SET OF SOIL QUALITY INDICATORS

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Soil quality is its ability to function as a living ecosystem, supporting agricultural production while preserving biological functions and ecosystem services. Several biological and agronomic indicators can be used to assess the impact of farming practices on soil life and sustainability.

WHAT ARE THE RELEVANT BIOINDICATORS TO ASSESS THE BIOLOGICAL QUALITY OF THE SOIL?

A biological indicator is a tool that reflects the activity, diversity or functionality of living organisms in the soil. These indicators make it possible to:

- measure the impact of farming practices on soil life;
- assess the soil's capacity to provide ecosystem services (fertility, carbon storage, water regulation, etc.);
- identify biological misfunctions or risks.

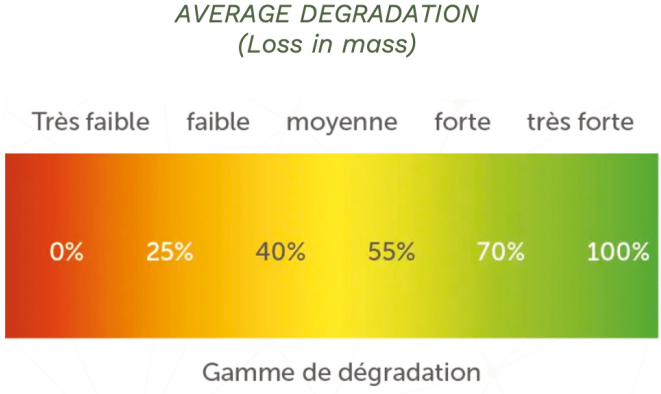
The biological quality of a soil can be assessed using biological and agronomic indicators, such as (i) soil physico-chemistry and structure, to characterise habitat quality; (ii) organic matter decomposition rate, to assess biological activity; (iii) microbial abundance and diversity; (iv) nematode abundance and diversity; and (v) earthworm abundance and diversity, to characterise the state of the living organisms present in the soil.

The following sections explain the main indicators.

HOW SHOULD SOIL BIOLOGICAL ACTIVITY BE MEASURED?

The biological activity of the soil, in particular its capacity to decompose organic matter, can be assessed using a simple field test using a litterbag such as the LEVAbag®. Other methods exist, such as the tea bag test or 'soil your undies challenge', giving the same result, but they are not standardised and therefore less scientific.

The kind of test is used to measure the rate of degradation of a reference organic matter in agricultural soil. Evaluation of the degradation of litter (above or below ground) in a cultivated environment has shown that the litterbag method, on which the indicator is based, is relevant for measuring the decomposition of crop residues and the impact of agricultural practices. Bags of a given size and mesh (pores that allow organisms smaller than 1 mm to pass through) filled with standardised organic matter (organic straw) are buried (in February–March) at a depth of 10 cm for four months, then they are dug up and the loss of mass is measured: the higher the loss of mass, the greater the biological activity (the soil organisms have 'digested' the contents).



HOW IS THE MICROBIOLOGICAL QUALITY OF SOIL ASSESSED?

Analysing the microbiological populations provides information on the biological state of the soil and its functional potential, which is directly linked to the quality and sustainability of production systems. Several indicators provide information on this quality:

- **microbial molecular biomass:** corresponds to the total abundance of soil microorganisms. It is measured by the quantity of microbial DNA extracted from the sample and is an indicator of the impact of soil use;
- **microbial balance:** the ratio between the density of fungi and the density of bacteria. It can reflect disturbances in the soil caused by certain uses or cultivation practices. An imbalance in this ratio reflects a sub-optimal state of biological functioning in the soil. Diversified crop rotations, intermediate crops, organic fertilisation and reduced tillage are practices that favour this balance. Fungi and bacteria are quantified by quantitative PCR;
- **microbial diversity:** an indicator of the richness of bacteria and fungi (in terms of the number of taxa), which provides information about the biological functioning of the soil and its resilience. For example, it has been shown that a 30% drop in diversity results in a 15–50% reduction in most major soil functions (Novasol Experts).

Microorganisms have a very short lifespan and their genome is plastic, so they are the quickest to respond to changes (in climate, land use, etc).

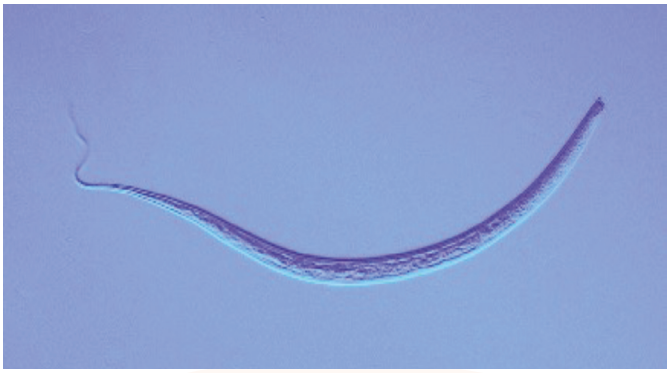
In France, there is a national reference system (INRAe) that can be used to predict a critical threshold and reference values for each indicator (based on 2,200 soils).

