



Article

Research on the Carbon Sequestration Capacity of Forest Ecological Network Topological Features and Network Optimization Based on Modification Recognition in the Yellow River Basin Mining Area: A Case Study of Jincheng City

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Abstract: Forests are vital for terrestrial ecosystems, providing crucial functions like carbon sequestration and water conservation. In the Yellow River Basin, where 70% of forest coverage is concentrated in the middle reaches encompassing Sichuan, Shaanxi, and Shanxi provinces, there exists significant potential for coal production, with nine planned coal bases. This study centered on Jincheng City, Shanxi Province, a representative coal mining area in the Yellow River Basin, and combined the MSPA analysis method and MCR model to generate the five-period forest ecological network of Jincheng City from 1985 to 2022 under the background of coal mining and calculate the degree centrality, closeness centrality, betweenness centrality, and eigenvector centrality; the correlation between the four centralities and carbon sequestration ability is further explored. Simultaneously, employing the RAND-ESU algorithm for motif identification within forest ecological networks, this study integrates the ecological policies of the research area with the specific conditions of the coal mining region to optimize the forest ecological network in Jincheng City. Findings reveal the following. (1) Forest ecological spatial networks: Forest ecological networks exhibit robust overall ecological connectivity in the study area, with potential ecological corridors spanning the region. However, certain areas with high ecological resistance hinder connectivity between key forest ecological nodes under the background of coal mining. (2) Correlation between topological indices and carbon sequestration ecological services: From 1985 to 2022, the carbon sequestration capacity of Jincheng City's forest source areas increased year by year, and significant positive correlations were observed between degree centrality, betweenness centrality, eigenvector centrality with carbon sequestration ecological services, indicating a strengthening trend over time. (3) Motif Recognition and Ecological Network Optimization: During the study, four types of motifs were identified in the forest ecological network of Jincheng City based on the number of nodes and their connections using the RAND-ESU network motif algorithm. These motifs are 3a, 4a, 4b, and 4d (where the number represents the number of nodes and the letter represents the connection type). Among these, motifs 3a and 4b play a crucial role. Based on these motifs and practical considerations, network optimization was performed on the existing ecological source areas to enhance the robustness of the forest ecological network.

Keywords: forest ecological network; motif-based network optimization; motif recognition; carbon sequestration capacity; MSPA combined with MCR



Citation: Li, M.; Yu, Q.; Xu, C.; Zhao, J.; Zeng, Y.; Wang, Y.; Liu, Y. Research on the Carbon Sequestration Capacity of Forest Ecological Network Topological Features and Network Optimization Based on Modification Recognition in the Yellow River Basin Mining Area: A Case Study of Jincheng City. *Remote Sens.* **2024**, *16*, 1986. <https://doi.org/10.3390/rs16111986>

Academic Editor: Hubert Hasenauer

Received: 17 April 2024

Revised: 23 May 2024

Accepted: 30 May 2024

Published: 31 May 2024



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1. Introduction

Since the advent of the Industrial Revolution, characterized by the relentless progression of economic and societal development alongside advancements in industrialization, there has been an unprecedented reliance on fossil fuel resources such as coal in human production and livelihoods [1]. Extensive coal mining has led to significant emissions of

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Study on the Driving Factors of the Spatiotemporal Pattern in Forest Lightning Fires and 3D Fire Simulation Based on Cellular Automata

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Abstract: Lightning-induced forest fires frequently inflict substantial damage on forest ecosystems, with the Daxing'anling region in northern China recognized as a high-incidence region for such phenomena. To elucidate the occurrence patterns of forest fires caused by lightning and to prevent such fires, this study employs a multifaceted approach, including statistical analysis, kernel density estimation, and spatial autocorrelation analysis, to conduct a comprehensive examination of the spatiotemporal distribution patterns of lightning-induced forest fires in the Greater Khingan Mountains region from 2016–2020. Additionally, the geographical detector method is utilized to assess the explanatory power of three main factors: climate, topography, and fuel characteristics associated with these fires, encompassing both univariate and interaction detections. Furthermore, a mixed-methods approach is adopted, integrating the Zhengfei Wang model with a three-dimensional cellular automaton to simulate the spread of lightning-induced forest fire events, which is further validated through rigorous quantitative verification. The principal findings are as follows: (1) Spatiotemporal Distribution of Lightning-Induced Forest Fires: Interannual variability reveals pronounced fluctuations in the incidence of lightning-induced forest fires. The monthly concentration of incidents is most significant in May, July, and August, demonstrating an upward trajectory. In terms of temporal distribution, fire occurrences are predominantly concentrated between 1:00 PM and 5:00 PM, conforming to a normal distribution pattern. Spatially, higher incidences of fires are observed in the western and northwestern regions, while the eastern and southeastern areas exhibit reduced rates. At the township level, significant spatial autocorrelation indicates that Xing'an Town represents a prominent hotspot ($p = 0.001$), whereas Oupu Town is identified as a significant cold spot ($p = 0.05$). (2) Determinants of the Spatiotemporal Distribution of Lightning-Induced Forest Fires: The spatiotemporal distribution of lightning-induced forest fires is influenced by a multitude of factors. Univariate analysis reveals that the explanatory power of these factors varies significantly, with climatic factors exerting the most substantial influence, followed by topographic and fuel characteristics. Interaction factor analysis indicates that the interactive effects of climatic variables are notably more pronounced than those of fuel and topographical factors. (3) Three-Dimensional Cellular Automaton Fire Simulation Based on the Zhengfei Wang Model: This investigation integrates the fire spread principles from the Zhengfei Wang model into a three-dimensional cellular automaton framework to simulate the dynamic behavior of lightning-induced forest fires. Through quantitative validation against empirical fire events, the model demonstrates an accuracy rate of 83.54% in forecasting the affected fire zones.



