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Editorial: Ecosystem condition assessments: progress towards a global standard

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Editorial on the Research Topic
Ecosystem condition assessments: progress towards a global standard

1 Introduction

Ecosystem services (ES), as diverse benefits that natural ecosystems provide to human societies, are the bedrock of human well-being and sustainable development (see e.g. Costanza et al., 1998, 2017; Hicks et al., 2015). However, the escalating pressures of global climate change, rapid urbanization, and intensified human activities have led to a discernible deterioration in ecosystem condition worldwide, raising significant concerns among governments and the scientific community (Valencia Torres et al., 2021; Aryal et al., 2022). Understanding the complex spatiotemporal dynamics of these services (De Valck et al., 2023), identifying their key drivers, and anticipating future changes are therefore critical for developing effective environmental policies and management strategies (Xia et al., 2023). Recent research across diverse regions and ecosystems, from mainland and coastal China to East Africa forests, highlights the urgent need for comprehensive and data-driven assessment approaches, to support science-driven management and policy decisions for our natural capital.

2 Main considerations and management implications

The spatial and temporal evolution of ES reveals nuanced trends, often reflecting the interplay between natural processes and human interventions. For instance, a study conducted in Wanjiang River Basin, indicated that vegetation productivity generally improved in the area, based on the Remote Sensing Ecological Index, with ecological restoration efforts contributing to this positive change; however, the variation trend of annual net primary productivity (NPP) showed a slight decrease, maintaining a basically unchanged overall level (Wang et al.). A study for the Nanchang metropolitan area, revealed that various ES, e.g. carbon storage and habitat quality experienced declines, while soil conservation and water yield have an upward general trend, influenced significantly by the regional land use patterns (Zhang et al.). Additionally, a study in the Yunnan-Guizhou Plateau, shows that ES significantly fluctuate, e.g., water yield initially declined but later increased, habitat quality and carbon storage showed a steady decline and soil conservation, continuously improved (Li et al.). These diverse findings underscore the complexity of ecological responses to environmental changes, and the drivers of these changes are multifaceted, stemming from both natural and anthropogenic factors. Abiotic attributes like climate (precipitation, temperature, potential evaporation) and topography (elevation, slope), fundamental determinants of ES (Li et al.; Zhang et al.; Sun et al.), affect differently ES distribution. For instance, precipitation is identified as a primary determinant of water resource generation (Li et al.), the elevation and slope significantly restrict the spatiotemporal distribution of carbon storage (CS), habitat quality (HQ), and soil conservation (SC), while climate characteristics such as temperature, potential evapotranspiration, and precipitation primarily influence CS, HQ, SC, and water yield (see e.g. Sun et al.; Zhang et al.).

However, anthropogenic factors, particularly land use changes, population density, and economic development (GDP), emerge as dominant forces shaping ecosystems and their functioning. Urbanization often leads to a reduction in high-value ecological areas such as cultivated land and forestland, replacing them with construction land. This conversion directly impacts ES; for example, increased construction land contributes to the loss of carbon storage and habitat quality (Sun et al.; Xie and Zhang, 2023), human-induced pressures like over-exploitation of forest resources, deforestation, increased demand for wood energy, and land use change are cited as major causes for loss in forested areas and decrease in ES (Osewe et al.). In urban centers, a significant negative correlation between NPP and population density is documented, illustrating the direct impact of human concentration on vegetation productivity; in rapidly urbanizing areas, rising population levels accelerate urbanization, leading to extensive conversion of arable land for construction purposes, which reduces vegetation cover and subsequently, carbon storage and habitat quality (Zhang et al.). On the other hand, in areas with agricultural activities, a positive correlation between NPP and population density suggests that human activities, when managed sustainably, can contribute positively to ES (Wang et al.).

Understanding the complex interactions, trade-offs, and synergies among different ES is crucial for effective management. Research consistently shows a persistent negative correlation (trade-off) between WY and HQ or CS, often due to water regulation and the expansion of water bodies disturbing natural ecological environments. On the other hand, strong synergistic relationships are frequently documented between HQ, CS, and SC, with good HQ typically leading to higher biodiversity and enhanced CS (Li et al.; Sun et al.). The example from the Henan Province demonstrates that even if some trade-offs exist, the relation among five assessed ES (CS, HQ, SC, WC, WY) are predominantly synergistic, with trade-offs tending to transform into synergistic effects over time (Sun et al.). Additionally, advanced modelling, remote sensing technologies, and earth observation data and products are revolutionizing ES assessments, prediction for future scenarios and natural capital accounting (Kokkoris et al., 2024). Models like ARIES (Villa et al., 2014), InVEST (Sharp et al., 2015), and PLUS (Liang et al., 2021), combined with machine learning algorithms, provide powerful tools for quantifying ES, simulating complex, future land use changes, and identifying the spatial heterogeneity of driving factors at a fine (operational) spatial scale, enabling more accurate forecasting (Zhang et al.; Sun et al.). Additionally, the integration of machine learning techniques enhances predictive accuracy, particularly for identifying nonlinear relationships and complex interactions within ecological data (see e.g. Zhang et al.).

Multi-scenario modelling offers vital insights for managers and policymakers into how land-use changes will affect ES under different socio-economic development pathways. Scenarios that are typically simulated are projections for business-as-usual, specific management (goal)-oriented, smart scenarios, eco-friendly (see e.g. Kokkoris et al., 2019). Results consistently show that scenarios prioritizing environmental protection lead to the most favourable outcomes for fostering synergies and enhancing overall ES performance (Li et al.). For example, in the Yunnan-Guizhou Plateau, the ecological priority scenario demonstrated the best performance across all ES (Li et al.). Similarly, in Henan Province, the ecological protection scenario effectively safeguards forest land and grassland, mitigating the degradation of CS, HQ, and WC (Sun et al.).

