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The Ecosystem Service Value Calculation and Distribution of Ecological Compensation Based on Land Utilization—Take Hainan Rainforest National Park as an Example

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Abstract: *With the system of "Ecological Conservation Red Line" appearing, the ecosystem of national parks is gradually of great significance, but it is also necessary to concern about restoring ecosystem and ecological compensation. This study use the equivalent factor method to access the ecosystem services value and through natural breaks method in ArcGIS to spatially divide ecosystem service value and types of land use, and finally, calculate ecological distribution costs in different areas considering the demand intensity coefficient of ecological compensation. This paper aims to evaluate the ecosystem service of Hainan Rainforest National Park and further promote land utilization and the spatial distribution of ecological compensation to be more reasonable.The results are as follows:(1) The proportion of forest kept above 97%, and the total proportion of other land use types was less than 3%, showing obvious spatial and temporal differences. (2) From 2001 to 2019, the ecosystem service value showed an upward trend from 2001 to 2011 and a downward trend from 2012 to 2019, which was due to the gradual transformation of land use type to cropland, the decrease of support services and the increase of supply services. (3) The water has the highest priority of ecological compensation, indicating that the economic development level of the water is relatively backward, and more ecological compensation should be given. (4) In 2019, the total theoretical ecological compensation quota of Hainan Rainforest National Park was 1.435 billion yuan, of which the ecological compensation quota of water and forest was the highest.*

Keywords: *Land utilization; Ecosystem service value; Equivalent factor; Ecological compensation; Hainan Rainforest National Park*

1. Introduction

In recent years, the concept of protecting ecosystem environment and maintaining the coordination between resource exploitation and environmental protection under the "double carbon" strategy has attracted more and more attention from the society. In the 20th National Congress of China, General Secretary put forward the concept of green development, promoting harmonious coexistence between human and nature, deepening beautiful China Initiative, promoting integrated protection and management of mountains, rivers, forests, fields, lakes, grass and sand, advocating green and low-carbon development. Under such a macro background, the significance of ecological conservation and service of national parks is becoming more and more prominent. In the process of ecological resources development, the compensation and distribution of national parks have triggered a wide discussion in social circles. Exploring the impact of land use change on ecosystem service value and ecological compensation is conducive to promoting the rational utilization of forest and other land use resources in Hainan, and providing scientific basis for the development and protection of ecological resources under the background of social economy and local tourism industry recovery.

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2. Literature Review

Ecosystem services (ES) refer to the sum of benefits that humans get from the ecosystem, including supply services, regulating services, cultural services and support services [1]. At the end of the 19th century, some scholars carried out researches on quantitative accounting and value assessment of ecosystem services [2]. Since then, researches on the ecosystem service value have gradually developed into quantitative evaluation of ecosystem services by monetary value based on basic data, ecological principles, economics and sociological methods [3]. Eco-compensation is a relevant institutional arrangement aimed at protecting the ecological environment and making sustainable use of ecosystem services, adjusting the stakeholder relationship by economic means, promoting compensation activities and mobilizing the enthusiasm of ecological protection [4]. At present, international research focuses on the economic reasons, specific mechanisms, marketing approaches [5] and stakeholder distribution [6] of ecological compensation. While domestic research focuses on the formulation of ecological compensation policies [7], evaluation of ecological benefits and the standard and scope of compensation. With the widening of regional development gap, the method of taking economy as a single index to measure the level of social development is unscientific to a certain extent. In order to clarify the urgency of compensation between different units caused by the social development gap, ensure that areas with different ecological backgrounds can obtain reasonable compensation funds, and improve the timeliness and accuracy of ecological compensation, domestic and foreign scientists are committed to incorporating indicators evaluating the overall level of social development into the research on ecological compensation distribution [8].

