

Ecosystem Health Assessment of Shangqiu Section of Old Yellow River Course Basin Based on Landscape Patterns

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ABSTRACT

The Old Yellow River Course features unique hydrological structures and ecological environments, directly influencing regional biodiversity and socio-economic development. This study focuses on Shangqiu Section of Old Yellow River Course Basin and its surrounding areas. Utilizing four phases of LandsatTM remote sensing images we integrated eight landscape pattern indices with the Pressure-State-Response (PSR) model to construct an Ecosystem Health Index (EHI). This framework quantifies the evolution of ecological health over 30 years, and the dynamic changes of ecosystem health in Shangqiu Old Yellow River Basin are evaluated. Key findings include: 1) Land use changes: Cultivated land decreased cumulatively by 9.13%, while construction land expanded in a multi-nuclei diffusion pattern (+9.04%). Wetlands and forest land showed fluctuating trends, declining initially before partial recovery. 2) Landscape pattern evolution: From 1993 to 2003, fragmentation intensified (PD increased) and diversity decreased (SHDI decreased); from 2003 to 2013, artificial landscapes aggregated (CONTAG increased) and biological corridors were fragmented; from 2013 to 2023, local restoration slightly increased SHDI, but connectivity continued to degrade (CONNECT decreased). 3) Ecological health trend: EHI showed a continuous decline (1993: 0.440→2003: 0.332 →2013: 0.269→2023: 0.228), dropping from the "sub-healthy" to "sick" grade; spatially, it presented a "low in the west and high in the east" pattern, with high-health areas concentrated in wetland parks and forest belts. This study reveals the chain ecological degradation mechanism under human activity interference, providing a scientific basis for landscape optimization in Yellow River floodplain.

Keywords: Landscape Pattern; Ecosystem Health; PSR Model; Old Yellow River Course; Shangqiu

1 Introduction

The lower reaches of Yellow River are frequently diverted, among which the "taking Huai River into the sea" in the second year of Southern Song Jianyan (1128 AD) had the most far-reaching influence. Yellow River invaded south for a long time, forming a large area of yellow floodplain in the four provinces of Henan, Shandong, Anhui and Jiangsu, until the Lanyang Tongwaxiang burst in the fifth year of Xianfeng in Qing Dynasty (1855 AD), and Yellow River moved north to capture the Daqing River in Shandong Province from

Lijin to the sea, which ended the situation of 700 years of entering the sea with Huai River, leaving behind abandoned channels. Among them, the old Yellow River course in Ming and Qing Dynasties is the lower reaches of the Xinghe River in Ming and Qing Dynasties, and it is the upper end of the old course in Shangqiu section, which breeds unique settlement landscape and rich and diverse rural landscape. These rural landscapes are not only the spatial carriers of local residents' production and life, but also an important part of the ecosystem. However, with the acceleration of urbanization and the

continuous increase of human activities, the landscape of the old Yellow River basin is facing unprecedented challenges. As an important part of studying the optimal management of Yellow River Basin ecosystem, the assessment and identification of its landscape function is of great significance for improving the ecological protection and high-quality development of Yellow River Basin.

Shangqiu Section of Old Yellow River Course Basin represents an overlapping area of ecological fragility and core grain production within Yellow River Basin, long grappling with issues such as farmland fragmentation and degradation of ecological functions. In recent years, GIS-based spatial analysis and landscape ecology metrics have been extensively applied to quantify land-use changes in the Old Yellow River Course. For instance, Zhou Tianhong et al. employed methods including the Single Factor Index Evaluation Method (SFIEM), Random Forest regression models, and Backpropagation (BP) neural networks to develop predictive models correlating land use/landscape indices with water quality parameters. Gao Mengyao et al. conducted quantitative research on the spatiotemporal patterns and mechanisms of urban green space evolution in downstream Yellow River urban areas using land-use transfer matrices, landscape pattern indices, urban-rural gradient analysis, and geographical detectors. Meng Yangyang et al., leveraging five-phase land-use data from Henan Section of Yellow River Basin, analyzed the spatiotemporal evolution of wetland landscape patterns, predicted future wetland configurations using CA-Markov modeling, and assessed wetland ecosystem service values (ESV). Shao Yajing et al. evaluated the spatial evolution and interrelationships of ecosystem services (ESS) at the grid scale, providing insights into trade-offs, synergies, and drivers among ecosystem service zones. Zheng Guoqiang et al. utilized the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) model in the Qinghai section of Yellow River Basin, calculating seven landscape pattern indices to characterize the spatiotemporal dynamics of habitat quality and landscape patterns. Addressing comprehensive land consolidation

