ETHOIKOS

TEACHING AID - EVALUATION OF BIOLOGICAL SOIL QUALITY

Aim

The overall goal of this educational project is to show school children that soil is alive and that human activities have an impact on soil biodiversity and ecosystem health. This is achieved by assessing the biological quality of soils (in English also referred to as BSQ: Biological Soil Quality) subject to different land uses, and placing the results within the context of biodiversity conservation, land management, and the impact of human activities on soil. To this end, we have chosen the Biological Soil Quality-arthropods (QBS-ar) index, developed by Parisi (Parisi, 2001, Parisi et al. 2005). This index relates soil vulnerability to the biodiversity of its fauna, evaluating soil health through the study of soil organisms (pedofauna or edaphic fauna), in particular microarthropod communities. Methods and materials used in this teaching aid are partly based on a master's degree thesis (Evaluation of the conservation status of edaphic fauna by means of the Biological Soil Quality Index QBS, Antonella Martini, University of Rome La Sapienza, 2006).

QBS-ar method (Biological Soil Quality-arthropods)

The QBS-ar method is based upon the concept that soil fauna is particularly sensitive to land management practices and environmental stress. Soil microarthropods are effective bioindicators of soil quality, as they respond to changes in the soil environment. They are easy to sample and are relatively easy to classify at the level required by the QBS-ar method. This method applies the concept of life-form (ecotype), i.e. the set of organisms that have adapted to specific environments, whose morphological characteristics are the result of biological adaptation. Different groups of organisms have different degrees of adaptability to habitat changes. In particular, organisms that spend their entire lifecycle in soil are the most sensitive to changes in the soil environment. Under environmentally stressed conditions, the most specialised soil-dwellers disappear. As a result, healthy soils contain a higher number of microarthropod groups morphologically better adapted to soil life than low quality soils. QBS-ar experimental work involves the identification, at the level of order or class (but not species), of microarthropods collected in soil samples, and it does not require highly specialised taxonomic classification. It is carried out by attributing scores, defined as the EMI, 'Ecomorphological Index', to each group of organisms observed in the soil samples. EMI values are proportional to the degree of adaptation of a group to life in the soil, and range between a minimum value of 1 to a maximum of 20. EMI 1 is given to organisms that live on the soil surface, and EMI 20 to life-forms highly specialised to life in the deeper layers of the soil. The QBS-ar value of a given sample, the biological quality

index of the soil examined, is the sum of the highest EMI values recorded for each group of organisms in that sample (only one EMI score for each group is included in the calculation). Samples from high quality soils have the highest QBS-ar values. The quantity of microarthropods found in the sampled soils is not taken into account in the analysis.

PROJECT PHASES

Choice of land management types for QBS-ar assessment, and of sampling sites.
Sample collection.
Extraction and identification of the edaphic fauna.
Data recording, determination of EMI values, and calculation of QBS-ar.
Classification of the soils examined, according to the Biological Soil Quality Index (QBS-ar).
Discussion of results and conclusions.

ACTIVITIES IN THE CLASSROOM

Choice of environments and sampling sites

During a participatory classroom session, students will be asked to consider and discuss the environments they are familiar with and to decide which land use types they would like to analyse for the biological quality of soils assessment. It is important that the environments they choose differ in land management type, soil characteristics and vegetation coverage (e.g., a woodland area, a wheat field, an olive grove, a pasture). Suitable sampling sites will then be selected for the collection of soil samples. Sampling sites should ideally be chosen within land uses typically represented in the local territory, e.g., woodland, non-cultivated land, agricultural land under mixed cropping or monocropping, organic farmland, etc. Soils from different environments in public parks or municipal gardens, e.g., a wooded area, a meadow, a flowerbed and an orchard, would be suitable for the analysis, in case a class field trip is not possible.

FIELD WORK

Collection of soil samples

One or two sampling sessions shall be carried out at each sampling site on the same day, at homogenous points, and if possible at a short distance from each other. Sampling points must be representative of the sampling site (reflect as much as possible the characteristics of the site) in order to reduce the likelihood of obtaining biased samples. It is important that each sample contains approximately the same amount of soil. At each sampling site, students will be asked to fill out a sheet (TA-BSQ_Field_Data_Sheet_EN_v1.0.pdf) and record their observations on the sampling site and the examined soils. This sheet can be used in the last phase of evaluation and discussion of results. It is important that students record all observations, even if some information may at first seem banal. Soil samples are collected with a bulb-planting tool, which can be bought in garden centres and hardware stores.

