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Exploring Spatiotemporal Changes in Ecosystem Service Values and Hot Spots in Xishuangbanna, Southwestern China

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Abstract:
Xishuangbanna, on the southwestern border of China, is located in the upper reaches of the Mekong River between the Indo-China Peninsula and the East Asian continent. It is the largest tropical rain forest and monsoon forest in China. These forests have an irreplaceable ecological service function, and are an important barrier to maintaining the ecological security of the Mekong River transboundary basin of the Lancang River. We based this study on four sets of remote sensing data (1996, 2003, 2010 and 2016), and explored the spatiotemporal changes inXishuangbanna. We also made an assessment of the different ecosystem values of six types of ecosystem in Xishuangbanna, based on related theories of ecological economics. Results showed that thevalues of its ecosystem services (ES) in 1996, 2003, 2010 and 2016 were 70.4014 billion yuan, 70.2115 billion yuan, 68.5129 billion yuan and 63.6098 billion yuan, respectively. The total value shows a continuously decreasing trend, reflecting the continuous decline in the ability of the ecosystem to provide services to humans. If divided by types, forest and rubber ecosystems supplied the greatest proportion of service values. From the perspective of service types, soil formation and protection accounted for the largest proportion, followed by gas regulation and biodiversity protection. It was useful to study the ES value (ESV) when exploring the sustainable development of resources and economy.
***Keywords**: Ecosystem service values, Hotspots, Spatiotemporal changes, SouthwesternChina*

I. INTRODUCTION

Ecosystem services (ES) are the various benefits that humans receive from ecosystems, and include supply services, regulation services, support services and cultural services [1, 2]. The intensification of human activities has greatly accelerated changes in the climate, environment and ecosystems of the planet. Urban ecosystems are increasingly threatened by urban population growth, urban land use expansion [3-6] and socioeconomic activities [7, 8], which affect the value of ES and ultimately the sustainable development of human society [9, 10]. Accurate assessment of ESV is essential for urban construction planning and for the improvement and restoration of urban ecosystems[11], so it has received increasing attention from the research community[4, 12-14].

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As Costanza et al. proposed the value of ES, especially after the Millennium Ecosystem Assessment, the impact of human activities on ecosystems has become an important research direction[10, 15]. Many scholars have emphasized that human activities are an important driving force in changing ES[16, 17]. The true economic value of ES depends on the interaction between the supply of ecosystems and the needs of society [15, 18]. Monetary valuation of the importance of ES to society can serve as a powerful and essential communication tool to provide a basis for better and more balanced decisions[19]. Scholars have found that basic income transfers can be a convenient way to determine ESVs globally and nationally, assuming a constant unit value per hectare for a given ecosystem type multiplied by the area of each type to arrive at a total [14].

The value of ES reflects not only the functions of ES, but also the significance of the human ecological environment and the demand for ES. Similarly, many scholars have analyzed the spatiotemporal changes of ESV, and their responses to land use changes[20-22] or other human activities[23]. Although it is important to have a better understanding of the temporal changes in ESVs, there is an increasing focus on determining the spatial changes in ESVs by identifying “hot spots” of ES[24]. These spatial studies can provide a range of useful tools that can effectively integrate ES into planned or current conservation plans[25], assess the effectiveness of implementing ecological policies and prioritize the management of ES[24, 26]. This information is particularly important for modifying current ecological protection plans and policies in a more beneficial and targeted manner. For example, by linking the spatial changes in wetland areas with the provision of ES and economic value, some scholars have analyzed the spatiotemporal changes in the service value of coastal landscapes in southern Sinaloa (Mexico) [23]. Bottalico evaluated the spatial distribution of Molise ESV by developing a spatial explicit method[27]. Li et al. verified the spatiotemporal changes in ESV and its hot and cold issues in China[24]. However, ESVs are less well characterized by hot spots that change over a specific spatial range, especially globally and nationally.

Policy change in Xishuangbanna has led to economic development and increased urbanization. As a result the transformation and occupation of land resources has intensified, resulting in a periodical sharp change in land use types and areas. This change has had a great impact on ESV. We investigated the spatiotemporal changes in ESV and identified hot spots of ESV change. The analysis was based on four-phase remote sensing image data from 1996 to 2016. In this context, studying the impact of ES in Xishuangbanna from the perspective of land use change in Xishuangbanna can clarify the state of the ecosystem under the "stress-state-response" in Xishuangbanna. This is of great significance in allowing managers to adjust and optimize the land use pattern there, promoting the coordination of its sustainable development and protecting the stability of cross-border ecological security.

