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Research on the Value of Land Ecological Service in Yunnan Province Based on the Perspective of Spatial Pattern

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Abstract: (1) Background: Ecosystem service value assessment is a trending area of sustainable development research and ecological civilization construction. Ecosystems provide supply, regulation, support, and cultural services, and the value assessment of ecosystem services is helpful for people to understand the importance of natural ecosystems to production and life. Based on the insufficiency of the current research on the value of land ecological services, this paper discusses the research direction of the evaluation of the value of ecosystem services in the future, provides a reference for the evaluation of the value of ecosystem services, and promotes multi-scale and multi-directional research experiments on the value of land ecological services. (2) In this paper, the basic information data are obtained through the interpretation of remote sensing images, and the value equivalent factor is corrected according to the average grain yield per unit area and grain price data in 2000, 2010, and 2020 to calculate the land ecological service value. The relevant data obtained by processing the ecological service value are classified into different levels to discuss the changes and trends of 129 county-level administrative units in three periods and analyze the quantitative and spatial variation characteristics of the ecological service value of 129 county-level administrative units. The paper studies the spatial agglomeration state of the total value of ecological services and finds the hotspot areas of the land ecological service value in the study area. (3) During the study period, great changes have taken place in the land use pattern of Yunnan Province, with the area of construction land expanding and the area of wetland decreasing. The ecological service value level of 129 county-level administrative units is relatively stable. The total value of each service is ranked as soil formation and protection > gas regulation > water conservation > biodiversity protection > climate regulation > raw materials > waste treatment > entertainment culture > food production. In the three periods, Shangri-La City has the highest value of ecological services per unit of land and Wuhua District has the lowest. The value of ecological services per unit of land in 129 county-level administrative units continues to rise. The areas with high average values are mainly in western Yunnan, southwestern Yunnan, southern Yunnan, and southeastern Yunnan. (4) The development speed of land ecological service value in Yunnan Province is far less than the development speed of GDP. There is still a lot of room for the development of ecological service value in Yunnan Province. The economic influence of Kunming is radiating to various cities through expressways and high-speed railways. The spatial distribution of land ecological service value in Yunnan Province has a strong correlation, showing a pattern of spatial agglomeration distribution, and the clustered areas are very stable.

Keywords: land use; land ecological service value; spatial pattern; Yunnan Province

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1. Introduction

The ecosystem is the foundation of human survival and development, and it continuously provides ecosystem products and services to human beings. It is an irreplaceable natural resource and natural asset. The decline of biodiversity and the degradation of ecosystem services is one of the major environmental crises facing the world today. Ecosystem services have extremely high or even immeasurable value and are extremely closely related to human well-being [1]. From an ecological point of view, the land itself is an ecosystem, which can be called a land ecosystem [2]. As the carrier of natural resources, the spatial pattern and utilization of land have an impact on natural resources, which in turn has an impact on the value of ecosystem services. Research on ecosystem services can be carried out from multiple perspectives, such as land use change, classification of ecosystem services, and measurement of ecosystem service values. The change of ecosystem service value is directly or indirectly related to the sustainable development of regional society. Therefore, the valuation of ecosystem services has become an urgent need for ecological civilization construction and sustainable economic and social development. In 1970, SCEP assessed the impact of human activities on the global ecological environment and proposed the concept of ecosystems providing services to human beings. In 1997, Costanza et al. [3] first evaluated the value of global ecosystem services, which gradually became a research hotspot. In addition to the research on the regional land ecological service value based on land use change [4–10], domestic scholars also conduct single land type service value of ecosystem service value [11–15], ecological service driving force [16–18], ecological risk [19–24], ecological service trade-off synergy [25,26], and other aspects. In recent years, with the maturity and application of spatial prediction models, many scholars have made scenario predictions of land ecological service value based on land benefit simulation [27–44]. During this period, the service classification of ecological service value [45], the ecosystem evaluation index system [46,47] and evaluation methods have been enriched and improved. The exploration of ecosystem service value and the research on the interaction of human production and life are in their infancy, and the valuation of ecosystem services is still in the exploratory stage. The valuation of ecosystem services should focus on in-depth integration with social sciences in future research and explore the interaction between changes in ecosystem service value and human survival and development, social economy, and other human activities.

Yunnan Province has been in a stage of rapid development since 2000; especially after 2010, Yunnan has developed rapidly in other aspects such as economy, education, medical care, and urban development. These activities significantly affect the structure and function of land use, which will seriously damage and threaten the ecological environment, affecting the stability and service value of the ecosystem. Based on this, on the basis of sorting out related research, this paper takes Yunnan Province as the research area and 129 county-level administrative divisions as the research unit to correct the economic value of the equivalent factor in Yunnan Province and measure the value of land ecological services. Refining the research on ecological service value in the province to the acquisition and analysis of county-level data can more accurately analyze the spatial differences in the value of land ecological services in the study area [48], in order to provide ecological protection and rational utilization of land resources in Yunnan Province.

2. Overview of Study Area

Yunnan Province is located in the southwestern border of China, with a geographical location 97°31′–106°11′ east longitude and 21°8′–29°15′ north latitude. It has jurisdiction over 8 prefecture-level cities and 8 autonomous prefectures. Yunnan is a mountainous plateau terrain, and the area of mountains and plateaus accounts for 94% of the total area of the province. There are 3 climate zones that range from cold to sub-tropical. By the end of 2020, the province had a total population of 47.22 million and a regional GDP of 2452.19 billion yuan. Gaodi Xie pointed out in “The Value of Ecosystem Services in China” that in 2010, the value of ecosystem services in Yunnan Province ranked first in the country, accounting for 8.80% [1]. In recent years, Yunnan has been in the process of urbanization and the westward transfer of China’s industrial belt. The construction of industries and infrastructure has changed the original ecosystem structure and function of Yunnan Province to a certain extent. In addition, the ecological protection measures have not been effectively implemented. As a result, a series of ecological and environmental problems have arisen.

3. Materials and Methods

3.1. Data Source and Processing

The basic data used in the research are the Landsat5 TM and Landsat8 OLI remote sensing image data of Yunnan Province in 2000, 2010, and 2020, with a spatial resolution of 30 m × 30 m, from the Geospatial Data Cloud platform (http://www.gscloud.cn, accessed on 1 October 2021). Combined with the ecosystem service land classification system as defined by Gaodi Xie and the land use/cover characteristics of the study area, the land use types in the study area were divided into seven categories: cultivated land, forest land, grassland, water area, wetland, unused land, and construction land. The field ridge coefficients of 129 county-level administrative units were revised for the cultivated land area from 2000 to 2020, and the data table of land use structure in different years was summarized (Table 1).

Table 1. Land use in Yunnan Province from 2000 to 2020 (km^2).

Year	Cultivated Land	Woodland	Grass Land	Waters	Wetland	Construction Land	Unused Land
2000	64,892.71	271,133.60	29,367.24	2049.69	385.12	491.18	16,025.29
2010	64,768.82	273,597.13	27,091.23	2107.50	227.89	913.94	15,638.34
2020	68,744.94	273,471.99	22,285.81	2422.08	198.98	1325.40	15,895.64

The remote sensing images of the three periods are preprocessed. The steps are opening data, radiometric calibration, atmospheric correction, image mosaicking, geometric correction, and administrative area cropping. After preprocessing, the step is to select the sample points of each land use type as the area of interest, establish interpretation signs, and finally carry out supervised classification. After the classification results are exported, the accuracy is verified, and the land types with obvious judgment errors are modified at the same time. The Kappa coefficients of land use interpretation in 2000, 2010, and 2020 were 78.3%, 81.1%, and 80.3%, respectively. The interpretation results meet the accuracy requirements and are used for subsequent research on the value of land ecological services. The socio-economic, grain output, sown area, and grain price data used in the study came from the Yunnan Statistical Yearbook (2001–2021) and the China Agricultural Product Price Survey Yearbook (2021).