Soil sampling instructions for the students are provided in a separate file on sampling methodology (TA-BSQ_Soil_Samples_Collection_EN_v1.0.pdf).

LAB ACTIVITES

Lab activities are carried out during four or five consecutive days following sampling. To meet schools' didactic and operative needs, and in order to minimise students' travelling time, a temporary lab may easily be set up on the school premises.

The soil biology lab necessary for the application of the QBS-ar method should be set up as follows:

1. A simplified version of the Berlese Tullgren funnel (or Berlese Trap), for the extraction of the edaphic fauna from soil samples, one for each analysed soil. This consists of:
   - 1.1 A funnel, with a diameter of 30 cm;
   - 1.2 A mesh cylinder sieve, diameter 25 cm, height 16 cm, mesh size 2 mm, placed inside the funnel;
   - 1.3 A glass container with a diameter of 10 cm, positioned below the funnel, for fauna collection.
   - 1.4 A table lamp with a flexible arm, fitted with a 40 W light bulb.

   Simplified Berlese-Tullgren funnels can be bought in specialist shops, or may be easily assembled for this purpose, with materials obtained from dairy production equipment providers.
2. Stereomicroscopes, for the observation and classification of the extracted organisms.
3. Petri dishes of various sizes, tweezers, needles and fine-tip paintbrushes.
4. Dichotomous keys and other didactic materials for arthropod identification, and for assessing their degree of adaptation.
5. Data recording sheets for noting observations and results (provided in this teaching aid).

Extraction of edaphic fauna

The process of extracting the edaphic fauna must be initiated immediately after soil sample collection. First, students place the soil samples inside the extractor sieves. Soil samples collected from the same sampling site are merged and placed into the same extractor. Each extractor is labelled with the sample collection date, the name of the sampling site, and the type of environment analysed.
Once this is done, the lamps are turned on and positioned above the extractors (as shown in the photo) so that they are approximately 20 cm from the samples. The lamps must remain turned on, day and night, during the entire extraction phase.
Extraction takes place because the heat generated will dry out the topsoil, creating a desiccation gradient in the sample, and the edaphic fauna will move towards the more humid, cool and dark bottom, falling into the glass container positioned beneath the extractor. Placing small pieces of damp kitchen towel in the glass containers would help to keep the fauna alive for as long as possible. The time needed to complete the extraction depends on the size of the samples.

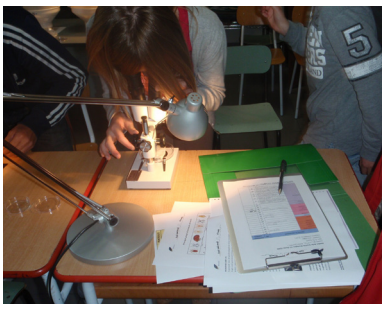
Analysis of edaphic fauna extracted from the samples

Students analyse the edaphic fauna extracted from the samples over three or four consecutive days, after transferring the contents of each glass container into the petri dishes. The containers are emptied, cautiously, once a day, and each sample site examined separately. Since most soil-dwellers are not visible to the naked eye

(with a few exceptions, such as ants and some scolopendra), the petri dishes will appear to contain no living organisms. The edaphic fauna can be observed through the stereomicroscopes, and organisms identified at order or class level. Students can determine the degree of adaptation of the life-forms observed, and attribute the appropriate EMI values to each group of organisms they have identified with the help of the didactic materials provided in this teaching aid.