WHAT INFORMATION DO NEMATODES PROVIDE?

Soil is a habitat for a wide variety of organisms, including nematodes, microscopic metazoans generally measuring a few millimetres in length and tens of micrometres in diameter. As bio-indicators, nematodes are particularly relevant for assessing the biological functioning of soils, due to:

- their high abundance in a wide variety of ecosystems (between 200 and 20,000 individuals per kilogram of 'ordinary' soil).
- their taxonomic and functional diversity;
- their sensitivity to physical or chemical changes.

In the agricultural context, nematodes are often perceived negatively due to the presence of plant-parasitic species that can cause significant crop damage. However, parasitic species represent only a fraction of the soil nematofauna, the majority being made up of 'free-living', i.e., non-parasitic, nematodes. The functional classification of nematodes according to their trophic group can be used to infer information about soil ecosystem processes. A distinction is made between:



(source : Elisol Environnement)

Nématode

- **plant-feeding nematodes** (obligatory or facultative), indicators of the state of the plant cover and the risk of agronomic losses;
- **bacterivorous and fungivorous nematodes**, which reveal microbial activity and organic matter and nutrient recycling dynamics;
- **higher trophic level nematodes** (omnivores and carnivores), which reflect the ecological integrity of the soil despite human disturbance.

Moreover, nematodes' small size means that entire communities can be analysed from small quantities of soil (generally less than 500 g), making them easier to sample and study in the laboratory.

Find more

WHAT ABOUT EARTHWORMS?

Earthworms are also indicators of soil quality and are often referred to as 'soil engineers'. They play an important role in the degradation and recycling of organic residues in the soil. They create a network of galleries between the surface and the depths of the soil, helping to aerate the soil and facilitating the development and progress of roots.

Around a hundred species have been listed, classified into the ecological categories:

- **Epigeic**

Adult spadefoot (Satchellius mammalis)

Small (1–5 cm) and dark (red, brown). They live on the surface (top 1 cm) and in piles of dead organic matter (forest litter, manure, compost, green waste, sewage sludge, etc.). They dig few or no galleries in the soil. They have a high reproductive capacity and feed on organic waste, helping to break down this dead organic matter (diet: saprophagous). Epigeids are the most exposed to surface action.

• **Anecic**

Adult red-headed beetle *(Lumbricus terrestris)*

Large species, between 10 and 110 cm. Their colours vary from red to brown, with a common gradient of colour from head to tail. They live in the entire soil profile (galleries up to 5 m long). They dig permanent galleries vertically to sub-vertically that are open at the surface, allowing water to infiltrate. They deposit their droppings (castings) on the surface of the soil, increasing the roughness of the surface and limiting erosion. They return to the surface to feed, breaking up organic matter, burying it and mixing it with the ingested soil (diet: saprogeophagous). Aneceic worms are more sensitive to chemical action (weeding) than mechanical action (tillage). There are two main genera of aneceics. Redheads (of the genus *Lumbricus*), or epi-anecic at the juvenile stage, are very reactive to changes in temperature and humidity, and resume their activity when soil moisture conditions are favourable. Their gallery network is not very branched. Epi-anecium need organic matter that is easy to consume (leaves, for example). Blackheads (of the genus *Aporrectodea*) systematically have a period of inactivity between June and August and create a highly branched network of galleries.

Juvenile black-headed anteater *(Aporrectodea giardi)*

• **Endogeic**

Juvenile endo *(Allolobophora icterica)*

Species varying in size from 1–20 cm. They are very lightly coloured to apigmented (grey, pink or green). They live mainly in the top 30 centimetres of soil and dig temporary horizontal to sub-horizontal galleries. They help to create a 'lumpy structure', influencing water retention and infiltration in the soil (diet: geophagous).

Learn more about earthworms

TO FIND OUT MORE

Related links and material

- *Earthworms – architects of fertile soils*, Technical guide FiBL No 1629, 2022. Available at https://www.fibl.org/fileadmin/documents/shop/1629-earthworms.pdf
- *Why use nematofauna as a bioindicator of soil biological functioning?* ELISOL Environnement. Availableat:https://www.elisol.fr/services/pourquoi-la-nematofaune-comme-bio-indicateur-du-fonctionnement-biologique-du-sol/
- *Learning more about earthworms*, EcoBioSoil. Available at: https://projets.ecobio.univ-rennes.fr/opvt/node/4

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