Integrated Environmental Assessment and Management

INDICATORS FOR MONITORING SOIL BIODIVERSITY

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Introduction

The EU Soil Strategy (EC 2006a) describes the European Union (EU) soil policy in general terms and the draft Soil Framework Directive (SFD; EC 2006b) proposes the legally binding elements of that policy. In these documents, the EU Commission identifies 8 main threats to soil. The EU FP6 project ENVASSO (Environmental Assessment of Soil for Monitoring) aimed to design a single, integrated, and operational set of EU-wide criteria and indicators to provide the basis for a harmonized, comprehensive soil and land information system for monitoring in Europe. Here, a proposal is made for a set of suitable indicators for monitoring the decline in soil biodiversity (Bispo et al. 2007). These indicators were selected both from a literature review and an inventory of national monitoring programs. Decline in soil biodiversity was defined as the reduction of forms of life living in soils (both in terms of quantity and variety) and of related functions, causing a deterioration of one or more soil functions or ecosystem services. Whereas literature review allows the identification of about 100 possible indicators, the inventory of existing monitoring networks shows that few indicators are actually measured.

For monitoring application it was considered in ENVASSO that only 3 key indicators per soil stress were practical. For indicating biodiversity decline it was difficult to arrive at a small set of indicators due to the complexity of soil biota and functions. Therefore, 3 stringent criteria were applied: an indicator should 1) have a standardized sampling and/or measuring methodology; 2) be complementary to other indicators; and 3) be easy to interpret at both scientific and policy levels.

Proposed set of indicators

The key indicators selected were chosen as representative of 3 very different taxonomical groups and functional levels: a) abundance, biomass and species diversity of earthworms—macrofauna; b) abundance and species diversity of Collembola—mesofauna; and c) microbial respiration. Biodiversity (species level) as well as ecological functions (or services) of soil organisms are covered by these groups and levels. Of course, in principle, when considering soil biodiversity, all soil organisms and the biological functions that they provide are important and should be assessed. However, for priority level I (Table 1) 3 indicators were selected to act as surrogate measures for overall decline in biodiversity. Depending on the

Table 1. Priority level of indicators for decline in soil biodiversity (ENVASSO)

Key issue	Groups of species	Level I (all core points of the monitor-ring network)	Level II (all core points or selected points relevant for specific issues and availability of resources)	Level III (optional)
Species diversity	Macrofauna	Earthworm species	All macrofauna	
	Mesofauna	Collembola species (Enchytraeidae if no earthworms)	Acarina suborders	Activity based on litter bags or on bait lamina
	Microfauna		Nematode (functional) diversity based on feeding habits	Protista
	Microflora		Bacterial and fungal diversity based on DNA/PLFA[a] extraction	
	Vascular plants			For grassland and pastures
Biological functions	Macrofauna			Macrofauna activity (e.g., biogenic structures, feeding activity)
	Mesofauna			Mesofauna activity
	Microflora	Soil respiration	Bacterial and fungal activity	

[a] PLFA = phospholipid fatty acids.

availability of resources and specific requirements, this minimum set of indicators could be extended to include priority levels II and III (Table 1); e.g., all macrofauna, nematode diversity, bacteria and fungi diversity and activity, faunal activity as biogenic structures, or feeding activity. The 3 priority level I selected indicators are as follows.

1. Earthworm diversity, abundance and biomass (or enchytraeids if no earthworms are present)

Earthworms are considered "soil engineers" due to their beneficial influence on soil properties. Earthworms positively affect soil structure, aeration, water infiltration and water holding capacity, litter decomposition, and nutrient cycling. They also decrease run-off and erosion by their burrows and casts deposited on the soil surface creating a soil surface roughness. They can increase soil fertility and help to build up good soil structure. Therefore, earthworms are very good indicators for soil degradation in most soils. They are rare or even missing in acid and water-logged soils where they are replaced by enchytraeids, a group of taxonomically related but usually smaller worms.

