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Spatial–Temporal Evolution of Ecosystem Service Value in Yunnan Based on Land Use

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Abstract: Exploring the changes in ecosystem service value (ESV) caused by land use transition is important for regional ecological protection. According to the land use data from 2000 to 2020, the alterations in the land use and ESV in Yunnan over the past 20 years were calculated and analyzed. At the same time, spatial autocorrelation analysis was established to analyze the spatial relationships of ESV in 16 states and cities. The results show that from 2000 to 2020, cultivated land, grassland and unused land are on a decreasing trend, while forest land, water body and built-up land are on an increasing trend, with the largest change in built-up land. The total ESV is on an increasing trend, with water supply, gas regulation, climate regulation, environmental purification and hydrological regulation being the highest value of individual services. Spatially, the total ESV showed that high levels were in the northwest, southwest and east, and low levels were in the northeast, west and central parts. At the same time, it shows a positive spatial correlation with a weakening trend. It is dominated by high–high cluster and low–low cluster. The change in the value of ecological services in forest land, grassland and water body have a greater impact on the change in total service value in the region, and was the main contributing and sensitive factor.

Keywords: land use; ecosystem service value; spatial autocorrelation analysis; Yunnan

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1. Introduction

Ecosystem services are services and products provided directly or indirectly to humans by specific ecosystems under ecological conditions of good structural and functional integrity that play an important role in making ecological conservation and economic green development decisions [1–3]. The stock and flow of ecosystem services affect the functioning of modern societies and economies [4], and land use is the most significant contributor to changes in ecosystem services [5], while having economic advantages in maintaining ecological environments and enhancing human health and living standards [6]. The systematic study of land use change and the impact of different land types on ecosystem services can improve the planning and management of land use [7]. Starting from the 21st century, the world has entered a phase of rapid land urbanization at the expense of ecosystem service value [8], and optimizing land use structure has also become the best means to balance economic development and ecosystem service value.

Human research on ecosystem services has been conducted since the 1960s, but quantifying them only from an ecological perspective has made it difficult for the public to understand their meaning and to analyze them in comparison with economic indicators [9]. In 1997, Costanza et al. [10] proposed a monetary approach to valuing global ecosystem services. In 2003, Xie et al. [11] synthesized various research results on ecosystems and developed the "ecological service value per unit area equivalence scale for terrestrial ecosystems in China", which has been continuously revised in the light of economic development and land use status [12]. In addition, scholars have also conducted a lot of research on this topic. As for research scale, it primarily concentrated on watersheds [13], plateaus [14], nature reserves [2], urban agglomerations [15–17], arid regions [18], islands [19], lakes [20,21], water reserves [22], basins [23] and other levels of physical geographic units and socioeconomic functional areas. As for research content, it included the spatial and temporal patterns of ecosystem service value [24], factors influencing ecosystem service value [25] and the impact of land use change on the value of ecosystem services [26]. Research methods used to evaluate the worth of ecosystem services include the benefit transfer method [27], equivalent coefficients table method [28], meta-analysis [29,30], land cover proxy method [14] and shadow project approach [31]. In summary, scholars have paid attention to the influence of land use situation on ecosystem service value. It also formed a complete and scientific ecosystem service value assessment system, but there are relatively few spatial analyses on the mutual transfer situation between different land use types and the change of ecosystem service value, and few scholars have analyzed the influence of different land use types on ecosystem service value.

Yunnan is the ecological security barrier in southwest China, and it bears the strategic task and great responsibility of maintaining national ecological security. However, Yunnan is mostly dominated by plateaus and mountains, and also has unique karst landscapes and a relative lack of land resources, which seriously restricts regional economic development. Rapid population growth and accelerated urbanization have an impact on ecosystem services; it is important to establish a sound territorial spatial development and protection system, strengthen ecological space management and protect natural ecological security boundaries. By quantitatively analyzing the spatial evolution characteristics of ecosystem service values in 16 states and cities, changes in ecosystem service value under land use change were revealed. It provides a foundation for the development of land use planning to achieve sustainable social, economic and ecological development. The objective of this study are as follows: (1) Arcgis 10.7 software was used to analyze the characteristics of land use change, land use dynamic change, land use transfer and land use degree. (2) The equivalent factor method was used to measure the value of ecosystem services in Yunnan, and a spatial autocorrelation model was used to study the spatial and temporal evolution of the value of ecosystem services for various land use types in 16 states and cities. (3) Ecological contribution ratios were used to determine the contribution of different land use types to changes in ecosystem service value.

2. Materials and Methods

2.1. Study Area

Yunnan, which forms part of China's southwest border and consists of 16 states and cities (Figure 1), is the region's ecological barrier. The geography in Yunnan is separated into two parts, east and west, by the Yuanjiang Valley and the large valley in the southern part of the Yunling Mountains. The topography of the region exhibits a high northwest and low southeast. The western part is the longitudinal valley of the Hengduan Mountains, with deep valleys between high mountains, large elevation differences, and treacherous terrain, forming remarkable three-dimensional climate characteristics. The eastern part is the plateau of eastern and central Yunnan, mostly undulating and gently rolling low mountains and rounded hills, breeding various types of karst terrain. The study area has a climate of the subtropical plateau monsoon type with an average annual temperature of 17.6 °C. Yunnan has 65.04% forest cover and a storage capacity of 2.067 billion cubic meters. Yunnan has diverse soil types and a complex environment that creates the conditions for breeding a rich variety of species, making it one of the richest species hotspots in the world [32]. The economic development level of Yunnan has improved significantly, from 2030.08 billion yuan in 2000 to 24,521.90 billion yuan in 2020, with an average annual growth rate of 55.40%. In addition, the urbanization process of Yunnan Province has accelerated, with the total population growing from 42.41 million in 2000 to 47.22 million in 2020, of which the proportion of urban population has increased from 23.36% to 50.05%.

