health.

Keywords: [biodiversity, monitoring, quality index, Soil Biological Quality]

Introduction, scope and main objectives

The community of organisms living in the soil is highly sensitive to soil degradation. Anthropogenic pressures have led to an overall decrease also in soil biodiversity sometimes with serious consequences on their functionality. In 2009 ARPAV (Regional Agency for Environmental Prevention and Protection) started a soil quality monitoring plan in the Veneto region; since 2012 soil monitoring activity has been systematically carried out. The aim of the monitoring plan is to investigate the soil biological quality in the region and to identify reference values according to different land uses. This can be the mean to highlight soil degradation or pollution.

Methodology

The soil microarthropod community was analyzed using a soil biodiversity and quality index called QBS-ar (Soil Biological Quality based on soil arthropods, Parisi *et al.,* 2005). The QBS-ar index is based on the following concept: the higher the soil quality, the higher the number of microarthropod groups morphologically well adapted to the specific soil habitat. In "disturbed" soils, microarthropod groups morphologically well adapted tend to disappear and only those less adapted will remain (Menta *et al.,* 2018). The method consists in taking 3 top soil cubic clods (10 cm^3 each) from every monitoring area. A *Berlese-Tüllgren* funnel was used for microarthropod extraction (with a 2 mm mesh sieve and, above all, a light source; figure 1). In 10 days, the specimens fall from the soil into the funnel and are collected in a solution of alcohol and glycerine.

The extracted specimens were observed under a stereomicroscope. Soil organisms are classified into biological forms according to their morphological adaptation to soil environments. Degree of adaptation

to soil habitat depends on the presence and combination of some morphological characters: miniaturization, anophthalmia, flat body, short antennas and short legs. Each of these forms is associated with a score named “EMI” (eco-morphological index), which ranges from 1 to 20 (depending on degree of adaptation). The QBS-ar index value is obtained from the sum of the EMI scores of all collected groups, based on the principle that is more important the degree of soil adaptation than taxonomy (Parisi and Menta, 2008). If in a taxonomic group, biological forms with different EMI scores are present, the higher value (more adapted to the soil form) is selected to represent the group in the QBS-ar index calculation. The sampling methodology requires the collection of three soil cubes at each sample site, combined into a single sample.
The averages of the number of each taxon individuals and the percentages of total were calculated. The organisms belonging to each biological taxon were counted in order to estimate the average density per square meter (ind/m^2). The number of total taxa found was also considered.

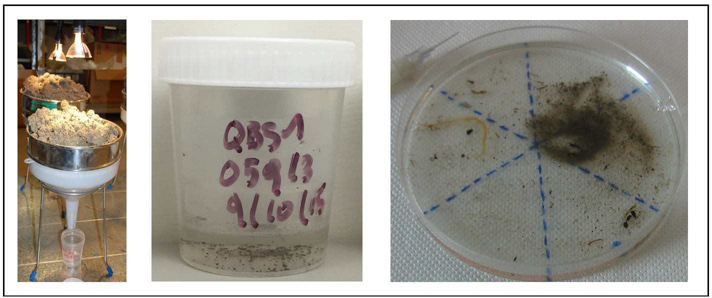
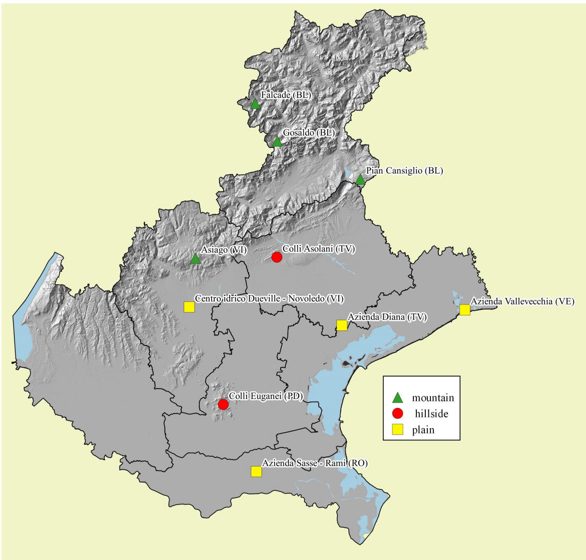


Figure 1: Extraction and microscopic reading

Since 2012, 10 monitoring stations have been set up in the Veneto region (figure 2), 4 in plain areas, 2 in hilly areas and 4 in mountain areas. All stations are representative of the regional environment for: land use, soil characteristics, parent material and climate conditions. 18 different types of land use (crops or natural vegetation) have been studied.



