The Living Soil[1]

Soil scientists normally have an expertise in the physical characteristics of soil--the type, the horizons, the chemistry. They often do not have as much knowledge about the life *of the soil. In the following excerpt from an interview from 1998 (see introduction to section on Ecosystem Management), forest ecologist David Perry talks about some of the complexities of life in the soil. The below-ground ecosystem can be as complex as or more more complex than the above-ground ecosystem. Compromising the complexity of life below the ground can have serious impacts on what lives above the ground.*

BA: You've described the soil-plant relationship as a "dance of mutual creation." Would you describe the role soils play in maintaining a stable ecosystem and explain how breaking the link between plants and soils can affect potential site productivity?

DP: Plants need about eighteen elements as nutrients; microbes and animals need another eight or nine. All but two of those come from the soil. So the soil is the repository of most of the building blocks for life. The soil is the bank that holds the water between rainfalls and that modulates it out either to streams or to the air in an orderly way.

Soil is, by far, the habitat of the greatest number of organisms in systems, probably 50% of the animal biomass in forests is below ground. The food chains below ground are generally long, more complex, more diverse than the food chains above ground. All of that life below ground in soils, and the physical structure of soils that gives them this capacity to store water and yet to drain water and to let air in, comes from energy that has been put in by plants. Plants pump about 50% of the energy they capture in photosynthesis below ground. Some people believe it's more than 50%, and I'm one of those people.

So a lot of the energy that's gathered by plants goes below ground, and it builds soil structure and feeds organisms, and a good share of these organisms are doing things that feed back in a very important way to the growth of the plant: they're cycling nutrients, they're gathering nutrients and water, they're helping to protect the plant against pathogens. That's what I was referring to when I said that plant and soil become joined together in a dance of mutual creation. The soil ecosystem depends on the energy from the plants and the ability of the plants, to gather that energy depends on a fully functioning soil ecosystem.

Forests everywhere are disturbed to one degree or another. We talk about ancient forests, and they may be ancient, but they're not immortal. Trees die. Sometimes large-scale disturbances come and wipe out large numbers of trees. One of the primary mechanisms of resilience is the ability of plants in a system to recover very quickly; and often they're a different set of plants than the one that we focus on commercially. They're hardwood shrubs that can sprout from roots or that store seed in the soil where it's triggered to germinate after a disturbance. Or they're annual plants whose seeds are dispersed widely on the wind--a whole collection of things that come up and stabilize the soils. And they maintain soil integrity as the system recovers.

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One of the classic studies in ecology was done on Hubbard Brook Experimental Forest back in the late 1960s. They logged some areas, herbicided all of the early-successional vegetation, and then looked to see what happened in the streams. What happened was predictable, but it had never been demonstrated quite so elegantly before. When you knock out that early-successional recovery mechanism, nutrients start bombing out of the system, soil integrity is disrupted. A lot of nutrients are lost, and it may take a long, long time to build those back up again.

It's an interesting thing--there has been much talk among ecologists over the last ten years or so about the importance of disturbance in systems and how changeable natural ecosystems are; and that's certainly true if you look above ground. Over decades and centuries there is quite a bit of flux in ecosystems, and in the plants that are present, and so forth. But if you look below ground, things change much less, they tend to be more stable, and those points of stability are what confers the ability of ecosystems to hang onto integrity and reform themselves over time after disturbance.

BA: I wanted to ask you about the role of mycorrhizal fungi.[2] You've already addressed this issue when you were speaking about the exchange of nutrients and the protection from pathogens in the below-ground ecosystem. But how key a role is this?

DP: It's absolutely essential. There are very few plants in the world that can grow successfully without mycorrhizal fungi. All forest trees in the temperate and boreal forests, and probably all of them in the tropical forests as well, require mycorrhizal fungi. The mycorrhizae gather water and nutrients, protect against pathogens, and extend the life of feeder roots. There may be thousands of times more gathering surface in the hyphae of mycorrhizal fungi than in roots. By far, the greatest presence of trees below ground is manifested through the mycorrhizal fungi.

It's now clearly established that mycorrhizal hyphae link trees of the same and different species, and the nutrients and carbon move between trees through these linkages. When you look above ground, you see a bunch of individuals. When you look below ground, that individuality becomes less clear.

The fungi do another thing. We're coming to believe that they confer a great deal of stability on the system because they're so diverse. If you take one tree, it's a single genotype, but that tree may have anywhere from twenty to fifty different species of mycorrhizal fungi on it. So the diversity of that one genotype all of a sudden gets manifested out into a minimum of twenty or fifty different genotypes that are present in its symbionts. When you account for the genetic diversity that is likely to exist within a given species of fungus on a tree, that diversity is magnified even more.

The fungus has a great deal of evolutionary capability over a short period of time that trees cannot have. Trees, being long-lived organisms, may produce a seed crop every two or three years, but how frequently do the conditions exist so that they can have progeny that will succeed? That may be a period of years or decades, and, in some forests, like the boreal, over a hundred years. Being long-lived organisms, trees have a fairly slow response capability in an evolutionary sense, and that puts them at a great disadvantage in their evolutionary sparring

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2 Fungi that form extensions of plant roots and increase nutrient and water .

match with tree-eating insects and pathogens, which can turn generations around rapidly, and therefore evolve very quickly.

Yet, if you factor in the tree's symbionts--the mycorrhizal fungi, the foliar endophytes[3] [...]--then an evolutionary capability is conferred on the tree, through it symbionts, that puts it on more of an even par with the pathogens and the tree-eating insects. That is a little explored, but potentially very important, aspect of the tree's symbiosis with fungi.

It's an interesting thing, if you look at both of the major surfaces with which trees interact with the environment--the crown and the roots--both are characterized by symbioses with fungi.

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3 [3]Foliar endophytes are microfungi that live symbiotically in plant leaves and help protect their hosts against pests and