The Life in the Earth: Understanding and Using Below-Ground Biodiversity

Given that the United Nations has designated 2010 as the international year of biodiversity, the timing of a recent week-long conference on what one author has called the "life in the earth"—could hardly have been better.

Organized by CIAT's Tropical Soil Fertility (TSBF) Research Area, the event examined the valuable functions of myriad plant and animal species that live below ground. It turns out that these species have much to offer agricultural research for development worldwide, as it contends with global climate change, faltering food and nutrition security, continuing environmental degradation, and worsening poverty.

Much research on soil deals with its mineral content and physical structure, overlooking the role of below-ground biodiversity in maintaining important ecological services, such as carbon sequestration and the provision of nutrients to plants. To remedy past neglect, CIAT and its national partners in seven tropical countries embarked on a major global initiative 8 years ago, aimed at finding ways to enhance agricultural productivity through sustainable management of this valuable soil resource. They also invested heavily in strengthening local research capacity through training and South-South exchanges.

The recent conference, attracting 70 experts to the headquarters of the World Agroforestry Centre in Nairobi, marked the successful conclusion of that initiative, which was funded mainly by the Global Environment Facility (GEF).

This CIAT Brief provides a summary of key results, following a brief description of below-ground biodiversity and the consequences of its loss.

A wealth of soil organism communities

The life in the earth consists of an extremely diverse community of soil organisms, which include bacteria, fungi, protozoa, and invertebrates. The first two groups play especially important roles in maintaining soil health.

Bacteria form much of the world's biomass. A milliliter of fresh water typically holds a million bacterial cells, while a gram of soil can contain 40 million. Though bacteria contribute importantly to the recycling of nutrients—for example, fixing nitrogen from the atmosphere—yet most have not been characterized, and many cannot even be grown in laboratories.

Although abundant worldwide, fungi are small and inconspicuous, except when fruiting as mushrooms or molds. They occur in the soil, often in symbiotic relationships with plants, animals, and other fungi, performing fundamental functions in the decomposition of organic matter and in nutrient cycling. Fungi have long been used as a direct source of foods such as mushrooms and truffles, as a leavening agent for bread, and in the fermentation of products such as beer, wine, and soy sauce. In recent decades, fungi have also been used for the production of antibiotics and other industrial products like soap.

Missed opportunities for development

Below-ground biodiversity goes into decline when agriculture is introduced in forests and other natural environments and as agricultural production is intensified. Because of these species' critical role in providing ecological services, their loss reduces the sustainability of agricultural systems and makes them less resilient in the face of adverse weather, pest outbreaks, and other threats.

Another undesirable outcome is erosion of the vast genetic diversity represented by soil organisms. Current uses of these species (e.g., as agents for biological control of weeds and pests) already demonstrate their value. But thousands of species remain to be discovered, which could have economically important uses in chemical processes, for example, with wide application in agriculture and in the pharmaceuticals and other industries.

The loss of soil organisms represents a further missed opportunity that involves carbon sequestration, which is essential for mitigating climate change. Soil organic matter is one of the three main natural sinks for carbon dioxide, the others being oceans and photosynthetic plants and algae. Bacteria and fungi are by far the most active and efficient decomposers of organic matter in the soil, and for this reason, they strongly influence the dynamics of soil carbon sequestration. Yet, little attention has been paid to the possibilities for greatly enhancing this process through more sustainable management of below-ground biodiversity.

A mosaic of solutions

To show how those opportunities can be retrieved, CIAT-TSBF explored ways of making agricultural systems less dependent on chemical inputs, more sustainable and resilient, and more effective in sequestering carbon through improved management of soil organisms.

In the process, project scientists developed and published standard methods for evaluating this biodiversity, including indicators for gauging its loss. Using such tools, they inventoried soil organisms at 11 sites representing a wide range of ecosystems and land uses. CIAT-TSBF also investigated various practices, together with supporting systems and policies, for improved management of below-ground biodiversity, and partners demonstrated these practices in farmers' fields at diverse locations.

Among the most favorable options are those drawing on traditional farming methods that retain high levels of biodiversity, such as agroforestry practices, intercropping, crop rotations, and integrated crop-livestock systems. In contrast, intensive monocropping based on heavy use of chemical inputs is the option least conducive to the preservation of biodiversity in the soil.

Project scientists found much evidence that mosaics of different systems, including some intensive ones, can maintain high levels of below-ground biodiversity. They also showed that within such combinations, soil organisms can help control plant diseases while resulting in more efficient use of inorganic fertilizers, thus reducing farmers' expenditures on chemical inputs.

Using rhizobia bacteria as bio-fertilizers, for example, in combination with Triple Super Phosphate fertilizers, can give a benefit-cost ratio of two to three, which translates into net benefits worth US$253 per hectare through cost reductions.

Such gains will become ever more necessary, as the demands on agriculture increase (for food, feed, fiber, and fuel) and as the impacts of climate change make it more difficult to satisfy those demands. It is perhaps no exaggeration to say that the quality of future life on earth will depend to a surprising extent on better management of the life in the earth.

For further information on the conservation and sustainable management of below-ground biodiversity, see www.bgbd.net

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