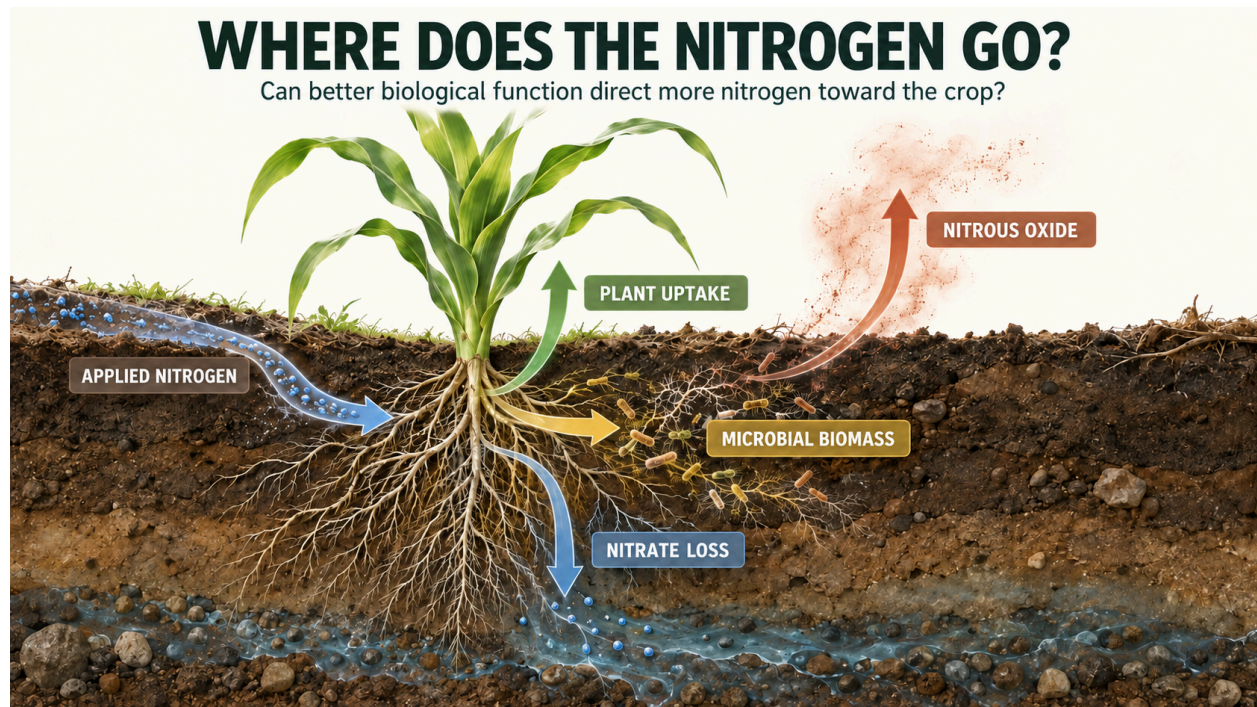


Can Living Soil Help Agriculture Use Less Nitrogen?

Improving soil biology may help crops use nutrients more efficiently. Demonstrating that it can reduce fertilizer use without sacrificing yield is a more demanding question.

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This is the first in a Climate Week series examining soil biology, agricultural resilience, and food security.



Nitrogen fertilizer helped transform agriculture. It increased crop yields, supported a growing population, and made modern food production possible on a scale otherwise unimaginable. Any serious discussion of nitrogen must begin by acknowledging that achievement.

But not all nitrogen applied to a field becomes part of the crop. Some remains in the soil. Some moves into groundwater or surface water. Some returns to the atmosphere, including as nitrous oxide, a greenhouse gas considerably more potent than carbon dioxide.

This is not an argument that agriculture can simply stop using nitrogen fertilizer. Plants require nitrogen to synthesize proteins, nucleic acids, chlorophyll, and many other molecules that support growth. The more useful question is whether we can help crops obtain and use nitrogen more efficiently.

That question leads directly to the biology beneath our feet.

Nitrogen does not move through soil on its own.

A bag of fertilizer may carry a precise number indicating its nitrogen content, but what happens after that nitrogen enters the soil is much less tidy.

Nitrogen changes form. Microorganisms can incorporate it into their cells, release it during the decomposition of organic matter, absorb it, temporarily immobilize it, leach it as nitrate, or transform it into gases. Microorganisms accomplish much of this.

Some bacteria and archaea oxidize ammonia, while others reduce nitrate when oxygen is limited. Certain microorganisms fix atmospheric nitrogen, while others break down organic matter and release nitrogen previously unavailable to plants.

The nitrogen cycle is therefore not merely a chemical pathway but also a biological network.

That distinction matters because adding more nitrogen does not necessarily correct a poorly functioning network. If nitrogen is supplied at a rate, in a form, or at a time that doesn't match the crop's needs, excess is vulnerable to loss. Improving nitrogen-use efficiency means aligning nutrient availability more closely with plant demand.

The soil microbiome may be one part of that alignment.

What might better soil biology accomplish?

A functional soil community could assist a crop in several ways.