in the Old Yellow River Course basin, Zhang Yiyan et al. proposed a three-step methodology of "multifunctional landscape evaluation—functional zoning—trade-off and synergy coordination." Applied in Suining County, Xuzhou City, this approach used multidimensional assessments (regulating, provisioning, and cultural services) to establish a suitability evaluation system for soil-water resource allocation, optimizing "production-living-ecological" (PLE) spaces by integrating ecological protection redlines and urban development boundaries. Additionally, other studies have investigated land allocation, soil moisture content, and biodiversity within the Old Yellow River Course environment. However, existing research predominantly focuses on single functions or localized regions, lacking comprehensive assessment of landscape patterns and their dynamics, as well as an analysis of the long-term synergistic evolution mechanisms of multifunctionality in Henan Section.

Research on ecosystem health originated in North America in the 1980s. Since then, scholars worldwide have conducted extensive studies on related topics in this field. The Pressure-State-Response (PSR) model and the Vigor-Organization-Resilience (VOR) model are among the most commonly used indicator systems for ecosystem health assessment. The conceptual PSR model was first proposed by Rapport and Singh. By examining the relationships between pressures, states, and responses within ecosystems, this model has been widely applied to evaluate ecosystem health conditions.

Shangqiu Section of Old Yellow River Course Basin exhibits a complex mosaic of villages, farmland, and wetlands. Landscape index analysis can reveal land-use conflicts (e.g., cropland encroaching on wetlands), while multifunctional assessment quantifies the integrated benefits of different land types. This enables evidence-based optimization of "Production-Living-Ecological" (PLE) spatial configurations. By integrating remote sensing and ground monitoring data, we evaluated ecosystem service values across the old course, identifying significant functional variations between segments. Incorporating ecological protection redlines and urban development boundaries refines spatial

planning outcomes, facilitating targeted PLE space optimization. Notably, the Shangqiu Old Yellow River Course has been designated a demonstration zone for cross-provincial ecological restoration within the Henan Provincial Territorial Plan for Yellow River Basin (2021–2035). This recognition positions the area as a scientific reference model for integrated river management, wetland conservation, and rural revitalization across Yellow River Basin and similar watersheds.

2 Materials and Methods

2.1. Study Area

The study focuses on Shangqiu Section of Old Yellow River Course Basin, extending approximately 134 km from Suizhou Dam in Minquan County westward, through Minquan County and Liangyuan District of Shangqiu City, to Xiaoqiaoji in Yucheng County eastward. Bordered by the Henan-Shandong provincial boundary to the north, the basin spans 34°31′–34°43′N and 115°09′–116°11′E, covering a drainage area of approximately 10,704 km². Characterized by complex climate patterns, the region experiences mean annual temperatures of 13.9–14.3°C and receives 686.5–872.9 mm of precipitation annually. Rainfall exhibits distinct seasonality, with approximately 70% concentrated during July to September.

2.2. Data Sources and Processing

This study acquired multiple cloud-free Landsat remote sensing images (30-meter resolution) for late

April to May of 1993, 2003, 2013, and 2023 from the US Geological Survey website (<http://glovis.usgs.gov>). Following radiometric calibration and atmospheric correction of these images, supervised classification was employed to extract land use/cover types, achieving an overall accuracy exceeding 85% and a Kappa coefficient greater than 0.82. Land use data were subsequently refined through visual interpretation with manual refinement.

Supplementary Data: (1) Socioeconomic statistics were sourced from the China Statistical Yearbook, Shangqiu Statistical Yearbook, and Shangqiu Regional Land Records. Data on comprehensive land consolidation were obtained through field surveys and historical records provided by the Shangqiu Municipal Bureau of Natural Resources and Planning. (2) Physiographic data included: Precipitation and temperature data: Resource and Environment Science and Data Center (RESDC; <http://www.resdc.cn>). Soil data: Harmonized World Soil Database (HWSD; Food and Agriculture Organization of the United Nations). Topographic data and evapotranspiration data: Geospatial Data Cloud (<http://www.gscloud.cn>).