3.2. Research Method

3.2.1. Accounting Method of Land Ecological Service Value

According to the different accounting units of land ecological service value, it can be divided into the ecological service product price method and the value equivalent factor method. The data required by the ecological service product price method is complex, the amount of data collection is large, it takes a long time, and there are many evaluation and calculation steps. The evaluation results are easily affected by the selected evaluation method, but the obtained value evaluation results are highly accurate. The value equivalent factor method requires land use data as the basic data, and then corrects the equivalent factor. The estimation method is simple to operate and requires a single type of data. It is suitable for use in larger spatial scale research and can be widely used. Considering the complex and diverse characteristics of the land ecosystem in Yunnan Province, the study takes 129 county-level administrative units as the research unit, and the data types required for the estimation of the ecological service product price method are complex, data acquisition is difficult, and there is no unified estimation method and parameter standard. This paper chooses to use the equivalent factor method to measure the value of land ecological services in Yunnan Province. In this paper, the economic value of a land ecological service value equivalent factor proposed by Gaodi Xie [4] is 1/7 of the average grain market value per unit area in the study area. The equivalent factors in 2000, 2010, and 2020 are 61,960.24 yuan/km^2, 137,565.86 yuan/km^2, and 187,659.74 yuan/km^2, assuming that the ecological service value of the construction land is 0, and other land use types are the same as the ecosystems in the "Equivalence table of ecological service value per unit area of terrestrial ecosystems in China" proposed by Gaodi Xie [4], one-to-one correspondence, directly assigning equivalent values to land use types, and finally obtaining the land ecological service value coefficients in Yunnan Province in 2000, 2010, and 2020 (Table 2).

Table 2. ESV coefficient per unit area of Yunnan Province from 2000 to 2020 (yuan/km^2).

Year	Cultivated Land	Woodland	Grass Land	Waters	Unused Land	Wetland
2000	428,145.23	1,353,831.14	448,592.10	2,848,312.02	26,023.30	3,885,526.36
2010	950,580.12	3,005,814.13	995,976.86	6,323,902.77	57,777.66	8,626,755.34
2020	1,296,728.82	4,100,365.36	1,358,656.53	8,626,718.33	78,817.09	11,768,142.40

The annual land ecological service value in Yunnan Province was calculated by the following formula.

$$ESV_{\mathrm{f}} = \sum (A_{\mathrm{k}} \times VC_{\mathrm{fk}}) \quad (1)$$

$$ESV = \sum_{k=1}^{n} (A_{\mathrm{k}} \times VC_{\mathrm{k}}) \quad (2)$$

In the above formula: ESV_{f} is the f service function value of the ecosystem; VC_{fk} is the f service function value coefficient of land use type k; ESV is the total value of ecosystem services; A_{k} is the area of land use type k.

3.2.2. Land Use Dynamic Degree

The dynamic degree of land use is the speed of land use change. The calculation formula of dynamic degree of land use is:

$$K_i = \frac{S_{it2} - S_{it1}}{S_{it1}} \times \frac{1}{t_2 - t_1} \times 100\% \quad (3)$$

In the formula, K_i is the dynamic degree of land type i from time t_1 to t_2, the K_i greater the number, the greater the amount of this type of land converted into other types of land; s_{it1} and s_{it2} represent the land use area of land type i in t_1 and t_2, respectively.

3.2.3. Spatial Autocorrelation Analysis

As a phenomenon of human–land relationship, land ecological service affects each other between different spatial units within a geographical scope. The aggregation and discrete distribution of land ecological services in the study area can be understood by analyzing their spatial correlations. Spatial autocorrelation is divided into global autocorrelation and local autocorrelation, which are generally reflected by Moran's I index and LISA graph. The calculation formulas are:

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

$$I_i = \frac{n(x_i - \overline{x}) \sum_i w_{ij} (x_j - \overline{x})}{\sum_i (x_i - \overline{x})^2} \quad (5)$$

where I is the global Moran index; I_i is the local Moran index; n is the number of spatial units; x_i and x_j are the observed values of units i and i; W_{ij} is the spatial weight matrix; $\overline{x}$ is the average value of x_i.

3.2.4. Hot Spot Analysis

The LISA map can show the level of local observations, and the hot spot analysis can show the spatial aggregation of high and low values. The calculation formula is:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j}x_j - \overline{X}\sum_{j=1}^{n} w_{i,j}}{S\sqrt{\frac{\left[n\sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2\right]}{n-1}}} \quad (6)$$

In the formula, G_i^* is the z score; x_j is the observed value of unit j; $w_{i,j}$ is the spatial weight of unit i and j; n is the number of spatial units.

4. Results

4.1. Speed of Land Use Change

Based on the summary of the land use situation in Yunnan Province from 2000 to 2020, Table 1, the data were calculated by a single land use dynamic degree to obtain the land use dynamic degree results (Table 3).

Table 3. Dynamic degree of single land use in Yunnan Province from 2000 to 2020.

Land Use Type	Single Land Use Dynamics		
	2000–2010	2010–2020	2000–2020
Cultivated land	−0.019%	0.614%	0.297%
Woodland	0.091%	−0.005%	0.043%
Grass land	−0.775%	−1.774%	−1.206%
Waters	0.282%	1.493%	0.908%
Wetland	−4.083%	−1.269%	−2.417%
Construction land	8.607%	4.502%	8.492%
Unused land	−0.241%	0.165%	−0.040%

During the whole study period, the dynamic degree of construction land is the largest, and the dynamic degree is 8.607%, 4.502%, and 8.492% respectively. This shows that the area of construction land in Yunnan Province has increased sharply in the past 20 years. During the study period, the area of grasslands and wetlands in Yunnan Province has been greatly and continuously reduced, and the dynamic degrees of the whole study period were −1.206% and −2.417%, respectively. The grasslands and wetlands were obviously occupied by other land use types. The total area of woodland and unused land is very stable, with the slowest rate of change among all land types, with a dynamic degree of 0.043% and −0.040%, respectively. The area of cultivated land and unused land decreased in different degrees in the first 10 years of the study period and increased in the 10 years after the study period. During the study period, the area of cultivated land did not change much, and the dynamic degree was 0.297%. The area of water area and construction land showed an increasing trend during the study period, but the increase rate of water area was slow, and the dynamic degree was 0.908%. During the study period, the change rate of land use types in Yunnan Province was in the order of construction land > wetland > grassland > water area > cultivated land > forest land > unused land. On the whole, Yunnan Province has undergone great changes in the land use structure and spatial layout from 2000 to 2020, and the urbanization rate is very fast.

