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Editorial

Special issue on “Bioindication in soil ecosystems”: Editorial note

1. Introduction

Soils are home to a vast and still poorly known diversity of organisms that perform essential ecosystem functions. Soil communities also respond to and can reflect ecological gradients and perturbations, including direct and indirect human impact [1,2]. Soil quality indicators are physical, chemical, and biological properties, processes, and characteristics that can be measured and interpreted to monitor patterns and changes in the soil.

Among the different soil quality indicators, bioindication, the use of the information contained in the biological properties and processes, represents a powerful approach for assessing and interpreting the impact of natural or anthropogenic perturbations in soil ecosystems. Living organisms provide information on the cumulative effects of environmental stressors and as such bioindication is complementary to direct physical and chemical measurements. Bioindication is thus a highly valuable tool for soil managers.

An important challenge for soil scientists and managers is to distinguish “real” changes in soil quality from the background generated by the “natural” soil heterogeneity and dynamics. Determining the sensitivity and resolution of bioindicators requires in depth descriptive and experimental studies, and of course knowing the identity of the organisms, which, for soil organisms, is certainly not trivial.

This special issue illustrates how soil organisms can provide valuable information on the status and functioning of a soil, and how this information can be used to assess the impact of environmental stress and human activities on soils. The contributions in this issue bring new insights into the development and application of bioindication systems, in a multi-disciplinary perspective toward improving our current understanding of bioindication in soil ecosystems.

This special issue includes fifteen research studies and reviews i) on the response of different taxonomic and functional groups of soil organisms (Fig. 1) to natural ecological perturbations and anthropogenic gradients, ii) on the selection of bioindicators across different taxonomic groups, and iii) on the integration of biodiversity indices and on methods and new approaches to characterize organism diversity and community structure in soils. Several articles highlight the usefulness of integrative approaches that combine different methods and groups of organisms to assess the status of soils. When measuring and interpreting the response of soil organisms, these approaches often benefit from on-going advances in molecular ecology, including high-throughput DNA sequencing and metagenomics.

2. Response of taxonomic and functional groups of soil organisms to natural ecological gradients

Two studies assess the response of soil organisms to ecological processes in wetland soils. Bullinger-Weber et al. [3] report the impact of flood deposits on earthworm communities, using both taxonomic and functional categories, in a subalpine floodplain while Yu and colleagues [4] assess the responses of soil bacterial communities along a vegetation succession of the Yellow River estuary. The results of the latter study based on Biolog EcoPlates® and pyrosequencing data reveal that bacterial communities are significantly correlated with vegetation and soil characteristics. These two studies illustrate the potential of bioindicators to follow natural disturbance and resilience of dynamic ecosystems across ecological gradients.

3. Impact of farming practices and anthropogenic disturbances on soil organisms

In this section, Imfeld and Vuilleumier [5] give an overview of current research and critical issues on the responses of soil bacteria to pesticide exposure, and discuss the most useful techniques for quantifying the diversity and resilience of soil bacterial communities exposed to pesticides. Heger et al. [6] compare the impacts of organic and conventional farming practices on testate amoebae and diatoms in a long-term trial. In another study, Liu et al. [7] examine the dynamics of nematode communities and functions (decomposition) in soils subject to treatments with heavy metal (copper) or pest control chemical treatment (chloroform fumigation), and/or heat and drying shocks. Finally, Hauser et al. [8] highlight the potential of surface cast depositions of earthworm as indicator of soil quality in West and Central African Ultisols and Alfisols.

4. Integrated soil bioindicators and integrating biodiversity in soil quality monitoring

There is no such thing as the universal (bio)indicator. Given the complexity of the soil environment and the broad diversity of soil organisms, bioindication approaches based on single taxonomic or functional groups of organisms will have a limited range of applications. Overcoming this limitation requires the integrated use of several indicators, which take advantage of the contrasting sensitivity of different groups of organisms to environmental perturbation, to evaluate the impact of soil management practices and pollution.

