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*Brief Report*

# Integrating microbial function and social-ecological dynamics

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Ecosystem function and human well-being are increasingly influenced by the complex interplay between microbial communities and social-ecological systems. Soil and water microbes drive essential processes such as nutrient cycling, carbon sequestration and stress tolerance, forming the foundation of ecosystem resilience. Meanwhile, human activities, land-use decisions and governance frameworks shape these ecological processes, creating feedbacks that affect both environmental health and societal outcomes. This article synthesizes current understanding of microbial function within ecosystems and its integration with social-ecological dynamics. Case studies from coastal wetlands, terrestrial soils and agricultural systems illustrate how microbial processes mediate ecosystem services and how human interventions modulate resilience. By bridging microbiology, ecology and social sciences, this framework provides actionable insights for sustainable ecosystem management under global environmental change..

**Keywords:** Microbial function, Social-ecological systems, Ecosystem resilience, Coastal wetlands, Soil microbiome, Nutrient cycling, Carbon sequestration, Climate adaptation, Human-environment interactions, Ecosystem services.

## Introduction

Ecosystems are shaped by interactions across multiple scales—from microbial activity in soils and water to human land-use and policy decisions. Microorganisms, including bacteria, fungi and archaea, are central to ecosystem processes, facilitating nutrient transformations, soil fertility and carbon cycling. These microbial processes underpin ecosystem services that directly support human well-being, such as food production, water purification and climate regulation.

Social-ecological systems emphasize the interconnectedness of human societies and ecosystems. Decisions regarding agriculture, urban development and resource management feed back into ecological processes, influencing microbial activity and ecosystem resilience. Integrating microbial ecology with SES frameworks allows a holistic understanding of how ecosystem services are maintained, enhanced, or degraded. Such integration is particularly critical in the context of global change, where climate extremes, pollution and habitat modification challenge both ecological and societal resilience. Soil microbes drive nutrient cycling and carbon dynamics through decomposition, nitrogen fixation and organic matter transformation. Functional diversity and redundancy within microbial communities ensure ecosystem stability under environmental stress. Specialized microbial taxa, such as ectomycorrhizal fungi, facilitate plant growth in nutrient-limited soils and enhance drought resilience by improving water and nutrient uptake. Coastal wetlands provide a unique interface between terrestrial and marine ecosystems (Xu C, et al. 2021). Microbial communities in wetland soils regulate biogeochemical cycles, influencing greenhouse gas emissions ($CO_2$, $CH_4$, $N_2O$) and nutrient retention. Vegetation type, inundation frequency and hydrological regimes shape microbial composition and activity, demonstrating that microbial-mediated processes are tightly linked to both biotic and abiotic ecosystem components.

## Description

Environmental disturbances, such as drought, flooding and pollution, can alter microbial community structure and function. Pre-exposure to stress can enhance microbial resistance, creating an "ecosystem memory" that promotes resilience. Microbial feedbacks influence plant physiology, soil fertility and carbon cycling, thereby modulating ecosystem recovery after disturbances. Microbial decomposition and soil organic matter stabilization directly affect carbon storage in terrestrial and wetland ecosystems. Mycorrhizal networks and bacterial consortia influence plant productivity, soil structure and carbon fluxes. Effective management of microbial communities can enhance carbon sequestration, mitigating climate change impacts. Microbial-mediated nitrogen fixation, phosphorus solubilization and organic matter decomposition underpin soil fertility (Kjøller R 2006). In agricultural landscapes, promoting beneficial microbial interactions enhances crop yield and nutrient use efficiency while reducing dependency on chemical fertilizers. These practices link microbial ecology with sustainable land management and food security.

Wetlands, through microbial-driven denitrification and pollutant degradation, maintain water quality and reduce eutrophication. Microbial activity in these systems also modulates greenhouse gas fluxes and supports biodiversity, illustrating the critical role of microbes in maintaining ecosystem services in both natural and restored landscapes. Land-use change, agricultural intensification, urbanization and pollution profoundly influence microbial community structure and function. Practices such as monocropping, overfertilization and wetland drainage can reduce microbial diversity, impair nutrient cycling and decrease ecosystem resilience. Recognizing these impacts is essential for designing sustainable management strategies. Integrating social dynamics into ecological management involves participatory governance, stakeholder engagement and knowledge co-production (Bergmark L, et al. 2012). Communities that actively participate in ecosystem management can implement locally adapted strategies, such as sustainable agriculture, wetland restoration and conservation programs, which support both microbial function and ecosystem services. Adaptive management frameworks that incorporate ecological monitoring, microbial assessments and social feedback loops enable dynamic responses to environmental change (Stokols D 1992). Policies promoting ecosystem restoration, biodiversity protection and sustainable resource use enhance the resilience of social-ecological systems and their microbial foundations.

Studies in southern Australian temperate wetlands reveal that inundation patterns and vegetation types shape microbial communities, influencing greenhouse gas emissions and nutrient cycling. Management strategies that restore hydrological regimes and native vegetation optimize microbial-mediated services, enhancing resilience against climate extremes. Drylands, despite water scarcity, contribute disproportionately to global productivity due to microbial and plant adaptations. Biological soil crusts, symbiotic fungi and drought-tolerant bacterial communities stabilize soils, enhance nitrogen availability and promote carbon storage, illustrating the critical role of microbial mediation in ecosystem services under stress (Stokols D 1996). In managed agricultural systems, integrating microbial monitoring with land-use planning improves soil fertility and productivity. The use of biofertilizers, crop rotation and organic amendments fosters beneficial microbial interactions, balancing production with ecosystem sustainability. Community involvement ensures that these practices are socially acceptable and economically viable.

## Conclusion

Microbial communities are fundamental drivers of ecosystem function, mediating nutrient cycling, carbon storage and resilience across biomes. Social-ecological dynamics—including land-use practices, governance and community engagement—modulate these microbial processes and their associated ecosystem services. Coastal wetlands, drylands and agricultural landscapes exemplify the interplay between microbial function and human systems, highlighting the importance of integrative approaches to ecosystem management. By combining microbial ecology with social-ecological frameworks, scientists, policymakers and communities can foster resilient ecosystems that sustain biodiversity, productivity and human well-being in the face of environmental change. By linking microbial ecology with social dynamics, this framework supports decision-making that enhances ecosystem resilience and human well-being under global change. Evidence-based strategies that incentivize restoration, sustainable land use and conservation.

## Acknowledgement

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## Conflict of Interest

The authors declare no conflict of interest.

## References

Xu, C., Wong, V. N., Reef, R. E. (2021). Effect of inundation on greenhouse gas emissions from temperate coastal wetland soils with different vegetation types in southern Australia. Science of the Total Environment 763:142949.

Kjøller, R. (2006). Disproportionate abundance between ectomycorrhizal root tips and their associated mycelia. FEMS Microbiology Ecology 58:214-224.

Bergmark, L., Poulsen, P. H. B., Al-Soud, W. A., Norman, A., Hansen, L. H., Sørensen, S. J. (2012). Assessment of the specificity of Burkholderia and Pseudomonas qPCR assays for detection of these genera in soil using 454 pyrosequencing. FEMS Microbiology Letters 333:77-84.

Establishing and maintaining healthy environments: Toward a social ecology of health promotion. American Psychologist 47:6.

Stokols, D. (1996). Translating social ecological theory into guidelines for community health promotion. American Journal of Health Promotion 10:282-298.

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