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Perspective

Integrating social-ecological dynamics, microbial ecology and biodiversity conservation for sustainable landscape management

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Sustainable landscape management requires an integrated understanding of ecological processes, microbial dynamics and social-ecological systems. Human activities, land-use change and climate variability impact biodiversity and ecosystem function, yet the resilience of landscapes depends on the interactions among microbial communities, plant and animal diversity and human socio-economic behaviors. Soil microbes, including fungi and bacteria, regulate nutrient cycling, carbon storage and plant productivity, while social-ecological factors influence land-use decisions, resource management and conservation outcomes. This article synthesizes current research on microbial ecology, biodiversity conservation and social-ecological dynamics, highlighting strategies to enhance ecosystem services across natural and managed landscapes. By linking microbial processes with human governance and biodiversity objectives, we propose a framework for resilient and sustainable landscape management in the context of global environmental change.

Keywords: Social-ecological systems, Microbial ecology, Biodiversity conservation, Sustainable landscapes, Ecosystem services, Soil health, Landscape management, Climate adaptation, Ecosystem resilience.

Introduction

Landscapes are shaped by the interplay of ecological, microbial and human processes. Biodiversity underpins ecosystem services, while microbial communities mediate critical soil functions such as nutrient cycling, carbon sequestration and plant health. Human land-use practices—from agriculture and forestry to urban expansion—interact with these ecological components, influencing the sustainability and resilience of ecosystems. Social-ecological systems theory emphasizes that human and natural components are interconnected and managing landscapes sustainably requires integrating ecological knowledge with socio-economic and governance structures. The emerging challenge of global environmental change, including climate variability, habitat loss and soil degradation, necessitates an integrative approach. Understanding microbial dynamics, biodiversity patterns and social-ecological interactions is essential to maintain ecosystem function, optimize services and support sustainable resource use. This article explores these interactions across multiple scales, emphasizing strategies to manage landscapes in ways that balance human needs with ecological sustainability (Poulter B, et al. 2014). Soil microbes, including bacteria, fungi and archaea, drive essential ecosystem processes. Mycorrhizal fungi enhance plant nutrient uptake and drought tolerance, while saprotrophic fungi and bacteria decompose organic matter, recycling nutrients and regulating carbon fluxes. Nitrogen-fixing bacteria contribute to soil fertility, supporting primary production and ecosystem productivity. Microbial diversity promotes functional redundancy, ensuring that ecosystem processes persist under environmental stress.