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Original Research

Spatio-Temporal Evolution and Simulation Prediction of Ecosystem Service Value in Huaihe River Basin

Yiwen Fu#, Gang He#, Shuhang Zhao#*, Jie Li**

School of Economics and Management, Anhui University of Science and Technology, Huainan, 232001, China

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Abstract

Studying the ecosystem service value is of great value for solving the contradiction between ecological protection and economic development in the Huaihe River Basin. The characteristics of land use change were studied by using the Landsat remote sensing image data of Anhui section and Henan section of Huaihe River Basin from 2010 to 2020. The equivalent factor method was used to estimate the ecosystem service value, and the spatial autocorrelation model was used to analyze the spatial distribution characteristics of ecosystem service value The GM-BP model was used to predict the land use change in 2025. The results showed that: (1) From 2010 to 2020, cultivated land and construction land dominated the land use in the study area, and the degree of land use change changed from severe to stable. (2) The value of ecosystem services is in the transition stage from low level (II) to medium level (III). (3) ecosystem service value has a significant positive spatial correlation, and the spatial distribution is generally high in the southeast and low in the northwest. (4) Compared with 2020, ecosystem service value will rise by 0.54 % in 2025.

Keywords: land use, equivalent factor method, spatial autocorrelation, GM-BP

Introduction

Ecosystem services refer to the ecology and services obtained directly or indirectly through the structure, process and function of the ecosystem [1]. Ecosystem service value can quantify ecosystem service capability. From the perspective of nature, Daily defines the environmental conditions and processes of natural ecosystem and its component species to maintain and satisfy human life as Ecosystem service values (ESV). Ecosystem service functions are divided into 13 types [2]. From the human perspective, Costanza et al. believe that ESV is the well-being that humans directly or indirectly obtain from the ecosystem [3]. According to the research of Xie Gaudi, the basin was divided into six ecosystems: forest, grassland, farmland, water area, wetland and desert. Regional ESV was obtained according to the area of each ecosystem and the unit price of each ecosystem service function [4]. Assessing ESV can improve the awareness of ecological environment protection, promote the integration of natural resources into the national economic accounting system, and effectively promote the sustainable development of the national economy [5].

#These authors contribute equally to this work
*e-mail: ZSHang1001@163.com
**e-mail: lijie198200@163.com

Land Use/Cover Change (LUCC) is the main driving force affecting ecosystem services [6]. Land use change affects the ability of land to provide human services. Reasonable land use layout can effectively improve regional ESV and protect ecological environment [7].

The research on ESV is mainly carried out from different perspectives, such as research methods, research scales and research fields. The research content mainly focuses on land use change [8-11], spatial and temporal distribution characteristics [12, 13], driving factors [14-16] and so on. In-depth exploration of provincial [17-19], city [20, 21], county [22, 23] and other administrative units and watershed [24, 25] natural units and other different research scales. The research objects are mostly concentrated in single ecosystems such as wetlands [26], grasslands [27], and deserts [28]. The evaluation method mainly involves the equivalent factor method [29-31] and the functional value method [32, 33]. At the same time, models such as InVEST [34, 35] and geodetector [36, 37] are more and more widely used in evaluating ESV and exploring its driving factors. The equivalent factor method was proposed by COSTANZA et al. [3], later modified by Xie Gaodi et al. [38, 39] based on a questionnaire survey of more than 200 ecologists in China, and obtained "Table of equivalent Factors of ecosystem Services in China", which was then known by the academic circle. The equivalent factor method needs to be combined with land use change, and is widely used because of easy data acquisition and intuitive evaluation results. Later, some scholars revised Xie Gaodi's ecosystem service value model based on the actual situation of the study area, making the evaluation results more scientific [40]. At present, although the ESV research system has been enriched and improved from different perspectives, there are few studies on predicting and simulating the spatial distribution of ESV in the future from the perspective of land use change, and then evaluating the spatial profit and loss characteristics of ESV, and failing to comprehensively consider the spatial heterogeneity of ecosystem services.

In recent years, with the rapid advancement of urbanization and industrialization, the scale of construction land has expanded rapidly, and the regional land use structure has changed significantly, which has affected the regional ecosystem service value. In this study, three remote sensing images of Anhui and Henan sections of the Huaihe River Basin from 2010 to 2020 were selected to analyze the land use situation in the past 10 years. The adjusted ESV equivalent factor was used, and the equivalent factor method and spatial autocorrelation analysis were used to quantitatively analyze the spatial and temporal evolution characteristics of ecosystem service value. The GM-BP model was used to predict future land use. Discuss the evolution trend of ecosystem service value in Huaihe River Basin in the future, and put forward suggestions for its future sustainable development.

Material and Methods

Study Area

The Huaihe River Basin is located between the Yangtze River and the Yellow River. It is rich in mineral resources, agricultural industry resources, and has obvious geographical advantages. It is an important water transportation hub in China [41]. It is one of China's traditional food bases. It is one of the regions with the greatest potential for social and economic development in China [42]. However, due to the particularity of the natural environment, economic society, and water system changes, the Huaihe River Basin has slow economic development, uneven spatial and temporal distribution of water resources, and serious water pollution, which restricts the sustainable development of the social economy in the basin. How to effectively identify the ESV in the Huaihe River Basin has an important impact on the ecological and economic development of the Huaihe River Basin.

The Henan section of the Huaihe River Basin is located in the upper reaches of the Huaihe River Basin, and the Anhui section is located in the middle reaches of the Huaihe River Basin. It includes 9 cities in Anhui Province and 9 cities in the Henan section, accounting for 67.5 % of the total area of the Huaihe River Basin. Therefore, evaluating the ESV of Anhui section and Henan section of Huaihe River Basin, excavating the regional differences of ESV, and studying the dynamic change trend of ESV are conducive to promoting the healthy development of ecology in Huaihe River Basin (Fig. 1).