Environment	n° station	Land Use
PLAIN	4	wheat
		rape
		corn
		soybean
		sorghum
		vineyard
		orchard
		farm tree forest
		alfalfa
		meadow
		coastal pine wood
HILL	2	vineyard
		deciduous forest
MOUNTAIN	4	meadow
		pasture
		beech forest
		spruce wood
		white fir wood

Figure 2: Monitoring stations in Veneto region, locations and land uses

At each site, information on soil characteristics was derived from semi-detailed soil maps (ARPAV, 2005 and 2020) and samples were collected for organic carbon, soil texture, electrical conductivity and pH

analysis. Temperature and soil moisture conditions may influence soil fauna behaviour, so climate data have also been collected from the closest weather stations.
For each area one undisturbed sample was taken in order to measure bulk density and soil moisture.
Statistical processing have been worked out with "Statistica®" software, version 8.0. Significant differences between the land uses, in taxa abundance and QBS-ar index values, were tested using Analysis Of Variance (ANOVA). Statistical tests using parametric methods (test HSD-Honestly Significant Difference di Tuckey, test t) and non parametric (Kruskal-Wallis) were also performed to highlight statistical variability in the QBS-ar index.

Results

Plain environment

In plain areas the following crops were studied in detail: arable crops, alfalfa, meadows, vineyard, orchard (pome fruit), forest tree farming (in previous arable lands), a deciduous forest and a coastal pine forest. Analysis Of Variance (ANOVA) points out relationship between QBS-ar index and land use, post hoc analysis (Tuckey test HSD) was worked out in order to highlight differences between land uses (figure 3, table 1).

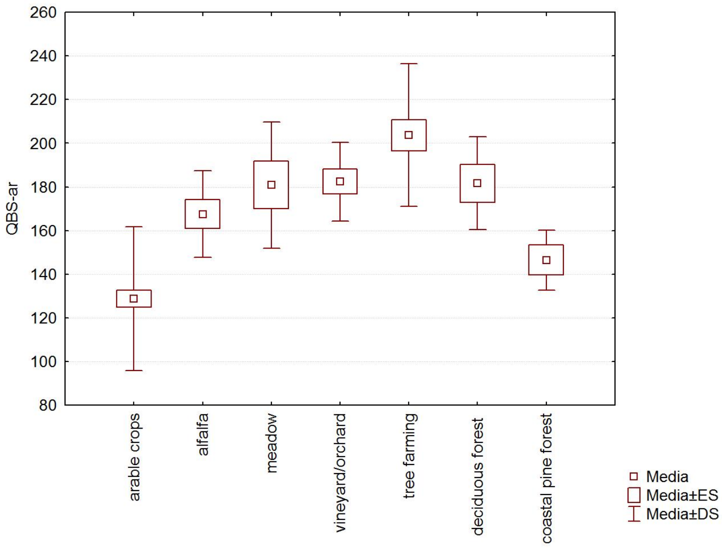


Figure 3: QBS-ar index in relation to land uses in plain areas; 2012-2018

Table 1: Post hoc, Tuckey test, differences in the QBS-ar depending on land use in plain areas. In red bolt significant differences (p-value>0,05)

land use	arable crop	alfalfa	meadows	vineyard orchard	forest tree farming	deciduous forest	coastal pine forest
arable crop		0,095721	**0,022506**	**0,001522**	**0,000026**	**0,040716**	0,982495
alfalfa	0,095721		0,982934	0,945157	0,14873	0,984455	0,958017
meadows	**0,022506**	0,982934		1,000000	0,796638	1,000000	0,680934
vineyard/orchard	**0,001522**	0,945157	1,000000		0,700611	1,000000	0,633421
forest tree farming	**0,000026**	0,14873	0,796638	0,700611		0,870421	0,106394
deciduous forest	**0,040716**	0,984455	1,000000	1,000000	0,870421		0,656195
coastal pine forest	0,982495	0,958017	0,680934	0,633421	0,106394	0,656195	

