Research on the Spatial Differentiation Characteristics and Ecological Protection Paths of "Mountains, Rivers, Forests, Fields, Lakes, and Grasslands" in the Shandong Section of the Yellow River Basin

Haodong Shang, Yiying Liu, Lijie Zhang, Mengzheng Zhang, Qinghong Hu, Lei Zhang*, Li Shi
School of Tourism, Taishan University, Taian, Shandong, China
**Corresponding Author.*

Abstract: This article is based on the current strategic drivers of China's "coordinated management of mountains, waters, forests, fields, lakes, and grasslands" and "ecological protection and high-quality development in the Yellow River Basin". By combining "3S" spatial analysis technology with mathematical statistical analysis and drawing on semi-structured interviews and other methods, the spatial differentiation characteristics and ecological protection paths of "mountains, waters, forests, fields, lakes, and grasslands" in the eastern section of the Yellow River Basin are analyzed. The research findings are as follows: First of all, the mountains in the eastern section of the Yellow River basin are mainly distributed at the intersection of Jinan and Tai'an. Secondly, over time, the proportion of spatial area of "mountains, rivers, forests, fields, lakes, and grasses" in the Yellow River Basin has undergone significant changes. Among them, the increase in water body area is mainly concentrated in the Dongying section located at the estuary and the Tai'an section located in the Dongping Lake area. The area of land area growth is mainly located in the Dongying section of the Yellow River estuary. The urban differences in grassland area changes are significant, and the decrease in grassland area in the Dongying section is significantly higher than in other cities. From 1990 to 2020, there were significant differences and varying degrees of decline in the comprehensive ecosystem function index among 9 cities in the Shandong section of the Yellow River Basin. Among them, the Dongying section had the highest land use index and the strongest comprehensive ecosystem function, while the Dezhou and Heze sections had the most significant decline.

Keywords: "Mountains, Waters, Forests, Fields, Lakes, and Grasses"; Spatial Differentiation; Land Use; Ecological Protection; The Shandong Section of the Yellow River Basin

1. Introduction

With the acceleration of industrialization and urbanization in our country, problems such as imbalanced development of national territory, low efficiency of resource utilization, and deterioration of ecological environment are becoming increasingly prominent. The contradiction between natural resource development and ecological environment protection is intensifying. As an important component of ecological civilization and the construction of a beautiful China in the new era, the "mountains, waters, forests, fields, lakes, and grasslands" ecosystem has also been significantly damaged. In recent years, with the promotion and improvement of the "Yellow River Strategy", there has been a significant increase in research on the spatial distribution of "mountains, waters, forests, fields, lakes, and grasslands" in the Yellow River region of Shandong Province. Liu et al[1]studied the ecological and environmental effects based on the transformation of "three living spaces" using the eastern section of the Yellow River Basin as an example; Wang et al[2]measured the high-quality development of central cities and urban agglomerations along the Yellow River in Shandong Province; Wang et al[3] analyzed the spatial expansion and driving forces of Jinan, a leading city along the Yellow River; Fan et al[4] studied the evolution of urban spatial pattern in the Yellow River Delta and its coupling with ecological efficiency. From a research perspective, scholars often conduct research from a single disciplinary perspective such as geography, history, sociology, planning, environmental science, ecology, etc., lacking comprehensive research that integrates multiple disciplines. From the perspective of research theory and methods, research results tend to focus on the evaluation of the current status of the spatial evolution of mountains, rivers, forests, fields, lakes, and grasslands, or static analysis of spatial evolution cross-sections. Long term, dynamic, and composite research conducted around the time axis is not sufficiently rich. From the perspective of research types, there is a tendency towards specialized discussions on a certain aspect, and there are not many systematic analysis results and comprehensive data analysis platforms based on the spatial structure of land use in multiple dimensions and aspects at the regional level[5,6]. It can be seen from the integration that the current research on "mountains, waters, forests, fields, lakes, and grasslands" and ecological protection in the Yellow River Basin is relatively rich, but mostly focuses on scientific connotations, mechanism systems, the concept of a community of life, the improvement of ecosystem services, ecological processes, and implementation paths. There is relatively little research on the spatial differentiation characteristics of natural environmental elements such as "mountains, waters, forests, fields, lakes, and grasslands" and the construction of ecological protection paths. There is insufficient research on the Shandong section located in the lower reaches of the Yellow River Basin[7,8]. Therefore, this project aims to construct a systematic analysis framework for the spatial evolution of "mountains, waters, forests, fields, lakes, and grasslands" in the Shandong section of the Yellow River Basin. Based on this framework, combined with the timeline, the long-term changing trend and fireworks trajectory of the research area from 1990 to 2020 will be revealed, and a reasonable path to promote the coordinated coexistence of mountains, waters, forests, fields, lakes, and grasslands in space will be explored, providing visual and thematic references for promoting regional rational and sustainable development.