4.2. Spatial Pattern of Land Ecological Service Value

After the economic value correction, the equivalent factors of Yunnan Province in 2000, 2010, and 2020 were 61,960.24 yuan/km^2, 137,565.86 yuan/km^2, and 187,659.74 yuan/km^2, respectively, with a ratio of 1:2.22:3.03. The size of the equivalent factor is related to the grain yield in the study area. It is related to price. In 2010, the price of food doubled compared with that in 2000. In 2020, the price of food in 2020 will increase significantly based on that in 2010. During the research period, various technologies and equipment applied to agricultural production became more and more mature, resulting in the equivalent factor in 2010 being 2.22 times the equivalent factor in 2000. The equivalent factor in 2020 is 1.36 times that of 2010. Compared with the first ten years of the research period, the increasing trend of the equivalent factor has slowed down. This shows that the economic and social development level of Yunnan Province was low in 2000, and the economy of Yunnan Province experienced explosive growth from 2000 to 2010. After Yunnan Province had a relatively large economy in 2010, the economic development of Yunnan Province was relatively slow from 2010 to 2020. This can be confirmed from the GDP data of Yunnan Province. This shows that the ecological service value of a region can indirectly reflect the economic development stage of the region. The average land ecological service value of the statistical unit can explore the growth trend and magnitude of the overall land ecological service value, calculate the ratio of the land ecological service value to the GDP, and compare the two ratios to explore the development space of ESV and the development degree of Yunnan Province.

4.2.1. Spatial Pattern of Total Land Ecological Services

Through the equivalent factor method and the collection of GDP data of 129 county-level administrative units in Yunnan from 2000 to 2020, the total value of various services in Yunnan in 2000, 2010, and 2020 was 415.778 billion yuan, 927.129 billion yuan, and 1265.246 billion yuan, respectively. The ratio is 1:2.23:3.04, which is close to the ratio of the equivalent factor. In the process of rapid urbanization in Yunnan Province, the construction land has increased sharply, but the ratio of land ecological service value in 2010 and 2020 has had a small increase compared with the ratio of the equivalent factor. Combining Tables 1 and 2, it shows that during the study period, in the net inflow and outflow of land use types in Yunnan Province, a lot of unused land and grassland were changed to forest land and water area. From the perspective of the three periods alone, the smallest service value of each service type is food production, and the largest is soil formation and protection. Ranking the value proportions provided by each service type in the three periods, the results are all soil formation and protection > gas regulation > water source conservation > biodiversity conservation > climate regulation > raw materials > waste treatment > entertainment culture > food production. This shows that the service value provided by each service type is relatively stable. From the perspective of the development trend of various service types, the service value of entertainment culture and water conservation is on the rise, which shows that people's awareness of ecological protection is increasing, and the increase in water area provides important support for the overall ecological service value in the study area; the service value of climate regulation and soil formation and protection is on the downward trend, and the reduction of wetland and grassland area indirectly affected the functions of climate regulation and soil formation and protection; the service value of food production, raw materials, and waste treatment has fluctuated and increased. Food production affects thousands of households. The changing trend of food production requires special attention to ensure the food security of the country; biodiversity protection and gas regulation have fluctuated and decreased. The wetland area has decreased, the ability of climate regulation and gas regulation in Yunnan Province has declined, and biodiversity has also declined. In recent years, extreme weather in Yunnan Province has increased, and climate change has become apparent. Based on the above analysis, this paper calls on the government to pay attention to the changes in ecological service value, and on the premise of ensuring food security, implement policies such as returning farmland to lakes and forests, and promote cultivated land to forest land, wetlands, and other land use types with high ecological service value conversion, which will play a positive role in enhancing the value of ecological services in Yunnan Province. (Table 4).

Table 4. Value of individual ecological services in Yunnan Province from 2000 to 2020 (10^8 yuan).

Service Type	2000		2010		2020	
	Value	Proportion	Value	Proportion	Value	Proportion
Food production	62.76	1.51%	138.52	1.49%	193.74	1.53%
Raw materials	441.75	10.62%	989.40	10.67%	1349.38	10.66%
Gas regulation	623.07	14.99%	1392.25	15.02%	1894.82	14.98%
Climate regulation	510.41	12.28%	1135.75	12.25%	1546.56	12.22%
Water conservation	606.14	14.58%	1352.27	14.59%	1852.41	14.64%
Waste disposal	337.38	8.11%	746.62	8.05%	1028.36	8.13%
Soil formation and protection	749.99	18.04%	1671.62	18.03%	2272.65	17.96%
Biodiversity conservation	603.18	14.51%	1346.19	14.52%	1832.60	14.48%
Entertainment culture	223.10	5.37%	498.68	5.38%	681.95	5.39%
Total	4157.78	100%	9271.29	100%	12,652.46	100%

This paper calculates the land ecological service value of 129 county-level administrative units in Yunnan Province in 2000, 2010, and 2020. According to the value estimation results, it can be found that the land ecological service values in the three periods are mainly concentrated in five different value ranges. In this paper, the value equivalents of the three periods are revised, and the differences in the value of land ecological services in the three periods are relatively large. Therefore, this paper studies the relative level of land ecological service value in the same period. The natural discontinuity method can reduce the differences within the same class and maximize the differences between different classes. Considering that the ecological service value of Yunnan Province ranked first in the country in 2010 [1], in order to show the level of ESV in space, with the help of the GIS platform natural discontinuity classification method (Jenks), we divided the total value of land ecological services into 5 grades: low, relatively low, medium, relatively high, and high (Figure 1).

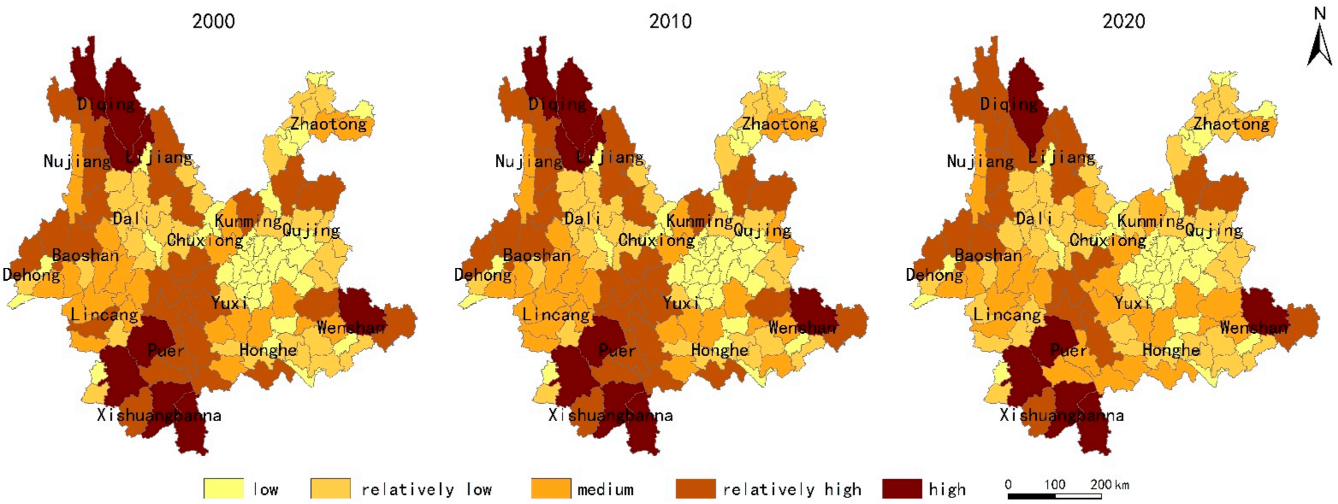

Figure 1. Spatial distribution pattern of total land ecological service value in Yunnan Province from 2000 to 2020.

