Plant microbiomes: Humans are not the only organisms that need healthy biomes. Here is how to grow safer and more nutritious food and feed

A "physical examination" is the standard way to track human health. It involves a variety of measurements such as blood pressure, cholesterol levels, body-mass-index, cognitive index, bone density, vitamin and mineral status etc. Those measures are important, but it is becoming increasingly clear that our health is also influenced by what is going on with our "gut microbiome" – the huge and diverse communities of bacteria, viruses and fungi that live in our intestines and stomach.

What does our gut microbiome do? It can be both beneficial and harmful if out of balance. It helps drive disease immunity, protects against pathogens, helps modulate energy metabolism, syntheses of vitamins, and fat storage and has significant influence on mental health.

Until recently it was very difficult to monitor or even study that microbiome, but the plummeting cost of DNA sequencing has opened a whole new window on human and animal health because it makes it possible to track what is going on with those organisms down to the species level. Now those advances in tracking the inner working of micriobiomes is also poised to revolutionize agriculture.

Advancing sustainable farming

Affordable DNA sequencing technology has opened the window on the microbiomes found in the soils of the farms that feed us. Many scientists believe that understanding soil health could enable significant advancements in sustainable, regenerative farming. Soil is not just "dirt." It is a living, breathing ecosystem. Its "health status" is extremely important whether it is in a natural state or if it is being pastured or farmed.

As with human health, there are key physical, chemical and functional measures of soil health. Healthy soil has a lot of long-term stable organic matter. It has a complex and resilient three-dimensional texture that allows the movement of oxygen and the rapid infiltration of rainfall or irrigation water. It does a good job of hanging on to moisture and mineral nutrients.

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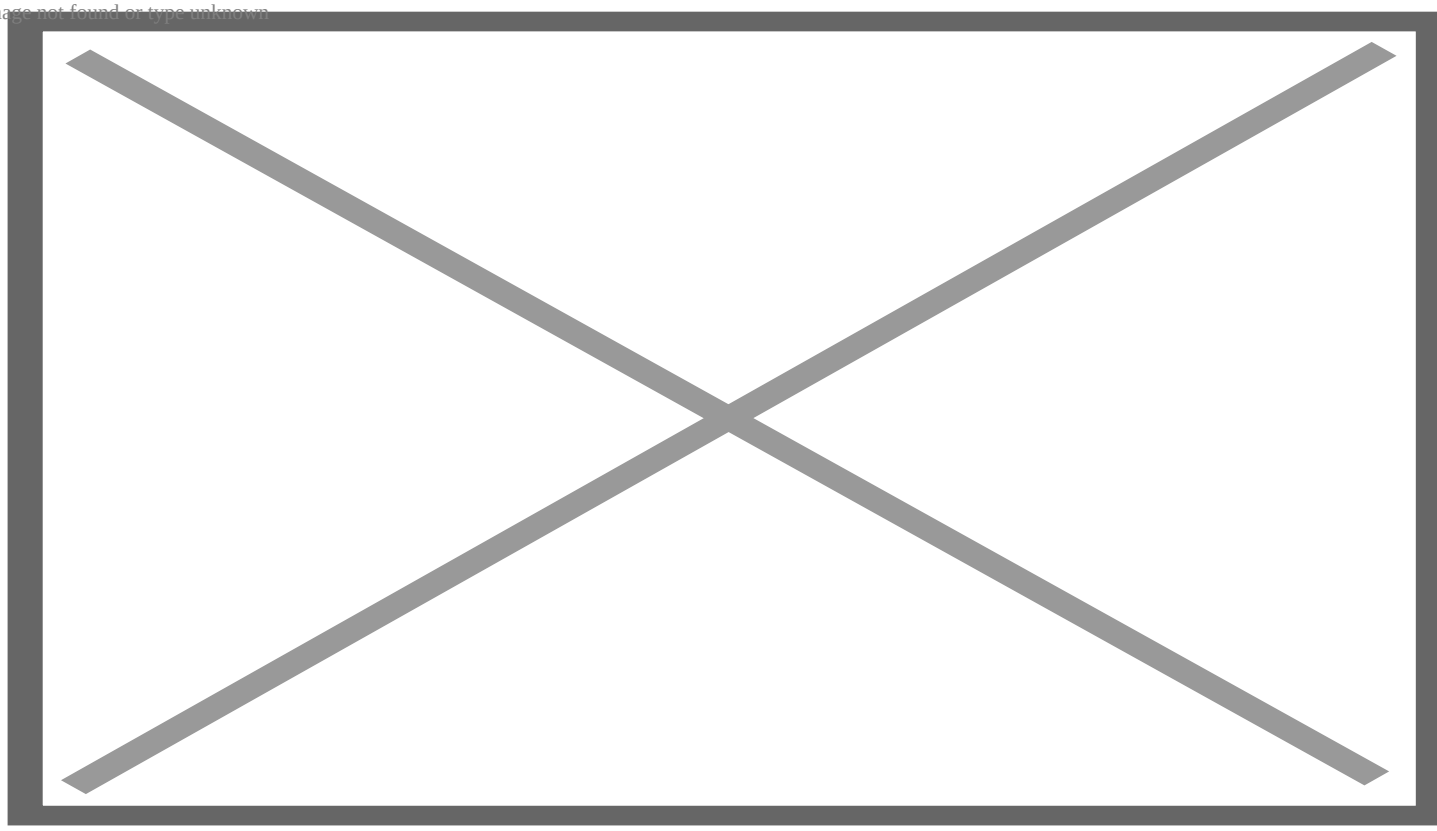

Assessing soil health. Credit: Euractiv

There are ways to assess the chemical and biological status of a soil (e.g. the Haney Test which uses unique soil extracts in the lab to determine what quantity of soil nutrients are available to soil microbes and their respiratory potential). But until recently there hasn't been a way to track the details of what is going on with the soil microbiome because it is made up of millions of different organisms, very few of which could ever grow in a lab let alone be measured in their natural state.