At present, the research methods of ecosystem service value (ESV) mainly include energy method, value-based assessment method and equivalent factor method [9]. Energy method uses the energy system theory to construct, mainly through the standardization of the capacity and material in the ecological economy, to conduct quantitative analysis and research on the value of ecosystem services. Value-based assessment methods include carbon tax law [10], shadow price method, outcome reference method [11], willingness to pay method, etc. This kind of method relies on the classification and calculation of functional value, with numerous model parameters and complicated data information, which is suitable for the measurement of ecosystem services of a small range and a single category. The equivalent factor method directly calculates the average ecosystem service value per unit area, or indirectly estimates the ecosystem service value services by modifying methods such as biomass and biodiversity [12]. Most of them refer to the evaluation system of Costanza[13] and Gaodi Xie [14] in use, so the equivalent factor method system is more normative in accounting, simpler than the functional value method in calculating ecological value, with less data demand [15] , and has horizontal comparability. In the study of longitudinal spatial temporal changes, equivalent factor method can conveniently calculate watershed ecological assets, and has strong applicability in management practice [16]. At the same time, equivalent factor method can quickly sum up and compare different services, which is closer to non-professional government personnel and the public [17]. In summary, the improved equivalent factor method is suitable for estimating the ecosystem service value of national parks from the perspective of land use type. Although the amount of research in the field of ecological compensation has increased significantly, there are still some problems, such as focusing on the macro and broad sustainable concept, insufficient case studies on regional ecological compensation and lack of innovative research methods [18]. Therefore, how to accurately calculate the urgency of compensation and improve the accuracy and timeliness of ecological compensation research through empirical research is the current research hot spot. At the same time, at the present stage, the research objects of ecological compensation are mainly concentrated in river basin, province, city, etc, and there is a lack of micro subject area research.

In this paper, based on the current research hot spot of national park governance, taking Hainan Rainforest National Park as the empirical research object. We calculate ESV by the equivalent factor method proposed by Gaodi Xie and other scholars. By natural breaks method, the ecosystem service value and the type of land use were divided into regions, and then introduce land use/ land cover change (LUCC) factors caused by human development and utilization which had significant influence on the value of ecosystem services. The results are then combined with local resources, to construct the demand intensity coefficient of ecological compensation in Hainan Rainforest National Park. As a result,the ecological compensation allocation quota of different regions is obtained, and then we can make local scientific suggestions for local development, utilization and environmental protection, so as to provide data reference and positive reference value for future research on Hainan Rainforest National Park.

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3. Study Area and Data Resources

3.1. Study Area

Hainan Rainforest National Park is located in the domed structural mountain area of the south-central mountain range of Hainan Island. The highest point is 1,867 meters above sea level, and its planning scope covers nine cities and counties including Wuzhishan, Qiongzhong, Baisha, Dongfang, Lingshui, Changjiang, Ledong, Baoting and Wanning, with a total area of 4,403 square kilometers, accounting for 1/7 of the total area of Hainan Island [19]. Hainan Rainforest National Park is a treasure house of tropical biodiversity and genetic resources. There are 3,653 species of wild vascular plants in 1159 genera and 210 families, accounting for 11.7% of the total in China. And there are 5 classes, 38 orders, 145 families, 414 genera, 540 species of terrestrial vertebrates, accounting for 18.62% of the total in China. At the same time, it is also the ecological high point of Hainan Island. Major rivers in Hainan, such as Nandu River, Changhua River and Wanquan River, all originate here. The dense tropical rainforest in the park is also an important water conservation reservoir and an important ecological security barrier for wind and flood prevention [20].

3.2. Data Resources and Processing

The land use data came from the distribution map of China Land Cover Data set (CLCD) from 1985 to 2019 established by the School of Resources and Environmental Sciences of Wuhan University in 2021 according to the Google Geographic Data Engine (https://zenodo.org/ record/ 4417810#.YpM9vFRBybg) and Vector map of Hainan Rainforest National Park (http://www.hntrnp.com/). Through ArcGIS mask extraction function, the land use type distribution diagram shown in Figure 1 was obtained. Local annual GDP data comes from the National Bureau of Statistics (http://www.stats.gov.cn/). Data of annual grain output were obtained from the official website of the National Food and Strategic Reserves Administration (http://www.lswz.gov.cn/) and the Hainan Provincial Bureau of Statistics (http://stats.hainan.gov.cn/tjj/index.html). According to the differences of land resource characteristics and landscape changes in the study area, referring to the "Technical Regulations for Land Use Investigation" and the Land Classification System adopted by Costanza and Gaodi Xie et al, we divided the land use types of Hainan Tropical rainforest National Park into 7 categories: Cropland (paddy field, irrigated land, dry farmland, etc), Forest (woodland, shrubbery, open woodland, etc), Shrub (bush, copse), Grassland, Water (rivers, lakes, ditches, reservoirs, tidal flats, reeds, etc), Barren (desert, rock desert, mud desert, etc), Impervious (grassy land, saline-alkali land, sandy land, bare land, bare rock gravel land, etc).