II. MATERIALS AND METHODS

2.1 Study Area

Xishuangbanna is located at 21°10′–2°40′ N and 99°55′–101°50′ E, on the southernmost edge of the Tropic of Cancer. The land area is 19,124.50 km2. It is bordered by Puer City in the northeast and northwest, Laos in the southeast and Myanmar in the southwest, and its border extends for 966.3 km. The highest altitude

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is 2429 m and the lowest is 477 m. The whole state has jurisdiction over one city (Jinghong City) and two counties (Menghai County and Mengla County). The climate is warm and moist all year round. There are only two seasons: dry and wet. The dry season runs from November to April, and the wet season runs from May to October.

2.2 Data Sources and Processing

The social and economic data of Xishuangbanna included publicly released data such as the website of the National Bureau of Statistics of the People's Republic of China and the statistical yearbook of Xishuangbanna. The remote sensing image data included images from vegetation-free, cloud-free data sets. These consisted of four Landsat TM/TM + / OLI remote sensing images from March to April in 1996, 2003, 2010 and April 2016.

To construct a remote sensing interpretation mark for land use we referenced the second-level survey data of forest resources in 2006 and 2016, based on field surveys, combined with remote sensing data spectral information. We used the support vector machine (SVM) supervised classification method for We interpreted the land use type data and obtained the land use types in the fourth phase of the study area. After the four-phase image classification, the total accuracy Kappa coefficients were 85.9%, 86.7%, 89.9% and 93.5%, and these values met our research needs.

2.3 Calculation of ESV in Xishuangbanna

2.3.1 Ecosystem classification

We divided the ecosystem in Xishuangbanna into forest ecosystem, rubber ecosystem, tea garden ecosystem, farmland ecosystem, watershed ecosystem and construction land ecosystem (Table I), according to China's latest classification standard for land use status (GB/T21010-2007), and combined with the actual local conditions.

TABLE I.The ecosystem classification system in Xishuangbanna

	Forest ecosystem	Tea garden ecosystem	Farmland ecosystem	Watershed ecosystem	Rubber ecosystem	Construction land ecosystem
Classification	Natural forest	Tea garden	irrigate farmland	Langcang River	Rubber	Residential area
	Plantation		Rice Fields	Reservoir		Road
	Secondary forest		dry land	River		Mining farm
	Economic forest			Wetlands		Public land

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2.3.2 ESV evaluation method in Xishuangbanna

(1) Modification of Xishuangbanna ESV equivalent factor

In this study we took the tea garden ecosystem as the average value of woodland and grassland[28]. The forest ecosystem equivalent factor was revised to 1.96 times the national average[29], and the rubber ecosystem equivalent factor was revised to 1.60 times the national average[30]. These amendments allowed us to obtain the Xishuangbanna ESV equivalent scale (Table **II**).

TABLEII. Xishuangbanna ESV Equivalent Scale

	Forest ecosystem	Tea garden ecosystem	Farmland ecosystem	Watershed ecosystem	Rubber ecosystem	Construction land ecosystem
Air egulation	6.86	2.15	0.5	0	5.6	0
Climate regulation	5.292	1.8	0.89	0.46	4.32	0
Water conservation	6.272	2	0.6	20.38	5.12	-7.51
Soil formation and protection	7.644	2.92	1.46	0.01	6.24	0.02
Waste treatment	2.5676	1.31	1.64	18.18	2.1	-2.46
Biodiversity conservation	6.3896	2.17	0.71	2.49	5.22	0.34
Food production	0.196	0.2	1	0.1	0.16	0.01
Raw material	5.096	1.33	0.1	0.01	4.16	0
Recreation and culture	2.5088	0.66	0.01	4.34	2.05	0.01
Total	42.826	14.54	6.91	45.97	34.97	-9.59

(2) Functional value of food production per unit area of cultivated land ecosystem in Xishuangbanna

To eliminate the influence of crop price fluctuations on the total value in each year and region, the basic data were selected from the sown area, total output and average price of three main crops (rice, upland rice and corn) in 1997. According to research by XieGaodi, the economic value of a standard unit ecosystem service value equivalent factor is equal to 1/7 of the average market value of a single grain[29, 31]. The calculation (Eqn 1) is:

$$E_n = \frac{1}{7}\sum_{i=1}^{n}\frac{m_i q_i p_i}{M}\,(n = 1,2,3) \qquad (1)$$

where E_n is the economic value (yuan/hm2) of providing food production and service functions for a unit of cultivated land ecosystem; i is the type of crop; p_i is the price of $i$crops (yuan/kg); q_i is the yield of i food crops (kg/hm2); m_i is the area of i food crops (hm2); and M is the total area of n food crops (hm2).

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By referring to the Yunnan Statistical Yearbook 2006 we obtained relevant data about the three main crops in Xishuangbanna. According to the formula, the economic value of the ecosystem service value equivalent factor of a standard unit in Xishuangbanna was 959.34 yuan/hm2.