2. Research Area

The Yellow River flows from southwest to northeast through nine cities along the Yellow River in Shandong Province, including Heze, Jining, and Dongying, with a total length of over 600 kilometers and a drainage basin area of nearly 20000 square kilometers. In recent years, with the promotion of "ecological protection and high-quality development in the Yellow River Basin", various regions in the eastern section of the Yellow River Basin have also brought about severe problems such as soil and water resource protection, increased ecological risks, and spatial development differences while maintaining a good socio-economic development trend[9]. In view of this, this project takes the eastern section of the Yellow River Basin as the research area, and based on high-precision remote sensing image analysis data, evaluates the spatial differentiation characteristics of "mountains, waters, forests, fields, lakes, and grasses" in this area and further explores its ecological protection path. This can provide background support for the restoration of "mountains, waters, forests, fields, lakes, and grasses", and provide reference for promoting the construction of ecological corridors and the enhancement of ecosystem service value in the eastern section of the Yellow River Basin(Figure 1).

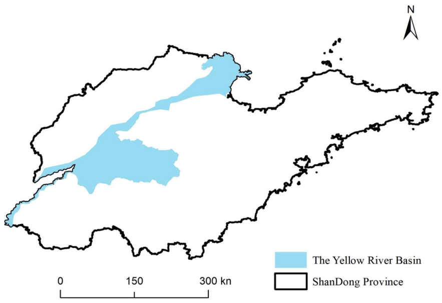


Figure 1. Geographical Location of the Shandong Section of the Yellow River Basin

3.Model Construction and Data Source

3.1 Landscape Centroid Translation Degree

The landscape centroid translation model analyzes the spatial distribution trend and formation mechanism of a landscape type by calculating the area weighted centroid changes of patches. As an important indicator for measuring the overall distribution of a certain land type in a region, it can be used to represent the overall trend and central location of the landscape spatial distribution of the land [10]. The calculation formula is:

$$X_t = \sum_{i=1}^{n} X_i \times C_{it} \Big/ \sum_{i=1}^{n} C_{it} \quad (1)$$

$$Y_t = \sum_{i=1}^{n} Y_i \times C_{it} \Big/ \sum_{i=1}^{n} C_{it} \quad (2)$$

In the formula, and are the longitude and latitude coordinates of the centroid of a certain land type in the year; The number of patches, as well as the centroid longitude and latitude of the patch; The area of the th patch of the year (Km²).

3.2 Land Use Classification Analysis Model

The land use conversion analysis model is mainly used to describe the conversion situation between various land use types. It can not only reflect the land use type structure at the beginning and end of the research period, but also reflect the transfer and change situation between various land use types during the research period. It is of great significance for characterizing the direction of regional land use change and the source and composition of various land use types at the end of the research period. Referring to relevant research, this article constructs a land use conversion analysis model to measure the mutual transformation trend between urban land and other land types in the study area[11]. The calculation formula is:

$$S_{ij} = \begin{bmatrix} S_{11} & S_{12} & \dots & S_{1n} \\ S_{21} & S_{22} & \dots & S_{2n} \\ \dots & \dots & \dots & \dots \\ S_{n1} & S_{n2} & \dots & S_{nn} \end{bmatrix} \quad (3)$$

In the formula, is the area of land use type (Km ²); The number of land use types The land use types in the early and late stages of the study are respectively.

3.3 Data Sources and Processing

The data analyzed in this article mainly includes two parts: land use/cover image data and regional development attribute data. Among them, land use/cover data is mainly taken from Landsat TM/ETM/OLI series images (resolution of 30m). Based on unified projection and spatial registration of the data, reference is made to the 1:50000 topographic map of the Shandong section of the Yellow River Basin and Google Earth high-definition images (resolution of 2.5m), and geometric correction and other preprocessing methods are used to preprocess the data using control point correction; Referring to the Globe Land30 land cover classification system and combining with the current situation of the study area, the land use types in the study area are divided into six categories: urban land, rural residential areas, forests and grasslands, cultivated land, water bodies, and bare land; Based on the Globe Land30 data product and real surface ROI data, the accuracy of land use/cover in the study area was evaluated, with Kappa coefficients of 0.87, 0.89, 0.89, and 0.93, respectively. The attribute data in this article are mainly taken from the Shandong Statistical Yearbook (1989-2020) and the Shandong Provincial Statistical Bulletin on National Economic and Social Development (2010-2020).