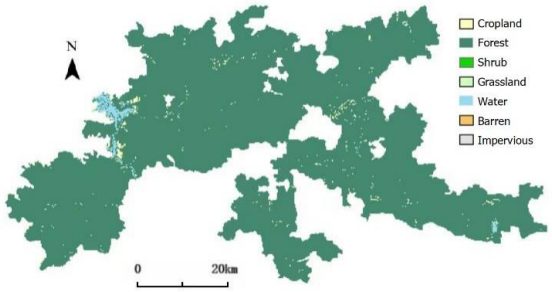

Figure 1: Map of land use in Hainan Rainforest National Park.

4. Research Methods

This study uses ArcGIS mask extraction technology to obtain land cover datasets of Hainan Rainforest National Park from 2001 to 2019, and cites the net change rate of a single land use type to describe the annual average change rate of land use types in Hainan Tropical Rainforest National Park from 2001 to 2019. The calculation formula is as follows[21]:

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$$k = \left[\sqrt[T]{\frac{U_b}{U_a}} - 1\right] \times 100\% \quad (1)$$

In the formula, k represents the annual net change rate of a certain land use type; U_a represents the area of land use types in the early stages of a research period; U_b represents the area of land use types in the late stages of a research period; T represents the length of research time. The changes in the area of land use types mentioned in this study are all net changes, without considering the mutual conversion of different land use types.

In this study, the service value equivalent of the ecosystem type per unit area was calculated according to the basic value equivalent table of the ecosystem service function per unit area constructed by Xie et al. (2015). According to the statistical yearbooks of Hainan Province over the years, we have calculated that the average grain yield per unit area from 2001 to 2019 was 2004.98kg/hm^2, and the average grain purchase price was 3.40yuan/kg. In the research process, we considered that the economic value provided by natural ecosystems without human input is 1/7 of the value of food production services provided by existing unit area farmland [22]. Therefore, we calculated the price of an equivalent factor for Hainan Rainforest National Forest Park to be 973.85yuan/hm^2. Finally, we obtained the ecosystem service value coefficients of different local ecosystem types based on the basic equivalence table, and further calculated the ecosystem service value of land use types and the service price value of individual functions of Hainan Rainforest National Park from 2001 to 2019 (as shown in Table 1). The calculation formula is [23]:

$$ESV = \sum A_k \times VC_k \quad (2)$$

$$ESV_k = A_k \times VC_k \quad (3)$$

$$ESV_f = \sum A_k \times VC_{fk} \quad (4)$$

In the formula, ESV represents the ecosystem services value (yuan); ESV_k represents the ecosystem services value (yuan) of the k land use type; VC_k represents the value coefficient (yuan//hm^2/a) of the ecosystem services value of the i land use type; $A_k$represents the area (ha) of the k land use type; ;ESV_f represents the service value (yuan) of the f function of the ecosystem; VC_{fk} represents the value coefficient (yuan/hm^2/a) of the service value of the f function of the ecosystem corresponded to the k land use type.

By introducing the dynamic degree of ecosystem service value to describe the rate of change in ecosystem service value of land use types over a certain period of time, this study compares the differences in changes in ecosystem service value among different land use types. The formula is as follows [24]:

$$d = \frac{ESV_b - ESV_a}{ESV_a} \times \frac{1}{T} \times 100\% \quad (5)$$

In the formula, d represents the dynamic degree of ecosystem service value; ESV_arepresents the ecosystem service value of a certain land use type or area in the early stage of the study; ESV_b represents the ecosystem service value of a certain land use type or area in the late stage of the study; T is the research period. If $d > 0$, the value of ecosystem services shows an increasing trend; if $d < 0$, the value of ecosystem services shows a decreasing trend; if $d = 0$, the value of ecosystem services remains unchanged.