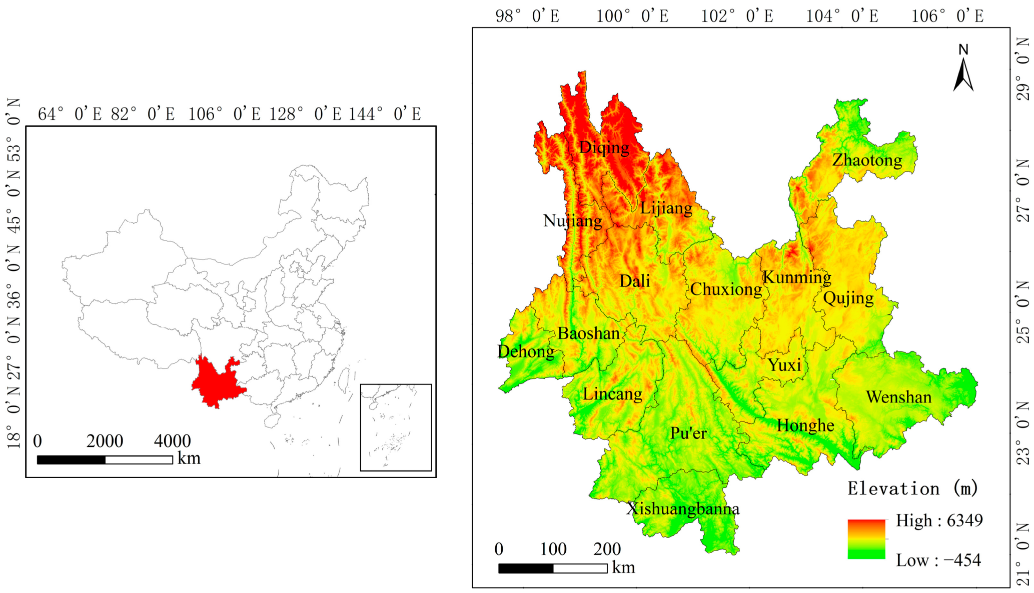

Figure 1. Geographic location and topography of the study area.

2.2. Data Source

The remote sensing data of land use in Yunnan for a total of 5 periods from 2000 to 2020 were obtained from the Resource and Environment Science and Data Center of the Chinese Academy of Sciences (http://www.resdc.cn, accessed on 15 September 2022), and the land use types were classified into: cultivated land, forest land, grassland, water body, built-up land and unused land according to land resources and attributes. Data on grain production, prices and planted area were obtained from the *China Agricultural Products Price Survey Yearbook* and the *China Statistical Yearbook*.

2.3. Research Methods

2.3.1. Land Use Change Study

The parameters of land use dynamics, transfer Matrix, and land use degree were used to describe land use changes in the study area.

(1) Land use dynamics is a measure of the speed of change of land use types, which is divided into single land use dynamics and comprehensive land use dynamics; the single land use dynamics were used to evaluate the rate of conversion between different land use types during the study period [33].

$$K = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\% \quad (1)$$

where K is the single dynamics of land use type (%); U_a is the area of a land use type at the beginning of the study period (ha); U_b is the area of a land use type at the end of the study period (ha); T is the time year interval of the study period.

The comprehensive land use dynamics represents the rate and magnitude of land use-type change in the study area as a whole, with the following equation.

$$L_c = \frac{\sum_{i=1}^{n} \Delta LU_{i-j}}{2\sum_{i=1}^{n} LU_i} \times \frac{1}{T} \times 100\% \quad (2)$$

where L_c is the comprehensive land use dynamics (%); LU_i is the area of land use type i at the beginning of the study (ha); ΔLU_{i-j} is the absolute value of the area of land use type i changing to non-i land use type during the study period (ha).

(2) The land use transfer matrix is used to study the dynamic transformation of each land use type in the research period [18]. ArcGIS 10.7 is used to perform spatial

superposition and statistical analysis of land use remote sensing maps in Yunnan at different periods to obtain land use transfer matrices, so as to determine the status and number of land use mutual transformations.

$$S_{ij} = \begin{bmatrix} S_{11}S_{12} & \cdots & S_{1n} \\ \vdots & \ddots & \vdots \\ s_{n1}S_{n2} & \cdots & S_{nn} \end{bmatrix} \quad (3)$$

where S_{ij} is the area of change (ha), i and j represent the study start time and end time, respectively, and n is the number of land use types.

(3) Land use degree (L) reflects the extent to which human activities have led to land use change [34].

$$L = 100 \times \sum_{i=1}^{n} \frac{A_i P_i}{A_T} \quad (4)$$

where A_i is the area of the land use type of Category I (ha); A_T is the total area of the study area (ha); P_i is the i-type land use degree parameter, of which the unused land is assigned 1, the forest land, grassland and water body are assigned 2, the cultivated land is assigned 3, and the built-up land is assigned 4.

2.3.2. Ecosystem Service Value Assessment

The value of service functions in ecosystems is calculated by equivalent factor method, and the economic value created per unit area of grain production is revised based on the revised ecological service equivalent scale of China's ecosystem per unit area by Xie et al. [12], and the economic value created per unit area of grain production is revised in combination with the socioeconomic development of Yunnan [19]. Among them, the ESV of the built-up land is low and the degree and scope of influence are small, and its coefficient is set to 0 in this equivalent scale [35]. The coefficient of the ESV is calculated as follows.

$$E_{ij} = \frac{1}{7}\alpha \times P \times Q \times E_{0ij} \quad (5)$$

where E_{ij} is coefficient of j ecosystem services value for land use type i in Yunnan the j ecosystem service value factor for the modified i land use type (yuan/ha); p is the average price of grain in Yunnan (yuan/kg); Q is the grain yield per unit sown area (kg/ha) in Yunnan; α is correction factor and expressed as the ratio of Yunnan's economic income per hectare of grain to the national economic income per hectare of grain; E_{0ij} is the ecosystem service equivalence in China, from the Chinese ESV equivalence scale established by Xie et al. Coefficient of the ESV in Yunnan (E_{ij}) is shown in Table 1:

Table 1. Coefficient of the ESV in Yunnan (yuan/ha).