Research Method

Equivalent Factor Method

In terms of the correspondence between land use type and ecosystem type and value equivalent, the value of forest land was determined according to the tree species in the Huaihe River basin, that is, the value of forest land was the average modified equivalent of broadleaf, coniferous, mixed needle and broad and shrub. Grassland is the average of grassland, shrub and meadow. Unused land corresponds to bare land; Equivalent factor of construction land is 0 [43] (Table 1). Based on the ESV research proposed by Costanza et al. [3], referring to the research on ecosystem value in recent years [44], combined with the ecosystem service value equivalent table established by Xie et al. [4, 38] and Table 1, the ecosystem service value equivalent table of Huaihe River Basin was determined (Table 2). In order to eliminate human factors, the economic value of the annual average yield of 1/7 unit area (hm^2) is used to represent the value of 1 unit equivalent factor [45]. The calculation formula is as follows:

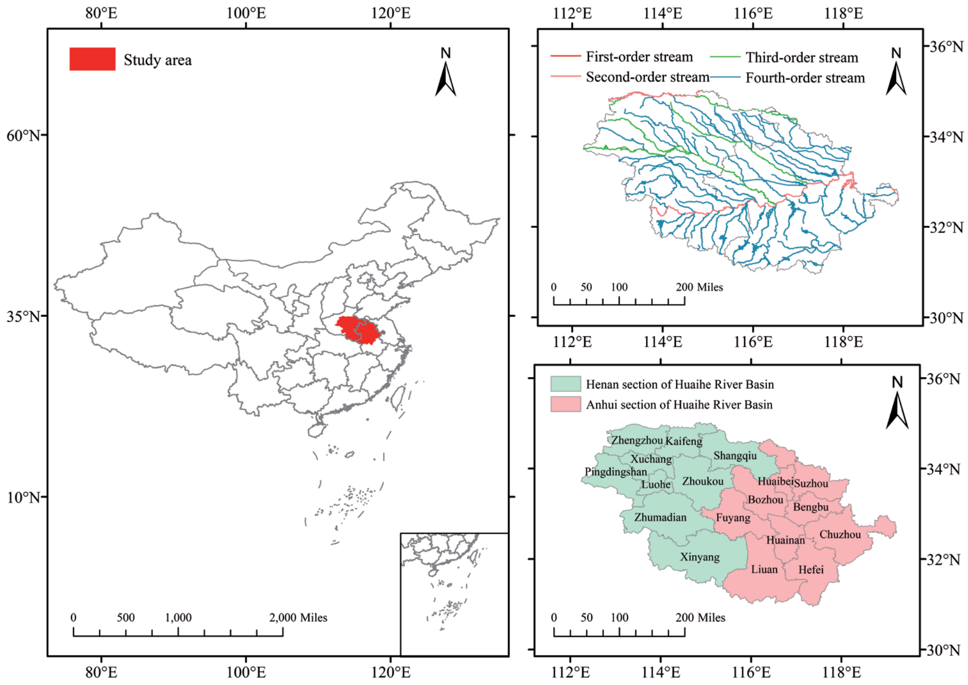

Fig. 1. Location of Anhui section and Henan section of Huaihe River Basin.

$$E_a = \frac{1}{7}\sum_{k=1}^{l}\frac{s_k p_k q_k}{s} \tag{1}$$

In the formula: E_a is the unit equivalent factor value (yuan/hm^{-2}); k is the k_{th} grain; l is the total type of grain; s_k is k kinds of grain planting area (hm^2); p_k is the average price of the k_{th} kind of grain (yuan/kg); q_k is the k_{th} grain yield (kg/hm^2); s is the total planting area (hm^2) of all grain. The main economic crops such as rice, wheat, corn and soybean in the study area were selected, and the economic value of the unit equivalent factor was revised. The value of one equivalent factor of ecosystem service value in Anhui Province was 2038.23 yuan/hm^2. The value of one ecosystem service value equivalent factor in Henan Province is 1768.17 yuan/hm^2, and the value coefficient of different ecosystem services in the study area is calculated.

Combined with the total area of land use types in Anhui section and Henan section of Huaihe River Basin, the total ESV is obtained. The calculation formula is as follows:

$$ESV = \sum_{i=1}^{n}\sum_{j=1}^{m} A_j E_{ij} = \sum_{i=1}^{n}\sum_{j=1}^{m} A_j (e_{ij} * E_a) \tag{2}$$

ESV is the total ESV (yuan); j is the land use type, which is mainly divided into six categories: cultivated land, forest land, grassland, water area, construction land and unused land. A_j is the area of the j_{th} land use type (hm^2). I_i is the type of ecosystem service function, using the definition and classification of ecosystem services provided by ecosystems and their components by Costanza et al. [3], which is divided into four categories, e_{ij} is the equivalent weight, E_{ij} is the economic value (yuan/hm^2) of the i ecosystem service function of the j_{th} ecosystem.

Table 1. Adjustment of ESV equivalent values in Anhui Province and Henan Province.

Anhui section ESV Class I	Actual situation of Anhui section	Chinese ESV Class I	Second-class value
Cultivated land	Dry land, paddy field are more abundant	Cultivated land	Take the equivalent mean values of dry land, paddy field
Woodland	Diversity of forest resources	Woodland	Take the equivalent mean values of needle, needle width mixed, broadleaf and shrub
Grass land	Warm temperate zone subhumid monsoon climate, moderate rainfall	Grass land	Take the equivalent mean values of grassland, shrub and meadow
Waters	Rich in water resources	Waters	Take the Waters equivalent values
Unutilized land	Temporarily idle	Nudation	Take the nudation equivalent values

Table 2. Adjusted equivalent factor table of ecosystem service value in the study area.

