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Editorial: Vegetation–soil–hydrology interactions and ecohydrological processes

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Editorial on the Research Topic
Vegetation–soil–hydrology interactions and ecohydrological processes

1 Introduction

The many complex interactions among vegetation, soil, and hydrological processes generate important feedbacks between different spheres that make up the Earth system (Steffen et al., 2020). Vegetation influences the land surface's biophysical characteristics by modifying surface roughness, albedo, and interception of precipitation, which together ultimately affect local hydrological processes. These changes further modulate regional climatic factors, such as rainfall regime and near-surface air temperature, which in turn affect vegetation growth (Forzier et al., 2017). Soil not only provides water and nutrients essential for the growth and development of plants, but also serves as a crucial link connecting the atmosphere, hydrosphere, biosphere, and lithosphere. In addition, soil constitutes the primary medium for numerous biological, physical, and chemical processes, while water acts as the main vector of the exchange of matter and energy between these layers (Li, 2011). However, under the dual pressure of climate change and human activities, pressing challenges like water scarcity, soil functional degradation, and extreme meteorological events are increasing in both frequency and magnitude are demanding even more from our conventional understanding of hydrology and ecological management. Therefore, a deeper understanding of how the ecohydrological ecosystem interacts with both hydrological and geochemical processes is now imperative for advancing ecological restoration, enhancing water-use efficiency, and addressing environmental risks.

2 Overview of this special issue

This Special Issue focuses on the central theme of vegetation–soil–hydrology interactions and consists of 16 papers. The specific topics include hydrological modeling and disaster risk prediction; mechanisms of preferential flow; aeolian landforms and water regulation in grassland ecosystems; the evolution of soil functions; groundwater stress and its ecological risks; the ecological regulation of lakes and reservoirs; and drought dynamics.

As extreme meteorological events increase in both frequency and magnitude, enhancing hydrological modeling capabilities, including risk prediction, is particularly crucial for disaster prevention and mitigation. Chai et al. introduced the M-Copula function to construct a multidimensional joint distribution of critical rainfall. By calculating critical rainfall under different risk combinations, they proposed two-tier warning thresholds of "preparation transfer" and "immediate transfer". The findings contribute to the prevention and control of flash flood disasters. Wang et al. combined HEC–HMS with LSTM to develop a hybrid la-LSTM model, which enhanced the accuracy of rainfall-runoff simulations. Such modeling results can be used to improve flood forecasting and water resources management. In another study, Li et al. used the HEC-HMS model to evaluate the effects of soil water content and different rainfall patterns on flash flood evolution in small watersheds. The corresponding results can provide support for the simulation and early warning of mountain flood disasters. In the domain of agricultural water resources management, Chen et al. optimized maize irrigation strategies under various water deficit scenarios to enhance water use efficiency while maintaining yield. This study offers guidance for mitigating regional water scarcity, enhancing the efficiency of irrigation, and tackling challenges arising from rigid water resource constraints. Additionally, Schwamback et al. devised an innovative tipping-bucket flow meter, providing an efficient and low-cost solution for continuous runoff monitoring.

A study on preferential flow is included. Du et al. conducted dye tracer experiments on typical slopes at different positions in the Miyun Reservoir Basin. Their results revealed the preferential flow infiltration mechanisms that operate at various slopes and their interactions with soil properties, enriching our understanding of hydrological processes governing the migration and distribution of water, nutrients, and contaminants in the ecosystem.

Aeolian landforms are widely distributed in arid and semi-arid regions, representing a concentrated manifestation of regional ecological vulnerability and land degradation. Huang et al. combined the revised wind erosion equation and partial least-squares regression model to uncover the spatial patterns and driving factors of soil erosion dynamics in a wind erosion region. Bao et al. demonstrated that, at microtopographic scales, the sand deposition zones within wind-eroded pits harbor a certain water storage capacity under rainfall conditions; however, that water retention capacity is limited, and moisture is prone to rapid loss. These research findings provide empirical support for the management of wind-eroded pits and the restoration of grassland vegetation.

