ALTERNATIVE WAYS OF assessing soil quality

Arvalis has assessed the sensitivity of microbiological parameters characterising soil function, that are affordably measurable and produce easily interpreted results.

Several long-term trials have been testing the relevance of various soil bio-indicators and their sensitivity to organic effluent inputs, the presence of covers and soil cultivation. Most are more sensitive to the cropping history over the previous five to ten years than just to the organic carbon and nitrogen dosage.

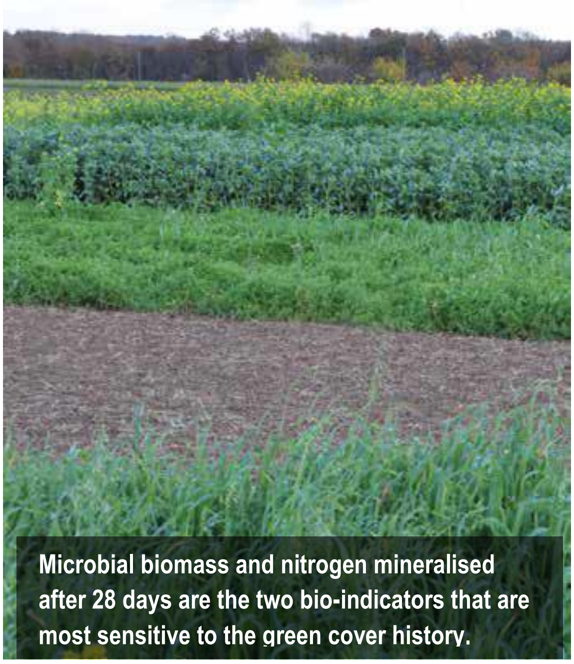
Soil quality is linked to its ability to fulfil certain functions related to the production of plant biomass or the protection of the environment in a given ecosystem.

Four broad biological functions contribute to this quality: organic carbon transformation (residue and soil organic matter decomposition, new molecule synthesis), nutrient recycling (mainly nitrogen and sulphur, the dynamics of which in the soil are linked to those of organic carbon, as well as of phosphorus), soil structure preservation and pest control. Microorganisms in the soil are involved in all those functions and are essential links in the first two.

Finding relevant soil bio-indicators

Today, the scope of an ordinary soil analysis is limited to the management of mineral fertilisation and alkaline mineral enrichment. It is rarely linked to the management of other cropping practices that have a significant impact on soil quality, such as organic enrichment and fertilisation, the establishment of green covers or soil cultivation.

There would be benefits to extending this scope and integrate soil bio-indicators (biological parameters giving information on the state and biological function of a soil). Those parameters must be the most relevant ones in relation to soil function, but also measurable at an affordable price, and the results of the measurements must be easily interpreted.



Microbial biomass and nitrogen mineralised after 28 days are the two bio-indicators that are most sensitive to the green cover history.

Arvalis, in partnership with AURÉA Agrosciences and SEMSE[1], launched a study in 2009 to assess the sensitivity to cropping practices of some bio-indicators that can now be routinely measured by laboratories. Those bio-indicators' reaction to various cropping practices (organic/mineral fertilisation, soil cultivation, nitrate trapping cover crop, etc.) were assessed in an arable cropping context, as well as in a mixed farming (various crops and livestock) system. The study focused especially on whether easily measurable biological parameters could be used as earlier and more sensitive indicators of the way a soil's biological status is evolving than simple organic carbon and nitrogen levels.

Here we will only examine the bio-indicators of two functions: organic carbon transformation and nitrogen recycling. The microbiological parameters examined characterise the abundance, activity and diversity of microbes in the soil. Microbial abundance is estimated by measuring microbial biomass (MB), and microbial activity, through the mineralisation potential of carbon (C_{MIN}28j) and nitrogen (N_{MIN}28j) after a 28-day incubation period and through the enzymatic activity of the FDA hydrolase. Finally, the soil's organic matter is characterised both by its fraction (divided into three categories: 0-50, 50-200 and 200-2000 µm) and its microbial metabolites[2].

This assessment was based on several long-term trial networks. The first network, with three "livestock effluent" trials, was established annually by Arvalis over an eight to ten-year period. Different types of livestock effluent were spread in order to quantify their direct "nitrogen effect", as well as their long-term impact on the evolution of the soil's organic status. A network of three nitrate-fixing intermediate crop trials studied the impact of implementing covers during the intercropping season, compared to bare soil, over a 16-to-19-year period, with a cover every year or every two years. Another trial focusing on green covers compared the impact of the repeated use of the same species versus associating different green cover species, over a period of ten years. Finally, Arvalis's "Boigneville experimental farms" assessed the way bio-indicators were affected by various cropping systems with different crop rotations, fertilisation and soil cultivation.

The impact of various effluents is clearly visible in the soil fraction

Out of all the bio-indicators that were tested, the soil fraction is the only one that shows up specifically the organic input history (raw or composted bovine manure): The extent of the 50-2000 µm fraction is significantly greater with manure inputs.

