Managing Our Grandchildren's Forests: The Role of Soil Biology and Soil Ecology[1]

James R. Boyle[2]

The papers of this volume provide some "nuggets" of insight into the complexity of soil biology and its potential relevance for considering options for forest management. The authors have presented a special perspective from which to view the rich diversity of soil biota and their roles in forest ecosystems.

Soil arthropods make the soil a lively place and can give us insights into soil processes. Matsutake mushrooms, fruiting bodies of mycorrhizal symbionts, are important as specialty human foods and indicators of intimate and crucial associations with tree roots. Truffle fungi provide significant connections between soil conditions and biota with flying squirrels and predators. Actinorhizal shrubs have important roles in a variety of forest ecosystems. In some cases their accretion of nitrogen appears to have a major significance for forests. Various forest cutting practices in the Pacific Northwest have different effects on soil organisms and organic matter decomposition processes. Effects are site- and cutting system-specific. Generalizations are risky and more research is needed to completely define important interactions and processes. Ectomycorrhizal associations undergo successional processes and are influenced by forest conditions and disturbance. Spatial variability in soils and variations of fungus-root associations over time mean that simple evaluations of possible mycorrhizal conditions are not likely to provide useful information. New techniques may help overcome some of this limitation.

The papers in these Proceedings suggest that we are challenged to take a truly holistic view of forest-soil systems and forest management. Thus, the sometimes-controversial concept of "ecosystem management" can have relevance for our consideration of soil biology and forest management. The term "ecosystem management" means managing forests with ecosystem principles in mind. This is an appropriate mental framework for putting forest soils in appropriate context within forest management. Because soils are essential, interactive components of forest ecosystems (*fig.* 1), let us consider some ecosystem principles and how soils relate to them.

A forest ecosystem can be viewed as a defined unit of forest landscape that lets us think usefully about inputs and outputs of matter and energy, essential structures and components of human value, and critical processes and dynamics (e.g., nitrogen compound transformations). An ecosystem is a "holistic system for accounting." For

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[2] Professor of Forestry and Soil Ecology, Forest Resources Department, College of Forestry, Oregon State University, Corvallis, OR 97330-5703.

convenience, we establish artificial boundaries to help define interactions with adjacent air, land, and water systems. Boundaries let us set the ecosystem of interest in an appropriate landscape setting. They give us points to measure incoming precipitation and outgoing water and sediments. An ecosystem has physical and biotic components: rocks, soils, microorganisms, and fauna above- and below-ground. It has structure: physical arrangement of slopes, herbs, shrubs, trees and water. And it is continuously being modified by myriad physical, chemical, and biological processes that move and transform matter and energy, water and nutrients, organic matter, and gases.

Soils within forest ecosystems support roots, water, and nutrients; store and transmit organic matter; and are habitats for a fantastic array of organisms. These organisms carry on numerous vital ecosystem processes. These include "chopping and shredding" organic matter as it passes through their guts, "tilling" the forest floor and mineral soil, burrowing and creating pores, "recycling" through decomposition processes, controlling each other by grazing and predation, and joining in symbioses of mycorrhizae and root nodules.

In relation to managed forests, it is appropriate to ask which critical forest ecosystem properties and processes influenced by soil biota are (1) *essential* to system maintenance, (2) *desirable* for system characteristics, and, (3) *likely to be influenced* by forest management. If we accept the "view from the bottom" (*fig. 1)*, we believe that any organisms involved in the following processes will be critical for forest productivity: effective plant rooting, water supply, plant nutrition, symbioses and rhizosphere processes. Plus, if we expand our view of critical processes to include those related to hydrology, we would consider habitats and other values of forests. By taking a "systems view" of potential forest management impacts on soil biology, we can evaluate changes to inputs of matter and energy to soils; transformation processes and related properties within soils (e.g., soil structure); and outputs from soils.

Forest management activities most often have two major effects on forest ecosystems: (1) simplification of the composition and diversity of plants at a site due to favoring desired crop trees and reducing or eliminating competing vegetation; and (2) altering, controlling, and reducing amounts and composition of organic residues by removing logs and "slash disposal." (Consider the implications of the latter: "slash" is bad; get rid of it; burn it; pile and burn it; windrow and burn it.) Of course, there are other management impacts on soils, including compaction and exposure to erosion, but these are likely to be under control via enlightened practices based on numerous workshops and current literature and knowledge. Thus, this discussion is limited to soil biota.