Classification	Provision services			Regulating service				Support services			Cultural service
	Food production	Production of material	Supply of water resources	Gas conditioning	Climate control	Clean-up operation	Hydrological regulation	Soil conservation	Maintaining nutrients	Biodiversity	Aesthetic landscape
Cultivated land	1.11	0.25	-1.31	0.89	0.47	0.14	1.50	0.52	0.16	0.17	0.08
Woodland	0.25	0.58	0.30	1.91	5.71	1.67	3.74	2.32	0.18	2.12	0.93
Grass land	0.23	0.34	0.19	1.21	3.19	1.08	2.34	1.47	0.11	1.34	0.59
Waters	0.80	0.23	8.29	0.77	2.29	5.55	102.24	0.93	0.07	2.55	1.89
Unutilized land	0.00	0.00	0.00	0.02	0.00	0.10	0.03	0.02	0.00	0.02	0.01
Construction land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

The expanding velocity (EV) is selected to describe the change trend and degree of ecological service value and land area of different spatial types in Anhui section and Henan section of Huaihe River Basin in different periods from 2010 to 2020. The calculation method refers to the previous research results [46, 47]:

$$EV = \frac{Q_b - Q_a}{Q_a} \times \frac{1}{T} \times 100\% \quad (3)$$

Among them, Q_a and Q_b are the initial and final values of the study period; T is the duration of the study.

Spatial Autocorrelation Analysis

The spatial autocorrelation model is used to measure the spatial heterogeneity or convergence of the research object. This paper measures the spatial distribution characteristics and agglomeration of ecosystem service value in Anhui section and Henan section of Huaihe River Basin through global Moran's I index, Moran scatter plot and LISA distribution.

$I \in [-1,1]$, when $I > 0$, it means that the attributes of spatial things are positively correlated in space, and the spatial agglomeration is high. $I < 0$, indicating that the attribute is spatially negatively correlated and the spatial dispersion is high; $I = 0$, which is expressed as a random spatial distribution. The calculation formula is as follows:

$$\mathrm{I} = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} \omega_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n} \sum_{j=1}^{n} \omega_{ij} \sum_{i=1}^{n} (x_i - \bar{x})^2} \quad (4)$$

In the formula, I is the global Moran index, n is the number of spatial units (n = 18), x_i and x_j are the ESV of cities i and j, $\bar{x}$ is the mean value of ESV, ω_{ij} is the spatial weight matrix of cities i and j, and S is the sample variance.

Local Moran's index (LISA) is used to test local autocorrelation, which can be used to further determine the spatial agglomeration, heterogeneity or random distribution characteristics of ESV.

$$I_i = \frac{(x_i - \bar{x})}{s^2} \sum_{j}^{n} \omega_{ij} (x_j - \bar{x}) \quad (5)$$

GM-BP Model

Grey prediction model (GM) can predict irregular time series, which is consistent with the data trend of land area. The deviation relationship is summarized into the BP neural network model to further improve the prediction results and improve the prediction accuracy. Based on the reference values of single land area in 2010, 2015 and 2020, the GM-BP prediction of single land area in 2025 is carried out. In order to eliminate the influence of dimension and limit the preprocessed data to a certain range, the collected sample data is normalized, and the normalized reference data is set as $x^{(0)} = (x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(10))$.

Make one accumulation to generate a sequence:

$$x^{(1)} = x^{(1)}(1), x^{(1)}(2), \ldots, x^{(1)}(k) \quad (6)$$

$$x^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i), k = 1,2,\ldots,10 \quad (7)$$

The mean series generation of X (1) series is carried out.

$$Z^{(1)} = (Z^{(1)}(1), Z^{(1)}(2), \ldots + Z^{(1)}(10)) \quad (8)$$

$$Z^{(1)}(k) = \frac{1}{2}(x^{(1)}(k) + x^{(1)}(k-1) \quad (9)$$

establishing differential equations:

$$x^{(0)} + aZ^{(1)}(k) = b \quad (10)$$

Among them, a represents the development coefficient, and b represents the grey action. To solve the value of a, b, suppose:

$$\mathrm{p} = \begin{bmatrix} a \\ b \end{bmatrix} \quad \mathrm{Y} = \begin{bmatrix} \boldsymbol{x}^{(0)}(\mathbf{2}) \\ \boldsymbol{x}^{(0)}(\mathbf{3}) \\ \vdots \\ \boldsymbol{x}^{(0)}(\mathbf{20}) \end{bmatrix} \quad \mathrm{B} = \begin{bmatrix} -Z^{(1)}(2) 1 \\ -Z^{(1)}(3) 1 \\ \vdots \\ -Z^{(1)}(n) 1 \end{bmatrix}$$

$$\mathrm{Y} = \mathrm{Bp} \quad (11)$$

When B is full rank matrix, the least square method is used to calculate the coefficients a and b, that is:

$$\mathrm{p} = \begin{bmatrix} a \\ b \end{bmatrix} (B^T B)^{-1} B^T Y \quad (12)$$

Solving the above differential equation:

$$x^{(1)}(k+1) = \left(x^{(0)}(1) - \frac{b}{a}\right) e^{-ak} + \frac{b}{a} \quad (13)$$

$X^{(1)}(k+1)$ is the predicted value of the model.

The GM (1,1) method is used to predict the single land area in 2025, which is used as a learning sample, and the artificial neural network is used to predict the ESV in 2025.

The first layer (input layer):

$$Out_i^{(1)} = In_i^{(1)} = x, i = 1,2,\ldots,m \quad (14)$$

The second layer (hidden layer):

$$\begin{cases} In_j^{(2)} = \sum_{i=1}^{n} w_{ij}^{(1)} * Out_i, j = 1,2,\ldots,l \\ Out_j^{(2)} = f(In_j^{(2)}) \end{cases} \quad (15)$$

Where f (x) is the transfer function, the Sgmoid function is used here.

The third layer (output layer):

$$y_k = Out_k^{(3)} = In_k^{(3)} = \sum_{j=1}^{l} w_j^{(2)} * Out_j^{(2)}, k = 1,2,\ldots,n \quad (16)$$

where m represents the number of nodes in the input layer (m = 6), n represents the number of nodes in the output layer (n = 1), and l represents the number of neurons in the hidden layer.

