land

Article

Spatial Divergence Analysis of Ecosystem Service Value in Hilly Mountainous Areas: A Case Study of Ruijin City

Hualin Xie *, Zhenhong Zhu and Zhe Li

Institute of Ecological Civilization, Jiangxi University of Finance and Economics, Nanchang 330013, China; 2202010105@stu.jxufe.edu.cn (Z.Z.); 2202021938@stu.jxufe.edu.cn (Z.L.)
* Correspondence: xiehualin@jxufe.edu.cn; Tel.: +86-139-7912-1643

Abstract: The southern hilly mountains are rich in natural resources and are one of the important ecological security barrier zones in China. However, the disturbance of the ecosystem caused by human activities has led to a differentiated character of spatial ecosystem services. Such spatially differentiated characteristics have not been well studied, and thus are bound to limit our ability to manage ecosystems sustainably. Taking Ruijin City, a typical hilly mountainous area in southern China, as an example, this paper evaluates the ecosystem service values (ESV) of Ruijin City from 2000 to 2020 by using equivalent factor method combined with GIS technology. On this basis, spatial autocorrelation analysis is used to identify unique heterogeneous units of ESV. The results show that the overall ESV of Ruijin City from 2000 to 2020 showed a trend of slow increase in the first decade and a significant decrease in the second decade. The ESV in Ruijin City has a high degree of spatial divergence, showing the distribution characteristics of low value in the central region and high value in the marginal region. With the acceleration of urbanization, the ESV in the central region of Ruijin City decreases significantly from 2010 to 2020. Therefore, for the high value areas of ecosystem services, attention should be paid to the balanced development of economy and ecology. For low-value areas, it is necessary to strengthen the control of the ecological environment, protect sensitive areas with serious loss of ecosystem services, change the development model, and improve the supply capacity of ecological products. The government should calculate green Gross Domestic Product (GDP) based on the evaluation results of ESV, and formulate a green GDP evaluation system in the performance evaluation.

Keywords: ecosystem service values; land use; spatial divergence; equivalent factor method; GIS; spatial autocorrelation analysis

Citation: Xie, H.; Zhu, Z.; Li, Z. Spatial Divergence Analysis of Ecosystem Service Value in Hilly Mountainous Areas: A Case Study of Ruijin City. *Land* **2022**, *11*, 768. https://doi.org/10.3390/land11060768

Academic Editor: Monika Kopecká

Received: 27 April 2022
Accepted: 23 May 2022
Published: 24 May 2022

1. Introduction

Ecosystem services (ES) are life supporting goods and services that are directly or indirectly derived from the structures, processes and functions of ecosystems [1]. In 2005, the results of the United Nations Millennium Ecosystem Assessment (MA) were released, and the academic literature on ES showed an exponential growth [2–4]. ES includes provisioning services, regulating services, supporting services and cultural services. Among them, the value of regulating services, supporting services and cultural services has not been reflected in the market for a long time is often ignored when people make decisions on economic activities [5–7]. With the expansion of cities and towns and the expansion of human activities, the disturbance to ES is increasing [8,9], and the affected ecological environment is expanding year by year, which poses a serious threat to the life support system of the earth [10–12]. Costanza et al. (2014) showed that the value of global ES declined by $4.3–$20.2 trillion per year during 1997–2011 because of land use change [13]. The global natural environment is facing a crisis of ecosystem degradation and depletion of natural resources [14]. Currently, ES have received increasing attention and their valuation studies have been one of the hot spots in ecosystem sustainability research [15–18].

Ecosystem service values (ESV) assessment includes both non-monetary and monetary values [19,20]. Monetary values are better at facilitating mapping and comparing different functional services, and therefore it easier for policy makers to monitor policies around monetary values [21]. Monetary values have been widely used to characterize changes in ES in the area of ecosystem-human interactions [22]. Although the research on the ESV in China started late, and was influenced by Costanza and MA, the research on ESV in China has made great progress. Xie et al. [23] introduced the value assessment method of Costanza, referred to the indicator system of MA, and developed the equivalent factor method according to the actual situation in China. The method takes the economic value of natural crops of 1 hm^2 farmland in China as a reference, establishes the relationship between the value of agricultural products and ESV through the concept of benefit transfer, and obtains ESV indirectly as representative of land use. The equivalent factor approach is more effective in evaluating large-scale ESV as it can quickly and accurately assess the ESV and can modify the assessment system according to the ecological context and climate change in different regions [24], and is therefore widely used, for example, in global studies [1,13], South Africa [25], the Central Ethiopian Plateau [26], Nigeria [27], the Qinghai-Tibetan Plateau in China [28] and the karst areas in southwestern China [29].

In addition, the current literature rarely reflects the spatial divergence characteristics of ESV, and the inherent spatial autocorrelation of ESV is largely ignored, which fails to effectively reveal the local spatial differences in the impact of human disturbance on ES [30,31]. Getis-Ord G_i^* is a spatial statistical method used to describe and visualize the spatial distribution of ES, discover local patterns of spatial association, identify heterogeneous units and propose spatial mechanisms [32]. Compared with the traditional method of identifying process-related regions, Getis-Ord G_i^* is effective in identifying cluster-related heterogeneous units, which lays a foundation for studying the spatial divergence characteristics of ESV.

The hilly mountainous areas in southern China are rich in natural resources due to their high altitude and low human activity range. However, against the background of rapid urbanization and industrialization, the countryside has gradually failed to keep up with the pace of urban development, resulting in a high positive correlation between poverty and environment [33]. Villages in remote mountainous areas have over-utilized natural resources in pursuit of increased economic benefits, which has led to serious problems of reduced ecological benefits such as reduced vegetation, water shortage, soil erosion and decreased soil fertility [34–36]. The overexploitation of natural resources (e.g., overcultivation and deforestation) has led to serious environmental pollution problems in China's hilly mountainous regions at present. At the same time, local environmental degradation can put greater pressure on the sustainability of farmers' livelihoods, and farmers are more likely to fall into poverty traps in hilly mountainous areas. However, the emergence of ES as a bridge linking nature and society, and the valuation of ES in quantitative terms, promises to make natural capital truly productive for society [37].

The geomorphological characteristics of the Gannan region in Jiangxi Province are typical of hilly mountainous areas, which is one of the important ecological barriers in the Ganjiang River basin and is of great significance for ecological conservation [38]. Ruijin is located in the mountainous and hilly region of Gannan, with backward economic development, high vegetation cover and well maintained species diversity, and is an area rich in natural resources. For Ruijin City, which is still economically underdeveloped, green rise is the best path for development. This study quantifies the ESV in Ruijin City from 2000 to 2020, and analyzes the temporal changes and spatial divergence characteristics of ESV in order to provide scientific reference for policies related to land use and ecosystem service protection.

2. Materials and Methods

2.1. Study Area

Our study area is Ruijin City (115°42′~116°22′ E, 25°30′~26°20′ N, Figure 1) in the southeastern border of Jiangxi Province. The total land area of Ruijin City is 244,800 hm^2. Ruijin City is a typical hilly mountainous terrain with high altitude, including 187,300 hm^2 of forest and 76.5% forest coverage. Ruijin City is located at the western foot of the Wuyi Mountain Range in the eastern part of Ganzhou City and the upper reaches of the Gongshui River, the eastern source of the Ganjiang River. The good geographical location makes Ruijin City rich in natural resources with high ESV.