As an important part of the ecological barrier in Hainan Province, Hainan Rainforest National Park has huge market value, ecological value, ornamental value and research value. Due to the different types of land use in the park, the ecosystem service value of some land use types can be converted into currency in the market mechanism. So when determining the amount of ecological compensation, the market value parts are abandoned, namely food, raw materials, supply parts such as water supply and so on, while non-market value parts are retained like the maintenance services such as soil conservation, nutrient cycling, biodiversity, and cultural values such as aesthetic landscapes. This article adopts the "Eco Compensation Priority Sequence" proposed by scholars such as Wang, which represents the urgency of ecological compensation in different regions. The specific formula is as follow:

$$ECPS_i = \frac{VAL_i}{GDP_i} \quad (6)$$

In the formula, $ECPS_i$ is the priority of ecological compensation; VAL_i represents the non market value in the total value of ecosystem services per unit area; GDP_i represents the Gross Domestic Product (GDP) per unit area.

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For compensation areas, the lower the priority value of ecological compensation, the smaller the impact on their economic situation after paying ecological compensation, and the less urgent the need to pay ecological compensation funds; on the contrary, for compensated areas, the higher the priority value of ecological compensation, the more priority should be given to receiving ecological compensation support. On the basis of considering the different payment capabilities of governments in different regions for ecological compensation, this study sets the ecological compensation conversion coefficient at 15%[25], and calculates the ecological compensation demand intensity coefficient and ecological compensation amount for different land use types based on the priority of ecological compensation. The formula is:

$$p_i = 2\arctan(ECPS)/\pi \tag{7}$$

$$R_i = V_i \times k \times p_i \tag{8}$$

In the formula, π is the circumference; R_i is the total amount of ecological compensation (yuan); i represents different types of land use; V_i Serve the non market value of ecosystems of different land use types; k is the ecological value conversion coefficient.

5. Empirical Analysis

5.1. Evolution of land-use in Hainan Rainforest National Park

According to the annual area values of different land-use types during the study period, the total land-use change of Hainan Rainforest National Park from 2001 to 2019 can be obtained in Figure 2 (unit: hectare). Among them, the type represented by red is reduced, and the type represented by green is increased. The land-use type is mainly forest land, accounting for more than 97% during the study period, occupying an absolute advantage in the study area. Among the other land-use types, cropland and water were more, while grassland, shrub and impervious were less, accounting for less than 0.2%.

The average annual change value of forest land showed an increasing trend from 2001 to 2011, but a decreasing trend from 2011 to 2019. In addition, the cropland area decreased from 2001 to 2011, and increased rapidly from 2011 to 2019, with the cropland area in 2019 being twice the area in 2011. Combined with the annual decline of shrub area from 2001 to 2019, it could be speculated that some forest land and shrub were converted to cropland for planting. In addition, the water area has generally shown an increasing trend year by year since 2001. The possible reason is that global climate warming has led to more vigorous transpiration in the tropical rainforest region and increased rainfall, thus increasing the water area.

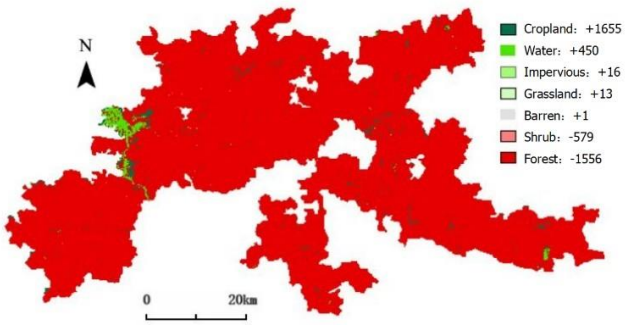

Figure 2: Changes of land-use during 2001-2019.

5.2. Spatial distribution of ESV in Hainan Rainforest Mational Park

Land use area and coefficient of ESV are important factors that influence the changes of ecosystem service value (ESV). This study calculates ESV and its changes of Hainan Rainforest National Park during different years according to the area and ESV coefficient of different types of land use. On the basis of international standards, there are six types of land use in Hainan Rainforest National Park

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which are: Cropland; Forest; Shrub; Grassland; Water; Barren; Impervious. Through calculation we can get results of ESV during 2001-2019 and their changes as Table 1 presents.

Table 1: Cross-sectional data of Ecosystem Service Value during 2001-2019.