In 2000, 2010, and 2020, the lowest total service value was 328 million yuan, 754 million yuan, and 1.043 billion yuan in Wuhua District, Kunming City, and the highest was 13.50 billion yuan, 29.255 billion yuan, and 39.992 billion yuan in Shangri-La, Diqing Prefecture. It can be seen from the figure that during the study period, the total ESV of 129 county-level administrative units did not increase or decrease continuously and across levels, and the level in 2020 did not increase compared with the level in 2000.

The total ESV level of 20 county-level administrative units changed during the study period. Among them, Fuyuan County in Qujing City and Maguan County in Wenshan Prefecture showed lower-medium-lower changes in the total ESV level, indicating that these two counties paid more attention to ecological construction in the first 10 years of the study period, and in the latter 10 years, urban development and land use changes have brought the total ESV rating down to the initial rating. The total ESV level of Gengma County, Lincang City changed from high to medium to medium, indicating that the pursuit of economic and social development during the study period did not pay enough attention to ecological construction. The total ESV level of 17 county-level administrative units in 2010 was the same as the total ESV level in 2000, but the total ESV level dropped by one level in 2020. In 2010, Yunnan Province experienced rapid economic development and rapid urban development and construction. In addition, the government's weak ecological awareness makes these cities' ecological civilization construction investment and protection planning lag behind the urban development process. The 17 county-level administrative units include Luquan County in Kunming City, Yulong County in Lijiang City, Deqin County in Diqing Prefecture, Qiubei County in Wenshan Prefecture, Jinping County, Honghe Prefecture, Chuxiong Prefecture (Dayao County, Shuangbai County, Wuding County), Yuxi City (Xinping County, Yuanjiang County), Pu'er City (Simao District, Ning'er County, Jiangcheng County), Lincang City (Linping County, Yuanjiang County) Xiang District, Zhenkang County, Cangyuan County).

Excluding the 20 counties and districts mentioned above, the total ESV level of the remaining 109 county-level administrative units in Yunnan Province did not change from 2000 to 2020, and the construction and protection of ecological civilization was at the mainstream level in Yunnan Province.

4.2.2. Spatial Pattern of Average Ecological Service Value per Unit of Land

Statistics show that the average ecological service value per unit area of land in Yunnan Province in 2000, 2010, and 2020 was 1,081,800 yuan/km^2, 2,412,200 yuan/km^2, and 3,292,000 yuan/km^2, respectively. The highest average ecological service value per unit of land in 2000, 2010 and 2020 was 1,305,000 yuan/km^2, 2,899,000 yuan/km^2, and 3,921,600 yuan/km^2 in Mengla County, Xishuangbanna, and the lowest was Ludian County, Zhaotong City. 680,200 yuan/km^2, Ludian County, Zhaotong City, 2,505,900 yuan/km^2, and Luliang County, Qujing City, 2,127,900 yuan/km^2. Considering the uniform distribution of the average ecological service value per unit of land, the average ecological service value per unit of land in the three periods was classified as 200,000 yuan/km^2, 350,000 yuan/km^2, and 500,000 yuan/km^2, respectively. The intervals were divided into four groups (Figure 2).

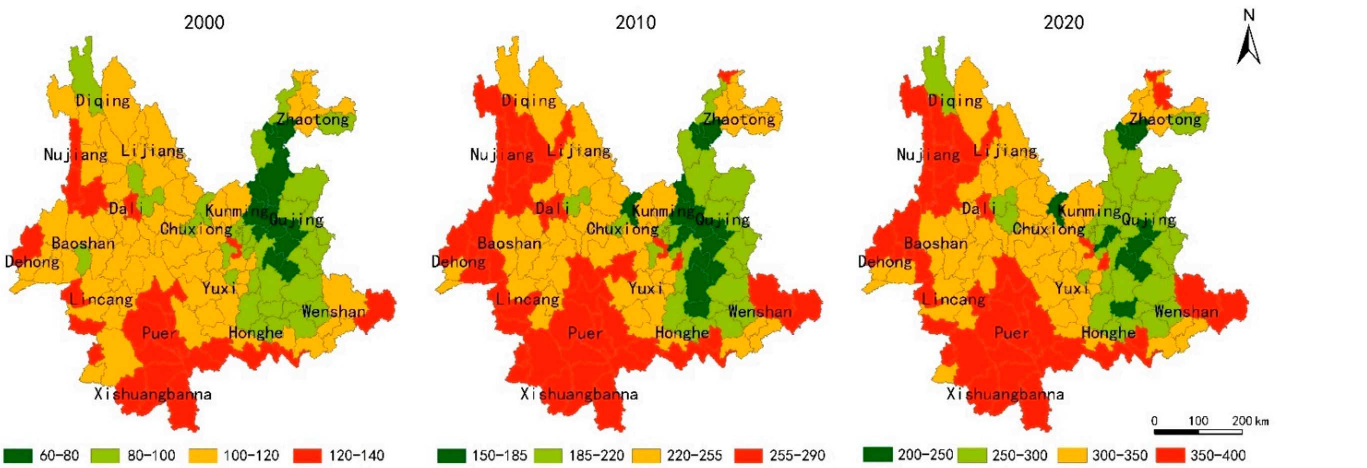

Figure 2. Spatial pattern of average ecological service value per unit of land in Yunnan Province from 2000 to 2020.

Although the values of the four groups are different, the average ecological service value per unit of land in each year is calculated based on the equivalent factor of the year, and is divided into four groups on average. The category interval corresponding to the service value is at the same level. Comparing the number of county-level administrative units with the average ecological service value of land in the four groups in 2000, 2010, and 2020, it can be seen that the lowest-level county-level administrative unit with the average ecological service value of unit land is decreasing, mainly in central Yunnan and Yunnan. Northeast and southern Yunnan gradually showed a discrete distribution state. Comparing the average ecological service value per unit of land in 2000 and 2010, it can be seen that there were many changes in the value level. Nearly one-third of county-level administrative units rose to the fourth tier in 2010. Comparing the average ecological service value per unit of land in 2010 and 2020, it is found that the number of changes in the value level is relatively small. The highest average ecological service value per unit of land is mainly distributed in western Yunnan, southwestern Yunnan, southern Yunnan, and southeastern Yunnan.

4.2.3. Spatial Distribution Pattern of the Ratio of Land Ecological Service Value to GDP

Statistics show that in 2000, 2010, and 2020, the ratio of the total value of land ecological services in Yunnan Province to the GDP of Yunnan Province was 2.54, 1.26, and 0.52, respectively. The ratio of the global ecological service value calculated by Costanza in 1997 to the GDP of that year was 1.8 [2], and the ratio of the total ESV value to GDP in Yunnan Province in 2000 was 2.54, which was significantly higher than the global average. In 2010 and 2020, the ratio of ESV to GDP in Yunnan Province gradually decreased, which indicates that the growth rate of GDP in Yunnan Province was higher than that of the land ecological service value in Yunnan Province. In 2000, the economic development level of Yunnan Province was not high. The annual ratio shows that there is still a lot of room for growth in the value of land ecological services in Yunnan Province. After calculation, the largest ratios in 2000, 2010, and 2020 were 67.55 in Deqin County, Diqing Prefecture, 29.78 in Gongshan County, Nujiang Prefecture, and 8.48 in Gongshan County, Nujiang Prefecture. The smallest ratios in the three periods is 0.04 in Hongta District, Yuxi City, 0.01 in Wuhua District, Kunming City, and 0.01 in Wuhua District, Kunming City. Considering that the ratios are mostly concentrated within 10, in order to better reflect the quantitative relationship between the land ecological service value and GDP, this paper uses 1 and 10 as the dividing points to divide the ratios into three categories: high, medium, and low (Figure 3).