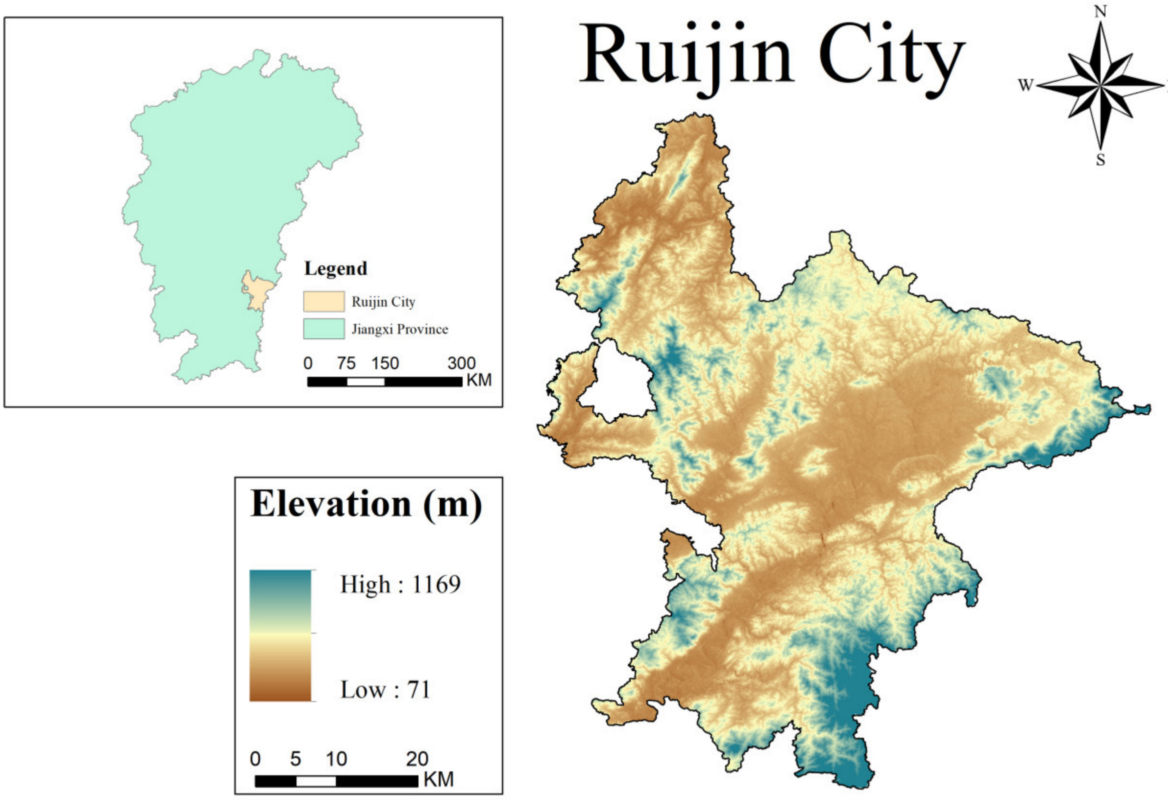

Figure 1. Study area.

2.2. Data Sources

The data sources for this study are shown in Table 1. The data used in this study include land use data, Net Primary Productivity (NPP) data, rainfall data, soil and water conservation data, food crop data and food price data. The land use data were obtained from the 30 m annual China land cover dataset (CLCD), and the NPP data were obtained from the Resource and Environment Science and Data Center of the Chinese Academy of Sciences. The above graphical data were processed with a raster size of 30 m × 30 m and projected coordinates of WGS_1984_UTM_Zone_50N. Rainfall data were obtained from the China Meteorological Science Data Center. Soil and water conservation data were obtained from the Soil and Water Conservation Bulletin. The data on planted area and production of grain crops in Ruijin City were obtained from the Ruijin City Statistical Yearbook, and the data on grain prices were taken from the 2018 China Farm Products Price Survey Yearbook.

Table 1. Data sources.

Type	Data	Data Source	Format	Year
Geographic information data	Land use data	The 30 m annual China land cover dataset (CLCD) (https://zenodo.org/record/5210928) (20 April 2022)	Raster data	2000, 2005, 2010, 2015, 2020
	NPP data	The Resources and Environmental Sciences and Data Center (https://www.resdc.cn/) (20 April 2022)	Raster data	2010
Climate data	Rainfall data	The China Meteorological Science Data Center (http://data.cma.cn/) (20 April 2022)	Numerical data	2010
Climate data	Soil and water conservation data	The Soil and Water Conservation Bulletin	Numerical data	2010
Food crops data	Planted area and production data	The Ruijin City Statistical Yearbook	Numerical data	2010
	Food price data	The 2018 China Farm Products Price Survey Yearbook	Numerical data	2010

2.3. Research Methods

The workflow of this study is divided into three steps as shown in Figure 2: first, establish the indicator system to assess the ESV in Ruijin City; second, conduct geostatistical analysis on the ESV with the help of ArcGIS to study the spatial distribution characteristics of the ESV in Ruijin City; third, conduct spatial autocorrelation analysis on the ESV to study its spatial aggregation characteristics, and here it is necessary to use the global Moran index; hot analysis and cold analysis were used here. Based on the spatial distribution characteristics and spatial aggregation characteristics of ESV in Ruijin City, we conclude with its spatial differentiation characteristics.

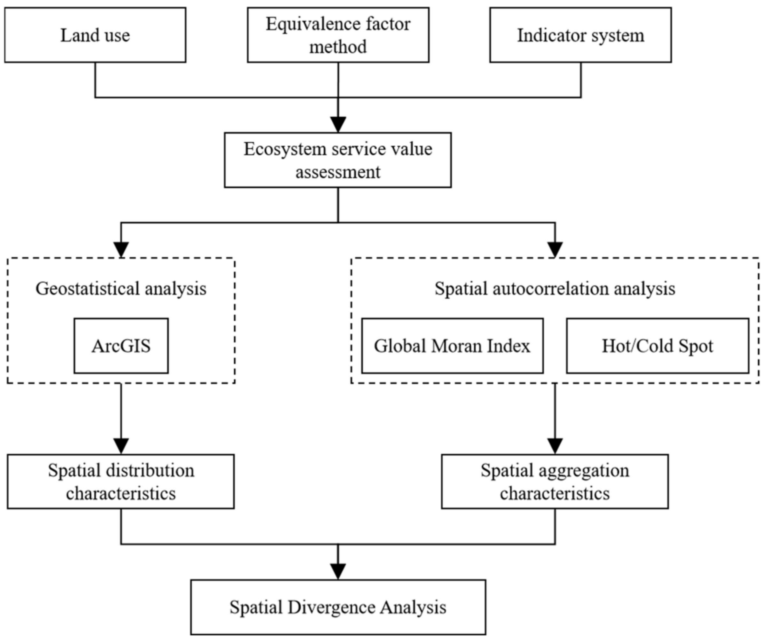

Figure 2. Workflow.

2.3.1. Ecosystem Service Value Assessment

(1) Indicator system

Our constructs the indicator system of ESV assessment based on the understanding of the connotation and definition of the concept of ES (Table 2). Firstly, according to the value attributes of ES, they are roughly divided into economic and ecological values; secondly, according to the classification method of MA, ES are classified into four major categories by service category: provisioning services, regulating services, supporting services and cultural services. Finally, they were classified into 11 indicators based on the process and functional characteristics of ecosystems [39].

Table 2. Ecosystem service values assessment indicator system.

Types	Categories	Subcategories	Symbol	Content
Economic Value	Provisioning Services (PS)	Food production	PS1	Provide food
		Raw material production	PS2	Supply of raw materials
		Good quality fresh water provision	PS3	Provide fresh water
Ecological value	Regulating Services (RS)	Purifying the environment	RS1	Absorption of pollutants
		Hydrological regulation	RS2	Water circulation
		Gas regulation	RS3	Oxygen release from solid carbon
		Climate regulation	RS4	Regulation of temperature and precipitation
	Supporting Services (SS)	Soil conservation	SS1	Accumulation of fertility
		Nutrient cycling	SS2	Accumulation of nutrients
		Biodiversity	SS3	Provide biological habitat
	Cultural Services (CS)	Landscape aesthetics	CS1	Recreation and Cultural experience

(2) The economic value of ecosystem services

With the equivalence factor method, the economic value obtained from the food production services of a 1 hm^2 cultivated land ecosystem is considered as a standard equivalent, which corresponds to an equivalence factor of 1 in the value equivalence table, while the equivalence factors of other ecological services are defined by the magnitude of their contribution relative to the standard equivalent. The calculation formula is as follows:

$$E_a = \frac{1}{7}\sum\nolimits_{i=1}^{n}\frac{m_i p_i q_i}{M} \quad (1)$$

where: E_a is the economic value of food production services of 1 hm^2 of cultivated land ecosystem (Yuan/hm^2), i.e., the economic value of one standard equivalent; i is the crop type; m_i is the planted area of the first crop (hm^2); p_i is the unit price of food for the first food crop (Yuan/ton); q_i is the yield of the first food crop (ton/hm^2); M is the total planted area of food crops (hm^2); 1/7 in the equation means that the economic value of natural food production (without human input) is 1/7 of the economic value of food production services of cultivated land [23].

Food production services refer to the three major food crops in China: rice, beans and potatoes. Rice crops in Ruijin City are dominated by rice, bean species are mainly soybeans and snap peas and the potato crops are mainly sweet potatoes. In this study, rice, soybeans, snap peas and sweet potatoes were used to calculate the economic value of one standard equivalent, taking into account the actual cultivation of food crops in Ruijin City. In order to avoid the possible influence of price fluctuations on the assessment results, all of the food crop prices in this study were based on the national average market prices of agricultural products in 2017. The economic value of one standard equivalent in Ruijin City in 2010 was obtained as 2525.37 Yuan/hm^2.