Microorganisms can release nitrogen from organic matter. They can affect root development and the volume of soil the plant explores. They can interact with other organisms that mobilize phosphorus and micronutrients, which may indirectly influence the plant's ability to use nitrogen. Microbial biomass can also temporarily hold nitrogen and release it later as organisms die or are consumed.

These functions do not occur in isolation. They form a network of exchanges among microorganisms, roots, organic matter, minerals, water, and gases.

This is why I am cautious about reducing the soil microbiome to a list of organism names. The presence of a bacterium with a specific metabolic capability does not prove that the function is occurring in the field. The organism must be active, appropriately positioned, and able to function under prevailing soil conditions. It must also interact successfully with the resident microbial community and the plant.

Who is present matters. What they are doing matters more.

The attraction—and limitation—of microbial products

Interest in microbial inoculants and other biological soil products is growing. The reasoning is understandable. If certain microorganisms can fix nitrogen, release nutrients, stimulate root growth, or improve nutrient-cycling efficiency, perhaps they can reduce agriculture's dependence on external inputs.

Science supports that possibility. Certain microbial inoculants have improved plant growth or nitrogen-use efficiency in specific crops and environments. Research on nitrogen-fixing symbionts is already well established in legumes, and some field programs involving other plant-associated microorganisms have produced encouraging results.

But performance is not uniform.

A microorganism that performs well in the laboratory may fail to establish itself in the field. A formulation that performs in one soil may behave differently in another. Temperature, moisture, pH, crop variety, fertilizer regimen, and the resident microbiome can all influence the outcome.

Soil is not an empty vessel waiting to receive a beneficial organism. It is an occupied ecosystem.

That is one reason I have become interested in functional communities rather than expecting a single microbial strain to solve a complex ecological problem. In a community, one organism's metabolic product may serve as another organism's substrate. Different members may perform complementary steps in nutrient cycling, and some functional overlap may help the community continue operating when conditions change.

That is the biological rationale. It is not, by itself, proof of an agricultural or climate benefit.

Where our work fits

At AOB, we design microbial communities around complementary functions and metabolic cooperation. The objective is not simply to add more microorganisms to the soil. It is to encourage a community capable of performing useful work within the soil–plant system.

Our field observations have included changes in measures of biological activity, nutrient cycling, and soil condition. These findings give us good reasons to continue the work. They do not yet justify claiming that our products reduce nitrogen fertilizer use or lower greenhouse-gas emissions.

To make the first claim, we would need properly controlled field trials comparing standard fertilization with progressively reduced nitrogen rates, both with and without the microbial treatment. Crop yield and quality would need to be maintained. The work should be repeated across soils, crops, seasons, and environmental conditions.

To make the second claim, we would need to measure greenhouse-gas emissions directly. Nitrous oxide is produced episodically, often after fertilization, irrigation, or rain. An occasional soil sample cannot tell us how much entered the atmosphere over an entire growing season.

The difference between a promising observation and a demonstrated outcome is important. It is also where the most valuable research begins.

What would convincing evidence look like?

A meaningful reduced-nitrogen study would include several treatment groups:

- the grower's customary nitrogen program;
- reduced nitrogen without a microbial treatment;
- the customary program with the microbial treatment;

- reduced nitrogen with the microbial treatment; and
- where practical, an untreated reference.

The experiment would measure more than yield. Plant nitrogen uptake, soil nitrate, microbial activity, crop quality, and nitrogen remaining after harvest would help explain where the nutrient went. Direct nitrous oxide measurements would be necessary if the study were intended to support a climate claim.

The key question would be straightforward: Can nitrogen application be reduced without compromising crop performance, and can the outcome be replicated?

If the answer is yes, the implications could be significant. Farmers could reduce input costs. Less surplus nitrogen would be available to leach or be lost as gas. Agriculture could maintain productivity with a smaller environmental burden.

If the answer is no—or yes only under certain conditions—that information would be equally valuable. Evaluate biological products based on where and when they work, not as universal solutions.

A climate question, but also a food-security question

Nitrogen management sits at the intersection of climate, water quality, farm economics, and food security. Too much nitrogen in the wrong place causes pollution. Too little nitrogen, where farmers cannot obtain it, restricts food production. The global problem is not simply abundance or scarcity. It is inefficient and uneven use.

Healthy soil biology will not eliminate the need for agronomy, fertilizer management, crop breeding, or careful land stewardship. Nor should microbial products be presented as replacements for all existing practices.

Their potential contribution is more specific: helping the soil–plant system use nutrients more efficiently and remain functional under changing conditions.

At a time when climate solutions are receiving unusual attention, it is tempting for every promising technology to declare itself part of the answer. I think the more responsible course is to define the mechanism, present the observations, and then conduct experiments capable of proving—or disproving—the claim.

Living soil may help agriculture use less nitrogen. We now need to establish where, by how much, and under what conditions.

That is the work ahead.

Disclosure: I am CEO and Chief Scientific Officer of Ancient Organics Bioscience and participate directly in the scientific development and interpretation of its microbial soil technologies. The distinction made here between observations, biological hypotheses, and demonstrated outcomes reflects my own scientific assessment.

References and further reading

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