Land-use type		Cropland	Forest	Shrub	Grassland	Water	Barren	Impervious	Total
ESV(¥)	2001	14696315.62	9709558537.00	10659683.80	1028514.15	440218222.40	0.00	11725.15	10176172998.12
	2011	9292490.72	9739096405.00	4970112.03	2476225.73	482765501.40	0.00	12591.88	10238613326.76
	2019	20966367.82	9674549103.00	2071818.74	1181566.85	493165060.00	632.03	14860.95	10191949409.39
Proportion (%)	2001	0.14	95.41	0.10	0.01	4.33	0	0.01	100
	2011	0.09	95.12	0.05	0.02	4.71	0	0.01	100
	2019	0.20	94.92	0.02	0.01	4.83	0.01	0.01	100
Dynamic degree	2001-2011	-0.37	0.00	-0.53	1.41	0.10	0.00	0.07	0.01
	2011-2019	1.26	-0.01	-0.58	-0.52	0.02		0.18	0.00
	2001-2019	0.43	0.00	-0.81	0.15	0.12		0.27	0.00

The distribution of ESV in Hainan Rainforest National Park can be acquired with the application of ArcGIS technology, which is visually shown in Figure 3, the bigger ESV one type of land use serves, the greener the color in the figure performs. Detailed results are as legends show (unit: ¥).

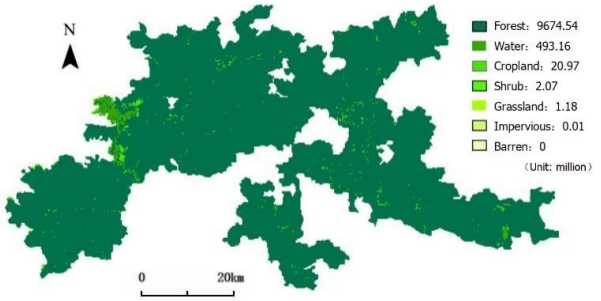

Figure 3: Distribution map of ESV in Hainan Rainforest National Park in 2019.

Forest has the biggest area, so the coefficient of ESV is higher and thus accounts for a larger proportion: in 2001, 2011 and 2019, the proportions are 95.41%, 95.12% and 94.93%. ESV Coefficient of water , which is about five times bigger than Forest, is far more bigger than other types of land use, but the ESV of water is only valued between 4%-5%, so the type that majorly influence the total ESV of Hainan Rainforest National Park is NO.1 forest, and the second is water.

Table 2: Changing trend of cross-sectional Supply and Support ESV during 2001-2019.

Service classification	Supply service						Support service					
Year	Food production	Growth rate	Production of raw materials	Growth rate	Water resources supply	Growth rate	Soil conservation	Growth rate	Maintain nutrient cycle	Growth rate	Biodiversity	Growth rate
2001	138568722.9	0	300071923.1	0	176080562.6	0	1207419558	0	93586291.42	0	1104639782	0
2011	137315087.9	-0.90%	300817356.4	0.25%	183072370.3	3.97%	1210925561	0.29%	93593815.58	0.01%	1108147707	0.32%
2019	140537734.4	2.35%	299003252.4	-0.60%	174797958.6	-4.52%	1202556053	-0.69%	93517828.99	-0.08%	1101287054	-0.62%

Table 3: Changing trend of cross-sectional Regulation and Cultural ESV during 2001-2019.

Service classification	Regulation service								Cultural service	
Year	Purify the environment	Growth rate	Hydrologic regulation	Growth rate	Climate regulation	Growth rate	Gas regulation	Growth rate	Aesthetic landscape	Growth rate
2001	840455446	0	1861979405	0	2969926132	0	996292011	0	487153165	0
2011	842607617	0.26%	1897785744	1.92%	2977736515	0.26%	997645301	0.14%	488966251	0.37%
2019	837246532	-0.64%	1904064190	0.33%	2958844896	-0.63%	994076119	-0.36%	486017792	-0.60%

According to Table 2, we can draw the changes of ESV between 2001 and 2019 as Figure 4 shows, which compares ESV in 2019 with that in 2001. In the figure, green means increasing and red means decreasing. The deeper the color presents, the more the ESV increases or decreases. The detailed value is signed in the legends (unit:¥).