Service Type	Service Type Subcategories	Cultivated Land	Forest Land	Grassland	Water Body	Unused Land
Provisioning service	Food production	1455.17	332.52	307.28	526.76	6.58
	Raw material production	322.64	763.80	559.68	151.44	19.75
	Water supply	−1718.55	395.07	309.73	6880.80	13.17
Regulating service	Gas regulation	1172.04	2511.99	1967.05	625.53	85.60
	Climate regulation	612.36	7516.21	5200.17	1863.41	65.85
	Purifying the environment	177.78	2202.52	1717.09	3759.75	269.96
	Hydrological regulation	1968.77	4918.62	3809.11	72,014.69	158.03
Supporting service	Soil conservation	684.79	3058.50	2396.32	612.36	98.77
	Maintaining nutrient circulation	204.12	233.75	184.75	46.09	6.58
	Biodiversity	223.87	2785.24	2178.97	1685.63	92.18
Cultural service	Aesthetic landscape	98.77	1221.42	961.79	1303.73	39.51
	Total	5201.76	25,939.64	19,591.94	89,470.20	855.99

ESV is the total value of ecosystem service functions and is calculated as follows.

$$ESV = \sum_{i=1}^{m} \sum_{j=1}^{n} A_i E_{ij} \quad (6)$$

where ESV represents the total value of ecosystem services in the study area (yuan); A_i is the area of land use for Category i (ha); m is the total number of land-use types; n is the total number of ecosystem service species.

2.3.3. Spatial Statistical Analysis

Global spatial autocorrelation is used to verify the clustering potential of a certain attribute value in the spatial distribution of the region as a whole, which is mainly measured using Moran's I index [36], and this paper is used to assess whether the distribution of ESV in each state and city of Yunnan Province is clustered. ArcMap10.7 was used to analyze spatial autocorrelation to determine whether correlation exists between ESV and the spatial distribution phenomenon, and to understand the spatial distribution characteristics of Yunnan ESV more intuitively. The expression of *Moran's I* index is as follows.

$$Moran's\ I = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} (x_i - \overline{x})(x_j - \overline{x})}{\sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} \sum_{i=1}^{n} (x_i - \overline{x})^2} \quad (7)$$

where n is the number of spatial cells; x_i, x_j is the ESV value of the i, j spatial cells respectively; $\overline{x}$ is the average value of ESV; W_{ij} is the spatial weight matrix. Where $Moran's\ I < 0$ indicates negative spatial correlation and discrete distribution, $Moran's\ I > 0$ indicates positive spatial correlation and spatial clustering; where $Moran's\ I = 0$ indicates no spatial autocorrelation and random distribution of spatial units.

2.3.4. Ecological Contribution Rate

Ecological contribution rate indicates the magnitude of influence of the amount of change in ecological service value generated by different land use types in a certain time period on the amount of change in total regional service value, and can be used to reveal the main contributing and sensitive factors affecting the change in regional ecological service value [33].

$$G_{it} = \frac{|\Delta ESV_{it}|}{\sum_{i=1}^{6} |\Delta ESV_{it}|} \times 100\% \quad (8)$$

where G_{it} represents the ecological contribution rate of the Type i land-use type over time period t (%); ΔESV_{it} represents the amount of ESV change in the Type i land-use type over time period t.

3. Results

3.1. Land Use Changes in Yunnan Province from 2000 to 2020

3.1.1. The Overall Characteristics of Land Use Change

The classification results of the land use changes in Yunnan between 2000 and 2020 is shown in Figure 2. Yunnan is mainly dominated by grassland and forest, with the highest proportion of forest area (57%). Forest land, water body, and built-up land all show an increasing trend during the study period, increasing by 1348.52 km^2, 784.60 km^2 and 2457.02 km^2, with built-up land increasing the most (135.99%). Cultivated land, grassland and unused land show a decreasing trend, with decreases of 1620.03 km^2, 2250.80 km^2 and 495.16 km^2.