Results and Discussion

Results

Changes of Land Use Structure

From 2010 to 2020, the land use types of Anhui section and Henan section of Huaihe River Basin have always maintained: cultivated land>construction land>forest land>grassland>water area>unused land. The main land use type in the study area is cultivated land, accounting for 69.29%~74.98% of the total area, followed by construction land and forest land, with ratios of 11.72%~15.16% and 8.34%~8.70%, respectively. The sum of the three areas accounts for about 90%. From the overall change in 2010-2020, the study area showed a two-increase and one-decrease model: the area of water and construction land increased year by year, from 2.56% and 11.72% in 2010 to 3.54% and 15.16 % in 2020, respectively. The area increased by 143537.49 hm^2 and 474980.73 hm^2, respectively. The construction land expanded significantly between 2010 and 2015. The area of cultivated land decreased year by year, from 74.98% in 2010 to 69.29% in 2020, and the area decreased by 1645960.05 hm^2. The area of grassland decreased first and then increased, and the area of forest land and unused land increased first and then decreased. The rate of land change in 2010-2015 was more obvious than that in 2015-2020, and the dynamic degree of unused land was the highest, followed by grassland and water area, indicating that land use changed dramatically first and then stabilized, and the dynamic degree of Anhui section was higher than that of Henan section during the study period (Fig. 2).

Temporal and Spatial Variation Characteristics of Ecosystem Service Value

From 2010 to 2020, the ESV in the Anhui and Henan sections of the Huaihe River Basin showed an overall upward trend, rising from 279.372 billion yuan to 302.291 billion yuan, with a change rate of 8 %. From the contribution of different land types to ecosystem service value, water area is the most important type to provide ecosystem service value, and the proportion of the three periods of data is more than 40%. Followed by cultivated land, accounting for about 30%; forest land and grassland accounted for about 20% and 4% respectively. The proportion of ecosystem service value of unused land is very low.

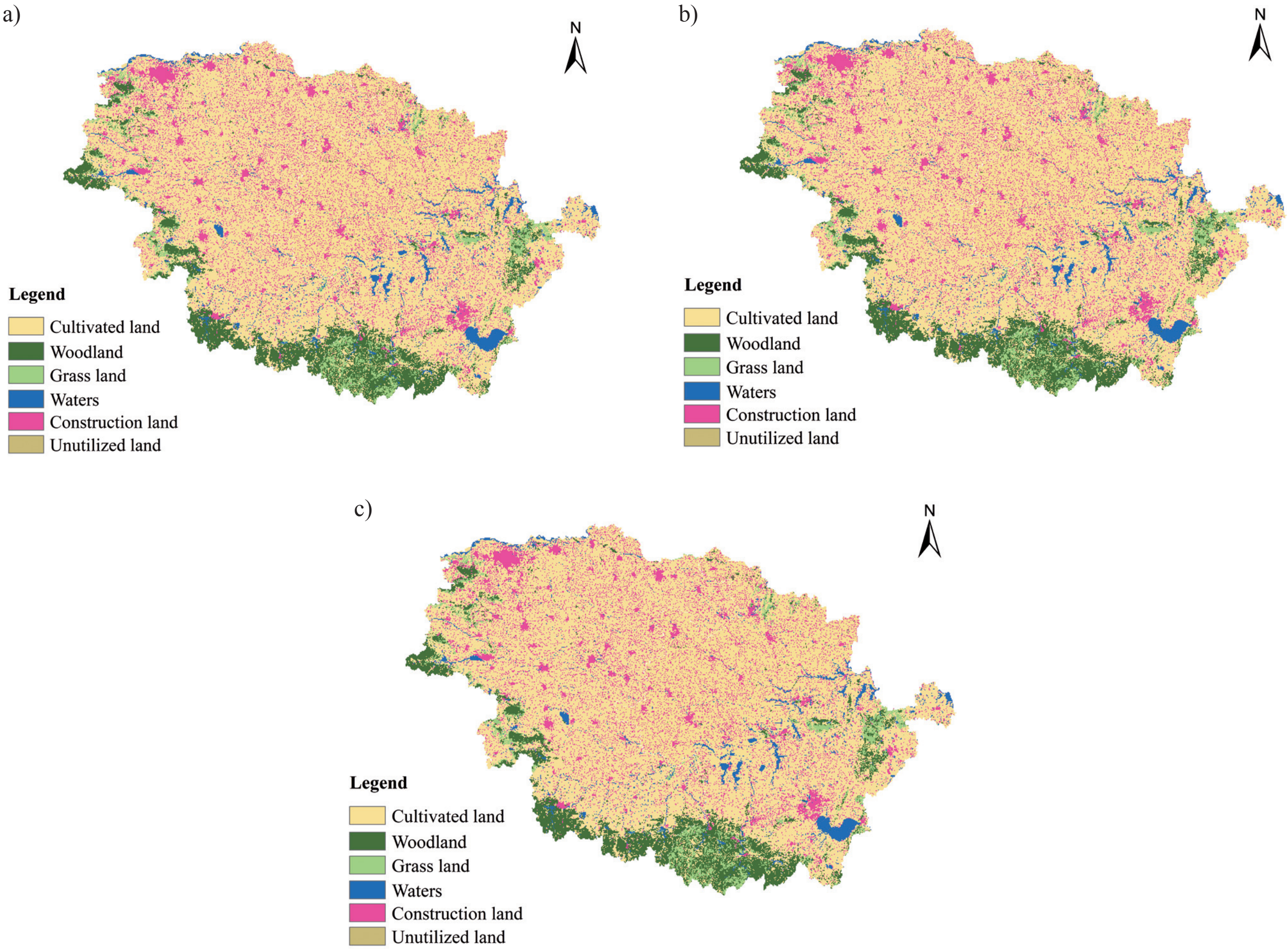

Fig. 2. Land use types in Anhui section and Henan section of Huaihe River Basin. a) 2010, b) 2015, c) 2020.