3 Conclusion

The collective findings emphasize the critical need for an integrated and adaptive approach to ecosystem management. Effective policy interventions, guided by data-driven assessments and multi-scenario predictions, are essential for mitigating ecosystem condition degradation and promoting sustainable development. This involves: (a) Strategic land use planning, to minimise the conversion of ecological land for urban expansion and agriculture in vulnerable areas; (b) Targeted conservation and restoration efforts, prioritizing forest conservation, reforestation, wetland protection, and biodiversity safeguarding in high-value ecological zones; (c) Balancing human activities with environmental protection, by managing population growth and urban sprawl to reduce ecological pressure, while incentivizing sustainable practices in agriculture and other sectors; (d) Refined assessment tools, i.e., continuing to develop and integrate advanced models and remote sensing technologies for more precise and localized understanding of ecosystems, ES dynamics and their drivers. While significant progress has been made, research gaps remain, particularly in refining model parameters to reflect local ecological conditions, comprehensively analysing multifactor interactions, and incorporating higher-resolution data for more precise spatial analyses. Addressing these limitations will further enhance our capacity to manage complex ecological challenges and secure a sustainable future. The integration of EO data and products is also crucial to standardise methods and processes towards a global standard (Kokkoris et al., 2024), such as the System of Environmental-Economic Accounting—Ecosystem

Accounting (SEEA EA) (United Nations et al., 2021). The path forward demands continuous innovation in research and a steadfast commitment from policymakers to translate scientific insights into actionable strategies for ecological protection and human well-being.

Author contributions

IK: Writing – original draft, Writing – review & editing, Conceptualization. AK: Writing – review & editing. PD: Writing – review & editing.

Conflict of interest

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References

Aryal, K., Maraseni, T., and Apan, A. (2022). How much do we know about tradeoffs in ecosystem services? A systematic review of empirical research observations. *Sci. Total Environ.* 806, 151229. doi: 10.1016/j.scitotenv.2021.151229

Costanza, R., De Groot, R., Braat, L., Kubiszewski, I., Fioramonti, L., Sutton, P., et al. (2017). Twenty years of ecosystem services: How far have we come and how far do we still need to go? *Ecosyst. Serv.* 28, 1–16. doi: 10.1016/j.ecoser.2017.09.008

Costanza, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., et al. (1998). The value of the world's ecosystem services and natural capital. *Ecol. Econ.* 25, 3–15. doi: 10.1016/S0921-8009(98)00020-2

De Valck, J., Jarvis, D., Coggan, A., Schirru, E., Pert, P., Graham, V., et al. (2023). Valuing ecosystem services in complex coastal settings: An extended ecosystem accounting framework for improved decision-making. *Mar. Policy* 155, 105761. doi: 10.1016/j.marpol.2023.105761

Hicks, C. C., Cinner, J. E., Stoeckl, N., and McClanahan, T. R. (2015). Linking ecosystem services and human-values theory: Ecosystem Services and Human Values. *Conserv. Biol.* 29, 1471–1480. doi: 10.1111/cobi.12550

Kokkoris, I. P., Bekri, E. S., Skuras, D., Vlami, V., Zogaris, S., Maroulis, G., et al. (2019). Integrating MAES implementation into protected area management under climate change: A fine-scale application in Greece. *Sci. Total Environ.* 695, 133530. doi: 10.1016/j.scitotenv.2019.07.336

Kokkoris, I. P., Smets, B., Hein, L., Mallinis, G., Buchhorn, M., Balbi, S., et al. (2024). The role of Earth observation in ecosystem accounting: A review of advances, challenges and future directions. *Ecosyst. Serv.* 70, 101659. doi: 10.1016/j.ecoser.2024.101659

Liang, X., Guan, Q., Clarke, K. C., Liu, S., Wang, B., and Yao, Y. (2021). Understanding the drivers of sustainable land expansion using a patch-generating land use simulation (PLUS) model: A case study in Wuhan, China. *Comput. Environ. Urban Syst.* 85, 101569. doi: 10.1016/j.compenvurbsys.2020.101569

Sharp, R., Tallis, H. T., Ricketts, T., Guerry, A. D., Wood, S. A., Chaplin-Kramer, R., et al. (2015). "InVEST 3.2. 0 user's guide," in *The natural capital project*, vol. 133. .

United Nations, European Union, Food and Agriculture Organization of the United Nations, International Monetary Fund, Organisation for Economic Co-operation and Development and World Bank. (2021). System of Environmental-Economic Accounting—Ecosystem Accounting (SEEA EA). White cover publication, pre-edited text subject to official editing. Available online at: https://seea.un.org/ecosystem-accounting.

Valencia Torres, A., Tiwari, C., and Atkinson, S. F. (2021). Progress in ecosystem services research: A guide for scholars and practitioners. *Ecosys. Serv.* 49, 101267. doi: 10.1016/j.ecoser.2021.101267

Villa, F., Bagstad, K. J., Voigt, B., Johnson, G. W., Portela, R., Honzák, M., et al. (2014). A methodology for adaptable and robust ecosystem services assessment. *PloS One* 9, e91001. doi: 10.1371/journal.pone.0091001

Xia, H., Yuan, S., and Prishchepov, A. V. (2023). Spatial-temporal heterogeneity of ecosystem service interactions and their social-ecological drivers: Implications for spatial planning and management. *Resources Conserv. Recycling* 189, 106767. doi: 10.1016/j.resconrec.2022.106767

Xie, B., and Zhang, M. M. (2023). Spatio-temporal evolution and driving forces of habitat quality in Guizhou Province. *Sci. Rep.* 13, 6908. doi: 10.1038/s41598-023-33903-8