(3) Correction equivalent factor

The value equivalence table proposed by Xie et al. [39] was developed based on national data in 2010. As China is a vast country, the equivalence factors of ES are very different between the country and regions, and if the calculation is directly quoted from the national-based value equivalence table, the accuracy of the assessment results will be seriously affected. Therefore, it is necessary to revise the "Ecosystem Service Value Equivalent Table per Unit Area" with some indicators so that it can be applied to the ESV assessment in Ruijin City.

The magnitude of ESV is closely related to the natural environmental conditions of the area, and in general, the intensity of food production, raw material production, climate regulation, gas regulation, nutrient cycling, environmental purification, biodiversity and landscape aesthetics services are positively related to NPP; the intensity of hydrological regulation and good quality fresh water provision services are positively related to rainfall; and soil conservation is positively related to soil and water conservation area [40,41]. The correction factors used in this study are as follows: the NPP, the average annual rainfall and the proportion of soil and water conservation area. The calculation formula is based on the assumption that the intensity of ecological services is linearly related to natural environmental conditions, and the correction formula is as follows:

$$\begin{cases} P = N/\overline{N} \\ R = W/\overline{W} \\ S = E/\overline{E} \end{cases} \tag{2}$$

where: P is the biomass correction factor, N is the average NPP value of ecosystem in Jiangxi Province in 2010 (g C/m^2), $\overline{N}$ is the national average NPP value of ecosystem in 2010 (g C/m^2), taking the value of 1.62, R is the rainfall correction factor, W is the average annual rainfall in Ruijin City in 2010 (mm), $\overline{W}$ is the average annual rainfall in the country in 2010 (mm), and takes the value of 6.46, S is the soil conservation service correction factor, E is the proportion of soil and water conservation area in Ruijin City in 2010, $\overline{E}$ is the national average proportion of soil and water conservation area in 2010, and takes the value of 2.43. It should be noted that NPP data are difficult to obtain and not easy to calculate. In this study, we only revised the Ecosystem service values equivalent table in Ruijin City in 2010, and the equivalence factor of an area will not change significantly in a short period of time, and the table will be used in subsequent assessments. The revised "Ecosystem service values equivalent table in Ruijin City" is shown in Table 3.

Table 3. Ecosystem service values equivalent table in Ruijin City.

Land Use Type	Provisioning Services			Regulating Services				Supporting Services			Cultural Services
	PS1	PS2	PS3	RS1	RS2	RS3	RS4	SS1	SS2	SS3	CS1
Cultivated land	1.79	0.40	−8.43	1.44	0.75	0.22	9.66	1.26	0.25	0.28	0.13
Forest	0.47	1.07	2.20	3.50	10.50	3.12	30.61	6.44	0.32	3.89	1.71
Grassland	0.36	0.53	1.16	1.84	4.88	1.62	14.27	3.38	0.18	2.05	0.90
Water	1.29	0.37	53.54	1.24	3.70	8.96	660.34	2.26	0.11	4.12	3.05
Bareland	0.00	0.00	0.00	0.03	0.00	0.16	0.19	0.05	0.00	0.03	0.02

(4) Value accounting

The total ESV was calculated based on the area of each land use type and the ESV coefficients, with the following formula.

$$\text{ESV} = \sum_{i=1}^{n} VC_i \times A_i \tag{3}$$

$$VC_{ij} = E_a \times V_{ij} \tag{4}$$

where: ESV is the total ecosystem service value (Yuan); VC_i is the ecosystem service value coefficient (Yuan/hm^2); A_i is the area of ith land use type (hm^2); V_{ij} is the ecosystem service value equivalent factor, also called the base equivalent (see Table 3); i is the land use type; j is the ecological service type.

2.3.2. Spatial Autocorrelation Analysis

(1) Global spatial autocorrelation analysis

To detect the overall characteristics of the spatial distribution of ESV in Ruijin City, this paper uses the Moran index as an evaluation index for global spatial autocorrelation analysis [42,43]. We used the Spatial Autocorrelation (Morans I) tool of ArcGIS to calculate the Moran index from 2000 to 2020. The formula for calculating the Moran index is as follows:

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \overline{x})(x_j - \overline{x})}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\sum_{i=1}^{n}(x_i - \overline{x})^2} \tag{5}$$

where: n is the total number of elements; x_i, x_j are the ESV of elements i and j; w_{ij} is the row-standardized contiguity matrix; $\overline{x}$ is the average of the ESV. The Moran's Index method is a common statistical method for spatial autocorrelation statistics. Its value is between -1 and 1. Moran's $I > 0$ indicates positive spatial data correlation, and the larger the value, the stronger the spatial correlation; Moran's $I < 0$ indicates negative spatial data correlation, and the smaller the value, the larger the spatial difference; Moran's I tends to 0, then there is no global spatial autocorrelation, and the whole is randomly distributed.

To interpret the Moran's I index, a p value and a Z value are required to determine that, in general, a correlation with the spatial distribution is considered when $p < 0.05$ and the Z value exceeds a critical value of 1.96 (the threshold set by rejecting the null hypothesis.) The Z value is obtained by normalizing the Moran's I index and is calculated as follows:

$$Z = \frac{I - E(I)}{\sqrt{VAR(I)}} \tag{6}$$

where: $E(I)$ and $VAR(I)$ are the mean and standard deviation, respectively. When Z value ≥ 1.96 or ≤ -1.96 and Moran's $I \neq 0$, the distribution has global spatial autocorrelation, and vice versa, it does not have global spatial autocorrelation. The distribution is aggregated if Z value > 1.96, discrete if Z value < -1.96, and random in other cases.

(2) Hot spot analysis

Spatial autocorrelation analysis can test whether the distribution of ESV in Ruijin City is spatially aggregated, but it cannot pinpoint the places of aggregation areas, and hotspot analysis can fill this gap [44]. Getis-Ord G_i^* index can measure the degree of spatial aggregation of ESV in Ruijin City, presented as hot spot areas and cold spot areas. G_i^* is calculated as follows:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j}x_i - \overline{X}\sum_{j=1}^{n} w_{i,j}}{S\sqrt{\frac{n\sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2}{n-1}}}, \forall i \neq j \tag{7}$$

where: G_i^* denotes the degree of correlation between element i and element j; when $G_i^* > 0$ and $p < 0.05$, the area is a hot spot area, indicating a local high-value aggregation area in the area; when $G_i^* < 0$ and $p < 0.05$, the area is a cold spot area, indicating a local low-value aggregation area in the area. Since the G_i^* statistic returned by ArcGIS for each dataset is the Z value, there is no need to further calculate the Z value. For statistically significant Z values, the higher the Z value, the tighter the clustering.

3. Results

3.1. Land Use Transfer Matrix

Ruijin City has a variety of land use types, and its land use classification is helpful for land class statistics and spatial expression. In this paper, according to the Classification of Current Land Use (GB/T 21010-2017), the land use of Ruijin City is classified into six categories: cultivated land, forest, grassland, water, construction land and bareland, after merging land use types in ArcGIS. Figure 3 shows the current land use status of Ruijin City for five time periods after land class division: 2000, 2005, 2010, 2015, 2020. In order to further analyze the land use change and transfer in Ruijin City from 2000 to 2020, the land use transfer matrix of Ruijin City from 2000 to 2020 was constructed on ArcGIS, which is shown in Table 4.