(3) Calculation method for Xishuangbanna ESV

We used the ESV formula of Costanza et al. to calculate the ESV of Xishuangbanna[32]. To facilitate analysis of the changes in the value of ES in Xishuangbanna and to compare the value of ES in different regions, we added two indicators to the method of calculating ecosystem service values, the ES contribution rate (ESCR) and ES value per unit (UESV) [33]. The value of the ecosystem per unit area was to reduce the difference in the size of different ecosystems and to facilitate comparison. The calculation (Eqn 2-5) was:

$$\mathrm{ESV} = \sum \mathrm{V_i} \times \mathrm{A_i} \qquad (2)$$

$$\mathrm{ESV_k} = \sum \mathrm{V_{ki}} \times \mathrm{A_{ki}} \qquad (3)$$

$$\mathrm{ESCR} = \frac{\Delta \mathrm{ESV_k}}{\mathrm{ESV}} \qquad (4)$$

$$\mathrm{UESV} = \frac{\mathrm{ESV}}{\mathrm{A}} \qquad (5)$$

where ESV is the total value of ES in the study area; V_i is the ecosystem service value coefficient of ecosystem type i per unit area; A_i is the area of ecosystem type in the study area; ESV_k is the value of the k-th service of the ecosystem; V_{ki} is the k-th ecosystem service value coefficient of the i-th ecosystem type; ESCR is the change in the value of a single ecosystem service ΔESV_k to the total value of ES; and UESV is the ratio of total ecosystem service value ESV to total area A.

(4) Method of calculating coefficients of sensitivity (CS)

This study applied CS to measure the representativeness of individual ES to each ecosystem type and the accuracy of the value of ES per unit area [34]. CS is the change in the ecosystem service value coefficient V_i of the ecosystem type i per unit area caused by a 1% change in the ESV of the total ecosystem service value in the study area. CS> 1 indicated that ESV was elastic to V_i and that the accuracy of V_i was low. CS <1 indicated that ESV was inelastic to V_i, which indicated that V_i was more accurate and that the ESV estimation was accurate. The value of the ecosystem service value of each ecosystem type was increased or decreased by 50%, and the change in the elasticity coefficient of the total value of ES was analyzed [34, 35]. The calculation (Eqn 6) was:

$$\mathrm{CS} = \left| \frac{(\mathrm{ESV_j} - \mathrm{ESV_i})/\mathrm{ESV_i}}{(\mathrm{VC_{jk}} - \mathrm{VC_{ik}})/\mathrm{VC_{ik}}} \right| \qquad (6)$$

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where ESV is the total value of ES in the study area; VC is the coefficient of ecosystem service value per unit area; A_i is the area of ecosystem type in the study area; k is the kth service of the ecosystem; and i and j are the adjusted values of initial value and ecological value coefficient, respectively.

III. RESULTS

3.1 Analysis of the Magnitude of Changes in the Ecosystem Types in Xishuangbanna

During 1996-2016 Xishuangbanna was mainly dominated by forest ecosystems and rubber ecosystems (TableIII). Followed by tea gardens, cultivated land, construction land and water ecosystems. The area of forest ecosystem has continued to decrease over the past 20 years. The forest ecosystem always occupied the most important place.

TABLEIII. The ecosystem area and it's changes of Xishuangbanna in 1996, 2003, 2010 and 2016 (Unit: hm2)

Region	Ecosystem types	1996	2003	2010	2016
Mengla	Forest Ecosystem	550200.8	556872.5	435086.3	411246.7
	Tea garden Ecosystem	6454.302	11547.04	5619.288	36118.85
	Cultivated Land Ecosystem	23642.56	9607.362	12267.72	22678.29
	Watershed Ecosystem	2988.622	1097.467	923.295	1349.821
	Rubber Ecosystem	93193.46	96851.19	224655.3	204837.3
	Construction Ecosystem	4342.409	4832.425	2258.433	4624.498
Jinghong	Forest Ecosystem	508889.2	501189.6	378588	360284.5
	Tea garden Ecosystem	10495.19	22042.06	16180.52	37872.7
	Cultivated Land Ecosystem	45614.42	27883.39	38082.99	60716.74
	Watershed Ecosystem	3508.773	3345.914	3544.311	5188.589
	Rubber Ecosystem	122066.9	136037	256865.7	225990.9
	Construction Ecosystem	7292.929	7366.34	4599.911	7877.452
Menghai	Forest Ecosystem	361071.7	309390.2	307818.9	268300.3
	Tea garden Ecosystem	13788.93	41001.85	39764.94	87537.86
	Cultivated Land	23735.12	31668.89	34964.58	62585.72

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	Ecosystem				
	Watershed Ecosystem	728.734	2067.243	1315.16	1924.097
	Rubber Ecosystem	125612.6	139054.2	141983	102277.3
	Construction Ecosystem	8823.285	10595.38	7931.704	11038.48
Xishuangbanna	Forest Ecosystem	1420162	1367452	1121493	1039831
	Tea garden Ecosystem	30738.42	74590.94	61564.75	161529.4
	Cultivated Land Ecosystem	92992.1	69159.64	85315.28	145980.8
	Watershed Ecosystem	7226.129	6510.624	5782.767	8462.507
	Rubber Ecosystem	340873	371942.3	623504	533105.5
	Construction Ecosystem	20458.62	22794.14	14790.05	23540.43

After 1996 the area of rubber ecosystem continued to increase until 2010. However, under the influence of natural rubber prices and the national policy of returning forests to forests, the area of rubber ecosystems decreased. From 2003 the situation changed significantly: from 2003 to 2010, the rubber ecosystem area of Mengla and Jinghong increased sharply.