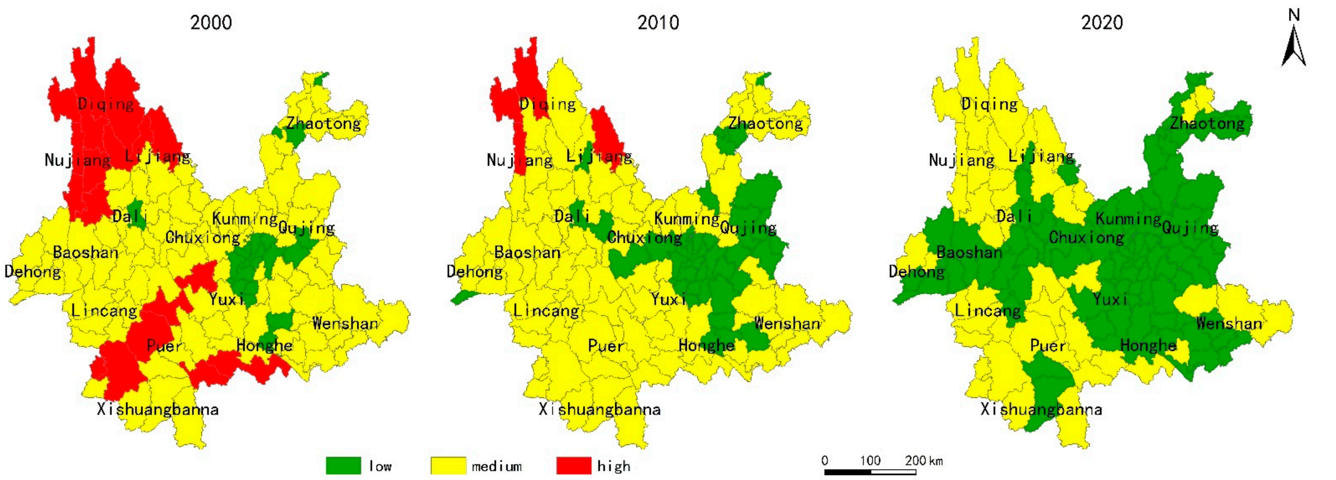

Figure 3. Spatial distribution pattern of ESV/GDP in Yunnan Province from 2000 to 2020.

It can be seen from the figure that the 2020 ratio has no high ratio area. Because the growth rate of land ecological service value in Yunnan Province is not as fast as that of GDP, the overall ratio decreases. In 2000, there were 18 high-value areas, which were distributed in Nujiang Prefecture, Diqing Prefecture, Lijiang City, Dali Prefecture, Chuxiong Prefecture, Pu'er City, and Honghe Prefecture. By 2010, there were only four high-value areas, namely Gongshan in Nujiang County and Fugong County, Deqin County in Diqing Prefecture, and Ninglang County in Lijiang City. The middle ratio area shows a trend of first increasing and then decreasing. This change indirectly indicates the inflection point of the economic and social development speed of Yunnan Province in 2010. Before 2010, Yunnan Province's economic and social development was rapid, and after 2010, the economic and social development was relatively slow. During the study period, the low-ratio areas were gradually scattered around the main urban area of Kunming City. The density of expressways and high-speed railways planned in Yunnan Province was observed, and it was found that the low-ratio areas in 2020 were consistent with the current high-density expressways and high-speed railway coverage areas, indicating that Kunming's economic influence radiates to various cities through expressways and high-speed railways.

4.3. Spatial Correlation Analysis of Land Ecological Service Value

By analyzing the spatial correlation of land ecological service value, we can explore the global and local clustering characteristics of land ecological service value and find areas with prominent land ecological service value. The de-global autocorrelation analysis was carried out on the land ecological service value of the three periods, and the Moran index of the three periods was 0.39, greater than 0, and the Z scores of the test coefficients of the three periods were 8.21, 8.29, and 8.18, respectively, which is significantly greater than 0. It shows that the spatial distribution of land ecological service value in Yunnan Province has a strong correlation, showing a pattern of spatial agglomeration distribution. Local spatial autocorrelation analysis was performed to obtain the LISA aggregation map of land ecological service value in Yunnan Province (Figure 4).

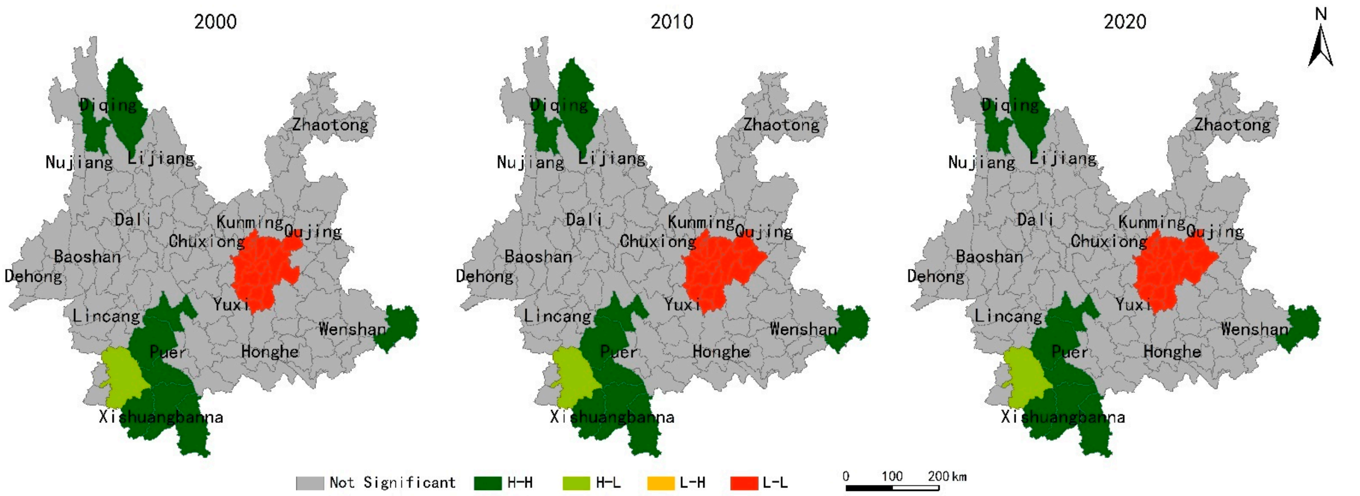

Figure 4. Clustering map of land ecological service value in Yunnan Province from 2000 to 2020.

In 2000, 2010, and 2020, the proportion of areas with insignificant high-low clustering was very high, and there was no low-high clustering in the three periods, but high-high clustering, low-low clustering, and high-low clustering were always significant. There are 9 high-high clustering areas, all of which belong to the high-value areas of total land ecological service value, and the high-high clustering areas did not change in 2000, 2010, and 2020. Only Lancang County, Pu'er City, clustered high and low in the three periods, indicating that the total ecological service value of land in Lancang County is higher than that of most surrounding areas. There are 18 areas with low-low clustering. These areas have a relatively high degree of economic and social development, which is in line with the fact that the total ecological service value of urban land is lower than that of surrounding areas. The low-low clusters are distributed in Kunming, Yuxi, and Qujing City. Among them, there are 11 in Kunming City, 5 in Yuxi City, and 2 in Qujing City. Except for Luliang County in Qujing City, which became a low-low clustering area in 2010, the other 17 county-level administrative units have been in the low-low clustering region.