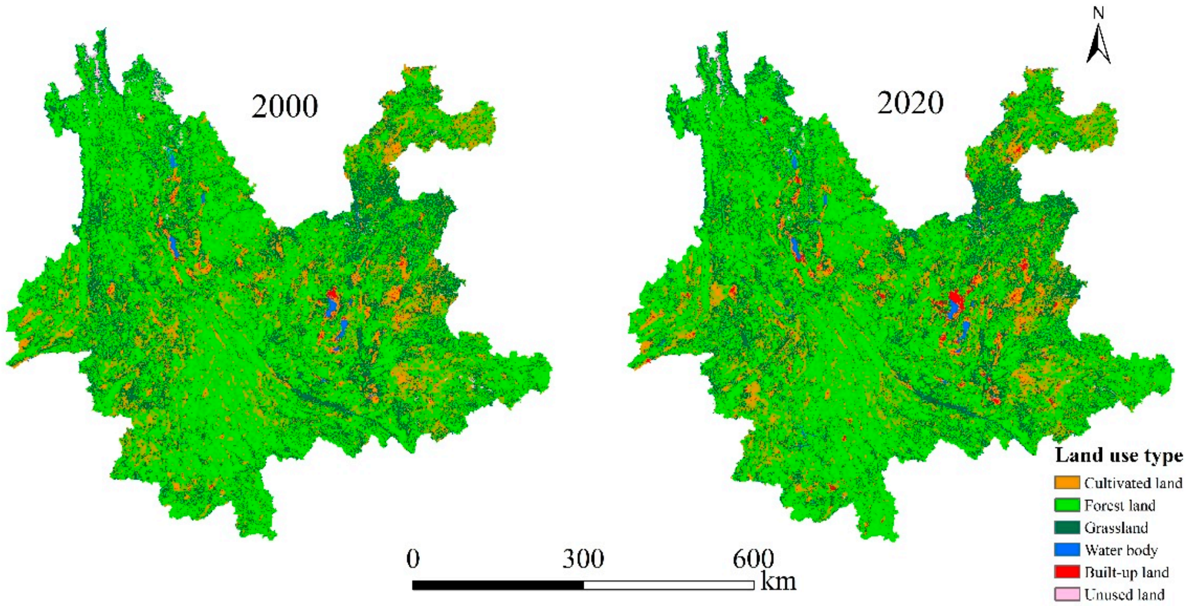

Figure 2. Spatial distribution of land use type between 2000 and 2020.

Over the past 20 years, accelerated urbanization and the application of ecological civilization strategies have led to significant changes in land use types in Yunnan. In order to meet peoples' needs for livelihood, more land is taken up for additional housing and road transport infrastructure construction. Cropland and forest land occupations require extensive permission processes and come at a considerable cost. As a result, while investing in infrastructure, grassland occupancy is given precedence. This has led to a decrease in grassland area. With the backing of ecological civilization, people have become more aware of the need to protect ecological land such as forests and water bodies.

3.1.2. Land Use Dynamic Change

The change of land use dynamics in Yunnan from 2000 to 2020 is shown in Table 2. The comprehensive land use dynamics in Yunnan are small during the whole study period, but the degree of land use change gradually increases by 0.19% from 2015 to 2020. This suggests that as Yunnan's economic development level has risen, as has the dependence of human economic activity on land resources. Among them, the expansion rate of built-up land is the most dramatic (27.20%), and the dynamic degree of land use reached 12.59% from 2015 to 2020. From 2000 to 2005, there was a decrease in the water bodies' degree of dynamics, and from 2005 to 2020, there was an increase. The dynamics of cultivated land and grassland were negative, and the overall dynamic of forest land shows positive changes, with a dynamic degree of 0.14%, which only showed a slight decrease from 2010 to 2015. There is no change in the land use dynamics of unused land from 2000 to 2015, but there is a significant decline from 2015 to 2020.

Table 2. Land use dynamics change in Yunnan from 2000 to 2020.

Period	Single Land Use Dynamics (%)						Comprehensive Land Use Dynamics (%)
	Cultivated Land	Forest Land	Grassland	Water Body	Built-Up Land	Unused Land	
2000–2005	−0.08	0.01	0.00	−0.05	1.54	0.00	0.01
2005–2010	−0.11	0.02	−0.01	0.12	1.30	0.00	0.02
2010–2015	−0.13	−0.03	−0.07	3.35	5.24	0.10	0.06
2015–2020	−0.22	0.14	−0.50	2.36	12.59	−5.37	0.19
2000–2020	−0.53	0.14	−0.57	6.20	27.20	−5.29	0.26

3.1.3. Land Use Transfer

The change in the transfer of land use types from 2000 to 2020 is shown in Table 3. The area of forest land transferred in and out is the largest, 51,177 km^2 and 50,018 km^2, respectively. The main types of transfer in and out are cultivated land, grassland and water body. The main reason is that the rich forest resources have created a unique advantage for the development of forestry industry in Yunnan. Forest conservation, ecological tourism and the forest economy are developing rapidly. The forest industry has become an important pillar for the economic development of forest people, requiring the occupation of more forest land. With the rapid development of economy and society, built-up land has increased significantly, resulting in a 2742 km^2 increase in its transfer in and out area between 2000 and 2020. The main sources of transfer in are cultivated land, forest land and grassland. Since the 21st century, Yunnan has gradually entered a phase of rapid urbanization and industrialization, with a large influx of people to the cities and increased construction of houses and factories to solve the employment problem as well as the housing problem.

Table 3. Transfer of land use types in Yunnan from 2000 to 2020 (unit: km^2).

2000	2020							
	Cultivated Land	**Forest Land**	**Grassland**	**Water Body**	**Built-Up Land**	**Unused Land**	**Total Transfer Out**	**Transfer Out Ratio (%)**
Cultivated land	32,237	21,821	11,783	674	2406	46	36,730	27.44
Forest land	20,530	168,251	27,540	916	730	302	50,018	37.37
Grassland	12,741	28,421	45,132	812	811	297	43,082	32.19
Water body	563	430	389	1340	95	11	1488	1.11
Built-up land	903	200	155	39	728	5	1302	0.97
Unused land	65	305	831	24	2	870	1227	0.92
Total transfer in	34,802	51,177	40,698	2465	4044	661		
Transfer-in ratio (%)	26.00	38.24	30.41	1.84	3.02	0.49		
Net transfer in	−1928	1159	−2384	977	2742	−566		

The area of arable land and grassland transferred out is larger than the area transferred in, the total area decreased by 1928 km^2 and 2384 km^2, respectively. The main sources of this transfer were forest land, grassland and built-up land. The main reason is that under the policy of "returning farmland to forest and grass" and the concept of ecological civilization, Yunnan gradually establishes and improves the management system of forest and grass industry, and actively carries out scientific implementation of artificial forestation, grass planting and subsequent nurturing and management work. In order to maintain food security and to prevent the red line of cultivated land, Yunnan is actively dealing with the relationship between the return of cultivated land to forest land and grassland and the protection of cultivated land, and some of the grassland has been transferred to cultivated land.

