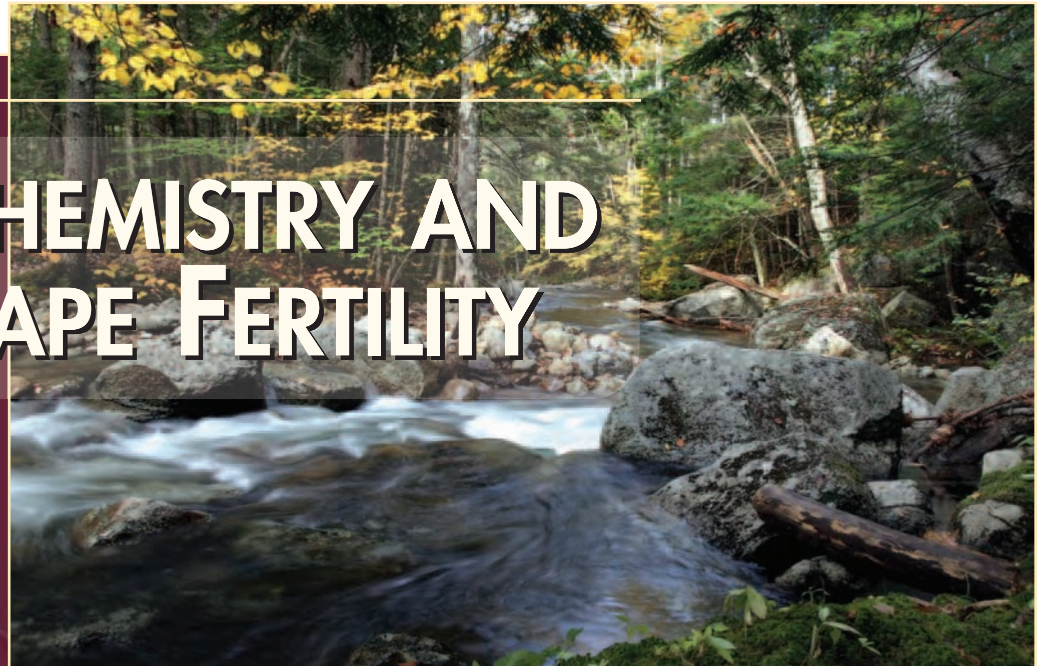
Biogeochemistry and Landscape Fertility



Healthy forests are part of natural biogeochemical cycles.

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Choosing sustainable and efficient practices to manage urban and community landscapes can be made a little easier by understanding how the natural environment functions. Nobody regularly fertilizes rural or wild forests yet they can be healthy and diverse natural communities. Yet in the urban and community landscape, fertilization is one of the most common practices. Fertilization is the application of chemical elements to promote desirable growth of plants. This would include nitrogen (chemical symbol "N") and phosphorus ("P") as well as other macro- and micro-elements. Those elements may be added as organic (carbon-containing) amendments such as compost or they may be applied as chemical salts or in some other purified form. What can be learned from natural landscapes about the "how and why" of fertilization? How do natural forests and grasslands continue to grow and be healthy without fertilization?

The answer lies in biogeochemistry, the cycling or flow of chemical elements through organisms and the landscape. Living plants and their associates both alter and are affected by their chemical environment. In natural forests and grasslands, the biogeochemistry that sustains plant growth is directed by fungi and bacteria. These microorganisms change the form of soil elements, capture N from the air, and liberate, store, and release elements from dead organic matter. The power for this work comes primarily from releasing the energy stored in organic matter. The need for landscape fertilization comes from the disruption of natural biogeochemical cycles.

A landscape is a system, a complex set of interacting parts and processes. Biogeochemistry involves the cycling of elements within a closed system and the flow of elements into and out of an open system. Sometimes, being considered open or closed depends on the scale or size of the landscape. Our Earth is essentially a closed system with respect to chemical elements. A forested watershed might be an open system with respect to water entering as rain or snow yet be closed with respect to mineral elements released by the weathering of rocks. The term "weathering" doesn't tell the whole story, as much of the release of essential chemical elements is through the concerted efforts of microorganisms that etch away the mineral elements from rocks and soil particles. With time, those elements become available for plant nutrition. Living processes continually rearrange and reuse chemical elements in closed systems.