2.3 Research Methods

Integrating the multidimensional characteristics and functions of rural landscapes, this study employs GIS technology and landscape index analysis to quantitatively assess the landscape patterns in the Old Yellow River Course basin. Using ENVI 5.3 and ArcGIS 10.3 software,

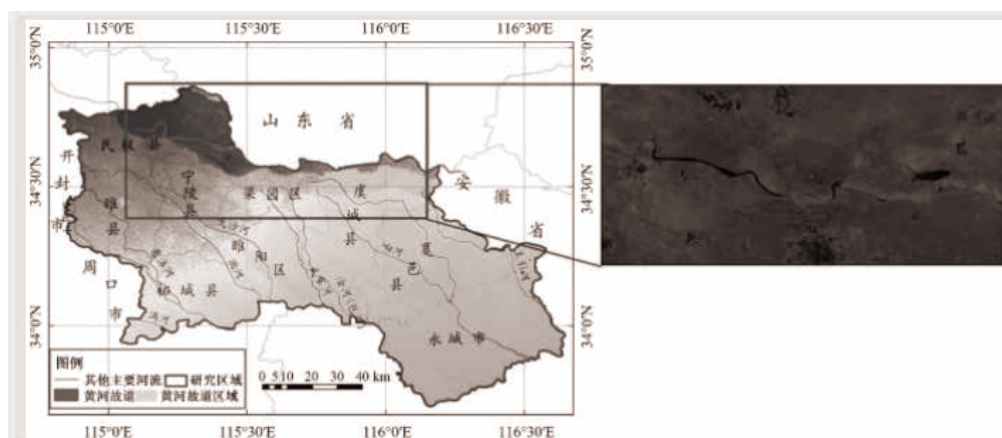


Fig. 1 Geographical Location of the Study Area

four phases of remote sensing images underwent the following processing: radiometric calibration, geometric correction, supervised classification, extraction of land use/cover types with reference to Google Earth imagery and land survey data. Categorization: Six land classes were defined—cropland, forest, water, grassland, built-up land, and unused land. Classification accuracies reached 87.3% (1993), 88.9% (2003), 90.1% (2013), and 91.6% (2023), validated by Kappa coefficients >0.82.

(1) Landscape Pattern Analysis of the Old Yellow River Course Basin

Landscape pattern indices quantitatively characterize the spatial distribution and heterogeneity of land cover

types. Drawing on the research framework of Ju Sen et al. and adapting it to the specific conditions of Shangqiu Section of Old Yellow River Course Basin, eight key indices were selected: Patch Density (PD), Largest Patch Index (LPI), Landscape Shape Index (LSI), Contagion Index (CONTAG), Division Index (DIVISION), Aggregation Index (AI), Connectance Index (CONNECT), Shannon’s Diversity Index (SHDI). These indices were computed using Fragstats 4.2 software. Subsequent analysis focused on elucidating their spatiotemporal differentiation characteristics across the study area.

(2) Ecosystem Health Assessment (PSR-EWM)