From 2010 to 2020, the value of cultivated land ecosystem services in Anhui section and Henan section of Huaihe River Basin decreased the most, which was − 4.56%, followed by cultivated land, and the value of water ecosystem services increased slightly. Although the decline in the value of forest ecosystem services was not high, the total amount decreased the most, which was 282 million yuan. In terms of stages, the ESV of cultivated land, forest land, grassland and unused land continued to decline, but the rate of reduction decreased in the later period, and the value of water ecosystem services increased first and then decreased (Table 3).

According to the statistics of the individual service value of the ecosystem in Anhui section and Henan section of Huaihe River Basin in 2010, 2015 and 2020, it

Table 3. Changes in ecosystem service value of different land types in Anhui and Henan sections of the Huaihe River Basin.

Type of land use	ESV							
	2010		2015		2020		Variable quantity/ ($\times10^8$yuan)	Rate of change /%
	ESV/ ($\times10^8$yuan)	Proportion /%	ESV/ ($\times10^8$yuan)	Proportion /%	ESV/ ($\times10^8$yuan)	Proportion /%		
Cultivated land	999.32	35.77	961.93	34.04	879.92	29.11	-119.40	-11.95
Woodland	555.47	19.88	571.14	20.21	550.19	18.20	-5.28	-0.95
Grass land	103.87	3.72	103.19	3.65	131.30	4.34	27.43	26.41
Waters	1127.24	40.35	1180.46	41.77	1456.58	48.18	329.34	29.22
Unutilized land	7.82	0.28	9.49	0.34	4.92	0.16	-2.90	-37.08
Total	2793.72	100.00	2826.21	100.00	3022.91	100.00	229.19	8.20

Table 4. The value and change of single ecosystem service function in Anhui section and Henan section from 2010 to 2020.

Types of ecological services	$ESV_i/(\times10^8$yuan)			Variable quantity /($\times10^8$yuan)	Rate of change /%
	2010	2015	2020		
Food production	288.18	278.53	258.25	-29.93	-10.39
Production of material	87.63	85.69	80.94	-6.69	-7.63
Supply of water resources	-207.63	-192.96	-150.64	56.99	27.45
Gas conditioning	290.41	284.17	268.25	-22.16	-7.63
Climate control	323.38	324.43	321.42	-1.96	-0.61
Clean-up operation	143.27	146.48	154.41	11.14	7.78
Hydrological regulation	1387.03	1420.60	1617.98	230.95	16.65
Soil conservation	233.01	229.88	220.46	-12.55	-5.39
Maintaining nutrients	44.76	43.50	40.60	-4.16	-9.29
Biodiversity	136.59	137.89	140.46	3.87	2.83
Aesthetic landscape	67.09	67.99	70.78	3.69	5.50
Total	2793.72	2826.20	3022.91	229.19	8.20

Table 5. Classification of ecosystem service value and dynamic degree in Anhui section and Henan section of Huaihe River Basin.

ESV classification	Value ranges	EV classification	Value ranges
Lower (I)	$[1\times10^9,10\times10^9)$	Rapid decrease	(-∞,-0.4)
Low (II)	$[10\times10^9,20\times10^9)$	Decrease	[-0.4,-0.02)
Middle (III)	$[20\times10^9,30\times10^9)$	Tiny change	[-0.02,0.02)
High (IV)	$[30\times10^9,40\times10^9)$	Increase	[0.02,0.4)
Higher (V)	$[40\times10^9,50\times10^9)$	Rapid increase	[0.4,+∞)

can be seen that the order of the individual service value of the ecosystem in Huaihe River Basin is: Hydrological regulation > Climate control > Gas conditioning > Food production > Soil conservation > Clean-up operation > Biodiversity > Production of material > Aesthetic landscape > Maintaining nutrients > Supply of water resources. Hydrological regulation ESV value is the highest, accounting for 49.65 % of the total. From 2010 to 2020, the water resources supply, purification environment, hydrological regulation, biodiversity and aesthetic landscape of single ESV in Anhui and Henan sections of Huaihe River Basin showed an increasing trend. The climate regulation increased first and then decreased, and the rest continued to decrease (Table 4).

Based on the spatial analysis of ESV in the Anhui and Henan sections of the Huaihe River Basin, the natural discontinuity method was used to divide the ESV and EV into five grades [48] (Table 5).

The ESV of 18 cities in Anhui and Henan sections of the Huaihe River Basin showed an overall upward trend, but it was still at a low level (II), and showed a trend of high in the southeast and low in the northwest. From 2010 to 2020, except Lu ‘an City, ESV was V, Hefei City, Chuzhou City, Xinyang City ESV was IV, Fuyang City, Huainan City, Bengbu City, Zhumadian City, Pingdingshan City 5 cities were II, the remaining 9 cities were I. From 2010 to 2015, there was no significant change in the overall EV of Anhui and Henan sections of the Huaihe River Basin.From 2015 to 2020, the overall EV changed from no significant change to improvement. From 2010 to 2020, the EV of 9 cities in Henan section increased, and there was no significant change in 5 cities in Anhui section. The EV of Chuzhou decreased rapidly, the change rate was 4 times the average level, Bozhou decreased, and Bengbu increased rapidly (Fig. 3).

Analysis of Spatial Variation Characteristics of ESV

In order to further explore the spatial relationship between ESVs in Anhui section and Henan section of Huaihe River Basin, the results of univariate spatial autocorrelation analysis showed that the global spatial autocorrelation analysis index in 2010 and 2015 passed the 1 % significance test, and the Z values were 3.57 and 3.54, respectively, which were greater than the critical value of 2.58.In 2020, the global spatial autocorrelation analysis index passed the 5% significance test, and the Z value was 0.24, which was greater than the critical value of 1.95, which was statistically significant. The Moran ‘I indexes of 18 prefecture-level cities in Anhui section and Henan section of Huaihe River Basin in 2010,