Citation: Li, M.; Wu, Y.; Liu, Y.; Zhang, Y.; Yu, Q. Study on the Driving Factors of the Spatiotemporal Pattern in Forest Lightning Fires and 3D Fire Simulation Based on Cellular Automata. *Forests* **2024**, *15*, 1857. <https://doi.org/10.3390/f15111857>

Academic Editors: Rafael De Ávila Rodrigues and Rafael Coll Delgado

Received: 30 September 2024

Revised: 19 October 2024

Accepted: 22 October 2024

Published: 23 October 2024



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Keywords: forest lightning fire; cellular automata; geographical detector; 3D simulation; spatiotemporal pattern



Article

Unveiling Drivers and Projecting Future Risks of Desertification Vulnerability in the Mongolian Plateau

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Abstract

Desertification presents a significant ecological challenge in arid and semi-arid regions, posing a severe threat to regional ecological security and sustainable development. This study introduces an integrated framework for desertification vulnerability assessment, combining the MEDALUS model with the XGBoost algorithm, to evaluate desertification dynamics across the Mongolian Plateau from 2000 to 2020 and project future trends under four Shared Socioeconomic Pathways (SSPs) for 2030. The findings are as follows: (1) Between 2000 and 2020, desertification vulnerability was most pronounced in the southern and western regions of the plateau, with lower vulnerability observed in the northern and eastern areas. High-vulnerability zones expanded over time, highlighting the need for targeted and prioritized management efforts. (2) Climate factors—particularly temperature, wind speed, and precipitation—emerged as the dominant drivers of desertification, followed by soil characteristics and vegetation (NDVI). The influence of human activities on desertification became increasingly significant, stressing the need for improved land management and sustainable practices. (3) Future risks show that desertification vulnerability in the Mongolian Plateau will intensify under high-emission scenarios (SSP3-7.0, SSP5-8.5), with significant expansion of high vulnerability areas. Lower-emission scenarios (SSP1-2.6, SSP2-4.5) may reduce some impacts, but high vulnerability will persist, highlighting the need for urgent climate mitigation and adaptation efforts.

Keywords: desertification; Mongolian Plateau; MEDALUS; XGBoost algorithm



Academic Editor: Dimitrios D. Alexakis

Received: 10 June 2025

Revised: 7 July 2025

Accepted: 8 July 2025

Published: 11 July 2025

Citation: Li, M.; Avirmed, B.; Bayanmunkh, G.; Liu, Y.; Wang, Y.; Yang, X.; Zhang, Y.; Yu, Q. Unveiling Drivers and Projecting Future Risks of Desertification Vulnerability in the Mongolian Plateau. *Remote Sens.* **2025**, *17*, 2389. <https://doi.org/10.3390/rs17142389>

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1. Introduction

Desertification is one of the most critical manifestations of global ecosystem degradation, representing a significant threat to regional ecological security and sustainable development [1–3]. The Mongolian Plateau, home to the largest contiguous temperate grassland ecosystem in Eurasia [4,5], serves as a vital ecological transition zone that connects the East Asian monsoon domain with the arid regions of Central Asia [6,7]. In recent decades, this region has experienced a marked decline in ecological stability, driven by the compounded effects of climate change and anthropogenic pressures [8–10]. Currently, over 72% of the land on the Mongolian Plateau is affected by desertification to varying degrees [11,12], making the region a critical hotspot for investigating desertification dynamics in dryland systems globally.

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