Table 1 Formulas and Ecological Significance of Landscape Indices

Index Type	Abbreviation	Formula	Ecological Significance	Index Direction
Patch Density	PD	$PD = N/A$, where N is the number of patches, and A is the total landscape area (ha)	Number of patches per unit area, reflecting the degree of landscape fragmentation. A higher value indicates more severe landscape division, which may hinder species migration and connectivity of ecological processes.	Negative
Largest Patch Index	LPI	$LPI = \max(a_{ij})/A * 100$, $\max(a_{ij})$ is the area of the largest patch, and A is the total landscape area (ha)	Proportion of the largest patch area, indicating the connectivity of dominant types. A higher value indicates better connectivity of dominant landscape types, which is important for ecosystem stability.	Positive
Landscape Shape Index	LSI	$LSI = 0.25E/\sqrt{A}$, E is the total edge length of the landscape (m), and A is the total landscape area (ha)	Complexity of patch boundaries; a larger value indicates more irregular shapes. Reflects the degree of human interference; natural landscapes usually have lower shape indices.	Negative
Contagion Index	CONTAG	$CONTAG = [1 + 2 \ln(m) \sum_{i=1}^m \sum_{k=1}^m (p_i \cdot g_{ik}) \cdot \ln(p_i \cdot g_{ik})]^{-1}$ p_i is the area proportion of type i, g_{ik} is the number of grids adjacent to type i and k, and m is the total number of landscape types	Degree of landscape spread; a high value indicates aggregation of dominant types. A high value indicates that the landscape is dominated by a few large patches, while a low value indicates scattered distribution of landscape types.	Positive
Division Index	DIVISION	$DIVISION = 1 - \sum_{i=1}^n (\frac{a_i}{A})^2$, a_i is the area of the i-th patch, A is the total landscape area, and n is the total number of patches	Degree of spatial separation of patches; a larger value indicates stronger fragmentation. Reflects the degree of landscape division, directly affecting the integrity of species habitats and migration resistance.	Negative
Aggregation Index	AI	$AI = [\overline{g_{ii}} / \max(g_{ii})] \times 100\%$, g_{ii} is the number of adjacent edges of the same type of patches, and $\max g_{ii}$ is the theoretical maximum number of adjacent edges	Proportion of adjacent same-type patches, reflecting aggregation status. A high value indicates a high degree of aggregation of the same type of patches, which is beneficial to the survival of internal species.	Positive
Connectivity Index	CONNECT	$CONNECT = [\sum_{i=1}^m \sum_{j=1}^n C_{ijk} / \sum_{i=1}^m (n_i(n_i-1)/2)] \times 100$ $0 \leq CONNECT \leq 100$, m is the total number of landscape types; n is the total number of patches in landscape type i; C_{ijk} is the connectivity of patches j and k of type i within the maximum threshold	Indicates the connection degree of the same type of patches in the landscape. The level of landscape connectivity mainly depends on the quantitative characteristics and spatial distribution of various landscape elements.	Positive
Shannon's Diversity Index	SHDI	$SHDI = -\sum_{i=1}^m (P_i \times \ln P_i)$, P_i is the area proportion of landscape type i, and m is the total number of landscape types	Landscape heterogeneity; a high value indicates rich types and uniform distribution. Reflects landscape diversity and stability, but an excessively high value may indicate a lack of dominant types.	Positive

Model)

Combined with the advantages and disadvantages of landscape pattern indices, the Min-Max normalization method was used to standardize the data, and EHI was recalculated based on the normalized data.

Min-Max normalization calculation:

$$\text{Positive indices: } X_{\text{norm}} = (X_i - X_{\text{min}})/(X_{\text{max}} - X_{\text{min}}) \quad (i = 1,2,3,4\dots n) \quad (1)$$

$$\text{Negative indices: } X_{\text{norm}} = (X_{\text{max}} - X_i)/(X_{\text{max}} - X_{\text{min}}) \quad (i = 1,2,3,4\dots n) \quad (2)$$

(Where X_i is the original value, $X_{\text{min}}/X_{\text{max}}$ are the minimum/maximum values of the index over the entire period from 1993Y to 2023Y)

Entropy weight method:

$$E_j = -1/[\ln m \sum_{i=1}^m (P_i \times \ln P_{ij})] \quad (3)$$

A comprehensive evaluation model including landscape pattern indices was constructed using the "Pressure-State-Response (PSR)" framework, and health was calculated as:

$$EHI = 0.30P + 0.45S + 0.25R \quad (4)$$

Eight landscape pattern indices were selected and linked to PSR dimensions using the entropy weight method (EWM). The ecological health grades were divided into: sick ($EHI < 0.3$), sub-healthy ($0.3 \leq EHI < 0.5$), general ($0.5 \leq EHI < 0.7$), healthy ($0.7 \leq EHI < 0.85$), and ideal ($EHI \geq 0.85$).

Table 2 PSR Model Index Weights (Entropy Weight Method)

PSR Dimension	Index	Weight
Pressure (P)	PD	0.20
	DIVISION	0.15
State (S)	LPI	0.10
	LSI	0.10
	AI	0.10
	CONNECT	0.10
Response (R)	CONTAG	0.10
	SHDI	0.15

