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Opinion

Integrating land-use planning, climate adaptation and human health in sustainable ecosystem management

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Sustainable ecosystem management has emerged as a critical framework for addressing the intertwined challenges of environmental degradation, climate change and human well-being. Land-use decisions, climate adaptation strategies and human health outcomes are deeply interconnected, influencing ecosystem function, biodiversity and service provision. This article examines the integrative approaches that link land-use planning with climate resilience and public health, highlighting mechanisms such as water regulation, soil microbiome dynamics and participatory governance. Drawing on evidence from flood control modeling, drought-affected agricultural systems, organic farming adoption and air quality impacts, we emphasize the need for multiscale, interdisciplinary strategies that promote both ecological integrity and societal resilience. By synthesizing recent advances in environmental management and socio-ecological research, this review underscores pathways for aligning land-use planning with climate adaptation and human health priorities to achieve sustainable ecosystem management.

Keywords: Land-use planning, Climate adaptation, Ecosystem services, Human health, Drought, Flood management, Soil microbiome, Participatory governance, Environmental sustainability.

Introduction

Human activities have profoundly reshaped terrestrial and aquatic ecosystems, altering biodiversity, carbon cycling and hydrological processes. Land-use change, driven by urbanization, agriculture and infrastructure development, represents a central driver of ecosystem disruption, influencing climate feedbacks and resource availability. Simultaneously, climate variability and extreme events, including floods and droughts, increasingly challenge the capacity of ecosystems to provide services critical to human health, such as clean water, food security and air quality. Sustainable ecosystem management requires a holistic understanding of the interconnections among land-use decisions, ecosystem function and human health outcomes. The integration of climate adaptation into land-use planning is essential for mitigating risks posed by extreme weather, maintaining ecosystem resilience and promoting equitable access to ecosystem services. In addition, the social dimensions of management—including participatory governance, community engagement and knowledge transfer—play a pivotal role in ensuring that ecological interventions translate into tangible benefits for local populations. Recent studies have highlighted key mechanisms linking land-use, climate adaptation and health outcomes (Zhang W, et al. 2022). For instance, flood regulation models demonstrate the importance of spatial planning for mitigating disaster risks, while investigations into drought effects on root exudates and rhizosphere microbiomes reveal how soil microbial communities mediate ecosystem resilience under stress. Moreover, participatory approaches to organic farming adoption illustrate the significance of human agency and institutional support in sustaining ecosystem services. Together, these perspectives underscore the need for integrative management frameworks that simultaneously address environmental, climatic and social dimensions.

Description

Land-use planning serves as a fundamental tool for aligning human development with ecosystem sustainability. Strategic zoning, green infrastructure development and landscape connectivity initiatives can reduce habitat fragmentation, enhance biodiversity and optimize the delivery of ecosystem services. Modeling studies, such as the MADM-GIS spatial-temporal analysis of flood control in China, highlight the importance of spatial prioritization for mitigating hydrological hazards and maintaining landscape functionality. By identifying sensitive areas and integrating ecological data into planning processes, policymakers can design interventions that simultaneously reduce environmental risks and enhance resilience to climate extremes. Agricultural landscapes, in particular, illustrate the trade-offs inherent in land-use decisions (Chen Y, et al. 2022). Conventional intensification often increases production but diminishes ecosystem services, including pollination, soil fertility and carbon sequestration. Conversely, adoption of organic and conservation-oriented practices can improve ecological integrity and support human well-being, though uptake depends on socioeconomic incentives and knowledge dissemination. Studies employing participatory causal loop mapping, such as those in Nigerian farming systems, reveal that farmer engagement, access to information and institutional support are critical determinants of sustainable land-use adoption.

Climate adaptation strategies are essential to buffer ecosystems against the impacts of droughts, floods and temperature extremes. Research on drought-induced changes in crop root exudates and rhizosphere microbial communities demonstrates how soil microbiomes influence plant performance under water stress. Such microbial mediation can enhance soil carbon retention, nutrient cycling and overall ecosystem productivity, highlighting the importance of integrating belowground processes into land-use and climate planning (Adebiyi JA, et al. 2022). Afforestation initiatives further illustrate the climate adaptation potential of land-use interventions. Studies in China have shown that large-scale tree planting not only sequesters carbon but also modifies local microclimates by cooling land surfaces, thereby reducing heat stress and enhancing human health outcomes. Similarly, wetland conservation and restoration provide multifaceted climate adaptation benefits, including flood mitigation, greenhouse gas regulation and support for biodiversity (Kale JR, et al. 2009). Integrating these strategies into land-use planning ensures that ecosystem services are maintained while communities are safeguarded from climate-induced hazards.

Human health outcomes are intricately linked to ecosystem function. Exposure to air pollution, for example, is exacerbated by land-use practices that reduce vegetation cover and increase particulate matter concentrations. Time-series studies in urban centers like São Paulo, Brazil, demonstrate the direct association between air quality and mortality rates, emphasizing the public health consequences of ecosystem degradation. Moreover, ecosystem services such as water regulation, pollination and soil fertility are foundational to food security and nutrition (Saldiva PH, et al. 1995). Research on insect pollination services in restored quarries indicates that both active and spontaneous restoration approaches can support pollinator communities, with implications for agricultural productivity and ecosystem resilience. Integrating such findings into land-use planning ensures that ecological interventions are aligned with the broader objective of promoting human well-being.

Conclusion

Integrating land-use planning, climate adaptation and human health into ecosystem management represents a pathway toward sustainable and resilient landscapes. Evidence from flood modeling, drought response studies, afforestation projects and participatory governance underscores the interdependence of ecological, climatic and social systems. By considering microbial mediation, biodiversity conservation and human dimensions, managers and policymakers can design interventions that simultaneously enhance ecosystem function, mitigate climate risks and promote well-being. Future efforts should prioritize multiscale approaches that link local ecological processes with landscape-level planning and national policy frameworks. Engagement of stakeholders through participatory mechanisms ensures that interventions are contextually relevant, socially accepted and ecologically effective. In an era of unprecedented environmental change, integrating land-use, climate adaptation and human health considerations is not only a scientific imperative but also a societal necessity for ensuring sustainable ecosystem services and resilient communities.

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Conflict of Interest

The authors declare no conflict of interest.

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