The dynamics of soil health

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Thomas Gumbricht from Stockholm University and xSpectre, with Sonia Meller from Digit Soil, discuss what we need to know about understanding the dynamics of soil health

Soils are formed by mineral debris, organic matter, water and living organisms. The soil ecosystem takes millennia to form and is sustained by a web of interplay both within the soil and with the vegetation ecosystem it harbours. Our human society wholly depends on soil for food, fodder, fibre, water cleaning, and climate control.

But we are mismanaging soils, and in Europe, the majority of soils are considered unhealthy. Intense use of chemicals has depleted soil organisms, compaction causes water to runoff from the surface rather than infiltrate, and ploughing destroys the soil's vital aggregate structure and oxidises soil organic carbon. The European Commission's Soil Health and Food Mission aims to address these issues by promoting sustainable soil management practices across the continent.

A prerequisite for improving soil health while maintaining the yields required for feeding a growing world population is soil information. Information that can be acquired efficiently and reach the world's 570 million farmers. The present paradigm of cumbersome soil sampling, expensive physico-chemical laboratory analysis and delayed results, needs to be complemented with in-situ methods that are quick, cheap, reliable and user-friendly. Methods that also look at broader structures and functions of soil, not only chemical and physical composition. As part of the AI4SoilHealth project, quicker and cheaper methods to collect soil information are being tested and evaluated to support the European Soil Mission.

Soil spectroscopy

Light is widely used to determine chemical and physical compositions in astronomy, industrial manufacturing, and science, including laboratory soil analysis. State-of-the-art microelectronics, light sensing technology and artificial intelligence (AI), have led to field spectrometers for in-situ soil analysis with various products on the market and in development like Agrocares and xSpectre.

Open soil spectral libraries over Europe and elsewhere are paving the way for apps that connect to cheap field spectrometers, transmit the light signal to an online database and return key soil health information. At present, an independent estimate of the soil moisture is required, and thus, a penetrometer is needed if you want the results directly in the field.

Photo: AI analytics powered xSpectre spectrometer supported by a soil penetrometer.

Soil penetrometers

We all know that water and salt affect electric conductivity. Developments in microelectronics and signal interpretation can now separate water and salt content and also detect specific ions, like hydrogen (pH) and those derived from nitrogen, phosphorus and potassium (NPK) – the key soil macronutrients. Soil penetrometers that can operate at the power levels of mobile phones have emerged only recently and are as yet scientifically unproven.

ISE and ISFET

Ion Selective Electrodes (ISE) and Ion Sensitive Field Effect Transistors (ISFET) are more mature technologies and are used in laboratory settings. ISE or ISFET probes use a reference solution and a membrane, with each instrument measuring only one particular ion. Probes for pH are cheap, easy to use and robust, and even recently developed in more sturdy versions for in-field soil observation. As pH is a key variable in soil health, pH-ISE probes are potential tools for rapid soil health surveying.

Macrofauna

The occurrence of earthworms has been used as an indicator of soil status for decades. You can lure the worms to the surface with dissolved mustard powder and count and weigh the worms that crawl out. However, insects, ticks, spiders, and molluscs are also important soil-transforming organisms. A monolith soil sample is required to count and weigh these. To get the creatures out, either hand extraction or heating is commonly used. At present, you have to be an expert to determine and sort different taxa and life stages, but AI-supported image analysis is paving the way for automation.

Environmental DNA (eDNA)

DNA analysis methods and databases have exploded over the past decades, and eDNA is emerging as a method for characterisation of the richness and variation of soil organisms and for determining dominating metabolic pathways. Field sampling requires care to get uncontaminated samples that must be immediately preserved or cooled and sent for complex processing.

The last step in the analysis chain, after extraction, amplification, purification and sequencing, is the bioinformatic mining vis-a-vis existing, but rather incomplete, databases. A simpler method for analysing your microbial community without sequencing is the commercially available Microbiometer, which determines the fungal-to- bacterial ratio.

Enzymatic activity

Soil enzymes, released by all living organisms in the soil, act as the workhorses of the ecosystem. Assessing key enzymatic activities and the rate at which these enzymes break down larger organic molecules into plant-accessible nutrients is becoming a direct and fast method for soil functional characterisation. Traditionally, evaluating soil enzymes involved complex laboratory procedures.

However, with the development of the Soil Enzymatic Activity Reader SEAR by the Swiss start-up Digit Soil, this is changing. Fresh soil is placed in small boxes and pressed with reaction plates with prepared sections targeting different enzymatic processes and products. Using built-in spectral analysis, the activity rate for each enzyme is reported in under an hour.

Photo: Digit Soil reaction plate and reader for assessment of soil enzymatic activity.

Soil aggregates and water infiltration

Soil aggregate structure is well known to relate to erosion resistance, nutrient pools and, thus, soil health. Visual inspection of soil structure is widely used, but is dependent on the individual observer. The Soil Health Institute has developed a more objective method using a smartphone camera and aggregate stability after water drowning.

Also, water infiltration rate is a widely used soil health indicator, with healthy soils swallowing more water. Among a wide range of methods and instruments, many of which require tens of litres of water, a single ring with a diameter of less than 10 cm (similar to an empty food tin) and filled with no morethan1cmofwateratatimeis emerging as a quicker and easier method, yet one that maintains scientifically documented accuracy.

To get more than a glimpse of existing and emerging soil characterisation methods please click here.

Please Note: This is a Commercial Profile

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