3 Results and Analysis

3.1 Analysis on Area Changes in Land Use Types in Shangqiu Section of Old Yellow River Course Basin

As shown in Figure 2, the total wetland area in the Old Yellow River Course basin exhibited a trend of initial decline followed by recovery over the 30-year period. Cropland and forest land remained the dominant green space types, though collectively decreased by 356.2 km² (annual change rate: -0.9%). Cropland area diminished by 132.6 km², with its annual change rate accelerating from -0.17% to -0.42%. Forest land area decreased initially before rebounding, resulting in a net increase of 82.14 km². Water bodies similarly declined then recovered, registering a net gain of 22.37 km². The reduction in cropland and expansion of forest land align with wetland restoration initiatives under the Shangqiu Land Remediation Plan. During 1993Y–2013Y, forest land, grassland, and water bodies all decreased, with water bodies experiencing the most significant loss (74.28 km²; annual rate: -2.37%). Settlement areas first expanded then contracted, yielding a net reduction of 67.3 km². Key trends post-2013Y: Cropland: Stabilized in total area but shifted toward peripheral zones, intensifying fragmentation. Urban expansion: Built-up land expanded concentrically, forming multi-nuclei clusters by 2023Y. Wetlands: Core water bodies remained stable under conservation policies, while low-intensity tourism developments emerged in buffer zones. Regional

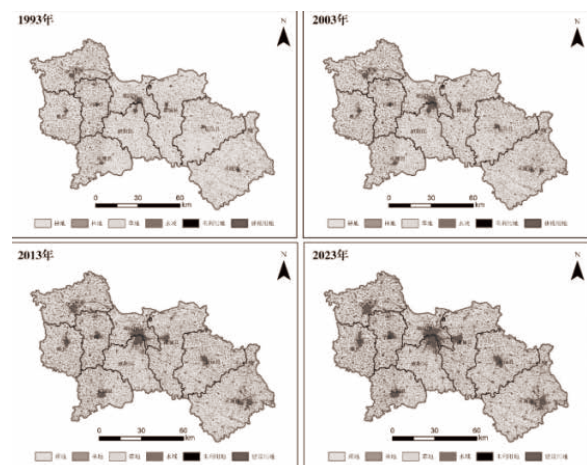


Fig. 2 Land Cover Maps of Shangqiu Section of Old Yellow River Course Basin in 1993, 2003, 2013, 2023

variations: Minquan County showed substantial forest land growth, whereas Liangyuan District recorded notable grassland expansion. Spatial dynamics: Urban edges progressively encroached on cropland, particularly near cities. Land types around water bodies remained relatively stable. Forest and grassland patches became increasingly dispersed yet maintained consistent spatial relationships with other land covers.

3.2. Analysis on Change in Landscape Pattern Index in Shangqiu Section of Old Yellow River Course Basin

As shown in Table 3, from 1993 to 2023, Shannon's Diversity Index (SHDI) and Connectivity Index (CONNECT) showed a downward trend, while Aggregation Index (AI), Patch Density (PD), and Division Index (DIVISION) showed an upward trend, indicating that the total area of cultivated land patches decreased, with fragmented and scattered distribution, stable boundary morphology, decreased connectivity, and significantly reduced landscape dominance. From 1993 to 2003: Fragmentation intensified (PD increased, LPI decreased), shape became more complex (LSI increased), and diversity decreased (SHDI decreased), indicating that core habitats such as woodlands and wetlands were encroached, large patches were divided, the dominance of dominant patches was weakened, and the landscape tended to be simplified and fragmented. From 2003 to 2013: Aggregation strengthened (CONTAG and AI increased), fragmentation continued (PD and DIVISION increased), and diversity continued to decrease (SHDI decreased), indicating that similar patches (e.g., construction land, cultivated land) were concentrated and contiguous, forming a pattern of "dominant patch aggregation + small patch fragmentation", with broken ecological corridors and further reduced landscape

heterogeneity. From 2013 to 2023: Aggregation stabilized (CONTAG slightly increased, AI slightly decreased), fragmentation persisted (PD and DIVISION increased), and diversity recovered (SHDI increased). Later ecological protection policies took effect, and small-scale restoration increased patch types (e.g., restoration of Old Yellow River Course wetland), but the long-term fragmented landscape pattern has not been reversed, and the restoration did not restore the overall connectivity of the landscape, which was still in a transitional state of fragmentation.