From 1996 to 2016, the area of tea garden ecosystem in Xishuangbanna increased first, then decreased and then increased. The process of tea garden change was related to the changes in rubber planting. After 2010, the area of rubber plantation decreased, and the price of tea in Xishuangbanna continued to rise, resulting in an increase in the area of tea gardens. From 1996 to 2016 the cultivated land ecosystem showed an overall increase trend of first decrease and then increase. Changes in water ecosystems and construction land ecosystems were less apparent than in other ecosystem types.

3.2 Changes in Total ES Values in Xishuangbanna from 1996 to 2016

3.2.1 ESV of different ecosystem types in Xishuangbanna from 1996 to 2016

The values of different ES from 1996 to 2016 are shown in Table IV.

TABLEIV. Ecosystem service values of each ecosystem type in Xishuangbanna from 1996 to 2016

Ecosystem types	1996		2003		2010		2016	
	Value(100 million yuan)	%	Value(100 million yuan)	%	Value(100 million yuan)	%	Value(100 million yuan)	%
Forest	583.2746	82.2	561.6264	79.9	460.6084	67.2	427.0692	66.7

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Ecosystem		3		9		3		7
Tea garden Ecosystem	4.2859	0.60	10.4002	1.48	8.584	1.25	22.522	3.52
Cultivated Land Ecosystem	6.1635	0.87	4.5839	0.65	5.6547	0.83	9.6756	1.51
Watershed Ecosystem	3.1857	0.45	2.8703	0.41	2.5494	0.37	3.7308	0.58
Rubber Ecosystem	114.3118	16.12	124.7308	17.77	209.0921	30.52	178.7769	27.95
Construction Ecosystem	-1.8814	-0.27	-2.0961	-0.30	-1.3601	-0.20	-2.1648	-0.34
Total	709.3401	100.00%	702.1154	100.00%	685.1285	100.00%	639.6097	100.00%

Among the ESV of different ecosystem types, the ecological value coefficients of forest ecosystems and rubber ecosystems were high. Changes in the area of such ecosystems will greatly affect the changes in ecosystem service values.

Table IV indicates that the ESV of Xishuangbanna in 1996, 2003, 2010 and 2016 showed a continuous decrease, reflecting that the ability of its ecosystems to provide services to humans has been continuously decreasing. Its ESV in 1996, 2003, 2010 and 2016 were 70.4014 billion yuan, 70.2115 billion yuan, 68.5129 billion yuan and 63.6098 billion yuan, respectively. The total value showed a continuously decreasing trend, reflecting the continuous decline in the ability of the ecosystem to provide services to humans.

In terms of the proportion of ecosystem service value, the forest land ecosystem showed the highest value, and was the most important component of the ESV (66.77%–82.23%), followed by the rubber ecosystem (16.12%–30.52%). The area had high levels of forest coverage, and the ecological environment was generally well preserved. However, as human society and economy developed, the ES showed a continuous decline. Where forest land and rubber ecosystems accounted for a large proportion of the whole, their ESV represented 94.71%–98.35% of the total value. It can also be seen that woodland and rubber ecosystems dominated the ES.

The construction land ecosystem had the lowest (and negative) value, and its service value continued to show negative growth, from -6.6847 billion yuan in 1996 to -7.6916 billion yuan. These figures were also in line with the reality of the increasing area of construction land.

According to research, the ESV of rubber in Xishuangbanna was far less than that of tropical rain forests and secondary vegetation (67.149 million yuan/(hm2.a)), the proportion of which was about 56.74%. The ecological service value of evergreen coniferous forest (13,315 yuan/(hm2.a)) was large[31]. The service value of the rubber forest ecosystem was far greater than the average value of tropical forests in China (16.056 million yuan/(hm2.a)) [36]. The ecological and economic value of rubber forests was only about 50% of the value of tropical rain forests and secondary vegetation. Cutting down tropical rain forests and planting rubber forests was not desirable from the perspective of total regional ecological and economic value, and was not

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conducive to regional natural asset appreciation and local sustainable development[37].

The direct economic output of a rubber forest is much larger than that of a tropical rain forest. This is the source of huge economic pressure on tropical rain forest protection. It is recommended to adopt environmental and economic policies such as ecological compensation to comprehensively protect tropical rain forest[37].

