ENVIRONMENTAL MANAGEMENT OF SOIL BIODIVERSITY AND ECOSYSTEMS FOR PRODUCTIVE AND SUSTAINABLE AGRICULTURE

Martinez Vila, Alvaro Martin
Universidad Nacional de Ingenieria, Lima, Peru

Biological indicators of soil health

It is well-known that there is a need for technical assessments to advise farmers, policy-makers and planners on indicators and methods for the assessment and monitoring of soil health and functions. These should focus on improving knowledge: on the roles and importance of diverse soil organisms in providing key goods and services; and on the positive and negative impacts of existing and new agricultural technologies and management practices.

In order to facilitate comparison at many scales, it is important to agree on and adopt standardized approaches to the use of soil health indicators. Currently, standard methodology is used for most bioindicator measurements (e.g. microbial biomass) but sampling strategies may vary (e.g. depth of soil used for sample collection). Basic requirements for the development of specific bioindicators would be:

- relevance to basic attributes of soil function;
- response to management in acceptable timeframes;
- ease of assessment or measurement;
- robust methodology with standardized sampling techniques;
- cost-effectiveness;
- compatibility with physical and chemical indicators of soil health.

Soil biotic systems are extremely complex, and assessment of soil health and ecosystem function by direct measurement of overall biodiversity is impractical. Therefore, the need to develop indirect assessment methods is compelling. In order to be practical for use by practitioners, extension workers, scientists and policy-makers, the set of basic soil health indicators should be applicable over a range of ecological and socio-economic situations.

Appropriate use of soil health indicators will depend to a large extent on how well these indicators are understood with respect to the ecosystem of which they are part. Tools and methodologies to measure soil health should be adapted to end users (Table A). Tests should be able to measure properties of soil health that are meaningful to the actor's understanding of soil and its process, and to give results that are reliable, accurate within an acceptable range, and easily understood and used.

Soil organism and biotic parameters, such as abundance, diversity, food web structure, and community stability, meet most of the criteria for useful indicators of soil quality. They respond sensitively to land management practices and climate. In addition, they correlate well with beneficial soil functions, including water storage, decomposition and nutrient cycling, detoxification of toxicants, and suppression of noxious organisms. Visible indicators such as earthworms, biogenic structures, e.g. termite mounds, insects and moulds are comprehensible and useful to farmers and other land managers, who are the ultimate stewards of soil quality. Several farmer-participatory programmes for managing soil quality have incorporated abiotic and simple biotic indicators.

The activities of soil organisms interact in a complex food web with some subsisting on living plants and animals (herbivores and predators), others on dead plant debris (detritivores), on fungi or on bacteria, and others living off but not consuming their hosts (parasites). One of the major difficulties in the use of soil organisms per se, or of soil processes mediated by soil organisms as indicators of soil health has been methodological, i.e. what to measure and how, when to measure it, and how to interpret changes in terms of soil function.

Table A, summarizes the characteristics of potential soil health indicators required at different levels. It presents examples that end users can select and use in order to provide a suitable set of indicators of soil health according to local monitoring capacities. There is also a need to ensure that they are relevant to the given region, farming system, soil type, climate, etc.

Development of an assessment and monitoring framework

The identification of appropriate indicators of soil health assessment is complicated by the fact that they must account both for multiple dimensions of soil functions, such as productivity and environmental well-being, and the multiple physical, chemical and biological factors that control biogeochemical process, and their variation over time and space.

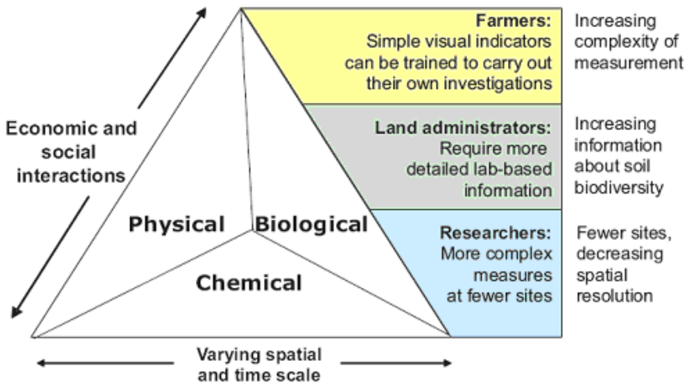
All of the soil parameters typically need to be measured simultaneously at a field site, although there can be gaps in the data if some analyses are not feasible or the facilities are not available. The database is most useful where the soil properties are analyzed in conjunction with one another. Thus, it is more useful to have data on all soil properties at a single point, than to have separate databases of generalized properties.

TABLE A
Practical tools for measuring soil health and their basic characteristics

Specific characteristic of soil health indicators for:			
Farmers	**Extension workers**	**Policy-makers**	**Researchers**
For use in the field: Self-assessed, easy and practical, based on visual indicators with interpretative guidelines relevant to region, farming system, soil type, climate, etc.	Visual indicators and simple low-cost field- and laboratory-based test kits that are easy to interpret	Minimum data set of soil health indicators, plus those associated with crop productivity and quality, environmental quality, off-site impacts, etc.	In-depth information on soil health, soil biodiversity, etc., including a range of laboratory-based indicators.
Practical examples of monitoring tools and indicators			
Nature of roots (density, morphology, colour, disease, depth). Decomposition of litter. Macrofauna, including indicators such as worm casts and pores. N-fixing organisms, e.g. legume root nodules. Plant population profiles (+ weeds). Smell and taste. Soil physical indicators, e.g. waterlogging and compaction.	Soil respiration measurement. Presence of pathogens (basic keys to symptoms). Soil pH, conductivity Total C/N ratio Microbial biomass. Nutrient levels. Physical indicators, e.g. bulk density, aggregate stability, and infiltration rate.	*Farm scale:* Percent of potential yield reached (based on water use efficiency). Farmer income, profitability. *Catchment scale:* Soil erosion. Depth of water table.	Enzyme activity (rapid techniques, e.g. BIOLOG) Molecular detection of mycorrhiza, biocontrol agents, etc. Molecular biodiversity assessments Nematode identification and assessment. DNA/RNA methods for detection of functional gene diversity (N-fixation, etc.)

Figure 1 presents the suite of soil health assessments in the form of a pyramid, with three sides corresponding to biological, chemical and physical indicators.

FIGURE 1
Pyramid of soil health indicators



The top of the pyramid represents the group of simple indicators that farmers would use, linked to the more complex measures lower in the pyramid. The more technical indicators occur in the lower part, but may move up as protocols are simplified or surrogate indicators are developed. There is a decrease in spatial resolution and scale with increasing complexity of the indicators. Therefore, simple indicators higher up the pyramid (e.g. total C) will be more useful for stakeholders who require soil health information at more detailed scales.