4.4. Hotspot Analysis of Land Ecological Service Value

The hotspot analysis of the land ecological service value in Yunnan Province was carried out to obtain the spatial pattern distribution of the cold and hot spots of the land ecological service value (Figure 5).

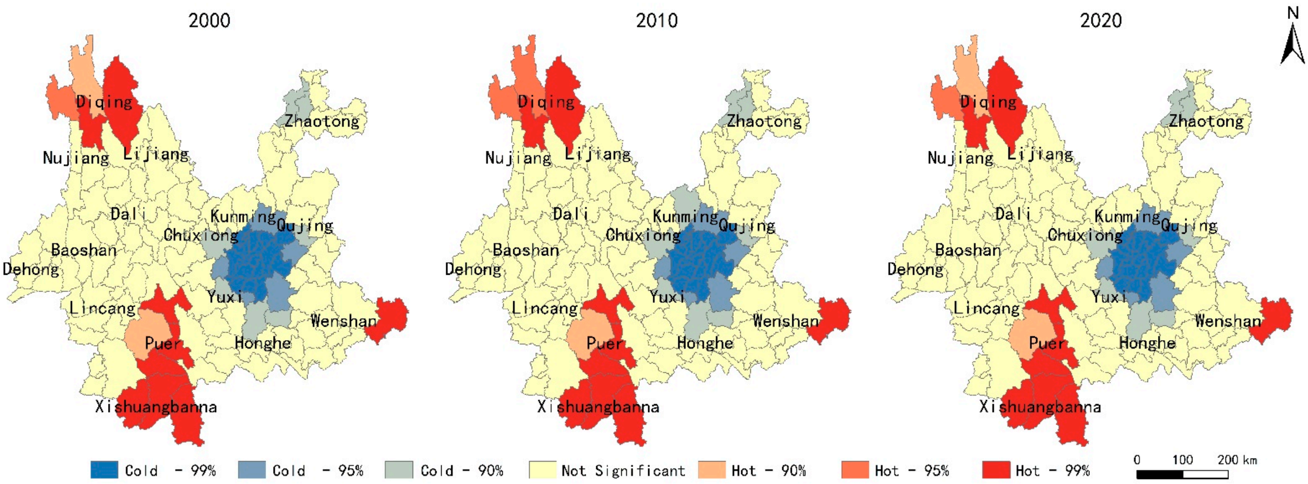

Figure 5. Spatial pattern of cold and hot spots of land ecological service value in Yunnan Province from 2000 to 2020.

It was found that the high-low clustering pattern in Figure 4 is similar to the distribution pattern of cold and hot spots in Figure 5. Most of the high- and high-clustered areas overlap with the hotspot areas, and the low- and low-clustered areas also basically overlap with the cold-spot areas. Most of the hot and cold areas with 95% and 90% confidence intervals correspond to insignificant areas in the high-low clustering pattern, while Lancang County, the only high-low clustering area, was classified as an insignificant area in the hotspot analysis. From Figures 4 and 5 as a whole, the area where the hotspot area of the 99% confidence interval coincides with the high-high clustering is an area with high ecological service value, in which the government should protect the ecological environment. The cold spot area in the 99% confidence interval overlapped with the low and low clusters, which is an area with low ecological service value. The government department in this area should formulate appropriate ecological protection plans and measures to enhance the ecological service value of the land.

5. Discussion

In this paper, the "Equivalent value of ecological services per unit area of China's ecosystems" is revised in the three periods of the study, so that the relative differences in time and space of ecosystem service values can be more objectively and truly reflected, which will not affect the analysis of temporal and spatial changes in ecological service values. On this basis, the macro-scale characteristics of temporal and spatial changes of ecological service value in Yunnan Province were quantitatively described from the county scale, and the correlation and hotspot areas of land ecological service value were analyzed, and the relative level changes of ecological service value of 129 county-level administrative units in Yunnan Province were explored, which provides a new research idea for the spatiotemporal analysis of ecological service value. The research has a certain effect on qualitatively measuring the impact of land use change on the change of ecosystem service value. The research has a certain significance in reflecting the spatial difference of ecosystem services and different service values in Yunnan Province, and provides a reference for large-scale ecological service value estimation.

From 2000 to 2020, the land use structure and spatial layout of Yunnan Province have undergone great changes and the urbanization rate was very fast. The urbanization process is accompanied by the agglomeration of population and economy and the expansion of urban construction land. The expansion of urban construction land will inevitably lead to a decrease in the value of ecosystem services. In order to promote the ecological construction of Yunnan Province and narrow the ecological gap between regions, it is necessary to further adjust the regional land use structure: the government should increase the management and control of construction land in areas with high ecological service value, and regulate the speed of construction land expansion; the government moderately promotes the process of urbanization in areas with low ecological service value, and strengthens the governance and restoration of the ecological environment. In the area, 95% of the hotspots with 90% confidence intervals have the potential to become more significant hot spots, while cold spots with 95% and 90% confidence intervals should be candidates for coordinated progress of ecological protection and economic construction to prevent them from becoming significant cold spots. This paper calls on the government to pay attention to changes in ecological service value, and, on the premise of ensuring food security, implement policies such as returning farmland to lakes and forests, and promote the conversion of cultivated land to land use types with high ecological service value such as forest land and wetlands. This will play a positive role in enhancing the value of ecological services in Yunnan Province.

China's current land resource classification system has some problems such as few classification levels, confusing classification standards, and unclear classification standards, resulting in a lack of scientific and logical rigor in the study of ecological service value [49]. These issues will lead to disagreements in how ecosystems are divided and the value of services assessed. As far as the estimation of ecosystem service value is concerned, there is still no unified calculation method and standard, and more scientific and accurate methods still need to be sought. This paper revises the "ecosystem service value equivalent per unit area of ecosystems in China" proposed by Gaodi Xie, but due to the limitation of data, it cannot solve the problem of spatial heterogeneity of the value equivalent of different research units. In the process of estimating the value of ecological services in the future, it is necessary to comprehensively consider the influence of its own unit elements and the elements of neighboring units or further units and correct the value equivalent of each research unit. This paper does not delve into the impact mechanism of ecological service value. In the future, based on collecting more socio-economic data, we will quantitatively analyze the impact of natural, socio-economic, and other factors on ecosystem service value. Because ecosystem service functions evolve and develop on different spatial and temporal scales, the spatiotemporal changes of ecosystem service value have obvious spatial heterogeneity and nonlinear characteristics. It is difficult to find local change information in the evolution process. We need to further study quantitative dynamic methods and models that can accurately describe the nonlinear change characteristics of ecosystem service value at different temporal and spatial scales, so as to grasp its local change information more scientifically and accurately.