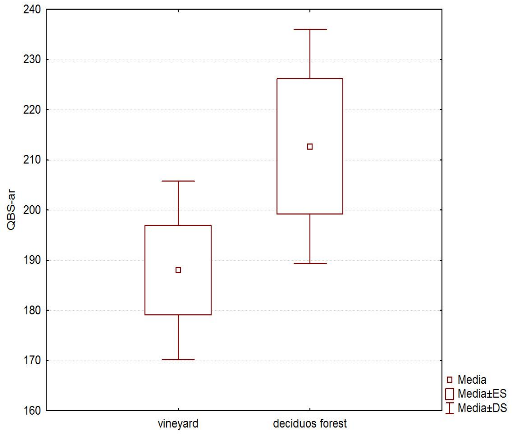
It can be seen that among land uses, arable crops differs from all, it has the lowest QBS-ar values (between 80 and 150), whereas meadows (above 150) proves to be a good biodiversity pool (Menta et al. 2011). In orchards and vineyards the soil between the rows was grass covered therefore showed QBS-ar high values (between 150 and 200), despite heavy machinery passages and phytosanitary treatments. Forest tree farming was found to be the richest habitat (index between 180 and 220) thank to low human impacts and high biodiversity shrub and tree species.
The lowland wood (planted in the 80's on an agricultural area) examined has QBS-ar values lower than forest tree farming due to lack of herbaceous vegetation. Sandy soil texture in "coastal pine wood" is an inhospitable environment to soil fauna. Looking at microarthropod communities (density of taxa per square meter), "Mites" is the largest group, followed by "Collembola" and "Hymenoptera" (table 2). Larvae of "Coleoptera", "Diplura" and "Chilopoda" are present in low percentages. "Pseudoscorpiones" can only be found in meadows and, rarely, in the vineyard.

Table 2: Percentage of each taxon in arable crops and meadows

	arable crops	**meadows**
taxa	**%**	**%**
Pseudoscorpiones	**0**	**0,6**
Araneae	0,5	0,5
Acari	48,6	**49,5**
Isopoda	0,3	**2,0**
diplopoda	**1,3**	0,7
Pauropoda,	**0,9**	0,3
Symphyla	1,0	**1,8**
Chilopoda	0,7	**0,9**
Protura	**0**	**0,5**
Diplura	1,5	**2,4**
Collembola	**35,4**	17,3
Psocoptera	**0**	**0,6**
Hemiptera	0,4	**1,2**
Coleoptera	**0,7**	0,3
Coleoptera larvae	**2,2**	1,3
Hymenoptera	4,3	**12,3**
Diptera	0,8	**0,3**
Diptera larvae	**1,3**	0,2
Thysanoptera	**0**	**0,8**

The effect of some soil parameters was additionally tested (texture, pH and organic carbon): only coarser soil texture and high soil salinity were found to provide a lower biological quality.

Hilly and mountain environment
In 2018 the monitoring network was implemented with two stations in hilly areas (<700 m asl) and four stations in mountain areas. In hilly areas vineyard and deciduous forest (chestnut, maple, alder and ash) have been studied. Deciduous forest showed higher QBS-ar index (average 213) and number of arthropod, but differences were not statistically significant, probably due to the short period of observation monitoring (figure 4). Deciduous forest with calcareous substratum (average 240) presents biological quality higher than deciduous forest with acidic substratum (average 190).