3.1.4. Land Use Degree Analysis

The land use degree and the rate of change are shown in Figure 3. The land use degree shows a fluctuating upward trend, of which the land use degree reached the highest of 219.63 in 2020, while the lowest land use degree in 2010 was 218.52, and the rate of change of land use degree from 2005 to 2010 was −0.01%, indicating that Yunnan is in a period of land use adjustment. In addition, from 2010 to 2020, the land use degree in Yunnan gradually increased, of which the change rate of land use degree in Yunnan has increased to 0.42% from 2015 to 2020, the growth rate has accelerated significantly, and land use degree has intensified.

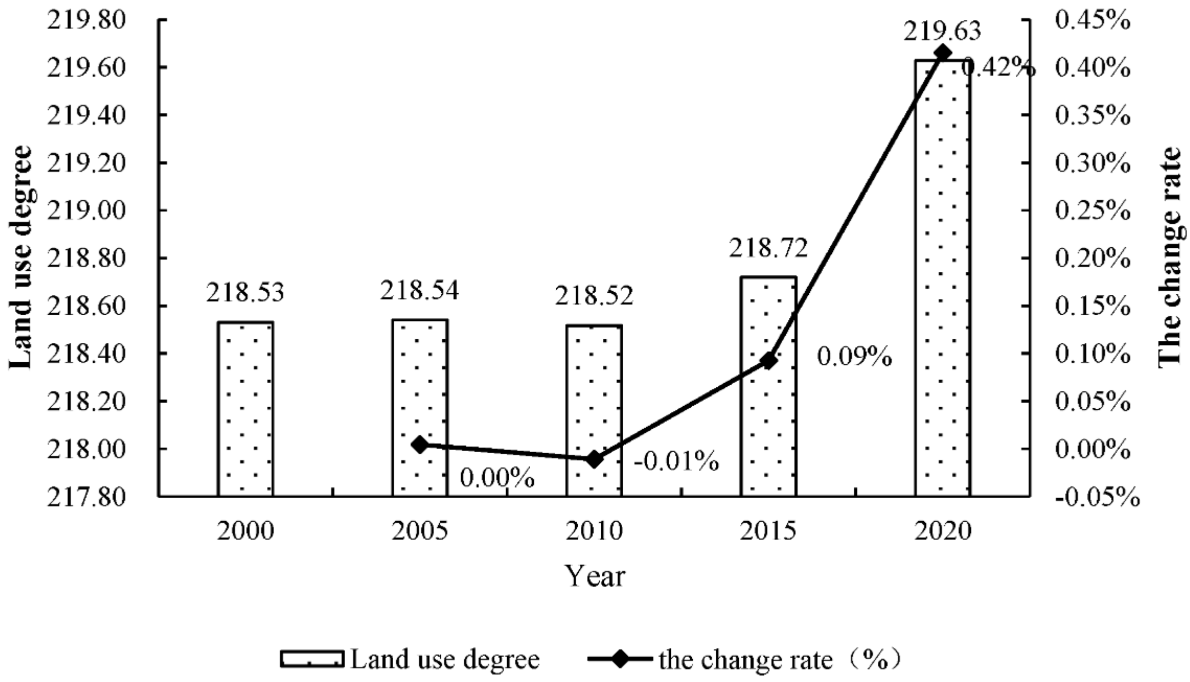

Figure 3. Land use degree and change rate.

3.2. Spatiotemporal Variation of Ecosystem Service Value

3.2.1. Changes in the Total Ecosystem Service Value

Land use changes have caused ESV in Yunnan to show a certain degree of change, and the specific changes are shown in Table 4. From 2000 to 2020, the value of ecosystem services in Yunnan showed an increasing trend, with the total value increasing from 7143.52 $\times$ 10^8 yuan to 7198.28 $\times$ 10^8 yuan, an increase of 0.77%. The ESV of cultivated land and grassland show a decreasing trend during the study period, decreasing by 8.43 $\times$ 10^8 yuan and 44.10 $\times$ 10^8 yuan respectively, with the largest decreases of 1.08% and 2.48% from 2015 to 2020. The main reason is that the implementation of the cultivated land reforestation policy and the accelerated urbanization construction are important factors leading to the decrease in ESV of cultivated land. The ESV of forest land, water body and unused land show an increasing trend, and the order of growth rate is unused land > water body > forest land. The ESV of unused land is the lowest, but the increase is the largest during the study period (135.99%). ESV in water body increased by 70.20 $\times$ 10^8 yuan, but the growth tends to slow down in 2015–2020. The overall ESV of forest land increases by 0.69%, and the share of total ESV remains above 70%. As the area of forest land declines from 2010 to 2015, it also leads to a decreasing trend of forest land ESV, with a decrease of 0.17%.

Table 4. ESV and change rate in Yunnan from 2000 to 2020.

Types	Ecosystem Service Value (10^8 Yuan)					Change Rate (%)				
	2000	2005	2010	2015	2020	2000–2005	2005–2010	2010–2015	2015–2020	2000–2020
Cultivated land	319.93	318.65	316.92	314.90	311.50	−0.40	−0.54	−0.64	−1.08	−2.63
Forest land	5049.87	5052.86	5058.53	5050.12	5084.85	0.06	0.11	−0.17	0.69	0.69
Grassland	1545.79	1545.73	1545.20	1539.95	1501.69	0.00	−0.03	−0.34	−2.48	−2.85
Water body	226.39	225.78	227.17	265.24	296.59	−0.27	0.61	16.76	11.82	31.01
Built-up land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unused land	1.55	1.67	1.77	2.24	3.65	7.71	6.51	26.22	62.97	135.99
Total	7143.52	7144.69	7149.59	7172.46	7198.28	0.02	0.07	0.32	0.36	0.77

