Ecosystem Health Assessment and Response Strategies for the Beijing-Zhangjiakou Region: Postprint

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Abstract

Utilizing remote sensing and GIS spatial analysis methods, with 66 small watersheds as evaluation units, this study analyzed the ecosystem status of the Beijing-Zhangjiakou region and proposed corresponding countermeasures. The research indicates: The overall ecosystem health level in the Beijing-Zhangjiakou region is poor, with nearly 60% of the area being ecologically unhealthy or relatively unhealthy; An ecological green belt with a high health index exists at the junction of Beijing and Zhangjiakou, from which the health index gradually decreases towards the southeast and northwest; Beijing' s overall ecological health index is higher than that of Zhangjiakou; The ecological health status in the Beijing-Zhangjiakou region exhibits polarization at the county scale, with most counties having either >80% or <30% of their area in healthy condition; Low mean patch area index is a global factor constraining ecological health across the entire Beijing-Zhangjiakou region; low primary productivity, high human disturbance, and low river network density are the main influencing factors in ecologically unhealthy areas. Countermeasures: Protect the ecological green belt at the Beijing-Zhangjiakou junction, with focused strengthening of ecological construction in watershed No. 37; Strengthen ecological construction in the marginal areas of the southeast and northwest wings of the Beijing-Zhangjiakou region; increase conversion of cropland to forest and grassland at the Bashang edge; watersheds No. 66 and No. 39 at Beijing' s southeastern margin should focus on controlling urban area expansion and increasing natural vegetation patch area; Enhance supervision of generally healthy watersheds to promote the development of small mosaic patches into contiguous healthy areas; prioritize the treatment of contiguous relatively unhealthy ecological areas in Zhangjiakou; The focus of ecological construction should be on increasing vegetation patch area and vegetation coverage, reducing large-scale cultivation and urbanization, and restoring river networks; Establish an ecological special zone in Zhangjiakou.

Full Text

Assessment and Countermeasures of Ecosystem Health in the Beijing-Zhangjiakou Area

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Abstract

This paper analyzes the status of ecosystems in the Beijing-Zhangjiakou region using remote sensing (RS) and geographic information system (GIS) spatial analysis, with 66 drainage basins serving as the evaluation units. The results show that the ecological health level in the Beijing-Zhangjiakou region is low, with nearly 60% of the area being unhealthy or relatively unhealthy. At the junction of Beijing and Zhangjiakou cities, there exists an ecological green belt with a high health index. From this junction toward the southeast and northwest, the ecological health index shows a decreasing trend. The ecological health index in Beijing is higher than that in Zhangjiakou. A polarization of regional ecological health status occurs at the county scale in the Beijing-Zhangjiakou region, with the majority of counties and districts having either more than 80% or less than 30% of their area in a healthy ecological state. The low average patch area index is the overall factor restricting ecosystem health in the Beijing-Zhangjiakou region. Low primary productivity, high levels of human disturbance, and low drainage density are the main factors affecting unhealthy ecosystems. The following countermeasures are proposed: (1) The ecological green belt at the junction of Beijing and Zhangjiakou should be well protected, and ecological construction in small watershed No. 37 should be emphasized; (2) It is suggested to promote ecological construction in the southeast and northwest marginal zones of the Beijing-Zhangjiakou region, enhance implementation of the Grain for Green Project in the Bashang Plateau, and control urban area expansion while enlarging natural vegetation patches in small catchments No. 66 and No. 39; (3) Focus should be placed on supervising drainage basins with general ecological health and promoting the connection of small mosaic patches with healthy ecosystems; (4) The priorities of ecological construction are to enlarge vegetation patch area and increase vegetation coverage, reduce large-scale farming and urbanization construction, and improve restoration of drainage basins; (5) It is also suggested to establish special ecological zones in Zhangjiakou.

Keywords: ecosystem health; small watershed; spatial feature; countermeasure; Beijing-Zhangjiakou region

1. Introduction

The Beijing-Zhangjiakou region serves as an important ecological barrier for the capital. Assessing ecosystem health in this area is crucial for regional sustainable development and ecological security. This study employs remote sensing and GIS technologies to evaluate ecosystem health at the watershed scale, providing scientific basis for ecological restoration and management.

2. Methods

2.1 Evaluation Index System

The ecosystem health evaluation index system (Table 1) comprises five primary indicators: vegetation coverage, landscape pattern, ecosystem service function, human disturbance intensity, and soil erosion intensity. Each indicator contains multiple secondary evaluation metrics.

Table 1 Evaluation index system of ecosystem health

Primary Indicator	Secondary Indicators
Vegetation coverage	Normalized Difference Vegetation Index (NDVI)
Landscape pattern	Patch density, average patch area, landscape shape index
Ecosystem service function	Soil conservation, water retention, carbon sequestration
Human disturbance intensity	Construction land proportion, population density
Soil erosion intensity	Soil erosion modulus

The ecosystem quality index (EQI) is calculated using the formula:

$$EQI = \text{ vegetation coverage}\times w_1 + \text{ landscape pattern}\times w_2 + \text{ ecosystem service function}\times w_3 + \text{ human disturba}$$

where w_1 through w_5 represent the weights of each indicator.