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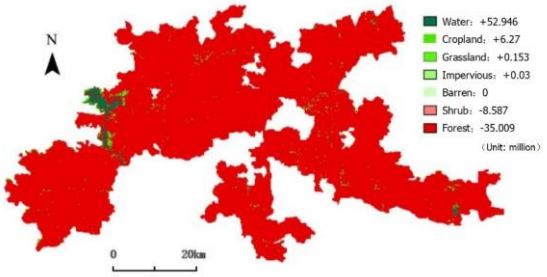

Figure 4: Changes of Ecosystem Service Value between 2001 and 2019.

In 2001, 2011 and 2019, the total ESV of Hainan Rainforest National Park was respectively 10.176 billion yuan, 10.239 billion yuan and 10.192 billion yuan. The overall ESV showed an increasing trend from 2001 to 2011 and decreased from 2012 to 2019, with the largest increase from 2008 to 2009 (43.888, 400 yuan). Correspondingly, the value of the water's ecological service system grown rapidly in the same year, with an increase of 43,542,100 yuan, accounting for 99% of the total increase. The reduction rate has been accelerated after 2012. As can be seen from the longitudinal comparison, the proportion of the ecosystem service value of cropland is increasing after 2012, while the proportion of forest land is decreasing. It can be concluded that the main reason for the loss of ecosystem service value is the decrease of forest land, and the overall change trend of land use types is the transformation of other types of land use to cropland.

As is shown in the Table 2 and Table 3, from the single ESV, the water area provides the largest regulation service function, accounting for about 65%; the cultural service is the second, accounting for about 25.5%; and the cultural service function is the smallest, and it only accounts for about 5%. According to each function of service value to the total contribution of ecosystem service value, from higher to lower, the order is: climate regulation, hydrology regulation, soil conservation, biodiversity, gas regulation, purify the environment, aesthetic landscape, raw material production, water supply, food production and the last one is maintaining nutrient cycle. The food production and hydrology regulation function is increasing, other functions are the same as the total change trend, which is first increase and then decrease. Due to the large increase of cropland area in 2012, the average annual growth rate of food production level was 0.26% from 2012 to 2019. Forest and water have the highest climate and hydrology regulation functions, which contribute the most to the total ecosystem service value, reaching 29% and 18.5% respectively.

5.3. ECPS and Eco-compensations calculation

5.3.1. Analysis of ECPS

Table 4: Ecosystem Service Value of Hainan Rainforest National Park in 2019.

Service value classification	**Service classification**		**Ecosystem service value in 2019(¥)**						
	Primary type	Secondary type	Cropland	Forest	Shrub	Grassland	Water	Barren	Impervious
Market value	Supply service	Food production	7330144.019	129887839.8	25863.70307	22742.31905	3271138.778	5.745715	0
		Production of raw materials	485083.0601	297485052.5	58533.64379	34113.47858	940452.3986	17.237145	0
		Water resources supply	-14175204.98	155027421.7	29947.44566	18607.35195	33897175.58	11.49143	0
Non-market value	Regulation service	Gas regulation	5982691.075	984633624.6	191935.9017	117846.5624	3148471.073	63.202865	1486.0951
		Climate regulation	3072192.714	2945521013	575807.7052	312190.0161	9363634.751	57.45715	0
		Purify the environment	916268.0024	833796133.2	174239.6838	103374.1775	2248907.91	178.117165	7430.4755
		Hydrologic regulation	14660288.04	1470665541	456017.9226	228456.9323	418051535.8	120.660015	2229.14265
	Support service	Soil conservation	53898.11779	1198320071	234134.5752	143690.1067	3802698.829	74.694295	1486.0951
		Maintain nutrient cycle	1024064.238	92178466.99	17696.21789	11371.15953	286224.643	5.745715	0
		Biodiversity	1131860.474	1089381883	213715.8622	131285.2054	10426754.85	68.94858	1486.0951
	Cultural service	Aesthetic landscape	485083.0601	477652056.2	93926.07957	57889.5394	7728065.362	28.728575	743.04755
Total			20966367.82	9674549103	2071818.741	1181566.849	493165060	632.02865	14860.951
Total non-market value			27326345.72	9092148789	1957473.948	1106103.699	455056293.2	597.55436	14860.951
Non-market value Unit Value (¥/hm^2)			4937.4195	21132.545	14003.963	10420.195	108379.7665	1012.804	194.77

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To evaluate the ecological compensation priority in each region of Hainan Rainforest National Park, we introduce ECPS, which is mainly related to ESV. It is known that the market value of ecosystem services has been transformed into money in the market mechanism to promote the regional economic development. Therefore, when determining the amount of ecological compensation, the market value of ecosystem services should be abandoned and part of the value that is not circulated in the market should be retained. According to the concept of ecosystem service functions, this paper defines the market value and non-market value of different land use types in Table 4.