3.2.2. Changes in the Value of Individual Ecosystem Services

From 2000 to 2020, the value and proportion of individual ecosystem services in Yunnan are shown in Table 5. Among the individual ecosystem service functions in the study area, ESV-regulating services, namely water supply, gas regulation, climate regulation, environmental purification and hydrological regulation, account for the highest proportion (67%). From the perspective of changes in various service functions, food production, raw material production, soil conservation and maintenance of nutrient cycles show a gradual decreasing trend, the main reason is the reduction in cultivated land. The importance of water supply and hydrological regulation is increased by the enormous increase of water body. The value of other service category has an increasing and then diminishing tendency. In the early stage, the economic development level of Yunnan was relatively backward. Cultivated land, forest land and grassland were not destroyed due to human economic activities and ESV showed a growing trend. In the medium term, the process of urbanization and industrialization has accelerated, which has led to changes in the mode of economic development, industrial structure and land use, resulting in a significant reduction in the area of cultivated land and grassland. This leads to a decline in the value of total ecosystem services. In the later period, under the guidance of policies such as the construction of ecological civilization and the green "three cards", Yunnan begins to transform the economic development model and pursue the coordination of economic, social and ecological benefits, so as to enhance the value of ecosystem services. In the process of urbanization and industrialization in the future, Yunnan should also optimize the structure and layout of land use, alleviate the pressure of economic growth on the ecological environment and strengthen the protection of ecological land such as forest land, grassland and cultivated land.

Table 5. Changes in the value and proportion of individual services in land ecosystems in Yunnan from 2000 to 2020 (unit: 10^8 yuan).

Category	2000		2005		2010		2015		2020	
	ESV	Percent Age (%)	ESV	Percent Age (%)	ESV	Percent Age (%)	ESV	Percent Age (%)	ESV	Percent Age (%)
Food production	179.82	2.52	179.50	2.51	179.09	2.50	178.56	2.49	177.65	2.47
Raw material	213.12	2.98	213.13	2.98	213.17	2.98	212.73	2.97	212.53	2.95
Water supply	13.09	0.18	13.51	0.19	14.27	0.20	17.66	0.25	21.14	0.29
Gas regulation	718.05	10.05	718.05	10.05	718.18	10.05	716.70	9.99	715.81	9.94
Climate regulation	1916.02	26.82	1916.72	26.83	1918.06	26.83	1914.82	26.70	1915.09	26.60
Purifying the environment	585.19	8.19	585.41	8.19	585.88	8.19	586.38	8.18	587.62	8.16
Hydrological regulation	1561.67	21.86	1561.28	21.85	1562.73	21.86	1590.09	22.17	1613.44	22.41
Soil conservation	828.33	11.60	828.52	11.60	828.92	11.59	827.34	11.53	826.68	11.48
Maintaining nutrient circulation	72.77	1.02	72.74	1.02	72.72	1.02	72.54	1.01	72.39	1.01
Biodiversity	732.34	10.25	732.61	10.25	733.12	10.25	732.31	10.21	732.38	10.17
Aesthetic Landscape	323.11	4.52	323.22	4.52	323.46	4.52	323.34	4.51	323.56	4.49
Total	7143.52	100.00	7144.69	100.00	7149.59	100.00	7172.46	100.00	7198.28	100.00

3.2.3. Spatial Distribution of Ecosystem Service Value

This study calculates the changes of ESV in 16 states and cities from 2000 to 2015 (Table 6), and overall, 50% of Yunnan's cities and towns have low and lower ESV, with Pu'er having the highest ESV at 867.11 × 10^8 yuan in 2020. Dehong is the lowest ESV at only 203.17 × 10^8 yuan in 2020. The natural breakpoint method was used to classify the levels of ESV in 16 states and cities into five classes (Figure 4), where darker colors represent higher ESV levels. Nujiang, Yuxi and Dehong had the lowest levels. Lincang, Kunming, Xishuangbanna, Zhaotong and Baoshan had lower levels. Qujing, Diqing and Lijiang are at an intermediate level. Honghe, Wenshan, Dali and Chuxiong are at a higher level. Pu'er was at the highest level.

Table 6. ESV in Yunnan states and cities from 2000 to 2020.

Area	ESV (10^8 Yuan)					Change Rate (%)
	2000	2005	2010	2015	2020	
Kunming	388.11	387.75	388.32	386.09	379.73	−2.16
Qujing	481.14	481.02	480.71	480.67	480.35	−0.17
Yuxi	291.02	290.95	291.04	290.85	290.36	−0.22
Baoshan	354.64	354.91	354.84	357.31	348.57	−1.71
Zhaotong	370.31	370.56	371.04	371.77	376.83	1.76
Lijiang	431.65	431.60	431.74	435.38	432.42	0.18
Pu'er	848.33	848.74	849.36	860.09	867.11	2.21
Lincang	403.31	404.11	404.48	410.49	410.11	1.69
Chuxiong	528.25	528.29	528.76	528.87	533.28	0.95
Honghe	596.67	596.62	597.02	595.17	597.75	0.18
Wenshan	560.82	560.76	561.40	560.70	565.59	0.85
Xishuangbanna	369.56	369.48	370.06	369.59	377.32	2.10
Dali	541.27	541.31	541.80	543.64	544.37	0.57
Dehong	202.96	202.97	203.10	204.83	203.17	0.11
Nujiang	305.56	305.56	305.72	305.62	309.78	1.38
Diqing	469.98	469.98	470.04	470.77	479.06	1.93