6. Conclusions

Based on Landsat image data, this paper interprets and corrects the equivalent factor of ecological service value in 2000, 2010, and 2020. The paper calculates the land ecological service value in Yunnan Province, conducts spatial autocorrelation analysis and hotspot analysis, and explores the spatial pattern and quantitative characteristics of the land ecological service value in Yunnan Province. It is found that the dynamic degree of construction land is the largest during the study period, the area of construction land increases sharply, and the dynamic degree of unused land is the smallest. On the whole, the land use pattern of Yunnan Province has undergone great changes during the study period, and the expansion of construction land has led to some ecological problems. During the study period, the GDP of Yunnan Province grew rapidly, and the whole province was in the stage of rapid urbanization. In 2000, the ratio of ESV total value to GDP in Yunnan Province was significantly higher than the global average level at that time, but the development speed of land ecological service value in Yunnan Province was far less than the development speed of GDP, and the ecological service value in Yunnan Province still has a lot of room for development, the low ratio area in 2020 is consistent with the current high-density expressway and high-speed railway coverage area, indicating that Kunming's economic influence is radiating to various cities through expressways and high-speed railways, promoting the development of each city. The ratio of the total value of land ecological services in the province in the three periods is close to the ratio of the equivalent factor in the three periods. The total ecological service value level of county-level administrative units is relatively stable, and the total value of each service is ranked as soil formation and protection > gas regulation > water conservation > biodiversity conservation > climate regulation > raw materials > waste treatment > entertainment culture > food production. The ecological service value per unit of land is the highest in Shangri-La City, and the lowest is in Wuhua District. The ecological service value per unit of land in 129 county-level administrative units continues to rise. The areas with high average values are mainly in western Yunnan, southwestern Yunnan, southern Yunnan, and southeastern Yunnan. The spatial distribution of land ecological service value in Yunnan Province has a strong correlation, showing a pattern of spatial agglomeration distribution. The regions with high and high agglomeration and low and low agglomeration are very stable, the regions with low and low agglomeration are economically developed regions, and the regions with high and high agglomeration are regions with good ecological environment. The results of the hotspot analysis are similar to the LISA plots, and the overlapping parts are basically the hot and cold areas of the 95% confidence interval.

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References

1. Xie, G.D.; Zhang, C.X.; Zhang, C.S. The value of ecosystem services in China. *Resour. Sci.* **2015**, *37*, 1740–1746. (In Chinese)
2. Yang, Z.S. *Research on Land Use Change and Ecological Effects in Different Landform Regions of Yunnan Driven by China's Converting Farmland to Forest Project*; China Science and Technology Press: Beijing, China, 2011; pp. 63–67. (In Chinese)
3. 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. *Nat. Int. Wkly. J. Sci.* **1997**, *387*, 253–260. [CrossRef]
4. 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. (In Chinese)
5. Xue, M.G.; Xing, L.; Wang, X.Y. Spatial correction and evaluation of ecosystem services in China. *China Land Sci.* **2018**, *32*, 81–88. (In Chinese)
6. Chen, W.X.; Li, J.F.; Zhu, L.J. Spatial heterogeneity and sensitivity analysis of ecosystem services value in the Middle Yangtze River region. *J. Nat. Resour.* **2019**, *34*, 325–337. (In Chinese) [CrossRef]
7. Yan, Y.; Yao, L.Y.; Lang, L.M.; Zhao, M.J. Revaluation of ecosystem services in inland river basins of China: Based on meta-regression analysis. *Acta Geogr. Sin.* **2019**, *74*, 1040–1057. (In Chinese)

8. Li, L.; Zhu, W.B.; Li, Y.H.; Zhu, L.Q.; Xu, S.B.; Feng, X.Y. Profit and loss of ecosystem service value in Qihe River Basin based on topographic gradient characteristics. *Soil Water Conserv. Res.* **2019**, *26*, 287–295. (In Chinese)
9. Jia, J.H.; Chen, J.Y.; Long, X.J.; Chen, J.C. Evaluation of the effect of hydropower development on river ecosystem services and analysis of temporal and spatial variation characteristics: Taking the main stream of Wujiang as an example. *J. Nat. Resour.* **2020**, *35*, 2163–2176. (In Chinese)
10. Liu, F.L.; Yang, R.Y. Land use change and its impact on ecosystem service value in Wuhan City. *Soil Water Conserv. Res.* **2021**, *28*, 177–183+193. (In Chinese)
11. Paudyal, K.; Baral, H.; Keenan, R.J. Assessing social values of ecosystem services in the Phewa Lake Watershed, Nepal. *For. Policy Econ.* **2018**, *90*, 67–81. [CrossRef]
12. 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.
13. Davidson, N.C.; van Dam, A.A.; Finlayson, C.M.; McInnes, R.J. Worth of wetlands: Revised global monetary values of coastal and inland wetland ecosystem services. *Mar. Freshw. Res.* **2019**, *70*, 1189–1194.
14. Soto, J.R.; Escobedo, F.J.; Khachatryan, H.; Adams, D.C. Consumer demand for urban forest ecosystem services and disservices: Examining trade-offs using choice experiments and best worst scaling. *Ecosyst. Serv.* **2018**, *29*, 31–39. [CrossRef]
15. Fan, H.Q.; Zhang, Y.L.; Zou, L.L.; Pan, L.H. Research on the Benchmark Value of Chinese Mangroves and the Value Allocation of Individual Plants. *J. Ecol.* **2022**, *42*, 1262–1275. (In Chinese)
16. Li, Y.Y.; Tan, M.H.; Hao, H.G. The impact of global cultivated land change on terrestrial ecosystem service value from 1992 to 2015. *J. Geogr. Sci.* **2019**, *29*, 323–333. [CrossRef]
17. Geng, T.W.; Chen, H.; Zhang, H.; Shi, Q.Q.; Liu, D. Spatiotemporal evolution of land ecosystem service value and its influencing factors in Shaanxi province based on GWR. *J. Nat. Resour.* **2020**, *35*, 1714–1727. (In Chinese)
18. Yang, X.T.; Qiu, X.P.; Xu, Y.; Zhu, F.B.; Liu, Y.W. Spatial differences and dynamic characteristics of the impact of ecosystem services on residents' well-being in typical mountainous areas: A case study in the mountainous areas of western Sichuan. *J. Ecol.* **2021**, *41*, 7555–7567. (In Chinese)
19. Arowolo, A.O.; Deng, X.Z. Assessing changes in the value of ecosystem services in response to land-use/land-cover dynamics in Nigeria. *Sci. Total Environ.* **2018**, *18*, 247–259. [CrossRef] [PubMed]
20. Ziaul, H.M.; Imranul, I.; Minhaz, A.; Shaikh, S.H.; Foyez, A.P. Spatio-temporal changes of land use land cover and ecosystem service values in coastal Bangladesh. *Egypt. J. Remote Sens. Space Sci.* **2022**, *25*, 173–180.
21. Rahul, T.; Chandra, M.K.; Sangita, M.; Suchismita, P.; Dibyendu, C.; Kumar, S.C.; Anjani, K.; Kumar, N.P.; Bihari, P.B.; Debarti, B.; et al. Impact of Land Use and Land Cover Change on Ecosystem Services in Eastern Coast of India. *Int. J. Environ. Res.* **2021**, *16*, 1–18.
22. Li, H.; Zhou, Q.G.; Li, B.; Guo, H.L.; Wang, F.H.; He, C.H. Spatiotemporal change and correlation analysis of ecosystem service values and ecological risk in Three Gorges Reservoir area in the past 30 years. *Resour. Environ. Yangtze Basin* **2021**, *30*, 654–666. (In Chinese)
23. Wang, S.; Zhang, Q.; Wang, Z.F.; Yu, P.; Xiang, S.J.; Gao, M. GIS-based Ecological Risk Assessment and Ecological Zone Construction in the Three Gorges Reservoir Area. *J. Ecol.* **2022**, *42*, 1–11. (In Chinese)
24. Ge, J.Z.; Li, T.; Qi, Z.X.; Gong, Y.B.; Wang, J.R.; Zhao, Y.P.; Wang, Z.Y. Identification and allocation of ecological compensation space based on ecological risk assessment: Taking Dongting Lake ecological economic zone as an example. *J. Ecol. Rural. Environ.* **2022**, *38*, 472–484. (In Chinese)
25. Chen, X.M.; Wang, X.F.; Feng, X.M.; Zhang, X.R.; Luo, G.X. Ecosystem service tradeoffs and synergies in the Qinghai-Tibet Plateau. *Geogr. Stud.* **2021**, *40*, 18–34. (In Chinese)
26. Yang, Q.Q.; Xu, G.L.; Li, A.J.; Liu, Y.T.; Hu, C.S. Evaluation and trade-off of ecosystem services in Qingyi River Basin. *J. Ecol.* **2021**, *41*, 9315–9327. (In Chinese)
27. Capitani, C.; van Soesbergen, A.; Mukama, K.; Malugu, I.; Mbilinyi, B.; Chamuya, N.; Kempen, B.; Malimbwi, R.; Mant, R.; Munishi, P.; et al. Scenarios of Land Use and Land Cover Change and Their Multiple Impacts on Natural Capital in Tanzania. *Environ. Conserv.* **2018**, *46*, 17–24. [CrossRef]
28. Kubiszewski, I.; Costanza, R.; Anderson, S.; Sutton, P. The future value of ecosystem services: Global scenarios and national implications. *Ecosyst. Serv.* **2017**, *26*, 289–301. [CrossRef]
29. Ouyang, X.; He, Q.Y.; Zhu, X. Simulation of impacts of urban agglomeration land use change on ecosystem services value under multi-scenarios: Case study in Changsha-Zhuzhou-Xiangtan urban agglomeration. *Econ. Geogr.* **2020**, *40*, 93–102. (In Chinese)
30. Wang, P.J.; Sun, H.; Hua, B.L.; Fan, S.L. Evaluation and dynamic simulation of ecosystem service value in coastal area of Fuzhou City. *Trans. Chin. Soc. Agric. Mach.* **2020**, *51*, 249–257. (In Chinese)
31. Chu, Z.; Xu, C.C.; Luo, Y.X.; Sun, Q. Land use simulation and ecological benefit evaluation in the Tarim River basin based on ecological protection red line management. *Acta Ecol. Sin.* **2021**, *41*, 7380–7392. (In Chinese)
32. Liu, Y.B.; Wang, X.L.; Hou, X.Y.; Song, B.Y.; Li, X.W.; Wang, C. Assessment of land use patterns and ecosystem service values in the Yellow River Delta in 2025 under four periods and simulated scenarios. *Wetl. Sci.* **2020**, *18*, 424–436. (In Chinese)
33. Chen, B.F.; Liao, T.J.; Zhang, L.K. Simulation of land use situation and ecological value assessment in Wanzhou District under the constraints of ecological red line. *Res. Soil Water Conserv.* **2020**, *27*, 349–357, 364. (In Chinese)