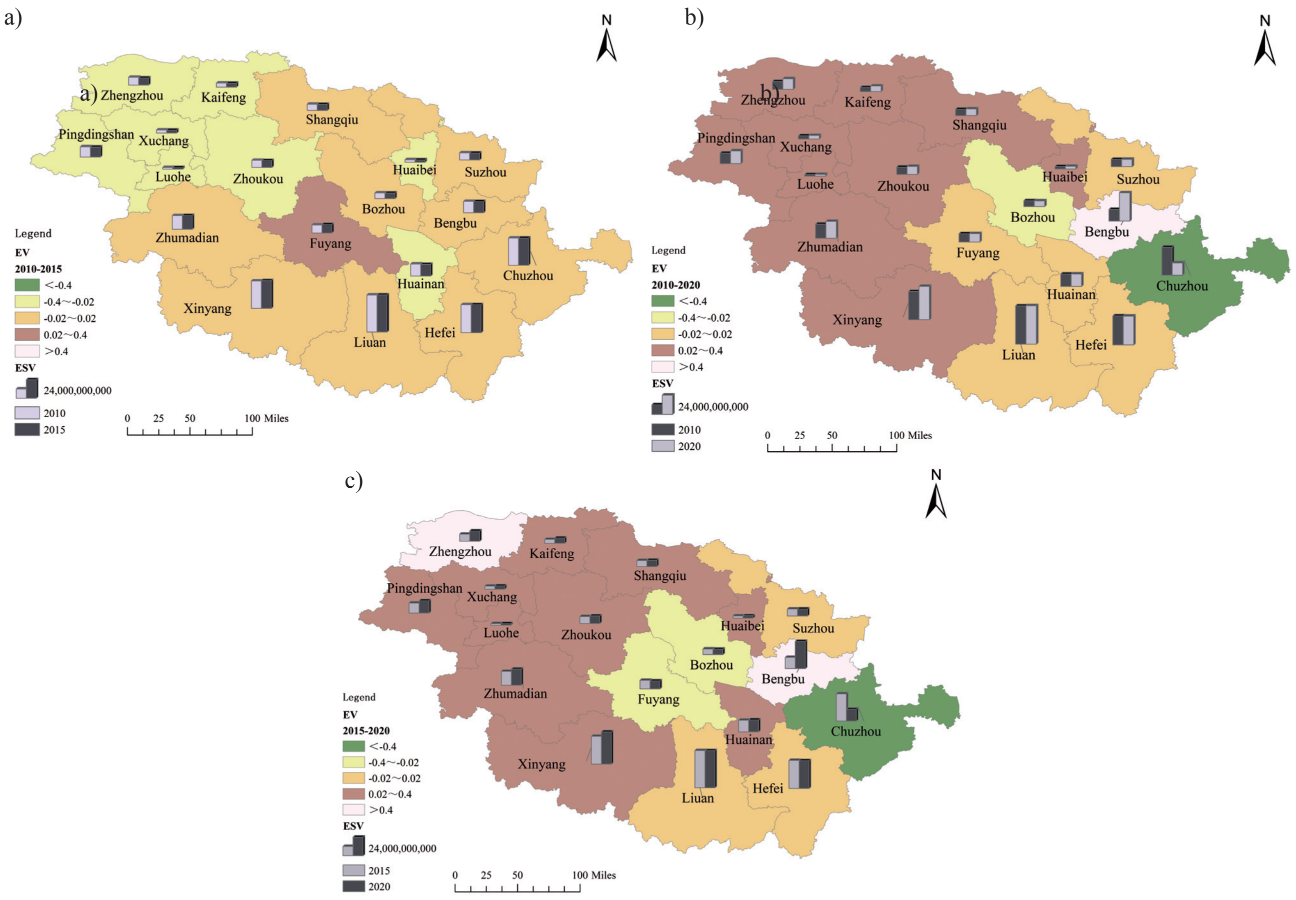

Fig.3. Spatial distribution of ESV and EV in Anhui section and Henan section of Huaihe River Basin.

2015 and 2020 were 0.483,0.488 and 0.291, respectively, which were all greater than 0, indicating that there was a significant spatial positive correlation between ESV, but the Moran 'I index showed a decreasing trend, reflecting that the spatial positive autocorrelation degree of the study area showed a decreasing trend (Fig. 4).

From 2010 to 2020, the ESVs of 18 prefecture-level administrative regions in Anhui and Henan sections of the Huaihe River Basin were mainly high-high and low-low clustering models. In 2010 and 2015, the low-low aggregation of ESVs was mainly in Henan section 3 cities (Xuchang City, Zhoukou City, Shangqiu City), high-high aggregation was mainly in Anhui section 2 cities (Lu 'an City, Hefei City), only Anhui section Huainan City was low-high aggregation ; in 2020, only two cities in Henan (Zhoukou City, Shangqiu City) ESV is low-low aggregation, only Lu 'an City in Anhui is high-high aggregation, and the rest are not significant (Fig. 5).

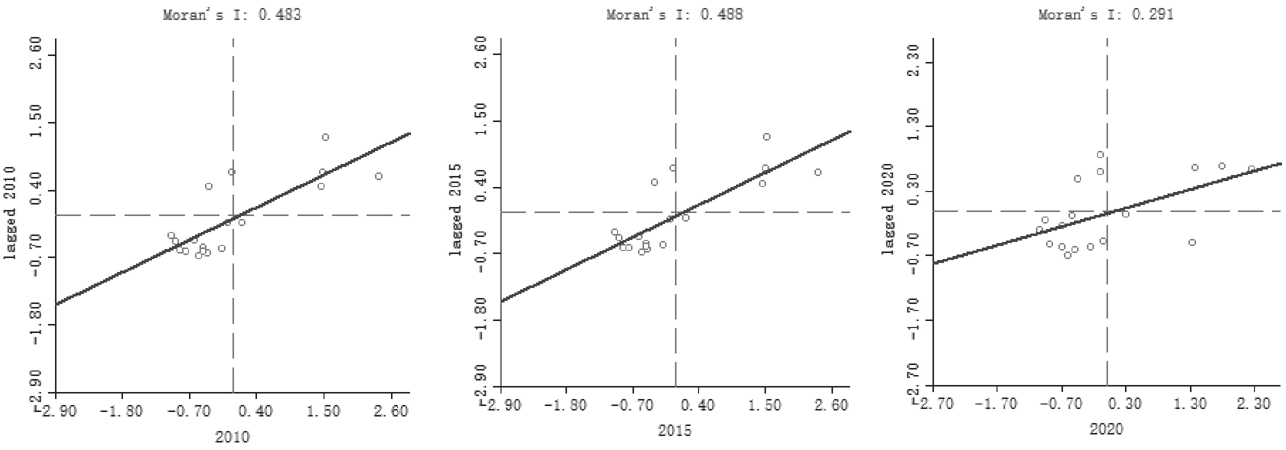

Fig. 4. Results of univariate global spatial autocorrelation analysis.