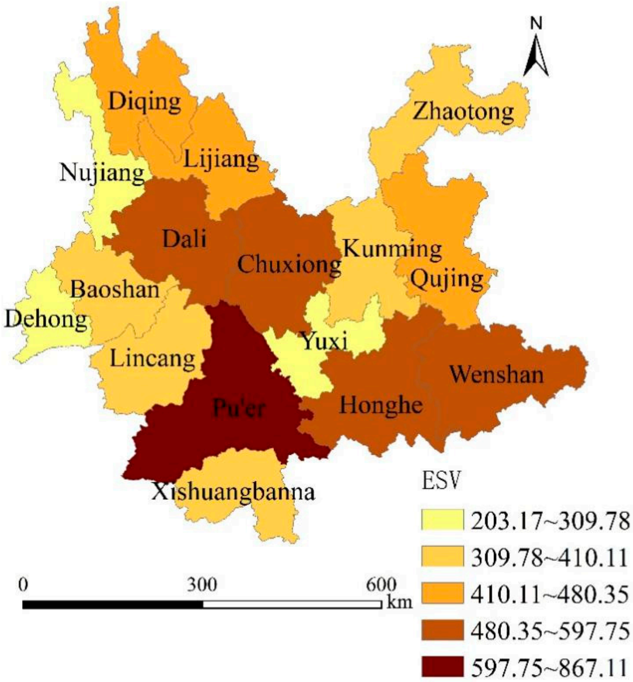

Figure 4. Spatial distribution of ESV in 2020.

Figure 4 and Table 6 show that: (1) From 2000 to 2020, no significant changes in ESV are observed in all the states and cities. The ESV of Kunming, Baoshan, Yuxi and Qujing show a decreasing trend, decreasing by 2.16%, 1.71%, 0.22% and 0.17%, respectively. The remaining states and cities show an increasing trend, with the largest increase of 2.21% in Pu'er. This outcome is mostly attributable to the enhancement of ecosystem services brought about by the proper preservation of forest land and the restoration of cultivated land. (2) Spatially, ESV in Yunnan shows high levels in the northwest, southwest and east, mainly because the ecological civilization strategy is well-practiced, which makes ecological land such as forest land and water body increase, contributing to high ESV levels. The low level of ESV is located at the northeast, west and central parts, mainly because of the high increase in the proportion of construction land caused by urban expansion, which reduced the ESV levels.

3.2.4. Spatial Autocorrelation Analysis of ESV in Yunnan

Through the spatial autocorrelation analysis of Yunnan ESV by Moran's I, it was found that the Moran's I index of Yunnan ESV from 2000 to 2015 is above 0.400 and the *p* value is less than 0.001, indicating that Yunnan ESV had significant spatial positive correlation and aggregation at the level of 0.001. Among them, the Moran's I index in 2020 is the lowest, only 0.3993. The spatial positive correlation had a weakening trend, as shown in Table 7.

Table 7. Spatial autocorrelation of ESV in Yunnan from 2000 to 2020.

Year	Moran's I	Z-Score	*p*-Value
2000	0.4113	36.8344	0.001
2005	0.4110	36.8122	0.001
2010	0.4102	36.7354	0.001
2015	0.4091	36.6358	0.001
2020	0.3993	35.7759	0.001

Figure 5 shows the spatial autocorrelated aggregation of ESV in 2000 and 2020. The high–high cluster area is dispersed, but the changes are not significant. On the whole, the spatial autocorrelation of ESV in Yunnan presents a distribution pattern of "west high-east low", of which the high–high clusters are concentrated in Diqing, Nujiang, Lijiang, Pu'er and Xishuangbanna. Low–low clusters are concentrated in Zhaotong and Qujing. Not significant areas are widely distributed throughout the province.

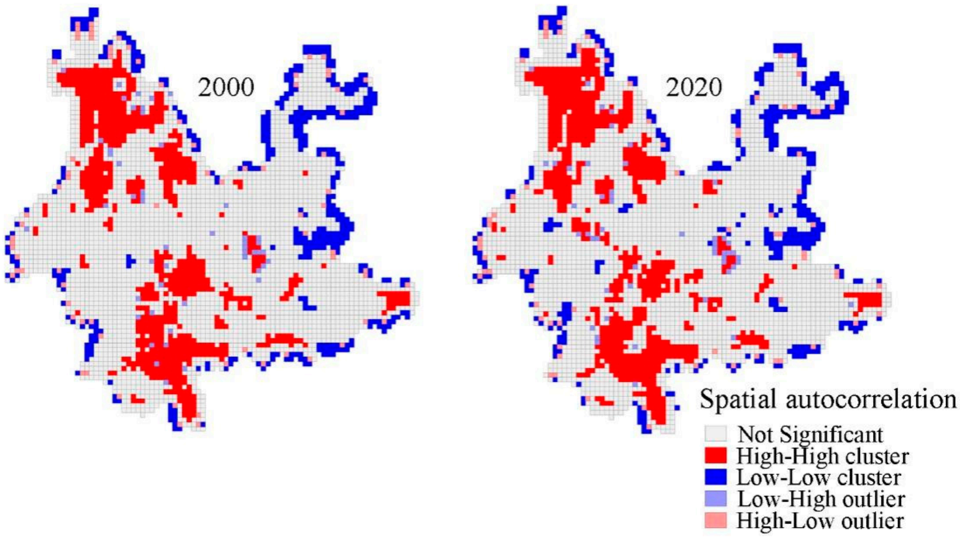

Figure 5. Spatial autocorrelation aggregation of ESV in 2000 and 2020.