3.2.2 Changes in ESV of different ecosystem types in Xishuangbanna from 1996 to 2016

The total reduction in ESV from 2010 to 2016 (16.17153 billion yuan) was 630.19% of the total reduction in ESV from 1996 to 2003, which is the time period when ESV changed the most. During 2010-2016 the rapid development of urbanization, continuous decline in rubber prices, rise in the prices of tea and crops, and the continuous advancement of the country's policy of "returning rubber to forests" made the value of the Xishuangbanna ecosystem the most significant. Total reduction in ESV from 2003 to 2010 (6.03301 billion yuan). The period from 1996 to 2003 experienced the smallest total reduction in ESV (2.556614 billion yuan).

The ESV of forest ecosystems continued to decline. The change in the forest ecosystem ESV was the most dramatic change among all ecosystem types, from 82.23% of the total ESV in 1996 to 66.77% of the total ESV in 2016. The period when the ESV of the forest land ecosystem changed the most was from 2003 to 2010. During this period, especially from 2003 to 2007, the continuous increase in worldwide rubber prices resulted in the replacement of a large number of forest land ecosystems with rubber ecosystems. The rubber ecosystem ESV increased sharply and the forest land ecosystem ESV decreased sharply. The total reduction in ESV of forest land ecosystems from 2003 to 2010 (35.87842 billion yuan) was 64.67% of the total reduction from 1996 to 2016 (55.49324 billion yuan).

The ESV of the tea garden ecosystem decreased first, then increased sharply and increased overall. From 2003 to 2010, the ESV of the tea garden ecosystem decreased. During this period, the tea price in Xishuangbanna was low, and rubber was the main source of income in the local economy. From 2010 to 2016, the tea market in Xishuangbanna was opened. The prices of tea rose sharply, especially those from several famous tea mountains, and the ESV (4.995 billion yuan) of the tea garden ecosystem increased sharply.

The ESV of cultivated land ecosystems showed a trend of first decline, then slow increase and overall growth. It decreased by 56106 million yuan from 1996 to 2003, then continued to increase from 2003 to 2010 and from 2010 to 2016. The biggest change was from 2010 to 2016. The total increase in ESV of forest land ecosystems (1.42819 billion yuan) from 2010 to 2016 was 114.49% of the total increase in ESV of forest land ecosystems (1.224746 billion yuan) from 1996 to 2016.

The ESV of water ecosystems first decreased, then generally increased slowly.

3.3 Changes inTotal Values in Single Ecosystem Services in Xishuangbanna from 1996 to 2016

3.3.1 ESV in the individual ES from 1996 to 2016

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Of the various ESVs in Xishuangbanna, soil formation and protection account for the largest proportion (17.86%–17.93%), followed by air regulation (15.80%–15.92%), biodiversity protection (14.86%–14.91%), water conservation (14.48%–14.57%), climate regulation (12.34%–12.35%), raw materials production (11.61%–11.78%) and – the smallest proportion – food production (0.56%–0.70%) (Table **V**).

TABLEV. Evaluation of ecosystem service of different types in Xishuangbanna from 1996 to 2016

Individual ecosystem services	1996		2003		2010		2016	
	Value(100 million yuan)	%	Value(100 million yuan)	%	Value(100 million yuan)	%	Value(100 million yuan)	%
Food production	4.1512	0.59	3.9549	0.56	4.0058	0.59	4.4911	0.70
Raw material	83.4826	11.77	82.6823	11.78	80.5464	11.76	74.2826	11.61
Air regulation	112.8175	15.90	111.8080	15.92	108.9442	15.90	101.0697	15.80
Climate regulation	87.5521	12.34	86.7146	12.35	84.5643	12.34	78.9300	12.34
Water conservation	103.2227	14.55	101.9738	14.52	99.8082	14.57	92.6174	14.48
Waste treatment	44.4557	6.27	43.7798	6.24	42.9431	6.27	41.5826	6.50
Soil formation and protection	126.6771	17.86	125.5667	17.88	122.4488	17.87	114.7029	17.93
Biodiversity conservation	105.6038	14.89	104.6699	14.91	101.9862	14.89	95.0425	14.86
Recreation and culture	41.3773	5.83	40.9656	5.83	39.8816	5.82	36.8908	5.77
Total	709.3401	100.00	702.1154	100.00	685.1285	100.00	639.6097	100.00

This ranking result was quite different from urban areas with low forest coverage. For example, in a study of urban ecosystem service values, hydrological regulation accounts for the largest proportion in various ESVs[33, 38]. The second largest proportion is waste treatment and biodiversity maintenance [33, 38].

The essence of ESV change is the area change in different ecosystems and the variation between equivalent factors in different ecosystems. Therefore, the trend in the value of individual ES in Xishuangbanna from 1996 to 2016 was consistent (Fig 1).