According to the Yearbook of Hainan Province, in 2019, Hainan covered an area of 2.0352 million square kilometers, with a GDP of 5.308.93 billion yuan and a GDP per unit area of 26.086 billion yuan per 10,000 square kilometers. According to the data of the yearbook and the calculation formula, the ECPS ranking of various land use types in Hainan Rainforest National Park in 2019 is calculated as shown in Table 5, and the ecological compensation priority classification map is drawn in Figure 5.

Table 5: Different types of land use and their Eco-compensation Priority.

Land-use type	Water	Forest	Shrub	Grassland	Cropland	Barren	Impervious
ECPS	4154.78	810.12	536.85	399.46	189.28	38.83	7.47
Order	1	2	3	4	5	6	7

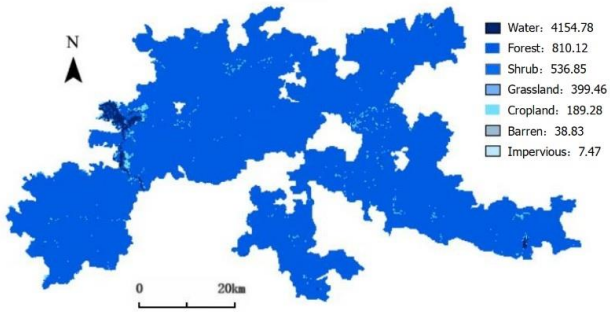

Figure 5: Eco-compensation priority of Hainan Rainforest National Park.

The results show that differences of Hainan Rainforest National Park ECPS between types of land use is huge and the water has the highest ECPS. The phenomenon indicates that Hainan Rainforest National Park has a good ecological protection of water, and its ecosystem service value is high. Due to the ecological environment limits the development of the economic level, the water area economic development level is relatively backward and need to get more ecological compensation. However, the ECPS of land use types in areas such as cropland, barren and impervious ranks lower, which is mainly due to the high level of economic development in these areas and the poor environmental protection, and also, the impact and restrictions of ecological protection on their economic development are small, so the urgency of ecological compensation is low.

5.3.2. Eco-compensation calculation

The reasonable determination of the amount of ecological compensation is the basis for the formulation of ecological compensation mechanism, and the reasonable determination of ecosystem service value is an important basis for the calculation of the amount of ecological compensation. According to the determined ecological service function benefits and compensation scope of various land use types of Hainan Rainforest National Park, the theoretical ecological compensation for various land use types in 2019 are determined, as shown in Table 6.

Table 6: Eco-compensation of different land use types in Hainan National Park.

	Cropland	Forest	Shrub	Grassland	Water	Barren	Impervious
Demand intensity coefficient	1.00	1.00	1.00	1.00	1.00	0.98	0.92
Total amount of eco-compensation(RMB)	4085165.52	1362750587.34	293272.90	165651.14	68247985.03	88.16	2040.20

According to the results, the total amount of ecological compensation of Hainan Rainforest National Park in 2019 was 1.435 billion yuan, among which the ecological compensation of each land use type was 1.363 billion yuan for forest, 68,248 million yuan for water, 4.0852 million yuan for cropland, 293,300 yuan for shrub, 165,700 yuan for grassland, 2,040.2 yuan for impervious, and 88.16

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yuan for barren. The standard theoretical compensation of forest accounts for as high as 94.93% of the total amount of ecological compensation, which is the core area of ecological compensation in the study area of Hainan Rainforest National Park.

6. Conclusion and suggestions

6.1. Conclusion

6.1.1. Reduced land use types were converted to cropland

After 2012, the partially reduced land use area of Hainan Rainforest National Park was converted into cropland. From 2001 to 2019, the value of local food production gradually increased, while the value of raw material production and water supply gradually decreased, indicating that the newly added cropland is mainly converted from woodland and water area. Forest retreated more obviously than water area. Influenced by the policy of expanding cultivated land area and red line of cultivated land in previous years, the decrease rate of forest in recent years showed a downward trend.