Soil acts as a nexus linking vegetation dynamics and hydrological processes (Shu et al., 2025), and its physicochemical properties and ecological functions continually evolve in the face of external disturbances. When Zha et al. compared different soil profiles in the Yangshao Village cultural relic site, they found that ancient humans were able to enhance the fertility of soil via various practices, such as slash-and-burn activity, habitation, and the application of human and animal feces. However, these activities also disrupted the original soil voids and structure, which prevented the downward leaching or precipitation of soil particles and minerals, thereby hindering soil development overall. Melkani et al. discovered in a subtropical nature reserve that wet and dry seasons, along with different land cover types, can regulate its hydrolytic enzyme activities and organic matter decomposition, thereby influencing both the carbon cycle and soil nutrient cycling. Saline-alkali land is an important and abundant land resource in China, but its high salinity and low fertility severely constrain agricultural productivity. Through field experiments carried out on saline-alkali land in Xinjiang, Chen et al. found that an appropriate application of FGD gypsum and aeolian sand is able to improve the physicochemical properties of saline-alkali soils and effectively inhibit greenhouse gas emissions. Overall, among the treatments used, the application of aeolian sand at 30 t/ha was the most effective improvement measure. This finding provides a key technological pathway for not only the reclamation of saline-alkali land but also the reduction of carbon emissions.

Groundwater, a vital water resource in arid and semi-arid regions, also faces dual pressure from intensified human activities and climate change. To address the ecological problems caused by groundwater overexploitation, Xiao et al. employed numerical modeling, finding that under overexploitation, the discharge of the BL Spring located in Xilin Gol League continues to decline, which could eventually lead to the spring's exhaustion and ecological degradation. Using 50 years of hydrological data, Zhang et al. analyzed the long-term evolution of surface water and groundwater interactions in the secondary perched reach of the lower Yellow River. They found that both river water and groundwater levels show a significant downward trend, while the recharge from river water to groundwater has markedly weakened and exhibits a notable time lag.

Lakes and reservoirs serve as nodes for regional water security and ecological conservation. Work by Liu et al. demonstrated that, while external water replenishment can improve the water quality of Ulansuhai Lake, its long-term enhancement still depends on pollution source control and protection of lake water ecology. Yang and Liu, focusing on ecological protection objectives, established an ecological operation model of sediment-laden river reservoirs for wetland protection. This model successfully balanced multiple objective requirements, including water supply, ecological, sediment transport, power generation, and flood control in the Xiaolangdi Reservoir. This study shows that an equilibrium between economic benefits and ecological protection is indeed achievable.

Finally, drought, among the most destructive natural disasters, is happening more frequently under the influence of climate change. Wan et al. revealed the propagation law and stage response relationship between meteorological elements and hydrological drought in the Xiangtan area, thus providing a scientific basis for bolstering drought mitigation and drought risk assessment there.

3 Conclusion

This Special Issue centers on "vegetation–soil–hydrology interactions" and features a collection of 16 representative research articles, covering an array of timely topics: hydrological modeling and disaster risk prediction, preferential flow mechanisms, soil-water processes in wind erosion regions, the evolution of soil functions, groundwater security, ecological regulation of lakes and reservoirs, and drought evolution. These studies entail advances not only in theoretical modeling, experimental observation, and methodological approaches, but also in practical applications such as agricultural water conservation, ecological restoration, and disaster prevention and control. Overall, their collective findings deepen our understanding of the complex feedback mechanisms among vegetation, soil, and hydrological processes, while providing a scientific foundation and practical references for water resource optimization and ecosystem sustainability.

Author contributions

X-DH: Funding acquisition, Writing – original draft, Writing – review and editing. G-ML: Writing – review and editing. P-PH: Writing – review and editing. JL: Writing – review and editing. JZ: Writing – review and editing.

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