4.The Spatial Distribution and Combination Status of "Mountains, Waters, Forests, Fields, Lakes, and Grasses" in the Shandong Section of the Yellow River Basin

Based on Figures 2, 3, and Table 1, it can be seen that the area of mountains (with an altitude of ≥ 500m) in the eastern section of the Yellow River Basin is 475.06km² , accounting for 2.25% of the total land area of the study area, mainly distributed at the intersection of Jinan and Tai'an cities.

According to the field survey and remote sensing image extraction, except for Dongping Lake, there are relatively few large lakes/reservoirs in the study area with little change, so this study will combine rivers, lakes, reservoir ponds and mudflat into a unified water system for analysis. Analysis has found that the water area in the Shandong section of the Yellow River Basin reaches 1816.7 km ² , accounting for a high proportion of 8.63%, and is widely distributed along the Yellow River and Dawen River, as well as near the mouth of Dongping Lake in the Tai'an section and the Yellow River estuary in the Dongying section.

According to Figure 2, the forest area in the study area is 1297.55km ² ; Further research found that Ji'nan and Tai'an, with Mount Taishan Mountains as the core, were the main distribution areas of forest land in the eastern section of the Yellow River basin.

As the dominant land type in the Shandong section of the Yellow River Basin, the field area is 12680.42 km² , accounting for 60.26% of the total land use area in the study area and widely distributed in various city sections. However, it is worth noting that the proportion of field area in the Dongying section near the mouth of the Yellow River is significantly lower than in other cities, mainly due to the widespread distribution of saline alkali land types in the area.

Compared to other land types, the grassland area in the study area accounts for a relatively small proportion, only 5.1% of the total land use area, and its distribution pattern is similar to that of forest land. It is concentrated in the Ji'nan and Tai'an sections of the city.

By comparing Figure 2 and Table 1, it is found that there are significant differences in the spatial distribution and structural composition of "mountains, waters, forests, fields, lakes, and grasses" among the nine cities along the Shandong section of the Yellow River Basin. Among them, the mountains are mainly distributed in the sections of Jinan and Tai'an cities; The proportion of water bodies in Dongying City is significantly higher than that in other cities, followed by Tai'an City, while cities such as Dezhou, Jining, Liaocheng, and Zibo have relatively lower proportions; Forest land is mainly distributed in the relatively high altitude sections of Jinan and Tai'an in the research area, and the combined forest area of the two cities accounts for more than 85% of the total forest area in the Shandong section of the Yellow River Basin; There is a significant difference in the distribution of farmland in the 9 city sections of the study area, with the Tai'an section (4414.9 km^2), Jinan section (2830.3 km^2), and Dongying section (2490.4 km^2) being significantly higher than other city sections; Similar to the spatial distribution of mountains and forests, 87.2% of the grassland in the study area is distributed in the Jinan and Tai'an sections, which indirectly reflects that the ecological background of the Jinan and Tai'an sections is significantly higher than that of other cities.

Table 1. Proportion of Spatial Area of "Mountains, Waters, Forests, Fields, Lakes, and Grasses" in the Shandong Section of the Yellow River Basin

Land type	Binzhou	Dezhou	Dongying	Heze	Jinan	Jining	Liaocheng	Tai'an	Zibo
Cultivated land	433.84	522.62	2490.37	464.88	2830.31	727.39	764.66	4414.94	401.62
Woodland	3.56	1.03	0.43	5.97	774.12	6.83	0.22	528.40	25.57
Meadow	5.22	5.52	26.15	5.27	587.17	4.09	2.05	445.08	30.78
Water bodies	64.78	20.11	1098.85	100.76	178.84	16.87	24.68	388.72	12.84

5.Analysis of Spatiotemporal Evolution of "Mountains, Waters, Forests, Fields, Lakes, and Grasses" in the Shandong Section of the Yellow River Basin

After on-site research and interviews with relevant land and planning departments by the research group, considering that mountainous areas with an altitude of over 500 meters are relatively fixed and have relatively small changes in the eastern section of the Yellow River Basin, we will not make any unnecessary discussion on the mountain body in this article's evolution analysis.