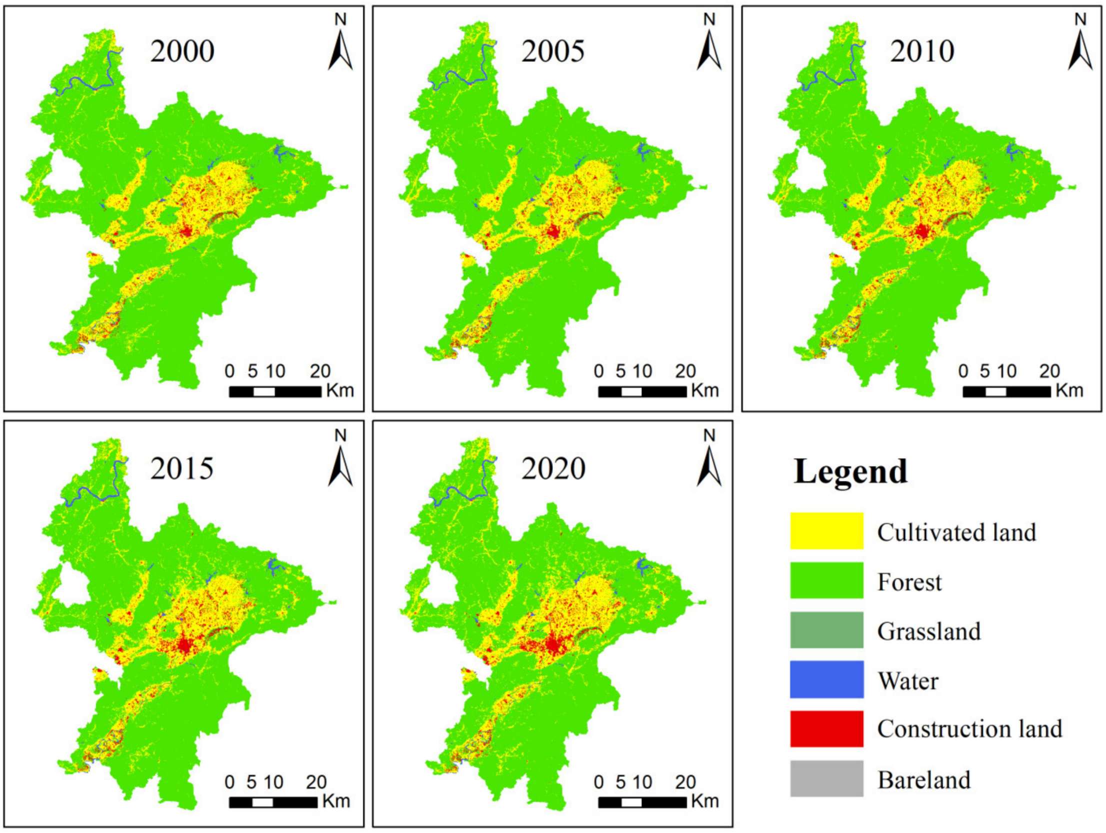

Figure 3. Status of land use in Ruijin City from 2000 to 2020.

Table 4. Ruijin City land use transfer matrix from 2000 to 2020 (Unit: hm^2).

	Cultivated Land	Forest	Grassland	Water	Construction Land	Bareland	2000
Cultivated land	34,596.16	3787.01	21.43	117.73	2781.56	0.90	41,304.78
Forest	11,939.85	181,388.10	10.52	47.68	712.35	0.36	194,098.86
Grassland	208.79	290.44	34.95	25.72	56.41	0.09	616.41
Water	145.12	112.40	0.29	1248.12	22.35	0.00	1528.29
Construction Land	507.77	129.31	0.13	68.98	5117.81	0.00	5823.99
Bareland	0.00	0.09	2.24	4.05	0.28	0.00	6.66
2020	47,397.69	185,707.35	69.57	1512.27	8690.76	1.35	243,378.99

According to the land use transfer matrix, it can be seen that in terms of transfer, cultivated land is transferred to 12,801.53 hm^2, which is the most transferred land type. This is followed by 4319.24 hm^2 of forest and 3572.95 hm^2 of construction land. Nearly half (41.11%) of Ruijin City's construction land area in 2020 comes from other land types, and the land type occupied by construction land is mainly cultivated land. In terms of conversion, 6708.62 hm^2 of cultivated land was converted to non-agricultural, accounting for 16.24% of the total cultivated land at that time; 9.17% was converted to forest and 6.73% was converted to construction land due to the policy of returning cultivated land to forest and the urbanization process, and cultivated land was under greater threat. There were also 12,710.75 hm^2 of forest converted, although these only accounted for 6.55% of the total forest area at that time and had little impact on the forest cover of Ruijin City, which was mainly converted to cultivated land, with 6.15% of forest converted to cultivated land.

Ruijin City has a large area of cultivated land, forest and construction land transferred in and out from 2000 to 2020. Specifically, the area of forest in Ruijin City decreased by 8391.51 hm^2 during 2000–2020, and the cultivated land and construction land increased by 6092.91 hm^2 and 2866.77 hm^2, respectively. This is closely related to the rapid development of Ruijin City in recent years, and the construction land mainly relies on the encroachment of cultivated land to achieve area expansion.

3.2. Ecosystem Service Values in Ruijin City

The results of the ESV assessment in Ruijin City from 2000 to 2020 are shown in Figure 4. From Figure 4, we can see that the ESV in Ruijin City increased year by year from 2000 to 2020, but after 2010, the ESV regressed significantly. The biggest reason is that with the accelerated urbanization of Ruijin City, the expansion of construction land area occupies ecological land, and the ESV decreased by 157,755.96 ten thousand Yuan during the decade of 2010–2020, and the ESV of Ruijin City in 2020 is lower than that in 2000.

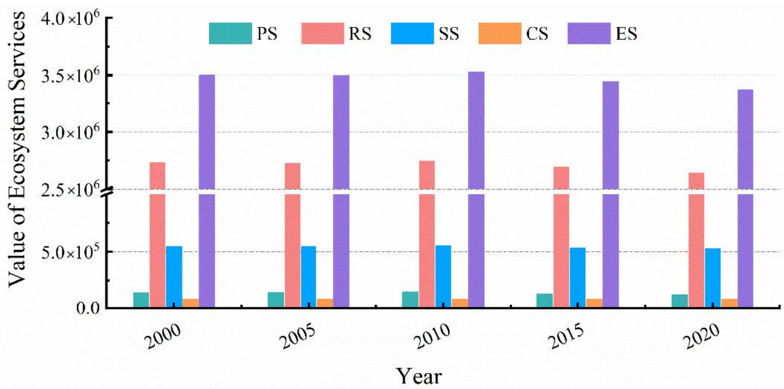

Figure 4. Ecosystem service values in Ruijin City from 2000 to 2020 (unit: ten thousand Yuan).

To study the utilization of ESV in the market, this paper distinguishes the ecological value and economic value of ES based on the principle of whether humans can directly obtain the benefits of ES. The economic value of ES contains only provisioning services, so the economic value of ES is consistent with the change in the value of provisioning services, and the economic value of ES in Ruijin City in 2020 is calculated to be 121,824.81 ten thousand Yuan, accounting for 3.62% of the total value. The ecological value of ES contains more ESV, including the value of regulating services, the value of supporting services and the value of cultural services. The ecological value of ES in Ruijin City in 2020 is calculated to be 3,247,205.31 ten thousand Yuan, accounting for 96.38% of the total value, which is about 26.65 times of the economic value. The economic value is negligible compared with the ecological value.

The comprehensive assessment shows that the total ESV in Ruijin City in 2020 is 3,369,030.12 ten thousand Yuan, and the average ESV for 1 hm^2 is 143,600 yuan. In Table 5, for different land use types, the ESV of forest is the highest, at 2,993,497.87 ten thousand Yuan, accounting for 88.85% of the total ESV; followed by watershed, accounting for 8.38% of the total value; the ESV of cultivated land and grassland is less, accounting for only

2.75% and 0.02% of the total; bare land accounts for the smallest proportion of the total value and is negligible.

Table 5. Ecosystem service values by land use type in Ruijin City in 2020 (unit: ten thousand Yuan).

Land Use Type	ESV	Percentage
Cultivated land	92,764.95	2.75%
Forest	2,993,497.87	88.85%
Grassland	547.63	0.02%
Water	282,219.51	8.38%
Bareland	0.16	0.00%
Total	3,369,030.12	100.00%

Due to the high forest cover in Ruijin City, forest covers a large area and creates a high ESV without particularly significant negative externalities; thus, forest is a high ESV land category and contributes to the ecological benefits of Ruijin City. Increasing the area of woodland will, on the one hand, improve the environment, reduce flooding and maintain soil and water; on the other hand, it will increase the species diversity in this area, thus making the ecological balance more stable. According to the principle of diminishing marginal benefits, when the expansion of forest exceeds a certain limit, the benefits generated will decrease step by step, and too much human intervention in nature may have many serious consequences. The basic national policy on nature conservation is "to give priority to natural restoration and to use natural forces to restore the ecosystem". Each ecosystem has its own unique ecological environment, and in order to maintain biological diversity, we must ensure the diversity of ecosystems.

The value of ecological services in Ruijin City in 2020 is shown in Table 6. In terms of individual ecological services, hydrological regulation services contribute the highest ESV at 1,803,611.44 ten thousand Yuan, accounting for more than half (53.54%) of the total ES. The other individual ecological services that contribute to the ESV in descending order are: climate regulation (502,904.79 ten thousand Yuan), soil conservation (318,027.26 ten thousand Yuan), biodiversity (187,394.11 ten thousand Yuan), gas regulation (181,885.14 ten thousand Yuan) and environmental purification (152,405.39 ten thousand Yuan), which constitute the bulk of the ESV. Among them, hydrological regulation, climate regulation, gas regulation and purification of the environment belong to regulating services, while soil conservation and biodiversity belong to supporting services. Food production, raw material production and good quality fresh water provision, which are provisioning services, are relatively weak.