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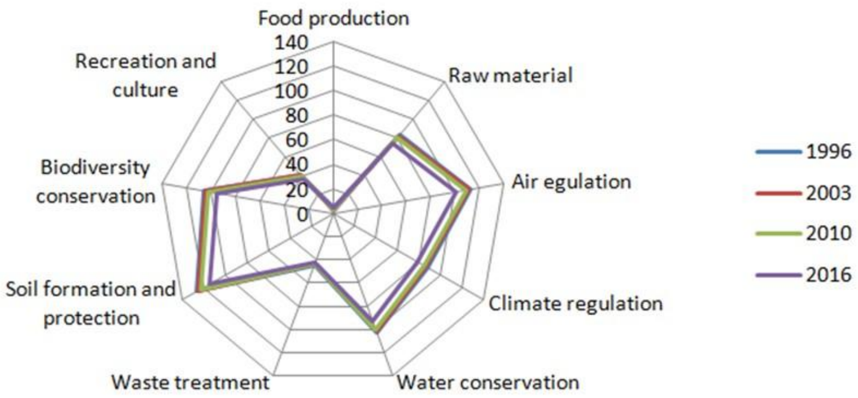

Fig 1:SingleESV of Xishuangbanna from 1996 to 2016

3.3.2 ESV changes in individual ES in Xishuangbanna from 1996 to 2016

Consideration of the contribution of each component to the reduction in total ESV indicated that the contribution of ESV change in water conservation from 1996 to 2003 was the largest (17.29%) (Table VI). The contribution of ESV change to soil formation and protection from 2003 to 2010 was the largest (18.35%). The largest contribution of gas-regulated ESV changes during the period 2010-2016 (17.30%). The largest contribution of changes in soil formation and protection of ESV during the period 1996–2016 (17.17%).

TABLEVI. Ecosystem services values change and its contribution rate

First classification	Second classification	Value billion				Contribution rate of value change/%			
		1996	2003	2010	2016	1996-2003	2003-2010	2010-2016	1996-2016
Supply services	Food production	4.1512	3.9549	4.0058	4.4911	2.72	-0.30	-1.07	-0.49
Supply services	Raw material	83.4826	82.6823	80.5464	74.2826	11.08	12.57	13.76	13.19
Regulation services	Air egulation	112.8175	111.8080	108.9442	101.0697	13.97	16.86	17.30	16.85
Regulation services	Climate regulation	87.5521	86.7146	84.5643	78.9300	11.59	12.66	12.38	12.36
Regulation services	Water conservation	103.2227	101.9738	99.8082	92.6174	17.29	12.75	15.80	15.21

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Regulation services	Waste treatment	44.4557	43.7798	42.9431	41.5826	9.36	4.93	2.99	4.12
Support services	Soil formation and protection	126.6771	125.5667	122.4488	114.7029	15.37	18.36	17.02	17.17
Support services	Biodiversity conservation	105.6038	104.6699	101.9862	95.0425	12.93	15.80	15.25	15.15
Cultural services	Recreation and culture	41.3773	40.9656	39.8816	36.8908	5.70	6.38	6.57	6.43
Total		709.3401	702.1154	685.1285	639.6097	100.00	100.00	100.00	100.00

3.3.3 Changes in the value of individual ES in different administrative regions of Xishuangbanna from 1996 to 2016

An analysis of the ecosystem service value of the three counties (Fig 2) showed that there were higher ESV values in Erhai County and Mengla County. Jinghong City (the seat of the state government) dominated urban construction in Xishuangbanna, and tourism there was developing rapidly. Erhai County was not suitable for planting rubber, and the proportion of the tea garden ecosystem there was relatively large; it was the main location for tea production in Xishuangbanna.

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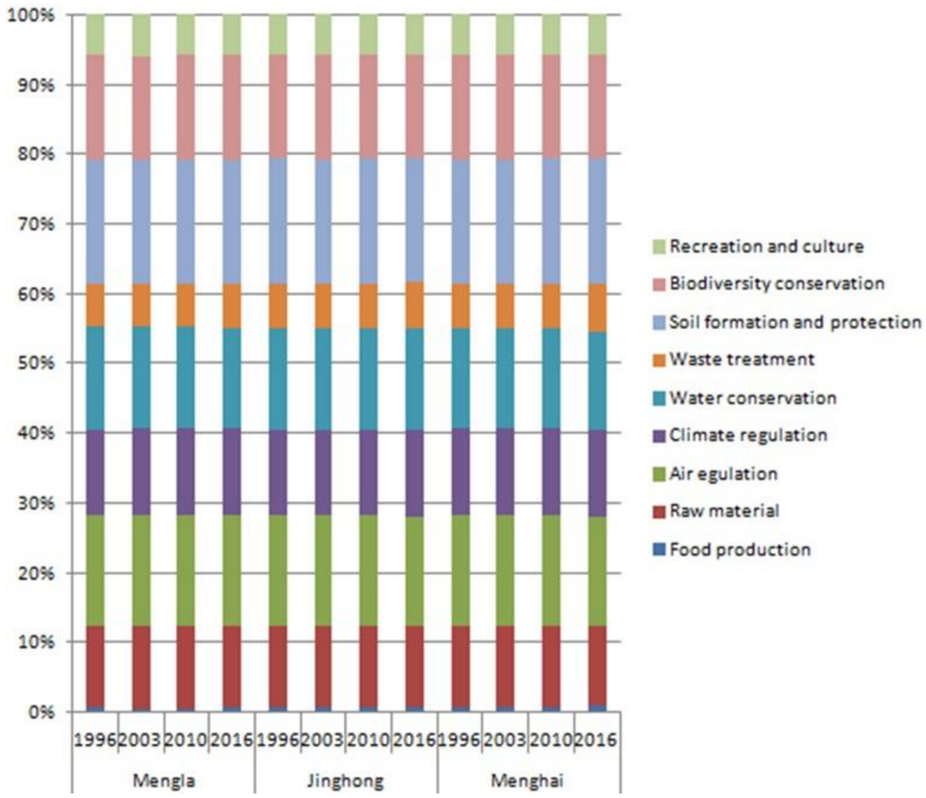