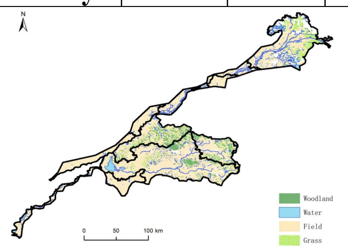
5.1 Time Evolution Analysis of "Mountains, Waters, Forests, Fields, Lakes, and Grasses" in the Shandong Section of the Yellow River Basin

From Figure 2 and Table 2, it can be seen that the overall water area in the Shandong section of the Yellow River Basin increased from 1990 to 2020, with the increase mainly concentrated in the Dawen River Basin in the Tai'an section and near the Yellow River estuary in the Dongying section. The proportion of ecological land in the study area increased from 6.67% to 10.77%, directly reflecting the significant effectiveness of water management in the Shandong section of the Yellow River Basin; The forest area decreased from 1396.77Km^2 to 1297.44Km^2 , with the reduction mainly concentrated in the eastern section of Tai'an City and the southern section of Jinan City. This indirectly reflects the impact of urban-rural and socio-economic development on the distribution and changes of ecological land in the study area; Similar to forest land, the field area in the study area has decreased from 13100 square kilometers to 12700 square kilometers, and the reduction in field area is mainly in the areas on both sides of the Yellow River. This reflects that the policies of "returning farmland to forests and water" implemented in the study area in recent years are gradually improving the ecological background of the study area; Over time, the grassland area in the Shandong section of the Yellow River Basin has significantly decreased, with the land area decreasing from 2302.78km^2 in 1990 to 1073.27Km^2 in 2020. The reduction and weakening of grassland ecological background also reflects the necessity and urgency of implementing the Yellow River strategy in Shandong Province.

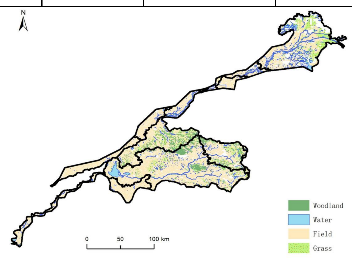
Based on Table 2, it is found that over time, the proportion of spatial area of "mountains, waters, forests, fields, lakes, and grasses" in 9 cities in the eastern section of the Yellow River Basin has also undergone significant changes. Among them, the increase in water body area is mainly concentrated in the Dongying section located at the estuary and the Tai'an section located in the Dongping Lake area, while the decrease in area is mainly distributed in the Dezhou and Heze sections; The forest area in all 9 cities in the study area shows a decreasing trend, and the decreasing areas are significantly distributed in the sections of Tai'an and Jinan; The increasing area of farmland is mainly located in the Dongying section of the Yellow River estuary, while the decreasing area is concentrated in the central part of the Shandong section of the Yellow River basin, including Jinan and Tai'an; The urban differences in grassland area changes in the research area are significant, and the decrease in grassland area in the Dongying section is significantly higher than in other cities..

Table 2. Changes in the Proportion of "Mountains, Waters, Forests, Fields, Lakes, and Grasslands" in Various Cities in the Shandong Section of the Yellow River Basin

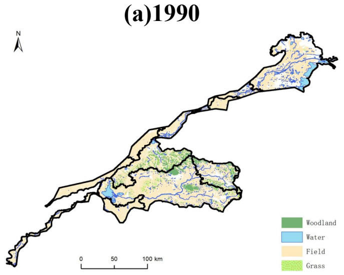
	Binzhou	Dezhou	Dongying	Heze	Jinan	Jining	Liaocheng	Tai'an	Zibo
1990 Cultivated land	439.81	540.54	2001.70	454.70	2983.56	761.39	795.04	4789.84	353.25
2000 Cultivated land	434.20	537.20	1990.72	496.22	2933.60	752.39	779.26	4706.75	356.19
2010 Cultivated land	456.83	575.88	2426.13	514.96	2730.89	742.43	767.85	4502.05	376.70
2020 Cultivated land	433.84	522.62	2315.99	464.88	2655.16	727.39	764.66	4419.73	375.43
Forest land in 1990	4.21	3.47	13.30	11.64	747.05	8.58	7.92	575.70	24.89
Forest land in 2000	4.21	3.47	13.59	11.63	747.46	8.58	7.92	575.70	24.88
	Binzhou	Dezhou	Dongying	Heze	Jinan	Jining	Liaocheng	Tai'an	Zibo
Forest land in 2010	2.04	1.20	8.23	5.40	726.07	6.81	0.23	530.19	23.86
Forest land in 2020	3.56	1.03	0.40	5.97	725.68	6.83	0.22	529.92	23.82
1990 Grassland	12.26	0.37	987.31	10.84	689.27	3.59	4.00	566.05	29.08
2000 Grassland	15.17	0.37	950.38	9.65	689.64	3.43	4.00	565.93	29.09
2010 Grassland	6.03	0.35	24.46	6.51	548.28	4.12	3.41	449.05	28.61
2020 Grassland	5.22	5.52	24.31	5.27	550.30	4.09	2.05	447.83	28.68
1990 WaterBody	58.40	45.77	388.01	127.42	174.41	19.91	23.75	343.99	19.18
2000 WaterBody	60.48	44.54	426.19	78.80	172.98	18.49	23.74	341.09	15.93
2010 WaterBody	53.34	17.35	664.81	69.88	170.68	17.46	23.39	411.80	9.68
2020 WaterBody	64.78	20.11	1020.63	100.76	167.78	16.87	24.68	388.74	12.00