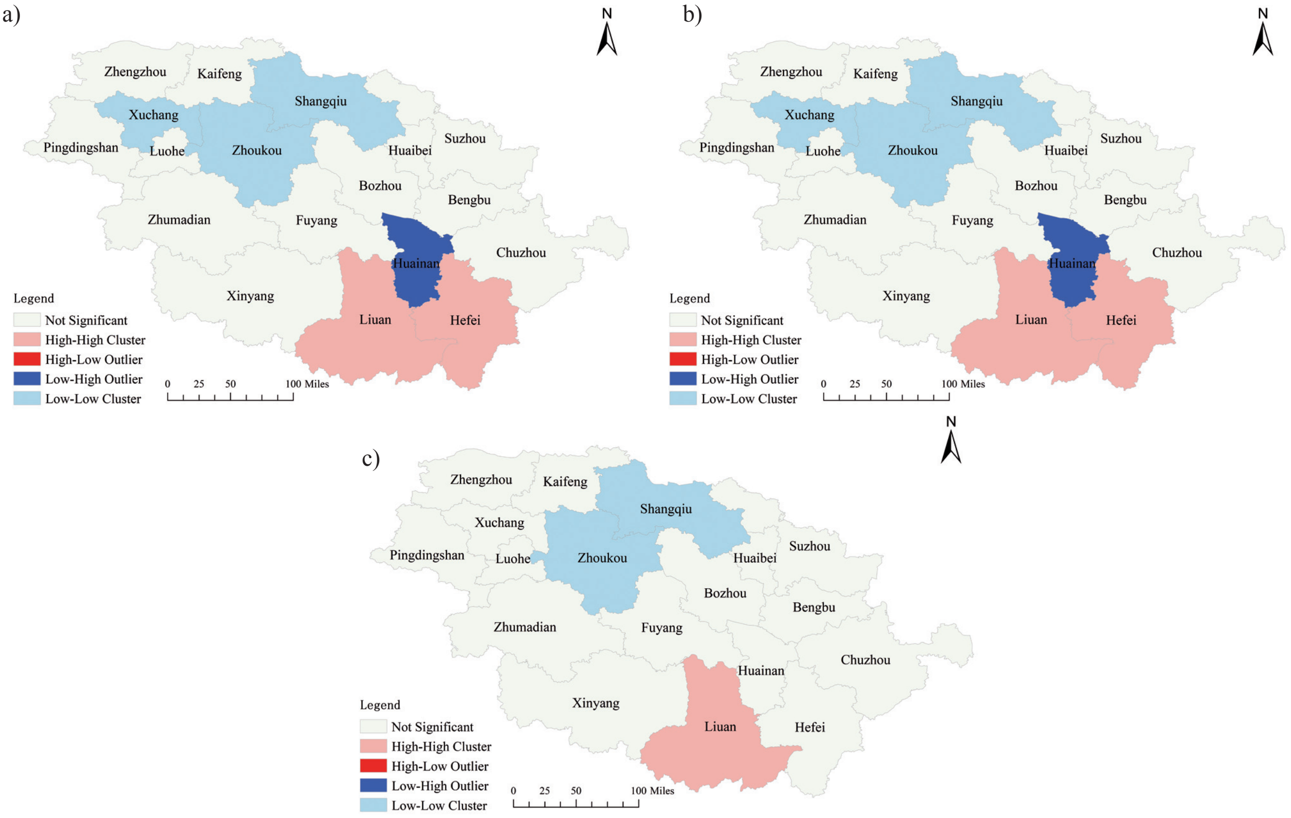

Fig. 5. LISA distribution of ecosystem service value in Anhui section and Henan section of Huaihe River Basin. a) 2010, b) 2015, c) 2020.

ESV Prediction Results Based on GM-BP Model

For the BP training algorithm function, the article selects the Scaled Conjugate Gradient training method. After many times of modifying the connection weights and thresholds, the number of neurons is determined, the optimal grid structure is reasonably determined, and the learning and training effect is good. It can be seen from the learning and training process of BP neural network in MALTAB that the algorithm achieves the predetermined goal through 6 trainings, and predicts the single land area and ESV of Anhui section and Henan section of Huaihe River Basin in 2025 (Fig. 6).

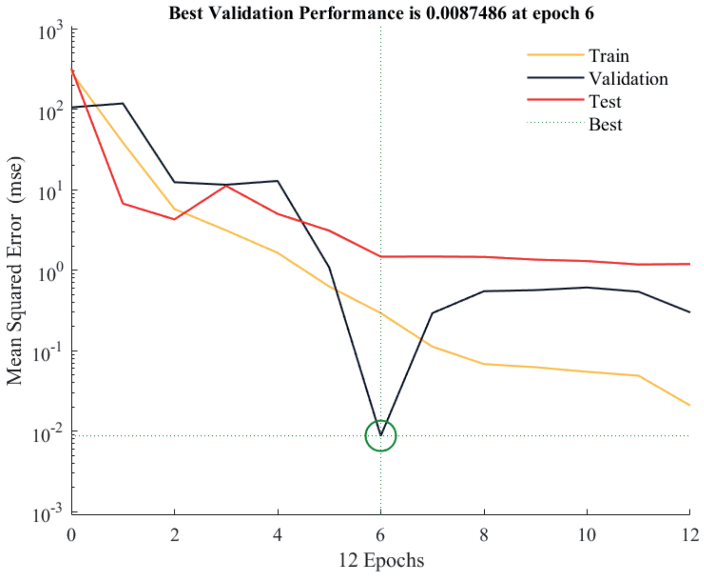

Fig. 6. GM-BP model training result diagram.