3.3 Analysis on Temporal and Spatial Distribution Changes of Ecosystem Health in Shangqiu Section of Old Yellow River Course Basin

In terms of spatial distribution, the level of landscape multi-functionality showed a "low in the west and high in the east" pattern. Areas with strong multi-functionality were mostly concentrated in the Liangyuan National Wetland Park, reservoirs, and Shangqiu Forest Park. Among them, the forest park in the eastern part of the study area and the surrounding areas of the wetland park had the strongest landscape multi-functionality, with ecosystem types mainly including woodlands, meadows, and wetlands; while areas with weak multi-functionality were concentrated in the western part of Minquan County and the eastern part of Yucheng County, with ecosystem types mainly including cultivated land and grassland.

(1) Temporal evolution

From 1993 to 2023, EHI showed a continuous downward trend, dropping from 0.4402 to 0.2277, with a decrease of 48.3%, indicating a significant deterioration in ecological health. From 1993 to 2003: EHI decreased from 0.440 to 0.332, a decrease of 24.5%, mainly driven by landscape fragmentation and biodiversity loss caused

Table 3 Characteristics of Changes in Landscape Pattern Index in Old Yellow River Course Basin

Year	PD	LPI	LSI	CONTAG	DIVISION	AI	CONNECT	SHDI
1993	0.536	16.946	84.422	51.068	0.942	93.086	96.323	0.937
2003	0.615	13.737	86.631	56.837	0.937	93.531	92.246	0.923
2013	0.693	14.362	85.935	63.144	0.958	94.442	83.216	0.785
2023	0.751	14.623	87.347	64.076	0.971	94.301	87.232	0.832

by urbanization. From 2003 to 2013: EHI continued to decrease to 0.269, a decrease of 19.1%, during a period of rapid urbanization, while the contiguous artificial landscapes and improved vegetation coverage alleviated the system state, with some ecosystems in a recovery period. From 2013 to 2023: EHI reached 0.228, a decrease of 15.3%, with the continuous increase in pressure being the main reason for the deterioration of ecological health, and fluctuations in the state and response dimensions also exacerbating system instability.

Table 4 Ecosystem Health Assessment

Year	PSR Dimension	Value	EHI Value	Health Grade
1993	P	0.3280	0.440	Sub-health
	S	0.6271		
	R	0.2384		
2003	P	0.3056	0.332	Sub-health
	S	0.3594		
	R	0.3161		
2013	P	0.1210	0.269	Sick
	S	0.3992		
	R	0.2116		
2023	P	0.0010	0.228	Sick
	S	0.3387		
	R	0.3011		

(2) Spatial distribution

The Ecosystem Health Index (EHI) continuously decreased from 0.440 (sub-healthy) in 1993 to 0.228 (sick) in 2023, with a decrease of 48.3%, and significant spatial differentiation: the average EHI in western Minquan County (0.21) was 45% lower than that in eastern Liangyuan District (0.38), which was consistent with the pattern of dense wetlands in the east and sparse in the west. High-health areas were concentrated in forest-wetland complexes such as Minquan National Wetland Park and Shangqiu Forest Park, distributed in a band along the old course, covering an area of approximately 150 km², serving as habitats for migratory birds and gene banks. Medium-health areas were located in the farmland-woodland ecotones in cities and counties, with alternating farmland and shelterbelt patches forming a "checkerboard" pattern, and ecological health fluctuated under the influence of irrigated agriculture. Low-health areas were mainly concentrated in urban construction

areas and sandy farmland areas, with low vegetation coverage in urban construction areas and severe fragmentation of sandy cultivated land, forming "cold spots" of ecological health.

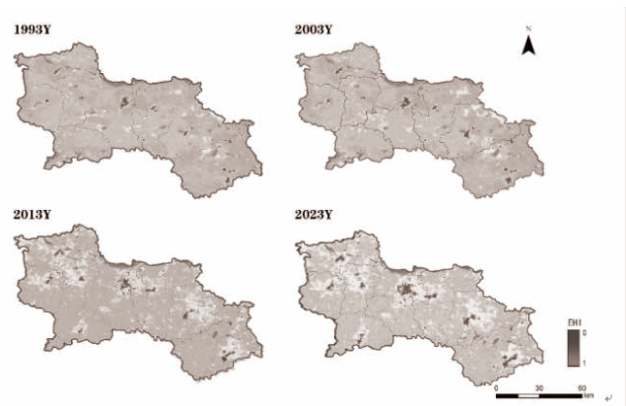


Fig. 3 Ecosystem Health Assessment Map of Shangqiu Section of Old Yellow River Course Basin