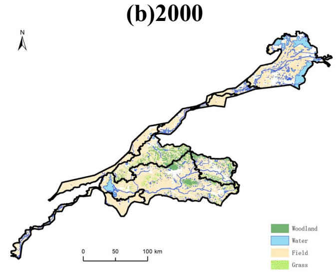
(a)1990



(b)2000



(c)2010

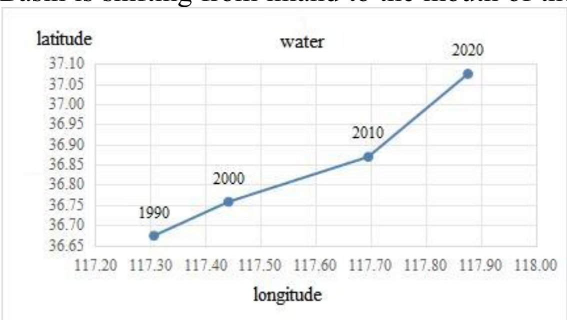


(d)2020

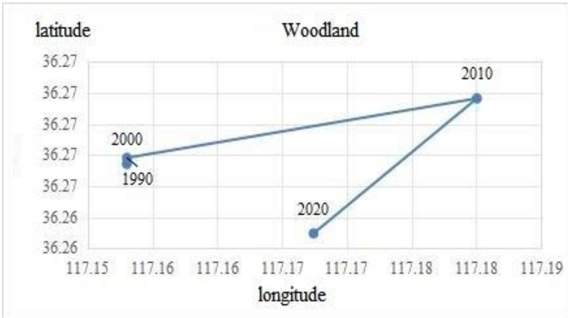
Figure 2. Temporal and Spatial Evolution of "Mountains, Rivers, Forests, Fields, Lakes, and Grasslands" in the Shandong Section of the Yellow River Basin (1990-2020)

5.2 Spatial Evolution Analysis of "Mountains, Waters, Forests, Fields, Lakes, and Grasses" in the Shandong Section of the Yellow River Basin

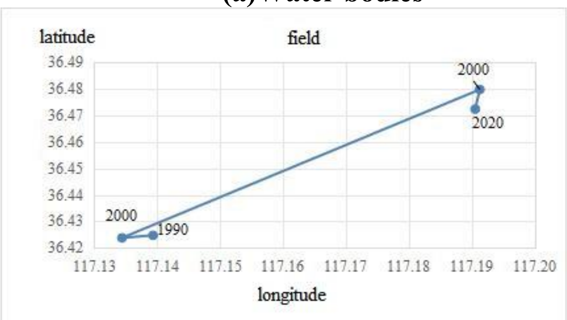
Based on the analysis in Figure 2, it was found that there were significant changes in the spatial distribution of "mountains, waters, forests, fields, lakes, and grasslands" in the Shandong section of the Yellow River Basin from 1990 to 2020. To further analyze the directional tendency and regional differentiation of these changes, a landscape centroid translation model was introduced to further analyze the changes in their spatial distribution centroids (Figure 3). Discovery: The center of gravity of water distribution continues to shift towards the northeast direction and its amplitude increases, indicating that the core area of water distribution in the Shandong section of the Yellow River Basin is shifting from inland to the mouth of the Yellow River over time; From 1990 to 2020, the trajectory of the spatial distribution centroid of forest land in the study area showed obvious phased characteristics. From 1990 to 2010, the forest geological center in the eastern section of the Yellow River Basin shifted to the northeast, while the spatial distribution centroid of forest land shifted to the southwest again between 2010 and 2020. This mainly reflects the spatial differentiation of forest land restoration and effectiveness in the study area and key sample areas; Over time, the spatial distribution centroid of the fields in the eastern section of the Yellow River Basin has shifted towards the northeast, while the spatial distribution centroid of the grasslands has shifted towards the southwest of the study area. The changes in spatial distribution centroids also indirectly reflect the layout center and transformation changes of the fields and grasslands in the study area.