In terms of the different ecological service categories, regulating services had the highest value of 2,640,806.77 ten thousand Yuan, accounting for 78.38% of the total ESV. For the remaining three services, the value of provisioning services accounted for 3.62% of the total value; the value of supporting services accounted for 15.54% of the total value; and the value of cultural services accounted for 2.46% of the total value. The results show that the greatest role of ES for human wellbeing lies in their regulating function, and that regulating services can improve the environment and maintain ecosystem stability, making a great contribution to the wellbeing and stability of human life.

Table 6. Value of each ecological service in Ruijin City in 2020 (unit: ten thousand Yuan).

ES	Cultivated Land	Forest	Grassland	Water	Bareland	Total	Percentage
PS1	21,425.71	22,042.05	6.32	492.66	0.00	43,966.74	1.31%
PS2	4787.87	50,180.84	9.31	141.30	0.00	55,119.32	1.64%
PS3	−100,904.32	103,175.55	20.38	20,447.15	0.00	22,738.75	0.67%
Provisioning Services	−74,690.74	175,398.43	36.02	21,081.11	0.00	121,824.81	3.62%

Table 6. *Cont.*

ES	Cultivated Land	Forest	Grassland	Water	Bareland	Total	Percentage
RS1	17,236.33	164,142.92	32.33	473.56	0.01	181,885.14	5.40%
RS2	8977.25	492,428.76	85.74	1413.05	0.00	502,904.79	14.93%
RS3	2633.33	146,321.69	28.46	3421.86	0.05	152,405.39	4.52%
RS4	115,627.02	1,435,547.08	250.71	252,186.57	0.06	1,803,611.44	53.54%
Regulating Services	144,473.92	2,238,440.44	397.24	257,495.04	0.13	2,640,806.77	78.38%
SS1	15,081.78	302,022.97	59.38	863.10	0.02	318,027.26	9.44%
SS2	2992.42	15,007.35	3.16	42.01	0.00	18,044.94	0.54%
SS3	3351.51	182,433.13	36.02	1573.45	0.01	187,394.11	5.56%
Supporting Services	21,425.71	499,463.46	98.56	2478.56	0.03	523,466.31	15.54%
Cultural Services	1556.06	80,195.54	15.81	1164.81	0.01	82,932.22	2.46%

3.3. Analysis of Spatial Distribution Characteristics

Based on the land use data of Ruijin City in 2000, 2005, 2010, 2015 and 2020, the spatialization of the ESV assessment results for these five years were analyzed using ArcGIS technology to analyze the spatial distribution characteristics and evolution, respectively. The obtained spatial distribution of ESV in Ruijin City from 2000 to 2020 is shown in Figure 5, and its distribution generally shows a general trend of low in the middle and high in the surrounding area remains unchanged during this period. The central land type in Ruijin City is mainly urban construction land and cultivated land, so the ESV is low, while forest is a high ESV land type, so the ESV around Ruijin City is shown to be higher. From 2000 to 2010 ESV in Ruijin City has changed less and is slowly increasing. However, the ESV in Ruijin City showed a significant decrease in 2015, and the area of low ESV area in the central part of Ruijin City increased significantly, which shows that with the expansion of construction land, the ecological function located in the central part of Ruijin City is degraded, and the affected area is expanding outward.

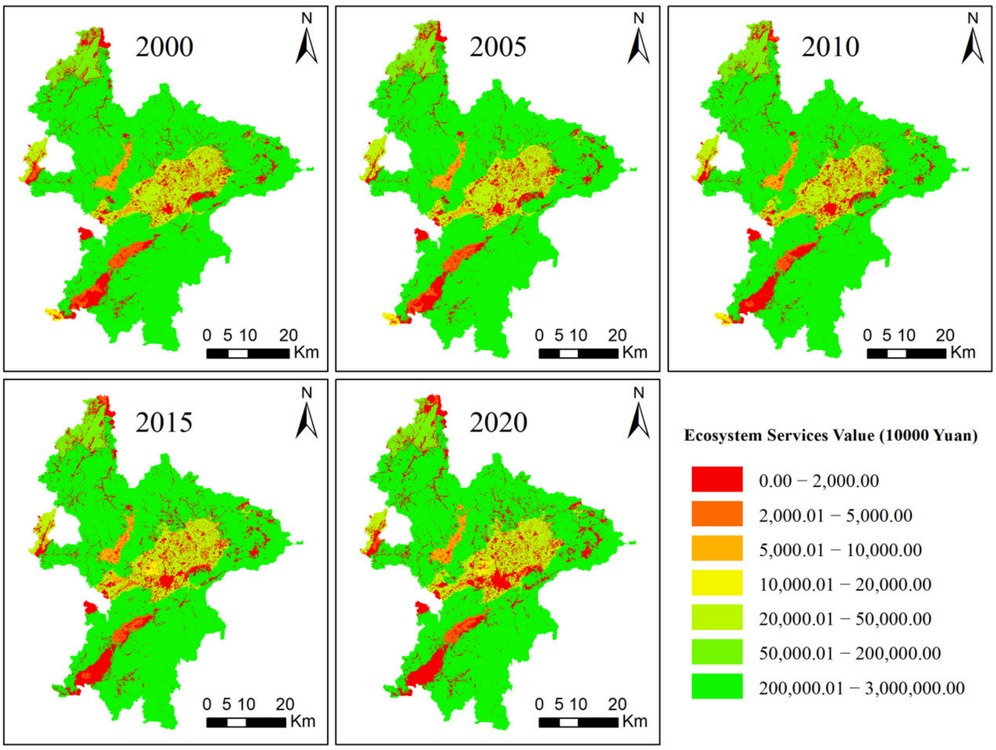

Figure 5. Spatial distribution of the ecosystem service values in Ruijin City from 2000 to 2020.

3.4. Spatial Autocorrelation Analysis

3.4.1. Global Spatial Autocorrelation Analysis

In this study, Moran's I was calculated using the Spatial Autocorrelation (Moran's I) tool of ArcGIS, and the results are shown in Table 7. since the p value < 0.01 and Z value > 2.58, it indicates that the ESV in Ruijin City from 2000 to 2020 has global spatial autocorrelation. the Moran's Indices from 2000 to 2020 are all The Moran index for 2000–2020 is greater than zero and tends to be close to 1, reflecting that the ESV in Ruijin City from 2000 to 2020 is completely positively correlated with its spatial distribution, and the spatial distribution shows an aggregated distribution, i.e., high values cluster with high values and low values cluster with low values. However, Moran's I decreased slightly from 2000 to 2020, reflecting that the correlation between the ESV and its spatial distribution in Ruijin City has weakened.

Table 7. Moran's I in Ruijin City from 2000 to 2020.

Year	Moran's I	Z value	p Value
2000	0.8599	833.5538	0.00
2005	0.8613	1368.4130	0.00
2010	0.8587	1260.3923	0.00
2015	0.8296	1217.5206	0.00
2020	0.8078	1283.3212	0.00

3.4.2. Hot Spot Analysis

In this study, the Hot Spot Analysis tool of ArcGIS was used to calculate and identify hot spot and cold spot with statistically significant ESV in Ruijin City from 2000 to 2020, see Figure 6. The high and low values in the figure are not simply scores according to the high or low level of a particular attribute of the data, but the spatial clustering of high and low values is calculated. To be a statistically significant hot spot, not only does the element itself have a high value, but it must be surrounded by other elements that also have a high value.

