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Introduction

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The contribution of soil biota to sustainability: it depends. Or does it?

The six chapters in the final section of the book address the role of soil biota in a wider context of maintaining soil resources for *sustaining* the Earth's capacity to provide critical ecosystem services. This is quite possibly the most important, and frequently overlooked, function that soil biota provide. Without soil biota, the soil resource as we know it would not exist, and soil recovery in most ecosystems would proceed at orders of magnitude less than a snail's pace. Net primary productivity would be dramatically reduced by much slower rates of nutrient cycling, and therefore lower plant nutrient availability and nutrient effects would be exacerbated by water limitations as the lack of a stable soil structure would maintain relatively low plant available water holding capacities and even lower infiltration rates.

Soil organisms are responsible for ensuring that the nutrients necessary to produce the ear of corn that we will consume next year will be made available from last year's roots and residues. They are also responsible for sustaining the soil's capacity to provide us with food in the decades and centuries to come. While fertilizer additions can temporarily maintain production by substituting for biologically-mediated nutrient cycling, only soil biota can create and maintain stable soil structure. Soil structural stability increases resistance to soil erosion. Higher infiltration rates associated with better soil structure effectively decrease the erosivity of storms, further reducing soil loss and degradation. The rate and extent of recovery following degradation (resilience; sensu Holling & Meffe 1996; Seybold *et al.* 1999) are similarly supported by soil biotic activity.

A world without soil biota is not necessarily inconsistent with local increases in provisioning services (Millennium Ecosystem Assessment 2005), as illustrated by the success of hydroponics and biologically simplified fertigation systems on sandy soils; but, these systems, at least in their current form, are unsustainable in the absence of significant external inputs. At the same time, the sheer complexity and diversity of soil biota, and their resistance and resilience in response to disturbance, has, ironically enough, made it virtually impossible to identify a universally consistent role of specific groups of soil organisms for sustaining ecosystem services.

In the following chapters, however, the authors only implicitly acknowledge that if the big elephants (all soil biota) were to leave all of the rooms (ecosystems) in the global house, the house would collapse. Instead, they explicitly focus on the precise nature of the elephants and the characteristics (other than their size and ubiquitousness) that define their contributions to sustaining soil resources and related ecosystem services under particular sets of conditions. For decades, wildlife biologists were puzzled by the reported, but unconfirmed, existence of a "dwarf" elephant, hidden deep in the forests of Central Africa. The discovery that the "dwarfs" were simply juvenile forest-savanna elephant hybrids was disappointing to some, but trivial in comparison to the virtually simultaneous recognition that forest and savanna elephants play a functionally similar role in maintaining herbaceous "gaps" in their respective habitats (Western 2002). The study of soil biology may be at a similar stage: while we dither about the existence and importance of individual species and functional groups, we frequently fail to simply recognize what life would be like in the absence of them all.

The primary objective of this section of the book is not to recognize the importance of soil biota for sustaining soil resources and related ecosystem services; rather it is to define the frontiers of our understanding of the complexity of the diverse roles that soil biota play in sustainable ecosystems, and to identify critical knowledge gaps. Nearly all of the chapters in this section effectively describe the limitations to our understanding of the contributions of specific groups of soil biota. They identify the contradictions found in the results of reductionist and more holistic approaches alike, and attribute the inconsistencies to site- and disturbance-specific interactions with the soil biotic community. Each chapter also identifies what we *do* know, what we *might* know, and how this new knowledge could help increase our ability to support the development of sustainable management systems that take full advantage of the contributions of the soil biotic community to a sustainable soil resource and, in general, sustainable ecosystem functioning.

Chapter 5.3 by Karlen begins with a quote attributed to Plato where he describes degraded soils as "the skeleton of a sick man." Karlen continues this chapter with a description of the re-emergence of the concept of soil health and associated emphasis on soil biota during the past several decades, and then continues with a brief description of two approaches to assessment and monitoring. In Chapter 5.2, Barrios, Sileshi, Shepherd, and Sinclair deepen the discussion of soil health monitoring systems with an emphasis on the value of local knowledge, and the potential for systematic, coordinated strategies. This is also the only chapter in the book addressing the unique role of trees in fostering the provision of soil-based ecosystem services. This is an important and often underappreciated issue, particularly in light of the authors' assertion that "nearly half of all agricultural land has more than 10% tree cover."

Soil erosion is one of the primary and most persistent results and causes of soil degradation. In Chapter 5.1, Van Oost and Bakker consider the extent of soil loss and the challenges of estimating the effects of these losses on crop production. They include a key figure illustrating the generalized relationship between incremental soil loss and relative crop yield. Interpreted in the context of other chapters in this section, this figure suggests that studies of soil biota–management–crop productivity relationships should focus on nutrient cycling on relatively undegraded soils, while at later stages of degradation they should focus on soil water infiltration and holding capacity. The figure also supports the importance of careful soil profile characterization for these studies, such as the long-term farming system comparison used to parameterize the erosion model simulation for three farming systems described by Barrios *et al.* in Chapter 5.2. Chapter 5.4 by Cavigelli, Maul, and Szlavecz clearly describes the complex relationships between soil biota and ecosystem services, and describes a recently published set of six steps necessary to "determine if organic management supports biodiversity that is functionally significant with respect to pest control." A similar set of steps could be usefully applied to many questions about the importance of soil biota for other issues. The last two chapters address resilience and recovery processes. In Chapter 5.5, Grandy, Fraterrigo, and Billings apply ecological theory to understanding long-term soil dynamics. This chapter, together with Baer, Heneghan and Eviner's (Chapter 5.6) review of the contribution of soil ecology to restoration, emphasizes the importance of recognizing hysteresis, whereby degradation and restoration processes can be quite different, and occur over very different time periods.

Together, these chapters provide a summary of current knowledge and remaining challenges to identify, measure, and generalize the importance of soil biota for sustaining soil resources and their related ecosystem services in agroecosystems.

References

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