6.1.2. The regulation ability of water bodies in national parks is outstanding

Based on the analysis of land use types, the total proportion of water ranks second. However, in the calculation of ecological compensation priority, the priority of water (ECPS) far exceeds that of forest, proving that in terms of the value and importance of ecosystem regulation, the contribution and vulnerability of water are much higher than that of forest. The value growth rate of ecological services such as hydrology regulation and water resource supply has mostly shown negative growth in recent years, which is not optimistic. Therefore, the urgency of compensation for water bodies is stronger.

6.1.3. Cropland development and soil erosion lead to serious desertification

In Hainan Rainforest National Park, desertification is a process from scratch. The transformation of other land use types to desertification appeared for the first time in 2017, indicating that the land carrying capacity has been close to the critical value under the trend of agricultural reclamation development, tourism destination development and industrial development. In this case, excessive development can lead to a decrease in vegetation coverage and a decrease in soil nutrients. In addition, the tropical rainforest in Hainan has a rainy climate and severe soil erosion. Desertification will further expand as a result.

6.1.4. Significant achievements in promoting ecological civilization construction through returning cropland to forests

Hainan Province attaches great importance to the excavation and protection of the non-market value of ecological resources and the practice of ecological civilization construction. For example, when developing the primary industry, adhere to the principle of moderation and protect while developing; Take relevant scientific suggestions when developing the secondary and tertiary industries to maximize the value of ecosystem services within the limits of available resources. In recent years, the coordinated development of Hainan Rainforest National Park has achieved significant results.

6.2. Suggestions

6.2.1. The government should strictly control the transformation of land types into cropland.

Cropland's overall contribution is lower than that of forest and water areas; Moreover, the main soils in the region are latosol and lateritic red soil, which are not suitable for agricultural development; In addition, the development process may lead to problems such as soil erosion, and cropland may also have sustained and irreversible adverse effects on the land due to fertilization and other reasons, making compensation difficult. Therefore, the local cropland area should not be too large. While reclaiming cropland, protect the stability of forest and water areas, control the scope of cropland, and attempt to explore the possibility of unused land. Or rely on agricultural science and technology to improve the growth conditions of crops such as soil and seeds to improve the efficiency of unit cropland. Local supervision should be strengthened and special supervision mode should be customized.

6.2.2. Prioritize ecological compensation for water areas

Firstly, the priority of ecological compensation in water areas far exceeds that of other land use

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types, and the government should prioritize ecological compensation in water areas. Depending on the situation, the water should be appropriately expanded or the existing water should be protected and maintained, and cropland should be reasonably converted to forests or water to reduce the pollution of local water bodies caused by soil erosion and the negative impact of water vapor evaporation on the water area; Secondly, tourism resource planning developers are concerned about the urgency of balancing development and protection, reducing water pollution caused by water activities, and regularly investing in ecological environment maintenance.

6.2.3. Pay attention to the protection of natural forest ecological advantages

The natural forest ecological advantage is difficult to restore once it is destroyed. Hainan gibbon, which depends on natural forests for survival, is a rare species endemic to China, but with the disappearance of natural forests, gibbon's living environment is also facing serious threats. In terms of natural forest protection, the first step should be to start with the reasons for the shrinking natural forest area, and the government should increase its efforts to investigate and punish illegal planting practices, and plan artificial forest projects reasonably. Secondly, further expanding the area of natural forests requires the construction of sustainable development mechanisms to ensure the continuous renewal of natural forests.

6.2.4. Emphasize the investment of artificial forests in ecological compensation for "near naturalization"

Forest is the main land type in Hainan Rainforest National Park, accounting for more than 97% of the total area, ranking the second in the priority of ecological compensation, and making the largest contribution to ecosystem service value, accounting for about 95% of the absolute proportion. Artificial forest affects the quality of forest resources, and its structural incompatibility leads to poor regional biodiversity, weakened ecological functions, reduced carrying capacity of wild animal populations, and deterioration of ecological environment, which seriously affects the authenticity and integrity of the tropical rainforest ecosystem in Hainan. The amount of ecological compensation should be reasonably allocated, and support the improvement of the technical system of near natural transformation of plantation in national parks, so as to effectively solve the problem of habitat fragmentation of rare wild animals such as gibbon in Hainan.

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