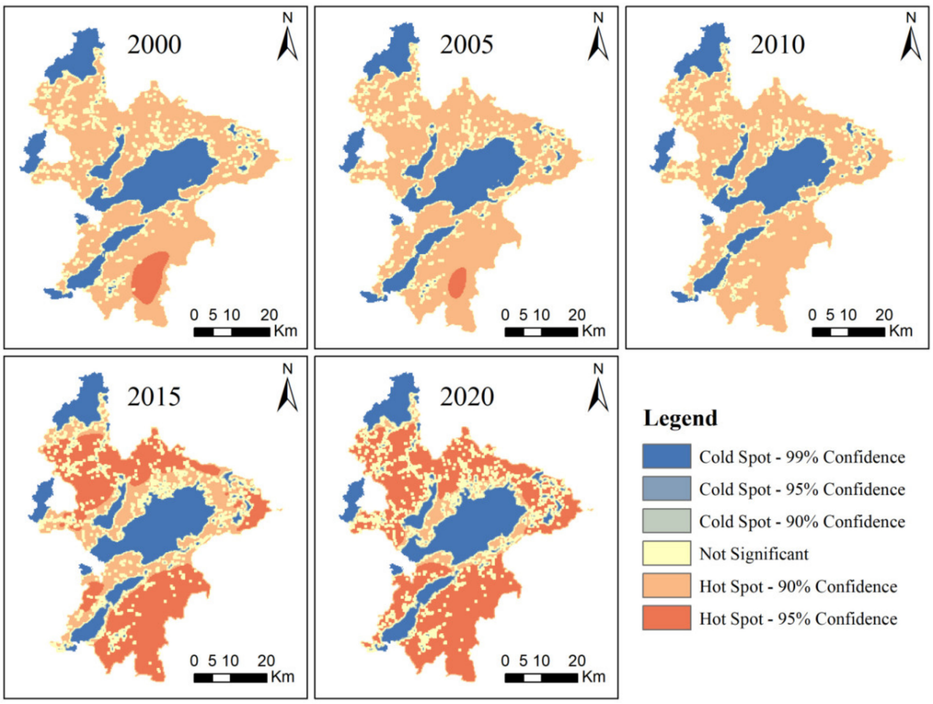

Figure 6. Cluster map of Hot/Cold Spot of ecosystem service values in Ruijin City from 2000 to 2020.

The results show that in 2000, the low-value clusters of ESV in Ruijin City were mainly in the central urban areas, and the high-value clusters were mainly in the southern areas, and most of the areas had insignificant spatial divergence, and the ESV tended to be homogeneous. In 2015, the high-value clusters of ESV in Ruijin City increased significantly, and in addition to the southern areas, some areas in the north and east also became high-value clusters. This is due to the expansion of low-value ecosystem service areas and the increase in the ESV in the surrounding areas compared to the decrease in the ESV in urban areas. In general, from 2000 to 2020, many areas in Ruijin City became low-value clusters and high-value clusters of ESV, and the distribution of large dispersal and small aggregation began to form, and the spatial heterogeneity of ESV in Ruijin City became more obvious in 2020 compared to 2000.

4. Discussions

4.1. Ecosystem Service Values and Forest Cover

In this study, we assessed changes in the ESV in Ruijin City over the past 20 years. The results of the study show that the total ESV increased between 2000 and 2010, while it decreased between 2010 and 2020. The ESV increased slightly between 2000 and 2010, thanks to the policy of returning farmland to forest, where a large amount of cultivated land was converted to forest, resulting in an increase in the value of local ecosystem services.

However, the biggest reason for the decline of EVS in Ruijin City from 2010 to 2020 is the occupation of forest by construction land and cultivated land. Various studies have also shown that loss of forest cover leads to loss of ESV [26,45]. For example, Kindu et al. [46] showed that the ESV decreased from $130.5 million in 1973 to $111.1 million in 2012 due to the loss of natural forest in the Munessa-Shashemene landscape of the Ethiopian highlands. Gashaw et al. [47] showed that between 1985 and 2015, the ESV decreased by $5.83 million due to forest loss in the Andassa watershed of the Upper Blue Nile basin in Ethiopia. Forest ES provide the highest value, and therefore the ESV is closely related to forest cover [48]. In summary, stopping land use changes and protecting ecological lands such as forest and wetlands can increase the supply of ES [49]. At present, the two Chinese ecological protection policies for forests, the Sloping Land Conservation Program (SLCP) and the Natural Forest Conservation Program (NFCP), are not popular enough in the southern hilly mountains, and local governments should introduce corresponding forest protection programs. In addition, combining with the current hotspot of ecological product value realization, market mechanisms should be introduced to solve the problem of difficult ecological product value realization, for example, by drawing on the trading of forest cover indicators in Chongqing.

4.2. Ecosystem Service Sensitivity Analysis

The equivalent factor method used in this study was derived by multiplying the area of a given land use category by the corresponding value factor. Although the revised equivalence factors better match the reality of the study area, the unpredictable, dynamic, and nonlinear nature of biological systems produces values with a high degree of uncertainty using this method [47]. Land use can be used as a proxy for ES, but the biomes used as a proxy are not always an exact match [29]. Some scholars would introduce a sensitivity index to make the results more accurate and reduce uncertainty. This index is the degree to which the value coefficient influences the ESV over time [29,45,50]. However, the results of the sensitivity analysis showed that the estimated ESV for the study landscapes were inelastic with respect to the value coefficients, and that the estimates were relatively robust despite the uncertainty in the value coefficients. Therefore, the use of the equivalent factor approach is valid for calculating the ESV over longer periods and larger scales. This point has also been highlighted in several previous studies [26,46].

4.3. Limitations

The equivalence factor method is widely used for ecosystem service valuation due to its simplicity and low data requirements, and is considered to be the most suitable method for regional ecosystem service valuation and dynamic assessment of spatial and temporal evolution analysis. However, the equivalence factor method is also controversial, and the results are not really satisfactory. One reason is that the results obtained by Xie et al. [23] through domestic experts are influenced by a strong subjective will [22]. On the other hand, the equivalence factor method was chosen as the assessment method in this study, which has the advantage of being simple and fast because the assessment mainly relies on the equivalence factor and the area of the land class, but its biggest shortcoming also lies in the fact that too few factors are considered to ensure the accuracy of the assessment. This paper does not consider enough regional characteristics, such as special crops and human landscapes in Ruijin City, so the final assessment results are lower compared with the actual ones.

In addition, most ecosystem valuation methods, including the one used in this study, can be described by a linear equation, which is the product of unit price and area, without considering consumer demand [22]. However, in economics, an increase in demand leads to a decrease in unit price. This reflects the complexity of ES and the immaturity of valuation methods, which need to continue to be improved. On the other hand, choosing a reasonable price system is still a challenge due to the lack of a well-developed market environment in China. The market price currently commonly used hardly reflects the consumer surplus in a true way, which leads to inaccurate unit value or final value assessment results. In the future, theoretical research on valuation methods should be expanded to determine the relationship between unit price, area and human demand.

4.4. Future Directions

In this study, the ESV is assessed as the value quantity assessment, while in addition to the value quantity assessment, the ecosystem service value assessment also includes the physical quality assessment and the energy value assessment. The value-volume assessment uses money as a uniform unit of measurement, which is more in line with the public's psychological judgment. However, the other two assessment methods also have their unique advantages. In the physical quality assessment, some key service functions are evaluated through a series of ecological equations, which are more complex to calculate, applicable to smaller spatial scales and can facilitate the judgment of the interactions between various ES [51–53]; energy value assessment has some application potential in solving the problem of repeated calculations in ecosystem service assessment [54–56]. Overall, ecosystem service valuation relies on theoretical research progress and technological advances in the field of ecological economy, and there is still much room for future development. In addition, there is also much room for development in the continuous dynamic assessment of ESV, and it is expected that a more complete dynamic assessment model will be established in the future to strengthen the monitoring of the dynamics of ESV and further study the spatial differentiation of ESV.

5. Conclusions

Taking Ruijin city as the case study area, this paper constructs an indicator system for assessing the ESV in hilly mountainous areas, evaluates the ESV in Ruijin city from 2000 to 2020, and explores the spatial divergence of the ESV using geostatistical analysis and spatial autocorrelation analysis. The following four conclusions were finally obtained.

(1) The ESV in Ruijin City in 2020 is 3,369,030.12 ten thousand Yuan, and the ratio of economic value to ecological value is 1:26.65, indicating that the ecological ESV is much higher than its economic value. From 2000 to 2010, the ESV in Ruijin City increased by 0.77%, while from 2010 to 2020 decreased by 4.47%. The time series shows a trend of slow increase in the first period and significant decrease in the later period, and the ESV in Ruijin City in 2020 has been lower than that in 2000.

(2) The ESV in Ruijin City from 2000 to 2020 is highly spatially heterogeneous, with obvious spatial characteristics, showing low in the middle and high around. According to Table 6, the highest ESV is forest, and the lowest is construction land and cultivated land. Therefore, the reason for the decline of ESV in Ruijin City from 2010 to 2020 is that the construction land and cultivated land occupy forest. According to the land use transfer matrix in Table 4, there is a large land use transfer of forest, arable land and construction land in Ruijin City from 2000 to 2020, the area of arable land increased by 14.75%, construction land expanded by 49.22% on the original basis, and the occupied land mainly comes from arable land and forest, and the area of forest decreased by 4.32%. 2010–2020 urbanization process in Ruijin City With the accelerated urbanization, the ESV showed a significant decline, especially in the central part of Ruijin City.

