



Scenario-based simulation of ecosystem service supply and demand in China's Yangtze River Economic Belt

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ARTICLE INFO

Keywords:

Ecosystem service supply/demand ratio
Simulated annealing algorithm
Bayesian modelling
Self-organizing mapping
Economic and ecological synergistic development

ABSTRACT

Balancing the supply and demand of ecosystem services is essential for achieving regional sustainable development. A key scientific challenge lies in identifying and improving areas with ecosystem service supply-demand ratio (ESR) imbalances across different spatial scales. Aiming to promote the coordinated development of the economy and ecology in China's Yangtze River Economic Belt (YREB), this study employed a simulated annealing algorithm coupled with the FLUS model to simulate five future land use scenarios for the year 2030. Based on the optimal scenario, ESRs for 2030 were calculated and compared with those in 2010 and 2020. Furthermore, self-organizing mapping (SOM) and Bayesian belief networks (BBNs) were applied to propose optimization pathways from macro and micro perspectives, respectively. The main conclusions are as follows: (1) Over the 30-year period, all four types of ecosystem services exhibited notable changes, with supply states increasing by approximately 4 %–6 % for all services except Carbon Sequestration. In terms of carbon sequestration and soil conservation, Jiangsu and Shanghai remained predominantly in a demand state, with proportions exceeding 90 %. (2) From a macro perspective, CLASS1 areas prioritize economic development, with average ESR values of 0.45, 0.25, 0.15, and 0.30, in contrast to CLASS3 areas, which emphasize ecological conservation. (3) From a micro perspective, the achieved areas for Carbon Sequestration services accounted for the largest share (99.20 %), while the pending optimization area for Water Conservation services accounted for the largest share (92.90 %). To achieve economic and ecological synergistic development in the YREB, differentiated and targeted regulatory strategies should be adopted based on the ESR supply-demand characteristics at multiple spatial scales.

1. Introduction

With the intensification of global climate change and increasingly frequent land use conflicts, ecosystem services (ES)—the various beneficial functions provided by natural ecosystems to human society—have become a central issue in regional sustainable development. The ecosystem service supply-demand ratio (ecosystem service supply-demand ratio, ESR) serves as a key metric to assess the rationality of spatial ecosystem service distribution and the level of ecological security. ESR is defined as the ratio between the supply capacity of ecosystem services and the societal demand for those services, reflecting the extent to which human needs are met by natural systems. It is an essential

evaluation tool in ecological management and land-use planning (Chen et al., 2024a,b; Xiong and Yang, 2025)

To achieve this, various evaluation approaches for identifying and quantifying ESR have been proposed. The earlier Ecosystem Service Demand-Supply Difference (ESD) method represents surplus or deficit through the difference between supply and demand. Although operationally simple, it lacks standardized units, leading to poor comparability across different services (Wu et al., 2022). To overcome this, scholars introduced the Ecosystem Service Supply-Demand Index (ESSDI), which standardizes supply and demand values into a relative ratio, enhancing cross-service and multi-regional comparability (Jiang et al., 2025; Zhai et al., 2025). While ESSDI is advantageous for

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<https://doi.org/10.1016/j.envres.2025.122264>

Received 6 May 2025; Received in revised form 29 June 2025; Accepted 29 June 2025

Available online 3 July 2025

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