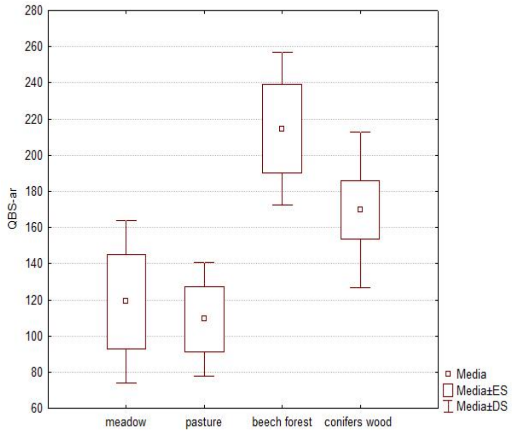


Figure 4: QBS-ar index in relation to land use in hilly areas

Figure 5: QBS-ar index in relation to land use in mountain areas

In mountain areas most common forest land uses were studied: beech forest and conifer wood (over 1100 m asl). In plain areas, meadows and pastures were considered. Despite the few data available being at an initial stage of monitoring it is quite clear that forests (values between 170 and 215) present biological quality higher than meadows (average 115) that are more “disturbed” (livestock grazing for example). Due to the acid litter, soil of spruce wood (170) is less hospitable for the microarthropod community than beech forest (215, figure 5).

Discussion

In plain areas the main factor influencing QBS-ar index is land use: arable crops have the lowest QBS-ar index, number of taxa and density per square meter. Among crops, wheat has the highest QBS-ar index (average 144), soybean the lowest (average 118), corn and rapeseed have intermediate values (average 130). These values were found for usual agricultural practices, but can be modified by the agronomic practices.

In crops less disturbed by farming processes (alfalfa, vineyard, orchard, meadow and forest tree farming) a greater porosity of soil lead to high values of QBS-ar. High biodiversity of plant species makes forest tree farming the richest habitat among agricultural land uses. Lowland woods have intermediate QBS-ar values (average 182 and lower number of taxa) compared to forest tree farming because of litter and the shadow of “high-trunk tree” (limiting the growth of grass). Coastal pine wood has QBS-ar index not very high (average 147) because of thick litter, soil sandy texture, poor undergrowth and problems regarding salinity.

In the hilly areas the highest biological value of natural environments is confirmed compared to the agricultural environment (vineyard). In the deciduous forest probably the pH of the substratum (calcareous or acid) influences indirectly the growing vegetation and directly soil fauna.

In mountain areas most common forest land uses were studied and in plain areas, meadows and pastures were considered. Forests present biological quality higher than meadows as livestock grazing limits arthropod development in soil.

Regarding vegetation, the conifer forests (spruce, white fir) have a lower QBS-ar index value than beech forest, as beech forest litter is more hospitable for microarthropod than conifer wood litter.

Future studies will be focussed on how the substratum (calcareous or acid) influences the soil fauna.

Conclusions

Since 2012, the soil biological quality monitoring activity was systematically carried out in four plain area stations. In 2018 two stations were added in hilly areas (altitude between 400 and 700 m asl) and four

stations in mountain areas (>700 m asl). All monitoring stations are representative of Veneto region habitats concerning land use, soil and substratum characteristics and climatic conditions.
Reference QBS-ar values have been established in different Veneto region land uses; the index was found to be helpful to highlight potential soil degradation or pollution. As reported in other studies, arable crops have the low QBS-ar values due to the environmental impact of farming. It has been confirmed that meadows are a reservoir of biodiversity. The same biological richness found in orchards and vineyards (despite the heavy machinery treading and phytosanitary treatments) is due to grass cover between rows.
In the agricultural land uses, the coexistence of different habitats has the higher protective value for biodiversity (Romero-Alcaraz and Avila 2000); in the same direction go practices preventing landscape simplification as farming hedges and wooded areas.
To assess impact of tillage on biological quality, a study has begun on different soil working techniques like minimum tillage or sod seeding, trying to evaluate differences in biodiversity versus conventional tillage.

Acknowledgements

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