2.2 Data Sources and Processing

The study utilized Landsat 8 OLI imagery, DEM data with 30m resolution, and statistical yearbook data. Image preprocessing included radiometric calibration, atmospheric correction, and image fusion. The watershed boundaries were delineated using hydrological analysis tools in ArcGIS.

3. Results

3.1 Spatial Distribution of Ecosystem Health

The ecosystem health index was classified into five levels (Table 4). The spatial distribution shows that healthy ecosystems are primarily concentrated in the mountainous areas at the Beijing-Zhangjiakou junction, forming an ecological green belt. The health status gradually deteriorates toward the southeast (Beijing Plain) and northwest (Zhangjiakou plateau region).

Table 4 Classification evaluation of ecosystem health index

Health Level	EQI Range	Ecological Status
Level 1	47-58	Healthy
Level 2	37-47	Relatively healthy
Level 3	27-37	Generally healthy
Level 4	17-27	Relatively unhealthy
Level 5	<17	Unhealthy

3.2 Watershed-Scale Assessment

Among the 66 evaluated watersheds (Table 5), 15 watersheds (29% of total area) were classified as unhealthy, primarily distributed in Zhangjiakou' s Bashang Plateau region. Eighteen watersheds (31% of area) were relatively unhealthy, mainly in the transitional zone between mountainous and plain areas. Only 10 watersheds (9% of area) achieved healthy status, concentrated in the Yanshan Mountains.

Table 5 Ecological health level of small watersheds in the Beijing-Zhangjiakou area

Health Level	Watershed Count	Area (km^2)	Area Percentage (%)
Level 1	10	4,968	9
Level 2	12	7,326	14
Level 3	11	8,875	17
Level 4	18	16,359	31
Level 5	15	15,641	29

3.3 County-Scale Analysis

At the county level, significant polarization is evident (Table 6). Counties such as Chicheng and Zhangbei show over 80% of their area as unhealthy, while Yanqing and Miyun in Beijing exhibit over 80% healthy ecosystems. This polarization reflects the sharp contrast between ecological protection efforts and economic development pressures.

4. Discussion

4.1 Key Restricting Factors

Correlation analysis reveals that the average patch area index shows the strongest negative correlation with ecosystem health ($q3jklm Tab. 7 Main affecting factors in the regions with unhealth y ecology (cid:135)(cid:132) EFR(cid:155) $), indicating that landscape fragmentation is the primary restricting factor. The low drainage density in Zhangjiakou' s plateau region limits water resource availability, further exacerbating ecological vulnerability.

4.2 Driving Forces of Ecological Degradation

Human disturbance intensity emerges as the dominant negative driver, particularly construction land expansion and population growth. In Zhangjiakou, the proportion of construction land increased by 37% during 2010-2020, directly reducing vegetation coverage and increasing soil erosion.

4.3 Regional Differentiation Mechanisms

The ecological green belt at the Beijing-Zhangjiakou junction benefits from: 1. Favorable topography with 40-60% vegetation coverage 2. Strict ecological protection policies 3. Lower population density

In contrast, the Bashang Plateau suffers from: 1. High elevation (>1500m) and cold climate limiting vegetation growth 2. Overgrazing and agricultural reclamation 3. Sandy soil prone to erosion

5. Countermeasures and Suggestions

Based on the assessment results, five targeted measures are proposed:

1. **Protect the Ecological Green Belt**: Strengthen conservation of the healthy ecosystem corridor at the Beijing-Zhangjiakou junction, particularly in watershed No. 37 where health indices exceed 60.
2. **Promote Marginal Zone Restoration**: Implement the Grain for Green Project in the Bashang Plateau' s northwestern marginal zone, converting slope farmland to forest/grassland. Control urban sprawl in the southeastern plain region.
3. **Enhance Patch Connectivity**: For watersheds with moderate health (EQI 27-37), focus on connecting fragmented vegetation patches through ecological corridors to improve landscape connectivity.
4. **Optimize Land Use Structure**: Reduce large-scale construction projects in ecologically sensitive areas. Increase vegetation coverage through afforestation and grassland restoration, particularly in watersheds No. 66 and No. 39.

5. **Establish Special Ecological Zones**: Create designated ecological protection zones in Zhangjiakou with stricter environmental regulations and ecological compensation mechanisms.

6. Conclusion

The ecosystem health assessment of the Beijing-Zhangjiakou region reveals a concerning overall status with significant spatial heterogeneity. Landscape fragmentation, human disturbance, and natural constraints collectively shape the ecological pattern. The proposed countermeasures, if implemented effectively, could improve ecosystem resilience and ensure long-term ecological security for the region.

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Note: Figure translations are in progress. See original paper for figures.