Biodiversity and Ecosystem Functioning in Soil

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Biodiversity and Ecosystem Functioning in Soil

We review the current knowledge on biodiversity in soils, its role in ecosystem processes, its importance for human purposes, and its resilience against stress and disturbance. The number of existing species is vastly higher than the number described, even in the macroscopically visible taxa, and biogeographical syntheses are largely lacking. A major effort in taxonomy and the training of a new generation of systematists is imperative. This effort has to be focussed on the groups of soil organisms that, to the best of our knowledge, play key roles in ecosystem functioning. To identify such groups, spheres of influence (SOI) of soil biota—such as the root biota, the shredders of organic matter and the soil bioturbators—are recognized that presumably control ecosystem processes, for example, through interactions with plants. Within those SOI, functional groups of soil organisms are recognized. Research questions of the highest urgency are the assignment of species to functional groups and determining the redundancy of species within functional groups. These priorities follow from the need to address the extent of any loss of functioning in soils, associated with intensive agriculture, forest disturbance, pollution of the environment, and global environmental change. The soil biota considered at present to be most at risk are species-poor functional groups among macrofaunal shredders of organic matter, bioturbators of soil, specialized bacteria like nitrifiers and nitrogen fixers, and fungiforming mycorrhizas. An experimental approach in addressing these research priorities is needed, using long-term and large-scale field experiments and modern methods of geostatistics and geographic information systems.

INTRODUCTION

Much of the terrestrial biosphere resides in the soil, largely unnoticed by professional biologists and lay people. This is ironic because the soil provides the physical substratum for virtually all human activities, e.g., agriculture, buildings, transport; it provides resources for industrial use and waste management; and it is central in elemental cycles, without which agriculture would not be possible. Soil organisms are not just **inhabitants** of the soil, they are **part** of the soil (1), heavily influencing soil properties such as hydrology, aeration and gaseous composition, all of which are essential for primary production and the decomposition of organic residues and waste materials.

ognition of the pivotal role of the world's biota as the life-support system for planet Earth, has revived interest in soil biodiversity as an asset to conserve, to understand and to manage wisely in terms of its contribution to ecosystem services.

The objective of this paper is to review the knowledge on the diversity of soil biota and its role in ecosystem functioning, and to identify key areas for future research.

Although the diversity of soil organisms is worth conserving and studying in its own right, their functional roles offer a useful framework for making this effort more meaningful. We will first define functional roles in a utilitarian way as ecosystem services. We will then have a closer look at what we mean by biodiversity in soil, emphasizing spheres of influence (2; 'biological systems of regulation' in 3) of the biota in soil and various ways of assembling species in size-classes and functional groups. Subsequently, we relate soil biodiversity to ecosystem processes. Finally, we will address the issue of the knowledge gap and what we need to ascertain in order to relate soil biodiversity to ecosystem functioning and ecosystem services.

ECOSYSTEM SERVICES OF THE SOIL BIOTA

The soil biota provides a number of ecosystem services that are used by society for its own purposes.

Decomposition of organic matter. When defined simply as mineralization of carbon, 90% decomposition is carried out by microorganisms such as bacteria and fungi (4). It is greatly facilitated by soil animals such as mites, millipedes, earthworms and termites that shred the residues and disperse microbial propagules. Together they are called decomposers. The soil decomposer community is used for waste management and the purification of polluted soil.

Nutrient cycling is closely associated with organic matter decomposition. Here again, the microorganisms do the job, but the rate at which the processes operate is determined by small grazers such as protozoa and nematodes, while larger animals enhance the process in 'hot spots' such as the gut and excrements. Nutrient cycling by soil biota is essential for all forms of agriculture and forestry. Efficient nutrient cycling on land is also essential for water quality. Specific groups of soil bacteria are involved in autotrophic elemental transformations, i.e. they do not depend on organic matter as a food source.

Bioturbation. Plant roots, ants, termites, earthworms and other soil macrofauna create channels, pores, aggregates and mounds that profoundly influence the transport of gases and water in soil. In so doing they create or modify microhabitats for other,

Whereas soils have been widely studied and classified in terms of physical and chemical characteristics, knowledge of soil biota lags far behind. This is partly due to a lack of recognition of the role of the biota in determining the physical and chemical properties and production potential of soils, and partly due to the bewildering diversity of soil organisms and the resulting taxonomic difficulties faced in identifying the soil's inhabitants. In high input agricultural systems, the importance of soil organisms has often been disregarded, as physical manipulation of the soil, disease and pest suppression, and nutrient supply have been increasingly provided by human inputs rather than by natural processes. However, the current shift towards sustainable land use, in particular sustainable agriculture and forestry, and the growing rec-

smaller, soil organisms. They are essential for maintaining the structure of soil in agriculture and forestry. Introduction of bioturbators is sometimes used to enhance the decomposition of organic pollutants in soil.

Suppression of soilborne diseases and pests. In natural ecosystems outbreaks of soilborne diseases and pests are relatively rare, whereas they are common in agriculture. It is widely assumed that low plant species diversity renders agroecosystems vulnerable to harmful soil organisms, but the causes of antagonism against pests and diseases in more species-rich systems can be manifold. The potential use of such antagonism in agriculture and forestry is enormous, but the subject is poorly studied.

Soil organisms—and, hence, soils as a whole—are affected

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Abstract:

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