For context, consider the status of the "original" forests and soils that confronted our predecessor foresters. These were sites of some inherent natural productivity that had developed over hundreds or thousands of years of vegetation growing, shedding, dying and decaying—being "processed" by soil organisms—and interacting with other soil formation processes. Natural disturbances—such as periodic fires, windstorms, insect and disease epidemics and erosion, and slides and slumps—affected ecosystem conditions. Many of today's forest sites have had some harvesting and perhaps some management. (In the past, harvesting and "forestry," or forest management, were not necessarily synonymous!) Thus, soils of today's forests may or may not be the same as the first forests that were cut. It is relevant that today we do have some reserved uncut lands in parks, wilderness, and other areas that can serve as baselines for comparisons of soils and other forest properties.

The ideal baseline conditions of soil properties (*fig. 1*) have been created and maintained by soil biological processes (i.e., soil organisms) interacting with parent materials and topography, vegetation, and dynamic climactic conditions over time (time is significant only in its substitution for some measures of numbers of chemical reactions, volumes of percolating water, heating and chilling cycles, etc.) For example, when a good forester decides that there will be no more tanoak, ceanothus, bearclover, alder or vine maple, or tops and branches left throughout the site, he or she has decided to change the physical and biochemical composition of organic matter potentially recycled through the soil ecosystems. This means that the diverse populations of millipedes, mites, springtails, bacteria, actinomycetes, fungi, protozooans, worms and gophers that have evolved in the forest soils and have developed the productive capacity of the site are now confronted with new "diets," differing in composition and timing from those of a previous time. The good forester expects that the soils will continue to be as productive as they previously were (or based on the findings of the Fast Fix Fertilizer Co-Op, the forester may need to apply a little N).

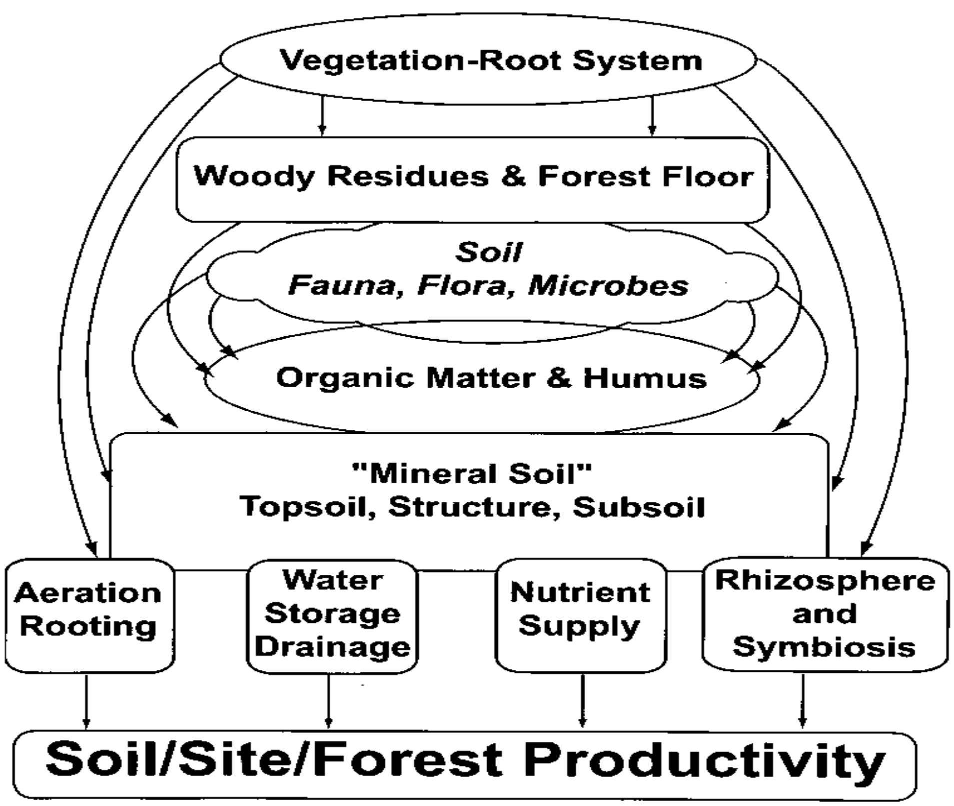

Figure 1—Forest productivity: a view from the bottom.

However, are we sure that soils will continue to be equally productive, harvest after harvest? If not, what indication will the forester have if there is a change? What will be the properties of the forest soils of our grandchildren's forest? How can we know the answers? What are the risks? What are the management options? In our quest for ecosystem management, should we view all sites the same? How can we evaluate forest management interactions with soil biology and related forest ecosystem properties and processes?