Fig 2: Value of individual ecosystem services in different administrative regions of Xishuangbanna from 1996 to 2016

3.4 Spatiotemporal Changes in ESV in Xishuangbanna

There were obvious spatial differences and temporal changes in ESV in Xishuangbanna (Fig 3). In 1996, land with an ESV of more than 3,000 yuan/ha accounted for more than 90% of the total area. The ESV value was the highest in the year. ESV dropped in 2003, mainly at 1000-2000 yuan/ha. In 2010, ESV rose, but the area was larger than 3,000 yuan/ha in 1996, and the change was mainly concentrated in Erhai County. The area of ESV of 1000-2000 yuan/ha in Erhai County increased. In 2016, ESV became more complicated and fragmented. High ESV areas were concentrated in Jinghong City and Mengla County, while Erhai County had fewer high ESV areas.

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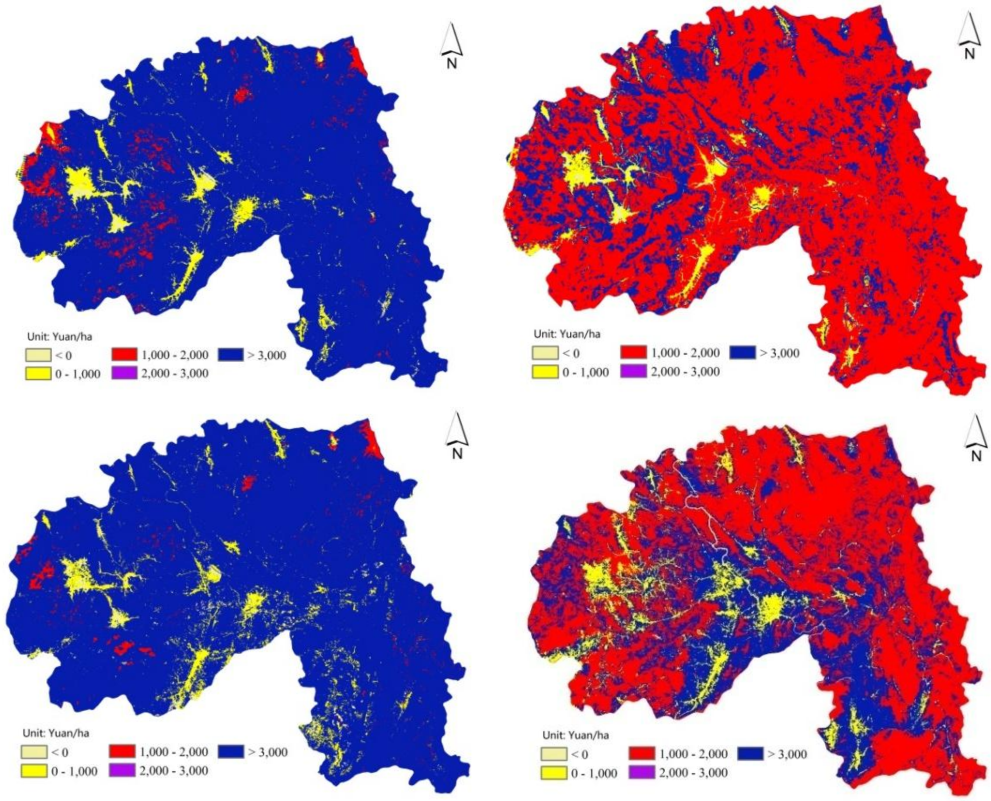

Fig 3: Spatial distribution of the total ESV in Xishuangbanna from 1996 to 2016

3.5 ES Sensitivity Analyses

CS results of all ecosystem types except forest land in 1996, 2003, 2010 and 2016 were all lower than 1. The equivalence factors used in the study appeared credible and accurate. This showed that the elasticity of the value coefficient of ESV was good, and that the estimation results of this study were credible.