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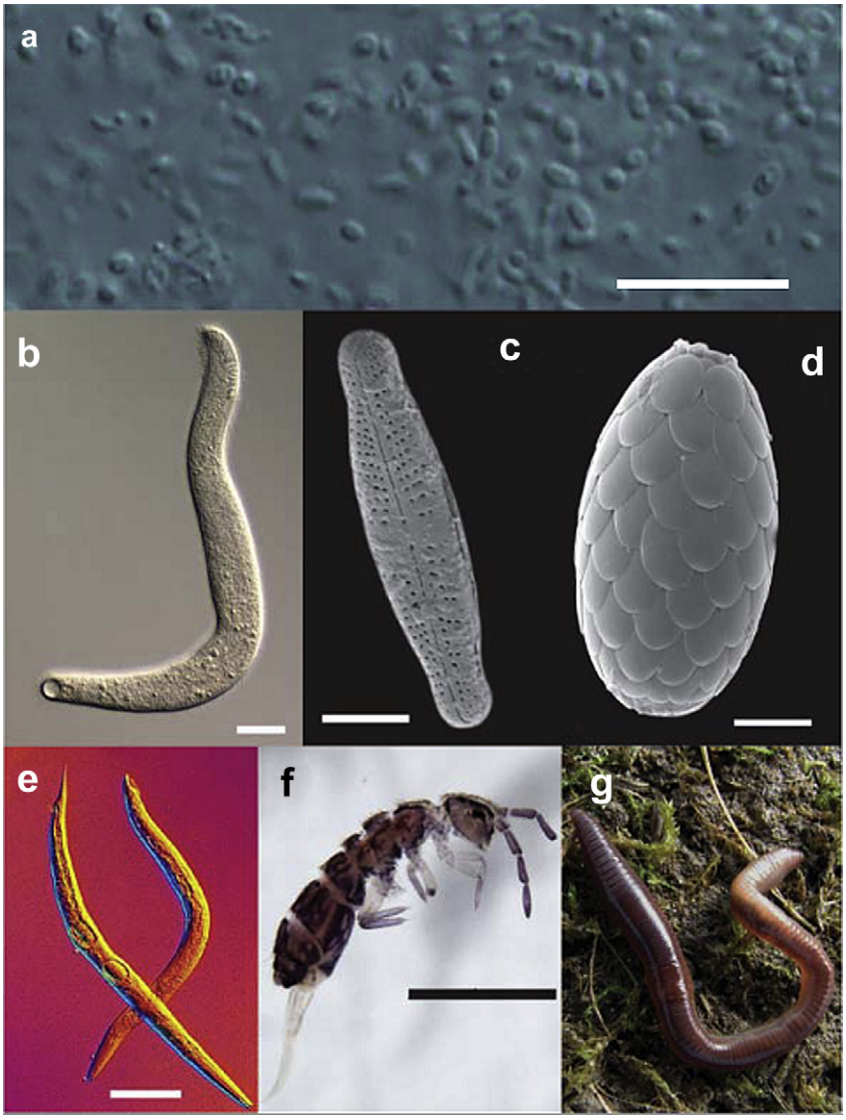

Fig. 1. Light and scanning electron microscopy pictures illustrating different groups of soil bioindicators studied in this special issue: a) Bacteria, b) Ciliate (*Arcuospathidium* sp), c) Diatom (*Stauroneis thermicola*), d) Testate amoeba (*Tracheleuglypha dentata*), e) Nematode (*Caenorhabditis* sp.), f) Collembola and g) Earthworm (*Lumbricus rubellus*). Scale bar equals approximately 10 μm in a, 25 μm in b, 3 μm in c, 10 μm in d, 100 μm in e and 1 mm in f. Photograph credits: a) Naoji Yubuki, b) William Bourland, c) Thierry Heger, d) Michèle Vlimant, e) Bryan Griffiths, f) Charlène Heiniger and g) Claire Le Bayon.

Three studies of this special issue present such cross-taxa indicator approaches. Keith et al. [9] jointly explore the diversity of bacteria, fungi, mycorrhiza, nematodes, mites, earthworms and ants, and highlight the linkage between key groups of soil taxa and land use in Ireland. Similarly, Cluzeau et al. [10] evaluate the relationship between land use and agricultural practices and the diversity of macro-invertebrate, acari, collembola, nematodes and micro-organisms in Brittany. Finally, Payne et al. [11] show that vegetation is affected by nitrogen fertilization, whereas no clear effect could be detected for testate amoebae (microbial heterotrophs) and enchytraeids (mesofauna).

Ideally, in the future, integrative frameworks will enable land managers and users to evaluate, at various scales, the quality and health of soils together with other natural resources. It would however be naïve to believe that this vision will be easily transformed into reality. Havlicek [12] reviews the use of bioindication in the context of national soil protection policy. Selection of bioindicator tools is not only determined by science but also depends on other constraints, especially financial. Likewise the implementation of soil protection policy and the management of soils should account for its complex and multi-functional environmental and societal roles but must rely on simple indicators. Yet the challenge in the field of soil bioindication is to translate “complex thinking” into “simple acting”!

5. Novel approaches for characterizing the composition and functional traits of soil organisms

The broad use of soil organisms as bioindicators is currently limited to a sub-set of the soil biota because basic knowledge of soil taxonomy is limited for several groups of organisms and reliable methods to characterize soil communities remain scarce. Five papers of this special issue focus on new approaches to overcome these limitations, using taxonomic and functional traits and new molecular methods. Fournier et al. [13] explore the relationships between classical diversity indices and