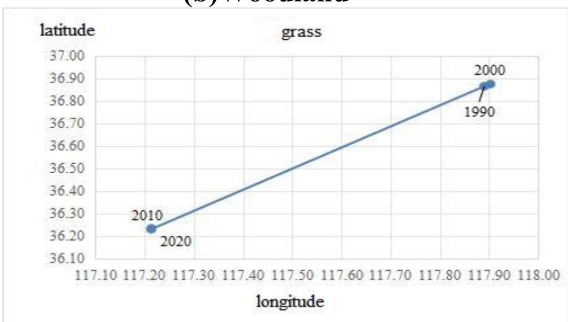
(a)Water bodies



(b)Woodland



(c)Field



(d)Meadow

Figure 3. Spatial Distribution Centroid Changes of "Mountains, Waters, Forests, Fields, Lakes, and Grasses" in the Shandong Section of the Yellow River Basin

5.3 Spatial Classification Analysis of "Mountains, Waters, Forests, Fields, Lakes, and Grasses" in the Shandong Section of the Yellow River Basin

Over time, the scale and distribution changes of "mountains, rivers, forests, fields, lakes, and grasses" in the Shandong section of the Yellow River Basin are closely related to their internal and inter land conversion. Therefore, this study introduces a land use transfer matrix to analyze the classification trend of "mountains, rivers, forests, fields, lakes, and grasslands" space in the study area (Table 3). Discovery:

From 1990 to 2020, the research area maintained a water body area of 797.34Km ^{2}, mainly distributed along the Yellow River and Dawen River, as well as in the Dongping Lake and Yellow River estuary areas; Over time, the area of water transfer in the research area has mainly changed to farmland, unused land, and construction land, with Tai'an and Dongying sections as the main distribution areas; During the research period, a considerable portion of the fields and grasslands located in the Yellow River beach area and Dongping Lake reservoir area were converted into water bodies. Over the past 30 years, the water body transfer area in the research area reached 655.35 km ^{2} , which indirectly reflects the policy effects of "returning farmland to the lake and returning grassland to water" in recent years in the area.

In comparison, the change of forest land area in the eastern section of the Yellow River basin is relatively small. The areas that continue to be forest land during the study period are mainly distributed along the Mount Taishan Mountains, concentrated at the junction of Jinan and Tai'an sections and the southern area of Tai'an section; Over time, the total area of forest land transferred out of the study area is 155.3km^2 and is distributed in a dotted pattern in the Ji (Nan) and Tai (An) sections of the city; Between 1990 and 2020, the area of forest land transfer in the study area was 54.8km ^{2} , with fields and grasslands as the main sources of transfer.

As the dominant land use type in the study area, there were significant changes in the area and distribution of farmland in the eastern section of the Yellow River Basin during the study period. From 1990 to 2020, the area of farmland transferred out reached 1983.2km ^{2} , mainly converted into construction land (1524.21km^2). Over time, the newly added area of farmland in the study area was 1543.72km ^{2} , mainly transferred from grassland and construction land; The transformation and changes of the farmland landscape in the Shandong section of the Yellow River Basin reflect, on the one hand, the encroachment and destruction of productive land represented by farmland on ecological land represented by forests and grasslands in the study area. On the other hand, it also indicates that the coordination of the three living spaces and the effectiveness of farmland protection measures in the study area are becoming increasingly prominent.

Between 1990 and 2020, there was a significant difference in the direction of grassland conversion in the Shandong section of the Yellow River Basin. The reduction of grassland mainly shifted to farmland and water landscape, with the sum of the two accounting for nearly 70% of the total grassland conversion area. It is worth noting that over time, the scale of grassland conversion to construction and unused land in the study area is gradually increasing, which also reflects the necessity of implementing the "mountain, water, forest, farmland, lake and grassland" management project in the area; Compared to others, the scale of grassland conversion from other land types during the study period was significantly lower than the area of grassland conversion. Therefore, the restoration and protection of grasslands in the study area need to be put on the agenda.

Table 3. Spatial Classification Area of "Mountains, Waters, Forests, Fields, Lakes, and Grasses" in the Shandong Section of the Yellow River Basin