Here are some suggestions. All sites and soils are not the same. We can learn about soil management from our colleagues in agriculture. Soil zoologists, biologists, and ecologists provide clues, but they do not always have definitive answers. It is wise to recognize resilient and sensitive soils and to maintain options. Consideration of a "land ethic" seems useful in thinking about forest management and long-term productivity.

Obviously, all forest sites are different. It follows that management impacts on soil biology will differ as well. Steep, rocky, shallow soils developed from granites on south-facing slopes are likely to need more care in ensuring maximum organic matter retention than deep, nutrient-rich, gently-sloping soils developed from marine sediments. These contrasting site-types are surely different in soil biology and in the historic processes that have contributed to their present-day productive capacity. The more resilient sites have greater reserves of nutrients and rooting capacities and likely have more diverse biota and more efficient processes for recycling organic matter and nutrients than do the sensitive sites. It is logical to think of contrasting forest ecosystems in terms of differentially managing forestry impacts on soil biology and other critical ecosystem properties.

Experience in agriculture long ago led to crop rotations for managing soil properties related to organic matter and nutrients. Even today, in the most intensive Iowa corn and soybean cropping, farmers rotate corn and beans and use "no-till" practices to retain organic matter. This, of course, influences soil biology, soil structure, rooting, and nutrient- and water-retention capacity. Certainly, fertilizers and other chemicals are used extensively, but now they are applied with much more efficiency than they were previously. Extrapolating from agriculture, forestry can take advantage of longer crop rotations, potentially more diverse vegetation, and less frequent machine entries to effectively minimize impacts on soils. In the process, we can potentially manage forests—our renewable resources—with fewer inputs of non-renewable energy- and petroleum-based resources.

The information on soil biology from these Proceedings provides some interesting and important understandings of relationships between soil organisms and forests. However, except for extreme situations, many of the relationships involved in long-term productivity are not definitive. Foresters are challenged to intimately know their individual forest ecosystems, including soils and soil ecology, and to have the wisdom to know and apply relevant information about management-soil biology interactions. The links between amounts and types of organic residues are becoming clearer with research, but holistic interpretations are needed to apply reasonable constraints on forestry and to avoid needless panic reactions. I recommend the book *Soil Ecology* (Killham 1994), as a thorough, concise reference for understanding this important and complex subject.

It seems wise, in most cases, to maintain a number of options for long-term productivity by keeping maximum amounts and diversity of organic residues available for biological recycling. (Yes, there are cold, wet sites where maximum organic matter could be too much of a good thing. Such sites are common in British Columbia but are rarely found in most parts of California, Oregon, and Washington.) However, if a management practice drastically alters a soil's capacity to supply water, nutrients, structure, and biological function, how long will the condition persist? How extensively should the practice be applied? What amendments or alternative practices might be used to prevent adverse impacts? There is no substitute for local, site-specific knowledge and understanding. For instance, where are the "soil monitoring plots" analogous to the forest inventory plots? How often does a field forester examine a forest floor, dig a spadeful of soil, or even think about the basic soil resource in relation to his or her grandchildren's forest? Is this the place to start?

In considering this matter of forest management and soil biology, I return to Aldo Leopold's concepts in his essay, "The Land Ethic." In his view, land is an "energy circuit" (a holistic ecosystem). Land is not merely soil: native plants and animals keep the energy circuit open. Human changes are of a different order than evolutionary ones and often have effects more comprehensive than is intended or foreseen. For forest management and soil biology, the processes of this energy circuit mean that:

- Forest land is not merely soil, but a forest-soil system where the soil ecosystem and soil biology are connected to the forest.
- Soil biology and soil organisms have kept the forest-soil system going, while modified soil ecosystems may or may not do so.
- Changes made by forest management may be more drastic than evolutionary changes, causing effects to our grandchildren's forests that may or may not be foreseen.

Thus, foresters and soil scientists can use the best aspects of the "ecosystem management" concept to help us view forest-soil systems as holistic systems connected to atmospheric and aquatic systems. In this way, we might begin to perceive "soil ecosystems" and soil biology as important factors in the process of forest management. We can thus help manage our grandchildren's forests with a "view from the bottom" as well as with a view from the forest. We can see the trees *and* the soil. The papers of this volume direct us toward this holistic vision.

Reference

Killham, Ken. 1994. **Soil ecology**. Cambridge: Cambridge University Press; 242 p.