Who Fertilizes the Forest?

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Tree fertilization is a common service provided by commercial arborists and landscapers. Customers and clients are familiar with fertilization from the care of house or garden plants. Any hardware or garden supply store has attractive packages of colored crystals or liquid solutions that promise rapid growth and abundant blossoms. This familiarity with fertilization of annual or herbaceous perennial plants is extended by the public to the care of landscape trees. Of course fertilization is a common service!

A walk through a wild forest or rural woodland prompts the question "Who fertilizes the forest?" The answer lies in understanding that natural landscapes are living systems. A system is a set of interconnected and organized parts and processes that form a complex whole. A living landscape contains a set of organisms interacting among themselves and with the external environment. These interactions establish, maintain, and extend the flow of energy, matter, and life. But what does that have to do with tree fertilization in natural forests or in urban landscapes?

Fertility is the ability of the soil to sustain plant growth. One way to express that growth is an increase in size, measured as dry weight or biomass. The bulk of biomass by far comes from photosynthesis, the harnessing of solar energy to split apart molecules of carbon dioxide from the atmosphere and water and to form new chemical bonds of sugar. The sugar contains the chemical energy to

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Healthy northern forests naturally contain wood decay fungi.

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fuel plant growth and to produce biomass. Trees make their own food, but they need more than air and water to do so.

Although not directly contributing much to biomass, a total of about 13 additional mineral elements are essential for plant growth and are naturally available in fertile soil. The most familiar fertilizer elements are nitrogen, phosphorous, and potassium. These three are the "N-P-K" listed on the fertilizer box or bag, usually with their relative proportions in the fertilizer such as "10-10-10." Although additional trace mineral or microelements are required in much lower concentrations, they are just as essential for plant growth.

Plants can be grown in purified, sterile solutions of these chemicals. Although a useful advance for some short-season specialty crops like greenhouse tomatoes, these practices tend to obscure the fact that fertility in natural forests is maintained through communities of plants, animals, and microorganisms.

In contrast to those controlled laboratory and greenhouse settings, forest tree nutrition is greatly affected by the presence of humus and soil organic matter (SOM). "Organic" here refers to compounds that contain carbon and which are derived from living or dead organisms. Experts distinguish between humus, identified as a discrete layer or forest floor located above mineral, and SOM which is mixed into the mineral soil. Both humus and SOM are progressive stages in the same decomposition process and this article will refer to them both simply as organic matter. The organic matter in forest soil originates from the biological breakdown or decay of foliage, branches, stems, and roots, particularly the woody parts. Much of the breakdown is by wood decay fungi with other fungi and bacteria also taking part. Arthropods such as beetles and millipedes can mechanically reduce the particle size of organic matter, increasing the surface area and the opportunity for microbial colonization.

The fate of deposited plant parts benefits forest ecology in seemingly contradictory ways. The long-term storage of organic matter in soil mitigates to some extent the carbon released into the atmosphere from the combustion of fossil fuels. The benefit of carbon storage may be reduced by the decay and respiration of organic matter and the release of biological energy. But it is these activities that cycle elements and maintain forest fertility that makes tree growth possible. Interestingly, the communities of organisms involved in the breakdown of organic matter and element cycling are in many ways more richly diverse than the more obvious communities of green plants in the forest.

Another more hidden source of soil carbon is the release of

Healthy trees on the National Mall in Washington DC benefit from soil treatments to resist compaction.

carbohydrates and other biomolecules by healthy roots into the soil. Rather than simply being "leaky," the roots stimulate beneficial microorganisms on the root surface and further out into the soil. The greatest intimacy in these nutritional relationships include trees in the legume family such as black locust that host specialized nitrogen-fixing bacteria in special nodules in the roots. Far more common is the beneficial infection of roots by diverse fungi to form mycorrhizae. The tree provides the fungi with sugar and other biomolecules and the fungi greatly extends root system function with fungal hyphae. Mycorrhizal fungi also greatly enhance tree uptake of essential elements such as phosphorus while conferring some resistance to drought and disease.

Organic matter benefits the soil environment by improving moisture retention and resisting soil compaction. Compaction is important in that the air spaces in uncompacted soil allows for natural aeration and the respiration of roots and soil microorganisms. Soil compaction is essentially unknown in the wild forest and for rural forests is largely localized to access roads and timber landings. In urban and community forest, soil compaction is likely the most common physical problem faced by established urban and community trees. Organic matter, along with clay particles, provides storage for essential mineral elements such as calcium, magnesium, and potassium.

Of course arborists and landscapers are usually not dealing with intact forest or woodland systems. Some commercial products and techniques are promoted to restore these natural relationships through the addition of microbial spores, mycelium, degradable or recalcitrant carbon, etc. To restore a damaged living system requires modifying the environment to support recovery. Even the best compost tea and mycorrhizal propagules need to have the proper soil aeration, pH, drainage, type and amount of organic matter. Merely spraying or broadcasting some miracle product will not be enough to restore lost biological cycles. A good first step to restore damaged sites is to recognize that the source of fertility in natural forests and woodlands is the community of organisms that drive both growth and decay. The degree to which traditional chemical fertilization or biological treatments is directly related to the degree that the living system has been impaired.

More information from the author on this and related topics may be found at: http://www.nrs.fs.fed.us/people/ktsmith.

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Human activity can disrupt the living soil system as well as damage roots.

Magnification shows healthy mycorrhizal associations between roots and fungi.