Data recording, evaluation of EMI values and calculation of QBS-ar

On each lab session day, for every soil sample examined, students fill out the microarthropod recording sheet provided in this teaching aid (TA-BSQ_Microarthropod_Recording_Sheet_EN_v1.0.pdf). This data sheet is a checklist of the major microarthropod groups of typical Italian fauna. It is designed as a multi-coloured table, to provide students with an immediate and intuitive sense of the degree of evolutionary affinity between groups. Orders and classes, in which organisms are placed, are listed in the left-hand side column of the table. Text boxes of the same colour highlight groups belonging to the same class and different orders, or to the same phylum and different classes. The nomenclature of groups has been simplified for didactic purposes. The recording sheet shows the EMI scores that can be assigned to each group. As mentioned above, EMI values are based upon the degree of adaptation to life in the soil and vary from 1 to 20. Organisms with the highest level of adaptation are given the maximum EMI score. As a general rule, life-forms within a group exhibit a similar level of adaptation. Therefore, each group is assigned a single EMI value. For example, soil-dwelling isopods score an EMI of 10, while mites are more specialised and have an EMI value of 20, regardless of the specific features of the organisms observed (such as size, form, colour, appendixes). A few edaphic groups, such as springtails and centipedes, include life-forms with different EMI scores, due to the high variability in their degree of adaptation. For example, springtails have EMI values ranging between 1 and 20. The recording sheet guides the students in the attribution of EMI values to organisms that belong to groups with variable EMIs, by defining sub-groups with specific adaptive traits characteristic of life in the soil. The life-forms are assigned different EMI values based upon the observation of these adaptive traits. The sub-group with the highest level of adaptation has the maximum EMI score. A different method is applied for the attribution of EMI values to beetles. The recording sheet lists the typical adaptive features of soil-dwelling beetles, and points are attributed to each of these features. The EMI of beetles is equivalent to the sum of the values of each adaptive feature in the life-form observed.



On each data sheet, students record the microarthropod groups observed and assign the EMI indexes to each group. When the daily data recording is completed for a sample, the QBS-ar value is calculated for that sample. The QBS-ar is the sum

of the highest EMI values recorded for each group of organisms in that sample (e.g. if a sample contains Collembola with EMI scores of 6, 2 and 10, only the highest EMI of 10 will be included in the sum).

At the end of the extraction process (which lasts three or four consecutive days) the daily results obtained for each soil sample are compiled and entered onto one recording data sheet (TA-BSQ_Microarthropod_Recording_Sheet_EN_v1.0.pdf). The total QBS-ar value of each sample is the sum of the highest EMI values recorded for each group of organisms throughout the data recording period.

QBS-ar reference values

Land use type	QBS-ar
Woodland	150-250
Permanent pasture/meadow	90-180
Lucerne pasture (Medicago sativa)	60-180
Wheatfield	60-100
Cornfield	30-40

As a final step, students enter the compiled final data onto a comparative data sheet (TA-BSQ_Summarising_sheet_EN_v1.0.pdf). This sheet will provide an overview of results, allowing students to more immediately evaluate the differences between environments, both relative to QBS-ar values, and to the distribution and levels of adaptation of the sampled soil fauna.
The QBS-ar values obtained for each type of soil analysed, can then be compared with reference values, typically detected for specific land uses, using the scheme provided in this teaching aid (TA-BSQ_Evaluation_of_Soil_Quality_Classes_EN_v1.0.pdf). The higher the QBS-ar values, the better the quality of the soils. Classes of biological soil quality can be attributed to each land use type by looking at the presence or absence of highly specialised groups (euedaphic) for samples with different QBS-ar values. Classes of biological soil quality range from 1 to 7, where 7 is the highest quality.

Discussion of findings

Thanks to this project, students will have the opportunity to apply a method widely used in research and environmental management. This work will give them a chance to observe that more specialised organisms are also those most vulnerable to disturbances and changes in their environment. Through field and lab activities, students will gain an understanding of why and how some organisms may be used as bioindicators, and how land management practices affect biodiversity. By examining soil samples, students will experience, first hand, the fact that soil is alive, and that woodland soils host higher biodiversity than monoculture fields. They will find out that in stressed soils, with a decrease in biodiversity, the frequency of some life-forms increases, while that of others decreases. Overall, this project will provide students with an opportunity to reflect upon the fundamental role that soil plays in human life. They will get an understanding of how soil is formed, and what function edaphic fauna plays in this process, and in maintaining the soil's capacity to sustain plant growth, which is crucial for our survival. The project will provide an opportunity for discussion, in the classroom, on the impact of human activities on soil quality and health, and on the value and significance of sound land management strategies for sustainable land use.

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