1990s	2020s	Changes from 1990 to 2020	1990s	2020s	Changes from 1990 to 2020
field	field	11131.32	meadow	meadow	1003.82
field	woodland	30.37	meadow	field	543.56
field	meadow	40.59	meadow	woodland	19.75
field	Water bodies	298.99	meadow	Water bodies	361.31
field	land used for building	1524.21	meadow	land used for building	164.66
field	Unutilized land	89.03	meadow	Unutilized land	208.20
woodland	field	90.13	field	meadow	40.59
meadow	field	543.56	woodland	meadow	15.35
Water bodies	field	241.32	Water bodies	meadow	4.57
land used for building	field	479.46	land used for building	meadow	6.02
Unutilized land	field	189.24	Unutilized land	meadow	2.86
woodland	woodland	1241.36	Water bodies	Water bodies	797.34
woodland	field	90.13	Water bodies	field	241.32
woodland	meadow	15.35	Water bodies	woodland	1.06
woodland	Water bodies	14.99	Water bodies	meadow	4.57

woodland	land used for building	33.06	Water bodies	land used for building	51.62
woodland	Unutilized land	1.78	Water bodies	Unutilized land	93.06
field	woodland	30.37	field	Water bodies	298.99
meadow	woodland	19.75	woodland	Water bodies	14.99
Water bodies	woodland	1.06	land used for building	Water bodies	163.41
land used for building	woodland	3.23	Unutilized land	Water bodies	177.96
Unutilized land	woodland	0.42			

6. Analysis of the Comprehensive Ecological Function of the Shandong Section of the Yellow River Basin

The focus of spatial measurement of "mountains, waters, forests, fields, lakes, and grasslands" in the Shandong section of the Yellow River Basin is to evaluate its comprehensive ecosystem function and provide a basis and reference for the construction of ecological barriers along the Yellow River. This project refers to the research of scholars and introduces LCSI to comprehensively measure the comprehensive function of the ecosystem in the study area. The Land Use Index (LCSI) refers to the proportion of the sum of the areas of three types of land with good comprehensive ecosystem functions, including water bodies, forests, irrigation land, and grasslands, to the total area of the study area. It is mainly used to measure the land use status of the research area and the quality of its reflected ecosystem comprehensive function. The higher the land use status index, the stronger its ecological comprehensive function, and vice versa. Based on Table 4, it is found that:

(1) Over time, the land use index in the Shandong section of the Yellow River Basin has shown an overall downward trend, with a decrease followed by an increase. The ecological background and comprehensive functions of the ecosystem have weakened as a whole, which indirectly reflects the negative impact of urbanization and socio-economic development on the ecological background and system in the region. It is worth noting that the land use status index of the study area has improved between 2010 and 2020, indicating that in recent years, ecological restoration and compensation measures such as the Yellow River Ecological Corridor in Shandong Province are improving its ecological background.

(2) By comparison, it can be seen that during the research period, there were significant differences and varying degrees of decline in the comprehensive ecological function index of the 9 cities in the Shandong section of the Yellow River Basin. Among them, the Dongying section had the highest land use index and the strongest comprehensive ecological function, followed by the Jinan section, Tai'an section, and Heze section, while the Dezhou section, Jining section, and Liaocheng section were significantly lower; Over time, the Dezhou and Heze sections in the research area have experienced the most significant decline, followed by the Dongying, Liaocheng, and Jinan sections. Compared to the Binzhou, Jining, Tai'an, and Zibo sections, the land use status index has decreased slightly.

Table 4. Land Use Status Index of the Shandong Section of the Yellow River Basin from 1990 to 2020 for the Whole Region and 9 City Sections

LCSI	The entire region	Binzhou	Dezhou	Dongying	Heze	Jinan	Jining	Liaocheng	Tai'an	Zibo
1990s	23.29	11.82	7.22	30.66	21.67	31.95	3.47	3.56	21.11	14.97
2000s	23.04	12.60	7.04	30.69	14.47	31.93	3.30	3.56	21.07	14.31
2010s	18.12	9.69	2.70	25.40	11.82	28.66	3.07	2.69	19.76	12.72
2020s	19.9	11.61	4.00	25.09	16.48	28.84	3.01	2.69	19.58	13.22