3.3. Contribution of Different Land Use Types to Changes in the Value of Ecological Services

Table 8 shows the ecological contribution rates of different land use types from 2000 to 2020. The changes of ecological contribution rates in different land use types from 2000 to 2010 is similar. Forest land has the largest contribution rates to the change of ecosystem service value, 59.23% and 60.13%, respectively. The ecological contribution rates of cultivated land, water body, grassland and unused land decrease sequentially. From 2010 to 2015, the ecological contribution rates of different land use types show great differences. The largest ecological contribution rate is seen from water body, accounting for 68.01%. The ecological contribution rates of forest land decrease from 60.13% to 15.01%. This mainly related to the significant increase in water body and the decrease of forest land at this stage. From 2015 to 2020, grassland contributed the most to the change in the value of ecosystem services, followed by forest land and water body, with 31.82% and 28.72%, respectively. Based on the conditions of the four stages, it is demonstrated that the key contributor and sensitivity element is the change in ecological service value produced by forest land, grassland and water body, which has a significant impact on the change in overall service value in the region.

Table 8. Ecological contribution rates of different land use types from 2000 to 2020 (unit: %).

Period	Cultivated Land	Forest Land	Grassland	Water Body	Built-Up Land	Unused Land
2000–2005	25.25	59.23	1.13	12.02	0.00	2.37
2005–2010	18.41	60.13	5.63	14.68	0.00	1.15
2010–2015	3.59	15.01	9.38	68.01	0.00	4.00
2015–2020	3.12	31.82	35.05	28.72	0.00	1.29

4. Discussion

Understanding the pattern and extent of land use change is conducive to improving the quality of the global ecological environment and promoting the coordinated development of human–land relations [37]. The implementation of Western development has led to rapid population growth, accelerated urbanization and rapid economic development in Yunnan, which has also led to changes in the land use structure. This study investigated land use and the value of ecosystem services in Yunnan based on five periods of land use data from 2000 to 2020 and analyzed the spatial and temporal evolution characteristics of the value of ecosystem services under land use change. The findings were largely consistent with Yang et al. [38], which showed that forest land is the main type of land use in Yunnan, and that cultivated land, grassland, water body and built-up land increased. Meanwhile, it also confirmed the prediction that the main features of land use change is a rapid expansion of building land and an upward trend in the value of ecosystem services in Yunnan in 2020 [39].

Some scholars also believe that land use change is driven by human economic activities, increasing human demand for food, water, shelter [40] and human actions [41], which have changed the way humans use land. Chen [42] argued that changes in forest land area are mainly associated with timber harvesting and urban expansion. Accelerated urbanization [43], massive labor migration out of the country, and the need for infrastructure construction, etc., to occupy large amounts of land, have changed the pattern of land use. In addition to this, the implementation of land policies, such as two different policies of deforestation and afforestation in different regions, has led to significant spatial heterogeneity in forest land change [44].

Land use change is the main driver of ecosystem services value. Wu [45] concluded that changes in land use and land cover cause ecosystem structure and function. Tariq Aziz [46] argued that the reduction of forest and grassland area makes the value of climate services decrease, while the increase in watershed area makes the value of water supply services increase. This study also maintained that the amount of change in the value of ecological services generated by woodlands, grasslands and watersheds are the main contributors and sensitive factors that affect the total value of regional services. At the same time, natural factors such as climate and topography, as well as socioeconomic factors such as population and industrial structure also have an impact on the value of ecosystem services [47]. Factors that quantitatively analyze ecosystem service value changes were not considered. Therefore, we will consider the influence of economic, social and ecological factors on the value of ecosystem services in the context of Yunnan in future research.

5. Conclusions

In this paper, the value of ecosystem services under different land use types was investigated with Yunnan as an example. We can draw the following conclusions:

(1) Yunnan is mainly based on cultivated land, grassland and forest land, accounting for about 97% of the total area, of which the forest land area accounted for the largest

proportion (more than 57%). From 2000 to 2020, cultivated land, grassland and unused land show a decreasing trend. Forest land, water body and built-up land show an increasing trend. During the study period, the dynamics change of comprehensive land use is small, of which the change in built-up land is the most obvious, and the positive change in water body and forest land was positive. The dynamics of cultivated land, grassland and built-up land were all negative. The transfer of forest land is the most obvious, and the main sources of transfer in and transfer out are cultivated land, grassland and water body. The rate of change of the land use degree composite index shows a fluctuating upward trend, of which the land use degree reaches a maximum of 219.63 in 2020.

(2) The ecosystem service value in Yunnan shows an increasing trend from 2000 to 2020, with the total value increasing by 0.77%. The ESV of cultivated land and grassland decreases, and the ESV of forest land, water body and unused land increases. ESV for water supply, gas regulation, climate regulation, environmental purification, and hydrological regulation account for 67% of total ESV. The value of food production, raw material production, soil conservation, and maintenance of nutrient cycles show a gradual decreasing trend, and the value of water resources supply and hydrological regulation increases. The values of other service functions show a trend of first increasing and then decreasing. The ESV of Kunming, Qujing, Yuxi and Baoshan decline, while the remaining states and cities show an upward trend, of which Pu'er is the largest.

(3) From 2000 to 2020, the Moran's I index of Yunnan ESV is above 0.400 and the p-value is less than 0.001, which has significant spatial positive correlation and aggregation, but the spatial positive correlation of ESV weakens. On the whole, the spatial autocorrelation of ESV in Yunnan shows a distribution pattern of "west high-east low", and high–high type and low–low type have significant aggregation effects in the study area.

(4) From 2000 to 2010, the ecological contribution rate of forest land is the largest, and the ecological contribution rate of cultivated land, water body, grassland and unused land decreases sequentially. From 2010 to 2015, the ecological contribution rate of water body to the change in the value of ecosystem services is the largest, accounting for 68.01%, while the ecological contribution rate of forest land is only 15.01%. From 2015 to 2020, grassland contributed the most to changes in the value of ecosystem services, followed by forest land and water body, with 31.82% and 28.72%, respectively. In summary, forest land, grassland and water body are the main contributors and sensitive factors causing ESV change.

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