Now DNA sequencing technology allows us to sort through that complexity and use the information to do an even better job of optimizing sustainable or regenerative farming practices based on a specific crop/geography/soil type/history situation. Data of this type are provided with comparisons to regional and crop-specific benchmarks derived from anonymized data from many customers. For efficiency and context, the companies doing microbiome analysis also offer to conduct traditional soil tests on the same samples.

The Big Three

There are three major players in this new and rapidly developing soil microbiome testing business.

Pattern Ag has focused its efforts on the very large corn and soybean industries in the US and is expanding to Brazil in partnership with Lavoro.

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Biome Makers also works on corn and soybeans but has also applied their technology in +170 other crops .

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Trace Genomics has been working on a wide range of crops since 2015, and offers a comprehensive soil analytics guide that includes soil microbiome testing.

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This business sector is at a pre-competitive stage with each company using a different sequencing approach. They all offer a range of assessments and recommendations, but they are also building their

databases with each successive season. That will enable them to continue to refine their offerings moving forward.

These tools have been used by academic and private-sector researchers for several years but now they are increasingly being used by farmers, agronomists, crop pest advisors, and other trusted experts. For instance, Biome Makers has a program to train and certify advisors about how to use this technology and interpret the data. Three hundred participants have already been certified and 1,200 more are enrolled in the training.

Integrating soil microbiome insights into farming practices

Now that scientists are beginning to understand more about the dynamics of the soil microbiome, the next challenge is translating that into practical farm management options. So far there are five main ways that is occurring:

Optimizing the Management of Soil-borne Pests: these new methods can identify and quantify many important crop pests that live in the soil, including fungal and bacterial pathogens that cause crop diseases. The tests also identify DNA from parasitic nematodes (e.g., the soybean cyst nematode which Pattern says they can detect at populations as low as 1 per pound of soil), and even the eggs of rootworm insects.

The client's data is presented as a crop and region-specific risk assessment which can then be used to guide decisions about crop rotation, the choice of resistant cultivars, or using an appropriate biological or chemical seed treatment. Trace Genomics' offers a "Seed Solution Guide" that makes it easy for customers to connect pathogen diagnostics to agronomic recommendations for seeds and seed treatments. The sequencing can also identify situations in which there is a high soil population of a biocontrol organism like the fungus *Trichoderma*, which may minimize certain disease risks.

Optimizing Crop Fertilization and Yield: The microbiome analyses also reveal what sort of nutrient-cycling organisms are present in each field. These include those that make nitrogen or phosphorus more available. If such populations are low the farmer may be able to apply optimized strains to release those nutrients. If those organisms are already in abundance in that soil, then the farmer can apply less fertilizer thus saving money and lowering the risk of runoff or groundwater contamination. If the microbiome assessment indicates a large population of "nitrifying" bacteria, the farmer knows that any added nitrogen fertilizer is at risk of being converted to the easily leached nitrate form in which case it would be wise to apply "nitrification inhibitors" or use a "split application" approach to minimize fertilizer loss.

Diagnosing Anomalies: If a given field or part of a field has unusually low yield or other symptoms it might be a pest issue or some other problem. A microbiome assessment can provide clues about why that is happening and what to do about it. Biome Makers says that just over one-half of their business involves anomaly investigations. For instance, a higher than usual population of "anaerobic bacteria" which can grow without oxygen suggests that there may be a layer of compacted soil from past tillage or from "wheel traffic." Some sort of intervention might be required to restore the land.

Applied Research: In their early days, microbiome companies provided the technology for public and private sector researchers interested in this cutting-edge tool to document how their products or protocols

impacted the soil and its inhabitants. There are a variety of “bio-stimulant organisms” available to farmers, but they have a reputation of working in some settings and not in others. Microbiome data have proven helpful in identifying fields where there is significant potential for a yield boost with these products.

That application continues. Bayer Crop Science used Biome Maker’s technology to identify soil biome indicators for where their potato biological product would be most likely to result in significant yield gains. Pattern Ag has a program through which farmers can sign up to be included in field trials linking biome testing with experimental soil health products and strategies and be paid for their participation on a per acre basis. Trace Genomics offers validation and verification services for companies developing biologicals.

Sustainability Reporting: This revolution in understanding the soil microbiome also helps the public. There is a growing focus by handlers, processors, food manufacturers and marketers to document the sustainability of their supply chain to support their product claims or in their ESG (Environmental, Social Governance) or other reporting efforts. These companies offer a summary of microbiome status and progress to support those needs. Trace Genomics offers a TESS™ report (Trace Environmental Soil System Engine). Biome Makers has an option they call BeCrop® Rate.

One of the core principles of sustainability is that “you can only manage what you can measure”. Another saying is, “if you treasure it, you measure it.” The new ability to measure microbiome composition and dynamics using DNA sequencing paves the way for a step change in the sophistication of sustainable soil health management. It will be very interesting to watch that development over the next several years.

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