2. Collembolan diversity and abundance

Collembola (commonly known as springtails) are one of the most studied groups in soil ecology since they have very high abundance and diversity in soil and litter. They take part in the process of organic matter decomposition and mostly feed on fungal hyphae, thus they play an important role as facilitators of microbial succession during decomposition. They are sensitive to physical soil degradation caused by several pressures (e.g., land-use intensity, nonsustainable agricultural and forest practices).

3. Respiration in soil is linked to the mineralization of organic matter and litter and thus provides insight into carbon cycling

Due to their abundance and metabolic diversity, bacteria and fungi are the key players in this process: organic substances are oxidized to carbon dioxide and water, with concurrent uptake of oxygen for aerobic microorganisms, and nutrients are remineralized and made available for plant growth. Changes in microbial diversity of key processes will potentially affect soil respiration. Soil respiration is measured by the determination of oxygen consumption and/or by carbon dioxide release.

Pilot testing of the proposed indicators

Procedures and protocols, based upon current ISO standards (Römbke et al. 2006) and adapted for assessment at a European scale, were tested in pilot sites established in France, Ireland, Portugal, and Hungary to assess the efficiency of the 3 indicators of decline in soil biodiversity. Standards were followed, for example, in terms of sampling time and design. The results obtained proved the effectiveness of each indicator and their sensitivity to detect change across a range of land-use categories at a European scale (Bispo et al. 2007). For example, it could be shown that parameters such as the total number of species is relatively stable when performing 2 consecutive samplings; whereas abundance and biomass are more variable. Baselines (i.e., reference values) for the diversity and abundance of the 3 indicator groups are not defined on the European scale, but ranges were published for selected land use and soil type categories in The Netherlands (Rutgers et al. 2009).

Outlook: How to proceed

In order to put this proposal into practice, activities on 3 different levels have to be performed. First, politically, basic requirements for soil protection in the EU have to be agreed on; i.e., the SFD has to be adopted. Second, scientifically, details of the monitoring program have to be defined. For this purpose, an EU working group on soil biodiversity was established at the Joint Research Centre (Gardi et al. 2008). Third, practically, a systematic sampling needs to be performed across the EU on main land-use and soil-type categories to derive baseline and threshold values for soil biodiversity.

REFERENCES

Bispo A, Peres G, Cluzeau D, Graefe U, Römbke J, Rutgers M, Fuchs M, Sousa JP, Schulte R, Dombos M, Simon B, Gál A, Cortet J, Chaussod R, Ritz K, Creamer R, Winding A, English M, Boixadera J. Rubio JL. 2007. ENVASSO (Environmental assessment of soil for monitoring) WP 5 – Decline in soil biodiversity. EU Contract No. 022713, 22 pp.

[EC] European Community. 2006a. Proposal for a directive of the European Parliament and of the council establishing a framework for the protection of soil and amending Directive 2004/35/EC. COM(2006) 232 final. http://ec.europa.eu/environment/soil/pdf/com_2006_0232_en.pdf. Accessed 23 July 2009.

[EC] European Community. 2006b. Thematic strategy for soil protection. COM(2006)231 final. http://ec.europa.eu/environment/soil/pdf/com_2006_0231_en.pdf. Accessed 23 July 2009.

Gardi C, Montanarella L, Arrouays D, Bispo A, Lemonceau P, Jolivet C, Mulder C, Ranjard L, Römbke J, Rutgers M, Menta C. 2009. Soil biodiversity monitoring in Europe: ongoing activities and challenges. *Eur J Soil Sci* (forthcoming).

Römbke J, Sousa JP, Schouten T, Riepert F. 2006. Monitoring of soil organisms: A set of standardised field methods proposed by ISO. *Eur J Soil Biol* 42:S61–S64.

Rutgers M, Schouten AJ, Bloemb J, van Eekeren N, de Goeded RGM, Jagers op Akkerhuis GAJM, van der Wala A, Mulder C, Brussaard L, Breure AM. 2009. Biological measurements in a nationwide soil monitoring network. *Eur J Soil Sci* (forthcoming).