4 Conclusions and Discussions

4.1. Discussions

The degradation of ecosystem health in the core area of Shangqiu section of Old Yellow River Course is essentially a chain reaction caused by agricultural expansion and urban construction squeezing ecological space. This study quantified the "pressure-state-response" transmission mechanism through the entropy-weighted PSR model, revealing that landscape fragmentation and broken ecological corridors are the core drivers of health deterioration. Compared with the Suining section in the lower Yellow River, the key reason for the lagged recovery of EHI in Shangqiu is that the proportion of cultivated land-urban ecotones in the study area exceeds 60%, higher than 45% in Suining. The special geomorphology in the upper reaches of the old course amplifies the effect of human interference, requiring an innovative model of "wetland-farmland collaborative restoration". Future research should integrate multi-source data to build an intelligent early warning system, providing precise decision support for ecological restoration in Yellow River floodplain.

4.2. Conclusions

Based on the coupling of land use classification,

landscape index method, and PSR model, this paper reveals the spatiotemporal evolution law of ecological health in Shangqiu section of Old Yellow River Course Basin, confirming the chain reaction of "human activity disturbance - landscape fragmentation - ecological function degradation". The research results provide a quantitative basis for ecological restoration in Yellow River floodplain area. In the future, it is necessary to explore sustainable paths in enhancing landscape connectivity and balancing the contradiction between agricultural development and ecological protection.

From the perspective of the target layer, from 1993 to 2023, the ecological landscape pattern of Shangqiu section of Yellow River Basin tended to stabilize amid fluctuations, and ecosystem health has improved to some extent. 1) Correlation between landscape pattern and ecological health: This study confirmed that Patch Density (PD) and Shannon's Diversity Index (SHDI) are key indices affecting EHI. For example, the peak PD in 2023 (0.751) corresponded to the valley EHI (0.228), indicating that fragmentation directly weakens ecosystem service functions; while the recovery of SHDI after 2013 was synchronized with the improvement of EHI, verifying the supporting role of diversity in ecological resilience. 2) Applicability of the PSR model: The Division Index (DIVISION) in the Pressure (P) dimension contributed 15% to EHI, revealing that patch fragmentation is the main pressure source of ecological degradation; the weight of Contagion Index (CONTAG) in the Response (R) dimension (15%) indicates that artificial landscape aggregation can improve health in the short term, but long-term restoration depends on natural corridors. 3) Comparison with similar studies: Compared with other sections in the lower Yellow River (e.g., Suining, Xuzhou), the recovery rate of EHI in Shangqiu section is slower (24.3% increase from 2013 to 2023 vs. 35% in similar studies), which may be related to the high proportion of cultivated land-urban ecotones (over 60%) and insufficient investment in ecological restoration in the region. The trend of "first decreasing and then increasing" in wetland area in this study is consistent with the research by Meng Yangyang et al. (2023) on

Henan section of Yellow River Basin, but the recovery of wetland ecosystem service value in Shangqiu section lags behind the improvement of landscape pattern. It is necessary to implement the "ecological corridor project in Shangqiu section" in the Henan Provincial Territorial Spatial Plan of Yellow River Basin (2021-2035) to strengthen wetland hydrological connectivity.

The optimization of landscape pattern and ecosystem management in Shangqiu section of Old Yellow River Course Basin need to comprehensively consider the relationships and feedback mechanisms among various subsystems, and coordinate multiple goals such as ecology, society, and economy. First, land use control in ecologically fragile areas should be strengthened, the land use structure optimized, the proportion of ecological land increased, key ecological processes maintained, and landscape connectivity and heterogeneity enhanced. Second, attention should be paid to the protection of traditional villages and cultural heritage, tap the connotation of local culture, promote urban-rural cultural exchanges, and enrich rural social and cultural functions. Third, road network layout should be optimized, rural infrastructure improved, characteristic agriculture and rural tourism developed, rural economy activated, and living environment quality improved. Finally, innovation in multi-subject participation in ecosystem management models should be strengthened, interest coordination mechanisms improved, public participation in landscape planning enhanced, and communication and cooperation among different stakeholders such as the government, communities, enterprises, and the public promoted to achieve comprehensive improvement of rural landscape functions and regional sustainable development.

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