34. Zhang, X.Y.; Zhang, X.; Li, D.H.; Lu, L.; Yu, H. Multi-scenario simulation of the impact of urban land use change on ecosystem service value: Taking Shenzhen as an example. *J. Ecol.* **2022**, *42*, 2086–2097. (In Chinese)
35. Zhang, M.F.; Liu, W.X.; Wang, J.E.; Luo, X.Q.; Chen, P.; Gong, Q.H. Scenario simulation of ecosystem service value change in Dongguan section of Shima River Basin based on Clue-S model. *Bull. Soil Water Conserv.* **2021**, *41*, 152–160. (In Chinese)
36. Sun, X.P.; Li, S.; Yu, J.P.; Fang, Y.J.; Zhang, Y.L.; Cao, M.C. The valuation of ecosystem services based on land use change scenarios: A case study of Qianjiangyuan National Park system pilot area. *Biodiversity* **2019**, *27*, 51–63. (In Chinese)
37. Ma, B.Y.; Huang, J.; Li, S.C. Optimal allocation of land use in Beijing-Tianjin-Hebei urban agglomeration based on ecological-economic trade-offs. *Adv. Geogr. Sci.* **2019**, *38*, 26–37. (In Chinese)
38. Zhang, X.Y.; Lu, L.; Yu, H.; Zhang, X.; Li, D.H. Multi-scenario simulation of the impacts of land-use change on ecosystem service value on the Qinghai-Tibet Plateau. *Chin. J. Ecol.* **2021**, *40*, 887–898. (In Chinese)
39. Wang, J.F.; Liu, F.; Bai, X.Y.; Dai, W.; Li, Q.; Wu, L.H. The spatial and temporal evolution and simulation forecast of ecosystem service values in southwest China. *Acta Ecol. Sin.* **2019**, *39*, 7057–7066. (In Chinese)
40. Zhu, Z.Y.; Alimujiang, K. Analysis and Simulation of Spatial Autocorrelation Pattern of Ecosystem Service Value in Oasis City in Arid Area. *J. Ecol. Rural Environ.* **2019**, *35*, 1531–1540. (In Chinese)
41. Liu, Y.; Ren, Y.; Zhou, Y.; Liu, C.Q. Dynamic Simulation of Ecosystem Service Value in Jianghan Plain Based on CA-Markov—Taking Qianjiang City, Hubei Province as an Example. *China's Agric. Resour. Zoning* **2020**, *41*, 159–167. (In Chinese)
42. Li, L.; Wu, D.F.; Liu, Y.Y.; Gong, J.Z.; Liu, Y.H.; Zheng, J.Y. Temporal and spatial evolution characteristics and simulation prediction of ecological and economic coordination degree in Huizhou City based on CA-Markov model. *J. Ecol. Rural. Environ.* **2020**, *36*, 161–170. (In Chinese)
43. Zuo, L.L.; Peng, W.F.; Tao, S.; Zhu, C.; Xu, X.L. Dynamic changes of land use and ecosystem service value in the upper reaches of the Minjiang River. *J. Ecol.* **2021**, *41*, 6384–6397. (In Chinese)
44. Gao, X.; Yang, L.W.Q.; Li, C.X.; Song, Z.Y.; Wang, J. Spatial response of land use change and ecosystem service value in Baiyangdian watershed under simulated multiple scenarios. *J. Ecol.* **2021**, *41*, 7974–7988. (In Chinese)
45. Guan, Q.C.; Hao, J.M.; Shi, X.J.; Gao, Y.; Wang, H.L.; Li, M. Research on the Change of Ecological Land and Ecosystem Service Value in China. *J. Nat. Resour.* **2018**, *33*, 195–207. (In Chinese)
46. Wang, P.J.; Liu, Q.; Sun, H.; Lin, X.L.; Fan, S.L. Study on the temporal and spatial changes of ecosystem service value in the red soil erosion area in southern China. *J. Agric. Mach.* **2021**, *52*, 219–228. (In Chinese)
47. Qi, J.; Deng, W.; Zhou, Y.; Liu, T.; Luo, X. Evaluation method and application of ecological protection red line effectiveness in Chongqing. *J. Ecol. Environ.* **2021**, *30*, 1532–1540. (In Chinese)
48. Yang, Z.S.; Yang, R.Y.; Liu, F.L. Research on the spatiotemporal evolution and influencing factors of urban-rural income gap in Yunnan Province based on poverty classification. *Geogr. Stud.* **2021**, *40*, 2252–2271. (In Chinese)
49. Yang, Z.S.; Yang, S.Q.; Yang, R.Y.; Wang, J.; Wu, Q.J. Classification method of land resources based on land use perspective. *Resour. Sci.* **2021**, *43*, 2173–2191. (In Chinese) [CrossRef]