(3) This paper explores the spatial divergence of ESV, and first analyzes whether there is a spatial aggregation effect of ESV using the global Moran index. from the Moran index, the ESV in Ruijin City from 2000 to 2020 has a strong correlation with its spatial distribution, and the spatial distribution shows an aggregated distribution. The correlation between the ESV and spatial distribution from 2010 to 2020 has weakened. From the hotspot analysis, the low-value clustering area of ESV in Ruijin City in 2000 is mainly the central town area, and the high-value clustering area is mainly the southern area. By 2015, the high-value clusters of ESV in Ruijin City significantly increased, and the spatial distribution characteristics of large dispersion and small aggregation began to form. The spatial heterogeneity of ESV in Ruijin City in 2020 is more obvious compared with that in 2000.

(4) In the formulation of ecological and environmental management policies, local governments should fully consider the spatial distribution characteristics of ESV, formulate zoning control measures, and implement ecological and environmental management policies according to local conditions. For areas with high ESV, special attention should be paid to the balanced development of economy and ecology, not only to avoid possible ecological damage caused by future development, but also to consider how to transform ecological values into economic values and improve the realizability of ecological products. As for the low value areas of ESV, priority should be given to protecting sensitive areas with serious loss of ES, changing the development mode and improving the supply capacity of ecological products. Finally, a green GDP assessment system should be developed in the government performance appraisal, so as not to simply judge heroes by GDP.

Author Contributions: Z.Z., H.X. and Z.L. conceptualized the research and performed the validation. Z.Z., Z.L. administered the project, developed the methodology, curated the data, conducted the formal analysis, produced the visualizations, and wrote and prepared the original draft manuscript. Z.Z., H.X. and Z.L. reviewed and edited the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This study was supported by the National Natural Science Foundation of China (Nos. 41930757 & 41971243); the Natural Science Foundation of Jiangxi Province (No. 20202ACB203004); the Student research project of Jiangxi University of Finance and Economics (No. 20210914110004846).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The authors would like to thank the reviewers and the editor whose suggestions greatly improved the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Costanza, R.; d'Arge, R.; de Groot, R.; Farber, S.; Grasso, M.; Hannon, B.; Limburg, K.; Naeem, S.; O'Neill, R.V.; Paruelo, J.; et al. The value of the world's ecosystem services and natural capital. *Nature* **1997**, *387*, 253–260. [CrossRef]
2. Fisher, B.; Turner, R.K.; Morling, P. Defining and classifying ecosystem services for decision making. *Ecol. Econ.* **2009**, *68*, 643–653. [CrossRef]
3. Costanza, R.; de Groot, R.; Braat, L.; Kubiszewski, I.; Fioramonti, L.; Sutton, P.; Farber, S.; Grasso, M. Twenty years of ecosystem services: How far have we come and how far do we still need to go? *Ecosyst. Serv.* **2017**, *28*, 1–16. [CrossRef]
4. Schroter, M.; Bonn, A.; Klotz, S.; Seppelt, R.; Baessler, C. Ecosystem services: Understanding drivers, opportunities, and risks to move towards sustainable land management and governance. In *Atlas of Ecosystem Services*; Springer: Cham, Switzerland, 2019; pp. 401–403.
5. De Groot, R.; Brander, L.; van der Ploeg, S.; Costanza, R.; Bernard, F.; Braat, L.; Christie, M.; Crossman, N.; Ghermandi, A.; Hein, L.; et al. Global estimates of the value of ecosystems and their services in monetary units. *Ecosyst. Serv.* **2012**, *1*, 50–61. [CrossRef]
6. Scholte, S.S.M.; van Teeffelen, A.J.A.; Verburg, P.H. Integrating socio-cultural perspectives into ecosystem service valuation: A review of concepts and methods. *Ecol. Econ.* **2015**, *114*, 67–78. [CrossRef]
7. Himes, A.; Puettmann, K.; Muraca, B. Trade-offs between ecosystem services along gradients of tree species diversity and values. *Ecosyst. Serv.* **2020**, *44*, 101133. [CrossRef]
8. Sutton, P.C.; Costanza, R. Global estimates of market and non-market values derived from nighttime satellite imagery, land cover, and ecosystem service valuation. *Ecol. Econ.* **2002**, *41*, 509–527. [CrossRef]
9. Jax, K.; Barton, D.N.; Chan, K.M.; de Groot, R.; Doyle, U.; Eser, U.; Görg, C.; GómezBaggethun, E.; Griewald, Y.; Haber, W.; et al. Ecosystem services and ethics. *Ecol. Econ.* **2013**, *93*, 260–268. [CrossRef]
10. Xu, W.; Xiao, Y.; Zhang, J.; Yang, W.; Zhang, L.; Hull, V.; Wang, Z.; Zheng, H.; Liu, J.; Polasky, S.; et al. Strengthening protected areas for biodiversity and ecosystem services in China. *Proc. Natl. Acad. Sci. USA* **2017**, *114*, 1601–1606. [CrossRef]
11. Schröter, M.; Stumpf, K.H.; Loos, J.; van Oudenhoven, A.P.E.; Böhnke-Henrichs, A.; Abson, D.J. Refocusing ecosystem services towards sustainability. *Ecosyst. Serv.* **2017**, *25*, 35–43. [CrossRef]
12. Hasan, S.S.; Zhen, L.; Miah, M.G.; Ahamed, T.; Samie, A. Impact of land use change on ecosystem services: A review. *Environ. Dev.* **2020**, *34*, 100527. [CrossRef]
13. Costanza, R.; de Groot, R.; Sutton, P.; van der Ploeg, S.; Anderson, S.J.; Kubiszewski, I.; Farber, S.; Turner, R.K. Changes in the global value of ecosystem services. *Glob. Environ. Chang.* **2014**, *26*, 152–158. [CrossRef]
14. Millennium Ecosystem Assessment (MA). *Ecosystems and Human Well-Being: Current State and Trends: Synthesis*; Island Press: Washington, DC, USA, 2005; pp. 829–838.
15. Jenkins, W.A.; Murray, B.C.; Kramer, R.A.; Faulkner, S.P. Valuing ecosystem services from wetlands restoration in the Mississippi Alluvial Valley. *Ecol. Econ.* **2010**, *69*, 1051–1061. [CrossRef]
16. Pettinotti, L.; Ayala, A.D.; Ojea, E. Benefits from Water Related Ecosystem Services in Africa and Climate Change. *Ecol. Econ.* **2018**, *149*, 294–305. [CrossRef]
17. Hynes, S.; Ghermandi, A.; Norton, D.; Williams, H. Marine recreational ecosystem service value estimation: A meta-analysis with cultural considerations. *Ecosyst. Serv.* **2018**, *31*, 410–419. [CrossRef]
18. Sagie, H.; Orenstein, D.E. Benefits of Stakeholder integration in an ecosystem services assessment of Mount Carmel Biosphere Reserve, Israel. *Ecosyst. Serv.* **2022**, *53*, 101404. [CrossRef]
19. Su, S.; Li, D.; Hu, Y.N.; Xiao, R.; Zhang, Y. Spatially non-stationary response of ecosystem service value changes to urbanization in Shanghai, China. *Ecol. Indic.* **2014**, *45*, 332–339. [CrossRef]
20. Zhang, Y.; Liu, Y.F.; Zhang, Y.; Liu, Y.; Zhang, G.X.; Chen, Y.Y. On the spatial relationship between ecosystem services and urbanization: A case study in Wuhan, China. *Sci. Total Environ.* **2018**, *637–638*, 780–790. [CrossRef]
21. Greenhalgh, S.; Samarasinghe, O.; Curran-Cournane, F.; Wright, W.; Brown, P. Using ecosystem services to underpin cost–benefit analysis: Is it a way to protect finite soil resources? *Ecosyst. Serv.* **2017**, *27*, 1–14. [CrossRef]
22. Zhang, Z.; Gao, J.; Fan, X.; Lan, Y.; Zhao, M. Response of ecosystem services to socioeconomic development in the Yangtze River basin, China. *Ecol. Indic.* **2017**, *72*, 481–493. [CrossRef]
23. Xie, G.D.; Lu, C.X.; Leng, Y.F.; Zheng, D.; Li, S.C. Ecological assets valuation of the Tibetan Plateau. *J. Nat. Resour.* **2003**, *18*, 189–196.
24. Richardson, L.; Loomis, J.; Kroeger, T.; Casey, F. The role of benefit transfer in ecosystem service valuation. *Ecol. Econ.* **2015**, *115*, 51–58. [CrossRef]
25. Anderson, S.J.; Ankor, B.L.; Sutton, P.C. Ecosystem service valuations of South Africa using a variety of land cover data sources and resolutions. *Ecosyst. Serv.* **2017**, *27*, 173–178. [CrossRef]
26. Tolessa, T.; Senbeta, F.; Kidane, M. The impact of land use/land cover change on ecosystem services in the central highlands of Ethiopia. *Ecosyst. Serv.* **2017**, *23*, 47–54. [CrossRef]
27. Arowolo, A.O.; Deng, X.Z.; Olatunji, O.A.; Obayelu, A.E. Assessing changes in the value of ecosystem services in response to landuse/land-cover dynamics in Nigeria. *Sci. Total Environ.* **2018**, *636*, 597–609. [CrossRef]
28. Jiang, W.; Lu, Y.H.; Liu, Y.X.; Gao, W.W. Ecosystem service value of the Qinghai-Tibet Plateau significantly increased during 25 years. *Ecosyst. Serv.* **2020**, *44*, 101146. [CrossRef]