7.Conclusion and Discussion

As a typical region within the Yellow River Basin with multiple overlapping characteristics such as active economic development areas, fragile ecological environments, and sensitive resource utilization areas, the eastern section of the Yellow River Basin has also brought about ecological resource destruction such as mountains, rivers, forests, fields, lakes, and grasslands, decreased natural restoration capabilities, and the decline of ecological barriers along the Yellow River, which restricts the optimization of regional land space layout and the organic coordination of human land relations. This article is based on the current strategic drivers of China's "coordinated management of mountains, waters, forests, fields, lakes, and grasslands" and "ecological protection and high-quality development in the Yellow River Basin". By combining "3S" spatial analysis technology with mathematical statistical analysis and drawing on semi-structured interviews and other methods, the spatial differentiation characteristics and ecological protection paths of "mountains, waters, forests, fields, lakes, and grasslands" in the eastern section of the Yellow River Basin are analyzed. It is found that over time, the proportion of spatial area of "mountains, waters, forests, fields, lakes, and grasslands" in the Yellow River Basin has undergone significant changes. The increase in water body area is mainly concentrated in the Dongying section located at the estuary and the Tai'an section located in the Dongping Lake area; The forest area in all 9 cities in the study area shows a decreasing trend, and the decreasing areas are significantly distributed in the sections of Tai'an and Jinan; The area of land area growth is mainly located in the Dongying section of the Yellow River estuary; The urban differences in grassland area changes are significant, and the decrease in grassland area in the Dongying section is significantly higher than in other cities. During the research period, the ecological background and comprehensive ecosystem functions of the Shandong section of the Yellow River Basin were overall weakened; From 1990 to 2020, there were significant differences and varying degrees of decline in the comprehensive ecosystem function index among 9 cities in the Shandong section of the Yellow River Basin. Among them, the Dongying section had the highest land use index and the strongest comprehensive ecosystem function, while the Dezhou and Heze sections had the most significant decline. This study not only outlines the spatial differentiation and evolution trajectory of "mountains, waters, forests, fields, lakes, and grasses" in the study area, but also provides reference for subsequent research on ecological protection and high-quality development in the Shandong section of the Yellow River Basin.

Acknowledgment

This paper is jointly supported by the 2023 Innovation and Entrepreneurship Training Plan for College Students in Shandong Province (202310453019), the 2023 Humanities and Social Sciences Project of the Shandong Federation of Social Sciences (2023-ESDZ-105), the Youth Fund Project of Mount Taishan University (QN-01-202207), and the Philosophy and Social Sciences Research Project of Shandong Universities "Research on the Non coordinated Coupling and Optimization Path of Urbanization Development and Ecological Environmental Effects in Shandong Section of the Yellow River Basin".

References

[1] Liu Jinhua, Congzhongxiao, Wang Zhijun. Multi scale study of ecological environment effects based on the transformation of the three living spaces: A case study of the Shandong section of the Yellow River Basin. China Environmental Science, 2023, 43 (05): 2519-2530.

[2] Wang Jiaming, Yu Zhilin. Measurement and influencing factors of high-quality development of central cities and urban agglomerations along the Yellow River. China Population, Resources and Environment, 2021 (31): 47-58.

[3] Wang Chengxin, Dou Wangsheng, Cheng Yu, et al. Research on the Urban Spatial Expansion and Driving Forces of Jinan during the Rapid Urbanization Stage. Geographic Science, 2020, 40 (09): 1513-1521.

[4] Fan Zaiyu, Yi Xiaoya, Geng Hong. A spatiotemporal coupling study on ecological efficiency and urbanization efficiency in the Yellow River Delta: an empirical analysis based on panel data from 2008 to 2017. Urban Issues, 2021 (03): 17-28.

[5] Su Min, Yu Fangbo, Fang Xiaobo. Health assessment of the community of mountains, waters, forests, fields, lakes, and grasses in the Qiantang River source area of Zhejiang Province. Soil and Water Conservation Bulletin, 2024, 44 (01): 97-108.

[6] You Chang, Qu Hongjiao, Guo Luo. Socio ecological system spatiotemporal coupling and simulation prediction under the concept of a community of life in mountains, waters, forests, fields, lakes, grasslands, and sands. Journal of Ecology, 2024, 44 (07): 2745-2760.

[7] Meng Pei, Jiang Shanshan, Zheng Chenghao, et al. Practice and Exploration of Comprehensive Management of Mountains, Rivers, Forests, Fields, Lakes, Grasslands and Sands in Ejin Horuo Banner. Forestry Construction, 2023, 41 (04): 62-65.

[8] Xiao Yingcai, Hu Wenmin, Huang Yihe, et al. Ecological changes and restoration strategies of mountains, rivers, forests, fields, lakes, and grasslands in the Dongting Lake area. People's Yangtze River, 2023, 54 (07): 47-54.
[9] Zhang Dongsheng, Chai Guigui, Ding Aifang, et al. Research on the Dynamics and Trends of Urban Spatial Development in the Yellow River Delta. Planner, 2012, 28 (12): 101-105.
[10] Chen Xiaohan, Zhang Lei, Shi Li, et al. Analysis of land use change in the "Golden Four Corners" of China, Myanmar, Thailand, and Laos based on geoscience information graphs. Journal of Yunnan Agricultural University (Natural Science), 2023, 38 (02): 333-342.
[11] Zhang Lei, Wu Youde, Li Jun, et al. Analysis of land use and landscape pattern changes in the Myanmar section of the "Golden Four Corners" region of China, Myanmar, Thailand, and Laos. World Geographic Research, 2018, 27 (04): 21-33+117.