



applied sciences

Article

Simulation and Optimization of Urban Multiscale Ecological Networks Integrating Human Demand and Natural Processes

Fengxiang Jin ^{1,2,†}, Yougui Feng ^{1,3,†}, Zhe Zhang ^{1,4,*}, Qi Wang ^{1,*} and Yingjun Sun ¹

¹ School of Surveying and Geo-Informatics, Shandong Jianzhu University, Jinan 250101, China; fengyougui@sdjzu.edu.cn (Y.F.)

² School of Geodesy and Geomatics, Shandong University of Science and Technology, Qingdao 266590, China

³ Zhejiang Zhengyuan Geographical Information Co., Ltd., Huzhou 313200, China

⁴ Urban and Rural Planning Department, School of Architecture, Southwest Jiaotong University, Chengdu 611756, China

* Correspondence: zzhe@my.swjtu.edu.cn (Z.Z.); wangqi19@sdjzu.edu.cn (Q.W.)

† These authors contributed equally to this work.

Abstract

Constructing ecological networks (ENs) is an effective measure to mitigate the conflict between urban development and ecological conservation. However, existing simulating methods lack adequate consideration of human ecological demands and the spatial scale differences between these demands and natural ecological processes. This might lead to issues such as incomplete ecological process cycles or structural mismatches being overlooked during ENs simulations. To address these gaps, this study proposed an urban multi-scale nested ENs simulating framework that integrates human ecological demands with natural ecological processes. The framework first simulated an ENs focused on natural ecological process cycles at a global scale (GS). Then, it simulated an ENs centered on human ecological needs within the core urban areas at local scale (LS). Finally, it nested these multi-scale ENs by using cross-scale ecological supply sources as connecting points. This framework was applied to simulate spatio-temporal pattern changes in ENs of Jinan City, a core city in downstream of the Yellow River in China, aiming to mitigate cross-scale ecological conflicts between human–nature interactions under the background of urbanization. The study's findings revealed that the area of demand sources increased by 8.56 times over 20 years, the area of cross-scale supply sources decreased by 15 km² relative to 2000, and the deterioration in connectivity was more pronounced in GS compared to LS, with a decline of approximately 13.8%. These changes indicate the presence of incomplete ecological process cycles and structural mismatches across the multi-scale boundaries within the study area, which have been worsening annually. We recommend optimizing Jinan City's multi-scale ecological network through three key strategies: rectifying internal structural mismatches, protecting core ecological areas, and aligning regional ecological demands. Implementing these strategies could significantly improve the network structure, reduce cross-scale mismatches, and enhance ecological connectivity by about 9%. This study highlights the importance of addressing structural mismatches and promoting complete ecological cycles in urban multi-scale ENs simulating, providing valuable insights for formulating urban multi-scale ecological conservation and restoration policies.

Keywords: multi-scale ecological networks; scale nesting; urbanization process; human ecological demands



Academic Editor: Alexandros A. Lavdas

Received: 7 December 2025

Revised: 25 January 2026

Accepted: 28 January 2026

Published: 30 January 2026

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