29. Chen, W.; Zhang, X.P.; Huang, Y.S. Spatial and temporal changes in ecosystem service values in karst areas in southwestern China based on land use changes. *Environ. Sci. Pollut. Res.* **2021**, *28*, 45724–45738. [CrossRef]
30. Li, C.; Zhao, J. Investigating the Spatiotemporally Varying Correlation between Urban Spatial Patterns and Ecosystem Services: A Case Study of Nansihu Lake Basin, China. *ISPRS Int. J. Geo-Inf.* **2019**, *8*, 346. [CrossRef]
31. Cimburova, Z.; Pont, M.B. Location matters. A systematic review of spatial contextual factors mediating ecosystem services of urban trees. *Ecosyst. Serv.* **2021**, *50*, 101296. [CrossRef]
32. Hu, X.S.; Hong, W.; Qiu, R.Z.; Hong, T.; Chen, C.; Wu, C.Z. Geographic variations of ecosystem service intensity in Fuzhou City, China. *Sci. Total Environ.* **2015**, *512–513*, 215–226. [CrossRef]
33. Wang, Y.; Zhang, Q.; Li, Q.; Wang, J.; Sannigrahi, S.; Bilsborrow, R.; Bellingrath-Kimura, S.D.; Li, J.; Song, C. Role of social networks in building household livelihood resilience under payments for ecosystem services programs in a poor rural community in China. *J. Rural Stud.* **2021**, *86*, 208–225. [CrossRef]
34. Feist, B.E.; Buhle, E.R.; Baldwin, D.H.; Spromberg, J.A.; Damm, S.E.; Davis, J.W.; Scholz, N.L. Roads to ruin: Conservation threats to a sentinel species across an urban gradient. *Ecol. Appl.* **2017**, *27*, 2382–2396. [CrossRef]
35. Peng, J.; Yang, Y.; Liu, Y.; Hu, Y.; Du, Y.; Meersmans, J.; Qiu, S. Linking ecosystem services and circuit theory to identify ecological security patterns. *Sci. Total Environ.* **2018**, *644*, 781–790. [CrossRef]
36. Zheng, H.; Wang, L.; Peng, W.; Zhang, C.; Daily, G.C. Realizing the values of natural capital for inclusive, sustainable development: Informing China's new ecological development strategy. *Proc. Natl. Acad. Sci. USA* **2019**, *116*, 8623–8628. [CrossRef]
37. Fu, B.; Yu, D. Trade-off analyses and synthetic integrated method of multiple ecosystem services. *Resour. Sci.* **2016**, *38*, 1–9.
38. Xu, N.; Guo, L.; Xue, D.; Sun, S. Land use structure and the dynamic evolution of ecosystem service value in Gannan region, China. *Acta Ecol. Sin.* **2019**, *39*, 1969–1978.
39. Xie, G.D.; Zhang, C.X.; Zhang, L.M.; Chen, W.H.; Li, S.M. Improvement of the Evaluation Method for Ecosystem Service Value Based on Per Unit Area. *J. Nat. Resour.* **2015**, *30*, 1243–1254.
40. Xie, G.D.; Zhang, C.X.; Zhen, L.; Zhang, L.M. Dynamic changes in the value of China's ecosystem services. *Ecosyst. Serv.* **2017**, *26*, 146–154. [CrossRef]
41. Wang, Y.; Pan, J.H. Building ecological security patterns based on ecosystem services value reconstruction in an arid inland basin: A case study in Ganzhou District, NW China. *J. Clean. Prod.* **2019**, *241*, 118337. [CrossRef]
42. Toledo-Gallegos, V.M.; Long, J.; Campbell, D.; Börger, T.; Hanley, N. Spatial clustering of willingness to pay for ecosystem services. *J. Agric. Econ.* **2021**, *72*, 673–697. [CrossRef]
43. Bing, Z.; Qiu, Y.; Huang, H.; Chen, T.; Zhong, W.; Jiang, H. Spatial distribution of cultural ecosystem services demand and supply in urban and suburban areas: A case study from Shanghai, China. *Ecol. Indic.* **2021**, *127*, 107720. [CrossRef]
44. Han, R.; Feng, C.C.E.; Xu, N.Y.; Guo, L. Spatial heterogeneous relationship between ecosystem services and human disturbances: A case study in Chuandong, China. *Sci. Total Environ.* **2020**, *721*, 137818. [CrossRef] [PubMed]
45. Tolessa, T.; Senbeta, F.; Abebe, T. Land use/land cover analysis and ecosystem services valuation in the central highlands of Ethiopia. *For. Trees Livelihoods* **2017**, *26*, 111–123. [CrossRef]
46. Kindu, M.; Schneider, T.; Teketay, D.; Knoke, T. Changes of ecosystem service values in response to land use/land cover dynamics in munessa–shashemene landscape of the Ethiopian highlands. *Sci. Total Environ.* **2016**, *547*, 137–147. [CrossRef]
47. Gashaw, T.; Tulu, T.; Argaw, M.; Worqlul, A.W.; Tolessa, T.; Kindu, M. Estimating the impacts of land use/land cover changes on ecosystem service values: The case of the andassa watershed in the upper blue nile basin of Ethiopia. *Ecosyst. Serv.* **2018**, *31*, 219–228. [CrossRef]
48. Liu, H.; Wu, J.; Liao, M.W. Ecosystem service trade-offs upstream and downstream of a dam: A case study of the Danjiangkou dam, China. *Arab. J. Geosci.* **2019**, *12*, 17. [CrossRef]
49. Song, X.P.; Hansen, M.C.; Stehman, S.V.; Potapov, P.V.; Tyukavina, A.; Vermote, E.F.; Townshend, J.R. Global land change from 1982 to 2016. *Nature* **2018**, *560*, 639–643. [CrossRef]
50. Aschonitis, V.G.; Gaglio, M.; Castaldelli, G.; Fano, E.A. Criticism on elasticity-sensitivity coefficient for assessing the robustness and sensitivity of ecosystem services values. *Ecosyst. Serv.* **2016**, *20*, 66–68. [CrossRef]
51. Remme, R.P.; Schroter, M.; Hein, L. Developing spatial biophysical accounting for multiple ecosystem services. *Ecosyst. Serv.* **2014**, *10*, 6–18. [CrossRef]
52. Remme, R.P.; Edens, B.; Schroter, M.; Hein, L. Monetary accounting of ecosystem services: A test case for Limburg province, the Netherlands. *Ecol. Econ.* **2015**, *112*, 116–128. [CrossRef]
53. Boithias, L.; Terrado, M.; Corominas, L.; Ziv, G.; Kumar, V.; Marques, M.; Schuhmacher, M.; Acuña, V. Analysis of the uncertainty in the monetary valuation of ecosystem services—A case study at the river basin scale. *Sci. Total Environ.* **2016**, *543*, 683–690. [CrossRef]
54. Zhan, J.Y.; Zhang, F.; Chu, X.; Liu, W.; Zhang, Y. Ecosystem services assessment based on emergy accounting in Chongming Island, Eastern China. *Ecol. Indic.* **2018**, *105*, 464–473. [CrossRef]
55. Yang, Q.; Liu, G.Y.; Giannetti, B.F.; Agostinho, F.; Almeida, C.M.V.B.; Casazza, M. Emergy-based ecosystem services valuation and classification management applied to China's grasslands. *Ecosyst. Serv.* **2020**, *42*, 101073. [CrossRef]
56. Xie, H.L.; Huang, Y.Q.; Choi, Y.; Shi, J.Y. Evaluating the the sustainable intensification of cultivated land use based on emergy analysis. *Technol. Forecast. Soc. Chang.* **2021**, *165*, 120449. [CrossRef]