Cold and hot spot distribution of ESV in Xishuangbanna

We used the Getis-OrdGi* tool in the spatial analysis module to perform cold and hot spot identification for the four ESVs of Xishuangbanna in 1996, 2003, 2010 and 2016. Spatial distribution of the high and low ESV agglomerations in the fourth phase of the study area was obtained. Compared with 1996, the area of high-value ESV accumulation in Xishuangbanna in 2003, 2010 and 2016 had been significantly reduced. The hot spots of ESV in 1996 were mainly distributed in Jinghong City and Mengla County. Cold spots were distributed in Erhai County. Since 2003, 99% of cold spots had increased and hot spots had disappeared (Fig 4).

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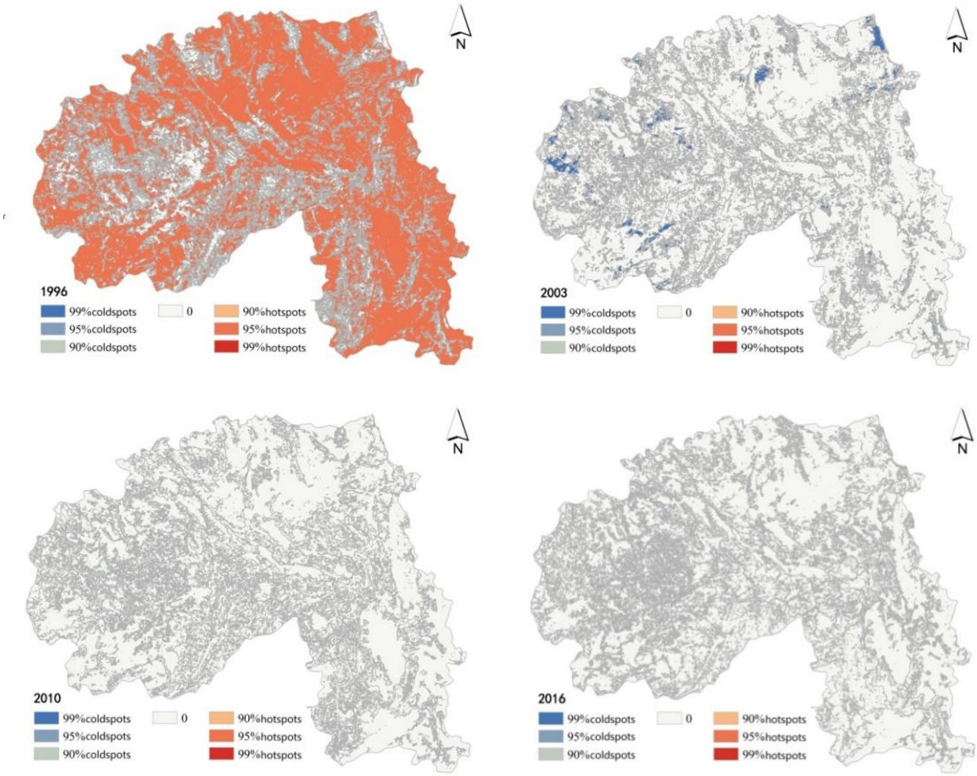

Fig 4: Cold and hot spot distribution of ESV in Xishuangbanna from 1996 to 2016

IV. CONCLUSION

Most scholars directly used the Chinese Terrestrial Ecosystem Unit Area Ecosystem Service Value Equivalence Table, such as XieGaodi, to assess the value of ecosystem services in counties, cities, and regions, and did not reflect regional differences. . Based on the actual situation of Xishuangbanna tropical area, this paper adjusts the equivalent factor of the ecological service value per unit area of the Xishuangbanna ecosystem.

During 1996–2016, the ESV in Xishuangbanna continued to decrease. Owing to the gradual decrease in the area of forest ecosystems, they had gradually been replaced by rubber, construction land, tea gardens, etc., in areas with low ecosystem service values. The overall value of ES in Xishuangbanna continued to decline. Forest land was the most important part of the ESV there, and so in future development a corresponding ecological compensation system should be introduced. This should strengthen the protection of forest land, especially natural forests, and continue to promote the policy of "returning rubber to forests" to avoid excessive development and natural forest cover The replacement of economic forests leads to ecological imbalances and ecological risks, and eventually triggers international ecological security issues.Therewere obvious spatial differences and temporal changes in ESV, and in hot and cold spots in Xishuangbanna. In 1996, land with an ESV of more than 3,000 yuan/ha accounted for more than 90% of the total area. ESV dropped in 2003, mainly at 1000-2000 yuan/ha. ESV rose in 2010, and changes were mainly concentrated in Erhai County. The area of ESV of 1000-2000 yuan/ha in Erhai County increased. In 2016, ESV became more

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