Table 6. Present situation and prediction results of the study area.

Year	Cultivated land / (hm^2)	Woodland /(hm^2)	Grass land / (hm^2)	Waters / (hm^2)	Unutilized land /(hm^2)	Construction land / (hm^2)	ESV (×10^{9}yuan)
2010	13358060	1485221	427626	455362	2088019	347	283.09
2015	12869313	1529735	424591	475463	2518636	1893	282.26
2020	11712100	1471100	555900	598900	2563000	1800	302.37
2025	10921625	1451705	677331	719014	2753989	2790	303.57

In 2025, the Anhui and Henan sections of the Huaihe River Basin are dominated by cultivated land and construction land. The proportion of cultivated land is the largest, reaching 66.09%, and the proportion of unused land is the smallest, only 0.02%. Compared with 2020, the decrease of cultivated land area in 2025 is the most obvious, which is 1.65%, and the increase of grassland and water area is the most obvious, which is 4.58 % and 4.09%. It is calculated that the ESV of Anhui section and Henan section of Huaihe River Basin in 2025 is 303.57 billion yuan. Compared with 2020, ESV will increase by 0.54% in 2025 (Table 6).

Discussion

In-depth study of ESV in Huaihe River Basin can better improve the ecological environment of the basin, identify the regional characteristics of the ecological environment of the basin, and promote the sustainable development of the ecosystem. In this paper, the overall and local ecosystem service values of Anhui section and Henan section of Huaihe River Basin are comprehensively analyzed. It can be seen that:

The change of construction land, cultivated land and water area in Anhui section and Henan section of Huaihe River Basin from 2010 to 2020 is the main influencing factor of spatial EV difference. The increase of construction land comes from the growth of population and industrial development, and the increase of water area comes from the implementation of policies such as water area protection. The reduction of forest land is relatively small, mainly due to climate change and industrial development leading to the destruction of the ecosystem. The decrease of food production is mainly due to the influence of the transfer of cultivated land area, and the continuous decrease of climate regulation is due to the decrease of forest land area.

The total area of cultivated land showed a decreasing trend, mainly due to the implementation of the ‘Grain for Green’ project, the conversion of cultivated land with poor natural conditions and low quality grades, forest land and grassland, and finally from the total area The number of cultivated land has decreased, and the overall quality grade of the actual cultivated land has increased, so the biodiversity has increased. From the changes and mutual influence of land use and ecosystem services, it can be seen that the water resources in the basin are abundant, and the increase of water area has a great impact on the ESV in the basin, thus affecting the change trend of the total ESV.

The spatial distribution of ESV in the Huaihe River Basin showed a trend of high in the southeast and low in the northwest, but both were at a low level (II), and the northwest EV was higher. The main reason is that the output value per unit area of crops in Henan Province is lower than that in Anhui Province from 2010 to 2020. The land use in the Anhui and Henan sections of the Huaihe River Basin is mostly cultivated land and construction land, and human activities are relatively strong. The ecosystem structure is affected by human disturbance, so the overall ESV is low, and it is high in the southeast and low in the northwest.

Conclusion and Suggestion

In this paper, the characteristics of land use change are studied by using Landsat remote sensing image data of Anhui and Henan sections of Huaihe River Basin in 2010,2015 and 2020. The ESV is estimated by the equivalent factor method. The spatial autocorrelation model is used to analyze the spatial distribution characteristics of ESV in each city, and the GM-BP model is used to predict the land use change in 2025. The following conclusions are drawn:

(1) From 2010 to 2020, cultivated land, construction land and forest land were dominant in the land use of Anhui section and Henan section of Huaihe River Basin. The overall change of land use was mainly manifested as the reduction of cultivated land and forest land, and the expansion of grassland, water area and construction land. During the study period, the degree of land use change changed from severe to stable, and the degree of change in Anhui section was higher than that in Henan section.

(2) The ESV in the basin is increasing year by year, and it is in the transition stage from low level (II) to medium level (III). The water area contributes greatly to the ESV in the Huaihe River Basin and the EV is the highest. Among the secondary services, the hydrological regulation ESV is the largest, the water resources supply ESV is the smallest, but the EV is the largest, and the food production EV is the smallest.

(3) The spatial distribution of ESV in Anhui section and Henan section of Huaihe River Basin generally

shows a trend of high in southeast and low in northwest. EV changes from no obvious change to increase. EV in Henan section of Huaihe River Basin is greater than that in Anhui section. ESV in the study area is significantly positively correlated in space. The degree of spatial agglomeration shows a downward trend, and the degree of heterogeneity changes little in different periods. 'Low-Low' clustering is mainly concentrated in Henan section, 'High-Highand' 'Low-High' are mainly concentrated in Anhui section.

(4) The model prediction results show that in 2025, the Anhui section and the Henan section of the Huaihe River Basin are still dominated by cultivated land, and the proportion of construction land is the smallest, but the increase is large. Compared with 2020, the ESV of Anhui section and Henan section of Huaihe River Basin will increase by 0.54 % in 2025.

Based on the above conclusions, the following suggestions are put forward for the reality and effective improvement path of Anhui section and Henan section of Huaihe River Basin:

(1) The expansion of the city makes the ecosystem service value of the Anhui and Henan sections of the Huaihe River Basin low. The government should strictly control the expansion of construction land, make high use of existing buildings, and implement intensive management of construction land.

(2) The grain output efficiency of Henan section is generally lower than that of Anhui section, which also reflects that the spatial pattern of grain production efficiency has a certain 'lock-in' effect, and it is difficult to completely reverse or change through human factors. Therefore, it is scientific to improve the efficiency of grain production according to local conditions.

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Conflict of Interest

The authors declare there is no conflict.

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