This fraction is the coarser part of the soil organic matter, with a shorter life span and playing a greater role in supplying nitrogen to the soil. It appears to be sensitive to the type of manure used; in the Jeu-les-Bois trial, the bovine manure composting resulted in a lower proportion of the 50-2000 µm fraction and lower nitrogen supply for the soil by mineralisation (0.49 and 0.6 kg N/ha/day respectively for composted and raw manure).

In the end, all three "effluent" trials show that, out of all the bio-indicators that were tested, coarse carbon and nitrogen fractions best renders the long-term effect of the quantity and type (composting) of product used.

In long-term trials, soil fraction does highlight the annual organic matter incorporation history but not the green cover history.

Covers have an impact on bio-indicators other than fractions

Ten to nineteen years of green cover establishment history during the intercropping period were analysed. The measurements show that repeated establishment of covers during the intercropping season has no significant impact on the organic carbon and nitrogen granulometric composition of the soil.

The quantity of organic carbon and nitrogen supplied by covers after 10 to 19 years would not be great enough to influence this indicator. The nature of the incorporated organic matter may also play a role.

Out of the three trials of the "nitrate-fixing intermediate crop" network, the case scenario that highlighted a significant rise in microbial biomass and organic carbon and nitrogen mineralisation in the top 12 cm of soil (compared with bare soil), was direct drilling as part of the Boigneville trial.

Conversely, the "cover species comparison" trial showed that microbial biomass, carbon and nitrogen mineralisation potential and nitrogen microbial metabolites are different depending on the cover species used. For all four indicators, bare soil gave the lowest figures. The highest figures were achieved by species that have absorbed more nitrogen on average over the whole trial period. MB and N_{MIN}28J are the two most sensitive bio-indicators.

Bio-indicators highlight differences between cropping systems

On the Boigneville experimental farms, samples taken from the top 20 cm of soil in "sensitive", integrated and organic systems, and from the top 10 cm as well as from the 10 cm to 20 cm depth layer in two min-till systems (direct drilling into cover crop and wheat monoculture) were analysed simultaneously.

There was little difference in carbon and nitrogen content from one system to another, except in the case of the two min-till systems, where it was higher in the top 10 cm of soil.

> « **Bio-indicators help to determine more precisely and quickly** the impact of organic matter input practices and of soil cultivation, than just the overall organic carbon and nitrogen content. »

Bio-indicators reveal more differences. Compared with the "sensitive" farming system which was taken as the control system, wheat monoculture with incorporation of straw shows the greatest positive impact in relation to MB, C_{MIN}28j and FDA hydrolase. This is probably due to the greater carbon incorporation level with this system, which produces and then reincorporates into the soil the largest amount of plant biomass.

The "direct drilling into a cover crop" system resulted in a greater organic carbon and nitrogen 50-2000 µm fraction, as well as greater FDA activity in the top 10 cm of soil than with the "sensitive farming" system, similar to the figures obtained with the monoculture system.

The integrated system does not really differentiate itself from the "sensitive" farming system. This would be due to similar rotations (cereal, oil-seed rape, protein crop) with similar yields.

The organic system, in place since 2008, does not differentiate itself clearly either from the "sensitive" farming system.

On the whole, bio-indicators reveal more differences than the organic matter content

In mid-term trials (5 to 10 years), where the overall organic carbon and nitrogen content is rarely significantly different, one or two bio-indicators always indicate a substantial reaction depending on the cropping history. In longer trials, the range of bio-indicator reactions, which is often wider than the organic carbon content range, confirms that they are more sensitive and more useful to forecast the nitrogen mineralisation gaps measured in the fields. However, the diversity of cropping practices being studied (organic residual products, green covers, soil cultivation) shows that the most sensitive indicators are different depending on the cropping practices used.

The carbon and nitrogen size fraction seems to quite often increase the overall organic carbon and nitrogen content, with a coarse fraction clearly showing the 8-to-10-year history of annual organic matter integration into the soil. However, this type of indicator does not show much difference from one green cover history to another; it shows greater differences with regard to microbial biomass and nitrogen microbial metabolites.

The reaction of the microbial biomass depending on the effluent input history is within the same range as the organic carbon content, but the analyses were carried out more than two years after the inputs had stopped; this indicator is therefore more sensitive to recent history.

> « There is a 60% increase in the microbial biomass of organic matter (top 25 cm of soil) after 10 years of legume covers during the intercropping season, compared with bare soil. »

FDA hydrolase, which is the only indicator of enzymatic activity that was tested in this study, did not turn out to be sensitive to the factors tested in the trials, whereas, like the other bio-indicators, it revealed a difference between the various Boigneville farms' cropping systems.

Finally, the implementation of the chosen bio-indicators in two experiments comparing cropping or crop management systems, revealed a marked difference for those with the greatest amount of carbon incorporation.

FDA hydrolase did not turn out to be sensitive to the factors tested in the trials, except for cropping systems.

(1) Services et Études en Microbiologie des Sols et de l'Environnement (Soil and environment microbiology services and studies).

(2) Microbial metabolites are the products that microbes discharge when they metabolise ("digest") fresh organic matter such as crop residue or organic effluent.

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October 2017