The fertilizer element applied most frequently is N. To many people, "fertilization" has come to mean the application of N. In most all grasslands and forests, plant growth is limited by the

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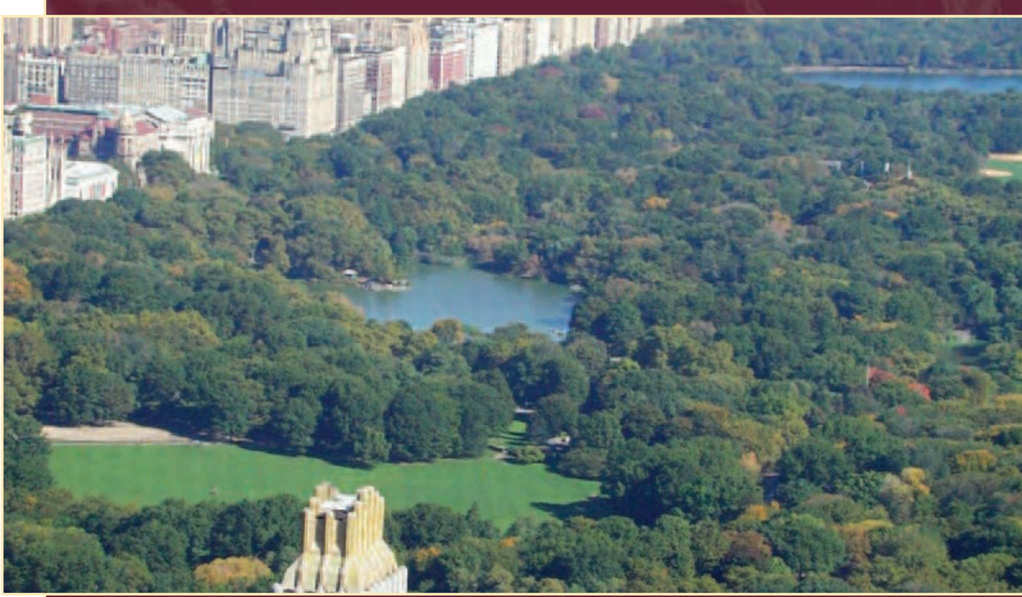

Central Park is a highly managed, instantly recognized and beautiful part of New York City.

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The decay of wood and foliage provides essential elements, storage capacity, and fuel to maintain healthy forests.

amount of N available for plants to use. This is in spite of our atmosphere containing about 78% N! However, atmospheric N needs to be "fixed" into inorganic compounds, such as nitrate or ammonia, to be taken up by roots and used by plants. In natural systems, N is fixed by specific bacteria including some of the photosynthetic "blue-green algae". In legumes, these bacteria form symbiotic associations in specialized nodules in plant root systems. Other nitrogen-fixers can be free-living in the soil or on exposed surfaces of soil, rocks, or trees.

In natural systems, the biological pool of P is incorporated into living organisms or strongly linked to organic compounds in soil humus. Healthy soils contain microorganisms that release inorganic phosphorous from the humus. Some of that inorganic phosphorus is taken up directly by plant roots, but more is taken up by fungi. Some of these fungi form mycorrhizae, a symbiotic partnership with the roots of trees and other plants. Mycorrhizal roots are especially effective at obtaining essential P from the soil, much of which is allocated to the plant partner.

When planted landscapes require fertilization, it is often because natural biogeochemical cycles have been disrupted. A large source of disruption is simply the mechanics of modern landscape installation, that six inches of "topsoil" spread over builder's sand or construc-

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tion rubble. Perhaps a greater disruption is from the partial clearing of building space among existing trees accompanied by altered patterns of soil drainage and increased soil compaction. These changes in the soil environment impede or prevent the normal biology of roots and soil. An ongoing source of disruption is the removal of shed organic matter such as leaves and branches. This may be necessary to maintain a "well-kept" look. However, the removal of organic matter directly removes essential mineral elements, soil storage capacity for those elements, and the fuel for the landscape to maintain its own fertility. The third type of cycle disruptions are landscape treatments that "short-circuit" these processes of natural fertility. Trees that are over-fertilized with N or P are less likely to form mycorrhizal associations and to support diverse communities of microorganisms that maintain soil fertility.

Over-fertilization, the addition of chemical elements above that needed for a healthy landscape, results from treating the landscape as an open sys-

Mycorrhizal tree roots grow around and through soil organic matter.

tem. In addition to simply being wasteful, the overuse of fertilizer salts can cause salt buildup, making water uptake by roots much more difficult even when soil moisture seems adequate. Over-fertilization can cause larger environmental problems as well. Runoff of N threatens the quality of drinking water. The flow of both N and P out of the planted landscape and into lakes and bays can cause a rapid proliferation or "bloom" of algae. As the algae die, the decomposition process can remove much of the available oxygen and greatly reduce the richness of aquatic life.

The planted landscape has always represented tradeoffs between natural processes and the needs and desires of society. Fertilizer elements provided in organic, inorganic, natural, and synthetic forms will all continue to be used. As we understand more about how the natural system maintains landscape fertility, we can integrate more biogeochemistry into landscape design and practice. This can start by considering the potential of the planted landscape, like our Earth, to maintain itself through healthy biogeochemical cycles.


Several different fungi are part of this mycorrhizal partnership on a single root.